1990
MICHIGAN POTATO RESEARCH REPORT

VOLUME 22

Michigan State University
Agricultural Experiment Station

In Cooperation With

The Michigan Potato Industry Commission

THE MICHIGAN POTATO INDUSTRY COMMISSION

February 25, 1991

To All Michigan Potato Growers & Shippers:

The Michigan Potato Industry Commission, Michigan State University's Agricultural Experiment Station and Cooperative Extension Service are happy to provide you with a copy of the results from the 1990 potato research projects.

This years report includes research projects funded by the Michigan Potato Industry Commission as well as projects funded through the USDA.

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

Best Wishes for a prosperous year,

The Michigan Potato Industry Commission

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

TABLE OF CONTENTS

1990 MSU POTATO RESEARCH REPORT

R.W. Chase, Coordinator

INTRODUCTION AND ACKNOWLEDGEMENTS

The 1990 Potato Research Report includes reports of potato research projects conducted by MSU potato researchers at several different locations. The 1990 report is the 22nd report which has been prepared annually since 1969. This volume includes research projects funded by the Special Federal Grant 88-34141-3372, the Michigan Potato Industry Commission and 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 type of support and cooperation that makes for a productive research program.

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 the needs and directions of Michigan potato research.

A special thanks to Dick Kitchen for his many years of dedication to the potato research program of the Department of Crop and Soil Sciences and the Montcalm Research Farm. In 1990, Richard Crawford was hired to assist in the day-to-day operations at the Montcalm Research Farm. This has allowed Dick Kitchen greater flexibility to assist in the potato variety breeding and evaluation work which is located at other MSU facilities beyond the Montcalm Research Farm. Thanks also to Dr. Kazimierz Jastrzebski, visiting scientist from Poland, for his contribution to the project. Also, a special thanks to Jodie Schonfelder for the typing and preparation of this report.

WEATHER

The 1990 weather data for the Montcalm Research Farm as compared to the 15 previous years are presented in Tables 1 and 2. Temperatures were very near the 15 year average throughout the season except for May when the average maximum temperature was 5° below the average. In general, emergence was very slow as soil temperatures remained in the 40's. The average minimum temperature for May was the same as the 15 year average, however, maximum air temperatures were not sufficient to warm the soil. There were only two days that temperatures were greater than 90° and six days that it was between 85 and 90°. Rainfall was well distributed throughout the growing season. The total rainfall for April through September was over 2 inches above the 15 year average.

SOIL TESTS

Soil tests for the general plot area were:

	lbs/A				%	Cation
pH	P_2O_5	K_2O	Ca	Mg	Organic Matter	Exchange Capacity
6.2	445	236	926	176	1.5	5 me/100 g

FERTILIZERS

The general plot area was planted to green manure soybeans in 1989, disked in the fall and seeded to rye, which was plowed down before planting. Except in fertilizer trials where the amounts of fertilizers used are specified in the project report, the following fertilizers were used in the potato trials:

Plowdown	0-0-60	70 lbs/A
Banded at planting	20-5-20	500 lbs/A
Sidedress with irrigation	28-0-0	whites and reds - 80 lbs N/A russets - 120 lbs N/A

HERBICIDES AND HILLING

Most of the hilling was completed by the end of May, before soil cracking. Immediately after hilling, a tank mix of metolachlor (Dual) at 2 lbs/A plus metrabuzin (Lexone) at 1/2 lb/A was applied on May 24. No further tillage was done until harvest. For the potato breeding projects, a tank mixture of Dual and Lorox was used.

IRRIGATION

During the growing season, potato plots received 7-8 inches of supplemental irrigation in 9-10 separate irrigations. Irrigation scheduling was followed using the MSU irrigation scheduling program. Nitrogen (28% liquid) was injected into the irrigation water with three applications of 30, 30 and 15 lbs N/A for the round whites and reds and four applications of 30 lbs N/A each for the russets.

INSECT AND DISEASE CONTROL

With the withdrawal of Aldicarb, Vapam was injected into the plowed plot area (thanks to equipment and material provided by Dr. George Bird and Mr. John Davenport) approximately two weeks before planting. At planting, Thimet was applied at 11.3 ounces/1000 row feet. Foliar fungicide application was initiated on June 26 which was determined by the MSU Potato Blight Forecaster Program. Fungicides used were Bravo and Dithane M45 which were alternated. Eleven separate applications were made during the season.

Foliar insecticides were initiated on June 26 and Imidan + PBO and Cygon were used. There were six applications of Imidan + PBO and three applications of Cygon.

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

Year	April		May		June		July		August		September		6-Month Average	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1976	58	35	63	41	79	57	81	58	80	53	70	46	71	48
1977	62	37	80	47	76	50	85	61	77	52	70	53	75	50
1978	50	31	67	45	78	50	81	56	82	57	75	52	72	49
1979	50	33	66	44	74	55	82	57	77	55	76	47	71	49
1980	49	31	69	42	73	50	81	58	81	58	70	49	71	48
1981	56	35	64	39	73	50	77	51	78	53	67	47	69	46
1982	53	28	72	46	70	44	80	53	76	48	66	44	70	44
1983	47	28	60	38	76	49	85	57	82	57	70	46	70	46
1984	54	34	60	39	77	54	78	53	83	55	69	45	70	47
1985	58	38	70	44	71	46	81	55	75	54	70	50	71	48
1986	60	36	70	46	77	50	82	59	77	51	72	50	73	49
1987	61	36	77	46	80	56	86	63	77	58	72	52	76	52
1988	52	31	74	46	82	53	88	60	84	61	71	49	75	50
1989	56	32	72	34	81	53	83	59	79	55	71	44	74	46
1990	NA	NA	64	43	77	55	79	58	78	57	72	47	NA	NA
15-YR. AVG.	55	33	69	43	76	51	82	57	79	55	71	48	72	48

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

Year	April	May	June	July	August	September	Total
1976	3.27	4.03	4.22	1.50	1.44	1.40	15.86
1977	1.65	0.46	1.66	2.39	2.61	8.62	17.39
1978	2.34	1.35	2.55	1.89	5.90	2.77	16.80
1979	2.58	1.68	3.77	1.09	3.69	0.04	12.85
1980	3.53	1.65	4.37	2.64	3.21	6.59	21.99
1981	4.19	3.52	3.44	1.23	3.48	3.82	19.68
1982	1.43	3.53	5.69	5.53	1.96	3.24	21.38
1983	3.47	4.46	1.19	2.44	2.21	5.34	19.11
1984	2.78	5.14	2.93	3.76	1.97	3.90	20.48
1985	3.63	1.94	2.78	2.58	4.72	3.30	18.95
1986	2.24	4.22	3.20	2.36	2.10	18.60	32.72
1987	1.82	1.94	0.84	1.85	9.78	3.32	19.55
1988	1.82	0.52	0.56	2.44	3.44	5.36	14.14
1989	2.43	2.68	4.85	0.82	5.52	1.33	17.62
1990	1.87	4.65	3.53	3.76	4.06	3.64	21.51
15-YR. AVG.	2.60	2.78	3.04	2.42	3.74	4.75	19.33

Funding Federal Grant/MPIC

1990 POTATO VARIETY EVALUATIONS

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The objectives of the evaluation and the management studies are to identify superior varieties for fresh market or for processing and to develop recommendations for the growers of those varieties. The varieties were compared in groups according to the tuber type and skin color and to the advancement in selection. The most promising varieties were tested in management profile studies for their reaction to the spacing and nitrogen fertilization. Total and marketable yields, specific gravity, tuber appearance, incidence of external and internal defects, chip color, consistency and after cooking darkening as well as susceptibilities to common scab and bruising were determined. Before testing for chip color, the varieties were stored at 45 and 50°F. Samples to be tested for bruising were stored at 40°F.

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

Both round and long variety groups were harvested at two dates. The yield was graded into four size classes, incidence of external and internal defects was recorded, and samples for specific gravity, chipping, bruising and cooking tests were taken. Chip quality was assessed on 20-tuber samples, taking one slice from each tuber. Chips were fried at 365°F. The color was measured with E-10 Agtron colorimeter. Prior to chipping, the tubers were stored at 45 and 50°F. Texture and after cooking darkening were assessed on five tuber samples. For the bruising test, the 20-tuber samples were stored at 40°F. Tubers were artificially bruised in a wooden drum after three months storage. After treatment, the tubers were stored three days for blackspot development and were peeled prior to bruise examination. Unbruised samples served as control.

RESULTS

A. ROUND WHITE VARIETIES

Eleven varieties and five breeding lines were tested in the trial. Onaway, Atlantic, Eramosa and Superior were planted as checks. The results are presented in Tables 1 and 2. The average yield level was high, but lower than in 1988-89. Onaway was consistently the top yielder in all three years at the first date of harvest. Its yield at second date of harvest was only slightly higher than at first date with high internal quality. Steuben was consistently good for the past three years at both harvest dates. The difference in yield between the two harvest dates was large. Steuben therefore is late, but early bulking. Steuben had better appearance than Onaway, higher specific gravity and acceptable chipping quality. It has a good potential in Michigan, both for fresh market and chipping industry. Snowden confirmed its potential as a chipping variety, however, it showed a susceptibility to blackspot bruising. Saginaw Gold, MS700-70 and MS716-15 produced satisfactory yields and their chipping quality was good. They appear superior to Atlantic in the overall rating. All varieties did not darken immediately after boiling. However, after one hour some of them were unacceptable. These were: Steuben, ND2224-5 and Coastal Chip. Some sloughing was observed in Atlantic, Snowden, MS716-15 and AF875-16. In the bruising test, the best varieties were Eramosa, MS700-70, MS401-1 and Onaway, while the worst ones were PGI-3, AF875-16 and AC80545-1 along with Snowden and Somerset.

Variety Characteristics

Eramosa - Very early variety with smooth, round to oblong tubers of good appearance. Yield and specific gravity were low. Chipping quality was low and had few internal defects.

Onaway - Early, high yielding variety. Specific gravity and chipping quality low. Tubers are round to oblong, large and rough. Susceptible to growth cracks and early blight and storability is low.

LaBelle - Late variety. Yield varied considerably between years. Specific gravity was medium. Chipping quality was rather low.

Gemchip - Late, high yielding variety. Tubers are large, round to oblong, good appearance. Specific gravity low. Chips were good and some hollow heart incidence was noted.

Steuben (NY81) - Late, supreme yielder and medium specific gravity. Tubers are very large, round, of good appearance and early set. Few internal defects. Chipping quality good out of the field.

Snowden (W855) - Medium late, high yielding variety. Specific gravity comparable to Atlantic, but higher internal quality and excellent chips. Tends to set many tubers. Rather susceptible to blackspot bruising.

Atlantic - Medium late, chipping variety. High specific gravity. Susceptible to internal defects (hollow heart, vascular discoloration, brown spots), scab, white knot and soft rot.

MS716-15 - Medium-late, chipping variety. Medium-high yielding, high specific gravity, well shaped tubers and medium sized. Excellent chips, no internal defects. Susceptible to common scab.

MS700-70 - Late, high yielder, high specific gravity variety and chips well out of field. Eyes are medium deep, appearance a little rough. Susceptible to common scab.

Saginaw Gold - Mid-season, high yielding variety. Good culinary quality. Chipping quality good, few internal defects, but specific gravity a little lower than in Atlantic. Susceptible to early blight in foliage and tubers.

Somerset - Medium late variety of oblong, well shaped and medium specific gravity tubers. Good chipping quality. Susceptible to greening in the field, scab and growth cracks. Yield varied much between years.

AF875-16 - Medium late variety of high specific gravity, but average yield potential. Good chipping quality, few internal defects.

AC80545-1 - Very late variety of very tall vine. Produced very high yields in 1990, but its yield potential is rather overestimated in 1-row experiments. Medium specific gravity. Tubers large and well shaped. Chips were good.

PGI-3 - High yielding variety of excellent specific gravity. Tubers were rather small in 1990. Hollow heart incidence was recorded, despite small size. Susceptible to scab.

Coastal Chip - Low yield and specific gravity. Many tubers had hollow heart. Susceptible to scab.

MS401-1 - Yellow-flesh variety with outstanding chipping quality, good tuber shape, but tubers are rather small. Specific gravity below that of Atlantic.

B. LONG VARIETIES

Seven varieties and five breeding lines were tested. They were harvested 112 and 142 days after planting (Tables 3 and 4). Castile was outstanding in yield. High yields were also produced by Calgold, W1005 and A7411-2. Castile has good potential in Michigan for fresh market and processing. A7411-2 showed good potential for processing. The other varieties require further testing. Long type varieties as a rule were very susceptible to blackspot. They all require careful handling. However, ND1538-1 was a good exception. It also had well shaped tubers and high culinary quality. In the boiling test, Russet Norkotah, Frontier Russet and MN10874 showed some darkening after one hour. Directly after boiling, however, all varieties were good to very good in color.

Variety Characteristics

Castile (B7592-1) - A late maturing variety and a top yielder. Produces oblong to long, very large, white-skin tubers of few internal defects. Specific gravity medium. Susceptible to blackspot.

Calgold - High yielding, russet variety. Large tubers of low specific gravity. Susceptibilities to blackspot and hollow heart were noticed in 1990. Resistant to scab.

W1005 - High yield and specific gravity. Resistant to scab, susceptible to blackspot.

A7411-2 - Late, medium yield, high specific gravity, good tuber appearance and few internal defects. Excellent potential for processing. Susceptible to blackspot.

Russet Nugget - Very late, average yield and very high specific gravity. Susceptible to hollow heart and blackspot.

A78242-5 - Medium late, russet variety. Average yield and specific gravity medium low. Tubers blocky with good appearance. Leaves display mosaic at early stage which is not due to virus infection.

Eide Russet (MN10874) - Yield in 1990 on the level of Russet Burbank. Specific gravity rather low. Few internal defects. Resistant to scab. Susceptible to blackspot.

ND1538-1 - Average yield, good culinary quality. Low specific gravity. Resistant to blackspot. Russet type, good shape and appearance.

Frontier Russet - Medium late variety with average yields. Specific gravity variable in years. Good appearance and cooking quality. Resistant to scab. Hollow heart might be a problem in some years.

Russet Norkotah - Early to mid-season variety. Tubers are oblong to long, well shaped. Yields were rather low, specific gravity low. Resistant to scab. Some after cooking darkening was noticed in some years as well as susceptibility to *Verticillium* wilt.

Russet Burbank - Used as a check. Late maturity, average yields. Good specific gravity for processing, but produced a high percent of undersized and off-shape tubers. Excellent appearance after boiling. Resistant to scab.

Cal-Ore - Low yield, low specific gravity. No prospect for success in Michigan.

C. RED VARIETIES

Eight varieties and one breeding line were tested. They were harvested 126 days after planting (Table 5). The group was distinguished in yield, resistance to blackspot and low to very low specific gravity. Viking was the best yielder among all varieties tested in 1990. It had no internal defects and was very resistant to blackspot. Iditared yielded very well, but had much hollow heart. In the boiling test all performed well. After one hour from boiling, ND2224-5 was unacceptably dark.

Variety Characteristics

Viking - Medium late, excellent yielder. Specific gravity low. Good appearance. Minimal internal defects. Very resistant to blackspot. Large tubers.

Iditared - Medium late, excellent yielder. Specific gravity very low. Much hollow heart in 1990. Large tubers.

Sangre - Medium late, good yielder. Specific gravity very low. Has excellent skin color at harvest. Very slow early establishment and pre-cutting of seed is recommended. Large tubers.

Rose Gold - Mid-season variety. Good yielder. Pink skin, yellow flesh. Specific gravity medium. Few internal defects.

Red Gold - Mid-season, high yielding variety. Pink skin, yellow flesh. Minimal internal defects. Specific gravity low. Has tendency to poor sizing.

ND2224-5 - Medium early, high yielding variety. Specific gravity very low. Resistant to blackspot.

Norland - Used as a check variety. Average yield. Light red skin color at harvest. Specific gravity very low. Minimal internal defects. Short dormancy.

Dark Red Norland - Line selection from Norland. Agronomic characters comparable to Norland, but has more desirable red skin color.

D. NORTH CENTRAL REGIONAL TRIAL

The North Central Trial is conducted in 14 states and provinces, in a wide range of environments, to supply the final data for the release of new varieties. Twelve breeding lines of various tuber type were compared in this trial in 1990. Red Pontiac, Russet Burbank, Norchip, Norland and Norgold Russet were planted as check varieties. Two MSU lines, MS401-1 and MS402-8, were included in the trial in 1990. The results are presented in Table 6.

The most perspective lines for Michigan seem to be: LA12-59, W856, W870, W877 and MS401-1. MN13540, MN13740 and ND1538-1 show promise and should be further tested.

LA12-59 is a red, high yielding line. Excellent tuber appearance, no internal defects. It chips well, but its specific gravity is rather too low for processing use. Wisconsin lines W856, W870 and W877 produced high yields at high to very high specific gravity. They all chipped well and had few internal defects. MS401-1 was the best chipper. However, its yield was medium high and tubers were small.

E. ADAPTATION TRIAL

More advanced lines from other states are compared in this trial for adaptation in Michigan (Table 7). Best of these should enter North Central Trial next year. The most promising lines are: (a) for fresh market - E11-45, NY84 and NY78. They are high yielding, but their specific gravity is low. (b) for chipping - E55-27, MS401-7, MS401-2 and E55-35. These are characterized by an average to good yield potential, high to very high specific gravity, lack of internal defects and an acceptable to good chipping quality.

Table 1.

ROUND WHITES - FIRST DATE-OF-HARVEST
MSU MONTCALM RESEARCH FARM
AUGUST 13, 1990 (98 DAYS)

VARIETY	YIELD(CWT/A) US #1	YIELD(CWT/A) TOTAL	PERCENT SIZE DISTRIBUTION US #1	<2"	2-31/4"	>31/4"	PO	SP.GR.	AGTRON COLOR	DEFECTS* HH	VAS	IBS	3 YEAR US # 1 YIELD**
ONAWAY	395	444	89	5	63	26	6	1.066	48	0	1	0/37	430
STEUBEN	385	404	95	4	75	20	1	1.077	75	6	0	0/40	390
AC80545-1	369	401	92	6	89	4	2	1.077	79	0	0	0/13	---
ERAMOSA	321	345	93	6	80	13	1	1.065	57	4	1	0/32	292
SUPERIOR	311	335	91	8	77	14	1	1.074	76	3	1	0/32	366[a]
MS401-1	299	365	82	17	79	3	1	1.085	81	4	0	0/9	---
GEMCHIP	286	321	89	9	82	7	1	1.070	70	0	0	0/15	---
MS716-15	280	319	88	12	84	3	1	1.086	72	0	0	0/6	310
ATLANTIC	274	316	87	11	75	11	3	1.085	76	11	0	0/25	344
COASTAL CHIP	274	311	88	10	77	11	2	1.077	79	7	0	0/26	---
AF875-16	274	306	89	9	83	6	2	1.090	73	1	0	0/15	296[a]
SAGINAW GOLD	264	320	82	16	81	1	2	1.078	75	0	0	0/3	341
MS700-70	264	309	85	14	81	5	1	1.083	75	1	0	2/11	319
SNOWDEN	257	328	78	21	77	2	0	1.085	76	0	0	0/4	283
LABELLE	235	258	91	8	77	14	1	1.075	73	0	0	0/27	325[a]
SOMERSET	202	254	80	16	78	1	5	1.076	76	0	0	0/2	306
AVERAGE	293	333	87					1.078					

* INTERNAL DEFECTS/NUMBER OF OVERSIZE (>31/4") TUBERS CUT
** MEAN OF 1988 - 90
a MEAN OF 1989 - 90

PLANTED MAY 7,1990
HARVESTED AUG.13,1990
SPACING 12" X 34"

Table 2. ROUND WHITE - SECOND DATE-OF-HARVEST
MSU MONTCALM RESEARCH FARM
SEPTEMBER 24, 1990 (140 DAYS)

	YIELD(CWT/AC)		PERCENT SIZE DISTRIBUTION						DEFECTS*						3 YEAR[a]
VARIETY	US #1	TOTAL	US #1	<2	2-31/4	>31/4	PO	SP.GR.	HH	VAS	IBS	SED[c]	BLACKSPOT RATING**	SCAB RATING	US# 1 YIELD
AC80545-1	573	632	90	6	65	25	4	1.076	8	4	0	0/37	M	MS	---
STEUBEN	540	568	95	4	63	32	1	1.076	2	3	1	1/40	S	S	540
GEMCHIP	480	514	93	5	81	13	1	1.071	10	1	0	1/39	M	MS	---
SNOWDEN	433	492	88	11	84	4	1	1.082	1	4	2	0/15	M	S	429
MS716-15	429	485	89	11	84	5	1	1.086	0	1	0	0/20	R	S	420
SUPERIOR	424	453	94	5	83	11	2	1.071	2	1	0	1/33	R	MR	---
MS700-70	410	457	90	9	77	13	1	1.081	2	4	1	2/36	R	S	464
ONAWAY	402	459	87	7	67	21	6	1.063	0	8	0	1/38	R	MS	447
PGI-3	396	481	82	17	79	3	1	1.104	3	1	0	0/10	HS	S	---
SAGINAW GOLD	374	443	84	16	78	5	1	1.074	0	0	2	0/17	R	MS	388
MS401-1	348	403	86	13	85	2	0	1.079	3	1	0	0/6	R	S	---
AF875-16	337	364	92	5	85	8	2	1.087	5	2	1	0/21	S	MS	[b]331
ERAMOSA	329	369	89	10	84	5	1	1.059	1	2	0	1/12	HR	S	324
COASTAL CHIP	316	356	89	9	74	15	2	1.074	14	3	1	1/34	M	S	---
LABELLE	309	346	89	8	67	22	3	1.069	0	1	0	4/37	M	-	[b]400
SOMERSET	295	346	85	13	78	8	2	1.077	5	0	1	0/16	M	S	373
ATLANTIC	284	332	85	12	74	12	3	1.081	8	3	1	0/25	M	S	370
AVERAGE	393	441	89					1.077							

* INTERNAL DEFECTS/NUMBER OF OVERIZE (>31/4") TUBERS CUT
** OBSERVATIONS FROM 1988 - 1990; HR - HIGHLY RESISTANT, R - RESISTANT, M - MODERATELY SUSCEPTIBLE, S - SUSCEPTIBLE
a MEAN OF 1988 - 1990; b - MEAN OF 2 YEARS; c - SED = STEM END DISCOLORATION
PLANTED MAY 7,1990
HARVESTED SEPT.24,1990
SPACING 12" X 34"

Table 3.

LONG VARIETIES - FIRST DATE-OF-HARVEST
MSU MONTCALM RESEARCH FARM
AUGUST 27,1990 (112 DAYS)

VARIETY	YIELD(CWT/A) US #1	YIELD(CWT/A) TOTAL	PERCENT SIZE DISTRIBUTION US #1	<4OZ	4-10OZ	>10OZ	PO	SP.GR.	DEFECTS* HH	VAS	IBS	3 YEAR US # 1 YIELD**
B7592-1(CASTILE)	418	502	83	14	59	24	3	1.077	0	0	0/38	410[a]
W1005	378	528	71	27	66	5	2	1.089	0	0	0/19	---
A7411-2	330	426	78	19	67	11	3	1.087	2	0	0/31	314
ND1538-1	312	423	73	25	64	9	2	1.071	0	0	0/24	---
A78242-5	283	339	82	17	58	24	1	1.074	4	0	0/32	348
FRONTIER RUSSET	266	364	72	23	55	17	4	1.075	16	0	0/30	295
MN10874	265	372	71	28	67	4	1	1.076	0	0	0/13	283
RUSSET NORKOTAH	254	371	67	32	61	6	1	1.072	0	1	1/17	276
RUSSET BURBANK	236	397	59	37	56	3	4	1.082	3	0	0/10	212
RUSSET NUGGET	146	237	61	38	57	4	1	1.092	6	0	0/8	---
AVERAGE	289	396	72					1.080				

* INTERNAL DEFECTS/NUMBER OF OVERSIZE (>10 OZ) TUBERS CUT
** MEAN OF 1988 - 1990; a - MEAN OF 2 YEARS

PLANTED MAY 7,1990
HARVESTED AUGUST 27, 1990
SPACING 12" X 34"

Table 4. LONG VARIETIES - SECOND DATE-OF-HARVEST
MSU MONTCALM RESEARCH FARM
SEPTEMBER 26, 1990 (142 DAYS)

	YIELD(CWT/AC)		PERCENT SIZE DISTRIBUTION						DEFECTS*					3 YEAR[a]
VARIETY	US #1	TOTAL	US #1	<4OZ	4-10	>10OZ	PO	SP.GR.	HH	VAS	IBS	BLACKSPOT RATING**	SCAB RATING	US#1 YIELD
B7592-1(CASTILE)	535	616	69	12	34	34	2	1.078	3	1	1/30	S	R	509[b]
CALGOLD	481	591	82	15	48	34	3	1.069	24	1	0/40	S	HR	---
W1005	455	553	87	16	74	13	1	1.085	5	0	0/36	S	HR	---
A7411-2	429	493	90	13	56	34	1	1.089	5	1	0/40	S	R	344
R. NUGGET	357	449	79	18	60	19	3	1.094	25	1	1/40	S	HR	---
A78242-5	347	410	85	13	53	31	3	1.070	0	1	1/40	M	MS	396
MN10874	341	451	83	24	69	14	1	1.073	0	1	0/37	S	MS	302
ND1538-1	313	421	74	23	59	16	3	1.066	0	0	0/35	HR	-	---
R. BURBANK	308	446	70	27	61	8	4	1.080	9	0	1/27	M	HR	238
FONTIER R.	289	352	82	16	50	32	2	1.072	17	0	5/40	M	R	300
R. NORKOTAH	268	377	71	28	57	14	1	1.069	2	1	0/32	R	HR	264
CALORE	143	248	68	42	66	3	0	1.073	5	0	0/15	M	R	---
AVERAGE	356	451	78					1.077						

* INTERNAL DEFECTS/NUMBER OF OVERSIZE (>10 OZ) TUBERS CUT
** OBSERVATIONS 1988 - 1990; HR - HIGHLY RESISTANT, R - RESISTANT, M - MODERATELY SUSCEPTIBLE, S - SUSCEPTIBLE
a MEAN OF 1988 - 1990; b - MEAN OF 2 YEARS

PLANTED MAY 7, 1990
HARVESTED SEPT. 26,1990
SPACING 12" X 34"

Table 5.

RED VARIETIES TRIAL
MSU MONTCALM RESEARCH FARM
SEPTEMBER 10, 1990 (126 DAYS)

	YIELD(CWT/A)		PERCENT SIZE DISTRIBUTION						DEFECTS*					3 YEAR[a]
VARIETY	US #1	TOTAL	US #1	<2"	2-31/4"	>31/4"	PO	SP.GR.	HH	VAS	IBS	BLACKSPOT RATING**	SCAB RATING	US#1 YIELD
VIKING	682	738	92	2	52	41	5	1.069	0	0	0/40	R	MS	[b]626
IDITARED	668	714	94	4	64	30	3	1.063	28	0	0/40	M	MS	---
SANGRE	476	530	90	7	71	18	3	1.067	8	0	1/39	HR	HR	438
ROSE GOLD	430	496	87	12	79	7	1	1.074	2	0	1/26	R	MS	[b]404
RED GOLD	369	469	78	20	75	3	2	1.070	0	0	0/12	M	MS	324
ND2224-5	355	415	86	12	76	9	3	1.056	8	0	0/27	R	R	372
NORLAND	354	403	87	10	84	4	3	1.057	0	0	0/14	HR	R	[b]348
DK RED NORLAND	308	371	82	17	82	1	1	1.056	0	0	0/6	HR	R	---
AVERAGE	455	517	87					1.064						

* INTERNAL DEFECTS/NUMBER OF OVERSIZE (>31/4") TUBERS CUT
** OBSERVATIONS 1988 - 1990; HR - HIGHLY RESISTANT, R - RESISTANT, M - MODERATELY SUSCEPTIBLE, S - SUSCEPTIBLE
a MEAN OF 1988 - 1990; b - MEAN OF 2 YEARS

PLANTED MAY 7, 1990
HARVESTED SEPT. 10, 1990
SPACING 12" X 34"

Table 6. NORTH CENTRAL REGIONAL TRIAL
MSU MONTCALM RESEARCH FARM
SEPTEMBER 12, 1990 (128 DAYS)

	YIELD(CWT/A)		PERCENT SIZE DISTRIBUTION							DEFECTS*		
VARIETY	US #1	TOTAL	US #1	<2	2-31/4	>31/4	PO	SP.GR.	AGTRON COLOR	HH	VAS	IBS
RED PONTIAC	579	618	94	4	68	25	3	1.065	35	4	0	0/40
LA12-59(R)	485	520	93	6	75	18	1	1.075	64	0	0	0/40
W856	482	500	96	3	70	26	1	1.083	63	0	1	0/40
MN13540	406	483	83	15	82	1	2	1.072	58	0	0	0/4
W870	402	427	94	5	84	10	1	1.092	64	3	0	1/28
MN13740	388	434	89	9	87	2	2	1.076	67	0	0	0/8
ND1538-1RUS	388	466	82	16	59	24	3	1.072	42	1	0	0/40
W877	371	403	92	8	87	5	0	1.096	58	0	0	0/18
R. BURBANK	366	482	76	16	59	17	12	1.082	60	20	0	0/35
MS401-1(Y)	351	407	86	13	85	2	2	1.081	72	3	0	0/6
ND2008-2	340	373	91	6	86	5	6	1.066	59	7	0	0/17
NORCHIP	340	405	84	12	81	3	7	1.077	68	0	0	1/8
MN12966(R)	335	378	89	9	83	6	3	1.069	52	0	0	2/17
ND1196-2R	323	375	86	14	83	3	1	1.056	59	1	0	0/8
NORLAND	278	319	87	10	79	8	7	1.058	53	4	0	0/18
MS402-8	205	217	94	4	63	31	5	1.070	63	4	0	0/34
NORGOLD RUS.	180	329	54	45	51	3	2	1.071	39	2	0	0/8
AVERAGE	366	420	86					1.074				

* NUMBER OF INTERNAL DEFECTS/OVERSIZE TUBERS CUT

PLANTED MAY 8, 1990
HARVESTED SEPT. 12, 1990
SPACING 12" X 34"

Table 7.

ADAPTATION TRIAL
MSU MONTCALM RESEARCH FARM
SEPTEMBER 17,1990 (133 DAYS)

	YIELD(CWT/AC)		PERCENT SIZE DISTRIBUTION						DEFECTS*		
VARIETY	US #1	TOTAL	US #1	<2"	2-31/4"	>31/4"	PO	SP.GR.	HH	VAS	IBS
E11-45	556	600	93	7	88	4	0	1.066	0	0	0/18
NY84	552	601	92	7	76	16	2	1.065	0	0	1/40
B9792-8B	514	635	81	8	73	8	11	1.096	26	1	0/28
F24-12	509	531	96	4	81	15	0	1.070	5	0	0/38
TRENT	508	536	95	4	75	20	2	1.099	12	2	0/40
E55-27	479	541	88	11	84	5	0	1.085	1	0	0/28
MS401-7	468	512	91	7	87	4	2	1.091	1	0	0/15
MS401-2	465	482	96	3	69	27	1	1.087	0	0	0/40
FG6-15	464	486	96	4	74	22	0	1.073	5	0	0/40
NY78	446	479	93	7	73	20	0	1.070	3	0	1/40
E55-44	426	454	94	6	84	9	0	1.076	6	0	1/27
E55-35	391	445	88	12	86	2	0	1.089	0	0	0/7
E57-13	364	400	91	9	79	12	0	1.072	1	0	0/31
MS401-4	282	373	75	24	75	0	1	1.079	0	0	0/0
MS402-8	260	270	96	3	58	39	0	1.072	3	0	0/40
B9792-61	252	330	76	23	75	1	1	1.078	0	0	0/13
F143-1	216	294	74	24	64	9	2	1.071	2	0	1/20
AVERAGE	421	469	89					1.079			

* INTERNAL DEFECTS/NUMBER OF OVERSIZE (>31/4") TUBERS CUT

PLANTED MAY 7,1990
HARVESTED SEPT. 17, 1990
SPACING 12" X 34"

Funding Federal Grant/MPIC

MICHIGAN STATE UNIVERSITY POTATO BREEDING PROGRAM

David S. Douches
Department of Crop and Soil Sciences

Cooperators: R.W. Chase, R. Hammerschmidt, J. Cash, G. Bird and K. Jastrzebski

The potato breeding program at MSU can be divided into three integrated directions: 1) breeding and varietal development, 2) germplasm enhancement, and 3) genetic studies. The breeding goals are based upon current and future needs of the Michigan potato industry. Traits of importance include chipping and boiling quality, disease resistance (ie. scab and early die), storability, along with shape, internal quality and appearance.

I. Varietal Development

Each year 25-40 cultivars and advanced seedling lines are chosen for the crossing block to generate new seedling families for variety development. These clones are chosen on the basis of yield, processing ability, specific gravity, disease resistance, adaptation, internal and external quality, etc. We make over 200 cross combinations to complement characteristics of the different clones to develop new varieties.

In 1990, approximately 200 single-hill selections were made from the initial population of 15,000 seedlings at Montcalm. These selections will be advanced to 4-8 hill plots in 1991. Specific gravity ranged from 1.098 to 1.051 with 70 of the selections having values 1.080 or greater. Fifty-five of these selections had not broken dormancy (at $50^{o}F$) after 2 1/2 months of storage, while, thirty-nine also had low glucose levels. Chip samples will be made from these selections at the end of the storage season. In addition to these selections, six 12-hill selections were made and will be advanced to 2x20 hill replicated trials in 1991.

II. Germplasm Enhancement

We have also developed a "diploid" breeding program in an effort to simplify the genetic system in potato and exploit more efficient selection of desirable traits. In general, diploid breeding utilizes haploids of cultivated species 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 exploiting 2n pollen. The diploid breeding program at MSU is a synthesis of five species: haploid _S. tuberosum_ (adaptation, tuber appearance), _S. phureja_ (cold-chipping, specific gravity), S. tarijense and berthaultii (tuber appearance, insect resistance) and S. chaconese (specific gravity, low sugars, dormancy).

From an initial population of 3,000 seedlings from 60 crosses, 183 diploid selections have been made. Selection criteria was based upon tuber appearance, size, dormancy, and internal quality, along with maturity, specific quality, and chip quality.

Sixty-two of these selections have specific gravity greater than 1.080, while 28 also have Agtron chip scores greater than 55. A total of eighty selections will be tested for cold-chipping (40°F) at the end of the storage season.

III. Advanced Selections

In 1990. 30 advanced selections from USDA Idaho, Maine, USDA Beltsville, Wisconsin, New York, Minnesota and North Dakota were grown and evaluated at the Montcalm Potato Research Farm. Each line was planted in two replications (23 hills/replication). Atlantic and Russet Burbank and Superior were used as standards in the trial. The field was planted May 15 and harvested August 27 (104 days). The plots were mechanically harvested then graded for size distribution, internal defects, external defects, specific gravity. Table 1 summarizes the data from all the lines tested. Tables 2 and 3 list the best lines for specific gravity and US#1 yield, respectively. In harvest, most of the round types were chipped. This data are reported in Agtron values (model E-10) in Table 1. Additional tubers of these lines were placed in 45°F and 50°F long-term storage (120 days) for further evaluation.

IV. Assessment of Potato Breeding Progress

During 1990, a field trial was conducted at Montcalm Experiment Station to examine the performance of 20 varieties that were bred in the United States. A RCB design with four replications and 23 plants per plot was used. The varieties were chosen on the basis tuber type (long, red and round white) and year of release (Pre-1900, 1932-1949, 1950-1969, 1970-1990). The varieties grown were Early Rose, Russet Burbank, Green Mountain, White Rose, Katahdin, Sebago, Ontario, Red LaSoda, Red Pontiac, Norland, Superior, Norchip, Norgold Russet, Atlantic, Sangre, Shepody, Eramosa, Snowden, Kennebec and Russet Norkotah. Current management practices under irrigted conditions with 12 inches between plants and 34 inches between rows were used. At harvest (140 days) tubers were graded according to diameter (reds and round whites) or weight (longs). Samples were taken to determine specific gravity, chip color analysis, visual merit rating, and internal defects. This data is summarized in Table 4.

The red-skinned varieties, as a group, yielded more and had a lower specific gravity than the round white or long type varieties. In addition the long type varieties produced significantly lower US No. 1 yields than the other two tuber types mainly due to significantly smaller percentage of marketable yield.

Looking at the varieties according to their year of release, we noticed a number of trends. We did not observe any increase in total yield over time, however, we did observe an increase in % marketable yield only among long-type varieties (Shepody, Norgold Russet). An upward trend over breeding periods was observed for visual merit ratings and an improvement in earliness was detected among the more recent varieties. Specific gravity showed an upward trend in the later three breeding periods among the round white varieties, whereas, chip color at harvest showed a consistent improvement through all four periods.

Table 1.

ADVANCED SELECTION TRIAL
MSU MONTCALM RESEARCH FARM
AUGUST 27, 1990

	YIELD CWT/A		PERCENT SIZE DISTRIBUTION							DEFECTS	
VARIETY	US #1	TOTAL	US #1	B	A	OVER	PO	SP. GR.	AGTRON NO.	HH	VD
ATLANTIC	480	523	91	7	74	17	2	1.092	43	4	0
B0178-34	465	531	88	8	61	26	4	1.095	50	1	0
B0172-15	462	520	89	4	56	33	7	1.087	42	12	0
B0257-12	455	507	90	9	78	12	2	1.083	47	1	0
MN13540	451	532	85	13	82	3	2	1.076	41	4	0
SUPERIOR	430	485	89	9	81	8	2	1.073	37	4	0
B0175-21	374	424	89	7	83	6	4	1.093	--	1	0
B0234-4	367	412	89	10	86	3	1	1.072	48	5	0
A80559-2	360	397	91	8	66	24	2	1.092	42	11	0
B9792-2B	347	396	88	10	75	12	3	1.089	46	0	0
R.BURBANK	343	474	72	25	65	8	3	1.083	--	1	0
B0257-3	333	383	87	12	83	5	1	1.087	45	0	0
B0202-4	327	370	88	10	79	10	1	1.086	54	5	0
MN9632	321	363	88	12	82	6	0	1.076	48	0	0
B0178-16	317	372	85	14	81	5	1	1.088	53	0	0
AF845-11	284	303	94	5	41	53	1	1.072	47	11	0
F100-1	278	303	92	8	81	10	0	1.081	44	9	0
B9955-11	260	312	83	13	78	5	3	1.083	45	4	0
B0179-19	258	349	74	17	70	4	8	1.094	43	5	0
A79141-2	257	355	72	23	67	5	5	1.080	--	9	0
B0405-4	235	319	74	24	74	0	2	1.092	--	0	0
AF879-3	235	291	80	17	76	4	2	1.087	45	4	1
B9972-2B	227	275	82	15	67	15	3	1.088	36	4	0
MN12828	210	292	72	7	54	18	21	1.075	37	1	0
W231	210	272	78	22	76	3	0	1.079	41	0	0
B9955-33	194	230	85	13	76	9	3	1.077	45	1	0
AF875-17	180	251	73	17	68	6	10	1.076	48	0	0
NDA2031-2	177	265	67	33	67	0	0	1.071	52	0	0
MN12823	158	212	74	17	68	5	9	1.074	34	0	0
D43	156	211	72	17	62	10	11	1.059	23	5	1
AF875-15	153	198	80	8	74	6	12	1.076	36	1	0
MN13740	149	214	70	28	55	15	2	1.072	52	0	0
S465	80	92	86	11	73	13	3	1.067	36	1	0
AVERAGE	289	346	82					1.081			

*INTERNAL DEFECTS/ NUMBER OF OVERSIZE TUBERS CUT

Table 2.

ADVANCED SELECTION TRIAL
MSU MONTCALM RESEARCH FARM
AUGUST 27, 1990 (104 DAYS)
BEST HIGH SPECIFIC GRAVITY VARIETIES

	YIELD CWT/A		PERCENT SIZE DISTRIBUTION							DEFECTS	
VARIETY	US #1	TOTAL	US #1	B	A	OVER	PO	SP. GR.	AGTRON NO.	HH	VD
ATLANTIC	480	523	91	7	74	17	2	1.092	43	4	0
B0178-34	465	531	88	8	61	26	4	1.095	50	1	0
B0257-12	455	507	90	9	78	12	2	1.083	47	1	0
B0175-21	374	424	89	7	83	6	4	1.093	--	1	0
B9792-2B	347	396	88	10	75	12	3	1.089	46	0	0
R. BURBANK	343	474	72	25	65	8	3	1.083	--	1	0
B0257-3	333	383	87	12	83	5	1	1.087	45	0	0
B0202-4	327	370	88	10	79	10	1	1.086	54	5	0
B0178-16	317	372	85	14	81	5	1	1.088	53	0	0
B0179-19	258	349	74	17	70	4	8	1.094	43	5	0
B0405-4	235	319	74	24	74	0	2	1.092	--	0	0

Table 3.

BEST FOR US #1 YIELD

	YIELD CWT/A		PERCENT SIZE DISTRIBUTION							DEFECTS	
VARIETY	US #1	TOTAL	US #1	B	A	OVER	PO	SP. GR.	AGTRON NO.	HH	VD
ATLANTIC	480	523	91	7	74	17	2	1.092	43	4	0
B0178-34	465	531	88	8	61	26	4	1.095	50	1	0
B0172-15	462	520	89	4	56	33	7	1.087	42	12	0
B0257-12	455	507	90	9	78	12	2	1.083	47	1	0
MN13540	451	532	85	13	82	3	2	1.076	41	4	0
SUPERIOR	430	485	89	9	81	8	2	1.073	37	4	0
B0175-21	374	424	89	7	83	6	4	1.093	--	1	0
B0234-4	367	412	89	10	86	3	1	1.072	48	5	0
A80559-2	360	397	91	8	66	24	2	1.092	42	11	0
B9792-2B	347	396	88	10	75	12	3	1.089	46	0	0
R. BURBANK	343	474	72	25	65	8	3	1.083	--	1	0

Table 4.

1990 OLD VARIETY TRIAL
RED VARIETIES
MONTCALM RESEARCH FARM
SEPTEMBER 26, 1990

VARIETY	YIELD CWT/AC US #1	YIELD CWT/AC TOTAL	% SIZE DISTRIBUTION US #1	% SIZE DISTRIBUTION <2"	% SIZE DISTRIBUTION 2-31/4"	% SIZE DISTRIBUTION >31/4"	PO	SP.GR.	AGTRON NO.	DEFECTS* HH	DEFECTS* VD	DEFECTS* IN
R. PONTIAC	591	633	93	5	73	21	1	1.066	37	17	2	0/40
R. LASODA	476	517	92	7	85	7	1	1.062	37	4	0	0/26
SANGRE	352	382	92	6	81	10	2	1.064	32	10	0	2/24
NORLAND	335	396	84	15	84	0	1	1.056	59	0	0	0/1
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	439	482	90					1.062				

1990 OLD VARIETY TRIAL
ROUND WHITE VARIETIES
MONTCALM RESEARCH FARM
SEPTEMBER 26, 1990

VARIETY	YIELD CWT/AC US #1	YIELD CWT/AC TOTAL	% SIZE DISTRIBUTION US #1	% SIZE DISTRIBUTION <2"	% SIZE DISTRIBUTION 2-31/4"	% SIZE DISTRIBUTION >31/4"	PO	SP.GR.	AGTRON NO.	DEFECTS* HH	DEFECTS* VD	DEFECTS* IN
KENNEBEC	538	581	93	5	78	14	3	1.075	58	5	0	0/39
GREEN MTN	510	559	91	8	82	9	1	1.088	48	6	0	0/27
SNOWDEN	466	497	94	6	85	9	0	1.082	72	2	5	0/30
ONTARIO	457	499	91	5	87	4	4	1.074	45	4	2	0/18
KATHADIN	370	390	94	6	83	11	0	1.066	55	8	0	0/30
SEBAGO	343	393	87	11	82	6	1	1.069	56	6	0	0/16
SUPERIOR	338	384	88	10	83	5	2	1.070	65	0	0	0/16
ATLANTIC	286	317	90	9	69	21	1	1.083	65	23	0	0/39
ERAMOSA	266	293	91	8	78	13	2	1.063	44	1	1	0/20
NORCHIP	253	294	86	10	82	4	4	1.072	67	0	0	0/11
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	383	421	91					1.074				

1990 OLD VARIETY TRIAL
LONG VARIETIES
MONTCALM RESEARCH FARM
SEPTEMBER 26, 1990

VARIETY	YIELD CWT/AC US #1	YIELD CWT/AC TOTAL	% SIZE DISTRIBUTION US #1	% SIZE DISTRIBUTION <4OZ	% SIZE DISTRIBUTION 4-12OZ	% SIZE DISTRIBUTION >12OZ	PO	SP.GR.	AGTRON NO.	DEFECTS* HH	DEFECTS* VD	DEFECTS* IN
SHEPODY	376	453	83	10	50	33	7	1.073	50	22	0	0/40
WHITE ROSE	285	384	75	13	50	24	13	1.066	37	8	2	0/40
EARLY ROSE	280	474	58	39	55	3	3	1.081	58	3	0	0/10
NORGOLD R.	262	422	62	37	58	4	1	1.072	47	8	0	0/13
R. NORKOTAH	248	362	68	30	58	10	2	1.066	51	5	2	0/25
R. BURBANK	232	446	52	47	50	2	1	1.082	55	3	0	0/6
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	281	424	66					1.073				

Funding MPIC and NPC

USE OF MOLECULAR MARKERS FOR THE STUDY AND ANALYSES OF QUANTITATIVE TRAITS IN POTATO

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Introduction

Two traits of economic importance in potato breeding are specific gravity and tuber dormancy. High specific gravity is particularly important in the potato chip industry because of an increased chip yield and a superior quality product. A specific gravity difference of 0.005 represents a gain in one pound of chips produced per 100 pounds of potatoes (Owings, 1979). In addition, chips produced from high specific gravity potatoes absorb less oil during the frying process and are therefore more desirable and cheaper to produce.

Long-term storage of potatoes without sprout growth is an important aspect of potato marketing. This can be obtained under storage temperature of 4°C (40°F) but with the inconvenience that it causes accumulation of reducing sugars which are undesirable for processing. To maintain low reducing sugar levels potatoes can be stored at 10°C (50°F), but only if they have long dormancy periods. Tuber dormancy is the obligate period of non-sprouting after harvest even under conditions favorable to sprouting (Thompson et al., 1980) and this trait can be found in wild species of potato.

Studies on specific gravity and dormancy have reported these tuber traits as polygenic. These desirable traits and others can be found in diploid wild and tuber-bearing relatives of the potato which are crossable to our cultivated varieties. The efficiency of this approach could be largely increased if the introgression of genes from the wild species could be closely monitored, such as with the use of molecular marker-assisted selection.

The concept of using genetic maps and marker-assisted selection to speed up the process of plant breeding has been considered for a long time. In 1923, Sax proposed identifying and selecting for "minor genes" of interest by linkage with "major genes", which could be scored more easily. Until recently, the genetic markers used to develop maps in plants have been those affecting morphological characters. In potato, various single gene markers that affect morphological characters (i.e. chlorophyll and anthocyanin pigments, tuber traits and seed markers) have been reported (Douches and Quiros, 1988). However, these markers have had little if any value to this crop's improvement.

During recent years, the potential use of molecular markers (isozymes and RFLPs) in plant breeding has been reported (Tanksley and Rick, 1980; Tanksley, 1983; Beckmann and Soller, 1983; Helentjaris et al., 1985). These offer the following advantages over morphological markers: 1) normally show codominance, so the genotype in a given locus is not obscured by dominance effects: 2) much greater levels of allelic variation; 3) they are phenotype-neutral, not causing alterations which could be undesirable in breeding; 4) do not show epistatic interactions, so a limitless number of segregating markers can be monitored in a single population (Tanksley et al., 1989). Thus, molecular markers offer a new direction for developing more efficient approaches to plant breeding which can be applied to the improvement of potato.

Isozymes have been used very successfully in certain aspects of plant breeding and genetics as nearly-neutral genetic markers. For example, marker-facilitated selection for root knot nematode resistance using isozymes has been demonstrated in tomato (Rick and Fobes, 1974). In potato, 15 enzyme-coding loci are presently known to segregate (Douches and Quiros, 1988) and can be used as markers. Nevertheless, their application is limited because of their small number.

Another set of molecular markers with greater potential lies on restriction fragment length polymorphisms (RFLPs). These give the possibility to "saturate" the genome and increase the probability of detecting linkages (Keim et al. 1990). RFLPs have been demonstrated in many crops and RFLP maps have been generated for potato (Bonierbale et al., 1988; Gebhardt et al., 1989).

The use of molecular markers for the analysis of quantitative traits has been described (Tanksley et al., 1982; Beckmann and Soller, 1988; Lander and Botstein, 1989). The concept is based on the fact that the marker locus serves to identify or "mark" the chromosomal region in its vicinity and enables that linked region to be followed in inheritance studies. Association of markers with the quantitative trait under investigation are determined by comparing marker genotypes with quantitative trait expression. If adequate markers are available and are distributed appropriately throughout the genome it is possible to evaluate all chromosomal regions for their effects on numerous traits of interest (Stuber et al., 1987; Stuber, 1989).

Overall Objectives

1. To develop and test the feasibility of approaches to breeding potatoes which integrate RFLP (restriction fragment length polymorphism) technology.

2. To contribute fundamental information to the understanding of quantitatively inherited traits through the examination of the numbers and genomic distribution of quantitative trait loci (QTLs) along with the types and magnitudes of gene effects attributed to QTLs.

3. To identify and transfer economically important genes from the Solanum species to the cultivated level.

Specific Objectives

1. Characterize two diploid populations with molecular markers (isozymes and RFLPs).

2. Conduct field and storage studies to characterize these populations for two polygenic tuber traits: specific gravity and tuber dormancy.

3. Identify associations between the molecular markers and quantitative trait variation for the tuber traits.

Materials and Methods

a. Plant material

Three different diploid clones of potato were used to generate the two families used in this study (named TRP132 and TRP133). In both cases the female used was 84SD22 which is a hybrid of _tuberosum_ (2x) and _chacoense_, and has high specific gravity and long dormancy. The males used were 84S11 in the case of TRP132, and 84S10 for TRP133. These two clones are _S_. _phureja_ and have low specific gravity and short dormancy. Progenies were grown in the field in 1989 and a preliminary evaluation of specific gravity and dormancy was performed during the first months of 1990. For this study, a total of 143 and 118 genotypes were used in families TRP132 and TRP133 respectively.

b. Measurement of traits

All genotypes for each of the families along with two of the parents (84SD22 and 84S10) and two 4x cultivars (Atlantic and Russet Burbank) were planted in the field following a RCBD with 3 replications in two locations (Montcalm and Clarksville). Each plot consisted of 8 plants. Distance between plants was 0.3 m and 1 m between rows.

After harvest, specific gravity was determined for each genotype for both locations using the weight in air/weight in water method. For the evaluation of dormancy, 4 tubers per genotype have been placed in storage at 10°C (50 F). The length of dormancy will be considered as the average of the days required for 2 mm long sprouts to be evident for each genotype.

c. Isozyme analysis

All the genotypes and the parents were characterized for 12 segregating isozyme loci (Mdh-1, Idh-1, Pgdh-3, Pgi-1, Got-1, Got-2, Pgm-1, Pgm-2, Dia-1, Prx-3, Adh-1, Est-1) using leaf or tuber tissue. For family TRP133, yellow flesh was also used as a morphological marker.

d. RFLP analysis

Total DNA from fresh leaf tissue was extracted for all the genotypes using a procedure adapted from Guri and Sink for eggplant (1988). This will be digested using EcoRI, HindIII, BamHI or XbaI restriction endonucleases and probed with tomato probes provided by Dr. Tanksley, Univ. of Cornell (Tanksley et al., 1982). Initially only the parental DNA will be used to detect enzyme/probe combinations which show polymorphism. Then these will be used for the characterization of the progenies.

e. Statistical analysis

Statistical analysis was carried out following a RCBD for each location for both traits considered using MSTATC. Single factor ANOVAs were conducted for each pairwise combination of quantitative trait and marker locus. In order to detect linkage of a marker locus with a QTL, the segregation data was divided into genotypic classes (testcross, F2 or triallelic segregations). F-tests were used to statistically test if the means of the genotypic classes are different. A significant difference in means is interpreted as linkage of the QTL to the marker locus.

For markers that show a significant effect, correlation, regression and multiple regression was used to identify QTLs associated with the markers. Correlation analyses was performed between the number of copies of the favorable allele for each locus and the phenotypic value for each trait. Regression (or multiple regression) was performed to develop equations which explain the phenotypic variation of the traits of interest attributable to the combination of marker loci assuming additive genetic models.

Results

For family TRP133, specific gravity values at Montcalm ranged from 1.046 - 1.099 with a mean of 1.079, whereas Clarksville values ranged from 1.057 - 1.110, with a mean of 1.083. In the case of family TRP132, the range was 1.061 - 1.105 and 1.062 - 1.115 in the first and second locations, respectively. In both locations the mean was 1.086. The mean for the high parent (84SD22) was 1.080 at Montcalm and 1.084 at Clarksville. For the low parent (84S10) the mean was 1.067 and 1.069, respectively.

To detect quantitative trait loci (QTLs) for specific gravity, one-way ANOVAs using genotypes for each isozyme locus as a source of variation were conducted. In family TRP133 significant differences for genotypes were found among three loci: 6-Pgdh-3, Got-2 and Pgm-1. These results were significant over both locations. In TRP132, significant differences were also found for 6-Pgdh-3 and Got-2 over both locations, however Pgm-1 and Dia-1 were significant only at the Montcalm location.

Preliminary storage studies in 1989 - 1990 detected significant associations between Pgm-2, Got-1, and Est-1 and tuber dormancy in TRP133.

In 1991 we will continue to characterize the families with molecular markers that are distributed throughout all chromosomes.

References

Beckmann, J. and M. Soller. 1983. Restriction fragment length polymorphisms in genetic improvement: Methodologies, mapping and costs. Theor. Appl. Genet. 67:35-43.

Beckmann, J. and M. Soller. 1988. Detection of linkage between marker loci and loci affecting quantitative traits in crosses between segregating populations. Theor. Appl. Genet. 76:228- 236.

Bonierbale, M., R. Plaisted and S. Tanksley. 1988. RFLP maps based on a common set of clones reveal modes of chromosomal evolution in potato and tomato. Genetics 120:1095-1103.

Douches, D. and C. Quiros. 1988. Additional isozyme loci in tuber- bearing Solanums: Inheritance and linkage relationships. J. Hered. 79:377-384.

Flewelling, H. 1987. Use of haploid Tuberosum-wild Solanum species F 1 hybrids to study the relationship between the cultivated and wild potatoes, and to analyze the genetic control of tuber dormancy. M.S. Thesis, University of Wisconsin, Madison.

Gebhardt, C., E. Ritter, T. Debener, U. Schachstabel, B. Walkemeir, H. Uhrig and F. Salamini. 1989. RFLP analysis and linkage mapping in Solanum tuberosum. Theor. Appl. Genet. 78:65-75.

Guri, A. and K. Sink. 1988. Agrobacterium transformation of eggplant. J. Plant Physiol. 133:52-55.

Helentjaris, T., G. King, M. Slocum, C. Siedenstrang and S. Wegman. 1985. Restriction fragment polymorphisms as probes for plant diversity and their development as tools for applied plant breeding. Plant Molec. Biol. 5:109-118.

Keim, P., B. Diers, T. Olson and R. Shoemaker. 1990. RFLP mapping in soybean: association between marker loci and variation in quantitative traits. Genetics 126:735-742.

Lander, E. and D. Botstein. 1989. Mapping Mendelian factors underlying quantitative traits using RFLP linkage maps. Genetics 121:185-199.

Mendoza, H. and F. Haynes. 1974. Genetic relationships among potato cultivars grown in the United States. Hortscience 9:328-330.

Owings, T. 1979. Cultural practices which influence the specific gravity of Russet Burbank. Proc. 18th Ann. Washington Potato Conf. Trade Fair. p. 41-47.

Rick, C. and J. Forbes. 1974. Association of an allozyme with nematode resistance. Rep. Tomato Genet. Coop. 24:25

Sax, K. 1923. The association of size differences with seed coat pattern and pigmentation in Phaseolus vulgaris. Genetics 120:597-604.

Stuber, C., M. Edwards and J. Wendel. 1987. Molecular marker- facilitated investigations of quantitative trait loci in maize. II. Factors influencing yield and its component traits. Crop Sci. 22:737-740.

Stuber, C. 1989. Comparative studies using RFLPs and Isozyme as molecular markers for the study and analyses of multigenic traits in maize. In: Development and Application of Molecular Markers to Problems in Plant Genetics. Helentjaris, T. and B. Burr (Eds.). Cold Spring Harbor Laboratory. pp. 103-106.

Tanksley, S. and C. Rick. 1980. Isozyme linkage map of the tomato: Applications in genetics and breeding. Theor. Appl. Genet. 57:161-170.

Tanksley, S., H. Medina-Filho and C. Rick. 1982. Use of naturally occurring enzyme variation to detect and map genes controlling quantitative traits in an interspecific backcross of tomato. Heredity 49:11-25.

Tanksley, S. 1983. Molecular markers in plant breeding. Plant Mol. Biol. Rep. 1:3-8.

Tanksley, S., N. Young, A. Paterson and M. Bonierbale. 1989. RFLP mapping in plant breeding: new tools for an old science. Biotechnology 7:257-264.

Thompson, P., F. Haynes and R. Moll. 1980. Estimation of genetic variance components and heritability for tuber dormancy in diploid potatoes. Am. Pot. J. 57:39-46.

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Development of a Colorado Potato Beetle Resistant Potato by Genetic Engineering

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I. Introduction:

Reports indicate that proteinase inhibitors are among natural defense mechanisms that plants have developed over millions of years of co-evolution with herbivorous insects. These inhibitors prevent the insects from deriving "optimal nourishment" from plant tissues. Proteinase inhibitors inhibit the midgut proteolytic activities of Colorado potato beetle (CPB)'s digestive system. Recently, a proteinase inhibitor (PI II) gene has been isolated from a potato cultivar, and expressed in tobacco. Reports also indicate that the the proteinase inhibitors can increase the activity of *Bacillus thuringiensis* [BT (both coleopteran and lepidopteran specific)] gene products, when genetically engineered in plants as translational fusions.

II. Goals and supporting objectives:

Our goals are to produce CPB-resistant potato plants by genetic engineering. To achieve our goals, we have been directing our efforts towards the following objectives.

1. To engineer a series of gene constructions containing PI II/BT, BT/NPT II, and PI II/NPT II translational fusion genes driven by constitutive or wound inducible promoters, in a disarmed *Agrobacterium.tumefaciens* vector.

2. To develop transgenic potato plants via co-cultivation of leaf discs (using an *Agrobacterium* Ti plasmid method), and protoplasts (using polyethylene glycol mediated plasmid uptake method), and the Biolistic shot gun method.

3. To confirm the integration and expression of the foreign genes in putatively transgenic plants by Southern, PCR, western, and northern analysis.

4. To test the growth and mortality of CPB in response to a diet of different doses of commercially available PI II.

5. To test the transgenic potato plants for response to CPB and to test the transgenic plant progeny for the stability of gene expression and for stability of resistance to CPB in the field.

III. RESULTS:

Within a year , we have been able to perform the majority of experiments related to the objectives 1, 2, and 3. In more details, the following results have been obtained:

Results from objective 1. Drs. Bolyard and Cheng have introduced a plasmid construction containing a proteinase inhibitor II/NPT II gene (driven by CAMV35S promoter), in a disarmed *Agrobacterium tumefaciens*, using the electroporation method.

Results from objective 2. Dr. Cheng has transformed potato leaf discs with *Agrobacterium* containing gene fusions of either PI II and NPT II driven by CaMV 35S promoter (from objective 1) or a translational fusion of BT/NPT II driven by a double [CaMV 35S - nopaline synthase (NOS)] promoter, using the *Agrobacterium* Ti plasmid mediated method. Dr. Cheng has also putatively transformed potato protoplasts using polyethylene glycol mediated gene transfer, and the Biolistic shot gun delivery of DNA methods.

As a result, hundreds of shoots were regenerated from leaf discs via the *Agrobacterium* transformation method. Upon transfer into a kanamycin selection media eighteen of these shoots were confirmed to be kanamycin Resistant. Kanamycin resistant shoots were rooted in media containing kanamycin, acclimated to the greenhouse condition, and grown for tuber formation.

Results from objective 3.

a) Confirmation of gene integration (at the genomic level) in the regenerated potato plants

DNA was isolated from two of the kanamycin resistant potato plants, from second progeny of a transgenic tobacco, and from a non-transformed potato plant which was regenerated *in vitro.* DNA was restriction digested and electrophoresed in 0.9% agarose gel. The digested DNA was then transferred onto a nylon filter and the filter was baked and probed with the NPT II DNA fragment. The results from the Southern analysis revealed that the NPT II (as a translational fusion portion with BT codons) genes has been integrated in the genome of regenerated potato plants

In addition, the integration of NPT II gene (as the portion of translational fusion with BT codons) in the greenhouse grown regenerated potato plants was confirmed using polymerase chain reaction (PCR). In this experiment, primers were synthesized from the NPT II codon sequence, DNA was isolated from putatively transformed and non-transformed potato plants which were regenerated in vitro and PCR was conducted. The DNA from the progeny (second generation) of a transgenic tobacco plant was used as a positive control. The experiment was performed following our previous PCR method for confirmation of gene integra tion.

b) Confirmation of gene expression (at the protein level) in the regenerated potato plants

To confirm the integration of NPT II (as a portion of translational fusion with BT codons) in transformed potato leaf tissues, an antibody raised against the NPT II protein was used for western analysis. Protein preparations were electrophoresed on polyacrylamide gels and electroblotted onto nitrocellulose. Following incubation of the filter with primary antisera, bound rabbit anti-NPT II protein was detected using goat anti-rabbit alkaline phosphatase conjugated secondary antisera. The bound secondary antisera was then visualized using the substrates nitro blue tetrazolium and 5-bromo-4-chloro- 3-indolylphosphate. Dr. Bolyard performed this portion of the experiment following our previous experience on gene expression studies [Sticklen et. al. 1990].

In conclusion, we have been able to efficiently and stably transform potato plants with *Agrobacterium* containing a BT/NPT II translationally fused gene [Cheng et. al. 1991]. In addition, work is in progress to confirm the stable integration and expression of proteinase inhibitor II gene in the regenerated potato plants.

VI. References

Cheng J., Bolyard M. G., and Sticklen M. B. (1991). In preparation for J. Plant Physiol.

Sticklen M. B. (1990). In: D. Schumacher (ed). Proc. Midwest Plant Biotechnology Consortium. Indianapolis, IN. In press.

Sticklen M. B., Bolyard M. G., and Cheng J. (1990). Int. Energy Agency (IEA) Symp. Gent, Belgium. In press.

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POTATO SCAB RESEARCH

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Scab Trial 1990

In order to assess resistance to common scab, 90 varieties were planted in a replicated trial at East Lansing in 1990. There were three replications with five plants per plot. At planting, scab inoculum was broadcast into the open rows. At harvest, 20 tubers per plot were collected for the detailed estimation of infection.

Five classes were distinguished: 0, 1, 5, 10 and 25% of the surface area affected by scab on individual tubers. In addition, the type of scab lesion (e.g. surface, pitted) was recorded.

Various criteria were used for the expression of infection in a five degree scale: A) percentage of healthy tubers; B) percentage of tubers infected up to 1% of the surface area; C) up to 5%; D) 5% to 10%; E) 10% or more; F) average coverage; G) average severe coverage; and H) a general rating. Lastly, the scores were corrected by one degree if the type of scab presented was pitted.

The most resistant varieties were: 84S10 (2x), W1005, Norgold Russet, Russet Norkotah, Lemhi Russet, Russet Burbank, Frontier Russet, Early Rose and Sangre. The most susceptible varieties were Atlantic, ND860-2, S465, Coastal Chip, Norwis, B0178-16, AF875-15, A80599-2, and MS700-70. Table 1 summarizes the 1990 results for the 90 varieties tested.

Greenhouse Scab Studies

To determine the genetic basis of scab resistance, we have initiated a series of greenhouse studies. To study the genetics within cultivated varieties, we extracted haploids from the varieties Saginaw Gold, Atlantic, Superior, ND860-2 and Nooksack. The 50% reduction in chromosome number now allows us to study the inheritance of scab resistance in a less complicated manner and will help us to identify scab resistance genes. We will begin to screen these haploids for their level of scab resistance during the next year. Secondly, a series of crosses between cultivated varieties were made to study the resistance at the cultivar level and also to determine the most efficient time to screen for scab resistance in the breeding program. During 1990, seedlings from a series of combinations of five different varieties were grown in seedling trays with soil infested with the scab organism .Scab was evaluated at harvest. The tubers from this harvest were further analyzed by planting into pots containing scab infested soil. Scab was again evaluated on the tubers generated on these plants. These tubers are being held for field evaluation in 1991. This sequence of screens will allow us to more precisely determine the level of resistance as well as serve at a check for disease escapes.

In conjunction with the research of Douches and Freyre (see their MPIC report) we are attempting to "tag" the scab resistance genes in a diploid population using molecular markers. To facilitate this aspect of the research, crosses were made in 1990 between scab resistant and susceptible clones. A summary of the scab reaction in the diploids is shown in table 2. These crosses are now ready for evaluation in the greenhouse. In order to identify new sources of resistance to scab, 38 plant introductions of *Solanum* species obtained from the Potato Introduction Station (IR-1) were induced to tuberize. These tubers will be used to grow plants in pots for scab resistance evaluation.

Variety by strain evaluation

Observations that varieties, such as Onaway, were exhibiting more scab than previously noted suggested that we may be dealing with more virulent strains of the scab pathogen. In order to test this, a scab stain by variety analysis was carried out. In these tests, 6 varieties of potato were tested against four strain of scab causing *Streptomyces* isolated in Michigan. The results are shown in tables 3-5. These results indicate that there is some degree of interaction between the isolate of *Streptomyces* and the severity of the scab coverage and/or the type of lesion that develops. These results indicate that both the isolate of the scab organism and the genotype of the host plant will influence the type and severity of scab.

Because of the variation in scab reaction, we further investigated the characteristics of one of the isolates that appeared to be more virulent. This isolate was found to be different from the common scab and in a number of characteristics (Table 6). The acid intolerance of this strain suggests that it is not the acid scab pathogen. Thus, it is possible that some of the scab that is now being observed on varieties generally thought to be resistant (e.g. Onaway) may be due to changes in the pathogen.

Biochemical markers for resistance

Since the mature periderm provides an effective barrier to scab infection, we examined young periderm samples from scab resistant and susceptible varieties for differences in peroxidase isozymes. This enzyme is needed for the final step in part of suberin formation. Both varieties and diploids could be distinguished, and we are now trying to determine if these differences can be correlated with resistance.

Table 1

1990 SCAB TRIAL
Michigan State University

Variety	Scab Rating[1/]	Type[2/]	Variety	Scab Rating	Type
191-11	2.9	S	LEMHI RUSS	1.5	S
84S10	1.1	S	MN 10874	1.8	S
84SD22	2.3	S	MN 12823	3.5	P
A 74114-4	2.5	S	MN 12828	2.8	S
A 7411-2	2.2	P	MN 13540	3.8	P
A 76147-2	2.2	S	MN 13740	2.8	S
A 78242-5	2.8	P	MN 9632	2.8	S
A 79141-2	3.0	S	MS 401-1	3.3	P
A 80559-2	4.2	P	MS 401-2	3.2	P
AC 80545-1	3.5	S	MS 401-7	2.0	P
AF 845-11	2.0	P	MS 402-7	3.3	S
AF 875-15	4.0	P	MS 402-8	2.2	P
AF 875-16	2.8	P	MS 700-70	4.8	P
AF 875-17	2.1	S	MS 716-15	3.3	P
AF 879-3	2.7	S	ND 2224-5	2.3	P
ATLANTIC	4.0	P	ND 860-2	3.7	S
B 0172-15	2.2	S	NDA 2031-2	3.7	P
B 0175-21	2.7	P	NORCHIP	2.3	S
B 0178-16	4.5	P	NORGOLD R	1.5	S
B 0178-34	3.8	P	NORLAND	2.7	S
B 0179-19	3.5	P	NORWIS	4.0	S
B 0202-4	3.7	P	ONAWAY	3.3	S
B 0234-4	2.8	S	ONTARIO	2.3	P
B 0257-12	3.7	P	PG 1-3	3.8	P
B 0257-3	3.7	P	R NORKOTAH	1.3	S
B 0405-4	3.5	P	RED GOLD	3.2	P
B 7592-1	1.8	R	RED LASODA	3.2	P
B 9792-2B	2.5	S	RED PONTIAC	3.8	P
B 9955-11	2.7	P	ROSE GOLD	2.8	P
B 9955-33	2.7	P	RUSS BURBANK	1.7	S
CALGOLD	1.0	S	RUSS NUGGET	2.0	S
CALORE	2.0	S	S 465	3.7	P
COASTAL CHIP	4.3	P	SAGINAW GOLD	2.7	S
D 43	3.2	P	SANGRE	1.7	S
DONNA	2.8	P	SEBAGO	3.3	P
E 55-27	3.0	S	SHEPODY	4.2	P
E 55-35	3.5	P	SNOWDEN	2.5	P
EARLY ROSE	1.8	P	SOMERSET	3.3	P
ERAMOSA	3.0	P	SPARTANPEARL	3.0	S
FG 6-15	3.2	P	STEUBEN	2.5	S
FRONTIER R	1.5	S	SUPERIOR	2.8	P
GEMCHIP	2.5	P	TRENT	2.5	P
GREEN MTN	2.8	S	VIKING	2.7	S
IDITARED	2.8	P	W 1005	1.3	S
KATAHDIN	2.5	P	W 231	3.0	P
			WHITE ROSE	2.8	P

[1/] 1 = highly resistant, 5 = highly susceptible.

[2/] S = surface, P = pitted.

TABLE 2

SCAB REACTION OF DIPLOID PARENTS

NAME	SCAB REACTION	ORIGIN
84S10	Resistant	*Phureja* haploid
84SD22	Resistant	*Chacoense* x tuberosum
W5295.7	Mod. Res.	*Phureja* x tuberosum
P100-2	Mod. Sus.	tuberosum x *tarijense*
W5337.3	Susceptible	*Phureja* x tuberosum
DM56-4	Susuceptible	*Phureja* x tuberosum

TABLE 3

VARIETY X STRAIN - %SURFACE COVERAGE

STRAIN	SUP	ONT	ATL	ONA	SP	ND
F945	R	R	MS	S	S	S
DPZ	MS	R	MS	MS	MS	S
ONA	R	R	R	MS	MS	R
RP	R	R	MS	MS	S	MS

R=0-5% COVERAGE; MS=5-25% COVERAGE; S=>25% COVERAGE

TABLE 4

VARIETY X STRAIN - TYPE OF LESION

STRAIN	SUP	ONT	ATL	ONA	SP	ND
F945	R	R	MS	MS	S	S
DPZ	R	R	MS	MS	MS	S
ONA	R	R	R	R	MS	R
RP	R	R	MS	R	R	MS

R=NO SCAB OR SURFACE; MS=SLIGHTLY PITTED; S=DEEP PITTED

TABLE 5

VARIETY X STRAIN - %SURFACE X TYPE OF LESION

STRAIN	SUP	ONT	ATL	ONA	SP	ND
F945	R	MR	MS	S	S	S
DPZ	MR	R	MS	MS	S	S
ONA	R	R	R	MR	MS	MR
RP	R	R	MS	MR	S	S

R= <1% COVERAGE; SURFACE SCAB; MR=<1% DEEP PITTED OR 1-5% SURFACE TYPE; MS=1-5% PITTED OR 5-25% SHALLOW PITS OR SURFACE; S=>5% PITTED OR >25% SHALLOW PITS OR SURFACE.

TABLE 6
CHARACTERISTICS OF DP STRAIN OF STREPTOMYCES

CHARACTERISTIC	DP	S. scabies
Spore chains	Straight	Spiral
Spore color	Light gray	Gray
Reverse color	Tan	Golden-brown
Melanin pigments	No	Yes
Pitting on Burbank	Yes	No
Acid tolerant	No	No
Salt tolerant	70 g/l	40 g/l
Sugar use	All used (good growth)	All used (poor-good growth)
Growth on pectins	fair to poor	fair to good

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NITROGEN MANAGEMENT TO IMPROVE POTATO YIELD, QUALITY AND WATER QUALITY

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INTRODUCTION

There is a critical need to improve on-farm N management strategies to determine the optimum rate and time of N application to produce the highest quality tuber yields but minimize the amount of nitrate left in the soil at harvest time. In Michigan there currently is little that can be done after harvest to prevent the leaching loss of residual nitrate. This problem has received considerable attention since contamination of groundwater with nitrate-N has been observed in Michigan and several other potato producing areas of the Northeast.

The amount of fertilizer N needed for potatoes varies greatly depending on the variety, previous crop, soil type, N mineralization and weather. Fertilizer studies in Michigan and elsewhere have indicated that delayed or split applications of N fertilizer can greatly improve N fertilizer recovery. Plant tissue and soil analysis could be used to evaluate the nitrogen status of the crop during the season. More information is needed on the critical levels of plant and soil N at various stages of potato growth.

The results from preliminary studies in 1989 revealed that plant analysis was more reliable than soil analysis for determining the N adequacy during the growing season. In 1990, a great deal of emphasis was placed on plant sap analysis during the growing season.

OBJECTIVES

(1) To evaluate delayed nitrogen applications on yield and quality of potatoes and residual levels of nitrate N left in the soil at harvest;

(2) To develop critical levels of nitrate-N in the potato petiole sap;

(3) To develop a quick test for nitrate-N analysis of soil and plant tissue to be used in the field during the growing season.

MATERIALS AND METHODS

Information regarding the location, cultural practices, and N application dates for the six test sites are shown in Table 1. The initial soil test results are presented in Table 2. All treatments received 100 lbs of 10-34-0 as starter fertilizer at planting. Preplant applications of potash were made according to soil test recommendation at each site. The eight N treatments tested in 1990 are presented in Table 3. The sidedress N source was ammonium nitrate. Treatments 2, 3 and 4 received all of their sidedress N at tuber initiation time. For treatments 5 and 6, N was split between emergence and tuber initiation. In treatments 7 and 8, the N was split between planting and emergence.

Petiole samples were taken from each N treatment commencing about 2 weeks after the final N application. Nitrate-N was measured in petiole sap using a nitrate ion-specific electrode. The sap was diluted 1:100 with 0.01 M aluminum sulfate solution before the measurement.

RESULTS AND DISCUSSION

Tuber Yield and Quality:

The data for tuber yields, size distribution and specific gravity for the six locations are shown in Tables 4-9.

At the Crawford location (Table 4), both total and US #1 yield of Onaway potatoes were maximized when 130 lbs N/A was split between planting and emergence (treatment 7). Much of the yield increase came as a result of increased tuber size. Delaying N application until tubers were initiated resulted in smaller tubers and lower yields . Specific gravity was not significantly affected by any of the N treatments.

At the Crooks location (Table 5), both total and US#1 yield of Snowden potatoes were not significantly affected by the N treatments ($P<0.05$), although the lowest yield was obtained with 10 lbs N/A and the highest yield with 190 lbs N/A. Tuber size and specific gravity were also unaffected by the N rates due to high field variability.

The Montcalm research farm location had six replications; 3 replications where the previous crop was corn, and 3 replications where the previous crop was rye. Statistical analysis indicated that the previous crop did not influence tuber yield or specific gravity of Snowden potatoes (Table 6). However, N treatments produced significant effects on both US#1 and total tuber yield. All treatments receiving 130 and 190 lbs N/A produced significantly higher yields compared to 10 and 70 lbs N/A rates. Much of this yield increase can be attributed to increased tuber size. Although there was no significant difference between 130 and 190 lbs N/A, US#1 yield and the size distribution tended to be greater when 190 lbs N/A was split between planting, emergence and tuber initiation (Treatment 6). Delaying the N application until tuber initiation did not appear to be detrimental to yield. This may be due to the late maturity of Snowden in contrast to Onaway. Specific gravity was excellent and was not significantly affected by the N treatments.

The data from MSU research farm at E. Lansing (Table 7) showed that the N rates applied did not influence tuber yield and size distribution of R. Burbank potatoes. Increased N levels, however, resulted in decreased specific gravity.

The yield data for R. Burbank potatoes grown on the Verbrigh farm in the upper peninsula are presented in Table 8. N rates had no significant affect on yield, size distribution or specific gravity. Although the yield response was not significant ($P<0.05$), the lowest yields were found where only 10 lbs of N was applied.

The data obtained from the Haindl farm (Table 9) are similar to the Verbrigh farm. Nitrogen applications produced no response in tuber yield, size distribution or specific gravity. Yields of R. Burbank potatoes were in general much lower than at the Verbrigh or MSU research farm.

Petiole Nitrate N

The petiole nitrate N content and the sampling dates of the 6 locations are shown in Tables 10-15. The petiole nitrate N content at all locations was in general directly related to the N application rate. With the exception of few sampling dates, the N content declined as the season progressed.

At the Crawford Farm (Table 10), yield reductions associated with low N application rates (10 and 70 lbs /A) were closely correlated with lower petiole N (less than 1100 ppm) throughout July. Petiole N fluctuated with sampling date at this site. Some of this difference may be due to turgidity of the plant tissue at the time of sampling. At the Crooks farm (Table 11), petiole N was significantly lower in the 10 and 70 lbs N/A treatments, which produced the lowest yields. At the Montcalm research farm (Table 12), the petiole N content closely followed the tuber yield. In 2 of the 4 sampling dates, the petiole N levels were significantly higher in the treatments 3 and 4, compared to treatments 1 and 2. At the MSU location (Table 13), reduced petiole N associated with lower N rates were evident, but no significant response in tuber yield was observed. At both upper peninsular sites, (Tables 14 and 15), significantly lower petiole N content was evident in the 10 lbs N/A treatment for several sampling dates.

Although petiole N content was predictable related to the N treatments applied, significant differences in the petiole N between the N treatments were not always evident at all locations. In two of the six locations, where significant yield differences occurred (Crawford and Montcalm Research Farms), the yields from treatments 1-3 were associated with increases in petiole N content. Evidence from these 2 farms also suggested that the maximum petiole N content observed in the 1st sampling date occurred when the N was split between emergence and tuber initiation (treatment 6). In all but one location, the petiole N content at the first sampling date was less than 1000 ppm in treatment 1, where only 10 lbs N/A were applied at planting.

Soil Nitrate N

The initial and mid-season(June 28) soil N levels are presented in Table 16. The two locations that produced a significant yield response to applied N (Crawford and Montcalm Research Farm) initially had 50-60 lbs total N/A-2ft. The other 4 farms had higher soil N ranging from 80 to 108 lbs N/A-2ft. This may partly explain the lack of response to applied N at these farms. The data for the mid-season N levels indicate considerable mineralization of organic N and nitrification of the ammonium N. This process may be significant for soils with high organic matter or where legumes have been previously grown. The 120 lbs of total N found at the MSU location may have been carry-over N from the previous sugar beet crop. In this situation excess use of N fertilizer for potato production could have been avoided by assessing the soil N supply prior to planting.

The soil nitrate-N levels in the soil profile at harvest from each N treatment are presented in Table 17. In all locations except the Crawford farm, there was no significant relationship between the soil nitrate N levels and the N treatments. At the Crawford location, treatments 6 and 8 had significantly higher residual nitrate levels in the soil profile compared to all other N treatments. This possibly means that over-fertilization for the early maturing Onaway potatoes occurred in these treatments. This trend was not evident at other locations, where full season varieties Snowden and R. Burbank were grown. At several locations, the amount of nitrate N present in the subsurface was slightly higher than in the surface, indicating the movement of nitrate-N downwards during the season.

CONCLUSIONS

This study dealt with some crucial aspects of N fertilizer management for potatoes. Further detailed analysis of the data are necessary to determine the usefulness of this year's data. It appears that the initial nitrate-N levels in the soil and potential for mineralization are critical factors in determining the optimum N rate for potatoes. The petiole N and yield data from several of the sites indicate that a significant improvement in N fertilizer efficiency can be derived from split N applications made according to crop growth needs. The petiole sap analysis procedure needs some refinement. It may be necessary to account for the variation in the sap water content (turgidity) as affected by soil-plant water relationships at the time of sampling. Expressing the nitrate content on a dry weight basis, rather than on a fresh basis as reported in 1990, may improve the development of critical nitrate values for potato petiole sap at different stages of growth.

Table 1. Agronomic characteristics of the six test locations and the nitrogen application dates at planting, emergence, and tuber initiation for potatoes in 1990

Grower/ Location	County	Cultivar	Soil Type	Previous Crop	Planting	Emergence	Tuber Initiation	Harvest Date
Crawford Farm	Montcalm	Onaway	Mcbride Sandy Loam	Summer fallow fall Rye	May 7	May 30	June 21	Aug 9
Crooks Farm	Montcalm	Snowden	Montcalm Sandy Loam	Wheat	May 12	Jun 5	Jun 26	Sep 25
Montcalm Res.Farm	Montcalm	Snowden	Mcbride Sandy Loam	Corn and Rye	May 8	May 30	Jun 21	Sep 18
MSU East Lansing	Ingham	Russet Burbank	Metea Sandy Loam	Sugar Beet	Apr 27	May 29	Jun 19	Oct 1
Verbrigh Farm	Delta (UP)	Russet Burbank	Onaway Fine Sandy Loam	Alfalfa	May 24	Jun 15	Jul 2	Oct 4
Haindl Farm	Schoolc-raft(UP)	Russet Burbank	Onaway Fine Sandy Loam	Fallow	May 20	Jun 15	Jul 2	Sep 26

Table 2. Soil tests results from 1990 test locations.

Grower/Location	% O.M.	pH	P ----	K lbs/A	Ca -----	Mg -----
Crawford Farm	1.1	6.0	480	236	686	133
Crooks Farm	1.9	6.3	399	204	1067	236
Montcalm Res.Farm	1.4	5.9	445	160	762	160
MSU East Lansing	2.0	5.8	226	227	1067	147
Verbrigh Farm	2.9	6.5	174	94	2442	344
Handl Farm	2.6	6.0	190	267	1333	290

Table 3. Nitrogen applied (lbs/A) to 1990 test treatments at different stages of potato growth.

Treatment #	Planting	Emergence	Tuber Initiation	Total N Applied
1	10	0	0	10
2	10	0	60	70
3	10	0	120	130
4	10	0	180	190
5	10	60	60	130
6	10	120	60	190
7	10 + 60	60	0	130
8	10 + 60	120	0	190

Table 4. The effect of rate and time of nitrogen fertilizer application on yield, tuber size and specific gravity of Onaway potatoes (Crawford).

Trt. no.	N rate -lb/A-	Yield: U.S. no. 1 (cwt/A)	Total yield (cwt/A)	Tuber size distribution: #1 (%)	<2" (%)	2-3¼" (%)	>3¼" (%)	Specific gravity
1	10	137[c]	158[c]	87.1	12.9[a]	86.2	0.9[ef]	1.066
2	70	173[bc]	195[bc]	88.8	10.7[ab]	88.1	0.8[f]	1.069
3	130	181[abc]	201[abc]	89.5	9.8[abc]	87.7	1.8[def]	1.069
4	190	204[ab]	228[ab]	89.4	8.7[bc]	86.1	3.4[bcd]	1.068
5	130	195[ab]	218[ab]	89.3	8.2[bc]	85.3	4.1[bc]	1.066
6	190	199[ab]	218[ab]	91.2	7.6[bc]	88.4	2.9[cdf]	1.068
7	130	235[a]	258[a]	91.0	7.4[bc]	85.8	5.2[ab]	1.067
8	190	227[ab]	250[ab]	90.5	6.8[c]	83.7	6.8[a]	1.070

[1] Means within a column followed by the same letter are not significantly different (P<.05) according to the DMR test.

Table 5. The effect of rate and time of nitrogen fertilizer application on yield, tuber size and specific gravity of Snowden potatoes (Crooks).

Trt. no.	N rate -lb/A-	Yield: U.S. no. 1 (cwt/A)	Total yield (cwt/A)	Tuber size distribution: #1 (%)	<2" (%)	2-3¼" (%)	>3¼" (%)	Specific gravity
1	10	219	246	89.1	10.9	82.6	6.5	1.087
2	70	268	292	91.5	8.5	83.1	8.4	1.088
3	130	274	296	92.1	7.9	83.2	8.9	1.089
4	190	298	325	91.5	8.5	79.6	11.9	1.089
5	130	274	300	91.2	8.8	83.3	8.0	1.087
6	190	276	300	91.7	6.9	86.5	6.6	1.086
7	130	274	302	90.7	9.3	81.7	9.0	1.088
8	190	292	317	92.1	7.9	81.6	10.5	1.087

[1] Means within a column followed by the same letter are not significantly different (P<.05) according to the DMR test.

Table 6. The effect of rate and time of nitrogen fertilizer application on yield, tuber size and specific gravity of Snowden potatoes (MRF).

Trt. no.	N rate -lb/A-	U.S. no. 1 -- cwt/A ----	Total yield	Yield: Tuber size distribution #1 ---------- %	<2"	2-3¼"	>3¼" -------------	Specific gravity
1	10	150^{c}	166^{c}	89.7^{d}	10.3^{a}	83.0^{a}	6.7^{d}	1.091
2	70	202^{b}	217^{b}	93.1^{c}	6.9^{b}	81.2^{a}	11.9^{cd}	1.093
3	130	244^{a}	256^{a}	95.2^{ab}	4.8^{cd}	78.4^{abc}	16.7^{bc}	1.094
4	190	261^{a}	273^{a}	95.4^{ab}	4.6^{cd}	73.8^{bc}	21.6^{ab}	1.092
5	130	262^{a}	274^{a}	95.5^{ab}	4.5^{cd}	75.1^{bc}	20.5^{ab}	1.092
6	190	272^{a}	282^{a}	96.4^{a}	3.6^{d}	72.6^{c}	23.7^{a}	1.093
7	130	269^{a}	285^{a}	94.4^{bc}	5.6^{bc}	79.2^{ab}	15.2^{bc}	1.093
8	190	269^{a}	281^{a}	95.8^{ab}	4.2^{cd}	78.4^{abc}	17.3^{bc}	1.092
Previous Crop								
Rye		256	269	94.7	5.3	80.5	14.2	1.093
Corn		227	239	94.2	5.8	74.9	19.3	1.093

[1] Means within a column followed by the same letter are not significantly different (P<.05) according to the DMR test.

Table 7. The effect of rate and time of nitrogen fertilizer application on yield, tuber size and specific gravity of R Burbank potatoes (MSU-East Lansing).

Trt. no.	N rate -lb/A-	U.S. no. 1 -- cwt/A ----	Total yield	Yield: Tuber size distribution #1 ---------- %	<2"	2-3¼"	>3¼" -------------	Specific gravity
1	10	285	368	78.0	11.9	73.1	4.9	1.086^{a}
2	70	298	368	81.1	11.5	73.7	7.4	1.080^{b}
3	130	295	395	75.7	9.8	68.5	7.2	1.081^{b}
4	190	294	383	77.2	10.6	68.4	8.7	1.080^{b}
5	130	275	365	74.9	12.1	66.7	8.1	1.083^{b}
6	190	293	378	77.8	11.0	69.1	8.7	1.080^{b}
7	130	270	348	77.8	10.6	69.3	8.4	1.078^{b}
8	190	271	357	76.1	11.5	67.6	8.5	1.076^{b}

[1] Means within a column followed by the same letter are not significantly different (P<.05) according to the DMR test.

Table 8. The effect of rate and time of nitrogen fertilizer application on yield, tuber size and specific gravity of R Burbank potatoes (Verbrigh).

Trt. no.	N rate -lb/A-	U.S. no. 1 (Yield, cwt/A)	Total yield (cwt/A)	Tuber size distribution #1 (%)	<2" (%)	2-3¼" (%)	>3¼" (%)	Specific gravity
1	10	243	283	86.8	10.4	75.2	11.6	1.088
2	70	258	286	89.5	8.7	83.8	5.7	1.087
3	130	267	293	90.4	6.9	81.7	8.6	1.088
4	190	273	296	92.2	6.1	82.2	10.0	1.087
5	130	256	278	92.0	5.7	83.5	8.5	1.086
6	190	260	283	91.8	6.4	81.2	10.6	1.088
7	130	265	295	90.0	8.4	85.3	4.7	1.087
8	190	270	297	90.8	7.6	81.5	9.3	1.087

[1] Means within a column followed by the same letter are not significantly different (P<.05) according to the DMR test.

Table 9. The effect of rate and time of nitrogen fertilizer application on yield, tuber size and specific gravity of R Burbank potatoes (Haindl).

Trt. no.	N rate -lb/A-	U.S. no. 1 (Yield, cwt/A)	Total yield (cwt/A)	Tuber size distribution #1 (%)	<2" (%)	2-3¼" (%)	>3¼" (%)	Specific gravity
1	10	101	171	58.8	19.8	49.5	9.3	1.081
2	70	114	179	62.9	13.6	53.2	9.7	1.080
3	130	116	198	58.4	15.2	48.3	10.1	1.080
4	190	99	173	57.3	17.4	47.7	9.6	1.080
5	130	116	188	61.4	16.0	52.9	8.5	1.079
6	190	126	187	66.1	14.7	53.0	13.1	1.079
7	130	125	189	64.7	15.6	52.9	11.8	1.081
8	190	117	194	61.9	16.1	52.2	9.7	1.079

[1] Means within a column followed by the same letter are not significantly different (P<.05) according to the DMR test.

Table 10. Potato petiole nitrate content of Onaway potatoes as affected by nitrogen rate and time of application. (CRAWFORD)

Trt. No.	N Rate lb N/A	7-6	7-13	7-20	7-27
		ppm[1]			
1	10	462[e]	93[e]	159[e]	99[e]
2	70	1082[d]	432[d]	708[d]	307[de]
3	130	1335[bc]	688[bc]	1277[bc]	569[cd]
4	190	1430[abc]	887[ab]	1468[ab]	995[b]
5	130	1413[abc]	806[abc]	1355[bc]	659[bcd]
6	190	1588[a]	874[abc]	1745[a]	1434[a]
7	130	1293[c]	624[cd]	1068[c]	540[cd]
8	190	1526[ab]	974[a]	1567[ab]	880[bc]

[1] Any means followed by the same letter are not statistically different at the 5 percent level of probability.

Table 11. Potato petiole nitrate content of Snowden potatoes as affected by nitrogen rate and time of application. (CROOKS)

Trt. No.	N Rate -lb N/A-	7-10	7-17	7-24	7-31
		ppm[1]			
1	10	835[c]	561[c]	289[d]	651[c]
2	70	1092[b]	796[b]	505[c]	1093[b]
3	130	1173[ab]	947[ab]	765[ab]	1296[ab]
4	190	1310[ab]	942[ab]	874[ab]	1378[ab]
5	130	1185[ab]	887[ab]	725[b]	1307[ab]
6	190	1389[a]	926[ab]	871[ab]	1483[a]
7	130	1276[ab]	888[ab]	702[bc]	1124[ab]
8	190	1400[a]	1026[a]	979[a]	1486[a]

[1] Any means followed by the same letter are not statistically different at the 5 percent level of probability.

Table 12. Potato petiole nitrate content of Snowden potatoes as affected by nitrogen rate and time of application (MRF).

Trt. No.	N Rate -lb N/A-	7-3	7-10	7-17	7-24
		ppm[1]			
1	10	989^{c}	496^{b}	346^{d}	61^{c}
2	70	1278^{b}	850^{a}	597^{c}	198^{c}
3	130	1642^{a}	893^{a}	756^{b}	570^{a}
4	190	1620^{a}	947^{a}	933^{ab}	650^{a}
5	130	1595^{a}	821^{a}	823^{ab}	415^{b}
6	190	1670^{a}	973^{a}	959^{a}	599^{a}
7	130	1525^{ab}	890^{a}	764^{b}	422^{b}
8	190	1621^{a}	900^{a}	780^{b}	664^{a}

[1] Any means followed by the same letter are not statistically different at the 5 percent level of probability.

Table 13. Potato petiole nitrate content of R. Burbank Potatoes as affected by nitrogen rate and time of application (MSU-East Lansing).

Trt. No.	N Rate -lb N/A-	7-2	7-9	7-16	7-23	7-30
		ppm[1]				
1	10	606^{d}	265^{c}	217^{d}	243^{c}	98^{d}
2	70	1486^{c}	931^{b}	799^{c}	684^{b}	424^{cd}
3	130	1526^{bc}	1184^{a}	1102^{ab}	1010^{a}	701^{bc}
4	190	1708^{abc}	1278^{a}	1265^{a}	1090^{a}	1175^{a}
5	130	1767^{a}	994^{b}	982^{bc}	694^{b}	521^{cd}
6	190	1726^{ab}	1175^{a}	1117^{ab}	1143^{a}	1129^{ab}
7	130	1609^{abc}	928^{b}	828^{c}	655^{b}	507^{cd}
8	190	1540^{abc}	1165^{a}	1124^{ab}	1074^{a}	1048^{ab}

[1] Any means followed by the same letter are not statistically different at the 5 percent level of probability.

Table 14. Potato petiole nitrate content of R. Burbank potatoes as affected by nitrogen rate and time of application. (VERBRIGH)

Trt. No.	N Rate -lb N/A-	7-20	7-23	8-8	8-28
		ppm[1]			
1	10	1040	909	1096^{b}	1079^{c}
2	70	1062	1106	1316^{a}	1387^{b}
3	130	927	1150	1356^{a}	1471^{b}
4	190	990	1054	1276^{a}	1572^{ab}
5	130	1046	1057	1285^{a}	1548^{ab}
6	190	1208	1124	1404^{a}	1756^{a}
7	130	1013	1151	1422^{a}	1563^{ab}
8	190	1109	992	1316^{a}	1715^{a}

[1] Any means followed by the same letter are not statistically different at the 5 percent level of probability.

Table 15. Potato petiole nitrate content of R. Burbank potatoes as affected by nitrogen rate and time of application. (Haindl)

Trt. No.	N Rate -lb N/A-	7-20	7-23	8-8	8-28
		ppm[1]			
1	10	931^{bc}	890	1152^{c}	646^{d}
2	70	1042^{abc}	963	1535^{ab}	919^{cd}
3	130	1018^{abc}	958	1713^{ab}	1175^{bc}
4	190	906^{c}	971	1690^{ab}	1558^{ab}
5	130	1034^{abc}	990	1487^{b}	1351^{ab}
6	190	1093^{ab}	1118	1697^{ab}	1620^{a}
7	130	1128^{a}	923	1779^{ab}	1340^{ab}
8	190	1126^{a}	973	1849^{a}	1376^{ab}

[1] Any means followed by the same letter are not statistically different at the 5 percent level of probability.

Table 16. Initial and mid season soil nitrogen levels at the 1990 test locations.

N Form	Crawford	Crooks	MRF	Lansing	Verbrigh	Handl
	--------------------lbs N/A-2ft----------------					
Initial Soil N						
NO_3-N	13	20	8	40	30	56
NH_4-N	48	60	41	80	49	52
Total-N	61	80	49	120	79	108
Mid-Season Soil N						
NO_3-N	29	79	39	47	*	*
NH_4-N	15	16	26	20	*	*
Total-N	44	95	65	67	*	*

*sites not sampled

Table 17. The soil Nitrate-N levels in the soil profile at harvest in the N levels tested in 1990.

Treatment	Crawford	Crooks	MRF	E. Lansing	Verbrigh	Handl
	------Soil Profile Nitrate-N (lbs N/A-2ft)-------					
1	40	60	31	205	83	83
2	45	60	30	233	116	79
3	52	47	47	207	145	118
4	63	49	45	267	181	184
5	78	43	39	205	128	151
6	131	42	41	316	173	204
7	62	67	34	234	92	131
8	126	107	41	312	121	206

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Effects of Nitrogen Fertilizer Management on Nitrate Leaching

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This study represents the continuation of research initiated in 1988 at the MSU Potato Research Farm to evaluate the impact of contrasting nitrogen (N) management strategies on potato yields and nitrate leaching. Two permanently-installed drainage lysimeters have been used to monitor soil water drainage and nitrate leaching at this site. Each year, a treatment consisting of conventional nitrogen management (CON) was applied to one lysimeter area and a "Better Management System" (BMS), involving reduced input of fertilizer N, was applied to the second.

It was necessary to plant the lysimeter site to corn in 1989 due to problems with Potato Early Die Complex during the previous year. Tracer techniques were employed in 1989 to determine whether nitrate appearing in the drainage water originated from fertilizer additions or from other sources such as mineralization of soil organic matter. The total amount of nitrate lost from the lysimeter profiles during 1989 was 121 lb/A for the CON treatment and 107 lb/A for BMS. Virtually none of this nitrate originated from fertilizer applied to the 1989 crop (results of the tracer data were not included in the 1989 report). This report contains the 1990 results and focuses on the sources of N appearing in the drainage water.

Methods

The lysimeters (48" X 68" X 6 ft. deep) used in this study consist of steel boxes that are open at the top and closed at the bottom except for an opening used to collect water that drains through the lysimeter profile. The lysimeters intercept water at the 7½ ft. soil depth, the sum of the distance from the soil surface to the top of each lysimeter (1½ ft.) and their depth (6 ft.). Drainage depths and nitrate leaching were determined by measuring the volume of water collected and sampling it each time for nitrate concentrations using standard autoanalyzer techniques. Sampling frequency was dictated by drainage rates during the season.

Because the 1990 results were influenced substantially by management practices used in 1989, the fertilizer N rates applied that year will be recapped. Each plot received N as ammonium sulfate at a rate of 13 lb/A at planting and one additional application of ammonium sulfate on June 21, 1989. The second application involved an N rate of 187 lb/A (200 lb/A total) for the CON treatment and 116 lb/A (130 lb/A total) for BMS. The ammonium sulfate applied to each lysimeter area on June 21 was labeled with the stable isotope ^{15}N. Drainage water samples collected after this date were also analyzed for ^{15}N concentrations. Four microplots (46" X 29") were established adjacent to the lysimeters in each treatment to provide replication of soil and plant ^{15}N measurements. They also received the ^{15}N labeled ammonium sulfate at the prescribed rates (187 lb/A for CON and 116 lb/A for BMS) on June 21. The microplots were maintained through the 1990 season.

The CON and BMS plots were planted to Russet Burbank potatoes on May 31, 1990. The row spacing and seed spacing within the row were 34 inches and 12 inches, respectively giving a population of 15,370 plants/A. At this plant density, the 68-inch lysimeter dimension accommodates two rows, each containing 4 seed pieces over the 48-inch length for a total of 8 seed pieces over each lysimeter. Each microplot accommodated 3 seed pieces. Unlabeled fertilizer was applied in 1990. Nitrogen application rates were 193 lb/A including 75 lb/A at planting for the CON treatment. Nitrogen applied to the BMS plot was 110 lb/A for the season and 28 lb/A at planting. Both plots were irrigated as needed during the season using the same irrigation schedules for each treatment. Potatoes were harvested from each lysimeter, each microplot, and from areas bordering the microplots (10 ft. of row) in each treated area. Tuber quality was evaluated by measuring the size distribution and the specific gravity of tubers weighing less than 10 oz.

Results

Tuber yield and quality differed substantially between treatments in 1990 (Table 1). Total tuber yield averaged 311 cwt/A for the CON treatment compared to 206 cwt/A for BMS. The CON treatment also produced the most favorable tuber size distribution as BMS decreased the yield of U.S. No. 1's by a factor of three. The plant responses in 1990 contrast those reported in previous years when potato yields (1988) and corn yields (1989) were the same for the two treatments.

Figures 1 to 6 illustrate data collected from the lysimeters during 1990. Because each treated area received the same irrigation management, the lysimeters drained at similar rates during the season (Fig. 1). Drainage was negligible during the January to March period when frozen soil impeded the downward movement of water. Monthly rainfall was consistently greater than 4 inches from May to November causing the soil in the lysimeters to drain continually during the growing season totalling about 20 inches as of the last measurement date on December 15. Cumulative drainage is averaged for the two treatments in Fig. 2 and compared with precipitation over the same time period. The difference between the two curves (shaded area) is due to evaporation of water from the soil surface and water taken up by plants. Runoff represents another component of the soil water balance but galvanized steel borders constructed around each lysimeter eliminated runoff. The difference between the two curves in Fig. 2 amounted to about 20 inches by the end of the measurement period, the majority of which can be attributed to water utilized by the potato crop.

Nitrate concentration in the drainage water was consistently lower where the BMS treatment existed than where the CON treatment was applied (Fig. 3). Cumulative nitrate loss for the season is illustrated in Fig. 4. Unlike previous years when drainage (and therefore nitrate leaching) ceased for a two or three month period at some time during the season, nitrate leached at a significant rate prior to planting, during the growing season, and after fall harvest in 1990. As of the last measurement date, the BMS treatment decreased total nitrate loss from 160 lb/A to 110 lb/A.

Because the fertilizer applied to each lysimeter on June 21, 1989 was labeled with ^{15}N, the nitrogen (mostly nitrate) appearing in the drainage water should eventually exhibit this label. Figures 3 and 4 make no distinction between nitrogen exhibiting the ^{15}N label and that which is unlabeled. Results of ^{15}N analyses, completed on samples collected through September 15, were used to separate total nitrate leaching and leaching of soil derived N for each treatment (Fig. 5 and 6). The difference between the "TOTAL N" and "SOIL N" curves (shaded area) represents the amount of ^{15}N applied as ammonium sulfate in 1989 that was recovered in the drainage water. Several important results are illustrated in these figures. First, the curves diverge in March for each treatment indicating a substantial time lag of about 9 months between the application of the labeled fertilizer and its appearance in drainage water intercepted at the 7½ ft. soil depth. Second, the "SOIL N" curves are about the same for each treatment but a significant amount of the ^{15}N labeled fertilizer was leached from the CON lysimeter accounting for most of the differences reported in Fig. 4. Finally, completion of the soil and plant ^{15}N analyses should demonstrate increased fertilizer N use efficiency with the BMS treatment substantiating the premise that management practices which increase N use efficiency decrease the potential for nitrate leaching.

Recommendations

This study provides solid evidence that nitrate leaching data collected from the lysimeters installed on McBride sandy loam reflect management practices applied in previous year(s). The full impact of N and/or irrigation management on nitrate leaching cannot be evaluated through short term analyses as a result. Continued monitoring efforts will provide the long term record needed to thoroughly evaluate the nitrate leaching problem.

Table 1. Tuber yield and quality in terms of size distribution, pick outs, and specific gravity.

Treat-ment	Sub-sample	Yield (cwt/A) Total	Yield (cwt/A) No. 1	Percent Size Distribution <4oz	Percent Size Distribution 4-10oz	Percent Size Distribution >10oz	Percent Size Distribution Pick Outs	Specific Gravity
CON	L*	322	169	34.6	37.1	15.5	12.8	1.070
	M	303	163	30.9	48.7	5.1	15.3	1.064
	B	309	136	43.3	40.7	3.3	12.7	1.067
	Avg	311	156	36.2	42.2	8.0	13.6	1.067
BMS	L	200	41	72.1	20.2	0.0	7.7	1.067
	M	171	37	75.9	21.4	0.0	2.7	1.059
	B	246	82	55.5	33.5	0.0	11.0	1.068
	Avg	206	53	67.9	25.0	0.0	7.1	1.065

* L = Lysimeter; M = Microplots; B = Border; Avg = Average for all subsamples.

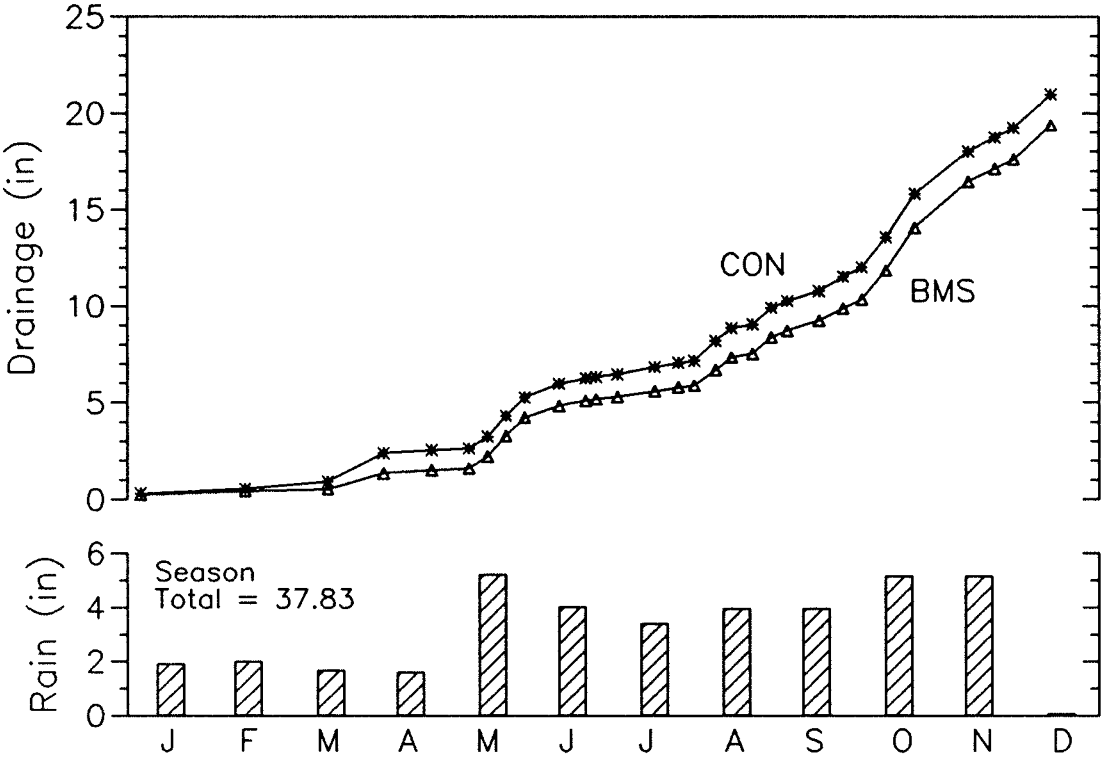

Figure 1. Monthly precipitation and cumulative soil water drainage during 1990.

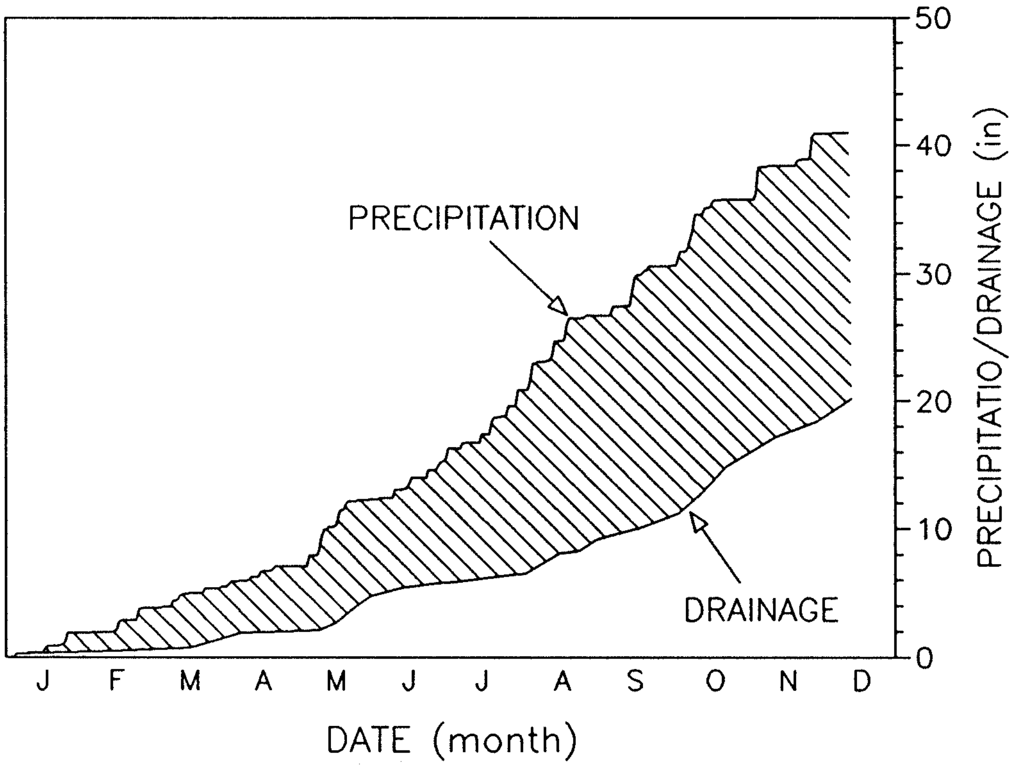

Figure 2. Cumulative precipitation (rain + irrigation) and drainage (CON and BMS treatment averages) during 1990.

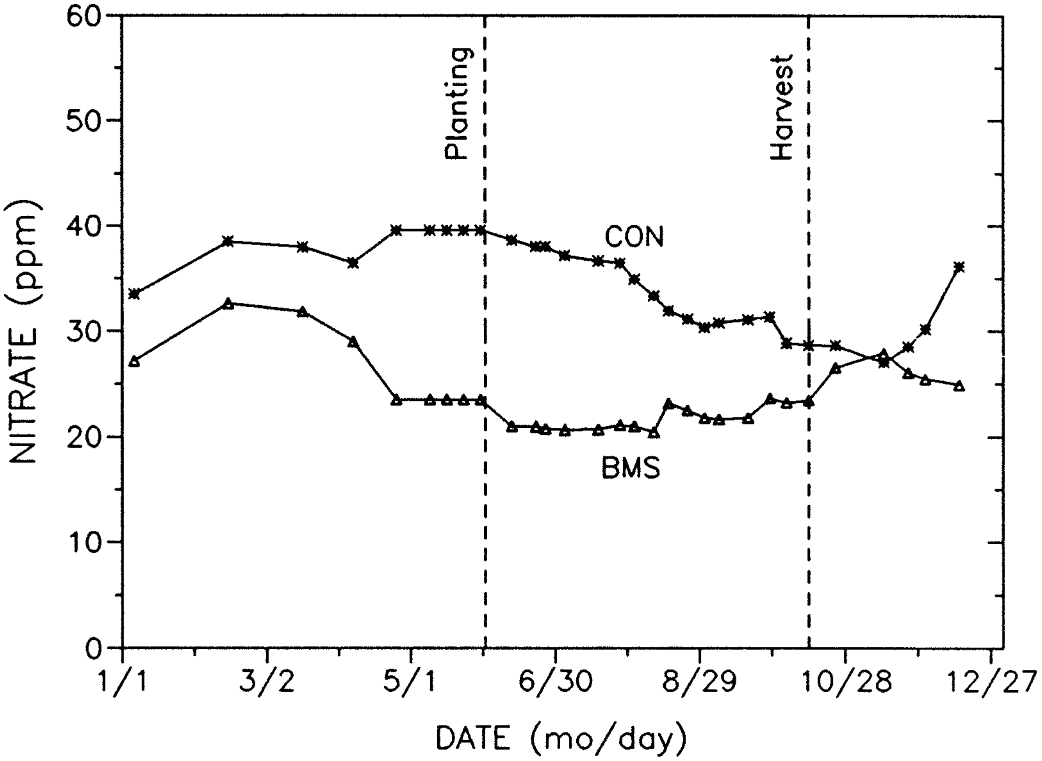

Figure 3. Drainage water nitrate concentrations during 1990.

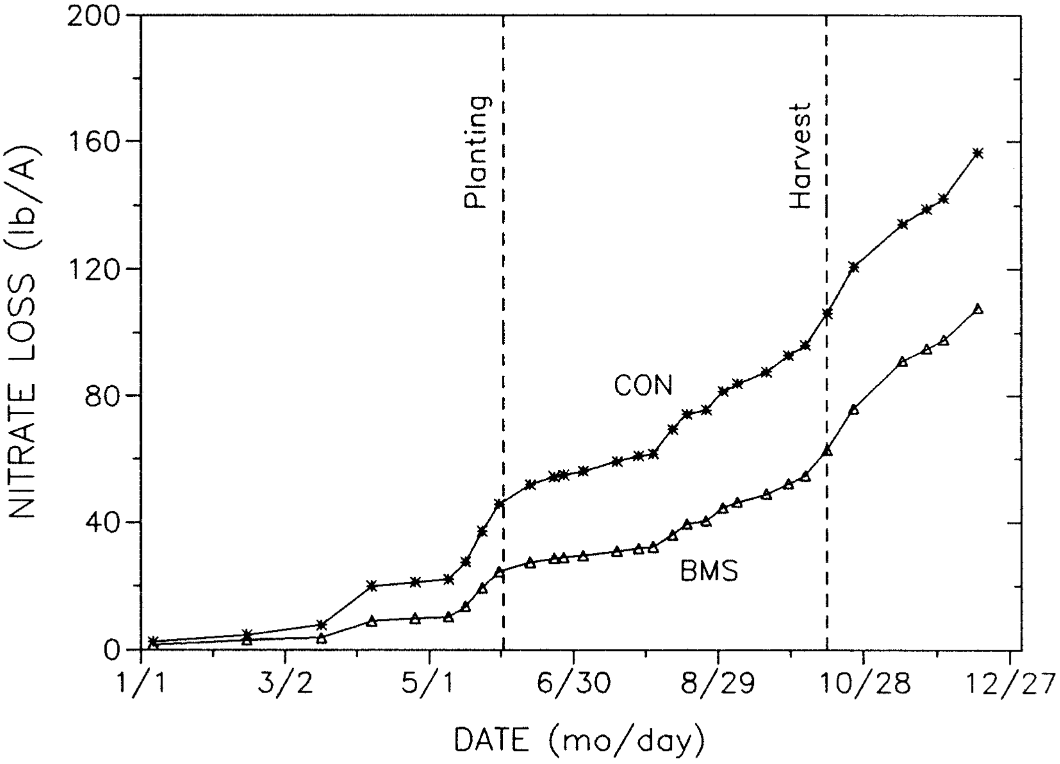

Figure 4. Cumulative nitrate leaching during 1990.

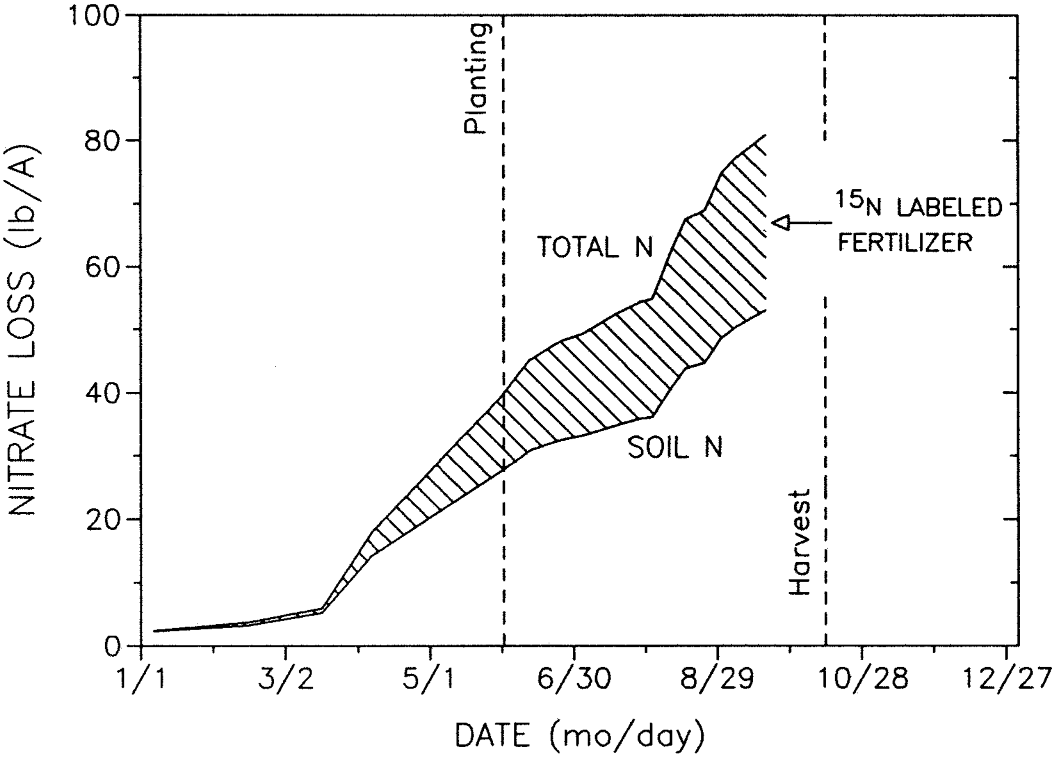

Figure 5. Nitrate leaching from soil N and fertilizer N sources for the Conventional treatment in 1990.

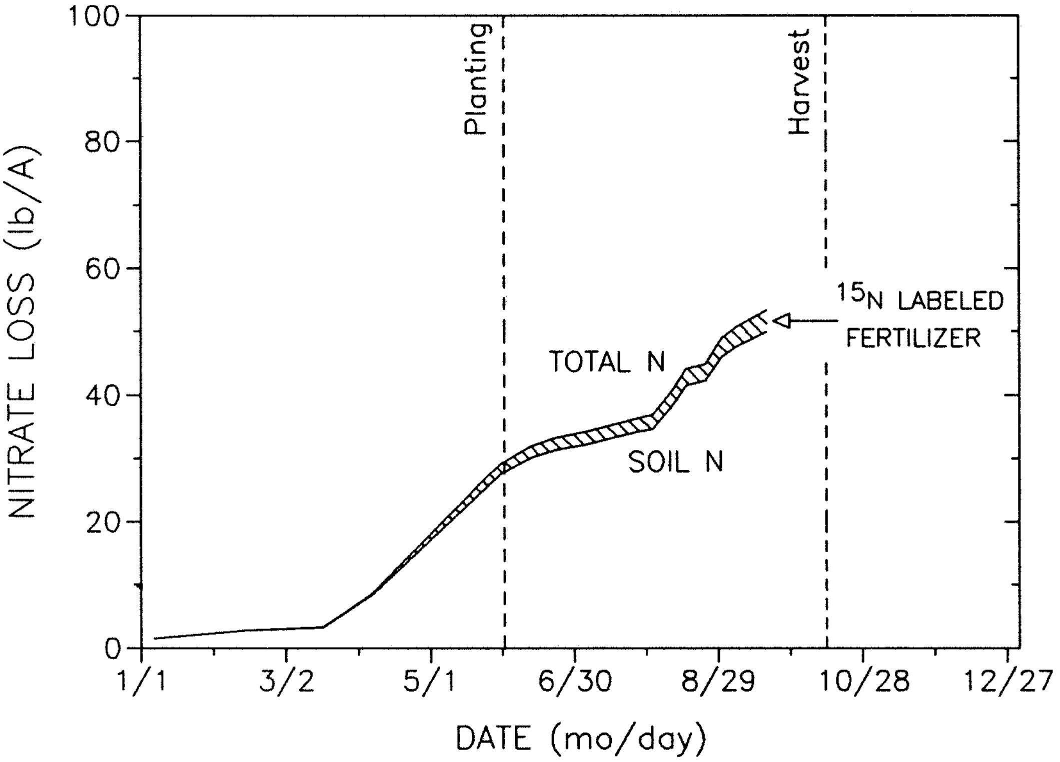

Figure 6. Nitrate leaching from soil N and fertilizer N sources for the Better Management System in 1990.

Funding Federal Grant

RESPONSE OF SPARTAN PEARL AND NORCHIP TO RATES AND SOURCES OF POTASSIUM FERTILIZER

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Introduction

A study was initiated in 1988 to determine the effects of rates and sources of potash on yields, specific gravity and chip quality. The varieties selected were Spartan Pearl and Norchip which are similar in maturity and specific gravity. The three year study was conducted at the Montcalm Research Farm.

Procedure

Two sources of potash (muriate of potash and potassium sulfate) and four application levels (0, 100, 200 and 300 lbs/A K_2O) were tested in a randomized complete block design with four replications. The potash treatments were applied broadcast with a Gandy applicator just prior to planting. The Norchip and Spartan Pearl seed were cut and hand planted at 12 inches and 9 inches, respectively. Fertilizer applied at planting was a special mix of nitrogen, phosphorus and extender so that the only plot variable was the potash rate and source. The plots were irrigated and supplemental nitrogen was applied through the irrigation system. The recommended practices of insect and disease control were followed.

The initial soil tests for K_2O were: 1988 - 282 lbs/A, 1989 - 185 lbs/A and 1990 - 236 lbs/A. For a projected yield of 400 cwt/A, the MSU fertilizer recommendations for potash based on these soil test levels, were 1988 - 98 lbs/A, 1989 - 195 lbs/A and for 1990 - 144 lbs/A. The applied levels of 0, 100, 200 and 300 lbs/A K_2O represented levels both below and above these recommendations. Planting and harvest dates for each year are as follows: 1988 - May 6 and September 22, 1989 - May 5 and September 12, 1990 - May 14 and September 17.

At harvest, yields, size distribution, specific gravity and chip quality ratings were obtained. Samples were collected for out-of-storage chip tests and for blackspot bruise.

Results

Table 1 provides the yields and specific gravity of Spartan Pearl for each year and the three year average. Similar results were observed each year with a minimum effect on marketable yields and the greatest effect on specific gravity. The marketable yield difference between the check plot and the addition of K_2O was only 14 cwt. When comparing the check vs. the two sources, there was a 26 cwt/A increase with potassium sulfate, however, these were not significant.

The highest specific gravity of 1.081 (Table 1, three year average) was obtained in the check treatment whereas it was 1.070 from the plots treated with 300 lbs/A of muriate of potash. The KCL source had the lowest specific gravity of 1.073 when compared with 1.081 for the check and 1.078 for the potassium sulfate source.

The results obtained with Norchip (Table 2) are very similar to Spartan Pearl. There was essentially no effect on either marketable or total yields. The effects on specific gravity, in terms of the range of difference were less. The difference between the highest and lowest specific gravity values for Norchip were .007 whereas for Spartan Pearl it was .011. In this study, Spartan Pearl produced approximately 40% higher yields than did Norchip.

There were no detectable differences in out-of-the-field chip color as all Agtron values were in the very acceptable range each year. In terms of blackspot bruise, the results are not consistent (Table 3). Considerable research has been done demonstrating that adequate potassium is needed to minimize blackspot damage. It has also been demonstrated that soil moisture conditions at harvest have an influence on the degree of blackspot. Low soil moisture at harvest increases the incidence of blackspot. The incidence of blackspot is very low for both Spartan Pearl and Norchip on tubers that were not artificially bruised. For the artificially bruised tubers, there is a definite increase in the amount of blackspot. It readily demonstrates that handling potatoes with a 40° pulp temperature results in significant and severe blackspot damage. The data from 1989 shows the highest level of blackspot damage and this is related to the drier than normal soil conditions at harvest.

Summary

The data from this study has consistently shown that the rates and source of potash do influence the quality of both Spartan Pearl and Norchip. The influence of potash rates and sources has had considerable research for several years and these results are consistent with that research. A 500 cwt/A crop will remove approximately 300 lbs of K_2O/A. The results of this study show that particularly for processing potatoes, it is desirable not to over-fertilize with potassium. Growers should collect soil samples before planting potatoes and apply the recommended potash for the realistic yield goal.

Table 1. Effect of Potash Sources and Rates on Yields and Specific Gravity of Spartan Pearl.

MSU Montcalm Research Farm, 1988-1990

	1988			1989			1990			3 Year Average		
	Yield (cwt/A)			Yield (cwt/A)			Yield (cwt/A)			Yield (cwt/A)		
Treatment	No. 1	Total	S.G.	No. 1	Total	S.G.	No. 1	Total	S.G.	No. 1	Total	S.G.
Check	491	530	1.076	457	539	1.082	423	485	1.084	457	518	1.081
KCL 100	514	564	1.073	442	506	1.080	429	485	1.076	462	518	1.076
KCL 200	435	478	1.070	480	562	1.075	431	487	1.073	449	509	1.072
KCL 300	474	514	1.068	492	562	1.072	429	486	1.070	465	521	1.070
K_2SO_4 100	485	537	1.076	473	540	1.081	463	520	1.082	474	532	1.079
K_2SO_4 200	496	547	1.074	499	589	1.080	464	525	1.078	486	554	1.077
K_2SO_4 300	485	533	1.074	502	576	1.078	485	532	1.078	491	547	1.076
Check	491	530	1.076	457	539	1.082	423	485	1.084	457	518	1.081
K	482	528	1.072	481	556	1.078	450	506	1.076	471	530	1.075
Check	491	530	1.076	457	539	1.082	423	485	1.084	457	518	1.081
KCL	474	518	1.070	471	543	1.076	430	486	1.073	458	516	1.073
K_2SO_4	488	539	1.075	491	568	1.080	471	526	1.079	483	544	1.078
Check	491	530	1.076	457	539	1.082	423	485	1.084	457	518	1.081
100	499	550	1.075	458	523	1.081	446	503	1.079	468	525	1.078
200	465	512	1.072	490	576	1.078	448	506	1.075	468	531	1.075
300	479	523	1.071	496	569	1.075	457	509	1.074	477	534	1.073

KCL = muriate of potash.

K_2SO_4 = potassium sulfate.

Table 2. Effect of Potash Sources and Rates on Yields and Specific Gravity of Norchip.

MSU Montcalm Research Farm, 1988-1990

	1988			1989			1990			3 Year Average		
	Yield (cwt/A)			Yield (cwt/A)			Yield (cwt/A)			Yield (cwt/A)		
Treatment	No. 1	Total	S.G.	No. 1	Total	S.G.	No. 1	Total	S.G.	No. 1	Total	S.G.
Check	392	464	1.077	283	355	1.078	292	382	1.080	322	400	1.078
KCL 100	400	473	1.073	258	340	1.078	294	383	1.078	317	399	1.076
KCL 200	417	520	1.072	271	364	1.072	334	421	1.074	341	435	1.073
KCL 300	337	433	1.070	271	351	1.071	325	409	1.071	311	398	1.071
K_2SO_4 100	384	489	1.075	285	377	1.079	362	455	1.077	344	440	1.077
K_2SO_4 200	376	460	1.074	268	357	1.078	334	411	1.077	326	409	1.076
K_2SO_4 300	408	498	1.073	280	379	1.075	343	420	1.077	344	432	1.075
Check	392	464	1.077	283	355	1.078	292	382	1.080	322	400	1.078
K	387	479	1.073	272	361	1.074	332	417	1.076	330	419	1.074
Check	392	464	1.077	283	355	1.078	292	382	1.080	322	400	1.078
KCL	385	475	1.072	267	352	1.074	318	404	1.074	323	410	1.073
K_2SO_4	389	482	1.075	278	371	1.077	346	429	1.077	338	427	1.076
Check	392	464	1.077	283	355	1.078	292	382	1.080	322	400	1.078
100	392	481	1.074	272	359	1.079	328	419	1.077	331	420	1.076
200	397	490	1.073	270	360	1.075	334	416	1.075	334	422	1.074
300	373	466	1.072	275	365	1.073	334	415	1.074	327	415	1.073

KCL = muriate of potash.

K_2SO_4 = potassium sulfate.

Table 3. Percent Spartan Pearl and Norchip Tubers with Blackspot Damage.

Spartan Pearl

	Check 1/				Artificially Bruised 2/			
Treatment	1988	1989	1990	3 Year Average	1988	1989	1990	3 Year Average
Check	0	20	5	8	10	85	85	50
KCL - 100	5	15	5	8	25	65	45	45
KCL - 200	0	0	0	0	5	50	60	35
KCL - 300	5	0	0	2	10	40	15	30
K_2SO_4 - 100	5	10	0	5	5	70	85	65
K_2SO_4 - 200	5	10	0	5	5	65	30	30
K_2SO_4 - 300	0	5	5	3	15	55	65	45

Norchip

Check	10	15	10	12	15	95	50	53
KCL - 100	5	10	10	8	50	70	45	55
KCL - 200	10	15	5	10	15	45	35	32
KCL - 300	5	5	0	3	15	45	30	30
K_2SO_4 - 100	10	5	10	8	40	75	65	60
K_2SO_4 - 200	10	0	0	3	35	45	30	37
K_2SO_4 - 300	0	0	5	2	10	50	45	35

1/ Tubers (20) are taken at random at harvest from research plot harvester.

2/ Artificially bruised evaluation is a severe test. Tubers (20) are taken from 40° storage and immediately placed in a hexagonal plywood drum and turned for 10 revolutions. Samples are held at room temperature at least 48 hours before being peeled and scored.

Funding MPIC

EVALUATION OF FACTORS AFFECTING PHOSPHORUS UPTAKE BY POTATOES

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Response of potatoes (Solanum tuberosum L.) in terms of yield to phosphorus fertilizer banded near the seed piece at planting appears to be somewhat unique and variable. When levels of available soil phosphorus as indicated by the Bray-Kurtz Pl test are very high (> 300 lb/A) most field and vegetable crops no longer give a yield response to applied phosphorus fertilizer. However over the years field studies on McBride sandy loam have shown potatoes to give an economic yield response. The response of potatoes on other soils and at other sites have been less consistent. The continued use of phosphorus fertilizer in a band at planting time has resulted in increasing levels of Bray-Kurtz Pl extractable phosphorus which is presumably available for plant uptake. High levels of phosphorus in soil, especially the surface soil, is of concern because it is subject to loss by soil erosion into surface waters (streams and lakes) where it contributes to the degradation of water quality. Phosphorus stimulates eutrophication. In very sandy soils phosphorus may begin to move downward as soil phosphorus levels exceed 300 lb/A. Due to concerns for water quality, regulations are being developed which may restrict the use of phosphorus fertilizer when soil phosphorus levels already exceed 300 lb/A. Documentation of the economic benefit of phosphorus fertilization even at high soil phosphorus levels is essential for justifying its continued use in potato production.

The nature of the response of potatoes to phosphorus is not well understood. Why do potatoes respond to applied phosphorus in some soils and not others? Is the potato plant less efficient in taking phosphorus from the soil than other plants? A better understanding of factors affecting the utilization of soil phosphorus is essential for the development of production management practices that may improve the use of indigenous soil phosphorus by potato.

Studies were undertaken in 1990 to: a) further substantiate the response of potatoes to phosphorus fertilizer banded at planting time; b) determine the ability of potatoes to take up phosphorus; and c) determine the ability of different soils to supply phosphorus for plant uptake.

Field studies were established on a McBride sandy loam, a Capac loam and a Palms muck to evaluate the response of potatoes to banded phosphorus fertilizer. Phosphorus rates of 0, 50, 100, 150 and 200 lb/A were applied in a band two inches to each side of the seed piece. Test rows were 50 feet long and separated by a row receiving no phosphorus. Each phosphorus rate was included at random in each of four replications. Russett Norkotah potatoes were planted in the

McBride sandy loam on May 8 and in the Capac loam on May 23. Sebago potatoes were planted in the Palms muck on May 17. The tubers were harvested and graded on September 5 from the McBride soil, on September 24 from the Palms soil and on September 25 from the Capac soil. Pertinent yield data are presented in Tables 1 through 3.

In a McBride sandy loam (P soil test near 415 lb/A) total and marketable tuber yields were maximized with 100 lb P_2O_5 per acre banded at planting (Table 1). These yield increases were related to increased numbers of harvested tubers. However the numbers were variable and not statistically different beyond the 50 lb P_2O_5 /A rate. Specific gravity of the tubers was increased slightly by the 50 lb rate, but higher rates provided no further benefit. The phosphorus content of petioles collected in late June did not reflect the amount of phosphorus applied at planting.

Table 1. Response of potatoes (cv. Russett Norkotah) to phosphate fertilizer when grown in a McBride sandy loam. 1990.

P_2O_5 Rate	Total Yield	Total Tubers	Marketable Yield	Marketable Tubers	Specific Gravity	Petiole P
lb/A	cwt/A	#/hill	cwt/A	#/hill	g/cm^3	%
0	323 c	7.2 b	225 b	3.7 b	1.063	.55
50	355 bc	7.9 ab	243 b	3.8 b	1.065	.51
100	370 ab	8.2 a	260 ab	4.2 ab	1.066	.51
150	373 a	8.7 a	285 a	4.4 a	1.065	.52
200	374 a	8.1 a	259 ab	4.0 ab	1.066	.52

Means within a column followed by different letters are statistically different at the 95 % level of probability.

In the Capac loam total and marketable tuber yields were the highest with the 200 lb P_2O_5 /A rate. The soil test phosphorus level in this soil was only near 185 lb/A. Hence more phosphorus was required to maximize yields. However the percent yield increase do to fertilizer phosphorus was similar in the Capac and McBride soils. Harvestable tuber numbers were improved by phosphorus fertilization, but did not affect the specific gravity of the marketable tubers. The highest phosphorus concentration in petioles collected in early July occurred in the plants receiving no phoshporus fertilizer. This may have been do to slower growth. Phosphorus rate had no effect on the phosphorus concentration in petiole tissue.

Table 2. Response of Russett Norkotah potatoes to phosphate fertilizer when grown in a Capac loam. 1990.

P_2O_5 Rate	Total Yield	Total Tubers	Marketable Yield	Marketable Tubers	Specific Gravity	Petiole P
lb/A	cwt/A	#/hill	cwt/A	#/hill	g/cm^3	%
0	280	6.1	184	2.7	1.076	.25
50	284	6.5	176	2.7	1.074	.21
100	307	6.7	199	2.9	1.074	.20
150	298	6.7	188	2.8	1.076	.21
200	328	6.8	221	3.0	1.076	.22

Means within each column were not statistically different at the 95 % level of probability.

In the Palms muck (P soil test near 235 lb/A) phosphorus fertilization provided no benefit for total or marketable tuber yields of Sebago potatoes. Tuber numbers were variable and not significantly different among the various phosphorus rates. Specific gravity was not affected by phosphorus fertilization. However the phosphorus content in petioles collected in early July was increased by the addition of phosphorus.

Table 3. Response of Sebago potatoes to phosphate fertilizer when grown in a Palms muck. 1990.

P_2O_5 Rate	Total Yield	Total Tubers	Marketable Yield	Marketable Tubers	Specific Gravity	Petiole P
lb/A	cwt/A	#/hill	cwt/A	#/hill	g/cm^3	%
0	365	7.9	325	5.6	1.065	.43
50	381	8.8	341	6.3	1.065	.49
100	340	7.8	300	5.3	1.065	.46
150	332	8.7	285	5.7	1.064	.52
200	345	8.7	299	5.9	1.064	.51

Means within each column were not statistically different at the 95 % level of probability.

To evaluate the response of potatoes to applied phosphorus at increasing levels of soil phosphorus soil was collected from two different fields of McBride sandy loam. Both fields had been used for potato production in the recent past. One soil had a Bray-Kurtz P1 soil test phosphorus level near 200 lb/A and the level in the other soil was near 700 lb/A. The two soils were blended to give soils with soil test phosphorus levels near 325, 450 and 675 lb/A. One foot lengths of 10 inch diameter corrugated plastic drainage tile were placed in a trench and filled halfway with the appropriate soil blend. Phosphorus fertilizer was placed on the soil surface in a circle and then two inches of additional soil was added to the tiles. One uniform Russett Norkotah tuber ("B" size) was placed in the center on the soil surface and covered with soil to fill the tile. The experimental design included five soil phosphorus levels and five levels of phosphorus fertilization (0, 50, 100, 150 and 200 lb/A equivalent) in all combinations. Treatments were randomized in six replications. After the vines had died in Early October the soil and tubers were removed from the tiles.

Across all soil phosphorus levels the addition of phosphorus fertilizer increased the total and greater than 4 ounce tuber yields (Table 4). The increase in yields was associated with increases in tuber numbers per plant as the phosphorus rate was increased.

Table 4. Yields of Russett Norkotah potatoes grown in McBride sandy loam at five levels of phosphate fertilization.[x]

P_2O_5 Rate	Total Yield [z]	Total Tubers	Marketable Yield	Marketable Tubers
lb/A	lb/plant	#/plant	lb/plant	#/plant
0	1.45	7.6	0.94	2.2
50	2.38	7.2	1.06	2.5
100	2.71	8.2	1.28	3.1
150	2.81	7.8	1.32	3.0
200	2.94	8.7	2.06	3.2

[x]Potatoes were grown in soil contained in 12 inch lengths of corrugated 10 inch diameter plastic tile.
[z]Yield data is across five soil test levels.

The effect of phosphorus fertilization at the various levels of soil phosphorus on tuber yields of Russett Norkotah potatoes are presented in Tables 5 and 6. The yields were confounded by the occurrence of the "early die" complex in the lower phosphorus soil. Therefore the comparison of yields across soil phosphorus levels at each fertilizer rate is not directly possible. At each soil phosphorus level the addition of phosphorus fertilizer increased the yields of total and greater than 4 ounce tubers. However the total yield with no phosphorus fertilizer as a percent of the top yield attained within each soil phosphorus level increases as the soil phosphorus level increases. At a 200 lb P/A test level the no phosphorus total yield is 48 percent of the top yield whereas at a 700 lb /A test level the no phosphorus total yield is 89 percent of the top yield. Similarly the yield of greater than 4 ounce tubers with no phosphorus fertilizer added increased from only 29 percent to 87 percent of the top yield attained (within each soil P level) as the soil phosphorus level increased from 200 and 700 lb P/A. These results indicate that Russett Norkotah potatoes continue to respond to applied fertilizer at very high levels of extractable soil phosphorus but that the degree of response decreases as the soil phosphorus level increases.

Table 5. Total yield of Russett Norkotah potatoes grown in Mcbride sandy loam at five soil phosphorus levels and five levels of phosphate fertilization.

P_2O_5 Rate	Soil Test P Level[z] (lb/A)				
	200	325	450	575	700
lb/A	- - - - - - - - - - -		lb/plant	- - - - - - - - - - - - -	
0	0.68	0.84	1.39	1.89	2.47
50	1.10	1.32	1.59	1.65	2.40
100	1.28	1.41	1.98	2.07	2.38
150	1.41	1.30	1.74	2.09	2.99
200	1.37	1.56	2.20	2.14	2.64

[z] The range of soil P levels was attained by blending two McBride sandy loam soils. One had a Bray-Kurtz Pl test level of near 200 and the other near 700 lb P/A.

Table 6. Yield of marketable potato tubers (cv. Russett Norkotah) grown in McBride sandy loam at five soil phosphorus levels and five levels of phosphate fertilization.

P_2O_5 Rate	Soil Test P Level[z] (kg/ha)				
	200	325	450	575	700
lb/A	- - - - - - - - - - - - -		lb/plant	- - - - - - - - - - - - -	
0	0.26	0.40	0.88	1.17	2.03
50	0.64	0.90	0.79	1.19	1.74
100	0.81	0.86	1.47	1.45	1.74
150	0.92	0.75	0.97	1.67	2.31
200	0.68	0.99	1.52	1.63	2.94

[z] The range of soil P levels was attained by blending two McBride sandy loam soils. One had a Bray-Kurtz Pl test level of near 200 and the other near 700 lb P/A.

The phosphorus content of the tubers increased with each increment of phosphorus added up to 150 lb P/A at all levels of soil phosphorus. The total phosphorus content of the tubers was highest at a soil phosphorus level of 325 lb/A and was the lowest at 700 lb P/A. This may partially reflect a lower phosphorus content in the larger tubers.

Table 7. Phosphorus content of potato tubers (cv. Russett Norkotah) grown in a McBride sandy loam in 10 inch diameter plastic tile.

P^2O_5 Rate	Soil Test P Level[z] (lb/A)					
	200	325	450	575	700	Average
lb/A	- - - - - - - - - - % P in dry tissue - - - - - - - - - -					
0	.210	.235	.234	.233	.200	.222
50	.231	.256	.244	.230	.230	.238
100	.242	.279	.234	.245	.230	.246
150	.261	.283	.276	.252	.239	.261
200	.283	.266	.243	.273	.248	.263
Average	.245	.263	.246	.246	.229	.246

[z] The range of soil P levels was attained by blending two McBride sandy loam soils. One had a Bray-Kurtz P1 test level of near 200 and the other near 700 lb P/A.

Rooted cuttings of Russett Burbank potatoes were grown in nutrient solution culture to determine the ability of potatoes to take up phosphorus at various solution concentrations. Cuttings were taken from field grown plants and placed in aerated 1/5 strength Hoagland's nutrient solution for rooting. Once adequately rooted the cuttings were transferred into nutrient solution containing different concentrations of phsophorus; 0.14, 0.29, 0.68 or 2.33 mg P/l. The plants were grown in these solutions for 24 hours for acclimation. Beginning at 8 AM the plants were transferred into fresh nutrient solution with the appropriate phosphorus concentration. An aliquot was withdrawn from each container every four hours over the next 12 hours. Changes in the phosphorus concentration in the nutrient solutions was assumed to be do to uptake. Each treatment was replicated three times. At the end of the uptake period the plants were harvested and root length was determined. Table 8 shows that the rate of uptake by the Russett Burbank potato roots increased curvilinearly with concentration.

Table 8. Rate of phosphorus uptake from solution culture by Russett Burbank potatoes.

Intial solution P concentration	Phosphorus Uptake Rate
mg P/l	ug P/M/hr
.15	.279
.29	5.58
.68	10.85
2.33	16.74

As the solution phosphorus concentration is increased the rate of uptake should eventual reach a constant value, the maximum uptake rate. The solution concentration at which one-half the maximum uptake is achieved (K_m value) and the minimum solution phosphorus concentration from which active uptake can be achieved are indicators of a plants ability to take up phosphorus. Based on data from this study the K_m value for is near .47 mg P/l as compared with K_m values for corn and tomato of 0.18 and 0.19. The minimum phosphorus concentration for active uptake by Russett Burbank potatoes was near 0.12 mg P/l. Similar values reported for corn and tomatoes are .003 and .004 indicating potatoes is less effective in taking up phosphorus. This is important because in the soil solutions of many Michigan potato soils (Table 9) the phosphorus concentration is less than 0.10 mg P/l. Hence phosphorus concentration in the soil solution may severely limit the growth of potatoes.

Twenty seven soils were collected from Michigan potato fields to determine the levels of soluble phosphorus along with other parameters. As shown by the data in Table 9 there is a very large range in the expected soil solution phosphorus concentrations. Over half of the soils have very low soluble phosphorus levels. However there are also some soils which have very high phosphorus levels in the soil solution. These differences may help explain why potatoes respond to phosphorus fertilization at some locations and not at others. And the soluble phosphorus levels are not related to the levels of Bray-Kurtz P1 extractable phosphorus. The McBride sandy loam from Montcalm County has a very low soluble phosphorus level even though the Bray-Kurtz P1 test level is very high. And use of phosphorus fertilizer results in an economic yield. Potatoes grown on a Palms muck having a soil solution phosphorus concentration of near 5.0 mg/l and a soil test value of 235 lb/A gave no yield response to phosphorus fertilization. The Capac loam had a soil test of less than 200 lb P/A and a soluble phosphorus level of near 1.0 mg/l. Therefore the yield response was expected.

Table 9. An aproximation of phosphorus concentrations in the soil solution of soils collected from Michigan potato fields.[x]

County	Soil Type[z]	Soil Solution P Conc. mg/l	County	Soil Type[z]	Soil Solution P Conc. mg/l
Allegan	muck	0.9	Lenawee	loam	6.0
	muck	2.9		loam	<0.1
	muck	2.1		s loam	<0.1
Arenac	l sand	<0.1	Monroe	s loam	<0.1
	muck	62.8		s loam	16.0
	sand	81.9		l sand	4.7
Bay	s loam	6.8		c loam	<0.1
	l sand	176.5		l sand	<0.1
Delta	s loam	<0.1	Montcalm	s loam	<0.1
	s loam	<0.1		s loam	<0.1
	s loam	<0.1		s loam	<0.1
Dickinson	s loam	<0.1	Presque Isle	l sand	<0.1
Eaton	muck	5.1		fs loam	21.0
				fs loam	33.5

[x]Values calculate from 0.01 M $CaCl_2$ extractable P and an approximation of the soil moisture content under field conditions.
[z] c=clay, f=fine, l=loam, s=sandy

In summary research conducted during the past year has shown that yield responses with potatoes as the result of phosphorus fertilization varies from soil to soil. Where a yield response does occur the degree of response decreases as the level of soil phosphorus increases, as indicated by Bray-Kurtz P1 extraction. Solution culture studies indicate potatoes require solution phosphorus concentrations higher than are found in many Michigan potato fields to maximize phosphorus uptake and presumbably growth and yield. Determinations of soluble phosphorus levels in soils from Michigan potato fields revealed a wide range and that the soluble phosphorus levels are not related to current soil test levels. This information taken as a whole helps shed light made on observations made in past. Much research is still needed to better understand the factors affecting the phosphorus nutrition of potatoes and to develop management approaches of benefit for potato growers.

Funding Federal Grant

MANAGEMENT PROFILES OF SNOWDEN (W855) AND SAGINAW GOLD

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Introduction

Management profile studies were initiated in 1986 in order to evaluate the effect of plant spacing and nitrogen levels on new potato varieties. These are designed as two year studies and have been completed for Michigold, Spartan Pearl, MS716-15, MS700-70, Russet Norkotah, Saginaw Gold and Snowden.

Procedure

Three levels of nitrogen (100, 150 and 200 lbs/A) and three in-row spacings (6, 9 and 12 inches for Saginaw Gold and 9, 12 and 15 inches for Snowden) were studied in 1989-90. The trials were planted May 8, 1990. Harvest for Saginaw Gold was September 10, 1990 and for Snowden, September 19, 1990. Rows were spaced at 34 inches and the treatments were studied in a split plot design with four replications.

The previous crops in 1989 were soybeans disked down in late summer and rye plowdown before planting in 1990. The area was field injected with metam-sodium (Vapam) at 50 gpa approximately two weeks before planting. The plots were hand planted to insure proper spacing. Fertilizer applied through the planter was 500 lbs/A of 20-5-20. A sidedressing of urea providing 50 lbs/A N was applied to the 150 and 200 lb/A plots in early June and an additional 50 lbs/A N was applied to the 200 lb/A plots in early July. Thimet was used as the systemic insecticide and foliar insect and disease controls were applied as needed. The plots were irrigated using the MSU Irrigation Scheduling Program.

Results

Snowden

The yields, percent size distribution and specific gravity of Snowden for 1990 are shown in Table 1. The entries are in descending order of cwt/A of U.S. No. 1 potatoes. Average total yields in 1990 were nearly 10% lower than in 1989. Snowden is a late maturing variety and the cool soil temperatures during May and early June, 1990 may have interfered with potential yields. When comparing the effects of nitrogen levels over all of the spacings (Table 1), there is an increase from 100 to 150 lbs/A and no significant increase at 200 lbs/A. In 1989, there was a significant yield increase with the higher N rates. There was no effect on size distribution or specific gravity. When comparing the three spacings over all levels of N, there was a decrease in yields with the wider spacing. This is the opposite response noted in 1989.

Table 2 is the average data for the two years of the study. These data show an increased yield of both total and U.S. No. 1 yields with increased N. There is also a reduction in the percent of tubers under 2 inches. There is less of a response to spacings in terms of yields, however, there is a reduction in tubers under 2 inches with a wider spacing and an increase in tubers over 3¼ inches.

The numbers of tubers per plant was also determined for each spacing and nitrogen level. In 1989, the total number of tubers per hill ranged from 11 to 14 per hill with the higher set occurring at the wider spacing and highest nitrogen level. In 1990, the set was smaller and ranged from 8-10 per hill.

Saginaw Gold

Total yields of Saginaw Gold in 1990 were approximately 9% higher than 1989. There was little difference in yields of U.S. No. 1 between any of the treatments (Table 3). Saginaw Gold maturity is earlier than Snowden and would be rated as mid-season.

When comparing the nitrogen levels over all of the spaces, there is no significant difference between either total or U.S. No. 1 yields. There is also no effect on size distribution or specific gravity. In 1989, there was a significant increase in yield of U.S. No. 1 from 100 to 150 lbs/A but not at 200 lbs/A N.

There was more response to spacing with a reduction in both total and U.S. No. 1 yields at the 12 inch spacing (Table 3). There was also a reduction in the percentage of tubers under 2 inches with the wider spacing. Spacing or nitrogen had no affect on specific gravity.

Table 4 summarizes the combined results of both 1989 and 1990. These data similarly show a trend to increased U.S. No. 1 yields from 100 to 150 lbs/A N and a smaller increase at the 200 lb/A level. Closer spacings of 6 inches and 9 inches had the highest yields of U.S. No. 1, however, the percentage of tubers under 2 inches decreased with the wider plant spacing.

Summary

Based on the results of these data it appears that Snowden does respond to the higher levels of N, however with its late maturity, N levels used should not delay maturity. Plant spacing appears most optimum at 12 inches. It does set heavier than Atlantic and most trial reports indicate a small tuber size.

Saginaw Gold did not respond to the high level of N. It did not set as heavy as Snowden and a 9 inch plant spacing seems desirable based on these results.

Table 1. Snowden — 1990 Management Profile.

		Yield (cwt/A)		Percent Size Distribution					
Nitrogen (lbs/A)	Space (in.)	No. 1	Total	No. 1	<2"	2-3¼"	>3¼"	Pick Outs	Specific Gravity
200	9	406 a[1/]	459 a[1/]	89	11	85	4	0	1.089
150	9	390 ab	456 a	86	14	83	2	0	1.089
200	12	381 abc	419 ab	91	9	86	5	0	1.088
150	12	367 abcd	409 bc	89	10	85	4	0	1.088
150	15	345 bcd	373 c	93	7	85	7	0	1.089
200	15	345 bcd	377 bc	91	9	85	6	0	1.089
100	9	339 cd	398 bc	85	15	82	3	0	1.088
100	15	330 d	368 c	90	10	83	6	0	1.091
100	12	321 d	366 c	88	12	83	4	0	1.087
AVERAGE		358	403	89					1.089
100	over	330	377	88	11	83	4	0	1.089
150	all	367	413	89	10	84	4	0	1.089
200	spaces	377	418	90	10	85	5	0	1.089
over	9	378	438	86	13	83	3	0	1.089
all	12	356	398	89	10	85	4	0	1.088
rates	15	340	373	91	9	84	6	0	1.090

[1/] Values followed by same letter were not statistically different at the .05 level of probability. Duncan's Multiple Range Test.

Table 2. Management Profile Study of Snowden (W855) at Three Spacings and Three Nitrogen Levels, MSU Montcalm Research Farm (1989-90).

		Yield (cwt/A)		Percent Size Distribution					
Nitrogen	Space (in.)	No. 1	Total	No. 1	<2"	2-3¼"	>3¼"	Pick Outs	Specific Gravity
100	9	317	401	79	20	78	1	1	1.085
	12	322	384	84	15	81	4	0	1.085
	15	337	382	88	11	82	6	1	1.087
150	9	375	451	83	16	80	3	1	1.087
	12	378	425	89	11	83	6	0	1.087
	15	385	417	92	8	85	7	0	1.087
200	9	416	480	88	11	84	4	1	1.087
	12	405	450	90	9	82	8	1	1.087
	15	395	435	91	8	82	9	1	1.086
100	over	325	389	84	15	80	4	1	1.086
150	all	379	431	88	12	83	5	0	1.087
200	spaces	405	455	89	9	83	7	1	1.087
over	9	369	444	83	16	81	3	1	1.086
all	12	368	420	88	12	82	6	0	1.086
rates	15	372	411	91	9	83	7	1	1.087

Table 3. Saginaw Gold — 1990 Management Profile.

		Yield (cwt/A)		Percent Size Distribution					
Nitrogen	Space (in.)	No. 1	Total	No. 1	<2"	2-3¼"	>3¼"	Pick Outs	Specific Gravity
150	6	397 a[1/]	494 a[1/]	80	19	78	2	1	1.076
200	6	386 ab	473 ab	81	18	80	2	0	1.077
200	9	382 ab	438 abc	87	13	85	2	0	1.076
100	12	377 ab	413 cd	91	7	87	4	1	1.076
150	9	366 ab	426 bcd	86	13	81	5	1	1.076
100	9	364 ab	437 abc	83	16	83	1	1	1.076
200	12	361 ab	400 cd	90	9	85	5	0	1.077
100	6	351 ab	443 abc	79	20	78	1	1	1.077
150	12	327 b	373 d	88	11	85	2	1	1.074
AVERAGE		368	433	85					1.076
100	over	364	431	84	14	83	2	1	1.076
150	all	363	431	84	14	81	3	1	1.075
200	spaces	376	437	86	13	83	3	0	1.077
over	6	378	470	80	19	79	2	1	1.077
all	9	371	434	85	14	83	3	1	1.076
rates	12	355	395	90	9	86	4	1	1.076

[1/]Values followed by the same letter were not statistically different at the .05 level of probability. Duncan's Multiple Range Test.

Table 4. Management Profile Study of Saginaw Gold at Three Spacings and Three Nitrogen Levels. MSU Montcalm Research Farm, 1988-89.

		Marketable Yield	Total Yield	Percent Size Distribution					
Nitrogen (lbs/A)	Space (in.)	cwt/A	cwt/A	No. 1	<2"	2-3¼"	>3¼"	Pick Outs	Specific Gravity
100	6	336	433	77	21	77	Tr	1	1.078
	9	346	417	83	14	83	Tr	2	1.077
	12	333	387	85	11	83	3	2	1.076
150	6	377	468	80	18	79	1	2	1.076
	9	354	421	84	13	81	3	2	1.076
	12	333	382	87	10	84	3	3	1.074
200	6	373	459	81	17	80	1	1	1.077
	9	367	426	86	13	85	1	1	1.076
	12	345	395	87	11	82	5	Tr	1.076
100	over	338	412	82	15	81	1	2	1.077
150	all	355	424	84	13	81	2	2	1.075
200	spacing	362	427	84	13	82	3	1	1.076
over	6	362	453	80	19	79	1	1	1.077
all	9	356	421	85	13	83	2	2	1.076
levels	12	337	388	87	10	83	4	2	1.076

Funding MPIC

CONTROL OF INTERNAL BROWN SPOT (IBS) IN ATLANTIC (1988-90)

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Introduction

Heat necrosis/internal brown spot (IBS) has been reported as a significant concern in the Atlantic variety in many production areas, particularly in the Southeastern, Atlantic Coast and Northeast areas. It has similarly occurred in various potato regions of Michigan but has had the greatest frequency in Southeastern Michigan.

Symptoms of IBS include localized areas of rust brown necrotic tissue in the parenchyma tissue inside the vascular ring and generally appears first in the largest tubers in the hill and in the apical half of the tuber. As reported by Sterrett, et al., 1989, both the percentage of tubers affected and the color intensity of the necrosis increases over time. Since the grade specifications for U.S. No. 1 limit internal defects to 5% by weight, the presence of IBS in even a few large tubers can result in severe penalties or rejection by the processor.

Research at University of Wisconsin reported that chemical analysis has found tubers to be very low in calcium. Calcium has long been recognized as an essential element for numerous plant growth processes including cell growth and development, membrane integrity and as an important component in the cell wall. Calcium concentrations in the soil solution are usually more than adequate to achieve normal plant growth and calcium fertilization other than liming is generally not needed. In Wisconsin, Ca soil test levels even on very sandy soils rarely fall below 500 lbs/A and Ca recommendations for potatoes were usually not made. Other researchers (Collier et al., 1978; Dyson and Digby, 1975; McGuire and Kelman, 1984; and Tzeng et al., 1985) have reported that potato disorders such as IBS, subapical necrosis on sprouting tubers, and susceptibility to bacterial soft rot have been shown to be Ca disorders. Iritani at Washington in 1988 reported that localized Ca deficiency in rapidly growing areas of the tuber is a direct cause of IBS. He further reported that Ca related disorders are due to inefficient distribution in the plant rather than poor uptake from the soil. He reported that only 5% of the total Ca in the potato plant is contained in the tuber. He also reported that with Russet Burbank, later dates of planting and the application of maleic hydrazide have decreased the incidence of IBS. Coffin et al., 1987 reported no benefits were observed from foliar Ca or in-furrow applications on yield or quality of Atlantic.

Procedure

In 1988, two planting dates of Atlantics (April 15 and May 15) were established at the W.J. Lennard and Sons, Inc. farm in Samaria. Four treatments of supplemental gypsum were applied as follows: check, - no gypsum, 750 lbs/A at planting, 750 lbs/A at hilling and 375 lbs/A at planting and at hilling. Main plots received one application of an anti-transpirant (Vaporgard).

In 1989, a single planting of Atlantic was made on May 3. Supplemental gypsum was applied similar to 1988 and the main plot treatment was maleic hydrazide (MH) applied to the foliage on July 28. In 1990, the treatments were the same as 1989 except that 1500 lbs/A of gypsum at planting was used instead of the split application. The plots were planted on May 11 and the MH applied on August 17.

At harvest, yields, specific gravity (1988-89) and incidence of IBS were determined. Peel and core samples were collected and analyzed for Ca. Following harvests in 1989 and 1990, soil samples were collected from the different treatments to determine changes in Ca levels.

Results

There were no apparent differences in plant growth, yields and specific gravity between the two planting dates in 1988, so data from the two plantings were combined. There was no effect of the gypsum or anti-transpirant on yields, specific gravity or chip color. There was a significant reduction in the incidence of IBS with 40% of the check plot tubers affected and 27% for the plots which received the supplemental gypsum (Table 1). Despite this reduction in the incidence of IBS, an acceptable level of control was not obtained.

Similarly in 1989, there were no emergence growth or yield effects from any of the levels of gypsum when compared with the untreated check (Table 1). There was, however, a significant effect from the MH. The incidence of IBS on the 0-gypsum check without MH was 58% and 11% for the 0-gypsum with MH. Similar to 1988, there was a reduction in IBS with the addition of 750 lbs/A of gypsum, however, the average of 41% is not an acceptable level. Where MH was used, the reduction of IBS did not appear related to the gypsum but were the result of the MH.

In 1990, there were no yields or specific gravity data taken as stands were not uniform among plots. Samples were collected at harvest and 25 tubers from each plot were evaluated for common scab and IBS. There was no evidence of IBS. Although some pitted and surface scab was noted in each plot, there was no significant effect of MH on either type or severity of scab or rate of gypsum used (Table 2).

Table 3 shows the analysis of post-harvest soil sample tests taken from each treatment. There was no detectable change in soil test Ca levels even when 1500 lbs/A of gypsum were applied. Although the data are not presented, similar results were obtained in 1989.

Conclusions

Based on the results of this three year study, there appears to be no acceptable benefit from the use of supplemental gypsum for the control of heat necrosis/IBS in Atlantic. These results are similar to studies conducted at the Montcalm Research Farm. The results of these trials also revealed that the treatments had no effect on either the severity or type of scab. Thus, our preliminary results suggest that MH may be useful in reducing IBS without causing increased scab severity.

As noted in 1988, there was no effect from the use of an anti-transpirant. There was, however, a positive benefit from the use of MH in 1989. It would seem appropriate to evaluate this further on selected fields and farms where the IBS problem has most frequently occurred.

Table 1. Yields, Specific Gravity and IBS of Atlantic Treated with Supplemental Gypsum, Anti-Transpirant (1988) and MH (1989).

	Total Yield (cwt/A)		Specific Gravity		Percent IBS		
						1989	
Treatment	1988	1989	1988	1989	1988	-MH	+MH
Check - 0 gypsum	360	239	1.074	1.083	40	58	11
750 lbs/A gypsum planting	343	243	1.073	1.082	24	45	9
750 lbs/A gypsum hilling	344	244	1.074	1.082	31	40	7
375 lbs/A gypsum P + H	336	244	1.074	1.082	26	37	11

TABLE 2
EFFECT OF MALEIC HYDRAZIDE AND GYPSUM ON SCAB EXPRESSION

MH	GYPSUM (lbs/A)	%TUBERS 0 SCAB	%TUBERS <5% SCAB
-	0	50.0±4.3	97.5±1.3
-	750 P	34.0±14.5	96.8±3.3
-	750 H	41.5±6.8	91.8±5.5
-	1500 P	51.5±15.6	98.3±1.8
+	0	49.8±5.8	97.0±0.5
+	750 P	43.0±4.1	95.0±3.1
+	750 H	52.3±3.5	97.5±2.5
+	1500 P	28.8±7.7	90.5±8.2
-		44.3±5.5	96.3±1.7
+		43.4±3.4	95.0±2.2
	0	49.9±3.3	97.3±1.2
	750 P	38.5±7.4	95.9±2.1
	750 H	46.9±4.1	94.6±3.0
	1500 P	40.1±9.1	94.8±4.2

Table 3. Soil Test Results of Post-Harvest Samples.

	1990			
Treatment	pH	P_2O_5	K_2O	Ca
Check	6.0	400	371	1143
750 P	5.7	469	312	990
750 H	6.1	487	429	1067
1500 P	5.8	580	421	1143
Pre-plant	6.6	400	344	1067

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Colorado Potato Beetle Management

1990 Potato Research Report

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Summary. Colorado potato beetle research projects that were completed in 1990, include: development and evaluation of the insecticide resistance monitoring kit, and inheritance and characterization of resistance to Furadan and Guthion. New projects were started on potato beetle dispersal and crop rotation to reduce beetle movement.

The resistance test kit was evaluated for the third year and is now being produced for sale through the Michigan State University Plant Pest Diagnostic Laboratory ($10 each). Results indicated a rapid increase in insecticide resistance to all insecticides in the kit, compared with 1988 and 1989 results. Other options are available to growers whose beetles are resistant to all of the materials in the kit, but the other insecticides that are effective in the field, such as the BT products, may need to be eaten to be toxic or cannot be included in the test kit for other reasons.

Beetles in Michigan show at least three patterns of resistance: (1) Ambush/Pounce (pyrethroid) resistant but susceptible to Guthion (organophosphate) and Furadan (carbamate), (2) resistant to Guthion and Furadan but susceptible to Ambush/Pounce, and (3) resistant to all three insecticides. These patterns are related to the underlying resistance mechanisms and their relationships. Furadan resistance in Michigan has been positively identified as an altered acetyl cholinesterase, transmitted by a single, semi-dominant gene. Furadan resistance in Long Island beetles appears to be due to detoxification enzymes, but the Long Island beetles exhibit cholinesterase that gives resistance to Guthion (Wierenga and Hollingworth, PRC). Furadan resistance is not linked to Temik resistance, even though both are carbamates. Guthion resistance in Michigan beetles is largely due to detoxification enzymes that can be blocked with piperonyl butoxide, in the field, as well as in laboratory bioassays.

Preliminary analysis of flight data suggests that CPB flights are rare, mating and insecticide resistance has little effect on flight behavior, and summer adults tended to fly or attempt flight more often when fed than if they were starved. Volunteer potato plants can strongly reduce dispersal of overwintered beetles and dispersal may be rare from a corn crop (potatoes the previous year) with volunteer potatoes between the rows.

Introduction. Quality and cost of production in relation to yield and market are major concerns of Michigan potato producers. The Colorado potato beetle (CPB) is the most significant insect pest of potatoes in the eastern U.S. and throughout the world. It can cause severe defoliation to potato plants and has demonstrated the ability to rapidly develop resistance to all commercial insecticides. In many locations control costs exceed $43 per treatment and $300 per acre for insecticides and application. The U.S. Environmental Protection Agency is being requested to issue an emergency insecticide registration for 1991 for control of CPB in parts of its range for the <u>15th consecutive year</u> - a record unmatched by any other pest.

Michigan State University researchers are approaching CPB management from several different directions, involving six faculty from four departments. Diverse interactions, approaches and sources of funding are being utilized. Our goal is to design management systems to optimize insecticide use and non-chemical controls for CPB management in Michigan potatoes to reduce costs and increase yields for the producer and minimize environmental, economic, and public health impacts and improve marketability of Michigan potatoes. A critical part of Colorado potato beetle management is the use of crop rotation. Distances of 1/2 mile or more between fields in successive years reduce beetle numbers in new potato fields and delay their arrival, reducing the time available for reproduction. Dispersal also allows the opportunity for interbreeding of insecticide resistant and susceptible beetles and reduction of resistance levels. Unfortunately, many fields in Michigan are grown continuously in the same field or in adjacent fields, due to limitations of soil type, irrigation availability, etc. Effective use of crop rotation in side-by-side or split field situations requires that beetles be strongly inhibited from leaving last year's potato site.

Experiments in 1990 focused on: (1) completion of insecticide resistance inheritance and mechanisms, (2) final development and testing of the insecticide resistance monitoring kit, (3) identification of environmental and physiological factors that encourage beetle dispersal, especially by flight, and (4) design and evaluation of a corn / potato rotational system constructed to minimize Colorado potato beetle dispersal.

Insecticide resistance inheritance and mechanisms. Beetles in Michigan show at least three different patterns of resistance: (1) Ambush/Pounce (pyrethroid) resistant but susceptible to Guthion (organophosphate) and Furadan (carbamate), (2) resistant to Guthion and Furadan but susceptible to Ambush/Pounce, and (3) resistant to all three insecticides. These patterns are related to the underlying resistance mechanisms and their relationships.

Guthion resistance studies indicate that resistance is inherited almost completely dominantly and offspring of a resistant x susceptible beetle cross are nearly as resistant as the resistant parent. Either the male or female parent may carry the resistance genes (Figure 1). At least two factors are involved. One of the factors involves detoxification by mixed function oxidase enzymes that are blocked by the synergist piperonyl butoxide (PBO). This appears to be common in Michigan populations and most Michigan beetles that are resistant to Guthion are still susceptible to Guthion plus PBO (or Imidan plus PBO). The Long Island beetles have at least one other factor and PBO treatment does not return them to susceptible status (Figure 2).

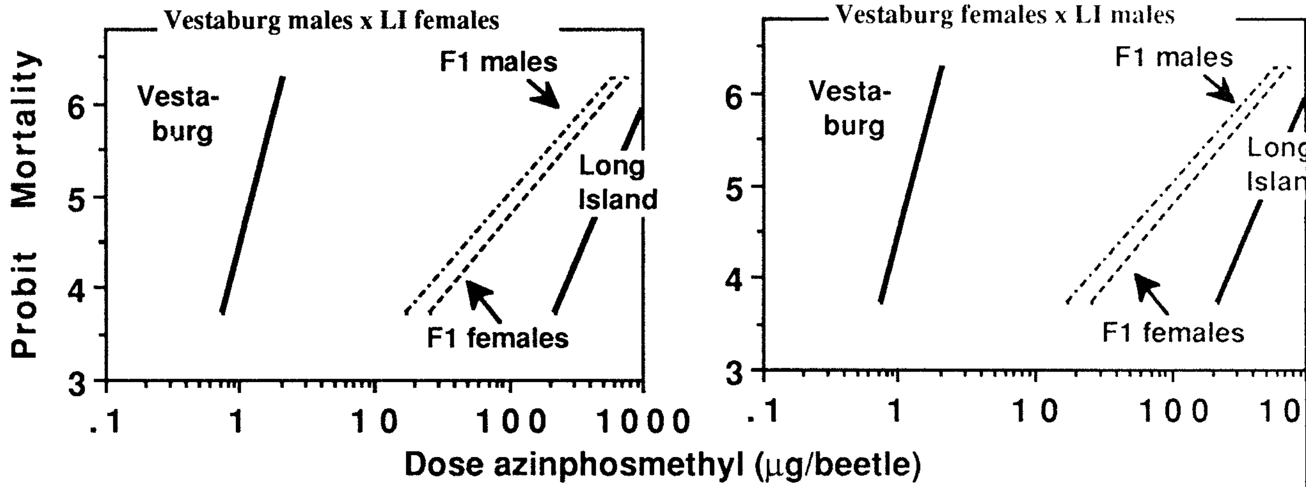

Figure 1. Susceptibility of parents and offspring of male x female reciprocal crosses to Guthion (azinphosmethyl). (Probit of 5 = 50% mortality.)

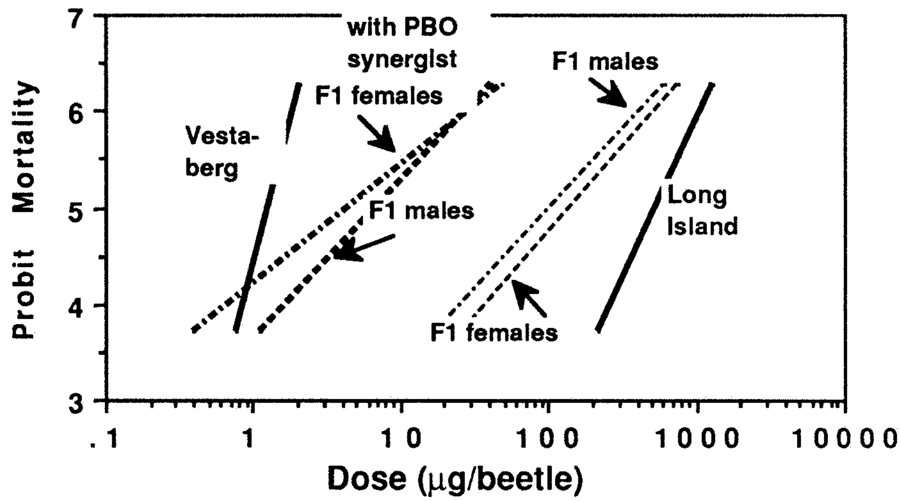

Figure 2. Susceptibility of parents and offspring to Guthion (azinphosmethyl) and Guthion plus piperonyl butoxide (PBO).

Studies on Furadan resistance inheritance and characterization using synergists were summarized in the 1989 report. Since that time, laboratory data of Wierenga and Hollingworth (Pesticide Research Center) demonstrate that acetyl cholinesterase from Furadan-resistant Michigan beetles is much less affected by Furadan than cholinesterase from other beetles (Figure 3).

An unexpected result of the biochemical studies was the observation that beetles from Long Island also had an altered cholinesterase, giving them resistance to Guthion. This may partially explain why PBO is effective as a tank mix with Guthion in Michigan, but not in Long Island. Michigan beetles use mixed function oxidase enzymes for Guthion resistance (blocked by PBO) and Long Island beetles use an altered cholinesterase and probably also esterase enzymes.

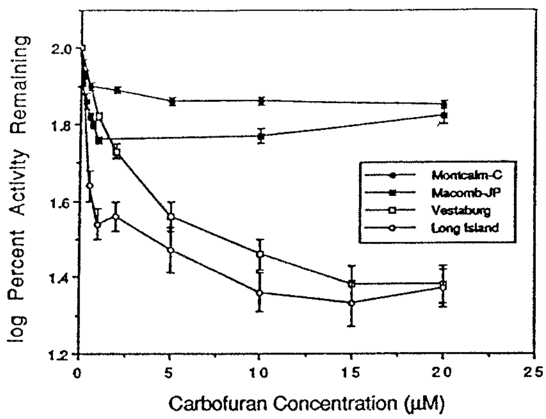

Figure 3. Inhibition of acetyl cholinesterase from several strains of Colorado potato beetles by Furadan, *in vitro*.

Researchers are beginning to reveal a very diverse and flexible set of resistance mechanisms in potato beetles from various locations (Table 2). The type of resistance is probably determined partly by the history of selection. For example, long-term selection with organophosphates (Long Island) may give very high levels of enzymes, active enough to detoxify Furadan with only slight modifications. Without these very high pre-existing levels of detoxification enzymes (for example, the Montcalm Research Farm, Michigan), Furadan may be so rapidly toxic to the beetle that resistance appears most readily as an altered cholinesterase that is completely insensitive to Furadan. The history of selection, original genetic background of the beetles, and other factors result in many different forms of resistance to the same insecticides.

Development and testing of the insecticide resistance monitoring kit. The purpose of the kit was to allow growers to accurately test beetles from individual fields for insecticide resistance prior to treatment and to monitor changes in resistance that occur even within a single growing season. The kit contains tests for four insecticides and one insecticide - synergist combination, representing the four major types of insecticides commercially available. Beetles are placed in petri dishes with treated filter paper and mortality recorded after 24 hours. An article describing the research conducted to establish the discriminating doses used in the tests and results obtained in 1988 is in press for publication in the American Potato Journal. Requests continue to come in for information about the kits from other states and Canadian provinces.

An extensive publicity campaign was initiated in the spring of 1990, including press releases, articles in trade journals, and a direct mailing to growers . A $10 per kit charge was initiated ($5 if kits did not need mailing). This money was placed in an account with the M.S.U. Plant Pest Diagnostic Clinic for production of kits for distribution in 1991. There were no complaints about the $10 charge, although the demand was not as great as in 1989 (132 kits were distributed in 1990 compared with 296 in 1989). The cost may have reduced demand and kits were not given out *en mass* at field meetings as they were in 1989. Also, many growers had tested beetles in 1989 and knew that none of the insecticides in the kits were effective or felt that they already knew the status of their beetles and did not need a retest (not always true). The rate of data return to us was much higher in 1990 than in 1989, suggesting that purchased kits were more likely to be used than free ones.

Table 2

General Mechanisms of Resistance to Insecticides In the Colorado Potato Beetle

Insecticide (class)	Mechanism	Supporting Evidence
Ambush/Pounce	MFO (type 1)	synergist activity [a,b]
(pyrethroid)	esterase	synergist activity [a,b]
		in vitro studies [c]
	kdr	neg. temp. coefficient [d]
		DDT cross-resistance [a]
		time response [a]
		no synergism [a]
	penetration	in vitro studies [e]
Guthion	MFO (type 2)	synergist activity [a,b]
(organophosphate)		in vitro studies [c]
	esterase	synergist activity [b,c]
	altered AChE	no synergism [a]
		in vitro studies [f]
Furadan	Altered AChE	no synergism [a]
(carbamate)		in vitro studies [f]
	MFO (type 2)	synergist activity [a]

[a] Ioannidis and Grafius, Michigan State Univ.
[b] Argentine and Clark, U. Mass.
[c] Ahammad-Sahib, Whalon, Grafius & Hollingworth, Mich. State Univ.
[d] Grafius, Michigan State Univ.
[e] Ahammad-Sahib and Ioannidis, Michigan State Univ.
[f] Wierenga and Hollingworth, Michigan State Univ.

Results of tests conducted in 1990 indicate surprisingly rapid increases in resistance, especially with respect to some of the insecticides. Nearly all Asana, Imidan, Thiodan, Furadan, and Asana + PBO tests indicated less than 50% susceptible beetles (Figures 4 - 6, Imidan not shown). Only 8% of the sites tested for Furadan indicated > 90% mortality, compared with 39% of the sites in 1988. Even less than 8% of all fields probably have susceptible beetles, since fields with known problems were probably not retested in 1990. Asana plus PBO had been moderately to highly toxic to beetles from most sites tested in 1988. The decrease in effectiveness, down to 3% of the sites with susceptible beetles, indicates a change in resistance mechanism, away from the mixed function oxidase enzymes that can be blocked with PBO.

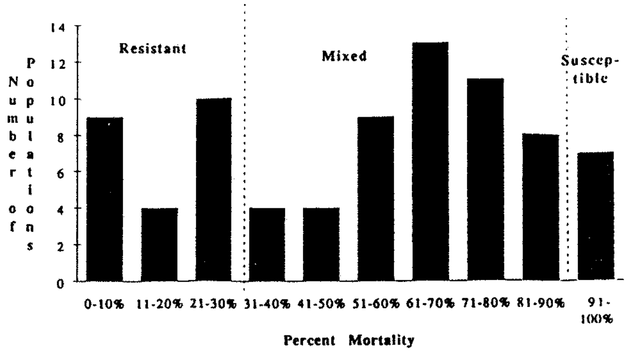

Figure 4. Numbers of Colorado potato beetle populations tested in 1990 with various degrees of resistance or susceptibility to Thiodan.

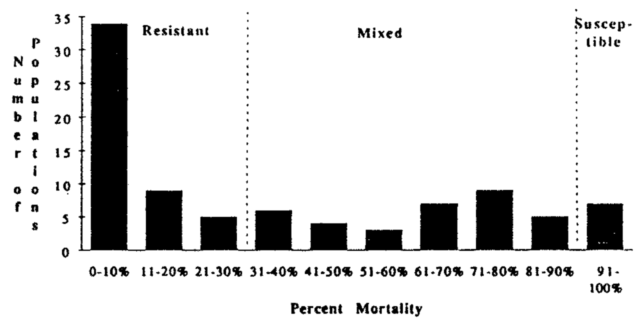

Figure 5. Numbers of Colorado potato beetle populations tested in 1990 with various degrees of resistance or susceptibility to Furadan.

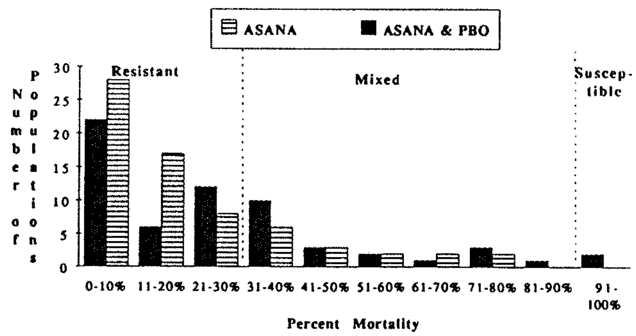

Figure 6. Numbers of Colorado potato beetle populations tested in 1990 with various degrees of resistance or susceptibility to Asana or Asana plus piperonyl butoxide (PBO) added as a synergist.

Such rapid changes in resistance status reinforces the need for frequent monitoring of resistance. Even in situations where beetles were susceptible to none of the materials in the kit, alternatives are still available to the grower. The new BT products (*Bacillus thuringiensis san diego or tenebrionis*) and cryolite must be ingested by the beetle (or larva) and therefore cannot be tested in a contact toxicity test. Also, a reliable discriminating dose for Imidan plus PBO was not found in laboratory tests and this combination was not included in the kit, although Imidan plus PBO (or Guthion plus PBO) continues to be one of the most successful treatments in the field.

As an additional benefit to Michigan agriculture, data from the tests were used by Michigan State University and Michigan Department of Agriculture to support emergency registration of cryolite in 1989, 1990 and 1991 (requested but not yet approved) and will be useful in future for documenting the status of resistance to obtain further emergency pesticide registrations and research grants.

Kits will continue to be available through the Michigan State University Department of Entomology and the Plant Pest Diagnostic Clinic. Fees collected will be used only to support the preparation of kits for future distribution.

Environmental and physiological factors affecting dispersal. Studies in this area are just beginning. Our long term goal is to manipulate potato beetle dispersal to prevent them from leaving last year's field and finding the new potato field, even if fields are side-by-side. Results may also be useful in developing techniques to concentrate beetles for mechanical control.

Environmental and physiological factors evaluated included: post-diapause or new summer adults, starved or fed, released prior to or after mating, and insecticide resistant or susceptible populations. Beetles were released in the field and observed for walking, flight, or flight attempt (wing fanning but no take-off). After observation, the beetles were frozen individually, for future analysis of wing muscle development (number and diameter of fibers) by light microscope and electron microscope. Based on preliminary analysis of the data, it appears that flights were rare, as previously observed. Flight attempts (wing fanning) were more common. Apparently some factor prevented many beetles from taking off. This may relate to the condition of the wing muscles. If specific factors can be manipulated to result in poor wing muscle development, CPB flight can perhaps be "switched" on or off. Overall, fed newly emerged adults tended to fly or attempt flight more often than starved beetles. There was no apparent difference between mated and non-mated females in flight behavior.

A crop rotational system to minimize potato beetle dispersal. A corn / potato rotational system with volunteer potatoes (or intentionally planted potatoes) in the corn crop following the potato crop year was evaluated. Beetles were collected from within a corn field that had been in potatoes in 1989, marked, and released within 2 hours after collection at two sites in the corn field. Different colors and position of marks were used to distinguish between release dates. Each beetle received at least two marks, to determine if marks were wearing off rapidly. Beetles were collected and marked one or two times per week. A total of 4720 overwintered and summer adult beetles were marked. Samples were taken 1 to 3 days after release, at 10 m, 25 m and 50 m from the release site, N, S, E, and W of the release point. Sample sizes were larger at 50 m (200 m^2) than at 10 or 25 m (25 m^2) to compensate for the greater circumference around the release site at 50 m. Volunteer potato plants were relatively abundant in the corn field, especially during the early part of the season (mean density = 0.43 stems / m^2).

Nearly all of the beetles recaptured after marking were within 10 to 25 m of the release site (Figure 7). Very few beetles were found at 50 m, in spite of the larger sample size. Also, very few were found at potato plants placed at the edges of the field and no marked beetles were found in potato fields within 1/4 mile N, S, E, or W of the release. Dispersal of the beetles was probably largely by walking, especially after June 1. More than 50 flights were observed during late May, including several beetles that flew shortly after being marked and released. All but one flight were short (<50 m) and less than 2 m high. One beetle was observed taking off and flying at > 10 m high, out of sight (probably left the potato field).

The direction of dispersal differed significantly between release dates, probably due to wind direction (Figure 8). Over the season, more beetles were recaptured north and south of the release sites than east or west (see Figure 4), probably because volunteer potatoes were more abundant to the north and south, and perhaps because the corn rows, planting furrows, etc. ran north and south.

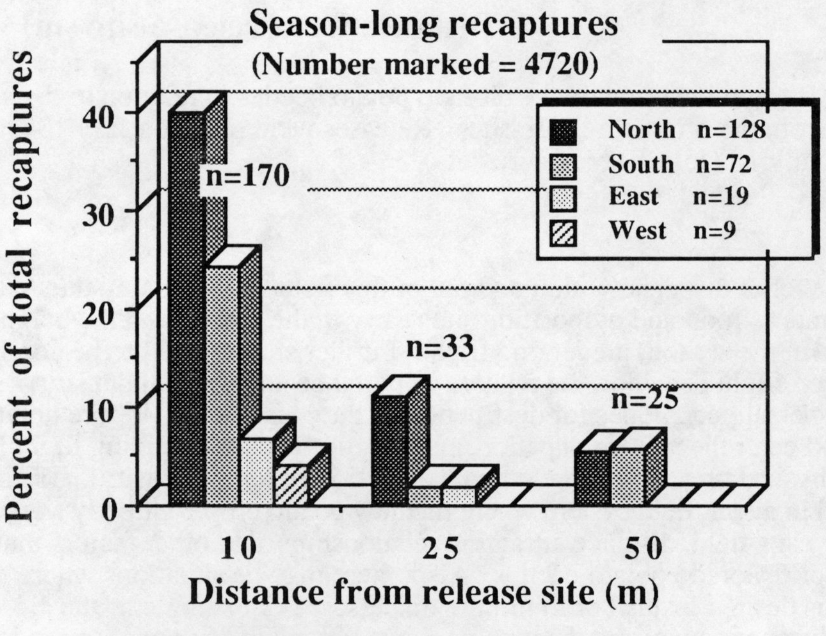

Figure 7. Seasonal recaptures of marked Colorado potato beetles in relation to distance and direction from the original release sites.

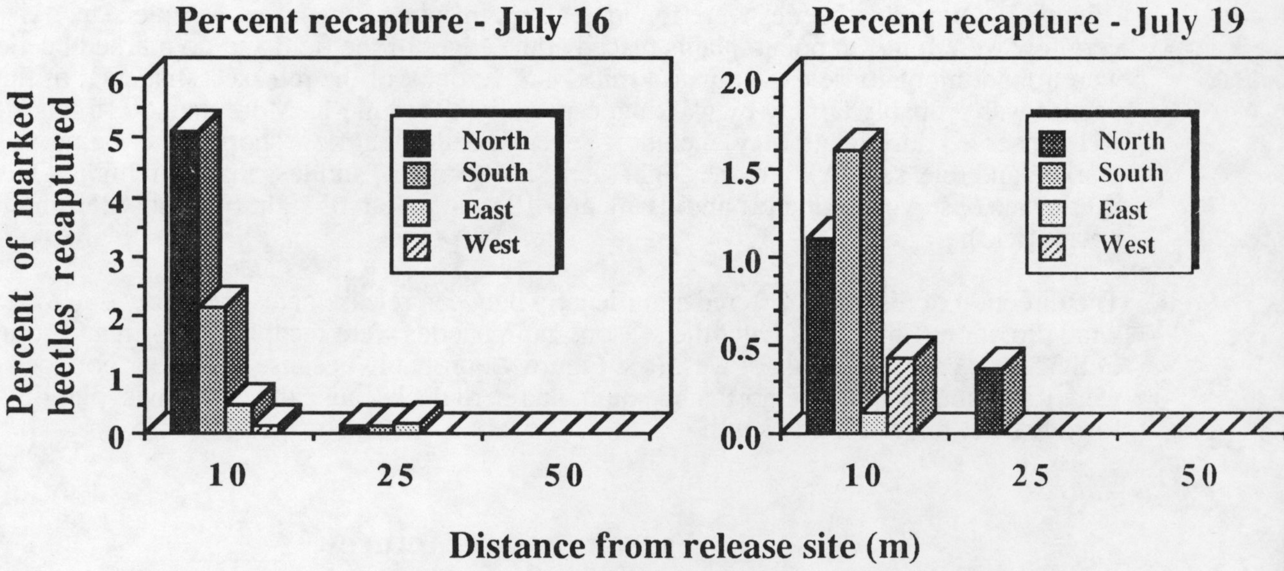

Figure 8. Recaptures of marked Colorado potato beetles in relation to distance and direction from the original release sites. Releases were made on July 13 (July 16 recapture data) and July 18 (July 19 recapture data).

The low level of dispersal within and out of this field was probably due to the presence of potato plants as food and oviposition sites early in the season and the height of the corn plants late in the season, preventing flight. Further studies need to be conducted on the early season flight behavior, the relative importance and optimal density of potato plants to inhibit dispersal, techniques for destruction of the potato plants before potato beetle larvae mature and enter the soil for pupation, and the mechanism inhibiting flight later in the season (physical presence of the corn or reduction of light intensity). Trials also need to be conducted in a split field system where the new potato crop is directly adjacent to the previous year's field, distance attraction relationships, and other factors that might affect dispersal of Colorado potato beetles. Also, there may be situations where maximum dispersal is desired instead of minimum dispersal. For example, if the closest potato fields are long distances away and the grower wants to replant after one year out of potatoes.

Future studies will be directed at factors that affect potato beetle dispersal and can be manipulated in commercial situations. For example, food in the form of volunteer or planted potatoes can be provided if the benefits are large enough. Knowledge about the effects of day length during larval development or ambient air temperature may also be interesting, but is more difficult to use. We also hope to develop trap crop / repellent systems that can be used to reduce the area that needs to be treated with vacuum cleaners, propane burners, or costly new insecticides or insecticide combinations.

Funding Federal Grant

1990 NEMATOLOGY REPORT

G.W. Bird, Professor
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Department of Entomology

- Nematicide Trial

The objective of the 1990 potato nematicide trial was to determine if metham (Vapam/Busan 1020) could be used on an in-row soil injection basis. Temik 15 G resulted in the highest total tuber yield and comparative revenue (Table 1). Metham worked well on an in-row basis (20 gal/A) at a cost of $80 per acre. All of the registered nematicides resulted in increased tuber yields. The experimental CIBA Geigy material did not provide a tuber response. All of the materials except the CIBA Geigy compound provided control of the Penetrans Root-Lesion Nematode (Table 2). A Fermenta experimental product (ASC-66824) provided good nematode control and resulted in increased tuber yields and lower population densities of Pratylenchus penetrans (Table 3).

- Nematicide Use Survey

The North Central Pesticide Impact Assessment Program Potato Nematicide Use Survey results for Michigan are summarized in Table 4. The nematicide information is integrated with irrigation, crop rotation, nitrogen and economic data. Adjusted revenue appeared to increase to an optima, and then decline with excessive potato production system inputs (Fig. 1).

- Crop Rotation

The first of the crop rotation studies associated with the USDA Special Grant is located at the Montcalm Potato Research Farm. The current rotation crops under investigation include corn, sudax, sweet clover and alfalfa. Population densities of P. penetrans varied with the different rotation crops and throughout the year (Table 5). The most significant finding was the difference between alfalfa and sweet clover; including the early spring reproduction on sweet clover roots. No significant differences in tuber yields were observed (Table 6).

The second major component of the USDA Special Grant was established in 1990 at the Montcalm Potato Research Farm. It consists of a 10,000 m^2 area divided into 1 m^2 study units. The basic principles of the Science of Landscape Ecology were used in establishment of the site and collection of the first year data.

Because of increases in potato in organic soil rotations and increases in carrots in mineral soil rotations, an existing crop rotation study in organic soil was included in this project. In the organic soil, a three-year rotation was more beneficial than a two-year rotation. Both root-lesion nematode reproduction and northern root-knot nematode reproduction were greater on carrots in mineral soil than in organic soil or on potato in mineral or organic soil.

- Biological Control

The first part of the biological control component of the USDA Special Grant was initiated in 1990. Rhizoplane bacterialization with Pseudomonas cepatia was successfully demonstrated. In addition, bacterialization with P. cepatia was shown to inhibit nematode penetration of root tissue.

- Genetic Control

The first Michigan nematode-host resistance research was initiated in 1990. It was conducted using microplot technology in a sandy loam soil. Ten potato varieties were evaluated in the presence and absence of P. penetrans and V. dahliae. Tuber yields were ranked according to each of the four experimental treatments (Table 7). Snowden had the highest overall tuber yield. When the Penetrans root-lesion nematode/Verticillium wilt fungus Disease Complex (PDDC) expected and actual yields were compared, antagonistic, additive and synergistic responses were detected (Table 8), including possible susceptible and resistant reactions to the individual pathogens (Table 9).

In the absence of V. dahliae, Norkota Russett was the worst host for P. penetrans, and the nematode had the greatest reproductive success on Desiree. Superior was a poor host in the presence of V. dahliae; while Desiree remained an excellent host in the presence of this fungus. Both antagonistic and synergistic nematode reproduction responses were observed (Table 10).

Table 1. Tuber yields and economics associated with the 1990 potato nematicide evaluation at the Montcalm Research Farm.

Treatment (rate)	Tuber yield (cwt/A) A	B	J	Total	Revenue ($/A)[2]	Cost ($/A)	Revenue ($/A)
Temik 15G (20 lb/A, in-row)	273a	14a	50a	337a	1779	50	1729
Metham (20 gal/A, in row)	267a	13a	44ab	327a	1700	80	1620
Vorlex (4 gal/A, in-row)	253a	12a	32b	298b	1533	80	1453
Vydate 2L (2 gal/A, in-row)	254a	16c	29b	300b	1518	100	1418
Mocap 10G (30 lb/A, in-row)	249a	15a	13c	277b	1364	30	1334
Telone II (5 gal/A, in-row)	219b	12a	30b	261b	1422	75	1347
Non-Treated Control	203b	13a	6c	222c	1076	0	1076
CG-460 (1.5 lb ai/A, in-row)	184b	16a	7c	208c	992	50 (est.)	942

Table 2. Mid-season population densities of Pratylenchus penetrans associated with the 1990 potato nematicide trials at the Montcalm Research Farm.

Treatment	Pratylenchus penetrans 100 cm3 soil	1.0 g root
Check	30 a	278a
Ciba Geigy 460	33 a	242ab
Telone II	25 a	154bc
Vydate L	19 a b	80cd
Mocap	7b	42cd
Metham	5b	25d
Temik	5b	29d
Vorlex	9b	52cd

Table 3. Influence of ASC-66824 on Pratylenchus penetrans and potato tuber yields.

Treatment	Rate	Yield (cwt/A)	P. penetrans/ 100 cm^3 soil
ASC-66824	4.0 lb/A	161.7a	29a
ASC-66824	2.0 lb/A	153.8a	42ab
Non-treated	control	126.3b	58b

Table 4. Irrigation, rotation and nematicide usage.

Irrigation (%)	Rotation (yes)	Nematicide[1]	N (lb/A)	Farm Size	Selling Price	Yield (cwt/A)	Revenue ($/A)
0	0	None	123.74	370	5.43	129.05	731.76
	1-2	None	165.00	8	8.00	120.00	960.00
	3-4	None	258.66	157	7.59	209.46	1596.24
<=.50	0	None	109.01	715	5.44	165.73	911.01
	1-2	None	219.88	1090	7.14	171.33	1229.99
< 1.0	1-2	None	130.82	405	6.57	171.91	1131.94
		APN	232.88	565	5.70	275.00	1524.13
		APN+F	254.00	250	11.00	150.00	1518.80
1.0	0	None	160.00	340	4.65	260.00	1209.00
	1-2	None	108.05	262	5.24	263.74	1378.75
		APN	204.24	2365	5.20	242.56	1232.00
		SF	243.00	510	8.50	350.00	2814.00
		C	219.06	1690	6.93	396.42	2494.62
		APN+C	212.39	575	6.42	350.00	2159.74
		APN+SF +C	157.00	580	4.75	375.10	1239.75
	3,4,10		113.77	325	3.83	352.31	1622.17
			215.00	59	6.00	275.00	1175.00

1 APN = At=plant nematicide, SF = soil fumigant, Ç = chemigant.

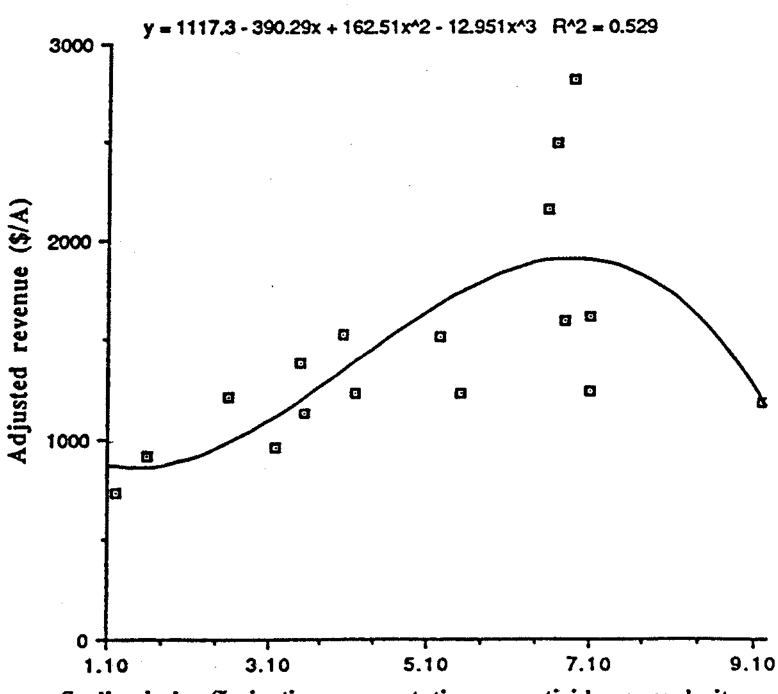

Fig. 1. Influence of potato production system inputs on adjusted revenue (revenue-nematicide cost).

Table 5. Influence of rotation crops on the population dynamics of Pratylenchus penetrans in 1989 and 1990.

Rotation Crop	Pratylenchus penetrans/100 cm^3 soil & 1.0 g root						
	1989				1990		
	(5/5)	(7/25)	(8/24)	(12/20)	(5/18)	(7/9)	(9/6)
Potato/Rye	10a	97ab	151b	126ab	36b	155a	85a
Corn	8a	155b	302c	206b	111b	580b	404b
Sudax	13a	37a	42a	149ab	66b	98a	91a
Sweet Clover	17a	97ab	117b	83a	1037a	266ab	407b
Alfalfa	6a	139b	145b	225b	299b	138a	160ab

Table 6. Influence of 1989 rotation crops on the population dynamics of Pratylenchus penetrans and on 1990 potato tuber yields.

Rotation	P. penetrans/100 cm^3 soil & 1.0 g root							
	1989				1990			Tuber
	(5/5)	(7/25)	(8/24)	(12/20)	(5/18)	(7/9)	(9/6)	yield cwt/A
Potato/Potato	10a	97ab	151b	126ab	36a	64a	31b	250a
Corn/Potato	8a	155b	302c	206b	109b	80a	30b	270a
Sudax/Potato	13a	37a	42a	149ab	50a	64a	15a	232a
Sweet Clover /Potato	17a	97ab	117b	83a	1067c	112a	26ab	252a
Alfalfa/Potato	6a	139b	145b	225b	254b	92a	14a	262a

Table 7. Influence of Pratylenchus penetrans, Verticillium dahliae and PDDC on tuber yields Solonum tuberosum.

	Tuber yield rank (1-10)				
Variety	Fumigated	P. penetrans	V. dahliae	PVDC	Mean
Snowden	1	2	2	3	1 (2.0)
Rosa	2	1	5	1	2 (2.3)
Russet Burbank	3	9	9	8	9 (5.8)
Red Dale	4	4	8	5	6 (5.3)
Norkota Russett	5	5	6	2	3 (3.8)
Kennebec	6	3	7	4	4 (4.0)
Atlantic	7	10	10	10	10 (7.4)
Hudson	8	7	1	9	5 (5.0)
Superior	9	6	4	7	6 (5.3)
Desiree	10	8	3	6	8 (5.4)

[1] PDDC = Penetrans root-lesion nematode/Dahliae Verticillium wilt fungus Disease Complex.

Table 8. PDDC analysis of tuber yields of 10 varieties of Solanum tuberosum.

	Tuber Yield loss (g)		Response	
Variety	Expected	Actual	Difference (%)	type
Snowden	157.9	106.5	51.4 (13)	Antag
Rosa	95.9	53.0	42.9 (12)	Antag
Russet Burbank	258.6	143.5	115.4 (33)	Antag
Red Dale	77.4	62.3	15.1 (5)	Add
Norkota Russett	84.8	14.0	70.8 (23)	Antag
Kennebec	50.3	43.8	6.5 (2)	Add
Atlantic	152.9	75.3	74.6 (28)	Antag
Hudson	+82.8	39.4	122.2 (49)	Syn
Superior	+27.9	20.8	48.7 (19)	Syn
Desiree	+45.2	1.5	46.7 (19)	Syn

[1] PDDC = Penetrans root-lesion nematode/Dahliae Verticillium wilt fungus Disease Complex.

Table 9. Pathogenic responses of 10 varieties of Solanum tuberosum to Pratylenchus penetrans, Verticillium dahliae and PDDC.

Variety	PDDC Disease Response		
	P. penetrans	V. dahliae	PVDC
Snowden	S	S	Antag
Rosa	R	S	Antag
Russet Burbank	S	S	Antag
Red Dale	R	S	Add
Norkota Russett	S	S	Antag
Kennebec	R	S	Add
Atlantic	S	S	Antag
Hudson	R	R	Syn
Superior	R	R	Syn
Desiree	R	R	Syn

[1] PDDC = Penetrans root-lesion nematode/Dahliae Verticillium wilt fungus Disease Complex.

Table 10. Host suitability of 10 varieties of Solanum tuberosum for reproduction of Pratylenchus penetrans.

Variety	Pratylenchus penetrans reproductive potential			
	Without V. dahlaie		With V. dahliae	
	Type	Rank	Type	Rank
Snowden	Good	6	Fair (Antag)	9
Rosa	Good	3	Fair (Antag)	8
Russet Burbank	Good	8	Fair (Antag)	7
Red Dale	Good	2	Fair (Antag)	4
Norkota Russett	Fair	10	Poor-Fair (Antag)	5
Kennebec	Fair	9	Good (Syn)	2
Atlantic	Good	7	Fair (Antag)	3
Hudson	Good	5	Fair (Antag)	6
Superior	Good	4	Poor (Antag)	10
Desiree	Very Good	1	Excellent (Syn)	1

Funding Federal Grant

USE OF DYE DIFFUSION TO MONITOR WOUND HEALING

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Dept. of Botany and Plant Pathology

Proper suberization of tubers is necessary to prevent excessive water loss and infection of stored tubers as well as to help prevent the decay of cut seed. There have been several reports describing different ways to measure the suberization process including monitoring resistance to water loss, measurement of the suberin poylmer itself, microscopic methods and failure of water soluble ions and dyes to pass through the suberized layer.Of these methods, diffusion of dyes has the potential of being adapted to on farm use. The following experiments were carried out to confirm if the resistance to diffusion of dyes through the healing surface of wounded tuber tissue could be correlated with the suberization process.

PROCEDURE

Discs of tuber tissue of the varieties Atlantic and a russet (A78242-5). Suberization was monitored in one set of discs by the thioglycolic acid method described in previous reports. Waxes were semi-quantitatively analyzed by TLC. We used the water soluble dye, toluidine blue, for these studies after preliminary studies indicated it was the most satisfactory dye to use. At daily intervals after cutting, the discs were examined for the presence of suberin, waxes, and ability to prevent dye diffusion. The dye diffusion assay was carried out by placing a drop of the dye (0.1% in water) on the surface of the disc. After one hour, the surface of the tissue was blotted to remove remaining dye and the upper layer (0.5 mm) containing the suberizing tissue was removed with a peeler and the underlying tissue examined for the presence of dye. Tissue was scored as either "Yes" (dye diffused into the tissue) or "No" (no dye present in the tissue).

RESULTS AND CONCLUSIONS

The thiolglycolic acid test revelaed that Atlantic suberized at a faster rate than did the russet (Table 1). The inability of dye to diffuse past the cut surface of tubers was first seen in Atlantic at 5 days after suberization began and at 6 days for the russet (Table 1). Increases in waxes were first noted at 3 and 4 days after suberization began for Atlantic and A78242-5, respectively.

These results suggest that the diffusion of dyes could be used as a rapid means to evaluate the progression of wound healing in tuber tissues that are in storage or have been cut for seed use. We are currently testing the procedure with other varieties and more readily available dyes to confirm the usefulness of the technique.

TABLE 1
SUBERIZATION AND DYE DIFFUSION OF WOUNDED TUBER TISSUE

DAYS SUBERIZED	RELATIVE SUBERIN AMOUNT*	DYE DIFFUSION**
	ATLANTIC	
1	0.06	YES
2	0.32	YES
3	0.95	YES
4	1.63	YES
5	2.02	NO
6	1.86	NO
7	3.02	NO
	A78242-5	
1	0.02	YES
2	0.26	YES
3	0.50	YES
4	1.39	YES
5	1.38	YES
6	1.81	NO

*Measured as A280 units per disc

** Yes=dye diffused into tissue; No=dye did not diffuse into tissue.