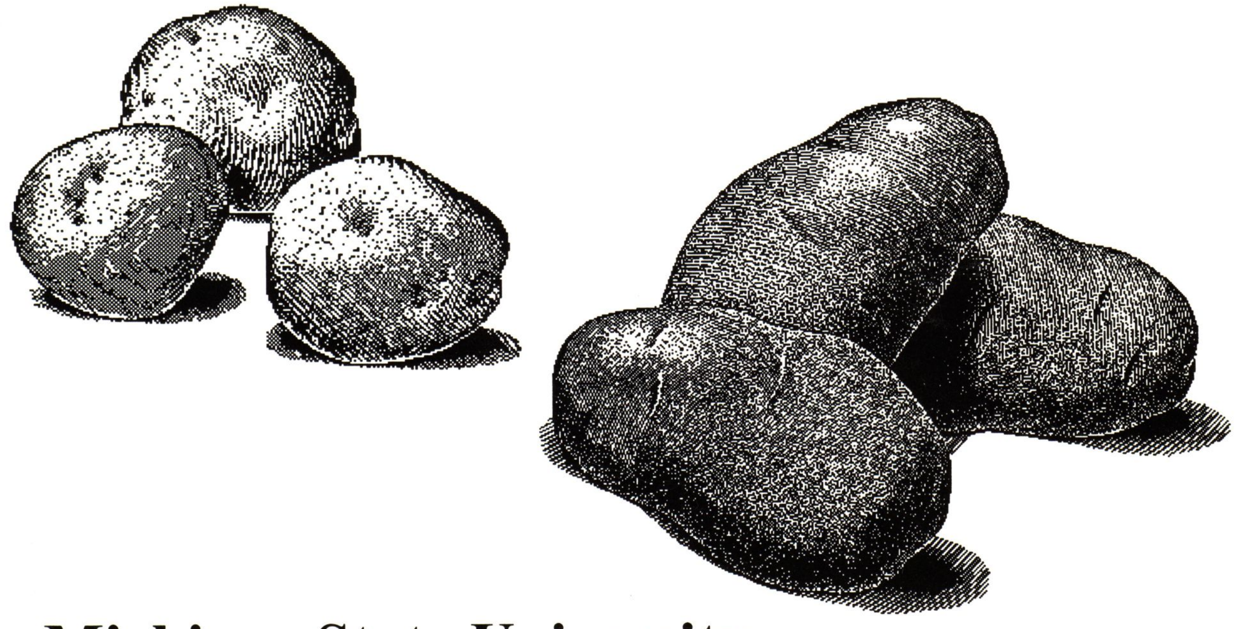
1999
MICHIGAN POTATO RESEARCH REPORT

VOLUME 31



Michigan State University
Agricultural Experiment Station

In Cooperation With
The Michigan Potato Industry Commission

THE MICHIGAN POTATO INDUSTRY COMMISSION

February 18, 2000

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 1999 potato research projects.

This report includes research projects funded by the Michigan Potato Industry Commission, the USDA Special Grant and special allocations by the Commission. Additionally, the Commission expresses appreciation to suppliers of products for research purposes and special grants to the Commission and researchers.

Providing research funding and direction to principal investigators at MSU is a function of the Michigan Potato Industry Commission's Research Committee. The Commission is pleased to provide you with a copy of this report.

Best wishes for a prosperous 2000 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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1999 MICHIGAN POTATO RESEARCH REPORT

R.W. Chase, Coordinator

INTRODUCTION AND ACKNOWLEDGMENTS

The 1999 Potato Research Report contains reports of the many potato research projects conducted by MSU potato researchers at several locations. The 1999 report is the 31st report which has been prepared annually since 1969. This volume includes research projects funded by the Special Federal Grant, 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 participate in 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.

A special thanks goes to Dick Crawford for the management of the MSU Montcalm Research Farm and the many details which are a part of its operation. Thanks also go to Chris Long, CSS Potato Technician. Also, a special thanks to Jodie Schonfelder for the typing and preparation of this report and to Don Smucker, Montcalm CED for maintaining the weather records from the MRF computerized weather station.

WEATHER

The weather during the 1999 growing season was cooler than 1998 but slightly warmer than the 15 year average (Table 1). There were nine days that the temperature reached 90F or above and seven days in April that the temperature was below 32F. The fall and harvest season weather was excellent.

Rainfall for April through September was 30.16 inches which was 8 inches above the 15 year average (Table 2). Rainfall recorded during April and May were the highest for those months during the past 15 years. Irrigation applications were six and were completed in early August.

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
1985	58	38	70	44	71	46	81	55	75	54	70	50	71	48
1986	60	36	70	46	77	50	82	59	77	51	72	50	73	49
1987	61	36	77	46	80	56	86	63	77	58	72	52	76	52
1988	52	31	74	46	82	53	88	60	84	61	71	49	75	50
1989	56	32	72	34	81	53	83	59	79	55	71	44	74	46
1990	NA	NA	64	43	77	55	79	58	78	57	72	47	NA	NA
1991	60	40	71	47	82	59	81	60	80	57	69	47	74	52
1992	51	34	70	42	76	50	76	54	75	51	69	46	69	46
1993	54	33	68	45	74	55	81	61	79	60	64	46	70	50
1994	57	34	66	43	78	55	79	60	75	55	73	51	71	49
1995	51	31	66	45	81	57	82	60	82	65	70	45	72	50
1996	50	31	64	44	75	57	76	55	80	59	70	51	69	50
1997	54	31	59	39	79	56	80	57	73	55	69	50	69	48
1998	60	37	75	51	77	56	82	58	81	60	76	52	75	52
1999	59	37	71	48	77	55	84	62	76	56	73	48	73	51
15-YR. AVG.	56	34	69	44	78	54	81	59	78	57	71	48	72	49

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
1985	3.63	1.94	2.78	2.58	4.72	3.30	18.95
1986	2.24	4.22	3.20	2.36	2.10	18.60	32.72
1987	1.82	1.94	0.84	1.85	9.78	3.32	19.55
1988	1.82	0.52	0.56	2.44	3.44	5.36	14.14
1989	2.43	2.68	4.85	0.82	5.52	1.33	17.62
1990	1.87	4.65	3.53	3.76	4.06	3.64	21.51
1991	4.76	3.68	4.03	5.73	1.75	1.50	21.45
1992	3.07	0.47	1.18	3.51	3.20	3.90	15.33
1993	3.47	3.27	4.32	2.58	6.40	3.56	23.60
1994	3.84	2.63	6.04	5.16	8.05	1.18	26.90
1995	3.65	1.87	2.30	5.25	4.59	1.38	19.04
1996	2.46	3.99	6.28	3.39	3.69	2.96	22.77
1997	2.02	3.13	3.54	2.80	2.71	1.46	15.66
1998	2.40	2.21	1.82	0.40	2.22	3.05	12.10
1999	5.49	5.07	5.82	4.29	5.46	4.03	30.16
15-YR. AVG.	3.00	2.82	3.41	3.13	4.51	3.90	20.77

GROWING DEGREE DAYS

Table 3 summarizes the cumulative, base 50F growing degree days for May through September. The total GDD were 2,401, similar to 1991 but 200 GDD less than 1998 which was the warmest during the past decade.

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

	Cumulative Monthly Totals				
	May	June	July	August	September
1991	452	1014	1632	2185	2491
1992	282	718	1210	1633	1956
1993	261	698	1348	1950	2153
1994	231	730	1318	1780	2148
1995	202	779	1421	2136	2348
1996	201	681	1177	1776	2116
1997	110	635	1211	1637	1956
1998	427	932	1545	2180	2616
1999	317	865	1573	2070	2401

*1991 and 1992 data calculated from Vestaburg weather station in Montcalm County (Dr. Jeff Andresen, Geography). 1993-1998 data from the weather station at MSU Montcalm Research Farm (Don Smucker, Montcalm County Extension Director).

PREVIOUS CROPS, SOIL TESTS AND FERTILIZERS

The general potato research area was planted to field corn in 1998, harvested, leaving the stubble until plowing in the spring of 1999. The plot area was not fumigated and potato early die was a serious problem in 1999.

The soil test analysis for the general crop area are as follows:

	lbs/A			
pH	P_2O_5	K_2O	Ca	Mg
6.0	473	276	700	120

The fertilizers used in the general plot area are as follows. Variances in fertilizers used for specific research projects are included in the individual project report.

Application	Analysis	Rate	Nutrients ($N-P_20_5-K_20$)
Broadcast at plowdown	0-0-60	125 lbs/A	0-0-75
At planting	19-17-0	18 gpa	25-23-0
At emergence	46-0-0	125 lbs/A	58-0-0
Sidedress	46-0-0	200 lbs/A	92-0-0

HERBICIDES AND PEST CONTROL

Hilling was done in late May, followed by pre-emergence Dual and Sencor at 2 pints/A and .67 lbs/A, respectively.

Admire was applied at planting and Cygon was applied twice. Fungicides used were Bravo ZN and Polyram 80DF in the 11 applications.

Funding: Federal Grant/MPIC

MICHIGAN STATE UNIVERSITY POTATO BREEDING PROGRAM 1999 STATUS REPORT

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INTRODUCTION

At MSU we conduct a multi-disciplinary program for potato breeding and variety development that integrates traditional and biotechnological approaches. We conduct variety trials of advanced selections (at MSU and in grower fields), through conventional crosses we develop new genetic combinations in the breeding program, and identify exotic germplasm that will enhance the varietal breeding efforts. With each cycle of crossing and selection we are seeing directed improvement towards improved varieties. In addition, our program utilizes genetic engineering as a tool to introduce new genes to improve varieties and advanced germplasm. We feel that these in-house capacities (both conventional and biotechnological) put us in a position to respond and focus upon the most promising directions and can effectively integrate the breeding of improved chip-processing and tablestock potatoes. The breeding goals at MSU are based upon current and future needs of the Michigan potato industry. Traits of importance include yield potential, disease resistance (scab, late blight and early die), insect (Colorado potato beetle) resistance, chipping (out-of-the-field, storage, extended cold storage) and cooking quality, bruise resistance, storability, along with shape, internal quality and appearance. If these goals can be met, we will be able to reduce the grower's reliance on chemical inputs such as insecticides, fungicides and sprout inhibitors.

PROCEDURE

I. Varietal Development

Each year, during the winter months, over 500 crosses are made between the most promising cultivars and advanced breeding lines. The parents are chosen on the basis of yield potential, tuber shape and appearance, chip quality, specific gravity, disease resistance, adaptation, lack of internal and external defects, etc. These seeds are being used as the breeding base for the program. Approximately 35,000 seedlings are grown annually for visual evaluation at the Montcalm and Lake City Research Farms as part of the first year selection process of this germplasm each fall. Then each selection is then evaluated for specific gravity and chip processing. These selections each represent a potential variety. This generation of new seedlings is the initial step to breed new varieties and this step is an on-going process in the MSU program. This step is followed by evaluation and selection at the 8-hill and 20-hill stages. The best selections out of the four-year process are then advanced for testing in replicated trials (Preliminary, Adaptation, Dates-of-Harvest, Grower-cooperator trials, North Central Regional Trials, Snack Food Association Trials and out-of-state trials) over time and locations.

II. Germplasm enhancement

We have a "diploid" (2x chromosomes) breeding program in an effort to simplify the genetic system in potato (which normally has 4x chromosomes) and exploit more efficient selection of desirable traits. In general, diploid breeding utilizes haploids (half the chromosomes) from potato varieties, and diploid wild and cultivated tuber-bearing relatives of the potato. These represent a large source of valuable germplasm, which can broaden the genetic base of the cultivated potato and also provide specific desirable traits such as tuber dry matter content, cold chipping and dormancy, along with resistance to disease, insects, and virus. Even though these potatoes have only half the chromosomes of the varieties in the U.S., we can cross these potatoes to transfer the desirable genes by conventional crossing methods via 2n pollen. The diploid breeding program germplasm base at MSU is a synthesis of six species: *S. tuberosum* (adaptation, tuber appearance), *S. phureja* (cold-chipping, specific gravity), *S. tarijense* and *S. berthaultii* (tuber appearance, insect resistance), *S. microdontum* (late blight resistance) and *S. chaconese* (specific gravity, low sugars, dormancy and leptine-based insect resistance).

III. Integration of Genetic Engineering with Potato Breeding

Genetic engineering offers the opportunity to introduce new genes into our cultivated germplasm that otherwise would not be exploited. It has been used in potato as a tool to improve commercially acceptable cultivars for specific traits. Our laboratory is set up to use *Agrobacterium*-mediated transformation to introduce genes into important potato cultivars. We presently have genes that confer resistance to PVY, Colorado potato beetle, potato tuber moth, broad-spectrum disease resistance via the glucose oxidase (GO) gene, late blight resistance with the resveratrol synthase (RS) gene and cold/frost resistance (COR15). We also have the glgC16 gene (ADP-glucose pyrophosphorylase (AGPase) or starch gene) from Monsanto to modify starch and sugar levels in potato tubers. Using this gene (from Monsanto) we can manipulate the metabolism of the cultivated potato to limit the accumulation of reducing sugars during low temperature storage and to increase starch content. AGPase is a key enzyme in the starch biosynthetic pathway responsible for catalyzing the conversion of glucose-1-phosphate to ADP-glucose. Although the biochemical basis for the accumulation of reducing sugars at low temperatures has yet to be fully elucidated, this process is intimately associated with the process of starch synthesis and degradation. Monsanto provided evidence for AGPase as the rate-limiting step for starch synthesis and produced transgenic potato plants containing a bacterial AGPase gene (glgC16) under the control of the tuber-specific patatin promoter and targeted to the amyloplast via a plastid transfer peptide.

IV. Evaluation of Advanced Selections for Extended Storage

In 1999, the Michigan Potato Industry Commission constructed a demonstration storage facility to evaluate management systems to achieve extended storage of potatoes for chip processing. Fifteen lines and check varieties were placed in this facility this October. Throughout the winter we will be sampling the tubers for their ability to chip-process from 42F.

RESULTS AND DISCUSSION

For the 1999 field season over 500 crosses were planted and evaluated. Of those, 80% were crosses to select round whites. During the 1999 harvest, approximately 750 selections were made from the 35,000 seedlings grown at the Montcalm Research Farm and Lake City Experiment Station. Following harvest, specific gravity was measured and chip-processing (from 42F storage) will be tested January, 2000 directly out of storage. This storage period allows enough time for reducing sugars to accumulate in these selections. Atlantic (50F chipper) and Snowden (45F chipper) are chipped as check cultivars. When the 1998 single-hill selections were chipped directly out of 42F storage, about 20% of the single-hill selections had acceptable chip color. These selections are being evaluated as 8-hill selections in 1999. Of the 8-hill selections from 1998, 30% of the 400 clones chip-processed with acceptable color directly out of 42F, while the 200 twenty-hill selections, 25% had acceptable chip color from 42F storage. Thirty of these clones were tested in the 1999 Preliminary Trial. In addition to chip processing qualities, some of these lines also show resistance to scab and/or late blight. In summary, the frequency of good chip-processors in the breeding program has increased over the previous years even with in spite the more stringent screening temperature (42 vs. 45F storage).

One of our critical objectives is to breed potato varieties that will not accumulate reducing sugars in cold storage (40F). We commonly call these varieties "cold chippers". Breeding for cold-chipping varieties requires a broad genetic base. From a broad base we can then combine genes for cold-chipping while maintaining other important characteristics for agronomic performance and host plant resistances. The probability of identifying many cold-chippers in the initial rounds of crosses that have the required agronomic traits has been low. Therefore, we have been using a three-tier storage temperature evaluation (50, 42 and 40F) for chip processing.

The testing procedure on the selections is as follows. Processing at 50F is initiated in December. Those selections that process out of 50F storage are then tested from 42 storage in January. The good 42F chippers are then tested from 40F in February. We also believe that there is no long-term value in 2-4 week reconditioning out of 40F storage. All chip-processing in our program is done directly from cold storage, however, reconditioning studies are done at times to differentiate 42F or 40F chip-processors.

At this time we consider any selections that chip from 45/42F as cold sweetening resistant. These selections then form the parental material for our next cycle of crosses. From these crosses we hope to find a higher percentage of 42 and 40F chippers. If this occurs, then we can expect to continue to find a greater percentage of cold-chippers in the further rounds of crossing and selection.

Based upon the pedigrees of the parents we have identified for breeding cold-chipping potato varieties, we have a diverse genetic base. We believe that we have at least eight cultivated sources of cold-chipping. We have made various hybrid combinations with these parents from which to pyramid cold-chipping traits, and the hybrid populations have been grown out, selected and evaluated (**Table 1**). We now have advanced into the crossing block these new MSU selections that have chip quality directly out of 42F storage. For the 1998 selections, following the 42F chip-processing results, these good processors were chipped out of 40F in February. Of all of the 8-hill and 20-hill selections, only 3 of the lines chipped acceptably from 40F. Examination of pedigrees shows that at least two different cold-chipping germplasm sources have been combined in these selections.

One of our objectives is also to develop improved cultivars for the tablestock industry. Efforts have been made to identify lines with good appearance, low internal defects, high marketable yield and resistance to scab. From our efforts we have identified mostly round white lines, but we have a number of yellow fleshed and russet selections which carry many of the characteristics mentioned above. We are also looking for a dual-purpose russet, round white and improved Yukon-type yellow-fleshed potatoes. Some of the tablestock lines were tested in on-farm trials in 1999, while others were tested under replicated conditions at MRF. Our goal now is to 1) improve further on the level of scab resistance, 2) incorporate resistance to late blight, 3) select more russet lines and introduce the *Bt-cry3A* gene into Yukon Gold, Norwis, Onaway, MSG274-3 (late blight resistant line) and MSE018-1.

In 1999, in addition to the grower-cooperator trials, we also initiated a large-scale field testing program (1 acre blocks per line on five farms) between the breeding program, the seed industry and the commercial growers called CHIPS2001 (**see attachement 1**). We have targeted four lines in 1999 (A091-1, NT-1, F099-3 and G274-3) and will add two lines in year 2000 (G227-2 and E246-5). We have also initiated a grower testing program for tablestock cultivars called Tablestock One-on-One (**see attachement 2**). In this program we work with specific growers to identify their agronomic and market needs and match up these needs with seed of advanced selections from the breeding program. Three growers participated in 1999. We also distributed a number of advanced selections to other states (California, North Carolina, Nebraska, Pennsylvania and Ontario) for agronomic evaluations. As of December, 1999 the lines that performed well include A091-1, B106-7, B107-1, E018-1, E149-5Y, E228-1, E221-1 and NT-1. **Table 2** lists some of the potential lines for grower trials in year 2000.

Diploid Germplasm Enhancement In recent years the diploid germplasm (20 of the best lines with differing pedigrees) formed the crossing block to generate new populations. From this material we expect to find improved diploid *Solanum* species parents to be used in crosses to select new varieties. These crosses were planted in 1996 and again in 1999. We have found some selections that have acceptable chip-processing quality and tuber appearance. In 1999, about 10% of the populations evaluated as single hills were diploid. From this breeding cycle, we plan to screen the selections through the three-tier storage temperature evaluation for chip-processing. Through GREEEN funding, we were able to initate a breeding effort to introgress leptine-based insect resistance. From previous research we determined that the leptine-based resistance is effective against Colorado potato beetle. In the fall, we made selections from 3,000 progeny that we segregating for leptine synthesis and day length adaptation. This winter we will determine the processing quality of the sélections and the leptine levels in the foliage (via HPLC analysis). This overall germplasm enhancement effort is the base from which long-term genetic improvement of the potato varieties in the MSU breeding program is generated.

Late Blight Breeding and Genetics A high priority objective of the breeding program is to identify sources of late blight resistance and use these sources for breeding varieties with late blight resistance. Based upon greenhouse screenings, we have been using USDA/ARS and

European sources of late blight resistance in our crossing block. The objectives of this specific study were 1) to evaluate the potential use of LB resistant parents in varietal breeding, 2) to identify individuals that have good LB resistance combined with good tuber quality and acceptable maturity, and 3) to evaluate a selection procedure for developing LB resistant cultivars. Eight clones (B0718-3, Bertita, Bzura, Greta, Libertas, Stobrawa, Tollocan and Zarevo) with reported LB resistance and different genetic backgrounds were crossed with susceptible clones adapted to the north central United States. Seedlings of 95 families (4,750 seedlings) were evaluated in the field in 1997 based upon tuber appearance, number and defects. A total of 408 clones (9%) were selected for LB evaluations in the greenhouse and in the field using A2 mating type US-8 genotype of *P. infestans*. Clones with a $< 10\%$ foliar infection in the greenhouse or relative area under the disease progress curve ≤ 0.30 in the field were selected for re-evaluation in 1999, resulting in 119 (29%) putative LB resistant clones. The LB resistant parents differed in both the ability to transmit LB resistance and in the level of LB resistance transmitted to the offspring. Tollocan and B0718-3 transmitted LB resistance in a higher level and to a higher percentage of the progeny than any other LB resistant parent evaluated in this study, while Zarevo, Greta, Libertas, and Stobrawa transmitted only moderate LB resistance to the offspring. Cluster analysis was able to rank the clones in discrete groups differing in LB resistance. Using the cluster group with intermediate resistance to LB as a threshold resulted in 80 (67% of 119 clones) selected clones. Among them, 19 clones had vine maturity readings equal or less than mid-season (**Table 3**). Five-LB families were represented by the clones, in which 12 clones of Tollocan, three clones of B0718-3, two clones of Stobrawa and one clone of each Libertas and Zarevo families. Using LB resistant parents as Tollocan and B0718-3 it is of value to select first for tuber quality and other agronomic characteristics than for LB resistance. We are planning to cross some of the best selections to combine different late blight resistance sources. This strategy may lead to late blight resistance with a more durable and broader genetic base.

In 1999 we initiated a set of studies (via GREEEN) to identify the genes in potato associated with late blight resistance. If we can identify the genes that contribute to late blight resistance we feel that we could more effectively breed varieties with durable late blight resistance. We have focused this research on one 2x population that derives its resistance from *S. microdontum* and a 4x population that derives its resistance from MSG274-3. During the summer of 1999 the populations were planted at the Muck Soils Research Farm for disease evaluation and DNA marker analysis was started in the lab this fall. In addition, we are collaborating with the Scottish Crops Research Institute on this gene mapping project so that we can draw their expertise and experience in this area of research. A fall visit to Scotland helped us learn the AFLP technology so that we can quickly generate a genetic map and begin to identify the late blight resistance genes. We are also using SSR markers. The advantage of the specific SSRs we are using is that they were previously identified to be linked to late blight resistance genes in other potato lines.

Our germplasm enhancement efforts have been focusing on screening wild *Solanum* species for late blight resistance. Numerous plant introductions from Mexico and South America were tested in the greenhouse late blight chamber. The selections that showed the strongest resistance were retested. As a result, we have identified approximately 30 lines with strong resistance that constitute a broad genetic base to work with. These lines have been crossed to our best diploid lines to introgress the late blight resistance. These populations will be planted in the field in year 2000.

<u>Genetic Engineering</u> The Colorado potato beetle, *Leptinotarsa decemlineata* Say, is the leading insect pest of potato (*Solanum tuberosum* L.) in northern latitudes. Host plant resistance is an important tool in an integrated pest management program for controlling insect pests. During the 1998 and 1999 seasons, field studies were conducted to compare natural (glandular trichomes and leptine glycoalkaloids) and engineered (*Bt-cry3A, Bt-cry5,* and *Bt-cry5*+glandular trichomes transgenic potato lines) host plant resistance mechanisms of potato for control of Colorado potato beetle. Twenty-two different potato lines representing five different host plant resistance mechanisms were evaluated in a choice situation under natural Colorado potato beetle pressure at the Montcalm Research Farm in Entrican, Michigan. Greenhouse-grown tissue-culture plantlets were transplanted to the field between rows of a susceptible guard Snowden in a randomized complete block design consisting of four replications of ten plants each. Observations were recorded weekly for a visual estimation of percent defoliation by Colorado potato beetles, the number of egg masses, eggs per mass, and the number of first, second, third, fourth instar larvae, and adults. The *Bt-cry3A* transgenic lines and high leptine expressing lines were most effective for controlling defoliation by Colorado potato beetle adults and larvae (**Figure 1**). Although one *Bt-cry5* transgenic had significantly lower defoliation than the other *Bt-cry5* lines, in general the *Bt-cry5* lines were not as effective as the *Bt cry3A* transgenic lines. The glandular trichome and *Bt-cry5*+glandular trichome lines proved to be ineffective in this choice field situation. Based on these results, the *Bt-cry3A* transgenic and high leptine lines are effective resistance mechanisms that could be incorporated in a resistance management program for control of Colorado potato beetle.

The program has been conducting transformations of potato to introduce a variety of transgenes. Currently we have genetically engineered plants that express the *Bt-cry3A* gene to control the Colorado potato beetle, the glucose oxidase and resveratrol synthase genes for disease resistance, and the AGPase gene for low sugars and high solids. In 1999, we had an extensive field testing of our transgenic lines. In general, the transgenic lines had agronomic and tuber characteristics of the non-transgenic parent line. Of interest, we have targeted transformation with the AGPase gene towards lines that have excellent chip processing, but a below average solids content (i.e. MSE149-5Y). Using this strategy, we hope to broaden our opportunities for identifying cold-chipping cultivars.

<u>Development of Bt-cry5-transgenic potato lines for host plant resistance to potato tuber moth in Egypt</u> Dave Douches and Joe Coombs, traveled to Egypt to harvest three field trials involving Bt-transgenic potato lines (at CIP and AGERI) (planted February 1999). The purpose of these trials was to obtain field data toward agronomic performance (CIP location) and resistance to potato tuber moth (PTM) damage to the foliage and tubers (CIP and AGERI) of these Bt-transgenic potato lines. These trials are now in their third year at AGERI and second year at CIP, and are under the supervision of Drs. Taymour El-Nasr and Magdy Madkour. In addition to the field trial harvest and evaluation, our other objective was to establish linkages with the Egyptian private and public sector (scientists and regular people) seed and commercial growers to disseminate information regarding the potential commercial use of Bt-transgenic potato lines.

The field trials in 1999 involved transgenic lines derived from Atlantic (chip-processing), L235-4 (breeding line with glandular trichome-based natural resistance), and Spunta (tablestock). Atlantic and L235-4 lines have been field tested in Egypt and the US since 1997 and 1996, respectively, while 1999 was the first field trial for Spunta lines. The CIP field trials were harvested June 7 and in the PTM trial, tubers were evaluated for PTM damage. On the average, the percent tuber moth damage was 27 and 28% for the Spunta and Atlantic cultivars, whereas the Bt-transgenic Atlantic lines averaged between 80-88% clean tubers, and the four best Bt-transgenic Spunta lines averaged 99.8 -100% clean tubers. The Bt-transgenic L235-4 line (L235-4.13) had 99% clean tubers compared to the 84% clean tubers observed with L235-4. These tuber results parallel the laboratory tuber bioassays of Douches, et al. (1998) and Mohammed et al. (in Press). Following field evaluation, the clean tubers from the CIP trials were placed in the nahwalla at CIP to evaluate PTM tuber damage after one and two months of storage. In the Agronomic trial at CIP, the yields were low compared to commercial fields, however, the Bt-transgenic Spunta and Atlantic lines performed comparably to their non-transgenic cultivar. The PTM trial at AGERI was harvested June 8, 1999. On this trial, the tuber moth infection was low. Only 10% of the Atlantic tubers were damaged by PTM. The best Bt-transgenic lines showed less tuber damage (92-100% clean tubers). The clean tubers from these trials will be used for tuber bioassays and as seed for a fall trial at AGERI.

Table 1.
Promising Early Generation Cold-Chipping Selections from Michigan State University.

LINE	LATE BLIGHT RESISTANCE	COLD CHIPPING	SPECIFIC GRAVITY (H= >1.080)	PARENTAGE FEMALE	PARENTAGE MALE
MSI111-A		X	H	E251-1	OP
MSJ042-3		X	H	BRODICK	ZAREVO
MSJ093-5		X	H	E041-1	S440
MSJ107-4	X	X	H	E230-6	ZAREVO
MSJ143-4		X	H	ND01496-1	S440
MSJ147-1		X	H	ND2417-6	S440
MSJ163-7R	X	X	H	PIKE	ZAREVO
MSJ165-1		X	H	PRESTILE	S440
MSJ167-1		X	H	P84-13-12	E250-2
MSJ212-2	X	X	H	S438	ZAREVO
MSJ223-1	X	X	H	ZAREVO	E250-2

Table 2. Potential Lines for 2000 Grower Trials					
TABLESTOCK	**COMMENTS**		**PROCESSING**	**COMMENTS**	
MSE018-1			MSA091-1	SCAB R	SFA
MSE028-1			MSE018-1		
MSE221-1	SCAB R		MSE246-5	SCAB MR	SFA
MSE228-1			MSF099-3		
MSE228-11			MSF313-3		
MSF313-3			MSF373-8	SCAB MR	
MSF373-8	SCAB MR		(MSG015-C)	SCAB R	
MSG004-3			MSG227-2	SCAB R	
MSG050-2			MSH031-5	SCAB MR	
MSG141-3			(MSH094-8)		
MSG274-3	LBR		(MSH095-4)		
			(MSH098-2)		
(MSE048-2Y)			MSNT-1	SCAB R	SFA
MSE149-5Y	SCAB MR				
(MSG145-1Y)					
MSE192-8RUS	SCAB R				
MSE202-3RUS	SCAB R				
(MSF087-3RUS)	SCAB R				
(MSH026-3RUS)	SCAB R				
(MSE040-6RY)					
MI PURPLE					
WOLVERINE					
( ) = Limited Seed					

Table 3.

Late blight clones selections in 1999 based on LB reaction and maturity

Clone	LB Parent	Other Parent	Specific Gravity 1998	Tuber Appearance Rating 1998	Chip Score 1998	RAUDPC	Cluster Groups*	Vine Maturity Ratings
J310-3	B0718-3(M)	E251-1	1.083	1	3	0.455	2	3
J319-1	B0718-3	W870	1.086	1	2	0.378	2	3
J319-7	B0718-3	W871	1.075	1	3	0.423	2	2
J399-1	Libertas	C127-3	1.097	1	4	0.539	2	3
J452-3	Stobrawa	Yukon Gold	1.086	2	6	0.502	2	3
J452-4	Stobrawa	Yukon Gold	1.083	2	5	0.549	2	3
J455-4	Tollocan	Chaleur	1.066	2	6	0.268	2	3
J456-2	Tollocan(M)	Conestoga	1.082	1	5	0.342	2	3
J458-2	Tollocan(M)	Krantz	1.075	2	4	0.095	1	3
J459-3	Tollocan(M)	Lenape	1.087	2	5	0.157	1	3
J459-4	Tollocan(M)	Lenape	1.076	3	5	0.16	1	3
J461-1	Tollocan(M)	NY88	1.074	1	3	0.071	1	3
J462-2	Tollocan(M)	Pike	1.080	3	3	0.106	1	3
J464-1	Tollocan(M)	Snowden	1.089	4	3	0.237	2	3
J464-4	Tollocan(M)	Snowden	1.076	2	3	0.222	2	3
J466-3	Tollocan(M)	Superior	1.081	2	6	0.256	2	3
J467-6	Tollocan(M)	W870	1.098	2	2	0.553	2	2
J468-1	Tollocan(M)	W877	1.086	3	3	0.395	2	2
J488-4	Zarevo(M)	MS716-15	1.104	1	5	0.509	2	3

* 1 = Resistant and 2 = intermediate resistant to late blight.

CHIPS2001

1. Choose 3-4 lines; Start T.C. propagation — January, 1999
2. Transplant 1000 plants/line to GH — May 15, 1999
3. Transplant to field at Lake City (MSU) — June 15, 1999
4. Harvest tubers (10-20 cwt/line) — October, 1999
5. Plant field by Seed Grower (1/2 - 1 acre) — Spring, 2000
6. Harvest tubers (125-250 cwt) — Fall, 2000
7. Plant commercial fields (5 acres) & seed field (1 acre) — Spring, 2001
8. Harvest 300-500 cwt/line — Fall, 2001
   Send load to chip-processor
   Fill research storage bins
   Seed harvest for 2002
9. Chip-process storage samples — Winter, 2002

Candidate Chip Line	Priority	Pedigree	Comments
MSG274-3	1	Tollocan X Chaleur	Late blight resistant, dual table/chip
MSF099-3	2	Snowden X Chaleur	Cold-chipping, exc. internals & shape
MSNT-1	3	-	Scab resistant, exc. internals
MSA091-1	4	MS702-80 X Norchip	Scab resistant
MSG227-2	4	Prestile X MSC127-3	Cold-chipping, scab resistant, exc. shape
MSE246-5	4	E55-27 X W870	Cold-chipping, scab resistant

Tablestock One-on-One

Michigan State University
Potato Breeding Program

The MSU potato breeding program has been generating advanced selections that have commercial potential. Many of these selections have been tested in MSU research trials and in grower-cooperator trials around the state. This year we initiated a program we call Tablestock One-on-One to cooperate with tablestock growers to evaluate specific selections on specific farms.

We want to work with individual growers to understand their agronomic needs, production constraints and market targets. In this way we can identify specific advanced selections that you can test on your farm. At this time, we can supply seed for testing at small levels (10 lbs. to 100 lbs.).

The goal of the on-farm testing is to compare our advanced selection to your current variety. Therefore, we want to compare the MSU line side-by-side with your currently-grown variety. Our suggestion is to plant the lines at a minimum of 3-4 row plots (depending on your planter). In this way the middle rows could be sampled for yield checks.

If you are interested in testing lines or learning more about the program, please contact Dr. Dave Douches, potato breeder, at Michigan State University. You can also check out the variety images on the MSU Potato Breeding and Genetics web site (www.msu.edu/user/douchesd).

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MSU Tablestock Breeding Lines

MSE192-8RUS: A russet tablestock selection. The tubers are long with an attractive russet appearance like Russet Norkotah. In comparison to Russet Norkotah it has a bright white flesh, a good taste and expresses PVY symptoms. Its strengths are scab resistance, low incidence of internal defects, and bruise resistance. The vines have early-mid season maturity. We view this as a potential Russet Norkotah replacement.

MSB106-7: A high yielding, long white type. Internal quality is excellent with a bright white flesh, however, specific gravity in only 1.070. It has performed well in Louisiana and Nebraska. We regard this as a niche variety.

MSF313-3: A high yielding selection with acceptable specific gravity for chip-processing. It has cold-chipping (45°F) potential. The tubers have an attractive appearance and have excellent internal quality. Scab resistance is above average. We regard this as a potential Onaway replacement.

MSG141-3: A round white selection. Tubers are smooth and round with a bright skin. Internal quality is excellent and yield potential is above average. The vines have a mid-season maturity. We regard this as a potential Onaway replacement.

MSF373-8: A very high yielding selection with acceptable specific gravity for chip-processing. It will chip out-of-the-field and from 50°F storage. Produces large tubers with a low incidence of internal defects. Scab tolerance is intermediate. This selection also has tablestock potential. We regard this as a potential Onaway/Ontario replacement.

MSB107-1: A high yielding selection which produces large tubers that have excellent internal characteritics. Scab tolerance is intermediate and maturity is medium-late. We regard this as a potential Onaway/Ontario replacement.

MSE018-1: A very high yield potential, high specific gravity, and moderate tolerance to scab. It has a late maturity, large vine and some reduced susceptibility to late blight. Tuber appearance is bright and smooth with a round-oval shape. We regard this as a potential Katahdin replacement (baker).

MSE221-1: A high yielding selection with scab resistance and a moderately early vine maturity. Tubers are netted with an attractive appearance. The internal qualitites of the tubers are excellent. We regard this as a potential Superior replacement.

MSE149-5Y: A light yellow-fleshed selection with smooth, round tubers that have a bright appearance. Specific gravity is low but the selection has high yield potential. Internal qualities are excellent and the vine maturity is medium-early. We regard this as a potential Norwis replacement.

MSE228-11: A selection with smooth, round tubers that have a bright attractive appearance. Internal qualities are excellent and scab resistance is intermediate. Plants have a heavy tuber set (can lead to high percentage of B sized tubers). Vine maturity is mid-season.

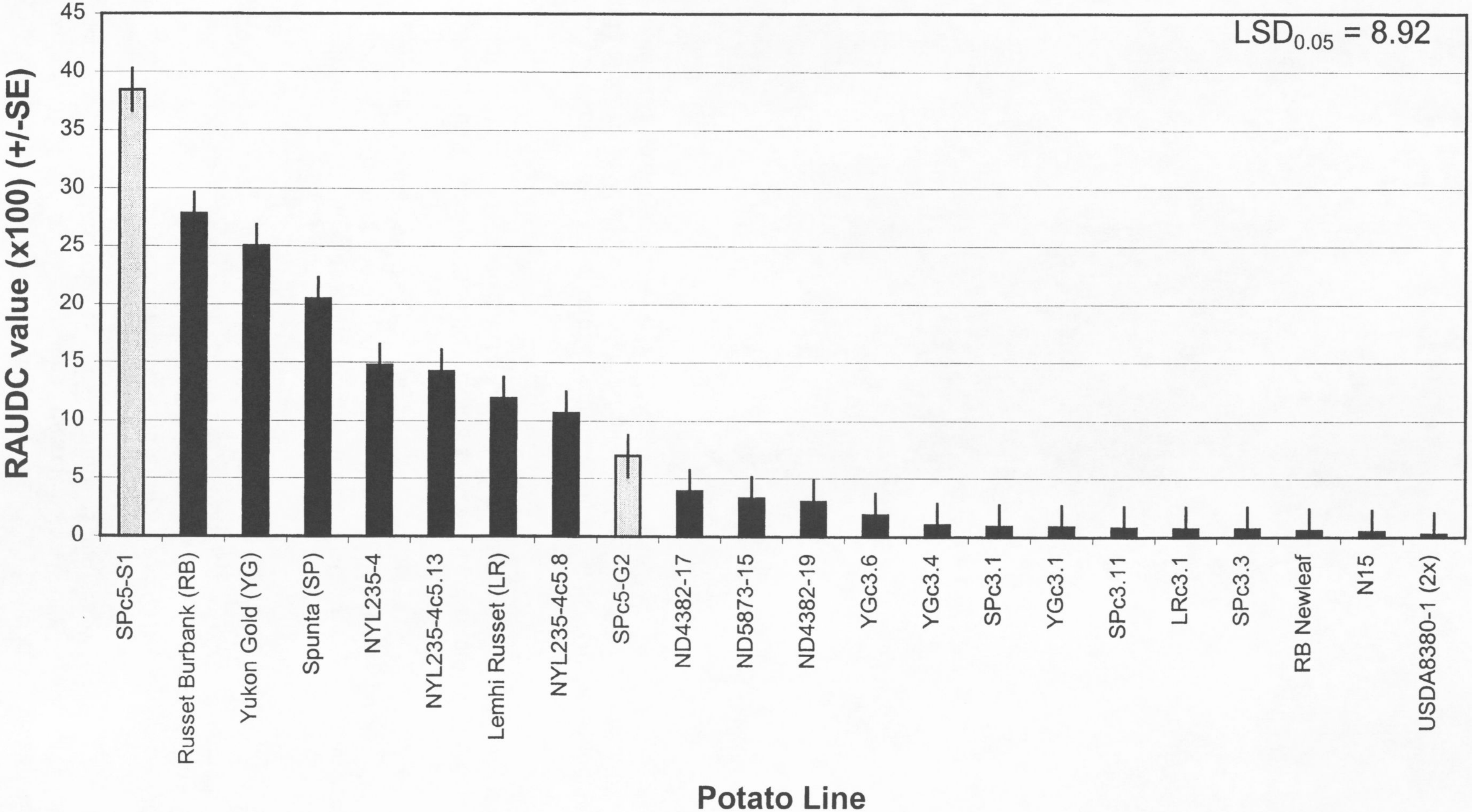
MSG274-3: An oval/oblong table stock selection with a high tuber set. The tubers have the bright skinned, smooth and attractive appearance that is typical of many European cultivars. The tubers have very low incidence of internal defects and good baking quality. The strength of this selection is its strong foliar resistance to the US8 genotype of late blight. Vine maturity is similar to Snowden.

MSG145-1Y: A selection with smooth, round tubers with a bright attractive appearance. The flesh is golden yellow. Vine maturity is mid-season. Tubers are bruise resistance. We regard this selection as a potential Yukon Gold replacement.

MSE040-6RY: A red-skinned tuber with yellow flesh. The tubers are smooth and the red color is equivalent to Chieftan. Yield is intermediate and has an early vine maturity. We regard this as a novelty type.

Michigan Purple: A tablestock selection with an attractive purple skin. This selection has high yield potential and the tubers have a low incidence of internal defects. The vine maturity is mid-season. We regard this as a novelty type.

Mean Relative Area Under the Defoliation Curve (RAUDC) Values of Host Plant Resistant Potato Lines by Colorado Potato Beetles



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1999 POTATO VARIETY EVALUATIONS

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The objectives of the evaluations are to identify superior varieties for fresh market or for processing and to develop recommendations for the growing of those varieties. The varieties were compared in groups according to the tuber type and skin color and to the advancement in selection. Each season, total and marketable yields, specific gravity, tuber appearance, incidence of external and internal defects, chip color (from field, 42 and 50 F storage), dormancy (at 50F), as well as susceptibilities to late blight, common scab, Fusarium dry rot, Erwinia soft rot and blackspot bruising are determined.

Seven field experiments were conducted at the Montcalm Research Farm in Entrican, MI. They were planted in randomized complete block design with four replications. The plots were 23 feet long and spacing between plants was 12 inches. Inter-row spacing was 34 inches. Supplemental irrigation was applied as needed.

The round white tuber types were harvested at two dates (Date-of-Harvest trial). The other field experiments were the Russet, North Central Regional, European, Adaptation and Preliminary trials. In each of these trials the yield was graded into four size classes, incidence of external and internal defects in > 3.25 in. diameter or 10 oz. potatoes were recorded, and samples for specific gravity, chipping, dormancy, disease tests, bruising and cooking tests were taken. Chip quality was assessed on 25-tuber samples, taking two slices from each tuber. Chips were fried at 365°F. The color was measured visually with the SFA 1-5 color chart. Tuber samples were also stored at 42 and 50°F for chip-processing out of storage in January and March.

Results

A. Round White Varieties

Six varieties and 21 breeding lines were compared at two harvest dates. Atlantic, Snowden, Superior and Onaway were used as checks. The plot yields were below average in the early harvest (98 days), however, and a moderate yield increase was observed for the second harvest date (140 days). The low yields and early vine senescence were attributed to potato early die. Tuber specific gravity readings were above average. The results are presented in Tables 1 and 2. In the early harvest trial NY112, E018-1, NY120, Atlantic and MSF313-3 had the highest yields of the 27 entries. At the later harvest MSE018-1, NY112, Atlantic and MSF313-3 were still the top yielders along with MSE228-1. NY112, Atlantic and MSE018-1 were also top yielders in the on-farm processing trials, while MSE228-1 was the top yielder in the on-farm tablestock trial. Internal brown spot and hollow heart incidence were low within the trial, however vascular discoloration was more prevalent as in 1998. NY112 was the only line with significant hollow heart in the oversize tubers.

Variety Characteristics

MSA091-1 - a MSU selection for chip-processing with strong scab resistance. Yields in 1999 were below average, but it has performed well in other states (Nebraska, Pennsylvania and California) the late blight trials indicate a reduced susceptibility to late blight. It is in the national SFA and the North Central regional trials. It is also in the CHIPS2001 program.

MSE018-1 - a MSU chip-processing selection with high yield potential. It was an outstanding yielder in the MSU and on-farm trials the past three years. Specific gravity is high and it has a good general appearance. Scab tolerance is intermediate and it has a reduced susceptibility to late blight. This line was in the 1998 SFA Trials. Chip-processing has been variable in the on-farm trials.

MSE149-5Y – a MSU tablestock selection. It has high yield potential and produces attractive round tubers with a bright skin and light yellow flesh. It has been a top yielder in the on-farm trials. It chips out of 45F cold storage, but has a low specific gravity. It has been transformed with the starch gene to raise the specific gravity. These transgenic lines will be field-tested in year 2000.

MSE221-1 - a MSU tablestock selection. It has high yield potential as seen in the MSU and on-farm trials. General appearance is good, but it has a netted appearance similar to Superior. It has strong resistance to scab.

MSE228-1 – a MSU tablestock selection. It has high yield potential as seen in the MSU trial and on-farm trials. It has a medium vine maturity, excellent internal quality and intermediate scab tolerance.

MSE246-5 – a MSU chip-processing selection. It produces round tubers, has some scab tolerance along with reduced susceptibility to late blight. It also chip-processes from 45 F cold storage and has a very high specific gravity. In the 1999 on-farm trials, despite average yield potential, the chip quality was better than many of the other lines. It is a candidate for the CHIPS2002 program.

MSF099-3 – a MSU chip-processing selection. It has high specific gravity, smooth attractive tubers, excellent chip quality and will chip-process from 45 F cold storage. It yielded well on the on-far trials, but the large tubers tended to elongate. It is also scab susceptible. This line is in the CHIPS2001 program.

MSF313-3 – a MSU tablestock and chip-processing selection. It has a medium vine maturity, above average yield potential. The tubers have few defects and the shape is smooth and round with a bright appearance. It will chip-process out of the field and from storage.

MSG227-2 – a MSU chip-processing selection with strong scab resistance. It has a high specific gravity, excellent chip quality and cold-chipping potential. The tubers are smooth-shaped with a flattened round appearance that is attractive. This line is a candidate for CHIPS2002.

MSG274-3 – a MSU tablestock selection. It has strong late blight resistance to US8, but susceptible to scab. The line has high yield potential and a very high tuber set that can lead to a high percentage of B-size tubers. The tubers are oval with an attractive smooth shape and a bright skin. It has chipped out of the field and is in the CHIPS2001 program.

MSNT-1 - an MSU chip-processing selection. It has above average yield potential, excellent chip quality and strong resistance to scab. Yield was below average in the MSU trial. It was in the 1998 and 1999 SFA trials along with the on-farm trials. It performed well in Ontario trials in 1999. It is in the CHIPS2001 program.

NY112 – a Cornell University chip-processing selection. It has high yield potential and was the top yielder in the 1998 SFA trials. The specific gravity is in the range of 1.080 or lower. Blackspot bruise has been observed in simulated bruise tests in the past two years.

Chipeta – a chip-processing variety released in 1993. It is a high yielding line with a moderate specific gravity. The vine is strong. Scab resistance is intermediate.

B. Long Varieties

Three varieties and seven breeding lines were tested in 1999. Russet Burbank and Russet Norkotah were grown as check varieties. The trial was dug at 122 days from planting and results are shown in Table 3. Early die was present in the trial resulting in early vine senescence and low yield. All specific gravity levels were below normal with Russet Burbank at 1.069. Within the 10 entries MSG088-6RUS, MSE202-3RUS and MSH026-3RUS produced the highest yields.

Variety Characteristics

A7961-1 - is an USDA-Aberdeen entry with good performance. It has uniform appearance, heavier russeting than Russet Burbank and minimal internal defects. It can be used for frozen-processing. It will be named in the Northwest.

Innovator - a European selection that has attractive russetting and produces excellent fry color, but has a low specific gravity.

MSB106-7 - a MSU tablestock selection. It has high yield potential as seen in the on-farm trials, but performed poorly at MSU. Tubers are oblong-long with a light netting. In 1999 it was the top yielder in Nebraska.

MSE192-8RUS - a MSU tablestock selection. The tubers have an attractive russeting and shape. The yield in on-farm trials have been disappointing, but performed well in some on-farm trials in 1999. The vine is small which may make this line uncompetitive in small plot trials.

MSE202-3RUS – a MSU dual purpose russet selection. It has a medium maturity and above average yield potential. Its specific gravity is equivalent to Russet Burbank and the tubers are long with an attractive russet skin. Scab resistance is also high.

C. North Central Regional Trial

The North Central Trial is conducted in a wide range of environments (10 states) to provide adaptability data for the release of new varieties from North Dakota, Minnesota, Wisconsin, Michigan and Canada. Nineteen breeding lines and seven varieties were tested in Michigan. The results are presented in Table 4. Like all the other trials, potato early die influenced the trials, making it hard to judge the yield potential of these lines. The range of yields was wide and the specific gravity was average. The MSU selections MSE018-1 and MSB107-1 performed well. The line ND2470-27 performed well as a chip-processing selection. The MSU line MSA091-1 performed well in the Nebraska trials, despite low yields at MSU. The red-skinned North Dakota line, ND5084-3R, had high yield and excellent red color, but it has a very late maturity and severely sticky stolons.

D. European/Yellow Trial

Fourteen European varieties and advanced selections were tested along with six yellow-fleshed MSU seedlings. Yukon Gold and Saginaw Gold were used as checks. The results are summarized in Table 5. Typically, most of the European selections and varieties tend to be late to very-late in maturity, but the vines senesced early and we observed a high percentage of 'B' size tubers. The yields were below average and varied considerably. The best performing lines in 1999 were Columbo, MSE048-2Y and Sierra. Victoria and Gigant had severely late vine senescence. Bolestra shows chip-processing potential, while Lady Claire made excellent chips despite low yields. Yukon Gold, MSE048-2Y and MSG145-1Y had the best percentage of marketable tubers. Hollow heart was noted in the oversize tubers of MSG145-1Y and MSE048-2Y. The selection MSE040-6RY is a yellow-fleshed selection with a red skin color equivalent to Chieftain. MSA097-1Y performed below average compare to other years, but should be noted for its scab resistance.

E. Adaptation Trial

Nine varieties and 37 advanced breeding lines were evaluated in the Adaptation trial (Table 6). The trial was harvested after 141 days, but potato early die led to early vine senescence in late August in most cases. The highest yielding lines were MSE028-1 (tablestock), MSE273-8 (chip-processing) and MSG124-8P (blue-fleshed chip-processor). MSE028-1 has a bright skin and scab tolerance, while MSE273-8 has susceptibility to scab. IdaRose is a late maturing, red-skinned variety with promise. MSH333-3 and MSH031-5 show promise and note that MSH031-5 has an attractive bright skin and smooth appearance along with chip-processing potential. Other lines worth noting include Michigan Purple (attractive purple skin and white flesh), MSG147-3P (blue-fleshed chip-processor), MSG004-3 (bruise resistant tablestock), and MSG015-C (scab-resistant chip-processor).

F. **Preliminary Trial**

The Preliminary trial, harvested at 122 days, is the first replicated trial for evaluated new advanced selections from the MSU potato breeding program. Potato early die was a factor in this trial too. Sixty advanced selections were tested, but some were dropped from Table 7 because of poor tuber qualities noted at harvest and grading. MSF373-8 shows the highest yield potential with a high percentage of oversize tubers. It has excellent internal quality, some scab tolerance and will chip-process, but has medium-deep eyes. Other promising chip-processing lines include MSI172-7, MSH017-C, MSI103-5, MSI002-3, MSI117-1 and MSH067-3. MSI03-5 and MSH067-3 are both scab tolerant too. Other tablestock selections with promise include MSI053-2, MSI005-20Y, MSG106-5 and MS178-8.

G. Potato Scab Evaluation

Each year a replicated field trial at the MSU Soils Farm is conducted to assess resistance to common and pitted scab. The varieties are ranked on a 1-5 scale based upon a combined score for scab coverage and lesion severity. Usually examining one year's data does not indicate which varieties are resistant but it should begin to identify ones that can be classified as susceptible to scab. Our goal is to evaluate important advanced selections and varieties in the study at least three years to obtain a valid estimate of the level of resistance in each line. Table 8A categorizes many of the varieties and advanced selections tested in 1999 at the MSU Soils Farm Scab Nursery. This disease trial is a severe test. The varieties and lines are placed into five arbitrary categories based upon scab infection level and lesion severity. A rating of 1.0 indicates zero to a trace amount of infection. A moderate resistance (1.2 – 1.8) correlates with <10% infection. These two categories are good levels of scab tolerance. Susceptible lines have greater than 25% infection with pitted lesions. Scores of 4.0 or greater are found on lines with >50% infection and severe pitted lesions. The check varieties Russet Burbank, Superior, Onaway, Red Pontiac, Yukon Gold, Atlantic and Snowden can be used as references (bolded in Table 8). Scab results are also found in the Trial Summaries (Tables 2,3,4, 5, 6 and 7). Table 8B summarizes the 1997-9 scab trial results for the varieties and lines that have been tested at least two years in the past four years. These multi-year results give a more stable rating score for the clones tested in these trials.

H. Late Blight Trial

In 1999 a late blight trial was conducted at the Muck Soils Research Farm. Over 170 entries were evaluated in replicated plots. The field was inoculated late-July and ratings were taken during August. Most lines were highly susceptible to the US-8 genotype of late blight. Lines with the least infection were LBR8, LBR9, AWN86514-1, B0718-3, NY121 (Q237-25), MSG274-3 and Torridon (a Scottish variety). The good agronomic and tuber qualities of MSG274-3 make this selection the strongest late blight resistant line a candidate for commercialization. Lines with reduced susceptibility to late blight are Umatilla Russet, Legend Russet (C0083008-1), B9922-11, MSG124-8P and MSA091-1. Foliar susceptibility of all the lines tested against the US-8 genotype of late blight is summarized in Table 9.

I. Blackspot Susceptibility

Increased evaluations of advanced seedlings and new varieties for their susceptibility to blackspot bruising has been implemented in the variety evaluation program. Check samples of 25 tubers were collected (a composite of 4 reps) from each cultivar at the time of grading. A second 25 tuber sample was similarly collected, placed in 50F storage overnight and then was placed in a hexagon plywood drum and tumbled 10 times to provide a simulated bruise. Both samples were peeled in an abrasive peeler in October and individual tubers were assessed for the number of blackspot bruises on each potato. These data are shown in Tables 10A and 10B. Table 10A summarizes the data for the samples receiving the simulated bruise and Table 10B, the check samples. The bruise data are represented in two ways: 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 greater than Atlantic are approaching the bruise-susceptible rating. In addition, the data is grouped by trial, since the bruise levels can vary between trials. We are also hoping the uniform tuber temperature prior to bruising may help reduce variability observed in previous years. These results become more meaningful when evaluated over 3 years which reflects different growing seasons and harvest conditions. The data indicates that bruise levels were average compared to other years. The most bruise resistant lines were MSE228-1, A7961-1, MSE192-8RUS, ND3574-5R, MSG145-1Y, MSG147-3P, MSI178-8 and MSF015-1.

J. Post-harvest Disease Evaluation: Fusarium Dry Rot

As part of the postharvest evaluation, resistance to *Fusarium sambucinum* (fusarium dry rot) was assessed by inoculating 8 whole tubers post-harvest from each line in the variety trials. The tubers were held at 20°C for approximately three weeks and then scored for dry rot infection depth and width. These data are summarized in Table 11. The clones in this table are ranked according to infection depth. Infection levels within a clone can vary as seen by the multiple tests of the check varieties. Snowden, which has tolerance to fusarium, had infections from 3.4-6.0 mm in depth. Russet Burbank infections ranged from 4.5- 5.9 mm, while Atlantic infections were from 6.3-16.6 mm. No clones showed immunity to dry rot, however, some lines show tolerance at levels equivalent to Russet Norkotah, Snowden and Superior. Some key lines with identified tolerance are MSH106-2, MSG004-3, P83-11-5, MSH031-5, MSE018-1, NY112, MSE202-3RUS, MSG227-2, MSF313-3, MSG145-1Y.

TABLE 1

MICHIGAN STATE UNIVERSITY
POTATO BREEDING and GENETICS

ROUND WHITES: EARLY HARVEST
MONTCALM RESEARCH FARM
AUGUST 9, 1999 (98 DAYS)

	CWT/A		PERCENT OF TOTAL[1]							TUBER QUALITY[2]				TOTAL	3-YR AVG US#1
LINE	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	SFA†	HH	VD	IBS	BC	CUT	CWT/A
NY112	332	371	89	11	85	5	0	1.083	1.0	5	1	0	0	40	435*
MSE018-1	315	391	81	19	77	3	0	1.087	1.0	2	3	0	0	40	256
NY120	272	301	90	8	83	7	2	1.083	1.0	0	11	0	0	40	-
ATLANTIC	267	319	84	13	73	11	3	1.091	1.0	12	0	0	0	40	259
MSF313-3	262	310	85	14	78	6	1	1.081	1.0	2	1	0	0	40	-
MSF014-9	235	295	80	20	79	1	1	1.074	1.0	1	0	0	0	40	-
CHIPETA	231	265	87	11	82	5	2	1.075	1.0	3	0	0	0	40	-
MSG050-2	230	298	77	21	76	1	2	1.070	-	0	0	1	0	40	-
MSE228-1	230	324	71	29	70	1	0	1.080	-	0	0	0	0	40	306*
MSE221-1	229	300	76	13	71	5	11	1.071	-	0	1	1	0	40	274
ONAWAY	222	303	73	24	73	1	3	1.064	-	0	4	0	0	40	222
REBA	220	263	84	14	81	2	2	1.075	1.0	0	0	0	0	40	151*
MSE228-11	218	343	64	36	64	0	0	1.084	-	0	2	0	0	40	177
NY115	212	270	78	21	70	8	0	1.075	1.0	0	0	0	0	40	270*
MSNT-1	200	267	75	24	75	0	0	1.088	1.0	0	0	0	0	40	198
MSE149-5Y	197	262	75	23	72	3	1	1.066	1.0	0	1	0	0	40	267*
MSG227-2	190	284	67	30	66	0	4	1.084	1.0	0	0	0	0	40	-
MSF099-3	183	274	67	31	65	2	2	1.092	1.0	2	0	0	0	40	295*
MSE246-5	183	254	72	27	72	0	1	1.093	1.0	0	0	0	0	40	223*
SNOWDEN	180	252	71	28	70	1	1	1.084	1.0	1	7	0	0	40	191
P83-11-5	174	264	66	31	65	1	2	1.085	1.0	2	1	0	0	40	-
SUPERIOR	172	219	78	20	78	0	1	1.070	-	1	9	0	1	40	-
MSA091-1	168	239	70	28	70	0	2	1.082	1.0	0	3	0	0	40	184
MSB076-2	164	283	58	40	58	0	2	1.081	1.0	0	1	0	0	40	176
MSC148-A	144	272	53	47	53	0	0	1.087	1.0	0	1	0	0	40	152
MSE250-2	124	198	62	36	62	0	1	1.090	1.0	0	0	0	0	40	160*
MSG274-3	89	340	26	73	26	0	1	1.081	1.0	0	0	0	0	40	-
MEAN	209	287						1.081							
$LSD_{0.05}$	34	33						0.003							

[1]SIZE
B: < 2"
A: 2 - 3.25"
OV: > 3.25"
PO: PICKOUTS

[2]QUALITY
HH: HOLLOW HEART
BC: BROWN CENTER
VD: VASCULAR DISCOLORATION
IBS: INTERNAL BROWN SPOT

†SNACK FOOD ASSOCIATION CHIP SCORE
OUT OF THE FIELD
RATINGS: 1 - 5
1: EXCELLENT
5: POOR

* TWO-YEAR AVERAGE
PLANTED MAY 3, 1999

TABLE 2

MICHIGAN STATE UNIVERSITY
POTATO BREEDING and GENETICS

ROUND WHITES: LATE HARVEST
MONTCALM RESEARCH FARM
SEPTEMBER 20, 1999 (140 DAYS)

	CWT/A		PERCENT OF TOTAL[1]							TUBER QUALITY[2]				TOTAL			3-YR AVG US#1
LINE	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	SFA†	HH	VD	IBS	BC	CUT	SCAB[3]	MAT[4]	CWT/A
MSE018-1	386	449	86	13	81	6	1	1.089	2.0	8	6	0	0	40	3.0	5.0	363
NY112	385	422	91	9	80	12	0	1.079	1.5	16	2	1	0	40	1.5	3.5	448*
ATLANTIC	324	374	87	11	76	11	3	1.090	1.5	5	3	1	1	40	3.0	2.5	312
MSE228-1	321	405	79	19	75	4	2	1.070	-	0	4	0	0	40	3.0	3.0	339*
MSF313-3	318	370	86	12	75	11	2	1.077	1.5	0	5	0	0	40	2.7	3.5	-
CHIPETA	296	353	84	10	75	9	6	1.073	1.5	5	6	0	0	40	2.3	4.5	-
NY120	284	312	91	6	81	11	3	1.078	2.0	0	22	0	0	40	1.3	3.0	-
MSG050-2	283	332	85	14	78	7	1	1.069	-	0	2	1	0	40	2.0	2.0	-
MSE228-11	279	387	72	27	71	1	1	1.082	2.0	0	2	0	0	40	3.0	4.0	245
REBA	254	301	85	14	78	6	1	1.073	1.0	2	5	0	0	40	2.0	3.0	219*
MSF014-9	253	311	81	18	77	4	0	1.072	1.5	0	0	0	0	40	3.0	3.0	-
SNOWDEN	247	314	79	21	74	4	1	1.080	1.5	0	8	0	1	40	3.0	3.0	241
ONAWAY	245	315	78	17	77	1	6	1.062	-	0	9	0	0	40	1.2	1.5	236
NY115	244	310	79	21	74	5	1	1.074	1.5	0	2	0	0	40	1.5	2.0	301*
MSE149-5Y	240	298	81	18	78	3	1	1.062	1.5	0	0	0	0	40	2.0	2.0	304*
MSE221-1	240	295	82	9	73	9	10	1.067	-	0	3	0	0	40	1.2	1.5	274
MSG227-2	236	321	73	23	72	1	3	1.080	1.5	1	0	0	0	40	1.1	3.5	-
MSF099-3	230	314	73	25	72	1	2	1.086	1.5	0	1	0	0	40	2.7	3.0	307*
SUPERIOR	228	277	82	16	81	1	2	1.069	-	0	12	0	0	40	1.0	1.0	-
MSNT-1	228	296	77	22	75	2	1	1.084	1.0	1	1	0	0	40	1.5	3.0	211
MSE246-5	218	285	76	22	74	2	1	1.090	1.0	1	9	0	0	40	2.0	3.0	262*
P83-11-5	201	313	64	32	64	1	4	1.082	1.0	0	5	1	1	40	1.7	2.5	-
MSA091-1	197	273	72	22	72	0	6	1.080	1.0	0	6	1	0	40	1.0	2.5	221
MSG274-3	178	409	44	55	43	0	1	1.079	1.5	0	0	0	0	40	3.5	4.0	-
MSB076-2	170	283	60	39	60	0	1	1.078	2.0	0	0	0	0	40	1.5	1.5	193
MSE250-2	159	238	67	29	67	0	4	1.090	1.5	3	0	0	0	40	2.3	4.5	194*
MSC148-A	148	264	56	43	56	0	1	1.084	1.0	0	0	0	0	40	2.5	1.0	166
MEAN	252	327						1.078									
$LSD_{0.05}$	46	42						0.002									

[1]SIZE
B: < 2"
A: 2 - 3.25"
OV: > 3.25"
PO: PICKOUTS

[2]QUALITY
HH: HOLLOW HEART
BC: BROWN CENTER
VD: VASCULAR DISCOLORATION
IBS: INTERNAL BROWN SPOT

[3]SCAB DISEASE RATING
(FROM MSU SCAB NURSERY)
1: NO INFECTION
3: INTERMEDIATE
5: HIGHLY SUSCEPTABLE

[4]MATURITY RATING
RATINGS: 1 - 5
1: EARLY
5: LATE

* TWO-YEAR AVERAGE
PLANTED MAY 3, 1999

†SNACK FOOD ASSOCIATION CHIP SCORE
OUT OF THE FIELD
RATINGS: 1 - 5
1: EXCELLENT
5: POOR

TABLE 3

MICHIGAN STATE UNIVERSITY
POTATO BREEDING and GENETICS

LONG WHITES and RUSSETS
MONTCALM RESEARCH FARM
SEPTEMBER 2, 1999 (122 DAYS)

	CWT/A		PERCENT OF TOTAL[1]						TUBER QUALITY[2]				TOTAL			3-YR AVG US#1
LINE	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	HH	VD	IBS	BC	CUT	SCAB[3]	MAT[4]	CWT/A
MSG088-6RUS	276	369	75	22	69	6	3	1.068	0	5	0	0	40	2.0	3.5	343*
MSE202-3RUS	206	295	70	27	65	5	3	1.074	1	2	0	0	40	1.2	3.5	173*
MSH026-3RUS	204	320	64	36	62	1	1	1.071	1	2	0	0	40	1.5	2.0	-
MSB106-7	197	311	63	32	60	4	5	1.060	0	3	0	0	40	1.3	1.5	175
INNOVATOR	173	288	60	35	56	4	5	1.069	0	1	0	0	40	3.0	3.0	232*
A7961-1	141	267	53	45	52	1	3	1.075	5	7	0	0	30	1.0	3.5	209
ND4093-4RUS	116	245	47	52	47	1	1	1.068	2	0	0	0	30	1.3	1.5	-
MSE192-8RUS	102	255	40	56	38	2	4	1.065	0	2	0	0	20	1.2	1.5	164*
RUSSET NORKOTAH	99	223	44	55	44	1	1	1.064	0	1	0	0	10	2.0	1.0	153*
RUSSET BURBANK	83	242	34	59	34	0	7	1.069	0	0	0	0	10	1.0	2.5	157
MEAN	160	282						1.068								
$LSD_{0.05}$	49	47						0.002								

[1]SIZE
B: < 4 oz.
A: 4 - 10 oz.
OV: > 10 oz.
PO: PICKOUTS

[2]QUALITY
HH: HOLLOW HEART
BC: BROWN CENTER
VD: VASCULAR DISCOLORATION
IBS: INTERNAL BROWN SPOT

[3]SCAB DISEASE RATING
(FROM MSU SCAB NURSERY)
1: NO INFECTION
3: INTERMEDIATE
5: HIGHLY SUSCEPTABLE

[4]MATURITY RATING
RATINGS: 1 - 5
1: EARLY
5: LATE

* TWO-YEAR AVERAGE
PLANTED MAY 3, 1999

TABLE 4

MICHIGAN STATE UNIVERSITY
POTATO BREEDING and GENETICS

NORTH CENTRAL REGIONAL TRIAL
MONTCALM RESEARCH FARM
SEPTEMBER 7, 1999 (127 DAYS)

	CWT/A		PERCENT OF TOTAL[1]							TUBER QUALITY[2]				TOTAL		
LINE	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	SFA[†]	HH	VD	IBS	BC	CUT	SCAB[3]	MAT[4]
ND5084-3R	422	469	90	7	53	37	3	1.056	2.5	1	5	1	0	40	1.8	4.0
SNOWDEN	371	411	90	9	87	3	1	1.087	1.5	2	26	0	0	40	3.0	4.5
RED PONTIAC	359	421	85	13	82	4	2	1.060	3.0	1	8	0	0	40	3.8	4.0
ATLANTIC	351	400	88	11	83	4	1	1.091	1.5	11	6	1	0	40	3.0	3.5
MSE018-1	346	425	82	16	78	4	3	1.084	1.5	1	12	0	0	40	3.0	5.0
ND2470-27	326	399	82	15	79	2	3	1.077	1.0	0	14	0	0	40	2.5	3.0
MSB107-1	318	352	90	7	84	6	3	1.074	1.5	0	9	2	0	40	1.5	4.0
FV8957-10	280	332	84	12	82	3	3	1.070	1.0	4	15	0	0	40	4.0	3.0
W1148R	261	323	81	18	79	2	1	1.069	2.0	0	12	0	0	40	1.3	2.5
NORLAND	255	325	79	19	78	1	2	1.056	2.5	1	7	0	0	40	-	1.0
ND3574-5R	255	322	79	20	79	0	1	1.053	3.0	0	4	0	0	40	2.0	1.0
MN16966	250	375	67	30	63	4	3	1.078	1.5	0	9	1	2	40	2.5	4.0
MN17922	236	261	90	8	74	16	2	1.057	3.0	0	15	0	0	40	-	3.0
MSE263-10	218	271	80	19	80	0	1	1.073	1.5	0	8	0	0	40	-	2.0
MSA091-1	215	294	73	22	73	0	5	1.079	2.0	0	7	0	0	40	1.0	3.0
W1355-1	212	315	67	32	67	0	0	1.080	1.0	0	7	0	0	40	2.8	3.5
WIS75-30	205	337	61	37	61	0	2	1.074	1.5	0	4	0	0	40	2.0	2.0
NORVALLEY	196	323	61	36	60	1	4	1.072	1.5	0	2	0	0	40	-	2.5
MN18713	183	305	60	38	55	5	2	1.082	1.5	0	8	0	0	40	1.0	3.0
FV9649-6	161	280	57	40	52	6	2	1.062	2.5	2	0	1	0	40	3.0	2.0
ND4093-4RUSS	151	295	51	47	49	2	2	1.068	2.5	3	0	0	0	40	1.3	1.0
W1348RUS	146	280	52	45	52	0	2	1.073	1.5	3	1	0	0	30	1.0	3.0
RUSSET BURBANK	129	261	50	40	49	0	10	1.068	2.0	0	4	0	0	30	1.0	3.5
ND2937-3	126	286	44	39	44	0	16	1.060	2.5	0	0	0	0	30	4.0	1.0
RUSSET NORKOTAH	99	208	48	52	45	3	0	1.063	2.0	1	1	0	0	10	2.0	1.0
MN18153	62	168	37	62	36	1	1	1.062	2.0	0	0	0	0	0	-	1.5
MEAN	236	325						1.070								
$LSD_{0.05}$	50	49						0.003								

[1]SIZE
B: < 2"
A: 2 - 3.25"
OV: > 3.25"
PO: PICKOUTS

[2]QUALITY
HH: HOLLOW HEART
BC: BROWN CENTER
VD: VASCULAR DISCOLORATION
IBS: INTERNAL BROWN SPOT

[3]SCAB DISEASE RATING
(FROM MSU SCAB NURSERY)
1: NO INFECTION
3: INTERMEDIATE
5: HIGHLY SUSCEPTABLE

[4]MATURITY RATING
RATINGS: 1 - 5
1: EARLY
5: LATE

PLANTED MAY 3, 1999

[†]SNACK FOOD ASSOCIATION CHIP SCORE
OUT OF THE FIELD
RATINGS: 1 - 5
1: EXCELLENT
5: POOR

TABLE 5

MICHIGAN STATE UNIVERSITY
POTATO BREEDING and GENETICS

YELLOW FLESH and EUROPEAN TRIAL
MONTCALM RESEARCH FARM
SEPTEMBER 13, 1999 (133 DAYS)

	CWT/A		PERCENT OF TOTAL[1]							TUBER QUALITY[2]				TOTAL		
LINE	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	SFA[†]	HH	VD	IBS	BC	CUT	SCAB[3]	MAT[4]
COLUMBO	304	444	69	30	67	1	1	1.065	2.0	0	0	0	0	40	3.2	3.0
ACCENT	278	426	65	26	64	1	9	1.060	4.5	0	12	1	0	40	2.0	3.0
MSE048-2Y	277	343	81	16	78	3	3	1.072	-	7	0	0	0	40	2.0	3.0
SIERRA	270	359	75	21	69	6	4	1.063	3.5	2	11	1	0	40	2.3	3.5
MSE222-5Y	255	376	68	26	65	3	6	1.075	-	2	0	0	0	40	2.7	2.5
GIGANT	244	343	71	24	70	1	5	1.082	-	0	3	12	0	40	2.5	5.0
YUKON GOLD	242	279	87	12	77	10	1	1.074	-	2	3	0	0	40	2.5	2.0
MSG145-1Y	212	278	76	22	75	1	2	1.070	-	14	0	1	0	40	2.0	1.5
BOLESTRA	207	334	62	34	62	0	5	1.084	1.0	0	6	0	0	40	3.0	5.0
MSE226-4Y	205	326	63	35	61	2	2	1.066	-	0	1	0	0	40	1.1	2.0
ELOGE	187	328	57	41	56	1	2	1.066	3.0	0	0	6	0	40	4.0	2.0
VICTORIA	184	339	54	40	54	0	5	1.076	-	0	20	0	0	40	2.0	5.0
TORRIDON	170	358	48	48	47	0	5	1.090	1.5	0	5	2	0	40	4.0	4.5
SAGINAW GOLD	166	285	58	37	58	0	4	1.073	-	3	2	0	0	40	1.3	1.0
ACCORD	151	322	47	51	47	0	2	1.080	2.0	0	0	2	0	40	2.3	2.5
MSA097-1Y	144	260	55	44	54	2	1	1.074	2.5	0	0	0	0	40	1.0	1.5
MSE040-6RY	140	318	44	55	43	0	1	1.068	-	0	2	0	0	40	2.0	1.5
APELL	109	297	37	56	37	0	7	1.064	3.0	0	1	0	0	30	2.7	3.0
MATILDA	107	349	31	68	31	0	1	1.082	-	0	4	0	0	10	2.8	4.0
ZAREVO	95	195	49	35	47	2	16	1.086	-	7	3	3	0	30	2.8	4.0
SW93107	91	258	35	61	35	0	4	1.079	3.0	0	1	0	0	20	1.8	4.0
LADY CLAIRE	62	253	25	75	25	0	0	1.077	1.0	0	0	0	0	0	2.0	1.5
MEAN	186	321						1.074								
$LSD_{0.05}$	47	37						0.003								

[1]SIZE
B: < 2"
A: 2 - 3.25"
OV: > 3.25"
PO: PICKOUTS

[2]QUALITY
HH: HOLLOW HEART
BC: BROWN CENTER
VD: VASCULAR DISCOLORATION
IBS: INTERNAL BROWN SPOT

[3]SCAB DISEASE RATING
(FROM MSU SCAB NURSERY)
1: NO INFECTION
3: INTERMEDIATE
5: HIGHLY SUSCEPTABLE

[4]MATURITY RATING
RATINGS: 1 - 5
1: EARLY
5: LATE

PLANTED MAY 3, 1999

[†]SNACK FOOD ASSOCIATION CHIP SCORE
OUT OF THE FIELD
RATINGS: 1 - 5
1: EXCELLENT
5: POOR

TABLE 6

MICHIGAN STATE UNIVERSITY
POTATO BREEDING and GENETICS

ADAPTATION TRIAL
MONTCALM RESEARCH FARM
SEPTEMBER 21, 1999 (141 DAYS)

LINE	CWT/A US#1	CWT/A TOTAL	PERCENT OF TOTAL[1] US#1	Bs	As	OV	PO	SP GR	SFA[†]	TUBER QUALITY[2] HH	VD	IBS	BC	TOTAL CUT	SCAB[3]	MAT[4]
MSE028-1	388	470	83	14	80	3	4	1.079	-	0	11	3	0	40	1.0	4.5
MSE273-8	363	409	89	10	77	12	1	1.073	2.0	6	5	2	0	40	4.5	3.5
MSG124-8P	362	381	95	4	71	24	1	1.071	2.0	13	0	0	0	40	1.3	5.0
IDA ROSE	338	377	90	9	77	13	1	1.070	-	1	1	3	0	40	1.3	5.0
MSH333-3	328	376	87	10	82	5	3	1.077	2.0	0	1	0	0	40	3.3	3.5
MSH031-5	322	401	80	19	79	2	0	1.081	1.5	0	1	0	0	40	2.0	3.0
MSF001-2	309	363	85	14	82	3	1	1.070	1.5	0	1	0	0	40	3.5	3.5
MSG049-4	307	341	90	5	77	13	5	1.069	-	6	4	0	2	40	3.3	2.0
MSH041-1	306	377	81	15	75	6	4	1.070	1.0	5	3	0	0	40	2.3	3.0
ATLANTIC	303	359	84	13	79	5	2	1.088	1.0	6	0	1	2	40	3.0	3.5
MSF060-6	298	345	86	14	85	1	0	1.084	2.0	0	3	5	0	40	-	4.0
MSH101-2	293	342	86	14	80	6	1	1.078	2.0	1	4	1	0	40	3.0	3.0
MICHIGAN PURPLE	288	344	84	16	77	7	0	1.071	-	0	6	0	0	40	3.0	3.0
MSH106-2	279	328	85	15	77	8	0	1.093	1.5	2	4	6	6	40	1.0	4.0
MSG147-3P	278	340	82	17	79	3	1	1.066	1.5	0	0	0	0	40	2.5	4.0
MSG004-3	268	307	87	12	81	7	1	1.066	-	0	0	0	0	40	3.0	3.5
MSG015-C	264	364	73	27	71	2	0	1.079	1.5	0	4	1	0	40	1.2	4.0
ROCKET	259	358	73	25	71	2	3	1.074	-	2	3	0	0	40	2.3	2.5
MSG007-1	256	316	81	18	80	1	0	1.094	1.0	0	1	1	0	40	1.8	3.0
ONAWAY	254	324	78	19	75	3	2	1.063	-	0	8	0	0	40	1.2	2.0
SNOWDEN	248	317	78	21	76	3	1	1.080	1.5	1	11	0	0	40	3.0	3.0
NAVAN	243	327	74	22	61	13	4	1.082	2.5	18	3	13	0	40	2.8	5.0
MSH098-2	241	316	76	10	70	7	14	1.085	1.5	0	0	0	0	30	2.5	3.5
MSH018-5	237	397	60	38	59	1	2	1.088	1.0	0	2	1	0	40	2.5	3.5
MIDAS	234	403	58	23	58	0	19	1.081	1.5	0	7	0	0	40	1.3	5.0
MSH217-1	234	309	76	23	73	2	2	1.086	1.5	6	2	1	0	40	3.3	4.5
SAXON	229	330	69	29	69	1	2	1.057	-	1	2	1	0	40	1.8	2.5
MSH384-1Y	227	336	67	30	67	0	3	1.080	3.0	0	10	0	0	40	3.8	3.0
MSI201-2PY	225	385	58	39	58	1	3	1.073	-	0	0	0	0	40	3.5	4.0
MSF002-1	224	285	78	22	78	1	0	1.070	2.0	0	2	0	0	40	3.3	3.0
MSH123-5	222	289	77	23	73	4	0	1.083	1.5	0	10	0	0	40	1.5	4.0
MSG141-1	220	291	75	23	75	0	2	1.089	1.5	0	1	0	0	40	1.7	2.5
MSH094-8	219	298	74	23	73	1	3	1.080	1.0	1	2	2	0	40	2.5	3.0
MSH380-3Y	215	287	75	23	74	1	2	1.084	2.0	2	1	0	0	40	3.0	3.0
MSH228-6	212	270	79	19	75	4	3	1.076	1.5	2	4	2	0	40	1.5	4.0
MSH015-2	205	285	72	18	70	2	10	1.088	1.5	0	1	0	0	40	1.5	2.0
SUPERIOR	200	247	81	18	79	2	1	1.071	-	0	5	0	1	40	1.0	1.5
MSH095-4	199	256	78	19	74	4	3	1.077	1.0	3	8	0	0	40	2.0	2.5
MSH419-1	185	253	69	29	67	2	3	1.087	1.5	2	3	0	0	40	3.0	3.0
MSH321-1	166	311	53	42	53	1	5	1.079	2.0	1	1	0	0	30	-	3.0
MSF087-3RUS	164	319	51	47	50	2	1	1.080	-	3	0	0	0	40	1.0	2.0
MSH120-1	153	281	54	43	54	0	3	1.080	2.0	0	4	1	2	30	1.2	3.0
MSH418-1	147	234	63	36	62	1	1	1.092	1.5	2	0	1	0	30	2.5	3.0
MSH370-3	145	232	63	32	60	3	5	1.076	1.0	1	3	0	1	40	2.0	2.0
MSH361-2	102	266	38	58	38	0	4	1.086	2.0	0	0	0	0	0	1.0	2.0
NY121	74	233	32	68	32	0	0	1.077	-	0	0	0	0	0	1.0	2.0
MEAN	244	326						1.078								
$LSD_{0.05}$	55	53						0.003								

[1]SIZE
B: < 2"
A: 2 - 3.25"
OV: > 3.25"
PO: PICKOUTS

[2]QUALITY
HH: HOLLOW HEART
BC: BROWN CENTER
VD: VASCULAR DISCOLORATION
IBS: INTERNAL BROWN SPOT

[3]SCAB DISEASE RATING
(FROM MSU SCAB NURSERY)
1: NO INFECTION
3: INTERMEDIATE
5: HIGHLY SUSCEPTABLE

[4]MATURITY RATING
RATINGS: 1 - 5
1: EARLY
5: LATE

PLANTED MAY 3, 1999

[†]SNACK FOOD ASSOCIATION CHIP SCORE
OUT OF THE FIELD
RATINGS: 1 - 5
1: EXCELLENT
5: POOR

TABLE 7

MICHIGAN STATE UNIVERSITY
POTATO BREEDING and GENETICS

PRELIMINARY TRIAL
MONTCALM RESEARCH FARM
SEPTEMBER 2, 1999 (122 DAYS)

	CWT/A		PERCENT OF TOTAL[1]							TUBER QUALITY[2]				TOTAL			
LINE	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	SFA[†]	HH	VD	IBS	BC	CUT	PEDIGREE	SCAB[3]	MAT[4]
MSF373-8	401	424	95	5	73	22	1	1.083	1.5	0	0	0	0	20	MS702-80 X NY88	1.7	5.0
MSI172-7	392	435	90	8	80	11	1	1.071	1.5	1	2	0	0	20	NORVALLEY X F191-9	4.3	4.0
MSI077-5	363	398	91	8	82	9	0	1.076	3.5	0	1	0	0	20	C084-1 X W870	4.0	4.0
MSH017-C	351	381	92	7	84	8	1	1.085	1.5	1	3	0	0	20	ATL X NOVACHIP	3.0	2.5
MSI103-5	333	409	82	16	79	3	3	1.079	1.0	0	0	3	0	20	E149-5Y X LEMHI	1.0	4.5
MSI002-3	320	380	84	15	82	2	1	1.082	1.0	3	0	0	0	20	A091-1 X F134-1	4.3	2.0
MSH063-A	316	392	81	18	79	1	1	1.074	1.0	0	1	1	0	20	C121-7 X C086-7	2.0	3.0
MSI117-1	315	370	85	11	79	6	4	1.080	1.5	0	5	0	0	20	PIKE X ND860-2	1.0	3.0
MSI053-2	311	340	91	8	87	5	0	1.077	2.5	0	0	0	0	20	BRODICK X E234-3	2.0	3.0
ATLANTIC	309	374	83	14	79	4	4	1.089	1.0	2	0	0	0	20		3.0	3.0
MSH067-3	308	335	92	6	77	15	2	1.085	1.5	4	3	1	0	20	C127-3 X W877	1.8	2.5
MSI005-20Y	306	403	76	23	74	2	1	1.073	2.5	0	1	0	0	20	A097-1Y X PENTA	1.8	3.0
MSI050-4	304	393	77	22	76	2	1	1.083	1.0	1	0	0	0	20	BRODICK X C127-3	2.5	3.0
MSG106-5	302	341	88	11	73	16	1	1.067	2.5	3	1	0	1	20	PRESTILE X L235-4	2.3	2.0
MSH013-A	299	374	80	15	80	0	5	1.076	1.5	0	3	0	0	20	ATL X C135-2	2.0	1.5
MSH306-B	297	353	84	12	84	1	4	1.094	1.5	3	6	0	0	20	ATL X F077-8	2.7	3.0
MSI178-8	292	343	85	14	84	1	1	1.072	2.5	3	2	0	1	20	NY101 X CHALEUR	1.7	3.5
MSI057-1	289	391	74	24	74	0	2	1.080	1.0	5	1	0	0	20	BRODICK X F090-1	4.0	3.0
B1865-2	281	345	82	14	76	6	4	1.069	2.0	0	1	1	0	20		3.7	4.0
SNOWDEN	279	346	81	19	77	4	1	1.083	1.0	1	4	0	0	20		3.0	3.0
MSI004-2Y	275	344	80	19	80	0	1	1.072	1.5	0	3	0	0	20	A097-1Y X LEMHI	1.0	3.5
MSI160-7	275	352	78	21	78	0	1	1.088	1.0	0	0	0	0	20	NDA2031-2 X F077-8	3.0	3.5
MSI223-6	272	371	73	25	72	1	2	1.090	2.0	0	2	0	0	20	STOBRAWA X NDO1496	3.0	4.5
MSI037-7	269	331	81	18	75	6	1	1.082	1.0	1	4	0	0	20	B110-3 X NDO1496-1	3.8	3.0
MSI055-5	262	366	72	26	72	0	2	1.080	1.0	0	0	0	0	20	BRODICK X E263-10	4.5	2.5
MSI083-5	260	330	79	21	78	1	0	1.080	1.5	1	1	0	0	20	C135-5 X B0718-3	-	3.5
MSI039-8Y	257	327	78	17	77	2	4	1.073	1.0	0	0	0	0	20	B116-1Y X YUKON	2.8	3.0
MSH360-1	250	288	87	13	87	0	0	1.087	1.0	2	2	0	0	20	PIKE X F077-8	3.3	3.5
MSI193-5	250	289	87	13	84	3	1	1.075	1.0	1	0	0	0	20	PRESTILE X YUKON	2.0	3.5
MSI234-6Y	250	360	69	30	69	0	1	1.082	1.0	0	1	0	0	20	W870 X I. SUNSHINE	2.5	1.5
ONAWAY	245	338	72	25	72	0	2	1.064	4.0	0	6	0	0	20		1.2	1.0
MSI085-10	244	320	76	24	76	0	0	1.089	1.0	1	6	0	0	20	C135-5 X ND01496-1	4.7	4.0
MSI083-4	242	299	81	18	81	0	2	1.077	2.0	0	1	0	0	20	C135-5 X B0718-3	-	3.0
MSI060-3	238	315	75	24	72	3	1	1.068	2.0	6	2	0	0	20	BRODICK X LEMHI	1.0	3.0
MSF015-1	232	284	82	15	81	1	3	1.066	2.0	0	0	0	0	20	PIKE X W877	1.3	1.5
MSI026-2	227	335	68	29	68	0	3	1.074	1.0	0	1	0	0	20	B076-2 X C135-4	2.8	4.0
MSI066-2	227	369	61	38	61	0	0	1.081	2.0	0	1	0	0	20	BZURA X NDO1496-1	1.5	2.5
MSI082-3	223	302	74	26	73	1	0	1.086	1.0	0	4	0	0	20	C135-4 X NDO1496-1	4.0	3.0
MSI005-11Y	205	308	67	29	67	0	4	1.071	3.0	0	0	0	0	20	A097-1Y X PENTA	3.5	3.0
MSI168-5	203	327	62	38	62	0	0	1.083	2.0	0	0	0	0	20	NDO1496-1 X F134-1	3.3	2.0
MSI004-3	202	309	65	33	65	0	1	1.076	2.0	1	0	0	0	20	A097-1Y X LEMHI	1.5	3.0
MSI005-12Y	195	316	62	37	62	0	2	1.069	2.5	0	0	0	0	20	AO97-1Y X PENTA	2.0	2.5
MSF090-9	192	267	72	23	69	3	5	1.072	1.5	0	1	0	0	20	PIKE X W870	1.3	2.5
MSH009-A	186	298	62	35	62	0	2	1.075	1.0	0	4	0	0	20	AO91-1 X LEMHI	2.0	3.0
MSI168-2	180	255	71	27	70	1	2	1.084	1.0	0	2	0	0	20	ND01496-1 X F134-1	4.0	3.5
MSI043-1	165	311	53	45	53	0	2	1.085	1.0	0	2	0	0	20	B1254-1 X F191-9	2.0	2.5
MSF382-2	151	244	62	38	62	0	0	1.065	1.0	0	2	0	0	20	PIKE X L234-5	2.4	3.0
MEAN	267	342						1.078									
$LSD_{0.05}$	72	66						0.004									

[1]SIZE
B: < 2"
A: 2 - 3.25"
OV: > 3.25"
PO: PICKOUTS

[2]QUALITY
HH: HOLLOW HEART
BC: BROWN CENTER
VD: VASCULAR DISCOLORATION
IBS: INTERNAL BROWN SPOT

[3]SCAB DISEASE RATING
(FROM MSU SCAB NURSERY)
1: NO INFECTION
3: INTERMEDIATE
5: HIGHLY SUSCEPTABLE

[4]MATURITY RATING
RATINGS: 1 - 5
1: EARLY
5: LATE

PLANTED MAY 3, 1999

[†]SNACK FOOD ASSOCIATION CHIP SCORE
OUT OF THE FIELD
RATINGS: 1 - 5
1: EXCELLENT
5: POOR

TABLE 8A

MICHIGAN STATE UNIVERSITY
POTATO BREEDING and GENETICS

1999 SCAB DISEASE TRIAL
SCAB NURSERY, EAST LANSING, MI

LINE	RATING	LINE	RATING	LINE	RATING	LINE	RATING	LINE	RATING
MSA091-1	1.0	MSB106-7	1.3	ACCENT	2.0	**ATLANTIC**	**3.0**	B1865-2	3.7
MSA097-1Y	1.0	MSF015-1	1.3	B0564-9	2.0	BOLESTRA	3.0	MSH384-1Y	3.8
A7961-1	1.0	MSF056-1	1.3	MSE040-6RY	2.0	MSE018-1	3.0	MSI037-7	3.8
B0564-8	1.0	MSF090-9	1.3	MSE048-2Y	2.0	MSE228-1	3.0	**RED PONTIAC**	**3.8**
MSE028-1	1.0	MSG124-8P	1.3	MSE149-5Y	2.0	MSE228-11	3.0	ELOGE	4.0
MSF087-3	1.0	MSH356-A	1.3	MSE246-5	2.0	MSF014-9	3.0	FV8957-10	4.0
GEM RUSSET	1.0	IDA ROSE	1.3	MSG050-2	2.0	MSF019-11	3.0	MSI057-1	4.0
MSH106-2	1.0	MIDAS	1.3	MSG088-6RUS	2.0	MSF105-10	3.0	MSI077-5	4.0
MSH361-2	1.0	ND4093-4RUS	1.3	MSG145-1Y	2.0	FV9649-6	3.0	MSI082-3	4.0
MSI004-2Y	1.0	NY120	1.3	MSH009-A	2.0	MSG004-3	3.0	MSI168-2	4.0
MSI060-3	1.0	SAGINAW GOLD	1.3	MSH013-A	2.0	MSH017-C	3.0	ND2937-3	4.0
MSI103-5	1.0	W1148R	1.3	MSH031-5	2.0	MSH101-2Y	3.0	TORRIDON	4.0
MSI117-1	1.0	AF1668-60	1.5	MSH063-A	2.0	MSH380-3Y	3.0	MSI002-3	4.3
MN18713RUS	1.0	MSB076-2	1.5	MSH095-2	2.0	MSH419-1	3.0	MSI172-7	4.3
NY121	1.0	MSB107-1	1.5	MSH370-3	2.0	MSI160-7	3.0	P88-6-19	4.3
RUSSET BURBANK	**1.0**	MSE230-6	1.5	MSI005-12Y	2.0	MSI222-9	3.0	MSE273-8	4.5
SUPERIOR	**1.0**	MSH015-2	1.5	MSI043-1	2.0	MSI223-6	3.0	MSI055-5	4.5
W1348RUS	1.0	MSH026-3RUS	1.5	MSI053-2	2.0	INNOVATOR	3.0	MSI085-10	4.7
MSE226-4Y	1.1	MSH123-5	1.5	MSI065-2Y	2.0	MI PURPLE	3.0		
MSG227-2	1.1	MSH228-6	1.5	MSI193-5	2.0	**SNOWDEN**	**3.0**		
MSE192-8RUS	1.2	MSI004-3	1.5	LADY CLAIRE	2.0	COLUMBO	3.2		
MSE202-3RUS	1.2	MSI066-2	1.5	ND3574-5R	2.0	MSF002-1	3.3		
MSE221-1	1.2	MSNT-1	1.5	**RUSSET NORKOTAH**	**2.0**	MSG049-4	3.3		
MSG015-C	1.2	NY112	1.5	REBA	2.0	MSH217-1	3.3		
MSH120-1	1.2	NY115	1.5	VICTORIA	2.0	MSH333-3	3.3		
ONAWAY	**1.2**	MSF373-8	1.7	WIS75-30	2.0	MSH360-1	3.3		
		MSG141-1	1.7	ACCORD	2.3	MSI168-5	3.3		
		MSI178-8	1.7	CHIPETA	2.3	W1313	3.3		
		ND2676-10	1.7	MSE250-2	2.3	MSF001-2	3.5		
		P83-11-5	1.7	MSG106-5	2.3	MSG274-3	3.5		
		MSG007-1	1.8	MSH041-1	2.3	MSI005-11Y	3.5		
		MSH067-3	1.8	ROCKET	2.3	MSI201-2PY	3.5		
		MSI005-20Y	1.8	SIERRA	2.3				
		ND5084-3R	1.8	MSF382-2	2.4				
		SAXON	1.8	MSC148-A	2.5				
		SW93107	1.8	MSG147-3P	2.5				
				GIGANT	2.5				
				MSH018-1	2.5				
				MSH094-8	2.5				
				MSH098-2	2.5				
				MSH418-1	2.5				
				MSI032-6	2.5				
				MSI050-4	2.5				
				MSI234-6Y	2.5				
				MN16966	2.5				
				ND2470-27	2.5				
				YUKON GOLD	**2.5**				
				APELL	2.7				
				MSE222-5Y	2.7				
				MSF099-3	2.7				
				MSF313-3	2.7				
				MSH306-B	2.7				
				MSF059-1	2.8				
				MSI026-2	2.8				
				MSI039-8Y	2.8				
				MATILDA	2.8				
				NAVAN	2.8				
				W1355-1	2.8				
				ZAREVO	2.8				

SCAB DISEASE RATING
1: PRACTICALLY NO INFECTION
2: LOW INFECTION
3: AVG. SUSCEPTIBILITY (i.e. ATLANTIC)
4: HIGH SUSCEPTIBILITY
5: SEVERE SUSCEPTIBILITY

TABLE 8B

MICHIGAN STATE UNIVERSITY
POTATO BREEDING and GENETICS

SCAB DISEASE TRIAL, THREE-YEAR AVERAGES
SCAB NURSERY, EAST LANSING, MI

LINE	1997 RATING	1998 RATING	1999 RATING	AVG.	LINE	1997 RATING	1998 RATING	1999 RATING	AVG.
A7961-1	1.0	1.0	1.0	1.0	MSE246-5	1.4	1.0	2.0	1.5
ATLANTIC	**3.3**	**3.3**	**3.0**	**3.2**	MSE250-2	3.2	4.0	2.3	3.2
MATILDA	2.3	2.5	2.8	2.5	MSF001-2	2.0	4.0	3.5	3.2
MSA091-1	1.8	1.5	1.0	1.4	MSF019-11	2.8	3.3	3.0	3.0
MSA097-1Y	1.7	2.0	1.0	1.6	MSF099-3	2.5	3.7	2.7	3.0
MSB076-2	1.8	1.2	1.5	1.5	MSF313-3	1.8	2.7	2.7	2.4
MSB106-7	1.3	2.3	1.3	1.6	MSF373-8	3.0	2.3	1.7	2.3
MSB107-1	1.8	1.0	1.5	1.4	MSG050-2	2.0	4.0	2.0	2.7
MSC148-A	2.4	3.3	2.5	2.7	MSG124-8P	1.5	1.7	1.3	1.5
MSE018-1	2.6	3.0	3.0	2.9	MSG227-2	1.0	1.0	1.1	1.0
MSE048-2Y	2.1	1.0	2.0	1.7	MSNT-1	1.0	1.8	1.5	1.4
MSE149-5Y	2.0	1.8	2.0	1.9	ND2676-10	1.5	1.5	1.7	1.6
MSE192-8RUS	1.3	1.0	1.2	1.2	**ONAWAY**	**1.0**	**1.5**	**1.2**	**1.2**
MSE202-3RUS	1.0	-	1.2	1.1	**RED PONTIAC**	**2.6**	**3.3**	**3.8**	**3.2**
MSE221-1	1.0	1.5	1.2	1.2	**RUSSET BURBANK**	**1.0**	**1.0**	**1.0**	**1.0**
MSE222-5Y	3.0	2.0	2.7	2.6	**RUSSET NORKOTAH**	**1.8**	**2.0**	**2.0**	**1.9**
MSE226-4Y	1.9	2.3	1.1	1.8	SAGINAW GOLD	1.5	2.0	1.3	1.6
MSE228-1	2.7	2.8	3.0	2.8	**SNOWDEN**	**2.5**	**3.5**	**3.0**	**3.0**
MSE228-11	1.5	3.2	3.0	2.6	W1313	3.0	2.7	3.3	3.0
MSE230-6	1.5	2.3	1.5	1.8	**YUKON GOLD**	**3.0**	**2.7**	**2.5**	**2.7**

SCAB DISEASE RATING
1: PRACTICALLY NO INFECTION
2: LOW INFECTION
3: AVG. SUSCEPTIBILITY (i.e. ATLANTIC)
4: HIGH SUSCEPTIBILITY
5: SEVERE SUSCEPTIBILITY

TABLE 9

LATE BLIGHT VARIETY TRIAL
MUCK SOILS RESEARCH FARM

Inoculated July 22, 1999
Rating based on a 28-day evaluation period
RAUDPC Max = 1.000

LINE	RAUDPC[1] LSMEAN	LINE	RAUDPC LSMEAN
LBR8	0.0336	LBR1R2R3R4	0.2064
LBR9	0.0369	**SHEPODY**	**0.2066**
MSG274-3	**0.0377**	NAVAN	0.2157
B0767-2	0.0379	MIDAS	0.2189
Q237-25	0.0452	LBR4	0.2195
AWN86514-2	0.0522	MSH120-1	0.2257
TORRIDON	0.0696	NORDONNA	0.2258
ROBIJN	0.0717	NORVALLEY	0.2315
B0718-3	0.0742	ND69488-5RUS	0.2319
B0288-17	0.0788	**GOLDRUSH**	**0.2345**
A90586-11	0.0866	GIGANT	0.2366
B1865-2	0.0942	CHIPETA	0.2377
ND6947B-15	0.0957	ACCORD	0.2381
LBR7	0.1070	BOLESTRA	0.2397
C086218-2	0.1265	COLUMBO	0.2419
C0083008-1	0.1304	SIERRA	0.2433
DORITA	0.1427	**ATLANTIC**	**0.2434**
ZAREVO	0.1529	**YUKON GOLD**	**0.2445**
NY121	0.1618	VICTORIA	0.2457
B9922-11	0.1669	SAXON	0.2472
A082611-7	0.1673	**SUPERIOR**	**0.2529**
LBR2	0.1682	ELOGE	0.2564
RUSSET NORKOTAH	0.1753	APELL	0.2620
LBR5	0.1764	ACCENT	0.2622
ND6948B-12	0.1772	**RED PONTIAC**	**0.2779**
W91-9459	0.1798	IDA ROSE	0.2781
ND02438-7R	0.1810	LADY CLAIRE	0.2916
RED LASODA	**0.1824**	GEM RUSSET	0.2938
LBR3	0.1836	**RED NORLAND**	**0.2940**
MSG124-8P	0.1854	ROCKET	0.2962
RUSSET BURBANK[2]	0.1930	SAGINAW GOLD	0.2986
SNOWDEN	**0.1933**	**ONAWAY**	**0.3076**
PIKE	**0.1959**	REBA	0.3126
RANGER RUSSET	**0.2052**	W1355-1	0.6101
		$LSD_{0.05}$ =	0.0837

[1] Ratings indicate the RAUDPC (Relative Area Under the Disease Progress Curve) over the entire plot.

[2] 170 varieties and breeding lines were tested in all. For brevity purposes, only selected varieties and breeding lines with a RAUDPC value greater than Russet Burbank are listed.

TABLE 10A

1999 BLACKSPOT BRUISE SUSCEPTIBILITY TEST
SIMULATED BRUISE SAMPLES*

VARIETY	NUMBER OF SPOTS PER TUBER 0	1	2	3	4	5+	TOTAL TUBERS	PERCENT (%) BRUISE FREE	AVERAGE SPOTS/TUBER
ROUND WHITES: LATE HARVEST									
MSE228-1	20	4	1				25	80	0.240
MSF014-9	18	7					25	72	0.280
MSE149-5Y	18	5	1				24	75	0.292
MSE228-11	18	5	2				25	72	0.360
CHIPETA	15	8	1				24	63	0.417
ONAWAY	14	4	1	1			20	70	0.450
MSG227-2	17	5	1		1		24	71	0.458
NY115	13	8	2				23	57	0.522
SUPERIOR	13	7	3				23	57	0.565
MSF099-3	16	4	6	1			27	59	0.704
P83-11-5	9	10	2	3			24	38	0.958
MSE246-5	10	10	3	3			26	38	0.962
MSC148-A	10	6	7		1		24	42	1.000
MSE221-1	9	6	8	2			25	36	1.120
SNOWDEN	7	7	5	1	1		21	33	1.143
MSG050-2	6	11	4	3			24	25	1.167
MSB076-2	8	5	6	4			23	35	1.261
MSG274-3	7	6	8	3			24	29	1.292
REBA	6	5	6	4			21	29	1.381
MSA091-1	5	8	6	3	1		23	22	1.435
MSF313-3	8	9	3	2	2	2	26	31	1.500
MSE250-2	4	8	9	3	1		25	16	1.560
NY112	5	7	4	8		1	25	20	1.760
ATLANTIC	5	7	5	3	2	3	25	20	1.960
NY120	4	8	3	6	3	1	25	16	1.960
MSE018-1	1	4	8	10	1		24	4	2.250
MSNT-1		5	10	6	1	3	25	0	2.480
LONG WHITES and RUSSETS									
A7961-1	24	1					25	96	0.040
RUSSET NORKOTAH	23	2					25	92	0.080
MSE192-8RUS	19	2					21	90	0.095

* A-size tuber samples were collected at harvest, held at 50 F at least 12 hours, and placed in a six-sided plywood drum and rotated ten times to produce simulated bruising. Samples were abrasive-peeled and scored on October 20, 1999. The table is presented in descending order of average number of spots per tuber.

VARIETY	NUMBER OF SPOTS PER TUBER 0	1	2	3	4	5+	TOTAL TUBERS	PERCENT (%) BRUISE FREE	AVERAGE SPOTS/TUBER
RUSSET BURBANK	18	5					23	78	0.217
MSH026-RUS	19	6					25	76	0.240
MSE202-3RUS	13	12					25	52	0.480
ND4093-4RUS	10	12	2				24	42	0.667
INNOVATOR	14	6	7				27	52	0.741
GEM RUSSET	10	7	5	1			23	43	0.870
MSG088-6RUS	10	6	4	3			23	43	1.000
MSB106-7	4	9	7	3	2		25	16	1.600
NORTH CENTRAL REGIONAL TRIAL									
ND3574-5R	29	1					30	97	0.033
MN17922	20	5					25	80	0.200
NORLAND	19	7		1			27	70	0.370
ND5084-3R	15	7	1				23	65	0.391
FV8957-10	16	9	1				26	62	0.423
RED PONTIAC	19	6	3				28	68	0.429
W1148R	9	11	3	1	1		25	36	0.960
NORVALLEY	9	8	11	2			30	30	1.200
ND4093-4RUS	11	8	5	4	1	1	30	37	1.300
MSB107-1	8	7	9	3	1		28	29	1.357
MSE018-1	7	8	10	4			29	24	1.379
MN16966	7	11	4	4	2	1	29	24	1.517
MN18713	5	7	5	6	2	2	27	19	1.963
ATLANTIC	5	4	9	7	4	1	30	17	2.133
SNOWDEN	2	6	11	3	3	2	27	7	2.185
W1355-1	2	7	10	6	3	2	30	7	2.233
YELLOW FLESH and EUROPEAN TRIAL									
MSG145-1	24	1					25	96	0.040
LADY CLAIRE	23	2					25	92	0.080
YUKON GOLD	22	2					24	92	0.083
COLUMBO	24	3					27	89	0.111
MSE040-6RY	18	3					21	86	0.143
BOLESTRA	18	6					24	75	0.250
APELL	18	7					25	72	0.280
ELOGE	15	5	2				22	68	0.409
MSE048-2Y	13	8	1				22	59	0.455
VICTORIA	12	12					24	50	0.500
WIS75-30	17	9	3				29	59	0.517
MSA097-1Y	14	8	3				25	56	0.560
SIERRA	14	4	4	1			23	61	0.652
ZAREVO	12	7	5				24	50	0.708
MSE226-4Y	10	11	1	1	1		24	42	0.833
ACCORD	6	14	3	1			24	25	0.958

	NUMBER OF SPOTS PER TUBER						TOTAL	PERCENT (%) BRUISE	AVERAGE
VARIETY	0	1	2	3	4	5+	TUBERS	FREE	SPOTS/TUBER
MATILDA	8	9	5	3			25	32	1.120
ACCENT	8	8	2	5			23	35	1.174
SW93107	2	8	7	4	1	1	23	9	1.870
GIGANT	2	7	8	5	2		24	8	1.917
SAGINAW GOLD	2	6	7	5	3		23	9	2.043
TORRIDON		5	6	4	3	1	19	0	2.421
ND2470-27	2	4	6	8	5	2	27	7	2.593
MSE222-5Y		2	7	6	4	5	24	0	3.125
ADAPTATION TRIAL									
MSG147-3P	20	6					26	77	0.231
MSI201-2PY	16	7	1				24	67	0.375
SAXON	15	8	3				26	58	0.538
MSH370-3	14	8	1	2			25	56	0.640
MSH384-14	14	6	4	1			25	56	0.680
IDA ROSE	12	9	4				25	48	0.680
MSF002-1	12	8	3	1			24	50	0.708
MSE028-1	11	12		2			25	44	0.720
MSG124-8P	10	10	4				24	42	0.750
MSH031-5	12	7	3	2			24	50	0.792
ONAWAY	11	9	2	1	1		24	46	0.833
MIDAS	9	9	6				24	38	0.875
MSH041-1	10	11	2	1	1		25	40	0.880
MSH321-1	7	7	3	2			19	37	1.000
MSG141-3	7	11	6	1			25	28	1.040
NAVAN	8	10	5	2			25	32	1.040
MSH098-2	7	11	5	2			25	28	1.080
MSH101-2	10	6	4	4			24	42	1.083
MSH361-2	9	7	6	2	1		25	36	1.160
MSH333-3	7	10	5	2	1		25	28	1.200
MSF001-2	7	10	5	1	2		25	28	1.240
MSH217-1	10	9	3		2	2	26	38	1.269
MSG004-3	6	8	8	3			25	24	1.320
MSH380-3Y	8	9	3	3	1	1	25	32	1.320
SNOWDEN	5	9	9	2			25	20	1.320
SUPERIOR	4	13	7	1		1	26	15	1.346
MSH015-2	8	5	7	4	1		25	32	1.400
MSH228-6	5	10	4	3	2		24	21	1.458
ROCKET	4	8	10	2	1		25	16	1.520
MSH018-5	4	8	8	5			25	16	1.560
MSH418-1	4	9	6	6			25	16	1.560
MSH094-8	5	7	6	5	1		24	21	1.583
MSH120-1	4	11	3	5	1	1	25	16	1.640
MSH123-5	3	10	7	4		1	25	12	1.640

VARIETY	NUMBER OF SPOTS PER TUBER 0	1	2	3	4	5+	TOTAL TUBERS	PERCENT (%) BRUISE FREE	AVERAGE SPOTS/TUBER
MSE273-8	4	3	10	4	3	1	25	16	2.080
MSH419-1	3	5	7	6	1	2	24	13	2.125
MSG007-1	1	8	7	5	2	2	25	4	2.200
MI PURPLE	1	7	8	5	3	1	25	4	2.200
MSF060-6		4	12	5	4		25	0	2.360
MSF087-3	4	4	6	4	3	4	25	16	2.400
MSH095-4		9	5	6	2	3	25	0	2.400
MSG015-C	2	5	5	5	3	3	23	9	2.478
MSH106-2		6	7	7	3	2	25	0	2.520
ATLANTIC	1	3	6	4	8	3	25	4	2.960
MSG049-4	1	6	3	2	3	8	23	4	3.043
PRELIMINARY TRIAL									
MSF015-1	23	1					24	96	0.042
MSI178-8	19	4					23	83	0.174
ONAWAY	22	3	1				26	85	0.192
MSH063-A	20	4	1				25	80	0.240
B1865-2	15	3	1				19	79	0.263
MSI005-20Y	17	5	1				23	74	0.304
MSH013-A	18	6	1				25	72	0.320
MSI005-12Y	17	8					25	68	0.320
MSI039-8Y	17	8					25	68	0.320
MSI077-5	16	9					25	64	0.360
MSI004-3	14	6	1				21	67	0.381
MSI005-11Y	15	10					25	60	0.400
MSI193-5	14	8	2				24	58	0.500
MSF090-9	16	5	4				25	64	0.520
MSI002-3	11	12					23	48	0.522
MSI057-1	13	7		2			22	59	0.591
MSI037-7	9	10	1				20	45	0.600
MSI082-3	15	6	3	1			25	60	0.600
MSI103-5	12	10	1	1			24	50	0.625
MSI083-5	12	10	3				25	48	0.640
MSI117-1	11	12	2				25	44	0.640
MSI234-6Y	12	10	3				25	48	0.640
MSF373-8	11	9	3				23	48	0.652
MSI168-5	12	9	2	1			24	50	0.667
MSF382-2	11	11	3				25	44	0.680
MSI004-2Y	12	10	2	1			25	48	0.680
MSI005-5	10	11	3				24	42	0.708
MSI066-2	18	10	6	1			35	51	0.714
MSI160-7	10	7	4				21	48	0.714
MSI026-2	11	9	2	2			24	46	0.792
MSH009-A	7	7	2	1			17	41	0.824

VARIETY	NUMBER OF SPOTS PER TUBER 0	1	2	3	4	5+	TOTAL TUBERS	PERCENT (%) BRUISE FREE	AVERAGE SPOTS/TUBER
MSH360-1	13	6	4	1		1	25	52	0.880
MSI083-4	10	6	3	1	1		21	48	0.905
MSI168-2	9	6	5	1			21	43	0.905
MSI085-10	14	7	7	3			31	45	0.968
SNOWDEN	9	6	5	3			23	39	1.087
ATLANTIC	11	4	3	3	2		23	48	1.174
MSI060-3	7	8	6	4			25	28	1.280
MSH017-C	7	7	5	3	1		23	30	1.304
MSI053-2	6	8	7	4			25	24	1.360
MSG106-5	1	15	5	4			25	4	1.480
MSI223-6	8	7	3	4	3		25	32	1.480
MSH306-B	5	11	3	2	1	2	24	21	1.542
MSH067-3	4	8	10	2	1	1	26	15	1.654
MSI043-1	1	11	6	7			25	4	1.760
MSI050-4	1	6	8	10	1		26	4	2.154
MSI172-7		6	8	8	3		25	0	2.320
SNACK FOOD ASSOCIATION TRIAL									
ND2676-10	17	3					20	85	0.150
NY115	21	2	1				24	88	0.167
AF1668-60	12	9	1				22	55	0.500
B0564-8	13	7	2				22	59	0.500
MSA091-1	12	13					25	48	0.520
B0564-9	11	10	1				22	50	0.545
MSNT-1	11	7	2				20	55	0.550
W1313	13	7	2	1			23	57	0.609
SNOWDEN	12	8	3	1			24	50	0.708
ND2470-27	4	12	8	2			26	15	1.308
NY112	2	4	8	7	4		25	8	2.280

TABLE 10B

MICHIGAN STATE UNIVERSITY
POTATO BREEDING and GENETICS

1999 BLACKSPOT BRUISE SUSCEPTIBILITY TEST
CHECK BRUISE SAMPLES**

VARIETY	NUMBER OF SPOTS PER TUBER 0	1	2	3	4	5+	TOTAL TUBERS	PERCENT (%) BRUISE FREE	AVERAGE SPOTS/TUBER
ROUND WHITES: LATE HARVEST									
MSE228-11	24						24	100	0.000
MSE149-5Y	20	1					21	95	0.048
ONAWAY	22	2					24	92	0.083
SNOWDEN	22	3					25	88	0.120
SUPERIOR	20	3					23	87	0.130
MSF014-9	21	4					25	84	0.160
P83-11-5	21	4					25	84	0.160
MSF099-3	20	4					24	83	0.167
REBA	21	2	1				24	88	0.167
MSE228-1	21	3	1				25	84	0.200
NY120	20	3	1				24	83	0.208
MSE221-1	18	5					23	78	0.217
MSB076-2	17	6					23	74	0.261
CHIPETA	17	6					23	74	0.261
MSG227-2	19	3		1			23	83	0.261
MSE246-5	17	4	1				22	77	0.273
MSC148-A	18	6	1				25	72	0.320
MSE018-1	19	5		1			25	76	0.320
MSG274-3	16	7	1				24	67	0.375
MSA091-1	18	4	3				25	72	0.400
NY115	16	8	1				25	64	0.400
MSE250-2	19	2	3	1			25	76	0.440
MSG050-2	15	9	1				25	60	0.440
MSF313-3	20	9	1	1			31	65	0.452
MSNT-1	15	7	2				24	63	0.458
NY112	10	9	4				23	43	0.739
ATLANTIC	9	6	3	1	1	2	22	41	1.318
LONG WHITES and RUSSETS									
MSH026-RUS	25						25	100	0.000
MSE202-3	24	1					25	96	0.040
MSE192-8RUS	24	1					25	96	0.040

** Tuber samples were collected at harvest, graded, and held until evaluation.
Samples were abrasive-peeled and scored on October 20, 1999.

VARIETY	NUMBER OF SPOTS PER TUBER 0	1	2	3	4	5+	TOTAL TUBERS	PERCENT (%) BRUISE FREE	AVERAGE SPOTS/TUBER
ELOGE	24	1					25	96	0.040
RUSSET BURBANK	24	1					25	96	0.040
RUSSET NORKOTAH	24	1					25	96	0.040
A7961-1	23	2					25	92	0.080
GEM RUSSET	22	3					25	88	0.120
ND4093-4RUS	22	3					25	88	0.120
INNOVATOR	21	4					25	84	0.160
MSG088-6RUS	20	2	1				23	87	0.174
MSB106-7	20	5					25	80	0.200
NORTH CENTRAL REGIONAL TRIAL									
ND3574-5R	27	3					30	90	0.100
FV8957-10	25	3					28	89	0.107
W1575-30	27	4					31	87	0.129
MN17922	23	6					29	79	0.207
NORVALLEY	23	7					30	77	0.233
MSE018-1	22	8					30	73	0.267
ND5084-3R	20	5	1				26	77	0.269
NORLAND	19	8					27	70	0.296
RED PONTIAC	21	5	2				28	75	0.321
W1148R	21	5	2				28	75	0.321
SNOWDEN	18	9	2				29	62	0.448
MN1696 6	19	8	4				31	61	0.516
MSB107-1	19	10	5				34	56	0.588
ND4093-4RUS	15	9	4				28	54	0.607
W1355-1	15	12	4	2			33	45	0.788
ATLANTIC	15	9	5	2			31	48	0.806
MN1871 3	11	12	4	1			28	39	0.821
ND2470-27	10	10	6	2			28	36	1.000
YELLOW FLESH and EUROPEAN TRIAL									
YUKON GOLD	25						25	100	0.000
COLUMBO	24	1					25	96	0.040
MSG145-1	24	1					25	96	0.040
ACCENT	23	2					25	92	0.080
ACCORD	23	2					25	92	0.080
APELL	23	2					25	92	0.080
BOLESTRA	23	2					25	92	0.080
MSE226-4Y	23	2					25	92	0.080
LADY CLAIRE	22	3					25	88	0.120
SW93 107	22	3					25	88	0.120
ZAREVO	22	3					25	88	0.120

VARIETY	NUMBER OF SPOTS PER TUBER 0	1	2	3	4	5+	TOTAL TUBERS	PERCENT (%) BRUISE FREE	AVERAGE SPOTS/TUBER
MATILDA	21	4					25	84	0.160
TORRIDON	22	2	1				25	88	0.160
MSA097-1Y	20	5					25	80	0.200
MSE048-2Y	21	3	1				25	84	0.200
SIERRA	22	1	2				25	88	0.200
VICTORIA	20	5					25	80	0.200
MSE040-6RY	16	6					22	73	0.273
GIGANT	19	5	1				25	76	0.280
SAGINAW GOLD	17	6	2				25	68	0.400
MSE222-5Y	9	9	4	1	1	1	25	36	1.160
ADAPTATION TRIAL									
MSE273-8	24	1					25	96	0.040
MSG049-4	23	1					24	96	0.042
ONAWAY	23	1					24	96	0.042
MSH370-3	22	1					23	96	0.043
MSH120-1	23	2					25	92	0.080
MSG007-1	22	2					24	92	0.083
MSG141-3	22	2					24	92	0.083
MSH384-1Y	22	2					24	92	0.083
MSG124-8P	21	3					24	88	0.125
MSH098-2	21	3					24	88	0.125
IDAROSE	20	4					24	83	0.167
MSE028-1	19	5					24	79	0.208
MSF002-1	20	3	1				24	83	0.208
MSH031-5	20	3	1				24	83	0.208
MSH041-1	19	5					24	79	0.208
MSH419-1	19	5					24	79	0.208
MSH321-1	15	5					20	75	0.250
MSI201-2PY	17	7					24	71	0.292
MSG004-3	18	4		1			23	78	0.304
MSH380-3Y	16	7					23	70	0.304
MSH101-2	17	3	2				22	77	0.318
MSH015-2	18	5		1			24	75	0.333
MIDAS	18	5		1			24	75	0.333
MI PURPLE	17	6	1				24	71	0.333
MSH018-5	18	7	1				26	69	0.346
MSH123-5	16	6	1				23	70	0.348
MSH094-8	12	4	1				17	71	0.353
SAXON	16	7	1				24	67	0.375
SUPERIOR	20		3	1			24	83	0.375
MSH228-6	15	7	1				23	65	0.391

VARIETY	NUMBER OF SPOTS PER TUBER 0	1	2	3	4	5+	TOTAL TUBERS	PERCENT (%) BRUISE FREE	AVERAGE SPOTS/TUBER
SNOWDEN	13	9					22	59	0.409
MSH418-1	16	7	1	1			25	64	0.480
MSF001-2	16	3	2		1		22	73	0.500
MSH217-1	19	5			1	1	26	73	0.538
MSH361-2	13	6	3	1			23	57	0.652
MSH333-3	13	6	2	2			23	57	0.696
MSH106-2	11	7	4	1			23	48	0.783
ROCKET	10	11	4	1			26	38	0.846
MSH095-4	10	7	4	2			23	43	0.913
NAVAN	11	8	1		3	1	24	46	1.125
MSF087-3	9	8	4	2	1	1	25	36	1.240
MSF060-6	8	6	5	3	2		24	33	1.375
ATLANTIC	8	4	5	4	1	1	23	35	1.522
MSG015-C	4	8	5	6	1	1	25	16	1.800
PRELIMINARY TRIAL									
MSI004-2Y	25						25	100	0.000
MSI004-3	25						25	100	0.000
MSI005-20Y	25						25	100	0.000
MSI160-7	25						25	100	0.000
SNOWDEN	21						21	100	0.000
MSF015-1	24	1					25	96	0.040
MSH009-A	24	1					25	96	0.040
MSI026-2	24	1					25	96	0.040
MSI039-8Y	24	1					25	96	0.040
MSH360-1	24	2					26	92	0.077
MSF090-9	23	2					25	92	0.080
MSI005-11Y	23	2					25	92	0.080
MSI005-12Y	23	2					25	92	0.080
MSI050-4	23	2					25	92	0.080
MSI117-1	23	2					25	92	0.080
MSI193-5	23	2					25	92	0.080
ONAWAY	23	2					25	92	0.080
MSI053-2	21	2					23	91	0.087
MSI037-7	15	2					17	88	0.118
B1865-2	22	3					25	88	0.120
MSI057-1	23	1	1				25	92	0.120
MSI083-4	22	3					25	88	0.120
MSI083-5	18	3					21	86	0.143
MSI085-10	19	1	1				21	90	0.143
MSI082-3	21	4					25	84	0.160
MSI103-5	21	4					25	84	0.160

VARIETY	NUMBER OF SPOTS PER TUBER 0	1	2	3	4	5+	TOTAL TUBERS	PERCENT (%) BRUISE FREE	AVERAGE SPOTS/TUBER
MSI178-8	21	4					25	84	0.160
MSI234-6Y	21	4					25	84	0.160
MSH013-A	18	4					22	82	0.182
MSH063-A	20	5					25	80	0.200
MSH067-3	21	3	1				25	84	0.200
MSI168-2	20	5					25	80	0.200
MSI066-2	29	4		1			34	85	0.206
MSI055-5	21	2	2				25	84	0.240
MSI168-5	22	1	1	1			25	88	0.240
ATLANTIC	19	2	1	1			23	83	0.304
MSI002-3	20	3	1	1			25	80	0.320
MSF373-8	17	7	1				25	68	0.360
MSF382-2	19	2	2	1			24	79	0.375
MSG106-5	16	6	2				24	67	0.417
MSI060-3	16	4				1	21	76	0.429
MSH306-B	17	5	2	1			25	68	0.480
MSH017-C	15	8	1	1			25	60	0.520
MSI223-6	15	4	5				24	63	0.583
MSI172-7	13	8	2	1	1		25	52	0.760
MSI043-1	7	8	4	5	1		25	28	1.400
SNACK FOOD ASSOCIATION TRIAL									
B0564-9	26						26	100	0.000
ND2676-10	24						24	100	0.000
SNOWDEN	24						24	100	0.000
AF1668-60	25	1					26	96	0.038
MSNT-1	24	1					25	96	0.040
MSA091-1	23	1					24	96	0.042
B0564-8	22	2					24	92	0.083
NY115	22	2					24	92	0.083
W1313	19	5					24	79	0.208
ND2470-27	18	4	2	1			25	72	0.440
NY112	14	3	5				22	64	0.591

TABLE 11

MICHIGAN STATE UNIVERSITY
POTATO BREEDING and GENETICS

1999 *FUSARIUM* DRY ROT TRIAL

LINE	TRIAL	LESION DEPTH (mm)	LESION DIAMETER (mm)	LINE	TRIAL	LESION DEPTH (mm)	LESION DIAMETER (mm)	LINE	TRIAL	LESION DEPTH (mm)	LESION DIAMETER (mm)
Russet Norkotah	LONG	2.9	11.4	MSI060-3	PRE	6.1	20.5	MSI172-7	PRE	10.1	20.5
MSH106-2	AD	3.1	7.5	MSI103-5	PRE	6.1	15.2	MSH013-A	PRE	10.2	28.5
Midas	AD	3.3	7.4	Matilda	EURO	6.1	12.4	HLG3-A	PRE	10.2	18.2
MSG004-3	AD	3.4	6.9	MSI168-2	PRE	6.2	15.8	MSI005-12Y	PRE	10.3	31.4
Snowden	NC	3.5	8.8	ND3574-5R	NC	6.2	17.2	MSH321-1	AD	10.5	14.9
MSI050-4	PRE	3.5	7.5	MSF002-1	AD	6.2	17.3	MSE228-11	DOH	10.5	19.5
MSG106-5	PRE	3.7	14.8	Bolestra	EURO	6.2	14.0	ND4093-4RUS	LONG	10.5	19.4
NY120	DOH	3.7	9.4	**Atlantic**	DOH	6.3	15.2	MSI160-7	PRE	10.5	17.0
P83-11-5	DOH	3.8	11.3	MSC148-A	DOH	6.3	16.2	MSI083-4	PRE	10.6	16.8
Navan	AD	3.8	12.8	MSE018-1	NC	6.3	12.1	MSH015-2	AD	10.8	17.8
Snowden	AD	3.8	7.9	Sierra	EURO	6.4	13.7	MSH418-1	AD	10.8	17.5
MSH031-5	AD	3.8	8.3	Gigant	EURO	6.4	16.8	MSE250-2	DOH	10.9	20.6
Superior	AD	3.9	7.5	Wis75-30	NC	6.5	17.5	MN17922	NC	10.9	26.5
MSH228-6	AD	4.0	10.8	MSE040-6RY	EURO	6.5	17.7	MSG141-3	AD	11.0	15.7
Ida Rose	AD	4.1	8.8	MSNT-1	DOH	6.6	11.6	FV8957-10	NC	11.0	30.0
Rocket	AD	4.1	12.7	MSF014-9	DOH	6.7	22.6	MSI178-8	PRE	11.2	21.2
Chipeta	DOH	4.1	9.2	W1355-1	NC	6.8	14.8	MSG147-3P	AD	11.2	16.1
Russet Burbank	CHECK	4.5	9.2	MSG015-C	AD	6.8	14.1	MSH041-1	AD	11.4	19.7
MSI193-5	PRE	4.6	8.0	MSI004-2Y	PRE	6.9	16.2	MSI005-20Y	PRE	11.5	22.2
Superior	DOH	4.6	9.2	MSI082-3	PRE	6.9	14.4	MSF015-1	PRE	11.5	24.0
MN16966	NC	4.6	14.5	MSE221-1	DOH	6.9	12.6	MSI004-3	PRE	11.6	20.4
MSH120-1	AD	4.7	10.6	MSG050-2	DOH	7.1	12.9	MSH095-4	AD	11.6	21.2
HLG7-3	PRE	4.7	10.4	A7961-1	LONG	7.1	14.6	MSG274-3	DOH	11.8	15.6
Zarevo	EURO	4.7	10.9	Accent	EURO	7.1	33.6	Saginaw Gold	EURO	11.8	27.5
MSE018-1	DOH	4.7	11.1	MSH098-2	AD	7.2	15.4	MSH217-1	AD	12.1	16.7
Lady Claire	EURO	4.7	12.0	Accord	EURO	7.2	13.9	MSI043-1	PRE	12.1	24.4
MSG049-4	AD	4.8	10.0	Gem Russet	LONG	7.3	22.6	MSI085-10	PRE	12.2	26.2
Russet Burbank	LONG	4.8	13.2	**Onaway**	PRE	7.3	13.7	MSI057-1	PRE	12.3	17.7
Saxon	AD	4.8	10.3	MSI066-2	PRE	7.4	13.5	MSE226-4Y	EURO	12.8	27.1
Reba	DOH	4.8	10.2	MSH333-3	AD	7.5	13.1	MSI005-11Y	PRE	12.8	25.0
NY112	DOH	4.9	10.1	MSH009-A	PRE	7.5	17.0	MSI026-2	PRE	13.1	30.2
MSE202-3RUS	LONG	4.9	10.5	Innovator	LONG	7.6	28.4	MSF090-9	PRE	13.3	19.6
MSF099-3	DOH	5.0	10.4	MSA097-1	EURO	7.7	19.5	SW93107	EURO	13.5	20.9
MSH101-2	AD	5.0	11.1	MSH384-1Y	AD	7.7	16.3	MSE028-1	AD	13.7	20.3
MSE246-5	DOH	5.1	13.9	ND2470-27	NC	7.7	22.0	MN18713	NC	14.2	17.4
Red Pontiac	NC	5.3	8.6	MSA091-1	DOH	7.8	13.1	Eloge	EURO	15.4	24.7
MSH018-5	AD	5.4	14.4	W1148R	NC	7.8	17.1	MSB107-1	NC	16.4	30.8
MSG227-2	DOH	5.4	11.4	MSI055-5	PRE	7.8	15.5	**Atlantic**	NC	16.6	28.8
Onaway	AD	5.4	10.3	MSE192-8RUS	LONG	7.9	13.3	Apell	EURO	17.5	29.4
MSG007-1	AD	5.5	10.4	B1865-2	PRE	8.0	15.3	MSE048-2Y	EURO	18.5	38.6
MSF087-3	AD	5.6	9.1	MSH360-1	PRE	8.0	19.9	MSI002-3	PRE	18.7	38.6
MSI223-6	PRE	5.6	9.6	MSH094-8	AD	8.0	20.0	ND5084-3R	NC	19.5	25.5
MSH123-5	AD	5.6	10.5	MSH419-1	AD	8.1	15.1	MSF382-2	PRE	20.0	34.7
Yukon Gold	EURO	5.6	14.5	MSE149-5Y	DOH	8.1	19.8	MSG124-8P	AD	20.7	51.4
MI Purple	AD	5.6	10.4	Norland	NC	8.1	17.6				
Onaway	DOH	5.6	10.8	MSI037-7	PRE	8.1	14.2				
Torridon	EURO	5.7	21.3	MSI083-5	PRE	8.1	17.9				
Snowden	PRE	5.7	10.0	MSH306-B	PRE	8.3	15.4				
MSH380-3Y	AD	5.8	9.8	MSE222-5Y	EURO	8.4	15.3				
MSH361-2	AD	5.8	10.0	ND4093-4RUS	NC	8.4	12.2				
MSF313-3	DOH	5.8	11.0	MSI053-2	PRE	8.5	25.4				
MSB076-2	DOH	5.8	14.7	MSG088-6RUS	LONG	8.5	15.0				
Russet Burbank	CHECK	5.9	11.0	MSF373-8	PRE	8.6	14.1				
MSH370-3	AD	5.9	12.2	Columbo	EURO	8.6	16.9				
MSG145-1	EURO	5.9	23.6	MSI117-1	PRE	8.6	19.8				
Snowden	DOH	6.0	11.2	Victoria	EURO	8.7	15.1				
MSH026-3RUS	LONG	6.0	17.2	NY115	DOH	8.9	13.9				
				MSI039-8Y	PRE	8.9	16.6				
				MSH017-C	PRE	9.0	16.2				
				NY121	AD	9.1	14.0				
				MSE273-8	AD	9.2	14.8				
				MSB106-7	LONG	9.3	21.7				
				Atlantic	PRE	9.3	24.8				
				MSI168-5	PRE	9.4	19.2				
				MSE228-1	DOH	9.4	15.8				
				MSF060-6	AD	9.5	18.0				
				MSI234-6Y	PRE	9.6	15.5				
				MSI201-2PY	AD	9.7	21.5				
				MSF001-2	AD	9.7	22.5				
				Norvalley	NC	9.8	31.9				

Depth $LSD_{0.05}$ = 4.1
Diameter $LSD_{0.05}$ = 7.0

Funding: Federal Grant, MPIC and SFA

1999 On-Farm Potato Variety Trials

Dr. Dick Chase, Dr. Dave Douches, Don Smucker (Montcalm),
David Glenn (Presque Isle), Paul Marks (Monroe) and Jim Isleib (Alger)

Introduction

On-farm potato variety trials were conducted on eleven farms in 1999; four evaluating fresh market entries, five evaluating processing entries, one for yellow fresh entries and the SFA Chip Trial. The fresh market cooperators were Horkey Bros. (Monroe), Brian Williams (Sanilac), Cliff Wilk (Presque Isle) and Lippens Potato Farm (Delta). The processing trial cooperators were Crooks Potato Farms (St. Joseph), L. Walther and Sons, Inc. (St. Joseph), W.J. Lennard and Sons, Inc. (Monroe), Kevin Denniston (Allegan) and Sandyland Farms (Montcalm). The SFA Chip Trial was at V & G Farms (Montcalm) and a specialty variety trial at Fedak Farms (Bay).

Procedure

There were 12 entries in both the fresh market and processing trials and 14 of the total entries were from the MSU potato breeding program. For each trial, 25 pounds of seed were provided for planting in single rows. At the Walther Farm in St. Joseph County, the seed was planted so that three separate harvest dates could be evaluated.

During the growing season, observation of emergence, stands, vigor, general growth and maturity are noted. At harvest, a yield check was made for each entry from a uniformly sized plot area. Size distribution, yields, specific gravity and internal defects were determined. From each processing trial location, chip samples were collected and processed in the MSU Potato Processing Lab.

Results

A. Freshpack Trial Results

The overall average of the three locations are shown in Table 1. The yield data from the Horkey Farm in Monroe County are not included because of severe water damage (5½ inches) on June 12-13. The trial locations in Sanilac and Delta County were not irrigated.

NY112 (Atlantic x Q155-3). This entry is primarily targeted for chip processing. It is a high yielder with a very scurfy skin texture and medium SG. It has scab resistance similar to Superior. The only internal defect noted was 3/10 HH at the Delta County location.

MSE228-1 (Russet Nugget x Spartan Pearl). Has above average yields and was the highest yielder in 1998. Specific gravity is medium-low and scab susceptibility is intermediate, similar to Atlantic and Snowden. Defects noted at harvest that were minimal were vascular discoloration, HH and growth cracks. General appearance was good.

MSE149-5Y (Saginaw Gold x ND860-2). Continues to be a high yielder with a light yellow flesh and low SG. General appearance has been very good with only minimal defects of vascular discoloration and IBS noted in Delta County. It may set shallow as greening was noted in Sanilac County. Scab tolerance is better than Yukon Gold and similar to Russet Norkotah.

MSE018-1 (Gemchip x W877). Was evaluated in both the fresh market and processing trials. It is a late maturing, high yielding and high specific gravity advanced seedling with an erect, large vine. It has an attractive, blocky-oval shape and is intermediate in scab susceptibility. It has variable chip quality.

MSE221-1 (Superior x Spartan Pearl). Has an above average yield and very good scab resistance. It has a medium-early maturity and low SG. Growth cracks and HH have been significant and air checks were noted in Presque Isle County.

Onaway. Included as a check variety.

Reba (Monona x Allegany) formerly, NY87. Is a recent release from Cornell. Yields were average with bright skin and good general appearance. Scab resistance is intermediate and similar to Russet Norkotah. Hollow heart and brown center were noted at the Delta County location.

MSF313-3 (Spartan Pearl x NY88). Had average yields with zero pick-outs at all locations. Internal defects were minimal and scab susceptibility is intermediate. This was a new entry to on-farm trials.

MSG141-1 (Spartan Pearl x Zarevo). Had average yields. It was a new entry in 1999 and scab resistance is above average. It had a high SG and tuber sizing was in the mid-size range, minimal internal defects, very low pick-outs and good general appearance.

MSE228-11 (Russet Nugget x Spartan Pearl). Had below average yields. Scab susceptibility similar to Atlantic and Snowden. Size range was generally small, zero pick-outs and some growth cracks and irregular shape in Delta County.

MSE250-2 (Andover x W877). Produced a below average yield. It has been in previous processing trials and has medium-high SG and has chipped from below 50F storage. Tuber shape is blocky to oblong.

MSG274-3 (Tollocan x Chaleur). Is a late maturing selection which has a high tuber set (15-18), oval shape, shallow eyes and very attractive fresh market appearance. This entry was also in the processing trial and has excellent late blight tolerance. Due to the heavy tuber set, sizing was generally small.

B. Processing Trial Results

Table 2 contains the overall average yields, size distribution and specific gravity from the Processing Trials in St. Joseph, Allegan, Monroe and Montcalm Counties. The data from the Walther Farm in St. Joseph County are not included in the table as there were three harvest dates and the size parameters were different.

Atlantic. Check variety. Considerable HH and some IBS were the major defects.

MSE018-1 (Gemchip x W877). Produced high yields similar to freshpack trials. High SG and very few pick-outs. Slight internals, mostly VD and HH. Chip scores averaged 2.0 and mostly internal defects of SED, VD and color.

NY115 (Pike x NY88). Produced above average yields with low SG. Tubers are bright, good general appearance and pick-outs are very low. The chip score average 1.7 on a sample out-of-the field. During the early growth, the plants showed herbicide susceptibility but did not appear damaging.

MSF099-3 (Snowden x Chaleur). Had above average yields of blocky-oval shaped tubers. SG is high and it is susceptible to scab; at the Monroe location it was severe. No internal defects were noted and the chip scores averaged 2.4. Average chip quality was 1.7.

Chipeta. Had been evaluated several years ago and was judged to be a late variety. With some interest to evaluate it for out-of-the field harvest and lower N, it was included in 1999. Yields were variable and pick outs of HH and cracks averaged 8%.

MSA091-1 (MS702-80 x Norchip). Had average yields and medium SG. MSA091-1 has very good scab tolerance similar to Superior. It had very good early growth. At harvest, apical IBS was noted in St. Joseph County and only traces of HH and VD. Average chip score was 1.8 with some SED and VD.

Snowden. Check variety. Yields were erratic and appeared to be below those normally expected. At harvest, internal defects were minimal with some VD and HH. Average chip score was 1.7.

MSG227-2 (Prestile x MSC127-3). Produced average yields with good SG. It was below average in early plant vigor with smaller plants. Scab resistance is similar to Superior. Tuber size was generally small and some growth crack was noted. Average chip score was 1.8 with mostly SED and VD.

Pike. Check variety was included at three locations of St. Joseph, Allegan and Montcalm. Yields were below average and high SG. There was no internal necrosis noted at all locations. The average chip score was 1.6.

MSNT-1 (MS716-15 OP). Produced below average yields and a 1.080 SG. It has very good scab tolerance and minimal internal defects. It had above average early growth and plant vigor and a trace of growth cracks. Average chip score was 1.7 and very similar to Snowden.

MSE246-5 (E55-27 x W870). Produced below average yields and high SG. Size was generally small with 24% below 2 inches. Scab susceptibility is similar to Russet Norkotah, but better than Atlantic and Snowden. Early plant growth was above average with good vigor. Plants are dense and appear to be heavily branched. Internal and external at-harvest tuber defects were zero and no scab was noted at the Monroe location. Average chip score was 1.7.

MSG274-3 (Tollocan x Challeur). Yields were very similar to freshpack trial with a heavy set and generally small sizing. Excellent general appearance for fresh market.

The plantings at the Walther Farm in St. Joseph County were designed for three harvest intervals of 98, 119 and 140 days after planting on May 11. These data are shown in Tables 3, 4 and 5 and the sizes used were those of the Walthers Farms evaluation. Pick-outs and culls were not recorded.

NY115 was the highest yielder across the three harvest dates, suggesting that it sets and sizes tubers early. MSE018-1, a late variety, shows consistent high yields and SG at 119 and 140 days. Atlantic, Snowden and Chipeta all showed considerable hollow heart. MSG274-3 had similar results when compared with the other trials.

C. Specialty Variety Trial

A selection of advanced seedlings with various tuber types was conducted at Fedak Farms in Bay County. The performance data are shown in Table 6. Yields were lower than normal due to a second year of being planted to potatoes. A foliar application of metribuzin was made five days before a June 24 observation and any effects are noted.

Reba (Monona x Allegany). Is a release from Cornell and was tested as NY87. It has received interest in the Northeast because of a bright skin and good general appearance. It was the highest yielder with good size distribution and no pick-outs. It was slower in its early growth and showed symptoms of metribuzin injury. Scab tolerance is better than Snowden and Atlantic.

MSE048-2Y (Saginaw Gold x MS702-80). Produced good yields, medium-high SG and a good yellow flesh. Emergence and early growth were average and it showed some metribuzin symptoms. Scab tolerance is better than Snowden and Atlantic.

Eva [NY103-Steuben x (Neotbr x tbr)]. Has been a high yielder in most of our trials. It has a bright appearance, shallow eyes and minimal internal defects. It has intermediate scab tolerance. It showed slight metribuzin symptoms.

MSE149-5Y (Saginaw Gold x ND860-2). Produced good yields of uniform size and smooth potatoes. It has a light yellow flesh. Scab tolerance is better than Yukon Gold. Plant vigor was uniform, above average and showed very slight effect from metribuzin.

MI Purple. Has a purple skin and white flesh. Most of the tuber size was between 2" and 3¼" with no internal defects.

Yukon Gold. Included as a check variety. Early growth and vigor were below the average. Some metribuzin injury was noted.

MSE192-8Rus (A8163-8 x Russet Norkotah). Was slower in emergence and early growth and had a smaller plant. In some trials, the tuber type has been very good with uniform russetting, smooth and it has scab tolerance similar to Superior. It has a low SG and very minimal internal defects.

NYE11-45 (Rosa x Q155-3). Is an advanced seedling from Cornell for tablestock use. It is reported to have resistance to scab and no decision has been made for release.

MSA097-1Y (Superior x Norchip). Yielded below average and did have a nice yellow flesh. It has very good scab tolerance.

MSE040-6RY (Rose Gold x Fontenot). Produced below average yields with a medium red skin and a good yellow flesh. Scab resistance is better than Yukon Gold.

MSG274-3 (Tollocan x Chaleur). Has very good tolerance to late blight. Tuber size is small with very good fresh market appearance.

MSE202-3Rus (selection f rom a USDA-Aberdeen cross). Produced low yields of small potatoes.

D. SFA Chip Trial

Michigan is one of the seven locations of the SFA Potato Chip Variety Trial sponsored by the Snack Food Association. The trial was located at V & G Farms in Stanton. There were 10 advanced seedlings which were compared with Atlantic and Snowden. The 10 entries were provided by six potato breeders: MSA091-1 and MSNT-1 (MSU-Douches); NY112 and NY115 (Cornell-Plaisted); ND2676-10 and ND2470-17 (ND-Novy); W1313 (WI-Groza); AF1668-60 (ME-Reeves) and BO564-8 and BO564-9 (USDA-Beltsville-Haynes). During 1999 the ND2676-10 advanced seedling was named Dakota Pearl and application for Plant Variety Protection has been made.

Table 7 summarizes the yields, size distribution, specific gravity and relative maturity. Yields were generally lower than normal, however, five entries produced greater than 300 cwt/A of U.S. No. 1's. Atlantic was not included and Snowden yields were well below normal. Hollow heart was severe in BO564-9 and was also noted in NY112, Snowden and W1313. The latest maturing entries were NY112 and W1313. Dakota Pearl (ND2676-10), AF1668-60 and NY115 showed the earliest maturity. Entries showing the greatest tolerance to blackspot bruise were ND2676-10 and NY115. Those showing the greatest susceptibility were NY112, ND2470-27 and W1313.

Table 8 summarizes the chip quality data for out-of-the field samples processed and scored at MSU and post-harvest samples chipped and scored by Jays Foods on September 29, 1999.

Table 1. **1999 Freshpack Potato Variety Trials**

Overall Average — Three Locations

(Presque Isle, Sanilac, Delta)

	Yield (cwt/A)		Percent Size Distribution					
Entry	No. 1	Total	No. 1	<2"	2-3¼"	>3¼"	Pick Outs	S.G.
NY112	392	421	93	7	82	11	0	1.087
MSE228-1	377	406	92	7	77	15	1	1.079
MSE149-5Y	369	407	90	8	82	8	1	1.079
MSE018-1	365	398	92	8	70	22	0	1.097
MSE221-1	348	385	90	5	77	13	4	1.080
Onaway	329	357	92	7	72	20	1	1.073
Reba	306	338	90	9	79	10	2	1.082
MSF313-3	300	334	90	10	78	12	0	1.083
MSG141-1	300	340	88	11	83	5	1	1.092
MSE228-11	283	333	85	15	84	1	0	1.091
MSE250-2	203	235	86	14	79	6	0	1.099
MSG274-3	199	324	62	37	60	2	1	1.087

Table 2. **1999 MSU Potato Processing Trial**

Overall Average - Four Locations

(St. Joseph, Allegan, Monroe, Montcalm)

	Yield (cwt/A)		Percent Size Distribution					
Entry	No. 1	Total	No. 1	<2"	2-3¼"	>3¼"	Pick Outs	S.G.
Atlantic	373	401	93	7	81	12	0	1.085
MSE018-1	339	401	85	13	74	11	2	1.085
NY115[1/]	336	390	85	13	77	8	1	1.070
MSF099-3	334	382	87	12	75	12	1	1.083
Chipeta	317	377	83	9	71	12	8	1.079
MSA091-1	313	366	85	10	74	10	5	1.080
Snowden	312	378	82	17	76	6	0	1.081
MSG227-2	281	336	83	14	79	4	3	1.083
Pike[2/]	281	326	87	13	85	2	0	1.092
MSNT-1	265	321	82	16	79	3	2	1.080
MSE246-5	240	316	76	24	75	1	0	1.091
MSG274-3	239	410	57	38	57	0	4	1.079

[1/]Three locations.

[2/]Two locations.

Table 3. **1999 MSU Potato Processing Trial** (1)

L. Walther and Sons, Inc. — St. Joseph County

Entry	Yield (cwt/A) No. 1	Yield (cwt/A) Total	Percent Size Distribution[1/] No. 1	<1.87"	1.87-4"	>4"	S.G.	Comments
NY115	437	474	92	8	92	0	1.073	0/10
MSA091-1	387	406	95	5	95	0	1.076	2/10 VD
MSF099-3	344	398	87	13	87	0	1.086	2/10 BC
Snowden	340	387	88	12	88	0	1.077	2/10 VD
MSNT-1	338	361	94	6	94	0	1.081	3/10 BC, 1/10 BC
Pike	322	377	85	15	85	0	1.081	2/10 VD
MSE018-1	318	379	84	16	84	0	1.079	0/10
Atlantic	318	359	89	11	89	0	1.078	0/10
MSG274-3	306	469	65	35	65	0	1.074	0/10
MSE246-5	301	359	84	16	84	0	1.088	0/10
Chipeta	295	320	92	8	92	0	1.065	1/10 VD, 1/10 IBS
MSG227-2	260	336	77	23	77	0	1.074	0/10
AVERAGE	330	385	85				1.077	

Planted: May 11, 1999 Harvested: August 17, 1999 (98 days)

Table 4. **1999 MSU Potato Processing Trial** (2)

L. Walther and Sons, Inc. — St. Joseph County

Entry	Yield (cwt/A) No. 1	Yield (cwt/A) Total	Percent Size Distribution[1/] No. 1	<1.87"	1.87-4"	>4"	S.G.	Comments
NY115	631	654	97	3	97	0	1.084	2/10 HH
MSE018-1	627	652	96	4	96	0	1.084	4/10 HH
Atlantic	580	584	99	1	99	0	1.084	8/10 HH
Pike	551	580	95	5	95	0	1.091	0/10
Snowden	545	562	97	3	97	0	1.080	1/10 HH
MSG227-2	517	611	85	15	85	0	1.083	1/10 HH
Chipeta	517	539	96	4	93	3	1.077	6/10 HH
MSG274-3	504	736	69	31	69	0	1.085	0/10
MSA091-1	455	474	96	4	96	0	1.080	3/10 BC
MSF099-3	428	476	90	10	90	0	1.082	0/10
MSNT-1	400	408	98	2	98	0	1.078	1/10 HH, 1/10 BC
MSE246-5	346	371	93	7	93	0	1.092	0/10
AVERAGE	508	554	92				1.082	

Planted: May 11, 1999 Harvested: September 7, 1999 (119 days)

[1/]Sizes used in Walther Farms evaluation. Pick-outs/culls not determined.

Table 5. **1999 MSU Potato Processing Trial** (3)

L. Walther and Sons, Inc. — St. Joseph County

Entry	Yield (cwt/A) No. 1	Yield (cwt/A) Total	Percent Size Distribution[1/] No. 1	<1.87"	1.87-4"	>4"	S.G.	Comments
Atlantic	584	590	98	2	98	0	1.083	8/10 HH
Snowden	551	572	96	4	96	0	1.079	7/10 HH
NY115	549	572	95	5	95	0	1.077	2/10 int. nec.
MSE018-1	523	531	97	3	97	0	1.087	3/10 HH, sl. scab
Chipeta	512	533	95	5	95	0	1.077	9/10 HH
MSG274-3	480	609	76	24	76	0	1.078	
MSNT-1	433	449	91	9	91	0	1.074	2/10 HH, some gr. crack
MSF099-3	414	453	91	9	91	0	1.083	2/10 int. nec., sticky stems
MSA091-1	402	424	94	6	94	0	1.076	1/10 HH, 1/10 int. nec., gr. crack
Pike	387	422	91	9	91	0	1.085	
MSG227-2	338	379	88	12	88	0	1.074	Sticky stems, some pointed
MSE246-5	336	373	89	11	89	0	1.088	
AVERAGE	459	492	92				1.080	

Planted: May 11, 1999 Harvested: September 28, 1999 (149 days)

[1/]Sizes used in Walther Farms evaluation. Pick-outs/culls were not determined.

Table 6. **1999 Specialty Potato Variety Trial**

Fedak Farms — Bay County

Entry	Yield (cwt/A) No. 1	Yield (cwt/A) Total	Percent Size Distribution No. 1	<2"	2-3¼"	>3¼"	Pick Outs	S.G.	Comments
Reba	348	359	97	3	80	17	0	1.080	2/5 sl. VD. Smooth, bright.
MSE048-2Y	328	365	90	10	81	9	0	1.086	0/5 clean; nice yellow.
Eva (NY103)	287	306	94	6	94	0	0	1.071	1/5 sl. VD.
MSE149-5Y	285	324	88	12	88	0	0	1.070	0/5 smooth; uniform.
MI Purple	273	293	93	7	93	0	0	1.072	0/5 smooth white flesh.
Yukon Gold	242	265	91	9	91	0	0	1.078	1/5 HH.
MSE192-8Rus	234	264	89	11	89	0	0	1.066	0/5 clean, thin shape.
NYE11-45	195	243	80	20	80	0	0	1.071	3/3 sl. VD; oval to oblong.
MSA097-1Y	183	223	82	18	76	6	0	1.085	0/3 nice yellow.
MSE040-6RY	176	268	66	34	66	0	0	1.075	0/5 med. red, nice yellow.
MSG274-3	147	329	44	56	44	0	0	1.086	0 small.
MSE202-3Rus	144	214	67	33	67	0	0	1.075	1/2 sl. VD.
AVERAGE	237	288	82					1.076	

Planted: May 10, 1999. Harvested: September 17, 1999 (130 days).

Table 7. **1999 SFA Chip Trial — V & G Farms**

	Yield (cwt/A)		Percent Size Distribution							% Vine Maturity
Entry	No. 1	Total	No. 1	<2"	2-3¼"	>3¼"	Pick Outs	S.G.	Comments	(8/30/99
NY112	410	438	94	6	72	22	0	1.073	4/30 HH, 1/30 VD	15
W1313	358	418	86	11	83	3	3	1.091	3/30 HH, 1/30 BC	15
ND2470-27	344	431	80	14	69	11	6	1.071	Clean	60
MSNT-1	328	395	83	17	80	3	0	1.081	1/30 HH	85
MSA091-1	317	360	88	10	69	19	2	1.079	1/30 IBS	80
AF1668-60	296	322	92	8	88	4	0	1.077	3/30 VD; 1/30 BC	95
ND2676-10	274	364	75	25	73	2	0	1.071	1/30 BC	100
BO564-8	271	307	88	11	77	11	1	1.068	3/30 VD; 1/30 IBS	90
BO564-9	239	269	89	10	65	24	1	1.064	26/30 HH	90
NY115	212	256	83	18	76	6	0	1.066	1/30 VD; 1/30 IBS	95
Snowden	196	237	83	17	77	6	0	1.082	3/30 HH; 2/30 VD	50
AVERAGE	295	345	85					1.075		

Table 8. **1999 SFA Chip Quality**

	Out of Field Samples[1/]		Post Harvest Samples[2/]			
	SFA Score	Defect Comments	Agtron Color	External	Internal	Total
NY112	1.5	Sl. SED, VD	66.8	5.0	0	5.0
W1313	1.5	Scab, color, HH, VD	69.7	4.8	0	4.8
ND2470-27	2.0	SED, scab, VD	63.3	12.8	0.8	13.6
MSNT-1	1.5	Sl. SED, HH, color	64.5	3.6	0	3.6
MSA091-1	1.5	Sl. SED, VD, sl. color	64.5	12.1	0	12.1
AF1668-60	2.0	SED, color, sl. VD	67.1	2.0	0	2.0
ND2476-10	2.5	Sl. SED, VD, dark centers	67.8	4.4	0	4.4
BO564-8	2.0	SED, HH, dark centers	66.3	2.4	0	2.4
BO564-9	2.5	SED, HH, color, VD	62.3	3.0	0	3.0
NY115	2.0	Color	63.6	6.6	0	6.6
Snowden	1.5	Sl. SED, VD, HH	64.1	4.1	0	4.1

[1/]Samples collected at harvest on September 23 and chipped on September 24 at MSU Potato Processing Lab. SFA color score on acceptable chips only after defect chips were removed. SED = stem end discoloration, VD = vascular discoloration, HH = hollow heart.

[2/]Samples collected at harvest on September 23 and sent to Jays Foods, LCC in Chicago. Samples were processed and scored on September 29, 1999.

Funding: MPIC

Effect of Whole Seed Piece Weight, Planting Density and a Soil Stimulant on Yield in Commercial Seed Potato and Chip Potato Fields

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Abstract

Whole seed pieces were compared to cut seed pieces on commercial seed potato and chip potato farms. The seed piece weight and planting density were varied in the seed potato field and a mycorrhizal soil stimulant was applied to 2oz whole pieces and cut pieces in a separate treatment. Overall yields from 2oz seed pieces planted at 6" (36" row spacing) were not different between cut and whole seed, although whole seed tended to result in a higher proportion of smaller (<2oz) tubers in the seed potato field. Large seed pieces (6oz) and closer spacing (3") tended to increase yield per acre, but significantly decrease yield per pound of seed. Wider spacing (9") had no effect on yield per acre and significantly increased yield per pound of seed. Application of the soil stimulant had no significant effect on yields.

Plot Designs

Grower-initiated field trials of whole and cut seed were conducted on two separate commercial potato farms in Michigan. Potato seed pieces were planted and cultivated as per good agricultural practice. For test plots in both locations, Myconate was dissolved in water and applied as a soil drench to the base of the potato plant (cv. FL1833) once the plants had reached approximately 10" in height, before row closure. Dose rate was 10mg Myconate per plant. Growth and development of the canopy in treated and untreated plants was observed. At season's end, potatoes were harvested, sorted by size and weighed.

<u>Seed potato field</u>

The trial examining planting density and seed size was conducted at Iott Seed Farms, Kalkaska, MI. The plots consisted of eight rows, 36" row spacing, 50' in length, four plots per treatment. The industry standard practice is to plant cut potato seed pieces weighing 2oz at 6" spacing in rows 36" apart. For this trial, three treatments examined whole seed weighing approximately 2oz, 3.5oz or 6oz, planted at 6" spacing. Two additional treatments examined whole seed pieces, 2oz, planted at 3" or at 9" spacing. Myconate was applied to plants arising from 2oz cut seed pieces and 2oz whole seed pieces using 6" spacing. The trial was hand-planted on May 18, Myconate was applied on June 23, and the four center rows of each eight-row plot were hand-harvested on September 17. The results of this study are in Fig.1. The results of other treatments in the agronomic trial are presented in Fig. 2 and Fig. 3 for comparison.

Chipping potato field

A full-scale trial of whole seed vs. the industry standard of cut seed was conducted near Cass City, MI conducted by Walther Farms, Clio, MI. The overall trial covered 100 acres, 50 acres planted to 2oz cut seed pieces, 50 acres planted to 2oz whole seed pieces. Pieces were planted at 6" spacing, with 36" row spacing. The Myconate test plots consisted of eight rows, 50' in length, four plots per seed type. The fields were machine planted on May 25, Myconate was applied to the plots on July 9 and plots were separately machine harvested, sorted and weighed by the grower in conjunction with the harvest of the rest of the field on September 27. The results of this trial are in Fig. 4.

Results and discussion

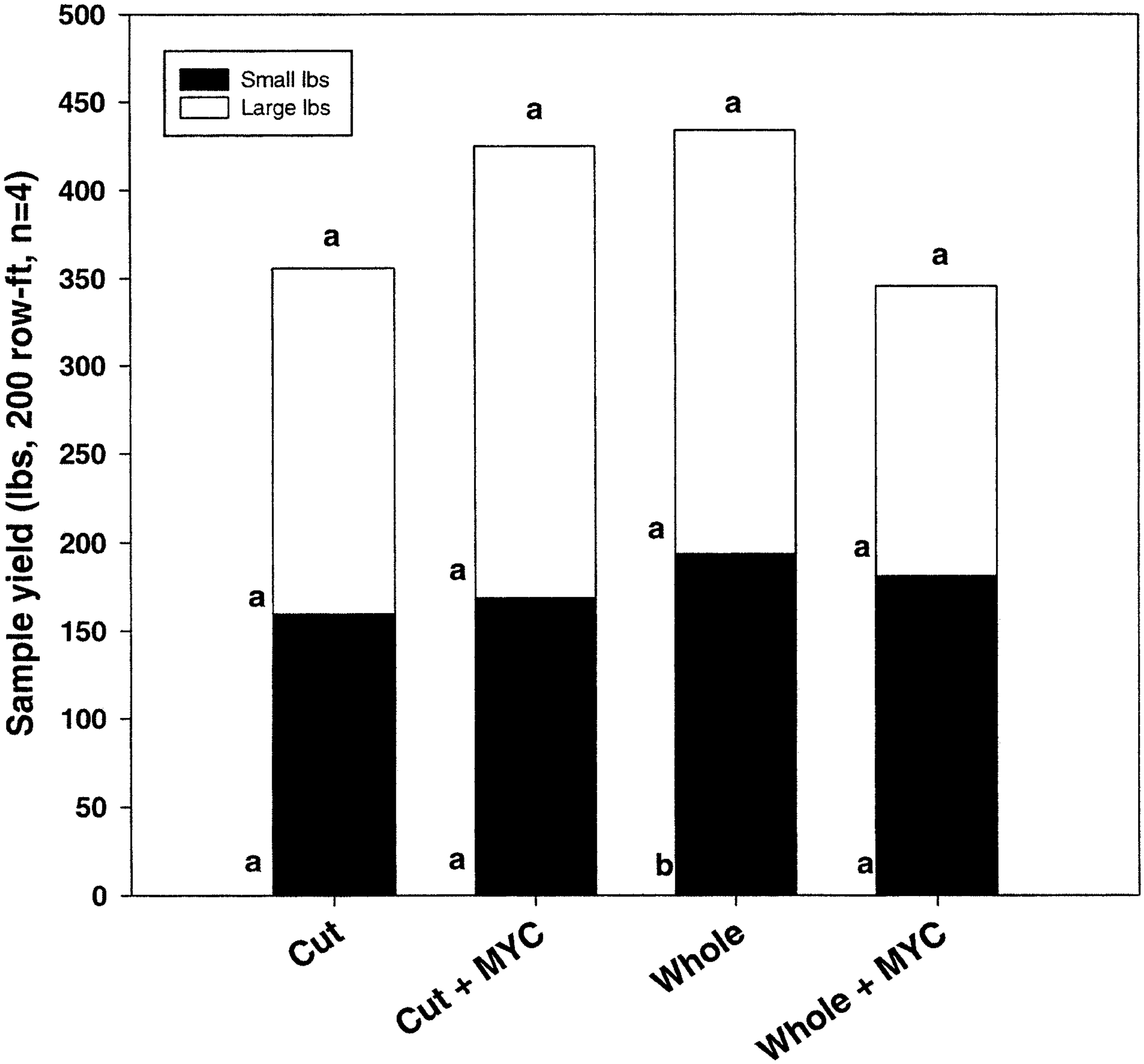
Overall yields from 2oz seed pieces planted at 6" (36" row spacing) were not different between cut and whole seed, although whole seed tended to result in a higher proportion of smaller (<2oz) tubers in the seed potato field (Fig. 2). Large seed pieces (6oz) and closer spacing (3") tended to increase yield per acre (Fig. 2), but significantly decrease yield per pound of seed (Fig. 3). Wider spacing (9") had no effect on yield per acre (Fig. 2) and significantly increased yield per pound of seed (Fig. 3).

Yields from plants treated with the soil stimulant did not differ significantly from the industry standard practice at either test location.

Planting of whole seed eliminates seed cutting as a preparation step. Also, tubers which are held intact are less susceptible to tuber rots (*Erwinia carotovora* and *Fusarium sambucinum*). In this study, cut seed was treated with a fludioxinil product (Maxim) immediately after cutting, and there were no differences in emergence percentage. The necessity for potato seed treatments may be reduced for seed that is not cut, however. The increase in yield per acre resulting from closer seed spacing or the use of large (3.5oz) or very large (6oz) whole seed pieces should be considered carefully in light of the increased seed requirements and seed handling costs. However, the increased proportion of small tubers may be of sufficient interest to a seed potato grower to warrant further investigation into the interaction of seed preparation and spacing.

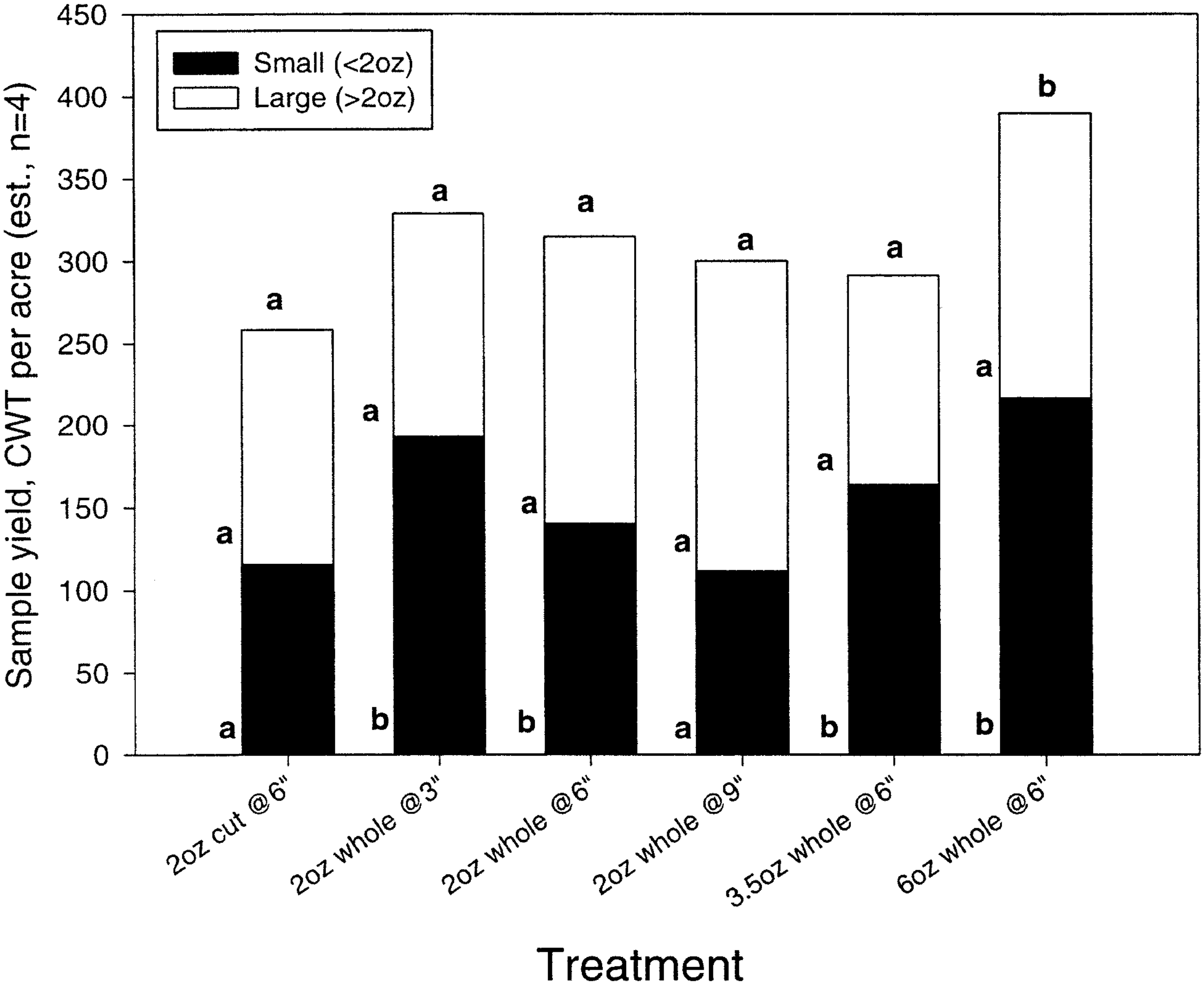
The authors wish to that Iott Seed Farms, L. Walther and Sons, Inc., and VAMTech for support of this research.
Mention of a product or brand name does not constitute an endorsement.

Fig. 1. Whole vs. cut seed, myconate trials
gross sample yields, 2oz pieces, 6" spacing



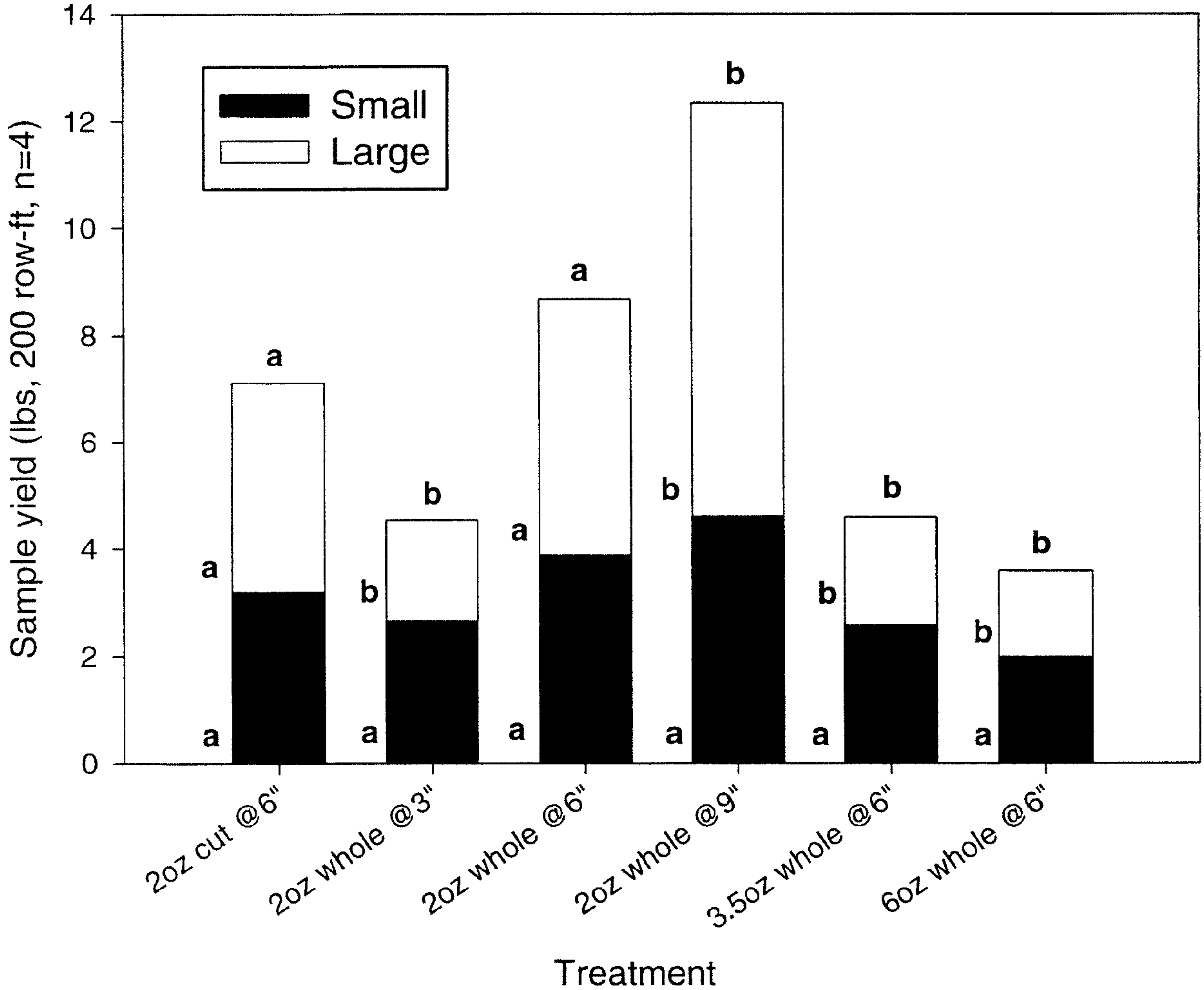
Samples consisted of 200 row-feet, planted at 36" spacing, four plots per treatment. Myconate was applied as a soil drench when the plants were 10 inches high. Letters above a column indicate significant ($P<0.05$) difference from industry standard treatment (2oz cut pieces, 6" spacing) in TOTAL yield. Letters to the side of a column indicate significant difference from industry standard for yield of LARGE or SMALL tubers (see legend).

Fig. 2. Whole vs. cut seed gross sample yields per acre (est.)



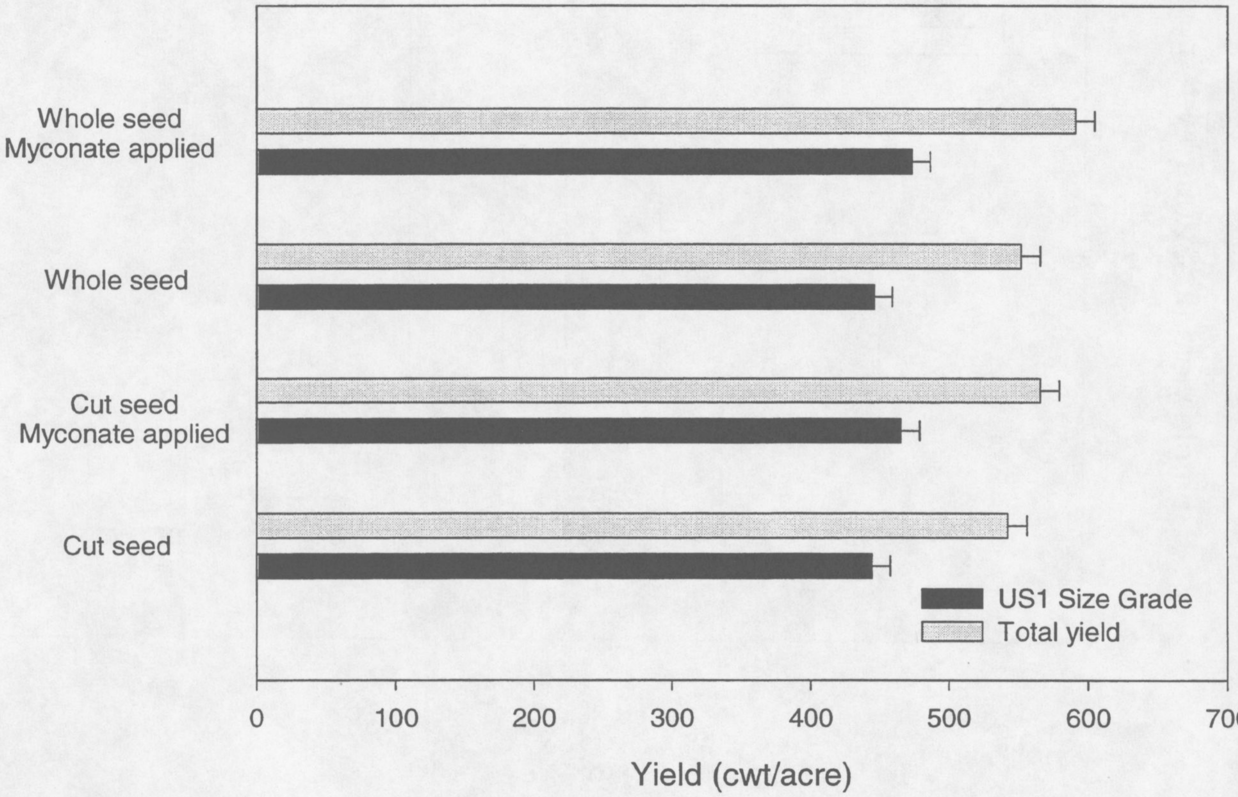
Samples consisted of 200 row-feet, planted at 36" spacing, four plots per treatment. Yields per acre are estimated from the 200 row-foot samples. Letters above a column indicate significant ($P<0.05$) difference from industry standard treatment (2oz cut pieces, 6" spacing) in TOTAL yield (ANOVA, SNK). Letters to the side of a column indicate significant difference from industry standard for yield of LARGE or SMALL tubers (see legend).

Fig. 3. Whole vs. cut seed sample yields per pound of seed



Samples consisted of 200 row-feet, planted at 36" spacing, four plots per treatment. Yields per pound of seed are calculated based on the seed used for the entire 200 row-foot sample. Letters above a column indicate significant ($P<0.05$) difference from industry standard treatment (2oz cut pieces, 6" spacing) in TOTAL yield (ANOVA, SNK). Letters to the side of a column indicate significant difference from industry standard for yield of LARGE or SMALL tubers (see legend).

Fig. 4. Effect of Myconate on whole vs. cut seed, mechanically harvest chipping potato field



Effect of cutting potato seed and the application of myconate on yield of potatoes (cv. FL 1833) in a comercial field operation (co-operator Walther Farms). Bars are sem (p = 0.05) no significant differences between treatments.

Funding: MPIC

Potato seed cutting and seed treatment application: agronomic effect of timing on plant emergence and tuber yield

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ABSTRACT

In the second year of a two-year study, seed potatoes (cv. Onaway and Russet Burbank) were cut at different times: 180, 150, 120, 90, 60, 30, 10, 5, 2, 1 and 0 days before planting (DBP). A subset of these were treated with a fludioxinil-based seed treatment (Maxim) at the time of cutting, at the time of planting or left untreated. The plants were assessed for emergence, canopy development and yield. At the earliest cutting dates (180, 150, 120, 90 DBP), seed treatment at the time of cutting prevented reductions in biomass, emergence and yield seen in cohort seed treated at the time of planting or cohort seed left untreated. Date of chemical treatment was not a factor in later seed cutting dates. This variable response to the seed treatment date was not observed with R. Burbank. Although Onaway was more sensitive than R. Burbank to detrimental effects of very early seed cutting, immediate treatment of the cut seed negated these effects.

Introduction

Potato production in North America commonly includes the use of certified seed. This seed is frequently cut before planting to increase the plants set from each pound of seed. This practice can lead to the development of pathogens such as Fusarium dry rot (*Fusarium sambucinum*) and soft rot (*Erwinia carotovora*) in cut seed pieces. In deciding how far in advance to cut seed, growers must balance the time required to allow full suberization of the cut surface of the tuber with the danger of creating and maintaining an environment that may encourage pathogen development. An additional consideration is the management effort of a cutting operation in the period preceding planting. The logistical challenges of moving seed from controlled storage to a cutting operation site, back to storage and then to planting equipment are compounded by the increased use of potato seed treatments applied pre-planting.

The most advantageous time to apply seed treatments, especially in relation to seed cutting, is not fully established. Seed treatments that suppress the development of seed-borne pathogens may counteract the negative consequences of a long delay between seed cutting and planting. The objectives of this experiment were to determine the effect on plant emergence, growth and tuber yield of a) varying delay between potato seed cutting and planting, b) varying timing of seed treatment application with respect to seed cutting, and c) varying late blight disease pressure (high and low).

Materials and Methods

Seed potatoes (cv. Onaway and R. Burbank) were held in storage, 42°F, 95% rel. humidity. Seed potatoes were cut by hand at 180, 150, 120, 90, 60, 30, 10, 5, 2, 1 and 0 days before planting. On each cutting date, 100 cut pieces were immediately treated with a fludioxinil-based seed treatment (0.5 lb/cwt) (Maxim, a product of Novartis) and placed in storage, 42°F, 95% rel. humidity, until the day of planting. On each cutting date, a separate group of 100 cut pieces were held in storage until the day of planting, and treated just before planting. On each cutting date, a separate group of 100 cut pieces were held in storage until the day of planting, and were planted with no seed treatment. On the day of planting, seed potatoes were cut, immediately treated and planted, while a separate group of seed potatoes were cut, planted, and the seed treatment applied in furrow over the cut pieces. Each treatment was hand planted with 25 seed pieces, and repeated 4 times. Treatments were examined for emergence and canopy development at 33 DAP. Canopy volume was calculated by an ellipsoidal approximation. The volume of an ellipsoid is derived as: $V=(4/3)(\pi)(ABC)$, where A, B an C are the semiaxes of the ellipsoid. In a potato plant, A=plant height (h) and B=C=radius of plant at ground level (r). The volume of the individual plant is therefore derived as: $V_{plant}=(4/3)(\pi)(hr^2)$. The average plant estimation is derived from and average of the two largest and the two smallest emerged plants. Total treatment canopy volume is the average single plant volume for each treatment multiplied by the number of emerged plants. Tubers were harvested and yields were recorded. Dta were examined with one-way analysis of variance (ANOVA).

Results

There were significant difference between the different cutting dates. For Onaway, the earliest cutting dates were generally detrimental to biomass (Fig. 1) and emergence (Fig. 2). Seed treatment at the time of cutting alleviated this, relative to cohort seed that was left untreated, or stored untreated until the day of planting. Reduced biomass and emergence resulted in reduced yield for these treatments (Fig.3). Later cutting dates did not show significant differences. For R. Burbank, there were no significant differences between earlier and later cutting dates in biomass (Fig.4), emergence (Fig.5) or yield (Fig.6).

When yield data is combined by the date of cutting (Fig. 7), R. Burbank shows a slight trend toward increased yield as the interval between cutting and planting decreases. Onaway shows no clear pattern. Yield data combined by the date of treating (including those seed pieces left untreated, Fig. 8), does not show a clear pattern for either variety.

Discussion

In this study, Onaway was more sensitive to detrimental effects of very early cutting than was R. Burbank. Application of the chemical seed treatment was effective at reducing this negative impact for seed cut very early, but had no clear effect on seed cut closer to the date of planting. In general, variability in results was more pronounced for seed cut earlier than later. Under commercial seed storage conditions, this variability may be a primary factor in how early seed cutting and/or treatment is implemented.

Mention of a product and/or brand name does not constitute an endorsement.

Fig. 1. Total biomass in row under various cutting/treating patterns (33 DAP): ONAWAY

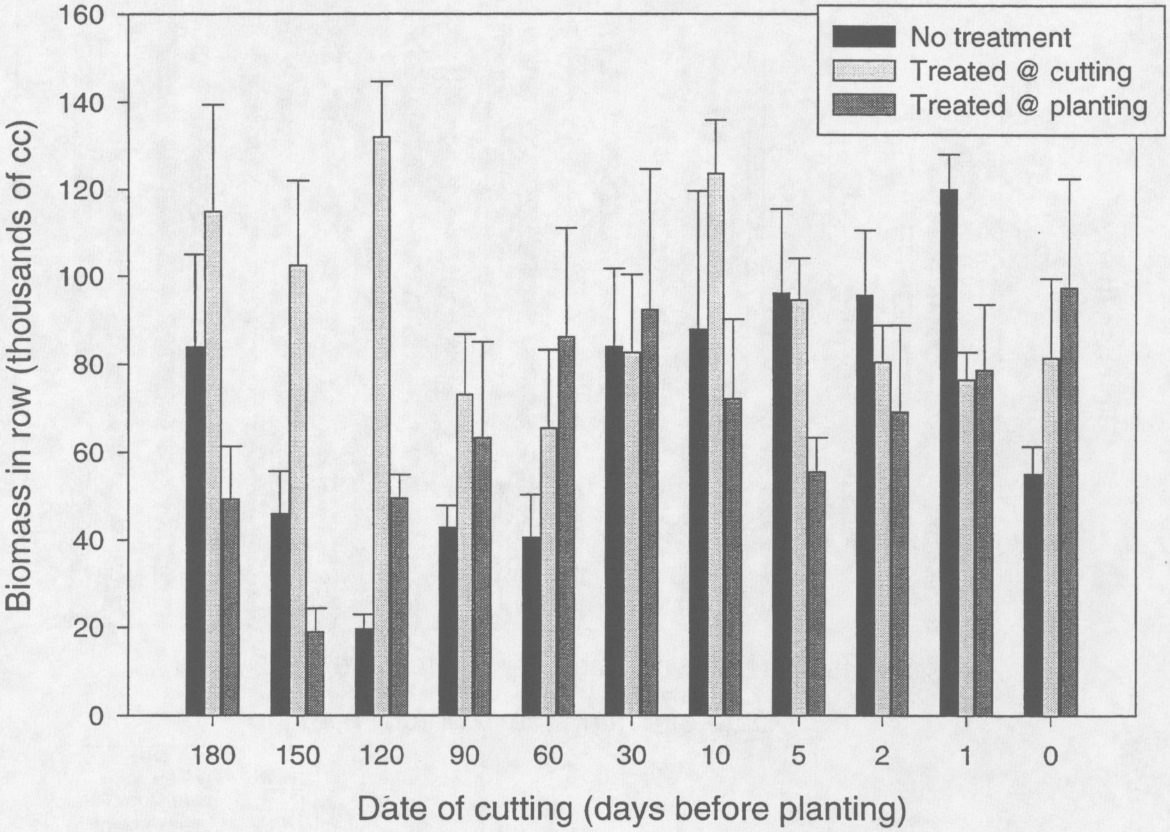


Fig. 2. Emergence (%) under various cutting/treating patterns (33 DAP): ONAWAY

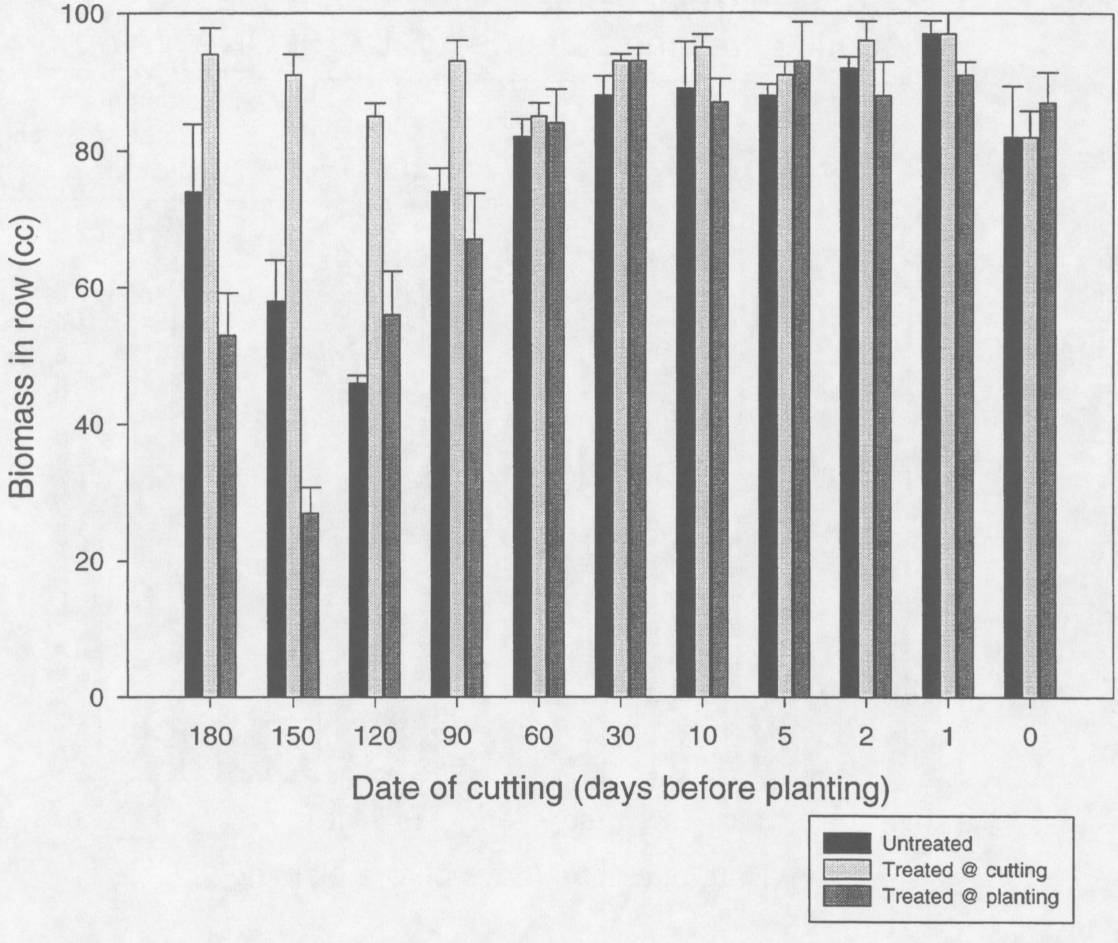
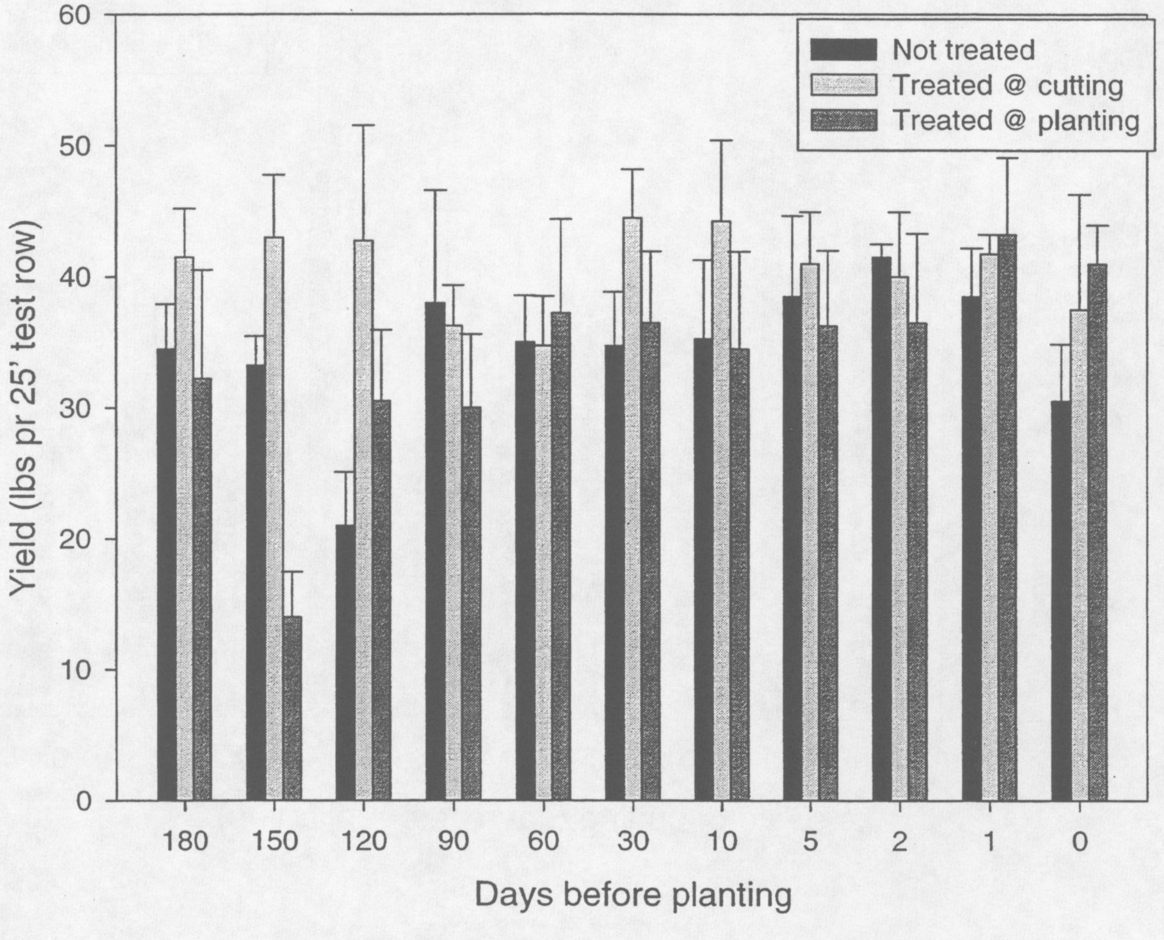


Fig. 3. Yield under various cutting/treating patterns: ONAWAY



Trials conducted at MSU's Montcalm Potato Research Farm, 1999.
Bars indicate standard deviation, n=4.

Fig. 4. Total biomass in row under various cutting/treating patterns (33 DAP): R. BURBANK

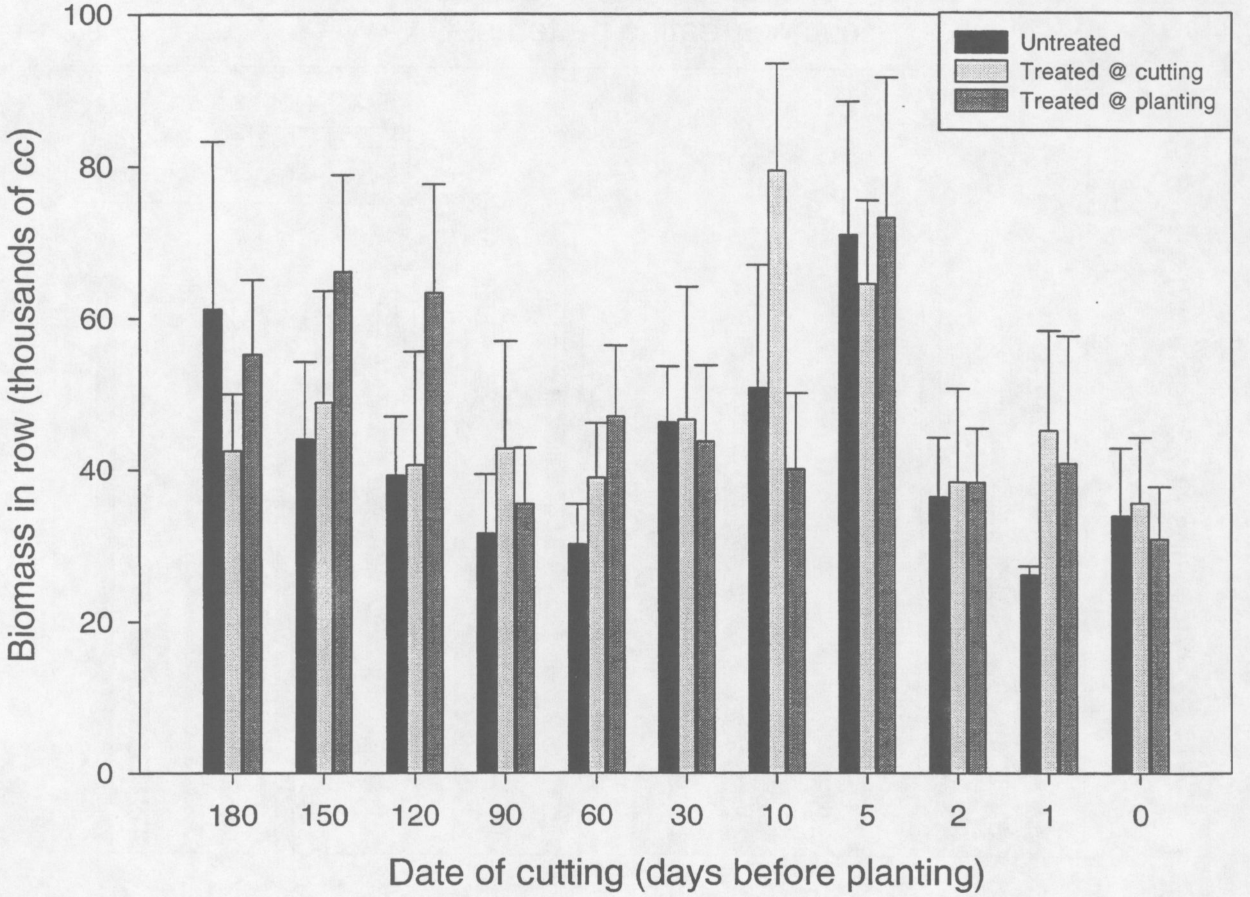


Fig. 5. Emergence (%) under various cutting/treating patterns (33 DAP): R. BURBANK

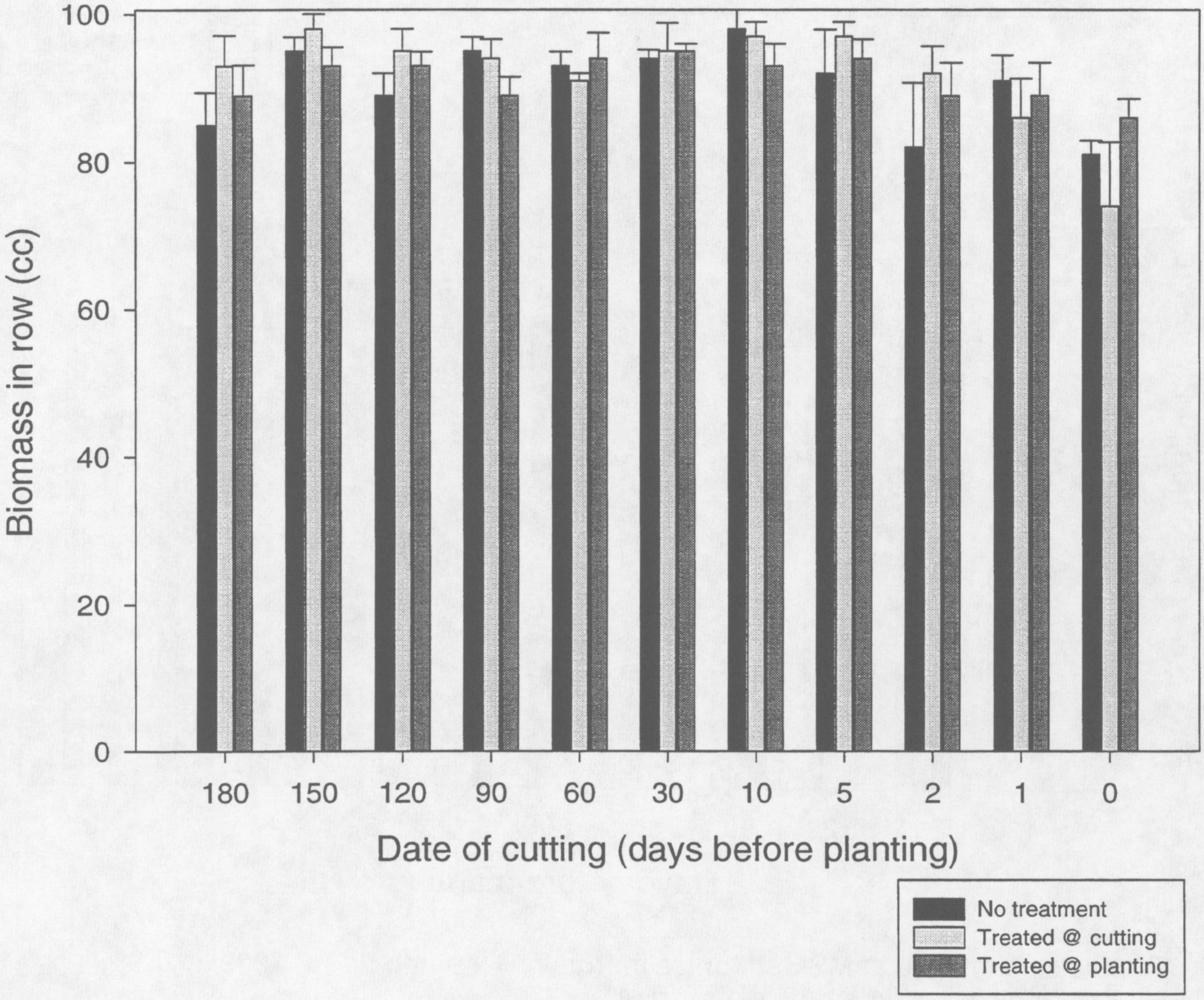
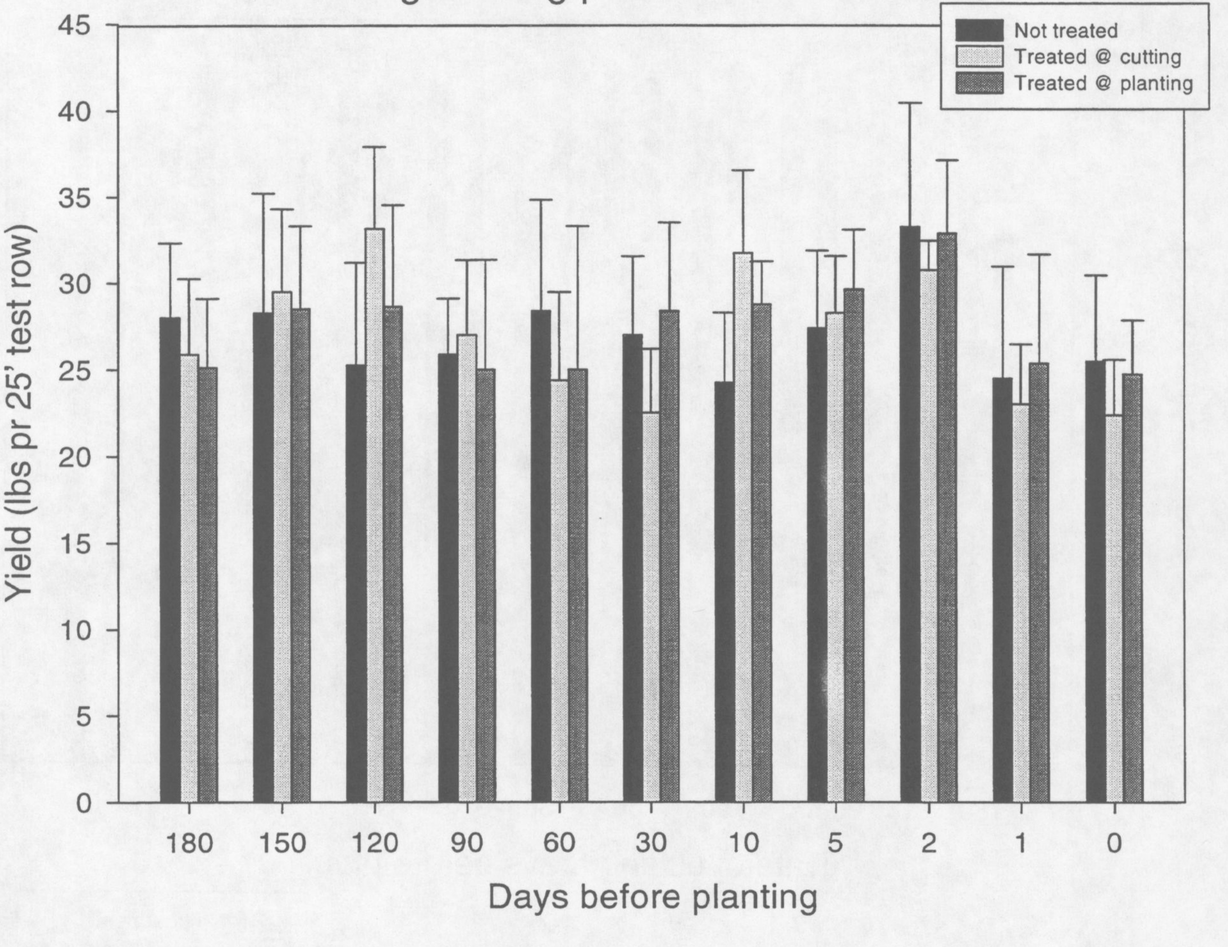
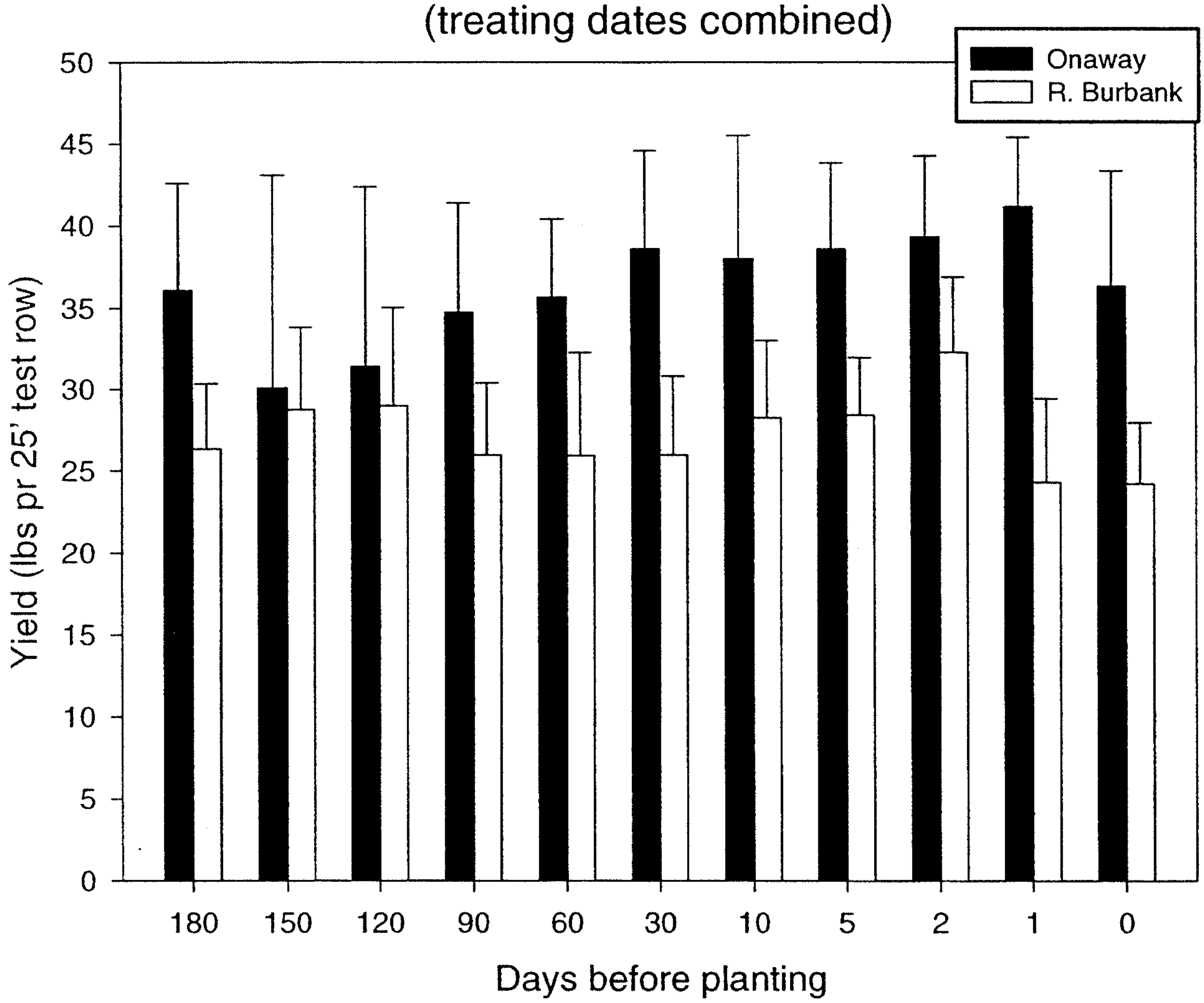


Fig. 6. Yield under various cutting/treating patterns: R. BURBANK



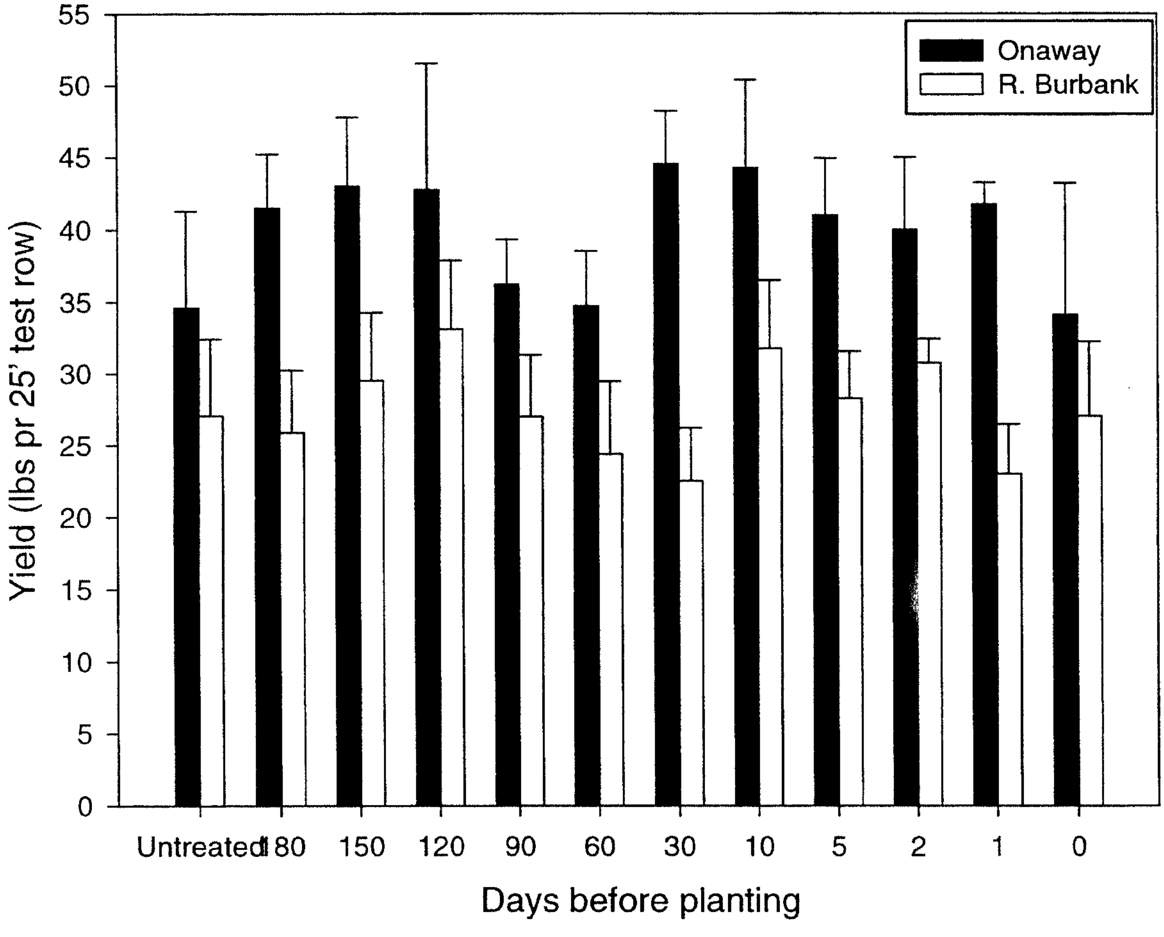
Trials conducted at MSU's Montcalm Potato Research Farm, 1999.
Bars indicate standard deviation, n=4.

Fig. 7. Yield, average by cutting date (treating dates combined)



Trials conducted at MSU's Montcalm Potato Research Farm, 1999.
Bars indicate standard deviation, n=4.

Fig. 8. Yield, average by treating date (cutting dates combined)



Trials conducted at MSU's Montcalm Potato Research Farm, 1999.
Bars indicate standard deviation, n=4.

1999 POTATO NEMATODE RESEARCH REPORT

GEORGE W. BIRD, PROFESSOR OF NEMATOLOGY
DEPARTMENT OF ENTOMOLOGY
MICHIGAN STATE UNIVERSITY

The 1999 MPIC-MSU Potato Nematode Research Report consists of a summary of the results of four projects: 1) two nematicide trials funded jointly by MPIC, MSU and agribusiness; 2) potato cultivar/line and glucose-oxidase transgenic line evaluation for resistance/tolerance/susceptibility to plant-parasitic nematodes and the potato early-die disease complex funded jointly by USDA and MSU; 3) long-term potato farming systems research for development of alternative potato nematode and potato early-die disease complex management tactics funded jointly by MPIC and MSU; and 4) precision agriculture research for nematode and potato early-die disease complex management, funded jointly by MPIC and MSU. The report consists of descriptions of the projects, project results, key findings and new references of significance..

1999 Nematicide Trials.- Two nematicide trials were conducted at the Montcalm Potato Research Farm. The first trial used the potato variety Pike and was designed to evaluate various fumigant and non-fumigant nematicides in relation to tuber yield and quality responses and nematode population suppression. It consisted of eight treatments (five fumigant and three non-fumigant) and an associated check (Table 1). The research site was infested with both root-lesion and northern root-knot nematodes. The highest total, A-size and jumbo-size tuber yields were associated with metham pre-plant soil injected at 75 gallons per acre in a 3:1 water to product mixture. The second nematicide trial involved the potato variety Snowden and was part of the first year of the Montcalm Potato Research Farm Precision Agriculture Initiative. Metham was used on a pre-plant soil injection basis at 75 gallons per acre in a 3:1 water to product mixture. The site was infested with a low population density of root-lesion nematode. Excellent nematode control was obtained in addition to a tuber yield response of 125 to 175 cwt per acre (Table 2).

<u>Key Findings</u>:

1. Temik 15 G is an excellent nematicide for control of root-lesion nematodes. It is not, however, as good a nematicide for management of northern root-knot nematodes.
2. Recent FQPA information indicates that most Mocap used in potato production in the west is applied at 90 lbs per acre. This is in agreement with MSU research.
3. Proper application of metham is essential for optimal benefits from this material. It must be mixed with at least 3 parts water to 1 part product for the 37.5 gallon per acre to provide consistent nematode control and tuber yield response.
4. Vydate 2L can be phytotoxic when it is applied on an at-plant basis with poor quality seed.
5. The 1,3-D component of Telone C-35 is essential for optimal nematode control and tuber yield response. Telone C-35 applied in-row at 6 gallons per acre is not adequate under Michigan conditions.

Potato Cultivar/Line Evaluation for Resistance/Tolerance/Susceptibility to Nematodes and the Potato Early-Die Disease Complex.- 1999 was the third year of the potato nematode/early-die component of the USDA Project. During the first years, twenty-two potato lines/varieties were field evaluated in relation to their susceptibility/tolerance/resistance to potato nematodes and the early-die disease complex. Definitions for these terms are provided in Table 3. Twenty-five lines/cultivars were evaluated in 1999 (Table 4). The evaluation criteria used in 1999 are those developed at MSU for evaluation of resistance and tolerance in soybean lines to the soybean cyst nematode. Four data points, relative yield in nematode-infested soil, tolerance index, relative yield in fumigated soil and a PED index are reported for each line/cultivar. One line (MSG 050-2) was identified as having possible resistance to the root-lesion nematode (Table 5). The other lines and cultivars were identified as tolerant, having possible tolerance or susceptible. In general, there was excellent agreement between the 1998 and 1999 evaluations. It is recommended that this work not only continue, but that formal breeding for root-lesion and northern root-knot nematode resistance be added to the program.

The interactive literature database of potato germplasm with known resistance , tolerance and susceptibility to *Pratylenchus* spp., *Meloidogyne* spp., *Verticillium* spp., *Ditylenchus destructur*, *Globodera rostochiensis* and *G. pallida* was completed in 1998 and maintained and updated throughout 1999. It can be accessed at Http://nematode.ent.msu.edu/nematology.

Microtubers of Spunta, SGO-1, SGO-3 and SGO-9 were planted at the Montcalm Potato Research Farm in 1999 and subjected to one of the following four treatments (1. Root wounding plus inoculation with *Verticillium dahliae*, 2. root wounding, 3. inoculation with *V. dahliae*, or a non-disturbed. SGO-3 emergence was very slow and tuber yields were low compared to the other three lines. No significant differences were observed among the treatments or the other three lines.

Key Findings.

1. MSU Nematology Program definitions for resistance, tolerance and susceptibility have been formalized.
2. The potato nematode resistance website is being maintained and updated.
3. A significant number of lines and cultivars have been identified with potential resistance or tolerance to the root-lesion nematode.
4. A series of transgenic lines have been evaluated.
5. It is being recommended that the program be expanded to include formal breeding for resistance to root-lesion and northern root-knot nematodes.

1991-2000 Potato Farming Systems Trial.- The year 2000 is scheduled as the tenth and final year for the Long-Term Farming Systems Trial (Table 6). Because of the potential future value of the site, there appears to be significant interest in maintaining it for an additional period of time. During the past decade the plant parasitic nematode problem associated with the site has changed from one dominated by the root-lesion nematode to several farming systems that have high population densities of the northern root-knot nematode (Table 7). In 1999, Russet Norkotah tuber yields were once again highest in the two-year alfalfa conventional farming system (Table 8). For the past three years, the root-lesion nematode resistant alfalfa variety WL 252HQ, has been used, resulting in the lowest end-of-season population density of this nematode (Table 9). Corn, wheat, buckwheat and the two-year alfalfa system suppress population densities of the northern root-knot nematode. The buckwheat and the two-year alfalfa systems are the only ones that suppress both root-lesion and the northern root-knot nematodes. A summary of expected nematode control is presented in Table 10.

The project is also evaluating responses of other types of nematodes and microbes to the different farming systems. For example, at-harvest population densities of bacterial feeding nematodes are highest following wheat and buckwheat compared to the other potato farming systems. At-harvest population densities of fungivores were low, and the highest levels of omnivores were associated with alfalfa. The highest population densities of endomycorrizal spores were recovered from the conventional continuous potato system and following two years of corn. Population densities of both oligocheates and carnivorous nematodes were relatively low.

<u>Key Findings</u>.

1. When corn and wheat are removed from potato production systems in sandy soils, there is a high probability that it will result in development of a northern root-knot nematode problem. Although these crops are good hosts for root-lesion nematodes, they are very valuable in suppressing northern root-knot nemtodes.
2. Root-lesion nematode resistant alfalfa provides excellent suppresion of this nematode. After two years of growth, associated population densities of the northern root-knot nematode are relatively low.
3. Buckwheat is a poor host of both the root-lesion and northern root-knot nematodes.
4. The project resulted in a major conceptual change in thinking, evolving from a rotation crop to a potato farming system concept.
5. The significance of soil quality in relation to nematode problems and nematode management developed directly from this project.
6. Several aspects of the award winning publication entitled "Michigan Field Crop Ecology" and the associated education programs would not have been possible without this farming system project experience (MSU Extension Bulletin E-2646)..
7. It is anticipated that a new publication entitled, "Michigan Field Crop Pest Ecology and Management" will be available for distribution before the end of the MPIC Research Committee Meeting. The overall philosophy of this book is that "If the grower knows why, he will teach himself how (Liberty Hyde Bailey, 1916)". Many aspects of the chapter entitled "Nematodes and Soil Quality" are based on the findings and experiences associated with this project (MSU Extension Bulltein E-2704).
8. The idea of the importance and urgent need for root-lesion and northen root-knot nematode resistant potato varieties evolved from experiences associated with the long-term potato farming systems trial.

Precision Agriculture/Potato Nematode Projects.- It has been known for at least 25 years that populations of plant parasitic nematodes are distributed in fields in a clumped or aggregate manner. For the past two decades that MSU Extension Nematology Program has recommended that a stratified system be used for collection of soil and root tissue samples for nematode analysis. In general, this has not been possible because the lack of appropriate geo-referencing and associated data-base technology. 1999 was the first year that the MSU Nematology Program formally participated in potato research activities under the heading of Precision Agriculture. Two projects were initiated, one at the Montcalm Potato Research Farm and the other at Anderson Brothers. The current objective of the Montcalm project is to geo-reference and characterize three research ranges: with special reference to calcium and nematode management. This work is being done jointly with Dr. Warncke and Dr. Brook. It will be recommended that the project be expanded to geo-referencing and characterizing the entire research farm, as a prototype project for MSU Land Management. The second project is being conducted at an Andersen Brother Farm in Vestaberg, Michigan. This is being done jointly with Dr. Brook, Dr. Warncke and Mark Otto of Agribusiness Consultants. The nematode component of one 62.1 acre site was characterized in 1999 and the results being used for year 2000 management decisions. Other precision agriculture nematology research is being conduct in carrot and soybean production systems. It is anticipated by sugar beets will be added to the list in the near future.

Initial Findings.

The technologies of precision agriculture appear to be ideal for: 1) characterization of field population of plant parasitic nematodes, 2) identification of specific locations of low yields associated with nematode problems, and 3) use in the implication of variable tactic/rate nematode management procedures.

New References of Significance to Potato Producers.-

Michigan Field Crop Ecology (1998). MSU Extension Bulletin E-2646. 86 pp. This very well illustrated and award winning publication contains information about nitrogen, carbon, covercrops, nematodes, insects, soil ecology, pest management and the principles of ecology. The book was designed and written based on needs identified by Michigan farmers. Prior to publication, the initial draft of the book was reviewed in a public hearing, and then the final draft evaluated by selected Michigan farmers.

Michigan Field Crop Pest Ecology and Management (2000). MSU Extension Bulletin E-2704. 102 pp. This recently published book contains new and innovative ways of presenting information about the ecology and management of weeds, insects, and plant pathogens. It also contains chapters about soil ecology and how nematodes relate to soil quality. The book uses case studies of three Michigan farms as reference points for discussion. It also contains lists and evaluations of key management practices.

Table 1. 1999 Potato Nematicide Trial (Montcalm Potato Research Farm).

Treatment	Tuber yield (cwt)			Stand (50 ft)	Nematodes[1] (100 cm^3 soil)
	Total	A size	Jumbo		
Control	359abc	306a	21a	69bc	706
Metham (37.5 gal/A)	387bc	319a	41b	65bc	3
Metham (75 gal/A)	455c	390a	41b	68bc	5
Telone II (12 gal/A)	406bc	348a	33b	60b	8
Telone C-35 (12 gal/A)	322ab	273a	24a	59b	5
Telone C-35 (6 gal/A)	292ab	243a	19a	53ab	331
Temik 15G (20 lbs/A)	382bc	330a	20a	63bc	23
Mocap 10G (30 lbs/A)	382a	330a	20a	76c	50
Vydate 2L (2 gal/A)	238a	190a	28ab	38a	337
ANOVA	<0.01	<0.01	<0.01	<0.01	0.081

[1]Root-lesion and northern root-knot nematodes (7/21/1999)

Table 2. 1999 Montcalm Potato Research Farm Precision Agriculture Trial tuber yields and mid-season nematode population densities.

Treatment	Tuber yield (Cwt/acre)	Root-lesion nematodes (No. per 1.0 g root tissue)
Control	255.3 a	11.7 a
Gypsum	297.7 a	60.0 b
Metham (75 gal/A)	430.6 b	0.00 a
Metham (75 gal/A) & Gypsum	422.5 b	0.00 a

Table 3. Nematology definitions for host plant resistance, tolerance and susceptibility.

Resistance: Cultivars/lines containing genes that prevent nematodes from entering roots, reproducing and causing significant yield losses are known as **resistant varieties/lines**. With some crops, genes for resistance provide resistance to only a limited number of races of a specific nematode. If a single source of resistance is used in a location for a long period of time, it is possible for composition of a race complex to change and the resistance to break down.

Tolerance: Cultivars/lines that allow nematodes to invade roots and reproduce without causing significant yield loss are known as **tolerant varieties/lines**. Tolerance can be an important tool for use in nematode management. It can be used to reduce selection pressure associated with the break kown of resistant cultivars.

Susceptibility: Cultivars/lines that allow plant pathogenic nematodes to invade roots, reproduce and cause significant crop yield losses are known as **susceptible varieties/lines**. Rotation of susceptible and resistant varieties can be used to decrease risk associated with the break down of resistant varieties/lines.

Table 4. 1999 Potato Early-Die Resistance/Tolerance/Susceptibility Research

Line/Variety	Relative Yield (Infested soil)	Tolerance index	Relative Yield (Fumigated soil)	PED Index (0.0-5.0)
Superior	0.56	0.67	**0.79**	5.00
MSB 106-7	0.44	**1.09**	0.38	4.25
MSE 192-8	0.39	0.75	0.50	3.23
MSE 149-5Y	0.68	0.78	**0.82**	3.25
MSN 4-T	0.62	0.75	**0.78**	2.75
MSF 099-3	0.51	0.72	0.67	2.50
Atlantic	0.57	0.78	0.69	3.00
MSA 091-1	0.47	0.67	0.67	2.75
MSG 227-2	0.28	0.56	0.48	3.25
Onaway	0.66	0.71	**0.87**	3.75
MSB 107-1	0.46	0.65	0.67	1.25
Russet Norkotah	0.38	0.75	0.49	4.00
Russet Burbank	0.30	0.61	0.48	3.25
MSE 226-4Y	0.52	0.69	**0.71**	2.25
MSE 246-5	0.55	**1.23**	**0.77**	2.75
MSE 228-11	**0.95**	**1.19**	0.42	3.00
MSE 048-2Y	0.51	0.65	**0.74**	2.00
MSE 018-1	**0.75**	**0.96**	**0.73**	----
Snowden	0.51	0.72	0.67	2.75
Reddale	**0.77**	**0.92**	**0.78**	3.00
MSE 228-1	**0.70**	**0.89**	**0.71**	2.50
MSE 033-1	**1.00**	**0.93**	**1.00**	4.25
MSG 050-2	**0.79**	**1.09**	0.68	4.00
MSG 274-3	0.50	0.50	**0.93**	2.75
MSF 373-8	0.36	**0.83**	0.40	1.67

Table 5. Summary of the results of the 1997-1998 Potato Early-Die and Nematode Tolerance/Resistance Research.

1997.

Possible Tolerance	Susceptible
Chieftain	Atlantic
	Onaway
	Russett Burbank
	Russet Norkotah
	Shepody
	Snowden

1998

Possible Resistance	Possible Tolerance	Susceptible	Inconclusive
F349-1RY	E226-4Y	E018-1	B107-1
	E228-1	F-313-3	C103-2
	E-228-11	E149-5Y	E026-B
	F373-8	Russett Burbank	E030-4
	G104-6	Reddale	E033-1RD
	G119-1R	Shepody	
	MSB107-1[1]	Superior	
	E048-2Y[1]		
	Chieftain		

1999

Possible Resistance	Tolerance	Possible Tolerance	Susceptible
MSG 050-2	Reddale	MSB 106-7	**Superior**[2]
	MSE 228-11[1]	MSE 246-5	MSE 192-8
	MSE 018-1	MSF 337-8	**MSE 149 5Y**
	MSE-228-1		**MSN 4-T**
	MSE 033-1		MSF 099-3
			Atlantic
			MSA 091-1
			MSG 227-2
			Onaway
			MSB 107-1
			Russet Norkotah
			Russet Burbank
			MSE 226-4Y
			MSE 048-2Y
			Snowden
			MSG 274-3

[1]Tolerant cultivars/lines in boldface were evaluated in both 1998 and 1999.
[2]Susceptible cultivars/lines in boldface yield exceptional well in fumigated soil.

Table 6. Description of the crops and soil nutrition programs used in a 10-Year Farming System - Nematode Management Research Project (1991-2000) at the Montcalm Potato Research Farm in Entrican, Michigan.

Farming System	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1	Potato Rye[1]	Potato Rye[1]	Potato Rye[1]	Potato Rye[1]	Potato Rye[1]	Potato Rye[1]	Potato Rye[1]	Potato Rye[1]	Potato Rye[1]	Potato Rye[1]
2	Alfalfa[1]	Potato Rye[1]	Potato Rye[1]	Potato Rye[1]	Hairy vetch[1]	Potato Rye[1]	Buckwheat Rye[1]	Potato Clover[1]	Wheat Clover[1]	Corn Clover[1]
3	Oats Rye[1]	Alfalfa[1]	Potato[1]	Potato[1]	Nematode mix[1]	Oats[1]	Potato Rye[3]	Potato Clover[3]	Potato Rye[3]	Potato Rye[3]
4	Oats Rye[1]	Alfalfa[1]	Alfalfa[1]	Potato Rye[1]	Alfalfa[1]	Alfalfa[1]	Potato Rye[1]	Alfalfa[1]	Alfalfa[1]	Potato Alfalfa[1]
5	Oats Rye[1]	Potato Rye[1]	Potato Rye[1]	Potato Rye[1]	Annual rye grass[1]	Oats/Red Clover[1]	Potato Rye[1]	Wheat Clover[1]	Potato	Wheat
6	Oats Rye[1]	Soybean Rye[1]	Alfalfa[1]	Alfalfa[1]	Potato Rye[2]	Alfalfa[1]	Alfalfa[3]	Potato Alfalfa[1]	Alfalfa[1]	Alfalfa[1]
7	Oats Rye[1]	Soybean Rye[1]	Light red kidney beans, Rye[1]	Alfalfa[1]	Alfalfa[1]	Potato Rye[1]	Alfalfa[3]	Alfalfa[1]	Potato Alfalfa[1]	Alfalfa[1]
8	Oats Rye[1]	Soybean Rye[1]	Light red kidney beans, Rye[1]	Green pea[1]	Oil seed radish[1]	Potato Rye[1]	Oil seed radish Rye[3]	Corn Clover[1]	Corn	Potato
9	Oats Rye[1]	Soybean Rye[1]	Light red kidney beans, Rye[1]	Green pea[1]	Potato Rye[2]	Oil seed radish[1]	Potato Rye[1]	Buckwheat Clover[3]	Potato Clover[3]	Buckwheat Clover[3]
10	Oats Rye[1]	Soybean Rye[1]	Light red kidney beans, Rye[1]	Green pea[1]	Buckwheat[2]	Potato Rye[1]	Buckwheat Rye[3]	Potato Clover[3]	Buckwheat Clover[3]	Potato Clover[3]

[1]Conventional soil nutrition program.
[2]30 T/A cow manure compost.
[3]Alternative soil nutrition program.

Farming System Descriptions:
- Continuous Potato (No. 1 and No. 3)
- Potato-Wheat-Rye Rotation (No. 2, No. 5, and No. 8)
- 2-year Alfalfa-Potato (No. 4, No. 6, No. 7)
- Buckwheat-Potato (No. 9 and No. 10)

October 20, 1999

Table 7. 1999 mid-season population densities of root-lesion and northern root-knot nematodes recovered from root tissue associated with ten potato farming systems at the Montcalm Potato Research Station.

Farming System (1999 crop)	Nematodes per 1.0 gram root tissue		
	Root lesion	Root-knot	Total
1. Continuous potato-c (Potato)	120 cd	636 b	756 b
2. Wheat/corn/potato-c (Wheat)	86 bcd	14 a	100 a
3. Continuous potato-a (Potato)	138 d	506 b	644 b
4. 2^{nd}-year alfalfa-c (Alfalfa)	40 ab	55 a	95 a
5. Wheat/corn/potato-c (Potato)	129 d	60 a	189 a
6. 1^{st}-year alfalfa-c (Alfalfa)	46 ab	26 a	73 a
7. Potato/alfalfa-c (Potato)	37 ab	144 a	181 a
8. Wheat/corn/potato-c (Corn)	61 abc	14 a	75 a
9. Potato/buckwheat-a (Potato)	74 bcd	61 a	146 a
10. Potato/buckwheat-a (Buckwheat)	2.5 a	<1 a	1.6 a

Table 8. Relative potato tuber yields associated with a Ten-Year Farming System/Nematode Management Research Project at the Michigan State University Montcalm Potato Research Farm in Entrican, Michigan.

Farm system	Crop									Relative Yield, U.S. No. 1 Potato Tubers[1]								
	1991	1992	1993	1994	1995	1996	1997	1998	1999	1991	1992	1993	1994	1995	1996	1997	1998	1999
1	Potato[2]	Potato[2]	Potato[2]	Potato[2]	Potato[2]	Potato[2]	Potato[2]	Potato[2]	Potato[2]	**1.00**	0.69	0.34	0.29	0.79	0.87	0.45	0.61	0.33
2	Alfalfa[2]	Potato[2]	Potato[2]	Potato[2]	Hairy vetch[2]	Potato[2]	Buck-wheat[3]	Potato[2]	Wheat[2]	---	**1.00**	0.54	0.34	---	0.95	---	0.77	---
3	Alfalfa[2]	Alfalfa[2]	Potato[2]	Potato[2]	Nematode tri-mix[2]	Oats[2]	Potato[4]	Potato[4]	Potato[4]	---	---	**1.00**	0.57	---	---	**1.05**	0.33	0.56
4	Oats[2]	Alfalfa[2]	Alfalfa[2]	Potato[2]	Alfalfa[2]	Alfalfa[2]	Potato[2]	Alfalfa[2]	Alfalfa[2]	---	---	---	**1.00**	---	---	**1.00**	---	---
5	Oats[2]	Potato[2]	Potato[2]	Potato[2]	Annual rye grass[2]	Oats/Red clover[2]	Potato[2]	Wheat[2]	Potato[2]	---	0.97	0.53	0.32	---	---	0.88	---	0.74
6	Oats[2]	Soybean[2]	Alfalfa[2]	Alfalfa[2]	Potato[2]	Alfalfa[3]	Alfalfa[4]	Potato[2]	Alfalfa[2]	---	---	---	---	**1.00**	---	---	**1.00**	---
7	Oats[2]	Soybean[2]	Light red kidney beans[2]	Alfalfa[2]	Alfalfa[2]	Potato[2]	Alfalfa[4]	Alfalfa[2]	Potato[2]	---	---	---	---	---	**1.00**	---	---	**1.00**
8	Oats[2]	Soybean[2]	Light red kidney beans[2]	Green peas[2]	Oil seed radish[3]	Potato[2]	Oil seed radish[4]	Corn[2]	Corn[2]	---	---	---	---	---	**1.14**	---	---	---
9	Oats[2]	Soybean[2]	Light red kidney beans[2]	Green peas[2]	Potato[3]	Oil seed radish[3]	Potato[2]	Buck-wheat[4]	Potato[4]	---	---	---	---	0.93	---	0.97	---	0.56
10	Oats[2]	Soybean[2]	Light red kidney beans[2]	Green peas[2]	Buck-wheat[3]	Potato[2]	Buck-wheat[4]	Potato[4]	Buck-wheat[4]	---	---	---	---	---	**1.35**	---	0.86	---

[1]Relative yields calculated by assigning a yield of 1.0 to the standard farming system (2 years of alfalfa followed by one year of potato) and dividing the U.S. No. 1 tuber yields for each farming system by the U.S. No. 1 tuber yield for the standard. The two exceptions were in 1991 and 1992, where the U.S. No. 1 tuber yields for the only potato system and the potato system following a single year of alfalfa were used as the standard, and in 1996 and 1997 when situations of over-yielding existed.

[2]Conventional potato production soil nutrition program.

[3]Application of 30 T/A of cow manure compost.

[4]Alternative potato production soil nutrition program.

Table 9. 1999 At-harvest population densities of root-lesion, northern root-knot and ring nematodes recovered from 100 cm^3 soil associated with ten potato farming systems at the Montcalm Potato Research Station.

Farming System (1999 crop)	Nematodes per 100 cm^3 soil		
	Root lesion	Root-knot	Ring
1. Continuous potato-c (Potato)	29 a	349 bc	0 a
2. Wheat/corn/potato-c (Wheat)	66 c	39 a	26 a
3. Continuous potato-a (Potato)	34 ab	395 cd	11 a
4. 2nd-year alfalfa-c (Alfalfa)	14 a	33 a	80 b
5. Wheat/corn/potato-c (Potato)	63 c	91 ab	8 a
6. 1st-year alfalfa-c (Alfalfa)	19 a	181 ab	143 c
7. Potato/alfalfa-c (Potato)	27 a	589 d	25 a
8. Wheat/corn/potato-c (Corn)	24 a	14 a	1 a
9. Potato/buckwheat-a (Potato)	59 bc	208 abc	1 a
10. Potato/buckwheat-a (Buckwheat)	34 ab	27 a	1 a

Table 10. Pratylenchus penetrans (root-lesion nematode and Meloidogyne hpala (northern root-knot nematode management summary for potato production..

Procedure	Expected nematode control[1]	
	Root lesion nematode	Northern root-knot nematode
Metham (75 gal/A)	99%	95%
Metham (37.5 gal/A)	90%	85%
Telone II (12 gal/A)	90%	85%
Mocap 10G (9.0 lbs a.i./A)	80%	80%
Temik 15G (3.0 lbs a.i./A)	80%	70%
Vydate 2L (2.0 gal/A)	75%	85%
Alfalfa (2-year rotation)	75%	75%
Oilseed Radish (green manure)	70%	70%
Mocap 10G (3.0 lbs a.i./A)	70%	70%
Buckwheat (rotation crop)	50%	90%
Wheat (rotation crop)	0%	90%
Corn (rotation crop)	0%	90%
Peas, green beans, pickles, dry beans, soybeans, and carrots (rotation crops)	0%	0%

[1]Expected potato nematode control estimates based on comparative mid-season potato root population densities of the penetrans root-lesion and northern root-knot nematodes.

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Insect Management in Potatoes
1999 Research Report

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Summary:

During the 1999 growing season, Colorado potato beetle populations in most of Michigan were low to moderate. Aphid and potato leafhopper numbers were also reported as moderate. Admire ® and Provado® (imidacloprid, Bayer Corp.) continued to provide adequate control of Colorado potato beetle and aphids. Fulfill (Novartis Corp) received federal registration late in the year, and should provide good control of aphids in future years.

During 1999, our research focused again on resistance to Admire® (imidacloprid) in the Colorado potato beetle. Objectives included: 1) surveying Colorado potato beetle field populations for resistance to Admire®, thiamethoxam, (Novartis Corp) and previously-used insecticides, 2) determining how fast the level of resistance to imidacloprid increases in response to selection pressure, 3) studying how resistance to imidacloprid is inherited, and 4) evaluating the influence of synergists on imidacloprid toxicity to determine possible mechanisms of resistance.

We also continued our studies of biological control of Colorado potato beetle. We evaluated the effect of imidacloprid use on biological control by examining the interaction between imidacloprid poisoning in Colorado potato beetles and predation by ground beetles. We also began a new project to assess the potential for biological control of Colorado potato beetle with entomopathogenic nematodes and *Beauvaria bassiana,*.

Finally, we conducted several insecticide trials to determine the efficacy of registered and experimental insecticides for control of Colorado potato beetle and potato leafhopper.

Bioassays of Colorado potato beetle populations collected throughout Michigan and some out-of-state locations yielded LD_{50} values for imidacloprid that were similar to those obtained in previous years. Artificial selection with imidacloprid in the laboratory increased the resistance of Michigan potato beetles, but did so slowly; after six generations of selection, beetles were only 1.7 times more resistant than the original population. Studies conducted in 1998 and 1999 indicate that resistance to imidacloprid in the Colorado potato beetle is inherited autosomally as a recessive trait. These results collectively support the idea that, in most cases, resistance to imidacloprid develops slowly, at least at first. Methods to manage and reduce the risk of resistance development may be more successful for imidacloprid than for some other insecticides.

Populations collected from Long Island, NY expressed higher levels of resistance compared with susceptible, Michigan and upstate NY populations. Bioassays of slightly resistant and highly resistant Colorado potato beetles with the synergist piperonyl butoxide indicate that mixed function oxidases are an important mechanism, though not the only mechanism for resistance to imidacloprid. LD_{50} values for thiamethoxam were

significantly correlated with LD $_{50}$ values for imidacloprid in Colorado potato beetle populations for the second year in a row, indicating the strong possibility of cross resistance. Petri dish resistance test kits revealed that resistance to Furadan, Imidan and Thiodan is still present, to a substantial degree, in most Michigan Colorado potato beetle populations, even though these insecticides have been rarely used since 1995.

Biological control studies indicate that imidacloprid-poisoned Colorado potato beetles may be preyed upon in the field. Predatory ground beetles that consume poisoned potato beetles sometimes show signs of imidacloprid poisoning. More research is needed to determine the precise influence of imidacloprid treatment on predation. Both entomopathogenic nematodes and the fungal disease *Beauveria bassiana* show promise as biocontrol tools for Colorado potato beetle.

Admire (imidacloprid) resistance in Colorado potato beetle

Imidacloprid, (Admire®, Provado®, Bayer Corp.) a neonicotinyl insecticide, was first registered for use on potatoes in 1995. It immediately became the primary means to control organophosphate, pyrethroid and carbamate-resistant Colorado potato beetles in Michigan and other areas of the U.S. (Grafius, 1997). Because Colorado potato beetle has demonstrated an ability to evolve resistance to virtually any insecticide used to control it (Bishop and Grafius 1996), and because imidacloprid is so widely used, concerns about development of imidacloprid resistance in Colorado potato beetle have been present ever since.

In 1997, low levels of resistance were detected in a Michigan Colorado potato beetle population. That same year a population from Long Island, NY was found to be 100-fold more resistant than susceptible populations (Zhao et al. in press). On Long Island growers experienced reduced potato beetle control in many fields, indicating that the efficacy of imidacloprid against Colorado potato beetle has declined in that area (MacNeil 2000).

We began to investigate the potential development of imidacloprid resistance in the Colorado potato beetle in 1995 and have continued that research each year. The insecticides used in this study included imidacloprid (98.7%, technical grade), provided by Bayer (Kansas City MO), piperonyl butoxide (90%, technical grade), supplied by Aldrich Chemical Company, Inc., and piperonyl butoxide, (98% technical grade), provided by Chem Service, West Chester, PA.

<u>Survey of resistance in field populations of Colorado potato beetle</u>

Once again we assessed the level of imidacloprid resistance in field-collected Colorado potato beetle populations from Michigan and other locations. Many of these populations were also assessed for their susceptibility to thiamethoxam, another neonicotinyl insecticide (Novartis Corp.) that may be registered soon for use on potatoes. Finally, to determine if several years without exposure to previously-used (1995 and earlier) insecticides would reduce resistance to these insecticides, several field-collected populations were tested using the petri dish resistance test kit (Bishop and Grafius 1991).

Two different studies were conducted. In the first study, nine Colorado potato beetle populations were collected from seven different Michigan counties (Kent, Midland, Montcalm, Mecosta, Delta, Houghton, and Berrien). Cooperators also sent us populations from Maine, Wisconsin, Minnesota, and New York. Five of the Michigan populations, four out-of-state populations, and one highly resistant laboratory population collected from Long Island, NY in 1997, were tested for resistance to both imidacloprid and thiamethoxam .

Colorado potato beetle adults were either stored at room temperature (25±1°C) and fed foliage daily or, for long term storage, were kept in a controlled environment chamber (11±1°C) and fed weekly. Before each bioassay, potato beetles were combined and randomly assigned to treatments. Beetles were treated with 1 µl of a known concentration of acetone/insecticide solution applied to their abdomen. After treatment, beetles were placed in petri dishes lined with filter paper and provided with fresh potato foliage. The petri dishes were stored at 25±1°C and the foliage and filter paper were checked daily and changed as needed.

Each population was first screened to determine their relative susceptibility to imidacloprid and thiamethoxam; three concentrations of insecticide/acetone solution plus an acetone-only control were applied to 10 beetles each. Based on results of this screen, a range of five concentrations, plus an acetone control, was selected for each population. Each bioassay was replicated up to three times using serial dilutions prepared on different dates. Within each bioassay, from 12-15 beetles were treated with each concentration (4-5 beetles per dish and 3 dishes per concentration).

The responses of the beetles were assessed 7 and 10 days after treatment. A beetle was classified as dead if its abdomen was shrunken, it did not move when the legs or tarsi were pinched, and its elytra were darkened. Dead beetles were removed from the dish. A beetle was classified as walking if it was able to grasp a pencil and walk forward normally. A beetle was classified as poisoned if the legs were extended and shaking, it was unable to right itself or grasp a pencil, and it was unable to walk forward normally at least one body length. Probit analyses were conducted on all data obtained using Polo PC© statistical software.

The LD_{50} values for imidacloprid at 7 and 10 days after treatment did not vary significantly between populations (overlapping 95% confidence limits) (Table 1). LD_{50}'s 7 days after treatment ranged from 0.039 µg (Mecosta 1) to 0.070 µg (Kent) for Michigan populations. This is similar to the range of LD_{50} values found for Michigan potato beetle populations in 1998. The LD_{50} 's for out-of-state populations ranged from 0.029 µg (Maine) to 0.102 µg (Upstate New York). Basically, these values correspond to levels of insecticide resistance generally found in these areas, and are very similar to the values found in 1998.

As with imidacloprid, the LD_{50} values for thiamethoxam did not vary significantly between populations (overlapping 95% confidence limits) (Table 2). For Michigan populations, LD_{50} 's 7 days after treatment ranged from 0.059 µg (Mecosta 1) to 0.124 µg (Kent). This is similar to the range of LD_{50} valuess found for Michigan potato beetle populations in 1998. The LD_{50} 's for out-of-state populations ranged from 0.045 µg (Maine) to 0.101 µg (Upstate New York). In general, the LD_{50} values for thiamethoxam in 1999 were slightly higher than those obtained in 1998. However, once again the relative resistance to imidacloprid (as measured by LD_{50}) in Colorado potato beetle populations was significantly correlated with the relative resistance to thiamethoxam. Populations with the highest LD_{50} values for imidacloprid also had the highest LD_{50} values for thiamethoxam. Correspondingly, populations with the lowest LD_{50} 's for imidacloprid also had the lowest LD_{50} 's for thiamethoxam.

Table 1. LD_{50}'s (μg per beetle) for Colorado potato beetle populations treated with imidacloprid 7 and 10 days after treatment.

	7 days after treatment		10 days after treatment	
	LD_{50} (μg)	95% C.L.	LD_{50} (μg)	95% C.L.
Michigan populations				
Kent	0.070	0.049 - 0.102	0.067	0.047 - 0.096
Midland	0.067	0.054 - 0.086	0.069	0.057 - 0.090
Montcalm	0.058	0.048 - 0.071	0.067	0.055 - 0.082
Mecosta 1	0.039	0.028 - 0.053	0.065	0.047 - 0.094
Mecosta 2	0.085	0.065 - 0.120	0.073	0.056 - 0.099
Out-of-state populations				
Maine	0.029	0.022 - 0.038	0.029	0.022 - 0.037
Wisconsin	0.067	0.056 - 0.078	0.077	0.066 - 0.090
Minnesota	0.086	0.050 - 0.141	0.082	0.055 - 0.132
New York	0.102	0.080 - 0.126	0.122	0.097 - 0.151
Laboratory Strain				
Long Island	1.458	0.514 - 2.527	1.940	0.980 - 3.000

Table 2 LD_{50}'s (μg per beetle) for Colorado potato beetle populations treated with thiamethoxam 7 and 10 days after treatment.

	7 days after treatment		10 days after treatment	
	LD_{50} (μg)	95% C.L.	LD_{50} (μg)	95% C.L.
Michigan populations				
Kent	0.124	0.068 - 1.000	0.070	0.040 - 0.222
Midland	0.074	0.060 - 0.093	0.067	0.054 - 0.083
Montcalm	0.060	0.050 - 0.072	0.063	0.052 - 0.076
Mecosta 1	0.059	0.042 - 0.085	0.053	0.038 - 0.074
Mecosta 2	0.072	0.060 - 0.088	0.075	0.062 - 0.093
Out-of-state populations				
Maine	0.045	0.032 - 0.056	0.045	0.028 - 0.058
Wisconsin	0.089	0.073 - 0.107	0.078	0.064 - 0.093
Minnesota	0.069	0.056 - 0.086	0.061	0.049 - 0.075
New York	0.101	0.068 - 0.140	0.110	0.075 - 0.150
Laboratory Strain				
Long Island	0.149	0.110 - 0.204	0.147	0.108 - 0.200

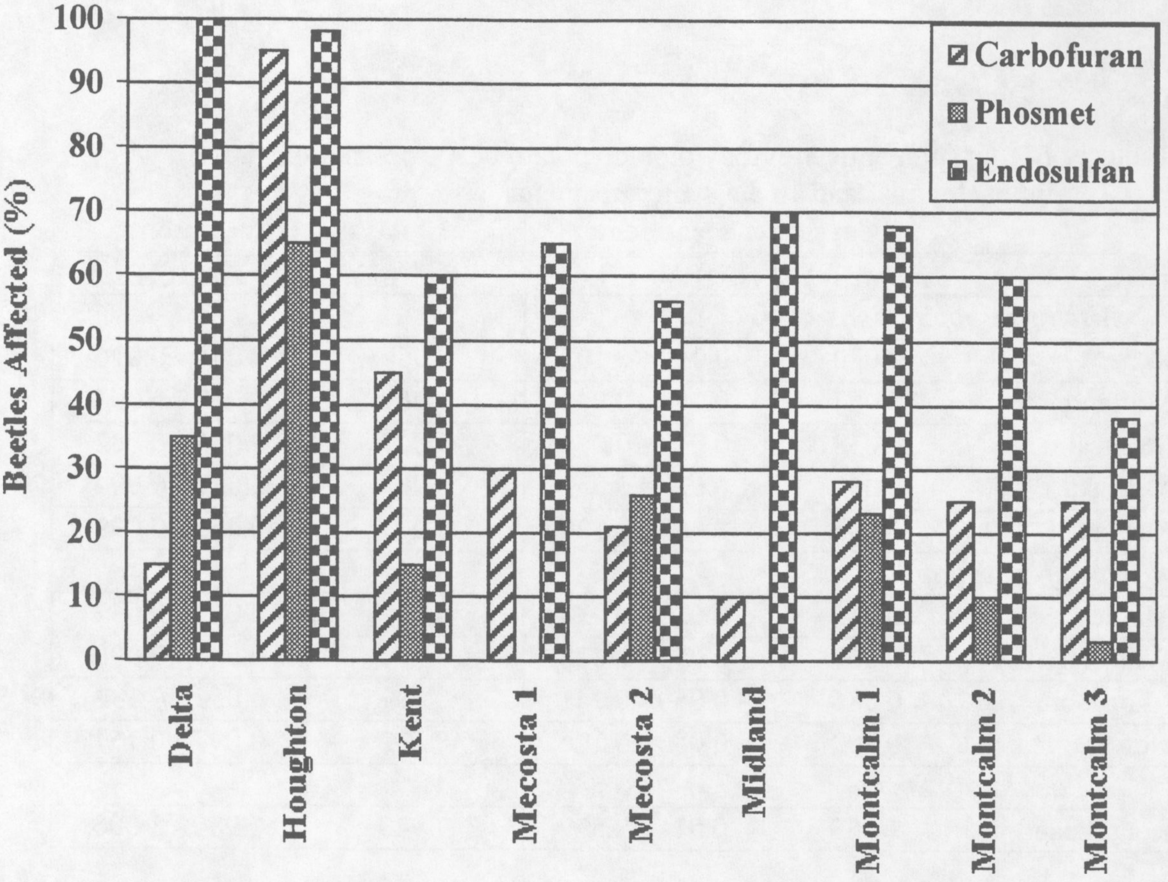

Figure 1. Percent of Colorado potato beetles from 9 different Michigan populations affected (dead or poisoned) by Furadan (carbofuran), Imidan (phosmet) and Thiodan (endosulfan) after being exposed to these insecticides in petri dish resistance test kits.

Nine Michigan populations from 6 counties (Delta, Houghton, Kent, Midland, Mecosta, and Montcalm), were tested for resistance to insecticides that, because of extensive use, most Michigan populations were resistant to before 1995. Petri dish resistant test kits were used (Bishop and Grafius 1991) and included separate tests for resistance to Furadan (carbofuran), Imidan (phosmet), and Thiodan (endosulfan), among others. Resistance is indicated by less than 70% of beetles affected by the insecticide. Resistance to Furadan (carbofuran) and Imidan (phosmet) was still present in most populations tested (Figure 1), although, compared with results from 1990-1994, the proportion of resistant individuals may have declined slightly. Resistance to Thiodan (endosulfan) declined during the years between 1995 and 1999, and many of the tested populations may be adequately controlled by this insecticide. However, previous experience has shown that control would likely be lost within one or two growing seasons after its reintroduction.

The Houghton population was collected from an organic farm and has not been exposed to synthetic insecticides directly. As expected this population was not resistant to Furadan (carbofuran) or Thiodan (endosulfan). However, a low level of resistance to Imidan (phosmet) was present. This may have resulted from the historical use of organophosphates to control mosquitoes and blackflies in the Upper Peninsula.

In the second study, field populations of Colorado potato beetles in areas of heavy imidacloprid use were monitored for resistance by calculating the time required for half of the beetles to be affected by a given dose of imidacloprid (knock down time 50 [KD $_{50}$]). Five field populations of Colorado Potato Beetle were collected in Long Island, NY in August, 1999 an additional population (Suffolk) was collected in July, 1997 (Zhao et al. 1998) and maintained without selection in the laboratory. Two other populations were collected from Hudson, NY and Midland, MI. The susceptible colony (S69), was collected in Michigan potato fields and has been reared in the laboratory at MSU for 10 years without exposure to insecticides.

Topical bioassays were used to assay adult resistance. Technical-grade imidacloprid was diluted with acetone. A dose of 3.16 µg of a.i./beetle was used. For each concentration, 10 beetles were treated with 1 µl of solution on the ventral area of the abdomen. After treatment, beetles were placed in petri dishes and were fed potato leaves. Control beetles were treated with acetone alone. Three replications were performed. Knockdown of beetles was assessed periodically for 24 hours after treatment, and at 24 hours, and 3, 5, 7, and 10 days after treatment. Beetles that were unable to stand on their legs and walk a body length were considered knocked down. Beetles that did not move and showed a progressive darkening were considered dead.

Table 3. The knockdown response of several strains of Colorado potato beetle to imidacloprid and imidacloprid plus piperonyl butoxide (PBO)

	Imidacloprid			**Imidacloprid plus PBO**		
population	**[a]KD_{50}**	**slope ± SE**	**[b]RR**	**[a]KD_{50}**	**slope ± SE**	**[b]RR**
Midland, MI	32 (28, 36)	3.0 ± 0.3	0.46	27 (25, 30)	5.0 ± 0.5	0.96
Susceptible	68 (63, 75)	4.0 ± 0.3	1	28 (26, 31)	4.5 ± 0.5	1
Hudson, NY	77 (69, 85)	3.3 ± 0.3	1.1	58 (54, 61)	7.1 ± 0.6	2
Suffolk, LI	106 (96, 116)	3.9 ± 0.3	1.5	91 (84, 98)	6.8 ± 0.9	3.2
Jamesport, LI	135 (117, 157)	2.1 ± 0.1	2	132 (120,146)	4.1 ± 0.3	4.6
Calverton, LI	142 (125, 160)	3.1 ± 0.2	2.1	89 (81, 99)	3.9 ± 0.3	3.1
Zilverton, LI	266 (216, 322)	2.8 ± 0.3	3.9	172 (152,193)	2.8 ± 0.2	6
Rutkoski, LI	318 (293, 344)	3.4 ± 0.2	4.6	164 (141,185)	2.7 ± 0.3	5.7
Wells, LI	515 (466, 574)	3.2 ± 0.4	7.5	325 (281, 337)	2.7 ± 0.3	11.3

RR= Ratio of resistance. KD_{50} of field population / KD_{50} susceptible population. [a]KD_{50} = Knock down fifty (minutes)

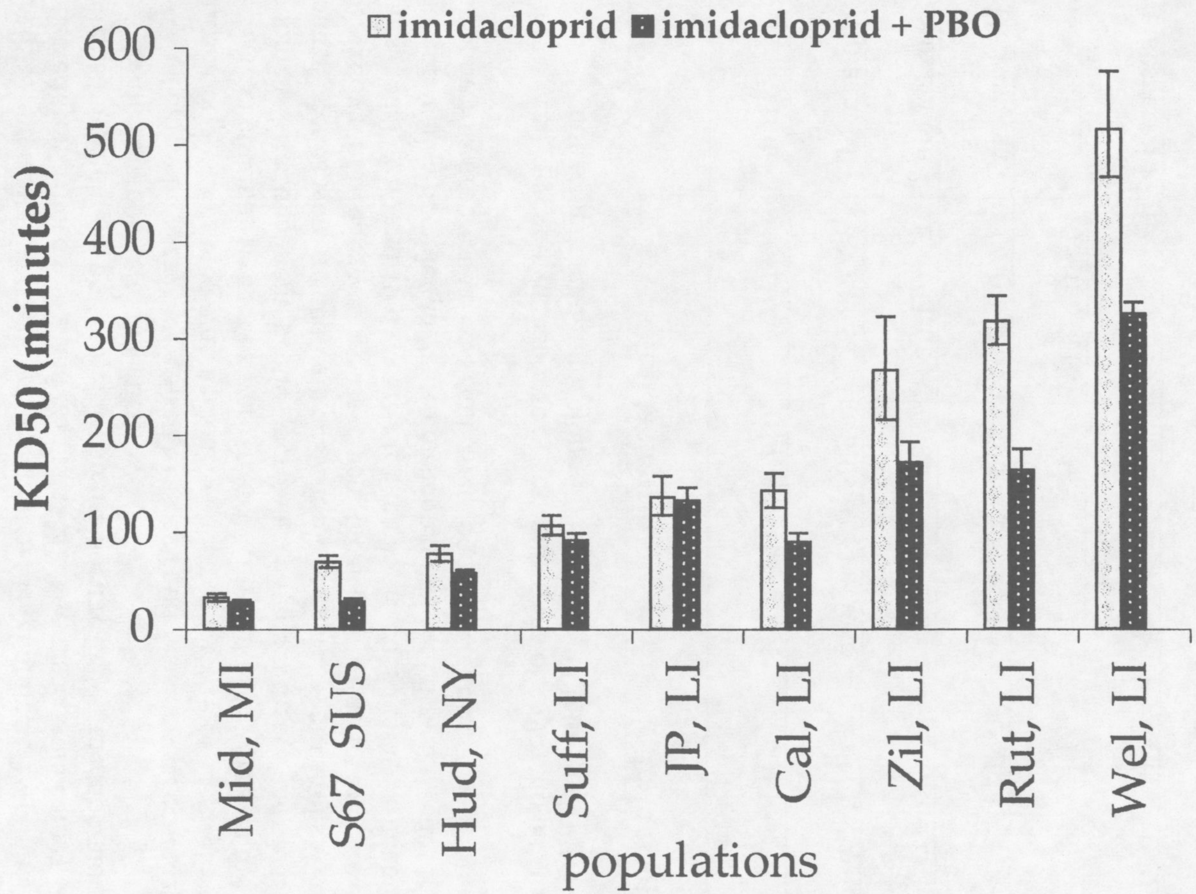

Figure 2. Knockdown (KD50) of several strains of CPB by imidacloprid and imidacloprid + PBO.

Data were analyzed by probit analysis (SAS Institute, 1988). Knock down (KD_{50}), fiducial limits, and slopes were determined. The resistance ratios were calculated as KD_{50} value of the resistance colony (Long Island) divided by the KD_{50} value of the susceptible colony (S69). To analyze the data for knock down beetles 10 days after treatment, an arcsine transformation was used with a factorial experimental design (populations (nine) and insecticide(alone or mixed) as factors). We used the PROC GLM procedure of SAS.

Knock down time ratios of Long Island populations ranged from 1.5 to 7.5 (Table 3) and Figure 2). The highest levels of Colorado potato beetle resistance were found at Wells, Rutkoski and Zilverton locations where these populations experienced eight or more imidacloprid treatments since 1995 (Admire and / or Provado). The Hudson, NY and Midland, MI population exhibited lower levels of resistance than the Long Island populations. Growers with the most resistant populations used Provado as a foliar application the first year or two (1995,1996) without using Admire in-furrow compared with growers at the Janesport site, which has the least resistant beetles, who used Admire in-furrow all four years,. The amount of active ingredient present in potato plants is higher and lasts longer for the Admire in-furrow treatments than for Provado treatments. Maybe this condition prevents the survival of some heterozygous resistant beetles. In contrast, Provado treatment has good efficacy initially. However, decay of imidacloprid residues is faster for Provado-treated plants, allowing the survival of heterozygous beetles. In addition, foliar treatments of Provado do not cover 100 % of the plant. The levels of resistance as determined by knockdown ratios in this study are lower in comparison with bioassays evaluated 7 to 10 days after treatment (results of previous bioassays evaluated in this manner indicated up to 150-fold levels of resistance). However, determination of knockdown ratios is a quicker way of diagnosing resistance.

Speed of development of resistance to imidacloprid in the Colorado potato beetle

Our major objective was to determine how rapidly resistance to imidacloprid increased with selection by the insecticide. We selected two different populations, a Michigan population with low-levels of resistance, and a highly resistant population from Long Island NY. Each generation individuals were treated with a dose of imidacloprid that produced 50 to 75% mortality and survivors were used to start the next generation.

The resistant strain (Evans) adults and large larvae were originally collected in Montcalm County, Michigan from July to September, 1997. Two generations were reared in the laboratory without exposure to insecticide.

Bioassays were conducted in March, 1998 on adults two generations removed from the original field population. Bioassays were conducted as described above in the section "Survey of resistance in field populations of Colorado potato beetle." Susceptibility to imidacloprid was about 4.6-fold compared with a susceptible strain. The survivors of the 0.2 µg dose (15 of 41) were used to continue the strain. Adults (now 3 generations removed from the field) emerging from the culture were treated at a dose of 0.2 µg/adult. Survivors (51 adults) designated as S_1 generation reproduced, and offspring were cultured to 2nd instars and used to start selection for resistance to imidacloprid.

Each generation, second instars were treated topically with imidacloprid. The dose increased from 0.22 µg/larva to 0.66 µg/larva during successive selections to maintain 60-80% mortality. About 1000 2nd instars were used in each selection and survivors were cultured to the next generation.

To assess the increase in level of resistance to imidacloprid, bioassays were conducted before selection and after each 2-3 selections using adults and the topical application method described above. Intoxication was evaluated at one, three, five, seven, and ten days after treatment. Beetles were supplied with fresh potato leaves during the bioassays. Beetles were recorded as walking, poisoned, or dead by the criteria described in the above section "Survey of resistance in field populations of Colorado potato beetle." Data were analyzed by probit analysis. Lack of overlap between LD_{50} 95% fiducial limits indicated significant differences ($P<0.05$).

To maintain between 50% and 75% mortality during selections, the concentration of imidacloprid was increased from 0.22 μg per larva to 0.66 μg per larva. Resistance to imidacloprid developed slowly between generations. The resistance ratio based on LD_{50} values at seven days after treatment increased by 1.7-fold by the S_6 generation of adults. The slope changed from 2.83 (generation $S_{0)}$ to 1.80 (generation S_6), indicating an increase of heterogeneity (Table 4).

Table 4. LD_{50} (μg/beetle), slope and resistance ratio (LD_{50} S_n/ LD_{50} S_0) of Colorado potato beetles, "Evans" strain, after 3 and 6 generations of selection.

generation	slope (st.error)	LD_{50} (95% f. l.)	$\_^{2}$	R ratio
3 days after treatment				
S_0	3.04 (0.51)	0.064 (0.043-0.095)	0.68	
S_3	3.02 (0.55)	0.099 (0.064-0.15)	17.38	1.5
S_6	2.02 (0.35)	0.14 (0.087-0.21)	6.15	2.2
7 days after treatment				
S_0	2.83 (0.49)	0.11 (0.070-0.16)	1.37	
S_3	2.97 (0.53)	0.11 (0.075-0.17)	5.65	1
S_6	1.80 (0.33)	0.19 (0.12-0.31)	4.69	1.7
10 days after treatment				
S_0	2.60 (0.45)	0.12 (0.074-0.18)	1.86	
S_3	2.68 (0.49)	0.13 (0.082-0.2)	2.81	1.1
S_6	1.92 (0.34)	0.21 (0.14-0.32)	3.46	1.8

Starting with the S_6 generation, selections were done on adults using 1.0μg imidacloprid per beetle (for the S_6 generation) and 1.5 μg imidacloprid per beetle (for the S_7 generation). Survivors were used to start the next generation. At present, the Evans strain is 11 generations removed from the field. Eight generations have been selected with imidacloprid, either at the adult or 2^{nd} instar stage. We are continuing selection and bioassays to determine how continued selection affects the speed of resistance development.

To determine how selection with imidacloprid would affect a population that already showed a high level of resistance, we began a potato beetle population in June 1998 (NY-sel) using individuals from a laboratory strain originally collected from a potato field on Long Island, NY in 1997. The LD_{50} of the original strain was 2.422 (1.581-->3.710) μg/beetle, 100-fold more resistant than our most susceptible potato beetle strain. Individuals were selected with imidacloprid as adults each generation using the topical application method described above. A dose of imidacloprid was chosen that produced 50 to 75% mortality. Survivors of the selection were used to start the next generation. At this point we have selected five generations of NY-selected strain. The dose of imidacloprid needed to produce 50 to 75% mortality increased from 5.0 μg/beetle to 10.0μg/ beetle.

Inheritance of resistance to imidacloprid in the Colorado potato beetle

In 1998 we found that resistance to imidacloprid found in the highly-resistant Long Island strain was inherited autosomally and in an incompletely recessive manner. In 1999 we investigated the inheritance of imidacloprid resistance in Evans strain.

The susceptible strain (UP) beetles were collected at the Hughes' Organic Farm in Houghton Co. in the upper peninsula of Michigan in July 1995 by Walter Pett. NY-sel resistant strain (NY-sel) beetles were collected at Sidor's farm, Mattituck, Long Island, NY on July 30, 1997 by Dale D. Moyer, Cornell Cooperative Extension, Riverhead, NY. After they were received, beetles were selected using a dose of 5.0 μg/adult using imidacloprid several times. All strains were reared at 25 ± 1 °C and 16/8 hour light dark cycle on potato plants grown in greenhouse without exposure to any insecticide.

The Evans strain was topically treated with imidacloprid at 0.22 μg per 2^{nd} instar larva for two generations to obtain high homogeneity. The UP and Evans strains were reciprocally crossed (RS and SR) as "single pair" matings to produce F_1 offspring. Newly emerged virgin males and females of each strain were separated until mating. One male and one female were paired in a plastic cup and fed with fresh potato leaves. There were 20 pairs for each of the reciprocal crosses. Progeny from each of the reciprocal crosses were tested. 20 pairs of backcrosses between F_1 (SR) males and UP females were mated to determine whether resistance is inherited as a monogenic or polygenic trait. Chi-square values from observed and expected responses of the F_1 backcrossed progeny were calculated to test the hypothesis that the resistance was monofactorially inherited (Preisler et al. 1990).

No significant differences in the LD_{50} values were observed between the progeny of two reciprocal crosses. The degree of dominance of resistance was -0.29 and -1.27 in the progeny of the two reciprocal crosses and -0.57 based on pooled results (Table 5). This indicated that resistance to imidacloprid was inherited as incompletely recessive without sex linkage. The χ^2 analyses of response ratio statistics from backcrosses for a monogenic model showed insignificant deviation between observed and expected responses, indicating that one loci may be responsible for resistance to imidacloprid in the Evans-R strain. In 1998, our research indicated that more than one loci is involved in the inheritance of imidacloprid resistance in the Long Island strain. This difference may explain why the Evans strain shows very low levels of resistance while the Long Island strain is already 100-fold resistant to imidacloprid.

Table 5. LD_{50} (µg/beetle), slope, resistance ratio and dominance of susceptible (UP) Colorado potato beetles and beetles with low levels of resistance (Evans) and offspring of reciprocal crosses.

strain	slope (st. error)	LD_{50} (95% f. l.)	χ^2	R ratio	dominance
3 days after treatment					
UP					
Evans	3.02(0.55)	0.099 (0.064-0.15)	17.3		
[1]F_1	2.39 (0.38)	0.091 (0.061-0.13)	4.27		
[2]F_1	1.91 (0.37)	0.069 (0.04-0.12)	2.08		
pooled	2.23 (0.25)	0.083 (0.066-0.1)	4.75		
7 days after treatment					
UP	1.96 (0.31)	0.071 (0.045-0.22)	7.86		
Evans	2.97 (0.53)	0.11 (0.075-0.17)	5.65	1.6	
[1]F_1	2.08 (0.36)	0.083 (0.054-0.13)	9.21	1.2	-0.29
[2]F_1	1.73 (0.36)	0.067 (0.037-0.12)	1.52	0.9	-1.27
pooled	1.97 (0.24)	0.078 (0.06-0.1)	5.05	1.1	-0.57

[1] Evans female x UP male

[2] Evans male x UP female

The NY-sel and Evans strains were reciprocally crossed as "single pair" matings to produce the F_1 generation. The degree of dominance of imidacloprid resistance in the progeny of crosses between the Evans and NY-Sel strains was -0.34, -0.21, and -0.29 at three, seven, and ten days after treatment (Table 6). This suggests that imidacloprid resistance is inherited as incompletely recessive. The slope value of 0.9 indicates a high degree of heterogeneity in the progeny.

Mechanisms of resistance to imidacloprid in the Colorado potato beetle and the effect of synergists

Piperonyl butoxide (PBO) is a synergist that increases toxicity of insecticides in resistant Colorado potato beetles by blocking detoxification enzymes (MFO's). Thus, an increase in toxicity of an insecticide after the addition of PBO means that those particular potato beetles use these enzymes as a mechanism of resistance. In 1998 we found that the addition of PBO reduced the resistance to imidacloprid in highly resistant (LI) beetles, although it did not make the beetles completely susceptible. In 1999, two studies were conducted evaluating the effect of piperonyl butoxide (PBO) on resistance to imidacloprid in Colorado potato beetle populations.

Five Long Island, NY populations, one upstate New York population and one Midland, Michigan population were collected and bioassayed for resistance for imidacloprid, as described above ("survey of resistance in field populations of Colorado potato beetle"). The same populations were also exposed to PBO before imidacloprid was applied. Previous experiments showed that 5 μg/beetle of PBO did not cause mortality or adverse effects on the feeding behavior of the susceptible and resistant populations. PBO was applied an hour before the insecticide treatment.

Table 6. LD_{50} (μg/beetle), slope, resistance ratio and dominance of highly-resistant (NY-sel) Colorado potato beetles and beetles with low levels of resistance (Evans) and offspring of reciprocal crosses.

strain	slope (st. error)	LD_{50} (95% f. l.)	^{2}	R ratio	dominance
7 days after treatment					
UP	1.96 (0.31)	0.071 (0.045-0.22)	7.86	1	
Evans	1.80 (0.33)	0.19 (0.12-0.31)	4.69	2.7	
NY-sel	1.85 (0.36)	2.19 (1.36-3.52)	2.16	30.8	
[1]F_1	0.90 (0.36)	0.5 (0.045-5.51)	0.07	7	-0.21
10 days after treatment					
UP	1.52 (0.29)	0.083 (0.052-0.28)	4.72	1	
Evans	1.92 (0.34)	0.21 (0.14-0.32)	3.46	2.5	
NY-sel	1.79 (0.35)	2.44 (1.52-3.9)	0.97	29.4	
[1]F_1	0.90 (0.36)	0.5 (0.045-5.51)	0.07	6	-0.29

PBO reduced the time for knock down in response to imidacloprid in most of the populations except for the Janesport, Suffolk and Midland populations (Table 3, Figure 2). Despite the reduction in the knock down time in the most resistant Long Island populations, PBO only partially suppressed resistance. Treatments using imidacloprid mixed with PBO suppressed the resistance in most of the populations indicating that P450 complex is a factor in the resistance to imidacloprid. However, in the Wells and Zilverton populations there was only a partial suppression of the resistance suggesting that other mechanisms of resistance may play an important role. The PBO dose may not have been high enough to totally inhibit detoxification enzymes, but, higher doses can cause mortality and reduce feeding behavior. We are conducting further research to learn more about mechanisms of resistance to imidacloprid in the Colorado potato beetle.

The second study tested the effect of PBO on imidacloprid resistance in the Evans populations (low resistance, Michigan population). PBO was topically applied one hour prior to an imodacloprid bioassay using adults of the Evans strain. The dose of PBO was 1 μg per adult. To obtain high homogeneity, three generations of second instars were topically treated with imidacloprid at 2.2 ng per larva (1st and 2nd generations) and 4.4 ng per larva (3rd generation). Offspring were used for the synergism tests. Five serial doses of imidacloprid plus PBO, plus a PBO control, were used and the tests were replicated at least three times.

Exposure to PBO decreased the resistance ratios of Evans potato beetles treated imidacloprid from 1.6 to 0.9, 7 days after treatment (Table 7). PBO significantly synergized imidacloprid 10 days after treatment in the Evans strain. These results indicate that mixed-function oxidase activity (which is inhibited by PBO) may be the major mechanism by which resistance develops.

Table 7. LD_{50} (μg/beetle), slope, resistance ratio and synergist ratio of imidacloprid susceptible (UP) Colorado potato beetles and beetles with low levels of resistance to imidacloprid (Evans) with and without exposure to piperonyl butoxide (PBO).

strain	with PBO	slope (st.error)	LD_{50} (95% f. l.)	$\_^{2}$	S ratio	R ratio
3 days after treatment						
UP	no	3.02 (0.35)	0.099 (0.064-0.15)	17.38		
Evans	no	n/a	n/a	n/a		
Evans	yes	2.70 (0.57)	0.043 (0.027-0.067)	1.31	2.3	
7 days after treatment						
UP	no	1.96 (0.31)	0.071 (0.045-0.22)	7.86		1
Evans	no	2.97 (0.53)	0.11 (0.075-0.17)	5.65		1.6
Evans	yes	2.33 (0.49)	0.062 (0.037-0.1)	2.15	1.8	0.9

Biological control of Colorado potato beetle

Interaction between imidacloprid poisoning in Colorado potato beetle and predation by ground beetles.

In 1998, we began a project to determine the effects of imidacloprid-poisoning in Colorado potato beetles on predation by ground beetles. Colorado potato beetles exposed to imidacloprid in the laboratory are often initially knocked off the plant and show signs of poisoning for several days, before recovering. We tested whether, in the field, these poisoned beetles would be vulnerable to predation, and, if so, would ingestion of poisoned potato beetles affect predatory ground beetles.

Colorado potato beetles from a laboratory strain with low levels of imidacloprid resistance were treated in the laboratory with 0.2 μg of imidacloprid. After 2 hours, potato beetles showing symptoms of poisoning were placed in the bottom of a 100 x 15 mm plastic petri dish lined with filter paper (4-5 beetles per dish). Half of the dishes were left uncovered, and the other half were placed inside a nylon "knee-high" stocking, that was stretched over the petri dish and tied with a knot.

One pair of petri dishes (covered and uncovered) was placed in each of 10 different locations in a potato field at the MSU Muck Research Farm, Bath MI. Dishes were checked 1 day, 2 days and 3 days later. The beetles left in each dish were counted and classified as "walking", "poisoned" or "dead" (see section above for classification criteria). Dead beetles were removed . This test was repeated weekly for a total of four weeks (27 July, 4 Aug, 9 Aug , and 16 Aug 1999).

Data are still being analyzed. During the first week (July 27), none of the poisoned beetles recovered over the three days of the test. Six beetles (13%) were missing from uncovered dishes the first day. Five beetles (11%) were missing the second day and eight beetles (17.7%) were missing the third day. In 1998 this study was conducted at the same location and up to 30% of beetles from uncovered dishes were missing by the first day. These beetles may have been consumed by predators, and evidence of predation (partially-eaten beetles and parts) was observed.

Implications of imidacloprid on predatory ground beetles (Carabidae)

In 1998 we had few beetles to work with. Ground beetles that fed on poisoned Colorado potato beetles did show symptoms of imidacloprid poisoning (extended legs, shaky legs and antennae, and uncoordinated movement).

To collect ground beetles to replicate this study in 1999, pitfall traps were placed in tall grass adjacent to vegetable research plots at the MSU Muck Research Farm, Bath MI, on 19 Aug 1999. Traps were checked regularly from 21 Aug to 20 Sep, and any captured *Pterostichus melanarus* ground beetles were transported to the lab. Each beetle was placed in a large petri dish with moist filter paper and cotton ball and an untreated Colorado potato beetle. All ground beetles were starved for two days prior to testing.

Two tests were conducted, one on 9 Sep and one on 20 Sep. Ten ground beetles were used in the first test and eight in the second. Ground beetles were randomly given either an untreated Colorado potato beetle or a Colorado potato beetle that had been poisoned by a topical application of 0.2 µg imidacloprid. Colorado potato beetles were treated two hours before being given to the ground beetles; this allowed us to use visibly poisoned beetles. Petri dishes were inspected at 4, 24, 48, and 72 hours, and any poisoning or mortality of either Colorado potato beetle or ground beetles was recorded, as was evidence of predation.

The two tests provided very different results. Six ground beetles (3 with untreated beetles, 3 with poisoned beetles) in the first trial fed on the Colorado potato beetle, but none showed signs of poisoning and all survived the trial. One ground beetle (paired with an imidacloprid-treated Colorado potato beetle) showed signs of poisoning, yet no indications of predation were detected.

In the second trial, most ground beetles attacked their Colorado potato beetle, but only one ground beetle consumed its Colorado potato beetle. This predation took place between days 3 and 4, and the ground beetle showed signs of poisoning at 72 hours. Four beetles died, two of which showed clear signs of poisoning.

Biological control by entomopathogenic nematodes and *Beauveria bassiana*

Soil samples were taken from four different locations in Michigan, washed and nematodes were extracted. Currently, no entomopathogenic nematodes have been found.

To test if foliar application of nematodes would be effective in the field, a solution of approximately 500 nematodes per ml of water was applied to potato leaves at room temperature (~24° C). Complete evaporation occurred in less than 15 minutes at which time all nematodes were dead. This indicates that foliar application may not be effective in the field. Soil application may be more appropriate.

Preliminary findings show that the best time to infect Colorado potato beetle is during the last (4th) instar, since they burrow into the soil to pupate, and soil applications of nematodes could target this stage. To test the pathogenicity of the entomopathogenic nematode *Heterorhabditis marelatus*, (Liu and Berry), a piece of filter paper was placed into a petri dish and inoculated with a 1 ml solution containing ~200 nematodes. Ten 4th instar Colorado potato beetle were then added. By two days, 100% of the treated instars were dead. None of the control insects were dead (treated with pure water). Further investigations will determine the most effective concentration of nematodes to use and the environmental conditions conducive to infection.

Initial tests to determine the efficacy of *Beauveria bassiana* as a biological control agent for Colorado potato beetle were conducted. Three concentrations of BotaniGard ES (Mycotech Corp.), within the recommended field rates were sprayed onto filter paper contained in petri dishes and 2nd instar Colorado potato beetle were added. After a few days fungal infection was observed in treated larvae. Studies are continuing to determine the most effective concentrations and environmental conditions conducive to infection.

Insecticide Tests

Colorado potato beetle control, 1999

Sixteen insecticide treatments (Table 8) were tested at the MSU Montcalm Research Farm, Entrican, MI for control of Colorado potato beetle. 'Snowden' potatoes were planted 12 inches apart with a 34-inch row spacing on 11 May. Treatments were replicated four times in a RCB design. Plots were 50 ft long and three rows wide. Five treatments were applied at planting. Admire was applied to seed pieces as an in-furrow spray using a single nozzle hand held boom (30 gpa, 35psi). Both Maxim + CGA 293343 treatments were pre-mixed dusts applied to seed pieces (in a plastic tub) before they were planted. Another treatment consisted of a dust application of Maxim followed by an in-furrow spray of Platinum. Lastly, a dust application of Maxim was followed by sprinkling a granular fertilizer impregnated with Platinum over the seed pieces in furrow. Foliar treatments were first applied at 80% Colorado potato beetle hatch on 15 Jun. Subsequent first-generation sprays were applied on 22 Jun, 30 Jun, and 6 Jul. Avaunt (all rates) and Kryocide/Spintor (Kryocide on first and third, Spintor on second and fourth applications) were applied on each of the spray dates. Agenda (high rate) was applied on 15 Jun only, and Agenda (low rate) and Actara were applied on 15 Jun and 30 Jun. Spintor (all rates) was applied on 15 Jun and 22 Jun. Post-spray counts were made two days after each application and consisted of complete counts of Colorado potato beetle adults and larvae (small and large) on five plants from the middle row of each plot. Defoliation ratings were taken on 29 Jun and 13 Jul. Maintenance sprays of Agrimek (16 Jul and 29 Jul) and Baythroid (22 Jul) were applied to all treatments to control second generation Colorado potato beetle. On 1 Sep, the middle row of each plot was harvested mechanically, and the tubers were separated by size and weighed. Data were analyzed using two-way ANOVA and significance was found at the 0.05 level with Fisher's Protected LSD.

There were significant differences in the seasonal means of egg masses, small larvae, and large larvae among treatments and check plots (Table 8). All treatments resulted in significantly fewer large larvae than the check on 24 June, 2 Jul, and 8 Jul. However, no significant differences were found between treatments on these dates, an effect most likely due to low Colorado potato beetle pressure. While most treatments provided good control of large larvae, the five treatments applied at planting provided the most consistent control. There was no significant effect between treatments on overall

Table 8. Seasonal mean number of Colorado potato beeltes per plant.

		Seasonal mean of 1st-generation CPB/plant			
Treatment/formulation	Rate	Egg Masses	Small Larvae	Large Larvae	Adults
Actara 25WG	14.2 g (AI)/acre	0.162 bcd	0.525abcd	0.038a	0.000a
Admire 2F[a]	13.0 fl oz (Form)/acre	0.050abc	0.006a	0.100a	0.025abc
Agenda 1.67SC	0.038 lb (AI)/acre	0.150abcd	0.444abc	0.000a	0.000a
Agenda 1.67SC	0.05 lb (AI)/acre	0.225 cd	0.256ab	0.000a	0.000a
Avaunt 30WG +	0.045 lb (AI)/acre	0.238 d	1.494 d	0.325ab	0.000a
PBO-8 +	0.25 lb (AI)/acre				
Dyne-amic	0.15 gal (Form)/acre				
Avaunt 30WG +	0.065 lb (AI)/acre	0.287 d	1.494 d	0.325ab	0.013ab
PBO-8 +	0.25 lb (AI)/acre				
Dyne-amic	0.15 gal (Form)/acre				
Avaunt 30WG +	0.11 lb (AI)/acre	0.275 d	0.775 bcd	0.250ab	0.000a
PBO-8+	0.25 lb (AI)/acre				
Dyne-amic	0.15 gal (Form)/acre				
Kryocide 96 +	9.6 lb (AI)/acre	0.225 d	0.775 bcd	0.062a	0.050abc
Spintor 2SC	4.5 fl oz (Form)/acre				
Maxim 0.5 DS[b] +	8.0 oz (Form)/cwt	0.025ab	0.006a	0.025a	0.088 bc
Platinum 2SC[a]	6.5 fl oz (Form)/acre				
Maxim 0.5 DS[b] +	8.0 oz (Form)/cwt	0.000a	0.013a	0.250ab	0.100 cd
Platinum 2SC (1999 Impregnation)[c]	250 lb (Form)/acre				
Maxim 0.5 DS +	8.0 oz (Form)/cwt	0.038ab	0.006a	0.100a	0.075abc
CGA 293343 (1:2 prepack)[b]					
Maxim 0.5 DS +	8.0 oz (Form)/cwt	0.050abc	0.000a	0.000a	0.075abc
CGA 293343 (1:2.4 prepack)[b]					
Spintor 2SC	3.0 fl oz (Form)/acre	0.150abcd	0.325abc	0.525 b	0.000a
Spintor 2SC	4.5 fl oz (Form)/acre	0.262 d	1.438 cd	0.563 b	0.038abc
Spintor 2SC	6.0 fl oz (Form)/acre	0.288 d	0.737 bcd	0.337ab	0.062abc
Untreated check		0.213 cd	0.962 bcd	4.200 c	0.175 d

Means within a column followed by different letters are significantly different ($P<0.05$, Fisher's Protected LSD). Data transformed for analysis with log (x+1), means presented in non-transformed units.

[a] treatment applied in-furrow at planting

[b] treatment applied to seed pieces as dust before planting

[c] fertilizer sprinkled over seed pieces in-furrow at planting

Table 9. Mean potato yield (pounds per row) harvested and mean defoliation rating [d] on two dates. CPB trial

Treatment/formulation	Rate	Yield (lb/plot)			Defoliation rating[d]	
		Size A	Size B	Total	29 Jun	13 Jul
Actara 25WG	14.2 g (AI)/acre	97.50	4.40abc	101.90	1.00 bc	0.50abc
Admire 2F[a]	13.0 fl oz (Form)/acre	103.65	6.20 cde	109.85	0.00abc	0.75 bcd
Agenda 1.67SC	0.038 lb (AI)/acre	91.55	5.95 bcde	97.50	1.00 bc	0.50abc
Agenda 1.67SC	0.05 lb (AI)/acre	99.40	5.00abcde	104.40	1.00 bc	0.00a
Avaunt 30WG +	0.045 lb (AI)/acre	81.90	4.05ab	89.95	1.00 bc	1.00 cd
PBO-8 +	0.25 lb (AI)/acre					
Dyne-amic	0.15 gal (Form)/acre					
Avaunt 30WG +	0.065 lb (AI)/acre	102.85	5.10abcde	107.95	1.50 c	1.00 cd
PBO-8 +	0.25 lb (AI)/acre					
Dyne-amic	0.15 gal (Form)/acre					
Avaunt 30WG +	0.11 lb (AI)/acre	96.05	4.65abcd	100.70	1.00 bc	1.00 cd
PBO-8+	0.25 lb (AI)/acre					
Dyne-amic	0.15 gal (Form)/acre					
Kryocide 96 +	9.6 lb (AI)/acre	98.90	5.75 bcde	104.65	0.75abc	0.50abc
Spintor 2SC	4.5 fl oz (Form)/acre					
Maxim 0.5 DS[b] +	8.0 oz (Form)/cwt	88.50	5.70 bcde	94.23	0.00a	0.25ab
Platinum 2SC[a]	6.5 fl oz (Form)/acre					
Maxim 0.5 DS[b] +	8.0 oz (Form)/cwt	83.75	3.20a	86.95	0.00a	0.75 bcd
Platinum 2SC (1999 Impregnation)[c]	250 lb (Form)/acre					
Maxim 0.5 DS +	8.0 oz (Form)/cwt	82.55	6.35 de	88.90	0.25ab	0.75ab
CGA 293343 (1:2 prepack)[b]	8.0 oz (Form)/cwt					
Maxim 0.5 DS +	8.0 oz (Form)/cwt	91.70	4.60abcd	96.30	0.25ab	0.25ab
CGA 293343 (1:2.4 prepack)[b]	8.0 oz (Form)/cwt					
Spintor 2SC	3.0 fl oz (Form)/acre	100.70	6.10 cde	106.80	1.00 bc	1.25 d
Spintor 2SC	4.5 fl oz (Form)/acre	97.60	6.60 e	104.20	0.75abc	1.00 cd
Spintor 2SC	6.0 fl oz (Form)/acre	90.60	6.60 e	97.20	1.00 bc	1.00 cd
Untreated check		89.30	4.65abcd	93.95	3.00 d	2.25 e

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

[a] treatment applied in-furrow at planting

[b] treatment applied to seed pieces as dust before planting

[c] fertilizer sprinkled over seed pieces in-furrow at planting

[d] Defoliation rating: 0, no defoliation; 1, slight damage to leaflets; 2, at least 50% defoliation of some compound leaves; 3, one or more stems at least 50% defoliated on some plants.

yield (Table 9). The highest yields were harvested from plots treated with Admire, Avaunt (0.065 lb. AI/acre), and Spintor (3 fl oz/acre), respectively. Compared with the check, defoliation ratings were significantly lower for all treatments.

Potato leafhopper control, 1999:

Seven insecticide treatments (Table 10) were tested at the MSU Montcalm Research Farm, Entrican, MI for control of potato leafhopper (PLH). 'Atlantic' Bt by NatureMark® seed potatoes were planted 12 inches apart with a 34-inch row spacing on 20 May. Plots were 50 ft single rows arranged in a RCB design with four replications per treatment. Five treatments were applied at planting. Admire was applied to seed pieces as an in-furrow spray using a single nozzle hand held boom (30 gpa, 35 psi). Both Maxim + CGA 293343 treatments were pre-mixed dusts applied to the seed pieces before they were planted. Another treatment consisted of a dust application of Maxim followed by an in-furrow spray of Platinum. Lastly, a dust application of Maxim was followed by sprinkling a granular fertilizer, impregnated with Platinum, over the seed pieces in the furrow. The foliar treatment, Actara, was applied when potato leafhopper numbers exceeded 1.0 adults/sweep or 0.5 adults/sweep and nymphs were present. Actara was sprayed on 30 Jun, 13 Jul, 20 Jul, 26 Jul, and 3 Aug. Post-spray counts were conducted two days after each application. Both a sweep net sample (ten sweeps per plot) and a visual count of potato leafhopper adults and nymphs on six leaves (two near top, two from middle, and two near base of plant) from five randomly selected plants were performed on each plot. On 1 Sep, each plot was harvested mechanically and the tubers were separated by size and weighed. Data were analyzed using two-way ANOVA and significance was found at the 0.05 level with Fisher's Protected LSD.

There were no significant differences in the seasonal means of potato leafhopper adults and nymphs among treatments and check plots for either sampling technique (Table 10). Also, there was no significant effect between treatments on overall yield (Table 11). The highest yields were harvested from plots treated with Maxim + Platinum (1999 Impregnation), Maxim + CGA 293343 (1:2 prepack), and Maxim + Platinum.

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Table 10. Seasonal mean number of potato leafhopper (PLH) adults and nymps per 10 sweeps and per 6 leaves.

		Seasonal mean of PLH/10 sweeps		Seasonal mean of PLH/six leaves	
Treatment/formulation	Rate	PLH adult	PLH nymph	PLH adult	PLH nymph
Actara 25WG	14.2 g (AI)/acre	6.167	0.042	0.233	0.100
Admire 2F[a]	13.0 fl oz (Form)/acre	4.375	0.375	0.375	0.033
Maxim 0.5 DS[b] + Platinum 2SC[a]	8.0 oz (Form)/acre 6.5 fl oz (Form)/acre	5.250	0.000	0.142	0.025
Maxim 0.5 DS[b] + Platinum 2SC(1999 Impregnation)[c]	8.0 oz (Form)/acre 250 lb (Form)/acre	5.041	0.042	0.143	0.033
Maxim 0.5 DS + CGA 293343 (1:2 prepack)[b]	8.0 oz (Form)/acre	5.334	0.000	0.183	0.033
Maxim 0.5 DS + CGA 293343 (1:2.4 prepack)[b]	8.0 oz (Form)/acre	3.208	0.042	0.133	0.008
Untreated check		4.750	0.000	0.233	0.117

Table 11. Mean yield of potatoes (pounds per row), potato leafhopper trial

		Yield (lb/plot)		
Treatment/formulation	Rate	Size A	Size B	Total
Actara 25WG	14.2 g (AI)/acre	34.80	2.20	37.00
Admire 2F[a]	13.0 fl oz (Form)/acre	32.60	2.60	35.20
Maxim 0.5 DS[b] + Platinum 2SC[a]	8.0 oz (Form)/acre 6.5 fl oz (Form)/acre	38.25	2.70	40.95
Maxim 0.5 DS[b] + Platinum 2SC(1999 Impregnation)[c]	8.0 oz (Form)/acre 250 lb (Form)/acre	43.60	1.85	45.45
Maxim 0.5 DS + CGA 293343 (1:2 prepack)[b]	8.0 oz (Form)/acre	38.60	2.75	41.35
Maxim 0.5 DS + CGA 293343 (1:2.4 prepack)[b]	8.0 oz (Form)/acre	37.60	2.05	39.65
Untreated check		33.25	2.40	35.65

[a]treatment applied in-furrow at planting
[b]treatment applied to seed pieces as dust before planting
[c]fertilizer sprinkled over seed pieces in-furrow at planting

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Combining Varietal Resistance with Managed Fungicide Applications for the Control of Potato Late Blight.

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INTRODUCTION

Late blight (*Phytophthora infestans*) is a major threat to the production of high quality potatoes in Michigan. The appearance of a more aggressive strain of *P. infestans* (US8), resistance of this pathogen to metalaxyl and the potential loss of some currently effective protective fungicides, compounds the serious nature of this problem. The economics of crop production demand that cost effective crop protection is a prime concern for the whole industry. Public pressure to reduce crop production inputs without compromising crop quality is increasing. The North American late blight workshop held at Tucson, AZ in 1997 identified that the development of integrated crop protection programs that focus on durable resistance to potato late blight should be considered as a priority for the North American potato industry. Durable resistance was defined as production systems that utilized potato cultivars with reduced susceptibility to late blight in combination with managed fungicide applications. Successful, long-term control of this disease will require a combined effort that will incorporate the use of carefully managed fungicide programs, resistant varieties developed through breeding and the use of novel resistance mechanisms such as those achieved via genetic engineering. The objective of this research was aimed at developing the tools necessary to control late blight using fungicides in combination with heritable host resistance.

Experiments in 1999 were set up to evaluate the efficacy of crop protection programs against potato late blight utilizing fungicides with a) reduced amounts of commercially available fungicide and with reduced amounts of novel fungicides with lower amounts of active ingredient fungicides and b) with reduced amounts of commercially available fungicide at reduced application frequency.

MATERIALS AND METHODS

Potato tubers were planted at the Michigan State University Muck Soils Experimental Station, Bath, MI on 1 June into two-row by 25-foot plots, (experiment a, reduced amounts of fungicide) and two-row by 12-foot plots (experiment b, reduced amounts of commercially available fungicide at reduced application frequency). Both experiments were planted with 9-inch between plants and at 34-inch row spacing) replicated four times in a randomized complete block design. The two-row beds were separated by a five-foot blank row. Plots were irrigated as needed with sprinklers and were hilled immediately before sprays began. All plants were inoculated (100 ml/25-foot row) with a zoospore suspension of *Phytophthora infestans* US8 (insensitive to metalaxyl, A2 mating type) genotype (10^3 zoospores/ml) on 23 Jul. Fungicides were applied from 25 Jun to 13 Aug (9 applications expt. a, 5 - 15 applications expt. b) with an ATV rear-mounted R&D spray boom delivering 25 gal/A (80 p.s.i.) and using three XR11003VS nozzles per row. Weeds were controlled by hilling and with Dual 8E (2 pt/A on 5 Jun), Basagran (2 pt/A on 15 Jun and 5 Jul) and Poast (1.5

pt/A on 23 Jul). Insects were controlled with Admire 2F (20 fl oz/A at planting on 26 Jun), Sevin 80S (1.25 lb on 1 and 23 Jul), Thiodan 3EC (2.33 pt/A on 1 and 21 Aug) and Pounce 3.2EC (8 oz/A on 23 Jul). Plots were rated visually for percentage foliar area affected by late blight on 23, 31 Jul, 7, 14 and 23 Aug. Late blight disease severity values were calculated using the Wallin model from temperature and relative humidity values recorded at canopy level with a remote access weather station.

Experiment a) active ingredient and variety interaction trial: the fungicides chlorothalonil (Bravo WS 6SC) and fluazinam 5SC were applied at 33, 67 and 100% of the recommended field application rates. Chemical treatments were begun before inoculation with the US8-A2 biotype of *P. infestans* (three applications).

Experiment b) application timing frequency and variety interaction trial: the fungicide chlorothalonil (Bravo WS 6SC) was applied at 33, 67 and 100% of the recommended field application rates at intervals of 5, 10 and 15 days in two varieties varying in susceptibility to late blight, MSG 274-3 (moderately resistant) and Snowden (susceptible). Chemical treatments were begun before inoculation with the US8-A2 biotype of *P. infestans* and varied from four applications (5 day program), 3 applications (10 day program) and 2 applications (15 day program).

Foliar late blight was assessed at various times after inoculation, with 32 days after inoculation (dai) taken as a key reference point. The average amount of disease that developed over the disease progress period was expressed as the relative area under the disease progress curve (RAUDPC). The area under the disease progress curve (AUDPC) was calculated by adding the area under the linear progression of disease between each successive estimation of disease from inoculation to 32 days after inoculation. The RAUDPC is calculated by dividing the measured AUDPC by the maximum AUDPC (100 x duration of the epidemic, from inoculation to 100% plant death). The RAUDPC was expressed with a maximum value of 100. An arbitrary scale of resistance to late blight was determined related to RAUDPC: 0 - 5, resistant; 5 - 10, moderately resistant; 10 - 20 moderately susceptible; > 20 susceptible. Data were analyzed by three-way analysis of variance and means compared at P = 0.05 level of significance by a multiple range comparison of means (Tukey, SAS).

Varietal Selection

Varieties for the active ingredient and variety interaction trial were selected form the 1998 breeding program late blight assessment trial. This material consisted of commercial cultivars, putative resistant germplasm and advanced breeding lines from MSU and other university potato breeding programs. No fungicides were applied during the season. Inoculation with the US8 biotype of *P. infestans* was made 23 Jul when foliage was vigorous and healthy. Foliar disease was assessed frequently after'inoculation (minimum 5 days) and RAUDPC (see above) was calculated to evaluate disease development over the season until 28 days after inoculation. The varieties that had low RAUDPC values (10 - 20) and with the best agronomic qualities were selected for inclusion in the 1999 active ingredient and variety interaction trial. The variety and the advance breeding line selected for the application timing frequency and variety interaction trial were selected as representative lines which were susceptible or moderately resistant to late blight consistently over three years of variety trials (data presented in late blight assessment reports, Michigan Potato Research Report 1996 - 1998).

RESULTS, 1999 FIE LD SEASON:

Late blight developed rapidly during August and untreated controls in susceptible varieties reached 85 - 95% foliar infection by 14 Aug. The accumulated late blight disease severity values from June 13 to Aug 30 were 78, which indicated that environmental conditions were highly conducive for the development of late blight.

Experiment a) active ingredient and variety interaction trial: The varieties had significantly different responses to the inoculation of *P. infestans*, US8 biotype (Fig 1, 0 rate of fungicide application). All varieties tested were classified as susceptible to late blight (RAUDPC > 20) were in the untreated controls except G 274-3 which was classified as moderately resistant (RAUDPC 5 - 10). A091-1 had significantly lower RAUDPC value (ca. 22) than the most susceptible varieties Atlantic, Snowden and E246-5 (≥40). Varieties E018-1, FL1833 and FL1533 had RAUDPC values between 30 and 40 and FL1625 and A091-1 were between 20 - 30.

Most fungicide programs (chlorothalonil and fluazinam, full rate) applied as protectants reduced the level of late blight foliar infection significantly (p = 0.05) compared to the untreated control of the most susceptible variety (Snowden) at the full rate of application in all varieties (Fig 1).

Fungicide application rates of 0.33 of chlorothalonil and fluazinam did not affect the RAUDPC value of G274-3 however rates of 0.67 and 1.0 of both fungicides reduced the RAUDPC values to below 5 (Fig 1). The reduction in RAUDPC in G274-3 was not statistically significant (p = 0.05) between rates of fungicide from 0 - 1.0 of either fungicide. Fungicide application rates of 100% chlorothalonil decreased the RAUDPC to about 10 in only Atlantic, FL1833 and E246-5 (Fig 1). There was a clear reduction in RAUDPC with increase in dose application rate for most varieties however, in some varieties e.g. A091-1, there was little change in RAUDPC between 0.0 and 0.33 rates after application of either fungicide. There was some indication that some varieties responded more to chlorothalonil (e.g. FL1833) than to fluazinam (e.g. FL1533)at the lowest rate of application (Fig 1) however most varieties responded more to fluazinam than to chlorothalonil at 0.33 application rate. Generally, the reduction in RAUDPC was linear between 0 and 0.67 application rates in most varieties then a lower reduction from 0.67 to 1.0 application rate for both fungicides (Fig 1).

Experiment b) application timing frequency and variety interaction trial: G274-3 and Snowden had significantly different responses to the inoculation of *P. infestans*, US8 biotype (Fig 2, 0 rate of fungicide application). Snowden was classified as susceptible to late blight (RAUDPC > 20) but G274-3 was classified as moderately resistant (RAUDPC 5 - 10). The interval and rate of application of chlorothalonil made no significant difference to the RAUDPC recorded in G274-3, which was less than 5 for all combinations (Fig 2). In Snowden, application of chlorothalonil at 0.33 - 1.0 full rate of application at 5 day application intervals significantly reduced the RAUDPC (to between 5 and 10) in comparison to the untreated Snowden control (Fig 2). There were no significant differences between the application rates of chlorothalonil at the 5 day application interval. At the 10 and 15 day application intervals the RAUDPC remained > 20 at all rates and intervals except at the 10 day interval, full application rate which was close to 20 (Fig 2).

Discussion

Combination of varietal resistance with chemical applications can provide effective disease control. This can be accomplished at lower rates of application with a conventional fungicide e.g chlorothalonil (Bravo WS 6SC) or with the novel fungicide fluazinam with a lower amount of active ingredient. In previous years, reduced amounts of both chlorothalonil and fluazinam were effective at all application rates tested on all varieties in comparison with the untreated controls. However, in 1999 the environmental conditions were more favorable for the development of late blight and the lowest application rates proved unsatisfactory. The least susceptible varieties as in previous years e.g. G274-3 did not respond to application of rates greater than 33% of the full recommended rate of either fungicide. This suggests that for control of current biotypes of late blight in the US, a fungicide program is barely necessary except perhaps for control of other pathogens such as early blight (*Alternaria solani*).

Trials conducted in 1997 and 1998, suggested that an application interval of 10 days only resulted in acceptable disease control in the least susceptible varieties and advanced breeding lines treated with 100% of the recommended rate of chlorothalonil. The results in 1999 confirmed this result. Application of fungicides at 10 and 15 day application intervals gave unsatisfactory control of late blight at all rates of chlorothalonil tested. The efficacy of fluazinam at an application interval of 10 or 15 days at reduced application rates was not evaluated. The similarity in efficacy against late blight between chlorothalonil and fluazinam in the 1998 trials suggests that fluazinam may not be effective at reduced application rates beyond a 7-day application interval. The activity of fluazinam at reduced rates of application and decreased frequency of application interval against late blight needs to be determined in the varieties that were least susceptible to late blight. The opportunity for reduction of fungicide applications by managing the rate of application of traditional fungicides and novel fungicides with lower amounts of active ingredient in varieties less susceptible to late blight is clear. More critical dose response studies are required for new chemicals to establish effective rates of application for the control of late blight. The efficacy of reduced rates of these fungicides against other potato pathogens such as *A. solani* (early blight) has not been established and may prove to be a major constraint in the adoption of managed rate fungicide applications.

The MSU advanced selection, G274-3, was the advanced breeding line with the most outstanding foliar resistance in the trial. G-274-3 also has good horticultural characteristics.G274-3 will continue to be used as a parent to transfer resistance to other genetic backgrounds and be developed as a commercial line. The varieties falling into the moderately susceptible category may be protected with reduced application rates of protectant fungicides and some of these lines will be evaluated in 1999 in the managed fungicide application trial.

Some of the lines that are most resistant to late blight will be used as parental material in the MSU Potato Breeding Project. This group included many unadapted varieties and breeding lines.

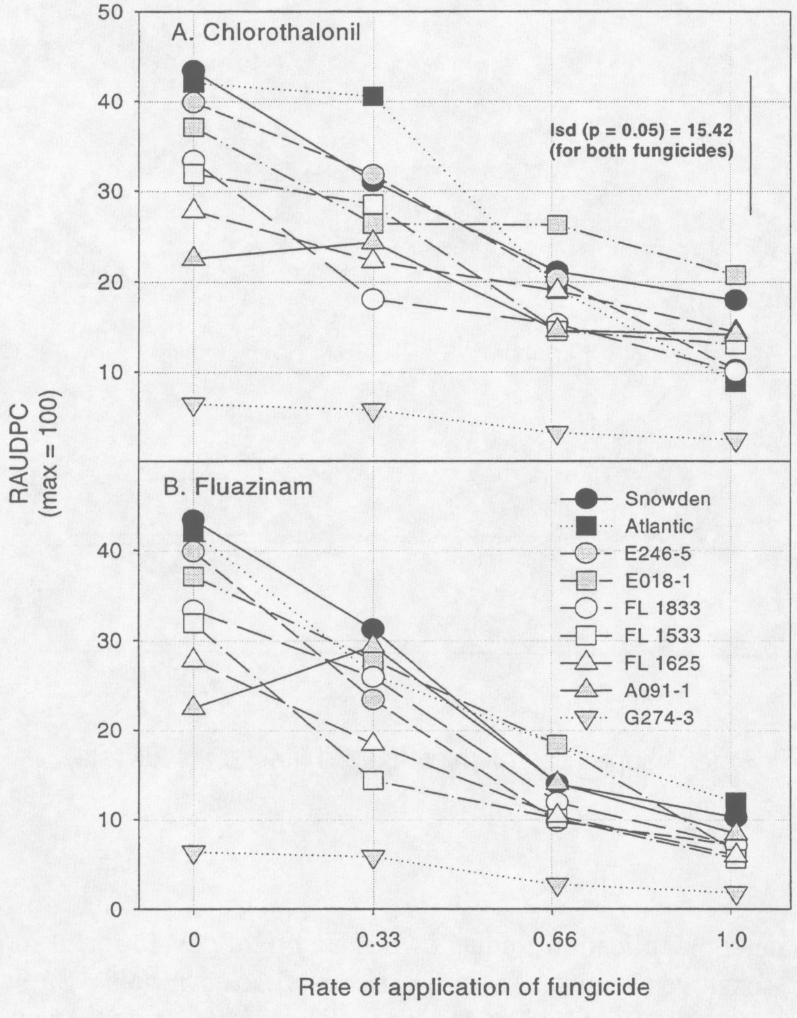

Figure 1. Relative area under the disease progress curve (max = 100) in potato varieties and advanced breeding lines protected with reduced and full rates of chlorothalonil or fluazinam and inoculated with *P. infestans* (US8, A2). Cvs ranked in decreasing order of susceptibility to *P. infestans* (determined in this trial). Accumulated late blight Disease Severity Values = 78 from June 13 to August 30, 1999.

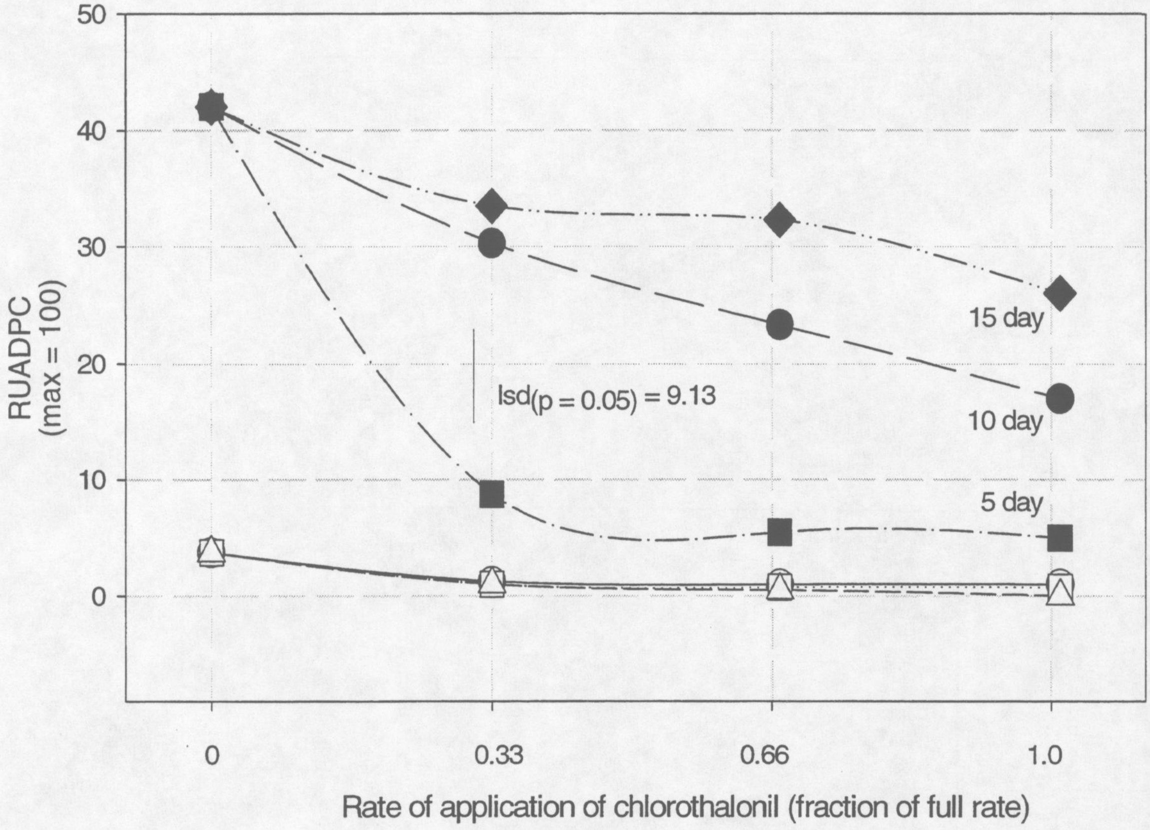

Figure 2. Effect of dose rate and application frequency on late blight development in moderately resistant (MSG 274-3) and sensitive (Snowden) potato varieties. Black symbols = Snowden, White symbols = MSG 274-3; ■, 5 day, ●, 10 day and ◆, 15 day application frequency. Accumulated late blight Disease Severity Values = 78 from June 13 to August 30, 1999.

Funding: Industry

The Role of Dimethomorph within a Potato Late Blight (Phytophthora infestans) Control Program. Mixture partners and optimal application timing.

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INTRODUCTION

Potato late blight (*Phytophthora infestans*) is the most important potato pathogen in the United States. Yield loss is direct through tuber infection and the associated rot or indirect through a reduction of photosynthetic potential. Control of late blight is achieved by cultural practices and foliar fungicide based control programs. In Michigan the standard program consists of regular preventative applications of chlorothalonil (e.g. Bravo WS) or EBDC (e.g. Penncozeb) based fungicides. The initiation of fungicide application typically occurs prior to row closure. Spray program factors may be partly based upon weather conditions. When late blight is present, or when weather conditions are conducive to disease, additional or alternative fungicides may be employed. These fungicides may also have properties (e.g. antisporulation or curative) that allow for the specific positioning of the product at certain points within the season and under certain conditions. Field trials were conducted in the presence of late blight in order to evaluate the optimal placement and rate of dimethomorph and mixture partners within a chlorothalonil based foliar fungicide control program with respect to foliar disease levels and tuber loss due to late blight.

METHODS

Cut potato seed (cv. Snowden) was planted at the Michigan State University Muck Soils Experimental Station, Bath, MI on 6 June 1999 into two-row by 25-foot plots (34-inch row spacing) replicated four times in a randomized complete block design. The two-row beds were separated by a five-foot unplanted row. Weeds were controlled by hilling and with Dual 8E (2 pt/A on 5 Jun), Basagran (2 pt/A on 15 Jun and 5 Jul) and Poast (1.5 pt/A on 23 Jul). Insects were controlled with Admire 2F (20 fl oz/A at planting on 6 Jun), Sevin 80S (1.25 lb/A on 1 and 23 Jul), Thiodan 3EC (2.33 pt/A on 1 and 21 Aug) and Pounce 3.2EC (8 oz/A on 23 Jul). Plots were irrigated as needed with sprinklers and managed under standard potato agronomic practices. Plots were inoculated (3.38 fl-oz/25-foot plot) with a mixed isolate zoospore suspension of *Phytophthora infestans* US8/A2 at 10^4 spores/fl-oz on 10 Aug. Fungicides were applied with an ATV rear-mounted R&D spray boom delivering 25 gal/A (80 p.s.i.) and using three XR11003VS nozzles per row. Application commenced on 6 July and continued on a seven day schedule for a total of eight applications. See Table 1 for fungicide programs. Vines were killed with Diquat 2EC (1 pt/A on 28 Aug and 4 Sep).

The number of plants emerged per row for both rows within each plot was counted on 16 July. Plots were rated visually for percentage foliar area affected by late blight on 6, 13, 20, and 28 Aug and 8 Sept. The relative area under the disease progress curve (RAUDPC) was calculated for each treatment. On 9 Aug four plants per plot were destructively harvested and the number and size of tubers per plant was counted. Tubers were separated into two groups, those smaller than (size B), or larger than (size A), ~1.25 inch diameter. On 21 Sep plots were harvested mechanically and yields were taken for each size group. The number of tubers per plot was then counted and an area under the tuber loss curve (AUTLC) was generated for both size classes. This is a season long measure of the number of tubers per plant. Larger AUTLC values indicated that tuber survival was greater over the growing season.

Excluding the untreated control and season-long mancozeb (Penncozeb) or chlorothalonil (Bravo WS) programs, each control program was based on chlorothalonil applications with a 7 day spray interval. The first replacement program consisted of two dimethomorph-based (Acrobat 50 WP) fungicide(s) applications prior to inoculation. The second program consisted of one application prior to inoculation and one prior to dessication. Rates used for dimethomorph and mancozeb are based upon those used in the label rate application of Acrobat MZ 69WP (2.25lb/A). Increased rate dimethomorph applications were twice the label rate. Chlorothalonil rates followed recommendations on the product label.

RESULTS

Foliar and yield results are in Table 1. The level of foliar infection for the fungicide programs was significantly lower than the untreated control for each assessment. In only the final foliar assessment did fungicide programs differ significantly from each other. The program in which mancozeb and dimethomorph were co-applied as replacements for chlorothalonil one application before inoculation and dessication had significantly lower foliar disease than the double rate dimethomorph treatment with the same application timing. The remaining programs did not differ from the previously listed programs. The RAUDPC followed the same trend as final foliar disease. The program with the highest marketable yield was the season-long mancozeb program. Six of ten fungicide programs had significantly lower marketable yield. Additional variation existed, but no patterns were noted. The total yield per plot did not differ significantly between treatments. Tuber number results are in Table 2. At the first tuber assessment point differences existed in the number of size B (< ~1.25 inch) tubers per plant, but not the number of marketable sized (size A) tubers per plant. A similar trend existed for the final number of tubers per plant for both size grades. For the size B tubers, the untreated control had the largest AUTLC value. The fungicide programs had significant differences. For the marketable tuber size class no significant differences existed between treatments for the AUTLC.

DISCUSSION

In terms of foliar disease, all of the fungicide programs were as effective as the season long chlorothalonil program, but none were significantly better. Excluding the difference between the program in which mancozeb and dimethomorph were co-applied as replacements for chlorothalonil one application before inoculation and dessication and the double rate dimethomorph treatment with the same application timing, the programs were essentially identical in terms of late blight foliar disease levels. The programs with early or full season mancozeb use tended to have increased yield regardless of the level of foliar late blight. This effect may be due to activity against non-target pathogens such as *Alternaria solani*. The use of dimethomorph alone, at both label and twice label rates for each timing program, tended to have increased foliar infection levels and reduced yield. Since the amount of active applied was relatively small, this was not surprising. The number of emerged plants per experimental plot did not differ significantly, indicating statistically acceptable comparisons of tuber number and AUTLC. The lack of significant differences between the number of marketable tubers per plant and the AUTLC for each treatment suggested that programs with larger yields were undergoing more tuber bulking and producing larger tubers without increasing tuber number.

The use of both chlorothalonil and mancozeb as mixture partners for dimethomorph is feasible. Economic considerations do not support the addition of dimethomorph as no apparent benefit was gained. However, recent legislative (FQPA) activities may eventually call for the reduction of the amount of chlorothalonil and mancozeb applied. The examination of reduced rate chlorothalonil or mancozeb applications with full rate dimethomorph may allow for an overall reduction in restricted fungicide usage without compromising efficacy. Additionally, certain fungicides with specific effects upon the pathogen and the optimal placement of these products within a prophylactic fungicide based program should be examined further.

Table 1. Treatments, schedule and rate of active components applied. Percent foliar late blight at each assessment date, relative area under the disease progress curve (RAUDPC) values, and yield for both marketable and total tubers.

Treatment	Schedule[1]	Rate Active (lbs/A)	Percent Foliar Blight[2]				RAUDPC[3]	Yield (cwt/A)	
			8/13/99	8/20/99	8/28/99	9/08/99		Size A[4]	Total
Bravo WS 6SC, Bravo WS 6SC	1 2-8	0.75, 1.00	0.00 a[5]	0.66 a	2.66 a	68.33 ab	0.13 ab	257.2 bc	294.9 a
Bravo WS 6SC, Penncozeb 80DF	1 2-8	0.75, 1.35	0.00 a	0.33 a	2.33 a	61.66 ab	0.12 ab	311.7 a	343.8 a
Bravo WS 6SC, Bravo WS 6SC + Acrobat 50WP, Bravo WS 6SC	1 2-3 4-8	0.75, 1.00 + 0.20, 1.00	0.00 a	0.00 a	2.33 a	70.00 ab	0.13 ab	240.6 bcd	280.1 a
Bravo WS 6SC, Bravo WS 6SC + Acrobat 50WP, Bravo WS 6SC	1 2,8 3-7	0.75, 1.00 + 0.20, 1.00	0.00 a	1.00 a	2.00 a	56.66 ab	0.11 ab	279.7 abc	310.4 a
Bravo WS 6SC, Penncozeb 80DF + Acrobat 50WP, Bravo WS 6SC	1 2-3 4-8	0.75, 1.35 + 0.20, 1.00	0.00 a	0.66 a	3.66 a	56.66 ab	0.11 ab	289.6 ab	318.2 a
Bravo WS 6SC, Penncozeb 80DF + Acrobat 50WP, Bravo WS 6SC	1 2,8 3-7	0.75, 1.35 + 0.20, 1.00	0.00 a	0.00 a	0.33 a	53.33 a	0.10 a	229.2 cd	260.2 a
Bravo WS 6SC, Acrobat 50WP, Bravo WS 6SC	1 2-3 4-8	0.75, 0.20, 1.00	0.00 a	0.33 a	1.66 a	68.33 ab	0.13 ab	250.1 bc	298.4 a
Bravo WS 6SC, Acrobat 50WP, Bravo WS 6SC	1 2,8 3-7	0.75, 0.20, 1.00	0.33 a	0.66 a	1.33 a	66.66 ab	0.12 ab	226.8 cd	251.4 a
Bravo WS 6SC, Acrobat 50WP, Bravo WS 6SC	1 2-3 4-8	0.75, 0.40, 1.00	0.00 a	0.00 a	1.00 a	66.66 ab	0.12 ab	260.0 abc	303.7 a
Bravo WS 6SC, Acrobat 50WP, Bravo WS 6SC	1 2,8 3-7	0.75, 0.40, 1.00	0.00 a	0.66 a	2.66 a	71.66 b	0.14 b	241.4 bcd	277.3 a
Untreated	n/a	n/a	4.00 b	26.00 b	93.33 b	100.0 c	0.52 c	192.3 d	250.3 a

1. Application schedule; 6, 13, 20, 27 July, 3, 10, 17, 24 Aug.
2. The foliar assessment on 6 Aug. represents a pre-inoculation assessment and was NSD at a = 0.05 (LSD)
3. Relative Area Under the Disease Progress Curve
4. Represents tubers > ~1.25 inch diameter
5. Values followed by the same numbers are NSD at $\alpha = 0.05$ (LSD)

Table 2. Treatments and schedule. Number of tubers per plant at both assessment points and the area under the tuber loss curve (AUTLC) for tubers sizes.

Treatment	Schedule[1]	Number Tubers / Plant[2]				AUTLC[3]	
		8/09/99		9/21/99		Size B	Size A
		B	A	B	A		
Bravo WS 6SC, Bravo WS 6SC	1 2-8	7.78 ab[4]	4.74 a	2.73 bc	7.10 a	63.09 abc	74.00 a
Bravo WS 6SC, Penncozeb 80DF	1 2-8	10.32 c	7.43 a	2.55 bc	9.02 a	77.29 cd	98.74 a
Bravo WS 6SC, Bravo WS 6SC + Acrobat 50WP, Bravo WS 6SC	1 2-3 4-8	7.95 abc	3.97 a	3.06 abc	8.14 a	66.06 abc	65.08 a
Bravo WS 6SC, Bravo WS 6SC + Acrobat 50WP, Bravo WS 6SC	1 2,8 3-7	8.67 bc	4.74 a	2.30 bc	7.15 a	65.87 abc	72.82 a
Bravo WS 6SC, Penncozeb 80DF + Acrobat 50WP, Bravo WS 6SC	1 2-3 4-8	9.30 bc	5.01 a	1.90 a	6.87 a	67.26 bc	72.99 a
Bravo WS 6SC, Penncozeb 80DF + Acrobat 50WP, Bravo WS 6SC	1 2,8 3-7	6.07 a	5.90 a	2.39 bc	7.39 a	50.80 a	76.32 a
Bravo WS 6SC, Acrobat 50WP, Bravo WS 6SC	1 2-3 4-8	7.26 ab	5.32 a	4.06 bc	7.58 a	68.00 bc	80.76 a
Bravo WS 6SC, Acrobat 50WP, Bravo WS 6SC	1 2,8 3-7	7.75 ab	4.40 a	2.01 a	7.59 a	58.60 ab	69.00 a
Bravo WS 6SC, Acrobat 50WP, Bravo WS 6SC	1 2-3 4-8	7.07 ab	4.10 a	3.41 bc	6.42 a	62.94 abc	70.17 a
Bravo WS 6SC, Acrobat 50WP, Bravo WS 6SC	1 2,8 3-7	7.45 ab	7.80 a	2.65 bc	7.10 a	60.70 ab	85.37 a
Untreated	n/a	9.46 bc	4.69 a	5.46 d	6.81 a	89.60 d	70.78 a

1. Application schedule; 6, 13, 20, 27 July, 3, 10, 17, 24 Aug.
2. Size B: tubers <~1.25 inch diameter, Size A: tubers >~1.25 inch diameter
3. Area Under the Tuber Loss Curve - larger values mean more tubers.
4. Values followed by the same numbers are NSD at $\alpha = 0.05$ (LSD)

Funding: Industry

Chemical control of potato late blight 1999

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INTRODUCTION

Potato late blight (*Phytophthora infestans*) is the most important potato pathogen in Michigan. For five years in succession, successful epidemics have been established at the Michigan State University Experimental Research Farm, Bath, MI. In 1999, several foliar fungicide efficacy trials were carried out to establish the efficacy of fungicides applied to control established infections and to prevent infections from becoming established. The following report outlines the efficacy of many products tested under different levels of disease conditions.

METHODS

Potatoes (cut seed) were planted at the Michigan State University Muck Soils Experimental Station, Bath, MI on 29 May into two-row by 25-ft plots (34-in. row spacing) replicated four times in a randomized complete block design. The two-row beds were separated by a five-foot unplanted row. Plots were irrigated as needed with sprinklers and were hilled immediately before sprays began. The center and outside guard double rows were inoculated (3.4 fl oz/25-foot row) with a zoospore suspension of *Phytophthora infestans* US8 biotype (insensitive to metalaxyl, A2 mating type) at 10^4 spores/fl oz on 23 Jul. Fungicides were applied weekly (unless otherwise stated) from 25 Jun to 13 Aug (9 applications) with an ATV rear-mounted R&D spray boom delivering 25 gal/A (80 p.s.i.) and using three XR11003VS nozzles per row. Weeds were controlled by hilling and with Dual 8E (2 pt/A on 5 Jun), Basagran (2 pt/A on 15 Jun and 5 Jul) and Poast (1.5 pt/A on 23 Jul). Insects were controlled with Admire 2F (20 fl oz/A at planting on 26 Jun), Sevin 80S (1.25 lb on 1 and 23 Jul), Thiodan 3EC (2.33 pt/A on 1 and 21 Aug) and Pounce 3.2EC (8 oz/A on 23 Jul). Plots were rated visually for percentage foliar area affected by late blight on 23, 31 Jul, 7, 14, 23 and 28 Aug when there was 100% foliar infection in the untreated plots. The relative area under the disease progress curve was calculated for each treatment. Vines were killed with Diquat 2EC (1 pt/A on 10 Sep). Plots (25 ft row) were harvested on 28 Sept and individual treatments were weighed and graded.

Results (general)

Late blight developed rapidly during August and untreated controls reached 85 - 95% foliar infection by 14 Aug. *Botrytis cinerea* and *Alternaria solani* developed during the last week of August, and potato plants in some treatments were severely infected. Most fungicide programs with seven-day application intervals applied as protectants reduced the level of late blight foliar infection significantly compared to the untreated control. Results are presented by trial blocks. In general yields were low due to late planting, extremely high late blight pressure and early desiccation of the plots. No significant tuber rot was detected 90 days after storage in any treatment.

General Conclusion

Under the conditions experienced at the research farm in 1999, it was clear that the initial applications of protectant fungicides are vital for effective control of potato late blight. Protectant products must be applied in order to build up a residual base to prevent initial infections of potato late blight.

Trial 1. EVALUATION OF QUADRIS 2.08SC, FLUAZINAM AND BRAVO ZN WS 6SC MIXED PROGRAMS AND BRAVO ZN 6SC + SUPERTIN 80WP PROGRAMS FOR POTATO LATE BLIGHT CONTROL, 1999:

Introduction

Quadris 2.08SC contains azoxystrobin and was registered for use as a late blight and early blight fungicide in 1999. This trial compared programs of Quadris 2.08SC in alternation with Bravo WS 6SC and Fluazinam 5SC with Bravo WS 6SC ± SuperTin 80WP programs.

Foliar disease (Table 1)

Late blight developed slowly after inoculation then rapidly during Aug and untreated controls reached 85 - 95% foliar infection by 20 Aug. *Botrytis cinerea* developed during the last week of Aug and potato plants in some treatments were severely infected.

Final foliar late blight: Taking 36 days after inoculation (dai) as a key reference point, all fungicide programs with seven-day application intervals reduced the level of late blight foliar infection significantly compared to the untreated control. The two Quadris 2.08SC and Bravo ZN WS 6SC alternating programs and the standard Bravo ZN WS 6SC program were not significantly different (p = 0.05). However, the Quadris 2.08SC and Bravo ZN WS 6SC alternating program with Fluazinam 5SC had significantly (p = 0.05) less foliar late blight than the Quadris 2.08SC and Bravo ZN WS 6SC alternating programs initiated with Quadris 2.08SC and the standard Bravo ZN WS 6SC program. Programs where the addition of Supertin 80WP (0.16lb/A) to Bravo ZN WS 6SC was delayed by two weeks were not significantly different (p = 0.05) but the program where the addition of Supertin was delayed by two weeks had significantly less (p = 0.05) foliar late blight at the end of the evaluation period than the standard Bravo ZN WS 6SC program. The season-long increasing rate Bravo ZN WS 6SC + Supertin 80WP had significantly (p = 0.05) less foliar late blight than the Bravo ZN WS 6SC alternating program but was not significantly different (p = 0.05) from the season-long highest rate program of the Bravo ZN WS 6SC + Supertin 80WP program (1.5 pt + 0.19 lb/A). A clear dose response was observed from the increased rates of Bravo ZN WS 6SC + Supertin 80WP programs however only the lowest (0.75 pt + 0.06 lb/A) and highest rates (1.5 pt + 0.19 lb/A) were significantly different (p = 0.05).

RAUDPC: the average amount of foliar late blight over the season from inoculation to 36 dai was significantly reduced by all fungicide programs with seven-day application intervals compared to the untreated control. The program where the addition of Supertin was delayed by two weeks and the Bravo ZN WS 6SC + Supertin 80WP (1.5 pt + 0.19 lb/A) had significantly less foliar late blight than the Quadris 2.08SC and Bravo ZN WS 6SC alternating programs initiated with Quadris 2.08SC, the standard Bravo ZN WS 6SC programs and the Bravo ZN WS 6SC + Supertin 80WP (0.75 pt + 0.06 lb/A) season-long program. None of the other programs were significantly different (p = 0.05) from each other.

Yield: In general yields were low due to late planting, extremely high late blight pressure and early desiccation of the plots. Quadris 2.08SC and Bravo ZN WS 6SC alternating programs the program where the addition of Supertin 80WP (0.16lb/A) to Bravo ZN WS 6SC was delayed by two weeks and the season-long Bravo ZN WS 6SC 1.0 pt/A + Supertin 80WP 0.09 lb/A had significantly (p = 0.05)higher yields in the US 1 size grade than the untreated check. The Quadris 2.08SC and Bravo ZN WS 6SC alternating programs (initiated with Quadris 2.08SC) had significantly (p = 0.05)higher yields in the US 1 size grade than the program where the addition of Supertin 80WP (0.16lb/A) to Bravo ZN WS 6SC was applied two weeks after the initial fungicide applications. There were no other significant differences (p = 0.05) between treatments in the US 1 size grade. The Quadris 2.08SC and Bravo ZN WS 6SC alternating programs (initiated with Quadris 2.08SC), the Quadris 2.08SC and Bravo ZN WS 6SC alternating program with Fluazinam 5SC, the program where the addition of Supertin 80WP (0.16lb/A) to Bravo ZN WS 6SC was delayed by two weeks and the season-long Bravo ZN WS 6SC 1.0 pt/A + Supertin 80WP 0.09 lb/A had significantly (p = 0.05)higher total yield than the untreated check. There were no other significant differences (p = 0.05) between treatments in total yield.

Phytotoxicity was not noted in any of the treatments.

Conclusions and Recommendations

Quadris 2.08SC applied at 0.8 pt/A can be recommended as an effective fungicide applied early within protectant protection programs in alternation with an appropriate residual fungicide for the control of foliar late blight.

The addition of SuperTin 80WP to Bravo ZN WS 6SC improved late blight control in several combination types especially when it was applied after inoculation of *P. infestans*.

All products are applied at full recommended rate, unless specified. No recommendations can be made for the application of any product at rates less than those tested.

Table 1.

Treatment and rate/acre	Final foliar disease (%) 36 dai[1]		RAUDPC[2] max = 100 0 - 32 dai		Yield (cwt/acre) US1		Total	
Quadris 208SC 0.80 pt (A,C,E[3])............................ Bravo ZN WS 6SC 1.5 pt (B,D,F,G,H,I)	47.5	bc[4]	9.3	b	115	a	231	a
Bravo ZN WS 6SC 1.5 pt (A,C,E,G,H,I).............. Quadris 2.08SC 0.8 pt (B,D,F)	37.5	ab	8.5	ab	100	ab	207	ab
Quadris 2.08SC 0.8 pt (A,D)................................ Fluazinam 5SC 0.42 pt (B,E) Bravo ZN WS 6SC 1.5 pt (C,F,G,H,I)	32.5	a	7.3	ab	83	abc	213	a
Bravo ZN WS 6SC 1.5 pt (A,B,C,D,E,F,G,H,I).....	47.5	bc	9.8	b	94	abc	200	ab
Bravo ZN WS 6SC 1.5 pt (A,B,C,D)..................... Bravo ZN WS 6SC 1.5 pt (E,F,G,H,I) + Supertin 80WP 0.16 lb	33.8	a	6.3	a	107	ab	216	a
Bravo ZN WS 6SC 1.5 pt (A,B)............................ Bravo ZN WS 6SC 1.5 pt (C,D,E,F,G,H,I) + Supertin 80WP 0.16 lb	37.5	ab	7.8	ab	82	bc	190	ab
Bravo ZN WS 6SC 0.75 pt (A,B).......................... + Supertin 80WP 0.06 lb pt Bravo ZN WS 6SC 1.0 pt (C,D,E,F) + Supertin 80WP 0.09 lb pt Bravo ZN WS 6SC 1.5pt (G,H,I) + Supertin 80WP 0.19 lb pt	35.0	a	7.8	ab	94	abc	196	ab
Bravo ZN WS 6SC 0.75 pt (A,B,C,D,E,F,G,H,I)... + Supertin 80WP 0.06 lb pt	51.3	c	9.8	b	89	abc	194	ab
Bravo ZN WS 6SC 1.0 pt (A,B,C,D,E,F,G,H,I)..... + Supertin 80WP 0.09 lb pt	42.5	abc	7.5	ab	101	ab	210	a
Bravo ZN WS 6SC 1.5pt (A,B,C,D,E,F,G,H,I)...... + Supertin 80WP 0.19 lb	32.5	a	6.0	a	91	abc	192	ab
Untreated..	100	d	19.2	c	66	c	154	b

[1] Days after inoculation with *Phytophthora infestans*, US8, A2.

[2] RAUDPC, relative area under the disease progress curve calculated from the day of inoculation to the last evaluation of late blight.

[3] Application dates: A= 23 Jun; B= 1 Jul; C= 8 Jul; D= 15 Jul; E= 22 Jul; F= 30 Jul; G= 7 Aug; H= 14 Aug; I= 21 Aug.

[4] Values followed by the same letter are not significantly different at P = 0.05 (Tukey Multiple Comparison).

Trial 2. EVALUATION OF CGA 279202 50WDG, ULTRA FLOURISH 4EC + DITHANE 75DF, BRAVO ZN WS 6SC + CHAMP 4.6FL ALTERNATED WITH DITHANE 75DF + AGRITIN 80WP AND PENNCOZEB 75DF-BASED PROGRAMS FOR POTATO LATE BLIGHT CONTROL, 1999

Introduction

Novartis are developing a novel strobilurine, CGA 279202 50WDG which was tested in this trial in programs in combination and alternated with Dithane 75DF. Ridomil Gold is recommended in Michigan for the control of tuber pathogens such as pink rot and Pythium leak. Soil applications of Ridomil Gold were tested in this trial along with the more traditional application recommendations for both products. In addition, programs with Ultra Flourish 4EC + Dithane 75DF, new formulations of Champ and Agritin 80WP were tested along with Penncozeb 75DF programs alone and in combination with Quadris 2.08SC.

Additional Methods

Ridomil 2EC was applied to the soil after planting in treatments 4 and 5 in Table 2.

Foliar disease (Table 2)

Final foliar late blight: Taking 36 days after inoculation (dai) as a key reference point, all fungicide programs with seven-day application intervals reduced the level of late blight foliar infection significantly compared to the untreated control. The Ridomil Gold 4EC 0.1pt/A at planting followed by CGA 279202 50WDG 0.25lb/A mixed with or alternated with Dithane 75DF 2.0 lb/A and the Ultra Flourish 4EC 0.38 pt/A + Dithane 75DF 2.0 lb/A programs gave significantly better control of final foliar late blight than other programs in this trial. The Bravo ZN WS 6SC + Champ 4.6FL alternated with Dithane 75DF 2.0 lb/A + Agritin 80WP 0.19 lb/A and the Bravo ZN WS 6SC 1.5 pt/A+ Ultra Champ 37.5DF 2.5 lb/A programs were not significantly different from the various Penncozeb 75DF-based programs.

RAUDPC: the average amount of foliar late blight over the season from 0 to 36 dai was significantly reduced by all fungicide programs with seven-day application intervals compared to the untreated control. The Ridomil Gold 4EC 0.1pt /A at planting followed by CGA 279202 50WDG 0.25lb/A mixed with or alternated with Dithane 75DF 2.0 lb/A and the Ultra Flourish 4EC 0.38pt/A + Dithane 75DF 2.0 lb/A programs gave significantly better control of foliar late blight over the season than other programs in this trial.

Yield: In general, yields were low due to late planting, extremely high late blight pressure and early desiccation of the plots. There were no other significant differences between treatments in the US 1 or total size grade.

Phytotoxicity was not noted in any of the treatments.

Conclusions and Recommendations

CGA 279202 50WDG (Flint 50WDG) mixed with or alternated with Dithane 75DF 2.0 lb/A should be recommended as an effective fungicide program for the control of foliar late blight.

Ultra Flourish 4EC + Dithane 75DF programs should be recommended as an effective fungicide program for the control of foliar late blight.

The inclusion of Ridomil Gold EC + Bravo WS 6SC in preventative strategies should continue to be recommended for effective control of foliar late blight.

Penncozeb 75DF programs should be recommended as an effective fungicide program for the control of foliar late blight.

All products are applied at full recommended rate, unless specified. No recommendations can be made for the application of any product at rates less than those tested.

Table 2.

Treatment and rate/acre	Final foliar disease (%) 36 dai[1]		RAUDPC[2] max = 100 0 - 36 dai		Yield (cwt/acre) US1		Total	
Bravo ZN WS 6SC 1.5 pt (B,D,F,H)[3]..................... + Champ 4.6FL 2.67 pt Dithane 75DF 2.0 lb (C,E,G,I) + Agritin 80WP 0.19 lb	56.3	d[4]	9.8	c	239	a	345	a
Bravo ZN WS 6SC 1.5 pt (B,C,D,E,F,G,H,I)......... + Ultra Champ 37.5 DF 2.5 lb	58.8	d	10.3	c	237	a	350	a
Dithane 75DF 2.0 lb (B,C,D,E,F,G,H,I)............... + Ultra Flourish 4EC 0.38 pt	28.8	ab	5.0	ab	264	a	392	a
Ridomil Gold 4EC 0.10 pt (A).............................. CGA 279202 50WDG 0.25 lb (B,D,F,H) + Nufilm 0.125EC 1.0 pt Dithane 75DF 2.0 lb (C,E,G,I)	27.5	a	4.3	a	259	a	362	a
Ridomil Gold 4EC 0.1 pt (A)................................ CGA 279202 50WDG 0.25 lb (B,C,D,E,F,G,H,I) + Nufilm 0.125 EC 1.0 pt +Dithane 75DF 2.0 lb	33.8	ab	4.3	a	229	a	331	a
Penncozeb 75DF 1.0 lb (B)................................... Penncozeb 75DF 1.67 lb (C,D,E,F,G) Penncozeb 75DF 2.0 lb (H,I)	45.0	bc	7.8	bc	221	a	314	a
Penncozeb 75DF 1.0 lb (B,D)............................... Quadris 2.08SC 0.8 pt (C,E,G) Penncozeb 75DF 1.67 lb (F,H) Penncozeb 75DF 2.0 lb (I,J)	58.8	d	9.8	c	236	a	338	a
Untreated	100	e	32.3	d	181	a	272	a

[1] Days after inoculation with *Phytophthora infestans*, US8, A2.

[2] RAUDPC, relative area under the disease progress curve calculated from the day of inoculation to the last evaluation of late blight.

[3] Application dates: A= 26 May; B= 23 Jun; C= 1 Jul; D= 8 Jul; E= 15 Jul; F= 22 Jul; G= 30 Jul; H= 7 Aug; I= 14 Aug; J= 21 Aug.

[4] Values followed by the same letter are not significantly different at P = 0.05 (Tukey Multiple Comparison).

Trial 3. EVALUATION OF EQUUS 6SC AND MANZATE 75DF + SUPERTIN 80WP PROGRAMS FOR POTATO LATE BLIGHT CONTROL, 1999

Introduction

Griffin are introducing a new product in 2000, Equus 6SC (chlorothalonil). Combinations and alternating programs of Equus 6SC with Manzate 75DF, Supertin 80WP and Kocide 4.5FL at different rates and timings within protectant strategy programs were evaluated for the control of foliar and tuber blight. In addition, Manex II was evaluated for the control of foliar blight.

Additional method

Supertin was added to Diquat in some treatments at desiccation.

Foliar disease (Table 3)

Late blight developed slowly after inoculation then rapidly during Aug, and untreated controls reached 85 - 95% foliar infection by 20 Aug. *Botrytis cinerea* developed during the last week of Aug and potato plants in some treatments were severely infected.

Final foliar late blight: Taking 36 days after inoculation (dai) as a key reference point, all fungicide programs with seven-day application intervals reduced the level of late blight foliar infection significantly compared to the untreated control. The mixed programs initiated by either Manzate 75DF 2.0 lb/A or Equus 6SC and continued with Manzate 75DF 2.0 lb/A + Supertin 80WP 0.16 lb/A (6 applications) and the Equus 6SC 1.5 pt/A + Kocide 4.5LF 2.67 pt/A had the lowest final foliar late blight of all programs but were not significantly different from any other programs except Manex II 4SC 3.0 pt/A which had significantly more foliar late blight.

RAUDPC: the average amount of foliar late blight over the season from 0 to 36 dai was significantly reduced by all fungicide programs with seven-day application intervals compared to the untreated control. None of the other programs were significantly different from each other.

Yield: In general, yields were low due to late planting, extremely high late blight pressure and early desiccation of the plots. All programs, except the Equus 6SC 1.5 pt/A + Kocide 4.5 LF 2.67 pt/A program, had significantly higher yields in the US 1 size grade than the untreated check. There were no significant differences between fungicide programs in the US 1 size grade. All programs, except the Equus 6SC 1.5 pt/A + Kocide 4.5 LF 2.67 pt/A, Equus 6SC 1.5 pt/A, Equus 6SC 1.5 pt/A + Equus 0.135SC 0.06 pt/A and the Equus 6SC 1.5 pt/A (applications 1 - 3) followed by Manzate 75WP 2.0 lb/A + Supertin 80WP 0.16 lb/A (applications 4 - 9) followed by Supertin 80WP 0.16 lb/A + Diquat 36.4EC 1.0 pt/A at desiccation, followed by Kocide 4.5 LF 2.67 pt/A 3 days prior to harvest program, had significantly higher total yield than the untreated check. There were no other significant differences between fungicide programs in total yield.

Phytotoxicity was not noted in any of the treatments.

Conclusions and Recommendations

Manzate + Supertin should be recommended as an effective fungicide combination for the control of foliar late blight.

Equus 6SC combinations and alternating programs of Equus 6SC with Manzate 75DF, Supertin 80WP and Kocide 4.5FL at different rates and timings within protectant strategy programs should be recommended as an effective fungicide combination for the control of foliar late blight.

All products are applied at full recommended rate, unless specified. No recommendations can be made for the application of any product at rates less than those tested.

Table 3.

Treatment and rate/acre	Final foliar disease (%) 36 dai[1]		RAUDPC[2] max = 100 0 - 32 dai		Yield (cwt/acre) US1		Yield (cwt/acre) Total	
Equus 6SC 1.5 pt (A,B,C,D,E,F,G,H,I[3])	43.8	ab[4]	9.5	a	207	a	305	ab
Equus 6SC 1.5 pt (A,B,C,D,E,F,G,H,I) + Kocide 4.5LF 2.67 pt	41.3	ab	8.3	a	193	ab	297	ab
Manex II 4SC 3.0 pt (A,B,C,D,E,F,G,H,I)	53.8	b	10.0	a	252	a	351	a
Manzate 75WP 2.0 lb (A,B,C) Manzate 75WP 2.0 lb (D,E,F,G,H,I) + Supertin 80WP 0.16 lb Supertin 80WP 0.23 lb + Diquat 36.4 EC 1.0 pt (J) Kocide 4.5LF 2.67 pt (K)	36.3	a	7.0	a	230	a	371	a
Equus 6SC 1.5 pt (A,B,C) Manzate 75WP 2.0 lb (D,E,F,G,H,I) + Supertin 80WP 0.16 lb Supertin 80WP 0.23 lb + Diquat 36.4EC 1.0 pt (J) Kocide 4.5LF 2.67 pt (K)	32.5	a	6.5	a	217	a	310	ab
Equus 6SC 1.5 pt (A,C,E,G,I) Manzate 75WP 2.0 lb (B,D,F,H)	45.0	ab	9.3	a	241	a	347	a
Equus 6SC 1.5 pt (A,B,C) Equus 6SC 1.5 pt (D,E,F,G,H,I) + Supertin 80WP 0.16 lb Supertin 80WP 0.23 lb + Diquat 36.4 EC 1.0 pt (J) Kocide 4.5LF 2.67 pt (K)	41.3	ab	7.5	a	217	a	321	a
Untreated	100	c	22.0	b	123	b	215	b

[1] Days after inoculation with *Phytophthora infestans*, US8, A2.

[2] RAUDPC, relative area under the disease progress curve calculated from the day of inoculation to the last evaluation of late blight.

[3] Application dates: A= 23 Jun; B= 1 Jul; C= 8 Jul; D= 15 Jul; E= 22 Jul; F= 30 Jul; G= 7 Aug; H= 14 Aug; I= 21 Aug; J= 10 Sep; K= 15 Sep.

[4] Values followed by the same letter are not significantly different at P = 0.05 (Tukey Multiple Comparison).

Trial 4. EVALUATION OF QUADRIS 2.08SC BASED PROGRAMS, CHLOROTHALONIL(ECHO AND BRAVO) BASED PROGRAMS AND OXIDATE SC PROGRAMS FOR POTATO LATE BLIGHT CONTROL, 1999

Introduction

The effect of initiating programs with either Quadris or Bravo ZN was also evaluated with Quadris 2.08 SC applied at both the recommended rates for early blight and late blight control. In addition, an increasing rate of Bravo ZN WS 4.2SC was compared with the Echo 6SC and Echo ZN 6.25SC, chlorothalonil products.

Foliar disease (Table 4)

Late blight developed slowly after inoculation then rapidly during Aug and untreated controls reached 85 - 95% foliar infection by 20 Aug. This trial experienced very high late blight pressure. *Botrytis cinerea* developed during the last week of Aug and potato plants in some treatments were severely infected.

Final foliar late blight: Taking 36 days after inoculation (dai) as a key reference point, all fungicide programs with seven-day application intervals, except the Oxidate SC 8.0 pt/A program, reduced the level of late blight foliar infection significantly compared to the untreated control . The final amount of foliar late blight at the final evaluation date was not significantly different between any other treatments except that the Bravo ZN WS 6SC 1.0 pt/A with Quadris 2.08SC 0.8 pt/A program had significantly more foliar late blight than the increasing rate of Bravo ZN WS 6SC program and the Echo ZN 6.25SC 2.13 pt/A program.

RAUDPC: The average amount of foliar late blight over the season from 0 to 36 dai was significantly reduced by all fungicide programs with seven-day application intervals compared to the untreated control. The Oxidate SC 8.0 pt/A program had a significantly higher RAUDPC than all other fungicide programs.

Yield: In general, yields were low due to late planting, extremely high late blight pressure and early desiccation of the plots. All of the fungicide programs except Oxidate SC 8.0 pt/A had significantly higher yields in the US 1 size grade than the untreated check. Echo ZN WS 6SC and Echo 6SC programs had significantly higher yields in the US 1 size grade than the Oxidate 6SC 8.0 pt/A program. There were no other significant differences between treatments in the US 1 size grade. Only the Echo 6SC program had significantly higher total yield than the untreated check. There were no other significant differences between treatments in total yield.

Phytotoxicity was not noted in any of the treatments.

Conclusions and Recommendations

Bravo ZN and Echo 6SC and Echo ZN 6.25SC should be recommended as effective fungicides for the control of foliar late blight applied on a 7day schedule.

The effect of initiating the late blight control program with either Bravo ZN or Quadris had no effect on late blight development and it is recommended that the program could be started with either fungicide.

The effect of increasing the rate of Quadris 2.08SC from 0.4 to 0.8 pt/A within a protectant program had no effect on late blight control and hence the lower of the two rates is adequate within a seven-day management strategy to control late blight.

All products are applied at full recommended rate, unless specified. No recommendations can be made for the application of any product at rates less than those tested.

Table 4.

Treatment and rate/acre	Final foliar disease (%) 36 dai[1]		RAUDPC[2] max = 100 0 - 36 dai		Yield (cwt/acre) US1		Total	
Bravo ZN WS 6SC 0.5 pt (A,B[3]) Bravo ZN WS 6SC 1.0 pt (C,D,E) Bravo ZN WS 6SC 1.5 pt (I,J,K,L)	53.8	a[4]	9.5	a	122	ab	235	ab
Quadris 2.08SC 0.8 pt (A,C,E,J,L) Bravo ZN WS 6SC 1.5 pt (B,G,I,K)	58.8	ab	10.8	a	131	ab	239	ab
Bravo ZN WS 6SC 1.0 pt (A,C,E,J,L) Quadris 2.08SC 0.8 pt (B,G,I,K)	62.5	b	10.5	a	133	ab	244	ab
Quadris 2.08SC 0.4 pt (A,C,E,J,L) Bravo ZN 4 SC 1.5 pt (B,G,I,K)	58.8	ab	11.5	a	144	ab	263	ab
Bravo ZN WS 6SC 1.5 pt (A,C,E,J,L) Quadris 2.08SC 0.4 pt (B,G,I,K)	60.0	ab	11.3	a	144	ab	251	ab
Quadris 2.08SC 0.4 pt (A,E) Bravo ZN WS 6SC 1.0 pt (B,C) Bravo ZN WS 6SC 1.5 pt (H,I,J,K,L)	57.5	ab	10.2	a	136	ab	240	ab
Bravo ZN WS 6SC 1.5 pt (A,B,C,D,E,I,J,K,L)	60.0	ab	12.0	a	127	ab	258	ab
Echo ZN 6.25SC 2.13 pt (A,B,C,D,E,I,J,K,L)	53.8	a	10.2	a	155	a	242	ab
Echo 6SC 1.5 pt (A,B,C,D,E,I,J,K,L)	60.0	ab	12.3	a	148	a	278	a
Oxidate SC 8.0 pt (A,B,C,D,E,F,G,H,I,J,K,L)	95.5	c	23.3	b	98	bc	200	ab
Oxidate SC 8.0 pt (A,B,C,D,E,I,J,K,L) + Bravo ZN WS 6SC 1.5 pt	53.8	a	9.3	a	139	ab	235	ab
Untreated	100	c	29.5	c	71	c	187	b

[1] Days after inoculation with *Phytophthora infestans*, US8, A2.

[2] RAUDPC, relative area under the disease progress curve calculated from the day of inoculation to the last evaluation of late blight.

[3] Application dates: A= 23 Jun; B= 1 Jul; C= 8 Jul; D= 15 Jul; E= 22 Jul; F=23 Jul; G=24 Jul; H=25 Jul; I= 30 Jul; J= 7 Aug; K= 14 Aug; L= 21 Aug.

[4] Values followed by the same letter are not significantly different at P = 0.05 (Tukey Multiple Comparison).

Trial 5 . EVALUATION OF RATE RESPONSE OF ACROBAT 50WP + BRAVO WS 6SC AND TATTOO 6.25SC PROGRAMS FOR POTATO LATE BLIGHT CONTROL, 1999

Introduction

Reduced rates of Tattoo C and Acrobat MZ were compared to the standard Bravo WS program in this trial for the control of foliar blight.

Additional Methodology

Two program initiation dates were compared, the first initiated on the accumulation of 10 late blight disease severity values (DSV) and the second initiated on the accumulation of 20 DSV. The DSV were accumulated using the Wallin model measured from an in-canopy Spectrum Instruments Weather Sation with remote cellular modem access

Foliar disease (Table 5)

All fungicide programs with seven-day application intervals reduced the level of late blight foliar Late blight developed slowly after inoculation then rapidly during Aug and untreated controls reached 85 - 95% foliar infection by 20 Aug. *Botrytis cinerea* developed during the last week of Aug and potato plants in some treatments were severely infected.

Final foliar late blight and RAUDPC: Applications of most treatments at increasing rates initiated at 10DSV tended to result in better late blight control than their corresponding treatments initiated at 20DSV. However, the differences were not always statistically significant ($p = 0.05$).

Applications of all treatments at increasing rates initiated at 10DSV: Taking 36 days after inoculation (dai) as a key reference point, all fungicide programs with seven-day application intervals reduced the level of late blight foliar infection significantly compared to the untreated control except the two lowest application rates of Tattoo C 6.25SC programs initiated at 10DSV. There were significant ($p = 0.05$) differences between Bravo WS 6SC (full application rate), Acrobat 50WP + Bravo WS 6SC and Tattoo C 6.25SC (applied at 0.25, 0.5, 0.75 and 1.0 of full application rate). Generally, the lowest application rates of Acrobat 50WP + Bravo WS 6SC and Tattoo C 6.25SCgave significantly poorer late blight control than the 0.75 and 1.0 application rates. There were no significant ($p = 0.05$) differences between Bravo WS 6SC (full application rate), Acrobat 50WP + Bravo WS 6SC and Tattoo C 6.25SC applied at 0.75and 1.0 of full application rate.

Applications of all treatments at increasing rates initiated at 20DSV: all fungicide programs with seven-day application intervals reduced the level of late blight foliar infection significantly compared to the untreated control. Only the full application rates of Acrobat 50WP + Bravo WS 6SC and Tattoo C 6.25SC resulted in levels of late blight control achieved with 0.5 of the full application rate when the programs were initiated earlier.

Yield: In general yields were low due to late planting, extremely high late blight pressure and early desiccation of the plots. There were few treatments with significant differences ($p = 0.05$) between fungicide programs in the US 1 size grade although generally the higher rate programs had higher yields. There were no significant differences ($p = 0.05$) between fungicide programs in total yield.

Phytotoxicity was not noted in any of the treatments.

Conclusions and Recommendations

Tattoo C and Acrobat 50WP + Bravo WS applied season long at about 0.75 - 1.0 of the recommended full rate of application gave similar levels of control to the standard programmed application of Bravo WS, full season when started at either 10 DSV. At lower rates under high disease pressure, late blight control was much reduced.

Tattoo C and Acrobat 50WP + Bravo WS applied season long at about 0.75 - 1.0 of the recommended full rate of application gave similar levels of control to the standard programmed application of Bravo WS, full season when started at either 20 DSV. At lower rates under high disease pressure, late blight control was much reduced.

Delaying the initiation of the protectant programs resulted in lower levels of late blight control at corresponding treatments and rates regardless of the products used.

All products are applied at full recommended rate, unless specified. No recommendations can be made for the application of any product at rates less than those tested.

Table 5.

Treatment and rate/acre	Final foliar disease (%) 36 dai[1]		RAUDPC[2] max = 100 0 - 32 dai		Yield (cwt/acre) US1		Total	
Bravo WS 6SC 1.5 pt (A,B,C,D,E,F,G,H)	50.0	abc	11.6	abc	194	ab	316	a
Tattoo C 6.25SC 0.58 pt (A,B,C,D,E,F,G,H)	93.3	hi	20.2	f	172	ab	280	a
Tattoo C 6.25SC 1.15 pt (A,B,C,D,E,F,G,H)	82.5	fghi	15.7	cde	198	ab	320	a
Tattoo C 6.25SC 1.75 pt (A,B,C,D,E,F,G,H)	46.3	ab	9.7	a	202	a	344	a
Tattoo C 6.25SC 2.3 pt (A,B,C,D,E,F,G,H)	42.5	a	9.0	a	206	a	336	a
Acrobat 50WP 0.1 lb (A,B,C,D,E,F,G,H) + Bravo WS 6SC 0.25 pt	80.0	fgh	15.2	cde	206	a	304	a
Acrobat 50WP 0.2 lb (A,B,C,D,E,F,G,H) + Bravo WS 6SC 0.5 pt	63.8	bcdef	12.2	abc	198	ab	332	a
Acrobat 50WP 0.3 lb (A,B,C,D,E,F,G,H) + Bravo WS 6SC 0.75 pt	56.3	abcd	10.5	ab	196	ab	316	a
Acrobat 50WP 0.4 lb (A,B,C,D,E,F,G,H) + Bravo WS 6SC 1.0 pt	42.5	a	9.1	a	204	a	322	a
Bravo WS 6SC 1.5 pt (C,D,E,F,G,H)	68.8	cdefg	15.3	cde	188	ab	324	a
Tattoo C 6.25SC 0.58 pt (C,D,E,F,G,H)	75.0	defgh	15.8	cdef	204	a	310	a
Tattoo C 6.25SC 1.15 pt (C,D,E,F,G,H)	73.8	defgh	14.3	bcde	176	ab	322	a
Tattoo C 6.25SC 1.75 pt (C,D,E,F,G,H)	76.3	defgh	15.6	cde	181	ab	308	a
Tattoo C 6.25SC 2.3 pt (C,D,E,F,G,H)	67.5	cdefg	14.3	bcde	178	ab	329	a
Acrobat 50WP 0.1 lb (C,D,E,F,G,H) + Bravo WS 6SC 0.25 pt	85.0	ghi	16.8	def	164	ab	324	a
Acrobat 50WP 0.2 lb (C,D,E,F,G,H) + Bravo WS 6SC 0.5 pt	75.0	defgh	17.1	def	195	ab	337	a
Acrobat 50WP 0.3 lb (C,D,E,F,G,H) + Bravo WS 6SC 0.75 pt	75.0	defgh	15.2	cde	188	ab	334	a
Acrobat 50WP 0.4 lb (C,D,E,F,G,H) + Bravo WS 6SC 1.0 pt	62.5	bcde	13.1	bcd	190	ab	320	a
Untreated	100	i	28.2	g	124	b	258	a

[1] Days after inoculation with *Phytophthora infestans*, US8, A2.
[2] RAUDPC, relative area under the disease progress curve calculated from the day of inoculation to the last evaluation of late blight.
[3] Application dates: 10 Late blight severity values at A= 8 Jul; B= 15 Jul; C= 22 Jul; D= 30 Jul; E= 7 Aug; F= 14 Aug; G= 21 Aug; H= 28 Aug. 20 Late blight severity values at C= 22 Jul; D= 30 Jul; E= 7 Aug; F= 14 Aug; G= 21 Aug; H= 28 Aug.
[4] Values followed by the same letter are not significantly different at P = 0.05 (Tukey Multiple Comparison).

Trial 6. Comparison of control of potato late blight (*Phytophthora infestans*) attained with Polyram and Curzate 60DF + Polyram in combination with adjuvants.

Introduction

This trial compared the contribution that different adjuvants made to late blight control when applied with a surface residual fungicide (Polyram 80DF) and with a translaminar/systemic fungicide (Curzate 60DF + Polyram 80DF).

Additional Methods

This trial block was not directly inoculated. The block was close to other trial blocks that had been inoculated as described in the general methods section.

Foliar disease (Table 6)

Late blight developed slowly after inoculation then rapidly during Aug, and untreated controls reached 85 - 95% foliar infection by 20 Aug. *Botrytis cinerea* developed during the last week of Aug and potato plants in some treatments were severely infected.

Final foliar late blight: Taking 36 days after inoculation (dai) as a key reference point, Polyram 80DF 2.0 lb/A, Polyram 80DF 2.0 lb/A + Tactic SC 0.25 pt/A, Polyram 80DF 2.0 lb/A + Activator SC 0.25 pt/A, Curzate 60DF 0.21 lb/A + Polyram 80DF 1.5 lb/A, Curzate 60DF 0.21 lb/A + Polyram 80DF 1.5 lb/A + Li700 SC 0.25 pt/A and Curzate 60DF 0.21 lb/A + Polyram 80DF 1.5 lb/A + Activator SC 0.25 pt/A were not significantly different from the untreated control. All other fungicide programs with seven-day application intervals reduced the level of late blight foliar infection significantly compared to the untreated control. However, no fungicide programs with or without adjuvants were significantly different from each other.

RAUDPC: the average amount of foliar late blight over the season from 0 to 36 dai was significantly reduced by all fungicide programs with seven-day application intervals compared to the untreated control. However, no fungicide programs with or without adjuvants were significantly different from each other and in general late blight control was poor.

Yield: In general, yields were low due to late planting, extremely high late blight pressure and early desiccation of the plots. The Curzate 60DF 0.21 lb/A + Polyram 80DF 1.5 lb/A + Tactic 0.25 pt/A program had significantly higher yields in the US 1 size grade than the untreated check and the Curzate 60DF 0.21 lb/A + Polyram 80DF 1.5 lb/A program. There were no other significant differences between treatments in the US 1 size grade and no other treatments had significantly higher yields in the US 1 size grade than the untreated check. Only the Polyram 80DF 1.5 lb/A program had significantly higher total yield than the untreated check. There were no other significant differences between treatments in total yield.

Phytotoxicity was not noted in any of the treatments.

Conclusions and Recommendations

Curzate 60DF applied in combination with Polyram 80DF gave moderate control of late blight and could be recommended for control of potato late blight under moderately conducive late blight conditions.

Polyram 80DF gave moderate control of late blight and could be recommended for control of potato late blight under moderately conducive late blight conditions.

The addition of Tactic, Li700 or Activator 90 to Curzate 60DF + Polyram 80DF or Polyram 80DF programs season long made no significant difference to the level of control of late blight and their addition is not justified for late blight control, however, their addition did tend to reduce the level of foliar late blight.

All products are applied at full recommended rate, unless specified. No recommendations can be made for the application of any product at rates less than those tested.

Table 6.

Treatment and rate/acre	Final foliar disease (%) 36 dai[1]		RAUDPC[2] max = 100 0 - 32 dai		Yield (cwt/acre) US1		Total	
Polyram 80DF 2.0 lb (A,B,C,D,E,F,G,H,I)[3]	80.0	ab[4]	15.5	a	146	ab	279	a
Polyram 80DF 2.0 lb (A,B,C,D,E,F,G,H,I) + Tactic SC 0.25 pt	82.5	ab	19.5	a	120	ab	248	ab
Polyram 80DF 2.0 lb (A,B,C,D,E,F,G,H,I) + Li700 SC 0.25 pt	78.8	a	17.5	a	149	ab	247	ab
Polyram 80DF 2.0 lb (A,B,C,D,E,F,G,H,I) + Activator 90SC 0.25 pt	81.3	ab	17.8	a	155	ab	253	ab
Curzate 60DF 0.21 lb (A,B,C,D,E,F,G,H,I) + Polyram 80DF 1.5 lb	87.0	ab	20.8	a	102	b	217	ab
Curzate 60WP 0.21 lb (A,B,C,D,E,F,G,H,I) + Polyram 80DF 1.5 lb + Tactic SC 0.25 pt	78.8	a	17.0	a	164	a	262	ab
Curzate 60WP 0.21 lb (A,B,C,D,E,F,G,H,I) + Polyram 80DF 1.5 lb + Li700 SC 0.25 pt	86.3	ab	20.0	a	123	ab	231	ab
Curzate 60WP 0.21 lb (A,B,C,D,E,F,G,H,I) + Polyram 80DF 1.5 lb + Activator 90SC 0.25 pt	80.0	ab	17.5	a	134	ab	257	ab
Untreated	100	b	30.3	b	103	b	205	b

[1] Days after inoculation with *Phytophthora infestans*, US8, A2.

[2] RAUDPC, relative area under the disease progress curve calculated from the day of inoculation to the last evaluation of late blight.

[3] Application dates: A= 23 Jun; B= 1 Jul; C= 8 Jul; D= 15 Jul; E= 22 Jul; F= 30 Jul; G= 7 Aug; H= 14 Aug; I= 21 Aug.

[4] Values followed by the same letter are not significantly different at P = 0.05 (Tukey Multiple Comparison).

Trial 7. Comparison of control of established potato late blight (*Phytophthora infestans*) attained with fungicides.

Introduction

This trial compared the efficacy of various fungicides with applied after late blight had started to develop within the crop. Three timings were evaluated, fungicide programs initiated (5 day interval, 3 applications) at a) 72 h before inoculation, b) 72 h after inoculation, c) when 1% and d) when 5% of the foliage showed late blight symptoms. Previous trials from 1995 - 1997 have shown that at infection levels above 5% foliar infection, no fungicides can contain the infection under continued conducive late blight conditions.

Additional Methods

Fungicides were applied on a 5 day interval for 15 days (3 applications). Fungicide applications were initiated at 4different timings a) 72 h before inoculation (72 hbi), b) 72 h after inoculation (72 hai), c) when plants were 1% infected and d) when plants were 3 - 5% infected. The first timing began on 20 July, the second on 26 Jul, the third on 1 Aug and the fourth on 3 Aug 1999.

Foliar disease (Fig 1)

Late blight developed rapidly during August and untreated controls reached 85 - 95% foliar infection by 14 Aug. Partial control of late blight was achieved when some of the fungicides were applied 72 hour before and after inoculation. No fungicide treatments gave control of late blight when the initiation of the control programs were delayed until 1 or 5% foliar infection.

Chlorothalonil (Bravo WS6SC), dimethomorph (Acrobat 50WP) + chlorothalonil or + triphenyltin OH (Supertin 80WP), cymoxanil (Curzate 60DF) + chlorothalonil, propamocarb + chlorothalonil (Tattoo C 6.25SC), mancozeb (Manzate 75DF) + triphenyltin OH (full and double rate of application) programs all had significantly less late blight than the untreated control (RAUDPC) at each timing comparison. All other programs were not significantly different from the untreated plots. The mean infections were shown for each timing and indicate the overall level of infection at each timing comparison. The treatments initiated 72 hai had lower overall mean infection than any other initiation timing however the programs initiated 72 hbi had similar levels of late blight control. The programs initiated at 1 and 5% foliar infection had similar levels of late blight infection but were much greater than those programs initiated at 72 hai and 72 hbi.

Conclusions and Recommendations

Mancozeb (Manzate 75DF 2.0 lb/A) + triphenyltin OH (Supertin 80WP 0.44 lb/A, double rate of labeled application) applied 72 h after inoculation and repeated twice at 5 day intervals reduced late blight development more than any other treatment. This combination could be recommended for control of potato late blight under conducive late blight conditions after infection is known to have occurred and should be included as an emergency control program to prevent late blight from developing from infection loci.

Chlorothalonil (Bravo WS6SC), dimethomorph (Acrobat 50WP) + chlorothalonil or + triphenyltin OH (Supertin 80WP), cymoxanil (Curzate 60DF) + chlorothalonil, propamocarb + chlorothalonil (Tattoo C 6.25SC), mancozeb (Manzate 75DF) + triphenyltin OH (full rate of application) programs all had significantly less late blight than the untreated control (RAUDPC) at each timing comparison. These combinations could be recommended for control of potato late blight under conducive late blight conditions after infection is known to have occurred within fields or areas where late blight is present.

Non-preventative application of any fungicide for late blight control should not be considered for management of late blight.

All products are applied at full recommended rate, unless specified. No recommendations can be made for the application of any product at rates less than those tested.

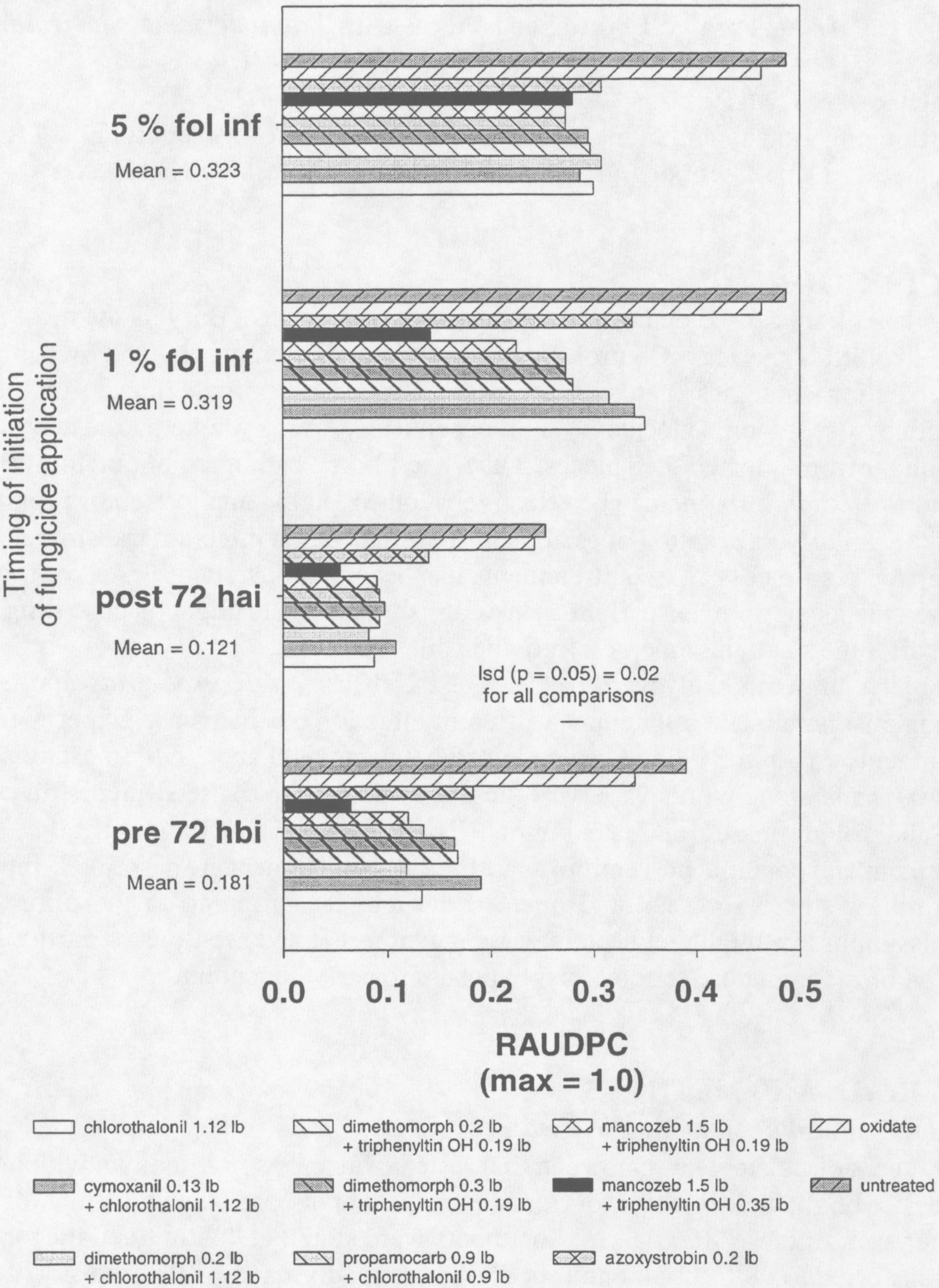

Figure 1. The effect of fungicides on the average amount of foliar late blight over the 36 day infection period (RAUDPC) on containing established foliar late blight. Initial applications applied 72 hours before inoculation (72 hbi), 72 hours after inoculation (72 hai), at 1% visible foliar infection and at 5% visible foliar infection and re-applied at 5 day intervals for a total of three applications. Rates are lb/A active ingredient.

Funding: MPIC

Control of Seed-Borne Late Blight (*Phytophthora infestans* Mont. De Bary) Development from Treated Potato Seed-Pieces with *Trichoderma atroaviride*.

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INTRODUCTION

Potato late blight caused by *Phytophthora infestans* (Mont. De Bary) is the most important potato disease in North America.[1] Control of late blight is traditionally achieved by cultural controls and crop protection strategies that rely on applications of foliar fungicides.[2] Late blight is readily transmitted by seed-borne inoculum[3,4] and consequently, immature stems and leaves may be exposed to late blight from infected seed pieces. Other seed-borne pathogens of potatoes, such as *Fusarium* spp. and *Rhizoctonia solani*, can be effectively controlled by application of fungicides to the seed piece.[5,6] Similarly, prevention of establishment of late blight infection transmitted from infected to disease-free seed pieces by seed treatments has been demonstrated.[7] Active ingredients in seed piece treatments may prevent early season establishment of late blight by persisting on the immature foliage after the plant has emerged from the soil.[8]

The objectives of this study were to determine the efficacy of *T. atroaviride* applied to potato seed-pieces against potato late blight under different infection mechanisms. Experiments in controlled environments and in the field were conducted between 1998 and 1999 to establish the efficacy of a *T. atroaviride* along with a variety of fungicides applied to the seed-pieces in controlling tuber-borne and foliar phases of late blight. Three separate simulations of late blight infection mechanisms and potential prevention of late blight establishment are described: infection carry-over within tubers stored for seed and infected during seed cropping in the prior growing season, transmission of late blight between infected and non-infected seed-pieces during seed cutting, and infection of the immature canopy after exposure to aerial inoculum.

MATERIALS AND METHODS

2.1 Selection and Preparation of Potatoes

Seed tubers of potatoes(cv. Snowden) harvested from crops in Michigan with no record of foliar or tuber late blight were selected for freedom from other diseases and uniformity of size (35 - 55 mm diameter size grade). After harvest, the tubers were stored at 4°C in the dark for at least 80 days, then transferred to 18°C, (14 h photo-period) to break dormancy[9]. Prior to storage the tubers were washed in distilled water, disinfected for 2 h in 2% commercial bleach solution (Clorox), dried and stored until used. The number of leaf initials at the time of seed treatment was established by counting the number of leaf initials on sprouts from apical, lateral and basal regions of the tuber under a dissecting microscope (n = 20 sprouts). Seed treatments were applied after inoculation. The timing of cutting of seed tubers into seed-pieces and application of seed-piece fungicides were dependent on the simulated infection mechanism and were described in the following sections. Seed-pieces were planted 48 - 72 h after the seed treatments were applied.

2.2 Experiment Design

Experiments testing infection transmission mechanisms from seed-pieces infected during the seed production season, transmission of infection from infected seed-pieces to late blight free seed-pieces and infection of the immature canopy were conducted during each of three runs in controlled environments and in the field in 1998 - 99. The controlled environment experiments were carried out in temperature and humidity-controlled environment chambers. The chambers (3.4 m^3) were situated within green houses and covered with 1mm transparent polyethylethene. Natural light was supplemented by high-pressure sodium lamps, 400w 14h-10h day-night. Relative humidity was maintained at greater than 90% by timer controlled humidifiers (Herrmidifier model 500). Temperature typically ranged between15 - 24°C. Ten plants per treatment were used for each experiment in concurrent experiments.

2.2.1 Seed tuber infection simulation and inoculation

This study examined the effect of seed treatments on suppressing transmission of *P. infestans* from infected seed tubers to emerging sprouts. Tubers were inoculated with a zoospore suspension (10^3 zoospores ml^{-1}) genotype of *P. infestans* US8 (insensitive to metalaxyl, A2 mating type) from cultures grown on rye agar plates[10] for 14 days in the dark at 15°C. Sporangia were harvested from the petri dishes by rinsing the mycelial/sporangial mat in cold (4°C) sterile, distilled H_2O and scraping the mycelial/sporangial mat from the agar surface with a rubber policeman. The mycelial/sporangial suspension was stirred with a magnetic stirrer for 1 hour. The suspension was strained through four layers of cheesecloth and the concentration of sporangia was adjusted to about 1×10^6 sporangia ml^{-1} using a hemacytometer. Tubers were inoculated with about 0.1 ml of the zoospore suspension (ca. 100 zoospores) injected to a depth of 2.0 mm below the periderm and 1.0 cm from the main apical sprout. The wound was covered with a smear of petroleum jelly to prevent desiccation. Seed treatments were applied 24 h after inoculation.

2.2.2 Transmission of infection at seed cutting simulation

Transmission of late blight infection at seed cutting was simulated by cutting seed and immediately exposing the seed to late blight inoculum. The seed tuber was cut into two pieces with a sterile knife. The exposed cut surface was placed face down on a 14 day old, homogenized mixture of mycelium and sporangia of *P. infestans* in rye agar for 30 s, removed and seed treatments were immediately applied. The homogenate was prepared from 20 plate cultures (9 cm diameter x 15 mm depth petri plates). Each plate produced between 10^5 - 10^6 spores ml^{-1} from 50 ml of wash water. An estimate of the amount of mycelium from each plate was not attempted.

2.2.3 Foliar infection simulation and inoculation

The effect of seed treatments applied to non-infected tubers on foliar infection was examined. Foliar late blight was evaluated on plants inoculated with late blight after the plants had emerged. After they reached the rapid expansion phase (15 days after emergence, 15 cm tall with an average of 10 main leaves on each stem), the plants in the chambers were inoculated with 1000 ml of a 10^3 zoospore ml^{-1} suspension, delivered as an aerosol. Plants were exposed to high relative humidity conditions (RH = 100%), for 8 h prior to inoculation to wet the leaves. In the field experiments all the rows were inoculated (100 ml 12 m^{-1} row) with a zoospore suspension (10^3 zoospore ml^{-1}) on 27 July, 1999.

2.2.4 Application of seed treatments (controlled environment and field experiments).

Conventional seed treatment fungicides were applied to whole seed for use in the transmission of late blight from seed harvested the previous season. Seed tubers cut once were used for experiments to examine transmission during seed-cutting and protection of the immature canopy from aerial inoculum. Treatment trade names, application rates, manufacturers and chemical compositions are listed in Table 1. Seed treatments were applied when sprouts had broken dormancy. Sprouts averaged 15 leaf initials at the time of application (15.1 ± 0.45, $n = 20$), with about eight internodes between the base of the sprout and the first emerged leaf. The amount of fungicide required to treat the seed tubers was calculated from manufacturer recommended seed application rates, e.g. for dust (D) formulations. Transmission of late blight from a) infected seed and b) seed infected at cutting included inoculated and untreated seed tubers (negative control) and uninoculated and untreated seed tubers (positive control). The foliar infection experiments included potato plants that developed from seed tubers that were untreated and uninoculated (positive control).

TABLE 1. Fungicides applied: trade names, manufacturers and active ingredients

Trade name	Rate of application kg/tonne	Manufacturer	Active ingredient
Maxim MZ 0.5D	0.5	Novartis	0.5% fludioxinil + 6% mancozeb
Trichoderma atroaviride	1.0		

2.3 Field experiments

The field experiments were planted at the Michigan State University Muck Soils Research Station, Bath, MI on 1 June, 1999, in five-row by five plant plots, 86 cm row spacing, total 25 plants, replicated six times in a randomized complete block design. Plots were irrigated as needed with sprinklers and were hilled immediately after emergence. No foliar fungicides were applied to the field experiment. Weeds were controlled by hilling and with metolachlor at 0.46 kg/ha 10 dap (days after planting), bentazon salt at 0.12 kg/ha, 20 and 40 dap and sethoxydim at 0.05 kg/ha, 58 - 60 dap. Insects were controlled with imidacloprid at 1.4 kg/ha at planting, carbaryl at 1.4 kg/ha, 31 and 55 dap, endosulfan at 0.98 kg/ha, 65 and 87 dap and permethrin at 0.56 kg/ha, 48 dap.

2.4 Data collection

Plant emergence was rated in all experiments. Rate of emergence was calculated as the relative area under the plant emergence progress curve (RAUEPC) with a modification of the method used to calculate the relative area under the disease progress curve (RAUDPC)[14]. The AUEPC was calculated by adding the area under the linear progression of number of plants emerged between each successive estimation of emergence from planting to full emergence. The RAUEPC was calculated by dividing the measured AUEPC by the maximum AUEPC (100 x duration of the emergence period, from planting to full or final plant number emerged).

Plots (field) and individual plants in each treatment (controlled environments) were rated visually for percent leaf area with symptoms of late blight. The average amount of disease that developed over the disease progress period was expressed as the relative area under the disease progress curve (RAUDPC)[14] which is used extensively to measure disease progress over a given time period[11,12,13 15]. The area under the disease progress curve (AUDPC) was calculated by adding the area under the linear progression of disease between each successive estimation of disease from inoculation to 100% plant death[14]. The RAUDPC is calculated by dividing the measured AUDPC by the maximum AUDPC (100 x duration of the epidemic, from inoculation to 100% plant death).

In the controlled environment foliar inoculation experiment, the ratio of infected to non-infected leaves was calculated with respect to the position of the leaf on the main stem at 14 days after inoculation. Number of leaves with symptoms was evaluated at each main stem leaf position above the soil surface, and the ratio of infected to non-infected leaves was calculated for each treatment. The first leaf above the soil was counted as leaf one. A leaf was considered infected if it had one or more late blight lesions on any of the leaflets or the petiole. The stem that was apically dominant [i) had most main stem leaves, ii) and had the greatest stem diameter] was selected for the evaluation on each of 10 separate plants.

Data were analyzed by two-way analysis of variance and means compared at p = 0.05 level of significance by a multiple range comparison of means (Tukey, SigmaStat). Data were combined in the controlled environment experiments (1998-99) because the variation between separate treatments in different runs of the experiment were not different.

RESULTS

Controlled environment experiments

Seed tuber infection simulation and inoculation

Plant emergence did not exceed 20%, except in the uninoculated untreated control, regardless of the seed treatment (Figure 1). With some of the treatments, fewer plants emerged than the untreated control but differences were not statistically significant (p = 0.05). The rate of emergence (RAUEPC) and number of plants emerged after tubers were inoculated by injection and treated with any seed treatment was significantly lower than the untreated and uninoculated control (Figure 1).

3.1.2 Transmission of infection at seed cutting simulation

The rate of emergence (RAUEPC) and number of plants emerged was not significantly different than the untreated and uninoculated control or the untreated and inoculated control for any inoculated seed treatment combinations (Figure 2).

3.1.3 Foliar infection simulation and inoculation

Tubers that were not inoculated but were treated with a seed treatment emerged at a rate (RAUEPC) not significantly different than the uninoculated and untreated control in the previously described simulations i.e. final stand count was 80 - 100% for all treatments and rate of emergence (RAUEPC) about 0.35 - 0.40. The number of plants emerged was not significantly different between treatments.

Initial foliage symptoms of late blight were significantly (p = 0.05) reduced by all seed-piece treatments ten days after inoculation in comparison with the untreated and inoculated check , however stem infection was not significantly reduced (Figure 3). The rate of late blight development (RAUDPC) after inoculation over a 21 day period was significantly higher in all treatments in comparison with the untreated and uninoculated control but not significantly different from the untreated and inoculated control (Figure 3).

The number of infected leaves was determined at each main stem leaf position above the soil surface, and the ratio of infected to non-infected leaves was calculated for each treatment 14 days after inoculation (Figure 4). In some of the plants that developed from treated seed, the lower leaves on the main stem had a lower ratio of infected leaves in positions 1 to about 3 (leaf 1 being the leaf closest to the soil and 6 a mid-stem leaf). The ratio of infected leaves among treatments was similar to the untreated plots above leaf position 6.

T. atroaviride and fludioxinil + mancozeb seed-piece treatments had low ratios of infected leaves from the lower canopy (leaves 1- 3), (Figure 4). For all treatments, the ratio of diseased to non-diseased leaves was lower in leaf positions above 10 (Figure 4).

3.2 Field Experiments

3.2.1 Tuber inoculation experiments

The number of emerged plants that developed from inoculated seed-pieces did not exceed 25%, regardless of the seed treatment (Figure 5). All treatments and the untreated inoculated control had significantly less plants emerge in comparison with the untreated and uninoculated control (Figure 5). No late blight was observed on plants that emerged.

3.2.2 Transmission of infection at seed cutting simulation

Rate of emergence (RAUEPC) and percent emergence of plants after the cut surfaces of seed tubers were inoculated and treated with *T. atroaviride* and fludioxinil + mancozeb seed-piece treatments was not significantly different than that of the untreated and uninoculated control (Figure 5), but was higher than that of untreated and inoculated tubers. *T. atroaviride* and fludioxinil + mancozeb and the untreated and uninoculated control had close to 100% emergence than the untreated and inoculated control Figure 5). No plants with lesions caused by late blight were observed after emergence of plants that developed from tubers exposed to the cut face inoculation.

3.2.3 Foliar inoculation experiments

No significant difference ($p = 0.05$) was observed in rate of emergence or final plant stand between any treatments emerged from treated seed tubers21 days after planting, final stand count was 90 - 100% for all treatments and rate of emergence (RAUEC) about 0.5 - 0.55.

Foliar late blight progress (RAUDPC) after inoculation of the immature canopy, in plants that developed from untreated and treated seed-pieces (all fungicide treatments) was not significantly higher ($p = 0.05$) in comparison with the untreated/uninoculated control which became infected soon after the inoculation and late blight developed to a final infection level of 100% and RAUDPC of about 0.30 for all treatments.

DISCUSSION

Potato seed piece treatments are useful for the control of seed-borne diseases such as black scurf and stem canker (*Rhizoctonia solani*), silver scurf (*Helminthosporium solani*) and dry rot (*Fusarium* spp) [5,16,17]. These results confirm that the addition of active ingredients that are effective in the management of foliar late blight e.g. mancozeb to existing seed treatments expands their spectrum of activity. However, it is the first indication that a biological control agent *T. atroaviride*, is as effective as conventional fungicides for the control of seed-borne late blight. The simulation of different phases of infection of potato late blight identified effective treatments for seed-borne late blight and aerial infection of the immature canopy.

Pathogens such as silver scurf, black scurf and dry rot, typically rely on seed infection to establish a moderate level of sprout infection, thereby initiating the seasonal epidemic on stems either above or below ground [18]. Severe infection of the sprout with *P. infestans* results in premature sprout death and non-emergence [3]. No seed treatments effectively controlled late blight spread inside the tuber. The application of seed treatments to infected seed did not enhance emergence and did not prevent disease developing on some of the emerged sprouts. Internal tuber infections were not controlled with the seed treatments tested. The low number of emerged plants and decreased rate of emergence indicated that sprouts were becoming infected and killed prior to emerging from the soil. The mechanism of infection of sprouts by *P. infestans* has not been fully described but a study by Kirk et al. (unpublished) has shown that infection of developing sprouts on potato tubers is initiated in connecting tissue at the point of attachment of the sprout to the mother tuber.

The development of products for late blight control is currently focused on products to prevent the transmission of the disease at seed cutting [7]. Simulation of cut surface spread of late blight from tuber to tuber in this study confirmed that cut surfaces exposed for as little as 30 seconds to late blight inoculum are readily infected. The cut surface is readily infected by *P. infestans*[7] but is also accessible to the active ingredients and biocontrol agents contained in the seed treatments. Infection may have been partially inhibited by the *T. atroaviride* and mancozeb component of the seed treatments. Mancozeb does not penetrate foliar tissue and the pathogen evades the fungicide once penetration has taken place[19] therefore mancozeb may not move far from the site of application on tuber tissue. The cut surface of the tuber may allow mancozeb to move sufficiently far inside the cut tuber to prevent the establishment of late blight and prevent the infection of sprouts. However, *T. atroaviride* is systemic in plant tissue [(reference please)] and may prevent late blight infection of sprouts in cut seed where the application of the seed treatment is delayed in blight infected seed-lots. It is not expected that *T. atroaviride* applied as a seed-piece treatment would be fully effective and the risk of plants emerging from the soil with late blight remains even when seed treatments with components effective against late blight are included in the formulation. The reduced rate of emergence of plants after treatment with seed treatments that did not contain mancozeb was evident. A slower rate of emergence may enable the late blight infection to become established and either kill the developing sprout or allow the infection to be carried above ground and initiate a new crop infection. These results confirm other findings[7] that pre-cutting and use of seed treatments (specific and unspecific for late blight) may increase the risk of blight spreading from the seed to the sprout and ultimately to foliage.

Secondary spread of late blight between plants may occur at an early stage in canopy development. The effect of biological and conventional seed treatments may endure sufficiently to help reduce the vulnerability of immature leaves to infection by *P. infestans*. Seed-piece treatments reduced overall disease in the immature canopy after foliar inoculation with *P. infestans* in controlled environment experiments. This was especially true for leaves near the base of the stem, but not all leaves were protected from late blight. Leaves that had a reduced ratio of infection were at the base of the main stem and may have been exposed to the seed treatments at the time of application. Immature leaf primordia were less than 0.5 cm in length at the time of treatment[20] and biocontrol agents and fungicides applied to seed may accumulate on tuber structures such as developing sprouts. The accumulated biocontrol agents and fungicides are likely to be stored, dispersed and taken up (if systemic) by the developing leaf, stolon and root primordia present on these sprouts. Redistribution of active ingredients may result in effective dose accumulations on the developing leaves and internodes. Leaves at the base of the stem in some varieties are less susceptible to late blight infection than leaves close to the flower [21].

Corresponding field studies designed to examine the effect of seed treatments on subsequent foliar infection did not confirm the controlled environment studies. The quantity of *P. infestans* inoculum and conducive environment in the field studies allowed infection of all unprotected foliage and resulted in rapid and complete plant death.

Seed health and quality is of paramount importance to seed and commercial growers in potato crop production [6]. Although it is not possible at present to be completely certain that a potato seed lot is 100% free of late blight, it is prudent to plant seed that meets established seed certification standards. The application of appropriate seed treatments to healthy seed may seem counterintuitive. However, the potential for late blight to establish itself in young post-emergence foliage before prophylactic fungicide applications begin suggests that additional early season protection may be warranted in potato growing areas with a history of late blight. Seed treatment applied to healthy seed may provide some protection against early season late blight and may persist sufficiently to overlap with the beginning of conventional foliar fungicide applications, providing more complete protection.

Some seed treatment fungicides, such as the fludioxinil + mancozeb and thiophanate-methyl + cymoxanil + mancozeb have systemic and non-systemic fungicide components. These formulations suppressed late blight development in newly emerged plants in controlled environments. It was encouraging that T. atroaviride attained levels of late blight control similar to fludioxinil +

mancozeb. The precise timing of application of seed treatments in relation to seed cutting, sprout development and timing of planting requires further study.

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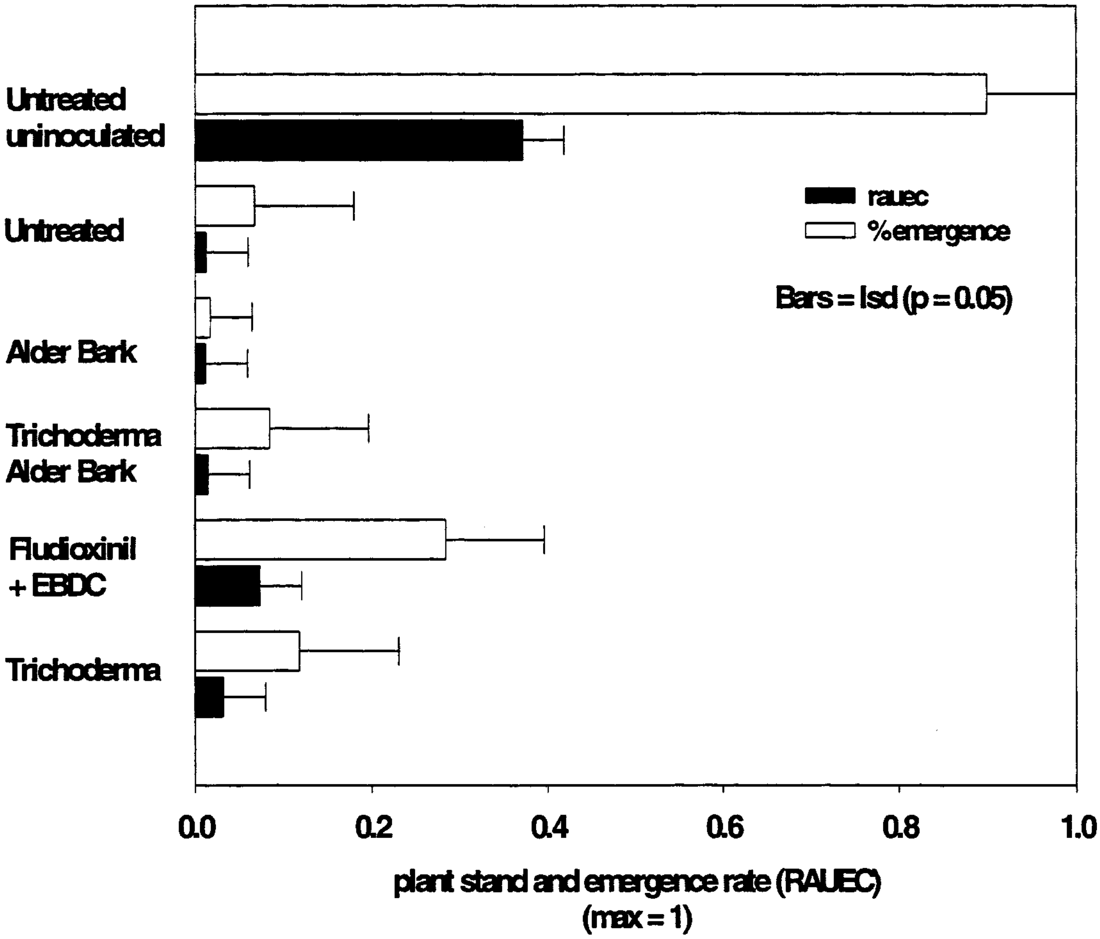


Figure 1. Final plant stand (max = 1) and rate of plant emergence (max = 1) of potato plants that emerged from fungicide-treated seed pieces. Seed tubers inoculated by sub-peridermal injection with *P. infestans* 24 h before seed treatments applied (averages of 3 experiments).

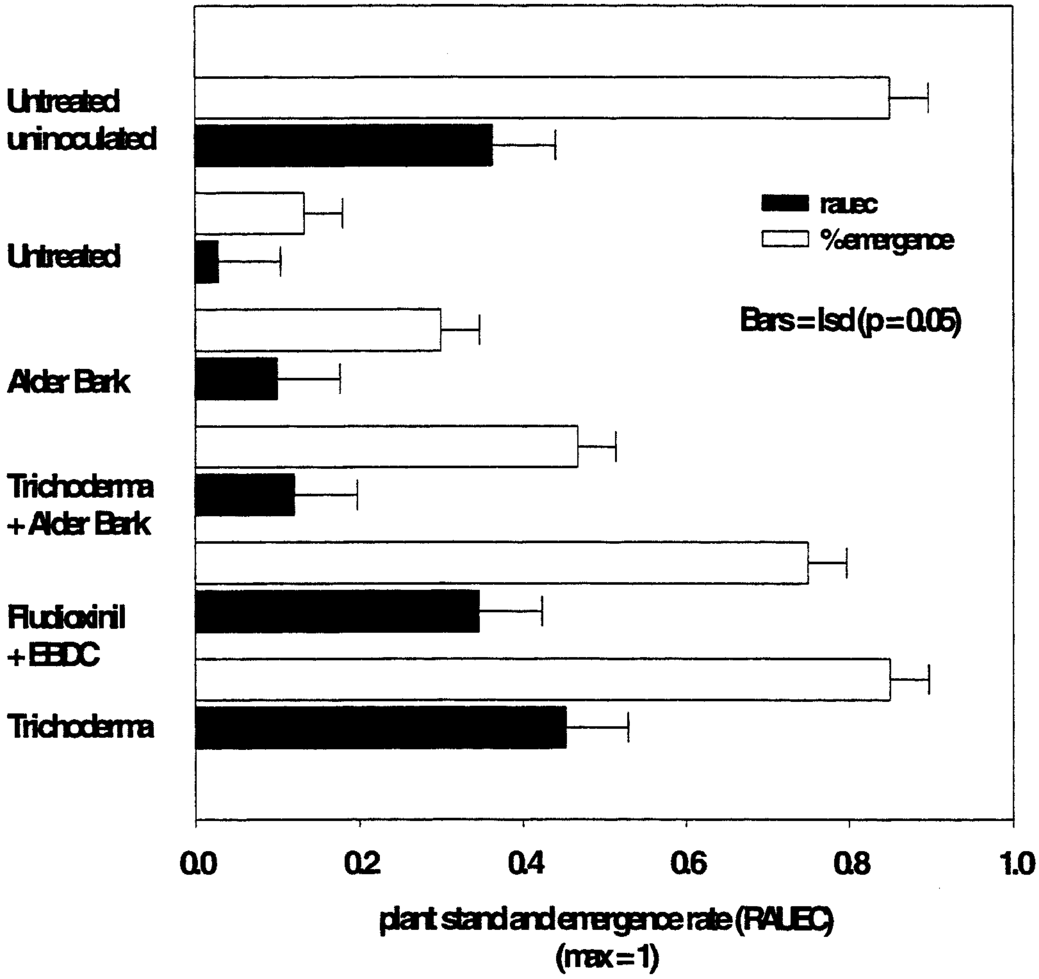


Figure 2. Final plant stand (max = 1) and rate of plant emergence (max = 1) of potato plants that emerged from fungicide-treated seed pieces. Seed tubers inoculated by exposure of cut surface of seed tuber to mycelial/rye agar homogenate of *P. infestans* 0.5 h before seed treatments applied (averages of 3 experiments).

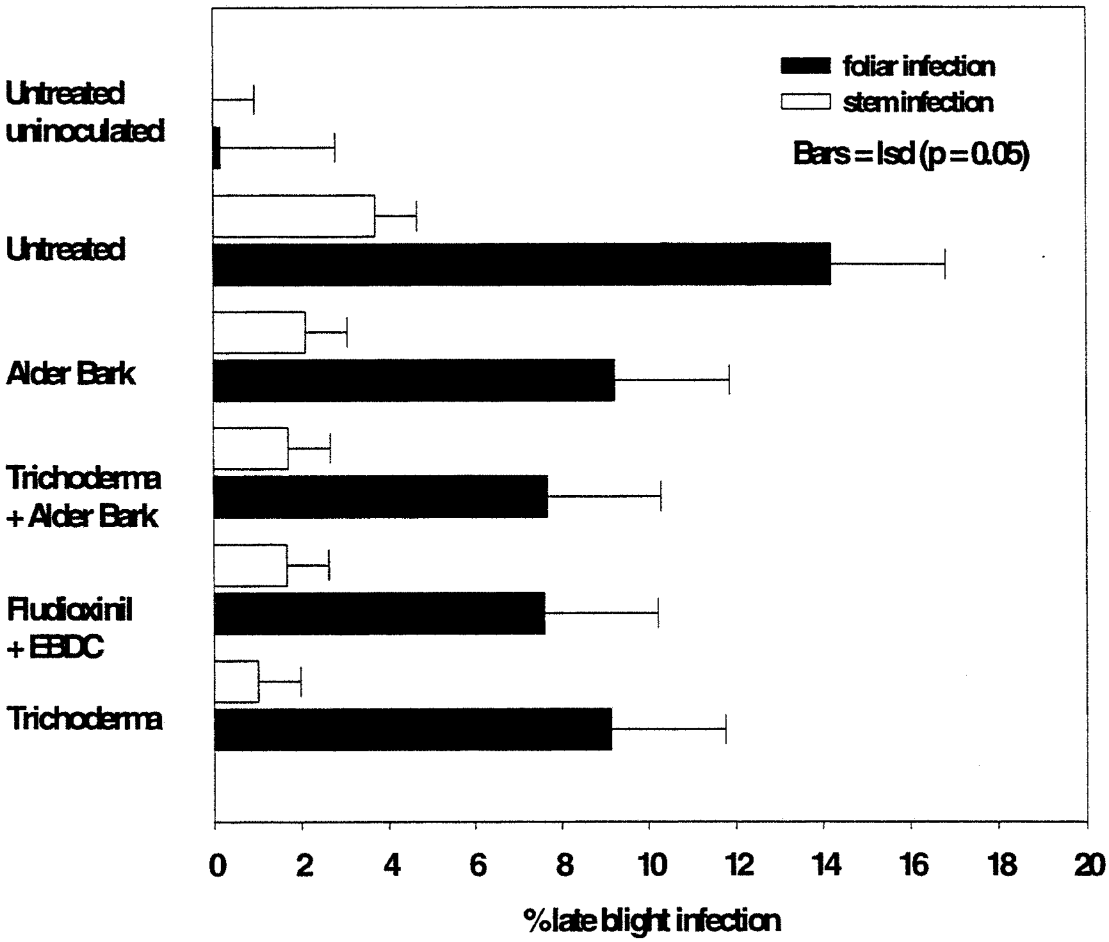


Figure 3. Foliar and stem late blight infection of potato plants that emerged from fungicide-treated seed pieces. Plants inoculated with *P. infestans* by foliar aerosol of zoospore suspension 10 days after emergence and evaluated 14 days after inoculation (averages of 3 experiments).

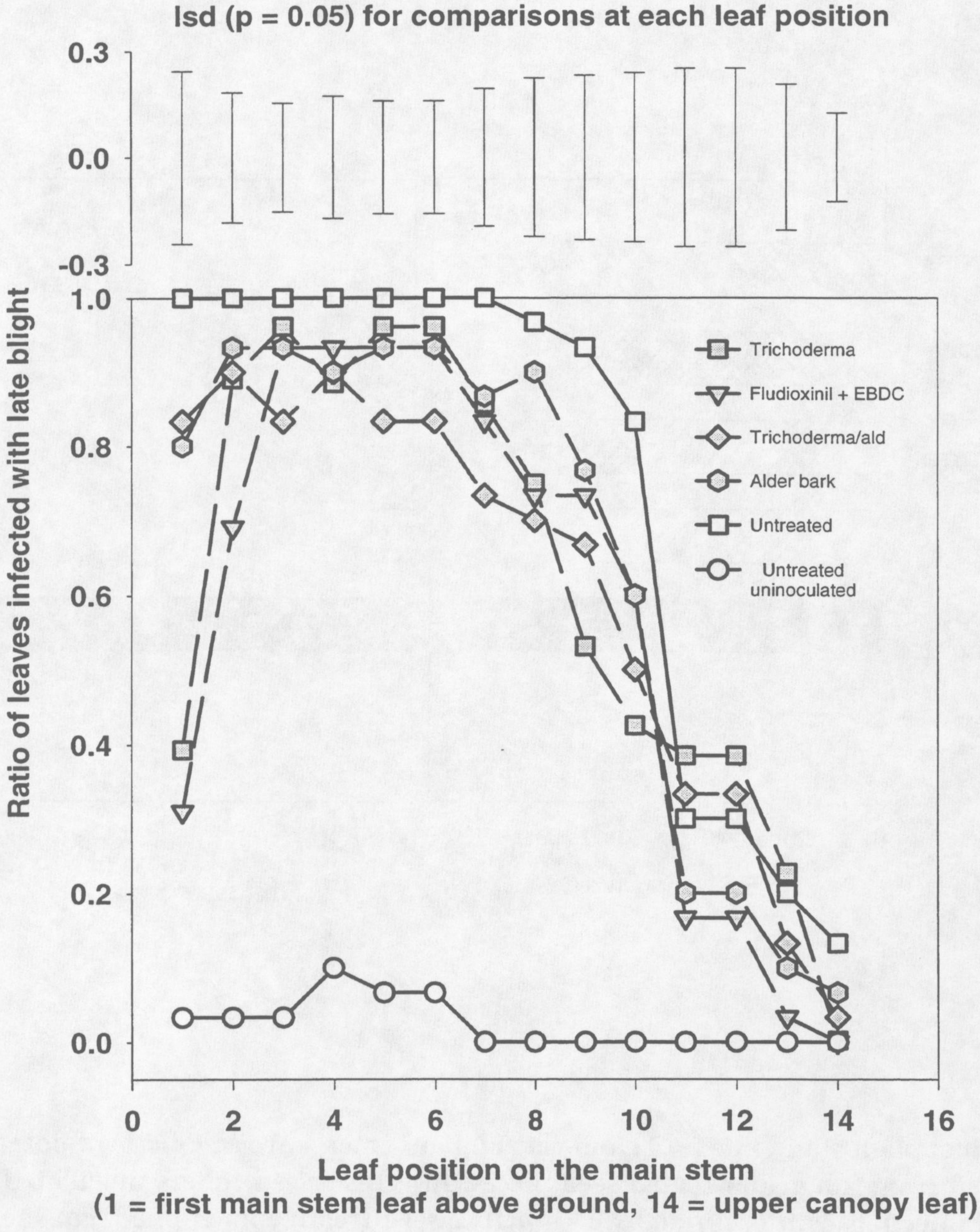


Figure 4. Ratio of infected:healthy potato leaves inoculated with *P. infestans* in relation to leaf position on the main stem (averages of 3 experiments). Foliar infection of potato plants that emerged from fungicide-treated seed pieces. Plants inoculated with *P. infestans* by foliar aerosol of zoospore suspension 10 days after emergence and evaluated 14 days after inoculation (averages of 3 experiments).

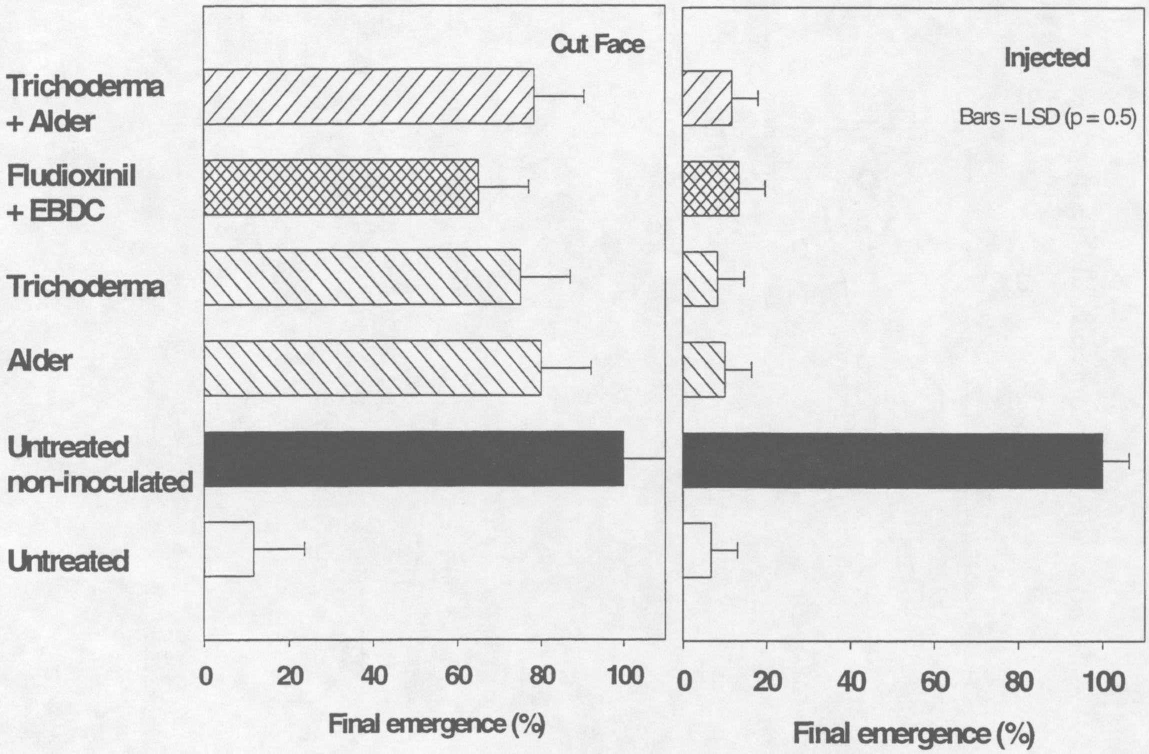


Figure 5. Final plant stand (max = 1) and rate of plant emergence (max = 1) of potato plants that emerged from fungicide-treated seed pieces. Injected - seed tubers inoculated by sub-peridermal injection with *P. infestans* 24 h before seed treatments applied, cut face - seed tubers inoculated by esposure of cut surface of seed tuber to mycelial/rye agar homogenate of *P. infestans* 0.5 h before seed treatments applied(averages of 3 experiments).

Spatial and Temporal Dynamics of Potato Production Sites in Relation to Precision Agriculture and Integrated Crop Management Systems

Potato Precision Ag Team:

- Roger Brook, Agricultural Engineering (coordinator)
- George Bird, Entomology (nematodes, verticillium and potato early die)
- Darryl Warncke, Crop & Soil Sciences (soil fertility)
- Scott Swinton, Agricultural Economics (profitability assessment)
- Dave Lusch, Center for Remote Sensing (analysis of aerial imagery)
- Mark Otto, Agri-Business Consultants (crop management)
- Nate Hough, Agricultural Engineering (data analysis)
- Don Smucker, Montcalm Co. Extension (extension liaison; information dissemination)
- Rich Hodupp, St. Joesph Co. Extension (extension liaison; information dissemination)

Project Goal: To evaluate the value and utility of precision agriculture practices, systems and concepts in the production of potatoes grown under Michigan conditions

Specific Objectives:

- to investigate the relationship between tuber quality (yield, size and market quality) and soil quality (soil properties, fertility, nematodes, disease, particularly in relation to supplemental calcium
- to understand the role of precision agriculture technologies in reducing within field variation for Michigan potatoes

Funding: MPIC for field sampling; In-Kind for sample analysis and field management; MAES/MSUE for technical support (starting fall 1999).

Research sites have been established in two potato production areas:

- Montcalm Co. -- two fields of about 60 acres each; one planted to potatoes (Pikes) in 1999 and the other to be planted to potatoes in 2000; primary soils are yellow sand mapped as Mancelona loamy sand and black sand mapped as Gladwin loamy sand and Palo sandy loam; we anticipate planting the 1999 field to potates in 2001
- St. Joseph Co. -- a 440 acre block, with potatoes in a three year rotation with seed corn; approximately 1/3 of the block is planted to potatoes each year; we anticipate planting the 1999 potato area to potatoes in 2002

Much of our efforts this year have centered on field characteristics that relate to the 1999 and 2000 potato crops.

- **elevation (topographic) mapping** - the research sites were mapped with a high-accuracy GPS system to establish both field elevation and electrical conductivity (EM38) characteristics.
- **fertility sampling** - in Montcalm Co., the 1999 field was sampled by the grower during the fall, 1998 on a 2.5-acre grid; the 2000 field was sampled on a 1-acre grid. The total St. Joseph site was sampled on a 1-acre grid, including all major and minor nutrients.

- **potato early die risk assessment** - the 2000 field in Montcalm Co. was sampled on a 1-acre grid for nematodes and verticillium.

Calcium vs. Fumigation (Montcalm Co. research site)
The 1999 research site in Montcalm Co. was used to conduct an experiment to look at the interaction of calcium and fumigation. Fumigation was applied to the southern half of the field fall 1998 using metham applied at 37.5 gal/acre. The field was planted using Pike variety potatoes on May 1-3, 1999. Supplemental calcium (pelletized gypsum) was applied to the whole field at 200 lb/acre at cultivation, with the exception of a strip of about 10-acres in each of the fumigation treated and not-treated sections of the field (see Figure 1). Additional calcium was supplied by calcium nitrate applied as a top-dress.

Prior to harvest, sample points were identified for locations of tuber samples to be taken for tuber quality analysis. There were four sample points identified for each of the four treatment combinations (see Figure 1).

During harvest, potato yield was monitored on the harvester using a HarvestMaster yield monitoring system. At each of the 16 sampling locations, samples of approximately 50-tubers each of large tubers (larger than 3 inches) and normal tubers (1-1/2 - 2-1/2 inches) were taken for quality analysis. Soil samples were also taken at each sampling location.

For each sample, 25 tubers were cut and evaluated for internal quality problems unique to the Pike variety. The tubers in each sample were classified as either no-defects, moderate internal defects or severe internal defects. Calcium (both pulp and peel) were determined for each sample for the no-defect tubers and for the defect tubers. The normal tubers were analyzed for sugars, chip color and total chip defects (both defect and non-defect tubers). Table 1 illustrates the treatment combination effects for percent non-defect tubers.

Table 1. Average of %no-defect tubers by treatment for Montcalm potato field 1999.

	Added Calcium	No Added Calcium	All Samples
Fumigated			
normal	95	79	87
large	54	39	47
Not Fumigated			
normal	96	86	91
large	78	67	73
All Samples			
normal	96	83	89
large	66	53	60

Preparations for Montcalm Co. 2000 Potatoes

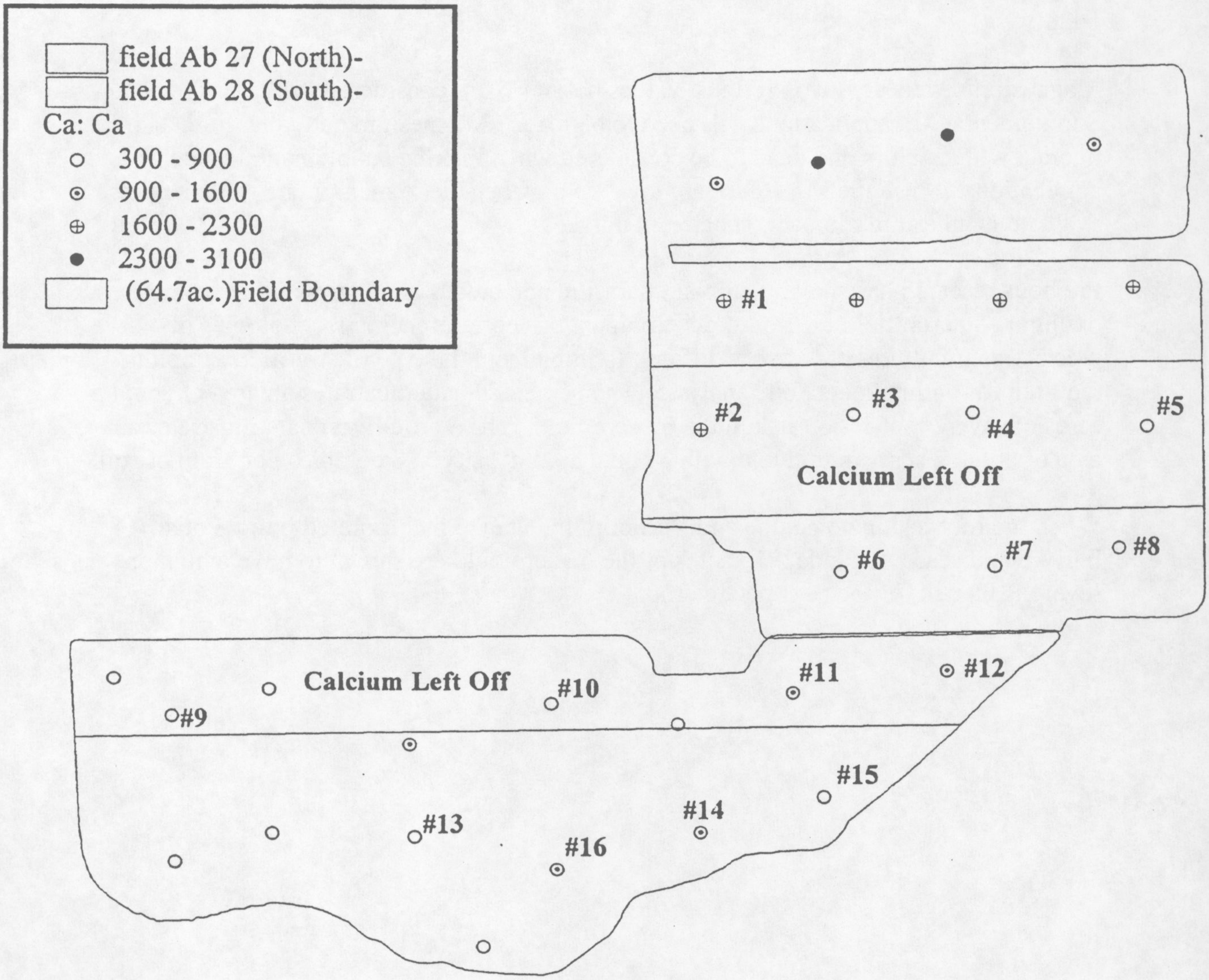
Calcium management is one focus of this project. The research site has relatively high calcium values compared to county averages (average 1,393 lbs. Ca per acre; range <500 to 3000). In most of the field, we would not expect a yield response from supplemental calcium applications. We are interested in the effects of supplemental calcium on tuber quality.

Magnesium levels are low. Soil test values below 75 are considered deficient. Supplemental Mg applications will need to be made. Magnesium and potassium also can interact with calcium and need to be considered when making supplemental calcium applications. Since the Mg values are low, we may be able to manipulate treatments to evaluate magnesium's impact on calcium uptake.

Previous research has shown that plant parasitic nematodes are distributed as aggregates or clumps in crop fields. Prior to development of geo-referencing technologies of precision agriculture, it was very difficult to implement the type of stratified sampling required for optimal nematode analysis. The nematode data illustrates an area of about 5 acres of severe root-lesion risk in the 62 acre field. The Verticillium data illustrates an area of about 2 acres in the field with a population density >16 colonies per gram of soil.

When the root-lesion nematode and Verticillium data are incorporated into a Potato Early-Die disease risk index, 16 acres of the 62 acre field are shown to have a high or severe PED risk for the next potato crop.

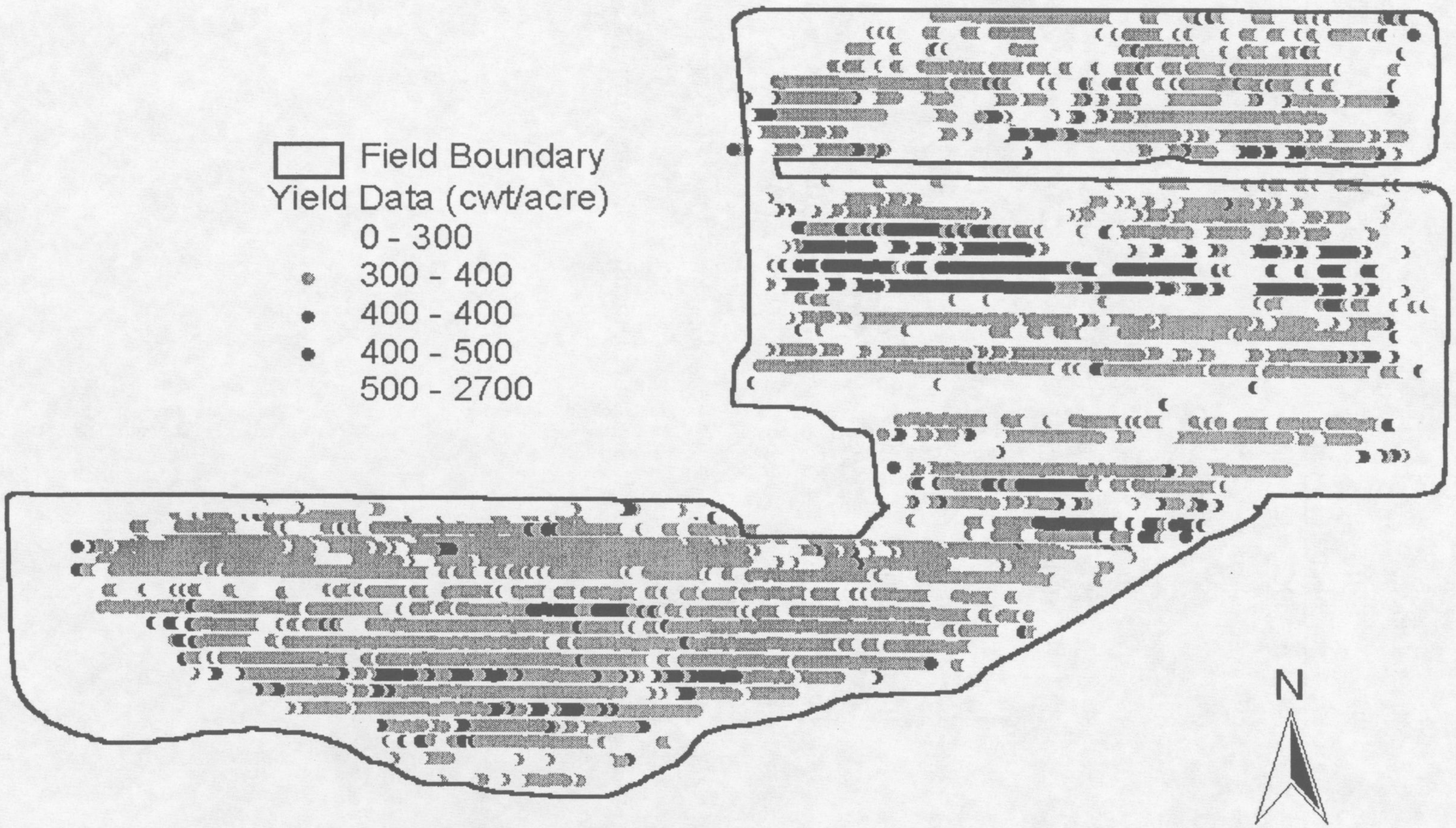
Figure 1. Field layout and sample points for the Montcalm field 1999; the bottom section of the field was fumigated, the top section was not; strips without supplemental calcium are indicated; available calcium values from sampling fall 1998.



Field Boundary Start Location:
Latitude: 43.43744131
Longitude: -84.87099467
No. of Observations: 30
Minimum Ca: 300
Maximum Ca: 3100
Average Ca: 1197

500 0 500 Feet

Figure 2. Potato yield map (cwt/acre) for the Montcalm field 1999; average yeild 417 cwt/acre; each of the three center legend ranges represents 20% of the data points; data points greater than 500 cwt/acre probably represent start/stop points or areas where 16-rows were harvested, but the yield monitor was set to 8-rows; data points less than 300 cwt probably represent row ends.



Appendix Table A. Soil test results for the Montcalm field, sampled at harvest 1999.

	% No Defect			Pounds per Acre		--- ppm ---	
Sample *	Large Tubers	Normal Tubers	pH	P	K	Ca	Mg
1	88	96	5.6	190	326	2000	236
2	80	88	5.4	254	379	2100	245
3	64	88	5.3	254	305	700	95
4	84	92	5.2	190	284	500	74
5	40	76	5.6	247	284	800	147
6	84	96	5.6	200	358	1000	209
7	72	100	5.5	190	200	600	126
8	68	92	5.8	200	242	700	158
9	40	76	5.6	190	221	500	126
10	52	84	6.1	154	263	800	209
11	40	76	5.8	240	337	900	218
12	24	80	5.9	262	253	800	209
13	44	92	5.7	247	170	700	255
14	84	92	5.8	190	200	800	218
15	44	100	5.9	174	221	800	189
16	44	96	5.8	166	274	800	218

* Samples 1, 6, 7, 8, 13, 14, 15, 16 had supplemental calcium; samples 9-16 were fumigated

Appendix Table B. Tuber pulp and periderm calcium for the Montcalm field 1999.

		Large Tubers			Normal Tubers		
		% No Defect	Periderm Ca (%DM basis)	Pulp Ca (%DM basis)	% No Defect	Periderm Ca (%DM basis)	Pulp Ca (%DM basis)
Sample *							
1	d **	88	0.141	0.042	96	0.163	0.050
	nd **		0.153	0.041		0.132	0.060
2	d	80	0.135	0.041	88	0.139	0.030
	nd		0.184	0.049		0.175	0.049
3	d	64			88	0.106	0.038
	nd					0.130	0.045
4	d	84	0.102	0.04	92	0.094	0.036
	nd		0.083	0.054		0.089	0.037
5	d	40	0.115	0.033	76	0.198	0.048
	nd		0.124	0.044		0.191	0.046
6	d	84	0.123	0.040	96	0.133	0.036
	nd		0.131	0.041		0.147	0.049
7	d	72	0.112	0.035	100		
	nd		0.128	0.041		0.112	0.039
8	d	68	0.115	0.033	92	0.099	0.046
	nd		0.106	0.033		0.087	0.033
9	d	40			76	0.125	0.024
	nd					0.176	0.047
10	d	52	0.074	0.03	84	0.079	0.032
	nd		0.113	0.032		0.079	0.038
11	d	40	0.118	0.026	76	0.103	0.038
	nd		0.100	0.037		0.133	0.037
12	d	24	0.117	0.037	80	0.073	0.029
	nd		0.113	0.035		0.129	0.040
13	d	44	0.130	0.030	92	0.091	0.028
	nd		0.130	0.041		0.101	0.036
14	d	84	0.119	0.042	92	0.119	0.036
	nd		0.183	0.037		0.117	0.044
15	d	44	0.113	0.029	100		
	nd		0.114	0.045		0.171	0.034
16	d	44	0.093	0.035	96	0.157	0.034
	nd		0.103	0.033		0.154	0.052

* Samples 1, 6, 7, 8, 13, 14, 15, 16 had supplemental calcium; samples 9-16 were fumigated

** d = tubers from sample that had defects; nd = tubers from sample without defects

Appendix Table C. Sugar content analysis and chip score and rating for normal size tuber samples for the Montcalm field 1999.

Sample *		% No Defect	Chip Score	% Color Defects	% Total Defects	Sucrose Rating	Glucose Rating
1	d **	96	1	0	50	0.34	0.004
1	nd **		1	6.7	6.7	0.243	0.003
2	d	88	1	50	50	0.316	0.004
2	nd		1	13.3	13.3	0.269	0.002
3	d	88	1	0	50	0.232	0.003
3	nd		1	13.3	13.3	0.206	0.002
4	d	92	1	0	75	0.262	0.003
4	nd		1	10	10	0.262	0.003
5	d	76	1	0	50	0.366	0.005
5	nd		1	13.3	13.3	0.305	0.002
6	d	96	1	0	100	0.32	0.005
6	nd		1	0	0	0.288	0.003
7	d	100					
7	nd		1	20	20	0.191	0.003
8	d	92	1	0	17	0.284	0.003
8	nd		1	0	0	0.314	0.002
9	d	76	1	0	50	0.161	0.003
9	nd		1	6.7	10	0.211	0.005
10	d	84	1	0	50	0.206	0.003
10	nd		1	0	0	0.196	0.003
11	d	76	1	0	33.3	0.249	0.003
11	nd		1	0	0	0.226	0.003
12	d	80	1	0	50	0.161	0.003
12	nd		1	0	0	0.234	0.003
13	d	92	1	0	25	0.224	0.003
13	nd		1	0	0	0.209	0.002
14	d	92	1	0	50	0.29	0.003
14	nd		1	20	20	0.2	0.003
15	d	100					
15	nd		1	13.3	20	0.234	0.003
16	d	96	1	0	100	0.346	0.004
16	nd		1	13.3	13.3	0.168	0.003

* Samples 1, 6, 7, 8, 13, 14, 15, 16 had supplemental calcium; samples 9-16 were fumigated

** d = tubers from sample that had defects; nd = tubers from sample without defects

Misc. Funding: MSU Potato Precision Ag Team

Calcium And Metham Effects on Potato Tuber Yield and Quality

George Bird, Dept of Entomology
Darryl Warncke, Dept. of Crop and Soil Sciences

New technologies are enabling measurement of field and soil properties and potato tuber yields and quality by site specifically. A better understanding of the landscape, soil and biological factor effects on potato growth, development and subsequent tuber quality and yield will improve production of quality potato tubers. Factors that may influence tuber yield and quality are insufficient available calcium in soil and the early die complex generally involving verticillium and parasitic nematodes.

This study focused on the effects of supplemental calcium and fumigation and was located in the NW 1 range of the Montcalm Potato Research Farm. All plots were sampled to determine the soil pH, available nutrient status, and the nematode population. The soil fertility data are presented in appendix table A. Two main treatments were applied separately and in combination (Table 1). In April after the soil had warmed up the soil was fumigated with 75 gallons of metham per acre. The soil was opened up with secondary tillage two weeks prior to planting. Calcium (294 lb/A) as calcium sulfate (1000 lb/A) was broadcast and incorporated prior to planting. Additional calcium (100 lb/A) as calcium nitrate was top-dressed directly over the row at tuber initiation. Planting occurred on May 14. Tubers were harvested on September 24. Samples of 2.5 to 3.25 inch diameter tubers were placed in 50°F storage. In December, 25 tubers were sliced, inspected for defects and fried for chips. Another sample of 24 tubers were bruised in an octagonal tumbler. After being at room temperature for 3 days the tubers were peeled and inspected for bruises.

RESULTS

Fumigation with metham had a significant effect on tuber yield and tuber size (Table 1). Calcium had a much smaller effect. The combination of metham and calcium resulted in the greatest yield and highest percent of over 3 inch tubers. The NW1 range has considerable variability in topography that resulted in considerable variability in yield data and a significant replication effect. The replications (3 and 4) with the lowest yields had the lowest elevation and some plots were quite wet at times during the growing season. Herbicide application was also missed in some plots in these two replicates which had an adverse effect. The tubers grown in fumigated soil had significantly less stem-end discoloration and vascular discoloration (Table 3). Supplemental calcium had little effect on the occurrence the various defects.

Table 1. Potato (cv Snowden) yield and quality as influenced by supplemental calcium and metham.

Treatment	Total Yield	Size Distribution >3"	2-3"	<2"	Specific Gravity
Check	266	6.2	71.3	19.1	1.074
Calcium[x]	297	8.1	71.3	16.8	1.073
metham[z]	436	18.1	70.9	8.1	1.075
Calcium + metham	424	13.9	72.6	10.2	1.075
$Lsd_{.05}$	85	6.2	ns	8.8	ns

[x] Calcium sulfate was broadcast and incorporated at 1000 lb/A. In addition 100 lb calcium per acre, as calcium nitrate, was topdressed directly over the row.
[z] metham was injected at 75 gallons per acre.

Table 2. Location (replicate) effect on potato (cv Snowden) yield and quality the calcium and metham treatments.

Replicate	Total Yield	Size Distribution >3"	2-3"	<2"	Specific Gravity
1 north	404	14.2	71.2	10.8	1.075
2	372	14.1	69.3	12.6	1.075
3	236	3.5	67.0	25.6	1.068
4	349	10.5	73.0	12.6	1.074
5	387	12.8	75.0	9.2	1.076
6 south	388	14.3	73.6	10.4	1.076
$Lsd_{.05}$	139	9.2	7.3	10.0	.002

[x] Calcium sulfate was broadcast and incorporated at 1000 lb/A. In addition 100 lb calcium per acre, as calcium nitrate, was topdressed directly over the row.
[z] metham was injected at 75 gallons per acre.

Table 3. Influenced of supplemental calcium and metham on potato (cv Snowden) tuber and chip quality.

Treatment	Bruise Index	Stem-End Discoloration	Vascular Discoloration	Hollow Heart	Chip Color
Check	1.93	2.3	2.7	0.5	1.4
Calcium[x]	2.29	2.0	3.3	0.7	1.6
metham[z]	2.48	0.8	0.7	1.0	1.6
Calcium + metham	2.20	1.2	1.0	0.0	1.6
$Lsd_{.05}$	ns	1.2	1.1	0.9	ns

[x] Calcium sulfate was broadcast and incorporated at 1000 lb/A. In addition 100 lb calcium per acre, as calcium nitrate, was topdressed directly over the row.
[z] metham was injected at 75 gallons per acre.

Appendix Table A. Soil pH and extractable P, K, Ca and Mg values for all plots sampled prior to application of treatments.

Plot	Rep	Trtmt.	pH	BpH	P	K	Ca	Mg
1	1	4	5.5	6.7	458	270	490	105
2	1	3	5.9	6.8	388	300	760	106
3	1	1	5.9	6.8	376	320	690	146
4	1	2	6.1	6.9	388	320	380	124
5	2	4	6.0	6.9	352	330	860	166
6	2	2	6.1	6.9	364	370	820	135
7	2	1	6.0	6.9	388	360	840	75
8	2	3	6.1	7.0	330	330	920	155
9	3	1	5.9	6.9	302	330	860	145
10	3	2	5.7	6.8	330	320	850	146
11	3	4	5.8	6.7	408	470	1030	170
12	3	3	5.9	6.8	392	370	870	150
13	4	1	5.9	6.9	342	320	810	195
14	4	3	5.9	6.9	352	280	550	124
15	4	4	6.0	6.9	330	340	610	108
16	4	2	6.0	7.0	320	270	720	121
17	5	1	6.1	7.0	320	300	740	96
18	5	2	6.2	7.0	342	290	760	135
19	5	3	6.2	7.0	330	350	780	118
20	5	4	5.8	6.8	424	370	720	139
21	6	3	5.9	6.7	528	430	900	127
22	6	4	6.1	6.9	376	370	740	173
23	6	1	6.3	7.0	342	290	700	154
24	6	2	6.0	6.9	320	260	580	153

Bray P1 extractable P. Ammonium acetate extractable K, Ca and Mg.

POTATO STORAGE EXPERIMENTS
Two Decades of Progress in Technology and Management

Round 1 : 1986 - 1989

Dr. Burt Cargill, Dr. Roger Brook, Todd Forbush, Keith Tinsey, John Mills
Agricultural Engineering Department, Michigan State University
Storage Location: Sandyland Farms, Montcalm Co.

Objective: test the influence of different rates of airflow on the performance of chip potatoes in storage.

Methods

Construct three experimental storage bins
- 8' x 8' floor area, 18' high
- independent ventilation
- control using Fancom 1056 computer
- different airflow rates
  1.5, 3.0 & variable 0 - 3.0 CFM/cwt

Fill in the fall with Atlantic variety potatoes
- sample bags placed at three levels for total weight loss
- temperature sensors at four levels in the pile
- sample from three levels for sugar content and chip color

Storage temperature management
- pre-conditioning: 60°F at 92-95% RH
- cool down: 1 - 2°F per week to 50°F
- holding: 50°F at 95% RH

Results for 1988-1989 Storage Season

	Bin #1	Bin #2	Bin #3
ventilation, cfm/cwt	1.5	3.0	variable ***
4' level			
color *	67	62	65
appearance **	0	8	0
% glucose	0.028	0.023	0.032
sucrose rating	0.74	1.1	0.49
weight loss, %	8.8	10.0	9.3
8' level			
color *	61	68	64
appearance **	2	3	3
% glucose	0.011	0.023	0.017
sucrose rating	0.45	0.90	0.41
weight loss, %	7.0	7.9	5.6
12' level			
color *	61	0.63	58
appearance **	0	0	1
% glucose	0.039	0.028	0.032
sucrose rating	0.70	0.65	0.70
weight loss, %	6.1	6.2	5.6

* Agtron scale calibrated red mode 0 and 90
** quality criterea: 0 = excellent; 15 = not acceptable
*** average of variable ventilation rate was 1.0 CFM/cwt

Conclusions
- Three years of research
- Average weight loss not a function of ventilation rate
- Weight loss more uniform at higher ventilation rates
- Pre-conditioning management strategy produced high quality potatoes from 50°F storage after 135 days
- Environmental control was effectively carried out using the Fancom environmental control computer

More Information

Michigan Potato Research Report. 1987, 1988. Simulated potato storage research.
Forbush, T.D. 1989. Influence of Ventilation Rate on Potato Quality Out-of Storage. M.S. Thesis, Michigan State University.
Forbush, T.D. and Brook, R.C. 1993. Influence of airflow rate on chip potato storage management. Am. Potato J. 70:869-883.

Round 2 : 1990 - 1991

Dr. Roger Brook, Robert Fick
Agricuultural Engineering Department, Michigan State University
Dr. Ray Hammerschmidt
Botany and Plant Pathology Department, Michigan State University
Storage Location: Bishop Potato Farms, Bay Co.

Objective: To store Atlantic and W855 (Snowden) potatoes for an extended season.

Methods

Move two research bins to Bay Co.
- modify bins to have same fan (capable of 3.0 cfm/cwt)
- install new Fancom 656 storage controller
- fill one bin with Atlantic potatoes and one with W855 (Snowden) potatoes

Environmental control goals
- Atlantic desired pile temperature 50°F
- W855 desired pile temperature 45°F
- maximum difference between pile and ventilation temperature 4°F
- maximum difference between any two pile temperature sensors 2°F
- relative humidity controlled above 90%

Dates and Sampling
- Harvest Sep. 26, 1990
- Cooling begins Oct. 31, 1990
- Sprout inhibitor Nov. 12, 1990
- Holding begins Jan 22, 1991
- Experiment ends Apr. 9, 1991

Sampled bi-weekly for sugar content, wound healing ability and Fusarium resistance

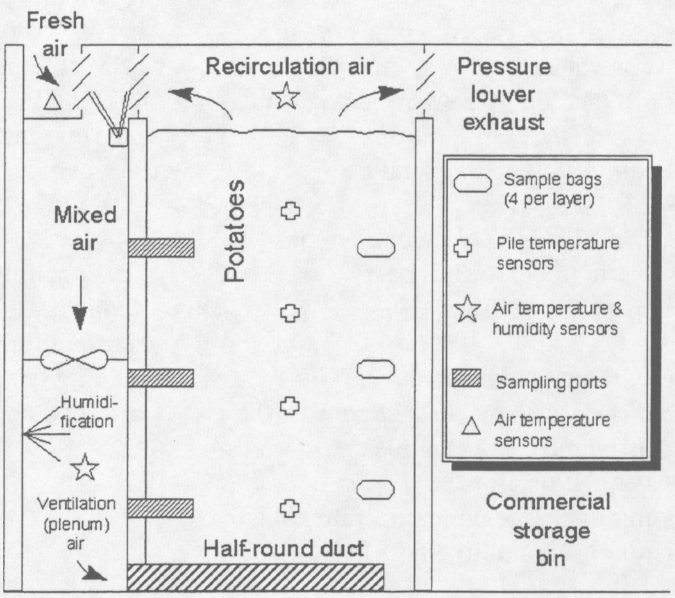


Figure 1. Schematic cross-section of potato storage research bins

Conclusions
- no significant difference in sucrose or glucose sugar contents between levels in any research bin
- all samples had acceptable fry color
- both varieties exhibited near constant ability to suberize and to restrict dry rot developemnt; after January the ability of both varieties to carry out these two functions declined
- Snowden appeared to have somewhat greater wound healing ability
- Snowden potatoes appeared to sprout earlier than the Atlantics, suggesting a need for faster cooling

Recommendations
- Snowden potatoes at 45°F respond similar to Atlantic potatoes stored at 50°F
- uniform and gradual temperature changes are important for maintaining potato color and quality through extended storage
- temperature of the cooling air should be maintained above 42°F at all times

Round 3 : 1992 - 1993

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Storage Locations: Bishop Potato Farms, Bay Co. and Iott Seed Potato Farm, Kalkaska Co.

Objective: investigate storage temperature management on out-of storage quality of Snowden potatoes

Methods

Move the remaining research bin to Kalkaska Co.
- modify bins to have same fan (capable of 3.0 cfm/cwt)
- install new Fancom 656 storage controller
- fill one bin with Atlantic potatoes

Desired storage temperature
- Bin #1 -- 45°F
- Bin #2 -- cool til color develops; warm til color disappears
- Bin #3 -- 40°F

Environmental control goals
- difference between pile sensors 0.5°F
- difference between pile and ventilation air 4°F
- minimum plenum temperature 42°F
- relative humidity 95%

Storage Dates and Paameters 1992-1993

	Bin #1	Bin #2	Bin #3
location	Bay Co.	Bay Co.	Kalkaska Co.
harvest date	10/5/92	10/5/92	9/16/92
harvest temp, °F	59	59	72
ventilation rate	1.5	1.5	1.5
fan run times,hr			
- suberization	24	24	24
- cooling	24	24	24
- holding	3 of 12	3 of 12	3 of 12
start cooling	10/25/92	10/25/92	10/15/92
cooling rate, °F/day	0.3	0.3	0.5
start holding	12/9/92	12/17/92	11/125/92
holding temp, °F	45	min 42	39
market date	3/31/93	3/30/93	4/21/93

Results

See figure on the following page for results from the 1992-1993 storage season.

Snowden Storage Recommendations

- wound healing at 55°F and 95% RH for 2 weeks
- pre-condition at 55°F until color reaches desired level; glucose about 0.01%
- cool tubers quickly at 0.5°F/day to a temperature of 50°F; uniform and gradual temperature changes are important for maintaining potato quality and color
- maintain difference between pile temperature and ventilation air temperature at no more than 3°F
- continue cooling to 45°F at a rate of 0.3°F/day, using ventilation air temperatures of no less than 43°F

More Information

Michigan Potato Research Report. 1993. Potato Storage Research.

Fick, R.J. 1993. Experiments On The Long-Term Storage Of Chipping Potatoes. Ph.D. Thesis, Michigan State University.

Fick, R.J. and Brook, R.C. 1999. Threshold sugar concentrations in Snowden potatoes during storage. Amer. J. Potato Res. 76:357-362.

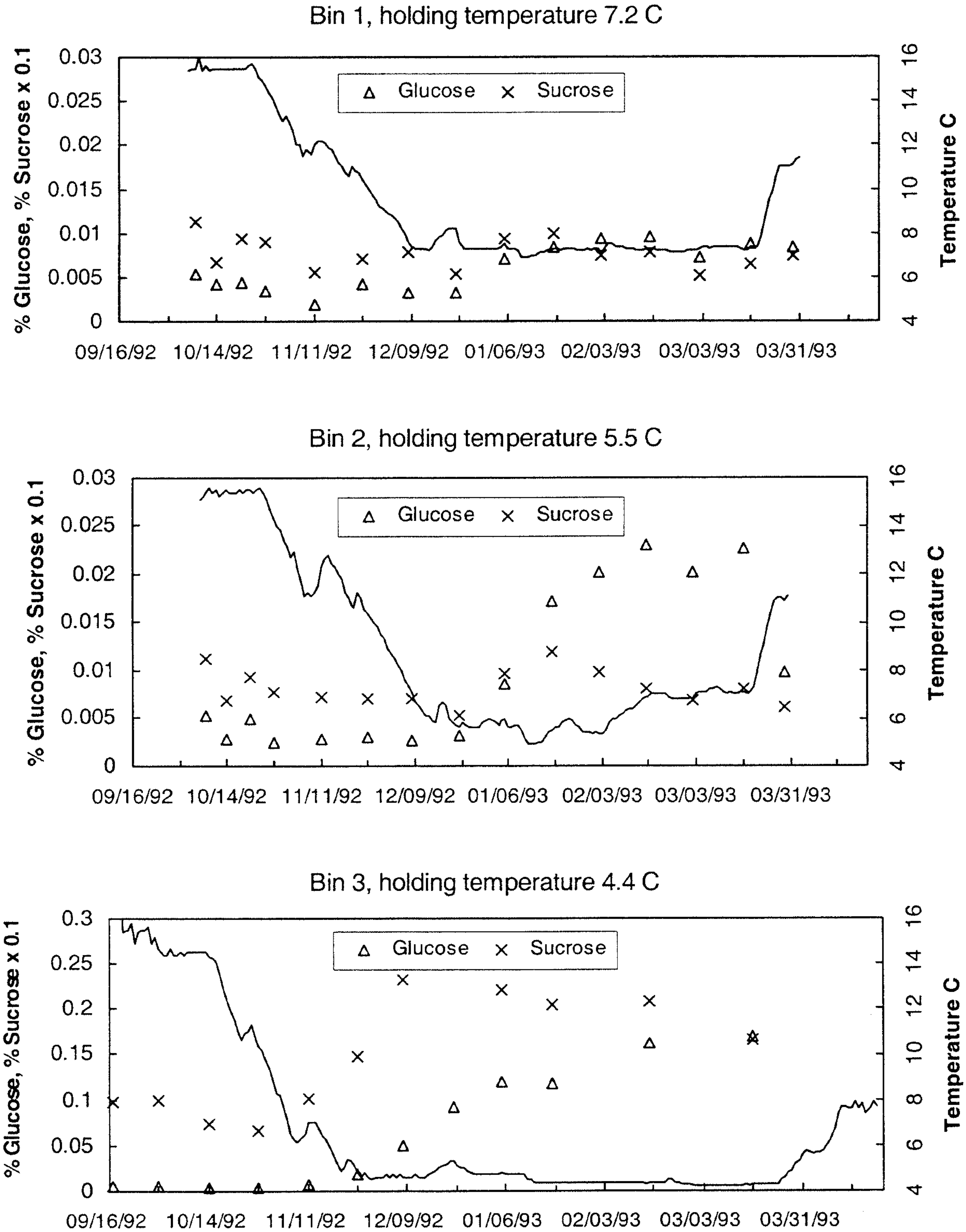

Figure 2. Temperature and sugar concentrations for samples taken during the 1992-1993 storage season (sucrose data was divided by 10 before plotting). Bin 1 (located at Bishop Farms) had a holding temperature of 45°F; bin 2 (located at Bishop Farms) had a holding temperature of 42°F; bin 3 (located at Iott Farm) had a holding temperature of 40°F. Bins were not actively managed relative to sugars.

Round 4: 1994 - 1997

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Storage Location: Bishop Potato Farms

Objective: monitor selected varieties during using different temperature management strategies.

Methods

During the summer of 1995, Bishop Potato Farms constructed a new storage facility. Within that storage, they designed four research bins similar to those used in the previous studies. These bins were used during the subsequent three storage seasons.

1995-1996 Storage Season: Snowden variety potatoes were placed in bins 21 (desired holding temperature 42°F) and 22 (desired holding temperature 45°F). Lemhi Russet variety potatoes were placed in bin 23 and Pike variety potatoes were placed in bin 24. All the potatoes were grown in Bay Co. by Bishop Potato Farms. The storage bins were actively managed relative to sugar contents of the bi-weekly tuber samples.

The Lemhi Russet potatoes were marketed for french fry production in late December, 1995. The other potatoes were marketed for potato chips in early April, 1996.

1996-1997 Storage Season: Snowden and Pike variety potatoes were grown in Montcalm Co. and in St. Joseph Co. The Snowden potatoes were stored in bins 21 and 22, with a desired holding temperature of 45°F. The Pike potatoes were stored in bins 23 and 24, with a desired holding temperature of 50°F. The storage bins were actively managed relative to sugar contents of the bi-weekly tuber samples.

The Pike potatoes were marketed in mid-February, 1997. The Snowden potatoes were held into early June, but were not successfully marketed due to excess glucose content.

1997-1998 Storage Season: Snowden variety potatoes were placed in bins 23 and 24. Selected numbered varieties were placed in bins 21 and 22. All potatoes were grown in Bay Co. by Bishop Potato Farms. The storage bins were actively managed relative to sugar contents of the bi-weekly samples.

All potatoes were successfully marketed in late February, 1998.

Results

Potato sample data for the three storage seasons is presented in the figures on the following pages.

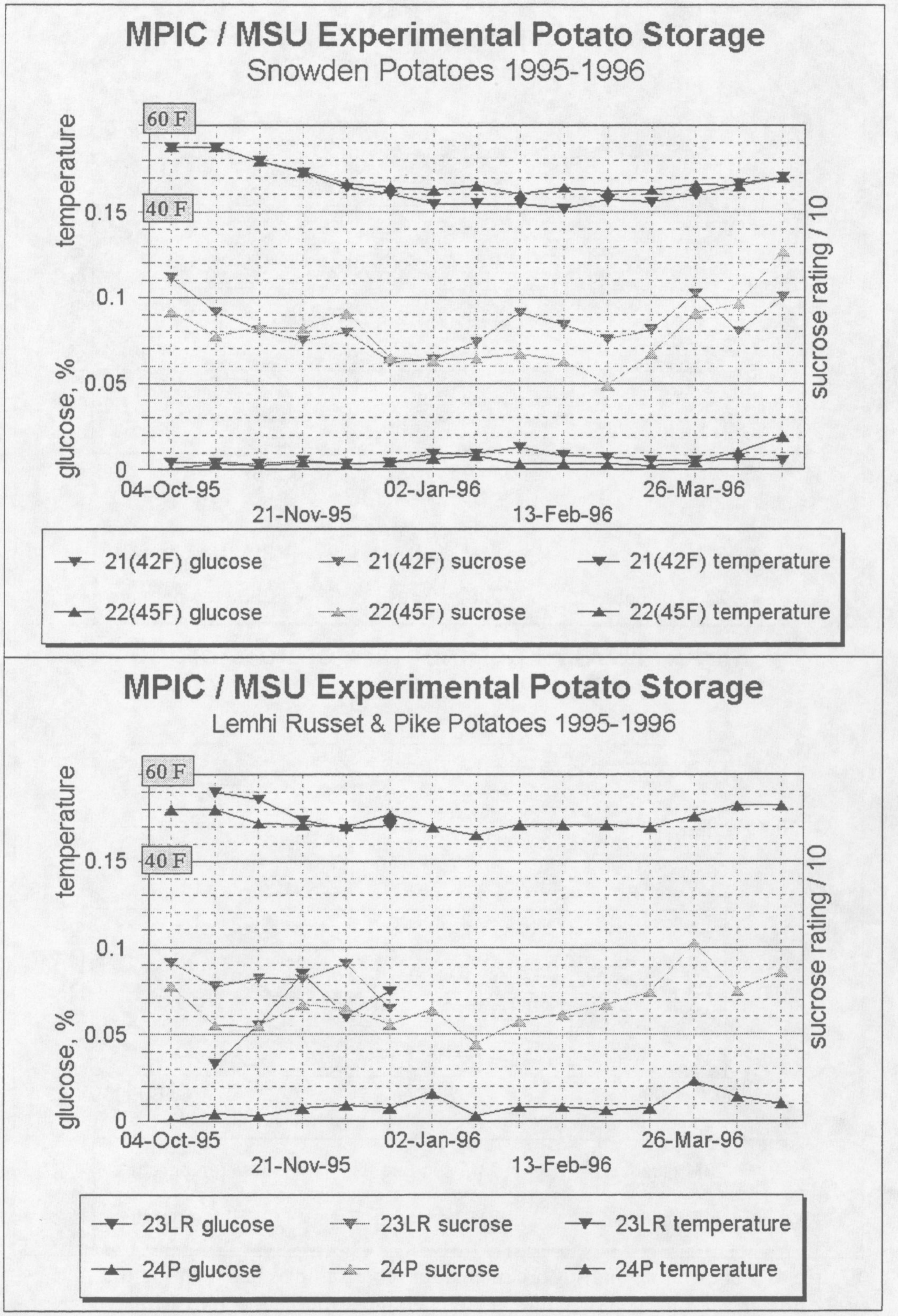
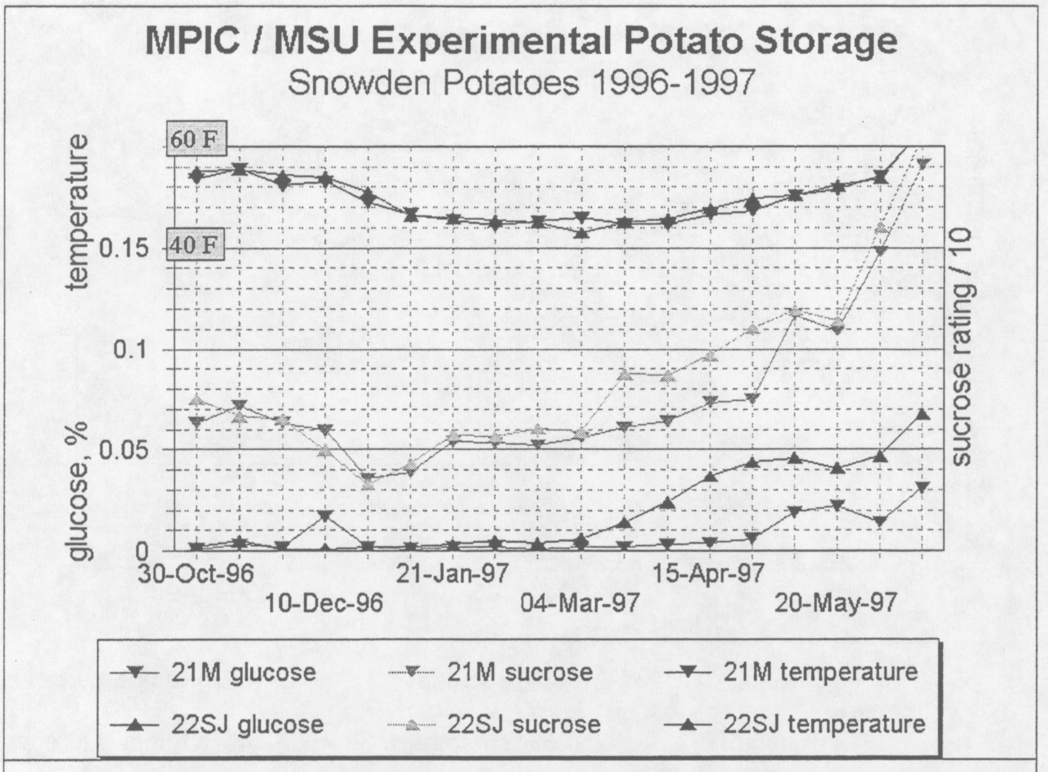


Figure 3. Temperature and sugar contents for tuber samples taken during the 1995-1996 storage season. Top two lines are temperatures for the two bins with a range of 40-60ºF; middle two lines are sucrose rating (divided by 10 before plotting); bottom two lines are glucose content. Bin 21 had Snowden potatoes with a desired holding temperature of 42ºF; bin 22 had Snowden potatoes with a desired holding temperature of 45ºF; bin 23 had Lemhi Russet (LR) potatoes; and bin 24 had Pike potatoes.



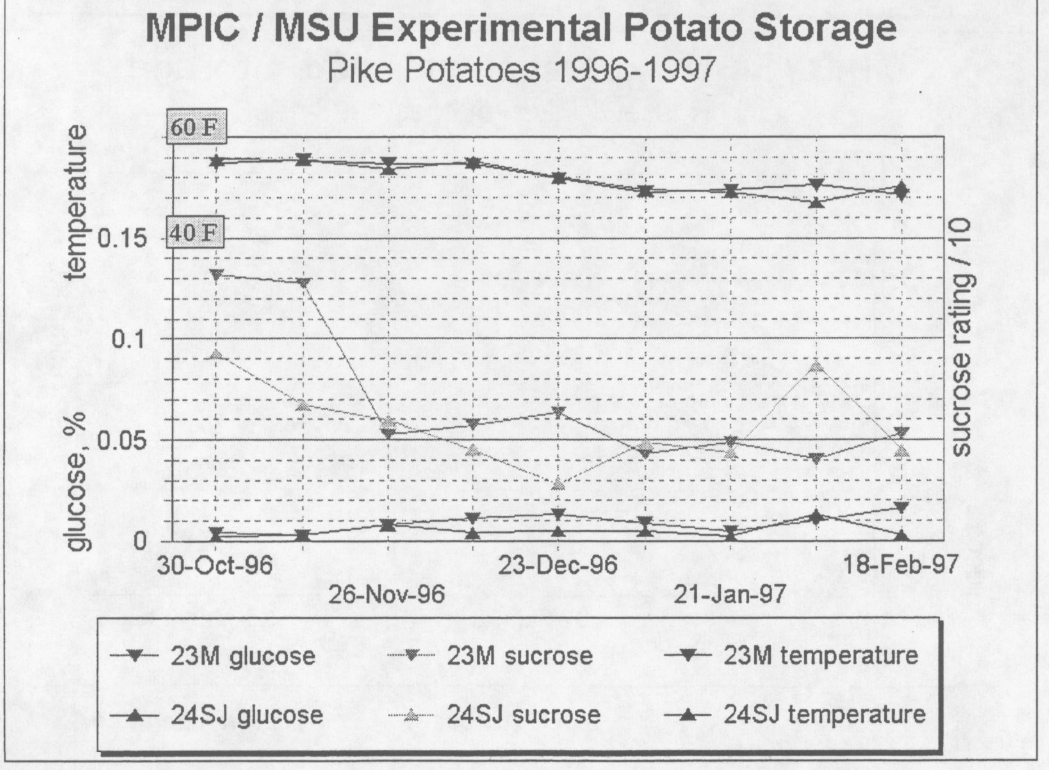
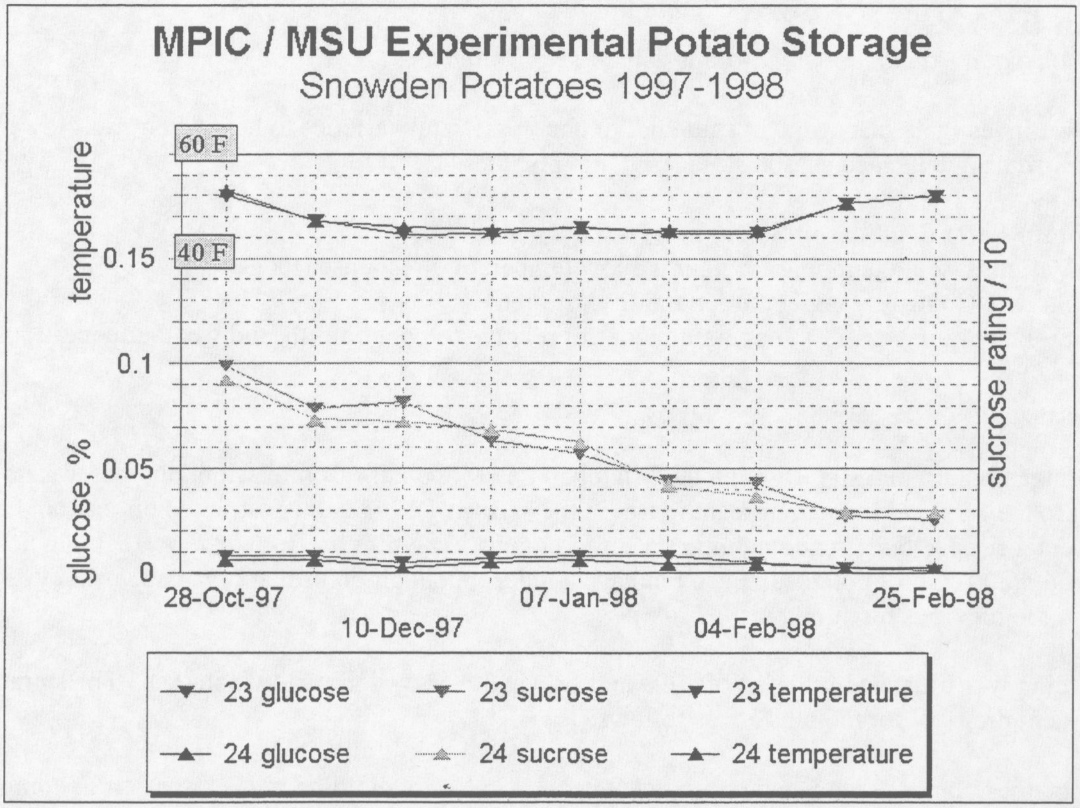


Figure 4. Temperature and sugar contents for tuber samples taken during the 1996-1997 storage season. Top two lines are temperatures for the two bins with a range of 40-60ºF; middle two lines are sucrose rating (divided by 10 before plotting); bottom two lines are glucose content. Bin 21 had Snowden potatoes grown in Montcalm Co. with a desired holding temperature of 45ºF; bin 22 had Snowden potatoes grown in St. Joseph Co. with a desired holding temperature of 45ºF; bin 23 had Pike potatoes grown in Montcalm Co. with a desired holding temperature of 50ºF; and bin 24 had Pike potatoes grown in St. Joseph Co. with a desired holding temperature of 50ºF.



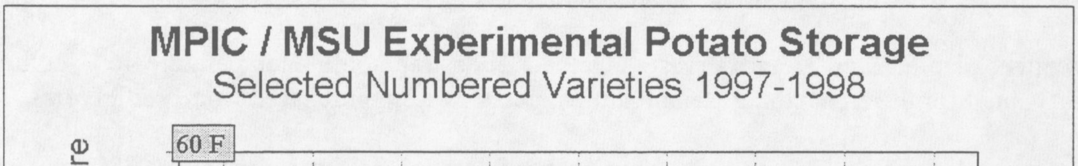


Figure 5. Temperature and sugar contents for tuber samples taken during the 1997-1998 storage season. Top two lines are temperatures for the two bins with a range of 40-60°F; middle two lines are sucrose rating (divided by 10 before plotting); bottom two lines are glucose content. Bins 23 and 24 had Snowden potatoes; bins 21 and 22 had selected numbered varieties.

Round 5 : 1999 - 20??

Michigan Potato Industry Storage & Handling Committee

Objective: investigate management strategies, technologies and varieties to help Michigan growers reduce risk during extended season storage of chip potatoes.

Chip Potato Extended Season Storage

- Varieties - cold chipping for minimal low temperature response (long-term)
- Storage Control - temperature, humidity, oxygen
- Storage Management - temperature control relative to potato needs and weather conditions

Methods

The Michigan potato industry, through the Michigan Potato Industry Commission, purchased land adjacent to the Montcalm potato research farm in the spring of 1999 and constructed on that land an experimental storage building containing six research bins. The bins are 10' x' 12' by 18' high, holding an estimated 500 cwt. of potatoes. Each bin has an independent air control and management system similar to the previous research bins.

The building was finished in the fall of 1999 and filled with Snowden variety potatoes. The storage management protocol for the bins are as follows:

Bin 1: potatoes planted June 5 and harvested October 18; desired holding temperature 46°F; comparison with bins 5 and 6 for different planting dates; potatoes were purchased from Sandyland Farms

Bin 2: potatoes planted May 23 and harvested October 5; desired holding temperature 46°F; comparison with bins 3 and 4 for different storage temperatures; potatoes were purchased from V&G Farms

Bin 3: potatoes planted May 23 and harvested October 5; desired holding temperature 38°F; comparison with bins 2 and 4 for different storage temperatures; potatoes were purchased from V&G Farms

Bin 4: potatoes planted May 23 and harvested October 5; desired holding temperature 42°F; comparison with bins 2 and 3 for different storage temperatures; potatoes were purchased from V&G Farms

Bin 5: potatoes planted May 15 and harvested September 25; desired holding temperature 46°F; comparison with bins 1 and 6 for different planting dates; potatoes were purchased from Sandyland Farms

Bin 6: potatoes planted May 4 and harvested September 18; desired holding temperature 46°F; comparison with bins 5 and 6 for different planting dates; potatoes were purchased from Sandyland Farms

The bins are being actively managed by the storage & handling committee relative to sugar contents of the bi-weekly tuber samples from each bin. Sprout inhibitor was applied to all bins on December 29, 1999.