1996
MICHIGAN POTATO RESEARCH REPORT

VOLUME 28

Michigan State University
Agricultural Experiment Station

In Cooperation With

The Michigan Potato Industry Commission

THE MICHIGAN POTATO INDUSTRY COMMISSION

February 5, 1997

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 1996 potato research projects.

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

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

Best wishes for a prosperous 1997 season,

The Michigan Potato Industry Commission

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

TABLE OF CONTENTS

1996 MSU POTATO RESEARCH REPORT

R.W. Chase, Coordinator

Introduction and Acknowledgements

The 1996 Potato Research Report contains reports of potato research projects conducted by MSU potato researchers at several different locations. The 1996 report is the 28th report which has been prepared annually since 1969. This volume includes research projects funded by the Special Federal Grant 95-34141-1399, the Michigan Potato Industry Commission and numerous other sources. The principal source of funding for each project has been noted at the beginning of each report.

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

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

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

Thanks go to Dick Crawford, for the farm management at the MSU Montcalm Research Farm; Chris Long, CSS Potato Technician and Dr. Kazimierz Jastrzebski, visiting scientist from Poland. Also, a special thanks to Jodie Schonfelder for the typing and preparation of this report and to MSUE Don Smucker, Montcalm CED for maintaining the weather records from the Montcalm Research Farm computerized weather station.

Weather

Weather during the 1996 growing season was variable. The average minimum temperatures were near normal for the season (Table 1), slightly below the average in April and July and above average in May, June, August and September. The average maximum temperature for the season was 3° below the average and below average for each month except August and September. The temperature exceeded 90° on only two days in early August and was greater than 85° on ten days throughout the season.

Rainfall for the season was nearly 2 inches above the 15 year average (Table 2). Rainfall was above average in May and nearly double the 15 year average for June. The greater soil moisture and cooler temperatures in April and May resulted in some emergence delay. Weather during September was very good for plot harvesting.

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

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

Year	April	May	June	July	August	September	Total
1982	1.43	3.53	5.69	5.53	1.96	3.24	21.38
1983	3.47	4.46	1.19	2.44	2.21	5.34	19.11
1984	2.78	5.14	2.93	3.76	1.97	3.90	20.48
1985	3.63	1.94	2.78	2.58	4.72	3.30	18.95
1986	2.24	4.22	3.20	2.36	2.10	18.60	32.72
1987	1.82	1.94	0.84	1.85	9.78	3.32	19.55
1988	1.82	0.52	0.56	2.44	3.44	5.36	14.14
1989	2.43	2.68	4.85	0.82	5.52	1.33	17.62
1990	1.87	4.65	3.53	3.76	4.06	3.64	21.51
1991	4.76	3.68	4.03	5.73	1.75	1.50	21.45
1992	3.07	0.47	1.18	3.51	3.20	3.90	15.33
1993	3.47	3.27	4.32	2.58	6.40	3.56	23.60
1994	3.84	2.63	6.04	5.16	8.05	1.18	26.90
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
15-YR. AVG.	2.85	3.00	3.31	3.41	4.23	4.17	20.97

Growing Degree Days

Table 3 summarizes the cumulative, base 50F growing degree days (GDD) for May through September. Similar to 1995, May was again very cool and the lowest since 1991. It continued to be the lowest throughout the season except for 1992 which had 1,956 GDD.

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

*1991 and 1992 data calculated from Vestaburg weather station in Montcalm County (Dr. Jeff Andresen, Geography). 1993-1996 data from the weather station at MSU Montcalm Research Farm (Don Smucker, Montcalm County Extension Director).

Previous Crops and Fertilizers

The general research plot area was planted to rye in the fall of 1994 and harvested for seed in 1995, disced and re-seeded to rye. The plot area was not fumigated and the following fertilizers were used in the general plot area during 1996:

Application	Analysis	Rate	Nutrients
Plowdown	0-0-60	250 lbs/A	0-0-150
In-furrow	20-10-10	300 lbs/A	60-30-30
Hilling - Round whites	45-0-0	125 lbs/A	56-0-0
- Long/Snowden	45-0-0	225 lbs/A	101-0-0
Fertigation - (two applications)	28-0-0	15 gpa (2X)	84-0-0

Soil Tests

Soil tests for the general plot area:

	lbs/A				
pH	P_2O_5	K_2O	Ca	Mg	Cation Exchange Capacity
5.9	360	216	655	89	3.5 me/100 g

Herbicides and Hilling

Hilling was done in late May, just prior to potato emergence, followed by a tank mix of metolachlor (Dual) at 2 lbs/A plus metribuzin (Sencor) at 2/3 lb/A.

Irrigation

Irrigation was initiated on June 28 and nine applications were made at 0.75 inches per application. There was one application in June, four in July, three in August and one in September.

Insect and Disease Control

Admire was used in all plantings with excellent control of CPB. One foliar insecticide application was made in late August using Asana + PBO and Monitor. Fungicide applications were initiated on June 13 and continued on a 7-10 day schedule using Bravo.

MICHIGAN STATE UNIVERSITY POTATO BREEDING PROGRAM 1996 STATUS REPORT

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Department of Crop and Soil Sciences

Cooperators: R.W. Chase, Ray Hammerschmidt, Ed Grafius Jerry Cash and Willie Kirk

INTRODUCTION

The MSU program has a multi-faceted approach to variety development. We conduct variety trials of advanced selections, 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 expect to see directed improvement towards improved varieties. We are also using the European germplasm as a source of disease resistance and quality traits. In addition, our program integrates genetic engineering to introduce traits. 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.

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, Fusariun dry rot, soft rot, early die and virus resistance), chipping and cooking quality, bruise resistance, storability, along with shape, internal quality and appearance.

PROCEDURE

Varietal Development

Each year, during the winter months, approximately 500 crosses are made between the most promising cultivars and advanced breeding lines. The parents are chosen on the basis of yield potential, processing or tablestock 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 30,000 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 step is followed by evaluation and selection at the 8-hill, 20-hill stages. The best selections are then tested in replicated trials over time and locations. This generation of advanced seedlings is the initial step to breed new varieties and this step is an on-going process in the MSU program since 1988.

Integration of Genetic Engineering with Potato Breeding

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, PLRV, Colorado Potato Beetle, Potato tuber moth and broad-spectrum disease resistance. We also have the glgC16 gene or starch gene from Monsanto to influence starch and sugar levels in potato tubers. We have transgenic lines that express the PVYcp and Bt genes. Transformations with the starch gene and disease resistance gene are presently being conducted.

Correlation of Chip-processing in Greenhouse and Field-grown Tubers

The initial field selection of single hills in the breeding program leaves a large percentage of seedlings behind (90%). If chip-processing quality is of primary importance, we must devise a procedure to identify the superior chip-processors. We are testing whether the greenhouse-generated tubers would chip-process and give comparable readings as in the field. If so, we can compare greenhouse chip color in place of field-grown chip color and save the field evaluation only for chip-processors. This study was established for 1995.

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 five species: S. tuberosum (adaptation, tuber appearance), S. phureja (cold-chipping, specific gravity), S. tarijense and berthaultii (tuber appearance, insect resistance) and S. chacoense (specific gravity, low sugars, dormancy).

We are also using other sources of germplasm to introgress disease resistance and tuber quality. Many European cultivars have high yield potential and resistance to various diseases such as scab, late blight and Erwinia soft rot. Some also have superior cooking qualities. These cultivars are being used in the crossing block each year. Dr. John Helgeson (USDA/ARS) has developed somatic fusion hybrids that have resistance to Erwinia soft rot, PLRV, Early Blight or Late Blight. We have those lines and have been crossing them to our best lines to initiate the adaptation of this germplasm source to Michigan.

RESULTS AND DISCUSSION

One of our objectives is 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. Some of these lines were tested in on-farm trials in 1996, 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 and 3) select more russet lines.

Another one of the objectives is to develop potato varieties that will not accumulate reducing sugars in cold storage (40F). We commonly call these varieties "cold chippers". There is a question as to which temperature is most appropriate to screen for cold-chipping. This storage season we have lowered the storage temperature from 45F to 42F, as our initial screen, to chip-process directly out of cold storage. We feel there is no long-term value in 2-4 week reconditioning out of 40F storage. We lowered the screening temperature because we felt that we have been identifying many selections from that process from 45F. As desirable cold-chipping genes accumulate in the breeding program, we will reduce the storage temperature for screening to 40F.

Some of the parents used in the crossing block over the past few years has included Snowden, ND860-2, MS702-80, Atlantic, S440, S438, Lemhi Russet, Pike, Chipeta, W877, and W870. In addition, we have advanced into the crossing block new MSU selections that have enhanced chip quality directly out of 45F storage and other new 45F chippers from the US and Europe such as ND2417-6, NDO1496-1, NDA2031-2 and Brodick. These clones constitute a diverse genetic base from which to combine good chipping quality with agronomic performance.

For the 1996 field season over 400 crosses have been planted. Of those 20% of the crosses were between long types, 75% between round whites, and 5% to select red-skinned and yellow-flesh varieties. During the 1996 harvest, approximately 1400 selections were made from the 30,000 seedlings grown at the Montcalm Research Farm and Lake City Experiment Station. Following harvest, specific gravity was measured and chip-processing (from 50F storage). The single hills in 1995, when chipped directly out of 45F storage, about 20% of the single-hill selections had acceptable chip color. These selections were evaluated as 8-hill selections in 1996. Of the 8-hill selections from 1995, 25% of the 300 clones chip-processed with acceptable color directly out of 45F. From the 90 twenty-hill plots, 30% had acceptable chip color from 45F storage. The best selections from the 20-hill plots will be advanced to replicated trials in 1997.

A high priority objective of the breeding program is to identify sources of late blight resistance and use these sources for incorporating resistance. Based upon greenhouse screenings, we have been using USDA/ARS and European sources of late blight resistance in our crossing block. We have made selections from these crosses and, in preliminary greenhouse screenings, some selections show some resistance to late blight. We will continue to evaluate these selections for resistance and agronomic performance. The best parent source of resistance at this time is the Ukrainian variety Zarevo.

Performance of fifty-four MSU seedlings are reported in the 2x23-hill and Adaptation trials in 1996 (Tables 1 and 2). There are many promising seedlings with high yield potential and good appearance. These include E018-1, E048-2y, E041-1, E202-3, E221-1, C103-2, B073-2, F349-1, F373-8, F059-1 and F020-23. The Erwinia soft rot and Fusarium dry rot tests, scab trial results and blackspot bruise tests are discussed in the 1996 Potato Variety Trial Report.

In the diploid germplasm about 20 of the best lines with differing pedigrees formed the crossing block to generate new populations in 1995. From this material we expect to find improved diploid *Solanum* species parents to be used in crosses to select new varieties (4x-2x crosses). In 1996 selections were made in these crosses at Lake City. These lines will be tested as 8-hill plots in 1997.

We added to the germplasm enhancement program a number of genetic lines that are derivatives of cell (protoplast) fusions between *S. brevidens* (from Argentina) and the cultivated potato. These lines were developed by J. Helgeson at the University of Wisconsin and have been noted for their *Erwinia* soft rot, early blight and PLRV resistance. Through further crossing and evaluation we hope to incorporate these resistances into the breeding populations we have been selecting for chip-processing. These populations were in the field in 1995 and 1996. Selections have been made and we are advancing some through the breeding program. Special attention will be placed upon these selections for disease resistance. This germplasm enhancement (diploid and protoplast fusion) is the base from which long-term genetic improvement of the potato varieties in the MSU breeding program is generated.

Transgenic lines, developed at MSU, which express the PVYcp and Bt genes were tested at MRF. Agronomic performance of these lines were similar to their non-transgenic derivative variety. These lines will be field tested again in 1997 using tubers rather than tissue culture transplants.

Table 1

ADAPTATION TRIAL
MONTCALM RESEARCH FARM
SEPTEMBER 17, 1996
(133 DAYS)

	CWT/A		PERCENT OF TOTAL[1]							TUBER QUALITY[2]				TOTAL		
	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	SFA	HH	VD	IBS	BC	CUT	SCAB[3]	MAT[4]
E018-1	566	625	9	8	6	27	1	1.088	2.0	0	1	0	0	40	3.0	5.0
E048-02Y	474	534	89	8	70	19	4	1.084	-	19	0	0	0	40	2.0	5.0
E041-1	448	516	87	10	66	20	3	1.083	3.0	1	8	0	0	40	3.5	4.8
ATLANTIC	442	489	90	9	81	10	0	1.093	1.5	14	0	4	4	40	3.5	3.3
E220-3	424	460	92	8	71	21	0	1.083	2.0	28	2	1	0	40	3.5	3.8
E202-3	404	506	80	15	52	28	5	1.078	-	11	1	0	0	40	2.0	4.5
E226-4Y	404	477	85	14	76	8	1	1.068	-	0	1	0	0	40	1.5	3.8
E221-1	403	437	92	5	67	25	3	1.072	-	1	0	0	1	30	1.0	2.3
E273-8	384	433	89	10	67	22	1	1.078	2.0	1	4	0	0	40	3.0	4.0
MSB110-3	382	466	82	18	79	3	1	1.084	1.5	0	1	2	0	30	4.5	4.8
C103-2	363	385	94	2	46	49	3	1.075	-	0	2	1	0	40	2.0	4.3
E149-5Y	359	416	86	9	55	32	5	1.068	-	3	0	2	0	40	2.0	3.8
B057-2	352	438	80	20	78	2	0	1.077	-	0	1	2	2	40	3.0	3.4
B073-2	350	406	86	13	82	5	0	1.082	1.5	0	0	0	0	40	1.5	3.5
E066-04	349	407	86	12	61	25	3	1.068	-	0	1	1	0	40	3.0	3.0
E247-2	334	424	79	19	69	9	2	1.081	1.5	3	1	1	0	40	1.5	3.3
NT-1	332	377	88	12	82	6	0	1.084	2.0	1	0	0	0	40	1.0	3.3
C121-7	324	365	89	11	83	5	0	1.076	-	0	0	2	0	40	4.0	1.3
SNOWDEN	317	370	86	14	78	8	1	1.083	1.5	3	4	0	2	40	3.0	1.3
E230-6	315	471	67	31	66	1	2	1.090	1.5	1	0	0	0	40	1.5	3.5
B094-1	304	356	86	12	82	3	3	1.080	-	0	1	0	0	40	3.0	2.3
E228-11	303	376	80	19	75	6	0	1.085	-	0	2	0	0	40	3.0	3.5
ND2676-10	288	346	83	15	81	1	2	1.073	1.5	1	0	0	4	40	1.5	1.5
B040-3	287	321	89	9	77	13	2	1.071	1.5	4	0	0	1	40	1.0	2.3
AF1433-4	271	317	85	14	78	8	0	1.074	-	0	1	0	0	40	3.0	1.5
E228-9	268	297	90	7	65	25	3	1.078	-	1	1	0	0	40	1.5	3.0
P84-13-12	259	308	84	15	82	2	1	1.083	1.0	1	0	0	0	40	3.0	1.8
B0952-1	257	309	83	16	74	9	1	1.077	1.5	0	0	0	0	40	2.5	1.8
E263-3	236	338	70	30	70	0	0	1.079	1.5	0	0	0	0	40	3.5	1.8
C148-A	224	288	78	22	73	5	0	1.080	1.0	3	1	0	1	40	2.5	2.3
C122-1	222	312	71	26	66	5	2	1.077	-	3	0	1	1	40	1.5	1.5
C120-1Y	222	276	80	17	76	4	2	1.078	-	0	2	0	0	40	2.5	3.0
B027-1R	202	268	75	23	68	7	1	1.071	-	5	1	0	0	40	4.0	1.0
ND860-2	135	241	56	43	56	0	0	1.077	1.0	0	0	0	0	0		1.0
MEAN	330	393						1.079								2.9
$LSD_{0.05}$	63	63						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 Rating 1996 from Scab Trial
1 - NO INFECTION
3 - INTERMEDIATE
5 - HIGHLY SUSCEPTABLE

[4]MATURITY
1 - EARLY
5 - LATE

PLANTED MAY 7, 1996

Table 2

MSU BREEDING LINE EVALUATION
MONTCALM RESEARCH FARM
SEPTEMBER 9, 1996
(125 DAYS)

	CWT/A		PERCENT OF TOTAL[1]							TUBER QUALITY[2]				TOTAL		
	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	SFA	HH	VD	IBS	BC	CUT	PARENTS	MAT[3]
F349-1Y	463	504	92	8	74	18	0	1.084	-	0	0	0	0	20	RG X W887	5.5
F373-8	447	468	95	2	42	53	3	1.076	1.5	2	0	0	0	20	MS702-80 X NY88	4.5
F020-23	391	517	76	24	65	11	0	1.079	1.5	0	0	0	0	20	E57-13 X W870	3.5
ATLANTIC	389	432	90	7	69	21	3	1.088	1.5	12	0	0	2	20	-	4.0
ONAWAY	387	438	88	8	68	20	3	1.067	-	0	0	0	0	20	-	1.5
F059-1	386	417	92	7	41	52	1	1.075	-	0	0	0	1	20	STB X CHALEUR	5.0
SNOWDEN	374	430	87	13	83	4	0	1.087	1	0	3	0	0	20	-	4.0
F002-01	359	397	90	8	70	20	1	1.074	-	1	0	0	1	20	ATL X CHALEUR	4.5
F019-2	349	387	90	10	74	16	0	1.080	2	3	0	0	0	20	E57-13 X LR	3.0
F100-1	344	400	86	14	84	2	0	1.083	2	1	0	0	0	20	SND X LR	4.0
F165-6RY	343	383	89	8	82	7	2	1.077	-	0	1	0	0	20	SUP X RG	2.0
E228-1	341	372	92	8	82	9	1	1.077	-	0	0	0	0	20	RN X SP	5.0
F019-11	336	416	81	19	75	6	0	1.083	3	5	0	0	0	20	E57-13 X LR	1.5
F001-02	317	368	86	14	84	2	0	1.082	2	6	0	0	0	20	ATL X CHIPETA	2.0
E026-A	317	360	88	12	77	10	0	1.083	-	0	2	0	0	20	MN13740 X SP	3.0
F023-4	313	373	84	15	68	16	1	1.091	1	13	0	0	0	20	LR X W877	5.0
E217-B	310	347	89	11	74	16	0	1.091	1	3	0	0	0	20	SUP X S465	1.5
F060-6	294	321	92	8	54	37	0	1.081	2	2	2	0	1	20	STB X 702-80	5.0
F376-1	292	327	89	9	63	26	2	1.081	-	11	0	1	0	20	PREST. X W877	4.0
F205-5	285	324	88	9	70	18	3	1.076	-	0	1	4	0	20	STB X W952	2.0
F017-3	285	305	93	7	65	29	0	1.070	2	0	0	0	0	20	E55-44 x LR	2.0
F015-1	270	316	85	15	72	13	0	1.097	1.0	2	0	0	0	20	Pike x W877	4.5
E192-8 RUS	263	340	77	21	62	16	2	1.064	-	1	0	1	0	20	A- X R. NORK	3.0
F087-3	257	372	69	29	65	4	2	1.087	-	0	0	0	0	20	PIKE X LR	4.0
F099-3	253	282	90	10	87	2	0	1.087	1.5	1	0	0	0	20	SND X CHALEUR	4.5
F014-9	249	295	84	15	82	2	1	1.072	-	0	0	0	0	20	PIKE X 702-80	2.0
F093-7	224	305	74	25	69	5	2	1.077	-	5	0	0	0	20	E55-44 X ND860-	1.0
MEAN	327	378						1.080								3.4
$LSD_{0.05}$	89	92						0.006								

[1]SIZE	[2]QUALITY	[3]MATURITY
B - < 2"	HH - HOLLOW HEART	1 - EARLY
A - 2-3.25"	BC - BROWN CENTER	5 - LATE
OV - > 3.25"	VD - VASCULAR DISCOLORATION	
PO - PICKOUTS	IBS - INTERNAL BROWN SPOT	

PLANTED MAY 7. 1996

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1996 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, 45 and 50 F storage), dormancy (at 50F), as well as susceptibilities to common scab, Fusarium dry rot, Erwinia soft rot and blackspot bruising are determined. We are now in the process of integrating late blight resistance testing into the evaluation procedure.

Six 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.

Both round and long variety groups were harvested at two dates. They are referred to as the Date-of-Harvest trials. The other two field experiments were the North Central Regional and European 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 45 or 50°F for chip-processing out of storage in January and March.

Results

A. Round White Varieties

Seven varieties and 13 breeding lines were compared at two harvest dates. Atlantic, Snowden and Onaway were used as checks. The average yield as well as specific gravity levels were typical. The results are presented in Tables 1 and 2. In the early harvest trial (94 days), AF1470-17 (Quaggy Joe), NY101, Onaway and Atlantic had the highest yields of the 20 entries.

At the later harvest (140 days), AF1470-17 and NY101 were still the top yielders. The MSU advanced seedling, MSB107-1 was third highest at 450 cwt/A, 52% higher than at the early harvest. Internal defects within the trial were variable, however vascular discoloration was more prevalent than in previous years.

Variety Characteristics

Mainestay (AF1060-2) - late, fresh market variety of high yield potential and excellent internal quality, but low specific gravity. It is susceptible to scab. Mainestay performed above average in the trials but has shown higher yield potential in some on-farm trials, but may have sticky stolons at harvest.

St. Johns - medium-late fresh-market variety of above average yield potential, but low specific gravity. There was some variation in shape, but general appearance was good with large tubers and excellent internal quality. It is susceptible to scab infection.

MSB076-2 - this MSU selection has high yield potential, has very high specific gravity, acceptable chip quality and resistant to scab. It is between Atlantic and Snowden in maturity and we observed, in some instances, a tendency for hollow heart in oversize tubers. It has a large and upright vine type.

NorValley (ND2417-6) - a cold-chipping selection with above average yield potential, but moderate specific gravity. It has performed well in regional trials, but it is susceptible to scab.

NY103 - a chip-processing/fresh market selection from New York which has high yield potential, excellent internal quality and smooth, bright appearance, but the specific gravity may be too low for chip-processing. NY103 is equivalent to Atlantic for scab reaction. This selection has had excellent yield potential in on-farm trials.

NY101 - a light-yellow-fleshed selection from New York. This line has an excellent shape, with netted tubers and very high yield potential. It is resistant to scab. In general, internal defects are low, but in 1995 we observed IBS in the oversize tubers.

Pike (E55-35) - an average yielding selection from New York. It chip-processes well and is resistant to scab similar to Superior. At times it has shown IBS in the tubers.

MSB083-1 - an MSU selection with a bright round appearance. This selection is in grower trials and its performance has been variable. IBS was noted in the oversize tubers for the first time.

MSB107-1 - an MSU selection for the tablestock market. It is a bright-skinned with large, round tubers with excellent internal quality. This selection performed well in grower trials in 1996.

MSA091-1 - an MSU selection for chip-processing. Yields have been variable, but it has some scab resistance.

Quaggy Joe (AF1470-17) - a high yielding tablestock selection from Maine. It produces large tubers, but is highly susceptible to scab. Brown centers were observed in the oversize tubers in 1996.

NY111 - a New York selection with chip-processing potential. It had average yield and equivalent to Atlantic in scab susceptibility.

B. Long Varieties

Five varieties and eight breeding lines were tested. Russet Burbank, Shepody and Goldrush were grown as check varieties. The first date-of-harvest trial was dug 107 days from planting rather than 94 days to give the trial greater time to bulk. Most of the entries in the long-type trial were late maturing resulting in low yields and small tuber size at the first date-of-harvest (Table 3). At the second harvest on September 23 (140 days), yields for all entries had increased substantially (Table 4). Yield and specific gravity values were higher than 1995. Within the 13 long-type entries, Century Russet and A7961-1 produced the highest yields at 107 days. Most of these entries have a late maturity, so tuber sizing is generally small. At the later harvest (140 days), Century Russet, JS111-28, Shepody and Russet Burbank produced yields greater than 300 cwt/A. Hollow heart was the most significant internal defect and was greatest in MSB106-8 and C082142-4.

Variety Characteristics

Century Russet - a russet variety from Oregon with high yield potential. It has excellent internal quality and bulks early despite a late vine maturity. It is susceptible to scab.

JS111-28 - provided by J.R. Simplot. JS111-28 has high yield potential with good general appearance, good russeting and shallow eyes. It is a somaclonal derivative of Lemhi Russet selected for lower incidence of blackspot bruise. It is also highly scab resistant.

A7961-1 - is an USDA-Aberdeen entry with above average yield. It has uniform appearance, heavier russeting than Russet Burbank and minimal internal defects. It can be used for frozen-processing.

AO82611-7 - this selection was below average in 1996. It is reported to have some resistance to early dying. Tuber shape is long but tuber width is narrow. Many pickouts were observed in 1996.

Legend (COO83008-1) - is an Oregon selection from the Colorado breeding program. Yields were below average in 1995 and 1996. The tubers were well shaped with good type.

Newleaf Russet Burbank - a variety from NatureMark which expresses the Bt gene for beetle control. Yield was below average this year despite good vine growth.

C. North Central Regional Trial

The North Central Trial is conducted in a wide range of environments, in 9 states to provide adaptability data for the release of new varieties from North Dakota, Minnesota, Wisconsin, and Michigan. Ten breeding lines and seven varieties were tested in Michigan. The results are presented in Table 5. The range of yields were wide. The MSU selections, MSB076-2 and MSB106-7, performed well. W1313, a Wisconsin seedling, had the highest yield but had almost one-third of its oversize tubers with hollow heart. The Minnesota selection, MN16489, had a high overall merit in the trial, but it has a blush skin which may limit its marketablity. The North Dakota seedling, ND2676-10, has a nice appearance, some possible scab resistance and a good chip score, but it had a below average yield and a specific gravity under the industry standards.

D. European Trial

Fourteen European varieties and advanced selections were tested along with three yellow-fleshed MSU seedlings. Yukon Gold, Michigold and Saginaw Gold were used as checks. The results are summarized in Table 6. Most of the European selections and varieties were late to very-late in maturity and many of these lines produced a small percentage of oversize tubers. Picasso, Latona, Morning Gold and Lily had yields over 500 cwt/A of US No. 1 potatoes. Erntestolz, SW88-112, SW88-113 and MSA097-1Y were the entries which exceeded 400 cwt/A. Internal defects were not serious except for 32% hollow heart in the oversize tubers of Morning Gold. The rose-skinned, yellow-fleshed selection from MSU, Julianna Rose (MSD040-4RY), has excellent eating quality and may fit well in a roadside stand or specialty market. Many of the European entries are oval to oblong in shape and flesh colors off-white to yellow.

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

As part of the postharvest evaluation, resistance to *Fusarium sambucinum* (fusarium dry rot) was assessed by inoculating 10 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 disease incidence and severity of the dry rot infection. In the first round of testing 55 out of 150 entries showed little to no infection. Many of these lines were diploid selections from the germplasm enhancement program. These lines with little infection will be retested to discriminate resistant lines from escapes.

Erwinia soft rot tests were conducted on tuber slices this fall. Most selections from the trials were tested along with somatic fusion hybrids from Dr. J. Helgeson which were noted to have some resistance to soft rot. All lines tested in 1996 had moderate to heavy levels of soft rot. Moderate rot levels were observed in 22 of the 150 lines. These lines will be retested.

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. We now have had three years of good trials (i.e. high levels of infection in susceptible lines).

Table 7 summarizes the 1994-6 scab trial results for the lines in these trials. Many russet lines showed resistance to scab infection with Century Russet an exception to this trend. The MSU lines, MSE192-8Rus and MSE202-3Rus, showed some resistance to scab in 1996. Some round white tablestock clones have resistance such as Superior, Onaway, Prestile, MSB040-3, and MSE221-1. Yellow-fleshed selections with resistance are NY101, MSE048-2y and MSA097-1y. Scab resistance was also identified in the chip-processing clones Pike and MSU selections MSB076-2, MSA091-1, MSB073-2, and MSNT-1.

G. Blackspot Susceptibility

Increased evaluations of advanced seedlings and new varieties for their susceptibility to blackspot bruising has been implemented in the variety evaluation program. Check samples of 25 tubers were collected (a composite of 4 reps) from each cultivar at the time of grading. A second 25 tuber sample was similarly collected and was placed in a hexagon plywood drum and tumbled 10 times to provide a simulated bruise. Both samples were peeled in an abrasive peeler in October and individual tubers were assessed for the number of blackspot bruises on each potato. These data are shown in Table 8.

Section A summarizes the data for the samples receiving the simulated bruise and Section B, 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 of 3 or more spots per tuber from the simulated bruise are approaching the bruise-susceptible rating. In addition, the data is grouped by trial, since the bruise levels can vary between trials. These results become more meaningful when evaluated over 3 years which reflects different growing seasons and harvest conditions. Bruising was more severe in 1996 than in 1995.

H. Late Blight Trial

In 1996 a late blight trial was conducted at the MSU Soils Farm in East Lansing. Over 150 entries were evaluated in replicated plots. The field was inoculated on July 30 and ratings were taken during August and September. Most lines were highly susceptible to the US-8 genotype of late blight. Lines with the least infection were AWN86514-1, B0767-2, B0718-3 and Zarevo. Lines that showed slower infection spread were Libertas, Pimpernel, Hampton, Island Sunshine, Lily, Matilda, MSA091-1, MSB110-3, Ontario and Picasso.

Table 1

ROUND WHITES: EARLY HARVEST
MONTCALM RESEARCH FARM
AUGUST 8, 1996
(94 DAYS)

	CWT/A		PERCENT OF TOTAL[1]						TUBER QUALITY[2]				TOTAL	3-YR
	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	HH	VD	IBS	BC	CUT	AVE
AF1470-17	335	388	86	13	74	12	1	1.063	0	0	0	1	39	-
NY101	314	360	87	13	86	2	0	1.069	0	0	0	0	31	339*
ONAWAY	296	330	90	10	84	6	1	1.070	0	0	0	0	40	281
ATLANTIC	266	310	86	13	81	5	1	1.085	8	0	1	0	40	280
NY103	253	288	88	12	82	6	0	1.071	2	0	0	0	40	311*
NY111	247	308	80	20	80	0	0	1.084	3	0	0	0	40	-
ST. JOHNS	241	286	84	15	84	0	1	1.066	0	0	0	0	40	286
MSB076-2	240	281	85	14	84	2	1	1.076	1	0	0	0	40	261*
MAINESTAY	240	309	78	22	76	2	0	1.073	0	0	0	0	40	282
AF1426-1	236	288	82	5	69	13	13	1.072	0	0	0	0	40	312*
FL1833	228	261	88	12	81	7	0	1.081	3	0	0	0	40	267
MSB107-1	217	239	91	8	84	7	1	1.069	3	0	0	0	40	200*
FL1863	216	243	89	11	77	12	0	1.078	0	0	0	0	40	274*
FL1867	215	272	79	21	78	1	0	1.090	7	0	1	1	40	-
MSA091-1	203	244	83	17	81	2	0	1.081	0	0	0	4	40	-
MSB083-1	202	272	74	25	74	1	1	1.075	0	0	0	0	31	199*
PIKE	192	238	81	19	78	3	1	1.082	2	0	1	0	40	207*
SNOWDEN	178	234	76	23	73	3	1	1.085	2	0	0	2	40	212*
ND2417-6	172	263	65	34	65	0	1	1.075	0	0	0	0	40	252
FL1887	137	167	82	17	80	2	1	1.070	0	0	0	1	40	-
MEAN	231	279						1.076						
$LSD_{0.05}$	48	50						0.006						

[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

* - two-year US #1 average

PLANTED MAY 6, 1996

Table 2

ROUND WHITES: LATE HARVEST
MONTCALM RESEARCH FARM
SEPTEMBER 23, 1996
(140 DAYS)

	CWT/A		PERCENT OF TOTAL[1]							TUBER QUALITY[2]				TOTAL			3-YR
	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	SFA	HH	VD	IBS	BC	CUT	SCAB[3]	MAT[4]	AVE
AF1470-17	463	517	90	10	73	17	1	1.062	-	1	1	1	11	40	4.0	1.8	459*
NY101	463	495	93	6	70	23	1	1.070	1.5	0	1	4	0	40	1.0	3.5	534*
MSB107-1	450	462	97	2	50	47	1	1.076	-	1	3	1	0	40	2.5	4.0	386*
FL1887	405	429	94	4	46	49	2	1.080	1.0	0	14	7	0	40	3.0	4.5	-
ATLANTIC	403	438	92	6	61	31	1	1.086	1.5	10	0	2	0	40	3.5	3.3	437
FL1833	399	420	95	4	73	22	0	1.084	1.0	9	2	2	0	40	1.5	3.1	429
MAINESTAY	397	473	84	14	73	11	2	1.074	-	0	1	0	0	40	4.5	2.0	438
NY103	384	415	93	7	71	21	0	1.069	1.5	0	2	0	0	40	3.0	1.6	454*
NY111	374	417	90	10	82	8	0	1.083	1.0	6	2	1	0	40	3.0	2.0	-
ST. JOHNS	367	405	91	9	76	15	0	1.069	-	0	6	0	0	40	4.0	2.5	401
MSB076-2	367	403	91	8	82	9	1	1.086	1.5	2	1	0	0	40	1.5	2.5	395
MSB083-1	366	432	85	15	81	4	0	1.077	1.5	0	9	0	1	40	3.0	3.3	382*
SNOWDEN	357	409	87	12	79	9	1	1.082	1.0	2	11	0	0	40	3.0	2.8	396
AF1426-1	340	407	84	5	50	34	11	1.071	-	0	9	0	2	40	1.0	2.8	370*
ONAWAY	339	375	90	9	77	14	1	1.065	-	0	1	0	0	40	1.5	1.0	359
FL1863	335	349	96	4	75	21	0	1.081	1.0	1	1	2	0	40	2.0	2.5	401*
MSA091-1	317	357	89	9	73	16	2	1.081	1.5	0	5	2	0	40	1.0	3.1	-
PIKE	305	344	89	11	82	7	0	1.086	1.0	1	1	9	0	40	1.5	3.3	308
ND2417-6	300	387	78	22	74	4	1	1.074	1.5	0	1	0	0	40	3.5	1.5	370
FL1867	261	310	84	16	80	4	0	1.086	1.0	4	0	0	0	40	2.0	1.6	-
MEAN	370	412						1.077								2.6	
$LSD_{0.05}$	55	53						0.002								0.6	

[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 Rating 1996 from Scab Trial
1 - NO INFECTION
3 - INTERMEDIATE
5 - HIGHLY SUSCEPTABLE

[4]MATURITY
1 - EARLY
5 - LATE

* - two-year US #1 average

PLANTED MAY 6, 1996

Table 3

LONG TYPES: EARLY HARVEST
MONTCALM RESEARCH FARM
AUGUST 21, 1996
(107 DAYS)

	CWT/A		PERCENT OF TOTAL[1]						TUBER QUALITY[2]				TOTAL	3-YR
	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	HH	VD	IBS	BC	CUT	AVE
CENTURY RU	377	491	77	23	66	11	0	1.072	1	0	0	0	40	253*
A7961-1	330	414	80	16	56	24	5	1.071	0	0	0	0	40	212
A082611-7	288	437	66	19	45	21	15	1.073	3	0	0	0	40	217
JS111-28	284	370	77	18	58	19	5	1.072	4	0	0	0	40	221*
SHEPODY	280	348	80	13	44	37	7	1.069	5	0	0	1	40	238*
GOLDRUSH	267	333	80	19	62	18	1	1.065	0	0	0	0	40	201
R. BURBANK	261	390	67	31	59	8	2	1.073	0	0	1	1	40	170
C0083008-1	220	281	78	19	67	11	2	1.074	1	0	0	2	40	168
C082142-4	209	253	82	16	57	26	2	1.068	7	0	1	0	40	-
A84118-3	188	260	72	24	58	14	3	1.073	10	0	0	0	40	118*
MSB106-8	187	244	77	20	49	28	3	1.073	15	0	0	0	40	-
NEWLEAF	164	294	56	41	53	3	3	1.069	1	0	0	1	40	-
C081082-1	81	139	59	39	53	5	3	1.065	1	0	0	0	30	-
MEAN	241	327						1.071						
$LSD_{0.05}$	80	90						0.003						

[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

* - two-year US #1 average

PLANTED MAY 6, 1996

Table 4

LONG TYPES: LATE HARVEST
MONTCALM RESEARCH FARM
SEPTEMBER 23, 1996
(140 DAYS)

	CWT/A		PERCENT OF TOTAL[1]						TUBER QUALITY[2]				TOTAL			3-YR
	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	HH	VD	IBS	BC	CUT	SCAB[3]	MAT[4]	AVE
CENTURY RU	409	498	82	16	55	27	2	1.079	1	0	0	0	40	3.5	4.4	375*
JS111-28	326	436	75	13	44	31	12	1.077	3	0	0	0	40	1.0	2.9	376*
SHEPODY	309	361	86	8	36	50	6	1.074	7	1	0	0	40	4.0	2.5	311*
R. BURBANK	302	428	70	25	56	15	5	1.078	8	4	2	0	40	1.0	2.5	256
A7961-1	298	370	81	18	56	25	1	1.077	0	0	0	0	40	1.0	2.1	323
MSB106-8	289	334	87	11	52	35	2	1.081	19	0	0	0	40	-	3.8	285*
C082142-4	284	316	90	9	51	39	1	1.076	12	1	1	0	40	4.0	4.0	-
GOLDRUSH	284	349	81	16	58	23	2	1.068	0	0	0	0	40	1.0	2.0	274*
A84118-3	270	337	80	15	49	31	5	1.084	9	5	0	0	40	1.0	4.0	215*
A082611-7	262	411	64	14	40	24	23	1.078	2	1	1	0	40	1.0	3.8	300
C0083008-1	255	294	87	13	68	19	1	1.078	1	0	0	1	40	1.0	3.6	244
NEWLEAF	208	345	60	36	48	12	4	1.072	0	1	1	1	40	1.0	2.3	-
C081082-1	88	139	64	30	50	14	7	1.067	1	0	0	0	30	3.0	1.0	-
MEAN	276	355						1.076							3.0	
$LSD_{0.05}$	61	67						0.002							0.5	

[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 Rating 1996 from Scab Trial
1 - NO INFECTION
3 - INTERMEDIATE
5 - HIGHLY SUSCEPTABLE

[4]MATURITY
1 - EARLY
5 - LATE

* - two-year US #1 average

PLANTED MAY 6, 1996

Table 5

NORTH CENTRAL REGIONAL TRIAL
MONTCALM RESEARCH FARM
SEPTEMBER 16, 1996
(132 DAYS)

	CWT/A		PERCENT OF TOTAL[1]							TUBER QUALITY[2]				TOTAL			MERIT
	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	SFA	HH	VD	IBS	BC	CUT	SCAB[3]	MAT[4]	RATING
W1313	457	496	92	6	69	23	2	1.095	1.5	13	1	0	2	40	2.5	4.0	5
MSB106-7	424	505	84	14	65	19	2	1.071	3.0	0	1	2	0	40	3.0	2.8	4
MSB076-2	389	459	85	13	81	4	2	1.094	1.5	3	0	0	0	40	1.5	3.0	1
RED PONTIAC	374	415	90	6	47	43	4	1.064	4.0	9	1	0	0	40	4.0	3.8	
ATLANTIC	345	387	89	8	73	16	2	1.092	1.5	20	0	3	1	40	3.5	3.5	
MN16489	313	361	87	12	82	5	1	1.075	1.5	0	0	0	0	40	2.0	2.0	2
NORLAND	313	352	89	9	83	6	2	1.063	3.5	2	0	2	0	40	2.0	1.3	3
W1242	299	330	91	8	80	10	2	1.085	1.5	14	0	0	1	30	3.0	4.0	
MSB007-1	296	345	86	13	74	12	1	1.070	2.5	0	0	0	0	40	4.0	3.8	
R.BURBANK	280	401	70	18	53	16	13	1.082	3.5	12	0	3	0	40	1.0	4.3	
SNOWDEN	277	330	84	12	73	11	5	1.086	1.5	1	2	0	0	30	3.0	3.0	
ND2676-10	273	329	83	16	79	4	1	1.076	1.5	1	1	1	3	30	1.5	3.0	
NORCHIP	271	334	81	18	77	4	1	1.077	1.5	1	2	1	0	40	3.0	3.0	
ND2225-1R	250	334	75	24	74	1	1	1.065	3.0	0	1	1	0	40	2.0	1.8	
W1151RUS	228	286	80	20	60	19	0	1.065	3.0	0	0	0	0	30	1.5	3.8	
MN16180	228	340	67	32	65	2	1	1.072	2.0	6	0	2	2	40	3.0	2.0	
RNORKOTAH	149	235	63	35	58	5	2	1.070	3.5	2	0	1	0	40	-	1.5	
MEAN	304	367						1.077								3.0	
$LSD_{0.05}$	82	81						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 Rating 1996 from Scab Trial
1 - NO INFECTION
3 - INTERMEDIATE
5 - HIGHLY SUSCEPTABLE

[4]MATURITY
1 - EARLY
5 - LATE

* - two-year US #1 average

PLANTED MAY 7, 1996

Table 6

EUROPEAN TRIAL
MONTCALM RESEARCH FARM
SEPTEMBER 19, 1996
(136 DAYS)

	CWT/A		PERCENT OF TOTAL[1]							TUBER QUALITY[2]				TOTAL			MERIT
	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	SFA	HH	VD	IBS	BC	CUT	SCAB[3]	MAT[4]	RATING
PICASSO	586	636	92	6	59	33	2	1.065	3.5	2	0	0	0	40	1.5	3.8	2
LATONA	541	658	82	16	78	4	2	1.075	-	3	1	1	0	40	-	4.3	
MORNING GOLD	528	599	88	10	74	14	2	1.071	-	13	0	4	2	40	-	3.3	5
LILI	528	629	84	14	74	10	2	1.070	-	2	2	2	0	40	4.5	4.5	
SW88-112	485	540	90	10	78	12	0	1.067	2.5	1	2	1	0	40	3.5	2.8	
ERNTESTOLZ	453	531	85	14	82	3	1	1.086	2.0	5	0	1	0	40	-	3.5	1
SW88-113	432	503	86	14	72	13	1	1.066	2.5	0	0	1	0	40	2.0	3.0	3
MSA097-1Y	412	442	93	7	73	20	0	1.072	-	0	0	2	0	40	2.0	2.3	
MATILDA	379	523	72	26	71	2	2	1.081	-	0	1	0	0	40	2.0	4.0	4
AMINCA	377	497	76	23	75	1	1	1.072	2.5	1	0	0	0	40	4.0	3.0	
DITTA	372	545	68	29	65	3	3	1.069	2.5	1	0	0	0	40	2.0	4.4	
ROMINA	360	465	77	21	74	3	2	1.068	1.5	1	2	2	0	40	4.0	1.8	
SAGINAW GOLD	341	392	87	11	81	6	2	1.071	1.5	0	0	1	0	40	2.5	1.8	
FELSINA	331	432	77	20	76	0	3	1.080	3.0	0	1	0	0	40	5.0	3.0	
YUKON GOLD	330	372	89	10	74	15	1	1.076	2.0	4	0	1	4	40	2.0	1.0	
PREMIERE	312	436	72	26	70	1	3	1.076	2.5	0	1	0	0	40	3.5	2.0	
MICHIGOLD	269	331	81	18	74	7	0	1.074	-	8	2	1	0	40	4.0	2.0	
MSD029-3Y	245	312	78	21	78	0	0	1.072	-	0	0	0	0	40	3.0	1.0	
IS. SUNSHINE	230	282	81	18	79	2	1	1.074	-	0	0	1	1	40	4.5	3.8	
MSD040-4RY	212	283	75	25	73	2	0	1.084	-	0	0	0	0	20	4.0	1.8	
MEAN	386	470						1.073								2.8	
$LSD_{0.05}$	81	80						0.010								0.8	

[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 Rating 1996 from Scab Trial
1 - NO INFECTION
3 - INTERMEDIATE
5 - HIGHLY SUSCEPTABLE

[4]MATURITY
1 - EARLY
5 - LATE

PLANTED MAY 7, 1996

Table 7A Ranking of Important Potato Varieties and Advanced Breeding Lines in Scab Trial (1994-1996)

Low Infection	Intermediate	Highly Susceptible
A7961-1	Atlantic	Agria
GoldRush	Century Russet	Mainestay
Legend (C0083008-1)	FL1833	MSB110-3
MSA091-1	MSB106-7	ND01496-1
MSA097-1Y	MSB107-1	NorValley
MSB076-2	NY103	Penta
MSE221-1	Portage	Quaggy Joe
NY101(Y)	St. Johns	Ranger Russet
Onaway	Yukon Gold	Red Pontiac
Pike		Shepody
Prestile		
R. Burbank		
R. Norkotah		
Superior		

Table 7B 1994-96 MICHIGAN SCAB TRIAL RESULTS
MSU Soils Farm

Line	1994 Rating[1]	1995 Rating	1996 Rating	Line	1994 Rating	1995 Rating	1996 Rating
A082611-7	2.5	1.0	1.0	MSB076-2	1.0	1.5	1.5
A7961-1	1.0	1.0	1.0	MSB083-1	1.5	2.5	3.0
A84118-3	-	1.5	1.0	MSB094-1	2.0	-	3.0
A8495-1	1.5	1.0	-	MSB095-2	2.0	3.0	-
AC PTARMIGAN	1.5	1.5	-	MSB0952-1	2.0	-	2.5
AF1426-1	-	1.5	1.0	MSB106-7	1.0	-	3.0
AF1433-4	1.0	-	3.0	MSB106-8	2.5	1.0	-
AF1470-17	4.0	4.0	4.0	MSB107-1	2.5	2.5	2.5
AF875-15	2.0	-	4.0	MSB110-3	1.5	3.0	4.5
AGRIA	3.5	3.5	-	MSB1254-1	2.5	-	4.0
Aminca	-	-	4.0	MSC010-20Y	-	1.5	2.0
ATLANTIC	2.5	3.0	3.5	MSC098-2	2.0	-	3.5
ATX 85404-8	-	-	3.0	MSC103-2	3.0	-	2.0
B0717-1	-	1.0	-	MSC120-1Y	1.0	-	2.5
B9922-11	1.0	1.0	-	MSC121-7	3.0	-	4.0
BC0894-2	-	-	2.0	MSC122-1	1.5	-	1.5
BRODICK	1.0	-	-	MSC125-8	1.0	-	2.0
C0008011-5	1.0	1.0	-	MSC126-6	2.5	-	1.0
C0083008-1	1.0	1.0	1.0	MSC148-A	-	2.5	2.5
C081082-1	-	-	3.0	MSD029-3Y	-	-	3.0
C082142-4	-	-	4.0	MSD040-4RY	3.0	2.0	4.0
CENTURY RUSSET	2.5	-	3.5	MSE007-8	-	1.0	-
CHALEUR	1.5	3.0	-	MSE011-25	-	2.0	-
DITTA	-	-	2.0	MSE011-7	-	1.5	4.5
ESTIMA	4.0	4.0	-	MSE018-1	-	3.5	3.0
FELSINA	-	-	5.0	MSE041-1	-	3.0	3.5
FL1533	2.5	3.0	-	MSE048-1Y	-	2.0	-
FL1833	3.0	2.0	1.5	MSE048-2Y	-	1.5	2.0
FL1863	-	3.0	2.0	MSE149-5Y	-	-	2.0
FL1867	-	-	2.0	MSE192-8	-	1.0	-
FL1887	-	-	3.0	MSE202-3	-	-	2.0
GOLDRUSH	1.5	1.0	1.0	MSE220-3	-	-	3.5
HINDENBURG	-	-	1.0	MSE221-1	-	1.5	1.0
ISLAND SUNSHINE	-	2.5	4.5	MSE222-5Y	-	2.0	-
JS111-28	-	-	1.0	MSE222-8	-	1.0	-
LEMHI RUSSET	1.0	1.0	-	MSE226-4Y	-	1.5	1.5
LILI	-	2.0	4.5	MSE228-1	-	2.0	-
MAINESTAY	4.0	3.0	4.5	MSE228-3	-	1.0	1.0
MATILDA	-	2.0	2.0	MSE228-9	-	1.5	1.5
MICHIGOLD	2.0	-	4.0	MSE228-11	-	3.5	3.0
MN15111	1.5	-	-	MSE230-3	-	3.0	-
MN16180	-	-	3.0	MSE230-6	-	2.5	1.5
MN16489	-	-	2.0	MSE247-2	-	2.0	1.5
MS716-15	4.0	-	-	MSE250-2	-	2.0	-
MSA091-1	2.0	1.5	1.0	MSE263-3	-	2.0	3.5
MSA097-1Y	1.5	-	2.0	MSE273-8	-	4.0	3.0
MSB007-1	3.0	4.5	4.0	MSNT-1	3.0	-	1.0
MSB027-1R	3.0	-	4.0	ND01496-1	4.5	4.5	-
MSB040-3	1.0	-	1.0	ND2225-1R	-	-	2.0
MSB057-2	3.0	-	3.0	ND2417-6	3.5	3.5	3.5
MSB073-2	-	-	1.5	ND2471-8	4.0	3.5	5.0

Table 7B, cont.

Line	1994 Rating[1]	1995 Rating	1996 Rating	Line	1994 Rating	1995 Rating	1996 Rating
ND2676-10	-	-	1.5	R. NORKOTAH	1.5	-	-
ND860-2	3.5	-	3.0	R. NUGGET	-	1.0	-
NDA2031-2	3.0	3.5	-	RANGER R.	4.0	-	-
NEWLEAF-RB	-	-	1.0	RED GOLD	4.5	-	-
NORCHIP	1.5	-	3.0	RED NORLAND	2.0	-	2.0
NY101	1.5	1.0	1.0	RED PONTIAC	5.0	2.5	4.0
NY102	2.0	3.0	-	REDDALE	-	-	2.0
NY103	-	3.5	3.0	ROMINA	-	-	4.0
NY111	-	-	3.0	ROSE GOLD	4.0	-	-
ONAWAY	1.0	1.5	1.5	SAGINAW GOLD	3.0	3.0	2.5
P84-13-12	1.0	1.5	3.0	SANTE	3.5	3.0	-
P88-13-4	-	2.0	-	SHEPODY	-	4.5	4.0
P88-15-1	2.5	3.5	-	SNOWDEN	2.0	3.5	3.0
P88-9-8	3.0	3.0	-	ST. JOHNS	3.0	3.0	4.0
PEMBINA CHIPPER	1.0	1.5	-	SUPERIOR	1.0	1.5	-
PENTA	3.0	4.5	-	SW88-112	-	-	3.5
PICASSO	-	-	1.5	SW88-113	-	3.0	2.0
PIKE	-	1.0	1.5	W1149	3.0	3.5	-
PORTAGE	3.5	2.5	-	W1151	-	-	1.5
PREMIER	-	-	3.5	W1242	-	3.0	3.0
PRESTILE	1.0	1.0	-	W1313	-	-	2.5
R. BURBANK	2.0	2.0	1.0	YUKON GOLD	-	3.5	2.0

[1]SCAB RATING
1 = practically no infection
2 = low infection
3 = avg. susc. (i.e. Atlantic)
4 = susc. (high)
5 = severe susc.

TABLE 8 1996 BLACKSPOT BRUISE SUSCEPTIBILITY SAMPLES

A. SIMULATED BRUISE SAMPLES*

DATE OF HARVEST: LONG-LATE

VARIETY	NUMBER OF SPOT PER TUBER 0	1	2	3	4	5+	TOTAL TUBER	% BRUISE FREE	AVE SPOTS/TUBE
C0083008-1	27	1					28	96	0.036
CENTURY R	25	1					26	96	0.038
C081082-1	23	2					25	92	0.080
NEWLEAF	24	3					27	89	0.111
GOLDRUSH	23	5					28	82	0.179
C082142-4	20	6					26	77	0.231
A7961-1	21	4	1				26	81	0.231
A84118-3	18	5	1				24	75	0.292
R. BURBANK	15	9	1				25	60	0.440
JS111-28	18	3	4	1			26	69	0.538
SHEPODY	13	12	2				27	48	0.593
A082611-7	17	2	5	1			25	68	0.600
MSB106-8	16	6	2	1	1		26	62	0.654

DATE OF HARVEST: ROUND WHITES-LATE

VARIETY	NUMBER OF SPOT PER TUBER 0	1	2	3	4	5+	TOTAL TUBER	% BRUISE FREE	AVE SPOTS/TUBE
NY101	24	1					25	96	0.040
PIKE	22	3	1				26	85	0.192
ST. JOHNS	19	6					25	76	0.240
ONAWAY	18	6					24	75	0.250
AF1426-1	19	4	1				24	79	0.250
AF1470-17	18	4	1	1			24	75	0.375
MSA091-1	19	5	1		1		26	73	0.423
FL1887	17	7	2				26	65	0.423
FL1867	13	7	3	1			24	54	0.667
NY111	15	4	5		1		25	60	0.720
NORVALLEY	11	9	3	1			24	46	0.750
MAINESTAY	11	5	6	1	2		25	44	1.120
SNOWDEN	9	3	11	2			25	36	1.240
FL1833	13	2	4	2	1	2	24	54	1.250
MSB083-1	7	8	6	4			25	28	1.280
MSB107-1	5	6	7	2	2		22	23	1.545
ATLANTIC	7	5	4	3	2	1	22	32	1.591
MSB076-2	6	8	3	6	4		27	22	1.778
NY103	6	6	6	4		3	25	24	1.800
FL1863	2	3	3	5	5	7	25	8	3.160

* Tuber samples were collected at harvest, graded, and placed in a six-sided plywood drum and turned ten times to produce simulated bruising. Samples were abrasive-peeled and scored on October 28, 1996.

NORTH CENTRAL REGIONAL TRIAL

NORLAND	20	5					25	80	0.200
ND2225-1R	20	4	1				25	80	0.240
R. PONTIAC	18	7					25	72	0.280
W1151RUS	18	7					25	72	0.280
ND2676-10	13	4	1				18	72	0.333
MN16489	18	4	3				25	72	0.400
R. NORKOTAH	17	6	2				25	68	0.400
R. BURBANK	16	7	1	1			25	64	0.480
W1242	16	5	4				25	64	0.520
NORCHIP	14	5	2	2			23	61	0.652
MSB007-1	14	6	3	1	1		25	56	0.760
MN16180	12	7	6	1			26	46	0.846
SNOWDEN	5	9	4	4	1	2	25	20	1.720
W1313	3	12		5	3	1	24	13	1.833
MSB076-2	3	5	8	2	7		25	12	2.200
ATLANTIC	3	3	5	3	8	3	25	12	2.760
MSB106-7	2	4	2	8	3	5	24	8	2.875

EUROPEAN TRIAL

YUKON GOLD	24	2					26	92	0.077
ROMINA	22	2					24	92	0.083
MICHIGOLD	21	4					25	84	0.160
IS. SUNSHINE	22	2		1			25	88	0.200
MSDO29-3Y	20	5					25	80	0.200
FELSINA	20	5					25	80	0.200
DITTA	21	2		1			24	88	0.208
SW88-112	22	5	1				28	79	0.250
PICASSO	22	2	1	1			26	85	0.269
SW88-113	20	4	2				26	77	0.308
MSA097-1Y	18	4	2				24	75	0.333
AMINCA	15	5	2				22	68	0.409
ERNTESTOLZ	13	5	4				22	59	0.591
PREMIER	14	5	3	1			23	61	0.609
MATILDA	14	7	2			1	24	58	0.667
MORNING GOLD	13	7	2			1	23	57	0.696
LATONA	10	9				1	20	50	0.700
SAGINAW GOLD	13	5	3	2			23	57	0.739
LILI	15	4	3	2	1		25	60	0.800
JULIANNA ROSE	10	12	1	1	2		26	38	0.962

MSU BREEDING LINES 2 X 23 TRIAL

F014-9	19	1					20	95	0.050
E228-1	19	1					20	95	0.050
F096-8	19	1					20	95	0.050
E217-F	17	1					18	94	0.056
F380-5	19	2					21	90	0.095
E192-8	16	3	1				20	80	0.250
E026-A?	15	4	1				20	75	0.300
F002-01	15	4	1				20	75	0.300
F085-3	8	1	1				10	80	0.300
F097-1	15	3	1	1			20	75	0.400
F020-23	13	6	1				20	65	0.400
F092-3	13	6	1				20	65	0.400
F194-3	15	1	2	1			19	79	0.421
F099-3	13	5	2				20	65	0.450
F001-02	13	4	4				21	62	0.571
F165-6RY	15	2	1		2		20	75	0.600
F059-1	13	3		3			19	68	0.632
F373-8	12	2	3		1		18	67	0.667
F349-1	8	6	4	2			20	40	1.000
F090-9	11	5	2		3		21	52	1.000
F326-1	9	6	2	2	1		20	45	1.000
F087-3	8	5	5	1	1		20	40	1.100
F023-4	9	6	1	3		1	20	45	1.100
F205-5	6	9	2	1		1	19	32	1.105
F382-2	6	7	4	2			19	32	1.105
F019-2	9	4	3	1	2		19	47	1.105
E217-D	7	5	3	3			18	39	1.111
E217-B	6	5	4	2	1		18	33	1.278
F019-11	7	3	3	2	2		17	41	1.353
SNOWDEN	3	5	7	2	2		19	16	1.737
F015-1	4	6	5	2	1	2	20	20	1.800
ATLANTIC	5	2	4	4	3		18	28	1.889
F060-6	3	4	2	5	1	3	18	17	2.333
F017-3	6	1	4	2	3	4	20	30	2.350
F026-7	2	5	4	4	2	3	20	10	2.400
F100-1	3	4	3	2	0	7	19	16	2.684
F093-7	2	3	2	3	4	5	19	11	3.000
F093-6	2		2	8	5	4	21	10	3.238
F012-5	2	0	1	2	6	10	21	10	3.905

ADAPTATION TRIAL

B073-2	23	1					24	96	0.042
B0952-1	21	4					25	84	0.160
E012-1	20	5					25	80	0.200
ND2676-10	20	5					25	80	0.200
E228-9	20	5					25	80	0.200
C121-7	19	6					25	76	0.240
AF1433-4	20	2	3				25	80	0.320
E221-1	18	4		2			24	75	0.417
B094-1	15	9	1				25	60	0.440
E149-5Y	17	5	2	1			25	68	0.480
C125-8	16	6	1	2			25	64	0.560
E228-11	15	7	4				26	58	0.577
E263-3	15	8	1	2			26	58	0.615
E202-3	17	4	2	3			26	65	0.654
E220-3	10	10	5				25	40	0.800
E273-8	11	5	5	1			22	50	0.818
E230-6	11	10	1	2	1		25	44	0.880
C103-2	15	6	1	1	3		26	58	0.885
SNOWDEN	8	9	6	1			24	33	1.000
ONAWAY	8	3	5	1	1		18	44	1.111
B040-3	12	4	4	3	1	1	25	48	1.200
E041-1	10	4	5	4		1	24	42	1.292
E226-4Y	7	10	2	3	1	1	24	29	1.333
MSB110-3	8	4	9	2	1		24	33	1.333
E048-2Y	8	9	2	3	2	1	25	32	1.400
C120-1Y	9		9	6	1		25	36	1.600
B057-2	10	3	3	2	1	6	25	40	1.960
E018-1	3	3	9	5	3		23	13	2.087
NT-1	1	8	4	9	1	2	25	4	2.280
ATLANTIC	2	6	5	7	3	2	25	8	2.360
P84-13-12		4	5	10	6	1	26	0	2.808
C148-A			4	4	8	9	25	0	3.880
ND860-2	1			4	8	10	23	4	4.087
E247-2			2	1	5	17	25	0	4.480

B. CHECK BRUISE SAMPLES**

VARIETY	NUMBER OF SPOT PER TUBER 0	1	2	3	4	5+	TOTAL TUBER	% BRUISE FREE	AVE SPOTS/TUBE
DATE OF HARVEST: LONGS-LATE									
NEWLEAF	25						25	100	0.000
SHEPODY	25						25	100	0.000
CENTURY R	25						25	100	0.000
A7961-1	25						25	100	0.000
C081082-1	24	1					25	96	0.040
C082142-4	23	2					25	92	0.080
R. BURBANK	23	2					25	92	0.080
MSB106-8	23	2					25	92	0.080
C0083008-1	24	2	1				27	89	0.148
GOLDRUSH	20	3	1	1			25	80	0.320
A84118-3	15	8	1	1			25	60	0.520
A082611-7	17	1	7				25	68	0.600
JS111-28	15	8	1	1	1		26	58	0.654
DATE OF HARVEST: ROUND WHITES-LATE									
MSB107-1	25						25	100	0.000
ST. JOHNS	25						25	100	0.000
NY101	25						25	100	0.000
MSA091-1	24	1					25	96	0.040
MAINESTAY	24	1					25	96	0.040
AF1470-17	23	1	1				25	92	0.120
SNOWDEN	20	4	1				25	80	0.240
PIKE	21	3		1			25	84	0.240
FL1887	20	2	1	1			24	83	0.292
MSB076-2	20	4	1	1			26	77	0.346
MSB083-1	20	3	1		1		25	80	0.360
ATLANTIC	17	6	2				25	68	0.400
ONAWAY	20		1	1	0	1	23	87	0.435
NORVALLEY	17	5	3				25	68	0.440
NY111	17	6	1			1	25	68	0.520
FL1833	16	4	2	2			24	67	0.583
NY103	15	2	3	2	2		24	63	0.917
FL1867	19		5	1	3	3	31	61	1.290
FL1863	2	3	8	4	3	2	22	9	2.409

** Tuber samples were collected at harvest and graded, with no further bruising. Samples were abrasive-peeled and scored on October 29, 1996.

NORTH CENTRAL REGIONAL TRIAL

NORLAND	25						25	100	0.000
R. NORKOTAH	24	1					25	96	0.040
MSB007-1	24	1					25	96	0.040
ND2676-10	23	2					25	92	0.080
NORCHIP	23	2					25	92	0.080
MN16489	23	2					25	92	0.080
W1151RUS	23	2					25	92	0.080
R. PONTIAC	22	3					25	88	0.120
W1242	21	4					25	84	0.160
MN16180	20	5					25	80	0.200
ND2225-1R	19	6					25	76	0.240
R. BURBANK	19	5	1				25	76	0.280
SNOWDEN	16	6	3				25	64	0.480
MSB106-7	17	4	2	2			25	68	0.560
MSB076-2	21		1		1	2	25	84	0.640
ATLANTIC	15	5	3	2			25	60	0.680
W1313	13	4	3	3	2		25	52	1.080

EUROPEAN TRIAL

MSD029-3Y	25						25	100	0.000
SW88-112	25						25	100	0.000
PICASSO	25						25	100	0.000
ROMINA	25						25	100	0.000
MICHIGOLD	24	1					25	96	0.040
IS. SUNSHINE	24	1					25	96	0.040
DITTA	24	1					25	96	0.040
AMINCA	24		1				25	96	0.080
SW88-113	23	2					25	92	0.080
ERNTESTOLZ	23	2					25	92	0.080
FELSINA	23	1	1				25	92	0.120
LILI	23	1	1				25	92	0.120
MSA097-1Y	22	3					25	88	0.120
SAGINAW GOLD	22	2		1			25	88	0.200
LATONA	18	5					23	78	0.217
PREMIER	19	6					25	76	0.240
JULIANNA ROSE	15	9	1				25	60	0.440
MORNING GOLD	15	5	1	2			23	65	0.565
MATILDA	13	11			1		25	52	0.600

ADAPTATION TRIAL

E220-3	24						24	1.00	0.000
E263-3	23						23	1.00	0.000
E228-9	25						25	1.00	0.000
E226-4Y	25						25	1.00	0.000
ND2676-10	25						25	1.00	0.000
C103-2	24	1					25	0.96	0.040
E228-11	22	1					23	0.96	0.043
B094-1	23	2					25	0.92	0.080
E041-1	23	2					25	0.92	0.080
C125-8	23	1	1				25	0.92	0.120
B0952-1	22	3					25	0.88	0.120
B073-2	23	1	1				25	0.92	0.120
C121-7	22	4					26	0.85	0.154
E202-3	22	2	1				25	0.88	0.160
SNOWDEN	22	1	2				25	0.88	0.200
E230-6	22	2	1	1			26	0.85	0.269
MSB110-3	20	3	2				25	0.80	0.280
E273-8	15	7					22	0.68	0.318
E048-2Y	19	4	2				25	0.76	0.320
E221-1	21		3	1			25	0.84	0.360
E012-1	19	4	1	1			25	0.76	0.360
AF1433-4	19	4	2	1			26	0.73	0.423
B040-3	20		3	2			25	0.80	0.480
NT-1	20	1	2	1		1	25	0.80	0.520
B057-2	18	2	3		2		25	0.72	0.640
C120-1Y	13	8	2		1		24	0.54	0.667
E149-5Y	14	5	1	4	1		25	0.56	0.920
E247-2	8	8	6	1		2	25	0.32	1.320
ATLANTIC	4	8	5	3	2	3	25	0.16	2.000
E018-1	8	4	1	4	4	3	24	0.33	2.042
ND860-2	3	4	8	5	1	5	26	0.12	2.462
C148-A	3	5	5	2	1	7	23	0.13	2.609
P84-13-12		4	7	4	5	5	25	0.00	3.000

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POTATO VARIETY AND MANAGEMENT STUDIES

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Introduction

On-farm potato variety trials in Michigan have a long history of contributing to the introduction of new potato varieties into the Michigan potato industry. In 1996, in cooperation with the MPIC Processing Committee, there were five locations where eighteen entries were evaluated for both chip and frozen French fry processing. There were four other locations where twelve entries were evaluated for the fresh market.

Russet Burbank has been grown for many years in Michigan, however, there has been no recent Michigan studies comparing seed preparation prior to planting. A study was initiated in 1995 and continued in 1996 to assess pre-plant seed management strategies. A similar Shepody study was initiated in 1996 at the MSU Montcalm Research Farm.

A. Procedure for On-Farm Variety Trials and Results

Twenty-five pound samples of each of the 18 processing variety entries were planted on the cooperating farms of W.J. Lennard and Sons, Inc. (Monroe), Crooks Farms (St. Joseph), Fertile Valley Farm (Allegan), Sandyland Farm (Montcalm) and L. Walther and Sons, Inc. (Tuscola). Seven of the entries for chip processing (MSB083-1, MSB110-3, MSB076-2, MSA091-1, MSB073-2, MSB095-2 and MSB0952-1) were from the MSU potato breeding program and were compared with the standard varieties of Snowden, Atlantic and Pike. Other chip entries were ND2417-6 (NorValley) and NY103. There were six entries also included to assess for frozen French fry processing. These entries were A7961-1 (USDA-Aberdeen), JS111-28 (J.R. Simplot), Legend (C0083008-1), Shepody, Russet Burbank, and Russet Burbank NewLeaf®.

For the fresh market trials, there were 12 entries planted on the cooperating farms of Terry Groulx (Bay), Hansen Farms, Inc. (Montcalm), Smith Bros. (Monroe) and Allen Erke (Presque Isle). Five of the entries (MSB107-1, MSB083-1, MSB106-7, MSB106-8 and MSC122-1) were from the MSU potato breeding program. Other entries were St. Johns, Mainestay, Quaggy Joe, AF1426-1 (all from Maine), NY103, Onaway and Goldrush.

Results

The overall average yields, size distribution and specific gravity are shown in Table 1 for the five processing trial locations. Among the chipping varieties, Snowden produced the highest yields of U.S. No. 1 potatoes followed closely by NY103 and Atlantic. The NY103 produces round white potatoes which are smooth, shallow eyes and have very good general appearance, however, the specific gravity is lower than desired for chip processing. MSB083-1 had above average yields, however, there have been some locations where internal brown spot was noted. NorValley (ND2417-6) produced good yields, however, specific gravity values have been medium. Its area of adaptability appears to be similar to Norchip. MSB110-3 was noted to have very good chip color, however, it appears to be susceptible to scab and testing will not be continued. MSB076-2 plants are large and very upright throughout the growing season. It has high specific gravity and yield potential with good tolerance to scab. Tubers are oblong to oval in shape and some hollow heart has been noted. MSA091-1 yields were variable and it does have some scab resistance. MSB0952-1 and MSB095-2 had the lowest yields.

Among the frozen processing entries the A7961-1 advanced seedling from USDA-Aberdeen produced the best yields. This seedling has produced well at the MSU Montcalm Research Farm also. Specific gravity is similar to that of Shepody and it has medium-late maturity. Its strengths are resistance to malformations, internal defects and shatter bruise, however, it is reported to have occasional sugar build up in storage. JS111-28 is an entry provided by J.R. Simplot. Yields are good and it has a very good tuber type. Legend (C0083008-1), a Colorado cross selected in Oregon had very good general appearance. It appears to have a small set and yields in Michigan have been below average. Russet Burbank NewLeaf® did not perform well in 1996. Plant growth appeared normal for Russet Burbank, however, yields and particularly tuber sizing were below average.

Table 1. 1996 Processing Potato Trial
Overall Average — Five Locations

	Yield (cwt/A)		Percent Size Distribution					
			A. Chip Processing					
Entry	No. 1	Total	No. 1	<2"	2-3¼"	>3¼"	Culls	S.G.
Snowden	414	445	93	7	79	14	0	1.083
NY103	408	436	93	5	75	18	2	1.073
Atlantic	400	438	91	6	71	20	3	1.082[1/]
MSB083-1	359	430	84	15	73	11	1	1.077
ND2417-6 (NorValley)	356	410	87	12	79	8	1	1.072
MSB110-3	347	434	80	19	73	7	1	1.083
MSB076-2	343	399	85	13	82	3	2	1.090
MSA091-1	334	373	89	8	75	14	2	1.079
MSB073-2	314	351	89	10	84	5	1	1.084
Pike	314	346	91	9	82	9	0	1.085
MSB095-2	260	318	81	18	77	4	1	1.080
MSB952-1	222	277	79	21	73	6	0	1.079[2/]
			B. Frozen Processing					
			No. 1	<4 oz	4-10 oz	>10 oz	Culls	
A7961-1	329	385	85	11	51	34	4	1.079
JS111-28	290	377	77	14	54	23	9	1.077
R. Burbank	275	397	69	23	55	14	9	1.078
Shepody	255	334	76	13	38	38	11	1.075
Legend	229	274	83	16	60	23	1	1.080
R.B. NewLeaf	186	348	53	42	43	10	4	1.074

[1/]Four locations.

[2/]Three locations.

Summary data for the four locations of the fresh market trial are shown in Table 2. St. Johns, MSB107-1 and Mainestay all produced over 400 cwt/A of U.S. No. 1 potatoes. In our Montcalm Research Farm trials, St. Johns has averaged 401 cwt/A over the past three years, Mainestay has averaged 438 cwt/A and in two years of trials, MSB107-1, 386 cwt/A. The interest in Mainestay has declined as it has shown sticky stolons, growth crack and some shatter bruise. In Maine during 1996, purple streaking in the flesh was also noted. MSB107-1 is a bright skin, round white with excellent internal quality. AF1470-17 was named Quaggy Joe in 1996 for a mountain in Maine. Yields were very good and it was the highest yielder at the late harvest at the Montcalm Research Farm. Internal quality was good except brown center was noted at two farm locations and the Montcalm Research Farm. It is scab susceptible.

NY103 was also included in the fresh trial because of its desirable tuber appearance. It has good fresh market prospects. It is intermediate in scab tolerance. MSB106-7 has good yields and scab reaction similar to Atlantic. AF1426-1 had several defects in tuber type and testing will be discontinued. MSB106-8 and MSC122-1 will also be deleted from further testing.

Table 2. 1996 Freshpack Potato Variety Trial
Overall Average — Four Locations

	Yield (cwt/A)		Percent Size Distribution					
Entry	No. 1	Total	No. 1	<2"	2-3¼"	>3¼"	Culls	S.G.
St. Johns	414	444	93	4	71	22	3	1.075
MSB107-1	411	442	93	5	66	27	2	1.082
Mainestay	404	453	89	9	78	11	2	1.078
Onaway	381	439	87	4	61	26	9	1.070
AF1470-17 (Quaggy Joe)	377	439	86	9	65	21	5	1.068
NY103	370	396	93	6	71	22	1	1.071
MSB083-1	358	418	88	10	71	17	2	1.085
MSB106-7	357	420	85	12	72	13	3	1.070
AF1426-1*	307	347	88	5	56	32	7	1.076
Goldrush	278	335	83	15	63	20	2	1.072
MSB106-8	267	307	86	13	68	18	1	1.086
MSC122-1	197	252	76	21	74	2	3	1.080

*Two locations.

B. Procedure for Seed Preparation Studies

Russet Burbank and Shepody seed were obtained from J.R. Simplot Co. in April and held at 40F. The Russet Burbank trial was initiated in 1995 and Shepody in 1996. At 12, 6, 3 and 1 day(s) before planting, whole seed was removed from the 40F storage and held for cutting just prior to planting. A second set of seed was also removed from 40F storage, warmed for 1 day and then pre-cut at 12, 6 and 3 days at 52F until planting.

Seed size was approximately 2 ounces and was not treated. The seed was hand planted at a 12 inch spacing for Russet Burbank and 10 inch spacing for Shepody in plots 23 feet long with four replications on May 8, 1996 at the MRF. Soil and air temperatures were 48F and 58F, respectively. The Shepody plots were harvested on September 10 and Russet Burbank on September 23, 1996.

Results

Table 3 shows the plants emerged, relative plant vigor and stem counts for Shepody. On June 3, 26 days after planting, plant emergence was greatest for pre-cut seed and cut and plant seed warmed for 12 days. These differences were not evident on June 11, 8 days later. There were no differences in stem counts.

The yields, size distribution, specific gravity and internal tuber quality are shown in Table 4. Size distribution and specific gravity were all very similar. Previous studies conducted in 1986-87 did result in a significant yield difference in favor of pre-cut seed. The advantage of pre-cut Shepody seed likely has the greatest effect during the period from planting to emergence and could be affected by adverse soil and weather conditions. Shepody has a more sparse distribution of eyes than Russet Burbank and eyes located near the stem end appear to be slower to develop. Holding pre-cut seed before planting under proper conditions of relative humidity, temperature and air will enhance suberization of the cut surface and more uniform sprout development.

Table 5 shows the plants emerged, relative plant vigor and stem counts for Russet Burbank. There was very little difference in plant stand counts on June 3 and on June 11. Plant vigor appeared better than average for cut and plant seed pre-warmed for 12 and 6 days and pre-cut seed held for 6 days, however, this did not result in the highest yields. Similar to the Shepody, there were no differences in stem numbers that resulted from these treatments.

Yields, size distribution, specific gravity and internal tuber quality are shown in Table 6. There were no significant differences in the yields of U.S. No. 1 potatoes except that pre-cut seed held for 6 days (PC-6) was significantly higher than for cut and plant seed pre-warmed for 3 days (CP-3). It appears that in 1996 seed which was warmed up to 6 days before planting produced higher yields than seed warmed for 12 days.

Table 7 shows a summary of the yield results for the two years of the Russet Burbank study. These results show that the higher yields of U.S. No. 1 potatoes appeared to result from seed which was pre-warmed whole and then cut and planted. Seed which was pre-cut and held at 50F for 12 days resulted in the lowest yields.

The Russet Burbank study will continue in 1997 and the Shepody study will continue in 1997 and 1998. This will provide three years of data which will represent different planting and growing seasons.

Table 3. Emergence, vigor and stem counts for Shepody (1996).

Treatment[1/]	Plants Emerged[2/] June 3	Plants Emerged[2/] June 11	Vigor[3/] Rating June 11	Stems/Plant
CP-12	6.7	25.8	A+	2.9
CP-6	4.0	25.0	A-	2.4
CP-3	4.8	23.5	A-	2.3
CP-1	2.0	24.8	A-	2.3
PC-12	9.0	24.0	A	2.5
PC-6	7.7	26.3	A+	2.5
PC-3	5.5	26.0	A+	2.4

[1/]CP = cut and plant — days held prior to planting.
PC = pre-cut — days held prior to planting.

[2/]28 seed pieces planted.

[3/]A = Average vigor.

Table 4. Yields, size distribution, specific gravity and tuber quality of Shepody (1996).

	Yield (cwt/A)		Percent Distribution						Internal Quality*			
Treatment	No. 1	Total	U.S. No. 1	<4 oz	4-10	>10	Pick Outs	S.G.	HH	VD	IBS	BC
PC-3	387	442	87	9	48	39	3	1.075	8	3	0	0
CP-6	382	433	88	10	53	36	2	1.076	7	1	0	1
CP-1	382	431	89	9	47	41	2	1.076	9	2	0	0
PC-12	375	427	88	10	53	35	2	1.077	5	1	0	0
CP-3	374	428	87	10	48	39	3	1.075	8	3	0	0
PC-6	362	425	85	11	49	36	4	1.075	2	1	0	0
CP-12	333	396	84	12	50	34	4	1.075	8	2	0	1

*Number of tubers with defect out of a total of 40 cut.

Table 5. Emergence, vigor and stem counts for Russet Burbank (1996).

Treatment[1/]	Plants Emerged[2/] June 3	Plants Emerged[2/] June 11	Vigor[3/] Rating June 11	Stems/Plant
CP-12	15.3	19.3	A+	3.1
CP-6	17.3	22.3	A+	3.4
CP-3	15.5	20.5	A-	2.5
CP-1	17.8	20.8	A	2.7
PC-12	13.8	20.3	A	2.4
PC-6	17.0	21.5	A+	3.3
PC-3	13.8	19.5	A-	2.8

[1/]CP = cut and plant — days held prior to planting.
PC = pre-cut — days held prior to planting.

[2/]23 seed pieces planted.

[3/]A = Average vigor.

Table 6. Yields, size distribution, specific gravity and tuber quality of Russet Burbank (1996).

	Yield (cwt/A)		Percent Distribution						Internal Quality*			
Treatment	No. 1	Total	U.S. No. 1	<4 oz	4-10	>10	Pick Outs	S.G.	HH	VD	IBS	BC
PC-6	350	450	78	21	63	15	1	1.079	1	0	0	0
PC-3	325	414	79	19	59	20	3	1.079	1	0	1	0
CP-6	322	432	74	23	63	12	3	1.076	3	0	0	0
CP-1	311	419	74	20	57	17	6	1.076	1	0	0	0
PC-12	307	400	77	20	59	18	3	1.078	3	0	1	1
CP-12	306	400	77	19	56	21	4	1.078	4	0	2	1
CP-3	299	392	76	18	55	21	5	1.078	1	0	1	0

*Number of tubers with defect out of a total of 40 cut.

Table 7. Two year average yields from Russet Burbank seed pre-warmed either whole or cut for various days prior to planting.

	1995		1996		Average	
Treatment*	No. 1	Total	No. 1	Total	No. 1	Total
CP-1	376	488	311	419	343	453
CP-6	346	486	322	432	334	459
CP-12	348	493	306	400	327	446
PC-6	303	439	350	450	326	444
PC-3	313	439	325	414	319	426
CP-3	276	408	299	392	287	400
PC-12	226	369	307	400	266	384

*CP = cut and plant — days held prior to planting.
PC = pre-cut — days held prior to planting.

FUSARIUM DRY ROT RESEARCH

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Fusarium dry rot, caused primarily by the fungus *Fusarium sambucinum*, is an important pathogen of tubers in storage as well as a cause of seed piece decay. However, because of the resistance of *F. sambucinum* to thiabendazole and thiophanate methyl, there are no choices for post-harvest chemical control of this disease in Michigan. Because of this, other means of chemical and non-chemical control are needed.

Over the last several years, we have investigated several aspects of the resistance of tubers to this pathogen. Overall, the results have not been very conclusive and have not led to any straightforward information that could be easily used in the breeding of Fusarium dry rot resistant tubers or in the engineering of potato that would have more resistant tubers.

As an alternative strategy, research was undertaken to attempt to understand the nature of pathogenicity of *F. sambucinum* by means of a genetic analysis of the pathogen in relation to its virulence on tuber tissue. In addition, testing of newer seed piece treatment materials was initiated.

Results:

As an initial step in determining the complexity of virulence in *F. sambucinum*, crosses were made between highly virulent and less virulent or non-virulent isolates of the fungus. The offspring of the crosses were tested for their ability to cause disease in tubers, resistance to thiabendazole, and for traits that are hypothesized to be related to pathogenicity.

TBZ Resistance:
Crosses between strains that were resistant or sensitive to TBZ were carried out. The offspring of the crosses were tested for growth on media containing TBZ and for the ability to cause disease. The results indicated that TB resistance was controlled by one gene. In addition, there appeared to be no relationship between the resistance of the pathogen to TBZ and virulence on tubers.

Steroid alkaloid resistance:
When injured, potato tubers naturally produce steroid glycoalkaloids solanine and chaconine. In addition to being negative quality factors, these compounds are antimicrobial and may function in the resistance of injured tubers to infection. Our previous research had shown that at the wounded surface of potato tubers, high enough quantities of glycoalkaloids accumulated to inhibit the growth of *F. sambucinum*. However, since *F. Sambucinum* can detoxify other defenses of potato, relationship of virulence of F. sambucinum to glycoalkaloid sensitivity was evaluated. In

general, it was found that the most virulent strains of F. sambucinum were the most tolerant or resistant to the glycoalkaloids while the less virulent isolates were more sensitive. Since more than one alkaloid occurs in tubers, the effects of mixing various amounts of solanine and chaconine were tested. In the more sensitive strains, there was a synergistic effect of having both alkaloids in the test. This was not evident in the most resistant strain.

The relationship between alkaloid production and resistance to Fusarium was tested by comparing the amount of disease that developed on Gold Rush with that on Lenape (a variety with very high glycoalkaloid content. Our samples contained 19mg TGA/100 grams of tuber tissue. This is more than sufficient to inhibit the pathogen). Lenape was much more resistant to Fusarium dry rot than was Gold Rush. The most alkaloid sensitive strains were clearly the least pathogenic on Lenape. Crosses between alkaloid resistant and susceptible Fusarium isolates were tested on Lenape, and there was a correlation between resistance to the alkaloid and the amount of disease produced on the tubers. There was less of a correlation between the level of virulence and alkaloid tolerance when the same fungal offspring were tested on Gold Rush. However, if the wounded surface of Gold Rush was treated with alkaloids prior to inoculation, the more tolerant isolates of the pathogen were able to cause more disease. Analysis of the numbers of glycoalkaloid resistant to sensitive offspring suggested that resistance to the alkaloids was controlled by a single gene.

Fusarium colonizes potato tissue, in part, by growing through and between the potato tuber cells. Because of this and the observation that the pathogen cannot grow through a well suberized periderm, the role of enzymes that the pathogen might use in tissue colonization were evaluated. Although Fusarium was capable of producing cellulose and pectin-degrading enzymes as well as some non-specific esterases, there was no correlation between enzyme production and the ability to cause disease. Different strains of the pathogen are also known to produce different colors in culture (from red to orange to yellow to white). No correlation between color and pathogenicity was found.

Conclusions

Virulence of *Fusarium sambucinum* appears to be controlled by several genes. Thus, it is unlikely that resistance will be based on single genes in the potato. Of significance is the finding that virlence appears to be associated with the tolerance of more virulent isolates of the pathogen to the steroid glycoalkaloids chaconine and solanine. Both of these compounds are synthesized by tubers at the site of wounding, and thus they probably function to help the wounded tuber fend off infection until a new periderm is established. Thus, it appears that part of the mechanism that *F. sambucinum* uses for successful infection is by being tolerant of these natural defenses. The role of alkaloids in resistance is partly supported by the results with Lenape. However, the fact that Lenape also expressed higher levels of resistance to infection by the alkaloid tolerant Fusarium isolates than were seen in Gold Rush suggests that Lenape may have other resistwnc mechanisms and, thus, could serve as a source of this resistance.

Funding MPIC

POSTHARVEST SUPPRESSION OF FUSARIUM DRY ROT AND OTHER STORAGE DISEASES OF MINITUBERS OF POTATO TUBERS BY APPLICATION OF BIOACTIVE FUNGAL INOCULUM DURING PLANT GROWTH

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PROGRESS AND JUSTIFICATION:

The Fusarium storage rots of potato are among the most important postharvest pathogens worldwide. Current methods for control of Fusarium storage rot rely on cultural practices and some chemical treatments, however, complete control of this problem has proved to be difficult. Research by Niemira, Safir and Hammerschmidt in cooperation with Sklarczyk Seed Farm, Johannesburg, MI has shown that growing tissue culture derived potato plantlets, for the production of prenuclear minitubers, in a commercial peat based fungal mycorrhizal inoculum (Micori-Mix, Premier Peat Moss, Quebec, Canada) can alter minituber production. Significantly, more of the valuable No. 1 and 2 as opposed to the less valuable No. 3 prenuclear minitubers were produced in the presence of the biological inoculum (Micori-Mix). Initial observations of minitubers in cold storage suggested that the minitubers that were produced in the presence of Micori-Mix had less dry rot than did the minitubers produced in the absence of the inoculum. Additionally, in subsequent experiments at both Sklarczyk Seed Farm and Michigan State University, minitubers that were produced in the presence of the inoculum again had substantially less dry rot when challenged with the dry rot fungus *Fusarium sambucinum*. The use of this commercial biological inoculum would become even more economical if it could be used in the field during tuber production and would result in increased tuber resistance to Fusarium and other storage rots. We would like to expand our studies to determine if this commercial inoculum, when used in the field for potato tuber production, will result in a significant reduction in both Fusarium sambucinum and Phytophthora infestans storage rots as well as late blight development. This would provide a potential economical and environmentally friendly partial control for these problems. Preliminary experiments have been conducted to determine if the mycorrhizal inoculum offers stored minitubers any protection against Phytophthora infestans. Minitubers of potato c.v. Atlantic produced in the presence and absence of the commercial biological inoculum were injected with approximately 1000 zoospores/minituber of the pathogen Phytophthora infestans race US8 (provided by W. Kirk). The minitubers produced in the presence of the commercial biological inoculum had lower levels of disease.

Since the preliminary results suggest that the commercial inoculum may offer some protection against these two pathogens we are proposing to expand our studies as follows:

1. Determine if the use of a commercial biological inoculum in the field will result in the production of potato tubers that are more resistant to storage rots caused by Fusarium sambucinum and Phytophthora infestans.

2. Determine if the commercial biological inoculum will enhance resistance of potato foliage to Phytophthora infestans.

Funding MPIC/MDA

NITROGEN STEWARDSHIP PRACTICES TO REDUCE NITRATE LEACHING AND SUSTAIN PROFITABILITY IN AN IRRIGATED PRODUCTION SYSTEM

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A collaborative effort by MSU crop and soil specialists, Michigan Department of Agriculture (MDA), Michigan Potato Industry Commission (MPIC), and Cooperative Extension Service (CES) was initiated to demonstrate how on-farm N stewardship practices influence farm profitability and nitrate leaching to groundwater. We proposed to (a) establish N stewardship plots on potato farms and evaluate petiole sap nitrate testing as a tool for adjusting mid-season N fertilization, and (b) install lysimeters to intensively monitor on-farm N leaching losses as affected by N practices and crop rotation for three consecutive years. We also plan to identify peak leaching periods and quantify nitrate losses to groundwater in relation to rainfall and irrigation.

MATERIALS AND METHODS

Installation of Lysimeters

In 1995 three types of undisturbed soil drainage lysimeters were installed on three irrigated potato farms in the Montcalm county. Lysimeter types were (a) zero-tension 6-ft long, semicircular troughs of 12 inch diameter, (b) low-tension quartz soil water samplers, and (c) medium-tension soil solution access tubes (SSAT). These types were selected to increase the precision of measurements and reduce the effects of variability due to channeled flow. At each site, lysimeters were laid out into eight separate workstations, four located inside and four outside the N stewardship plot. Each workstation consisting of one trough, one quartz, and one 3-ft long SSAT located at a depth of three feet and installed perpendicular to the rows. The 6-foot long troughs extended across two potato rows. These lysimeters were installed in April, before field preparation time to enable farmers to plant potatoes over the lysimeters. After the crop emerged, three additional SSAT's were installed, two at 12-inch depth, and one at 18-inch depth in the row between plants, to monitor soil solution nitrate levels in the root zone.

In 1996 seven different irrigated potato fields were selected to demonstrate nitrogen stewardship practices. This time the N stewardship plots were much larger, extending the entire length of the field. Trough and quartz lysimeter were not installed in the 1996 plots. Instead, six sets of SSAT's were installed. Three sets inside and three outside of the stewardship area. Each SSAT was installed in the potato row at depths of 12, 24 and 36 inches.

In another collaborative effort, MSU scientists, MPIC and CES have established a large drainage lysimeter facility at the Montcalm Research Farm. This facility provides direct measurements of nitrate leaching amounts for a potato-corn production system. This project was initiated in 1987 at the Montcalm Research Farm with the relatively long-term objectives of monitoring nitrate leaching as influenced by nitrogen fertilizer management. Data collected from these lysimeters and other research plots are being used to test and improve a computer simulation model, SUBSTOR which predicts not only crop growth and yield but also the important soil processes affecting nitrate leaching. This research will be used to establish the credibility of the model which will be used to predict long-term leaching from the Montcalm site and other locations in Michigan.

Establishment of N Stewardship Plots

The N stewardship plots were established at strategic locations, to serve as a reference point to judge the N status of the entire field. In 1996, the N stewardship plots were strips extending the entire length of the field. The width of each strip varied from six to 24 rows depending on the equipment available for applying fertilizer and harvesting. Each stewardship plot received a reduced N rate, about 60-120 lb/A less N than the conventional rate applied to the rest of the farm. The differential N rates were applied either at first cultivation or at hilling.

Residual Soil Nitrate and Soil Solution Nitrate Testing

Soil samples were taken to a depth of three feet, in one foot increments, prior to planting and after harvest to evaluate the initial and final residual soil nitrate levels. Soil solution samples were collected from each SSAT on a weekly basis starting June 10 and ending August 5. All samples were analyzed for nitrate N using an auto-analyzer.

Weekly Petiole Sap Testing and Leaf Chlorophyll Readings

Weekly testing of potato petiole sap commenced on June 25 and ceased on August 8. Four replicates of petiole samples were taken from inside the window and four replicates from outside. The test results were faxed to the growers on the next day via the Montcalm Extension Service. The results were used to assess N status of potatoes and adjust mid-season N fertilizer applications. Additionally, the sap testing service was available to other interested potato growers. We also worked closely and offered advice to private consultants who relied on the sap nitrate testing to manage N on clientele farms.

Leaf chlorophyll readings were also made at the same time petiole samples were collected. Approximately 150 readings were made in each plot with a hand held Minolta SPAD 502 chlorophyll meter. These readings were later correlated with the corresponding petiole nitrate content.

Drainage Water Sampling for Nitrate Analysis

In 1995 drainage water samples from the undisturbed lysimeters were collected throughout the growing season. In the fall the drainage tubes were buried just prior to harvest and brought back to the surface after a cover crop was established. Sampling resumed in November until the ground was frozen and again in April when the ground and tubes were free of frost. The tubing was again buried prior to planting of the 1996 crop and brought back to the surface after planting. Water samples from the tension lysimeters were used to measure nitrate concentration in soil water as it passes below the root zone. Water samples from the trough lysimeters were used to measure both the volume of drainage water and nitrate N in the leachate.

Potato Harvest

In 1996 potatoes were harvested in September and October with the farmers equipment. Four to twelve rows, 800 to 2000 feet long, were harvested and loaded into truck which were weighted at the nearest certified scale. Tuber yield and specific gravity from inside and outside the N stewardship plot were compared. Small samples of tubers were graded according to size and analyzed for specific gravity. For the round variety Snowden and Pike, US #1 grade included all tubers greater than 2 inches in diameter. Tubers smaller than 2 inches were graded as B's. Tubers greater than $3^1/_4$ inches were classified as premium oversized. For the long variety, Russet Burbank, tubers under 4-oz were graded as B's. Those weighing over 10-oz were classified as premium oversized.

RESULTS AND DISCUSSION

Rates and times of N application are presented in Table 1. These data include the large lysimeter plots at the Montcalm Research Farm, site number 8. Nitrogen fertilizer rates varied from a low of 160 lb/acre to a high of 283 lb/acre. The number of applications varied from two to seven times. The varieties grown were Snowden, Pike and Russet Burbank.

Potato Yield

Potato yield data from the eight N stewardship plots are presented in Tables 2. We were unable to calculate statistical differences due to the fact that strips were not replicated. At several sites we harvested more than one load from each strip. At other sites we harvested the entire strip into one truck load. Harvest strips varied from four to 12 rows wide and 800 to 2000 feet long. Truck loads varied from seven to 15 tons of fresh weight tubers.

In general higher rates of N produced the highest yields. Site number 6 and 8 were the only sites where the lowest N rate resulted in the highest yield. Yields at the Montcalm Research Farm were calculated from small plots, two rows 50 feet long. These plots were unreplicated because there are only two large drainage lysimeters installed at the site.

The largest difference in tuber size distribution was in the premium oversize category (those greater than $3^{1}/_{4}$ inches in diameter or heavier than 10 ounces). On average the highest N rates produced 5 percent more premium size tubers. Specific gravity of tubers decreased slightly with the higher N rates. Net economic returns, calculated as the gross margin minus the fertilizer N costs, favored the higher N rates by $77/A. Differences between high and low N rates varied from a loss of $362 per acre for site number 8 to a gain $346 per acre for site number 7. A price of $6.60/cwt for potatoes and $0.22/lb of N fertilizer was used in the analysis.

Although the yield data here do not appear to support the N stewardship practice of reducing N fertilizer use, we would like to caution everyone from making false conclusions. These data are not statistical proof that higher N rates will produce larger and more profitable yields. These yields were not from replicated plots, therefore, we do not have an estimate of experimental error. These yield differences may be due to normal field and sampling variability and not the N treatments. The use of farm equipment to harvest large plots has several advantages over small plot harvesting but we still need to characterize field variability by including replicated strips in future trials before we can draw definitive conclusions.

SAP NITRATE TEST AND LEAF CHLOROPHYLL READINGS

Weekly petiole sap nitrate tests from inside and outside the stewardship plots are summarized in Figures 1-8. The bar chart in these figures shows the critical sap nitrate levels we have established for that variety and planting date. Arrows point to in-season N fertilization events when they occurred during the sap testing period.

The effects of different N fertilizer rates on petiole sap nitrate levels were not always evident. At most sites, there were few noticeable differences between the two N treatments. The biggest difference occurred at sites three and eight. At these sites higher nitrate concentrations were closely associated with higher N fertilizer rates. The difference in total yield at site number 3 was smaller (38 cwt/acre) than we expected. Visual symptoms of N deficiency at this site were very evident early in the growing season. The reduced N strip at this site was established as a 6-row strip, however early in the season, only four rows were visible N deficient. Later in the season only two rows were visible in some areas of the strip. It appeared that the two outside border rows were being affected by the higher N rate on either side. Cross-contamination of the border rows may be the explanation for the small difference in yields observed between the two N rates.

Leaf Chlorophyll readings were also made each week when petioles were sampled for nitrate. Previous research has shown that leaf chlorophyll is closely correlated with N content of the leaf. Most scientists have shown that it is best to present the data as a percent of the high N treatment. Relative SPAD readings are shown in Figures 1-8 at the top of the chart using the right axis for interpretation of the values. The relative SPAD reading stayed above 90% throughout the sampling season at all sites except site number 3. At this site there was a steady decline throughout the season (Figure 3). The value dropped below 90% on about July 10th. Figure 13 shows the correlation between the actual SPAD readings and the sap nitrate concentration for both N treatments throughout the sampling season for site number 3. A very good correlation (R^2 = .88) was found between leaf chlorophyll readings and sap nitrate levels. **From this preliminary information we conclude that the chlorophyll meter has great potential for use as a diagnostic tool in evaluating the N status of the potato crop.**

Soil Water Analysis

The weekly nitrate N concentration and the volume of drainage water data were collected from the zero-tension trough lysimeters. Since the installation of these lysimeters in the spring of 1995, there has been very little drainage water collected in the trough lysimeters. There is also considerable variability in the volume of water collected from each trough. This can probably be attributed to the capillary rise of water above the trough and to preferential flow through the soil profile around the trough lysimeters. As a result of these findings, we have decided to cease collecting data from the trough lysimeters.

Biweekly soil solution nitrate N concentrations from the medium-tension SSAT lysimeters were collected at each site. For most sites, the nitrate N concentration at 12-inch depth was higher at the beginning and decreased toward the end of the season while the nitrate concentrations at the 36-inch depth were initially low and increased with time. These trends however, are less evident when looking at the average of the eight sites (Figures 9 and 10). The general trends show evidence of nitrate uptake by plants from the surface foot and downward movement through the profile with time due to leaching.

The nitrate N concentrations at many of these sites were extremely high at times, well in excess of 100 ppm. The implications of this are that excess N was probably available for plant growth at most of these locations and that excess rain could easily have caused considerable loss of N due to leaching. **Growers need to be more conscious of the N uptake pattern of potatoes and apply N more timely to meet the daily demands of the crop.**

From these data we were not able to determine a critical nitrate level in the surface foot for plant growth. The only site which might be classified as N deficient was the N stewardship plot at site number 3. At this site the inside area had concentrations in excess of 40 ppm throughout the sampling season except for the last date of August 8 (Data not shown here). **There appears to be considerable variability between tubes, dates and locations which makes it difficult to establish a critical nitrate N level for optimum plant growth in the field using the SSAT's.**

The data for the Quartz and SSAT lysimeters installed in the 1995 sites are presented in the Technical report to MDA. A summary of this information, showing average values for the three sites, is shown in Figures 11 and 12. There appears to be some differences between the three sites and the flow of nitrates through the soil, particularly site 1 versus 2 and 3. High levels of nitrate reached the 36 inch depth earlier at site 1 than the other two sites. Figure 14 shows the correlation between Quartz and SSAT lysimeters. A correlation coefficient of 0.77 was obtained indicating that there is a good relationship between the two lysimeter types and that either lysimeter type may be used to monitor nitrate leaching through soils.

Preplant And Post-harvest Residual Soil Nitrate

The residual soil nitrate N prior to planting and after harvest are presented in Table 3 and 4. Except for site number 7, relatively little soil nitrate (less than 20 lb N/acre) was found in the three-foot profile. At site number 7 there was a total of 32 lb N/acre-3 feet. Two-thirds of this N (19 lb/acre) was found below 24 inches deep. After harvest, some sites contained significant quantities of nitrate N ranging from 16 to more than 140 lb N/acre-3 feet. The average for all outside areas contained 22 lb more N per acre-3 feet than the inside areas (55-33). On average, the outside areas of the field received 67 lb more N fertilizer than the N stewardship plots and produce 17 cwt/a more yield. The higher average yield from the outside areas removed approximately 50 lb more N (17 cwt/acre x .33 lb N/cwt) leaving about 17 lb of N unaccounted for in the soil (67-50 = 17). Surprisingly the calculated value and the measure value for residual soil nitrate are very close.

Substor Potato Model Simulation Study

Considerable time was spent collecting and inputting weather data for each the 1996 sites into the SUBSTOR potato simulation model, version 2.0. A cursory study of the model indicates that it is very sensitive to water input and as a result does not estimate yields accurately. More time is needed to study and validate the model. The model appears to be giving good realistic information on drainage and runoff. If the yields can be properly estimated then we will be able to get realistic values on crop removal and the amount of N leached from out plots. We plan to continue to working on this model throughout the winter months so that we can give potato growers a more realistic estimate of their N losses to groundwater. Nine years of drainage and N leaching data have now been collected from the large lysimeters at the Montcalm Research Farm. This data will be very valuable in validating the SUBSTOR potato model and predicting N losses from growers fields.

CONCLUSIONS

Since this project was inaugurated in April 1995, we have made good progress toward achieving our objectives. With a combination of N stewardship plots, sap nitrate testing, and on-farm lysimeters, we have been able to demonstrate that N stewardship practices are (a) effective in maintaining potato yields and profitability; (b) reducing soil nitrate N residues at harvest, and (c) lowering nitrate N concentration of drainage water at a depth of 36 inches, compared to conventional N practices.

Furthermore, the weekly petiole sap nitrate testing program has gained acceptance as an excellent tactical approach to in-season N management of potatoes. The use of a chlorophyll meter for evaluating the N status of the potato crop appears promising. Once we have obtained a good calibration of the instrument with petiole nitrate content, it can be used in the field to quickly determine the N status of the crop.

Trough lysimeters do not appear to be suitable for evaluating nitrate N losses from potato fields. The use of soil solution access tubes (SSAT) is a practical way to follow nitrate movement in soils but inherent soil variability and preferential water flow are causing a great deal of variability in the values obtained. This variability will make it difficult to establish critical nitrate levels in the root zone for optimum plant growth.

In summary our data suggest that there is environmental justification to reducing the current N application rates on potatoes and that N stewardship practices can be utilized effectively.

Table 1. 1996 Nitrogen fertilizer application rates for nitrogen stewardship plots.

Site No	Treatment	----------------------- lb N per Acre -----------------------								
1&2	**Date applied**	**Preplant**	**5/8**	**6/13**	**6/19**	**6/21**	**6/28**	**7/1**	**7/10**	**Total**
Pike &	Red flag	21	29	--	1.5	76	0.7	69	0.7	198
Snowden	Yellow flag	21	29	85	1.5	18	0.7	69	0.7	225
	Outside	21	29	85	1.5	76	0.7	69	0.7	283
3	**Date applied**	**Preplant**	**5/7**	**6/11**	**6/15**					**Total**
Pike	Inside	--	47	51	120					218
	Outside	--	47	110	120					277
4	**Date applied**	**Preplant**	**5/7**	**6/1**	**6/15**					**Total**
Snowden	Inside	--	84	62	86					232
	Outside	--	84	62	130					276
5	**Date applied**	**Preplant**	**5/8**	**6/15**	**7/17**					**Total**
Russet Burbank	Inside	--	50	60	100					210
	Outside	--	50	90	100					240
6	**Date applied**	**Preplant**	**5/25**	**6/5**	**6/28**	**7/2**				**Total**
Snowden	Inside	--	55	45	105	0				205
	Outside	--	55	45	105	60				265
7	**Date applied**	**Preplant**	5/25	6/5	6/28	7/6				**Total**
Snowden	Inside	--	40	60	0	91				191
	Outside	--	40	60	76	91				267
8 (MRF)	**Date applied**	**Preplant**	**5/8**	**6/1**						**Total**
Snowden	Research	--	60	100						160
	Conventional	--	60	200						260

Table 2. **Tuber yield, size distribution, specific gravity and nitrogen economic returns for the nitrogen stewardship plots - 1996.**

Site No.	Variety	N Rate	US#1	Total	Percent of the Total US#1	B's	A's	OV	PO	Sp Gr	Gross Margin ($)*
1	Pike	198	443	459	96	4	91	5	--	1.092	$2878
		225	447	466	96	4	87	8	--	1.090	$2899
		283	456	472	97	4	83	13	--	1.096	$2945
2	Snowden	198	356	379	96	6	86	4	--	1.088	$2298
		225	391	409	94	4	90	7	--	1.083	$2537
		283	369	388	95	5	88	7	--	1.083	$2374
3	Pike	218	na	365	na	na	na	na	--	1.088	$2364
		277	na	403	na	na	na	na	--	1.081	$2596
4	Snowden	232	448	469	95	4	90	6	--	1.085	$2908
		276	464	487	95	5	87	9	--	1.085	$3001
5	Russet	210	441	508	81	4	74	8	15	1.081	$2864
	Burbank	240	438	502	87	5	73	15	7	1.080	$2838
6	Snowden	205	357	372	96	4	82	14	--	1.083	$2313
		265	387	406	85	5	81	15	--	1.083	$2498
7	Snowden	191	367	391	94	6	83	11	--	1.082	$2380
		267	422	449	94	6	77	17	--	1.079	$2726
8 MRF	Snowden	160	369	387	95	5	86	9	--	1.073	$2400
		260	317	327	97	3	82	15	--	1.072	$2038
Overall	**Low N**	202	397	416	93	4	85	8	--	1.084	$2550
Means	**High N**	269	407	429	94	5	82	13	--	1.082	$2627

* Gross margin = Gross returns - N fertilizer variable costs (based on $6.60/cwt for US#1 potatoes and $0.22/lb for N fertilizer).

Table 3. Preplant soil nitrate nitrogen for eight nitrogen stewardship plots. 1996,

	---------------- Sample Depth (inches) ------------------			
Site	**0 - 12"**	**12 - 24"**	**24 - 36"**	**Total**
	------------------ lb Nitrate Nitrogen per Acre ----------------------			
1	3.7	1.8	1.3	6.8
2	4.5	1.4	1.3	7.2
3	4.1	5.9	7.4	17.4
4	2.0	0.0	0.4	2.4
5	4.1	2.5	8.6	15.2
6	2.3	1.4	1.9	5.6
7	3.6	9.6	19.0	32.2
8	1.5	4.1	9.5	15.1
Mean	**3.2**	**3.3**	**6.2**	**12.7**

Table 4. Post harvest soil nitrate nitrogen for eight nitrogen stewardship plots. 1996

		--------------- Sample Depth (inches) --------------			
Site	**Location**	**0 - 12"**	**12 - 24"**	**24 - 36"**	**Total**
		----------------- lb of Nitrate Nitrogen per Acre ----------------			
1	Inside	6.8	8.3	9.5	24.6
	Outside	4.6	5.0	11.8	21.4
2	Inside	12.2	5.5	11.0	28.7
	Outside	12.4	14.9	25.7	53.0
3	Inside	28.5	6.3	7.3	42.1
	Outside	23.1	17.7	12.9	53.7
4	Inside	13.5	13.5	11.6	38.6
	Outside	14.9	24.6	19.1	58.6
5	Inside	6.7	3.3	6.3	16.3
	Outside	8.2	4.5	7.8	20.5
6	Inside	7.2	5.4	6.8	19.4
	Outside	6.9	12.0	18.9	37.8
7	Inside	8.9	11.7	16.8	37.4
	Outside	15.2	18.5	19.9	53.6
8	Research	29.7	26.4	-----	56.1
	Conventional	68.2	74.4	-----	142.6
Mean	**Inside**	**14.2**	**10.1**	**9.9**	**32.9**
	Outside	**19.2**	**21.5**	**16.6**	**55.2**

Fig 1. Petiole sap nitrate concentration in N stewardship plots.
Site 1 - Pike 1996

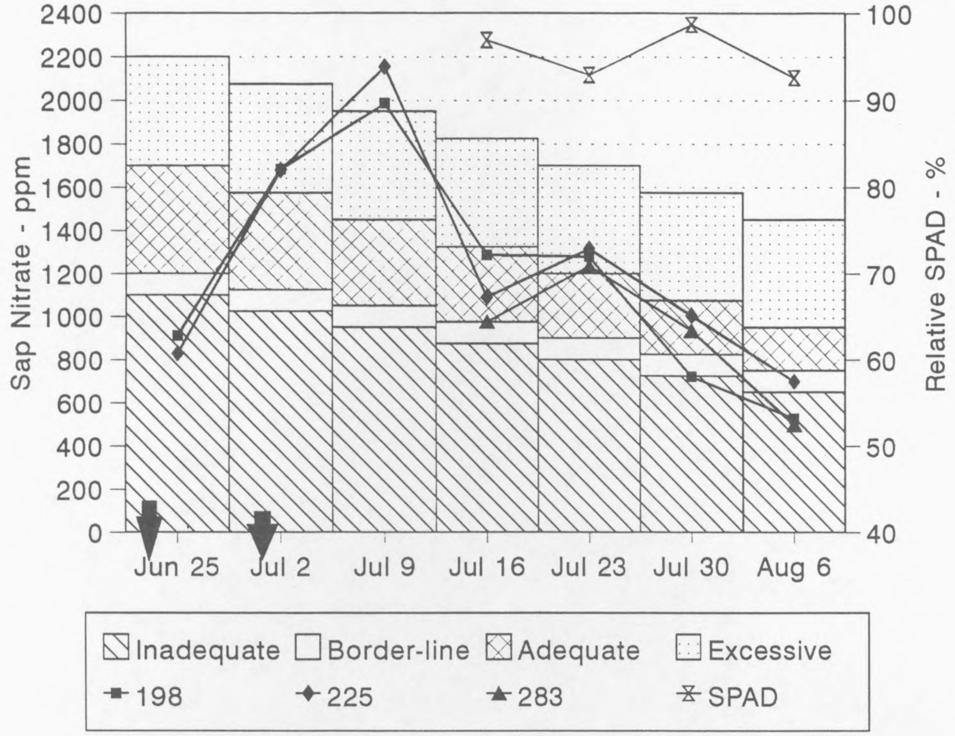


Fig 2. Petiole sap nitrate concentration in N stewardship plots.
Site 2 - Snowden 1996

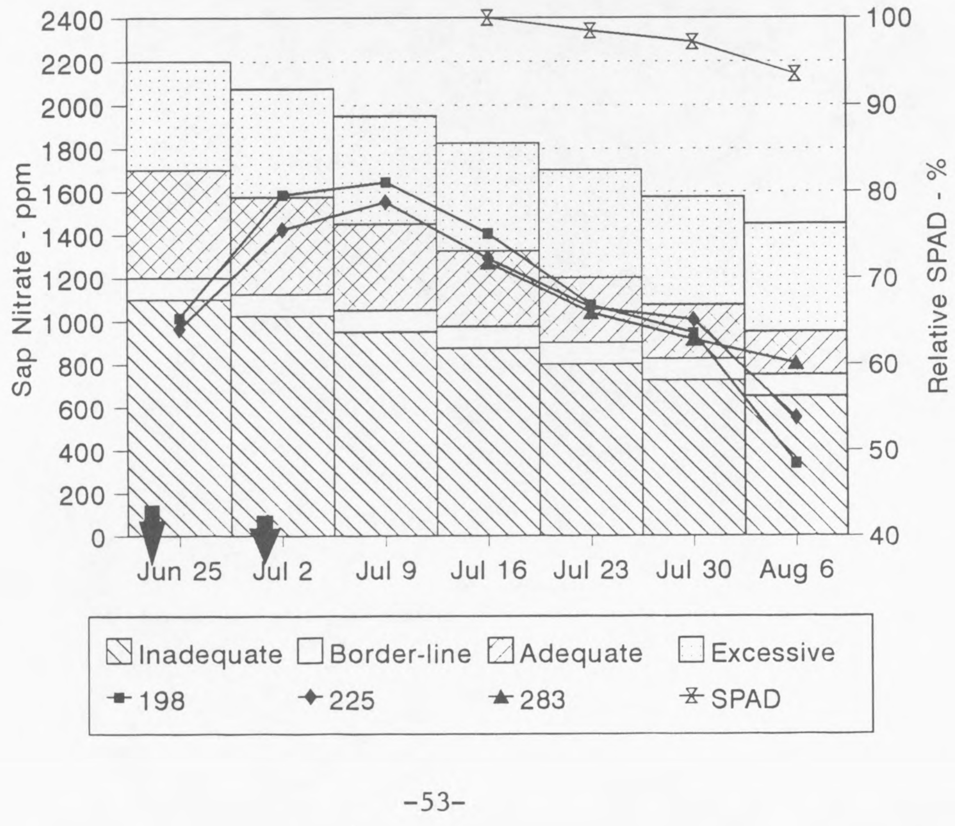


Fig 3. Petiole sap nitrate concentration in N stewardship plots.
Site 3 - Pike 1996

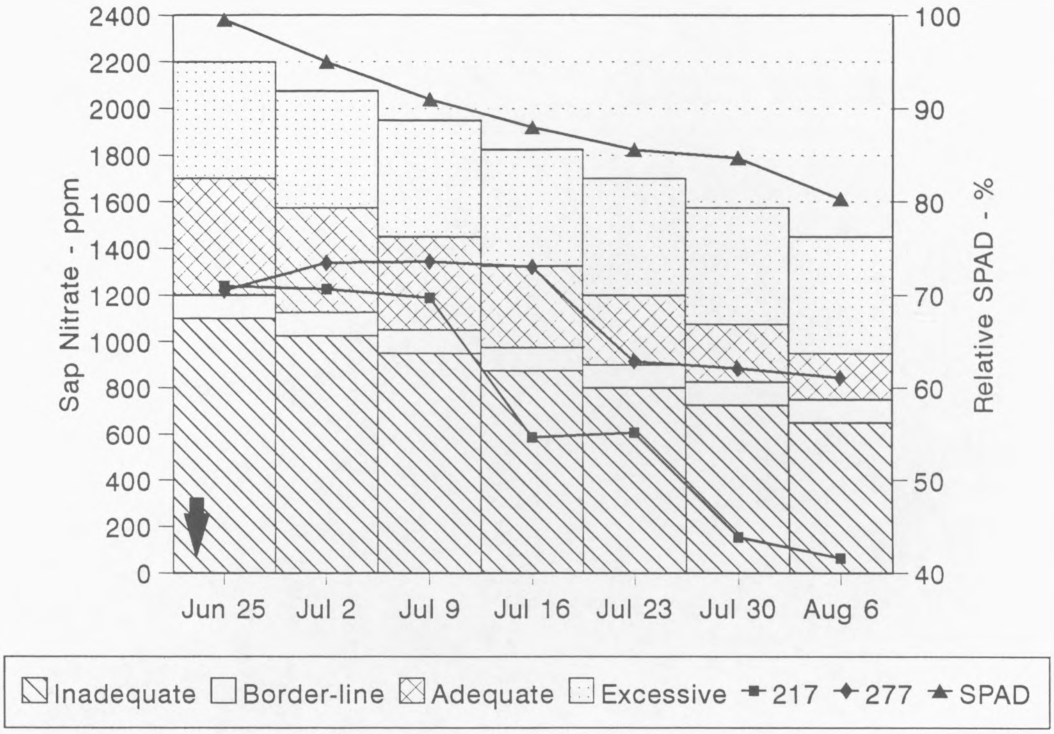


Fig 4. Petiole sap nitrate concentration in N stewardship plots.
Site 4 - Snowden 1996

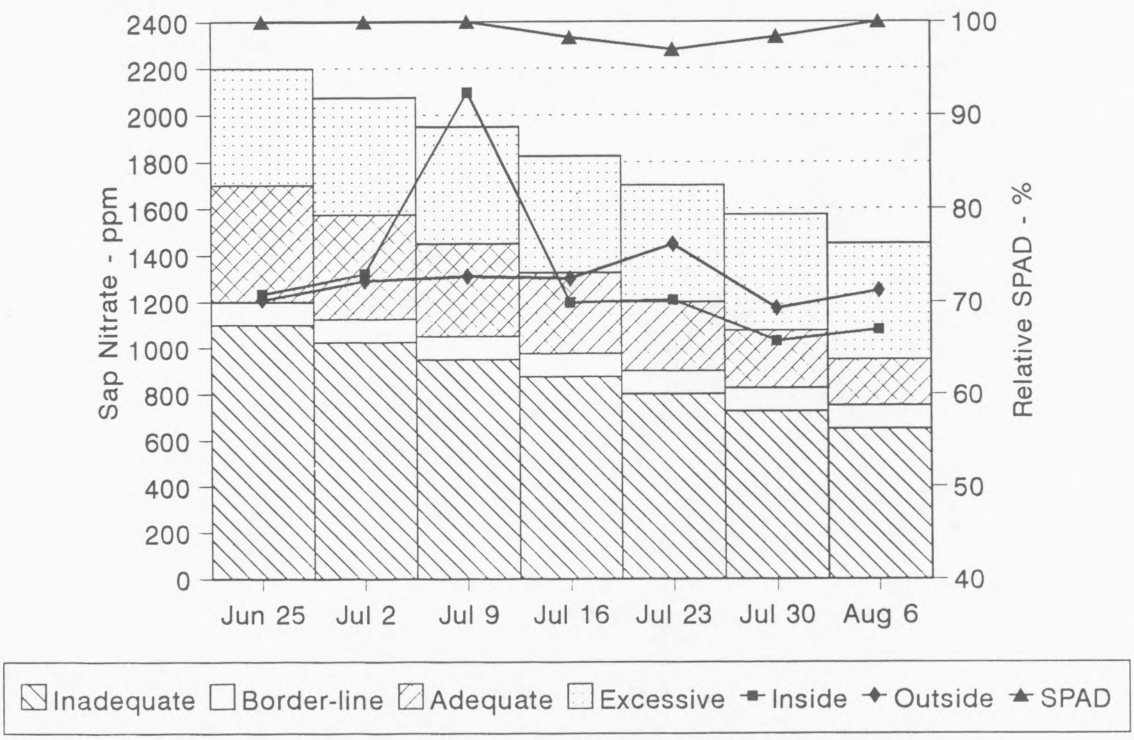


Fig 5. Petiole sap nitrate concentration in N stewardship plots.
Site 5 - Russet Burbanks 1996

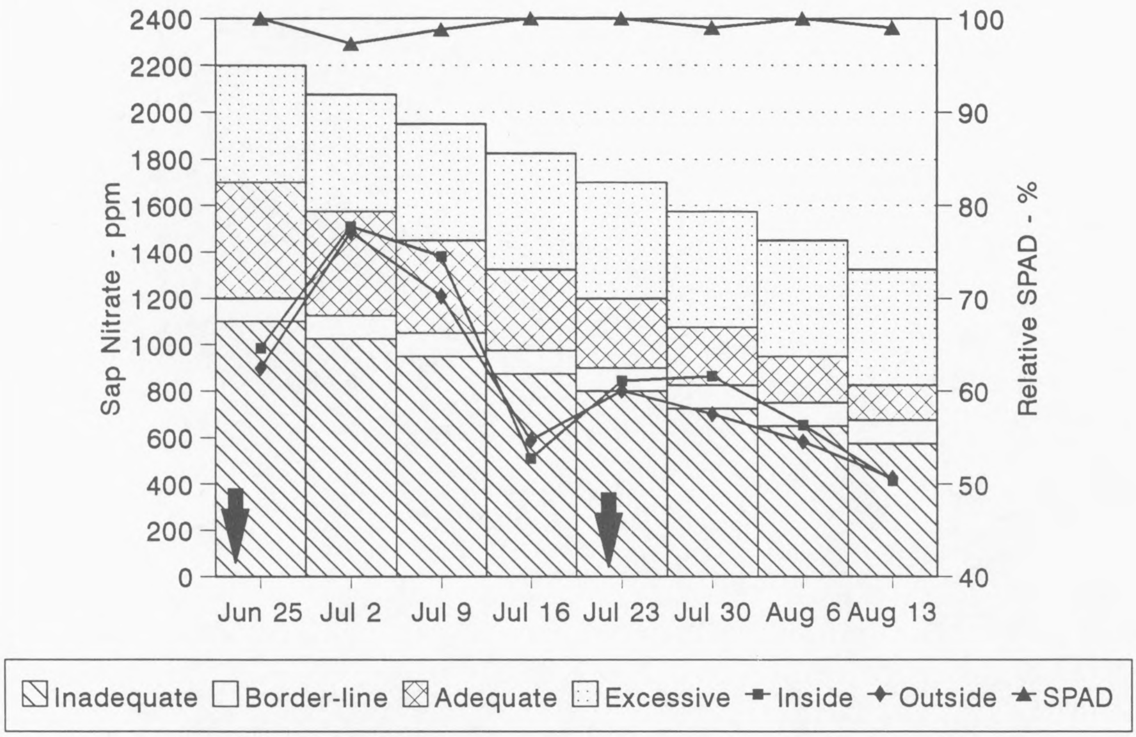


Fig 6. Petiole sap nitrate concentration in N stewardship plots.
Site 6 - Snowden 1996

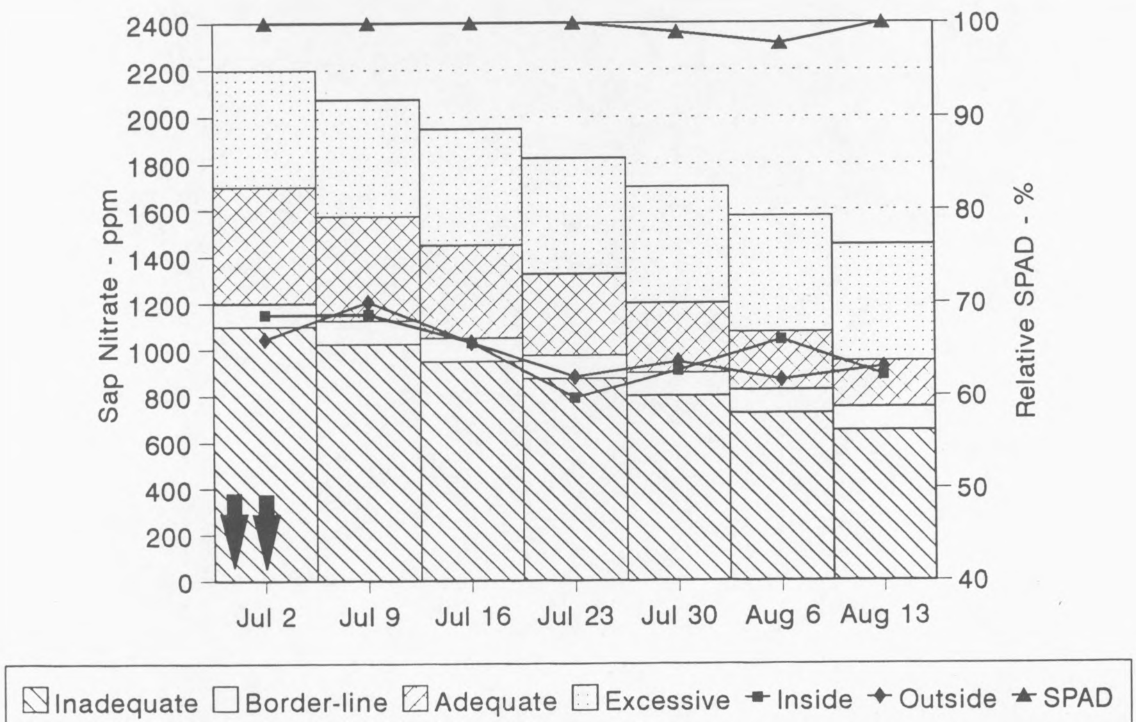


Fig 7. Petiole sap nitrate concentration in N stewardship plots.
Site 7 - Snowden 1996

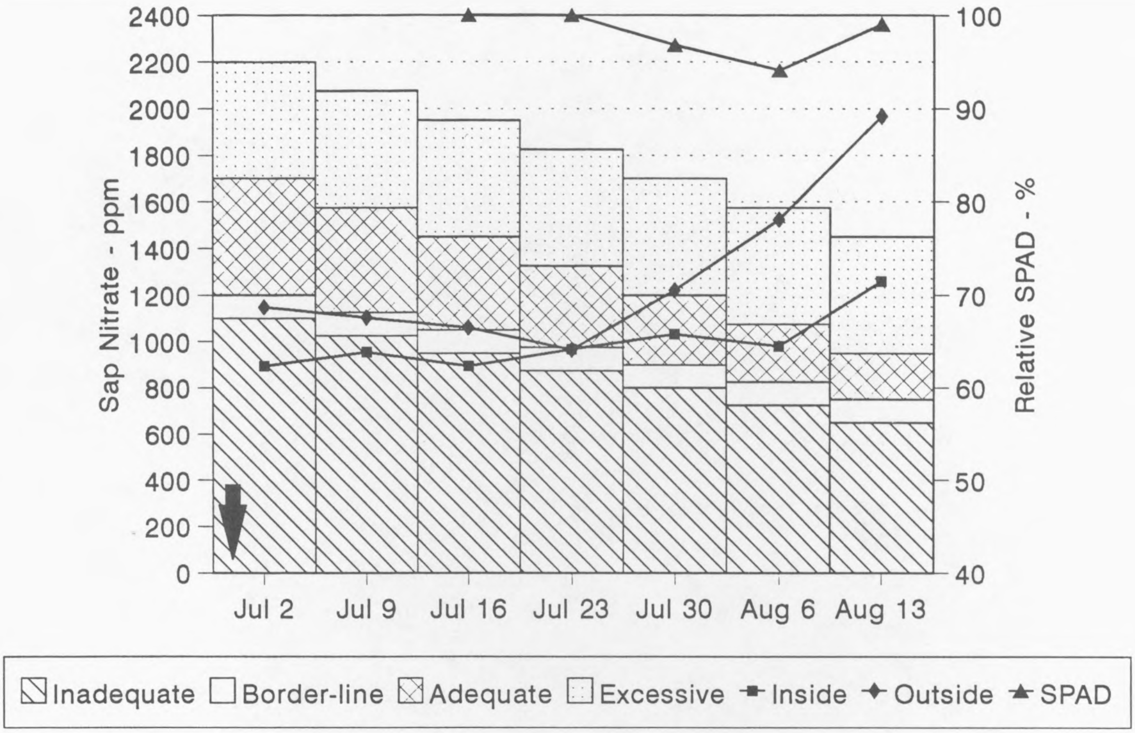


Fig 8. Petiole sap nitrate concentration in N stewardship plots.
Site 8 - Snowden 1996

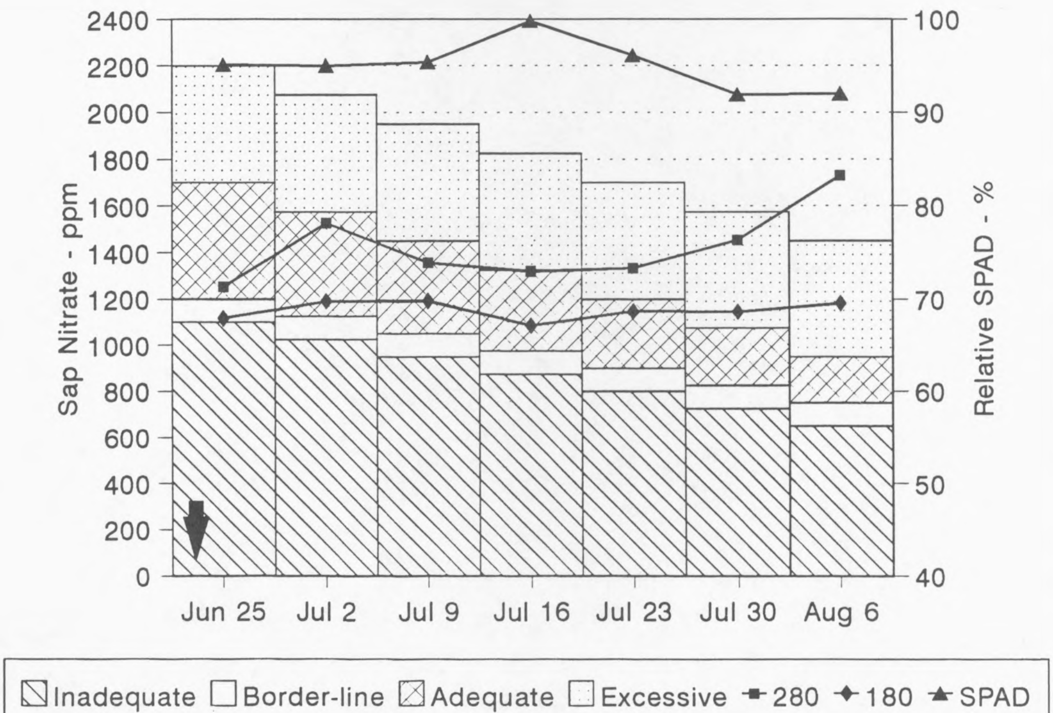


Fig. 9. Soil solution nitrate N at three depths measured by SSAT lysimeters

Eight Sites Combined - Inside - 1996

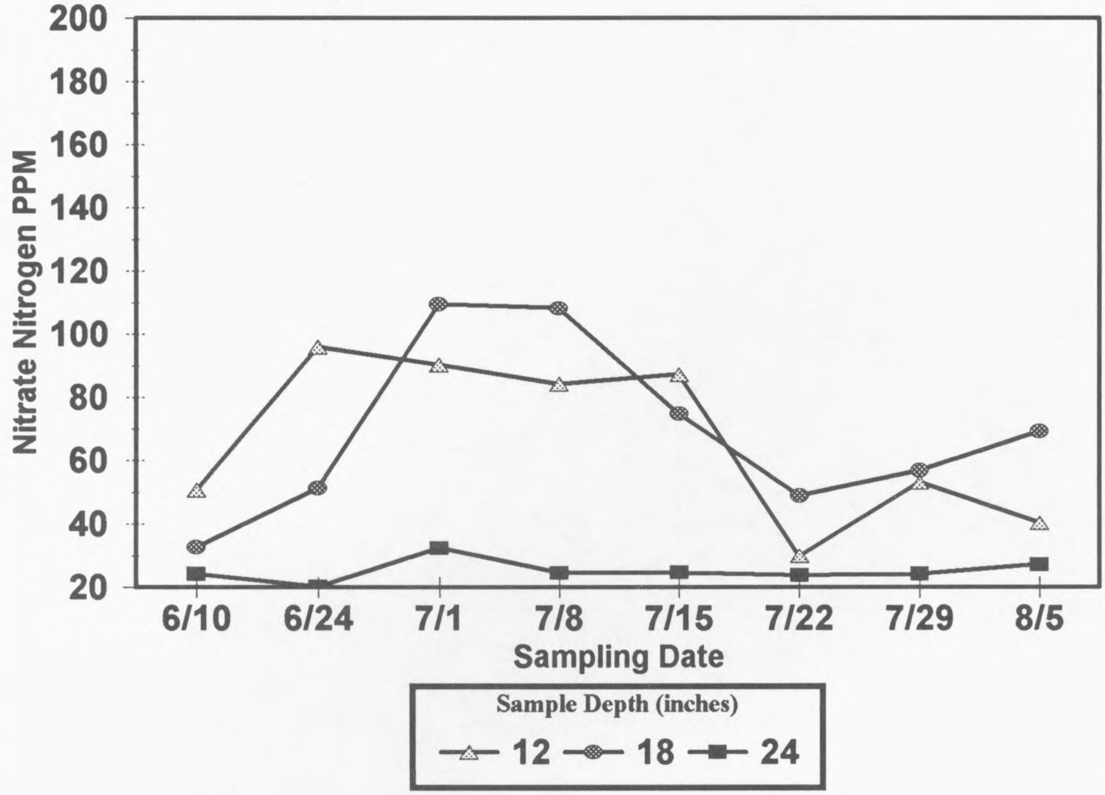


Fig. 10. Soil solution nitrate N at three depths measured by SSAT lysimeters

Eight Sites Combined - Outside - 1996

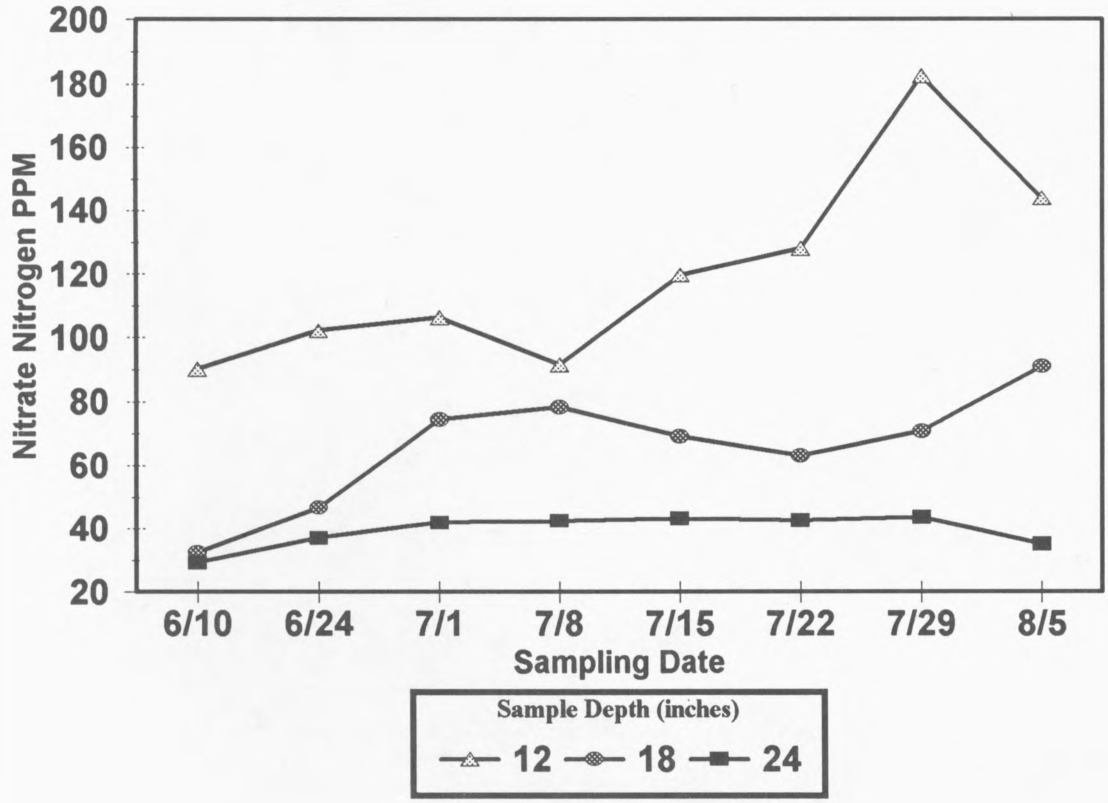


Fig. 11 Soil Solution Nitrate
SSAT Lysimeters - 36 " Depth

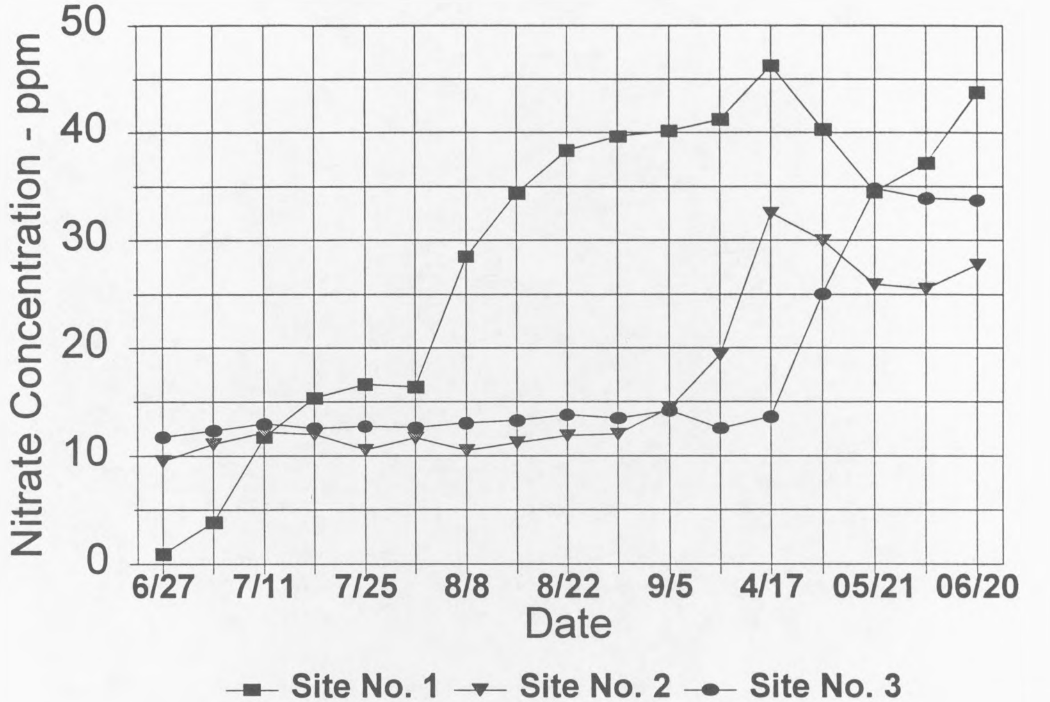
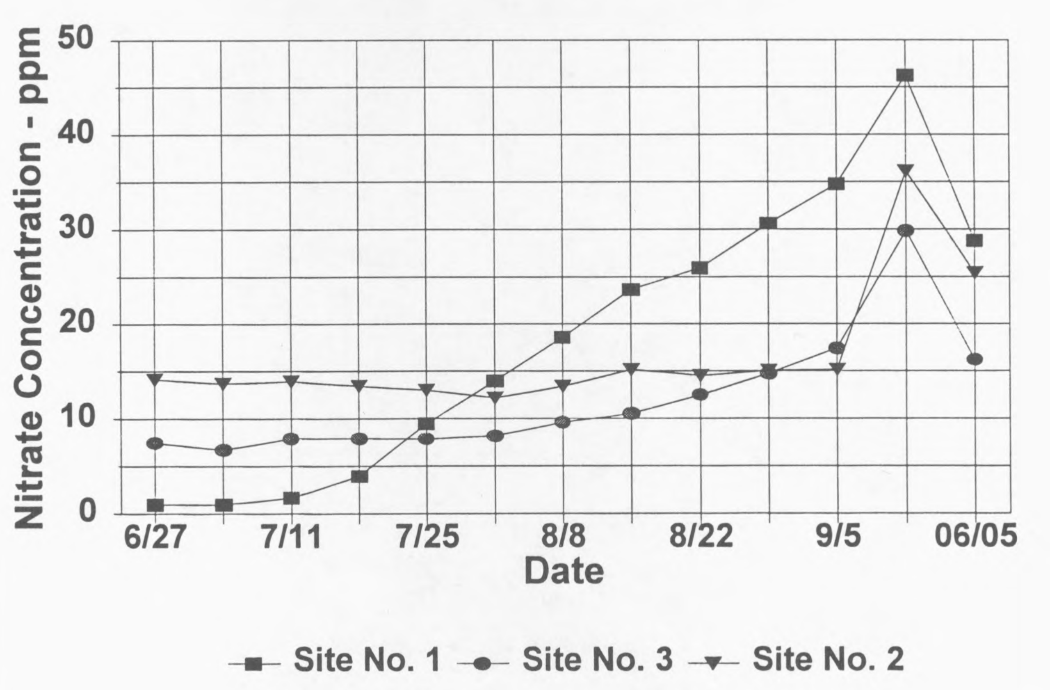


Fig. 12 Soil Solution Nitrate
Quartz Lysimeters - 36" depth



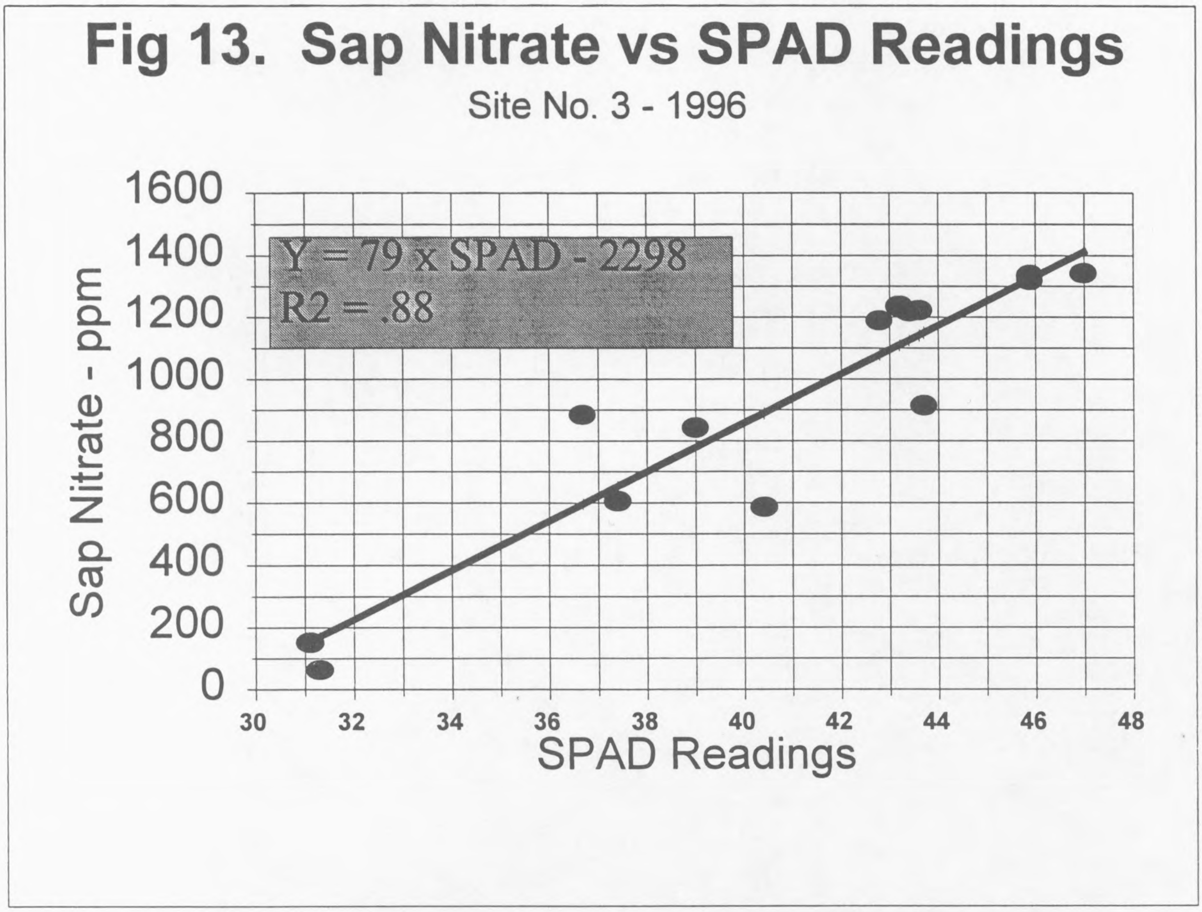


Fig 13. Sap Nitrate vs SPAD Readings
Site No. 3 - 1996
Y = 79 x SPAD - 2298
R2 = .88
Sap Nitrate - ppm
1600
1400
1200
1000
800
600
400
200
0
30
32
34
36
38
40
42
44
46
48
SPAD Readings

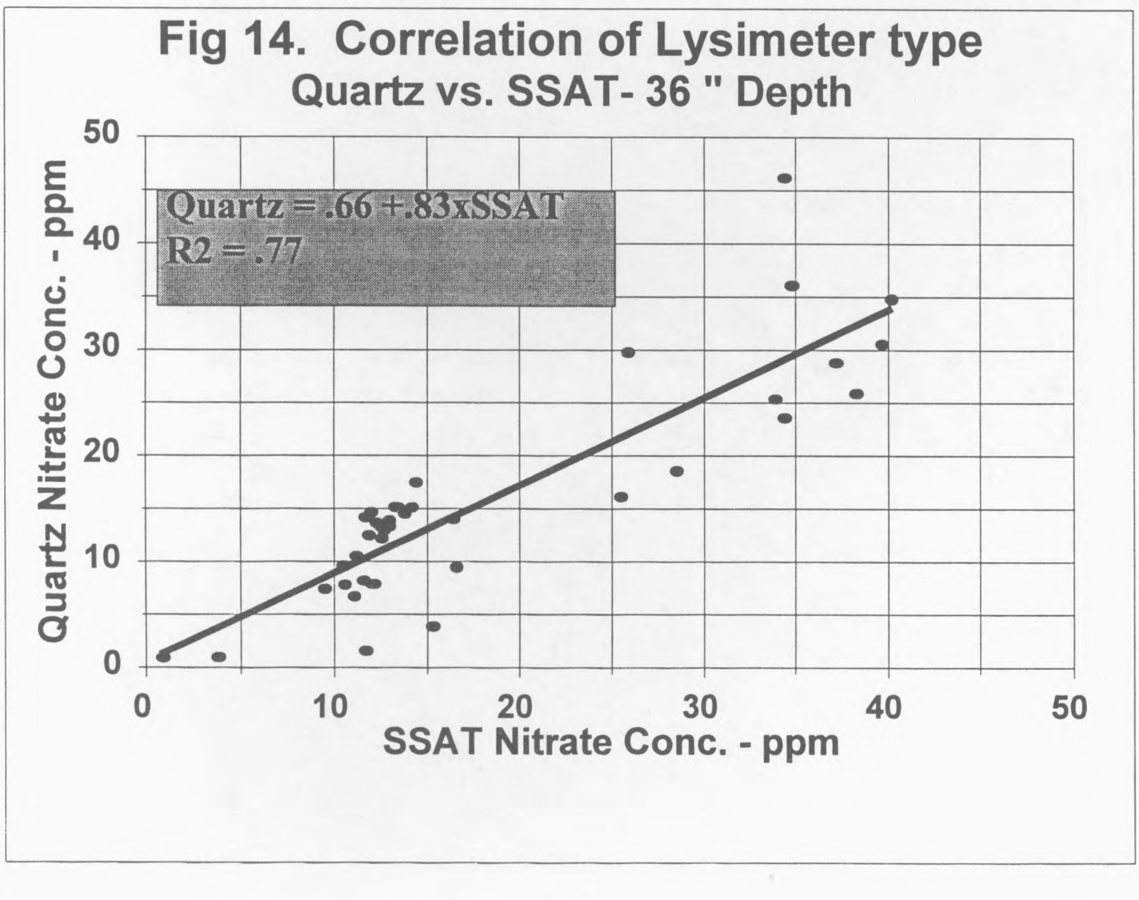


Fig 14. Correlation of Lysimeter type
Quartz vs. SSAT- 36 " Depth
Quartz = .66 +.83xSSAT
R2 = .77
Quartz Nitrate Conc. - ppm
50
40
30
20
10
0
0
10
20
30
40
50
SSAT Nitrate Conc. - ppm

Funding MPIC/Industry

1996 Potato Nematode Research

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The root-lesion nematode (*Pratylenchus penetrans*) is an important limiting factor in Michigan potato production. In addition, it is likely that the relatively recent introduction of carrots into some MI potato rotations may increase potato production risk to the root-lesion nematode, and also create an environment that will allow the northern root-knot nematode (*Meloidogyne hapla*) to become a limiting factor in MI potato production. Historically, the root-lesion nematode has been managed through the use of crop rotation, fumigant nematicides, non-fumigant nematicides and chemigants. It is highly probable, however, that nematicides will be less readily available in the future than in the past. The objective of the Michigan State University Potato Nematode Research Project is to provide new information about the best way to utilize existing nematode management strategies and tactics, and to discover ways to grow high quality and high yielding potato crops without the use of nematicides.

The 1996 Michigan State University Potato Nematode Research Project consisted of a non-fumigant nematicide trial, fumigant nematicide trial, evaluation of a bionematicide, a long-term (1991-2000) potato rotation study and a long-term (1994-2003) potato - carrot - nematicide investigation. In addition, one Master of Science Thesis investigating potato nematodes was completed in 1996. The following is a summary of the results of these research initiatives.

1996 Non-Fumigant Nematicide Trial

The 1996 non-fumigant nematicide trial consisted of seven treatments and a control, involving three nemticides (Mocap, Vydate and Temik). The highest tuber yield (420 cwt per acre) was obtained with Temik 15G applied at 3.0 lbs a.i. per acre in the fertilizer furrow at planting (Table 1). This nematicide also provided the best root-lesion nematode control (Table 2). Mocap 6EC at 6.0 lb a.i. per acre and Mocap 10G at 3.0 lb a.i. per acre did not increase tuber yields or reduce population densities of *P. penetrans*. as much as 9.0 lb a.i. per acre of Mocap 6EC. In-furrow application of Mocap 10G followed by a 14-day post-emergence application of Vydate 2L resulted in the second highest tuber yield response, and the second highest level of nematode population reduction.

1995 - 1996 Fumigant Nematicide Trial

The objective of the 1996 fumigant nematicide trial was to determine if two-years of control of *P. penetrans* and *M. hapla* could be obtained with a single application of Vapam at 50 gallons per acre before planting carrots in the spring of 1995. Application of Vapam resulted in tuber yields that were 123 cwt per acre greater than the control, and provided excellent two-season population reduction of *P. penetrans* (Table 3). By the end of 1996, however, population densities of *M. hapla* had increased significantly.

1996 Bionematicide Trial

ABG-9017 is a recently registered bionematicide derived from a killed fungus. Although it was possible to obtain increased tuber yields through use of this material, the data did not indicate that the response was due to control of the root-lesion nematode (Table 4).

Long-Term Nematode Management - Crop Rotation Project

The objective of the long-term (1991-2000) nematode management - crop rotation project is to develop ways to grow high quality potato crops in root-lesion nematode risk sites in the absence of synthetic nematicides. The research site consists of six different cropping systems divided among ten treatments, each replicated eight times (Table 5). In 1996, the decision was made to spend the last four years of the study on the most promising components identified during the first six years of the project. These include a two-year alfalfa standard, oats and red clover, oilseed radish, buckwheat and composting.

Until 1996, the highest tuber yields were always associated with the two-year alfalfa rotation with potato. This is indicated in the data analysis as a relative yield of 1.00 (Table 6). In 1996, however, over-yielding the standard was observed for the oilseed radish and buckwheat-compost rotations. Tuber yields associated with the sixth year of continuous potato production continued to remain significantly higher than relative yields from second, third or fourth year of continuous potato production. Tuber bulking took place much earlier in the buckwheat compost, oilseed radish, alfalfa and hairy vetch rotations than with continuous potato production. There were other very striking differences, including stolon length and the quality of young tubers. Final tuber yields ranged from 334 cwt per acre for the buckwheat-compost rotation to 219 cwt per acre for the continuous potato regime (Table 7).

Numerous striking and potentially very important preliminary conclusions can be drawn from the nematode population dynamics data (Table 8). The first is that the population density of *P. penetrans* stabilizes and remains low after six years of continuous potato production. The population density of *M. hapla*, however, increased, and may be a limiting factor in relation to tuber yield. Population densities of both nematodes are always much lower after the second year of alfalfa, compared to the densities following a single year of alfalfa. The use of oilseed radish as a green manure crop provides excellent nematode control. The greatest population reduction of both nematodes was associated with the buckwheat rotation. Preliminary conclusions related to composting will not be made until after the 1997 growing season.

Long-Term Carrot - Potato - Nematicide Project

The objective of the long-term (1994-2003) carrot-potato-nematicide trial is to determine the best way to minimize risk to the root-lesion and northern root-knot nematodes in carrot - potato production systems. The research site was established in 1994 and consists of six systems divided among nine treatments, each replicated six times (Table 9). 1996 potato tuber yields were highest following carrots grown in soil treated with Vapam in 1995, and lowest following carrots in non-treated soil (Table 10). The second highest tuber yield response was associated with the fallow/marigold-compost regime.

Carrot is an excellent host for both *P. penetrans and M. hapla* (Table 11). Population densities of both nematodes were significantly lower following two years of alfalfa or two years of hairy vetch, compared to those present after a single year of these crops. Oats resulted in a reduction in the population density of both species. Vapam applied in 1995 prior to a carrot crop resulted in low population densities of both *P. penetrans and M. hapla* in 1996, compared to the non-treated carrot-potato control. Application of Vydate did not provide multiple year nematode control.

Miscellaneous Potato Nematode Research

Rebecca Gore completed her Master of Science Dissertation entitled, "Relationship Between Selected Biological and Management Attributes of Michigan Potato Production Systems" (1996, Department of Entomology, 130 pp). The thesis includes a reasonably thorough analysis of existing literature related to the Potato Early-Die Disease and questions the theory of synergism related to *P. penetrans* and *Verticillum dahliae*. Likewise, synergism was also only demonstrated infrequently in Dr. Carl Chen's Ph.D. dissertation entitled, "Feature, Function and Nature of *Pratylenchus penetrans* and *V. dahliae* interactions associated with *Solanum tuberosum* (MSU Department of Entomology, 1995, 196 pp). A recent preliminary research report on photosynthesis and respiration rates associated with potato plants raised in the presence and absence of these organisms indicates the likelihood of two separate diseases, rather than synergism associated with a disease complex.

Table 1. Impact of 1996 non-fumigant nematicide applications on potato tuber yields.

Treatment	Tuber yields (cwt per acre)			
	a	b	j	Total
Control	256	11	64a	**331a**
Mocap 6EC[1]	281	11	47a	338ab
Mocap 6EC[2]	307	9	65a	380ab
Mocap 10G[3]	270	10	59a	338ab
Temik 15G[4]	**288**	**8**	**124b**	**420b**
Vydate 2L[5]	306	12	71a	390ab
Vydate 2L[6]	298	13	64a	375ab
Mocap 10G Vydate 2L[7]	302	9	90ab	401ab
ANOVA	0.241	0.043	0.003	0.025

[1] 6.0 lb a.i. per acre, broadcast, pre-plant incorporated..
[2] 9.0 lb a.i. per acre, broadcast, Pre-plant incorporated..
[3] 3.0 lb a.i. per acre, in-furrow, at planting.
[4] 3.0 lb a.i. per acre, in-furrow, at planting.
[5] 2.0 lb a.i. per acre, in-furrow, at planting.
[6] 2.0 lb a.i. per acre, 14 days post emergence, directed foliar spray.
[7] 3.0 lb a.i. per acre, in-furrow, at planting plus 2.0 lb a.i. per acre, 14 days pest emergence, directed foliar spray.1996

Table 2. Impact of 1996 non-fumigant nematicide applications on mid-season (July 16) population densities of root-lesion nematodes (*Pratylenchus penetrans*).

Treatment	No./100 cm^3 soil	No./1.0g root tissue	Total
Control	**20b**	**65b**	**85c**
Mocap 6EC[1]	9ab	25ab	34ab
Mocap 6EC[2]	9ab	41ab	50bc
Mocap 10G[3]	8ab	27ab	35ab
Temik 15G[4]	**6a**	**1a**	**7a**
Vydate 2L[5]	5a	9a	14ab
Vydate 2L[6]	8ab	13a	21ab
Mocap 10G Vydate 2L[7]	8ab	1a	9ab
ANOV	0.017	0.001	0.001

[1] 6.0 lb a.i. per acre, broadcast, pre-plant incorporated..
[2] 9.0 lb a.i. per acre, broadcast, Pre-plant incorporated..
[3] 3.0 lb a.i. per acre, in-furrow, at planting.
[4] 3.0 lb a.i. per acre, in-furrow, at planting.
[5] 2.0 lb a.i. per acre, in-furrow, at planting.
[6] 2.0 lb a.i. per acre, 14 days post emergence, directed foliar spray.
[7] 3.0 lb a.i. per acre, in-furrow, at planting plus 2.0 lb a.i. per acre, 14 days pest emergence, directed foliar spray.

Table 3. Impact of Vapam, applied as a soil fumigant in the spring of 1995 prior to a crop of carrots, on 1996 potato tuber yields and final 1996 population densities of the root-lesion nematode (*Pratylenchus penetrans*) and northern root-knot nematode (*Meloidogyne hapla*).

Treatment	Tuber yield (Cwt/acre)	*P. penetrans* No./100 cm^3 soil plus 1.0 g root tissue	*M. hapla* No./100cm^3 soil plus 1.0 g root tissue
Control	**233**	25	**604**
Vapam (50 gal/acre)	**356**	3	**287**

Table 4. Influence of ABG-9017 bionematicide on 1996 tuber yields and mid-season population densities of the root-lesion nematode (*Pratylenchus penetrans*).

Treatment	Tuber yield (cwt/acre)				*P. penetrans* per 100 cm^3 plus 1.0 gram root tissue
	a	b	j	Total	
25 lb/acre	312	13	36	351	30.8
50 lb/acre	319	11	46	**375**	36.7
100 lb/acre	315	11	36	326	27.7
Control	279	11	36	**325**	17.7
ANOVA	0.075	0.485	0.386	0.085	0.569

Table 5. Ten year nematode management - crop rotation research project design (1991-2000).

System 1. Continuous potato (Treatment 1).
System 2. Continuous potato - compost (Treatment 3).
System 3. Potato - two-year alfalfa rotation (Treatments 4, 6, & 7).
System 4. Potato - [oats - red clover] rotation (Treatment 5).
System 5 Potato - oilseed radish rotation (Treatments 8 & 9).
System 6 Potato - Buckwheat rotation (Treatments 2 & 10).

Ten Year Crop Rotation Study, Potato Research Farm, 1991-2000.

Treatment	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1	Potato Rye	Potato Rye	Potato Rye	Potato Rye	Potato	Potato	Potato	Potato	Potato	Potato
2	Alfalfa	Potato Rye	Potato Rye	Potato Rye	Hairy vetch	Potato	Buck-wheat	Potato		
3	Oats	Alfalfa	Potato	Potato	Tri-mix	Oats	Potato compost	Potato compost	Potato compost	Potato compost
4	Oats	Alfalfa	Alfalfa	Potato Rye	Alfalfa	Alfalfa	Potato	Alfalfa	Alfalfa	Potato
5	Oats	Potato Rye	Potato Rye	Potato Rye	Annual rye grass	Oats/ R. Clover	Potato	Oats/ R. Clover	Potato	
6	Oats	Soybean Rye	Alfalfa	Alfalfa	Potato 30T/A compost	Alfalfa	Alfalfa	Potato	Alfalfa	Alfalfa
7	Oats	Soybean Rye	LRK Rye	Alfalfa	Alfalfa	Potato	Alfalfa	Alfalfa	Potato	Alfalfa
8	Oats	Soybean Rye	LRK Rye	Green pea	OS radish	Potato	OS radish	Potato	OS radish	Potato
9	Oats	Soybean Rye	LRK Rye	Green pea	Potato	OS radish Sudax 30T/A Compost	Potato	OS radish	Potato	
10	Oats	Soybean Rye	LRK Rye	Green pea	Buck wheat 30T/A compost	Potato	Buck wheat	Potato		

Table 6. Relative tuber yields associated with the ten-year nematode-management-crop rotation research project.

Rotation	Cropping Sequences[1]						Relative Yields, U.S. No. 1[2]					
	1991	1992	1993	1994	1995	1996	1991	1992	1993	1994	1995	1996
1	P	P	P	P	P	P	1.00	0.69	0.34	0.29	0.79	0.87
2	A	P	P	P	Hv	P	---	1.00	0.54	0.34	---	0.95
3	A	A	P	P	Tm	O	---	---	1.00	0.57	---	---
4	O	A	A	P	A	A	---	---	---	1.00	---	---
5	O	P	P	P	Rg	O/Rc	---	0.97	0.53	0.32	---	---
6	O	S	A	A	P+Co	A+Co	---	---	--	---	1.00	---
7	O	S	Kb	A	A	P	---	---	---	---	---	1.00
8	O	S	Kb	Pe	Osr	P	---	---	---	---	---	1.14
9	O	S	Kb	Pe	P	Osr	---	---	---	---	0.93	---
10	O	S	Kb	Pe	Bw+Co	P	---	---	---	---	---	1.35

[1]Cropping Symbols; P = Potato; A = Alfalfa; Hv = Hairy Vetch; Tm = Nematode Mix (annual ryegrass, hairy vetch, marigold); O = Oats; R = Annual Ryegrass; S = Soybean; Kb = Light Red Kidney Bean; Pe = Green Pea, Osr = Oil Seed Radish, Co = Compost..

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

Table 7. 1996 potato tuber yields associated with the ten-year nematode management - crop rotation research project.

Rotation	Tuber yield (cwt/acre)			
	a	b	j	Total
Continuous potato	173	35	11	**219**
Hairy vetch	177	47	14	238
Two-year alfalfa standard	194	42	16	252
Oilseed radish	223	47	18	288
Buckwheat - compost	250	57	27	**334**

Table 8. Influence of rotation crops on the population dynamics of the root-lesion nematode (*Pratylenchus penetrans*) and northern root-knot nematode (*Meloidogyne hpala*) associated with the ten-year nematode-management crop rotation project.

Rotation (1995-1996)	Nematodes per 100 cm^3 soil plus 1.0 g root tissue					
	P. penetrans			*M. hapla*		
	P_{f95}	P_{i96}	P_{f96}	P_{f95}	P_{i96}	P_{f96}
Continuous potato	**10**	**11**	**3a**	**557**	**341**	**1288**
Hairy vetch - potato	359	19	25ab	3221	532	**2840**
Tri-mix - oats	119	24	21a	90	181	100
Alfalfa - alfalfa	196	10	**114ab**	2463	118	**861**
Ryegrass -oats/red clover	295	31	**1144c**	20	19	**2470**
Potato/compost - alfalfa	7	9	**319b**	161	51	**3095**
Two-year alfalfa - potato	28	9	26ab	451	126	**1457**
Oilseed radish - potato	75	6	60ab	4	17	829
Potato/compost - oilseed radish	**15**	13	**34ab**	183	129	83
Buckwheat/compost - potato	**9**	2	40ab	**2**	2	318
ANOVA			0.009			0.047

Table 9. Cropping system design for the long-term (1993-2003) mineral soil carrot - potato - nematicide rotation research project.

System No. 1 Continuous carrots (Treatment 1).
System No. 2 Continuous carrots plus compost (Treatment No. 9).
System No. 3. Potato/Vapam - carrots (Treatments 2 & 6).
System No. 4. Carrot/Vapam - potato (Treatments 4 & 6).
System No. 5 Oats - carrots - potato (Treatments 3 & 8)
System No. 6 Hairy vetch - carrots (Treatment 7).

Tmt	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
1	Green peas	Potato	Carrots	Carrots	Carrots	Carrots	Carrots	Carrots	Carrots	Carrots
2	Green peas	Carrots	Potato	Carrots	Potato (Vapam)	Carrots	Potato (Vapam)	Carrots -	Potato (Vapam)	Carrots
3	Green peas	Carrots	Oats	Potato	Carrots	Oats	Potato	Carrots	Oats	Potato
4	Green peas	Carrots (Vapam)	Potato	Carrots (Vapam)	Potato	Carrots (Vapam)	Potato	Carrots (Vapam)	Potato	Carrots (Vapam)
5	Green peas	Potato (Vapam)	Carrots (Vapam)	Potato	Carrots (Vapam)	Potato	Carrots (Vapam)	Potato	Carrots (Vapam)	Potato
6	Green peas	Carrots (Vydate)	Potato	Potato (Vapam)	Carrots	Potato (Vapam)	Carrots	Potato (Vapam)	Carrots	Potato (Vapam)
7	Hairy Vetch	Hairy Vetch	Potato	Hairy Vetch	Hairy Vetch	Carrots	Hairy Vetch	Hairy Vetch	Carrots	Hairy Vetch
8	Alfalfa	Alfalfa	Potato	Oats	Carrots	Potato	Oats	Carrots	Potato	Oats
9	Fallow	Marigold Compost	Potato	Carrots Compost	Carrots Compost	Carrots Compost	Carrots Compost	Carrots Compost	Carrots Compost	Carrots Compost

Table 10. 1996 potato tuber yields associated with the long-term carrot - potato - nematicide rotation research project.

Crop rotation (nematicide) (1994 - 1996)	Tuber yields (cwt/acre)				
	a	b	j	Knobs	Total
Green peas/carrots/potato	182	11	18	21	**233**
Green peas/carrots(Vapam)/potato	220	12	84	40	**356**
Green peas/carrots(Vydate)/potato	199	12	30	18	259
Hairy vetch/hairy vetch/potato	193	12	34	20	258
Alfalfa/alfalfa/potato	218	14	59	18	277
Fallow/marigold-compost/potato	232	8	60	18	**292**
ANOVA	0.402	0.059	0.014	0.021	0.042

Table 11. Influence of long-term carrot - potato - nematicide rotations on the population dynamics of the root-lesion nematode (*Pratylenchus penetrans*) and northern root-knot nematode (*Meloidogyne hapla*).

Rotation (nematicides)	Nematodes per 100 cm^3 soil plus 1.0 gram root tissue					
	M. hapla			*P. penetrans*		
	P_{f95}	P_{i96}	P_{f96}	P_{f95}	P_{i96}	P_{f96}
Green peas/potato/carrots	448	265	**2877**	86	62	**483**
Green peas/carrots/potato	**2238**	46	604	252	41	46
Green peas/carrots/oats	2238	83	**27**	252	61	**25**
Green peas/carrots (Vapam)/potato	**0**	**62**	287	252	**9**	**0**
Green peas/potato (Vapam)/carrots(Vapam)	**0**	**35**	779	86	**0**	**3**
Green peas/carrots **(Vydate)**/potato	2238	101	705	252	39	51
Hairy vetch/hairy vetch/ potato	115	278	699	6	69	41
Alfalfa/alfalfa/potato	**227**	**268**	**720**	**8**	**17**	**14**
Fallow/marigold -compost/potato	**24**	**19**	**175**	**14**	**32**	**87**

Funding Fed. Grant/MPIC/Industry

Colorado Potato Beetle Management 1996 Research Report

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Summary:

Colorado potato beetle management research in 1996 included several projects: 1) monitoring populations for resistance to Admire (imidacloprid), and development of a resistance test for Admire, 2)the use of *bt* transgenic plants and other non-insecticide controls as a barrier and to reduce resistance development, 3) evaluation of crop rotation systems for Colorado potato beetle control, and 4) insecticide efficacy tests for Colorado potato beetle control.

Monitoring Colorado potato beetle for resistance to Admire (imidacloprid)

Imidacloprid (Admire or Provado, Bayer Corp.) was registered for control of Colorado potato beetle on potatoes in 1995. Because of its effectiveness and the high level of resistance to other insecticides, over 80% of the potato acreage in Michigan was treated with Admire in 1995 and nearly 90% was treated in 1996. Such high use levels raise serious concerns about resistance development. The objectives or our research were to survey fields for Colorado potato beetle adults and larvae surviving Admire treatment and test for possible development of resistance. Characterization of resistance may help to design effective resistance management strategies.

Resistance to Imidacloprid - "Montcalm-R" strain. Twenty Colorado potato beetle adults were found on June 24 in an Admire-treated commercial potato field in Montcalm Co. Michigan. An additional 15 adults were collected from this site on June 27. These were not found on the border row or on row ends (as might be expected if they were new arrivals), but were two to five rows in from a field border, on plants scattered the length of the field. They were fed field-collected foliage for 1 day, then fed foliage from greenhouse potato plants (cv. 'Snowden') treated with Admire at normal field rate at planting. On both types of foliage, many of the beetles went through periods of intoxication (laying on their back, legs extended to the side, uncontrolled movement of legs, inability to walk, inability to right themselves) followed by periods of normal activity and feeding. Approximately 2/3 (21 out of 35) survived and were placed on untreated greenhouse potato foliage after 5 days on foliage from Admire-treated plants. Eggs were collected and larvae were reared on untreated potato foliage. Adults from these larvae were used in topical insecticide trials described below.

Thirty-five large larvae (4th instars) and 14 adults were collected from the same field on July 19 and returned to the lab for testing. Levels of imidacloprid in the foliage in the field had declined by this time (80% of susceptible Colorado potato beetle adults survived on it). However, these larvae must have been present for 2-3 weeks to be in the final instar. Fed on foliage from greenhouse plants treated with Admire, approximately 95% of the field-collected larvae and 85% of the adults survived.

Beetles that survived a dose of ≥ 0.1 µg in topical assays were kept for rearing and future testing. A single female from the Montcalm-R strain survived a dose of 1.0 µg (over 10 times the average lethal dose) in preliminary tests. A male that survived a dose of 0.1 μg was put in the cage with the female and eggs are being collected for future rearing and testing as a separate strain.

"Admire-selected" strain. Adults were collected from commercial potatoes treated with Admire in 1995 and fed on Admire-treated greenhouse plants for 2-3 days. Survivors were reared on greenhouse plants. Adults of the next generation were tested for resistance to imidacloprid in topical assays (no significant resistance was found in early generations) and survivors of the higher insecticide doses were used for the next generation.

"Montcalm" strain. These were susceptible beetles collected from a field research site at the M.S.U. Montcalm Potato Research Farm, Entrican, Michigan. They were summer adults, collected 1 week before the experiment, and fed on potato foliage to ensure that they were at least 1 week old, healthy and well fed. This strain is maintained in laboratory culture for use as a susceptible strain.

"BT Susceptible" strain. This strain has been reared in the laboratory for 7 years (approximately 30 generations), fed on greenhouse-grown potato foliage, without exposure to insecticides. Only 30 adults were available for treatment at the time of these experiments, too few to do statistical calculations, but mortality data is included for comparison with results for the other strains.

Topical insecticide tests. To determine levels of resistance, adults of each strain (1 to 2 weeks old) were treated on the underside of the abdomen with technical grade imidacloprid in acetone (1 μl/beetle, 0.001 to 1.0 μg imidacloprid/μl of solution). They were placed in petri dishes in groups of 5-10 per dish and kept at 25°C, photoperiod 16h light: 8 h dark. Intoxication was evaluated at 24, 48, 72 and 96 hours after treatment. Affected beetles were unable to walk their own body length forward and unable to hold onto and climb a pencil or pen. They often lay on their backs, with legs out to the sides and twitching. If upright, they showed abnormal leg movement and were unable to walk forward. Beetles still intoxicated after 72 hours were considered dead. Log dose-probit mortality regressions were used to analyze the data and calculate the dose required to kill 50% of beetles of each strain (LD50).

Mortality was higher for beetles from the susceptible and Montcalm strains than for beetles from the Montcalm-R and Admire-selected strains (Figure 1). Differences were largest at doses of 0.05 μg and 0.1 μg/beetle. Mortality at 0.05 μg/beetle was over 40% in the two susceptible strains and 10% or less in the Montcalm-R and Admire-selected strains (Figure 2). Beetles collected from the Collins Rd. Entomology Farm at M.S.U. where Admire had never been used were also tested at this dose and mortality was 69%. In the Admire-selected strain, 100% mortality did not occur until a dose of 1.0 μg/beetle and, as mentioned above, a single Montcalm-R female survived a dose of 1.0 μg/beetle in preliminary tests.

LD50 values (dose required for 50% mortality) for the Montcalm-R and Admire-selected strains were significantly higher than the LD50 value for beetles collected from the Montcalm Research Farm (Figure 3). The Montcalm-R and Admire-selected strains were 3.8 and 4.5 fold resistant, respectively, to imidacloprid compared with the field collected strain. Although resistance to insecticides is commonly 10 to 50 fold or greater, this low level of resistance is apparently sufficient to allow survival in the field, at least under some conditions.

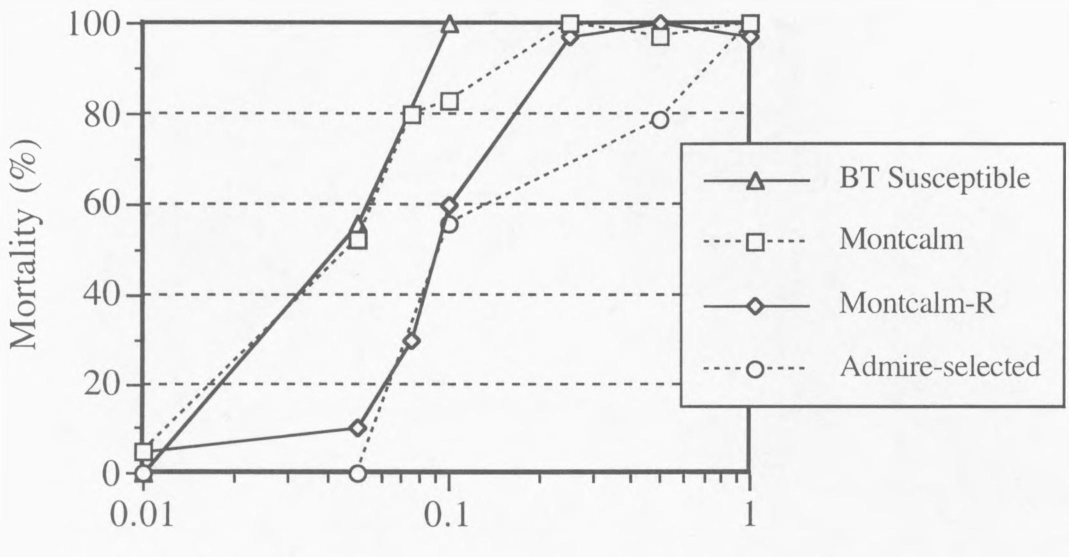

Figure 1. Mortality after 72 hours of Colorado potato beetles treated topically with a range of doses of imidacloprid. Mortality was defined as an ability to walk forward one body length. Other symptoms included beetles on their backs, legs rigid out to the side and twitching.

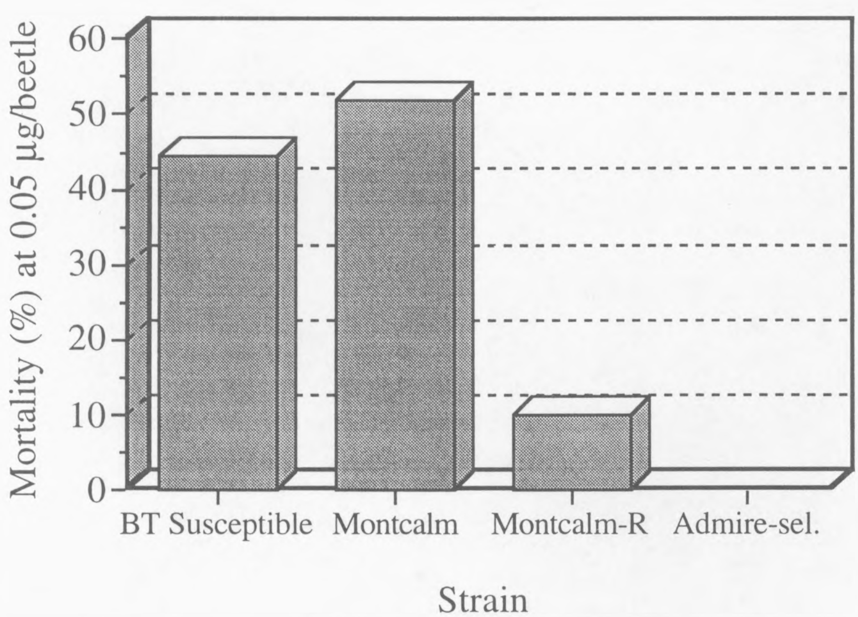

Figure 2. Mortality after 72 hours of Colorado potato beetles treated topically with 0.05 µg imidacloprid per beetle.

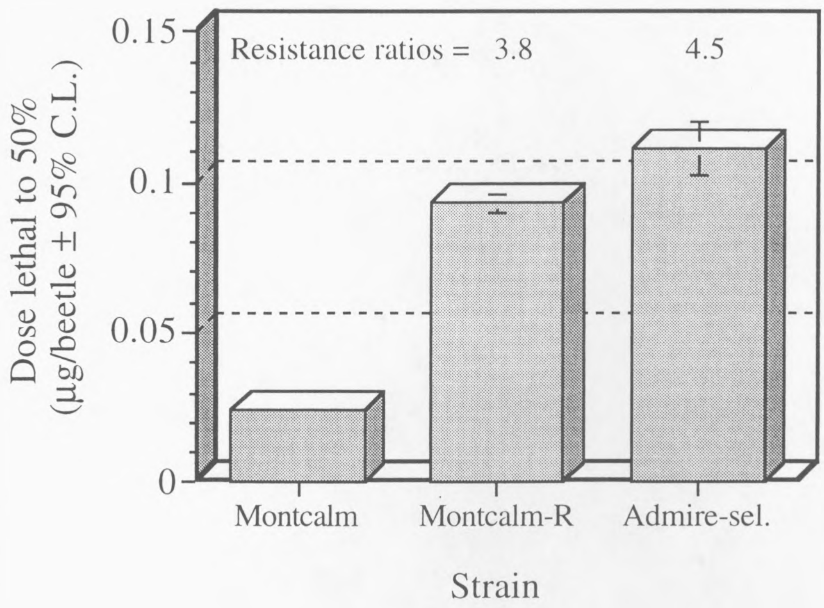

Figure 3. LD50 values (dose lethal to 50% of the beetles) 72 hours after treatment with imidacloprid. Resistance ratios are the ratio of the LD50 for the resistant strain (Montcalm-R or Admire-selected) divided by the LD50 for the susceptible (Montcalm) strain.

Recovery from toxic effects. Some beetles in the Montcalm-R and Admire-selected strains recovered from topical treatment after 2 days of intoxication and after expressing symptoms that led to death in other beetles (Figure 4). One group of Montcalm-R beetles treated with 0.25 µg/beetle was kept for observation beyond the 4-day experiment, because they were still moving, although they were unable to walk and expressed other symptoms of intoxication. One day after treatment, all ten beetles were scored as intoxicated. After the first 4 days, one had recovered and the other nine were scored as intoxicated. At the end of 8 days, six out of ten of the beetles had recovered completely from toxic effects and were feeding, mating and laying eggs. This level of recovery indicates that future resistance assays need to be run for a longer time than 72 - 96 hours normal for topical treatment studies. The LD50 values calculated after 72 hours, above, would likely be higher if more time was allowed for recovery of the intoxicated beetles.

The recovery after exposure to imidacloprid observed in the topical assay is similar to the recovery exhibited by the field collected Montcalm-R strain beetles fed on foliage from Admire-treated plants and may indicate that detoxification is occurring. Recovery following non-lethal intoxication could allow beetles to survive in the field until Admire levels in the plants decline to non-toxic levels.

Leaf dip assay. In a leaf-dip assay, beetles 2 to 4 weeks old were fed potato foliage dipped in a range of concentrations of Admire 2E. Foliage was allowed to dry for 1 hour and then fed to beetles for 24 hours. Uneaten foliage was removed after 24 hours and new foliage provided every 1 to 2 days. Number of beetles affected were assessed daily for 7 days. A portion of the beetles were followed to day 10. The LC50 value after 7 days was significantly higher for the Admire-selected strain than for either of the other strains (Figure 6); the resistance ratio for the Admire-selected strain was 4.5 compared to the UP strain. As in the previous study, significant recovery from intoxication occurred at low concentrations of Admire, up to 10 days after treatment (Figure 7).

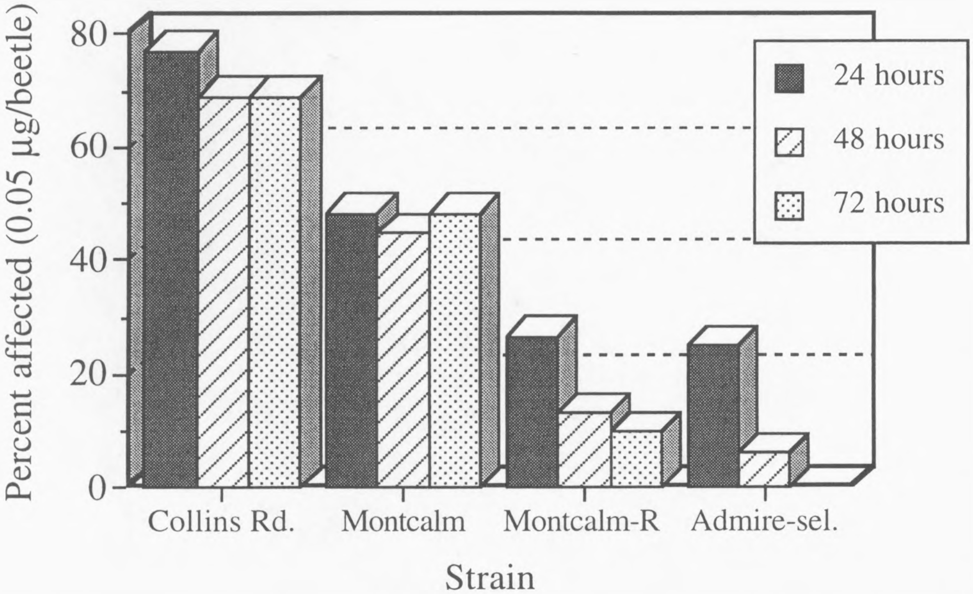

Figure 4. Percent of beetles affected 24, 48 and 72 hours after topical application of 0.05 µg imidacloprid per beetle.

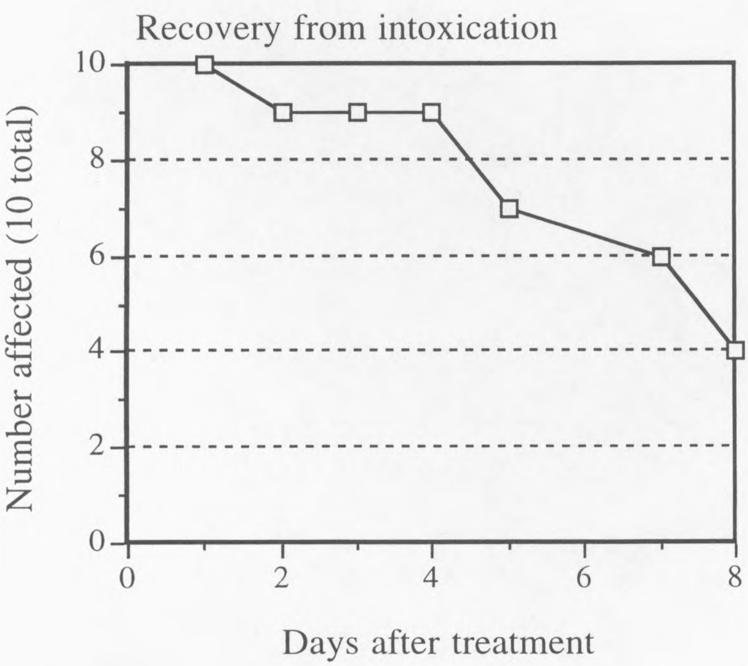

Figure 5. Recovery from intoxication of Montcalm-R strain beetles 1 to 8 days after treatment topically with 0.25 µg imidacloprid per beetle. By 7 days after treatment beetles had either recovered or were dead (no movement, darkened color, abdomen sunken and dry).

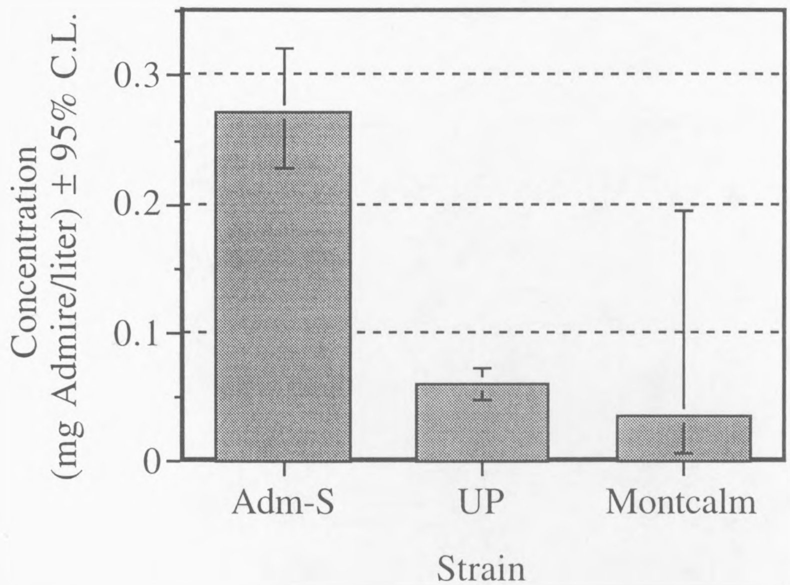

Figure 6. Concentrations lethal or affecting 50% of beetles (LC50 values) after 7 days for Admire-Selected resistant strain (n=89) and two susceptible strains in a leaf dip assay (n=123 for UP and 60 for Montcalm strains).

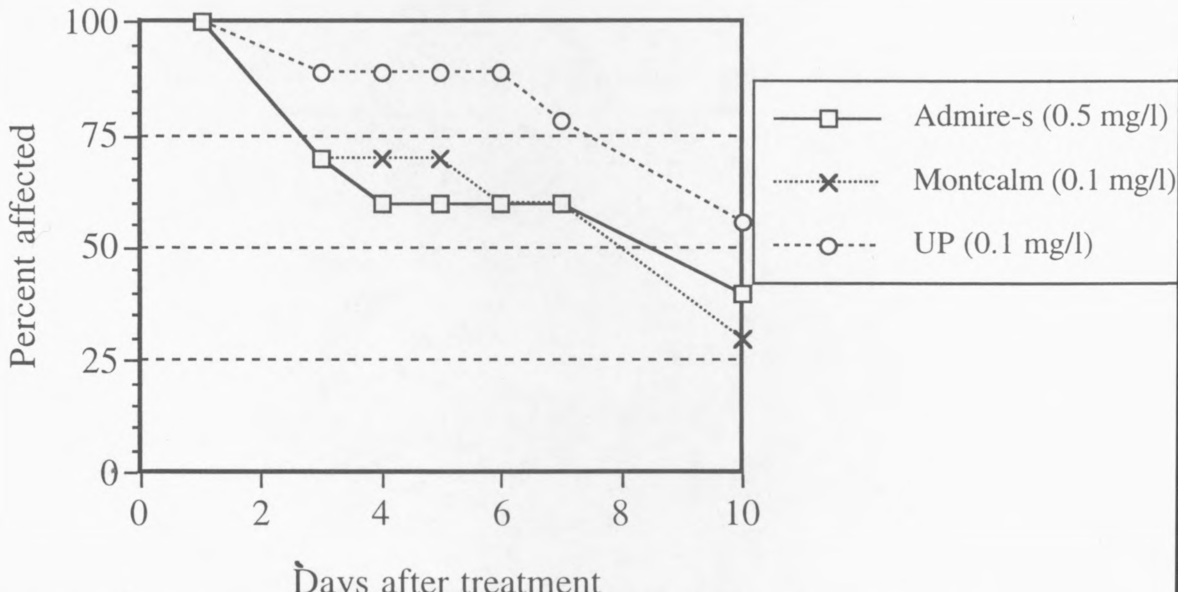

Figure 7. Recovery after feeding with Admire-treated foliage, 1 to 10 days after feeding.

These resistance levels are relatively low, but they are similar to resistance levels to Temik in a Monroe Co. Michigan potato beetle population in 1984 (4.4 fold). This level of resistance seems to be enough to allow beetles to recover from intoxication from feeding on foliage from Admire-treated plants (and may be higher if time for full recovery is allowed). Behavioral resistance may also add to the beetle's ability to survive Admire treatment. For example, if the feeding rate was slower than normal, beetles would eat less imidacloprid before beginning to experience effects and might not consume a toxic dose, before getting sick and stopping feeding. Late emergence from overwintering would also contribute to survival on potatoes treated at planting with Admire. A low level of resistance, as reported here, could be especially important combined with late emergence of Colorado potato beetle from overwintering or during a season with early potato planting but late potato beetle emergence.

Further studies of the effects of imidacloprid ingestion on beetles from the three strains, long-term recovery studies and studies of the interaction between resistance and feeding behavior and of the effects of non-lethal doses of imidacloprid on mating and egg laying are planned. Continued study of these resistant strains will be necessary to determine the speed at which resistance increases, the inheritance of resistance and potential resistance mechanism(s).

Management implications. Management strategies were widely discussed when imidacloprid was first introduced. Research results from these two resistant strains may help determine optimal management strategies. While it is not good news that resistance is appearing in only the second year of imidacloprid use, resistance levels are low and research at this time may help manage the build-up of resistance. Differences between populations in survival of first instars fed artificial diet were recently reported, although no field survival was indicated (Olsen et al. 1996).

Alternation of insecticides as a resistance management strategy assumes that resistance decreases in the absence of exposure to the insecticide. Unfortunately, resistance to insecticides in Colorado potato beetle is often very stable. For example, Michigan beetles are still resistant to DDT, although it has not been used since 1968. In some cases, resistance may be unstable at first, but become stable with continued use of the insecticide. Research results on the stability of imidacloprid resistance will be important.

High doses as a resistance management strategy assumes that resistance is inherited as a recessive gene and beetles carrying only one copy of the gene will not survive a high insecticide dose. Unfortunately, many insecticide resistance factors in Colorado potato beetle involve dominant genes and even very high doses are unable to kill beetles carrying one or two copies of the resistance gene (Bishop and Grafius 1996, Ioannidis 1990, Ioannidis et al. 1992). Also, imidacloprid in the potato plant from Admire treatment at planting starts as a high dose early in the season and then degrades to a low dose. Again, results from these resistant strains will help determine if a high dose strategy will be useful.

There are advantages and disadvantages to the use of Admire at planting versus Provado (imidacloprid registered for foliar application). Admire at planting always will degrade into a low dose at some time. A foliar spray of Provado will also degrade into a low dose, but will last only a few days. Using Admire only on late planted potatoes would increase the likelihood that late-emerging beetles would find high levels of Admire in the plants. In early-planted fields, Provado foliar sprays could be used instead of Admire; two or three foliar applications of Provado, at times of peak populations, would reduce the time beetles are exposed to low levels of the insecticide. Use of Provado instead of Admire would also reduce the proportion of the population that was contacted; some beetles in every field would remain susceptible to Admire/Provado.

Combining Admire treatment with another insecticide such as Agri-Mek (abamectin, Merck) might result in little or no survival of Admire-resistant beetles. However, a few beetles with resistance to both insecticides might survive - the worst possible outcome.

At this time, the most conservative strategy would be to avoid using Admire or Provado in 1997 at or near locations where it was used in 1996. Changing mortality agents to another insecticide and non-chemical mortality such as crop rotation and propane flaming would reduce the numbers of imidacloprid-resistant beetles surviving (although not reduce the proportion of imidacloprid-resistant beetles in the population). Preliminary research results will likely be available before next spring to help with management decisions.

Demonstrating the use of *Bacillus thuringiensis* transgenic potatoes and other non-chemical controls for management of resistance to Admire (imidacloprid) in the Colorado potato beetle.

The objectives of this study were to demonstrate that *Bt* transgenic potatoes could be used, alone or in combination with other control methods to reduce selection pressure from imidacloprid (Admire), thereby delaying the development of resistance to imidacloprid by the Colorado potato beetle.

Genetically-engineered Russet Burbank potatoes (NewLeaf®, NatureMark) were planted at three commercial sites in Montcalm County, MI in the spring of 1996. NewLeaf potatoes were planted on the edge of rotated potato fields, adjacent to fields that were in potatoes in 1995. Cool, wet weather in the spring delayed planting, and prevented us from establishing plots until late June. Heavy rains in mid-June also caused flooding; as a result one of the three sites was dropped from the study.

Up to three different plots, each 150 ft long and consisting of different treatments, were set up along the field edge at each site. The "Bt" treatment consisted of several rows of NewLeaf potatoes planted along the border of the potato field. The rest of the field was planted to non-transformed Russet Burbanks, to which "Admire" had been applied at planting. The "Trench" plot was similar, consisting of several rows of NewLeaf potatoes, followed by non-transformed Russets. Next to the first NewLeaf row, and parallel with the plot, a 150 ft long black plastic-lined trench (ca 6 in wide and 6 in deep) was constructed. Beetles migrating from overwintering sites in the 1995 potato field first encountered the plastic-lined trench, then the NewLeaf potatoes. At the "Schmeid Rd." site only, copper fungicide (Kocide DF @ 2 LB/A) was applied to the first three rows of non-transformed potatoes. The third treatment ("Admire", at the Schmeid Rd. site only) consisted of a field of non-transformed Russet Burbanks, to which Admire had been applied at planting.

At the "Schmeid Rd." site all three treatments were used. The field was bordered on the east by between 28 and 40 rows of NewLeaf potatoes. Demonstration plots were set up on the south end of the field, with a 40 rows NewLeaf border. The "Bt" and the "Trench" plots were adjacent and were separated from a corn field on the east by a farm road. The "Admire" plot was south of the NewLeaf field and was bordered on the east by a bean field, with no separating farm road.

At the "Cemetery" site, 40 Acres of NewLeaf potatoes were planted along the north field edge. The rest of the field consisted of Admire-treated Russet Burbanks. The potato field was bordered on the north by a hedge row, across from which was a field that was in potatoes in 1995. The "Bt" and the "Trench" treatments were set up at the "Cemetery" site. However, no Kocide was applied.

Colorado potato beetles were collected from locations throughout Montcalm County, MI. They were transported to the lab, and were marked with paint pens (DecoColor ®, Uchida of America, Corp.) before being released. The color and pattern of the markings indicated the date, site and plot in which they were released. Beetles were released across from the potato field and half-way between the length of the plot (ca 75 ft from each end). Release sites were on the other side of the farm road for the "Schmeid Rd." site, the "Bt" and the "Trench" plots. In the "Admire" treatment at the "Schmeid Rd. site" beetles were released directly next to the first row of potatoes. At the "Cemetery" site, Colorado potato beetles were released on the edge of the hedge row across from the plots.

Kocide DF (2 LB/A, 30 GPA) was sprayed on rows 41, 42 and 43 of the "Trench" plot at the "Schmeid Rd." site with a hand-held CO_2 sprayer on 26 Jun and 30 Jul, 1996 (1 day before beetles were released). Beetles were released at the release sites on 27 Jun. and 30 Jul 1996. Several hours after release, dead beetles at the release site were counted and removed. Potatoes were sampled 1, 3 and 7 (second release only) after release.

For the first release, 15 ft of every other row in the first 40 rows of potatoes was searched in each plot for marked beetles. Very few of the marked beetles were found in the potatoes on the first and the third day after release (Table 1). The majority of marked beetles found were in the first row of potatoes (46 out of 56 [82.1%]). Fifty-one beetles were found in the first five rows, and all beetles were found in the first 20 rows of potatoes. There was no discernible difference in beetle distribution between treatments (probably due to the low numbers of marked beetles recaptured). A number of marked beetles were found in the trench, but this did not affect the numbers found in the plots, for this release

Table 1. Number of marked Colorado potato beetles released and recaptured in different plots.

Release 1 (27 Jun 1996)

Site	**Cemetery**		**Schmeid Rd.**		
Plot	Bt	Trench	Bt	Trench	Admire
No. Beetles Released	313	309	316	313	385

1 Day After Release (28 Jun 1996)

Site	**Cemetery**		**Schmeid Rd.**		
Plot	Bt	Trench	Bt	Trench	Admire
In Plot	8 2.6%	2 0.6%	5 1.6%	16 (5.1%)	15 (3.9%)
In Trench	12	0	0	16	0

3 Days After Release (1 Jul 1996)

Site	**Cemetery**		**Schmeid Rd.**		
Plot	Bt	Trench	Bt	Trench	Admire
In Plot	0	1	2	1	6
In Trench	0	6	0	1	0

The method of searching for marked beetles was modified for the second release. At the "Cemetery" site, 3 different people each sampled 30 ft of row (90 ft of potato row total) in each plot. On 31 Jul (1 day after release), each person sampled rows 1,2,3,5,10,15 and 40. On 2 Aug (3 days after release), and on 6 Aug (7 days after release), each person sampled rows 1,2,3,4,5,7,10,20,40 and 43.

At the "Schmeid Rd." site, 4 different people each sampled 20 ft of row (80 ft total) in each plot. On 31 Jul (1 day after release), each person sampled rows 1,2,5,10,15 and 40 from the "Bt" and the "Trench" plot . We were unable to complete sampling of the "Admire" plot on this day because aerial pesticide application of the field began before we were through. On 2 Aug (3 days after release) and 6 Aug (7 days after release), each person sampled rows 1-5, 7,10,20,40 and 43.

Table 2. Number of marked Colorado potato beetles released and recaptured in different plots.

Release 2 (30 Jul 1996)

Site	**Cemetery**		**Schmeid Rd.**		
Plot	Bt	Trench	Bt	Trench	Admire
No. Beetles Released	518	420	555	578	400

Recaptured 1 Day After Release (31 Jul 1996)

Site	**Cemetery**		**Schmeid Rd.**		
Plot	Bt	Trench	Bt	Trench	Admire
In Plot	62 12.0%	5 1.2%	72 13.0%	11 1.9%	Not sampled
In Trench	65 12.5%	94 22.4%	0 0.0%	37 6.4%	Not sampled
In Other Plots*	3 0.6%	5 1.2%	0 0.0%	17 2.9%	Not sampled

Recaptured 3 Days After Release (2 Aug 1996)

Site	**Cemetery**		**Schmeid Rd.**		
Plot	Bt	Trench	Bt	Trench	Admire
In Plot	23 4.4%	5 1.2%	73 13.2%	5 0.9%	95 23.8%
In Trench	4 0.8%	12 2.9%	2 0.4%	2 0.4%	0 0.0%
In Other Plots*	5 1.0%	9 2.1%	1 0.2%	18 3.1%	0 0.0%

Recaptured 7 Days After Release (6 Aug 1996)

Site	Cemetery		Schmeid Rd.		
Plot	Bt	Trench	Bt	Trench	Admire
In Plot	3	1	2	1	14
In Trench	5	3	2	0	0
In Other Plots*	0	1	0	1	0

* Beetles released into "Trench" plots were found in potatoes in the "Bt" plots and beetles released into "Bt" plots were found in the "Trench" plots. No beetles that were released into the "Bt" or "Trench" plot were found in the "Admire" plot.

More marked beetles were found in the potatoes in the "Bt" plot than the "Trench" plot at both sites, 1, 3, and 7 days after release (Table 2). This difference was probably due to the trench, in which many of the marked beetles were found. In general the trench captured more beetles that had been actually released into the "Trench" plot, but it also captured a good number of marked beetles that had been released in the adjacent "Bt" plot (at least 75 ft from the trench). This may indicate that there is a good deal of beetle movement along the edges of potato fields. This is further supported by the finding that more beetles that were released into the "Trench plot" were found in the "Bt" plot than vice versa. Beetles may walk along the edge of the trench. A longer trench would minimize this problem.

Table 3. Distribution of marked Colorado potato beetles recaptured in potatoes after second release (30 Jul 1996)

Recaptured 1 Days After Release (31 Jul 1996)

Site	Cemetery		Schmeid Rd.		
Plot	Bt	Trench	Bt	Trench	Admire
Row No.	**No Beetles**	**Found**			
1	51	4	64	11	Not
2	7	1	8	0	Sampled
3	2	0	0	0	
4	0	0	0	0	
5	1	0	0	0	
>5	1 (row 40)	0	0	0	

Recaptured 3 Days After Release (2 Aug 1996)

Site	Cemetery		Schmeid Rd.		
Plot	Bt	Trench	Bt	Trench	Admire
Row No.	**No Beetles**	**Found**			
1	16	1	47	4	89
2	2	0	6	0	4
3	1	2	5	1	1
4	2	2	3	0	1
5	1	0	5	0	0
>5	1 (Row 7)	0	7 (4 in row 7) (3 in rw 10)	0	0

The highest proportion of marked beetles recaptured in the potatoes were in the "Admire" plot. This may have been a result of the beetles being released closer to the "Admire" plot than to the other two plots.

The distribution of beetles in the potatoes may have been affected by treatment (Table 3). Although the majority of marked beetles found were on the first few potato rows, beetles were more widely distributed through the "Bt" plot than through the "Trench" and "Admire" plots.

Crop rotation systems for controlling Colorado potato beetle

During 1996 we conducted the second and final year of a study investigating the effects of crop rotation on Colorado potato beetle control. In both 1995 and 1996, large plots were set up at the same location on the Montcalm Potato Research Farm, Entrican, MI and the Collins Road Entomology Research Facility, E. Lansing MI. Plots were 50 ft x 100 ft at Montcalm and 50 ft x 140 ft at Collins Road. Plots were divided into subplots (50 X 50 ft at Montcalm and 50 x70 ft at Collins Road). Treatments included: potato and seed corn subplots and potato and seed corn interplanted with rye grass subplots. At Montcalm a third treatment consisting of two potato subplots was included (continuous potatoes). The positions of the subplots in 1996 were reversed from that of 1995--i.e., the 1996 corn subplot was in potatoes in 1995 and vice versa. Treatments were replicated four times and arranged in a randomized complete block design.

The objective of this study was to compare Colorado potato beetle movement between subplots and the abundance of beetles and predators among different rotation treatments.

Colorado potato beetle movement. To measure Colorado potato beetle flight, flight intercept traps were set up between subplots in each plot on 28 May at the Montcalm Farm only. These traps consisted of a slick, yellow, vertical, plastic panel, supported by wooden posts. Beetles flew into the panel, and slid down into a trough filled with soapy water. Each trap had two troughs, one on each side of the panel, so flight from each subplot could be distinguished. Troughs were checked regularly, and any beetles found in them were counted and removed to be brought to the lab and sexed.

Troughs were checked every few days from May 29 through 1 July 1996. The first beetles were caught in traps on 3 Jun. We had repeated problems with the trough in plot 4 West leaking, and this subplot was eliminated from all flight trap analysis. Also, the trough in plot 12 West started leaking as of 24 Jun, and we were unable to repair the leak. Therefore, the number of beetles caught in each flight trap through 20 Jun includes plot 12 West while the number of beetles caught throughout the entire season does not include plot 12 West.

Few Colorado potato beetles were caught in flight intercept traps (Table 4). There was no apparent difference in the number of beetles caught or the percentage of those caught that were female between west-facing and east-facing traps, indicating no directional bias in flight. Fewer beetles were found in traps in corn & rye plots, but this difference was not significant. In most cases, most beetles caught in flight intercept traps were female, and this is especially true of traps facing potato subplots.

To measure Colorado potato beetle movement between subplots, we collected, marked and released beetles in the non-potato side of each subplot. This simulates the emergence of overwintering beetles in a rotated potato field. Beetles were collected from the Montcalm Research Farm and other locations throughout Michigan, and were brought back to the lab and marked with paint pens (DecoColor, Uchida of America, Corp.). Beetles were then released into the non-potato subplot (or one of the potato subplots for the continuous potatoes treatment). The color and pattern of the marking denoted the release date and the plot the beetles were released into. Beetles were released at Montcalm on 13 and 24 Jun and at Collins Road on 20 and 26 Jun.

Table 4. Mean number of Colorado potato beetles caught in flight intercept traps in different treatments through 20 Jun and through 1 Jul 1996.

		Through 20 June		
		Total Number Caught		
	Side	Mean	Std. Err.	% Females
	East	0.9	0.4	72.7
	West	1.1	0.4	83.3
		Total Number Caught		
Treatment	Side	Mean	Std. Err.	% Females
Corn & Rye	Corn & Rye	0.3	0.3	0.0
	Potatoes	0.5	0.3	100.0
Corn	Corn	1.5	1.0	66.7
	Potatoes	1.3	0.3	80.0
Potatoes	Potatoes	1.1	0.5	88.9
		Through 1 July		
		Total Number Caught		
	Side	Mean	Std. Err.	% Females
	East	1.8	0.5	61.9
	West	1.4	0.5	71.4
		Total Number Caught		
Treatment	Side	Mean	Std. Err.	% Females
Corn & Rye	Corn & Rye	1.0	0.6	0.0
	Potatoes	1.0	0.6	33.3
Corn	Corn	2.0	1.4	62.5
	Potatoes	1.8	0.3	57.1
Potatoes	Potatoes	1.8	0.5	92.9

The potato subplots were searched regularly for marked and unmarked Colorado potato beetles. The number and marking of any beetles found was recorded, but the beetles were not removed. For the first few samples at each location, 4 plants per row were searched. These samples were taken on 10, 12 and Jun at Montcalm and 20, 21 and 24 Jun at Collins Rd. For the last two samples at each site, 15 feet of every other row of potatoes were searched. These samples were taken on 25 and 28 Jun at Montcalm and 27 Jun and 1 Jul at Collins Rd.

Few marked beetles were recaptured in the potatoes (Table 5). There were no significant differences between treatments. At Montcalm, the majority of marked beetles recaptured were found in the continuous potatoes. However, almost all of these were found in the same subplot they were released into.

The mean number of unmarked adults and egg masses per plot varied considerably (Table 6). There were no real differences among treatments.

Table 5. Percentage of marked beetles released into the non-potato subplot in each treatment that were recaptured in potatoes.

Montcalm

	Released 13 Jun	Released 24 Jun	
% Recaptured	14-Jun	25-Jun	28-Jun
Treatment			
Corn	1.0	1.5	2.9
Corn & Rye	4.0	1.2	1.5
Potatoes	4.5	1.0	6.9

Collins Rd.

	Released 20 Jun		Released 26 Jun	
% Recaptured	21-Jun	24-Jun	27-Jun	1 Jul
Treatment				
Corn	0.4	2.3	0.8	6.6
Corn & Rye	1.9	1.1	1.6	4.1

Table 6. Mean of total number of Colorado potato beetle Adults and Egg masses counted in potato plots.

Montcalm

	12-Jun		14-Jun		25-Jun	28-Jun
Treatment	Adults	Eggs	Adults	Eggs	Adults	Adults
Corn	25.3	1.7	23.8	9.8	23.3	14.3
Corn & Rye	21.3	1.3	14.3	8.5	28.3	23.3
Potatoes	15.7	2.3	17.0	9.0	28.3	20.8

Collins

	20-Jun		21-Jun	24-Jun	27-Jun	1-Jul
Treatment	Adults	Eggs	Adults	Adults	Adults	Adults
Corn	6.3	15	16.5	9.8	15.5	7.5
Corn & Rye	11.8	8.3	18.3	13	8.8	7.8

Abundance of Colorado potato beetles and predators. The number of egg masses per plant were counted while searching for marked and unmarked beetles (see above) on 12 and 14 Jun at Montcalm and on 20 Jun at Collins Rd. Four plants per row in each plot were searched. Later, we sampled the number of eggs in various treatments and assessed egg predation. For first generation eggs, the number of egg masses were counted on 10 plants per plot (1 each in rows 1,2,3,5,7,9,11,13,15 and 17). One egg mass on each plant was flagged by tying loosely a piece of flagging tape around the leaf petiole. If a plant had no egg masses on it, other plants in the same row were inspected until an egg mass was found, and this was flagged. Flagged egg masses were checked at 2-4 day intervals. Eggs were classified as: unhatched, hatched (small larvae on leaf and egg mass broken up), chewed, collapsed (many eggs collapsed) sand blasted (broken up and pieces of soil in the remnants) or gone (all remnants of egg mass gone). First generation egg masses were counted and flagged at Montcalm on 20, 24 and 27 Jun and on 21, 25 and 28 Jun at Collins Rd.

Second generation eggs were more scarce, and 5 egg masses per plot were flagged on 29 Jul at Collins Rd. Ten egg masses per plot were flagged at Montcalm on 5 Aug, and were assessed for predation several days later. These data are still being analyzed.

To assess the abundance of Colorado potato beetles and predators, several sampling techniques were used. Entire plants were searched for Colorado potato beetles and predators at both locations three times during the season. Two plants per row in the same four rows in each potato subplot (one subplot in the continuous potatoes treatment) were searched. These "whole plant samples" were taken on 18 and 25 Jul and 1 Aug at Collins Rd. and on 19 Jul and 1 and 7 Aug at Montcalm. These data are still being analyzed.

In addition, we vacuumed plants in each potato subplot (both subplots in the continuous potatoes treatment) using a modified leaf-blower. Potatoes in row were vacuumed thoroughly for 15 seconds. Arthropods were trapped in a nylon knee-high stocking, which was emptied into a plastic bag. Three of these samples were taken per plot. Bags were marked and then placed in a freezer; the samples were counted and sorted later. Vacuum samples were taken at Collins Rd. on 25 Jun, and 2, 15, and 22 Jul. Vacuum samples were taken at Montcalm on 26 Jun and 3,16, and 23 Jul. These data are still being analyzed.

To sample for predators, pitfall traps were made from 8 dram glass vials, half filled with 50 % ethylene glycol. Ten traps were placed in each subplot by making a hole in the ground with a turf-borer and inserting the vial up to its rim. Pitfalls were placed between rows in the same locations in each subplot. Pitfalls were placed in plots on 20 Jun at Collins Rd. and were removed on 27 Jun. Pitfalls were placed in plots on 26 Jun at Montcalm and were removed on 3 Jul. A second set of pitfalls was placed in plots at Montcalm on 1 Aug and were removed on 8 Aug.

Shortly after the pitfalls were removed from the plots, they were strained and the arthropods were placed in 70% ETOH. Arthropods were sorted and counted later. These data are still being analyzed.

To assess parasitism by Tachinid flies, *Myiopharus* sp., fourth instars found "wandering" on the soil prior to pupation were collected on 8 Jul at both locations and were returned to the lab. Larvae were placed on the top of clay pots filled with potting soil, up to 50 larvae per pot, and were provided with food. The pots were covered with fiberglass screening secured with a rubber band. Larvae were kept separated by the plot they were collected from. Pots were checked daily, dead larvae were removed, and fresh potato foliage was added. When all larvae had entered the soil, the foliage was removed. Pots were checked daily for emergence of adult Colorado potato beetles or Tachinid flies. At 17 days after all larvae had entered the soil, the pot was searched for remaining pupae or flies. These data are still being analyzed.

Insecticide Efficacy Tests for Colorado potato beetle control

Fifteen insecticide treatments were tested at the MSU Montcalm Research Farm, in Entrican, MI, for control of Colorado potato beetles (CPB). 'Snowden' potatoes were planted 12 inches apart with a 34 inch row spacing on 9 May. Treatments were replicated four times in a randomized complete block design. Plots measured 40 ft long and were three rows wide. There was at least 6 ft of bare ground in between the plots and 5 ft of untreated potatoes between the plots in the same rows (see attached map). The Mocap treatment was applied in furrow at planting but due to rain, all of the rows had to be closed up before the Admire was applied. The Admire plots were then dug up the next day to expose the seed pieces and the Admire was applied. The first foliar treatment was applied, at 25% CPB hatch, on 27 Jun using a tractor-mounted sprayer (30 gal/A, 40 psi). Subsequent first generation CPB sprays were applied on 4 and 11 Jul. Insecticide effectiveness was determined by counting the number of CPB on two randomly chosen plants from the middle row of each plot on 24 Jun., 2, 9 and 16 Jul. Each plot was assessed for percent defoliation on 15 Jul. and 13 Aug. Because of poor stand, yield varied considerably among plots, and results are not included in this report.

Overall the CPB pressure was very low this year (Table 8). Only two of the weekly counts showed any significant differences but both small and large larvae showed seasonal differences. Admire, the high rate of AC303630, and some of the EXP60145A treatments provided the best control.

Table 7. Mean defoliation ratings

Treatment	Rate	Mean % Defoliation[1] 15 July	13 Aug[¥]
Trigard 75WP	140 g ai/Ha	8.8 abcd	25.0 b
Trigard 75WP followed by	210 g ai/Ha	7.8 abcde	22.5 b
Trigard 75WP	140 g ai/Ha		
AC303630 2SC	0.1 lb ai/A	6.2 abcde	22.5 b
AC303630 2SC*	0.2 lb ai/A	0.7 cde	13.3 b
AC303630 2SC* &	0.05 lb ai/A	6.7 abcde	28.3 b
Asana XL	4.8 fl oz/A		
AC303630 2SC* &	0.05 lb ai/A	2.3 bcde	16.7 b
Provado 1.6F	3.8 fl oz/A		
Admire 2F[3] &	1.3 fl oz/1000 ft	0.8 cde	15.3 b
AC303630 2SC[4]	0.075 lb ai/A		
EXP60145A 1.67SC**	0.025 lb ai/A	0.5 cde	10.0 b
EXP60145A 1.67SC*	0.050 lb ai/A	2.0 cde	23.3 b
EXP60145A 1.67SC &	0.025 lb ai/A	4.0 abcde	25.0 b
Sevin	1.0 lb ai/A		
EXP60145A 1.67SC &	0.025 lb ai/A	3.0 abcde	14.8 b
Dimethoate	1.0 pt/A		
Novodor	3.0 qt/A	6.8 abcde	22.5 b
Admire 2F[3]*	0.9 fl oz/1000 ft	5.3 abcde	11.7 b
Admire 2F[3] &	0.9 fl oz/1000 ft	0.0 e	10.3 b
Monitor 4L[3]	1.5 pt/A		
Admire 2F[3] &	0.3 fl oz/1000 ft	0.3 de	3.8 b
Mocap 10G[2]	2.1 lb/1000 ft		
Asana &	9.6 fl oz/A	10.0 abc	25.0 b
Piperonyl Butoxide(PBO)	8.0 fl oz/100 gal		
Untreated*		18.3 a	70.0 a
Untreated**		15.0 ab	27.5 b

Means within a column followed by different letters are significantly different ($P<0.05$, Tukey's HSD; a=0.05)

¥Defoliation % taken from green stems

*Analysis calculated from 3 plots instead of 4 plots

**Analysis calculated from 2 plots instead of 4 plots

[1] Data transformed for analysis with acrsin $(x)^{1/2}$

[2] Treatment applied in furrow at planting

[3] Treatment applied to second generation CPB

Table 8. Seasonal mean number of first generation CPB

Treatment	Rate	Mean number of CPB per plant ± SEM			
		Egg masses	Small larvae	Large larvae	Adults
Trigard 75WP	140 g ai/Ha	0.28 ± 0.09 a	1.50 ± 0.33 abcd	1.06 ± 0.53 abcd	0.06 ± 0.04 a
Trigard 75WP followed by Trigard 75WP	210 g ai/Ha 140 g ai/Ha	0.44 ± 0.15 a	1.13 ± 0.44 bcde	0.88 ± 0.45 abcde	0.06 ± 0.04 a
AC303630 2SC	0.1 lb ai/A	0.19 ± 0.11 a	1.28 ± 0.74 bcde	0.97 ± 0.31 abc	0.06 ± 0.04 a
AC303630 2SC*	0.2 lb ai/A	0.29 ± 0.15 a	0.13 ± 0.07 fg	0.08 ± 0.04 fg	0.08 ± 0.04 a
AC303630 2SC* & Asana XL	0.05 lb ai/A 4.8 fl oz/A	0.33 ± 0.11 a	4.17 ± 2.31 abc	2.04 ± 0.76 abc	0.00 ± 0.00 a
AC303630 2SC* & Provado 1.6F	0.05 lb ai/A 3.8 fl oz/A	0.13 ± 0.07 a	0.88 ± 0.25 defg	0.88 ± 0.36 bcdef	0.04 ± 0.04 a
Admire 2F† & AC303630 2SC∞	1.3 fl oz/1000 ft 0.075 lb ai/A	0.19 ± 0.08 a	0.06 ± 0.04 fg	0.19 ± 0.08 efg	0.19 ± 0.06 a
EXP60145A 1.67SC**	0.025 lb ai/A	0.31 ± 0.19 a	1.44 ± 1.31 efg	0.00 ± 0.00 g	0.00 ± 0.00 a
EXP60145A 1.67SC*	0.050 lb ai/A	0.21 ± 0.15 a	1.00 ± 0.66 defg	0.17 ± 0.17 fg	0.00 ± 0.00 a
EXP60145A 1.67SC & Sevin	0.025 lb ai/A 1.0 lb ai/A	0.16 ± 0.03 a	0.91 ± 0.52 cdef	0.72 ± 0.18 abcde	0.06 ± 0.04 a
EXP60145A 1.67SC & Dimethoate	0.025 lb ai/A 1.0 pt/A	0.34 ± 0.13 a	1.88 ± 0.60 abc	0.25 ± 0.11 defg	0.00 ± 0.00 a
Novodor	3.0 qt/A	0.16 ± 0.12 a	2.06 ± 0.67 ab	1.88 ± 0.89 a	0.00 ± 0.00 a
Admire 2F†*	0.9 fl oz/1000 ft	0.08 ± 0.08 a	0.63 ± 0.51 efg	0.83 ± 0.42 cdefg	0.08 ± 0.08 a
Admire 2F† & Monitor 4L∞	0.9 fl oz/1000 ft 1.5 pt/A	0.03 ± 0.03 a	0.00 ± 0.00 g	0.06 ± 0.06 fg	0.16 ± 0.08 a
Admire 2F† & Mocap 10G†	0.3 fl oz/1000 ft 2.1 lb/1000 ft	0.03 ± 0.03 a	0.06 ± 0.04 fg	0.09 ± 0.06 fg	0.16 ± 0.08 a
Asana & Piperonyl Butoxide(PBO)	9.6 fl oz/A 8.0 fl oz/100 gal	0.06 ± 0.04 a	3.44 ± 1.18 a	1.94 ± 0.96 a	0.03 ± 0.03 a
Untreated*		0.17 ± 0.08 a	1.63 ± 0.19 bcde	2.25 ± 0.81 ab	0.13 ± 0.07 a
Untreated**		0.31 ± 0.31 a	3.44 ± 2.56 bcde	3.06 ± 0.31 abc	0.00 ± 0.00 a

Means within a column followed by diferent letters are significantly different ($P<0.05$,Tukey's HSD; a=0.05)
Data transformed for analysis with log (x+1)
*Analysis calculated from 3 plots instead of 4 plots
**Analysis calculated from 2 plots instead of 4
†Treatment applied in furrow at planting
∞Treatment applied to second generation CPB

CHEMICAL CONTROL OF POTATO LATE BLIGHT 1996

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INTRODUCTION

Several spray trials were carried out at the MSU Muck Soils Experimental Research Farm, Bath, MI. A selection of these trials are described in this report. Fungicides were applied as a protectant program according to protocols defined by the sponsors (outlined in results tables). The spray application timings used in one trial were delayed until late blight had been introduced or had become established throughout the experimental block. The objective of the protectant programs was to evaluate the comparative efficacy of several fungicides compared to standard programs and to establish dose responses for chemicals as required. The containment programs were initiated to evaluate the ability of different fungicides to control established late blight in the field. The efficacy of the fungicides registered under the Section 18 applied prior to and after the establishment of disease was compared with other treatments.

METHODS

Potato plots were planted with Snowden cut seed using a pick-type planter on 30 May 1996 into two rows by 50 foot plots (34 inch row spacing) and hilled on 23 June. Fertilizer was drilled into plots before planting, formulated according to results of soil tests. Additional nitrogen (28% N, to give 28 lb N/acre) was applied to the growing crop along with an irrigation on 26 July. Maximum, minimum and average air and soil (½ inch deep) temperatures; high, low and average percent relative humidity; amounts of precipitation (including irrigation) and leaf wetness periods were recorded for each day by a SENSOR weather station (available on request).

Sprays were applied with a ATV-mounted R&D boom sprayer operated at 80 PSI at a ground speed (2.7 mph) calculated to deliver 25 gallons of liquid per acre. The plots were sprayed with three XR11003VS nozzles per row; two nozzles placed on both sides of each row at a 45-degree angle and one placed directly over the row for increased foliar surface coverage. The sprayer was calibrated several times during the spray season (10 July-22 Aug.) and all calibrations were in close agreement. All treatments for both trials were replicated four times in a randomized block design. Treatments together with rates of application (amount of formulation per acre) are shown in the tables.

All trials were inoculated with spore suspensions of *Phytophthora infestans* US8/A2 mating strain. Inoculations were carried out in the late afternoon or evening hours on days when conditions were favorable for disease development. The center and outside double rows of each block along with a five foot central section of each block was inoculated with spore suspensions (suspensions contained about 500,000 sporangiophores/ml) on 23 July. The block containing trial 12 was completely inoculated to allow even disease development. Irrigation was applied on 22 July (0.8 inch), 4 August (1.0 inch) and 15 August (0.2 inch). All blocks were soaked for about one hour during dry days to maintain constant leaf wetness after inoculation and after disease had become established. A permanent irrigation system was established prior to the commencement of fungicide sprays. Fungicide sprays began on 10 July and ended on 22 August (7 applications or less according to protocols). Sprays were applied weekly. In the containment trial, the first spray was applied 72 hours after inoculation with the spore suspension for timing a, when foliar infection was about 5% (timing b) and 15% (timing c). Foliar infections were estimated visually. Plots in sections for timing a and b received only three applications at seven day intervals but plots in the section for timing c received only two applications. (This method is not recommended for disease management and was followed for experimental reasons).

Herbicides and insecticides were applied as shown in Tables a and b.

Table a. Herbicide applications (rates are formulation per acre)

Herbicides applied	Rate/acre	Date(s)
Dual 8E	1 qt.	23 May
Basagran	1 qt.	5 Jun. & 3 Jul.
Poast	1.5 pt.	2 Aug.
Diquat	1 pt.	4 Sep. & 8 Sep.

Table b. Insecticide applications (rates are formulation per acre)

Insecticides applied	Rate/acre	Date(s)
Admire 2 F	20 oz.	30 May
Sevin 80 S	1.25 lb.	3 Jul, 25 Jul.
Thiodan 3EC	2.33 pt.	8 Jul., 9 Aug. & 17 Aug.
Pounce 3.2EC	8 oz.	12 Jul.

The plots were visually rated for % foliar late blight infection on 8, 13, and 20 August and 1 September and for % petiole (percentage of petioles infected from a sample of ten plants per plot) and % stem infection (percentage of stem tissue infected from a sample of ten plants per plot) on 2 September. The disease progress was evaluated as the relative area under the disease progress curve. The plots were harvested on 17 - 21 Sep. and individual treatments weighed and graded (protectant trials only).

Results and Discussion

All fungicide programs in the test delayed the development and reduced the level of foliar late blight infection significantly in comparison with the untreated checks (Tables 1 - 6). No treatments applied in seven day programs gave significantly better disease control than the standard treatment program Bravo WS 6SC or Bravo ZN 4FL. Until the final assessments (9/1 - 38 days after inoculation) no treatment was significantly different from any other. Results, conclusions for individual trials and recommendations are shown on pages opposite the corresponding tables.

Trial 1 - Table 1.

The efficacy of Acrobat MZ (2.25 lb/a), Curzate M8 +Manzate (1.5 + 0.75 lb/a) and Tattoo C (2.3 pt/a) applied within protection programs was not significantly different when applied three times at seven day intervals measured as foliar disease development, percentage of petioles infected or percentage of the stem infected. The activity of these three fungicides within protection programs was greatly reduced when the interval between the applications was extended to 14 days and none of the three programs gave adequate disease control. The efficacy of Acrobat MZ was numerically decreased by the addition of Latron-B 1956 but slightly improved numerically by the addition of LI700. The programs incorporating the systemic or trans-laminar compounds gave similar levels of disease control to the standard Bravo WS applied on a 7-day spray schedule. No yield differences were recorded between any treatment.

Recommendations

Acrobat MZ, Curzate M8 and Tattoo C should not be applied at more than a 7-day interval during high disease pressure periods.

A program to determine the efficacy of trans-laminar or systemic products applied early, mid and late season may be required to determine if these products have a specific appropriate timing in relation to disease development and canopy development in the field.

Table 1. Control of potato late blight with Acrobat MZ, Curzate M8 and Tattoo C fungicides applied in protectant programs at seven day intervals in 1996.

Chemical	Rate Formulation pints or lbs/acre	Spray Schedule [1]	% foliar late blight [2]					RAUDPC [3] max =100	% petiole infection	% stem infection	Yield (cwt/acre)	
			7/23 [4]	8/8 15 dai	8/13 20 dai	8/20 27 dai	9/1 38 dai		9/2 39 dai	9/2 39 dai	> 2" diameter	Total
1. BravoWS6SC BravoWS 6SC + SuperTin 80WP	1.5 pint 1.5 pint 0.13 lb	7 day (1st six applns) 7 day to season end	0	1.5a [5]	1.3a	2.0 b	8.3 d	2.3 bc	2.0 c	0.8 b	451.8a	552.8a
2. Bravo WS 6SC Acrobat MZ 69WP	1.5 pint 2.25 lb	7 day 7 day (final 2 applns)	0	0.8a	1.5a	2.0 b	8.3 d	2.1 bc	1.3 c	0.3 b	448.1a	534.5
3. Bravo WS 6SC Acrobat MZ 69WP	1.5 pint 2.25 lb	7 day (first 4 applns) 7 day (next 3 applns)	0	1.3a	1.8a	2.8 b	9.0 d	2.6 bc	2.3 bc	0.3 b	423.6a	526.2a
4. Bravo WS 6SC Acrobat MZ 69WP + Latron B-1956	1.5 pint 2.25 lb 0.19 lb	7 day (first 4 applns) 7 day (next 3 applns)	0	1.8a	2.0a	4.5 b	19.5 d	4.7 bc	6.3 bc	1.3 b	433.2a	509.0a
5. Bravo WS 6SC Acrobat MZ 69WP + LI 700	1.5 pint 2.25 lb 0.5 pint	7 day (first 4 applns) 7 day (next 3 applns)	0	0.5a	1.8a	2.3 b	5.5 d	1.7 c	1.0 c	0.3 b	463.7a	559.4a
6. Bravo WS 6SC Curzate M8 72WP + Manzate 75WP	1.5 pint 1.5 lb 0.75 lb	7 day (first 4 applns) 7 day (next 3 applns)	0	1.3a	1.0a	1.8 b	5.8 d	1.7 c	1.5 c	0.01 b	434.8a	523.4a
7. Bravo WS 6SC Tattoo C 6.25SC	1.5 pint 2.3 pint	7 day (first 4 applns) 7 day (next 3 applns)	0	0.3a	2.8a	3.0 b	5.3 d	1.9 c	3.5 bc	1.0 b	464.9a	550.8a
8. Bravo WS 6SC Acrobat MZ 69WP	1.5pint 2.25 lb	7 day (first 2 applns) 14 day (next 3 applns)	0	1.0a	1.8a	11.3 b	57.0 b	11.5 b	43.8 b	25.3 b	465.3a	553.8a
9. Bravo WS 6SC Curzate M8 72WP + Manzate 75WP	1.5 pint 1.5 lb 0.75 lb	7 day (first 2 applns) 14 day (next 3 applns)	0	1.3a	1.5a	3.5 b	56.3 bc	9.5 bc	30.0 b	11.0 b	475.8a	577.5a
10 Bravo WS 6SC Tattoo C 6.25SC	1.5pint 2.3pint	7 day (first 2 applns) 14 day (next 3 applns)	0	0.5a	1.8a	2.5 b	20.5 c	4.0 bc	21.8 bc	4.3 b	481.2a	597.9a
11. Untreated			0	1.8a	2.0a	32.0a	98.0a	22.5a	94.3a	75.0a	379.5a	449.1a

[1] applications initiated 7/10/96 and completed by 8/22/96
[2] percentage of foliage infected as estimated visually on dates indicated
[3] relative area under the disease progress curve
[4] inoculation date,
[5] numbers followed by same letter are nsd at p = 0.05 (Tukey)

Trial 2 - Table 2.

The efficacy of Acrobat MZ (2.25 lb/a), Curzate M8 +Manzate (1.5 + 0.75 lb/a) and Tattoo C (2.3 pt/a) applied alone was not significantly different when applied at seven, ten or fourteen day intervals measured as foliar disease development, percentage of petioles infected or percentage of the stem infected. None of these three fungicide treatments applied at a spray interval greater than 7 days gave adequate disease control.

The programs incorporating the systemic or trans-laminar compounds gave similar levels of disease control to the standard Bravo WS applied on a 7-day spray schedule. Numerical yield differences were recorded between some treatments but only the Acrobat MZ (10 day), Curzate M8 + Manzate, Tattoo C and Bravo ZN treatments were statistically different from the untreated plots at $p = 0.05$.

Recommendations

Acrobat MZ, Curzate M8 and Tattoo C should not be applied at more than a 7-day interval during high disease pressure periods.

A program to determine the efficacy of trans-laminar or systemic products applied early, mid and late season and at different spray intervals may be required to determine if these products are more effective at different intervals at different stages of canopy development.

Table 2. Control of potato late blight with Acrobat MZ, Curzate M8 and Tattoo C fungicides applied in protectant programs at seven, ten and fourteen day intervals in 1996..

Chemical	Rate Formulation pints or lbs/acre	Spray Schedule [1]	% foliar late blight [2]					RAUDPC [3] max =100	% petiole infection	% stem infection	Yield (cwt/acre)	
			7/23 [4]	8/8 15 dai	8/13 20 dai	8/20 27 dai	9/1 38 dai		9/2 39 dai	9/2 39 dai	> 2" diameter	Total
1. BravoZN 4FL	2.2 pint	7 day	0	0.5a [5]	2.3a	4.0 b	6.8 d	2.4 b	4.0 c	1.0 b	551.9a	682.8a
2. Acrobat MZ 69WP	2.25 lb	7 day	0	0.8a	1.3a	5.8 b	16.3 cd	4.1 b	5.8 bc	1.5 b	519.6a	627.6ab
3. Acrobat MZ 69WP	2.25 lb	10day	0	0.8a	2.3a	6.0 b	20.8 cd	5.0 b	11.5 bc	4.5 b	533.9a	647.7a
4. Acrobat MZ 69WP	2.25 lb	14 day	0	0.8a	1.8a	6.3 b	62.5ab	11.0 b	28.8 b	10.5 b	458.7ab	553.2ab
5. Curzate M8 72WP + Manzate 75WP	1.5 lb 0.75 lb	7 day	0	0.5a	1.8a	3.5 b	6.3 d	2.1 b	1.5 c	0.5 b	533.3a	657.5a
6. Curzate M8 72WP + Manzate 75WP	1.5 lb 0.75 lb	10 day	0	0.8a	1.5a	6.5 b	36.3 bcd	7.2 b	11.0 bc	2.3 b	501.2a	604.7ab
7.Curzate M8 72WP + Manzate 75WP	1.5 lb 0.75 lb	14 day	0	0.5a	2.8a	4.0 b	40.0abcd	7.2 b	11.3 bc	2.8 b	451.4ab	535.7ab
8. Tattoo C 6.25SC	2.3pint	7 day	0	0.8a	2.3a	2.3 b	5.8 d	1.9 b	0.3 c	0.3 b	522.2a	630.3a
9. Tattoo C 6.25SC	2.3 pint	10 day	0	1.3a	1.5a	12.0 b	34.0 bcd	8.3 b	8.8 bc	2.3 b	490.1ab	591.5ab
10 Tattoo C 6.25SC	2.3pin	14 day	0	0.8a	1.5a	6.5 b	56.3abc	10.1 b	21.3 bc	6.5 b	499.1a	596.7ab
11. Untreated			0	1.8a	1.8a	36.3a	82.8a	21.3a	72.5a	58.8a	393.2 b	469.4 b

[1] applications initiated 7/10/96 and completed by 8/22/96
[2] percentage of foliage infected as estimated visually on dates indicated
[3] relative area under the disease progress curve
[4] inoculation date,
[5] numbers followed by same letter are nsd at p = 0.05 (Tukey)

Trial 3 - Table 3.

All treatments were statistically different in comparison with untreated plots in terms of disease development but there were no statistical differences in disease control between any treatments. The efficacy of Manex C8 +Manex (1.5 lb/a + 0.94 pt/a) was numerically inferior to Bravo ZN (2.2 pt/a), Manex (2.4 - 3.2 pt/a) and Manex + SuperTin (2.4 pt/a + 0.16 lb/a) applied at seven day intervals. Polyram applied alone or in combination with SuperTin gave similar levels of disease control but were numerically inferior to the standard treatment (Bravo ZN). The Manex followed by Manex C8 (1.25 lb/a) program gave poorer control than the standard treatments and was probably due to the combination of the reduced amount of systemic and protectant available in the lower rate of Manex C8. SuperTin applied alone (0.16 - 0.23 lb/a) did not give adequate control of late blight and is clearly effective at a precise stage of disease development and requires the protectant component which is supplied in mixture with the EBDC fungicides such as Manex and Polyram. Mankocide (1.8 - 3.0 lb/a) was ineffective against late blight under high disease pressure. The Kocide program also failed to give good initial disease control which allowed disease to become established which the low rate of Manex plus SuperTin failed to contain.

All treatments gave numerically improved yield benefits over the untreated plots but only Manex C8 +Manex (1.5 lb/a + 0.94 pt/a) and Manex + SuperTin (2.4 pt/a + 0.16 lb/a) gave statistically significant differences at $p = 0.05$.

Recommendations

Manex C8 should not be applied at less than 1.5 lb/a in combination with Manex at ca. 1 pt/a.

SuperTin should only be applied in combination with an EBDC.

A dose rate response of SuperTin + EBDC should be established to determine phytotoxicity risk and efficacy of higher "rescue" rates of SuperTin.

Mankocide should not be recommended for late blight control under high disease pressure situations.

The approach to the use of copper-based products in potato late blight programs needs to be re-evaluated.

Table 3. Control of potato late blight with registered protectant fungicides and Manex C8 (active ingredient section 18 registration) applied in protectant programs at seven day intervals in 1996.

Chemical	Rate Formulation pints or lbs/acre	Spray Schedule [1]	% foliar late blight [2] 7/23 [4]	% foliar late blight [2] 8/8 15 dai	% foliar late blight [2] 8/13 20 dai	% foliar late blight [2] 8/20 27 dai	% foliar late blight [2] 9/1 38 dai	RAUDPC [3] max =100	% petiole infection 9/2 39 dai	% stem infection 9/2 39 dai	Yield (cwt/acre) > 2" diameter	Yield (cwt/acre) Total
1. Bravo ZN 4FL	2.2 pint	7 day	0	0.3a [5]	2.8a	2.8 b	4.8 b	1.8 b	0.8 b	0.5 b	484.7a	581.7ab
2. Polyram 80DF + SuperTin 80WP + Silwet + Bond	2.0 lb 0.16 lb 0.5 pint 0.1 pint	7 day	0	1.0a	2.3a	3.5 b	9.3 b	2.8 b	3.0 b	1.8 b	419.1a	501.0ab
3. Polyram 80DF + Silwet + Bond	2.0 lb 0.5 pint 0.1 pint	7 day	0	0.3a	1.8a	9.3 b	8.8 b	3.8 b	2.5 b	0.8 b	402.6a	488.3ab
4. Manex 4FL Manex 4FL	2.4 pint 3.2 pint	7 day first 4 applns 7 day to season end	0	0.8a	1.5a	3.0 b	5.3 b	1.9 b	0.8 b	0.3 b	440.4a	554.2ab
5. Manex C8 72WP + Manex 4FL	1.5 lb 0.94 pint	7 day	0	0.3a	2.0a	3.5 b	7.3 b	2.3 b	1.8 b	0.5 b	516.2a	635.6a
6. SuperTin 80WP SuperTin 80WP	0.16 lb 0.23 lb	7 day first 4 applns 7 day to season end	0	0.8a	1.5a	5.0 b	21.5 b	5.2 b	8.5 b	2.8 b	424.9a	524.0ab
7. Mankocide 39DF Mankocide 39DF	1.8 lb 3.0 lb	7 day first 4 applns 7 day to season end	0	0.3a	2.5a	4.5 b	35.5 b	6.7 b	13.0 b	2.5 b	417.9a	503.6ab
8. Manex 4FL + SuperTin 80WP	2.4 pint 0.13 lb	7 day	0	0.3a	1.5a	2.5 b	4.8 b	1.6 b	0.8 b	0.5 b	511.1a	613.8a
9. Manex 4FL Manex C872WP	2.4 pint 1.25 lb	7 day first 4 applns 7 day next 3 applns	0	0.5a	2.0a	4.0 b	15.0 b	3.6 b	7.3 b	1.8 b	416.9a	501.9ab
10. Kocide 5.5FL Manex 4FL + SuperTin 80WP	1.6 pint 2.4 pint 0.13lb	7 day first 4 applns 7 day next 3 applns	0	0.3a	2.3a	6.3 b	14.3 b	4.0 b	5.8 b	2.0 b	427.4a	505.8ab
11. Untreated			0	1.0a	2.0a	62.5a	98.3a	29.6a	94.5a	77.5a	325.4a	384.3 b

[1] applications initiated 7/10/96 and completed by 8/22/96
[2] percentage of foliage infected as estimated visually on dates indicated
[3] relative area under the disease progress curve
[4] inoculation date,
[5] numbers followed by same letter are nsd at p = 0.05 (Tukey)

Trial 4 - Table 4.

All treatments were statistically different in comparison with untreated plots in terms of disease development but there were no statistical differences in disease control between any treatments. There were however clear numerical differences between many of the treatments. The efficacy of Polyram 80DF plus SuperTin (2.0 lb/a +0.16 lb/a), Polyram 80DF (2.0 lb/a), Ensign (1.0 - 1.5 pt/a) and the alternate Polyram 80DF plus SuperTin (2.0 lb/a +0.16 lb/a)/Bravo ZN (2.2 pt/a) was numerically inferior to Bravo ZN (2.2 pt/a) applied in protectant programs at seven day intervals. Champ 2 4.6FL applied at increasing dose rates as the season progressed (1.33 - 2.67 pt/a) gave inadequate disease control in comparison with Bravo ZN applied at seven day intervals. When applied in a programmed approach in combination with Penncozeb 75DF, Champ 2 4.6FL was more effective in combination programs as the initial product in the program.

All treatments gave numerically improved yield benefits over the untreated plots but no treatment comparisons were statistically significant different at $p = 0.05$.

Recommendations

An increasing rate strategy for all protectant fungicides, such as Polyram 80DF, Ensign 6SC, Penncozeb 75DF and Champ 2 4.6FL should be matched to canopy development and may provide the basis of a strategy for crop protection in varieties with different patterns of foliage development e.g. lower recommended rates in open and determinate varieties and increased application rates in dense canopied indeterminate varieties.

Polyram should not be applied at less than 2.0 lb/a alone or in combination with SuperTin (0.16 lb) in a programmed approach for preventative control against potato late blight.

Ensign 6SC should not be applied at less than 1.0 (early season) then 1.5 pt/a (after canopy closure) alone in a programmed approach for preventative control against potato late blight.

The approach to the use of copper-based products in potato late blight programs needs to be re-evaluated.

Table 4. Control of potato late blight with EBDCs, chlorothalonil-based products and Champ (Copper-based product) fungicides applied in protectant programs at seven day intervals in 1996..

Chemical	Rate Formulation pints or lbs/acre	Spray Schedule [1]	% foliar late blight [2]					RAUDPC [3] max =100	% petiole infection	% stem infection	Yield (cwt/acre)	
			7/23 [4]	8/8 15 dai	8/13 20 dai	8/20 27 dai	9/1 38 dai		9/2 39 dai	9/2 39 dai	> 2" diameter	Total
1. Bravo ZN 4FL	2.2 pint	7 day	0	0.5a [5]	1.8a	2.0 b	5.3 b	1.6 b	0.8 b	0.3 b	424.4ab	512.6ab
2. Polyram 80DF + SuperTin 80WP	2.0 lb 0.16 lb	7 day	0	0.3a	1.8a	2.3 b	8.8 b	2.1 b	2.3 b	0.5 b	431.6a	527.1a
3. Polyram 80DF	2.0 lb	7 day	0	0.3a	1.8a	2.8 b	10.3 b	2.3 b	2.8 b	1.0 b	453.2a	543.2a
4. Ensign 6SC Ensign 6SC	1.0 pint 1.5 pint	7 day (to inoculation)[4] 7 day to season end	0	0.3a	1.5a	2.0 b	9.3 b	2.1 b	2.5 b	1.0 b	402.5ab	481.4ab
5. Polyram 80DF + SuperTin 80WP Bravo ZN 4FL	2.0 lb 0.16 lb 2.2 pint	7 day (alternate) 7 day (alternate)	0	0.3a	1.5a	9.5ab	14.5 b	4.6 b	6.5 b	1.8 b	446.1a	536.0a
6. Champ 2 4.6FL Champ 2 4.6FL Champ 2 4.6FL	1.33 pint 2.0 pint 2.67 pint	7 day (appln 1 - 2) 7 day (appln 3 - 6) 7 day to season end	0	1.0a	1.5a	2.8 b	32.5 b	5.8 b	16.3 b	6.0 b	398.0ab	485.0ab
7. Champ 2 4.6FL Champ 2 4.6FL Penncozeb 75DF	1.33 pint 2.0 pint 2.0 lb	7 day (appln 1 - 2) 7 day (appln 3 - 4) 7 day to season end	0	0.5a	1.3a	4.3 b	14.5 b	3.4 b	6.3 b	1.8 b	390.8ab	451.4ab
8. Penncozeb 75DF Penncozeb 75DF Champ 2 4.6FL Champ 2 4.6FL	1.5 lb 2.0 lb 2.0 pint 2.67pint	7 day (appln 1 - 2) 7 day (appln 3 - 4) 7 day (appln 5 - 6) 7 day to season end	0	0.1a	1.5a	3.3 b	35.0 b	6.1 b	17.8 b	5.8 b	410.4ab	483.3ab
9. Untreated			0	0.3a	1.8a	36.3a	98.5a	26.8a	95.5a	92.3a	320.7 b	378.5 b

[1] applications initiated 7/10/96 and completed by 8/22/96
[2] percentage of foliage infected as estimated visually on dates indicated
[3] relative area under the disease progress curve
[4] inoculation date,
[5] numbers followed by same letter are nsd at p = 0.05 (Tukey)

Trial 5 - Table 5.

All treatments were statistically different in comparison with untreated plots in terms of disease development but there were no statistical differences in disease control between any treatments applied at seven day intervals.

Terranil 6SC (1.5 pt/a), Terranil 90DF (1.25 lb/a) and Terranil ZN 4FL (2.13 pt/a) gave very good control of potato late blight when applied at seven day intervals but all were marginally numerically inferior to the standard Bravo WS (1.5 pt/a).

The Ridomil-Bravo 81WP program gave excellent disease control and was the same as the standard Bravo WS treatment. The Ridomil Gold program, although numerically inferior to the Ridomil-Bravo program also gave very good disease control.

Many treatments gave numerically improved yield benefits over the untreated plots but no treatment comparisons were statistically significant different at $p = 0.05$.

Recommendations

An increasing rate strategy for all protectant fungicides, such as Terranil-based and Bravo-based products should be matched to canopy development and may provide the basis of a strategy for crop protection in varieties with different patterns of foliage development e.g. lower recommended rates in open and determinate varieties and increased application rates in dense canopied indeterminate varieties.

Ridomil Gold 2.4SC should be recommended as a replacement for Ridomil pre-pack products in a programmed approach for preventative control against potato late blight.

Table 5. Control of potato late blight with Ridomil Gold-based fungicides, Terranil products and Bravo ZN fungicides applied in protectant programs at seven day intervals in 1996.

Chemical	Rate Formulation	Spray Schedule[1]	% foliar late blight[2]					RAUDPC[3] max =100	% petiole infection	% stem infection	Yield (cwt/acre)	
	pints or lbs/acre		7/23[4]	8/8 15 dai	8/13 20 dai	8/20 27 dai	9/1 38 dai		9/2 39 dai	9/2 39 dai	> 2" diameter	Total
1. Bravo WS 6SC	1.5 pint	7 day	0	0.5a[5]	1.5a	1.8 b	4.0 c	1.4 c	1.8 c	1.0 b	387.8a	464.7a
2. Terranil 6SC	1.5 pint	7 day	0	0.5a	1.5a	2.0 b	9.8 c	2.3 c	2.8 c	1.5 b	336.5ab	430.4ab
3. Terranil 90DF	1.25 lb	7 day	0	0.5a	1.5a	2.8 b	8.3 c	2.2 c	2.3 c	0.3 b	364.8a	431.3ab
4. Terranil ZN 4FL	2.13 pint	7 day	0	0.1a	1.0a	1.3 b	6.8 c	1.4 c	2.5 c	0.5 b	406.4a	480.3a
5. Bravo WS 6SC Ridomil-Bravo 81WP Bravo WS 6SC	1.5pint 2.0 lb 1.5 pint	7 day (applns 1 - 2) 7 day (applns 3, 5 & 7) 7 day (applns 4 & 6)	0	0.3a	1.5a	2.0 b	3.8 c	1.3 c	0.5 c	0.3 b	386.1a	456.6a
6. Bravo WS 6SC Ridomil Gold 4EC Bravo WS 6SC	1.5pint 0.2 pint 1.5 pint	7 day (applns 1 - 2) 7 day (applns 3, 5 & 7) 7 day (applns 4 & 6)	0	0.1a	0.8a	2.8 b	7.8 c	1.9 c	2.3 c	1.0 b	342.8ab	413.3ab
7. Bravo ZN 4FL	2.2 pint	7 day	0	0.3a	1.8a	4.5 b	5.8 c	2.2 c	1.3 c	0.5 b	361.8ab	442.7a
8. Untreated			0	0.3a	2.3a	61.3a	92.8a	28.4a	82.5a	76.3a	241.2 b	297.0 b

[1] applications initiated 7/10/96 and completed by 8/22/96
[2] percentage of foliage infected as estimated visually on dates indicated
[3] relative area under the disease progress curve
[4] inoculation date,
[5] numbers followed by same letter are nsd at p = 0.05 (Tukey)

Trial 6 - Table 6.

All treatments were statistically different in comparison with untreated plots in terms of disease development but there were no statistical differences in disease control between any treatments applied at seven day intervals even when programs were initiated 72 hours after inoculation.

There were no numerical differences between any of the IB 17022 4SC applied on a seven day interval treatments and initiated 72 hours after inoculation. The efficacy of IB 17022 4SC (0.11 - 0.18 pt/a) applied in containment programs against potato late blight was excellent and matched the standard Acrobat MZ 69WP (2.25 lb/a). IB 17022 4SC applied in combination with Silwet did not affect the control of late blight in this trial.

Quadris 80WDG showed a clear positive dose response with increasing rate of application and gave best disease control at 0.31 lb/a applied either season long or alternating with Bravo WS (1.5 pt/a).

Fluazinam 5SC (1.0 pt/a) gave excellent disease control applied at a 7 day interval.

Many treatments gave numerically improved yield benefits over the untreated plots but no treatment comparisons were statistically significant different at $p = 0.05$.

Recommendations

An increasing rate strategy for all protectant fungicides, such as Fluazinam 5SC should be matched to canopy development and may provide the basis of a strategy for crop protection in varieties with different patterns of foliage development e.g. lower recommended rates in open and determinate varieties and increased application rates in dense canopied indeterminate varieties.

The potato late blight containment properties of IB 17022 4SC should be re-evaluated.

A dose response for Quadris 80WDG should be re-evaluated and the contribution of the product within a programmed approach for preventative control against potato late blight should be established.

Table 6. Control of potato late blight with experimental fungicides (IB 17022, fluazinam and Quadris) applied in protectant and disease containment programat at seven day intervals in 1996.

Chemical	Rate Formulation	Spray Schedule[1]	% foliar late blight[2]					RAUDPC[3] max =100	% petiole infection	% stem infection	Yield (cwt/acre)	
	pints or lbs/acre		7/23[4]	8/8 15 dai	8/13 20 dai	8/20 27 dai	9/1 38 dai		9/2 39 dai	9/2 39 dai	> 2" diameter	Total
1. IB 17022 4SC	0.11 pint	7 day (72 h after inoc.)[4]	0	1.0a[5]	2.3a	2.8a	7.3 b	2.3 b	1.8 b	0.3 b	435.6ab	512.6a
2. IB 17022 4SC	0.14 pint	7 day (72 h after inoc.)	0	1.5a	2.5a	4.3a	7.5 b	2.9 b	3.0 b	0.8 b	451.4a	545.7a
3. IB 17022 4SC	0.18 pint	7 day (72 h after inoc.)	0	1.3a	1.5a	2.0a	8.3 b	2.2 b	4.3 b	1.8 b	437.0ab	522.9a
4. IB 17022 4SC + Silwet	0.14 pint	7 day (72 h after inoc.)	0	1.0a	1.5a	2.8a	6.3 b	2.1 b	1.8 b	0.5 b	435.5ab	528.2a
5. Acrobat MZ 69WP	2.25 lb	7 day (72 h after inoc.)	0	1.5a	2.3a	2.8a	7.5 b	2.5 b	2.8 b	1.0 b	424.4ab	504.5a
6. Quadris 80WDG + Bond Bravo WS 6SC	0.13 lb 0.1 pint 1.5 pint	7 day (alternate) 7 day (alternate)	0	1.5a	3.0a	5.8a	21.3 b	5.3 b	7.8 b	2.3 b	400.5ab	501.9a
7. Quadris 80WDG + Bond Bravo WS 6SC	0.19 lb 0.1 pint 1.5 pint	7 day (alternate) 7 day (alternate)	0	0.5a	1.8a	4.3a	12.8 b	3.2 b	3.3 b	0.5 b	391.1ab	509.6a
8. Quadris 80WDG + Bond Bravo WS 6SC	0.25 lb 0.1 pint 1.5 pint	7 day (alternate) 7 day (alternate)	0	0.3a	1.0a	1.8a	8.8 b	1.9 b	1.5 b	0.5 b	409.1ab	524.9a
9. Quadris 80WDG + Bond Bravo WS 6SC	0.31 lb 0.1 pint 1.5 pint	7 day (alternate) 7 day (alternate)	0	0.8a	1.8a	3.0a	6.8 b	2.2 b	1.5 b	0.5 b	467.3a	560.7a
10. Quadris 80WDG + Bond	0.31 lb 0.1 pint	7 day	0	0.5a	1.3a	2.8a	6.3 b	1.9 b	1.0 b	0.5 b	465.5a	559.4a
11. Fluazinam 5SC	1.0 pint	7 day	0	0.8a	1.3a	2.3a	5.8 b	1.8 b	1.5 b	1.8 b	452.6a	541.2a
12. Untreated			0	0.8a	1.5a	4.5a	90.8a	14.6a	52.5a	9.5a	343.5 b	425.0 a

[1] applications initiated 7/10/96 and completed by 8/22/96
[2] percentage of foliage infected as estimated visually on dates indicated
[3] relative area under the disease progress curve
[4] inoculation date,
[5] numbers followed by same letter are nsd at p = 0.05 (Tukey)

Trial 7 - Table 7a and 7b.

This trial was conducted to establish the containment properties of several products and is not a strategy recommended for the effective control of potato late blight.

Treatments applied 72 hours after inoculation gave better control than when applied after foliar disease had developed within the treatment block. Applications initiated after disease had developed to 5% within the block were generally ineffective although some treatments did hinder disease progress. When the treatments were delayed until disease had developed to 15% across the treatment block no treatment gave any disease control and were defoliated about 15 days after the first application of fungicide.

Curzate M8 72WP plus Manzate 75WP (1.5 + 0.75 lb/a) , Acrobat MZ 69WP (2.25 lb/a), Tattoo C (2.3 pt/a) applied alone or in combination with SuperTin 80WP (0.16 lb/a), Ridomil Gold 4EC + Bravo WS 6SC (0.2 + 1.5 pt/a), Polyram 80WP plus SuperTin (2.0 + 0.16 lb/a), Quadris 80WDG (0.31 lb/a) + Bond and IB 17022 4SC (0.18 pt/a) all showed excellent disease containment properties when applied 72 hours after inoculation. The addition of SuperTin made no numerical difference where applied to the trans-laminar/systemic products. Only Champ 2 4.6FL and Mankocide 39DF gave inadequate control of the disease (defined as ≥10% foliar infection).

Where treatments were delayed until disease had established to 5% across the treatment block only Curzate M8 72WP plus Manzate 75WP (1.5 + 0.75 lb/a) , Acrobat MZ 69WP (2.25 lb/a), Tattoo C (2.3 pt/a) applied alone or in combination with SuperTin 80WP (0.16 lb/a), showed some disease containment properties (defined as ≤35% foliar infection).

Recommendations

In situations where potato late blight has been identified within a crop at levels ≤1% (or has been confirmed within a potato growing locality) products such as Curzate M8 72WP plus Manzate 75WP (1.5 + 0.75 lb/a) , Acrobat MZ 69WP (2.25 lb/a), Tattoo C (2.3 pt/a) applied alone or in combination with SuperTin 80WP (0.16 lb/a) Ridomil Gold 4EC + Bravo WS 6SC (0.2 + 1.5 pt/a) and Polyram 80WP plus SuperTin (2.0 + 0.16 lb/a) **may** give adequate containment of the disease.

It is not recommended that growers wait until disease has been reported within their locality to begin their spray programs.

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Table 7a. Control of potato late blight through plots treated with registered fungicides, section 18 fungicides and experimental fungicides after the introduction of disease into the plots, 1996.

Chemical	Rate Formulation pints or lbs/acre	Spray Schedule 3 applications Timing a 72 hrs post inoc. Timing b 5% foliar inf'n Timing c 15% foliar inf'n* *= 2 applications	% foliar late blight [1]									
				timing a			timing b			timing c		
			7/23	8/13	8/20	8/29	8/8	8/20	8/29	8/14	8/20	8/29
			inoc. date	21 dai	28 dai	35 dai	16 dai	28 dai	37 dai	22 dai	28 dai	37 dai
1. Untreated			0	0.5a [2]	9.8a	73.8a	5.0a	78.8ab	99.0a	15.0a	86.3a	99.8a
2. Curzate M8 72WP + Manzate 75WP	1.5 lb 0.75 lb	7 day	0	0.8a	1.3a	4.3 b	5.0a	11.3 c	22.5 d	15.0a	77.5ab	99.3a
3. Acrobat MZ 69WP	2.25 lb	7 day	0	0.3a	2.5a	4.8 b	5.0a	14.0 c	22.5 d	15.0a	82.5ab	99.3a
4. Tattoo C 6.25 SC	2.3 pint	7 day	0	0.3a	2.3a	5.5 b	5.0a	11.3 c	26.0 d	15.0a	70.0ab	94.0ab
5. Mankocide 39DF	3.0 lb	7 day	0	1.0a	3.5a	10.0 b	5.0a	38.8abc	77.5abc	15.0a	83.8ab	99.3a
6. Ridomil-Gold 4EC + Bravo WS 6SC	0.2 pint 1.5 pint	7 day	0	0.5a	2.0a	5.0 b	5.0a	23.3 c	55.0 bcd	15.0a	81.3ab	99.3a
7. Champ 2 4.6FL	2.67 pint	7 day	0	0.3a	5.3a	19.5 b	5.0a	48.8abc	83.0abc	15.0a	82.5ab	99.8a
8. Curzate M8 72WP + SuperTin 80WP	1.5 lb 0.16 lb	7 day	0	0.5a	1.5a	3.5 b	5.0a	10.5 c	25.5 d	15.0a	67.5 b	89.8 b
9. Polyram 80DF + SuperTin 80WP	2.0 lb 0.16 lb	7 day	0	0.3a	3.8a	8.3 b	5.0a	22.0 c	55.0 bcd	15.0a	78.8ab	98.8a
10. Acrobat MZ 69WP + SuperTin 80WP	2.23 lb 0.16 lb	7 day	0	0.3a	2.3a	4.0 b	5.0a	20.3 c	32.0 cd	15.0a	76.3ab	96.8ab
11. Tattoo C + SuperTin 80WP	2.3 pint 0.16 lb	7 day	0	0.5a	1.5a	5.3 b	5.0a	11.5 c	23.3 d	15.0a	78.8ab	95.5ab
12. Quadris 80 WDG + Bond	0.31 lb 0.1 pint	7 day	0	0.5a	3.3a	7.0 b	5.0a	28.3 bc	61.0abcd	15.0a	83.8ab	99.3a
13. IB 17022 4SC	0.18 pint	7 day	0	0.5a	2.8a	8.8 b	5.0a	22.5 c	60.0abcd	15.0a	86.3a	99.3a

[1] percentage of foliage infected as estimated visually on dates indicated
[2] = numbers followed by same letter are nsd at p = 0.05 (Tukey)

Table 7b. Progression of potato late blight through plots treated with registered fungicides, section 18 fungicides and experimental fungicides after the introduction of disease into the plots, 1996.

Chemical	Rate Formulation pints or lbs/acre	Spray Schedule 3 applications Timing a 72 hrs post inoc.[1] Timing b 5% foliar inf'n Timing c 15% foliar inf'n [2]	Relative area under the disease progress curve (max = 100)		
			Timing a	Timing b	Timing c
1. Untreated			9.5a [3]	36.3a	33.5ab
2. Curzate M8 72WP + Manzate 75WP	1.5 lb 0.75 lb	7 day	0.1 c	7.8 d	31.7ab
3. Acrobat MZ 69WP	2.25 lb	7 day	1.1 c	8.6 cd	32.7ab
4. Tattoo C 6.25 SC	2.3 pint	7 day	1.1 c	8.4 d	29.5ab
5. Mankocide 39DF	3.0 lb	7 day	2.1 c	22.3abc	33.0ab
6. Ridomil-Gold 4EC + Bravo WS 6SC	0.2 pint 1.5 pint	7 day	1.1 c	15.2 bcd	32.5ab
7. Champ 2 4.6FL	2.67 pint	7 day	3.1 c	25.8ab	32.8ab
8. Curzate M8 72WP + SuperTin 80WP	1.5 lb 0.16 lb	7 day	0.9 c	8.0 d	28.5 b
9. Polyram 80DF + SuperTin 80WP	2.0 lb 0.16 lb	7 day	1.7 c	14.8 bcd	31.9ab
10. Acrobat MZ 69WP + SuperTin 80WP	2.23 lb 0.16 lb	7 day	1.0 c	11.5 bcd	31.1ab
11. Tattoo C + SuperTin 80WP	2.3 pint 0.16 lb	7 day	1.0 c	9.2 bcd	31.5ab
12. Quadris 80 WDG + Bond	0.31 lb 0.1 pint	7 day	1.6 c	17.3abcd	33.0ab
13. IB 17022 4SC	0.18 pint	7 day	1.6 c	15.6 bcd	33.5ab

[1] = inoculation 7/23
[2] = 2 applications
[3] = numbers followed by same letter are nsd at p = 0.05 (Tukey)

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Funding Fed. Grant/MPIC

PROGRESS REPORT FY 1996 TO THE MICHIGAN POTATO INDUSTRY COMMISSION

Title: Control of Colorado Potato Beetle Utilizing Transgenic Potatoes as a Barrier Crop and Treating a Conventional Barrier Crop with Imidacloprid.

Investigators: Mark E. Whalon & Michael R. Bush. Pesticide Research Center and Department of Entomology, Michigan State University

Cooperator: Ed Grafius. Department of Entomology, Michigan State University

Justification:

In Michigan state, losses attributed to the Colorado potato beetle, *Leptinotarsa decemlineata* Say are estimated at $11 million/year or 13% of the gross crop value. CPB has developed resistance to virtually every insecticide used to control it. In our laboratory, we have even selected for CPB resistance to *Bacillus thuringiensis* (*B.t.*) insecticides.

Last year, Michigan potato growers had two new tactics to control CPB. A novel insecticide, imidacloprid (Admire or Provado, Bayer Corp.) provided exceptional control of CPB throughout Michigan and over 80% of Michigan growers used Admire at planting last year. Transgenic russet burbank potatoes that express the *Bacillus thuringiensis* (*B.t.*) endotoxin (Newleaf, Naturemark) will offer yet another new tactic for CPB control. Nevertheless history has demonstrated over and over again, that CPB has the ability to overcome control measures. CPB resistance to *B.t.* in the field is anticipated. We recommended that researchers integrate *B.t.*s with other control tactics. We have also have warned growers to treat imidacloprid "like gold" and not to overuse, misuse or rely solely on imidacloprid to control CPB.

Many growers have adopted crop rotation as one means to control CPB populations. This project uses *B.t.*-transgenic russet burbank potatoes and imidacloprid-treated russet burbank potatoes as barrier crops around the main crop of russet burbank potatoes in combination with crop rotation to reduce overwintering CPB from reaching the main crop. Ideally as overwintering CPB pass through the potato barrier crops, they are exposed to the toxic effect of imidacloprid or *B.t.* and most CPB fail to reach the main crop.

Progress by Objectives:

1) To observe and compare adult CPB movement through barrier crop of B.t.-transgenic (Newleaf) potatoes and imidacloprid (Admire) treated potatoes.

Studies in the greenhouse revealed that adult CPB moved through a 2- row *B.t.*-transgenic barrier faster than they moved through a convention potato barrier. When first exposed to the *B.t.* transgenic potatoes, beetles appeared to feed on the plants and either move on immediately or cease activity for 3 to 4 days and then move on. Over a 7-day period, 33% of the released male CPB died and 42% of the female CPB died when exposed to transgenic plant (compared to 23% male and 15% female mortality in conventional potatoes). CPB oviposition never occurred on the transgenic potatoes even though eggs were found on nearly all conventional potato plants.

Studies in the field, supported greenhouse observations. Seven days after release, 80% beetles were found in the first row of each barrier crops. The fewest CPB were found in the transgenic potatoes with 60% of the CPB dead. Three-fold more CPB found were in the Admire-treated plots, but 42% of them were dead. Meanwhile, all CPB found in the untreated, conventional barrier were alive. By the end of July, we had observed very few egg masses or larvae on the transgenic plants and damage was almost nonexistent. Likewise, few egg masses were found on the imidacloprid treated plants. A few larvae were found on the imidacloprid barrier plants but only on the terminal leaves while damage was minimal and confined in the first row of the barrier. In the conventional potato barrier, egg masses and larvae were abundant and damage was apparent and scattered throughout the barrier.

2) To compare adult CPB movement into the main crop after passing through the barrier crops.

In the greenhouse, 24 % of the released CPB passed through a 2-row barrier of conventional potatoes into the main crop over a 7-day period. In comparison, over 60% of the CPB passed through a 2-row barrier of transgenic potatoes into the main crop over 7 days. Planting the barrier two weeks in advance of the main crop did not effect these results, presumably because of the low CPB density in the greenhouse study.

In the field, we recovered 4.7 % of the 1,500 marked CPB (released in front of the barrier potatoes) in trench traps located between the barrier crop and the main crop. Only 0.1% of CPB released adjacent to the conventional potato barrier passed through 24 rows to be captured in the trench; CPB appeared satisfied with feeding on these potatoes and did not move. Meanwhile, 0.1% of CPB released adjacent to the imidacloprid plot were recaptured in the trench. Presumably, most of these beetles perished in the barrier. However, 9.7% of the CPB released adjacent to the transgenic barrier were captured in the trench and few dead beetles were found suggesting that CPB movement was enhanced when exposed to transgenic plants.

Conclusions:

Based on plant damage, B.t. transgenic plants provided exceptional control of CPB in the greenhouse and in the field. CPB did not oviposit on these plants, larvae did not survive on these plants and there was some mortality among adults. However, both studies revealed that CPB adult movement was enhanced in transgenic potato crops. Therefore, a *B.t.*-transgenic barrier would not be an effective resistance management strategy against mobile CPB adults.

Potatoes treated with imidacloprid provided control of CPB in the field and was active against adults as well as larvae. Results show that a 24-row barrier of imidacloprid treated potatoes did reduce CPB movement into the main crop by 99.9% at low beetle densities. Adults that reach the main crop may be exposed to other mortality agents such as grower applied insecticides (excluding Provado). This strategy will conserve CPB susceptibility to imidacloprid by exposing only the migrating adults to the toxic effect of imidacloprid. This resistance management strategy will help prolong the market life of imidacloprid and can reduce grower costs (but field monitoring of CPB density in the main crop is advised).

Funding Fed. Grant/MPIC

PROGRESS REPORT FY 1996 TO THE MICHIGAN POTATO INDUSTRY COMMISSION

Title: Screening Green Peach Aphids for Resistance to Imidacloprid and Other Insecticides Used By Michigan Growers in Potatoes.

Investigators: Mark E. Whalon & Michael R. Bush. Pesticide Research Center and Department of Entomology, Michigan State University

Justification: In 1995, a new systemic insecticide, imidacloprid (Admire® and Provado®, Miles Corp.), was released to potato growers. This insecticide has a new mode of action (a nicotinergic acetylcholine receptor inhibitor, *i.e.* a nerve poison) that provided many Michigan growers with the only effective means to control Colorado potato beetle (CPB) populations. It is estimated that over 75% of the total potato acreage in Michigan was treated with imidacloprid. Although not the primary target of imidacloprid, this insecticide provides excellent control of green peach aphid (GPA) on potatoes early in the growing season. We anticipate that Michigan growers will continue to rely heavily on imidacloprid to control CPB and GPA, thus subjecting these pests to intense selection pressure. GPA has already demonstrated resistance to over seventy insecticides. This study generated the baseline susceptibility of GPA to imidacloprid. This baseline susceptibility will used by researchers to monitor for and confirm any reports of imidacloprid resistance.

Progress by Objectives:

1) To determine base-line susceptibility to imidacloprid for green peach aphid

We bioassayed each colony for their response to imidacloprid with a slide-dip technique. Adult aphids were exposed to serial doses of imidacloprid and their mortality assessed 48 hours after exposure. Standard probit-mortality analysis was used to produce an aphid dose-response curve to imidacloprid. The LD_{50} value of this curve was 8.0 ± 2.2 ppm imidacloprid.

2) To establish diagnostic doses of imidacloprid to screen green peach aphid for resistance.

The resulting dose/response curve was analyzed to select diagnostic doses to screen other colonies and field populations. When using the slide-dip technique, researchers should expose GPA to a diagnostic dose of 15-20 ug/ml or 15-20 ppm imidacloprid, and assess mortality after 48 hours. This dose will kill almost all susceptible GPA and survivors are likely to be resistant individuals.

Conclusions:

Four-fold resistance in GPA to imidacloprid has been reported in Europe. Thus it is advisable that GPA populations in Michigan be screened for resistance with the technique and diagnostic dose reported here. MSU researchers should be contacted immediately if resistance is suspected. By detecting resistance early, we can better manage resistance and avoid a control problem for the green peach aphid in Michigan potatoes and other vegetable crops.

Funding Fed. Grant

Contribution of Amino Acids and Reducing Sugars to Color Development in Potato Chips

V. Chonhenchob, J.N. Cash and R. Brook

Introduction

Browning or darkening of potato chips has received a great deal of study because consumers usually equate light colored potato chips with good quality. This dark color formed by frying potato slices into chips is due to the Maillard reaction involving reducing sugars, amino acids and high temperatures. Most previous studies have focused on the effect of sugar (reducing and non-reducing) concentrations in potato tubers at harvest or during storage and its relationship to chipping qualities of potatoes. Reducing sugar levels have usually been used as a predictive test of the suitability of material for processing. However, it has been shown that information on sugar alone may not always predict the final color formation of chips. This variation is most likely due to the differences in free amino acid content in the potato. A few studies have been aimed at determining the effect of amino compounds on color development in potato chips but more information in this area is needed.

Objectives:

The primary objectives of this study are:

I. To determine the contributions of selected amino acids on color development in potato chips, based on model systems.

2. To determble amino acid composition and amino group content of good chipping versus poor chipping potato varieties.

Experimental Procedures:

This work has been separated into model system studies and storage studies.

Part I: Model system study

1A. Filter paper disks impregnated with solutions of amino acids and sugars

Stock solutions (0.05M) of amino acids (arginine, aspartic acid, glutamic acid, glycine, isoleucine, leucine, lysine, methionine, tyrosine, valine) and sugars (fructose, glucose, and sucrose) were prepared in 0.2M phosphate buffer solutions. The working solutions were adjusted to pH 6.5 with 0. IM HCl or 0.IM NaOH. Solutions for impregnation of filter paper disks were prepared as follows: 1) buffer only (control); 2) glucose only; 3) fructose only; 4) sucrose only; 5) each amino acid only; 6) glucose plus each individual amino acid; 7) fructose plus each individual amino acid; and 8) sucrose plus each amino acid. For each treatment solution 30 whatman No. 2 filter paper disks, 5.5 cm diameter, were soaked for 30 mins., air-dried and fried in fresh vegetable oil at 360F for 2 minutes with stirring. Each sample was done in duplicate. The color of chips was evaluated using Hunter CDM and Agtron E-10 colorimeter.

1B. Filter paper disks impregnated with potato juices

Five potato varieties, Atlantic, Mainestay, Shepody, Snowden, and Superior were obtained from the Michigan State University Montcalm Research Farm. Two hundred gms of tuber tissue were taken from the middle of 8 peeled potatoes and juiced in an Acme juicerator. The potato juice samples were centrifuged at 3,500 rpm for 2 min To each tube containing 9 mL phosphate buffer solution (pH 6.5) was added 1 ml juice sample and the solution was mixed. Filter paper disks were loaded with l ml juice solution and fried in vegetable oil at 360F for 2 min. The remaining juices were kept frozen for ninhydrin analysis.

2. Solutions of amino acids and sugars: Effect of type and concentration of amino acids

Solutions ranging from 0.1 to 0.5M of glycine, leucine, and aspartic acid were prepared from lM stock solutions of these amino acids in 0.2M phosphate buffer (pH 6.5). One mL of each amino acid was mixed with l ml each of glucose and sucrose (0.lM prepared in 0.2M phosphate buffer, pH 6.5). The volume of the mixture was adjusted to 10 mL with 0.2M phosphate buffer. Tubes containing the mixture were vortexed for l min and heated to 300F for 2 mins. in an oil bath.

Analytical methods

1. Sugar determination: YSI-2700 Glucose Analyzer

The preparation of samples for glucose and sucrose analysis were according to Sowokinos and Preston (1988). The sugars in the extract were analyzed in duplicate using a YSI-2700 glucose analyzer (Yellow Springs instrument Co., Yellow Springs, OH). This instrument measures the hydrogen peroxide produced from the reaction of glucose with the immobilized glucose oxidase in the system.

2. Amino acid determination

Potato extract containing free amino acid was prepared by passing the juice through a C18 filter (Sep-Pak, Water Associates, Inc.), and washing twice with distilled water. Sample was derivatized with PITC (Phenylisothiocyanate) before injecting in the HPLC column. The analyzer unit (Water Associate, inc.) consisted of, the model 710B Waters WISP solvent delivery system, a Pico-Tag column (3.9 x 300 mm i.d.), and a model 440 UV-Visible wavelength detector at 254 nm. The flow rate was set at 1.0 ml/min. Standard amino acids were obtained from Sigma Chemical Company (St. Louis, MO).

3. Amino group determination

1) Ninhydrin assay

NinLydrin reaction was used to determine the concentration of free amino groups in potato juice samples. Ninhydrin was prepared by dissolving 2.0 g ninhydrin and 0.3 g hydrindantin in 75 mL dimethyl sulfoxide (DMSO). To the mixture was then added 25 mL of 4M lithium acetate buffer. One mL of sample solution was mixed with I mL ninhydrin solution in a test tube. The tube was vortexed and then heated in a boiling water bath for 15 mins. To the cooled reaction solution was added 6 mL of 50% ethanol-water. The tubes were vortexed and any insoluble particles were removed by centrifugation. Absorbance of the solution was read against a reagent blank. The mixture was diluted with additional 50% ethanol to get the absorbance within the most sensitive range. Concentration of free amino groups was determined spectrophotometrically at 570 nm.

4. Color measurement

The color of the fried paper disks and potato chips were measured using the Agtron E- 10 colorimeter (Fillper Magnuson, Reno, NV) and the Hunter CDM. An Ultraspec II LKB Biochrom spectrophotometer was used to measure the absorbance of the model solutions at 420 nm. Data for mean scores were reported (> 60 = excellent, 56-60 = acceptable, 50-55= marginally acceptable).

5. Statistical Analysis

Single and multiple regression analyses were performed using the Statview data analysis program.

Research progress

Part I: Model systems

1. Filter paper disks

Development of color in filter paper disks simulating potato chips is presented in Figure 1. Individual amino acids in combination with each sugar when fried in vegetable oil at 360F for 2 min produced varying degrees of Maillard browning, as measured by the Agtron colorimeter. Lysine, tyrosine, and glycine produced unacceptable dark colored disks, as shown by their low Agtron numbers, while arginine, aspartic, and glutamic acid produced acceptable light colored disks with high Agtron numbers.

As expected, amino acid-glucose systems produced more intense color than amino acid-sucrose systems. Filter paper disks impregnated with buffered sugar solutions yielded darker color than those with buffer alone since the Maillard reaction and caramelization of sugars can occur simultaneously upon heating. It is likely that some hydrolysis of sucrose may have occurred under these heating conditions at pH 6.5, generating glucose and fructose which could enter into the Maillard reaction. In contrast, buffered amino acid systems produced only slight color.

2. Solutions of amino acids and sugars (Figures 2,3 and 4).

Sugar concentration of 0.1 M in phosphate buffer when mixed with different concentration of amino acids produced various degrees of brown color. The least intense colors were formed at 0.3M amino acids for amino acid-glucose systems and at 0.4M for amino acid-sucrose system. As expected, glucose produced markedly pronounced brown color as compared to sucrose. The results indicated that the color development in the model systems depends on the relative proportion of amino acids and sugars as expressed in terms of molar ratio.

3. Color comparison of filter paper disks impregnated with potato juice and actual potato chips.

Five potato varieties, Atlantic, Mainstay, Shepody, Snowden, and Superior were selected based on their chipping qualities. Snowden and Atlantic generally produce light color chips, while Shepody and Mainstay generally give darker ships. The color development (Figure 5) of the model filter papers impregnated with potato juice of the these varieties was consistent with the color of chips produced from these tubers.

4. Comparison of amino acid content of selected varieties at harvest.

Total amino acid contents of Snowden, Atlantic, Superior, Shepody and Mainestay were determined at harvest. Snowden and Atlantic both had thhe lowest amino acid content and Shepody had the highest content, with Superior and Mainestay at intermediate levels between these extremes (Figure 6). However, when chips were manufactured from these samples, Mainestay had a darker Agtron color than any other variety but it also had the highest glucose content of all the samples.

Conclusions.

1. Amino acid content may be responsible for the variations in correlations between reducing sugar content and chipping color.

2. Amino acid type and amino group content may be significant in the Maillard browning reaction.

3. Prediction of chip color may be improved by combining information on amino acids with sugar content in chipping potato selections/ varieties.

Figure 1. Color Development of Filter Paper Disks with Amino Acids and Sugars

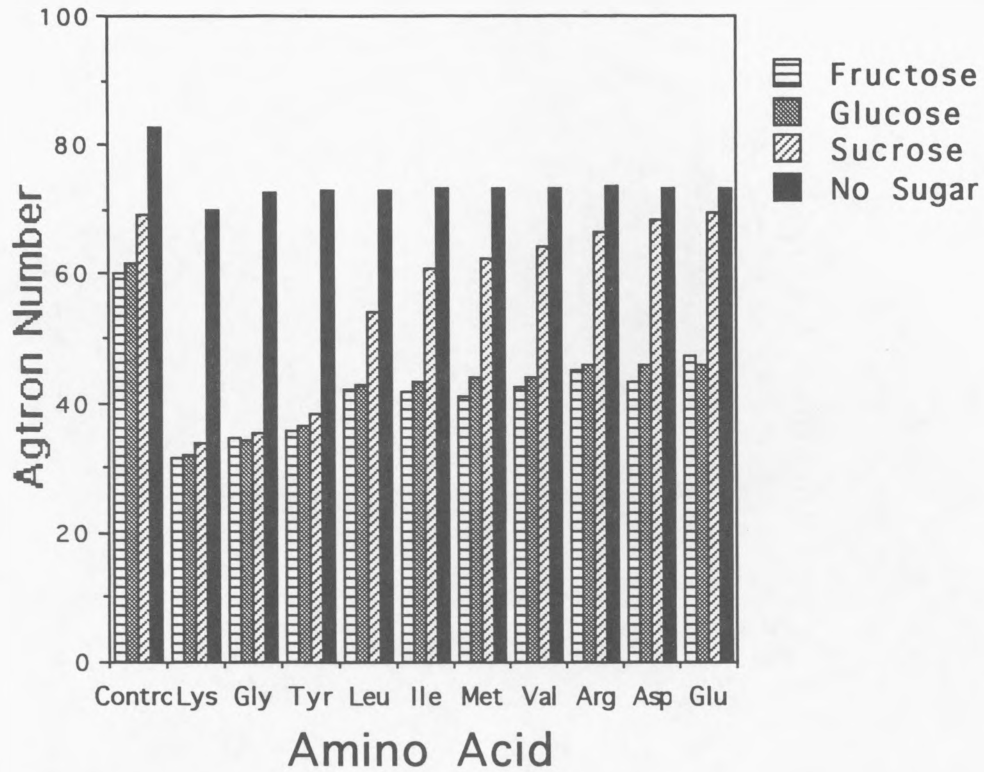

Figure 2. Color development with amino acid-sugar solutions at varying amino acid concentrations

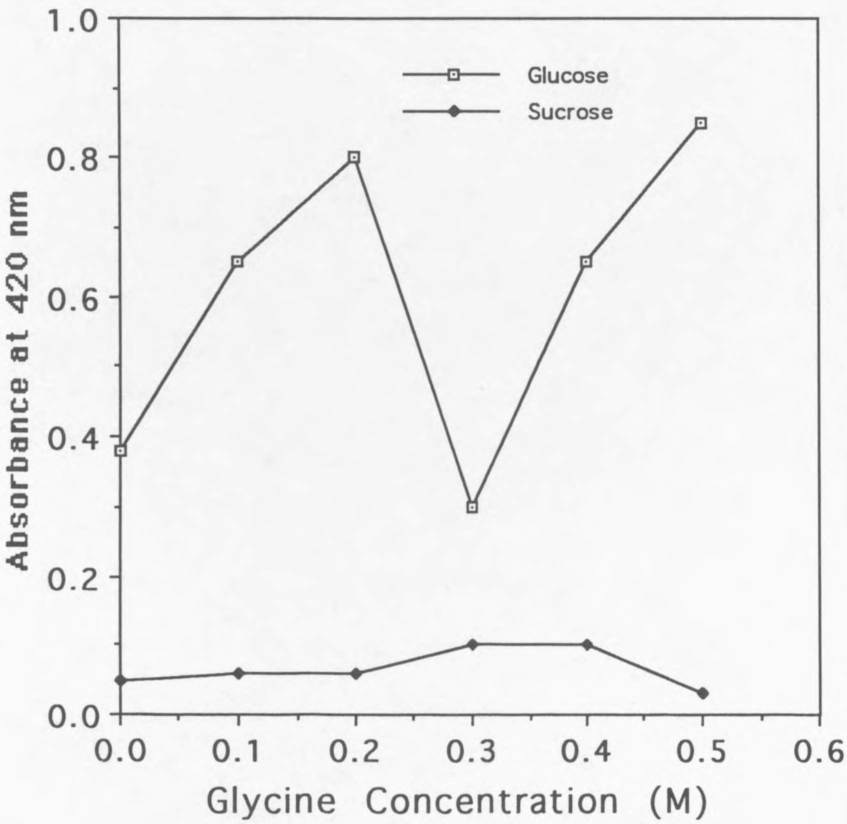

Figure 3. Color development with amino acid sugar solutions at varying amino acid concentrations

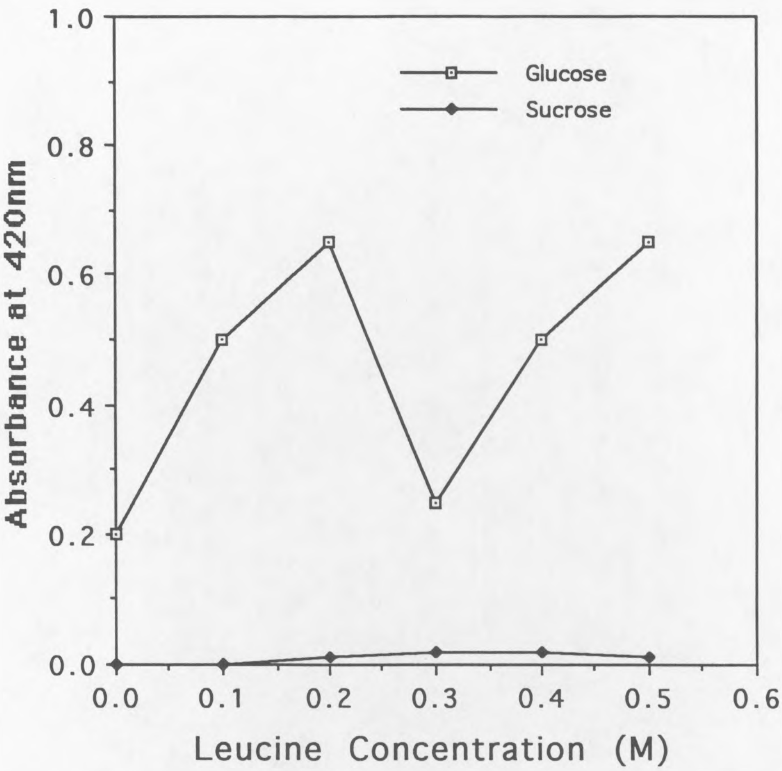

Figure 4. Color development of amino acid-sugar solutions with varying concentrations of amino acids.

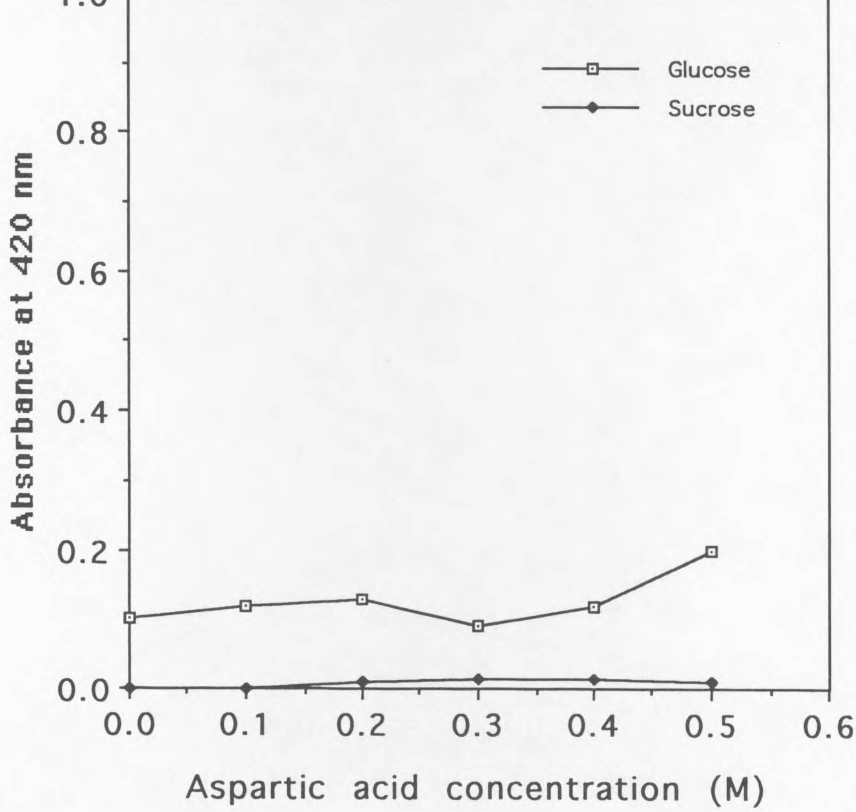

Figure 5. Color comparison between filter paper disks impregnated with potato juice and potato chips.

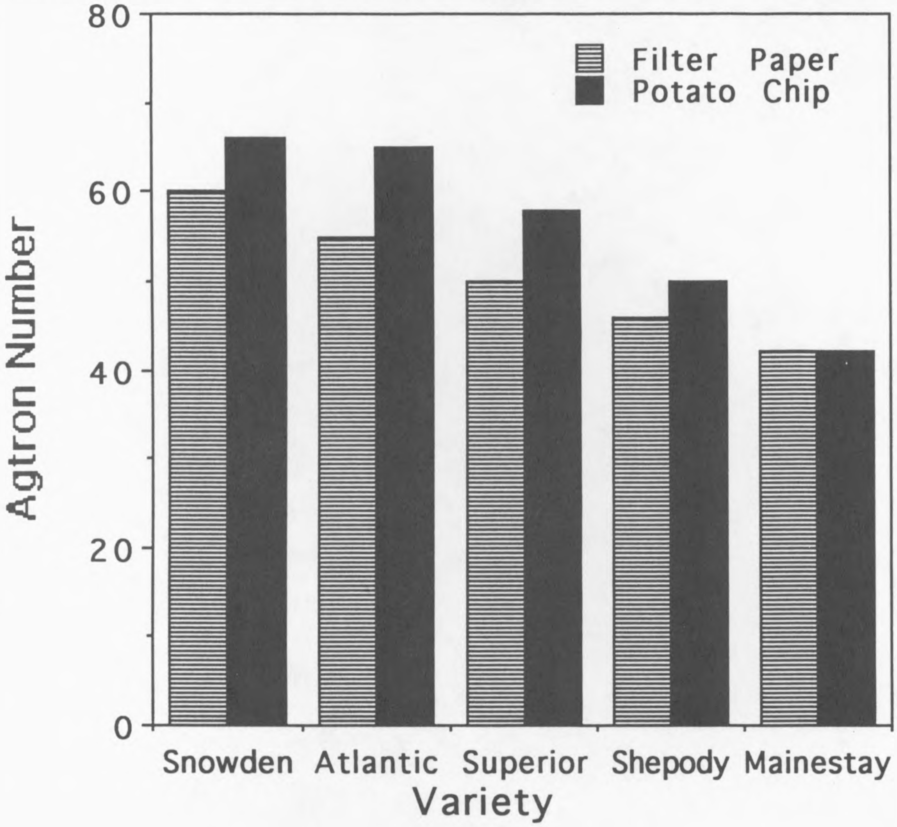

Figure 6. Total amino acid content of selected potato varieties.