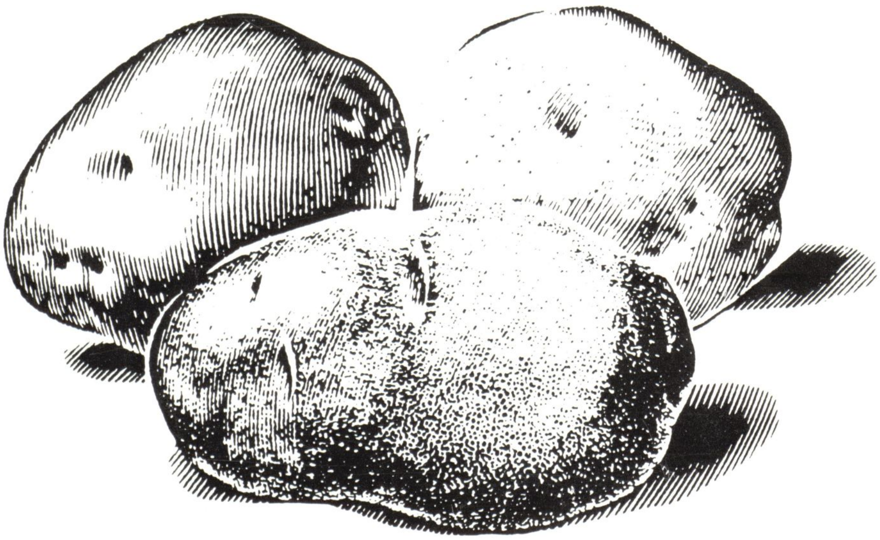
1993
MICHIGAN POTATO RESEARCH REPORT

VOLUME 25



Michigan State University
Agricultural Experiment Station

In Cooperation With

The Michigan Potato Industry Commission

THE MICHIGAN POTATO INDUSTRY COMMISSION

February 17, 1994

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 1993 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 1994 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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1993 MSU POTATO RESEARCH REPORT

R.W. Chase, Coordinator

Introduction and Acknowledgements

The 1993 Potato Research Report contains reports of potato research projects conducted by MSU potato researchers at several different locations. The 1993 report is the 25th 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.

Weather

Temperatures during April and May were near the average, but were cooler than 1991 (Table 1). The average minimum temperature was higher than the 15 year average for June, July and August, whereas the average maximum temperature was normal. This may be a factor relating to the generally lower dry matter of 1993 compared with 1992 which had cooler night temperatures.

The 1993 growing season started with above average rainfall in April, May and June (Table 2). July was more nearly normal, however, August exceeded the 15 year average by over 2½ inches and for the April through September growing season, 1993 had the second highest total following the 32.72 inches of 1986.

Previous Crops and Fertilizers

The general plot area was planted to drilled soybeans in 1992 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	300 lbs/A	0-0-180
banded at planting	20-10-10	400 lbs/A	80-40-40
sidedress at hilling	46-0-0	150 lbs/A	69-0-0
irrigation	28-0-0	15 gals/A	42-0-0
irrigation (RB ranges)	28-0-0	15 gals/A	42-0-0

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. Weed control was excellent throughout the season.

Irrigation

Irrigation was initiated on June 30 and seven applications were made during the growing season with the last application on August 13, 1993. Approximately 5 inches of irrigation water were applied. The MSU Irrigation Scheduling program was monitored by Don Smucker, Montcalm County Extension Director and these data were used to determine the timing for irrigation applications.

Insect and Disease Control

The general potato research plot area was treated in late fall of 1992 with Vapam at 50 gpa knifed into the soil. The nematology, insect and potato breeding plot areas were not fumigated. Phorate was applied at planting at 11.3 ounces/1,000 ft. of row.

The emergence of overwintering Colorado Potato Beetles was erratic and occurred over a long time period. This resulted in situations with overwintering adults, eggs and larvae all being present at the same time. Novodor was used initially (June 21) followed by subsequent applications of Imidan + PBO, Thiodan + PBO and Asana + PBO. Cygon was applied for aphid control in early August, however, a severe outbreak of aphids developed in mid August and Monitor was applied August 20.

Foliar sprays for disease control were initiated on July 1. Penncozeb and Bravo were the fungicides used during the season.

Growing Degree Days

Beginning in 1991, a very warm growing season which could be classed as a "fast-growing season", there has been increased interest and discussion about growing degree days as it relates to the potato crop. Prior to 1991, the term was more common with other high intensity crops and insect life cycles. Growing degree days will influence physiological aging and this item has been most commonly linked to seed potato performance. The question of physiological aging has now been considered as a possible factor relating to the reducing sugar profile of stored potatoes.

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. These data show that 1993 was cooler in May and June compared with 1992. At the end of August, it was intermediate between the August values of 1991 and 1992. Figure 1 shows the growing degree days for 1991-1993.

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

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

Soil Tests

Soil tests for the general plot area were:

	lbs/A				Cation Exchange Capacity
pH	P_2O_5	K_2O	Ca	Mg	
6.2	395	177	762	137	2.7 me/100 g

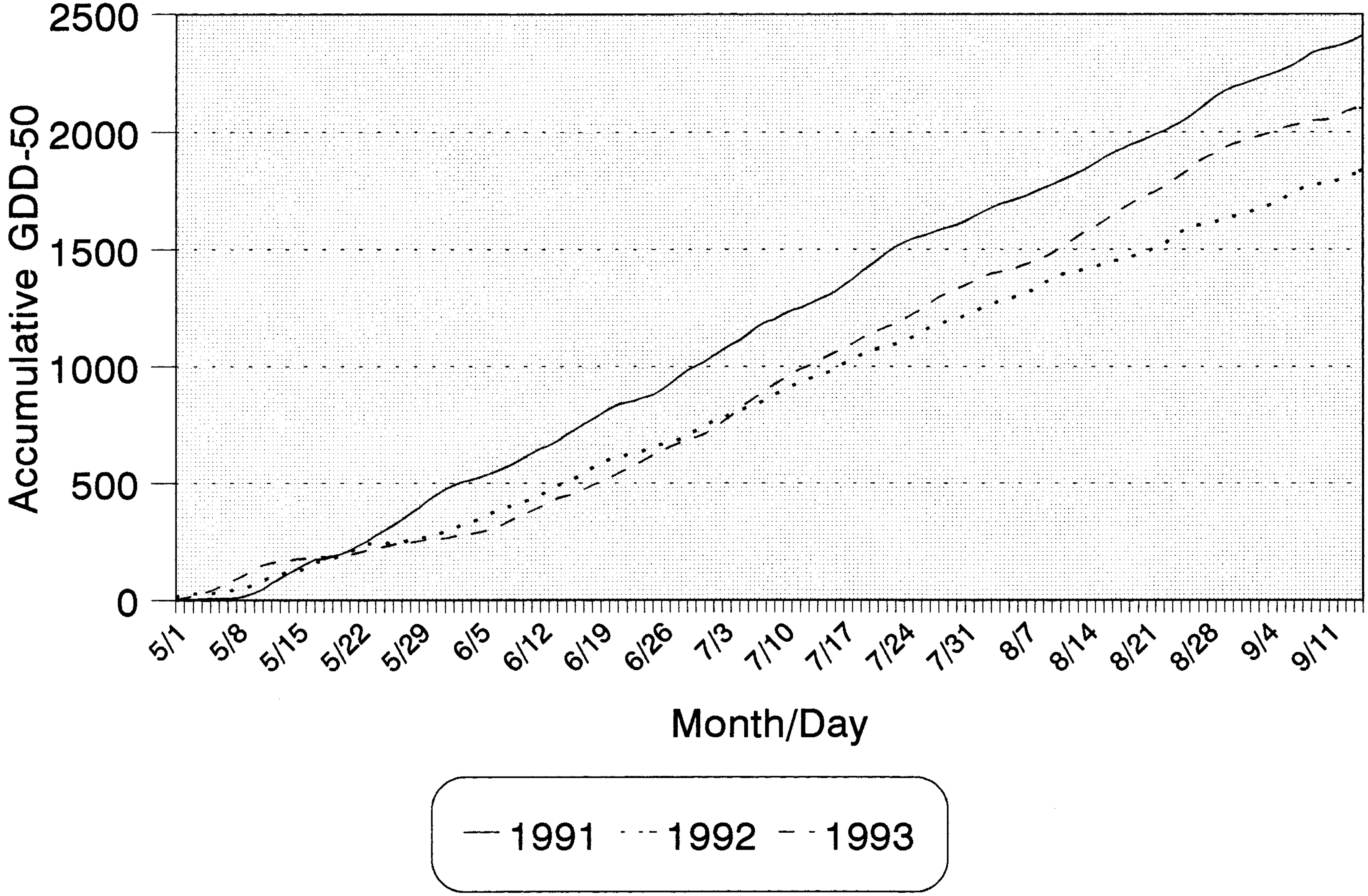
Table 1. The 15 year summary of average maximum and minimum temperatures during the growing season at the Montcalm Research Farm.

	April		May		June		July		August		September		6-Month Average	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1979	50	33	66	44	74	55	82	57	77	55	76	47	71	49
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
15-YR. AVG.	54	33	68	43	76	52	81	57	79	55	70	48	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
1979	2.58	1.68	3.77	1.09	3.69	0.04	12.85
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
15-YR. AVG.	2.87	2.89	3.11	2.82	3.83	4.50	20.02

Figure 1. Accumulative growing degree days base 50 for the Montcalm Research Farm. 1991-93



Funding Fed. Grant/MPIC

1993 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. The most promising seedlings are tested in management profile studies for their reaction to the spacing and nitrogen fertilization. Total and marketable yields, specific gravity, tuber appearance, incidence of external and internal defects, chip color, consistency and after cooking darkening as well as susceptibilities to common scab, fusarium dry rot, blackspot bruising, and dormancy were determined. Before testing for chip color, the varieties were stored at 45 and 50°F.

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.

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 four slices from each tuber. Chips were fried at 365°F. The color was measured with an M-35 Agtron colorimeter (90/90) 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

Eight varieties and 14 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 below the normal level. The results are presented in Tables 1 and 2.

Variety Characteristics

Standards

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.

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).

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.

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.

Varieties for Evaluation

Gemchip - late, high yielding, fresh market and chipping variety in some areas of the U.S. Tubers are large, round to oval and of good appearance. Specific gravity is low and has some tendency towards hollow heart.

Chaleur - medium early fresh market variety from Canada. Yield and specific gravity were low during 2 years of testing in Michigan. Tubers were large, few per hill, and of good appearance with a very good flesh color.

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.

Prestile - very late, fresh market variety from Maine. During 2 years of testing in Michigan, it showed an excellent yield potential and good tuber shape. Specific gravity was low. It was heavily infected with scab in 1992 while the internal brown spots were quite frequent in 1993. Reported to be susceptible to heat necrosis and air checks.

E55-35 - late maturity, medium yielding with high specific gravity and good chip quality. Tubers well-shaped, medium, and uniform in size. Few internal defects were noted and reported to have scab tolerance. It has a potential in Michigan.

E55-44 - medium early variety. Chipping quality is good, but specific gravity is below 1.08. Tubers are medium large, uniform, well shaped, and of excellent general appearance. It has some potential in Michigan as a fresh-market, medium early variety. It does produce a good chip color.

AF1060-2 - late, fresh market variety of high yield potential, but low specific gravity. Susceptible to scab.

St. Johns - tested in 1993 as AF828-5, medium late fresh-market variety of high yield potential, but low specific gravity. There was some variation in shape, but general appearance was good. Large tubers. Good internal quality. Scab infection was heavy in 1993.

BO172-15 - first time tested in this trial. Very late, fresh-market variety. Yield in 1993 was very high. Tubers were large, low specific gravity with strong tendency to hollow heart. Scab infection was heavy.

AF875-15 - first time tested 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. Scab infection was severe.

W887 - very late, high-yielding and high-specific-gravity chipping variety. Tubers are large, slightly flattened with medium deep eyes. Tendency to shatter bruises and short dormancy were noted. Susceptible to scab, but resistant to *Fusarium* dry rot.

W870 - medium late chipping variety. Medium yield potential, but high specific gravity and excellent chipping quality. Tubers are medium large, slightly flattened. Few internal defects. Susceptible to scab.

B0175-20 - late chipping variety, first time tested in Michigan. The yield was average, specific gravity high, but showed strong tendency to hollow heart.

AF1433-4 - first time tested in Michigan. It was early, yield was below average, specific gravity low, and some tendency to vascular discoloration was observed. Scab infection was heavy with few pitted lesions.

B9792-61 - first time tested in this trial. Medium maturity, low yield, small tubers of irregular shape and deep eyes. Greatest potential for direct harvest chip processing.

NY84 - first time tested in this trial. Medium late variety of high yield potential, but very low specific gravity. Good internal quality. Scab infection was low, but tubers were "rusted."

NY95 - first time tested in this trial. Medium late, high yielding variety of excellent chipping quality and high specific gravity.

B. Long Varieties

Five varieties and four breeding lines were tested. All were late or very late. The yield level was high. A78242-5, A84180-8, and W1005 produced U.S.#1 yields higher than Russet Burbank. The results are summarized in Tables 3 and 4.

Variety Characteristics

Standards

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.

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.

Varieties Evaluated

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.

Amisk - tested for the first time in Michigan. No distinction from Ranger Russet was noted in this trial.

W1005 - late variety of high yield potential and high specific gravity. Tubers are long and rather thin. Resistant to scab, but susceptibility to black spot was noted in 1992 and high frequency of hollow heart in 1993.

A78242-5 - medium-late, fresh market and processing variety. Yield potential is high, but specific gravity low. Tubers are oblong, blocky and attractive. It shows some tendency to hollow heart, brown centers, and internal brown spots in some years. Resistant to scab. Variety will be deleted from further testing.

W1099 - medium early, heavy-russet variety. Yield and specific gravity were low during two years of testing.

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

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-one lines were tested in 1993. Steuben, Snowden, Viking and Superior were used as checks. The results are presented in Table 5.

The average yield in adaptation trial was very high. The red-skinned Fontenot was the best yielder among named varieties, followed by Snowden. Yields of 9 breeding lines were comparable to Fontenot and Snowden: NY101Y, FL1533, MSB076-2, BO564-9, BO172-22, BO613-2, BO178-34, E11-45, and P88-9-8. NY101Y showed an excellent yield potential and its tubers are round, well shaped, and smooth with a light yellow flesh. Internal quality was very good, but specific gravity was low. The same can be said about FL1533. MSB076-2 had high specific gravity and its tubers were very uniform in size. BO178-34 had high specific gravity, while BO173-22 and BO613-2 showed a tendency to hollow heart. Out of new varieties tested, Brodick produced very high yield with high specific gravity, but the internal quality was very bad--hollow heart and internal brown spots. AC Novachip produced high yield, but specific gravity was too low for the chipping industry.

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 1993, nine breeding lines were compared to five standard varieties of various tuber type. The results are presented in Table 6.

Most breeding lines produced high yields, were rather early in maturity, but had very low specific gravity. Four lines: W1100R, MN15220, MN1871-3R, and MN13540 yielded on the level of Red Pontiac. W1100R and MN1871-3R are red skinned. MN15220 is violet, its tubers were very large, and frequently the shape was irregular. MN15111 produced medium-high yield, but tubers were very attractive. Its specific gravity was low. ND2471-8 produced average yield, at specific gravity acceptable for chipping quality and it is a potential cold chipper. However, it showed some tendency to hollow heart. W84-75R was the lowest yielder and tubers were very small.

E. Upper Peninsula Variety Trial

A potato variety trial was conducted by Dr. Rich Leep and Jim Lempke on the Mike VanDamme Farm. The plots were planted on May 21 and were harvested on October 6. In-row plant spacing was 12 inches and row width was 36 inches. The yield, size distribution and specific gravity data are shown in Table 7.

In general, yields were good; however, specific gravity values were lower than normally expected. Similar to other trials, Prestile (ME) was the highest yielder. It is a fresh market, round-white type which has a very good general appearance. AF1060-2 (ME) has also performed very well as a potential round-white variety. Goldrush and Russet Norkotah were very similar in yields and size distribution; however, Goldrush had a higher specific gravity.

W1005 and W1099 had the highest percentage of tubers under 2 inches. Chaleur had the earliest maturity; however, yields were very low. It does have excellent general appearance with shallow eyes and uniform shape.

F. Fusarium Dry Rot Evaluation

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. In two years of testing no absolute resistance was detected in the 80 varieties, advanced lines and genetic lines that were screened. Some lines did, however, exhibit a lesser degree of rot than others over the two years. These included W887, Snowden, and Frontier Russet. Other lines that had low levels of infection in 1993 included Superior, W870 and Russet Norkotah. Of the diploid genetic lines, 34-6 showed the least infection of all potatoes tested while 133-10 had little infection. The results of the 1993 test are summarized in Table 8.

G. Potato Scab Evaluation

Each year a replicated field trial is conducted to assess resistance to common and pitted scab. In 1993, 89 varieties and advanced breeding lines were planted in a scab inoculated field at the MSU Soils Farm. These data are summarized in Table 9. The varieties are ranked on a 1-4 scale based upon a combined score for scab coverage and lesion severity. 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. This year's trial had a good level of scab infection. 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. Some lines that show some promise include Goldrush, MN13540, W1005, Prestile and Viking. We are conducting additional greenhouse tests to assess the resistance levels in some of the advanced lines (i.e. E55-35, MSB076-2, MSB106-7, MSB073-2, Portage, Prestile, etc.).

H. 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 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 November and individual tubers were assessed for the number of blackspot bruises on each potato. These data are shown in Table 10.

Section A summarizes the data for the samples receiving the simulated bruise and Section B, the check samples. The simulated bruise is judged to be a severe test. When available, the 1992 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.

The incidence of blackspot bruising was very minimal among the check samples. From all of the trials, BO178-34, Amisk, Ranger Russet, and W1005 show the greatest blackspot incidence among the check samples.

Table 1. **EARLY HARVEST ROUND WHITES**

MONTCALM RESEARCH FARM

Planted: May 5, 1993 Harvested: August 12, 1993 (99 Days)

Variety	cwt/A No.1	cwt/A Total	Percent Distribution[1] No.1	B's	A's	OV	PO	S.G.	Int.[2] Quality HH	BC	Total Tubers Cut	Chip SFA#	3 Yr. Ave.[3] No. 1
AF875-15	426	463	92	7	87	5	1	1.081			29	1.5	-
Superior	389	420	93	5	85	8	2	1.073		2	31	2.0	291
E55-44	385	409	94	5	86	9	0	1.075	1	1	32	1.0	354
Atlantic	377	410	92	8	83	9	0	1.086	1	1	40	1.5	358
Portage	373	407	92	6	79	13	2	1.067	10		36	3.0	333*
NY95	350	415	84	15	83	1	1	1.084			22	1.0	-
AF1433-4	339	366	92	8	87	6	0	1.079			32	1.5	-
AF828-5	336	358	94	5	78	16	1	1.066	1		40	1.5	-
Gemchip	316	349	90	9	88	3	0	1.067	7		24	1.0	288
W887	309	331	93	5	79	14	2	1.086	2		40	1.5	291
NY84	306	337	91	9	77	14	0	1.062	2		40	2.0	-
W870	290	316	92	7	89	2	1	1.088	3		25	2.0	308
Onaway	281	307	92	6	77	15	2	1.064			32	4.0	325
Snowden	279	349	80	19	79	1	1	1.082			22	1.0	223*
AF1060-2	279	312	89	1	8	1	0	1.067			32	3.0	278*
Prestile	261	284	92	8	89	3	0	1.064			28	1.5	280*
E55-35	258	320	81	19	79	2	0	1.079			25	1.0	274
B0172-15	255	270	94	4	81	13	2	1.071	6		28	2.0	-
Chaleur	255	269	95	4	88	7	1	1.067	1		24	3.0	242*
B0175-20	243	262	93	6	84	9	1	1.088	12	7	37	2.0	-
B9792-61	219	264	83	16	82	1	1	1.080	1	4	24	1.5	204*
W877	206	250	82	16	81	1	1	1.090			22	1.5	225

Table 2. **LATE HARVEST ROUND WHITES**

Planted: May 5, 1993 Harvested: September 22, 1993 (140 Days)

Variety	cwt/A No.1	cwt/A Total	Percent Distribution[1] No.1	B's	A's	OV	PO	S.G.	Int. Quality[2] HH	VD	IBS	BC	Total Tubers Cut	3 Yr. Ave.[3] No. 1
Prestile	525	538	98	2	66	31	0	1.071	3	0	15	0	40	490*
Gemchip	498	529	94	4	82	12	2	1.068	5	3	0	3	39	430
Snowden	497	536	93	6	83	10	1	1.083	2	2	0	0	31	409*
AF1060-2	488	523	93	4	72	21	2	1.067	0	5	0	1	40	422*
AF828-5	468	503	93	3	58	35	4	1.070	1	1	0	0	40	-
B0172-15	452	501	90	2	56	34	7	1.074	26	1	0	0	40	-
AF875-15	452	488	93	5	86	7	2	1.076	1	0	0	1	28	-
W887	446	458	97	3	72	25	0	1.092	4	0	0	1	40	421
Portage	433	482	90	4	65	25	6	1.066	17	3	0	1	40	395
NY95	432	494	87	7	79	9	6	1.085	5	1	0	1	27	-
NY84	428	469	91	7	64	27	2	1.061	0	0	0	0	40	-
Atlantic	417	445	94	5	80	14	1	1.085	9	2	0	0	22	471
E55-44	394	412	96	3	82	13	1	1.073	3	0	0	1	35	341
Superior	387	418	93	7	89	4	1	1.073	0	0	0	0	20	278
B0175-20	372	408	91	2	68	23	7	1.089	28	0	0	9	40	-
W870	370	388	95	4	87	9	1	1.085	5	0	0	0	35	378
Onaway	349	378	92	3	67	25	4	1.064	0	0	1	0	28	397
Chaleur	344	357	96	3	78	18	1	1.065	3	0	0	0	35	274*
AF1433-4	332	352	94	5	78	16	0	1.072	0	8	3	0	38	-
W877	314	347	91	9	84	6	1	1.091	4	0	0	0	16	288
E55-35	304	349	87	12	83	4	1	1.075	0	0	0	3	13	371
B9792-61	263	308	86	11	82	3	3	1.078	0	0	1	1	9	242*

[1] Size
B's - <2"
A's - 2-3.25"
OV - >3.25"
PO - Pick outs

[2] Quality
HH - Hollow Heart
BC - Brown Center
VD - Vascular Discoloration
IBS - Internal Brown Spot

[3] 3 Yr. Ave.
*2 yr. data

Table 3.

EARLY HARVEST LONG RUSSETS

MONTCALM RESEARCH FARM

Planted: May 5, 1993 Harvested: August 12, 1993 (99 Days)

Variety	cwt/A No.1	cwt/A Total	Percent Distribution[1] No.1	B's	A's	OV	PO	S.G.	Int.[2] Quality HH	Total Tubers Cut	3 Yr. Ave.[3] No. 1
A78242-5	264	314	84	16	80	4	0	1.071	0	10	242
A84180-8	260	318	82	18	72	10	1	1.073	6	23	-
Goldrush	256	348	74	25	67	6	1	1.073	0	16	187*
W1099	254	346	73	26	66	7	1	1.068	0	12	183*
R. Norkotah	217	305	71	28	63	8	0	1.070	0	17	230
Ranger R.	166	275	60	39	60	0	1	1.076	0	1	186
R. Burbank	163	331	49	45	49	0	6	1.075	0	0	197
W1005	162	263	62	37	60	2	2	1.082	2	3	207
Amisk	138	249	55	45	54	1	0	1.082	0	2	-

Table 4.

LATE HARVEST LONG RUSSETS

Planted: May 5, 1993 Harvested: September 28, 1993 (146 Days)

Variety	cwt/A No.1	cwt/A Total	Percent Distribution[1] No.1	B's	A's	OV	PO	S.G.	Int. Quality[2] HH	VD	IBS	BC	Total Tubers Cut	3 Yr. Av[illegible] No. 1
A78242-5	442	463	95	4	58	38	0	1.070	4	0	5	0	40	386
A84180-8	437	485	90	6	58	32	4	1.071	25	0	0	0	38	-
W1005	433	511	85	12	75	10	4	1.081	29	0	1	0	38	376
R. Burbank	381	553	69	18	56	13	13	1.079	18	0	0	0	34	380
Ranger R.	370	446	83	14	67	16	3	1.087	5	0	2	1	34	356
Amisk	326	392	83	13	66	18	4	1.084	4	0	0	1	38	-
Goldrush	313	394	80	17	62	17	3	1.066	1	0	0	0	29	289*
W1099	305	378	81	18	72	8	1	1.063	6	0	0	0	23	258*
R. Norkotah	265	340	78	20	67	11	2	1.068	4	0	1	1	28	275

[1]Size
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

[3]3 Yr. Ave.
*2 yr. data

Table 5.

1993 ADAPTATION TRIAL

MONTCALM RESEARCH FARM

Planted: May 5, 1993 Harvested: September 22, 1993

Variety	cwt/A		Percent Distribution[1/]					S.G.	Int. Quality[2/]				Total tubers cut	Grading comments
	No. 1	Total	No. 1	B's	A's	OV	PO		HH	VD	IBS	BC		
NY101Y	596	614	97	3	64	33	0	1.073	0	0	0	1	40	Pale yellow flesh; nice appearance
Brodick	561	603	93	4	82	11	2	1.085	30	0	27	0	40	Splashes of red; smooth shapes
FL1533	554	596	93	4	62	31	3	1.072	0	0	0	0	40	
MSB076-2	552	591	93	6	88	5	1	1.094	3	0	0	0	24	Uniform sizing
Fontenot	535	569	94	4	61	34	1	1.076	4	0	2	0	40	Skinning; good red color
B0564-9	522	544	96	4	74	22	0	1.077	2	0	1	0	40	Good appearance
B0172-22	519	546	95	3	56	39	2	1.078	17	0	0	0	40	
B0613-2	506	562	90	6	67	23	4	1.072	17	0	0	0	40	
B0178-34	496	531	91	4	67	25	4	1.091	0	0	0	4	40	
E11-45	474	526	90	5	67	23	5	1.064	8	0	3	0	40	Poor ext. app.; prominant lenticels
Snowden	465	522	89	9	81	8	2	1.086	2	0	0	1	35	"The standard"
AC Novachip	458	518	88	3	62	27	8	1.074	8	0	0	1	40	Some flattened tubers
P88-9-8	452	508	89	7	71	18	4	1.073	0	0	3	0	40	Poor appearance; rough, knobby
Steuben	451	501	90	5	60	31	5	1.080	13	0	0	0	40	
Viking	449	483	93	2	58	35	4	1.068	2	0	0	0	40	
B0405-4	431	469	92	5	79	13	3	1.094	3	0	6	0	35	
MSB007-1	428	492	87	8	72	15	5	1.070	0	0	4	0	31	Oblong shape
B0257-9	413	444	93	5	79	14	2	1.081	0	0	0	0	40	
B0493-8	412	464	89	9	71	18	2	1.072	3	0	0	0	20	
MSB073-2	409	449	91	7	84	7	2	1.083	0	0	0	0	22	Some greens
DR Norland	404	434	93	6	91	2	0	1.058	0	0	0	0	8	Variation in red color
B0585-5	404	430	94	4	72	22	2	1.078	2	0	0	0	40	Some growth cracks
FL1625	388	426	91	6	82	9	3	1.087	0	0	0	1	33	
B0257-3	383	431	89	5	76	13	5	1.088	0	0	0	0	40	Some greens
B0257-12	367	484	76	10	69	7	14	1.082	2	0	0	0	25	Some knobs, greens; poor app.
MSA091-1	360	401	90	7	67	22	4	1.083	3	0	2	0	40	Some knobs and greens
B0339-1	355	433	82	17	71	12	1	1.071	20	0	1	0	24	
P83-11-5	351	433	81	11	75	6	8	1.082	2	0	0	0	23	Growth cracks; some shatter and grn
MSB083-1	343	399	86	7	77	9	7	1.073	0	0	5	0	33	Some misshapes
Superior	342	444	77	7	70	7	16	1.072	1	0	0	0	28	
MSB110-3	341	414	83	14	78	5	3	1.083	2	0	1	0	19	
P88-12-4	333	370	89	3	54	35	8	1.077	0	0	0	0	19	Sev. growth cracks; some knobs & grn
MSB095-2	331	385	86	10	71	16	4	1.073	0	0	2	0	40	
P88-13-4	324	421	77	20	72	5	3	1.083	0	0	0	0	21	
P83-6-18	306	402	76	20	75	1	3	1.079	0	0	2	0	5	Some off-types and knobby
MSB106-7	285	333	86	12	67	19	3	1.066	0	0	1	0	40	Long shapes
MSB107-1	268	294	91	8	67	24	1	1.070	0	0	0	0	38	Severe shatter
P84-13-12	262	302	87	10	75	12	3	1.079	2	0	0	0	26	Good appearance; some growth cracks
P84-9-8	240	324	74	21	72	2	5	1.075	0	0	0	0	7	Severe shatter; soft rot
P88-10-7	232	307	76	12	69	7	12	1.074	8	0	0	0	14	Severe skin spotting
MSA199-1	208	218	95	4	59	36	1	1.067	25	0	0	0	40	Purple flesh

[1/] B's - <2"
A's - 2-3¼"
OV - >3¼"
PO - Pick Outs

[2/] HH - Hollow Heart
VD - Vascular Discoloration
IBS - Internal Brown Spot
BC - Brown Center

Table 6.

NORTH CENTRAL REGIONAL TRIAL

MONTCALM RESEARCH FARM

Planted: May 5, 1993 Harvested: September 16, 1993

	cwt/A		Percent Distribution[1]						Int. Quality[2]				Total
Variety	No.1	Total	No.1	B's	A's	OV	PO	S.G.	HH	VD	IBS	BC	Tubers Cut
W1100R	453	551	82	13	80	2	5	1.062	0	0	0	0	12
MN15220	442	538	82	4	50	32	14	1.059	2	0	0	1	38
R. Pontiac	432	498	87	5	56	30	9	1.060	11	0	0	0	40
MN1871-3R	422	474	89	9	76	13	2	1.060	3	2	0	1	39
MN13540	416	465	89	7	74	15	4	1.068	4	0	5	1	40
MN15111	352	411	86	11	79	7	3	1.068	1	0	0	4	22
ND2471-8	351	394	89	9	77	12	2	1.080	13	0	0	1	29
R. Burbank	336	527	64	16	52	12	20	1.077	15	0	0	0	40
W1099	326	414	79	18	68	10	3	1.066	0	0	1	0	30
R. Norkotah	323	397	81	15	58	24	4	1.068	8	0	0	2	40
ND2417-6	300	354	85	11	76	8	4	1.071	1	0	0	1	26
Red Norland	299	339	88	9	81	7	3	1.060	1	0	0	1	19
Norchip	288	356	81	6	66	15	13	1.071	3	2	1	2	38
W84-75R	160	249	64	35	61	4	1	1.062	2	0	0	0	5

[1]Size

B's - <2"
A's - 2-3¼"
OV - >3¼"
PO - Pick outs

[2]Quality

HH - Hollow Heart
VD - Vascular Discoloration
IBS - Internal Brown Spot
BC - Brown Center

Table 7. **UPPER PENINSULA POTATO VARIETY TRIAL**

Mike VanDamme Farm

Planted: May 21, 1993 Harvested: October 6, 1993

	cwt/A		Percent Distribution					
Variety	No. 1	Total	No. 1	<2"	2-3¼"	>3¼"	Pick Outs	S.G.
Prestile	429	463	93	7	74	19	0	1.068
A78242-5	424	440	96	4	71	25	0	1.074
AF1060-2	414	458	91	9	71	20	0	1.066
Goldrush	362	418	86	13	75	11	1	1.070
Russet Norkotah	355	409	87	13	76	11	0	1.065
A84180-8	355	396	90	9	77	13	1	1.073
Ranger Russet	340	408	83	12	72	11	5	1.079
Russet Burbank	307	405	76	9	66	10	15	1.078
W1005	304	399	76	21	75	1	3	1.078
E55-35	304	346	88	12	78	10	0	1.078
W1099	282	363	78	16	71	7	6	1.066
Chaleur	251	286	88	12	73	15	0	1.063
AVERAGE	344	399	86					1.071

Spacing: 12" x 36"

Table 8. **FUSARIUM DRY ROT EVALUATION**

December 20, 1993

Variety	Bud Infection Rating	Variety	Bud Infection Rating
34-6 (2X)	0.2	B0172-15	6.9
Frontier Russet	0.8	T2381	7.0
Russet Norkotah	1.4	T1556	7.1
W887	1.5	B0339-1	7.1
W870	1.8	NY101	7.2
Snowden	2.0	T450	7.2
Superior	2.0	P88-9-8	7.4
T2252	2.1	E55-35	7.4
133-10 (2X)	3.0	189-04 (2X)	7.6
133-143 (2X)	3.0	AF875-15	7.7
P84-13-12	3.5	B0405-4	7.8
MSB007-1	3.6	B0613-2	7.8
B0257-12	3.7	Atlantic	7.8
T1732	3.7	Brodick	7.8
B0257-3	4.0	Novachip	7.8
B0172-22	4.4	Portage	7.8
P88-10-7	4.4	MSB076-2	7.9
B9792-61	4.8	T2253	7.9
W877	4.9	B0564-9	7.9
MSA091-1	5.2	NY84	7.9
FL1625	5.4	133-97 (2X)	8.0
MSB106-7	5.4	MSA199-1	8.1
AF1433-4	5.5	E11-45	8.2
T2146	5.6	Viking	8.3
Prestile	5.7	P84-9-8	8.4
AF8282-5	5.8	MSB073-2	8.4
Snowden	6.0	P88-12-4	8.4
Onaway	6.3	NY95	8.4
P83-11-5	6.4	AF1060-2	8.4
B0178-34	6.4	T1580	8.4
Gemchip	6.7	B0493-8	8.5
P88-13-4	6.7	E55-44	8.7
P83-6-18	6.7	T2377	8.7
Fontenot	6.7	T1984	8.7
B0585-5	6.8	MSB083-1	8.8
T1949	6.8	Steuben	8.8
B0257-9	6.8	Chaleur	8.8
DR Norland	6.9	B095-2	8.9
013-19 (2X)	6.9	MSB110-3	8.9
		FL1533	8.9
		MSB107-1	9.0

Table 9. **1993 SCAB EVALUATION**

MSU Soils Farm
East Lansing, MI

Level of Infection

Lowest			Highest
B0339-1	B0564-9	A78242-5	B0178-34
B0405-4	Chaleur	AF1060-2	B0257-12
B9792-61	E11-45	AF1433-4	B0257-3
DR Norland	E55-35	AF828-5	B0257-9
Goldrush	FL1533	AF875-15	B0493-8
Lemhi Russet	G8610-PY	Amisk	B0585-5
MN13540	Kerry Blue	Atlantic	B0613-2
MSA091-1	MSA199-1	B0172-22	Bintje
ND1871-3	MSB076-2	B0175-20	Blue Mac
NY101	MSB110-3	B0172-15	Gemchip
NY84	ND2417-6	Brigus	Green Mountain
Onaway	Norchip	Brodick	McIntosh Black
P84-13-12	NY95	Desiree	MSB007-1
P88-12-4	P83-11-5	E55-44	P83-6-18
Prestile	P88-13-4	FL1625	
Purple Viking	P88-9-8	MN15111	
Russet Burbank	W1099	MN15220	
Russet Norkotah		MSB073-2	
Superior		MSB083-1	
Viking		MSB095-2	
W1005		MSB106-7	
Yellow Finn		MSB107-1	
		ND2471-8	
		Novachip	
		P84-9-8	
		P88-10-7	
		Portage	
		Ranger Russet	
		Red Gold	
		Rose Gold	
		Russian Blue	
		Steuben	
		W1100R	
		W870	
		W877	
		W887	

Table 10A. **1993 BLACKSPOT SUSCEPTIBILITY STUDY**

A. SIMULATED BRUISE SAMPLES

	No. Spots/Tuber							1993		1992	
Variety	0	1	2	3	4	5+	Total Tubers	% Bruise Free	Ave.[a]	% Bruise Free	Ave.
ADAPTATION											
NY101	24	1					25	96	0.040		
DR Norland	23	2					25	92	0.080		
MSB073-2	21	1	1	1			24	88	0.250	52	0.64
P83-6-18	21	4					25	84	0.160	88	0.16
E11-45	20	4					24	83	0.167	65	0.65
B0257-12	20	4					24	83	0.167		
B0172-22	20	5					25	80	0.200		
P84-13-12	19	5					24	79	0.208	40	0.84
FL1533	19	5					24	79	0.208		
AC Novachip	19	5	1				25	76	0.280		
Fontenot	18	5		1			24	75	0.333	80	0.32
B0257-9	18	4	2	1			25	72	0.440		
Superior	18	7					25	72	0.280	100	0.00
P88-10-7	17	7					24	71	0.292		
Viking	17	7					24	71	0.292	78	0.30
B0585-5	17	7	1				25	68	0.360		
B0613-2	17	7	1				25	68	0.360		
MSB106-7	16	6	2				24	67	0.417		
P88-12-4	16	7	1				24	67	0.375		
Steuben	16	4	4	1			25	64	0.600	32	1.44
MSB095-2	15	7	3				25	60	0.520	72	0.60
P84-9-8	13	8	2				23	57	0.522	24	1.84
P83-11-05	14	4	3	4			25	56	0.880	24	1.52
MSB107-1	13	5	5	1			24	54	0.750		
MSB083-1	13	8	3	1			25	52	0.680	56	0.56
Snowden	13	9	3				25	52	0.600	24	1.20
P88-9-8	12	7	2	2		1	24	50	0.917		
Brodick	12	11	1				24	50	0.542		
B0564-9	12	10	2			1	25	48	0.760		
P88-13-4	12	7	6				25	48	0.760		
MSB076-2	12	12	1				25	48	0.560	52	0.64
B0257-3	11	7	2	4	1		25	44	1.080		
B0493-8	10	10	5				25	40	0.800		
MSA091-1	8	5	9	3			25	32	1.280	48	0.80
MSB007-1	7	7	6	3	1		24	29	1.333	48	0.76
B0405-4	6	5	3	5	3	3	25	24	2.120		
B0339-1	4	8	8	4			24	17	1.500		
B0178-34	4	1	7	7	2	4	25	16	2.560		
MSB110-3	4	6	8	6	1		25	16	1.760	24	1.32
FL1625	3	5	9	4	3	1	25	12	2.080		

[a]Average number of bruises/tuber.

Table 10A (continued).

Variety	No. Spots/Tuber 0	1	2	3	4	5+	Total Tubers	1993 % Bruise Free	1993 Ave.[a]	1992 % Bruise Free	1992 Ave.
DATES OF HARVEST - ROUND WHITES											
Chaleur	13	5	3				21	62	0.524	100	0.00
AF1433-4	14	8	3				25	56	0.560		
E55-44	12	5	4	4			25	48	1.000	96	0.04
Portage	11	7	6	1			25	44	0.880	84	0.24
AF828-5	11	10	2	2			25	44	0.800		
Onaway	10	9	3	1	2		25	40	1.040	84	0.20
B0175-20	10	8	5	1	1		25	40	1.000		
Gemchip	9	6	6	3		1	25	36	1.280	68	0.60
NY84	9	8	3	3	2		25	36	1.240	44	0.88
B0172-15	7	8	4	1	1		21	33	1.095		
AF1060-2	8	8	5	3	1		25	32	1.240	64	0.64
Prestile	8	11	5	1			25	32	0.960	88	0.16
E55-35	7	6	7	2	1	2	25	28	1.600	80	0.20
Atlantic	6	4	6	4	4	1	25	24	1.960	48	1.00
B9792-61	6	5	10	3	1		25	24	1.520		
Superior	6	8	7	4			25	24	1.360	100	0.00
W877	5	6	8	5		1	25	20	1.680	52	0.64
AF875-15	5	8	9	3			25	20	1.400		
Snowden	5	12	6	2			25	20	1.200	48	0.78
W870	4	6	8	1	3	3	25	16	2.080	68	0.36
NY95	3	3	4	7	4		21	14	2.286		
W887	3	6	6	7	2	1	25	12	2.080	63	0.54
DATES OF HARVEST - LONGS											
A78242-5	14	5	4	1			24	58	0.667		
W1099	14	8	2				24	58	0.500		
R Norkotah	11	5	5	1	1		23	48	0.957		
A84180-8	8	9	5	2			24	33	1.042		
Goldrush	7	7	6	4			24	29	1.292		
Ranger R	6	6	3	5	4		24	25	1.792		
RB	4	11	7	1	2		25	16	1.440		
Amisk	3	5	6	7	2	2	25	12	2.240		
W1005	2	5	2	7	4	5	25	8	2.840		

[a]Average number of bruises/tuber.

Table 10B.

B. CHECK SAMPLES

Variety	No. Spots/Tuber 0	1	2	3	4	5+	Total Tubers	1993 % Bruise Free	1993 Ave.[a]	1992 % Bruise Free	1992 Ave.
ADAPTATION											
AC Novachip	23	2					25	92	0.080		
B0172-22	23	2					25	92	0.080		
B0178-34	8	6	9	1	1		25	32	1.240		
B0257-12	25						25	100	0.000		
B0257-3	18	7					25	72	0.280		
B0257-9	25						25	100	0.000		
B0339-1	22	1	1				24	92	0.125		
B0405-4	15	7	2				24	63	0.458		
B0493-8	21	4					25	84	0.160		
B0564-9	20	5					25	80	0.200		
B0585-5	24	1					25	96	0.040		
B0613-2	21	4					25	84	0.160		
Brodick	23	1					24	96	0.042		
DR Norland	24	1					25	96	0.040		
E11-45	22	2					24	92	0.083		
FL1533	24						24	100	0.000		
FL1625	24	1					25	96	0.040		
Fontenot	23	1					24	96	0.042		
MSA091-1	24						24	100	0.000		
MSB007-1	21	3					24	88	0.125		
MSB073-2	24						24	100	0.000		
MSB076-2	23	2					25	92	0.080		
MSB083-1	23	2					25	92	0.080		
MSB095-2	25						25	100	0.000		
MSB106-7	22	3					25	88	0.120		
MSB107-1	23	1					24	96	0.042		
MSB110-3	22	3					25	88	0.120		
NY101	24	1					25	96	0.040		
P83-11-5	25						25	100	0.000		
P83-6-18	25						25	100	0.000		
P84-13-12	23	1					24	96	0.042		
P84-9-8	24	1					25	96	0.040		
P88-10-7	22	2					24	92	0.083		
P88-12-4	21						21	100	0.000		
P88-13-4	22	3					25	88	0.120		
P88-9-8	24	1					25	96	0.040		
Snowden	24	1					25	96	0.040		
Steuben	23	2					25	92	0.080		
Superior	17	7	1				25	68	0.360		
Viking	24						24	100	0.000		

[a]Average number of bruises/tuber.

Table 10B (continued).

Variety	No. Spots/Tuber 0	1	2	3	4	5+	Total Tubers	1993 % Bruise Free	1993 Ave.[a]	1992 % Bruise Free	1992 Ave.
DATES OF HARVEST - ROUND WHITES											
AF1060-2	22	3					25	88	0.120		
AF1433-4	24	1					25	96	0.040		
AF828-5	24	1					25	96	0.040		
AF875-15	23	2					25	92	0.080		
Atlantic	18	7					25	72	0.280		
B0172-15	20	3					23	87	0.130		
B0175-20	20	4	1				25	80	0.240		
B9792-61	21	3	1				25	84	0.200		
Chaleur	21	0					21	100	0.000		
E55-35	21	4					25	84	0.160		
E55-44	21	4					25	84	0.160		
Gemchip	22	3					25	88	0.120		
NY84	22	3					25	88	0.120		
NY95	20	1	1				22	91	0.136		
Onaway	25						25	100	0.000		
Portage	22	3					25	88	0.120		
Prestile	22	3					25	88	0.120		
Snowden	24	1					25	96	0.040		
Superior	21	4					25	84	0.160		
W870	20	4	1				25	80	0.240		
W877	23	1	1				25	92	0.120		
W887	23	2					25	92	0.080		
DATES OF HARVEST - LONGS											
A78242-5	23	1					24	96	0.042		
A84180-8	24	1					25	96	0.040		
Amisk	15	6	3	1	0		25	60	0.600		
Goldrush	22	1					23	96	0.043		
R Norkotah	22	2					24	92	0.083		
Ranger R	13	8	2	1			24	54	0.625		
RB	18	6					24	75	0.250		
W1005	11	8	5				24	46	0.750		
W1099	22	2					24	92	0.083		

[a]Average number of bruises/tuber.

Funding: Federal Grant

FRESHPACK VARIETY TRIALS

R.W. Chase, CSS; Mike Staton, Bay County EAA;
Paul Marks, Monroe County EAA; Don Smucker, Montcalm CED
and Dick Long, Presque Isle CED

Introduction

Grower-cooperator potato variety trials for the fresh market of advanced seedlings and varieties which were initiated in 1991 were continued in 1992 and 1993. The objective is to identify the most promising varieties which would enhance the Michigan tablestock industry. Entries are selected from round-white, long russets and red skin tuber types. Michigan has increased its market share of long russets since Russet Norkotah was released and now Goldrush offers another choice.

Procedure

The grower-cooperators are: Styma Farms in Presque Isle County, Pleasant Valley Farms in Montcalm County, Duyck Farms in Bay County and Smith Bros. Farm in Monroe County. The varieties evaluated in 1993 were Gemchip, Prestile, E55-44, Chaleur, Steuben, Ranger Russet, Dark Red Norland, W1005 and Goldrush. Onaway, Superior and Russet Norkotah were included as standards. At the Montcalm County location, Portage, AF1060-2 and St. Johns were also included.

Fifty pound samples of each entry were provided to each grower for planting in single rows. Observations on emergence, stand and growth were noted. At harvest, yields, size distribution, specific gravity, internal and external defects were recorded.

Results

Table 1 summarizes the average results from the four locations and Tables 2-5 are the results at each location. The plots in Presque Isle County were planted late and did not receive irrigation. The plots in Monroe County were irrigated twice and a dry season after June did reduce yield potential. At the Bay County location, the later maturing varieties of Gemchip, W1005 and Steuben showed early senescence.

<u>Gemchip</u> has been evaluated three years and has a high yield potential. It is late maturing with good general appearance, an oval tuber shape and frequently has lenticel spotting. It appears to have Verticillium tolerance, however, it is susceptible to scab and hollow heart.

<u>Prestile</u> is a late maturing and high yielding variety from Maine. It has good general appearance and minimal internal defects.

<u>E55-44</u>, from New York, has maturity and specific gravity similar to Superior. It emerges quickly and has vigorous early growth. At the Montcalm location it had 23% hollow heart in tubers larger than 3¼". The specific gravity is below 1.080, however, it does produce an acceptable chip color.

AC Chaleur is an early maturing variety from New Brunswick, Canada. It has excellent general appearance, shallow eyes and a bright skin color and white flesh. Yields are average and usually below Onaway.

Steuben has been evaluated for three years. It is late maturing, high yielding and sets and sizes tubers early so a close spacing is desired. Tuber appearance is good, however, hollow heart can be a problem in large tubers. It is susceptible to bruise damage which may relate to its late maturity.

Ranger Russet is a late maturing long russet with higher specific gravity and a higher percentage of U.S. No. 1's than Russet Burbank. It also has less internal defects, however, it is very susceptible to bruise damage, including blackspot. It is susceptible to surface scab. Flesh color after cooking is not as white as Russet Burbank.

W1005 is a long russet seedling from Wisconsin. It is late maturing and has a high specific gravity. At the Montcalm location, it had over 50% hollow heart in the over 10 ounce potatoes. Tuber shape is generally not as full and blocky as Russet Norkotah.

Goldrush is a recent release from North Dakota. It is very similar to Russet Norkotah in maturity, specific gravity and yields. It is reported to have more tolerance to scab and Verticillium wilt and it is a whiter flesh after cooking. It also has less internal defects, particularly hollow heart, than does Russet Norkotah.

The varieties planned for 1994 are Prestile, E55-44, Chaleur, Ranger Russet, Goldrush, AF1060-2, NY101, St. Johns and NY84. The standards will continue to be Onaway, Superior and Russet Norkotah.

Table 1. 1993 Freshpack Potato Variety Trial. Four Location Average.

Variety	cwt/A		% Size Distribution						3 Yr. Ave.	
	No. 1	Total	No. 1	<2"	2-3¼"	>3¼"	Pick Outs	S.G.	No. 1/ Total	S.G.
Gemchip[1]	369	403	92	9	79	11	1	1.062	361/413	1.068
Prestile	296	324	91	9	79	12	2	1.076	---	
E55-44	282	321	88	11	76	12	1	1.078	310/350	1.078[3]
Onaway	275	323	85	11	69	16	4	1.070	352/396	1.071
Chaleur	268	292	92	8	80	12	0	1.070	---	
Steuben	236	267	88	10	76	12	2	1.072	342/372	1.076
Ranger Russet	226	287	79	13	66	13	8	1.081	315/378	1.084[3]
Superior	231	282	82	17	79	3	1	1.074	248/284	1.072
D.R. Norland[2]	226	277	82	16	82	0	2	1.061	263/316	1.061[3]
Russet Norkotah	214	290	74	22	67	7	4	1.068	250/326	1.071[3]
W1005	207	311	67	30	66	1	3	1.077	---	
Goldrush	204	280	73	23	71	2	4	1.069	262/341	1.070[3]
AVERAGE	253	305	83					1.072		

[1] Two locations.

[2] Three locations.

[3] Two year average.

Table 2. 1993 Monroe County Freshpack Trial, Smith Bros. Farm.

Variety	cwt/A No. 1	cwt/A Total	% Size Distribution No. 1	<2"	2-3¼"	>3¼"	Pick Outs	S.G.	Scab
W1005	255	311	82	10	82	0	8	1.079	0
Prestile	229	246	93	5	89	4	2	1.073	0
Onaway	228	259	88	8	82	6	4	1.070	0
Goldrush	227	284	80	16	80	0	4	1.068	0
Russet Norkotah	197	246	80	16	80	0	4	1.066	0
E55-44	184	227	82	17	82	0	2	1.079	0
Chaleur	180	194	91	6	82	9	3	1.069	1
Steuben	176	207	85	8	80	5	7	1.075	1
Ranger Russet	155	225	79	13	79	0	18	1.078	1
Superior	122	170	72	26	72	0	2	1.071	1
AVERAGE	195	237	82					1.073	

Harvest: October 15, 1993.

Scab rating: 0 - none, 1 - detected, 2 - serious.

Table 3. 1993 Bay County Freshpack Trial, Duyck Farm.

Variety	cwt/A No. 1	cwt/A Total	% Size Distribution No. 1	<2"	2-3¼"	>3¼"	Pick Outs	S.G.	
Chaleur	323	346	94	5	82	12	1	1.070	Tr. Gr. Crack
E55-44	290	336	86	14	81	5	0	1.074	
Superior	280	323	87	12	84	2	2	1.074	
Onaway	271	320	85	14	84	1	1	1.068	
Prestile	265	297	89	11	79	10	0	1.069	
Ranger Russet	225	280	80	18	64	16	2	1.079	Cons. scab
R. Norkotah	222	309	72	28	70	2	0	1.070	
Goldrush	219	335	65	29	62	3	6	1.066	
D.R. Norland	203	268	76	24	76	0	0	1.056	Greening
Gemchip	196	229	86	14	81	5	0	1.054	Sev. scab
W1005	178	355	50	48	50	0	2	1.070	Scab
Steuben	170	200	85	13	78	7	2	1.066	Tr. vas. dis.
AVERAGE	237	300	73						

Harvested: September 10, 1993.

Table 4. 1993 Montcalm County Freshpack Trial, Dan Evans Farm.

	cwt/A		% Size Distribution							
Variety	No. 1	Total	No. 1	<2"	2-3¼"	>3¼"	Pick Outs	S.G.	HH*	
Gemchip	541	577	94	5	77	17	1	1.070	6/30	
Prestile	468	484	97	3	72	25	0	1.076		Tr. IBS Brown center Vas. dis.
E55-44	442	462	96	3	65	31	1	1.079	7/30	
Portage	395	440	90	8	73	17	2	1.070		Tr. scab IBS
Chaleur	380	406	93	7	79	14	0	1.069	1/30	
Onaway	355	420	84	5	56	28	11	1.071		
Steuben	355	392	90	7	70	20	3	1.067	13/30	
AF1060-2	352	401	88	9	84	4	3	1.069		
Superior	333	397	84	9	81	3	7	1.075		
AF828-5 (St. Johns)	330	346	96	4	80	16	0	1.067		Tr. vas. dis Brown center Scab
Ranger Russet	313	398	78	7	49	29	15	1.082	3/30	
Russet Norkotah	276	363	76	12	51	25	12	1.063	15/30	
Dark Red Norland	273	330	88	11	84	4	9	1.061	2/30	
Goldrush	181	236	77	21	72	5	2	1.064	3/30	Tr. vas. dis
W1005	175	273	64	33	61	3	3	1.077	16/30	
AVERAGE	345	395	87					1.071		

*Number tubers with hollow heart/number of large tubers cut.

Planted: May 14, 1993.

Harvested: September 16, 1993.

Table 5. 1993 Presque Isle County Freshpack Trial, Randy Styma Farm.

	cwt/A		% Size Distribution					
Variety	No. 1	Total	No. 1	<2"	2-3¼"	>3¼"	Pick Outs	S.G.
Onaway	245	293	84	15	58	26	1	1.070
Steuben	241	270	89	11	74	15	0	1.078
W1005	222	305	73	27	73	0	0	1.082
Prestile	222	267	83	15	75	8	2	1.077
E55-44	213	257	83	16	76	7	1	1.079
Ranger Russet	209	245	85	14	72	13	1	1.084
D.R. Norland	203	232	88	12	88	0	0	1.065
Superior	191	238	80	20	79	1	0	1.077
Goldrush	189	265	71	27	69	2	2	1.077
Chaleur	189	223	85	14	78	7	1	1.070
Russet Norkotah	162	242	67	33	67	0	0	1.072
AVERAGE	207	258	80					1.075

Planted: June 1, 1993.

Harvested: September 16, 1993 (Norland, Onaway, Superior and Chaleur).
October 2, 1993 (others).

Funding: Federal Grant

MANAGEMENT PROFILE STUDIES OF RANGER RUSSET, GEMCHIP AND E55-35

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Introduction

Management profile studies have been conducted on selected varieties and advanced seedlings since 1986 in order to evaluate the effect of plant spacings and nitrogen levels. In 1993, second year trials were conducted with Ranger Russet, Gemchip and E55-35.

Procedure

Three levels of nitrogen (100, 150 and 200 lbs/A) and three in-row spacings (6, 9 and 12 inches) were studied with Gemchip and E55-35. For Ranger Russet, spacings of 9, 12 and 15 inches were evaluated with nitrogen levels of 150, 200 and 250 lbs/A. All three cultivars were hand planted with cut seed on May 5, 1993. Plowdown soybeans were grown in 1992, disked in the fall and seeded to winter rye at 1½ bu/A. In November 1992, the area was fumigated with a field application using Vapam at 50 gpa.

Before plowing in the spring of 1993, 0-0-60 at 300 lbs/A was broadcast. In the planter, 400 lbs/A of 20-10-10 was applied. All subsequent applications were applied by hand on May 25, June 24 and July 7 until the total level for each main plot had been reached.

Each variety was a separate study in a randomized split plot design with four replications. The main plot was the nitrogen level and the sub plot consisted of the three plant spacings, each planted in a single row of 23 feet. Two border rows were planted between each plot with one row fertilized the same as the adjacent plot.

Fresh petiole samples were collected from Ranger Russet on June 29, July 6, July 13, July 20, July 27 and August 10 and tested for nitrate levels using the Petiole Sap Test developed by Dr. Vitosh.

Results

E55-35

In 1993, the greatest yields were obtained at the closer spacings and at the lower levels of N (Tables 1 and 2). There was no benefit from the higher levels of N and this may be due to the lack of adequate allowance for the contribution of N from the plowdown soybeans. The use of fumigation may also have reduced the response to higher N rates.

In 1992, when the plot area was not fumigated, there was an increase of 25 cwt/A at the 200 lbs/A rate vs. the 100 lb/A rate, however, it was not significant. Average yields in 1993 were 44% higher than in 1992. The greatest yield was obtained at the 6" spacing which was 16% higher than the 9" or 12" spacing. In both years, the production of tubers over 3¼" was very small.

E55-35 continues to show good tolerance to scab. It also has shown very minimal internal and external defects and chip color has been very good. Based on these two year results, it appears that E55-35 has an average yield potential and optimum yields are obtained at a close plant spacing at nitrogen levels of 150-170 lbs/A. Bruise free potatoes averaged 87% from the check samples compared with 57% from those receiving the simulated bruise.

Gemchip

In 1993, the greatest yields were obtained at the closer spacings and at the lower levels of N (Table 3). Results were very similar to E55-35 except that Gemchip has a higher yield potential. Average 1993 yields were 32% higher in 1993 when compared with 1992. There was a slight increase in yield (25 cwt/A) from 150 lbs/A vs. 100 lbs/A of N in 1992, however, the greatest response was from a closer spacing. No. 1 yields were 39% higher at 6" spacing vs. 12" and 12% higher than that at 9".

Table 4 summarizes the combined data from 1992 and 1993. When spacings are disregarded, there was no response to increased N levels in terms of yields or size distribution. When nitrogen levels are disregarded, there was a significant yield increase with a closer spacing. For Gemchip, a plant spacing between 6 and 9 inches is optimum. For nitrogen, it appears that a rate of 150-170 lbs of N/A is adequate. Bruise free potatoes averaged 88% for the check samples and 56% for those receiving the simulated bruise.

Ranger Russet

In 1993 the highest yields were recorded from the closer spacings, however, no effect was noted on the size distribution (Table 5). The percentage of tubers over 10 ounces ranged from 31 to 43. Hollow heart incidence was greatest at the 12 and 15 inch spacings. There was no advantage to the increased levels of N.

Petiole samples were collected at six stages of growth for the sap nitrate test (Figure 1). These data indicate that nitrate levels were above the threshold value throughout the season. This is consistent with the lack of a yield response from the increased N rates.

Average yields in 1993 were 12% higher than 1993. Similar to E55-35 and Gemchip, the two year summary shows no response to N rates (Table 6). The response to spacings had little impact on U.S. No. 1 yields and no effect on size distribution. It would appear that a spacing of 10-12 inch is satisfactory. When the contribution of N from the plowdown soybeans is taken into consideration, it would appear that 200 lbs N/A would be sufficient.

Table 1. 1993 Yields, Size Distribution and Quality of E55-35 Management Profile Study.

Treatment		cwt/A		% Size Distribution[1/]						Internal Quality[2/]				
Lbs N	Sp	No. 1	Total	U.S. #1	B's	A's	OV	PO	SG	HH	VD	IBS	BC	Total Tubers Cut
100	6	379	465	82	17	79	3	1	1.090	0	1	3	0	11
100	12	359	413	87	13	82	5	0	1.089	0	0	4	0	19
200	6	351	441	80	20	77	3	1	1.083	0	0	1	0	11
150	6	342	441	77	22	76	1	1	1.086	0	0	0	0	5
100	9	341	422	81	19	80	1	0	1.087	0	0	2	0	7
150	9	329	402	82	18	81	1	0	1.083	0	0	0	0	4
200	9	324	410	79	21	77	2	0	1.084	0	0	2	0	6
200	12	324	388	83	16	80	4	1	1.082	0	0	0	0	13
150	12	308	361	85	14	80	5	1	1.083	0	1	1	0	17

[1/] B's = <2"
A's = 2-3¼"
OV = >3¼"
PO = pick outs

[2/] HH = hollow heart
VD = vascular discoloration
IBS = internal brown spot
BC = brown center

Table 2. Two Year Summary of Effects of N Rates and Spacings on the Yield, Size Distribution and Specific Gravity of E55-35.

		cwt/A		% Size Distribution					
Lbs N	Sp	No. 1	Total	No. 1	<2"	2-3¼"	>3¼"	PO	SG
100	-	289	344	84	15	81	3	0	1.088
200	-	278	331	84	14	81	3	1	1.087
300	-	289	343	84	14	80	6	1	1.087
-	6	309	375	83	16	80	3	1	1.088
-	9	275	330	83	15	81	6	1	1.087
-	12	272	312	87	12	81	7	1	1.087

Table 3. 1993 Yields, Size Distribution and Quality of Gemchip Management Profile Study.

Treatment		cwt/A		% Size Distribution[1]						Internal Quality[2]				
Lbs N	Sp	No. 1	Total	No. 1	B's	A's	OV	PO	SG	HH	VD	IBS	BC	Total Tubers Cut
100	6	506	572	88	9	81	7	3	1.069	7	0	0	0	29
150	6	414	478	87	9	79	8	5	1.067	7	0	0	0	28
150	9	412	458	90	8	78	12	2	1.067	8	0	0	0	35
200	6	409	466	88	11	85	3	1	1.070	6	0	0	0	11
100	9	383	435	88	9	80	8	2	1.069	7	0	0	1	20
200	9	376	417	90	9	81	9	1	1.066	7	0	0	0	22
100	12	375	419	90	6	77	12	4	1.069	10	0	1	0	33
200	12	336	374	90	8	80	10	2	1.066	8	0	0	0	28
150	12	332	367	90	7	81	9	2	1.066	6	0	0	0	27

[1] B's = <2"
A's = 2-3¼"
OV = >3¼"
PO = pick outs

[2] HH = hollow heart
VD = vascular discoloration
IBS = internal brown spot
BC = brown center

Table 4. Two Year Summary of Effects of N Rates and Spacings on the Yield, Size Distribution and Specific Gravity of Gemchip.

		cwt/A		% Size Distribution				
Lbs N	Sp	No. 1	Total	No. 1	<2"	2-3¼"	>3¼"	PO	SG
100	-	352	400	87	8	77	10	3	1.077
150	-	347	389	89	7	80	9	3	1.075
200	-	338	378	89	8	81	9	2	1.076
-	6	393	446	88	9	80	8	3	1.076
-	9	348	389	89	8	79	10	2	1.076
-	12	297	332	89	7	78	11	3	1.075

Table 5. 1993 Yields, Size Distribution and Quality of Ranger Russet Management Profile Study.

Treatment		cwt/A		% Size Distribution[1/]						Internal Quality[2/]				
Lbs N	Sp	No. 1	Total	No. 1	B's	A's	OV	PO	SG	HH	VD	IBS	BC	Total Tubers Cut
150	12	335	390	86	7	48	38	8	1.084	8	2	0	1	40
150	9	319	386	83	9	47	36	8	1.082	5	2	0	0	40
200	9	299	344	87	10	49	38	4	1.084	2	0	0	0	40
200	12	292	353	83	11	49	34	7	1.081	3	1	1	0	40
250	9	291	336	86	10	52	34	4	1.081	2	0	0	0	40
150	15	289	337	86	7	47	39	7	1.082	6	1	0	0	40
250	12	283	335	84	11	53	31	5	1.080	3	0	0	1	40
250	15	266	305	87	7	44	43	6	1.083	6	0	1	1	40
200	15	259	312	83	9	44	39	8	1.082	1	1	0	0	40

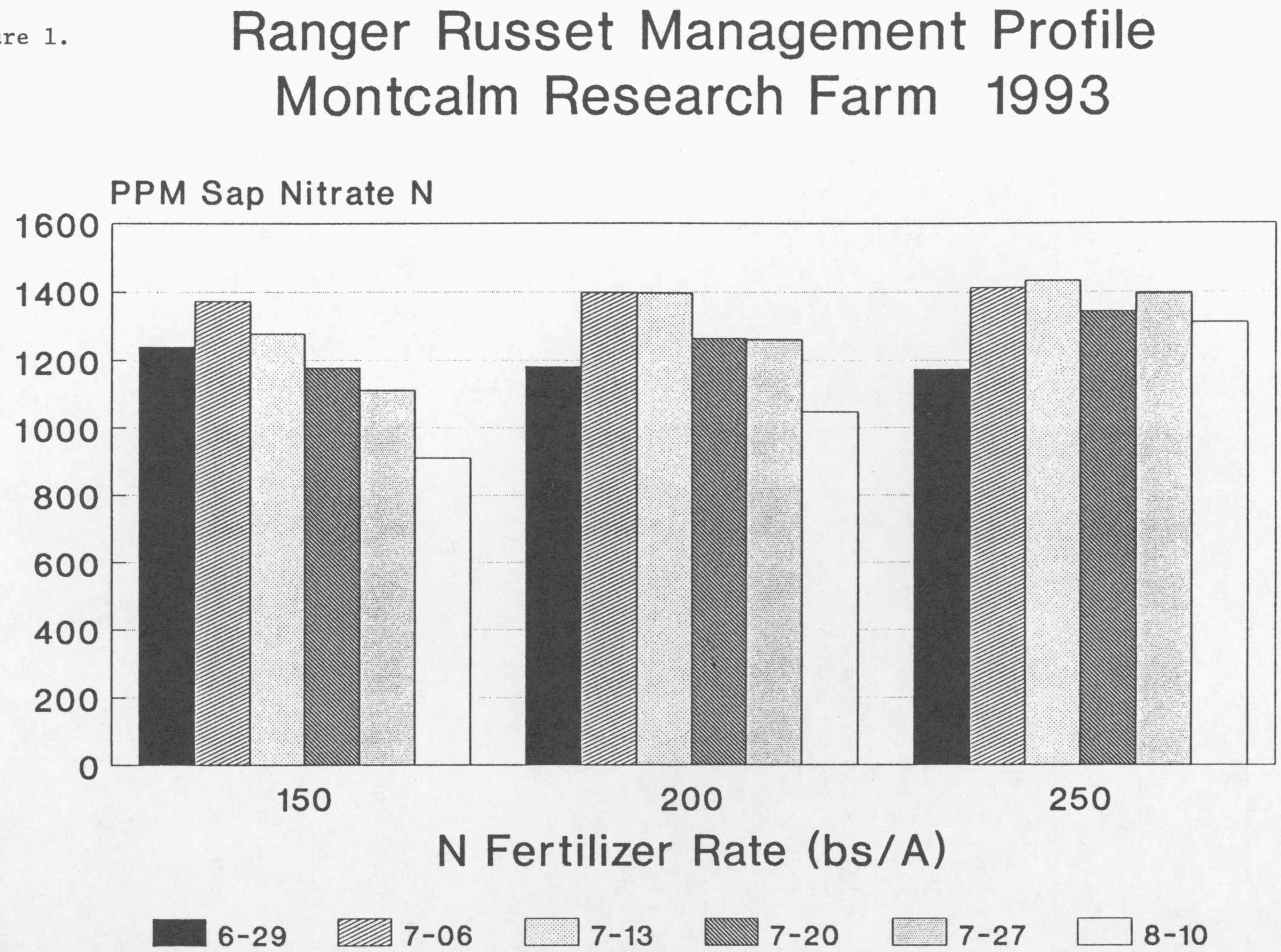
[1/]B's = <4 oz.
A's = 4-10 oz.
OV = >10 oz.
PO = pick outs

[2/]HH = hollow heart
VD = vascular discoloration
IBS = internal brown spot
BC = brown center

Table 6. Two Year Summary of Effects of N Rates and Spacings on Yield Size Distribution and Specific Gravity of Ranger Russet.

		cwt/A		% Size Distribution					
Lbs N	Sp	No. 1	Total	No. 1	<4 oz.	4-10 oz.	>10 oz.	PO	SG
150	-	285	348	82	10	51	31	8	1.086
200	-	280	335	83	10	49	34	7	1.084
250	-	267	321	83	11	49	33	7	1.084
-	9	290	350	83	11	53	30	6	1.085
-	12	278	340	82	11	49	32	7	1.084
-	15	264	315	84	9	46	36	7	1.085

Figure 1.



Date Sampled

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.

Procedure

In the spring of 1991, greenhouse tubers, year 1 and year 2 seed were obtained for Atlantic and Snowden. The seed was grown at the Lake City Research 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, warmed, cut and hand planted on May 6, 1992. Each variety was planted as a separate, randomized complete block with six replications. Each plot was 23 feet in length.

New greenhouse tubers of Atlantic and Snowden were obtained in 1992 and were increased at the Lake City Research Station. Seed of nuclear and GI were retained from the 1991 increase and was again increased in 1992. The seed was stored at 40°, removed, warmed, cut and hand planted on May 5, 1993. Each variety was planted as a separate, randomized complete block with six replications. The Atlantic's were harvested on September 17 and the Snowden's on September 21.

Results

Visual observations of the plantings in both 1992 and 1993 showed no marked differences in stand or vigor. There was no evidence of any visual disease symptoms during the growing season.

The yields and size distribution results are presented in Table 1. For Atlantic, when the two years were averaged, the yield from nuclear planted seed was 13% higher than either Gen I or Gen II. In 1992, there was a trend for reduced yield from the seed classes which were grown longer from the greenhouse tubers. In 1993, the Gen II seed produced higher yields than from Gen I seed, however, nuclear seed produced the highest yields.

For Snowden, the yield differences are more subtle. The differences in both 1992 and 1993 are not significant. As noted with Atlantic, the nuclear planted seed produced the highest yields, however, the difference is very small.

Seed of both varieties increased at the Lake City Research Station in 1993 will be planted at the Montcalm Research Farm in 1994.

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
Average		447	473	321	380
Gen I	1992	395	408	198	261
	1993	399	432	418	464
Average		397	420	308	363
Gen II	1992	366	386	193	253
	1993	425	448	415	451
Average		396	417	304	352

Funding: Fed. Grant/MPIC

Fusarium Dry Rot Research

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Dry rot, caused by *Fusarium sambucinum*, is a major problem in storage of tubers and as a cause of seed piece decay. A major part of the increase in severity of this disease is the appearance of resistance to the fungicide thiabendazole (TBZ). The research reported here is part of an attempt to understand this disease and to find new control measures.

Procedures

Controlled storage: Samples of Snowden potatoes were obtained at regular intervals from Dr. Roger Brook during the storage season. Tubers were evaluated for changes in resistance to *Fusarium* over time by inoculating small wound sites with a plug of agar containing the pathogen. Tubers were assessed for disease by measuring the width and depth of lesions at one month after inoculation.

Effects of chemical treatments on resistance: Several chemicals were tested to see if they would enhance the resistance of injured potato tuber tissue to infection by Fusarium. Treatments were applied to the cut surfaces of tubers and then the tuber tissue was inoculated with Fusarium. The amount of disease was recorded over time as described above. In addition to these tests, whole plants were sprayed with the resistance activating compound 2,6-dichloroisonicotinic acid. Atlantic and Snowden potato plants were sprayed four times with 50ppm of the compound starting at flowering. Tubers were tested for increased resistance by inoculation as described above.

Effects of natural volatiles on Fusarium growth: Several natural volatile chemicals were tested for their effect on the growth of Fusarium in culture. In this set of experiments, cultures of F. sambucinum were exposed to the chemicals in closed containers. The amount of growth was recorded and compared to the controls. Whole tubers were also exposed to the volatiles after inoculation of wound sites with plugs of agar containing *F. sambucinum.* Amount of disease was assessed visually. In these experiments, the tubers were exposed to the volatiles for only 3 days.

Fungicide resistance in *Fusarium sambucinum*: Samples of infected tubers were collected from various locations around the state. *F. sambucinum* was isolated from the tissue and assayed for resistance on potato dextrose agar amended with TBZ or thiophante methyl. In other experiments, TBZ resistant isolates were tested for resistance to other seed treatments, captan or M-45.

Wound reactions and resistance: Wounds are the primary means of entry for *F. sambucinum* into potato tuber tissue. The effects of time after wounding and the accumulation of antifungal compounds were assessed. Tuber tissue slices were prepared and allowed to heal at room temperature at high humidity. At intervals, the slices were inoculated with *F. sambucinum*. In some cases, the tuber tissues were re-wounded prior to inoculation. The accumulation of the steroid glycoalkaloids α-chaconine and α-solanine were also measured in wounded tissue and in tissues after inoculation with *F. sambucinum*. Since the SGAs have been reported to be toxic to other fungi, the activity of these compounds against *F. sambucinum* were tested.

Infection process: The process of infection by *F. sambucinum* was studied using light, scanning and transmission electronmicroscopy.

Results

Controlled storage: The level of susceptibility of Snowden potatoes stores in the three controlled environment bins was monitored twice a month. Of the three bins, Bin 0 exhibited the higher degree of rot than the other two bins. Over the time of the experiment, which was not as long as in previous years, only a small increase in susceptibility was observed (Table 1).

Chemical induction of resistance: Several types of chemical treatments were evaluated to see what effect they would have on the resistance of tubers to infection by *F. sambucinum*. Of the chemicals tested, arachidonic acid and chitosan both reduced the level of infection into the tubers. Jasmonic acid and salicylic acid had no effect. Foliar application of INA had a small effect in reducing dry rot infection.

Effects of volatiles on Fusarium and infection: In agreement with last year's results, only benzaldehyde exhibited any fungitoxicity. In whole tuber tests, some control of the disease was also noted. However, some phytotoxicity was also seen. Further time course/exposure studies are needed to evaluate the use of these materials as control agents.

Fungicide resistance: Samples of *F. sambucinum* were collected from several locations in Michigan. Isolates of the fungus that were resistant to TBZ were found in all locations sampled. In some cases, only resistant isolated were found. The tests showed that the resistant strains were capable of growth at 50ppm TBZ, while the sensitive isolates were inhibited at below 1 ppm. Since thiophanate methyl (TM), the active ingredient in many seed treatments, breaks down to the same active ingredient as in TBZ, all of the isolates were tested for resistance to TM. All TBZ resistant isolates were resistant to TM. A selected group of TBZ/TM resistant isolates were tested for resistance to mancozeb and captan. All isolates that were tested exhibited sensitivity to these compounds.

Wound responses: Suberization of wounded tissues results in the formation of a barrier that resists infection by *Fusarium*. We previously learned that this barrier can be effective with as little as two to three days of wound healing at 72F. In this work we examined the effect of introducing a second wound into a wound that had healed for one to three days. The second wound was a 2mm wedge cut into the surface of the tuber. Surprisingly, the resistance was expressed in the tuber even below the tuber surface (Table 2). Because wounded tubers accumulate SGAs at the wound site and SGAs are toxic to some fungi, we assessed the ability of tuber tissues to produce SGAs after wounding or wounding plus infection and determined the toxicity of the SGAs to *F. sambucinum*. Combinations of the two SGAs were found to be more toxic than either compound alone (Table 3). The concentration of the compounds that accumulate in the wound response tissues were nearly sufficient to inhibit the pathogen in vitro (figure 1). In infected tissue, however, the pathogen appeared to suppress the accumulation of SGAs (Figure 1). Thus, one mode of pathogenesis by this fungus may be through inhibiting the synthesis of SGAs.

Infection process: Microscopy revealed that *F. sambucinum* was readily able to penetrate into tuber tissue. Infect was established within 12 hours of inoculation. Histochemical tests showed that any cell wall barriers that formed occurred too late to be of use in blacking fungal development. It appears as if the pathogen is very capable of using enzymes to breakdown host cell walls and gain entry into the tissue in that way. In vitro assays confirmed the ability of *F. sambucinum* to produce cell wall degrading enzymes.

TABLE 1
Fusarium Dry Rot Susceptibility of Stored Snowden Tubers

LESION AREA (mm^2)

Date	Bin 0	Bin 1	Bin 2
4 Oct 92	102	85	52
30 Oct 92	90	60	64
11 Nov 92	100	68	96
25 Nov 92	140	72	84
8 Dec 92	230	140	147
22 Dec 92	176	102	126
5 Jan 93	168	90	90
19 Jan 93	250	152	148
19 Feb 93	266	204	140

Table 2
Effect of Wounding Healing Tuber Tissue on Infection

Time of Healing	Healing alone	Healing Surface Re-wounded[1]
0 hours	Severe infection	Severe infection
24 hours	Mild infection	Mild infection
48 hours	No infection	No infection
72 hours	No infection	No infection

[1]Tuber tissue surface wounded to a depth of 2mm (deeper than any barriers that would have formed).

Table 3
Effect of Wounding on Steroid Glycoalkaloid (SGA) accumulation and In Vitro Inhibition of Fusarium by SGA

Healing time	α-solanine (μM)[1]	α-chaconine (μM)[1]	Total SGA (μM)[1]	%Inhibition of Fusarium[2]
24 Hours	23	22	45	0
48 Hours	153	107	260	30
72 Hours	324	214	538	60
96 Hours	310	207	517	60

[1]Concentration of glycolakaloids in upper 1 mm of tuber tissue.
[2]In vitro assay of growth

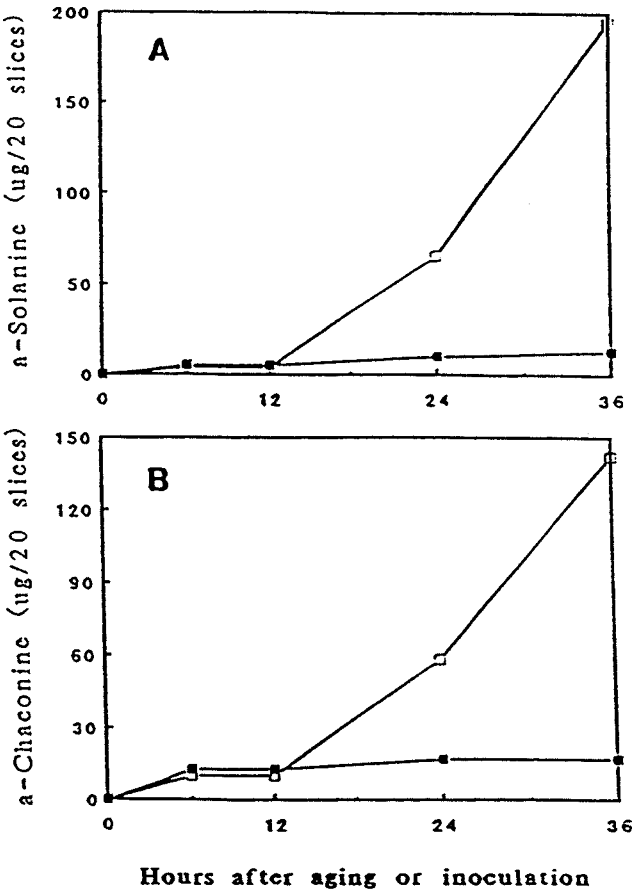

Figure 1. Time course of steroid alkaloid accumulation in wounded potato tissue potato tissue with or without inoculation with *F. sambucinum*. □ Uninoculated: ■ Inoculated. A: α-solanine; B: α-chaconine

Research Report
Integrated Crop Management (Federal Grant)

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Introduction

The green peach aphid (*Myzus persicae* Sulzer) is a pest of economic importance on potatoes and other crops throughout the U.S. and the world. A key factor of their importance as a pest is the fact that they are vectors of plant diseases (e.g. PLRV and PVY). With the exception of seed potato production, green peach aphid (GPA) populations are typically kept under control as a result of trying to control the Colorado potato beetle. The future use of transgenic potatoes for potato beetle control will iikely allow GPA to emerge as a more important pest.

Because GPA populations have experienced substantial selection with insecticides, resistance has developed in most populations, causing some difficulties in control, especially in seed production. Resistance to carbamate insecticides is often very high (ca. 200-fold). This is caused by elevated levels of esterase enzymes, the only known mechanism of resistance in this pest.

Through the years, several methods to measure esterase activity have been developed. Most of them are colorimetric tests which use a substrate for the enzyme, and a dye which reacts with the products of the enzymatic reaction. We have been working to exploit these methods to develop a simple, rapid test to determine the presence of resistant aphids in a grower's field.

Objective

We will use existing technology, and new techniques that we develop to begin monitoring for insecticide resistance in green peach aphids in Michigan and neighboring states.

Progress in 1993

We have completed research which shows that there is a relation between *in vitro* levels of carboxylesterase activity and insecticide resistance (O'Hara and Whalon, submitted). The correlation between *in vivo* bioassay using the "slide dip" test, and microplate assay of esterase activity was between .70 and .95 for the eight strains of resistant and susceptible aphids that were tested. Some of the difficulty in getting a stronger correlation is that elevated esterase activity confers higher degrees of resistance to insecticides that are easily metabolized by esterases, but a lower degree of resistance to insecticides that are mostly metabolized by other enzyme systems. However, the use of elevated esterase activity as an indicator of insecticide resistance is quite reliable and well accepted (Brown & Brogdon, 1987).

Another aspect of our research on green peach aphids is the development of a portable test for resistance. Initially, we adapted the "standard" esterase assay (based on

Gomori, 1953) for field use. This was accomplished using a portable photometer (System 10000, CHEMetrics Inc., Calverton, VA). Correlation with the microplate assay was very good (correlation coefficient = .90, for over 40 strains), and we achieved portability. However, the system required preparing and reading each sample individually. Each assay took at least 10 minutes. Even running several assays in parallel, it would be time consuming to assay a hundred aphids (the number required to detect 1-3% resistance). In addition, the portable photometer cost $450. Cost analysis showed that the portable assay costs about $100 for 25 assays, including labor and supplies, but not equipment.

In order to achieve our aim of sampling a large number of aphids from many different populations we began work on a faster, simpler assay method. We found a filter paper assay system that uses fast garnet for the color indicator (Pasteur & Georghiou, 1981). The aphids are squashed on a filter paper, can be assayed for esterase activity in only 5 minutes, and can easily assay 25 aphids at once. It also provides a permanent record. We can now easily assay 100 aphids in about 20 minutes. Our initial costs analysis indicates that this test has a total cost of about $10, and no equipment costs. This filter paper test was taken to the field and tested in Bay County, Michigan in August. However, there are still some difficulties with this test. We are concerned about non-specific staining, and our current inability to distinguish between resistant and susceptible individuals.

Plan for 1994

We still have to make further adjustments to the assay system to make it distinguish between resistant and susceptible individuals. This will require adjusting the concentrations of substrate and coloring agent, or may involve the addition of blocking agents to reduce non-specific staining. We must also adjust the conditions to allow latitude in the assay system (e.g. so the test is equally accurate between 4.5 and 5.5 minutes incubation time). These improvements will make the test a tool that growers and consultants can easily use. We hope to have the test ready for full field use by May, 1994. If we are unable to accomplish this, we can still survey aphid samples using a microtitre plate assay and portable microplate reader.

Through cooperators in Michigan, Wisconsin and Ohio, we will obtain aphid samples, and travel to seed potato fields to conduct our own field sampling. We will test the field populations using both the esterase test (either microplate or filter paper methods), and the slide dip test to assess the degree and frequency of resistance in the field. We will validate our test with at least 20 population samples, then test at least 20 additional samples with the field test only.

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Funding: MPIC

Research Report
Stability and Enhancement of Resistance to *Bacillus thuringiensis* in the Colorado Potato Beetle

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Introduction

Bacillus thuringiensis (B.t.) insecticides and transgenic plants are emerging tools for insect pest management. It is our contention that by the time transgenic plants are released for commercial potato production that there will be instances of resistance to B.t. in the field. Based on our experience, we feel that field resistance will be at a fairly low level, (ca. 25-fold), but the introduction of transgenic plants will place a high selection pressure on CPB populations. This presents a major concern with the use and deployment strategy for transgenic potatoes (McGaughey and Whalon, 1992).

Resistant strains could be useful for comparative studies to determine B.t. mode of action and to develop resistance management strategies. We have recently developed a strain of Colorado potato beetles (CPB) which is resistant to B.t. (Whalon et al. 1993). This strain (Bt-R) has resulted from selection of second instars with commercially formulated B.t. (M-One or Spudcap, Mycogen Corp.). In successive selections (to the 17th generation) resistance levels remained high, at about 200-fold (Rahardja and Whalon, submitted).We are in a unique position to investigate various aspects of B.t. resistance, since we have the only B.t. resistant strain of Colorado potato beetles.

It is generally accepted that small larvae are most susceptible to B.t. (Zehnder & Galernter 1989). However, the physiological basis for this generalization is uncertain. Comparing all of the life stages of the Bt-R strain for resistance levels may identify stage-specific factors of susceptibility or resistance. Investigation of the stability of B.t. resistance will promote understanding of the use of B.t. products in general, and offer information about the feasibility of some resistance management strategies.

Objectives

1. Select the Bt-R strain using transgenic plant foliage.
2. Determine the stability of resistance in the absence of selection, and the rate that resistance is re-established once selection resumes.
3. Examine resistance ratios of each life stage to determine if there are stage-specific mortality factors not present in the

Progress in 1993

Selection of the Bt-r strain using Spudcap continued, now into the 31st generation (Table 1). We have attained over 400-fold resistance in the Bt-R strain, and are now begining selections with B.t. transgenic potato foliage. The Bt-R strain cannot complete a life cycle on transgenic foliage as even late third instars do not survive to adulthood.

Reversion of resistance was tested in a strain having about 200-fold resistance (17th generation). After 5 generations without exposure to B.t., resistance dropped to about 50-fold (Table 2). However, in the succeeding 7 generations, resistance remained relatively stable at the 50- to 80-fold level.

We found that resistance ratios differ among various life stages of the insect. Specifically, the first instars of the Bt-R strain appear to be especially susceptible. The resistance ratios for the second instars may be the largest, and are certainly most easily and accurately determined. The resistance ratios for the various strains are shown in Table 3.

Table 1. Selection and resistance levels of the Bt-R strain

Generation	Resistance Ratio
17	200
21	223
29	291
31	443

Table 2. Reversion of resistance in the Bt-R strain in the absence of exposure to B.t.

# Generations w/o selection	Resistance Ratio
0	200
2	140
5	60
6	81
12	48

Table 3. Resistance ratios of the various stages of the Bt-R strain.

Instar	Resistance Ratio
First	21.2
Second	238
Third	>200

Plan for 1994

We will continue selecting with transgenic plant foliage, limiting exposure to 4 days until survival is greater than 80%. We will continue to bioassay with Spudcap, until we can no longer achieve 50% mortality. We will transition to a time-based assay on transgenic plants and determine resistance ratios based on LT50 values. We hope to establish a colony that can complete development on transgenic foliage.

We will start exposing our 50-fold resistant strain (unselected for 12 generations) to B.t. selection. Periodic bioassays will be conducted to determine the level of resistance in the strain. The reappearance of high levels of resistance will be monitored, and compared to the strain which has been under continuous selection.

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Funding: Federal Grant

Colorado Potato Beetle Management 1993 Potato Research Report

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Summary:

Colorado potato beetle (CPB) research in 1993 focused on 1) Factors influencing dispersal of postdiapause CPB out of rotated fields and colonization of new potato fields, 2) Factors influencing overwintering survival and spring emergence of diapausing CPB, 3) Insecticide efficacy test for CPB control, and 4) Control of CPB with *Bacillus thuringiensis* (Bt) and other biorationals.

Research showed that the type, size, and density of the crop in a rotated potato field influences the ability of CPB to leave the rotated field and colonize new potato fields. Leaving volunteer potatoes in a rotated field may delay or prevent beetles from moving to a new potato field. Two insecticides, Admire and AC303,630, provided good control of CPB larvae in field trials. Imidan failed to provide control probably due to resistance in the Montcalm population.In field trials using biorational insecticides, Agrimek plots had fewer small CPB larvae than all other products except the Asana + PBO standard. The numbers of large larvae in Agrimek treated plots were lower than Asana + PBO and comparable to Novodor followed by Kryocide. The experimental compound V-10004 and the untreated plots had the highest number of small and large larvae.

Introduction:

Research in 1993 included investigations of ability of overwintered CPB to leave a rotated field and find and colonize new potato fields. We are beginning to be able to characterize a "dispersal window" for Colorado potato beetle in crop rotation systems and to identify factors that influence it. Colorado potato beetles ability to leave a rotated field (to colonize new potatoes) is definitely influenced by the type, size and density of the crop. In general, dense plantings and larger plants inhibit dispersal more, but larger plants may facilitate dispersal by flight, rather than walking. From these preliminary results, winter wheat seems to be a good rotational crop for Colorado potato beetle control. It is more densely planted than many other crops, and is likely to be fairly large when CPB emerge in the spring, even during very hot years.

Collectively, results indicate that the presence of hosts (volunteer potatoes) in a rotated field very effectively reduces dispersal of postdiapause CPB out of the field. By reducing dispersal out of the field, colonization of new potato fields is also reduced. Results also show that volunteer potatoes effectively decrease dispersal even at low densities. In sum, leaving volunteer potatoes in a rotated field is a good strategy for managing CPB in rotated systems.

Preliminary results also show that certain "deterrent/repellent" fungicides may be effective at confining colonizing beetles to the edges of potato field. Control measures can then be concentrated on these field edges instead of the entire field.

Experiments are currently underway to test for the effects of soil type, soil temperature, soil moisture, and cover crop on overwintering survival of diapausing CPB.

Both conventional and alternative types of insecticides were tested in 1993. Field trials using conventional types of insecticides show that two relatively new products (Admire and AC303,630) provide very good control of CPB larvae. A variety of alternative types of insecticides were tested in a spearate field trial. Results indicate that Bt products continue to control CPB larvae, and other products such as Agrimek and Pyrellin are also effective.

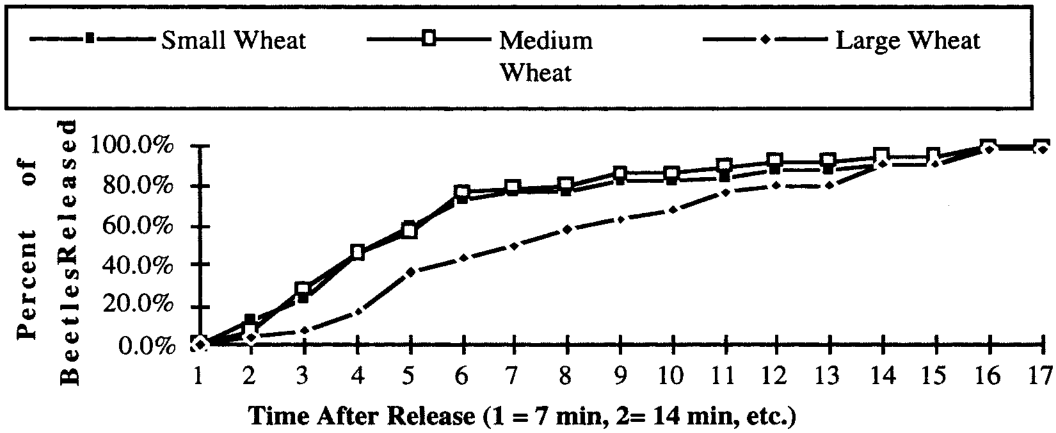
Factors influencing dispersal of postdiapause Colorado potato beetles out of rotated fields. The goal of this project is to develop crop rotation systems that maximize Colorado potato beetle control. A "dispersal window" has been defined, i.e., the period of time that postdiapause CPB can effectively move from the rotated field to the new potato field. Research for the past two years has focused on discovering how various factors influence this "dispersal window" by affecting emigration from the rotated field and colonization of the new potato crop. Factors investigated that potentially affect CPB dispersal include: type and size of rotational crop, presence of hosts (volunteer potatoes) in the rotational crop, and timing of beetle emergence from diapause vs. growth of the rotational crop. The potential use of feeding deterrents/repellents to limit the spread of colonizing beetles has also been studied.

Type and Size of Rotational Crop. The effect of the type of rotational crop planted, and the size of that crop, on dispersal of post-diapause beetles was investigated in field experiments in 1992 and 1993, and in greenhouse experiments during spring 1993.

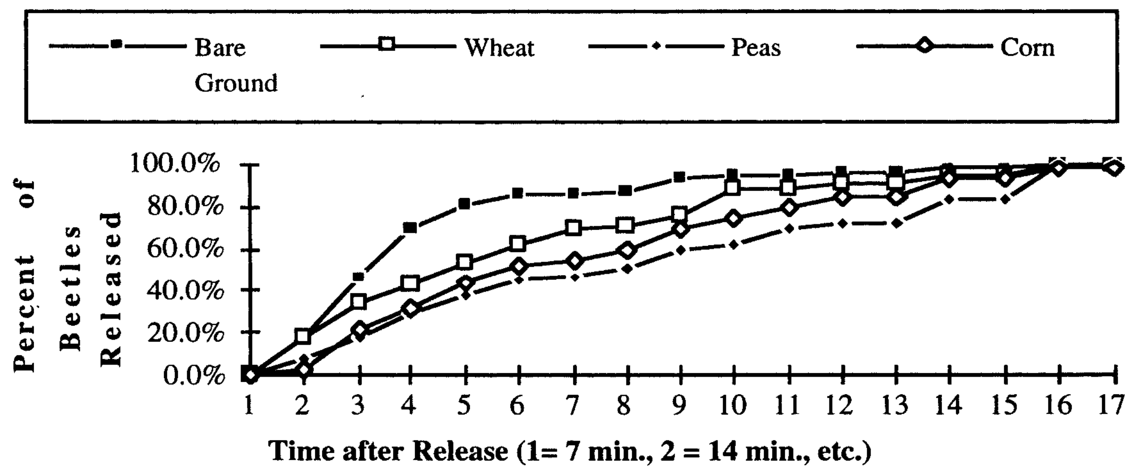
In spring 1993, plots (4 m x 8 m) were planted at the Entomology Research Farm. reatments included early and late planted corn, wheat and peas (planted 10 days apart); bare ground and weeds (fallow). There were three plots per treatment and ca 2 wks difference between early and late planting dates. Half of each plot (6 m x 6 m) was surrounded by a barrier of black visquine plastic painted with Fluon® (beetles are unable to climb barrier and had to fly to leave plot). The other half of each plot was surrounded by a black visquine barrier painted with white spray paint and sand (beetles were able to climb barrier). Each plot was surrounded by rows of potatoes 1.5 m from the plot edge. Postdiapause beetles were marked and released in the center of each half plot. Plots and surrounding potatoes were searched for marked beetles at one to three day intervals following release. All beetles found on potatoes were collected.

In early spring 1993, greenhouse experiments simulated field plots of corn, wheat, peas and bare ground. Arenas were constructed of four wooden boards, 2.5 cm x 20.3 cm x 0.9 m nailed together to form a frame 0.9 m x 0.9 m x 20.3 cm high. Black visquine was stapled to the inner side of this frame and was painted with Fluon®, (to prevent beetles from climbing out of the arena). Inside the arena were nine rows of nine each of square green plastic pots (10.2 cm x 10.2 cm) that were filled with potting soil. Potting soil was added to overflowing, so that the edges of the pots did not show, and this simulated a bare ground field. To simulate a rotated field surrounded by potatoes, in all of the outer pots (bordering the wooden frame) on all four sides a small, water-filled glass vial containing a small sprig of potato foliage was inserted into the potting soil so that only the potato foliage showed above the soil To simulate fields of different types of rotational crops, inner soil-filled pots were replaced by pots containing one corn, wheat, or pea plant. In wheat plots, all rows were replaced (7 rows of 7 plants each), and in corn and pea plots, alternate rows were replaced (4 rows of 7 plants each). Marked beetles were released in the center of each arena. Each potato sprig in each arena was checked every seven minutes for marked beetles. All beetles reaching the potatoes were collected, and the number, time and position of the beetle was recorded. Treatments were replicated three times. Several different runs of the experiment were done with different crop comparisons. Comparisons included: three different sizes of wheat, three different sizes of corn, three different sizes of wheat, and corn, wheat, peas and bare ground at two different sizes.

In general, fewer beetles released into plots with older (bigger) plants colonized the potatoes than beetles released into plots with younger (smaller) plants . However, for some crops (peas and corn), more beetles flew out of plots with larger plants than from plots with smaller plants. Beetles in field plots were often observed to climb plants to initiate flight, and the larger plants may have given them a better platform for "takeoff".

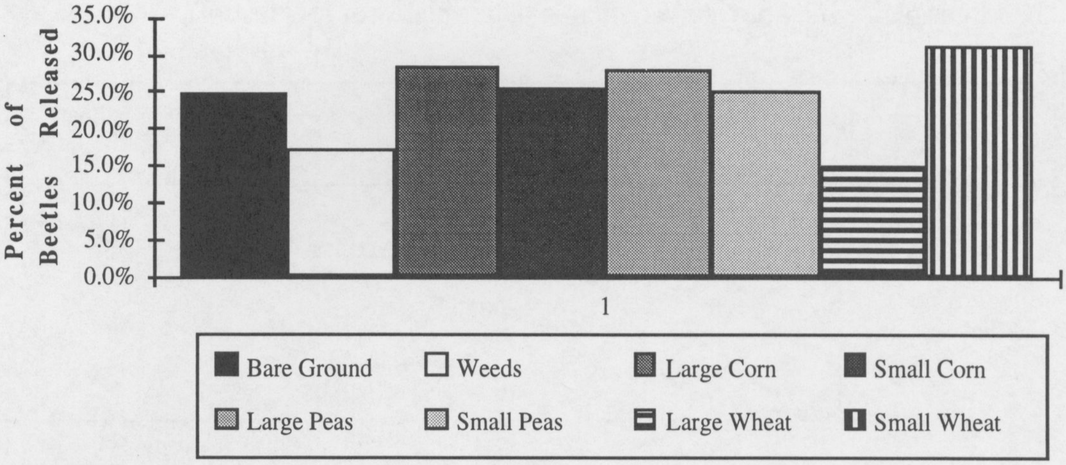


Cumulative percent of Colorado potato beetles released into arenas of different types in the greenhouse that found and colonized potatoes.



Cumulative percent of Colorado potato beetles released into arenas of different types in the greenhouse, that found and colonized potatoes.

In the field, more beetles released into pea and corn plots colonized potatoes than beetles released into wheat plots. In the greenhouse, beetles moved very quickly out of wheat. However, the density of wheat in greenhouse "fields" was very low (1 plant per 2" square), considerably lower than in the field. Plant density apparently has an effect on the ability of CPB to disperse. Weeds plots in the field were covered with a very dense plant cover. Fewer beetles released into weed plots colonized potatoes than beetles released into any other kind of plot.



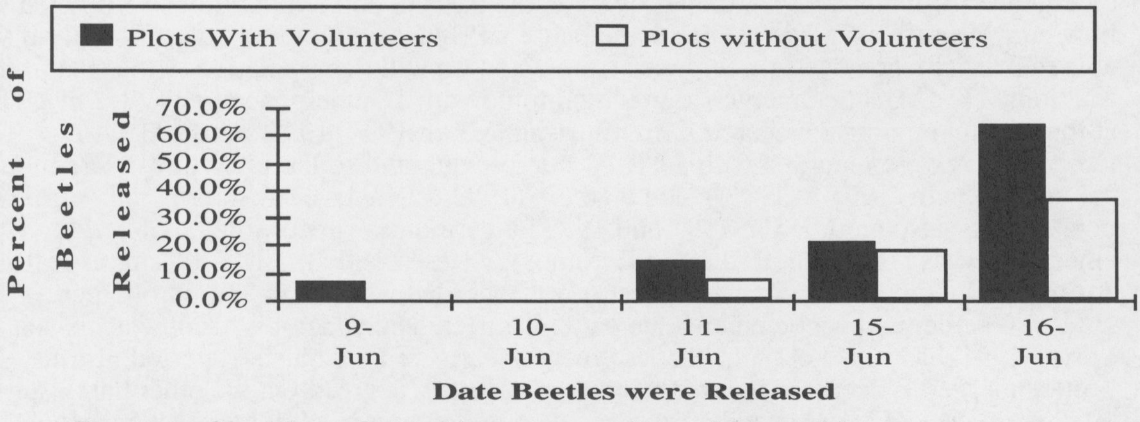
Percent of Colorado potato beetles released into different types of plots
that left the plots by flight and colonized nearby potatoes

Effect of Hosts in Rotational Crop. The effect of hosts (volunteer potatoes) in the rotated (non-host) crop on dispersal of postdiapause Colorado potato beetle was investigated in two field experiments in 1992. Plots (6 m x 6 m) were set up on a commercial farm in Clinton Co., MI (Keilens Farms). Plots were set up in a rotated carrot field (potatoes in 1991) that bordered a potato field. Eight plots were set up along the carrot-potato border. Sprouted potatoes were planted in half the plots to simulate volunteer potatoes.. During the experiment, naturally-occurring volunteer potatoes grew in all plots. These were removed periodically. However, the effect of these "real volunteers" was that the no-volunteer treatment was not devoid of potatoes, but simply had a lower number of volunteers than the volunteer treatment. Beetles were collected from the carrot and potato field, marked, and released into the center of each carrot plot. Plots were searched for marked and unmarked beetles at various intervals after release. The first three rows of the neighboring potato field were also searched for marked beetles.

The second field experiment conducted in 1992 involved the 6 x 12 m plots described above. The visquine barriers surrounding each plot were removed (the visquine in the center of each plot, dividing the plot in half was left intact.) Volunteers (1 per m^2) were planted in 1/ 2 of each plot. Marked beetles were released in the center of each plot, as described above. Plots and potatoes were searched for released beetles. and beetles were recaptured on the potatoes.

Beetles left rotated plots and colonized nearby potatoes less readily if hosts (volunteer potatoes) were present. This was true for all crops investigated, including: carrots, corn, wheat, peas and bare ground. A low density of volunteer potatoes (1 per 5 $m^{2)}$ was effective at reducing CPB dispersal. Higher densities of potatoes reduced dispersal only slightly more than low densities

In 1993, experiments investigated whether feeding status of postdiapause beetles affected their ability to disperse from rotated fields, in particular, their ability to disperse by flight. Postdiapause beetles were either provided with potato foliage for feeding, or were starved for four days prior to release Marked fed and unfed beetles were released into the center of the fluon-treated sides of the 8 m x 4 m plots described above. Preliminary results show no difference in the number of fed vs unfed beetles colonizing the potatoes.



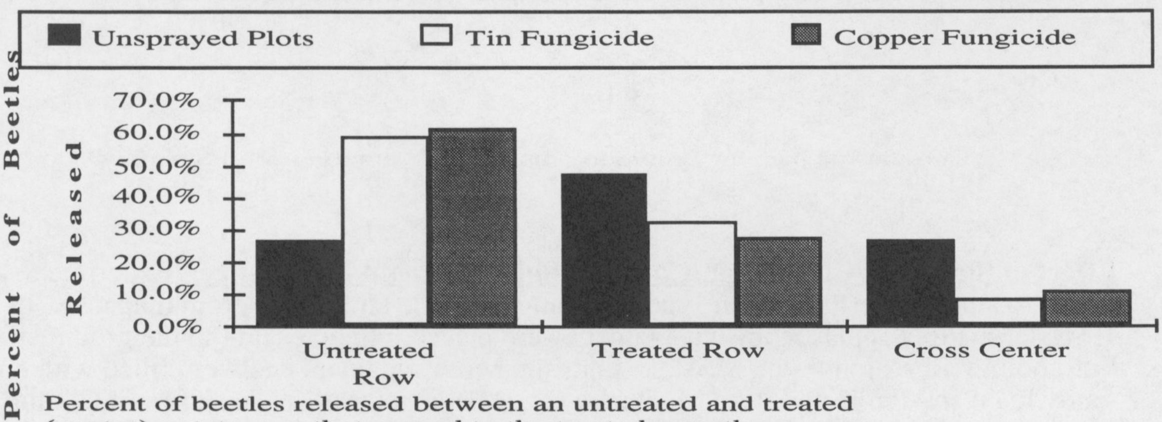
Percent of beetles released into carrot plots with or without volunteer potatoes that were recaptured in plots on June 19

__Use of Feeding Deterrents/Repellents to Confine Colonizing Beetles__. The focus of this research is to find methods of confining colonizing postdiapause CPB to small areas of the new potato field (e.g., field edges). Control methods can then be restricted to these areas, thus allowing the use of some methods (e.g., flamers, vacuums) that are less practical for whole-field use.

Potato Plots were planted at the Entomology Research Farm, MSU Campus. Plots were three rows wide (1.5 m between rows) and 6 m long .. The middle row of each plot was sprayed with a tin fungicide (Supertin ®), a copper fungicide (Kocide®), or was not sprayed. There were four replications (plots) per treatment. Marked beetles were released, 1 day and 2 days after spraying, on both sides of the middle row, between the first and center and third and center row. Plots were searched for marked beetles every day for 2 days after release. When found, beetle location and marking was recorded, but the beetles were not collected.

Similar plots were planted in 1993. Plots were 8 m long and 3 rows wide (1 m between rows). The middle row of each plot was sprayed weekly for two weeks with either a tin fungicide (Supertin ®), a copper fungicide (Kocide®), piperonyl butoxide (Butacide 8E®), or was not sprayed. There were three replications (plots) per treatment. Beetles were released daily for 3 days after the first spray application and 2 days after the second application, beginning the day after plots were sprayed. The three rows of each plot were searched daily for marked beetles. Again, beetles were recorded, but were not collected.

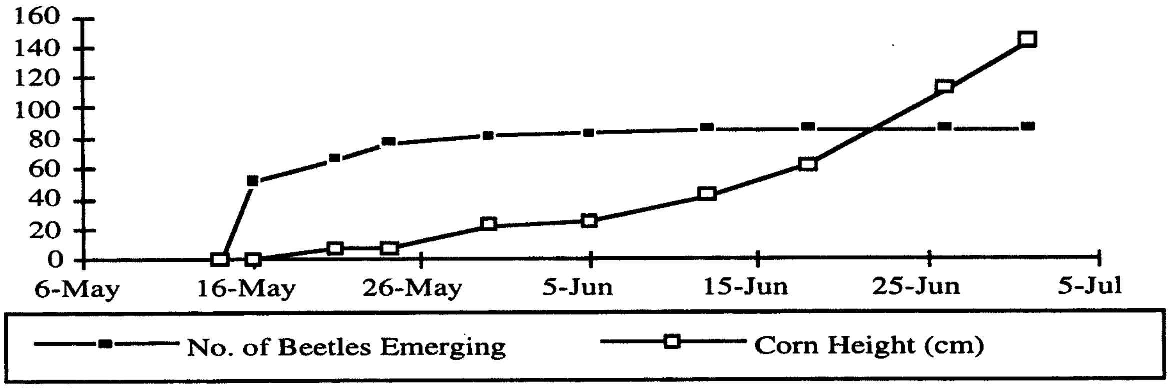
Currently, results are only available for 1992 data. Beetles released into plots treated with tin or copper fungicides were less likely to move to the treated (center) row than beetles released into untreated plots. They were also less likely to cross the center (treated) row and move to the opposite row. These results indicate that tin or copper fungicides may be an effective way of limiting beetle movement and confining beetles to the edges of fields.



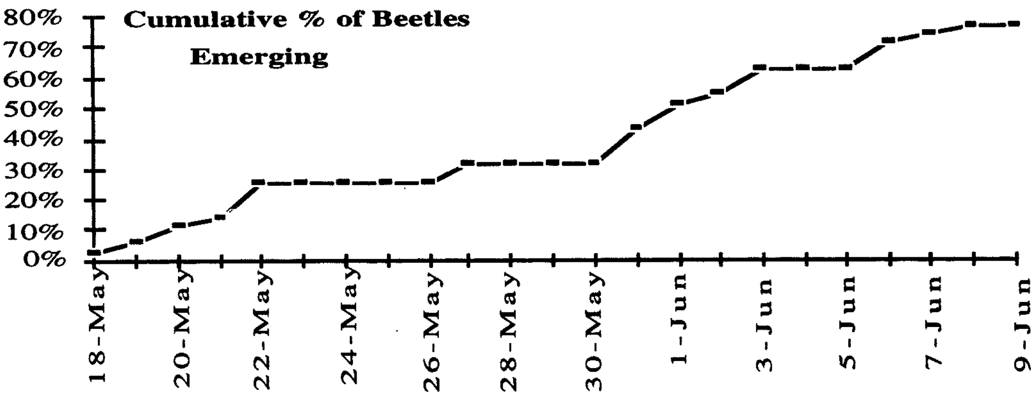
Percent of beetles released between an untreated and treated (center) potato row that moved to the treated row, the untreated row, or crossed the center (treated) row.

Timing of Emergence vs Plant Growth. Research continued on predicting beetle emergence from diapause vs. crop growth on the basis of soil temperatures. Knowledge of how crop size affects dispersal of postdiapause CPB (see above) will be useful only if we are able to predict when beetle emergence from diapause will occur relative to the size of the rotational crop. Beetle emergence was monitored with 12 emergence traps (1.2 m x 1.2 m) at the Montcalm potato research farm, Entrican, MI in 1991, 1992 and 1993. Air temperatures were recorded with a CR-21 micrologger and soil temperatures were monitored 5.1 cm, 20.3 cm (1991 & 1993), and 30.5 cm (1992 & 1993) Growth of nearby corn and potatoes was also recorded in 1991 and 1992 by periodically recording plant height. Beetle emergence was also monitored at the Entomology Research Farm, MSU Campus in 1992 . Air and soil temp (at 5.1 cm and 30.5 cm) was recorded with a CR-21 micrologger.

Weather and beetle emergence patterns differed considerably from year-to-year. Spring 1991 was very hot , and beetles emerged early and over a short period of time. Most beetle emergence occurred before the crop grew to any degree. On the other hand, spring 1992 was very cold, and beetle emergence occurred over a much longer time period.



Colorado potato beetle emergence and corn growth (height) in spring 1991.



Cumulative percent Colorado potato beetle emergence in Spring 1992

Effect of Soil Type/Cultivation/Cover on Soil Temp and Emergence: Experiments were begun to study the effect of soil-type on timing of beetle emergence from diapause. In Sept. 1992, large (46.2 l) plastic trash containers were placed into holes dug in the ground at the Entomology Research Farm, MSU, E. Lansing, MI. Containers and were filled with either sandy loam soil (collected from Montcalm Co., MI), muck soil (collected from Clinton Co., MI) or sand (Martin Block Co.). There were five containers for each soil type. Pre-diapause beetles (70 per container) were placed on top of the soil, and provided with food. Containers were covered with fiberglass screening. Beetles rapidly buried themselves in the soil.

In spring 1993, containers were checked daily for beetle emergence. Soil temperature was monitored. at 10.2 cm and 20.3 cm in one container of each type of soil. However, containers flooded in late fall and early spring, and many containers remained flooded during spring 1993. Only two beetles emerged from all of the containers combined, and both of these emerged from the sand.

Experiments were repeated the following year. In fall of 1993, soil was collected. from Montcalm Co., MI (sandy loam), Ingham Co., MI (clay loam,) and Clinton Co., MI (muck).. Soils were placed in trash containers, as described above. 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. One-half of the rye-planted containers will be turned over to a depth of 30.5 cm in the spring of 1994, to simulate cultivation. Pre-diapause beetles (120 per container) were placed on the top 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.

Containers will be checked daily for beetle emergence in spring 1994, and soil temperatures will be monitored.

Effect of cover crop, soil type, soil moisture, temperature on overwintering survival and spring emergence of CPB. Two experiments are in progress. A field study investigates the effect of soil-type, cover crop, depth of overwintering and soil moisture on overwintering mortality and emergence from diapause. A lab study investigates the effect of length of diapause and soil temperature on overwintering mortality.

In fall 1993, large (46.2 l) plastic trash containers were placed into holes dug in the ground at the Entomology Research Farm, MSU, E. Lansing, MI. Soil was collected. from Montcalm Co., MI (sandy loam), and Ingham Co., MI (clay loam,).. Soils were placed in trash containers to ground level. There were 12 containers for each soil type. Rye seed was planted in 6 of the containers of each soil type Six containers of each soil type remain unplanted. Pre-diapause beetles (120 per container) were placed on the top 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.

In February 1994, six containers of each soil type (3 each of rye-planted and unplanted) will be removed and brought to the lab. Containers will be searched for beetles. The number of beetles, the depth of diapause, and mortality will be recorded. Soil moisture will also be recorded. The remaining containers will be checked daily for beetle emergence in spring 1994, and soil temperatures will be monitored.

In fall of 1993, pre-diapause beetles (50 per container) were placed on the top of clay pots filled with clean potting soil. 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 ten treatments, including: diapause temperatures (2 C or 7 C) and 5 lengths of diapause (20, 25, 30, 35 and 40 weeks). There were 3 replications per treatment and each replication had 1 to three pots per treatment. Pots were checked at least once per week, and dead beetles appearing at the soil surface were removed.

In spring 1994, pots will be removed at the appropriate time, and beetles will be allowed to emerge from diapause naturally.

Evaluation of insecticides for Colorado potato beetle control. Seven insecticides were tested at the MSU Montcalm Research Farm in Entrican, MI. 'Snowdon' potatoes were planted on 6 May (12 inches apart, 34 inch row spacing in plots 45 feet long by three rows wide). The Admire in-furrow treatment was applied with garden spray bottles on 6 May. Foliar treatments were applied on 23 June, 30 June/2July, and 7 July using a tractor-mounted sprayer (30 gal/acre and 45 psi). AC303,630 at 5 GPA was applied with a CO_2 sprayer with a 3-nozzle hand-held boom. Asana was applied on 23 July and

Imidan on 4 Aug for control of adults. Two randomly selected plants from the middle row of each plot were sampled for CPB on 28 June, 6 July and 12 July. A visual defoliation assessment was done on 6 and 12 July. Potatoes were harvested on 14 Sept, separated by size and weighed.

Adult beetles were very abundant in the spring. Cool spring temperatures delayed egg hatch and compressed larval emergence. Small larvae were very high in number on the first spray date. Both Admire treatments and AC303,630 at 0.10 lb ai/A and at 50 and 100 GPA provided the best control of CPB larvae. Poor control with Imidan was probably due to resistance, as was indicated in results from a resistance test kit. Defoliation was severe in untreated and Imidan treated plots. Yield of size A potatoes was highest for AC303,630 and Admire treatments and lowest in Imidan treatments.

		Mean no. per plant (± SEM) over 3 sampling dates			
Treatment	Rate/acre	Adults[1]	Egg masses	Small Larvae[1]	Large Larvae[1]
Untreated		0.17 ± 0.10a	0.79 ± 0.32a	26.92 ± 5.59de	14.04 ± 2.08bc
Imidan 2.5 EC + LI-700	1 lb ai, 1 pt/100g	0.17 ± 0.07a	1.25 ± 0.32a	29.79 ± 10.02e	16.46 ± 2.46bc
Imidan 70 WP + LI-700	1 lb ai, 1 pt/100g	0.25 ± 0.14ab	0.67 ± 0.18a	21.79 ± 7.55cde	28.38 ± 6.71bc
Asana XL + PBO	6 oz., 8 oz.	0.75 ± 0.22cd	1.80 ± 0.17a	13.83 ± 2.13bcde	6.04 ± 4.17ab
Asana XL + Monitor + PBO	6 oz., 0.5 lb ai,8 oz.	0.58 ± 0.24abcd	0.92 ± 0.36a	10.63 ± 4.47abcd	6.38 ± 2.56ab
AC303,630 + Silwet	0.10 lb ai, 8 fl oz/100 g	0.17 ± 0.07a	0.88 ± 0.47a	7.29 ± 4.09ab	1.54 ± 0.30a
AC303,630 + Silwet	0.15 lb ai, 8 fl oz/100 g	0.42 ± 0.11abc	1.50 ± 0.49a	15.92 ± 6.43bcde	2.63 ± 1.31a
AC303,630 + Silwet	0.20 lb ai,8 fl oz/100 g	0.33 ± 0.07abc	1.50 ± 0.50a	15.96 ± 3.12bcde	2.33 ± 1.11a
AC303,630 + Silwet 5 GPA	0.10 lb ai,8 fl oz/100 g	0.17 ± 0.07a	1.13 ± 0.18a	13.79 ± 4.85bcde	3.54 ± 1.56a
AC303,630 + Silwet 50 GPA	0.10 lb ai,8 fl oz/100 g	0.33 ± 0.07abc	1.83 ± 0.31a	7.69 ± 3.29abc	1.48 ± 0.95a
AC303,630 + Silwet 100 GPA	0.10 lb ai,8 fl oz/100 g	0.50 ± 0.25abc	1.63 ± 0.36a	4.04 ± 1.50ab	0.33 ± 0.17a
Admire 240FS in furrow	0.90 fl oz/1000' row	1.04 ± 0.32d	1.17 ± 0.35a	1.25 ± 0.78a	1.08 ± 0.48a
Admire 240FS + Silwet	2.88 fl oz, 8 fl oz/100 g	0.17 ± 0.07a	0.75 ± 0.25a	3.25 ± 3.08a	0.33 ± 0.33a
Cryolite WDG	12 lb	0.63 ± 0.25bcd	1.42 ± 0.32a	20.79 ± 13.43bcde	3.17 ± 0.73a

Means within a column followed by the same letter are not significantly different ($P > 0.05$, LSD).

[1] Data transformed for analysis with square root (x + 0.5).

		Yield in lbs per 45 row feet		Defoliation Rating[1]	
		Size A	Size B	6 July	12 July
Untreated		6.25 ± 2.17	5.38 ± 1.21	5.2	5.7
Imidan 2.5 EC + LI-700	1 lb ai + 1 pt/100g	11.88 ± 5.66ab	5.38 ± 0.55ab	4.4	5.1
Imidan 70 WP + LI-700	1 lb ai + 1 pt/100g	4.00 ± 1.08a	4.38 ± 0.47a	5.2	5.8
Asana XL + PBO	6 oz. + 8 oz.	39.25 ±11.12abc	6.75 ± 0.95ab	2.3	2.7
Asana XL + Monitor + PBO	6 oz. + 0.5 lb ai + 8 oz.	47.75 ± 6.57bc	8.00 ± 1.08ab	2.3	2.7
AC303,630 + Silwet	0.10 lb ai + 8 fl oz/100 g	69.25 ± 6.77c	7.25 ± 1.36ab	1.7	1.7
AC303,630 + Silwet	0.15 lb ai + 8 fl oz/100 g	53.75 ± 3 .64c	6.75 ± 0.48ab	1.5	2.7
AC303,630 + Silwet	0.20 lb ai + 8 fl oz/100 g	61.50 ± 7.77c	6.13 ± 0.77ab	2.3	2.7
AC303,630 + Silwet 5 GPA	0.10 lb ai + 8 fl oz/100 g	63.13 ± 9.87c	6.75 ± 1.38ab	2.0	2.7
AC303,630 + Silwet 50 GPA	0.10 lb ai + 8 fl oz/100 g	57.88 ±10.90c	8.00 ± 0.46ab	2.0	1.9
AC303,630 + Silwet 100 GPA	0.10 lb ai + 8 fl oz/100 g	49.88 ± 4.63c	7.38 ± 0.94ab	1.2	1.8
Admire 240FS in furrow	0.90 fl oz/1000' row	71.00 ± 4.20c	8.13 ± 0.72ab	1.3	2.1
Admire 240FS + Silwet	2.88 fl oz + 8 fl oz/100 g	61.00 ±10.73c	10.13 ± 1.42b	1.2	1.2
Cryolite WDG	12 lb	41.50 ± 4.00abc	7.25 ± 2.25ab	2.1	2.0

Means within a column followed by the same letter are not significantly different ($P > 0.05$, Tukey's HSD).

[1] Defoliation Rating. 1, no defoliation; 2, 0% - 5% defoliation; 3, 5% - 25% defoliation (some whole leaflets eaten); 4, 25% - 50% defoliation (some whole leaves eaten); 5, 50% - 100% defoliation (whole stems bare).

Colorado potato beetle control with biorationals. Nine products were tested at the MSU Montcalm Research Farm, Entrican, MI. Plots were 20 ft long and 3 rows wide (34 inches between rows, 12 inches between plants in a row), and were separated by approximately 6 ft of bare ground. Potatoes were planted on 6 May and sprayed with a backpack sprayer (30 gal/acre, 30 psi, four nozzles) on 23 Jun, 1 Jul, and 7 Jul. Asana was sprayed on all plots on 4 Aug and 23 Jul to control adult CPB. Two randomly selected plants from the middle row of each plot were sampled for CPB on 28 Jun, 6 Jul and 12 Jul; defoliation was rated on the latter dates. Potatoes were harvested, sized, and weighed on 14 Sep.

Plots treated with all materials except V10004 had fewer large larvae than untreated plots on 28 Jun and 6 Jul. On 12 Jul, untreated plots and plots treated with Agri-Mek, Asana plus PBO, Novodor/Kryocide, and V10004 had significantly fewer large larvae than all other plots. For the season, numbers of large larvae were not significantly different in treated and untreated plots, due to pupation in untreated plots. Plots treated with all materials except V10004 and ATI-720F had fewer small larvae than untreated plots on 28 Jun. Untreated and V10004-treated plots had similar yield and defoliation. All other treatments were similar to each other in yield, CPB numbers, and feeding damage. However, Agri-Mek-treated plots had higher yield than plots treated with Foil BFC.

		Mean no. per plant (± SEM) over 3 sampling dates			
Treatment	Rate/acre	Adults[a]	Egg masses[b]	Small larvae[a]	Large larvae[a]
Untreated		0.5 ± 0.4ab	0.6 ± 0.6a	36.1 ± 17.0a	31.4 ± 13.8a
Asana XL + PBO	0.05 lb ai + 0.5 lb ai	1.0 ± 0.4ab	2.2 ± 0.8a	6.3 ± 2.7a	2.3 ± 0.7a
Novodor/ Kryocide	3 qts/ 11.5 lbs ai	1.5 ± 0.5ab	3.0 ± 1.0a	15.2 ± 5.6a	0.4 ± 0.3a
M-Trak	3 qts	0.8 ± 0.2ab	2.2 ±0.7a	13.5 ± 3.4a	5.8 ± 2.2a
ATI-720F	15 g ai	0.4 ± 0.1ab	0.7 ± 0.3a	28.0 ± 6.7a	8.5 ± 3.6a
Pyrellin + Novodor	0.01 lb ai + 3 qts	1.7 ± 0.6a	2.8 ± 1.5a	11.3 ± 4.6a	10.2 ± 3.6a
Novodor	3 qts	1.4 ± 0.4ab	2.0 ± 1.0a	10.8 ± 2.8a	10.6 ± 5.1a
Foil BFC	1.5 qts	0.7 ± 0.3ab	0.8 ± 0.4a	13.3 ± 4.3a	12.5 ± 2.9a
Foil BFC	2 qts	0.8 ± 0.4ab	0.9 ± 0.4a	11.0 ± 3.7a	13.7 ± 6.0a
V-10004	5 lbs ai	0.3 ± 0.2ab	1.5 ± 0.7a	34.4 ± 14.2a	12.9 ± 5.6a
V-10004	10 lbs ai	0.1 ± 0.1b	1.1 ± 0.7a	39.3 ± 13.5a	23.0 ± 8.5a
Agrimek	0.01 lb ai	1.5 ± 1.1ab	1.0 ± 0.5a	9.0 ± 5.9a	0.5 ± 0.2a

Means within a column followed by the same letter are not significantly different (Tukey's HSD; $P > 0.05$).

[a]Data for adults, small larvae, and large larvae transformed for analysis with natural log (x + 1).

[b]Egg mass data transformed for analysis with square root (x + 0.5).

		Yield in lbs per 20 row feet		Defoliation rating[b]	
Treatment	Rate/acre	Size A[a]	Size B	6 July	12 July
Untreated		0.5 ± 0.0c	2.3 ± 0.3a	5.8	5.8
Asana XL + PBO	0.05 lb ai + 0.5 lb ai	14.8 ± 1.0ab	3.9 ± 0.1a	2.4	2.6
Novodor/ Kryocide	3 qts/ 11.5 lbs ai	12.7 ± 0.7ab	3.2 ± 0.2a	2.6	3.2
M-Trak	3 qts	12.9 ± 1.9ab	4.0 ± 0.4a	2.6	3.6
ATI-720F	15 g ai	16.1 ± 3.1ab	3.5 ± 0.3a	3.0	3.4
Pyrellin + Novodor	0.01 lb ai + 3 qts	12.5 ± 1.0ab	3.5 ± 0.6a	2.6	3.4
Novodor	3 qts	10.5 ± 3.3ab	3.0 ± 0.5a	2.8	3.7
Foil BFC	1.5 qts	8.9 ± 1.8b	3.8 ± 0.3a	3.2	4.1
Foil BFC	2 qts	7.0 ± 2.5b	4.0 ± 0.3a	2.4	3.9
V-10004	5 lbs ai	0.6 ± 0.3c	2.1 ± 0.1a	5.7	5.8
V-10004	10 lbs ai	1.0 ± 0.7c	2.1 ± 0.3a	5.5	5.8
Agrimek	0.01 lb ai	20.1 ± 2.7a	3.6 ± 0.9a	2.4	2.7

Means within a column followed by the same letter are not significantly different (Tukey's HSD; $P > 0.05$).

[a]Size A tuber yield data square root transformed (x + 0.5) for analysis.

[b]Defoliation rating. 1, no defoliation; 2, 1% - 5% defoliation; 3, 6% - 25% defoliation (some whole leaflets eaten); 4, 26% - 50% defoliation (some whole leaves eaten); 5, 51% - 100% defoliation (whole stems bare).

Funding: Federal Grant

MANAGEMENT OF PLANT-PARASITIC NEMATODES IN MICHIGAN POTATO PRODUCTION WITH SPECIAL EMPHASIS ON CROP ROTATIONS AND COVER CROPS

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Introduction

Field and greenhouse trials were continued in 1993 to examine the influence of crop rotations on Pratylenchus penetrans populations and the effects on potato yields. Field studies were established at 4 locations in the state: the Montcalm Co. Potato Research Farm; Jim Butler's Farm in Crystal Falls; the Jon Haindl Farm in Cooks and the Kitchen Farm in Alba. These studies are 2 or 3 years in duration.

A Pesticide Impact Assessment Project (PIAP) was recently completed to determine the impact of the removal of Temik 15G on Michigan potato production and pesticide use. A summary of this project is included.

Crop Rotation Experiments

The greenhouse component consisted of the collection of 4 field soils with natural infestations of Pratylenchus penetrans and Verticillium dahliae and the use of these soils to evaluate the efficacy of 9 crop rotations for the suppression of potato early-dying. The rotations ranged from 3 to 60 weeks between potato crops. Alfalfa, annual rye and red clover were utilized as the rotational crops. At the conclusion of each rotation, potatoes were grown for 3 to 6 weeks. Nematodes were extracted from roots and soil. Potato stems and soil will be assayed for Verticillium wilt.

P. penetrans populations densities were higher in the potato crops in proportion to the number of weeks of alfalfa or clover growth. However, this trend is less pronounced if the soil was collected from a field that had been recently fumigated. The highest nematode numbers where associated with soils that had not been fumigated and where clover was grown. Potato plant survival was also monitored. All plants survived to 3 and 6 weeks of age except where alfalfa and clover had grown for up to 30 weeks. Percent plant survival was correlated directly with increases in the number of weeks of alfalfa and clover growth up to 30 weeks. Both tuber weight and tuber number decreased for all the soil treatments when measured at 3 and 6 weeks for treatments of more than 18 weeks or alfalfa or clover growth. This reflects a general trend in the reduction of early senesence (early die) shown by the increased rate of survival of potato plants to 3 and 6 weeks of age. This effect should result in a higher yield at 100 days in the field. All soils showed an increase in the ratio of tubers at 6 wks/3wks after 6 weeks (clover treatments) and 18 weeks (alfalfa treatments). This again reflects an increased effect of keeping the potato "young" and thus in its reproductive stage for a longer time resulting in an increased number of tuber initials.

This research also has a laboratory component investigating the impacts of crop rotations on myycorrhizal (beneficial) fungi. Under laboratory conditions, it was determined that spores of mycorrhizal fungi, present naturally in potato soil, germinated and infected a bioassay host more readily following a legume than after a potato crop. These results suggest that many complex interactions are occurring within the soil environment contributing to "rotational effects."

Crop rotation trials were established at the Montcalm Co. Potato Research Farm and at the Jon Haindl Farm in 1991. The rotation trial was terminated at the Haindl location in 1993. The cropping sequences and potato yields are shown in Table 1. Yields at this site have always been poor due to weed interactions and poor plant stands. However, the best yields were associated with 1993 potato crops preceded by 2 years of legumes or crops other than potatoes (these differences are not statistically significant at p=0.05). These trends, however, cannot be explained by comparing root-lesion nematode counts. Numbers of lesion nematodes have always remained quite low in these plots. Therefore, other factors are apparently responsible for the observed yield increases.

Potatoes, alfalfa and kidney beans cv. Isabella were grown in the trial at the Potato Research Farm. The cropping sequences, midseason root-lesion nematode counts and yields are shown in Table 2. Potato (Russet Norkotah) yields were higher when the crop was grown preceded by 2 years of alfalfa. However, the yields in these plots were very low. The plants in these plots died very early (approx. July 15) in 1993 due to undetermined cases. Yields were approximately 100 cwt/A higher in 1992 than 1993.

Differences exist in the numbers of root-lesion nematodes recovered from roots collected on July 13 but they cannot be explained by examining cropping patterns. These differences are probably due to the distribution of the nematodes within the test site. All the crops grown during the study are hosts for root-lesion nematodes, however, nematodes, in general, are aggregately distributed within a field. Their distribution may be responsible for the differences observed in nematode numbers.

This rotation trial will continue in 1994 and beyond. Potato yields have been fluctuating from year to year even within the potato monoculture plots. One goal of this research is to attempt to determine the duration of time necessary in continuous potato production for yields to stabilize. This has probably not occurred yet in this study.

A three-dimensional study was conducted to investigate stereoeffects and distribution patterns of _Pratylenchus penetrans_ and _Verticillium dahliae_ associated with potato at the Potato Research Farm in Entrican, MI. A north-south field-row ($0.4m^2x0.8m^2x0.3m$) representing a ladder-shaped polyhedron was used in this study. The ladder-shaped soil polyhedron was sampled first in two dimensions, and then in the third dimension. Sixty samples were from the 6x10 sectors of upper zone (_ca._ 0.5x0.9x0.1m), 80 from the 8x10 sectors of middle zone (0.7x0.9x0.1m), and 100 from the 10x10 sectors of lower zone (0.9x0.9x0.1m). The P. penetrans concentration in the upper, middle, and lower zones was 1.8, 8.7, and 14.4/100 cm^3 soil, respectively. The V. dahliae concentration in the upper, middle, and lower zones was 2.0, 0.6, and 0.7 cfu/g dry soil, respectively. The 3-D localsation images of the soilborne organisms were computer-stereopercepted. Two-dimensional semivariogram models were used on the third dimension. The results indicated that that P. penetrans population were in an independent distribution in the upper and middle zones, but in a spatial dependency distribution in the lower soil cuboid zone. Independent observations of V. dahliae distributions horizontally and vertically were suggested at this ladder-shaped polyhedron field-row site.

Pesticide Impact Assessment Project (PIAP)

Forty Michigan potato growers were surveyed in 1988 to assess nematicide usage in six different potato growing regions (Table 3). In 1990, Temik 15G was voluntarily withdrawn for use in potato production. It was the intent of the PIAP Project to assess the impact of its removal on Michigan potato growers, with a focus on its use as a nematicide. It was the assumption of the project that Mocap 10G would replace Temik 15G as a granular at-plant nematicide. The overall assessment, therefore, is based on MSU Nematology Research from 1975 to 1992, 1990 nematode sampling data obtained from the MSU Nematology Diagnostic Service, and an economic analysis based on PLANETOR, a whole-farm decision support system software package developed by the Sustainable Agriculture Research and Education Program.

It was found that prior to the removal of Temik 15G, three types of nematicides were used; non-fumigant at-planting nematicides (NFN), fumigants (F) and chemigants (C). The NFN, Temik 15G was the most common nematicide used (Table 4). Twenty-five of the 40 growers surveyed (62.5%) used Temik 15G either as an at-plant granular nematicide or as an insecticide (Table 5). Temik 15G was also used in conjunction with other nematicides. Approximately 30% of the growers used Temik at a nematicidal rate and 12% used it with other nematicides (Tables 5 and 6). Nematicide usage by different regions and farm sizes was also studied. It was found that the West Central region and mid-sized farms (50-250 acres) used Temik 15G most often at nematicide rates without any other type of nematicide (Tables 7 and 8). It was hypothesized that these groups were most effected by the removal of Temik 15G.

Each year the Michigan State University Diagnostic Laboratory receives several hundred soil samples from Michigan potato growers. The 1990 Extension samples were used to obtain an estimate of the frequency of root-lesion nematodes and V. dahliae associated with Michigan potato soils. Three separate action thresholds were used to assess potential tuber losses: root-lesion nematodes alone (>99 nematodes/100 cc soil), Verticillium alone (>9 colonies/gram soil) or the sum of both Verticillium and root-lesion nematode densities is greater than 10 (Bird 1981, Grafius, et al. 1990). Root-lesion nematodes were detected in approximately 85% of the samples, Verticillium was found in 78% of the samples, and only 5% of the samples had neither root lesion nematode or V. dahliae (Table 9). If both pathogens were present, and their combined density exceeded 10, control actions were recommended. These actions include the use of a nematicide or rotational strategy. If only one or both of the pathogens were present at below action threshold densities, then additional annual monitoring was recommended.

The computer program PLANETOR, is a whole farm planning system that inputs all costs associated with farming, pesticide usage, soil data, crop and livestock data, and farming practices and outputs economic data, risk assessment, and environmental impacts. The program was used to quantify increased risks associated with the use of Mocap 10G. In general, there were three responses: 1) there was no change in risk if the grower did not use Temik 15G in the management practice; 2) risk decreased, if Temik 15G was used when it was not needed either because the grower was using a fumigant or chemigant in addition to Temik 15G or yield goals were insufficient to justify the use of Temik 15G; and 3) risk increased, if Temik 15G was used alone and the yield goal was greater than 250 cwt/A.

PLANETOR calculates the economics and probability of risk. The probability is statistically obtained from inputs associated with expected yield, optimistic yield, pessimistic yield, and expected selling price, optimistic selling price and pessimistic selling price. When assessing the impact of Temik 15G being withdrawn, selling prices remained fixed. Yield information was changed in accordance to data obtained from MSU Nematology field trials.

The economic analysis consists of six parameters: (1) Return over direct costs and (2) probability of zero return; (3) Net farm income and (4) probability of zero net farm income; and (5) Net worth change and (6) probability of zero net worth change. The data needed to support the PLANETOR model were obtained either directly from the potato grower survey, or indirectly from a 1990 MSU Agricultural Economics Report that calculates budgets on a regional or statewide basis.

Return over direct costs included all variable costs associated with the growing season. The return over direct cost on a per acre and per field basis included only data provided directly from the grower; whereas, the return over direct cost per farm included generalized yield, price, and cost of materials obtained from the Agricultural Economics budgets for the State of Michigan and for the specific rotation crops on a per farm basis. Only the results from this section are presented here.

In Michigan, potato growers received about $1000/A of return over direct cost when using Temik 15G and an estimated $930/A without Temik 15G (Table 10). On an acre basis, the Upper Peninsula had the largest return over direct cost; but, when the farming unit as a whole is taken into account ($ per farm), several of the regions in the Lower Peninsula had a greater return. Large farms had a greater return than smaller farms (Table 11).

The average decrease in return resulting from the removal of

Temik 15G went from $1003 to $930 per acre; from $291,378 to $274,915 per field; and from $353,787 to $337,300 per farm (Table 10). Overall, the removal of Temik 15G decreased the returns for Michigan potato growers an estimated $3,175,500.

To summarize, the change in potential income to Michigan potato growers was not distributed equally throughout the six regions or equally by farm size. Growers in the west central region tended to be more adversely affected than growers in other regions, and mid-sized growers were also more effected than either large or small growers. In general, mid-sized growers in the west central region experienced the greatest change in risk, although the loss was less than the larger growers in absolute dollar amounts.

Table 1. 1993 Potato Rotation Research UP Component

Potato Rotation Systems			Potato yields (lb/10 hills)	*P. penetrans* population (100 cc soil)	
1991 Crops	1992 Crops	1993 Crops		6/7/93	10/10/93
Potato	Potato	Potato	16.0	18	17.4
Oats	Potato	Potato	17.3	23	20.2
Alfalfa	Alfalfa	Potato	21.8	13	15.0
June Clover	June Clover	Potato	22.0	17	19.3
Sweet Clover	Sweet Clover	Potato	23.2	16	27.2
Oats & Alfalfa	Turnip	Potato	22.4	12	21.4

Table 2. 1993 Potato Rotation Research Montcalm Component

Cropping Systems			*P. penetrans* 7/13/93 roots (1 g)	Tuber Yields	
1991	1992	1993		U.S. No.1 (cwt/A)	Total (cwt/A)
Potato	Potato	Potato	144 bcd	38.7 b	70.9 b
Alfalfa	Potato	Potato	162 bc	62.9 b	99.0 b
Alfalfa	Alfalfa	Potato	83 d	115.8 a	152.1 a
Oats	Alfalfa	Alfalfa	87 d		
Oats	Potato	Potato	118 cd	61.8 b	93.2 b
Oats	Soybean	Alfalfa	177 bc		
Oats	Soybean	Kidney Bean	119 cd		
Oats	Soybean	Kidney Bean	285 a		
Oats	Soybean	Kidney Bean	144 bcd		
Oats	Soybean	Kidney Bean	212 ab		

Table 3. Characteristics of the Michigan potato production regions included in the 1988 survey.

Region	n	Total acres	Surveyed acres	Percent surveyed
UP	3	3500	260	7.43
North	8	7600	2145	28.22
West Central	12	12,100	3489	28.83
East Central	11	12,800	2205	17.23
Southwest	4	3250	467	14.37
Southeast	2	4250	1700	40.00

Table 4. Nematicide use reported in the 1988 Michigan potato farm survey.

Nematicide	Common name	Trade name	Use in MI potato production (%)
Non-fumigant	aldicarb	Temik	43.20
	carbofuran	Furadan	2.19
	ethoprop	Mocap	1.70
Fumigant	1,3-D	Vorlex	13.63
	1,3-D	Telone C-17	0.57
Chemigant	Metham	Vapam	15.63
	Metham	Nemasol	9.54
	Metham	Busan-1020	8.18

Table 5. Temik 15G use in the 40 Michigan potato farms in the 1988 survey.

Treatment	Growers		Acres	
	No.	Percent	No.	Percent
No Temik	15	37.5	2388	23.3
Temik at insecticide rates	13	32.5	3618	35.2
Temik at nematicide rates	12	30.0	4260	41.5

Table 6. Types of nematicides used in conjunction with Temik 15G the in 1988 potato farm survey.

Type of application	(%)
Temik only	18
Temik with Soil Fumigant	2
Temik with Chemigant	6
Temik, Soil Fumigant, and Chemigant	4

Table 7. Nematicide use by region in Michigan.

Region	Acres/ field	Yield (cwt/a)	Temik ai/a	API (%)	Temik NFN (%)	Fumigant (%)	Chemigant (%)	None used (%)
Michigan	260	---	1.50	82	38	10	15	50
U.P.	88	242	0.00	66	0	0	0	100
Northern	268	249	1.83	75	25	13	38	50
West Central	291	278	2.60	100	75	25	25	0
East Central	200	270	0.39	73	9	0	0	91
Southwest	117	202	1.39	75	50	0	0	50
Southeast	850	205	2.25	100	50	0	0	50

Table 8. Nematicide use in Michigan by farm size.

Farm size	Yield (cwt/a)	Temik ai/a	Temik API (%)	Temik NFN (%)	Fumigant (%)	Chemigant (%)	None used (%)
<50 acres	191	1.09	50	0	0	0	100
50-250 acres	274	1.42	81	48	10	5	48
>250 acres	246	1.87	93	36	14	36	36

Table 9. Region, frequency and density of root-lesion nematodes and V. dahliae populations recovered from 1990 Extension samples from Michigan potato farms.

Root-lesion nematode and Verticillium thresholds[1]	MI n=190	UP n=29	N n=7	EC n=16	WC n=135	SE n=3	SW n=0
Above action threshold for Potato Early Die (PED)	52.1	75.9	85.7	25.0	47.4	100.0	---
Potential PED problem	8.4	0.0	14.3	12.5	9.6	0.0	---
Above action threshold for root-lesion nematode	5.8	10.3	0.0	12.5	4.4	0.0	---
Potential root lesion nematode problem	12.6	10.3	0.0	25.0	12.6	0.0	---
Slight potential for root-lesion nematode problem	4.7	0.0	0.0	0.0	6.7	0.0	---
Above action threshold for Verticillium wilt	0.5	0.0	0.0	0.0	0.7	0.0	---
Potential Verticillium wilt problem	10.5	3.4	0.0	18.8	11.9	0.0	---
Neither pathogen detected	5.2	0.0	0.0	6.2	6.7	0.0	---

[1]Pest thresholds

Nematode: >99 root-lesion nematode per 100 cc soil

Verticillium: >10 colonies per gram of root tissue

PED interaction: >10 units of root-lesion and colonies of Verticillium

Table 10. Average return over direct cost (variable costs associated with MI potato production) per region, on an acre, field, and farm level.

Region	Return over direct cost with Temik 15G		Return over direct cost without Temik 15G	
	$/acre	$/farm	$/acre	$/farm
Michigan (N=39)	1003	353787	930	337300
UP (n=3)	1550	114794	1550	114794
Northern (n=8)	1175	486792	1150	485809
West Central (n=12)	1186	493943	995	444835
East Central (n=10)	655	151746	628	149945
Southwest (n=4)	680	147784	653	136730
Southeast (n=2)	771	761539	783	769740

Table 11. Average return over direct cost (variable costs associated with MI potato production) per size, on an acre, field, and farm level.

Size	Return over direct cost with Temik 15G		Return over direct cost without Temik 15G	
	$/acre	$/farm	$/acre	$/farm
Small (<50 A)	472	11526	486	11762
Med (50-250 A)	954	166498	858	156234
Large (>250 A)	1226	732510	1164	701910

Funding: MPIC

MANAGEMENT OF PLANT-PARASITIC NEMATODES IN MICHIGAN POTATO PRODUCTION WITH SPECIAL EMPHASIS ON CROP ROTATIONS AND COVER CROPS

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Introduction

Studies were conducted in 1993 to further investigate the role of plant-parasitic nematodes, notably the root-lesion nematode, *Pratylenchus penetrans*, in Michigan potato production. Root-lesion nematodes are common in Michigan potato fields and will reduce yields particularly in the presence of the soil fungus, *Verticillium dahliae*. Soil fumigation is often the control practice of choice for these organisms, but due to environmental and human health concerns, it is imperative other tactics are investigated. The emphasis of this research was to examine the use of fall cover crops as green manures for management of *Pratylenchus penetrans*.

Carrot acreage is on the rise in some potato production areas of the state (Montcalm Co.). Carrots are very susceptible to nematodes especially root-knot nematodes. All of the research conducted on the control of nematodes in carrot production in Michigan has been completed in organic soils. In 1993, a carrot nematicide trial was established at the Potato Research Farm to examine the efficacy of three nematicides, fosthiozate, Mocap 6EC and Vydate, for nematode control in carrots grown in sandy-loam soil.

Fall Cover Crop/Green Manure Trial

This trial was established in the fall of 1992 at the Potato Research Farm. The primary objective was to determine if winter rapeseed could be utilized as a cover and green manure crop for root-lesion nematode control to alleviate the impact of these nematodes in a subsequent potato crop. Rapeseed has been demonstrated to control root-knot nematodes in Washington and its use as a soil amendment has resulted in potato yield increases in previous studies.

Three varieties of winter rapeseed, Askari, Bridger and Sollux, canola, oats and rye were planted in September of 1992. This site was planted to soybeans during the 1992 growing season. Samples were collected in the first week of Sept. and *P. penetrans* counts averaged 167 per gram fresh soybean root tissue at that time.

Half of the rapeseed and canola plots were disced in the fall (mid-November), the other half were disced in the spring (late April). Half of the rye and oat plots were treated with Vapam at 50 gal./A on May 3, 1993 and the other half of the plots were left untreated. Potatoes cv. Superior were planted in 4-row plots on May 17. This trial was harvested on Sept. 10, the center 2 rows of each plot were removed.

Nematode samples were collected 5 times during the course of the experiment, Nov. 4, 1992, May 3, 1993 (at fumigation), May 17 (at planting), July 20 and Sept. 10 (at harvest). Root tissue was collected on Nov. 4 and July 20. Soil was collected on all 5 sampling dates.

P. penetrans numbers increased considerably on all the cover crops utilized during the fall (Table 1). Nematode counts per gram of root tissue were 5-10 times higher in the cover crops on Nov. 4 than in soybeans on Sept. 6. It is very obvious that fall cover crops contribute to increases in nematode population densities preceding the winter months.

Vapam, applied at 50 gal./A, reduced *P. penetrans* numbers prior to planting the potato crop (Table 1). This control was also observed at midseason and at harvest. No differences were observed in *P. penetrans* numbers between the rapeseed, canola and untreated rye and oats plots on July 20 or at harvest. No differences were observed between fall and spring disced plots of rapeseed or canola when comparing nematode counts.

The application of Vapam resulted in statistically significant potato yield increases when compared to the other treatments (Table 2). These results were expected because *P. penetrans* population densities were significantly lower in the Vapam-treated plots throughout the season. No yield differences were observed with the other treatments.

Rapeseed is not recommended for management of root-lesion nematodes at the present time. The 3 cultivars investigated are all excellent hosts for *P. penetrans*. These results are identical to the results obtained in a greenhouse study and reported in 1992.

A plastic tarp may be necessary for use with soil amendments. Data collected in California demonstrated that the numbers and concentrations of nematicidal compounds were higher under tarp than unsealed soil after soil amendment with cabbage. These results may help to explain why utilizing rapeseed, as a soil amendment, in plastic bags, was so effective for *P. penetrans* control in a preliminary experiment conducted at MSU. As little as 5 grams of fall collected rapeseed leaves and stems reduced *P. penetrans* numbers 70% or more when these materials were added to plastic bags containing 100 cm^3 of nematode infested soil. Up to 99% control was achieved by adding 25 grams of rapeseed shoots to *P. penetrans*-infested soil. Therefore, it may be necessary to seal soil by some means after incorporating green manures particularly in the temperate climates of in Michigan.

Potato Nematicide Trial

A potato nematicide trial was conducted at the Potato Research Farm in 1993 investigating the efficacy of nonfumigant nematicides for root-lesion nematode control. Three nematicides were utilized, Fosthiozate 900, Mocap 6EC and Vydate L. The materials were either applied broadcast just prior to planting and incorporated with a rototiller or at-hilling. Potatoes cv. Superior were planted on May 10 and harvested on Sept. 13. Nematode samples were collected just prior to treatment, on July 13 and at harvest.

The application of Vydate L at hilling produced the highest potato yields. This treatment was the only treatment that resulted in statistically higher yields of U.S. No. 1 potatoes than the untreated control. However, all the nematicides were provided root-lesion nematode control.

Carrot Nematicide Trial

A carrot nematicide trial was established at the Potato Research Farm in the spring of 1993. Carrot growers from Montcalm Co. were concerned about the effectiveness of Vydate for nematode control for carrots grown in mineral soils. It was decided at a meeting in February that a nematicide trial, as opposed to a rotation trial, would be conducted.

Carrots cv. Scarlet Nantes were planted in 4-row plots with 34 inch rows on May 21. The plots were hand-harvested on Oct. 4. Carrots were graded, counted and weighed at a later time. Nematode samples were collected at planting, on Aug 11 and at harvest. The treatments are given below.

DESIGN (Randomized Complete Block with 4 blocks)
Treatments = 9 (all the treatments were applied broadcast, preplant incorporated in 25 gal. of water except treatment 2)

1. Untreated
2. Vydate L, 2 gal/A in 15 gal. water in a 6 in. band at planting
3. Vydate L, 4 gal/A
4. Mocap 6EC, 3.0 lbs a.i./A
5. Mocap 6EC, 6.0 lbs a.i./A
6. Mocap 6EC, 9.0 lbs a.i./A
7. Fosthiozate 900EC, 2.0 lbs a.i./A
8. Fosthiozate 900EC, 4.0 lbs a.i./A
9. Fosthiozate 900EC, 6.0 lbs a.i./A

No carrot yield increases were observed with any of the nematicide applications. No differences were observed in the percent marketable carrots or weights (Table 4).

Root-knot and root-lesion nematodes were present at the test location. Preplant densities were very low (Table 5). However, more root-knot and root-lesion nematodes were found in carrot roots collected from the untreated plots and the plots treated with Vydate L (treatment 3) on Aug. 11 than the other treatments. At harvest, more nematodes were recovered from the soil in the untreated plots than any of the treated ones.

Yield differences were probably not observed because of the low population densities of the nematodes at planting. Although, data are not available for carrots grown in mineral soils, nematode numbers, at planting, were probably below damage thresholds. Early season control, during initial formation of the tap root, is crucial to insure carrots of high quality. However, in this experiment nematodes were not at high enough numbers, early in the season, to cause measurable damage and yield losses.

Table 1. 1993 Green Manure/Cover Crop Potato Research Trial, *P. penetrans* densities.

Green Manure/Cover Crop Treatments	Sampling Date				
	11/4/92[1]	5/3/93[2]	5/17/93[2]	7/20/93[3]	9/10/93[2]
Rapeseed cv. Askari, disced in fall	1987.5	94.00	52 bc	137.00a	195a
Rapeseed cv. Askari, disced in spring	1540.5	114.00	32 bc	235.75a	188a
Rapeseed cv. Bridger, disced in fall	1127.0	60.25	59 bc	180.50a	177a
Rapeseed cv. Bridger, disced in spring	948.0	104.25	46 bc	188.00a	144a
Rapeseed cv. Sollux, disced in fall	1258.0	120.75	104a	209.25a	198a
Rapeseed cv. Sollux, disced in spring	916.5	124.50	51 bc	135.75a	224a
Canola, disced in fall	1223.0	67.00	50 bc	249.75a	259a
Canola, disced in spring	1135.5	88.75	71ab	141.25a	186a
Oats cv. Heritage, disced in spring & fumigated	1163.5	139.00	18 c	4.50 b	30 b
Oats cv. Heritage, disced in spring	980.5	151.00	59 bc	213.50a	259a
Rye, disced in spring & fumigated	1439.0	71.75	21 c	7.00 b	17 b
Rye, disced in spring	1063.0	102.25	74ab	137.67a	252a

1. Mean numbers of nematodes per g root tissue of cover crops.
2. Mean numbers of nematodes per 100 cc soil.
3. Mean numbers of nematodes per g potato root tissue.

Table 2. 1993 Green Manure/Cover Crop Potato Research Trial, Potato Yields.

Green Manure/Cover Crop Treatments	Tuber Yields (cwt/A)	
	U.S. No.1	Total
Rapeseed cv. Askari, disced in fall	252 a	265 a
Rapeseed cv. Askari, disced in spring	248 a	259 a
Rapeseed cv. Bridger, disced in fall	256 a	270 a
Rapeseed cv. Bridger, disced in spring	239 a	254 a
Rapeseed cv. Sollux, disced in fall	249 a	262 a
Rapeseed cv. Sollux, disced in spring	248 a	260 a
Canola, disced in fall	251 a	262 a
Canola, disced in spring	245 a	258 a
Oats cv. Heritage, disced in spring & fumigated	394 b	410 b
Oats cv. Heritage, disced in spring	234 a	245 a
Rye, disced in spring & fumigated	408 b	422 b
Rye, disced in spring	238 a	249 a

Table 3. 1993 Potato Nematicide Trial cv. Superior, Montcalm Research Farm.

Treatment	*P. penetrans* densities			Potato Yields (cwt/A)	
	Preplant[1]	Midseason[2]	Harvest[1]	Market	Total
Untreated	21.25	184.25a	163.75a	257.0a	273.0a
Vydate L, 4 gal/A, at hilling	16.50	5.50 b	10.50 b	387.1 b	402.7c
Mocap 6 EC at 6.0 ai/A, Broadcast PPI	12.00	29.50 b	25.25 b	334.4ab	350.1bc
Mocap 6 EC at 9.0 ai/A, Broadcast PPI	17.25	5.50 b	29.50 b	340.7ab	358.7bc
Mocap 6 EC at 12 ai/A, Broadcast PPI	22.25	1.75 b	18.50 b	313.4ab	332.5abc
Mocap 10 G at 3.36 oz/1000 row ft, applied in 5-7 in band	18.25	17.50 b	49.75 b	267.3a	284.8ab
Fosthiozate 900 at 4.5 lb ai/A, broadcast PPI	43.25	7.00 b	9.75 b	324.4ab	344.0bc
Fosthiozate 900 at 2.25 lb ai/A, Broadcast PPI, plus 2.25 lb ai/A at hilling	34.75	4.25 b	19.00 b	307.1ab	326.3abc
Fosthiozate 900 at 6.0 lb ai/A, Broadcast PPI	18.50	10.75 b	9.25 b	343.2ab	362.5bc
Fosthiozate 900 at 3 lb ai/A, Broadcast PPI, plus 3 lbs ai/A at hilling	14.50	10.00 b	10.50 b	313.2ab	338.2bc

1. Mean numbers of nematodes per 100 cc soil.
2. Mean numbers of nematodes per g potato root tissue.

Table 4. Mean yields of carrots (15 row ft.) from 1993 Nematicide Trial conducted at the Montcalm Co. Potato Research Farm.

	MARKETABLE			NONMARKETABLE		
TREATMENT	no.	wt (lbs)	%	no.	wt (lbs)	%
Untreated	100	22.4	79	24	5.1	21
Vydate, 2.0 gal (band)	105	23.5	83	23	5.1	17
Vydate, 4.0 gal	104	22.2	78	26	5.1	22
Mocap, 3.0 lbs	109	23.5	90	13	1.8	10
Mocap, 6.0 lbs	87	20.1	74	28	5.5	26
Mocap, 9.0 lbs	103	22.0	79	21	5.0	21
Fosthiozate, 2.0 lbs	93	25.6	85	12	3.8	15
Fosthiozate, 4.0 lbs	81	24.8	87	12	2.9	13
Fosthiozate, 6.0 lbs	108	21.6	83	20	4.7	17

Table 5. Mean numbers of root-knot and root-lesion nematodes recovered at planting (May 21)[1], Aug. 11[2] and at harvest (Oct. 4)[1] in the 1993 Carrot Nematicide Trial.

	root-knot			root-lesion		
TREATMENT	5/21	8/11	10/4	5/21	8/11	10/4
Untreated	1.0	241	104	2.75	38	5
Vydate, 2.0 gal (band)	0.0	0	25	0.5	4	0
Vydate, 4.0 gal	0.25	27	11	1.0	36	0
Mocap, 3.0 lbs	0.0	0	10	3.25	8	0
Mocap, 6.0 lbs	0.25	0	2	7.0	2	2
Mocap, 9.0 lbs	0.0	0	3	5.25	7	0
Fosthiozate, 2.0 lbs	0.0	0	2	6.5	1	0
Fosthiozate, 4.0 lbs	1.25	0	14	3.25	0	0
Fosthiozate, 6.0 lbs	0.0	0	13	1.0	2	0

[1]Numbers of nematodes per 100 cm^3 soil
[2]Numbers of nematodes per 1.0 gram fresh carrot root

Funding: MPIC

An Economic Analysis of Applying the Entomophagous Nematode, Steinernema carpocapsae with the Bacterium, Bacillus thuringiensis for Control of the Colorado Potato Beetle

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Project history:

Two laboratory experiments were initially conducted in 1991 to establish the susceptibility of Leptinotarsa decemlineata to Steinernema carpocapsae. Various rates (0, 1, 10, 100, 1000) of S. carpocapsae were applied directly onto the insect's surface and onto potato foliage. Four stages of the beetle were used, 2nd, 3rd, 4th instars and the adult. Applying the nematode to the leaf, at least 80% mortality was recorded for inoculation rates of 10 nematodes or more at day 2 for 2nd instars, at day 3 for third instars and day 4 for 4th instars. Applying the inoculum to the leaf surface was slightly more effective than directly on the insect. No mortality of adult beetles was observed.

In the summer of 1992 field studies were conducted using S. carpocapsae to control natural infestations of L. decemlineata. The applications were applied at dusk, on nights with high relative humidity. The nematodes were applied with a hand-held sprayer at five different densities ranging from 0 to 4 billion nematodes per acre. Each plant was caged 24 hr prior to spraying and all the beetles were collected from each cage 24 hr after spraying. The nematode successfully controlled the 3rd and 4th instar beetles at the 3 billion per acre rate, which is the commercially suggested rate. Mortality ranged from 85 to 100%.

Objectives:

1. To investigate Steinernema control of Colorado potato beetle with commercial spray applications.

2. To analyze the effect of the nematode alone, B.t. alone, and the nematode with B.t., along with a commercial pesticide, on population densities of the Colorado potato beetle and on potato yields.

Materials and Methods:

In the summer of 1993 a field study was conducted. Four replications of five treatments were used. These included: Control, Steinernema carpocapsae at 3 billion per acre, Bacillus thuringiensis at 121.3 ounces per acre, both S. carpocapsae and B.t., and Asana at 5.8 ounces per acre. The treatments were applied using an R&D CO_2 Back Pack Sprayer. The sprayer was set at 50 psi which required approximately 39 gallons of liquid per acre.

The treatments were applied twice during the season, on July 12th and July 26, 1993 at 8:00 pm. Both days had high humidity. The beetles were left uncaged overnight, and five beetles were collected from each plot the next day. Each beetle was placed in a 60x15 mm petri dish with filter paper and an untreated potato leaf. The temperature was set at 20 C. Every day the beetles were checked for mortality and received 0.01 ml. of water. At the end of five days, dead beetles were observed for emergence of the nematode.

Results:

Colorado potato beetles. On July 13th, beetles were found on only 50% of the plots. These 50 beetles were observed for five days, and five of them died during the five day observation period. Two were from the B.t. and S. carpocapsae treatment and three were from the Asana treatment (Table 1).

Similar results were found also on July 29th. Only seven of the 20 plots had at least five beetles. Of these thirty-five beetles, fourteen died during the five day observation period. Four were in the control group, three from S. carpocapsae alone, five from S. carpocapsae and B.t., and one from the Asana treatment.

Potato yields. Potato plots were hand harvested. Each plot was 40 row feet. Although Asana had increased yields, these yields were not statistically significant at p=.05 level (Table 2).

1994 Field Project:

In 1994, we plan to repeat this study and look more closely at the fate of S. carpocapsae in the field. In addition, it may be better to assure a high population of the Colorado potato beetle by releasing beetles into the field. S. carpocapsae worked well in the petri dish, and reasonably well in the field in 1992, but was not successful in 1993. In 1994 we want to determine if the problem was the commercial sprayer or low beetle densities. We will be investigating these studies further in close conjunction with Biosys, the company that produces S. carpocapsae commercially.

Table 1. Mortality of *Leptinotarsa decemlineata*, with five treatments.

Treatment	First Spray July 12, 1993		Second Spray July 26, 1993	
	No. of plots with CPB	Average mortality (%)	No. of plots with CPB	Average mortality (%)
Control	2	0	2	40
S. carpocapsae	2	0	2	30
B. t.	1	0	0	***
B. t. and *S. c.*	1	40	2	50
Asana	4	15	1	20

Table 2. 1993 Colorado potato beetle potato yields cv. Superior (40 row ft).

Treatment	A	B	J	Market	Total
Control	24.9	5.9	.55	25.4	31.3
S. carpocapsae	29.4	5.5	.75	30.1	35.6
B. t.	27.2	7.2	.55	27.8	35.0
B. t. and *S. c.*	24.8	4.5	1.1	25.8	30.3
Asana	38.6	7.2	1.7	40.2	47.4

Funding: MPIC

ROLE OF THE POTATO ROOT SYSTEM IN THE RESPONSE TO PHOSPHORUS

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Potatoes respond to planting time applications of phosphorus fertilizer even when the phosphorus soil test levels are very high relative to levels required for growing most other field and vegetable crops. Annual applications of phosphorus for potato production has resulted in very high soil phosphorus levels. Movement of phosphorus into surface waters by soil erosion and leaching is a concern in fields and areas where these processes take place. High phosphorus levels in streams and lakes contribute to the degradation of water quality by enhancing eutrophication. Hence, good management practices are important to prevent phosphorus loss from potato fields.

The total amount of phosphorus getting into a plant is a function of the root's ability to take up phosphorus from the soil solution and the total root surface area. Research has shown potato roots of several varieties have similar abilities to take up phosphorus from solution. The rate of uptake is very concentration dependent. At low concentrations of phosphorus, which are common in the solution phase of many potato field soils, the rate of phosphorus uptake may be limiting phosphorus uptake and growth unless an adequate root system is developed. Therefore potato varieties with a vigorous and extensive root system will be better able to obtain phosphorus from the soil than varieties with limited root systems. Studies in 1992 with seven varieties indicated that some varieties are more responsive to phosphorus fertilization than others. Although no data was collected on root growth, knowledge (personal communication with Westermann, USDA) about the overall growth and rooting characteristics contained in the literature would indicate the least phosphorus responsive varieties are those with better root growth. Research by Burpee and Pierce has shown improving physical soil conditions increases root development and potato yields, but they did not measure phosphorus uptake. Manipulation of the soil physical conditions may also influence the response to phosphorus. Hence knowledge about the vigor and habit of root growth is important in understanding the response of potato varieties to phosphorus.

Field studies in 1992 at three locations showed varieties respond differently to application of phosphorus at planting time. Differences in plant growth were evident among the varieties. General observation of the root systems at one location indicated there also were marked differences in root growth. Data collected in 1992 combined with these general observations indicated there is a relationship between root system development and response to applied phosphorus.

The objectives for the studies in 1993 were as follow.

1. Study the development of the potato root system of several potato varieties.

2. Evaluate the relationship between root system development and response to phosphorus application.

Research Approach:

Four potato varieties (Kennebec, Onaway, Snowden and Russet Norkotah) were planted on May 7 in a McBride sandy loam at the Montcalm Research Farm. Each variety was planted in four row plots with one set in each replication receiving 100 lb P_2O_5/A in the band placed fertilizer. A second set of four rows was planted without phosphorus. The Bray-Kurtz P1 soil test in the research area ranged from 435 to 510 lb P/A. Minirhizotron tubes (clear plastic tubes with an inside diameter of 2.5 inches) were installed at a 45 degree angle to a depth of about three feet below the surface. The tubes were placed just slightly to the side of the row. Two tubes were installed in each plot. Root development was followed by making video recordings of the roots present at five times throughout the growing season; June 24, July 2, July 13, July 23, and August 4. The mini-video camera slides inside the minirhizotron tube and photographs 0.12 square inch (1.4 cm^2) at a time. The slide is indexed so each position can be reproduced during each video taping. Whole plant samples including roots were collected on June 8 and June 24. The plants were separated into leaves, stems, stolons, roots and tubers for determination of dry weight and phosphorus (P) content. The tubers were dug, and yield and specific gravity data collected during September.

Results and Discussion:

By June 8 differences in P accumulation were apparent between the varieties in there response to the application of P at planting (Table 1). Phosphorus accumulation in the petioles of Onaway and Russet Norkotah potatoes was significantly increased by P application. Phosphorus accumulation in the petioles of Kennebec and Snowden potatoes was not affect by P application. There was a slight increase in the P content of the roots of all varieties except Kennebec.

By June 24 the plants had developed to the point of setting and sizing tubers. Table 2 presents information on the accumulation of P in the various plant parts. In most of the sampled tissues P concentrations were greater in the plants having received the band phosphorus. The main exceptions to this trend were the P contents of the Kennebec leaves and developing tubers. The increases in P content of the various plant parts was most marked in the Onaway plants. The P content of the tubers of all varieties was least affected by P application. In all varieties the P concentration was the highest in the leaves and main stems and were the lowest in the branches (secondary stems) coming off of the main stems. This data tends to indicate that the branches, stolons and roots are primary conduits for P whereas the leaves, main stem and tubers are the primary sinks for P accumulated in the plants. Phosphorus accumulated in the branches, stolons and roots may be viewed as temporary and is Probably more subject to translocation to the other plant parts.

The number of roots observed in the rhizotron tubes on June 24 varied significantly among varieties (Table 3). On this date roots were observed to a depth of 20 inches below the soil surface of the hill. Russet Norkotah plants had significantly fewer roots present than the other three varieties. Kennebec plants had the most roots present followed by Snowden and Onaway. With all varieties there were more roots present in the P treated plots than without P. More roots occurred in the upper 12 inches when P was applied. Without P fertilizer more roots occurred along the 12 to 16 inch segment of the tubes. Table 4 presents the root data by depth averaged across P treatments for the four varieties. It is quite apparent that Kennebec has the most vigorous and prolific root system and that of Russet Norkotah is the least vigorous. Averaging the data across the four varieties gives a good feel for the influence of P application on the root distribution (Table 5). Apparently there was a proliferation of roots in the top 8 to 12 inches of soil due to increased P availability.

Root distribution data for the four varieties and P treatments are presented in Tables 6, 7 and 8. Kennebec had the most roots along the top 28 inches of the tube followed by Onaway. The plants of Snowden and Russet Norkotah had significantly fewer roots (Table 7). As was observed on June 24 more roots developed in the surface soil when P was applied and without P applied more roots developed deeper in the soil. This was especially true for Kennebec which resulted in an overall more extensive root system without P applied. However, across all varieties (Table 8) and especially with Russet Norkotah and Onaway P application improved overall root growth.

The root distributions were last observed on August 4. Roots on this date were observed along 32 inches of the rhizotron tubes. This is equivalent to about 22 inches below the soil surface. There were tremendous differences in the number of roots observed for the four varieties. Kennebec plants had by far the most vigorous and extensive root system (Tables 9 and 10). As was observed at the early observation dates the plants receiving P fertilizer had more roots in the upper 8 inches of soil whereas the non P fertilized plants developed more roots deeper in the soil profile (Table 11). This was especially true for Kennebec and Snowden. Kennebec plants receiving no P had more roots overall than the P fertilized plants. For Onaway and Russet Norkotah P fertilization stimulated overall root development. There was no effect with Snowden. Averaged across P treatments the extensiveness of the Onaway, Snowden and Russet Norkotah root systems were about 75, 60 and 40 percent of that for Kennebec. In comparing root numbers between July 23 and August 4 it is apparent that the root systems of all varieties were on the decline by August 4. The degree decline was greatest with Russet Norkotah. The poorer root system of Russet Norkotah may be the main reason this variety is so adversely affected by early die complex. These differences relate to yield responses to P fertilization in the past. In general Kennebec has not be benefitted by P fertilization in high P soils whereas Russet Norkotah and Snowden have given the most frequent responses. The poorer root system of Russet Norkotah may also be the reason why good nitrogen management is so important to keeping this variety growing and getting a good yield.

Despite the differences in P accumulation and concentrations in plant parts among the four varieties in relation to P fertilization there were no significant yield differences (Table 12). However, in past years P response to P fertilization has occurred most frequently with Russet Norkotah and Snowden which are the two varieties with least extensive root systems. Phosphorus application had no effect on specific gravity for all varieties.

In summary the data presented demonstrates that there are significant differences in the vigor and extensiveness of the root systems among potato varieties. Varieties with the better root systems are less likely to respond to P application and should be less likely to be adversely affected by other stress factors. As new varieties are developed consideration should be given to incorporating a vigorous rooting habit.

Table 1. Influence of banded phosphorus at planting on phosphorus concentration in four commmercial potato varieties sampled June 8, 1993.

Variety	Phosphorus Applied	Phosphorus Concentration[z] Petioles	Roots
	lb P_2O_5/A	ppm	ppm
Onaway	0	5053b[y]	2768a
	100	6641a	3007a
Kennebec	0	5206a	2968a
	100	5875a	2828a
Russet Norkotah	0	4617b	2534a
	100	5822a	3048a
Snowden	0	5049a	2644a
	100	5268a	3013a

zAll values are parts per million (PPM) in dry tissue.
yMeans followed by different letters are significantly different at the 5% level, within varieties and columns.

Table 2. Influence of banded phosphorus at planting on phosphorus concentration in four potato varieties sampled June 24, 1993.

Variety	Phosphorus Applied	Phosphorus Concentration[z] Leaves	Branches	Main Stems	Tubers	Stolons	Roots
	lb P_2O_5/A	ppm					
Onaway	0	4211b[y]	1667b	2423b	3748a	2830b	2631a
	100	6037a	2787a	3812a	3788a	3921a	3275a
Kennebec	0	6414a	2475a	4472b	3095a	3050a	2946a
	100	5889a	3008a	5229a	2950a	4105a	3415a
Russet Norkotah	0	5287b	2069b	3161a	3231a	3057b	2544b
	100	5654a	2749a	3920a	3583a	4029a	3178a
Snowden	0	4370b	1923b	3442a	2867a	3170a	2624a
	100	5620a	2614a	4656a	3566a	3476a	2752a

zAll values are parts per million (PPM) in dry tissue.
yMeans followed by different letters are significantly different at the 5% level, within varieties and columns.

Table 3. Influence of banded phosphorus at planting on number of roots and depth of rooting in four commmercial potato varieties sampled June 24, 1993.

Variety	Phosphorus Applied	Mean number of roots/4 inches of depth[z] 0-4	4-8	8-12	12-16	16-20	Total
	lb P_2O_5/A						
Onaway	0	5.8	14.8	8.6	14.4	0.4	43.9
	100	7.3	27.1	11.3	8.9	0.1	54.6
Kennebec	0	7.6	18.5	20.4	13.9	1.6	62.0
	100	11.5	16.5	25.1	13.3	2.4	68.8
Russet Norkotah	0	1.8	9.6	12.1	7.0	0.6	31.1
	100	3.6	18.1	19.3	3.9	0.0	44.9
Snowden	0	8.0	13.6	9.4	14.5	5.4	50.9
	100	8.9	24.8	15.3	10.3	0.5	59.6

zAll values, except totals, are means of 8 replications and are counts of roots viewed in a region 4 inches X 0.5 inches. Totals are of roots viewed in a region 32 X 0.5 inches.

Table 4. Number of roots and depth of rooting in four commmercial potato varieties sampled June 24, 1993.

Variety	Mean number of roots/4 inches of depth[z] 0-4	4-8	8-12	12-16	16-20	Total
Onaway	6.5ab[y]	20.9a	10.0b	11.6a	0.3b	49.3ab
Kennebec	9.6a	17.5a	22.8a	13.6a	2.0ab	65.4a
R Norkotah	2.7b	13.9a	15.7ab	5.4a	0.3b	38.0b
Snowden	8.4a	19.2a	12.3ab	12.4a	2.9a	55.3ab

zAll values, except totals, are means of 8 replications and are counts of roots viewed in a region 4 inches X 0.5 inches. Totals are of roots viewed in a region 32 X 0.5 inches.

[y]Means followed by different letters are significantly different at the 5% level, within columns.

Table 7. Number of roots and depth of rooting in four commmercial potato varieties sampled July 23, 1993.

Variety	Mean number of roots/4 inches of depth[z]							
	0-4	4-8	8-12	12-16	16-20	20-24	24-28	Total
Onaway	16.6ab[y]	36.0b	40.7ab	42.3a	18.7a	9.9ab	5.3a	169.8b
Kennebec	23.2a	58.7a	57.4a	41.3a	30.9a	17.6a	7.2a	237.6a
R Norkotah	5.4c	23.8b	32.6b	22.1a	18.5a	2.8b	0.1a	105.3b
Snowden	11.5bc	26.1b	35.8b	31.9a	16.1a	9.5ab	3.4a	137.0b

zAll values, except totals, are means of 8 replications and are counts of roots viewed in a region 4 inches X 0.5 inches. Totals are of roots viewed in a region 32 X 0.5 inches.
[y]Means followed by different letters are significantly different at the 5% level, within columns.

Table 8. Influence of banded phosphorus at planting on number of roots and depth of rooting across four potato varieties, July 23, 1993.

Phosphorus Applied	Mean number of roots/4 inches of depth[z]							
	0-4	4-8	8-12	12-16	16-20	20-24	24-28	Total
lb P_2O_5/A								
0	11.2b[y]	26.2b	36.8a	36.8a	25.5a	14.7a	4.1a	156.0a
100	17.2a	46.1a	46.5a	32.0a	16.6a	5.2b	3.9a	168.9a

zAll values, except totals, are means of 8 replications and are counts of roots viewed in a region 4 inches X 0.5 inches. Totals are of roots viewed in a region 32 inches X 0.5 inches.
[y]Means followed by different letters are significantly different at the 5% level, within columns.

Table 9. Influence of banded phosphorus at planting on number of roots and depth of rooting in four potato varieties sampled Aug. 4, 1993.

Variety	Phosphorus Applied	Mean number of roots/4 inches of depth[z]								
		0-4	4-8	8-12	12-16	16-20	20-24	24-28	28-32	Total
	lb P_2O_5/A									
Onaway	0	3.9	22.5	31.8	34.6	14.6	14.0	4.5	0.9	126.8
	100	12.1	41.4	44.9	34.3	26.6	14.6	9.9	0.4	184.0
Kennebec	0	14.6	52.5	57.6	29.9	35.9	31.8	11.9	3.9	239.1
	100	16.4	56.0	41.5	31.0	20.1	5.6	3.2	0.0	173.9
Russet	0	1.9	7.6	16.6	21.1	21.1	8.6	1.8	0.9	79.6
Norkotah	100	2.4	24.0	36.8	13.4	9.1	6.3	0.9	0.0	92.8
Snowden	0	7.0	17.1	24.3	20.5	24.8	16.0	5.4	0.1	123.1
	100	12.0	29.9	38.9	29.0	7.0	1.4	3.3	0.0	121.3

zAll values, except totals, are means of 8 replications and are counts of roots viewed in a region 4 inches X 0.5 inches. Totals are of roots viewed in a region 32 X 0.5 inches.

Table 10. Number of roots and depth of rooting in four commmercial potato varieties sampled Aug. 4, 1993.

Variety	Mean number of roots/4 inches of depth[z]								
	0-4	4-8	8-12	12-16	16-20	20-24	24-28	28-32	Total
Onaway	8.0bc[y]	31.9b	38.3ab	34.4a	20.6a	14.3a	7.1a	0.6a	155.4ab
Kennebec	15.5a	54.3a	49.6a	30.4a	28.0a	18.7a	7.6a	1.9a	206.5a
R Norkotah	2.1c	15.8b	26.7b	17.3a	15.1a	7.4a	1.3a	0.4a	86.2c
Snowden	9.5ab	23.5b	31.6b	28.8a	15.9a	8.7a	4.3a	0.1a	122.2bc

zAll values, except totals, are means of 8 replications and are counts of roots viewed in a region 4 inches X 0.5 inches. Totals are of roots viewed in a region 32 X 0.5 inches.

[y]Means followed by different letters are significantly different at the 5% level, within columns.

Table 11. Influence of banded phosphorus at planting on number of roots and depth of rooting across four potato varieties sampled Aug. 4, 1993.

Phosphorus Applied	Mean number of roots/4 inches of depth[z]								
	0-4	4-8	8-12	12-16	16-20	20-24	24-28	28-32	Total
lb P_2O_5/A									
0	6.8a[y]	24.9a	32.6a	28.5a	24.1a	17.6a	5.9a	1.4a	142.2a
100	10.7a	37.8a	40.5a	26.9a	15.7a	7.0b	4.3a	0.1b	143.0a

zAll values, except totals, are means of 8 replications and are counts of roots viewed in a region 4 inches X 0.5 inches. Totals are of roots viewed in a region 32 inches X 0.5 inches.

[y]Means followed by different letters are significantly different at the 5% level, within columns.

Table 12. Tuber yields and specific gravity of four potato varieties with or without band applied phosphorus.

Phosphorus Banded	Yield					Specific Gravity
	Total	>3.25"	2.0-3.25"	<2.0"	Cull	
	- - - - - - cwt/A - - - - - -					
			Onaway			
No	435	133	262	15	23	1.065
Yes	457	114	309	16	18	1.065
			Snowden			
No	464	22	375	52	9	1.080
Yes	452	38	357	91	10	1.082
			Kennebec			
No	430	37	335	29	28	1.067
Yes	430	57	314	32	28	1.067
			Russet Norkotah			
		>10 oz	4-10 oz	<4 oz		
No	454	100	274	66	14	1.070
Yes	456	119	262	59	16	1.069

Funding: MPIC

On Farm Nitrogen Management Strategies Using Window plots and Petiole Sap Nitrate Testing

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INTRODUCTION

Nitrogen (N) fertilizer applications to potatoes requires skillful management. Potatoes have a shallow root system and a high demand for N. Moreover, most potatoes are grown on irrigated sandy soils where N leaching can easily occur. When deciding how much N fertilizes to apply, potato growers need to consider the soil N availability, which is associated with N residues from previous crop and N mineralized from soil organic matter. This N source is site specific, and dependent on previous management and soil characteristics. When N is added in excessive amounts, the potential for N leaching and groundwater contamination is high. This is a major concern to the public, environmental groups, and legislators in Michigan.

Our approach to N management research is based on increasing the efficiency of both soil N and applied fertilizer N to ultimately achieve an overall reduction in N fertilizer use for potatoes. This strategy relies heavily on petiole sap testing to determine fertilizer N needs during the season. For growers interested in testing an alternative N rate compared to the conventional rate, we have introduced the concept of N window plots. Studies conducted in 1992 on a limited scale indicated that N window plots can serve as an effective way for growers to monitor crop response N fertilizer. Based on the 1992 experience, several growers expressed their willingness to establish N window plots on their fields in 1993.

In several US states and abroad, potato researchers have achieved substantial progress towards the calibration of the petiole sap nitrate test for potatoes and other vegetable crops. The sap testing procedure developed at MSU is currently being tested as an on-farm N management tool. Based on weekly sap testing and yield data, a critical level of 1000 ppm has been established as an adequate mid-season nitrate level for several potato varieties. If the sap nitrate N level is found to be below the critical N range, then in-season corrective fertilizer can be applied, thereby increasing the N use efficiency and minimizing the risk of yield loss and N leaching.

OBJECTIVES

1. **To establish N window plots on commercial farms for an evaluation of current N management practices on potato yield and tuber quality;**

2. **Correlate weekly sap nitrate data with potato yield and soil N availability, in relationship to critical nitrate N levels.**

MATERIALS AND METHODS

A. Nitrogen fertilizer trial

A field trial was conducted at the Montcalm Research Farm, with var. Snowden and 4 N fertilizer rates. The N rates were 0, 80, 160, and 240 lbs N/A (Table 1). For treatments 2 and 3 and 4, 80 lbs of N was applied at planting (May 6), and the balance was sidedressed as ammonium nitrate at tuber initiation (June 15). Preplant application of P and K were made according to MSU soil test recommendation. The soil had a pH of 5.7. The plots were 4 rows wide each spaced 34 inches, and 50 feet long. Treatments were evaluated in a randomized complete block design with 4 replications.

Petiole samples from all plots were taken once a week starting on June 29, and continued for 7 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 into a zip lock bag and mixed with an extraction solution consisting of aluminum sulfate and boric acid. The nitrate N concentration of the extract was determined with a ion specific electrode.

The data obtained from this trial were used to validate the existing critical nitrate N levels, and as a standard for testing petiole samples from the 1993 window plots.

B. Nitrogen Window Plots

Six window plots (approximately 100 x 100 ft) were established on grower's fields in Montcalm county. Ideally these plots were to receive 60-80 lb/A less N than the conventional rate. These farms represented a broad range of soil types, potato varieties, management systems and crop rotations. These trials were done with the active participation of the growers and county extension personnel. To establish a reduced N rate in the window plot area, growers were advised to skip a sidedress N application during the season. The N status of these plots and the adjacent area which received more N, were monitored weekly by petiole sap testing beginning on June 29.

C. Soil Sampling for N mineralization

A random preplant soil sample (0-12" deep) from each site was taken just prior to planting. At the Montcalm Research Farm, the zero N plots were sampled consecutively for several weeks to study N mineralization. Immediately after harvest, all N plots at Montcalm Research Farm and the window plot sites were sampled to a depth of 2 feet in 1 foot increments to assess the residual soil N.

RESULTS AND DISCUSSION

The Montcalm research trial was harvested on Sept 16. Tubers were graded according to size and the total and percent of US # 1 yield determined. Specific gravity was measured by weighing tuber samples in air and water. The window plots were harvested at different dates based on maturity. Four replicated plots (15 ft long strips) from inside and outside the window plots were harvested by hand. Tubers were graded according to size and weighed.

Sap nitrate in response to N fertilizer rate, critical nitrate level, and yield

The effects of N fertilizer rate and sampling date on sap nitrate concentration in relation to the critical nitrate level are summarized in Figure 1. The sap nitrate level increased in proportion to the N fertilizer rate. In general, the nitrate level was higher at the beginning of the season and decreased as the season progressed. The sap nitrate concentration in the 0 and 80 lb N plots decreased steadily with time. At 240 lbs/A, the sap nitrate concentration remained steady and showed only a small decrease with time. The 0 N plots began to show visual N shortage symptoms as early as mid-June. In contrast, the 240 lb N plots remained green until September.

The tuber yield, percent US # 1, and specific gravity of potatoes are presented in Tables 2 and 3. Snowden showed a yield increase to N fertilizer up to 160 lb N/A. The tuber yield declined at 240 lb N. Increased N rates up to 160 lb significantly increased the percent of oversized (>$3^1/_2$") tubers. No significant differences in specific gravity were found among the N treatments.

The 1993 yield data further validate our guidelines for critical nitrate N levels that were established from previous research (Figure 1). The sap nitrate levels produced at 0 and 80 lb N remained below the critical (borderline) level during most of the season. The sap nitrate levels attained with 160 lb appears to be the optimum, since this treatment produced the most desirable tuber yield.

Soil N Mineralization

The soil N mineralization in the zero N plots at Montcalm is shown in Figure 2. The data indicate that a substantial quantity of nitrate N (50 lb nitrate N/A/Ft) was available for potatoes from the soil N pool on June 15. The nitrate level peaked about 38 days after planting which roughly corresponds to the time of tuber initiation. This coincides with the period of greatest N need to potatoes. In the following weeks, the crop demand for N increased and began to deplete the available soil N. Because potato roots utilize a soil depth of about 2 feet, we estimate that the check plots provided as much as 70-80 lb nitrate N/A to potatoes. The yield response to N observed in this trial is a result of this N availability. This data substantiate the fact that soil organic matter mineralization and transformation of N into plant available forms need to be taken into account in determining the optimum fertilizer N rate for potatoes.

Residual Soil N

The residual soil N measured to a depth of 2 feet at the Montcalm Research Farm is presented in Table 4. When 240 lb N/A were applied, the residual soil nitrate N in the first foot was significantly higher than the other 3 N treatments. In this treatment, a total of about 47 lb of nitrate N was found in the 2-foot profile at harvest. This leftover N is very susceptible to leaching during the winter months. A substantial quantity of ammonium N was also present at harvest, particularly in the first foot. This form of N may pose a threat to leaching and groundwater contamination next spring when it is converted to nitrate N forms.

Window plots

Data on previous crop, preplant soil N, and the N rates in the window plots are presented in Table 5. The yield, specific gravity, and size distribution on the 6 window plots are presented in Tables 6-17. The sap nitrate data for both inside and outside window plots relative to the critical nitrate levels are presented in Figures 3-8.

The preplant soil test on the 6 sites showed an average of 26 lb NO_3 N/A/Ft. The average N rate used on inside plots was 222 lb/A. The outside plots received 280 lb N/A. No significant yield differences between inside and outside plots were observed on sites 1, 2, and 6. On site 5, the high N rate produced a very high proportion of R. Burbank knobby tubers, thus reducing the US #1 yield. The total yield, however, was not significantly different for the two N rates. On sites 1, 2, 5, and 6, despite the N differences, the sap nitrate concentration of both inside and outside plots followed a similar trend, and the nitrate concentration of the inside plots was only slightly lower than the outside plots. On site 4 (Table 12), where the N difference was only 10 lbs, the two sap nitrate levels were strikingly similar (Figure 6). On site 3, the sap nitrate level of the inside plots was in the inadequate range for almost the entire season. At this location, the tuber yield of the inside plot was significantly lower than the outside plot (Table 10). No significant differences in specific gravity were observed among the N rates on all farms. The residual soil N measured at harvest on 3 sites, where results are currently available, are presented in Table 18. On two of these sites, almost doubled the quantity of nitrate N in the first foot was found outside the window plot area compared to inside the window plot.

The high variability in the yield data from field plots is reflected by the high coefficient of variation (CV), particularly for oversize and B grade tubers. Although the plots were in close proximity, there was a large variation in tuber size and grade. In the window plots, there was also an unexplained decrease and then an increase in the sap nitrate N levels on August 10 and 17. We have been unable to establish with certainty whether this was due to instrument error or a true phenomenon brought about by environmental conditions. In an attempt to see if these changes were influenced by the prevailing weather pattern, we examined the daily rainfall and growing degree days (base 50 F) for Montcalm in 1993 (Figure 9). It was apparent that there was an unusually cold period with rainy weather followed by a warm, dry weather period immediately preceding August 10. Researchers have shown that nitrate N taken up by roots will accumulate in the tops, rather than being utilized, under slow growing conditions of low temperature and cloudy overcast skies. Conversely, nitrate N assimilation into amino acids proceeds rapidly under climatic conditions favorable to growth and development, such as warm temperature and high light intensity. Thus the nitrate N concentration measured under normal conditions represents a balance between nitrate N taken up by roots and nitrate N assimilated into organic molecules in the leaves. We speculate that the unusual weather experienced during the first 2 weeks of August induced rapid changes in the tissue nitrate N levels, which was reflected in our petiole sap test data on August 3, 10 and 17.

The yield data provides further evidence that on some farms, the conventional N rate may be reduced by 60-70 lb/A, without incurring yield or economic losses to growers. The critical mid-season level of 1000 ppm serves as a reliable estimator of N sufficiency. These window plots also provided an opportunity to monitor petiole sap nitrate level as affected by N application through irrigation and spray programs.

Table 1. Nitrogen fertilizer rates (lb/A) and time of application at Montcalm 1993.

Treatment #	At-planting	Tuber Initiation	Total
1	0	0	0
2	80	0	80
3	80	80	160
4	80	160	240

Table 2. The effects of nitrogen fertilizer rate on tuber yield (cwt/A) and specific gravity of Snowden. Montcalm Research Station 1993.

N Rate lbs/A	< 2"	2-3¹/₄"	>3¹/₄"*	PO	US#1*	Total*	Sp.Gr
0	25.8	364.0	25.6 c	0	389.6 b	415.4 b	1.081
80	24.9	391.8	35.7 bc	0	427.4 a	452.4 a	1.080
160	23.7	377.7	57.0 a	0	438.6 a	462.3 a	1.081
240	25.1	361.4	44.9 ab	0	406.3 ab	406.3 ab	1.079

* Means followed by different letters are significantly different according to Duncan's Multiple Range test (p=0.05).

Table 3. The effects of nitrogen rate on percent size distribution by weight of Snowden. Montcalm Research Station 1993.

N Rate lbs/A	< 2"	2-3¹/₄"	>3¹/₄"	PO	US#1
0	6	88 a	6 c	0	94
80	6	87 ab	8 bc	0	95
160	5	82 c	13 a	0	95
240	6	84 bc	10 ab	0	94

* Means followed by different letters are significantly different according to Duncan's Multiple Range test at 5% level.

Table 4. Residual soil nitrogen at harvest in relation to N fertilizer rate applied to Snowden. Montcalm 1993.

N Rate lb/A	Soil depth -inches			
	0-12		13-24	
	NO_3-N*	NH_4-N	NO_3-N*	NH_4-N
	------------------lb N/A/Ft--------------			
0	11.2 b	20.7	7.6 b	11.9
80	12.1 b	23.9	6.0 b	9.3
160	14.6 b	26.0	10.5 ab	10.4
240	27.1 a	25.8	20.3 a	13.1

* Means followed by different letters are significantly different, as determined by Duncan's Multiple Range Test(P=0.05).

Table 5. Nitrogen fertilizer rates and agronomic features of window plot demonstrations in 1993.

Farm Designation	Variety	Previous Crop	Preplant Soil NO_3 lb/A/1ft	N inside lb/a	N Outside lb/a	N Diff. lb/a	Plant Date	Harvest Date
Site 1	R.Burbank	Cucumber	20	267	334	67	5/10	9/21
Site 2	Snowden	Wheat-rye	19	213	255	42	5/17	9/21
Site 3	Goldrush	Corn	38	170	239	69	5/06	8/31
Site 4	Snowden	Wheat	38	254	244	10	5/02	9/15
Site 5	R.Burbank	Corn	26	215	317	102	5/09	10/15
Site 6	Snowden	Corn	15	216	290	74	5/06	9/15
Average			26	222	280	58		

Table 6. The effects of N rates in the window plots on tuber yield (cwt/A) and specific gravity of R. Burbank (Site 1 - 1993).

Window	N lb/A	<4oz	4-10oz	>10 oz	PO	US#1	Total	Sp.Gr
Inside	267	54.8	263.9	56.4	54.8	320.3	430.0	1.079
Outside	334	45.1	217.3	54.8	54.8	266.5	366.4	1.076
Coeff. of Var. %		38	23	94	22	21	15	1

The US #1 and total tuber yields were not significantly different between inside and outside the window plots (p=0.05).

Table 7. The N effects on percent size distribution of R. Burbank potatoes (Site 1 - 1993).

Window	< 4oz	4-10 oz	>10 Oz	PO	US#1
Inside	13	61	13	13	74
Outside	12	59	13	15	72

Table 8. The effects of N rates in the window plots on tuber yield (cwt/A) and specific gravity of Snowden (Site 2 - 1993).

Window	N rate lbs/A	<2"	2-3$^1/_4$"	>3$^1/_4$	PO	US#1	Total	Sp.Gr
Inside	213	66.4	325.9	14.3	0	340.3	406.7	1.083
Outside	255	62.3	296.7	15.9	0	312.6	374.9	1.079
Coeff. of Var. %		39	14	76	-	16	9	0.4

The US #1 and total tuber yields were not significantly different between inside and outside the window plots (p=0.05)

Table 9. The N effects on percent size distribution of Snowden (Site 2 - 1993).

Window	< 2"	2-3 1/4"	>3 1/4"	PO	US#1
Inside	18	79	3	0	82
Outside	16	79	4	0	84

Table 10. The effects of N rates in the window plots on tuber yield (cwt/A) and specific gravity of Goldrush (Site 3 - 1993).

Window	N lb/A	<4oz	4-10oz	>10 oz	PO	US#1*	Total*	Sp.Gr
Inside	170	81.5	216.3	20.0	15.3	236.3 b	333.1 b	1.062
Outside	239	61.0	266.5	52.0	20.5	318.6 a	400.0 a	1.061
Coeff. of Var. %		22	15	49	47	7	5	0.2

* Means followed by different letters are significantly different according to Duncan's multiple range test (P=0.05).

Table 11. The N effects on percent size distribution of R. Burbank potatoes Site 3 - 1993).

Window	< 4oz*	4-10 oz	>10 Oz	PO	US#1*
Inside	25 a	65	6	4	71 b
Outside	15 b	67	13	5	80 a

* Means followed by different letters are significantly different according to Duncan's multiple range test (P=0.05).

Table 12. The effects of N rates in the window plots on tuber yield (cwt/A) and specific gravity of Snowden (Site 4 - 1993).

Window	N rate lbs/A	<2"	2-3$^1/_4$"	>3$^1/_4$	PO	US#1*	Total*	Sp.Gr
Inside	143	76.9	296.2	5.4	0	301.6 b	378.5 b	1.084
Outside	254	46.4	352.3	15.9	0	382.8 a	429.2 a	1.082
Coeff. of Var. %		26	11	77	-	10	6	0.4

*Means followed by different letters are significantly different according to Duncan's multiple range test (P=0.05).

Table 13. The N effects on percent size distribution of Snowden (Site 4 - 1993)

Window	< 2"*	2-3$^1/_4$"	>3$^1/_4$"	PO	US#1
Inside	21	78	1	0	79
Outside	11	82	7	0	89

Table 14. The effects of N rates in the window plots on tuber yield (cwt/A) and specific gravity of R. Burbank (Site 5 - 1993).

Window	N lb/A	<4oz	4-10oz	>10 oz	PO*	US#1*	Total	Sp.Gr
Inside	215	88.5	302.4	64.9	35.2 b	367.3 a	490.9	1.062
Outside	317	93.2	257.3	27.0	112.1 a	284.3 b	489.6	1.061
Coeff. of Var. %		19	10	53	2	3	5	0.5

*Means followed by different letters are significantly different according to Duncan's multiple range test (P=0.05).

Table 15. The N effects on percent size distribution of R. Burbank (Site 5 - 1993).

Window	< 4oz*	4-10 oz	>10 Oz	PO	US#1*
Inside	18	62	13	7 b	75 a
Outside	19	53	6	23 a	58 b

*Means followed by different letters are significantly different according to Duncan's multiple range test (P=0.05).

Table 16. The effects of N rates in the window plots on tuber yield (cwt/A) and specific gravity of Snowden (Site 6 - 1993).

Window	N rate lbs/A	<2"	2-3 1/4"	>3 1/4	PO	US#1	Total	Sp.Gr
Inside (West-K)	307	59.5	367.9	17.9	0	385.9	445.3	1.083
Inside (East+K)	216	58.4	337.9	18.7	0	356.7	415.1	1.079
Outside	290	57.2	302.3	23.3	0	325.7	382.8	1.084
Coeff. of Var. %		22	14	74	-	14	12	0.3

Table 17. The N effects on percent size distribution of Snowden (Site 6 - 1993).

Window	< 2"	2-3 1/4"	>3 1/4"	PO	US#1
Inside (West-K)	13	83	4	0	87
Inside (East+K)	15	81	4	0	85
Outside	15	79	6	0	85

Table 18. Residual soil N in the window plots. Montcalm County 1993.

Farm	Window	Soil depth -inches			
		0-12		13-24	
		NO_3-N	NH_4-N	NO_3-N	NH_4-N
		------------lb N/A/ft----------			
Site 3	Inside	18.0	31.7	11.5	14.4
	Outside	36.4	46.1	12.6	13.7
Site 4	Inside	10.4	37.4	6.1	17.6
	Outside	20.5	44.3	5.0	12.2
Site 6	Inside W	17.6	54.0	10.4	16.6
	Inside E	10.1	42.5	19.1	11.5
	Outside	10.4	29.9	4.3	13.7

Fig 1. 1993 Guidelines for Interpreting Potato Sap Nitrate Concentration

Montcalm Research Farm - Snowden

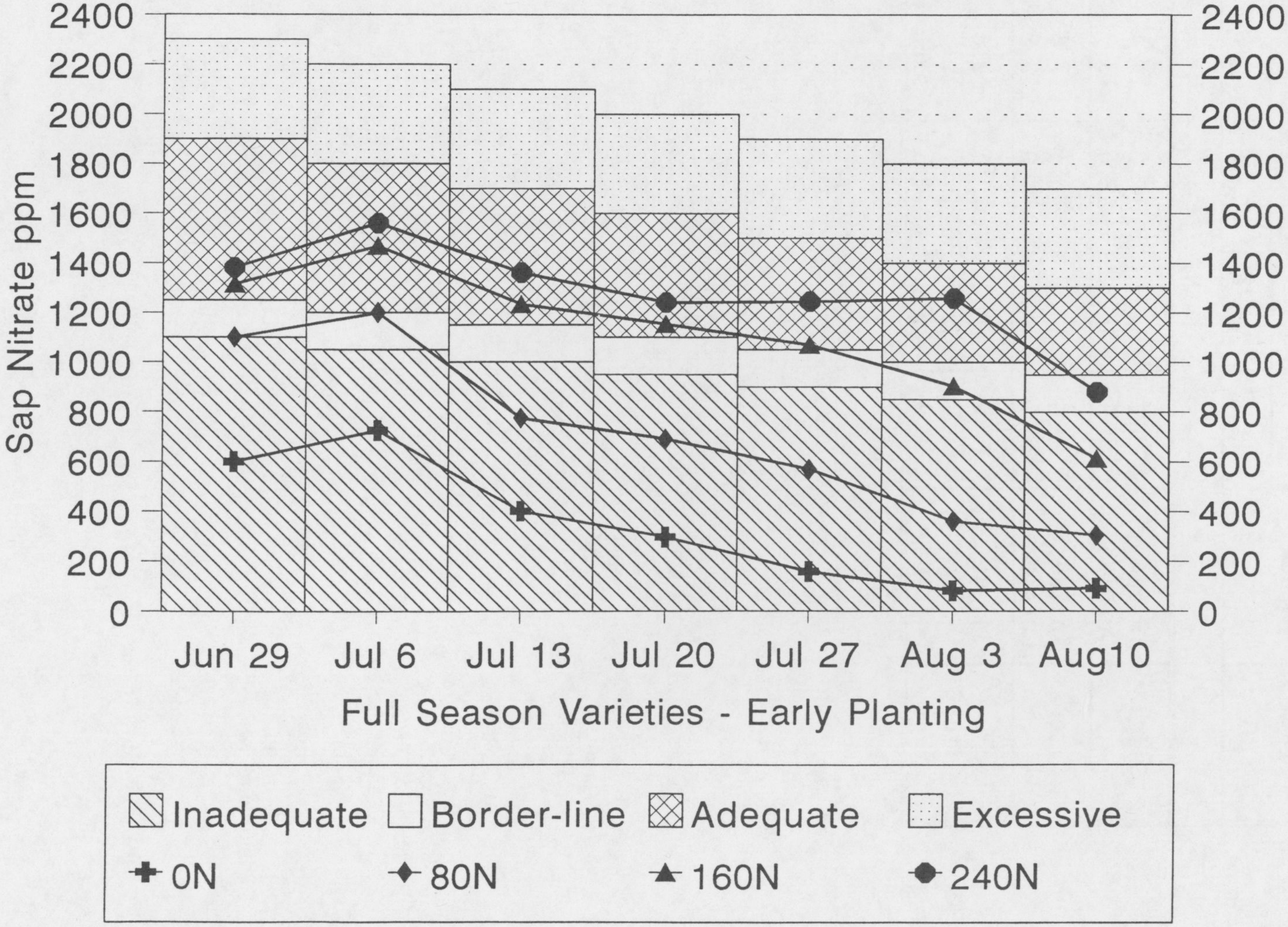


Fig 2. Nitrate N mineralization in the zero N plots Montcalm Research Farm 1993

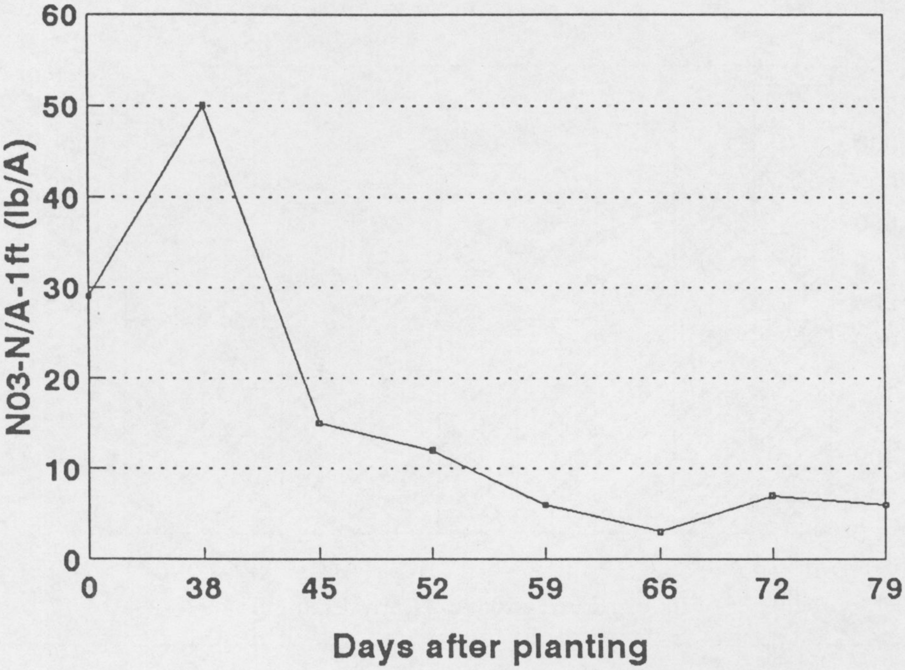


Fig. 3. Petiole sap nitrate concentration inside and outside window plots.
Site 1 - Russet Burbank

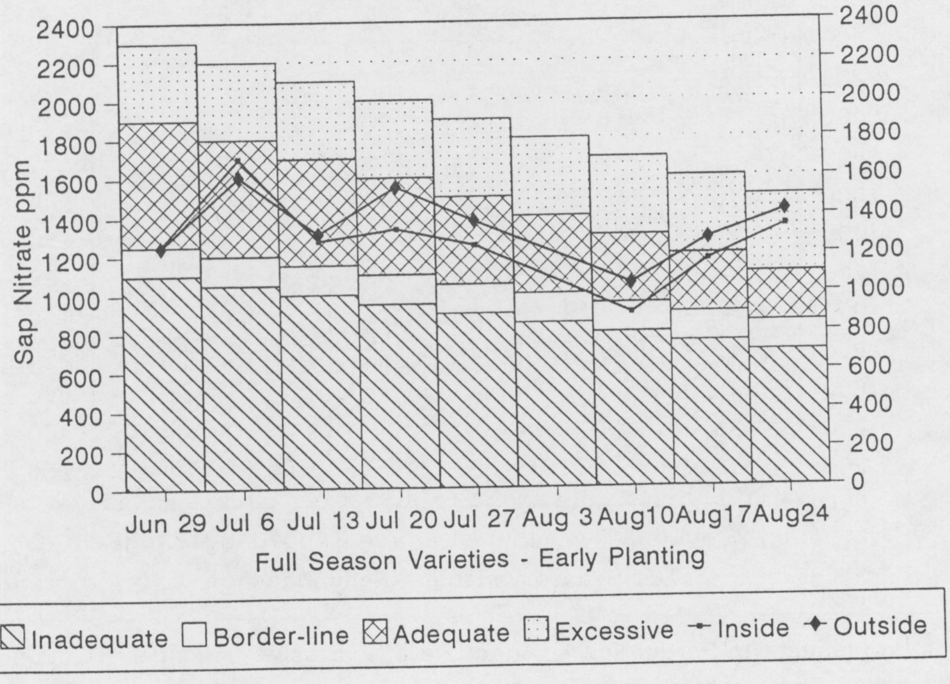


Fig. 4. Petiole sap nitrate concentration inside and outside window plots.
Site 2 - Snowden

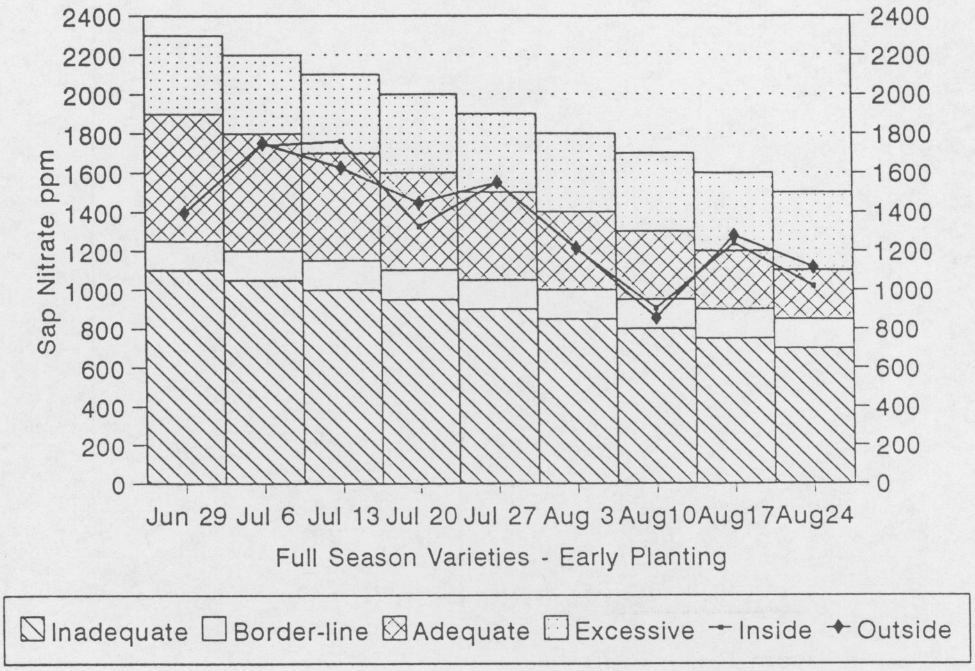


Fig. 5. Petiole sap nitrate concentration inside and outside window plots.
Site 3 - Goldrush

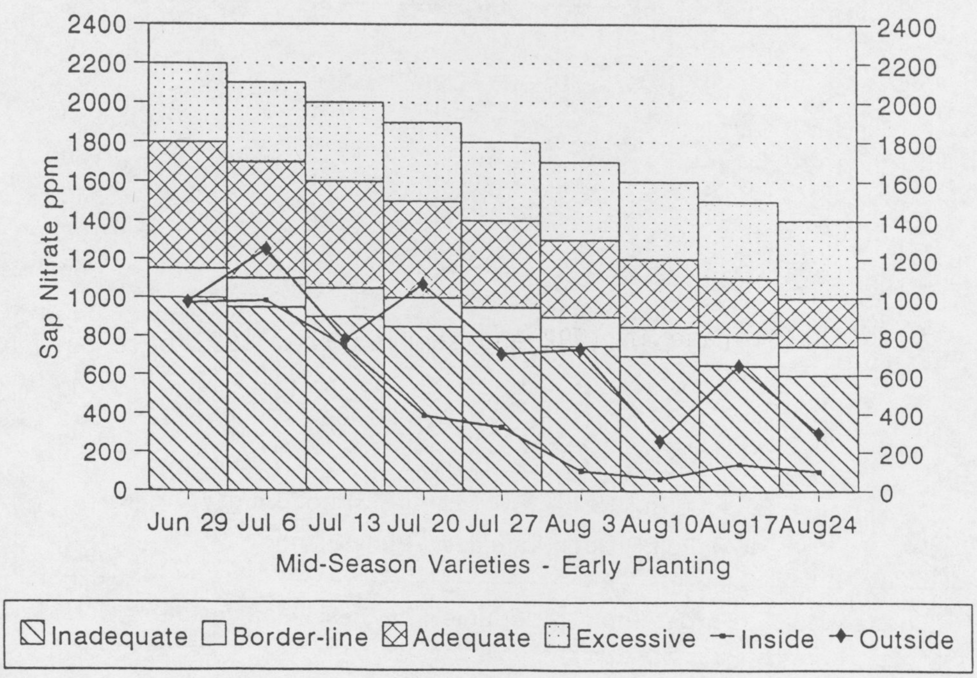


Fig. 6. Petiole sap nitrate concentration inside and outside window plots.

Site 4 - Snowden

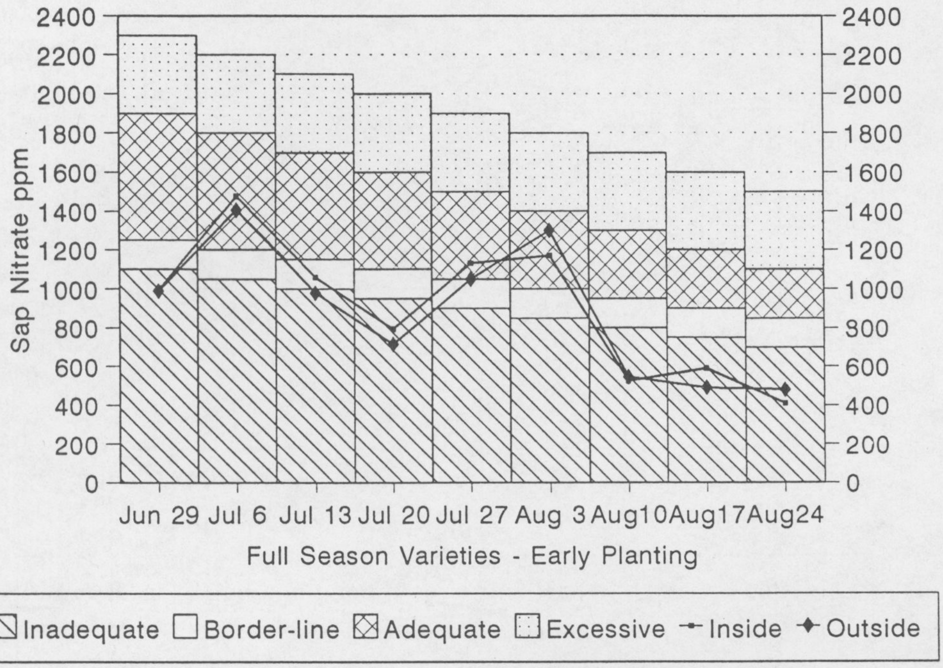


Fig. 7. Petiole sap nitrate concentration inside and outside window plots.

Site 5 - Russet Burbank

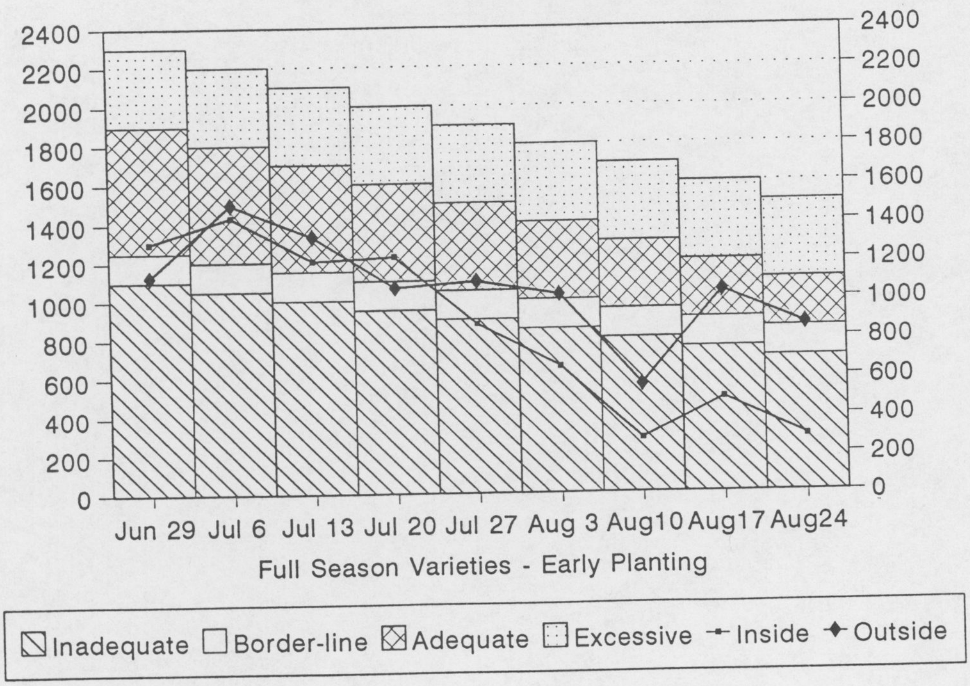


Fig. 8. Petiole sap nitrate concentration
inside and outside window plots.
Site 6 - Snowden

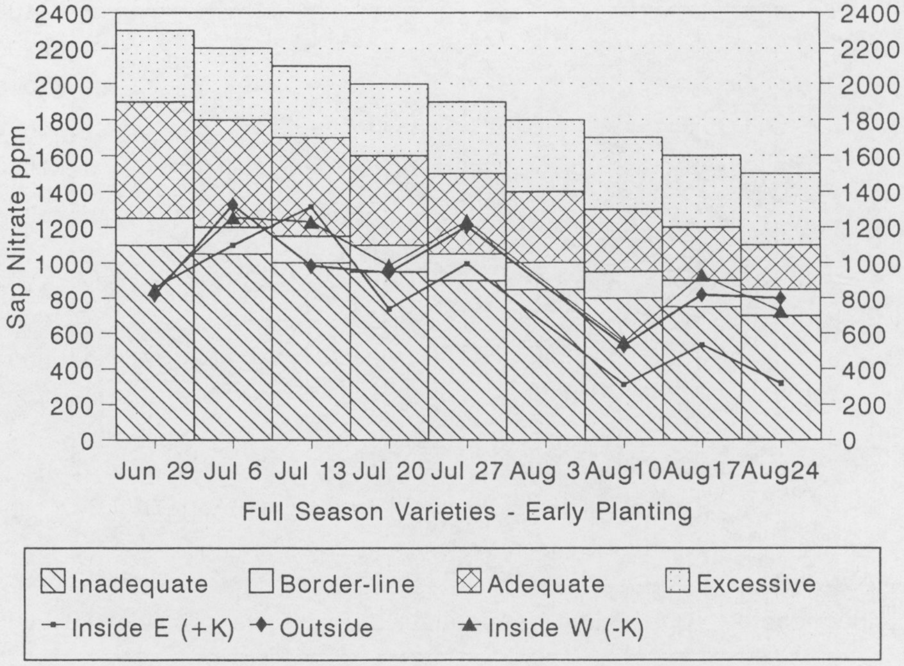
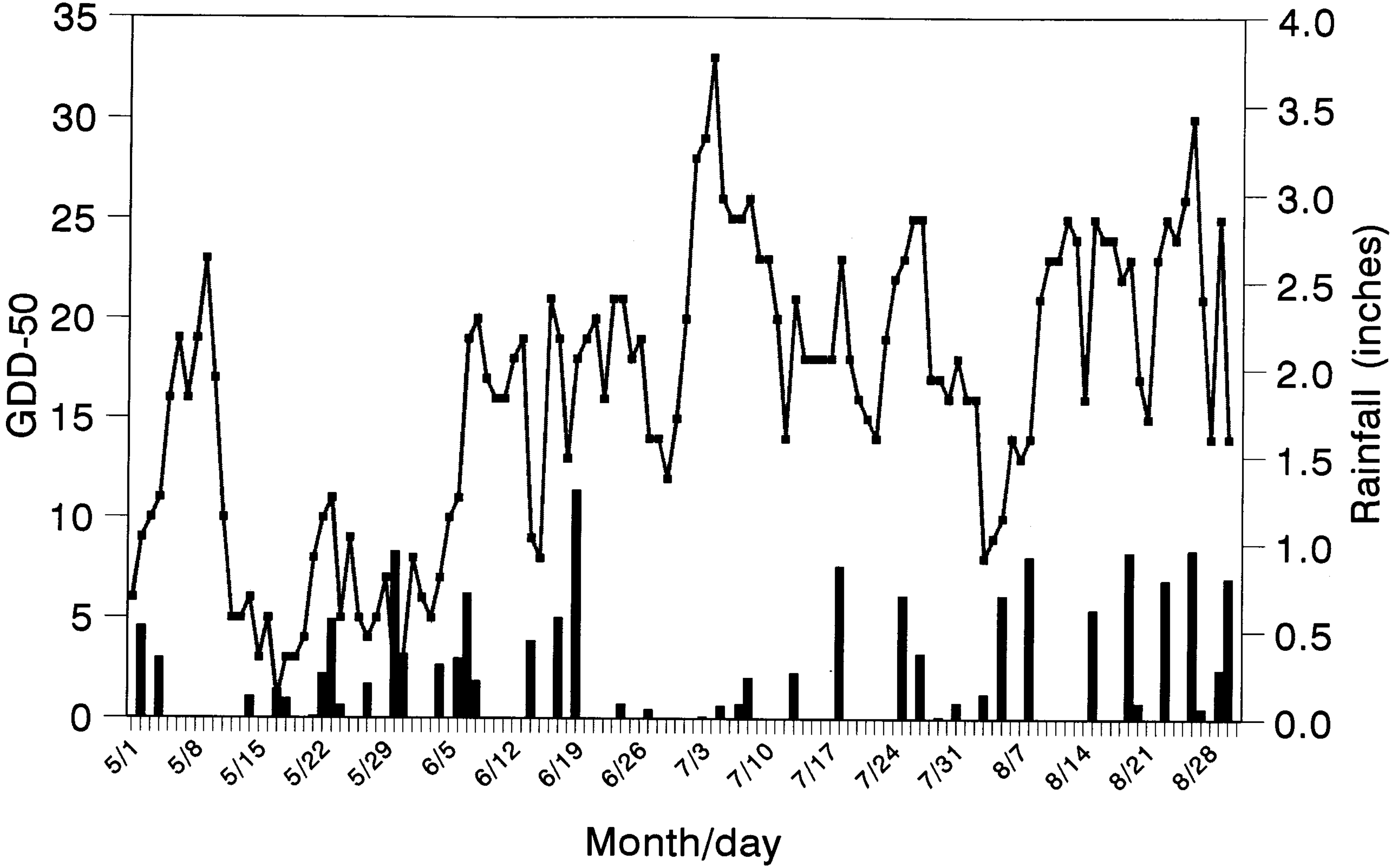


Fig. 9. Daily rainfall and growing degree days (GDD-50) at Montcalm 1993.



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Funding: MPIC

EFFECTS OF NITROGEN FERTILIZER MANAGEMENT ON NITRATE LEACHING

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Department of Crop and Soil Sciences

The goal of this study is to develop nitrogen fertilization strategies that minimize nitrate leaching to groundwater while still maintaining acceptable profitability. The use of permanently installed drainage lysimeters allows the direct measurement of nitrate leached. The permanent installation of the lysimeters also allows long term tracking 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 scrutiny of agricultural practices increases, this type of data becomes important for establishing leaching amounts from conventional fertilizer management as well as for more conservative lower input systems.

METHODOLOGY

The lysimeters used in this study are steel boxes that are 48 inches wide, 68 inches long and 6 feet tall. The boxes have open tops and are installed so that their tops are about 1.5 feet belowground allowing normal tillage operations. The bottoms of the lysimeters are closed except for a small opening through which the drainage water is channeled into a closed container. The volume of outflow is manually measured and samples of the outflow are analyzed for nitrates. The lysimeters are separated into two treatments, a conventional (CON) with somewhat high nitrogen input and a better management system (BMS), with lower input nitrogen scheduled according to plant needs. Each year since 1988, the BMS plot has received about half the nitrogen fertilizer compared to the CON plot.

Potatoes were planted in 1993 following a year of rotation with corn. Potatoes had been grown on the lysimeter field for two years prior to the 1992 corn crop. Both plots were planted with Russet Burbank potatoes on May 12, 1993, at which time a starter fertilizer containing 16 and 8 lbs/acres was applied to the CON and BMS respectively. This was five time lower than the intended amounts due to an error in calculation. The potatoes were planted in 34" row spacing and 12" seed spacing. The schedule of sidedress nitrogen on the BMS plots was 150 lbs./acre applied on June 28.

Sidedress nitrogen was applied at a rate of 140 lbs./acre on June 9 and 40 lbs./acre July 20 to the CON plot to be certain that enough nitrogen was available for plant growth.

Yield measurements were taken from a carefully controlled area directly over the top of each lysimeter and from 2 randomly chosen areas outside the lysimeter site when the treatments were the same.

Irrigation was supplied with overhead sprinkling. The system that is independent of the Montcalm Station's usual system failed to operate properly at a time when the plants needed irrigation during a period from July 10 to July 31, probably causing some yield and grade reduction of the potatoes.

RESULTS

The potato yields were 205 and 140 cwt/acre for the CON and BMS, respectively, for the areas over the lysimeter. The yield reduction below more normal yield was likely the result of lack of adequate irrigation during the last three weeks of July.

A small plot of potatoes was planted near the lysimeter field to determine chlorophyll meter responses to various nitrogen treatments. One treatment had no N fertilizer added throughout the season. Another treatment had no preplant and 100 lbs./acre added on June 28 and 40 added on July 20. Results of the chlorophyll readings are shown in Table 1.

Table 1. Results from chlorophyll meter readings taken for four nitrogen treatments on several dates in 1993.

	CHLOROPHYLL METER READINGS			
Date	16-140-40	8-150-0	0-0-0	0-100-40
	CON	BMS	ZERO	
June 9	44.6	43.7	41.1	--
June 23	48.1	44.2	40.2	--
July 1	47.1	45.4	39.8	40.9
July 6	48.4	45.0	39.5	40.9
July 16	45.3	43.4	36.3	39.8
July 20	43.5	42.4	36.6	40.4
July 26	43.0	42.2	35.4	40.1
August 2	44.5	44.7	35.9	42.6
August 9	44.5	41.5	34.5	43.0

Both the zero preplant treatments had vines considerably smaller than both lysimeter treatments. The zero treatment had considerably smaller chlorophyll readings and the CON treatment had considerably higher readings. The 0-100-40 treatment gradually increased in concentration, but was never able to completely obtain the values of the CON treatment. The BMS treatment always had a lower reading and the yield results reflected the lower N application.

The 1993 leachate concentrations are shown in Figure 1. Large rainfall and drainage in the spring of 1993 resulted in reduced combinations in both treatments. The leaching amount in 1993 was 8 and 54 lbs./acre for the CON and BMS, respectively. After the "flushing out" by July 1, the leaching amounts were smaller for both treatments. The concentration of both treatments began to increase toward the end of the year, likely due to the leaching of unused N from both treatments.

CONCLUSIONS

The 1993 leaching results were lower than most years because of a large drainage flow during the spring. This result demonstrates that the timing of nitrate concentration measurements is critical to the overall assessment of nitrate leaching and that several years of continuous measurements are necessary to accurately evaluate the nitrate losses resulting from N management strategies.

Funding: Federal Grant

Processing and Quality Evaluation of Fresh Peeled and Canned Potatoes from the MSU Variety Trials, 1992 and 1993.

J.N. Cash, R. Chase and D. Douches

INTRODUCTION

Although most of the processing potatoes produced in Michigan are made into chips or fries, a recent trend toward fresh peeling is beginning to utilize fairly significant quantities of tubers. At both the state and national levels, this use category is accelerating because of the increasing demand for convenience by food service establishments. Thermal processing (ie., canning) of potatoes has maintained a consistent moderate use niche for many years. It is unlikely that this niche market will expand significantly in the future but it may be possible to capture segments of this market with the proper cultivars to meet the quality needs of the end product user. In both of the aforementioned categories, processors tend to use whatever raw product is available (for the price they are willing to pay) without regard to growing location or cultivar because they have very little, if any, information about the end product quality. Although price will always be a factor, processors have indicated that they would like to buy cultivars of tubers which will consistently produce good quality end products. The purpose of this project was to evaluate the fresh peeled and canned quality of Michigan grown potato cultivars and selections.

PROCEDURE

In 1992 the cultivars selected for processing were Onaway, Russet Norkotah, Hilite Russet, Viking, Saginaw Gold, Superior, Chieftan and Russet Burbank. Due to poor performance in the processing trials, several of these cultivars were dropped. In 1993 the cultivars/selections chosen for processing as fresh peeled and canned product were Viking, NY95, St. Johns, Portage, Snowden, Chaleur, AF875-15, Gemchip, AF1060-2, Superior, Prestile, Atlantic and E55-44. In both years tubers from each processing lot were assessed for specific gravity and black spot. Samples were abrasion peeled to approximately 10-12% peel loss and divided into lots for holding as fresh peeled or diced for canning. Fresh peeled samples were held at 38°F after treating with 0.5% citric + 0.5% ascorbic + 0.1% $NaCl_2$ or after dipping in water (control). These samples were evaluated at 0, 3, 5, 7 and 10 days for color (visual rating). Canned samples were diced and canned under commercial conditions. These samples were removed from storage and evaluated at 0, 3, 6 and 9 months for drained weight, color (visual and Hunter CDM), and texture (shear press or Instron). Processing for fresh peeled was done at harvest and again after 6 months storage in 1992 and samples from 1993 have been placed in commercial storage for subsequent processing.

RESULTS AND DISCUSSION OF 1992 TRIALS

Results of the 10 day storage regime for fresh peeled potatoes are shown in Table 1. Changes in color and overall acceptability were slight during the first 3 days of refrigerated storage but by day 5 browning and discoloration were very apparent in most of the samples. Onaway and Superior still had acceptable color in both the ascorbic acid treated samples and controls but by day 7 all the samples were rated as unacceptable. After 6 months commercial storage, samples were removed and peeled. Table 2 summarizes the visual evaluation of these samples. Changes in color occurred more quickly in the stored samples than in the freshly harvested tubers. By day 3 of refrigerated storage only Russet Burbank and Superiors treated with ascorbic acid had acceptable color and by day 5 these had deteriorated to an unacceptable state. Table 3 summarizes the quality of canned samples 3 months after processing. All samples gained some weight in the can with Saginaw Gold, Russet Norkotah and Chieftan showing the greatest gains. Viking and Russet Norkotah had slightly better color than the other white fleshed varieties. Although there were no other golden fleshed varieties to compare with the Saginaw Gold it was judged to have very good yellow color and rated highly in this category. All the samples rated fairly high in visual texture, which was based on assessment of wholeness and integrity of the diced potato pieces. The shear press data showed very little difference between the various cultivars after canning. Shear values relate to the force necessary to move one or more shear cell blades through a given volume of sample inside a cell of defined size. Compression refers to the force exerted by elastic deformation of the sample against the blades as the sample is forced through the grid of a shear cell. Compression values were highest for Russet Burbank, Russet Norkotah and Onaway. It is likely that this is an indirect reflection of the starch content of these tubers and the changes which the starch granules have undergone during processing. Tables 4 through 6 show subsequent changes in the canned product after 6, 9 and 12 months storage. A slight amount of weight loss occurs with time because of sloughing but this is fairly inconsequential. Visual color and texture changes are small but shear and compression values indicate slight losses in firmness from 6 months to 12 months storage. All canned samples were still very acceptable after one year of storage.

RESULTS AND DISCUSSION OF 1993 TRIALS

Results of the 10 day storage regime for fresh peeled potatoes are shown in Table 7. Changes in color and overall acceptability for the control samples began to be apparent in most samples by the third day of storage. By the fifth day of storage only Viking, St. Johns, Portage, Superior and Atlantic in the untreated samples were still slightly accaptable but by the seventh day of storage none of the control samples were acceptable. All the ascorbic acid treated samples had acceptable color on the fifth day of storage but Chaleur, AF875-15, AF1060-2 and E55-44 were very marginal. By day 7, NY95, St. Johns, Portage, Gemchip and Atlantic were marginally acceptable but all others were unacceptable. By day 10, none of the samples had acceptable color.

Table 1 - Visual Color Evaluation of Fresh Peeled Potatoes, 1992.

Cultivar	Day 1 w/Asc	Day 1 CK[1]	Day 3 w/Asc	Day 3 CK	Day 5 w/Asc	Day 5 CK	Day 7 w/Asc	Day 7 CK	Day 10 w/Asc	Day 10 CK
Russet Burbank	8[2]	8	8	7	6	2	4	0	3	0
Onaway	8	8	8	7	8	7	5	3	4	0
Superior	9	9	8	7	7	7	4	1	2	0
Viking	9	9	9	7	6	5	3	2	1	0
Hilite Russet	8	8	7	5	6	2	4	1	3	0
Russet Norkotah	7	7	6	6	6	5	2	0	2	0
Chieftan	7	7	7	6	5	3	5	0	3	0
Saginaw Gold[3]	9	9	8	7	6	3	5	0	4	0

[1] w/Asc = with ascorbic acid; CK = control without ascorbic acid
[2] 1 to 10; 1 = poorest, 10 = best [3] Saginaw Gold is a yellow fleshed variety

Table 2 - Visual Color Evaluation of Fresh Peeled Potatoes from Tubers Which Were Stored 6 Months Before Peeling, 1992.

Cultivar	Day 1 w/Asc	Day 1 Ck[1]	Day 3 w/Asc	Day 3 Ck	Day 7 w/Asc	Day 7 Ck
Russet Burbank	9[2]	7	7	4	3	0
Superior	9	9	8	5	4	1
Viking	9	8	6	3	4	0
Hilite Russet	9	7	4	1	0	0
Russet Norkotah	8	7	5	2	3	0
Chieftan	7	7	3	2	2	0
Saginaw Gold[3]	9	9	5	2	2	1

[1] w/Asc = with ascorbic acid; Ck = control without ascorbic acid
[2] 1 to 10; 1 = poorest, 10 = best
[3] Saginaw Gold is a golden fleshed variety.

Table 3 - Quality Evaluation of Canned Potatoes After 3 Months Storage, 1992.

				Force in lbs/100g[3]	
Cultivar	Drained wt (g)[1]	Visual Color[2]	Visual Texture[2]	Shear	Compression
Russet Burbank	377	6	8	35	65
Onaway	345	8	8	32	57
Superior	380	8	7	29	64
Viking	380	10	8	30	65
Hilite Russet	385	7	8	31	67
Russet Norkotah	390	9	7	35	70
Chieftan	392	8	7	27	56
Saginaw Gold	441	9	8	31	61

1 Fill wt = 341 g (12 ozs)
2 1 to 10; 1 = poorest, 10 = best
3 Kramer Shear Press

Table 4 - Quality Evaluation of Canned Potatoes After 6 Months Storage, 1992.

				Force in lbs/100g[3]	
Cultivar	Drained wt (g)[1]	Visual Color[2]	Visual Texture[2]	Shear	Compression
Russet Burbank	375	6	9	32	68
Onaway	350	8	9	30	60
Superior	375	9	7	30	65
Viking	380	9	8	29	65
Hilite Russet	395	8	9	30	62
Russet Norkotah	380	8	7	34	65
Chieftan	390	8	7	20	50
Saginaw Gold	425	9	7	29	60

1 Fill wt = 341 g (12 ozs)
2 1 to 10; 1 = poorest, 10 = best
3 Kramer Shear Press

Table 5 - Quality Evaluation of Canned Potatoes After 9 Months Storage, 1992.

Cultivar	Drained wt (g)[1]	Visual Color[2]	Visual Texture[2]	Force in lbs/100g[3] Shear	Compression
Russet Burbank	360	6	6	25	60
Onaway	335	7	6	30	55
Superior	380	7	6	20	60
Viking	370	9	7	25	60
Hilite Russet	373	7	6	30	58
Russet Norkotah	370	9	5	28	60
Chieftan	375	7	6	20	51
Saginaw Gold	425	8	7	30	55

[1] Fill wt = 341 g (12 ozs)
[2] 1 to 10; 1 = poorest, 10 = best
[3] Kramer Shear Press

Table 6 - Quality Evaluation of Canned Potatoes After 12 Months Storage, 1992.

Cultivar	Drained wt (g)[1]	Visual Color[2]	Visual Texture[2]	Force in lbs/100g[3] Shear	Compression
Russet Burbank	365	6	6	25	57
Onaway	345	7	6	27	55
Superior	369	8	5	26	58
Viking	370	9	7	20	55
Hilite Russet	365	6	5	30	60
Russet Norkotah	368	6	5	25	62
Chieftan	370	7	4	22	50
Saginaw Gold	420	7	7	29	55

[1] Fill wt = 341 g (12 ozs)
[2] 1 to 10; 1 = poorest, 10 = best
[3] Kramer Shear Press

Table 7 - Visual Color Evaluation of Fresh Peeled Potatoes, 1993.

Cultivar	Day 1		Day 3		Day 5		Day 7		Day 10	
	w/Asc	CK[1]	w/Asc	CK	w/Asc	CK	w/Asc	CK	w/Asc	CK
Viking	9[2]	9	9	6	8	6	4	1	2	0
NY95	9	9	8	5	8	3	6	1	1	0
St. Johns	9	8	8	7	8	6	6	4	4	0
Portage	8	8	8	7	8	6	6	4	3	0
Snowden	9	9	9	6	7	4	5	2	3	0
Chaleur	9	8	7	7	6	3	5	0	1	0
AF875-15	9	7	7	5	6	4	5	2	0	0
Gemchip	9	8	8	5	7	5	6	4	4	0
AF1060-2	8	8	8	5	6	5	5	4	2	0
Superior	9	9	8	6	7	6	3	2	1	0
Prestile	8	7	7	7	7	5	5	1	2	0
Atlantic	9	7	8	7	7	6	6	3	3	0
E55-44	9	8	8	5	6	4	5	4	2	0

[1] w/Asc = with ascorbic acid; CK = water dip control without ascorbic acid
[2] 1 to 10; 1 = poorest, 10 = best

Total glycoalkaloid (TGA) content for selected Michigan grown potato cultivars, 1993.

Cultivar	Analytical Reps 1	2	3	X TGA
Snowden (source 1)	5.81[1]	6.22	5.90	5.98
Snowden (source 2)	11.90	11.45	12.15	11.83
Snowden (source 3)	4.95	5.10	4.47	4.84
Snowden (source 4)	2.90	2.51	2.60	2.67
Atlantic	3.35	2.95	3.20	3.17
Russet Burbank	7.20	7.95	7.75	7.63

TGA in mg/100g fresh weight of tubers.

Funding: Federal Grant

POTATO STORAGE RESEARCH
1992-93 Storage Season

Robert Fick and Roger Brook
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Objectives:

- to develop guidelines for the long term storage of Snowden potatoes, including the effects of early storage season stress
- to monitor the effects of various cooling rates and low temperature storage limits on the long term storability of chipping potatoes
- to develop guidelines for the critical sugar levels and the significance of changes in sugar levels during long term storage of Snowden potatoes

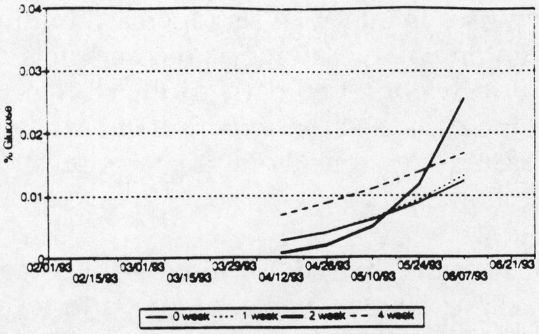
Effect of Early Storage Season Stress on the Storage of Snowden and Atlantic Potatoes

The potatoes used in the experiment were grown on irrigated clay soil at Bishop Farms in Bay Co., MI. The fields were sprayed with maliec hydrazide (MH30) in mid-August. Diquat was used for vine kill 10 to 20 days before harvest. The Snowden potatoes were harvested October 6 at a pulp temperature of about 60°F; the Atlantic potatoes on October 7 at about 58°F. Tubers for the experiment were collected form the sorting line going into the commercial storage and placed in mesh sacks. They were transported to the MSU Montcalm research station, dipped in a Sprout Nip solution, air dried and then transported to the MSU campus.

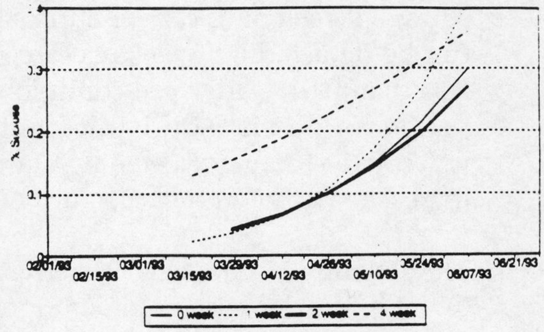
Different levels of early season stress were created by placing the tubers in a high humidity, 80°F storage for periods of 0, 1, 2, and 4 weeks. After heat treatment, the tubers were transferred to coolers at 60°F for two weeks and then moved to coolers preset to the final storage temperature(s). The Snowden potatoes had final storage temperatures of 45 and 50°F; the Altantic potatoes had final storage temperatures of 50 and 55°F.

Samples of eight tubers were taken bi-weekly or when a temperature change occurred. The samples were analyzed for glucose and sucrose sugar content; fried chip samples were scored for color using the Snack Food Association's 1-5 color chart using 0.5 steps. The sugar analyses were performed using a YSI 2700 analyzer at the Techmark Inc. facility. Sampling continued until mid-June.

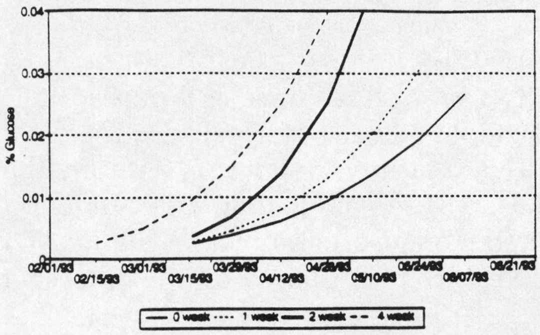
For potatoes that received no heat treatment, the Snowden tubers stored at 45°F sweetened approximately 4 weeks after the tubers stored at 50°F. The tubers stored at 45°F were inadvertently warmed to 65°F in mid-March. It con be concluded that tubers at 45°F will exhibit a change in color at least 4 weeks later than tubers at 50°F during 8-9 months of storage. Due to the warming



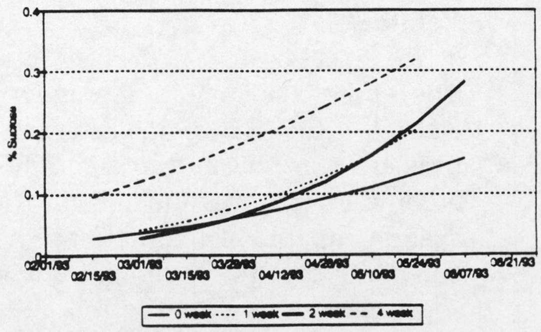
Glucose late storage season sweetening for Snowden variety stored at 7.2°C. (18.3°C after 3/16/93)



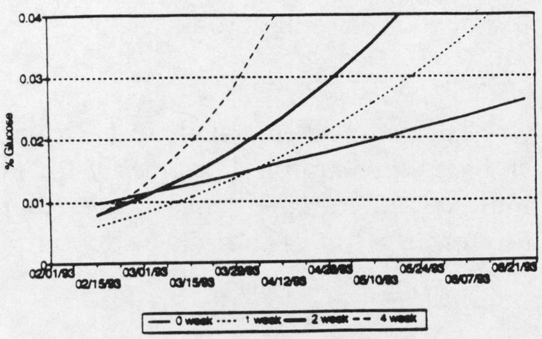
Sucrose late storage season sweetening for Snowden variety stored at 7.2°C. (18.3°C after 3/16/93)



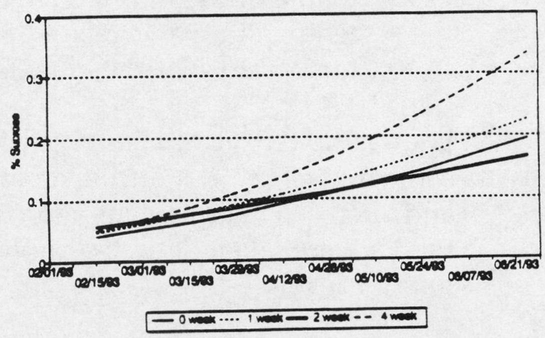
Glucose late storage season sweetening for Snowden variety stored at 10.0°C.



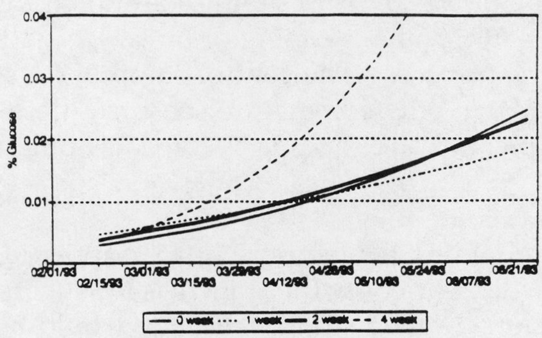
Sucrose late storage season sweetening for Snowden variety stored at 10.0°C.



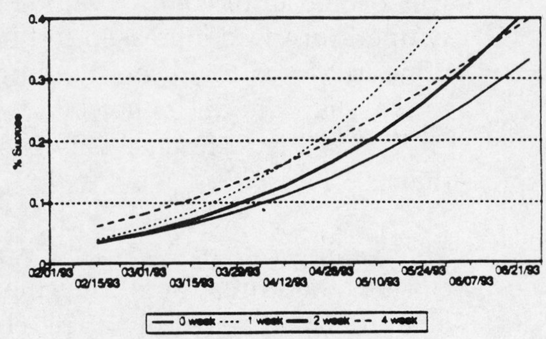
Glucose late storage season sweetening for Atlantic variety stored at 10.0°C.



Sucrose late storage season sweetening for Atlantic variety stored at 10.0°C.



Glucose late storage season sweetening for Atlantic variety stored at 12.5°C.



Sucrose late storage season sweetening for Atlantic variety stored at 12.5°C.

experienced, 8 weeks may be closer to the actual difference in timing. Based on the bi-weekly sampling of Snowden tubers for the 1992-93 storage season, late storage sweetening can be anticipated by rises in sugar levels. Increase in glucose can be detected 6-8 weeks before chips go off color, assuming glucose levels are less than 0.01% after pre-conditioning. Stresses imposed early in the storage period (or possibly during harvest) will increase the rate of increase in glucose when late storage sweetening starts. Greater stress results in greater rates of increase, as shown in the figure on the following page.

The Atlantic potatoes harvested were of marginal quality for long term storage. Overall, the Atlantic potatoes stored at 50°F exhibited sugar change patterns and responses similar to Snowden potatoes stored at 45°F.

Effects of Cooling Rates and Low Temperature Storage Limits on Snowden Potatoes

The MSU experimental storage system is a set of three bins, each measuring about 8 ft x 8 ft by 18 ft high. Each bin holds about 350 cwt of potatoes. Tow of the bins are were located in a commercial potato facility in Bay Co., with the third in a commercial potato facility in Kalkaska Co. Each bin had an independent air system capable of maintaining the desired storage environment. The FANCOM 656 control system managed the storage environment based on the following sensors:

- temperature at four levels within the pile
- temperature and relative humidity of the ventilation air
- temperature and relative humidity of the recirculation air
- temperature of the outside air

Four sample bags of about 20 lb each were placed at three levels in each bin to estimate weight loss during storage. All bins were sampled bi-weekly for glucose and sucrose sugar content and chip sample color. Independent samples of 15 tubers were taken at each sampling time from the top of the pile and from 3 interior levels.

The bins were cooled to the temperatures and at the rates listed in the following table. Bin 1 was stored at 45°F and bin 3 (Kalkaska Co.) was stored at 40°F. Bin 2 was cooled until color developed in the bi-weekly chip samples and then the temperature was increased to hold at 44°F. Some warming of bins 1 and 2 was done in March for reconditioning of the potatoes. The control computer was set to maintain the difference between any two pile temperature sensors at less than 0.4°F, and the difference between the plenum and the pile average at no more than 3.6°F.

The cooling rate of 0.5°f per day and a holding temperature of 45°F appear to be close to the limits for storing the Snowden variety without increasing sugars to a level that will adversely affect chip color. A good storage strategy would be one that cools the tubers to a minimum holding temperature as quickly as possible, within a limit of acceptable temperature differences between pile and plenum

TABLE: Storage Dates and Parameters (Snowden, 1992-93)

	BIN 1	BIN 2	BIN 3
Harvest date	Oct. 5, 1992	Oct. 5, 1992	Sep. 16, 1992
Harvest temperature	59°F	59°F	71°F
Suberization run time	24 hours	24 hours	24 hours
Cooling run times	24 hours	24 hours	24 hours
Ventilation rate	1.5 cfm/cwt	1.5 cfm/cwt	1.5 cfm/cwt
Slot velocity	760 ft/min	760 ft/min	760 ft/min
Desired R. H.	97%	97%	97%
Start Cooling	Oct. 25, 1992	Oct. 25, 1992	Oct. 15, 1992
CIPC Application	None	None	None
Set (actual) cool rate	0.54°F/day(0.31)	0.54°F/day(0.34)	0.9°F/day(0.47)
Start holding	Dec. 9, 1992	Dec. 17, 1992	Nov. 25, 1992
Holding run times	3/12 hours	3/12 hours	3/12 hours
Holding temperature	45°F	Approx. 42°F	39°F
Market date	March 31, 1993	March 30, 1993	April 21, 1993

temperatures. Bin 1 (holding temperature 45°F) was cooled allowing a plenum-pile differential of 3.6°F. This differential resulted in a minimum cooling air temperature of about 41.4°F. To prevent the rise in sugar levels observed in bin 1 late in the storage season, the cooling rate (plenum-pile temperature difference) should be lowered as the temperature approaches 45°F.

The weight loss from bins 1, 2, and 3 were 7.1, 7.8 and 7.4% respectively. The humidifiers in the experimental storage bins were undersize, resulting in higher than expected weight loss. The higher level for bin 2 was probably a result of the warming that was done to recondition the tubers. Minimal sprout growth occurred in any of the bins. None of the bins were treated with sprout inhibitors after harvest.

Guidelines for Critical Sugar Levels

All the samples from the experiments during the 1992-93 storage season were sorted by glucose in ascending order and divided into groups. Each group covered an internal of at least 0.001% glucose, with intervals expanded as necessary so that each group had at least five samples. For each group, the percent of acceptable samples was plotted in the following figure. Acceptable samples were defined as those loving either a 1 or 1.5 SFA color in one case, or those having a 1, 1.5 or 2 SFA color in the second case.

Based on the Snowden potatoes sampled in 1992-93, a sample with a glucose level of 0.0075% (fresh weight basis) will have a 90% probability of having a color of 1 or 1.5. A sample with a glucose level of 0.01% will have a probability of having a color of 1, 1.5 or 2.

The average glucose levels of samples with a chip color (SFA) of 1 were the same for the experimental storage bins and the early storage season stress experiment. At high color levels, the samples in the latter set were slightly higher in glucose. This is probably due to the overall higher sugar levels and higher variability in this experiment..

Recommendations for Storage of Snowden Potatoes

Follow conventional suberization for wound healing at 55°F for two weeks. Preconditioning should continue at the same temperature to reach desired sugar levels; glucose should be less than 0.01%.

Cool the tubers quickly at a rate of up to 0.5°F per day to a temperature of 50°F. Uniform and gradual temperature changes are important for maintaining potato quality and color through extended storage. Care should be taken that the difference between the average pile temperature and the plenum temperature does not exceed 3°F.

Cooling to a minimum of 45°F should be continued at a slower rate of 0.3°F per day using plenum air temperatures not less than 44°F.

If reconditioning is needed late in the storage period due to low temperature sweetening, warm the tubers to temperatures above 50°F. The difference between the minimum pile temperature and the plenum temperature should not exceed 3°F during the warming period. Storage of Snowden potatoes at temperatures that will induce low temperature sweetening is not recommended.

Probability of SFA Color for Levels of Glucose in Chip Sample