1988 MICHIGAN POTATO

RESEARCH REPORT

VOLUME 20

MICHIGAN STATE UNIVERSITY AGRICULTURAL
EXPERIMENT STATION

IN COOPERATION WITH

THE MICHIGAN POTATO INDUSTRY COMMISSION

February 28, 1989

TO ALL MICHIGAN POTATO GROWERS AND SHIPPERS:

The Michigan Potato Industry Commission and the Agricultural Experiment Station of Michigan State University are happy to provide you with a copy of the results of the 1988 potato research projects.

This years report includes research projects funded by the MPIC as well as projects funded through a special federal grant that the Michigan Potato Industry Commission helped secure. The federal grant data completes the fourth year of a five year project. Also included are reports on projects carried out by MSU which were not funded by the industry.

Providing research funding and direction to researchers is a major function of the MPIC on behalf of Michigan growers and shippers. Input from the industry regarding research is most welcome at anytime.

Regards,

The Michigan Potato Industry Commission

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

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1988 POTATO RESEARCH REPORT[1]

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INTRODUCTION AND ACKNOWLEDGEMENTS

The 1988 Potato Research Report includes reports of potato research projects conducted at the Montcalm Research Farm plus those conducted at other locations. This volume includes research projects funded by the Special Federal Grants (USDA 85-CRSR-2-2562 and 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 of the research areas. Many other contributions have been made in the form of fertilizers, pesticides, seed, supplies and monetary grants and we are very appreciative of this support also. A special thanks to Dick Kitchen for his excellent coordination of the production management needs and the day-to-day operations at the Farm.

We also want to acknowledge the donation to MSU of the equipment building, the land and 17 new acres of land purchased by the MPIC from Mr. and Mrs. Theron Comden. This new facility will definitely allow for the improvement of the facility and farm operations and will also provide greater land availability for additional research, field days and other events.

WEATHER

The 1988 weather data for the Montcalm Research Station as compared to the average of the previous 15 years are presented in Tables 1 and 2. The weather during the growing season was characterized by the well publicized drought and high temperatures. Rainfall was well below normal in May and June. In the 3 month period from May to July, there were only 8 days where a rainfall of 0.1 inches or greater was recorded (Table 3). Temperatures during May, June, July and August were well above the average. There were 9 days in August when the minimum night temperature exceeded 70°F. There were 8 days in July and 14 days in August when the minimum soil temperature at 4" depth exceeded 70°F. Higher night temperatures promote higher respiration rates and is detrimental to dry matter accumulation. The combination of inadequate rainfall and higher than normal temperatures resulted in more frequent irrigations than an average year. Higher than normal rainfall in September interfered with scheduled harvesting operations.

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[1]Printing and distribution of this report was made possible by the Michigan Potato Industry Commission and USDA grant 88-34141-3372.

SOIL TESTS

Soil test results for the general plot area were:

			lbs/a		%
pH	P	K	Ca	Mg	Organic Matter
5.9	504	282	1040	189	1.5

FERTILIZERS USED

The previous crop in the plot area was alfalfa planted in April, 1987. Except in fertilizer trials, where the amounts of fertilizer applied are specified in the project report, the following fertilizers were used in the potato trials:

banded at planting	15-10-15	500 lbs/a
sidedress with irrigation	23 lbs N in 2 separate applications	

HERBICIDES AND HILLING

Most of the hilling was completed by the end of May. At cracking, the potatoes were hilled, building a wide and flattened hill and placing minimal soil over the top of the ridge. Immediately after hilling, a tank mix of metolachlor (Dual) 2 lbs/a plus metribuzin (Lexone 4L) ½ lb/a was applied on May 20. No further tillage was done until harvest. Several hand weedings were performed during the season. Potato vines were killed with Diquat+ X77 on September 8.

IRRIGATION

Due to the extremely dry, hot summer, 18 supplementary irrigations were applied on June 3, 9, 13, 16, 20, 23, 28, July 1, 5, 8, 13, 22, 25, 28, August 2, 4, 15 and 31. Irrigation scheduling was done according to the Michigan State University irrigation scheduling program. The minimum profile moisture content allowed throughout the growing season was 50-60%. The amount of water applied was 0.75 inches per application. Urea (28%) was incorporated into irrigation water on June 28 and July 22.

Despite the prolonged dry spell, irrigation was sufficient to prevent any appearance of moisture stress. This was reflected in the average tuber yields which were about 15% higher than 1987.

INSECTS AND DISEASE CONTROL

Aldicarb (Temik 15G) was applied at planting at 20 lbs/a with the fertilizer. The foliar fungicide application was initiated on June 29 and 10 applications were made throughout the season. Fungicides used were Dithane M45 (5 applications), Ridomil (2 applications) and Bravo 500 (3 applications). Fungicides were generally used alternatively and were sprayed at 7-10 day intervals. Foliar insecticides used were Imidan (6/29, 7/12, 8/3 and 8/13) and Thiodan on 8/10. No serious disease or insect problems were encountered during the season.

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
1974	57	36	62	41	73	52	81	57	77	56	68	45	70	48
1975	48	28	73	48	75	56	80	57	79	58	65	44	70	49
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
15-YR. AVG.	54	34	69	43	75	52	82	56	79	55	70	49	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
1974	4.07	4.83	4.69	2.39	6.18	1.81	23.97
1975	1.81	2.05	4.98	2.71	11.25	3.07	25.87
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
15-YR. AVG.	2.70	2.74	3.09	2.45	4.27	4.72	19.97

Table 3. Weather highlights at Montcalm in summer 1988.

Days with	Number of Days					
	April	May	June	July	August	September
RF greater than 0.1"	5	2	2	4	8	6
Maximum day temp >90°F	0	1	8	10	12	0
Minimum night temp >70°F	0	0	0	2	9	0
Minimum soil temp >70°F	0	0	3	8	14	0

1988 POTATO VARIETY EVALUATIONS

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The potato variety evaluation and management program is designed to identify improved cultivars that will satisfy the needs of Michigan's fresh market and processing industry. Round whites, russets and red-skinned varieties are tested separately and their potential for specific markets are evaluated. Round whites and russets are harvested at 2 harvest dates to evaluate their marketable and physiological maturity and adaptability to Michigan. Selected varieties are then subjected for more intensive tests to determine optimum production management inputs that improve potato quality and marketability.

In all variety evaluations, special consideration was given to quality parameters. The focus was on tuber appearance, size distribution, external and internal defects, specific gravity (dry matter content), chip color, storability and culinary properties. Also of significant interest to Michigan is tolerance to common scab and bruising. Potential chipping varieties are stored in 2 storage environments (45 and 52°F) to evaluate chip color, reconditioning and storability.

A. DATES OF HARVEST TRIAL FOR ROUND VARIETIES

The 1988 dates-of-harvest trial was conducted at the Montcalm Research Farm. Seven named and 10 advanced selections were tested for their marketable maturity and adaptability to Michigan at 2 harvest dates of 98 and 143 days after planting. Four replications of a randomized complete block design were harvested at each harvest date. Plots were 23 ft x 34 inches with plant spacing of 12 inches.

The previous crop was alfalfa. Fertilizers and Temik 15G were applied as described in the previous chapter. The hilling and herbicide application were completed just prior to cracking, which was May 20. During the growing season the crop was irrigated 18 times according to the MSU irrigation scheduling program. The amount of water applied per irrigation was 0.75 inches totalling 13.5 inches for the season. Fungicides for early blight control were usually alternated as described in the previous chapter. An early and late blight forecasting program from Wisconsin was used as a guide to commence spraying. Relative humidity and temperature at canopy levels were monitored for this purpose. Weather data was collected with a programmed Campbell's CR21 micrologger.

For chip color determinations, 20 tubers were taken at random and a slice from each tuber used for the test. Agtron E-10 Colorimeter was used for color measurements. For after cooking darkening, peeled halves of 3 tubers picked at random were cooked in steam and evaluated at 0, 1 and 24 hours. Susceptibility to blackspot bruising was evaluated in artificially bruised and check treatments. Artificial bruising was done by taking potatoes out of 40°F storage and placing 20 tubers inside a wooden drum and turning 10 revolutions at a moderate speed. In the check treatments, potatoes were tested without artificial bruising, so that any blackspot observed occurred during harvest and handling. The artificially bruised tubers were kept for 48 hours at room temperature prior to peeling. A Hobart peeler was used for peeling the tubers.

Results

The yield and quality parameters of round potato varieties at 2 harvest dates are presented in Tables 1 and 2. Inspite of the prolonged dry summer, tuber yields were up by about 15% compared to 1987.

At 98 days, Onaway, Superior and Eramosa were the earliest in maturity. Eramosa, although the lowest yielder, matured very early (approximately 80 days) with smooth oblong tubers and good general appearance. However, some scab was noted.

Among the medium to medium-late maturing varieties, MS700-83, Michigold, Saginaw Gold, W855 and AF236-1 performed well. MS700-83 produced excellent yields and acceptable chip color but the gravity was low for processing. It has excellent potential as a fresh market potato but does have susceptibility to scab, growth cracks and after cooking darkening. Saginaw Gold, which is a joint release between MSU and Agriculture Canada, produced average yields with an excellent chip color, however, dry matter is lower than desired for processing. Michigold has a higher gravity than MS700-83 and an acceptable chip color out of field with susceptibility to scab and air checks. W855 appears to have the best potential for chip processing, produced average yields with medium-high gravity and excellent chip color. It was noted that the CPB is attracted to its foliage. Tubers were attractive and free of any internal defects with some susceptibility to scab. Somerset (AF236-1) produced an excellent chip color and tubers are cylindrical in shape. Kanona (NY71) has excellent chip color but had low gravity and was susceptible to scab. MS716-15 had excellent chip color and dry matter but the yields were unusually low in 1988.

Among the late maturing varieties, FL657, NY81, MS700-70 and LA01-38 produced prolific yields with a high percent of oversized tubers. MS700-70 produced the highest gravity but the type was average with medium deep eyes. There was a high percent of chip defects in FL657, MS700-70 and LA01-38 due to severe stem end browning.

In the culinary tests (Table 3), undesirable levels of after cooking darkening were found in LA01-38 1 hour after boiling. Other varieties that turned slightly dark were MS700-83, Onaway, NY71, W855 and Eramosa. Some sloughing was observed with Atlantic and MS716-15, which have high specific gravity.

Susceptibility of varieties to blackspot are presented in Table 4. In the artificially bruised treatments, varieties that had less than 30% of tubers with blackspot were Eramosa, MS716-15, Saginaw Gold, W848, MS700-83, and FL657. The varieties that showed a high percent of blackspot damage were LA01-38, W855, Atlantic and NY71. In the check treatments, most varieties showed no significant amounts of blackspot.

Variety Characteristics

MS700-83 - Mid season maturity and above average yields with medium gravity. Has excellent potential for fresh market and chipping. In some years, growth cracks and air checks have been reported. Some susceptibility to after cooking darkening in certain years and locations. Some scab was found in 1988 trials.

Michigold - Yellow fleshed and tubers are slightly flattened. Mid-season maturity with high gravity. It sets heavy and the flesh has an attractive golden color. It produces an attractive golden color chip when processed from field and short term storage. In some locations, air checks and growth cracks have been reported. Susceptible to scab.

MS716-15 - Medium-late maturity, tubers well shaped and smooth general appearance. It has high gravity, excellent chip color and no internal defects. It is susceptible to scab.

MS700-70 - Late season maturity with prolific yields. It has high gravity and excellent chip color out of field. Tubers are somewhat rough in appearance with medium deep eyes. Tends to produce a high percent of oversized tubers at 12" spacing.

Saginaw Gold - Round to oblong tubers with light yellow flesh and mid season maturity. It has an excellent chip color but the specific gravity was slightly lower than desired for processing. Good appearance after cooking.

NY81 - Very late maturity with medium gravity. Tends to produce a high percent of oversized tubers at 12" spacing. Produced above average yields with minimal internal defects.

Kanona (NY71) - Medium to late maturity with above average yields. Excellent chip color but the gravity was too low. Severe scab was noticed in the 1988 trials.

LA01-38 - Late season maturity with above average yields. It has an acceptable chip color with medium gravity. In 1988, it had a high percent of chip defects due to severe stem end browning. In artificially bruised treatments, it was susceptible to blackspot. Some susceptibility to after cooking darkening was observed.

W855 - Medium to late maturity with average yields. It has medium to high specific gravity and excellent chip color. Tends to produce undersized tubers if spaced too close. Some scab was present in 1988. Some reports of increased Colorado beetle attack to its foliage. Has potential in Michigan for chipping. Showed some susceptibility to blackspot in artificially bruised treatments.

Somerset (AF236-1) - Medium to late maturity, with average yields. Tubers are oblong in shape with medium gravity. Chip color is excellent. Some growth cracks were found in 1988 trials.

Eramosa - Very early maturity (80 days) with smooth, round to oblong tubers and good general appearance. It had no internal defects. Gravity is lower than Onaway. Some scab was found in 1988 trials. Has potential for first-early market.

W848 - Medium to late maturity, above average yields with medium gravity. It has excellent chip color. Produced a high percent of oversized tubers at 12" spacing. Tubers had a high percent of vascular discolorations. Some scab was present in 1988.

MN12823 - Medium to late maturity, above average yields with low gravity. Susceptible to hollow heart and tends to be oversized if spaced at 12".

Atlantic - Mid to late season maturity. High gravity, excellent chip color and is the major chipping variety in Michigan. It is susceptible to internal brown spot, hollow heart and scab.

Norchip - Mid-season maturity with below average yields. It has medium gravity but excellent chip color. Tubers vary in size and shape and the appearance is rough. It had some scab in 1988 trials.

Onaway - Early maturity with above average yields. Tubers are round to oblong. Minimal internal defects but vascular discolorations are found in some years. It has a tendency to produce oversized tubers and is susceptible to growth cracks and early blight.

FL657 - A variety released from Frito-Lay, Inc. Late maturing with prolific yields. It has light yellow flesh, low specific gravity and a rough appearance on the larger tubers. Tends to oversize at 12" spacing.

B. DATES-OF-HARVEST TRIAL FOR COUNT PACK VARIETIES

Eighteen russet and long varieties were evaluated for the count pack and processing potential at 2 harvest dates, 112 and 144 days (Tables 5 and 6).

Maturing early were Russet Norkotah, HiLite Russet, Norgold Russet and Krantz. Based on external appearance and internal defects, the varieties with count pack market potential were Russet Norkotah, HiLite Russet, A76147-2 and A74114-4. Those with high gravity and potential for processing were A7411-2, A79341-3, A79357-17 and A78242-5. A78242-5 is a very blocky russet with the lowest percent of 4 oz. tubers.

After cooking darkening data is presented in Table 7. None of the potato varieties showed any undesirable levels of darkening 1 hour after boiling. Russet Norkotah, Krantz and Russet Burbank rated exceptionally good after boiling.

Blackspot susceptibility data is presented in Table 8. In artificially bruised treatments, the varieties that appeared to be highly resistant to blackspot were Russet Norkotah, HiLite Russet, Norking Russet and Krantz. Varieties that had greater than 30% of tubers with blackspot damage were A78242-5, A79357-17, A7411-2, NEA71.72-1 and MN10874. In the check treatments, most varieties showed no significant blackspot.

Varieties that had the best appearance after peeling were A76147-2, A79341-3, Shepody, Russet Norkotah, HiLite Russet, Norking Russet, ND671-4R and Krantz.

Variety Characteristics

A76147-2 - Long, very light russet, late maturity with high yields and medium gravity. It has good external appearance and minimal internal defects. Has potential for fresh market. Some heat sprouts were observed in 1988 trials.

A78242-5 - Good early growth and vigor. Russet, maturity is late with above average yields and gravity. Has good external appearance and a tendency to produce a high percent of oversized tubers. Some internal defects were found in 1988 trials.

A79341-3 - Late maturing russet, with high solids. Good external appearance and quality. Some hollow heart developed in oversized tubers.

A79357-17 - Good early growth and vigor. Produced above average yields and medium gravity. Maturity is considered very late. Russet with good external appearance and quality.

A79239-8 - Has early emergence, good vine growth and early vigor. Maturity is considered very late and similar to Russet Burbank. Produced above average yields. Some hollow heart was observed in oversized tubers.

A74114-4 - Mid to late season maturity with average yields and medium gravity. Russet, has good cooking qualities. Has excellent external appearance, quality and potential for count-pack market. Internal defects are minimal.

HiLite Russet - A patented variety, mid-season maturity with average yields and low gravity, somewhat similar to Russet Norkotah. Has good cooking qualities and resistance to blackspot. Has good external quality, appearance and potential for count-pack market.

Shepody - Long white, mid-late season maturity. Maturity 2-3 weeks earlier than Russet Burbank normally. It has good external and internal qualities. Slow emergence and early establishment. Pre-cutting of seed is recommended. It is susceptible to scab and hollow heart may occur in larger tubers.

Norgold Russet - Mid-season maturity with below average yields and gravity. Good external appearance and quality. Produced a high percent of undersized tubers.

Krantz - Oblong russet, mid to late season maturity with below average yields and gravity in 1988. Produced a high percent of undersized tubers. Cooking qualities and blackspot resistance appeared to be very good.

SH-1 - A patented line introduced by Plant Genetics, Inc. Very late maturity, above average yields with medium gravity. It has a very high frequency of hollow heart in oversized tubers. At harvest tubers were skinned and pink eye was observed.

Russet Norkotah - Oblong to long russet, early to mid-season maturity. Tubers have a very smooth appearance with a gravity lower than Russet Burbank. Excellent potential for count pack market. Has excellent cooking qualities and blackspot resistance.

A7411-2 - Mid to late maturity, average yields with high gravity. Tubers have good external appearance. Excellent potential for processing with few internal defects. Should be handled carefully because of potential for blackspot damage.

NEA71.72-1 - Mid to late maturity, below average yields with low gravity. Tubers have a tendency for pointed ends and undersized.

ND671-4R - Mid season maturity with below average yields. It produced a high percent of undersized tubers. Tubers have a smooth appearance with no internal defects. The gravity is lower than desired for processing.

MN10874 - Late season maturity with average yields and low gravity. Tubers had no internal defects.

C. RED-SKINNED VARIETY TRIAL

Due to the increased interest in red-skinned varieties, 12 red selections were tested in a randomized complete block design with 4 replications (Table 9). The emphasis was on fresh market potential with uniform size, shape and color retention after storage. The varieties that showed the best appearance and color at harvest were ND2224-5R, NDT9-1068-11R, ND791-5R and Sangre. The internal defects were very minimal. The tubers were stored at 40°F to evaluate their storage performances.

After cooking darkening data is presented in Table 10. ND2224-5R showed severe after cooking 1 hour after boiling. Other varieties with a tendency for after cooking darkening were W949-R, Rideau and Red Gold.

Blackspot data is present in Table 11. In artificially bruised treatments, W948-R and Red Gold showed the highest frequency of blackspot. In check treatments, all varieties were tolerant to blackspot.

Variety Characteristics

Red LaSoda - Late maturity with above average yields. Has a tendency to oversize at 12" spacing.

W949R - Late maturity with above average yields. Has a tendency to oversize at 12" spacing. Some tendency for after cooking darkening.

NDT9-1068-11R - Late maturity with above average yields. Good appearance and red color at harvest. Has not performed well in storage in 1988 with decay and bruise problems.

ND791-5R - Early to medium maturity with above average yields. Good appearance and red color at harvest. Vigorous early growth and establishment.

Reddale - Late maturity with average yields. Susceptible to growth cracks.

ND2224-5R - Early to medium maturity with average yields. Very susceptible to after cooking darkening in 1988. Excellent color and appearance at harvest.

Rose Gold - Mid-season maturing with average yields. Has yellow flesh and a pink skin. Has excellent cooking qualities and blackspot tolerance. Tubers were somewhat undersized. Vigorous early growth and establishment.

Sangre - Mid-season maturing with average yields. Has excellent color at harvest. Very slow early establishment and pre-cutting of seed is recommended.

Rideau - Late maturing with below average yields. Had a tendency for dark ends after boiling in 1988. Very slow early establishment and pre-cutting of seed is recommended.

W948-R - Very late maturing with below average yields. Showed a higher percent of blackspot in artificially bruised treatments.

Red Gold - Mid-season maturing with below average yields. Has a pink skin and yellow flesh. Had a tendency to darken after boiling in 1988.

MN12949 - Mid-season maturing with below average yields. Tubers have a very low gravity and tendency to be undersized.

D. UPPER PENINSULA TRIAL

Nineteen potato varieties were tested in a randomized complete block design with 4 replications in the Upper Peninsula. The results are presented in Table 12.

Among the count pack varieties, those that produced the highest yields were A76147-2, A79341-3, A78242-5, MN10874 and A7411-2.

Varieties that produced above average specific gravities were A79341-3, MN10874, A7411-2, A79239-8, A79357-17 and Russet Burbank. The round varieties produced below average yields but MS716-15 produced an exceptionally high specific gravity.

E. NORTH CENTRAL REGIONAL TRIAL

This trial is conducted in 14 states and provinces with entries from various breeding programs to obtain data from a wide range of locations prior to a release decision. Two MSU lines (MS716-15 and MS700-70) were included in the 1988 trial. Eighteen varieties (10 round whites, 6 reds and 2 russets) were tested in a randomized complete block design with 4 replications. The results are summarized in Tables 13 and 14.

On a general merit rating based on external appearance and overall worth as a variety, the 5 top varieties in the trial were MS716-15, NDT9-1068-11R, W855, ND2224-5R and NEA22.75-1. The highest tuber yield was produced by MS700-70. Several other participating states have consistently given high merit ratings to the MSU seedlings tested in this trial.

In culinary tests (Table 15), undesirable levels of after cooking darkening were observed in ND2224-5R, ND1215-1, NEA219.70-3 and NEA22.75-1. ND1215-1 had a very occurrence of internal necrosis symptoms in the peeled potatoes.

In artificially bruised treatments, the varieties that showed any appreciable levels of blackspot damage were W855 and W1005 (Table 16). In the check treatments, most varieties showed no significant blackspot.

F. ADVANCED ADAPTATION TRIAL

Entries to this trial consisted of selections from 1987 adaptation trial and potential new lines for chipping released from other states. Two yellow varieties, ND1859-3 and ND2107-1, were included in the trial. The results are presented in Table 17.

Most varieties tested in this trial produced excellent chip color. However, the specific gravity of BR7093-24 was lower than desired for processing. BR7093-24 produced prolific yields and had a tendency to oversize at 12" spacing. AF875-16 had the highest gravity (1.089) and appeared promising for chipping.

In the culinary test (Table 18), undesirable levels of after cooking darkening were observed in ND1859-3, ND2109-7 and Atlantic 1 hour after boiling.

Blackspot results are presented in Table 19. In artificially bruised treatments, varieties that showed a high frequency of blackspot damage were NYD164-9, ND2330-3, ND1859-3, BR7093-24 and ND2109-7. In the check treatments, however, most varieties showed no significant blackspot.

Some of the promising varieties from this trial will be tested in the 1989 dates-of-harvest trial, depending on the availability of seed.

G. MSU SEEDLINGS TRIAL

Fourteen new MSU advanced seedlings were entered into this trial and tested in a randomized complete block design with 4 replications. These include 8 lines from the 401 series (Atlantic x Yukon Gold) and 6 lines from the 402 series (Atlantic x Onaway). Four lines from the 401 series were yellow fleshed varieties. The results are presented in Table 20.

Based on external and internal quality characteristics, 7 lines were selected for further testing. These lines were MS401-1, 401-2, 401-4, 401-7, 401-8, 402-7 and 402-8. MS401-1, 401-2 and 401-8 are yellow fleshed varieties with high gravity and excellent chip color. MS401-7 had the highest specific gravity (1.090) and produced excellent U.S. #1 yields.

In the culinary test (Table 21), only MS401-7 showed some tendency for after cooking darkening.

In the blackspot evaluation (Table 22), MS401-4 showed the highest frequency of blackspot in artificially bruised treatments. In the check treatments, all selected varieties showed no significant blackspot.

Depending on the availability of seed, some of the selected varieties from this trial will be tested in the 1989 dates-of-harvest trial.

Table 1. Michigan State University — Montcalm Research Farm — 1988 — Yield of First Date of Harvest — Round varieties (98 days).

	Yield (cwt/a)		Percent Size Distribution							No./15			
Variety	U.S. No. 1	Total	U.S. No. 1	<2"	2-3¼"	>3¼"	Pick Outs	Specific Gravity	Maturity*	HH	VD	IBS	Chip** Color
Onaway	481	502	96	4	81	15	0	1.064	2.2	0	4	0	49
FL657	463	480	96	3	69	27	1	1.062	4.0	0	0	0	71
Atlantic	453	486	93	7	76	17	0	1.084	3.4	1	0	1	71
MS700-83	444	489	91	9	82	9	0	1.071	3.3	0	1	1	76
Michigold	442	485	91	8	88	3	1	1.084	3.8	0	2	0	64
NY81	433	450	96	4	58	38	0	1.076	4.2	0	0	0	64
Superior	422	442	95	4	88	7	1	1.065	2.0	0	5	0	61
AF236-1	415	456	91	9	76	15	0	1.075	3.8	0	1	0	73
LA01-38	415	433	96	3	68	28	1	1.072	4.5	0	0	0	66
Saginaw Gold	390	449	87	7	82	5	6	1.074	3.0	0	1	0	70
MS700-70	384	417	92	5	76	16	1	1.079	5.0	0	1	0	70
NY71	383	401	95	4	75	20	1	1.071	3.8	0	0	0	70
W848	368	395	93	5	75	18	2	1.070	3.8	0	0	0	69
W855	338	396	85	15	83	2	0	1.079	4.0	0	0	0	72
MS716-15	334	378	88	11	86	2	1	1.083	4.0	0	0	0	70
Norchip	318	390	81	7	78	3	13	1.075	3.5	0	0	0	79
Eramosa	238	269	88	10	83	5	2	1.056	1.5	0	4	0	51
AVERAGE	395	430	92					1.073					67

*Maturity: 1 = very early; 5 = very late.

**Agtron chip color: >60 = excellent; 55-60 = good; 50-55 = fair; <50 = not acceptable.

Planting Date: May 3, 1988.

Harvest Date: August 11, 1988.

Table 2. Michigan State University — Montcalm Research Farm — 1988 — Yield of Second Date of Harvest — Round varieties (143 days).

	Yield (cwt/a)		Percent Size Distribution							No./20		
Variety	U.S. No. 1	Total	U.S. No. 1	<2"	2-3¼"	>3¼"	Pick Outs	Specific Gravity	Chip Color	HH	VD	IBS
FL657	554	598	93	1	44	49	6	1.064	60	0	2	0
NY81	500	529	95	4	45	50	1	1.074	58	1	3	0
MS700-70	498	533	93	4	54	39	3	1.081	66	1	4	2
MS700-83	496	555	90	8	76	14	2	1.071	60	0	2	0
LA01-38	491	524	94	4	63	31	3	1.073	59	0	2	1
W848	479	509	94	3	73	21	3	1.073	68	0	5	0
Onaway	473	521	91	6	75	16	3	1.068	38	0	2	0
NY71	466	490	95	4	64	31	1	1.071	69	1	4	0
MN12823	465	510	91	5	69	22	4	1.071	59	2	3	1
W855	464	523	89	10	80	9	1	1.078	78	1	3	1
Atlantic	447	476	94	5	75	19	1	1.081	71	3	1	4
Saginaw Gold	419	475	88	8	79	9	4	1.074	80	0	1	0
AF236-1	418	441	95	4	83	12	1	1.074	77	0	0	0
Michigold	414	462	90	9	79	11	1	1.077	60	0	2	0
MS716-15	413	471	88	12	82	6	0	1.083	64	0	1	0
Norchip	385	469	82	8	77	5	10	1.074	70	0	1	0
Eramosa	318	368	86	13	70	16	1	1.059	41	0	0	0
AVERAGE	452	497	91					1.073				

Planting Date: May 3, 1988.

Harvest Date: September 26, 1988.

Table 3. After cooking darkening* of Round varieties in the 1988 dates-of-harvest trial.

Variety	0 Hours	1 Hour	24 Hours	Comments
FL657	1	1	1	
NY81	1	1.5	1.5	Flesh turned yellow
MS700-70	1	1	1	Good
MS700-83	1	1.5	2.0	1 very dark
LA01-38	1	2.5	2.5	2 very dark
W848	1	1	1	
Onaway	1.5	1.5	2.0	All 3 slightly dark
NY71	1.5	1.5	2.0	1 very dark
MN12823	1	1	1	
W855	1.5	1.5	2.0	All 3 slightly dark
Atlantic	1	1	1	Some sloughing
Saginaw Gold	1	1	1	Good
Somerset	1	1	1	
Michigold	1	1	1	Nice yellow flesh
MS716-15	1	1	1.5	Some sloughing
Norchip	1	1.5	1.5	
Eramosa	1	1.5	2.0	Slightly dark

*Rating based on a scale of 1-5; 1 = no darkening, 5 = severe darkening (black).

Table 4. Blackspot susceptibility of 1988 dates-of-harvest trial for Round varieties.

	Artificially Bruised[y]		Check	
Variety[x]	Percent of Tubers with Blackspot	Severity[z]	Percent of Tubers with Blackspot	Severity
FL657	15	0.15	5	0.05
NY81	30	0.55	0	0
MS700-70	25	0.25	0	0
MS700-83	15	0.15	0	0
LA01-38	70	1.10	10	0.10
W848	25	0.45	10	0.10
Onaway	35	0.55	20	0.25
NY71	45	0.65	10	0.10
MN12823	30	0.35	5	0.05
W855	50	0.80	5	0.05
Atlantic	45	0.55	5	0.05
Saginaw Gold	25	0.25	5	0.05
Michigold	30	0.45	5	0.05
MS716-15	20	0.20	0	0
Norchip	30	0.30	15	0.20
Eramosa	5	0.05	5	0.05

[x]Varieties are arranged according to U.S. #1 tuber yield in the 1988 dates-of-harvest trial.

[y]Tubers removed from 40°F storage and bruised artificially with 10 revolutions in a wooden drum and peeled 48 hours later.

[z]Blackspot bruises per tuber.

Table 5. Yield of Count Pack Varieties at Harvest 1 — Montcalm Research Farm — 1988 (112 days).

Variety	Yield (cwt/a) U.S. No. 1	Yield (cwt/a) Total	Percent Size Distribution U.S. No. 1	<4 oz.	4-10 oz.	>10 oz.	Pick Outs	Specific Gravity	Maturity
A76147-2	498	591	84	8	59	25	8	1.074	5.0
A78242-5	478	522	92	4	45	47	4	1.074	4.0
SH-1	460	564	82	11	62	20	7	1.076	5.0
A79341-3	386	452	85	8	45	40	7	1.085	4.0
A79357-17	385	468	82	15	63	19	3	1.080	4.0
A74114-4	378	423	89	9	51	38	2	1.074	4.0
A7411-2	362	425	85	10	59	26	5	1.091	4.0
A79239-8	350	451	78	13	58	20	9	1.077	5.0
Shepody	349	435	80	13	56	24	7	1.079	4.0
HiLite Russet	309	399	77	22	68	9	1	1.070	3.0
MN10874	308	388	79	21	66	13	0	1.073	4.0
Norking Russet	303	377	80	15	61	19	5	1.074	3.5
Russet Norkotah	302	354	85	13	60	25	2	1.070	3.0
NEA71.72-1	298	402	74	20	64	10	6	1.071	4.0
ND671-4R	258	368	70	30	60	10	0	1.070	3.5
Russet Burbank	208	335	62	25	59	3	13	1.076	4.5
Norgold Russet	184	294	63	37	59	4	0	1.070	3.0
Krantz	150	229	66	30	58	8	4	1.070	3.5
AVERAGE	331	415	79					1.075	

Maturity: 1 = early; 5 = very late maturity.

Planting Date: May 2, 1988.

Harvest Date: August 24, 1988.

Table 6. Yield of Count Pack varieties at Harvest 2 — Montcalm Research Farm — 1988 (144 days).

	Yield (cwt/a)		Percent Size Distribution							Internal Defects		
Variety	U.S. No. 1	Total	U.S. No. 1	<4 oz.	4-10 oz.	>10 oz.	Pick Outs	Specific Gravity	Maturity	HH	VD	IBS
A76147-2	527	697	76	11	52	24	13	1.073	5.0	0	5	0
A78242-5	508	594	86	5	38	48	9	1.075	4.0	4	2	4
SH-1	452	592	76	10	51	25	14	1.075	5.0	22	0	1
A79239-8	388	489	79	12	53	26	9	1.078	5.0	6	8	0
A79341-3	358	471	76	12	51	25	12	1.081	4.0	4	2	0
A79357-17	356	495	72	16	49	23	12	1.078	4.5	1	5	0
Shepody	303	406	75	16	58	17	9	1.077	4.0	0	2	0
MN10874	301	394	76	23	68	8	1	1.071	4.0	0	0	0
A7411-2	298	397	75	11	51	24	14	1.087	4.0	2	2	2
A74114-4	297	377	79	17	60	19	4	1.073	4.0	0	1	0
NEA71.72-1	281	422	67	29	60	7	4	1.071	4.0	0	4	0
Russet Norkotah	261	335	78	18	57	21	4	1.068	3.0	0	2	0
HiLite Russet	247	362	68	30	60	8	2	1.070	3.0	0	0	0
Norking Russet	225	309	72	19	65	7	9	1.072	3.5	2	2	0
ND671-4R	196	320	62	36	58	4	2	1.068	3.5	0	0	0
Russet Burbank	184	375	49	30	47	2	21	1.075	4.5	0	1	0
Krantz	146	227	64	31	58	6	5	1.071	3.5	0	0	0
Norgold Russet	133	234	57	42	54	3	1	1.069	3.0	0	0	1
AVERAGE	303	416	73					1.074				

Internal defects of oversized (>10 oz.) tubers.

Maturity: 1 = early; 5 = very late maturity.

CV (U.S. No. 1) = 15.0%.

Planting Date: May 2, 1988.

Harvest Date: September 9, 1988.

Table 7. After cooking darkening* of potato varieties in the 1988 Count Pack trial.

Variety	0 Hours	1 Hour	24 Hours	Comments
A76147-2	1	1.5	1.5	
A78242-5	1	1	1	Yellowish
SH-1	1	1	1	Good
A79239-8	1	1	1	Good
A79341-3	1	1	1	Good
A79357-17	1	1	1	Good
Shepody	1	1	1	
MN10874	1	1.5	1.5	
A7411-2	1	1	1.5	
A74114-4	1	1.0	1.0	
NEA71.72-1	1	1.5	2	Dark streaks
Russet Norkotah	1	1	1	Very good
HiLite Russet	1	1	1	Good
Norking Russet	1	1	1.5	
ND671-4R	1	1.5	1.5	
Russet Burbank	1	1	1	Very good
Krantz	1	1	1	Very good
Norgold Russet	1	1.5	1.5	

*Rating based on a scale of 1-5; 1 = no darkening, 5 = severe darkening (black).

Table 8. Blackspot susceptibility of 1988 Count Pack varieties.

	Artificially Bruised[y]		Check	
Variety[x]	Percent of Tubers with Blackspot	Severity[z]	Percent of Tubers with Blackspot	Severity
A76147-2	30	0.30	0	0
A78242-5	35	0.45	10	0.15
SH-1	20	0.20	5	0.05
A79239-8	-	-	20	0.20
A79341-3	15	0.15	5	0.05
A79357-17	35	0.50	5	0.05
Shepody	30	0.40	0	0
MN10874	55	1.35	5	0.25
A7411-2	35	0.90	15	0.30
A74114-4	15	0.15	5	0.05
NEA71.72-1	35	0.55	5	0.25
Russet Norkotah	5	0.05	0	0
HiLite Russet	5	0.05	0	0
Norking Russet	5	0.05	0	0
ND671-4R	15	0.15	0	0
Russet Burbank	30	0.50	5	0.05
Krantz	5	0.05	0	0
Norgold Russet	15	0.20	0	0

[x]Varieties are arranged according to U.S. #1 tuber yield in the 1988 Count Pack trial.

[y]Tubers removed from 40°F storage and bruised artificially with 10 revolutions in a wooden drum and peeled 48 hours later.

[z]Blackspot bruises per tuber.

Table 9. Yield of Red Varieties — Montcalm Research Farm — 1988 (119 days).

Variety	Yield (cwt/a)		Percent Size Distribution					Specific Gravity	Maturity
	U.S. No. 1	Total	U.S. No. 1	<4 oz.	4-10 oz.	>10 oz.	Pick Outs		
Red LaSoda	515	577	89	5	64	25	6	1.066	4.5
W949-R	420	447	94	5	74	20	1	1.067	4.5
NDT9-1068-11R	412	468	88	9	75	13	3	1.058	4.5
ND791-5R	409	446	92	8	83	9	0	1.061	3.0
Reddale	400	465	86	8	66	20	6	1.060	4.0
ND2224-5R	388	438	89	11	85	4	0	1.060	3.0
Rose Gold	377	481	79	21	77	2	0	1.072	3.5
Sangre	372	424	88	12	83	5	0	1.063	3.5
Rideau	352	399	88	8	70	18	4	1.068	4.0
W948-R	345	398	87	11	84	3	2	1.074	5.0
Red Gold	320	401	80	19	78	2	1	1.073	3.5
MN12945	291	394	74	24	71	3	2	1.054	3.5
AVERAGE	383	445	86					1.065	

Maturity: 1 = early; 5 = very late maturity.

CV (U.S. No. 1) = 16.7%.

Planting Date: May 4, 1988.

Harvest Date: August 30, 1988.

Table 10. After cooking darkening* of Red-Skinned potato varieties in 1988.

Variety	0 Hours	1 Hour	24 Hours	Comments
Red LaSoda	1	1.5	1.5	
W949-R	1	2	2	All 3 slightly dark
NDT91068-11R	1	1	1	Good
ND791-5R	1	1.5	1.5	1 dark
Reddale	1	1	1	Good
ND2224-5R	1	3	3.5	All 3 very dark
Rose Gold	1	1	1	Good
Sangre	1	1	1	Good
Rideau	1.5	2	2	Dark ends
W948-R	1	1	1	Good
Red Gold	1	2	2	All 3 slightly dark
MN12945	1	1.5	1.5	

*Rating based on a scale of 1-5; 1 = no darkening, 5 = severe darkening (black).

Table 11. Blackspot susceptibility of 1988 Red-Skinned varieties.

	Artificially Bruised[y]		Check	
Variety[x]	Percent of Tubers with Blackspot	Severity[z]	Percent of Tubers with Blackspot	Severity
Red LaSoda	10	0.15	0	0
W949-R	20	0.25	5	0.05
NDT9-1068-11R	5	0.05	5	0.05
ND791-5R	5	0.05	10	0.10
Reddale	10	0.15	0	0
ND2224-5R	25	0.25	5	0.05
Rose Gold	10	0.10	5	0.05
Sangre	10	0.10	0	0
Rideau	15	0.15	10	0.10
W948-R	45	0.95	0	0
Red Gold	35	0.55	5	0.05
MN12945	5	0.05	0	0

[x]Varieties are arranged according to U.S. #1 tuber yield in the 1988 trial.

[y]Tubers removed from 40°F storage and bruised artificially with 10 revolutions in a wooden drum and peeled 48 hours later.

[z]Blackspot bruises per tuber.

Table 12. Tuber yield, size distribution and specific gravity of potato varieties in the Upper Peninsula — 1988.

Variety	Yield (cwt/a) U.S. No. 1	Yield (cwt/a) Total	Percent Size Distribution U.S. No. 1	<2"	2-3¼"	>3¼"	Pick Outs	Specific Gravity
A76147-2	475	492	96	2	41	55	2	1.073
A79341-3	415	441	94	3	36	58	4	1.081
A78242-5	383	395	97	3	34	63	0	1.075
MN10874	366	383	95	5	61	35	0	1.078
A7411-2	340	422	80	2	37	43	17	1.083
Shepody	324	356	91	3	56	35	6	1.075
A79239-8	324	355	91	2	26	64	7	1.076
ND671-4	309	323	95	5	61	34	0	1.067
Norking Russet	306	344	89	6	64	25	5	1.074
HiLite	303	323	93	7	56	37	0	1.071
Count	301	329	91	6	69	22	3	1.072
Michigold	297	317	94	6	70	24	0	1.077
Russet Burbank	294	338	89	3	58	31	8	1.079
A74114-4	294	315	93	6	46	47	1	1.074
MS716-15	276	292	94	5	67	28	0	1.087
MS700-83	270	291	93	7	61	32	0	1.076
Russet Norkotah	263	287	91	6	49	42	4	1.068
A79357-17	232	295	78	10	38	40	12	1.076
Krantz	228	237	96	4	52	44	1	1.071
AVERAGE	316	344						1.075

1988 NORTH CENTRAL REGIONAL POTATO TRIALS

Location Montcalm Experiment Station, Michigan State University, East Lansing, MI

Soil Type Sandy Loam - McBride

Fertilizer Treatment planter 500 lb/A - 15-10-15
sidedress 23 lbs N 6/28, 23 lbs N 7/22

Date Planted May 4, 1988

Date Harvested September 22, 1988

Size of Plots 25'

Spacing - Between Hills 12"

Spacing - Between Rows 34"

Replications 4

Number of Replications 4

Environmental Factors (rainfall, temperature, irrigations, etc.):

	RF"	Max. T.	Min. T.	Ave. T.
April	1.72	11.1	-0.2	5.1
May	0.52	23.1	7.9	16.3
June	0.56	27.9	11.4	20.1
July	2.44	29.6	17.9	26.5
August	3.44	28.7	16.3	22.3
September	4.47	21.6	9.2	15.3

Crop received 13.5" of irrigation water in 18 separate irrigations.

Sprays Applied:

Herbicides: Dual + Lexone - 1 application (5/20)

Fungicides:
- Dithane - 5 applications (6/29, 7/12, 7/26, 8/10, 8/26)
- Ridomil - 2 applications (7/12, 7/26)
- Bravo - 3 applications (8/3, 8/19, 9/2)

Insecticides:
- Imidan - 4 applications (6/29, 7/12, 8/3, 8/13)
- Thiodan - 1 application (8/10)

Other Data (vine killing, specific gravity, determinations, etc.):

Vine killing date: 9/8/88 (Diquat + X77).

Specific gravity measured by weight in air and weight in water method.

Extremely dry season but adequate irrigation water applied and no visible water stress was noticed.

Previous crop, plowdown alfalfa.

Table 13. North Central Regional Trial — 1988.

SUMMARY SHEET

Selection Number or Variety	Aver.[1/] Mat.	Most[2/] Representative Scab Area-Type	CWT/A Aver. Yield	CWT/A Aver. Yield US #1	Aver. Percent US #1	Aver.[3/] Total Solids	Gen.[4/] Merit Rating	*E-10 Agtron Colorimeter Chip[5/] Color	Early[6/] Blight Reading	Comments and General Notes
EARLY TO MEDIUM MATURITY										
Norland	1.5	0	445	419	94	15.0		50	4.0	Few off-shape
Norgold Russet	2.5	0	368	246	67	16.2		38	4.5	Nice type, early sprouting
Norchip	2.5	0	396	326	82	18.4		62	4.0	Few pointed ends
MN13053	2.0	T-2	456	389	85	16.0		43	4.0	Tubers have scurf
MN13056	2.5	T-1	315	211	67	16.7		51	4.0	High % small tubers
NEA 219-70-3	3.0	0	451	420	93	17.3		64	4.5	Deep eyes on both ends
MEDIUM LATE TO LATE MATURITY										
MN12823	4.5	0	547	496	91	16.0		58	4.5	Variable shape
MS700-70	5.0	0	687	655	95	19.7		63	5.0	Some EB rot in tubers
MS716-15	4.0	T-2	424	369	87	20.1	1	67	4.5	Good type, uniform
NEA22.75-1	5.0	0	623	584	94	17.1	5	35	5.0	Good type
NEA129.69-1	5.0	T-1	445	410	92	18.0		56	5.0	
NDT9-1068-11R	3.5	0	543	497	91	15.0	2	42	4.0	Good type, uniform
ND2224-5R	3.0	0	343	302	88	15.2	4	54	4.0	Good type, EB in tubers
ND1215-1	4.0	0	337	300	89	15.0		60	4.0	Severe IBS
W855	4.5	0	556	499	90	19.7	3	70	5.0	
W1005	3.5	0	457	315	69	19.0		58	4.5	Variable shape, small tubers
Rose Gold	3.0	0	493	426	86	18.0		43	4.0	
Red Potiac	4.0	T-2	627	560	89	15.4		30	4.5	Poor appearance

1/ 1-Very Early-Norland maturity; 2-Early-Irish Cobbler maturity; 3-Medium-Red Pontiac maturity; 4-Late-Katahdin maturity; 5-Very Late-Kennebec or Russet Burbank maturity.

2/ AREA - T-less than 1%; 1 - 10-20%; 2 - 21-40%; 3 - 41-60%; 4 - 61-80; 5 - 81-100%. TYPE - 1. Small, superficial; 2. Larger, superficial; 3. Larger, rough pustules; 4. Larger pustules, shallow holes; 5. Very large pustules, deep holes.

3/ Percent total solids, not total solids/acre.

4/ Place top five among all entries including check varieties; disregard maturity classification. (Rate first, second, third, fourth and fifth (in order) for overall worth as a variety).

5/ Chip Color - PCII Color Chart or Agtron. Indicate what Agtron you are using. Agtron E-10

6/ Early Blight - 1 susceptible; 5 highly resistant

Table 14. North Central Regional Trial — 1988.

SUMMARY OF GRADE DEFECTS

Selection Number or Variety	Percent External Defects (1): Scab (3)	Growth Cracks	Off Shape and Second Growth	Sun Green	Tuber Rot	Total (4) Tubers Free of External Defects	Percent Internal Defects (2): Hollow Heart	Internal Necrosis	Vascular Discolor-ation	Normal Tubers (5)
EARLY TO MEDIUM MATURITY										
Norland	0	0	8	0	0	92	20	0	5	75
Norgold Russet	0	0	0	0	0	100	0	0	5	95
Norchip	0	0	0	0	0	100	0	0	25 slight	75
MN 13053	4	0	0	10	0	86	0	0	15 slight	85
MN 13056	4	0	0	4	0	92	0	0	0	100
NEA 219-70-3	0	0	0	0	0	100	0	0	5 slight	95
MEDIUM LATE TO LATE MATURITY										
MN12823	0	0	0	0	0	100	0	0	25 slight	75
MS700-70	0	0	0	0	8	92	0	20	20	60
MS716-15	4	0	0	0	0	96	0	0	10	90
NEA22.75-1	0	0	0	4	0	96	0	0	25 slight	75
NEA129.69-1	5	0	0	0	5	90	0	0	20 slight	80
NDT9-1068-11R	0	0	4	4	0	92	0	0	25 slight	75
ND2224-5R	0	0	0	4	20	76	5	0	20 slight	75
ND1215-1	0	0	0	0	0	100	0	70	0	30
W855	0	0	0	4	0	96	0	5	40 slight	55
W1005	0	0	0	0	0	0	5	0	5 slight	90
Rose Gold	0	0	0	0	0	0	0	0	25 slight	75
Red Pontiac	10	0	0	0	0	90	0	0	30 slight	70

(1) Based on four 25 tuber samples (one from each replication). Percentage based on number of tubers.

(2) Based on four 25 tuber samples (one from each replication). Percentage based on number of tubers.

(3) Includes all tubers with scab lesions whether merely surface, pitted or otherwise and regardless of area. Be sure to count tubers with any amount of scab in this category.

(4) This total - tubers free from any external defect of any sort.

(5) Percentage normal tubers are those showing no internal defects. Some individual tubers will have more than one type of internal defect.

Table 15. After cooking darkening* of potato varieties in the 1988 North Central Regional trial.

Variety	0 Hours	1 Hour	24 Hours	Comments
MN13053	1.0	1.0	1.0	Good
NEA219.70-3	1	1.5	2.0	
MS700-70	1	1	1	Good
W855	1	1	1.5	
Norgold Russet	1	1.5	1.5	
Red Pontiac	1	1.5	1.5	
MN12823	1.5	1.5	1.5	
Norchip	1	1	1.5	
MS716-15	1	1	1	Very good
ND2224-5R	1.5	3	3.5	All 3 very dark
NDT9-1068-11R	1.5	2	2	
Rose Gold	1	1	1.5	
Norland	1	1.5	1.5	
W1005	1	1.5	1.5	
MN13053	1	1.5	1.5	
NEA22.75-1	1.5	2.0	2.0	
ND1215-1	1.5	2.5	3.0	All 3 dark

*Rating based on a scale of 1-5; 1 = no darkening, 5 = severe darkening (black).

Table 16. Blackspot susceptibility of 1988 North Central Regional trial varieties.

Variety	Artificially Bruised[y]		Check	
	Percent of Tubers with Blackspot	Severity[z]	Percent of Tubers with Blackspot	Severity
MN13056	15	0.15	-	-
NEA219.70-3	5	0.05	15	0.15
MS700-70	10	0.10	5	0.05
W855	30	0.45	15	0.15
Norgold Russet	5	0.05	0	0
Red Pontiac	0	0	0	0
MN12823	10	0.10	0	0
Norchip	15	0.15	10	0.10
MS716-15	0	0	0	0
ND2224-5R	10	0.10	15	0.15
NDT9-1068-11R	10	0.10	0	0
Rose Gold	0	0	0	0
Norland	5	0.05	0	0
W1005	25	0.25	10	0.10
MN13053	0	0	0	0
NEA22.75-1	0	0	0	0
ND1215-1	10	0.10	10	0.10

[y]Tubers removed from 40°F storage and bruised artificially with 10 revolutions in a wooden drum and peeled 48 hours later.

[z]Blackspot bruises per tuber.

Table 17. Tuber yield from Advanced Adaptation Lines — Montcalm Research Farm — 1988 (126 days).

	Yield (cwt/a)		Percent Size Distribution							
Variety	U.S. No. 1	Total	U.S. No. 1	<2"	2-3¼"	>3¼"	Pick Outs	Specific Gravity	Chip Color	Maturity
BR7093-24	559	600	93	4	63	30	3	1.073	67	4.0
Atlantic	467	513	91	7	78	13	2	1.083	69	4.0
ND1859-3(y)	432	469	92	7	82	10	1	1.075	60	3.5
NYD164-9	409	479	85	13	75	10	2	1.082	64	4.0
AF875-16	361	405	89	9	84	5	2	1.089	66	3.5
ND2330-3	350	402	87	12	83	4	1	1.076	60	3.0
D195-24	324	400	81	17	76	5	2	1.082	64	3.5
D2109-7	254	317	80	19	80	0	1	1.080	70	3.0
ND2107-1(y)	245	344	71	28	70	1	1	1.077	66	3.0
AVERAGE	377	439	85					1.080		

Planting Date: May 4, 1988.

Harvest Date: September 6, 1988.

Table 18. After cooking darkening* of potato varieties in the 1988 Advanced Adaptation trial.

Variety	0 Hours	1 Hour	24 Hours	Comments
NYD164-9	1	1	1	Good
ND2330-3	1	1	1	Good
D195-24	1	1	1.5	
ND1859-3(y)	1	2	3	3 dark ends
BR7093-24	1	1.5	1.5	
Atlantic	1	2	2	3 dark ends
ND2107-1(y)	1	1	1	Good
ND2109-7	1	2	2.5	3 dark stem ends
AF875-16	1.5	1.5	2.5	2 dark ends

*Rating based on a scale of 1-5; 1 = no darkening, 5 = severe darkening (black).

Table 19. Blackspot susceptibility of 1988 Advanced Adaptation trial varieties.

	Artificially Bruised[y]		Check	
Variety	Percent of Tubers with Blackspot	Severity[z]	Percent of Tubers with Blackspot	Severity
NYD164-9	65	1.00	5	0.05
ND2330-3	70	1.00	20	0.20
D195-24	30	0.40	5	0.05
ND1859-3(y)	50	0.90	10	0.10
BR7093-24	35	0.60	10	0.10
Atlantic	25	0.25	25	0.25
ND2107-1(y)	25	0.30	5	0.05
ND2109-7	50	0.65	10	0.10
AF875-16	30	0.65	15	0.15

[y]Tubers removed from 40°F storage and bruised artificially with 10 revolutions in a wooden drum and peeled 48 hours later.

[z]Blackspot bruises per tuber.

able 20. Tuber yield of MSU Advanced Lines — Montcalm Research Farm — 1988 (126 days).

	Yield (cwt/a)		Percent Size Distribution							Internal Defects			
ariety	U.S. No. 1	Total	U.S. No. 1	<2"	2-3¼"	>3¼"	Pick Outs	Specific Gravity	Chip Color	Maturity	HH	IBS	# VD/cut
S401-5	631	688	92	6	72	20	2	1.083	53	5.0	22	5	19/40
S401-7*	534	577	92	5	83	9	3	1.090	60	4.0	4	1	0/28
S402-1	471	519	91	5	70	21	4	1.070	51	3.5	14	23	0/30
S402-7*	459	485	95	4	74	21	1	1.074	61	3.0	0	5	8/39
S401-3(y)	441	498	88	9	70	18	3	1.079	60	3.0	10	10	7/34
S401-2(y)*	441	473	93	4	62	31	3	1.082	63	4.0	4	0	7/40
naway	428	468	91	6	77	14	3	1.067	48	2.5	0	0	9/40
S401-6	410	439	93	5	64	29	2	1.080	60	3.5	31	11	5/40
tlantic	408	457	89	10	77	12	1	1.084	64	4.0	10	4	4/31
S401-1(y)*	390	466	84	15	80	4	1	1.081	69	3.0	4	0	0/16
S402-6	383	434	89	6	77	12	5	1.074	52	3.0	6	19	2/30
S401-8(y)*	365	418	87	8	70	17	5	1.080	65	3.0	8	7	9/40
S401-4*	331	434	76	22	73	3	2	1.078	60	2.5	0	7	1/9
S402-8*	318	334	95	4	61	34	1	1.069	56	3.0	3	0	0/30
S402-2	309	396	78	20	77	1	2	1.073	66	2.5	0	3	0/4
S402-4	209	309	68	30	67	1	2	1.066	50	2.0	4	10	5/11
AVERAGE	408	462	88					1.077					

Selected for further testing.

Planting Date: May 4, 1988.

Harvest Date: September 6, 1988.

Table 21. After cooking darkening* of Michigan State University selections.

Variety	0 Hours	1 Hour	24 Hours	Comments
MS401-1	1.5	1.5	1.5	All 3 slightly dark
MS401-2	1	1	1	Good
MS401-4	1	1.5	1.5	
MS401-7	1	2	2.5	1 severely dark, 2 slightly dark
MS401-8	1	1.5	1.5	
MS402-7	1	1	1	Good
MS402-8	1	1	1	Good

*Rating based on a scale of 1-5; 1 = no darkening, 5 = severe darkening (black).

Table 22. Blackspot susceptibility of 1988 Michigan State University selections.

	Artificially Bruised[y]		Check	
Variety	Percent of Tubers with Blackspot	Severity[z]	Percent of Tubers with Blackspot	Severity
MS401-1(y)	15	0.15	0	0
MS401-2(y)	10	0.10	5	0.05
MS401-4	40	0.65	0	0
MS401-7	25	0.50	5	0.05
MS401-8(y)	10	0.10	10	0.10
MS402-7	30	0.55	0	0
MS402-8	5	0.05	0	0

[y]Tubers removed from 40°F storage and bruised artificially with 10 revolutions in a wooden drum and peeled 48 hours later.

[z]Blackspot bruises per tuber.

Development of new potato cultivars specifically suited to Michigan's fresh market and processing needs

David S. Douches
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Cooperators: R. Chase, G. Silva, R. Hammerschmidt, J. Cash

Objective:

The MSU potato variety improvement program's main objective is to develop and identify improved cultivars that will satisfy the needs of Michigan's fresh market and processing industry.

Justification:

Michigan's potato industry has become highly specialized and stringent marketing demands have forced growers to use specific varieties which are unpredictable because of serious production and storage limitations. Improved varieties are needed for chip processing with a higher dry matter content (19.5-21.5%) and less susceptibility to bruising and storage deterioration than the variety Atlantic. For fresh market use, there is a need for a disease resistant variety with a bright skin and smooth appearance for marketing from extended storage. The marketing of round white table stock potatoes has been very volatile and challenges of the immediate future must be met with improved raw product quality. It is essential that new varieties be developed and tested to meet the current and future needs.

Methods and Procedures:

The potato breeding program in the Crop and Soil Sciences Department has been reactivated in 1988 to develop improved cultivars specifically suited to Michigan. All variety and germplasm evaluations will focus on tuber appearance, size distribution, external and internal defects, specific gravity, chip color, storability, and culinary properties. Also of significant interest to Michigan is tolerance to scab (*Streptomyces scabies*) and bruising.

Short-term goals (3-5 years)

Adaptation trial: Twenty advanced lines from public breeding programs throughout the US and Canada were selected in 1988 for further evaluation at Montcalm and Clarksville Experiment Stations. In 1989, each line will be planted as 2x20 hill trials at both locations with check varieties. Only those that meet industry requirements will be selected for an advanced adaptation trial in 1990. Promising material will be maintained virus-free through tissue culture.

Scab evaluation: Parental lines utilized in the MSU breeding program will be tested for their ability to confer resistance to common scab through a greenhouse bioassay developed by Dr. Ray Hammerschmidt. Advanced selections will be evaluated in the scab trial located at the Soils Farm at MSU.

Mid-range goals (7-10 years)

Evaluation of first-year seedlings: Approximately 10,000 seedlings derived from 100 segregating families generated at MSU will be screened at Clarksville. In addition, 5,000 seedling tubers obtained from USDA (Idaho and Beltsville) programs will be tested for adaption. Selections from this trial will be advanced to 4-hill plots in the following year.

Advancement of first-year seedlings: Single hills selected in 1988 will be tested as 4-hill plots at Montcalm and Clarksville. Further advancement will be based upon their performance in relation to check cultivars at both locations.

Cultivated/Species hybrid (4x-2x) evaluations: Superior selections from the diploid exotic species have been hybridized to advanced selections and cultivars. These 4x-2x hybrid progenies (5,000 seedlings) will be grown at Clarksville to evaluate the breeding value of these diploid parents. In addition, superior hybrids will be advanced as 4-hill plots in the breeding program.

Long-term goals (12-15 years)

Evaluation of exotic germplasm: Plant introductions of various *Solanum* species (2n = 2x, 4x, and 6x) are to be evaluated for their ability to hybridize with the cultivated potatoes, to introgress disease resistances such as scab, fusarium, and virus along with tuber quality genes such as dry matter and low reducing sugars. Approximately 3,000 seedlings will be screened in 1989 and select hybrid families will be advanced for further evaluation. We expect to broaden our germplasm base with this genetic material.

Research

A biotechnological approach (RFLP analysis) is being tested to predict specific gravity in early rounds of selection and also to identify high specific gravity material in both cultivated and exotic germplasm.

Biochemical and mechanical factors are being characterized in a series of breeding lines and cultivars to determine if correlations exist between these factors and the expression of scab resistance. The genetic basis of the factors and scab resistance are being evaluated through a diallel mating design. (Cooperator: R. Hammerschmidt)

Research is being initiated to study the influence of genetic factors upon tuber reducing sugars (glucose and fructose) levels. Segregating families derived from a diallel mating are being evaluated. (Cooperator: J. Cash)

The information gained from this research is being integrated into the breeding of new cultivars through (1) the development of superior parental germplasm and (2) the development and utilization of efficient assays to select superior lines that express these economic traits that the industry needs.

Funding Federal Grant

EVALUATION OF PRODUCTION MANAGEMENT INPUTS TO IMPROVE QUALITY AND YIELD OF RUSSET NORKOTAH AND MS700-70

G.H. Silva, R.W. Chase and R.B. Kitchen

Russet Norkotah has potential in Michigan for the count pack market because of its high percentage of U.S. No. 1's and its smooth appearance. Under standard cultural practices in Michigan, it has a tendency to produce a higher percent of undersized tubers. MS700-70 is a round white, late maturing variety with high gravity and prolific yields. It has chipping potential in Michigan.

The management practices recommended for new releases are generally based on standard practices adapted for commonly grown cultivars. In 1988, the optimum nitrogen and spacing requirements of Russet Norkotah and MS700-70 were studied using 3 levels of nitrogen (100, 150 and 200 lbs/a) and 3 within row spacings (6, 9 and 12"). The treatments were studied in a split-plot design with 4 replications. In addition to determining the nitrogen and spacing requirements for optimizing tuber quality, the cost/revenue analysis of each treatment combination was determined.

The trial was planted on May 5. The previous crop was alfalfa and the plowdown alfalfa residue was credited with 75 lbs N/a to the potato crop. The basal fertilizer application with the planter was 500 lbs/a 5-10-15 mixture. For treatments receiving 150 lbs N, a topdressing of urea containing 50 lbs N/a was applied on June 15. For treatments receiving 200 lbs N/a, another topdressing of urea containing 50 lbs N/a was applied on July 5. Petioles for nitrogen analysis were taken on August 4. Russet Norkotah was harvested on August 30 and MS700-70 on September 28.

Results

Russet Norkotah - The results are summarized in Tables 1, 2 and 3. The N effect on tuber yield was not significant but the spacing effect was highly significant (Table 1). The highest tuber yield was obtained at 150 lbs N and 6" spacing. Excellent U.S. #1 yields were obtained at 6" spacing and at all 3 N levels. The percent tubers under 4 oz. size ranged from 15-17%. At higher N and spacing levels there was an increase in the oversized (>10 oz.) tubers. Although N rates produced no response in tuber yield, there was a significantly higher uptake of N in the petioles at higher N rates. This constitutes luxury consumption of N. Higher N levels were also associated with slight decreases in specific gravity. Nitrogen uptake significantly increased at wider spacings. Post harvest evaluations (Table 2) indicated that nitrogen and spacing treatments had no significant effects on after cooking darkening and blackspot. Nitrogen and seed costs/revenue per acre analysis (Table 3) indicated that 150 lbs/N and 6" spacing were the most economical for Russet Norkotah.

MS700-70 - These results are summarized in Tables 4, 5 and 6. There was no response to nitrogen treatments, but the response to spacing was highly significant (Table 4). The highest tuber yields were obtained at 6" spacing. As in previous years, prolific yields and higher specific gravities were produced in 1988. At wider spacings, MS700-70 produced a very high percent of oversized tubers. Although N levels produced no significant effects on tuber yield, there was luxury consumption of N in the petioles. Higher N levels decreased the specific gravity of tubers. Post harvest evaluations (Table 5) indicated that nitrogen and spacing levels in the test produced no significant differences in chip color, after cooking darkening and blackspot. Nitrogen and seed costs/revenue per acre analysis (Table 6) indicated that the highest net revenues are obtained at 6" spacings.

In summary, both varieties produced no responses to nitrogen rates but showed significant yield increases at 6" spacing. This field had alfalfa in the previous year and it is possible that alfalfa contributed a large share of nitrogen requirements and perhaps in a slow release form to render further applications of N ineffective. Russet Norkotah produced high U.S. No. 1 yields with a smooth appearance and showed excellent potential for count pack fresh market. It has excellent culinary properties and blackspot resistance. MS700-70 produced prolific yields with high specific gravity and good chip color. In Michigan, it is late maturing but has potential as a chipper.

Table 1. Russet Norkotah — Management Profile — Montcalm Research Farm — 1988 (118 days).

		Yield (cwt/a)		Percent Size Distribution							
Nitrogen (lbs/a)	Spacing (inches)	U.S. No. 1	Total	U.S. No. 1	<4 oz.	4-6 oz.	6-10 oz.	>10 oz.	Pick Outs	Specific Gravity	Petiole N %
150	6	435	528	82	15	19	45	18	3	1.069	3.08
200	6	393	491	80	17	23	32	25	3	1.067	3.56
100	6	388	479	81	17	16	52	13	2	1.070	2.49
100	9	377	468	81	13	16	44	21	6	1.068	2.70
100	12	360	416	87	12	15	38	34	1	1.069	3.22
200	9	358	419	85	12	16	39	30	3	1.068	3.42
150	12	354	413	86	11	22	40	24	3	1.068	3.38
200	12	348	413	84	11	14	35	35	5	1.066	3.64
150	9	327	407	80	14	16	37	27	6	1.066	3.31
AVERAGE		371	447	83						1.067	3.20
Nitrogen Effects											
		(ns)								(ns)	(*)
100		375	454	83	14	16	45	22	3	1.069	2.80
150		372	449	83	13	19	41	23	4	1.068	3.25
200		366	441	83	13	18	35	30	4	1.067	3.54
Spacing Effects											
		(*)								(ns)	(*)
	6	405	499	81	16	19	43	19	3	1.069	3.04
	9	354	431	82	13	16	40	26	5	1.067	3.15
	12	352	414	86	11	17	38	31	3	1.068	3.41

Table 2. Post Harvest Evaluations — Russet Norkotah.

			Percent Blackspot	
Nitrogen	Spacing	After Cooking Darkening[y]	Check	Bruised[z]
100	6	1	0	10
100	9	1	5	0
100	12	1	0	5
150	6	1	10	15
150	9	1	0	0
150	12	1	0	0
200	6	1.5	0	10
200	9	1	0	15
200	12	1	0	10

[y]Rating based on a scale of 1-5; 1 = no darkening, 5 = severe darkening (black) 1 hour after boiling.

[z]Tubers removed from 40°F storage and bruised artificially with 10 revolutions in a wooden drum and evaluated after 48 hours.

Table 3. Management Profile — Russet Norkotah — Nitrogen and Seed Costs and Revenue/Acre (118 days).

N Applied (lbs/a)	N + Application Cost ($)	Spacing (inches)	Seed Cost ($)	N + Seed Cost ($)	Yield (cwt/a)	Gross Revenue ($)	NET ($)
150	38	6	261	299	435	2,861.76	2,562.76
200	52	6	261	313	393	2,614.58	2,301.58
100	24	6	261	285	388	2,553.07	2,268.07
100	24	9	174	198	377	2,513.16	2,315.16
100	24	12	131	155	360	2,423.20	2,268.20
200	52	9	174	226	358	2,377.83	2,151.83
150	38	12	131	169	354	2,358.23	2,189.23
200	52	12	131	183	348	2,327.26	2,144.26
150	38	9	174	212	327	2,171.35	1,959.35

Nitrogen 100, 150 and 200 lbs/a applied in 1, 2 and 3 applications, respectively.

Nitrogen cost = $0.20/lb. Cost per application = $4.00/a. Seed cost = $7.00/cwt.

Revenue on the basis of $6.50/cwt for tubers 2-3¼" and $7.00 for >3¼".

Table 4. MS700-70 — Management Profile — Montcalm Research Farm — 1988 (148 days).

		Yield (cwt/a)		Percent Size Distribution						
Nitrogen (lbs/a)	Spacing (inches)	U.S. No. 1	Total	U.S. No. 1	<2"	2-3¼"	>3¼"	Pick Outs	Specific Gravity	Petiole N %
100	6	561	604	93	7	80	13	0	1.083	2.53
200	6	545	600	91	7	67	24	2	1.078	3.66
150	6	533	570	94	5	68	26	1	1.081	3.11
150	9	509	547	93	6	62	31	1	1.079	3.24
200	9	499	524	95	4	63	32	1	1.077	3.75
100	9	495	523	95	5	65	30	0	1.081	2.56
150	12	456	505	90	6	57	33	4	1.081	3.31
200	12	454	496	92	6	59	33	2	1.077	3.74
100	12	445	481	93	5	68	25	2	1.081	2.39
AVERAGE		499	539	93					1.080	3.42
Nitrogen Effects										
		(ns)							(*)	(*)
100		500	536	93	6	72	21	1	1.081	2.49
150		500	541	92	6	62	30	2	1.080	3.22
200		499	540	92	4	63	29	2	1.078	3.72
Spacing Effects										
		(*)							(ns)	(ns)
	6	546	591	92	6	71	21	1	1.080	3.10
	9	501	532	94	5	63	31	1	1.079	3.16
	12	452	494	92	6	61	31	2	1.079	3.16

Table 5. Post Harvest Evaluations — MS700-70.

Nitrogen	Spacing	Chip Color	After Cooking[y] Darkening	Percent Blackspot Check	Percent Blackspot Bruised[z]
(lbs/a)	(inches)				
100	6	60	1	5	15
100	9	62	1	0	30
100	12	58	1	0	15
150	6	59	1	10	10
150	9	60	1	5	40
150	12	63	1	0	20
200	6	58	1	0	25
200	9	59	1	0	30
200	12	60	1	0	15

[y]Rating based on a scale of 1-5; 1 = no darkening, 5 = severe darkening (black) 1 hour after boiling.

[z]Tubers removed from 40°F storage and bruised artificially with 10 revolutions in a wooden drum and evaluated after 48 hours.

Table 6. Management Profile — MS700-70 — Nitrogen and Seed Costs and Revenue/Acre (148 days).

N Applied (lbs/a)	N + Application Cost ($)	Spacing (inches)	Seed Cost ($)	N + Seed Cost ($)	Yield (cwt/A)	Gross Revenue ($)	NET ($)
100	24	6	261	285	561	3,648.16	3,363.16
200	52	6	261	313	545	3,621.00	3,308.00
150	38	6	261	299	533	3,556.80	3,257.80
150	38	9	174	212	509	3,391.40	3,179.40
200	52	9	174	226	499	3,319.54	3,093.54
100	24	9	174	198	495	3,307.98	3,109.98
150	38	12	131	169	456	3,037.58	2,868.58
200	52	12	131	183	454	3,047.92	2,864.92
100	24	12	131	155	445	2,967.77	2,812.77

Nitrogen 100, 150 and 200 lbs/a applied in 1, 2 and 3 applications, respectively.

Nitrogen costs = $0.20/lb. Cost per application = $4.00/a. Seed cost = $7.00/cwt.

Revenue on the basis of $6.50/cwt for tubers 2-3¼" and $7.00 for >3¼".

Funding Federal Grant

EFFECTS OF POTASSIUM RATE AND SOURCE ON YIELD AND QUALITY OF NORCHIP AND MS700-83

G.H. Silva, R.W. Chase and R.B. Kitchen

The effects of 2 sources (muriate of potash and potassium sulfate) and 4 levels of K (0, 100, 200 and 300 lbs K_2O) on specific gravity and culinary properties were investigated in 2 cultivars (Norchip and MS700-83). These 2 varieties were selected because of their chipping potential but their marginal specific gravities are frequently a major limitation in Michigan. The objective was to find out if the specific gravity could be increased with reduced K use or using alternate K sources.

All K was applied broadcast with a Gandy applicator before planting. The previous crop was alfalfa. The initial soil test showed 270 lbs K and a pH of 6.0. For a yield goal of 450 cwt/a, the recommendation was to apply another 150 lbs K_2O/a. Both varieties received 175 lbs N and 50 lbs P_2O_5. The treatments were tested in a randomized complete block design with 4 replications. Petioles for nutrient analysis were taken on August 4. The trial was planted on May 6 and harvested on September 22.

The results obtained from Norchip and MS700-83 are summarized in Tables 1 and 2, respectively. The data indicated that in both varieties, the highest specific gravities were obtained in treatments where no K was applied. Specific gravity decreased with increasing rates of K, but the decrease observed with muriate source was more profound compared to the sulphate source. In Norchip, the specific gravity at 0 K_2O was 1.077, at 300 lbs/a K_2O as sulfate was 1.073 and at 300 lbs/a K_2O as muriate was 1.070. In MS700-83, the specific gravity at 0 K_2O was 1.076, at 300 lbs/a K_2O as sulfate it was 1.074 and at 300 lbs/a K_2O as muriate, 1.068. There was a significant increase in the uptake of K in the petioles in K treated plots compared to untreated. No significant yield increases were obtained due to higher K applications. Potassium source or rate did not significantly effect the chip color.

Post harvest evaluations in Norchip (Table 3) indicated that K rate or source produced no significant differences in after cooking darkening and susceptibility to blackspot. Similar results were obtained with MS700-83 (Table 4). Although a slightly higher tendency for after cooking darkening with the sulfate source was observed on the first boiling date (December 20), this effect was not evident at the second boiling date (January 4).

Based on this study, it appears that using more potassium than the recommendations from a soil test may lead to decreases in specific gravity. With 270 lbs K in the soil before the test, further additions of K resulted in a decrease in specific gravity with no yield response. Most of the K applied to potatoes in Michigan is in the form of muriate. This study confirms the previously reported view that excess chloride could interfere with the efficiency of the plant photosynthetic system. A potential exists to increase dry matter by using an alternative K source such as sulfate if the increase in cost can be justified. This study will be repeated in 1989.

Table 1. Effects of Potassium Rate and Source on Yield and Quality of Norchip — Montcalm Research Farm — 1988 (139 days).

	Yield (cwt/a)		Percent Size Distribution							Percent Petiole	
Source/K_2O	U.S. No. 1	Total	U.S. No. 1	<2"	2-3¼"	>3¼"	Pick Outs	Specific Gravity	Chip Color	N	K
KCl/200	417	520	80	6	68	12	14	1.072d	62	3.60	9.3a
K_2SO_4/300	408	498	82	7	72	10	11	1.073cd	58	3.51	9.7a
KCl/100	400	473	85	7	74	11	8	1.073cd	65	3.46	9.2a
Check	392	464	84	7	73	11	9	1.077a	63	3.79	7.6b
K_2SO_4/100	384	489	79	7	64	15	14	1.075b	60	3.66	9.0a
K_2SO_4/200	376	460	82	6	69	13	12	1.074bc	60	3.40	9.6a
KCl/300	337	433	78	7	62	16	15	1.070e	62	3.31	9.7a
AVERAGE	388	477	81	7	69	12	12	1.073	62	3.53	9.2
Check vs. K											
Check	392	464	84	7	73	11	9	1.077a	63	3.79	7.6b
+K	387	479	81	7	68	13	12	1.073b	61	3.49	9.4a
Check vs. K Source											
Check	392	464	84	7	73	11	9	1.077a	63	3.79	7.6b
KCL	385	475	81	7	68	13	12	1.072c	63	3.46	9.4a
K_2SO_4	389	482	81	6	69	12	12	1.075b	59	3.52	9.4a
Check vs. K Amount											
Check	392	464	84	7	63	11	9	1.077a	63	3.79	7.6b
K (100)	392	481	81	7	69	13	11	1.074b	63	3.56	9.1a
K (200)	397	490	81	6	70	11	13	1.073bc	61	3.50	9.5a
K (300)	373	466	80	7	67	13	12	1.072c	60	3.41	9.7a

le 2. Effects of Potassium Rate and Source on Yield and Quality of MS700-83 — Montcalm Research Farm — 1988 (139 days).

	Yield (cwt/a)		Percent Size Distribution							Percent Petiole	
rce/K_2O	U.S. No. 1	Total	U.S. No. 1	<2"	2-3¼"	>3¼"	Pick Outs	Specific Gravity	Chip Color	N	K
/100	514	564	91	8	76	15	1	1.073b	59	3.16	10.9b
O_4/200	496	547	91	8	74	17	1	1.074b	56	3.30	11.4ab
ck	491	530	92	6	74	18	2	1.076a	59	3.38	9.1c
O_4/100	485	537	90	9	77	13	1	1.076a	56	3.37	10.8b
O_4/300	485	533	91	7	73	18	2	1.074b	55	3.32	11.6ab
/300	474	514	92	7	78	14	1	1.068d	59	3.10	12.2a
/200	435	478	91	7	75	16	2	1.070c	60	3.14	11.9ab
AVERAGE	482	529	91					1.073	58	3.25	11.1
ck vs. K											
Check	491	530	92	6	74	18	2	1.076a	59	3.38	9.1b
+K	482	528	91	8	76	16	1	1.072b	58	3.23	11.5a
ck vs. K Source											
Check	491	530	92	6	74	18	2	1.076a	59	3.38	9.1b
KCL	474	518	91	7	76	15	1	1.070b	59	3.13	11.7a
K_2SO_4	488	539	91	8	75	16	1	1.075a	56	3.33	11.3a
ck vs. K Amount											
Check	491	530	92	6	74	18	2	1.076a	59	3.38	9.1b
K (100)	499	550	91	9	77	14	1	1.075ab	58	3.27	10.9a
K (200)	465	512	91	8	75	17	2	1.072bc	58	3.22	11.7a
K (300)	479	523	92	7	75	16	2	1.071c	57	3.21	11.9a

Table 3. Post Harvest Evaluations — Norchip.

Source/K_2O	After Cooking Darkening[y] 12/20/88	Percent Blackspot Check	Percent Blackspot Bruised[z]
Check	1	10	15
KCl/100	1	5	50
KCl/200	1	10	15
KCl/300	1	5	15
K_2SO_4/100	1	10	40
K_2SO_4/200	1	10	35
K_2SO_4/300	1	0	10

[y]Rating based on a scale of 1-5; 1 = no darkening, 5 = severe darkening (black) 1 hour after boiling.

[z]Tubers removed from 40°F storage and bruised artificially with 10 revolutions in a wooden drum and evaluated after 48 hours.

Table 4. Post Harvest Evaluations — MS700-83.

Source/K_2O	After Cooking Darkening[y] 12/20/88	After Cooking Darkening[y] 1/4/89	Percent Blackspot Check	Percent Blackspot Bruised[z]
Check	1.3	1.5	0	10
KCl/100	1.0	1.5	5	25
KCl/200	1.3	1.0	0	5
KCl/300	1.2	1.5	5	10
K_2SO_4/100	1.7	1.0	5	5
K_2SO_4/200	1.7	1.0	5	5
K_2SO_4/300	2.2	1.5	0	15

[y]Rating based on a scale of 1-5; 1 = no darkening, 5 = severe darkening (black) 1 hour after boiling.

[z]Tubers removed from 40°F storage and bruised artificially with 10 revolutions in a wooden drum and evaluated after 48 hours.

Funding MPIC

NITROGEN MANAGEMENT STRATEGIES FOR RUSSET BURBANK POTATOES

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Introduction

Nitrate contamination of groundwater from non-point sources has developed into a serious and well publicized environmental issue. The present potato production system is quite susceptible to nitrate leaching because potatoes are a shallow rooted crop grown mainly on coarse-textured soils under irrigation. The relatively high economic value of the crop has historically led to an excessive use of fertilizer nitrogen (N) and irrigation water, which further contributes to the nitrate leaching potential of the potato production system. There is a need to develop N management strategies for potatoes that will improve their N use efficiency and reduce their nitrate leaching potential. The primary objective of this study was to evaluate several N management strategies for their ability to reduce residual N in the soil profile after harvest (thereby reducing nitrate leaching potential) without reducing crop quality or yield.

Procedure

This study was initiated in 1986 at the Montcalm Research farm on a Montcalm-McBride sandy loam soil. A three year rotation sequence of potatoes-rye-corn-rye was established. The experimental design selected for this study was a randomized complete block with four replications. Six N management practices (combinations of N rates and application times) were used as treatments for this investigation. Russet Burbank was the potato cultivar used. Ammonium sulfate, $(NH_4)_2SO_4$, was the fertilizer N source applied to the crop. ^{15}N depleted ammonium sulfate was applied on approximately 50 percent of each plot to determine fertilizer N uptake and N use efficiency. Soil samples were taken to a depth of four feet four times during the growing season in the potato experiment. The soil samples were analyzed for nitrate and ammonium so that N movement could be followed through the profile during the growing season. Suction lysimeters were installed in treatment five at a depth of three feet to monitor N levels in the soil water under this high N treatment.

In 1988, corn was grown in the 1987 potato area at location 1 without the addition of any fertilizer or irrigation water, to determine the crop's ability to remove any residual N left in the soil from the previous potato crop.

In 1988, potato studies were conducted at the Montcalm Research farm (location 1) and on a producer's field (location 2).

1988 Results

The potato yield data for locations 1 and 2 are shown in Tables 1 and 2, respectively. For location 1, total yield and large tuber yields were influenced by the N management treatments. From this data it appears that 120-180 lb of N applied by the end of tuber set (late June) was sufficient for optimum yields. No beneficial effects were observed by splitting the N applications in 1988. The tuber yields at location 2 were much higher than at location 1, but no significant treatment effects were observed due to the large variability in yields within each treatment. Potato tuber quality, as indicated by specific gravity, was not significantly affected by the N treatments at either location.

The percent N in petiole samples taken throughout the growing season and percent N in whole plant and tubers at physiological maturity and harvest are presented in Tables 3 and 4 for location 1, and Tables 5 and 6 for location 2. Percent N increased with increasing N fertilization rates in all plant samples except the first petiole sample. Tissue N in the petioles reached their maximum concentrations at the third sample date (2 weeks after the onset of flowering). The percent N in the tops and tubers at physiological maturity and tubers at harvest was maximized with 120-180 lb of N. The effects of split applications were inconsistent.

Data for the percent N derived from the N fertilizer in the plant tissue samples mentioned above are shown in Tables 7 and 8 for location 1, and Tables 9 and 10 for location 2. The percent N derived from the fertilizer increased in all samples with increased N fertilization rates. At location 1, maximum percent uptake of N from the fertilizer occurred with 180 lb N. There did not appear to be any benefits from the split N applications at location 1. The data for location 2 indicate that 120-180 lb N yielded the maximum fertilizer N concentrations in the plant tissue. Maximum N in the plant derived from fertilizer was approximately 40 percent, and no benefits of split N applications were observed.

Soil data for the 4 sample dates are presented graphically in Figures 1 through 4 for location 1, and Figures 5 through 8 for location 2. No significant differences were observed between treatments at either location. As expected, there were differences in N concentration with depth at both locations. For location 1, the preplant soil samples showed approximately 5 ppm potassium chloride (KCl) extractable N throughout the profile. A dramatic increase in N concentration, up to 20-30 ppm, was observed for the surface sample at tuber initiation, but below 1.5 feet, the soil was still near the 5ppm N level. By mid-season, the surface sample had decreased to approximately 15-20 ppm, but the N levels in the lower depths were approximately 10 ppm N. The soil sample taken after harvest showed that the soil N concentrations in the lower depths were near their preplant levels. Data for location 2 show approximately 10-15 ppm N in the surface and 5-10 ppm N in the lower part of the profile for the preplant soil sample. A large increase in N, up to near 30 ppm, in the upper profile was again apparent at the second sample date, with the lower depths having N levels slightly above the N levels for the spring sample. The mid-season soil sample showed a decrease in surface N levels to 10-15 ppm N, but there was no apparent increase in the N levels at the lower depths. The fall sample was very similar to the fall sample at location 1. The N concentrations were at or below those of the spring sample.

Summary data showing the N in the profile at each date are presented graphically in Tables 9 and 10 for locations 1 and 2, respectively.

The N concentration data for soil water samples collected with suction lysimeters installed at a depth of three feet are located in Table 11. The N concentrations for location 1 were fairly constant at 3-5 ppm N from June through August and then nearly tripled to 13.5 ppm N in September. Nitrogen concentration values for location 2 were much higher from June through August. The average N concentrations for June, July, and August were 42, 31, and 17 ppm. By September the N levels were down to 14 ppm, the same as location 1.

The grain yield of corn grown without irrigation water or fertilizer (data not presented) on the 1987 potato site were not significantly influenced by the N management practice for the 1987 potato experiment, and averaged 81 bushels per acre at 15.5 percent moisture.

Conclusions

From the results of the 1988 investigation, we conclude that 120-180 lb N was sufficient for optimum yields of Russet Burbank potatoes. There did not appear to be any significant beneficial effects of splitting the applications unless some N was applied after the end of tuber set as it seems that N applied before the end of tuber set was taken up more readily by the plant. The soil data indicated that leaching of N below the root zone of the crop was limited in 1988 due to the drought. The large discrepancy in soil water N concentrations between the two locations is not apparent at this time but may partially explain the large yield differences between the two locations. The corn yield data show the N supplying capacity of the soil itself to be approximately 100-120 lb N per acre. The extreme heat and drought experienced during the 1988 growing season must be taken into consideration when analyzing this yield data and the soil N leaching potentials of the different N management treatments.

Table 1. The effect of N rate and application time on yield of Russet Burbank potatoes. Location 1.

----N fertilization rate----					--------------Yield---------------						
					------Tuber size distribution-----						
-N application date-				Total	Off	Under	4-10	Over	U.S.	Total	Specific
5-12	6-21	7-06	7-18	N	type	4 oz.	oz.	10 oz.	no.1	yield	gravity
------lb N per acre-------					----------cwt per acre-----------						--g/cc--
--	--	--	--	0	54a	54a	167a	1 b	168a	276 c	1.068a
60	--	--	--	60	60a	62a	186a	4ab	190a	311ab	1.070a
120	--	--	--	120	62a	57a	185a	5a	190a	309ab	1.070a
60	60	--	--	120	62a	59a	195a	6a	201a	322a	1.067a
60	60	60	--	180	60a	63a	178a	7a	185a	308ab	1.067a
30	30	30	30	120	58a	61a	173a	5a	178a	297 b	1.068a

Values followed by the same letter were not statistically different at the .05 level of probability.

Table 2. The effect of N rate and application time on yield of Russet Burbank potatoes. Location 2.

----N fertilization rate---					-------------Yield----------------						
					-----Tuber size distribution------						
-N application date-				Total	Off	Under	4-10	Over	U.S.	Total	Specific
5-17	6-24	7-06	7-18	N	type	4 oz.	oz.	10 oz.	no.1	yield	gravity
-----lb N per acre-------					----------cwt per acre------------						--g/cc--
--	--	--	--	0	120a	44a	219a	5a	224a	388a	1.072a
60	--	--	--	60	141a	39a	213a	14a	227a	407a	1.075a
120	--	--	--	120	177a	48a	214a	13a	227a	452a	1.076a
60	60	--	--	120	162a	51a	237a	25a	262a	476a	1.077a
60	60	60	--	180	167a	40a	219a	31a	250a	457a	1.073a
30	30	30	30	120	196a	49a	221a	40a	261a	506a	1.073a

Values followed by the same letter were not statistically different at the .05 level of probability.

Table 3. The effect of N rate and application time on petiole N concentration of Russet Burbank potatoes. Location 1.

N fertilization rate: N application date 5-12	6-21	7-06	7-18	Total N	Tissue N concentration, Petiole sample date: 6-21	7-05	7-18	8-01
lb N per acre					% N			
--	--	--	--	0	3.36a	2.99 c	3.75 d	2.33 c
60	--	--	--	60	3.45a	3.65 b	4.67 c	2.56 c
120	--	--	--	120	3.60a	4.28a	5.30 b	3.25 b
60	60	--	--	120	3.63a	4.54a	5.54ab	3.41 b
60	60	60	--	180	3.58a	4.26a	5.75a	3.91a
30	30	30	30	120	3.47a	3.77 b	5.11 b	3.41 b

Values followed by the same letter were not statistically different at the .05 level of probability.

Table 4. The effect of N rate and application time on N concentration in above ground biomass and tubers of Russet Burbank potatoes. Location 1.

N fertilization rate: N application date 5-12	6-21	7-06	7-18	Total N	% N in plant tissue, Sample growth stage: Physiological maturity Tops	Physiological maturity Tubers	Harvest Tubers
lb N per acre					% N		
--	--	--	--	0	1.33 d	1.53a	1.49 b
60	--	--	--	60	1.95 c	1.62a	1.50 b
120	--	--	--	120	2.94a	1.61a	1.56 b
60	60	--	--	120	2.81ab	1.67a	1.76a
60	60	60	--	180	3.00a	1.59a	1.71a
30	30	30	30	120	2.51 b	1.67a	1.72a

Values followed by the same letter were not statistically significant at the .05 level of probability.

Table 5. The effect of N rate and application time on petiole N concentration of Russet Burbank potatoes. Location 2.

----N fertilization rate----					------Tissue N concentration------			
-N application date-				Total	-------Petiole sample date--------			
5-17	6-24	7-06	7-18	N	6-21	7-05	7-18	8-01
------lb N per acre-------					---------------% N-----------------			
--	--	--	--	0	3.39a	3.33 b	2.89 d	2.18 d
60	--	--	--	60	3.57a	4.70a	4.08 c	2.79 c
120	--	--	--	120	3.29a	4.82a	4.59 b	3.21 c
60	60	--	--	120	3.21a	4.71a	5.10 b	3.39 bc
60	60	60	--	180	3.35a	4.71a	5.80a	4.19a
30	30	30	30	120	3.41a	4.47a	5.08 b	3.88ab

Values followed by the same letter were not statistically different at the .05 level of probability.

Table 6. The effect of N rate and application time on N concentration in above ground biomass and tubers of Russet Burbank potatoes. Location 2.

---N fertilization rate---					--------% N in plant tissue--------		
					---------Sample growth stage-------		
-N application date-				Total	-Physiological maturity-		-Harvest-
5-12	6-21	7-06	7-18	N	Tops	Tubers	Tubers
-----lb N per acre------					--------------% N--------------		
--	--	--	--	0	1.66 b	1.03 c	1.23 b
60	--	--	--	60	1.88 b	1.19 bc	1.45ab
120	--	--	--	120	2.29a	1.29ab	1.58a
60	60	--	--	120	2.39a	1.26ab	1.50ab
60	60	60	--	180	2.64a	1.47a	1.53a
30	30	30	30	120	2.40a	1.28ab	1.49ab

Values followed by the same letter were not statistically significant at the .05 level of probability.

Table 7. The effect of N rate and application time on percent N from fertilizer in petioles of Russet Burbank potatoes. Location 1.

---N fertilization rate---					---------% N from fertilizer---------			
-N application date-				Total	-------Petiole sample date--------			
5-12	6-21	7-06	7-18	N	6-21	7-05	7-18	8-01
-----lb N per acre------					----------------% N------------------			
--	--	--	--	0	0.0 e	0.0 f	0.0 e	0.0 c
60	--	--	--	60	20.9 b	28.4 d	23.0 d	22.2 b
120	--	--	--	120	30.2a	41.9a	36.9ab	38.2a
60	60	--	--	120	18.0 bc	37.7 b	35.7 bc	34.0a
60	60	60	--	180	15.3 c	30.3 c	41.5a	38.9a
30	30	30	30	120	8.9 d	27.1 e	31.9 c	39.4a

Values followed by the same letter were not statistically different at the .05 level of probability.

Table 8. The effect of N rate and application time on percent N from fertilizer in above ground biomass and tubers of Russet Burbank potatoes. Location 1.

---N fertilization rate---					--------% N from fertilizer--------		
					---------Sample growth stage-------		
-N application date-				Total	-Physiological maturity-		-Harvest-
5-12	6-21	7-06	7-18	N	Tops	Tubers	Tubers
-----lb N per acre------					--------------% N---------------		
--	--	--	--	0	0.0 b	0.0 d	0.0 d
60	--	--	--	60	38.5a	21.4 c	20.3 c
120	--	--	--	120	33.0a	38.3a	33.6 b
60	60	--	--	120	29.8a	32.4 b	29.7 b
60	60	60	--	180	38.2a	39.9a	40.0a
30	30	30	30	120	32.1a	33.2 b	31.2 b

Values followed by the same letter were not statistically different at the .05 level of probability.

Table 9. The effect of N rate and application time on percent N from fertilizer in petioles of Russet Burbank potatoes. Location 2.

---N fertilization rate---					--------% N from fertilizer--------			
-N application date-				Total	-------Petiole sample date-------			
5-17	6-24	7-06	7-18	N	6-21	7-05	7-18	8-01
-----lb N per acre------					---------------% N---------------			
--	--	--	--	0	0.0 d	0.0 d	0.0 d	0.0 c
60	--	--	--	60	10.0ab	34.9 bc	29.4 c	22.2 b
120	--	--	--	120	14.9a	45.6a	43.9 b	38.2a
60	60	--	--	120	11.0a	41.5ab	45.4 b	34.0a
60	60	60	--	180	3.5 cd	34.6 bc	53.0a	38.9a
30	30	30	30	120	5.8 bc	28.0 c	40.6 b	39.4a

Values followed by the same letter were not statistically different at the .05 level of probability.

Table 10. The effect of N rate and application time on percent N from fertilizer in above ground biomass and tubers of Russet Burbank potatoes. Location 2.

---N fertilization rate---					---------% N from fertilizer---------		
					---------Sample growth stage-------		
-N application date-				Total	-Physiological maturity-		-Harvest-
5-17	6-24	7-06	7-18	N	Tops	Tubers	Tubers
-----lb N per acre------					--------------% N--------------		
--	--	--	--	0	0.0 d	0.0 e	0.0 c
60	--	--	--	60	19.8 c	21.4 d	20.3 b
120	--	--	--	120	39.7a	38.3 b	33.6a
60	60	--	--	120	31.0 b	32.4 c	29.7a
60	60	60	--	180	44.4a	39.9a	40.0a
30	30	30	30	120	33.9 b	33.2 c	31.2a

Values followed by the same letter were not statistically different at the .05 level of probability.

Table 11. Average N concentrations in suction lysimeters placed three feet below soil surface.

Location	Month				
	June	July	August	September	October
	ppm				
1	4.52	4.21	5.32	13.53	---
2	42.05	31.38	16.92	14.12	13.34

Funding MPIC

Nitrogen Management Strategies for Potatoes to Maximize Profit and Minimize Nitrate Leaching: 1988 Results

J. T. Ritchie and B. S. Johnson

Conventional management practices for potato production in Michigan cause high levels of nitrate leaching that are potentially damaging to the environment. A field experiment was established to investigate the possibility for minimizing nitrate leaching while maintaining adequate tuber yields and quality. Results were used to test the nitrate leaching submodel of SUBSTOR, a model of potato growth and development.

Methods

The experiment was conducted on McBride sandy loam at the Montcalm Potato Research Farm. Two plots, 10 rows X 50 ft. in length, were planted to Russet Burbank potatoes on May 11. The row spacing and seed spacing within the row were 34 in. and 12 in., respectively. A treatment consisting of "conventional" nitrogen (N) and irrigation management was compared with a "research" treatment involving reduced N inputs and a modified irrigation schedule. For the conventional treatment fertilizer N was applied at a rate of 200 lb/A including 75 lb/A at planting (500 lb/A of 15-10-15). The input of N was lower for the research treatment as the total amount of N applied was 110 lb/A for the season and 28 lb/A at planting (558 lb/A of 5-10-15). Irrigation amounts for the treatments also differed as the conventional treatment received 9.8 in. of water during the season compared to 6.4 in. for the research treatment. Figure 1 illustrates the timing of the irrigation and fertilizer N applications. Pesticides were applied as needed by the farm manager.

Permanently installed drainage lysimeters, one in each plot, were used to monitor soil water drainage and nitrate (NO_3) leaching on a weekly basis. The lysimeters (4 ft. X 68 in. X 6 ft. deep) intercept water at the 7 ft. soil depth. Drainage depths and NO_3 leaching were determined by measuring the volume of water collected and sampling it each time for NO_3 and selected pesticides. Soil samples for ammonium (NH_4) and NO_3 measurement were collected prior to planting, at midseason, and after fall harvest. Samples were obtained from four locations in each plot and at five depths at each location. Sampling depths were at 6 in. increments to a depth of 1 ft., and at 1-ft. increments to a depth of 4 ft. A complete set of weather data including solar radiation, maximum and minimum temperatures, and rainfall was collected daily and used as inputs to the computer simulation model, SUBSTOR. Tuber and haulm growth rates were determined by periodically measuring tuber and haulm dry weights. Potatoes were harvested on October 6 from 80 ft. of row (227 ft^2). Tuber quality was evaluated by measuring the size distribution, and the specific gravity and dry matter content of tubers in the 4 to 10 oz. size class.

Results

Tuber yields and quality are given in Table 1. Yields were the same for both treatments averaging 244 cwt/A which is slightly greater than the state average potato production of 230 cwt/A in 1988 (Michigan Agricultural Statistics, 1988). Tuber size distribution, specific gravity, and dry matter content were also about the same for each treatment. No. 1's accounted for only 45 percent of the total tuber yield in this experiment. The specific gravity of 1.067 was lower than normal for Russet Burbank suggesting that heat and water stress may have been factors during 1988.

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

	Yield (cwt/A)		Percent Size Distribution						
Treatment	Total	No.1	No.1	<4oz	4-10oz	>10oz	Pick outs	Spec. Grav.	%Dry Matter
Conventional	245	112	46	20	42	4	35	1.068	17.6
Research	242	103	43	22	41	3	35	1.065	18.0

Important objectives of this experiment were to monitor soil water drainage and NO_3 leaching and to use these results to test the NO_3 leaching model of SUBSTOR. Because NO_3 leaching is dominated by soil water drainage, rain and irrigation strongly influence the extent of NO_3 leaching that occurs. Figure 2 illustrates cumulative rainfall and precipitation (rainfall + irrigation) at the site during 1988. Rainfall was below normal during 1988 as only 10 in. of rain fell from the beginning of the measurement period (April 13) until vine kill (September 10). Nearly the same amount of rainfall (8 in.) occurred during the next 50-d period ending on November 1.

Figure 3 compares measured drainage depths for the two treatments with simulated values produced by SUBSTOR. Due to the dry conditions in 1988 drainage was negligible during the majority of the growing season. About 3.4 in. of water drained through the lysimeter soil in the research treatment during the period April 11 to October 26. Soil water drainage was slightly greater for the conventional treatment as 4.1 in. of drainage water was collected during the same period. For both treatments, most of the drainage occurred after vine kill when plant water uptake ceased and rainfall increased dramatically at the Montcalm Research Farm. Figure 3 also shows that simulated soil water drainage compared favorably with the observed values, especially during the unseasonably wet post harvest period.

Measured and simulated loss of NO_3 from the lysimeter soil is reported in Figure 4. Cumulative NO_3 leaching was 73 lb/A for the conventional treatment compared to 58 lb/A for the research treatment. These results are consistent with the observation that the two treatments produced the same yields with much different fertilizer N inputs. Assuming a relative constant tuber N content of 0.33 lb/cwt, about 80 lb/A of N (244 cwt/A X 0.33 lb/cwt) should have been removed from the soil for both treatments. The difference between the amount of fertilizer N applied and the amount of N assimilated in tubers is equal to 120 lb/A (200 - 80) for the conventional treatment but only 30 lb/A (110 - 80) for the research treatment. This calculation and the observation that a significant amount of drainage occurred after the last measurement date reported in Figure 4 suggest that the diverse management strategies used in this experiment may cause substantial differences in NO_3 leaching when considered on an annual basis.

The simulated curves in Figure 4 represent the extent of NO_3 leaching for each treatment as calculated by SUBSTOR. Although the model simulated the drainage process quite well (Figure 3), estimates of NO_3 loss were lower than the measured values for each treatment. This discrepancy can be accounted for as follows. Because plants extract water and nutrients (e.g., nitrogen) from the soil, the computer simulation model must calculate the growth and development of potatoes reasonably well in order to simulate the soil water and nitrogen dynamics accurately. Figure 5 compares measured haulm weights with simulated values and Figure 6 compares measured and simulated dry matter accumulation in the tubers. These Figures demonstrate that SUBSTOR underestimated haulm growth rate for the research treatment (Figure 5) but overestimated tuber growth for both treatments (Figure 6). Thus, N uptake as calculated by the model was also overestimated leaving little residual soil NO_3 for leaching.

Summary and Future Objectives

Treatments consisting of "conventional" and "research" N and irrigation management produced the same yields. Cumulative NO_3 leaching under conventional management exceeded NO_3 leaching under the research approach by about 15 lb/A as of the last measurement date in 1988. Differences between these two management strategies may prove to be much greater when considered on an annual basis. This possibility will be evaluated by analyzing the soil samples collected during 1988 for NO_3 and NH_4 and by monitoring drainage and NO_3 leaching from the lysimeters on a year-around basis. SUBSTOR simulated soil water drainage accurately but underestimated NO_3 leaching during 1988. The model needs to be refined to more accurately calculate growth and development of the potato for all possible combinations of weather and management variables used as inputs. Those aspects of soil N dynamics affected by plants, especially N uptake, can then be calculated in a manner that will allow SUBSTOR to be used estimate NO_3 with the desired level of confidence.

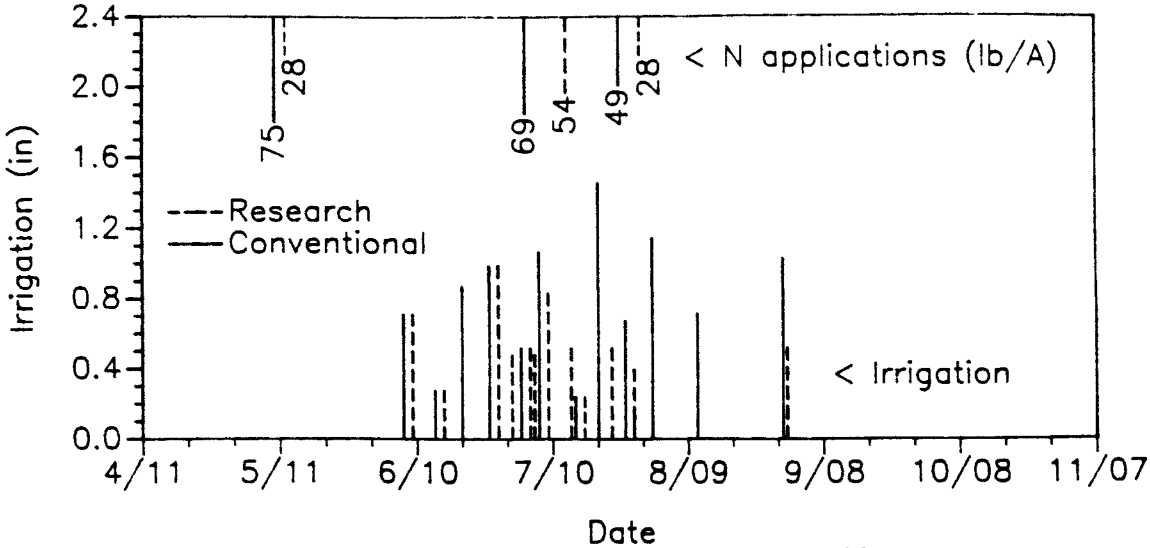

Fig 1. Timing of irrigation and fertilizer N applications in 1988.

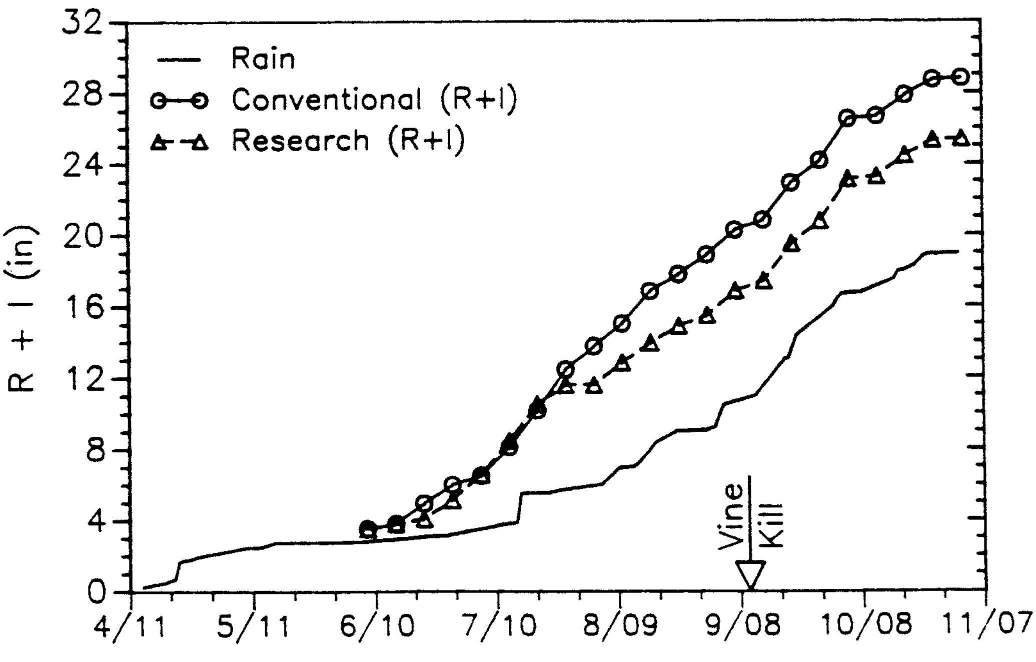

Fig 2. Cumulative rainfall (R) and irrigation (I) during 1988 for the two treatments.

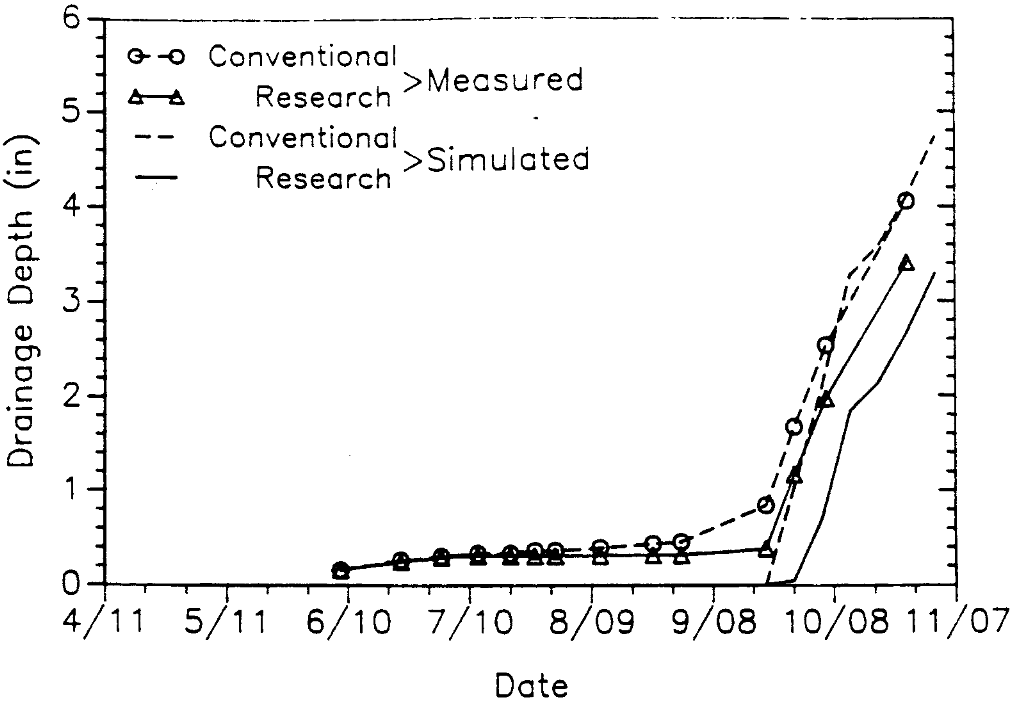

Fig 3. Measured and simulated soil water drainage during 1988.

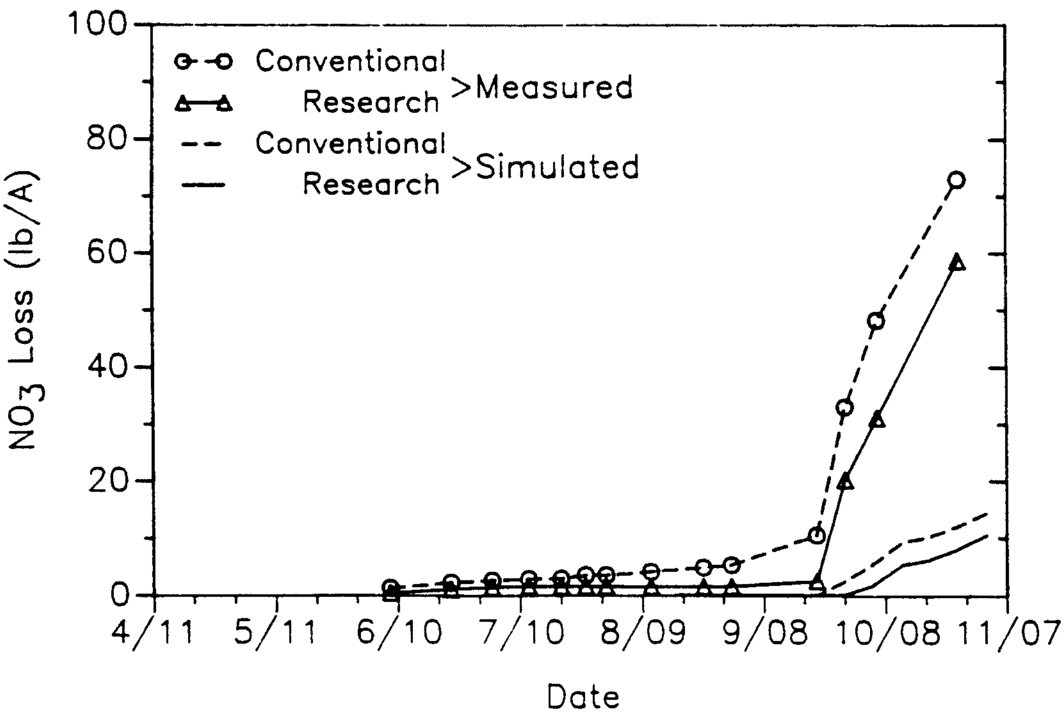

Fig 4. Measured and simulated nitrate leaching during 1988.

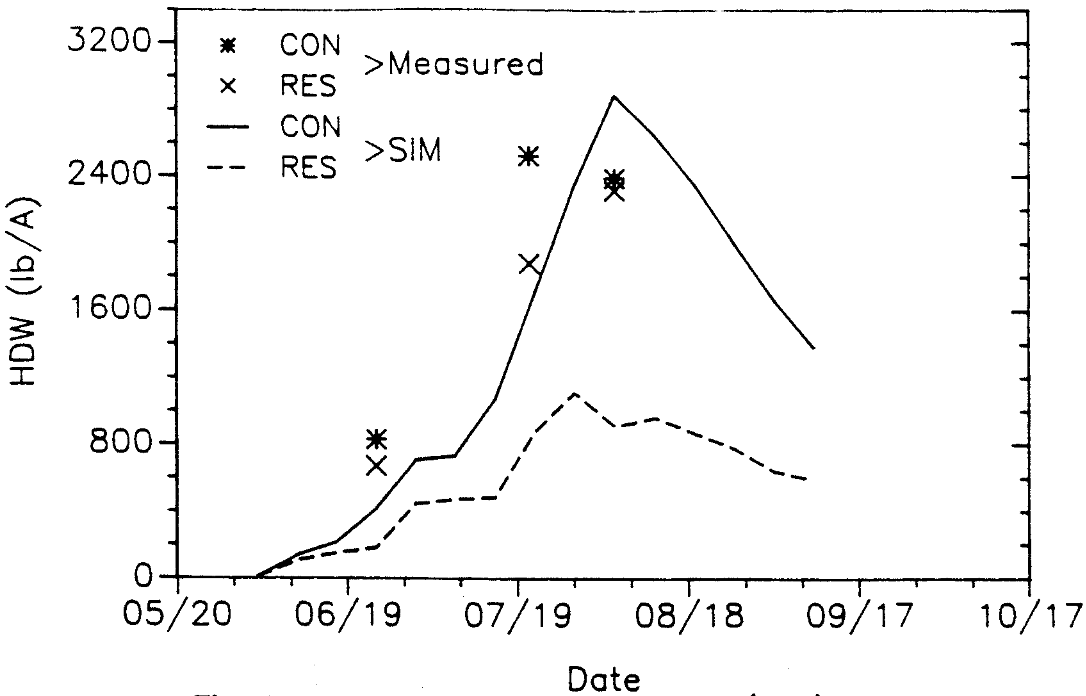

Fig 5. Measured and simulated (SIM) haulm dry weight (HDW) accumulation during 1988.

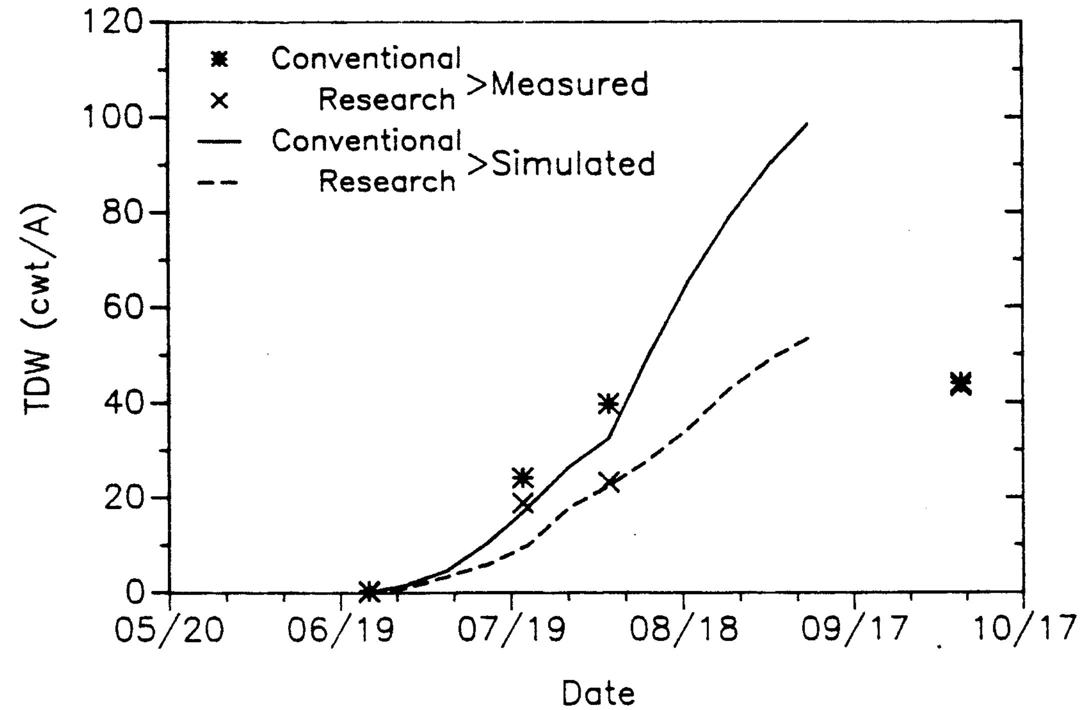

Fig 6. Measured and simulated tuber dry weight (TDW) accumulation during 1988.

Funding MPIC

EFFECT OF INCREASING NITROGEN RATES UPON PRODUCTION OF RUSSET BURBANK POTATOES IN THE UPPER PENINSULA 1988

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This study was continued from previous years to evaluate the effect of nitrogen rates upon the production of russet burbank potato production in the Upper Peninsula. Questions have risen on how much nitrogen credit should be given for the previous legume crop plowed down for green manure and nitrogen. This study was designed to evaluate the effect of increasing nitrogen rates on russet burbank potatoes where alfalfa was the previous crop.

PROCEDURE

The study was established on the Paul VanDamme Farm in Marquette County on an Onaway sandy loam. The previous crop was alfalfa which was plowed down in the late summer and rye was planted as a winter cover. The treatments were arranged in a randomized complete block experimental design with 4 replications. 1000 pounds of 6-24-24 per acre were applied in the row at planting. Nitrogen consisted of 0, 60, and 120 pounds nitrogen per acre, applied sidedressed as urea, and 60 pounds nitrogen applied sidedressed as sulfur coated urea. This gave a total of 60, 120 and 180 pounds nitrogen per acre for the treatments. Petioles were sampled for nitrogen content on July 26 and September 2. The soil was sampled prior to fertilizer application for total nitrogen content at six inch increments down to 2 feet. The soils were sampled for total nitrogen content for each treatment at harvest to a depth of two feet. The potatoes were planted on May 6 and harvested on September 24. All pesticide applications and cultivations were completed by the farm cooperator as the plots were established within a commercial field of potatoes.

RESULTS

Yields, percent size distribution, and specific gravity is given in Table 1. There were no significant differences in yield, size distribution or specific gravity due to nitrogen treatment. Petiole nitrogen analysis revealed no significant differences between treatment means on the first sampling date, however, on the second sampling date the 120 pound nitrogen rate of sulfur coated urea and 180 pound nitrogen rate of urea were significantly higher in nitrogen content than the 60 and 120 pound per acre nitrogen urea treatments (Table 2). As observed in previous studies specific gravity decreased slightly with increasing nitrogen rates, however, the differences were not significantly different at the five percent confidence level. Soil analysis has not been completed at this time but will be reported at a later date.

RESULTS continued

In summary, potato yields and size distribution were not significantly affected by the nitrogen rate or source in this study. Sulfur coated urea at 120 and urea at 180 pounds per acre significantly increased nitrogen content of potato petioles at the second sampling date on September 2.

Table 1. Influence of nitrogen upon yield, size distribution and specific gravity on Russet Burbank potatoes grown in the Upper Peninsula.

Treatment		Yield cwt/A		Percent Size Distribution					
N-Source	Rate lbs/A	Total	No. 1	No. 1	Under 4 oz.	4 to 10 Oz.	Over 10 oz.	Pick Outs	Specific Gravity
Urea	60	443	320	72	7	38	34	21	1.072
Urea	120	462	317	69	5	36	33	26	1.071
SC Urea	120	433	288	66	7	38	29	26	1.067
Urea	180	426	293	68	5	35	34	26	1.069
Mean		441	305	69	5.5	37	33	25	1.070

Table 2. Influence of nitrogen fertilizer upon petiole nitrogen content in Russet Burbank potatoes grown in the Upper Peninsula.

Treatment		Petiole Nitrogen Content (%) Sampling Date	
N-Source	Rate lbs/A	7-26-88	9-2-88
Urea	60	3.9 a*	2.2 b
Urea	120	3.8 a	2.6 ab
SC Urea	120	3.8 a	3.0 a
Urea	180	4.0 a	3.0 a

*Means followed by the same letter are not significantly different.

Funding MPIC

LEGUME NITROGEN CONTRIBUTIONS IN LEGUME-POTATO ROTATIONS

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Nitrogen-fixing legumes have been used in rotational cropping systems for many years. In addition to significant nitrogen (N) contributions to subsequent non-legume crops, the inclusion of legumes in crop rotations may disrupt weed and pest cycles, and improve soil aeration and structure. A renewed interest in legume-based crop rotations has emerged because farmers want to reduce their purchased inputs, diversify their cropping systems, and decrease the potential for environmental contamination from fertilizers and pesticides.

Potato production in Michigan typically involves intensive management with high fertilizer (mainly N) and pesticide inputs. Legume-based potato rotations are becoming an attractive alternative to continuous potato or corn-potato cropping sequences. The objectives of this study were:

1. To determine the N contribution from forage legumes to a subsequent potato crop.

2. To evaluate the effect of seeding year legume management (no harvest vs. 2 or 3 harvests) on the N contribution to potatoes.

3. To monitor populations of root-lesion nematode (RLN) and Verticillium fungus, the causative agents of Potato Early Die disease, through the course of the 2-year rotations.

4. To evaluate the effect of rotation crop and N fertilizer rate on tuber quality of the subsequent potato crop.

Materials and Methods

Two-year crop rotations were established in 1987 at the Montcalm Research Farm (MRF) and at the Kellogg Biological Station (KBS). The rotation crops and legume harvest schemes in the first year were: 'Saranac' alfalfa, 0 and 3 harvests; 'Mammoth' red clover, 0 and 3 harvests; 'Viking' birdsfoot trefoil, 0 and 2 harvests; 'Nitro' alfalfa, 3 harvests (KBS only); sweetclover, 0 harvests (MRF only); spring seeded hairy vetch, 0 harvests; potatoes + fall seeded hairy vetch; corn; potatoes ('Shepody' at MRF, 'Atlantic' at KBS); and fallow.

Experimental plots were 24 by 50 feet. In 1987, legumes, potatoes and corn were planted on April 20, May 4 and May 9, respectively. Potato and corn plots were split into subplots and fertilized with 0, 67, 133 and 200 lb N/acre, as ammonium nitrate. Legumes were harvested for hay on July 9, August 10 and October 30. Potatoes and corn (for grain) were harvested on September 4 and October 10, respectively. Plots were sampled for RLN and Verticillium on April 20, July 23 and November 5. Legumes were sampled for dry matter and N production on October 20.

In 1988, potatoes (variety 'Shepody') were planted on all plots on May 9 and May 15 at KBS and MRF, respectively. Plots were split into subplots and fertilized with 0, 67, 133 and 200 lb N/a (67 lb N/a at planting, remainder applied just prior to hilling). Potato vine samples were taken August 20 for biomass and N yield measurements. Tubers were harvested from the center two rows of each four-row plot on September 30 and November 15 at MRF and KBS, respectively. Tubers from Montcalm were evaluated for common scab, Rhizoctonia, growth cracks and specific gravity.

Results

All results discussed here are from the Montcalm location only. All forage legumes were successfully established in 1987. End-of-season N yields (1987) and plowdown N (May, 1988; includes spring regrowth) are shown in Table 1. The N yield at plowdown, which represents the maximum potential N contribution from the legumes, ranged from 65 to 281 lb N/a. However, only 20-30% of the total N in legumes generally becomes available to the first subsequent crop. Although multiple hay harvests of red clover in the seeding year (3.5 tons/acre) did reduce plowdown N yield somewhat, harvesting alfalfa 3 times in the seeding year (3.8 tons/acre) actually increased total N available for plowdown. This was due to the increased root mass when alfalfa was harvested.

Population trends of the root lesion nematode during the 1987 growing season (Table 2) confirm the concerns of some potato growers in Michigan. Nematode populations reached high levels in roots and soil in the legume plots when compared to nematode populations in corn and fallow plots (potato plots were treated with a nematicide; data not shown). Alfalfa, birdsfoot trefoil and red clover supported similar populations. Hairy vetch (an annual crop) supported even higher populations (563 nematodes/g root) than the other legumes, while sweetclover had much lower populations (53 nematodes/g root). Without chemical control for nematodes, the potential increase in nematode population may become an important criterion in the selection of an appropriate legume species for short-term rotations.

Yields of 'A' grade (Table 3) and total tubers (Table 4) demonstrate a substantial benefit from legumes to a subsequent potato crop. Potatoes following legumes either did not respond to N fertilizer applications (as measured by 'A' grade tuber yield) or decreased as N fertilizer rate increased. This suggests that either potato growth became indeterminate due to excess nitrogen, or that some other factor (e.g., moisture) limited growth. Non-legume treatments either showed linear increases in yield with increased N rates (e.g., following potato or fallow) or a quadratic response, increasing to a maximum yield, then decreasing, following corn.

In all rotation sequences except fallow-potato, N inputs (plowdown N + fertilizer N) reached a level where additional fertilizer N either failed to increase tuber yield or decreased tuber yield. For example, tuber yield following alfalfa hay decreased if any fertilizer N was applied, while tuber yield following corn decreased when N fertilizer rate was increased from 134 to 200 lb N/a. The fertilizer response of potatoes following different rotation crops suggests that greater attention should be given to N applications in rotational cropping systems for maximum economic benefit.

One method of estimating legume N contributions is the Fertilizer Replacement Value (FRV), defined as the amount of inorganic N required to produce a yield identical to that following a legume without N fertilizer. FRV values at Montcalm in 1988 ranged from 12 (birdsfoot trefoil, 0 harvests) to 115 lb N/a (alfalfa, 3 harvests). For all rotations systems, FRV's were much lower than plowdown N yield, indicating that N released from slowly-decomposing legume residues is not entirely available to the first subsequent potato crop. Comparison of plowdown N yield and FRV's also indicates that the benefit of legume-based rotations is not solely a function of the amount of N incorporated. For example, sweetclover contained the highest amount of N at plowdown (281 lb N/a), but the FRV of 62 lb N/a was exceeded by three other legumes. The most likely reason for this relationship is variation in the chemical composition of the incorporated legume material, with more mature, highly lignified residue decomposing to a lesser extent in the soil.

Repeated harvests of alfalfa and red clover in 1987 did not decrease the benefit (as measured by the FRV) to the 1988 potato crop. Previously, it was thought that to obtain the maximum benefit from legumes, particularly in short rotation cycles, the legume should not be harvested. This research shows that the producer need not sacrifice income (from hay) to obtain significant N contributions from forage legumes.

Although the yield benefits from legume-based rotations are important, tuber quality of the subsequent potato crop must also be considered. In 1988, rotation crop and N fertilizer rate had a significant effect on tuber quality (Table 5). The severity of common scab (measured as the percent of tuber area with scab) increased following red clover hay and potatoes (10.38 and 10.40%, respectively), while tubers following sweetclover exhibited 5.80% coverage of scab. The scab severity is due primarily to previous rotation crop, as severity decreased with increased N fertilizer applications.

The incidence of Rhizoctonia or black scurf (as percent of plots showing symptoms) was similar for all rotations crops except hairy vetch. Rhizoctonia was observed in 63% of plots following hairy vetch, compared to 6 to 25% for other rotation crops.

Cracking of tubers is generally caused by factors which promote the rapid growth of the tubers, such as excess N. In this study, the percent of tubers with cracks increased following sweetclover and hairy vetch (9.38 and 11.88%, respectively), both of which contained over 200 lb N/a at plowdown. The increase in cracking as fertilizer N rate increased confirms that N influences the severity of cracking, regardless of N source.

Conclusions

Nitrogen-fixing legumes can significantly reduce the requirements for N fertilizer in potato production. Furthermore, such N contributions can be realized even if the legume is harvested repeatedly during short (2-year) rotation cycles, thereby generating income for the producer. At current N fertilizer price levels, it is doubtful that producers can justify the implementation of legume-based rotations solely for potential N contributions.

Definitive evidence is lacking on whether the decomposition of high N-yielding legumes (e.g., sweetclover) can lead to high nitrate levels in soil. This is particularly important on sandy soils, used for potato production, that are more prone to nitrate leaching problems. The selection of legume species based on populations of soil-borne pathogens and their impact on tuber quality also deserves additional attention.

Table 1. Nitrogen yield of legumes at Montcalm Research Farm in Fall, 1987 and at plowdown in Spring, 1988.

Crop/Harvests	Fall, Shoot	1987 Root	Spring 1988 Shoot[1]	Total at Plowdown[2]
	lb N/a			
Alfalfa/0	66	71	55	192
Alfalfa/3	57	106	55	218
Red Clover/0	137	65	51	263
Red Clover/3	59	95	51	205
Birdsfoot Trefoil/0	29	22	17	68
Birdsfoot Trefoil/2	26	26	13	65
Sweetclover/0	116	106	59	281
Hairy Vetch/0	185	19	--[3]	204

[1]Spring regrowth in 1988.

[2]Plowdown N equals 1987 N yield plus 1988 spring regrowth.

[3]Hairy vetch did not survive winter.

Table 2. Soil and root populations of root-lesion nematode (RLN) from July 23, 1987, sampling at Montcalm Research Farm[1].

Crop/Harvests	RLN/100cc Soil	RLN/1.0g Root
Alfalfa/0	23.5	119.5
Alfalfa/3	15.0	409.5
Red Clover/0	80.5	248.8
Red Clover/3	34.0	244.0
Birdsfoot Trefoil/0	17.8	251.0
Birdsfoot Trefoil/2	15.8	385.4
Sweetclover/0	7.8	52.5
Hairy Vetch/0	74.5	563.5
Corn	7.3	19.8
Fallow	35.5	109.5
LSD (P = 0.05)	50	350

[1] Potato plots treated with nematicide; data not shown.

Table 3. Yield of 'A' grade tubers (4-10 oz.) and fertilizer replacement values (FRV) for 1987 rotation treatments and 1988 nitrogen fertilizer rates at the Montcalm Research Farm.

	N Fertilizer Applied (lb/acre)				
1987 Crop/Harvests	0	67	133	200	FRV[1]
	----------cwt 'A' tubers/a----------				(lb N/a)
Alfalfa/0	233	241	222	234	68
Alfalfa/3	252	232	225	211	115
Red Clover/0	219	242	235	201	35
Red Clover/3	226	224	235	233	52
Birdsfoot Trefoil/0	209	230	239	194	12
Birdsfoot Trefoil/2	210	220	201	218	13
Sweetclover/0	231	234	204	189	62
Hairy Vetch/0	238	244	210	202	84
Potato	227	261	257	251	57
Fallow	220	244	259	254	37
Corn	203	230	263	217	--
LSD (P = 0.05)					
Between Crops	19				
Between N Rates	11				

[1]Nitrogen response curve of corn-potato system used as control. FRV equal to inorganic nitrogen input required to produce yield identical to that following legume with no fertilizer applied.

Table 4. Total tuber yield in 1988 for 1987 rotation crops and 1988 N fertilizer rates at the Montcalm Research Farm.

	N Fertilizer Applied (lb/acre)			
1987 Crop/Harvests	0	67	133	200
	cwt/a			
Alfalfa/0	282	310	302	317
Alfalfa/3	305	285	292	306
Red Clover/0	269	306	321	290
Red Clover/3	274	277	320	316
Birdsfoot Trefoil/0	247	282	309	275
Birdsfoot Trefoil/2	262	272	275	287
Sweetclover/0	301	328	313	301
Hairy Vetch/0	287	335	282	301
Potato	271	325	317	349
Fallow	269	316	338	360
Corn	236	291	335	312
LSD (P = 0.05)				
Between Crops	22			
Between N Rates	13			

Table 5. Effect of rotation crop and N fertilizer rate on the incidence of common scab (SCAB), Rhizoctonia (RHIZ) and growth cracks (CRACK), and on the specific gravity (GRAV) of tubers at Montcalm Research Farm in 1988.

Crop/Harvests	SCAB[1]	RHIZ[2]	CRACK[3]	GRAV
Alfalfa/0	6.23	6.3	5.00	1.080
Alfalfa/3	7.23	8.3	6.25	1.083
Red Clover/0	7.69	18.8	6.88	1.083
Red Clover/3	10.38	18.8	3.13	1.083
Birdsfoot Trefoil/0	7.98	8.3	6.25	1.081
Birdsfoot Trefoil/2	7.16	25.0	1.25	1.082
Sweetclover	5.80	12.5	9.38	1.082
Hairy Vetch	7.63	62.5	11.88	1.081
Potato + Vetch	9.53	25.0	3.75	1.082
Corn	8.20	18.8	4.38	1.082
Potato	10.40	18.8	5.00	1.082
Fallow	7.00	18.8	6.88	1.085
LSD (P = 0.05)	2.4	24.8	5.24	NS
<u>N Fertilizer Rate (lb/a)</u>				
0	10.61	10.4	2.71	1.080
67	8.43	13.2	3.75	1.082
134	7.35	35.4	6.25	1.083
200	5.81	21.5	10.63	1.083
LSD (P = 0.05)	1.4	14.3	3.03	NS

[1]Percent of tuber area with scab; 10 tubers/plot evaluated.

[2]Percent of plots with Rhizoctonia present.

[3]Percent of tubers with cracks; 10 tubers/plot evaluated.

Funding Federal Grant

INFLUENCE OF IRRIGATION, NITROGEN AND CALCIUM LEVELS ON SPECIFIC GRAVITY AND INTERNAL DEFECTS OF ATLANTIC AND RUSSET BURBANK POTATOES

G.H. Silva, R.W. Chase and R.B. Kitchen

Specific gravity and internal defects are two important quality parameters, particularly for processing potatoes. These attributes are largely influenced by environmental and management factors and show wide variations among growers, management levels and seasons. A study was initiated in 1987 to investigate the role of irrigation, nitrogen and supplementary calcium applications in relation to specific gravity and internal defects. This study was continued in 1988 with some modifications based on the 1987 data.

A split-split plot design with four replications was used to evaluate 2 irrigation levels (irrigation scheduling and over-irrigation), 2 nitrogen levels (125/200 for Atlantic and 150/225 for Russet Burbank) and 4 calcium treatments [750 gypsum/a applied: (a) at planting, (b) at hilling, (c) split at planting and hilling and (d) untreated]. Supplementary calcium applications were specifically directed towards controlling internal brown spot (IBS). Most of the literature points towards localized calcium deficiency in the tubers as a cause of this disorder. In light of its relative immobility within the plant, calcium was placed in close proximity to the developing tubers. The 2 varieties, Atlantic and Russet Burbank, were planted in 2 separate experiments.

A drip irrigation system was installed to facilitate application of different quantities of water to the treatments. Irrigation scheduling treatment was based on Michigan State University irrigation scheduling system. Accordingly, this treatment received 10.7 inches of irrigation water during the season. Over-irrigation treatment was applied one month before harvest and received an excess of 5.5 inches during this period in 7 separate irrigations.

The trial was planted on May 5. The previous crop was alfalfa. Initial soil test showed a pH of 5.6 and a calcium level of 730 lbs/a. The fertilizers applied were 500 lbs/a 5-10-15 with planter and a topdressing of 25 lbs N/a for Atlantic and 50 lbs N/a for Russet Burbank as urea on June 15. For those treatments receiving the higher level of N, a second topdressing of 75 lbs N/a was applied on July 6.

Petiole samples for nutrient analysis were taken on August 4. The trial was harvested on September 27. Following harvest, 100 tubers (25 from each replication) were cut to determine the frequency of IBS and hollow heart. Tuber peel samples were taken from each treatment and sent to MSU Soil Testing Laboratory for analysis.

The results obtained with Atlantic and Russet Burbank are summarized in Tables 1 and 2, respectively. In both varieties, over-irrigation resulted in decreased specific gravity and slightly higher yields. Higher nitrogen level decreased specific gravity of Russet Burbank more than in Atlantic. Although both varieties showed significantly higher N uptake at higher N application rate, there was no response in tuber yield. There was a tendency for hollow heart to increase with over-irrigation. In Atlantic, calcium treated plots showed a decrease in the occurrence of IBS from 21% for untreated to an average of 14% for the 3 calcium treatments. Calcium applied to the furrow at planting had the lowest frequency (11%) of IBS. In Russet Burbank, the occurrence of IBS in all treatments was very low compared to Atlantic.

It is evident that gypsum applications reduced the frequency but did not eliminate the problem of IBS nor did it reduce IBS to an acceptable level. More soluble forms of calcium need to be tested to enhance the uptake of calcium by the tubers. Preliminary investigations of Dr. R. Hammerschmidt have shown that increased calcium levels in the tuber is helpful in resisting some of the storage diseases such as soft rot. In both varieties, calcium treatments produced no significant effects on tuber yield, specific gravity and hollow heart.

Post harvest evaluations showed that irrigation, nitrogen and calcium treatments produced no significant effects on chip color of Atlantic (Table 1). Furthermore, these treatments did not appear to have significant effects on after cooking darkening and blackspot susceptibility (Tables 3 and 4).

The results from irrigation treatments point towards an important management strategy to improve specific gravity. Traditionally, Michigan receives excess rainfall late in the growing season and it is not uncommon for this rain to occur on a day when the crop was irrigated. It appears that holding back on irrigation, particularly in the last month before harvest would lead to increased dry matter and reduced hollow heart. Equally important is to avoid a delay of harvest in order to avoid periods of excess water after the crop has matured and the vines are dead.

Table 1. Dry Matter and Internal Defects — Atlantic — Montcalm Research Farm — 1988 (141 days).

Treatment		Tuber Yield U.S. No. 1	Tuber Yield Total	Specific Gravity	Chip Color	Percent Petiole N	Percent HH	Percent IBS
Irrigation scheduling		431	486	1.086a	64	2.9	8	13
Over-irrigation		466	521	1.081b	62	2.8	14	17
Nitrogen:	125 lbs	445	498	1.084	61	2.5b	10	14
	200 lbs	453	509	1.083	63	3.2a	12	16
Calcium:	(1) 0	451	507	1.084	60	2.9	13	21a
	(2) 750(P)	458	513	1.084	64	2.7	10	11b
	(3) 750(P+H)	443	496	1.083	63	2.9	11	13b
	(4) 750(H)	446	499	1.083	63	2.8	10	16ab

Table 2. Dry Matter and Internal Defects — Russet Burbank — Montcalm Research Farm — 1988 (142 days).

Treatment		Tuber Yield (cwt/a) U.S. No. 1	Tuber Yield (cwt/a) Total	Specific Gravity	Percent Petiole N	Percent HH	Percent IBS
Irrigation Scheduling		280	399	1.078a	3.7	3	5
Over-irrigation		301	432	1.073b	3.6	6	7
Nitrogen:	150 lbs	284	403	1.077a	3.4b	3	6
	225 lbs	297	432	1.074b	3.8a	6	7
Calcium:	(1) 0	292	417	1.077	3.6	6	9
	(2) 750(P)	293	428	1.075	3.6	4	5
	(3) 750(P+H)	286	421	1.075	3.7	3	5
	(4) 750(H)	275	417	1.076	3.5	6	6

Table 3. Post Harvest Evaluations — Atlantic.

Treatment		After Cooking Darkening[y]	Percent Blackspot Check	Percent Blackspot Bruised[z]
Irrigation scheduling		1.3	4	45
Over-irrigation		1.2	3	49
Nitrogen:	125 lbs	1.2	3	53
	220 lbs	1.3	4	48
Calcium:	(1) 0	1.1	5	48
	(2) 750(P)	1.4	3	52
	(3) 750(P+H)	1.1	4	52
	(4) 750(H)	1.4	3	50

[y]Rating based on a scale of 1-5; 1 = no darkening, 5 = severe darkening (black) 1 hour after boiling.

[z]Tubers removed from 40°F storage and bruised artificially with 10 revolutions in a wooden drum and evaluated after 48 hours.

Table 4. Post Harvest Evaluations — Russet Burbank.

Treatment		After Cooking Darkening[y]	Percent Blackspot	
			Check	Bruised[z]
Irrigation scheduling		1	4	34
Over-irrigation		1	3	41
Nitrogen:	150 lbs	1	3	40
	225 lbs	1	4	35
Calcium:	(1) 0	1	4	38
	(2) 750(P)	1	1	31
	(3) 750(P+H)	1	4	44
	(4) 750(H)	1	5	36

[y]Rating based on a scale of 1-5; 1 = no darkening, 5 = severe darkening (black) 1 hour after boiling.

[z]Tubers removed from 40°F storage and bruised artificially with 10 revolutions in a wooden drum and evaluated after 48 hours.

Funding MPIC

CONTROL OF INTERNAL BROWN SPOT (HEAT NECROSIS) OF POTATOES

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Internal brown spot (IBS) presents a major problem in the production of high quaility potatoes. This problem is particulary evident with the variety Atlantic. Since Calcium deficiency and heat stress have been associated with this disorder, we have evaluated the influence of additional calcium and an antitranspirant treatment on the expression of IBS.

PROCEDURE

A location on the farm of W.J. Lennard and Sons, Smaria, was chosen for this study because of a history of IBS in this location. The variety Atlantic was used. Two planting dates were also used (April 15 and May 15). At each planting date plots were set out to receive the antitranspirant (AT) or no AT in combination with four calcium applications. At harvest, the tubers were scored for IBS. Since calcium has been showed to decrease soft rot expression, samples of tubers were also infected with *Erwinia carotovora* subsp. *carotovora* to determine if there were any changes in the expression of this disease.

RESULTS

Due to little obvious differences in plant growth, the tubers from both planting dates were analyzed as a single group. Application of Calcium did have a significant effect on reducing the amount of IBS. However, it should be pointed out that an acceptable level of control was not obtained (Table 1). The calcium treatments also reduced the severity of soft rot in the no AT plots. No effect was observed on the plots treated with the AT (Table 2).

Tuber Yield and Internal Defects in Potato Variety Atlantic
Monroe County, MI 1988

Treatment	Yield(cwt/a) US#1	Total	US#1	Sp.Gr.	IBS%	Chip Color
First Planting	275	339	81	1.073	29	55 b
Second Planting	284	353	80	1.074	31	60 a
Anti-transpirant (-)	270	332	81	1.073	31	58
Antitranspirant (+)	289	359	81	1.074	29	57
Calcium 1(0 lbs)	296	360	82	1.074	40 a	58
2(750lbs,P)	278	343	81	1.073	24 c	59
3(750lbs,H)	276	344	80	1.074	31 b	57
4(750lbs,P+H)	269	336	80	1.074	26 bc	57

Higher percentage of chip defects in the first planting due to severe stem end browning. Frequency of hollow heart being very low, data was not analysed.

TABLE 2

EFFECT OF CALCIUM AND ANTITRANSPIRANT
ON SOFT ROT DEVELOPMENT

TREATMENT	WEIGHT OF DECAYED TISSUE (G) NO AT*	AT*
0 Ca	1.79	1.87
750 lb Ca (P)	1.45	1.93
750 lb Ca (H)	1.60	1.83
SPLIT APPLICATION	1.46	1.89

*AT=Antitranspirant

 Funding: Federal Grant

Annual Report

Improved Production and Utilization Technology for Michigan Potatoes
USDA Project ORD. NO. 38543 and 40818

Soil Management through Tillage for Improved Quality and Yield of Potatoes and Erosion Control

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Crop and Soil Sciences Department

Quality improvement of potatoes represents the major objective of potato growers in Michigan. A major factor affecting potato quality is the physical condition of the soil in the zone of rooting and tuber development. Wind and water erosion are serious problems on the sandy and organic soils which dominate potato acreage in Michigan. Conventional practices for potato production in Michigan use cover crops for overwinter protection of soil and limit plowing to spring primary tillage followed directly by planting to avoid excessive tillage and soil structure degradation. Michigan farmers, therefore, are well aware of the potential limitations of poor soil physical conditions and soil erosion. However, the potential for serious problems related to poor soil physical condition and erosion remain. Excessive traffic, often with heavy axle loads repeated over several years, has created compact soil conditions below the depth of normal tillage and degraded soil structure in the tillage zone. Soil erosion potential in Michigan from wind and water is highest during the period from tillage and planting to hilling or canopy closure when the soil is bare and unprotected.

Tillage systems, designed to fracture soil in a zone in-the-row (zone tillage) and leave the interrow undisturbed with a cover of standing rye as protection against wind and water erosion, were evaluated in field experiments in 1985, 1986 and 1987. In 1985, zone tillage treatments tended to improve yield and quality of Russet Burbank potatoes although the 35.4 cwt/acre increase was not significant. In 1986, zone tillage treatments significantly increased yield of Russet Burbank potatoes up to 77.7 cwt/acre with a corresponding trend for improved quality. Related experiments in 1986 showed significant differences in size distribution due to seed spacing. In 1987, the effects of zone tillage on soil properties, plant development in Russet Burbanks and varietal response to zone tillage were evaluated in more detail. When plant spacing in the row was 14 inches, there were no differences in yield due to tillage. When planted at 10 inch plant spacing, Russet Burbank yields were significantly increased in both zone tillage treatments, 446.0 cwt/acre and 425.0 cwt/acre for the paratill and Bush Hog Ro-till treatments, respectively, versus 376 cwt/acre for the conventional tillage treatment. Specific gravity was low, averaged 1.067 g/cm3 overall, and was not affected by tillage. It would appear that zone tillage is beneficial to Russet Burbanks only when sufficient plant populations are present in the field. Root length density was significantly increased in the zone tillage treatments and increased just above the plow layer in the conventional tillage treatment. Yields of the Shepody variety were not affected by tillage although the paratill treatment resulted in significantly lower No. 1 potatoes than either the conventional or Bush Hog treatments. Yields of two round white potato varieties, Onaway and Atlantic, were significantly lower in the paratill treatments than the Bush Hog or conventional tillage treatments. These results suggest that the zone tillage offers a significant advantage over conventional plow systems for improved yield and quality of potatoes, for erosion control, and improved trafficability. However, questions remain about varietal response to zone tillage and seed spacing, zone tillage effects on plant development of the Russet Burbank variety, and the impact of plant residues on early growth and development in Russet Burbank potatoes.

The objectives of this research for 1988 were (1) to develop and evaluate alternatives to existing tillage systems on sandy soils that improve tuber quality and yield and reduce the potential for wind and water erosion, (2) evaluate zone tillage and seed spacing effects on yield and quality of selected potato varieties, (3) to determine the impact of the physical environment induced by tillage on potato growth and development, and (4) to determine the effects of crop residues on potato growth and development.

Methods/Procedures:

Three field experiments were conducted in 1988 as described below:

A. Effect of zone tillage on growth and development of irrigated Russet Burbank potatoes.

Russet Burbank potatoes were grown under five tillage treatments replicated five times in a randomized complete block design. Tillage treatments included: conventional tillage (spring disk and moldboard plowing followed immediately by planting) and zone tillage, accomplished with the use of a Bush Hog Ro-till in the fall or spring and a paratill in the spring either pre- or post-planting (note, only final yields taken on this treatment). Russet Burbank potatoes were hand planted at 10 inch seed spacings. Whole plant samples were taken for above and below-ground biomass (including root weight and tuber numbers, weight and size distribution) determination from ten feet-of-row three times during the growing season at approximately three week intervals beginning at early bloom stage. Petiole samples were taken for nutrient analysis at early bloom stage. Roots were measured bi-weekly to weekly using mini-rhizotron techniques on .4 inch increments to a depth of three feet and mechanically three times during the growing season at 3 inch intervals to 17 inch depth. Tuber yield and quality were measured by harvesting 2 rows 50 feet long from each plot and determining size distribution, specific gravity and incidence of hollow heart. Soil moisture was monitored throughout the growing season using tensiometers and a neutron probe and used to schedule irrigation.

B. Effect of zone tillage on growth and development of non-irrigated Russet Burbank potatoes.

Russet Burbank potatoes were grown under conventional and zone tillage (paratill) in five replications in a randomized complete block design. Russet Burbank potatoes were hand planted at 10 and 14 inch seed spacings. Whole plant samples were taken for above and below-ground biomass (including root weight and tuber numbers, weight and size distribution) determination from ten feet-of-row three times during the growing season at approximately three week intervals beginning at early bloom stage. Petiole samples were taken for nutrient analysis at early bloom stage. Roots were measured mechanically once during the growing season at 3 inch intervals to 17.75 inch depth. Tuber yield and quality were measured by harvesting 20 feet long from each plot and determining size distribution and specific gravity.

C. Zone tillage and seeding rate effects on selected potato varieties.

Four varieties - Russet Burbank, Shepody, Atlantic, and Onaway - were grown in conventional tillage and two zone tillage (spring Bush Hog and paratill) tillage treatments at plant spacings of 10 and 14 inch for the Russet Burbank and Shepody varieties and at 6 and 8 inch for the Onaway and Atlantic varieties. All cultural practices such as fertilizer and pest control followed recommended practices for each variety. At harvest, size distribution, specific gravity and incidence of hollow heart were measured on potatoes harvested from two 50 foot rows for each tillage, variety, and seeding rate treatment.

Results:

Zone Tillage Effects on Soil Physical Properties

The effects of zone tillage on the physical properties of the McBride soil are shown in Figures 1 and 2. Intact soil cores for bulk density determination were sampled directly in the potato row which corresponds to the zone of maximum loosening in the zone tillage treatments. Figure 1 plots a histogram of bulk density for each tillage treatment for the 0-3, 4-7 and 9-12 inch depths. Bulk density was not significantly affected by tillage system in the 0-3 and 4-7 inch soil depths. However, bulk density was reduced by zone tillage in the 9-12 inch depth from 1.78 g/cm3 to approximately 1.6 g/cm3. All zone tillage treatments were significantly different from conventinoal tillage at this depth. The fall paratill treatment (PTF) was significantly lower in bulk density than the spring paratill (PTS) and the spring Bush Hog (BHS) treatments indicating improved loosening of soil when zone tillage is done in the fall under drier moisture conditions. Penetration resistance of the soil was measured using a cone pentrometer at the same time soil cores were sampled for bulk density determination. Cone index is plotted versus soil depth from the top of the potato hill for each tillage treatment in Figure 2. The higher the cone index the higher the soil strength. The major point of the graph in Figure 2 is the dramatic increase in soil strength (higher cone index) between 25 and 30 cm (10 - 12 inches) depth below the hill. By 30 cm (12 inches), the soil strength was too hard for the penetrometer to penetrate the soil. This soil then has a compact layer at approximately 10 to 12 inches characterized by high bulk density and high soil strength, both of which will limit root growth and penetration. The cone index below 30 cm (12 inches) in the zone tillage treatments is at reasonable levels for root growth indicating that zone tillage has at least temporarily removed the soil compaction problem in this soil.

Zone Tillage Effects on Potato Development and Yield

In the irrigated study, yields of Russet Burbank potatoes (Table 1) were significantly lower in conventional tillage (347.9 cwt/acre) than Bush Hog fall (361.3 cwt/acre), Bush Hog spring (374.6 cwt/acre), or paratill spring pre-plant (373.7 cwt/acre). Yields of paratill post-plant were significantly lower than all tillage treatments (331.8 cwt/acre) indicating tillage after planting may be detrimental to yield but this practice of post-tillage needs further evaluation. Specific gravities of Russet Burbanks was significantly higher in the Bush Hog spring (BHS) treatment than fall Bush Hog (BHF) and the conventional tillage (Conv) treatment. The whole plant biomass (Table 2) showed zone tillage treatments produced larger tubers than conventional tillage. Dry weight ratios of tubers to above-ground biomass were higher for the zone tillage treatments early in the season but lower than conventional tillage in the mid to late season. Root data for 1988 are being processed at this time.

In the non-irrigated study, record drought conditions resulted in plant stress and low tuber production in Russet Burbank potatoes during the major portion of the growing season. Potatoes produced in the non-irrigated plots were small, deformed and unmarketable. However, significant differences in growth and development were measured due to tillage and seed spacing. Conventionally tilled potatoes and those at the 14 in seed spacing were bigger and had more tubers at the plant sampling dates, being significantly different at the early and mid-season sampling dates only (Table 3). At harvest, zone tillage produced significantly fewer tubers but a higher yield than conventional tillage (Table 4). Plants at the lower seeding rate (14 inch seed spacing) were larger and produced more tubers at the three whole plant sampling dates. However, there were no significant differences in potato yield due to seed spacing.

Yield and quality of Russet Burbank, Shepody, Onaway, and Atlantic potatoes as affected by tillage and seed spacing are given in Tables 5, 6, 7, and 8 respectively. Yield differences in varieties due to tillage were found only in the Shepody variety where the yield of No 1 potatoes was reduced in the paratill treatment (PTS). This reduction was also observed in the Shepody variety in 1987. Specific gravities were also significantly higher in conventional tillage than zone tillage for the Shepody variety. This would indicate that zone tillage, in the form used in these studies, is not well suited to the production of Shepody potatoes.

Yield data for the Russet Burbank variety does not agree with results from experiment A and may be due to canopy effects of different varieties in adjacent plots. At harvest time, it did appear that plants in adjacent rows influenced yields. It seems clear from these data that variety trials with two rows are confounded by edge effects and do not allow for a rigorous assessment of tillage effects on yields. Plot size should be increased in the future so that each variety has guard rows bordering the two harvest rows.

Seeding rate increased yield and quality of the Onaway variety but had little effect on the other varieties. Specific gravity of Onaways was signficantly higher (1.071 versus 1.069 g/cm3) at the 6 inch seed spacing than the 8 inch seed spacing.

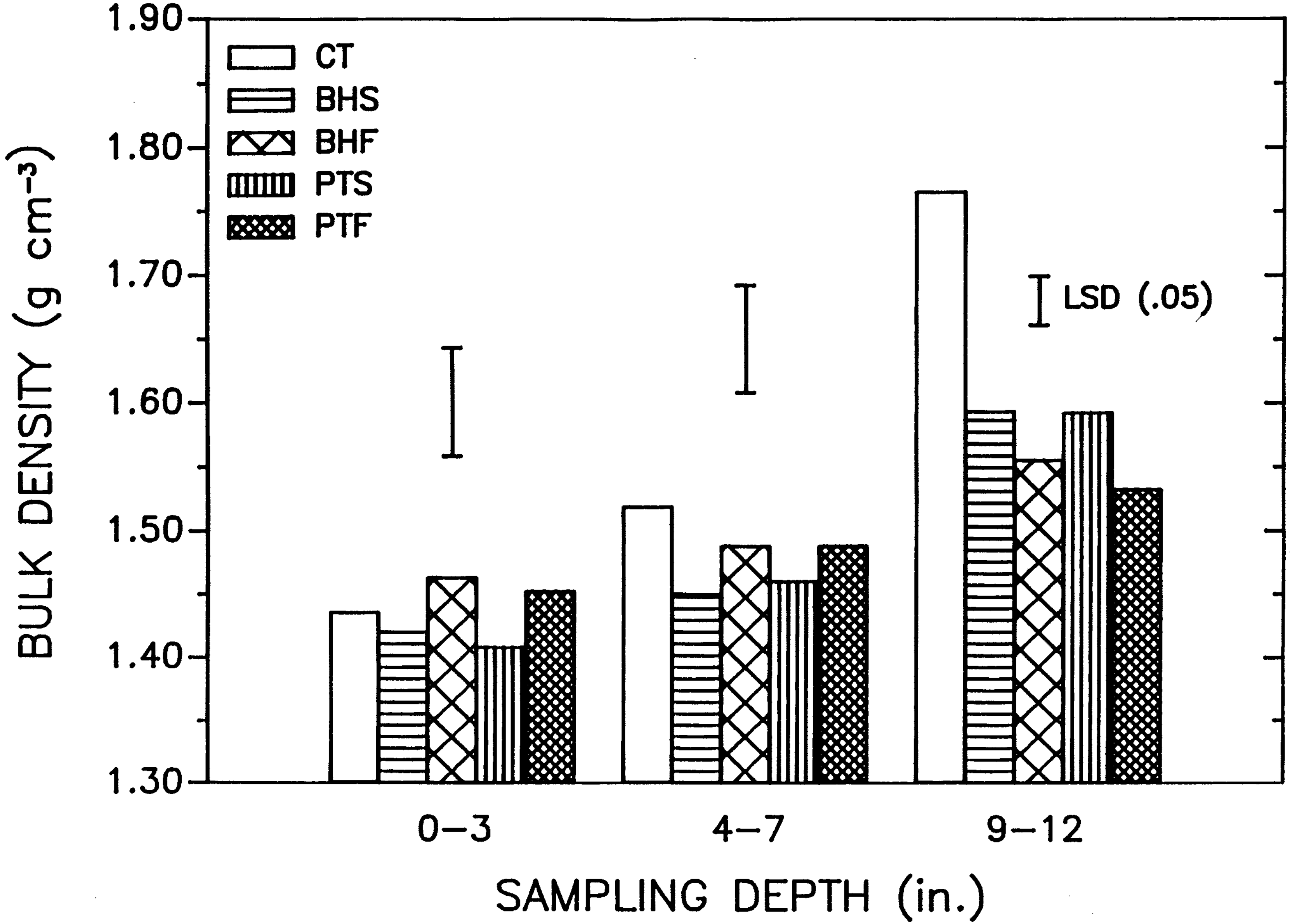

Figure 1. Effect of Zone Tillage on bulk density

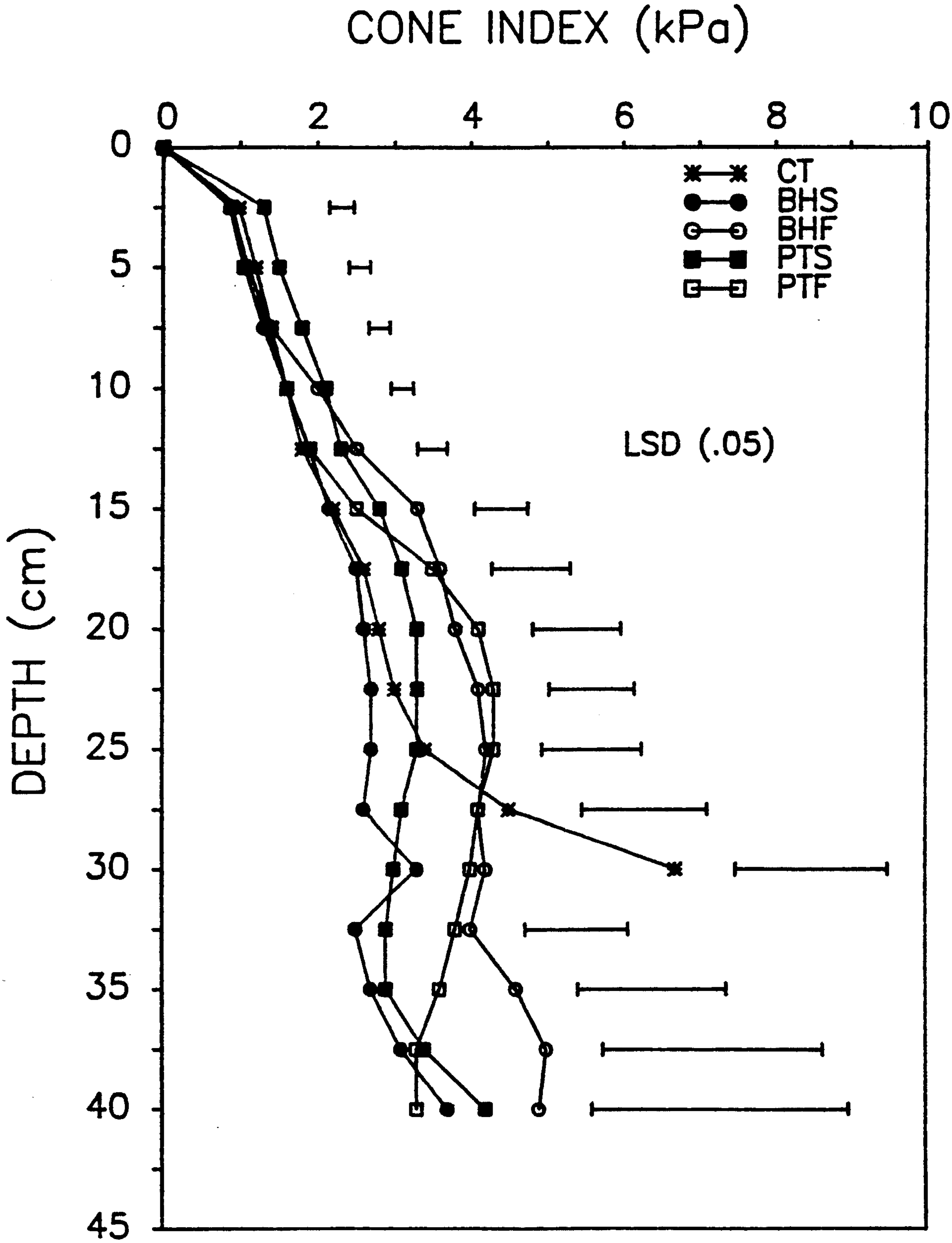

Figure 2. Penetration resistance (cone index, KPa) of a McBride sandy loam as affected by tillage.

Table 1. Yield and quality of Russet Burbank Potatoes as affected by tillage in 1988.

	Size Class				Pick Outs		
Tillage	<4 oz	4-6 oz	6-10 oz	>10 oz	<10 oz	>10 oz	Total
	cwt/acre						
Conv.	84.7a	113.3a	70.4a	12.5a	49.1a	16.9b	347.9bc
BHS	83.9a	104.4ab	84.7a	20.5a	56.2a	25.9ab	374.6a
BHF	75.8a	108.8a	73.1a	17.84a	61.5a	24.1ab	361.3ab
PTS	77.6a	101.7ab	84.7a	25.0a	50.0a	27.7ab	373.7a
PTP	72.3a	88.3b	62.4a	21.4a	58.0a	29.4a	330.9c

	Hollow Heart	Plant Population	Yield/ Plant	#1's	#1's	Specific Gravity
	#/10	plants/acre	lbs	cwt/acre	%	
Conv.	0.4a	18247ab	1.92c	197.1a	56.5a	1.066b
BHS	0.4a	18186ab	2.07ab	208.7a	55.5ab	1.069a
BHF	0.2a	18432a	1.96bc	199.8a	55.2ab	1.066b
PTS	0.4a	17848b	2.09a	210.5a	56.3a	1.067ab
PTP	0.0a	18125ab	1.83c	172.2b	51.8b	1.067ab

Table 2. Tuber wet weights and above ground biomass dry weights of Russet Burbank potatoes as affected by tillage at three sampling dates in 1988.

	Sampling Dates					
	7/6		7/25		8/19	
	Tubers	Above ground Biomass	Tubers	Above Ground Biomass	Tubers	Above Ground Biomass
	lbs/10 ft row					
Conv	8.3	1.4	16.8	1.7	23.3	1.2
BHF	7.6	1.5	14.1	1.5	24.4	1.4
BHS	6.5	1.2	15.5	1.9	24.6	1.30
PPS	6.3	1.2	15.0	1.7	24.4	1.4

Table 3. Dry tuber(T) and aboveground biomass per plant(A) of nonirrigated Russet Burbank potatoes as affected by tillage and seeding rates.

		Sampling Date						
		7/14		8/2		8/24		9/15
Tillage	Seeding Rate (in)	T	A	T	A	T	A	Harvest Tubers
		oz/plant						
CT	10	.648a	.809a	1.102a	1.232a	1.976a	0.972a	1.782a
	14	.875b	1.069b	1.166a	1.394b	2.592a	1.523b	2.494b
BHS	10	.648a	.582a	0.875a	1.069a	1.750a	0.907a	2.333a
	14	.809b	.680b	0.777a	1.458b	2.333a	1.491b	3.078b
LSD (.05) for tillage		NS	.270	.166	NS	NS	NS	.062

Table 4. Yield of non-irrigated Russet Burbank potatoes as affected by tillage and seeding rate.

Till	Seed Rate (in)	Seed Size (oz) <.07oz	.07-2.0oz	2.0-4oz	4-6oz	6-8oz	Total	Harvest Yield
		cwt/acre						
CT	10	2.7	49.1a	16.1a	4.5	0.0a	69.6a	106.0a
	14	1.8	41.9b	18.7a	5.3	1.8a	67.8a	102.0a
BHS	10	1.8	48.2a	23.2a	9.8	4.5b	85.6a	129.1a
	14	2.7	37.5	25.0	11.6	7.1b	81.2a	122.7a

Table 5. Yield and quality of Russet Burbank as affected by tillage and seeding rate.

Tillage	Seeding Rate in	<4	Size Class (oz) 4-6	6-10	>10	Pick outs <10	>10	Total
		cwt/acre						
Conv.	10	108.8	99.0	83.8	9.8	44.6	13.4	358.6
	14	71.4	88.3	91.0	14.3	50.8	20.5	335.4
BHS	10	72.3	87.4	74.0	8.9	68.7	12.5	324.7
	14	73.1	84.7	95.4	8.9	56.2	13.4	333.6
PTS	10	78.5	85.6	75.8	8.9	47.3	18.7	314.9
	14	62.4	77.6	83.0	11.6	49.0	24.9	309.5

Hollow Heart	Plant Population	Yield/ Plant	#1's	#1's	Specific Gravity
#/10	Plants/acre	lbs	cwt/acre	%	
0	17739	2.00	192.7	53.6	1.066
0	12877	2.60	192.7	57.5	1.066
0.3	17740	1.81	170.4	52.5	1.066
0.3	13032	2.60	110.0	57.0	1.065
0.3	18263	1.70	170.4	53.9	1.068
0.3	13078	2.40	173.0	55.6	1.064

Table 6. Yield and quality of Shepody potatoes as affected by tillage and seeding rate.

Tillage	Seeding Rate (in)	<4 oz	4-6oz	6-10oz	>10oz	Pick outs <10oz	Pick outs >10oz	Total
		----------	----------	----------	cwt/acre	----------	----------	----------
Conv.	10	33.9	62.4	94.6	77.6	55.3	28.5	351.4
	14	25.0	53.5	88.3	84.7	40.1	25.9	316.7
BHS	10	35.7	62.4	80.3	73.1	50.0	31.2	332.7
	14	29.4	62.4	80.3	75.6	45.5	32.1	326.5
PTS	10	26.8	57.1	86.5	52.6	52.1	28.5	307.7
	14	26.8	45.5	70.5	75.6	41.0	37.5	296.1

Hollow Heart	Plant Populations	Yield/ Plant	#1's	#1's	Specific Gravity
#/10	plants/acre	lbs	cwt/acre	%	
0.8	17740	2.01	234.6	66.4	1.072a
0.8	12893	2.51	226.6	71.5	1.073a
0.5	17970	1.90	215.9	65.0	1.069b
0	12970	2.51	218.5	67.0	1.071b
0.3	18355	1.70	196.2	63.6	1.069b
0.5	12816	2.29	190.9	64.0	1.071b

Table 7. Yield and quality of Onaway potatoes as affected by tillage and seeding rate.

Tillage	Seed Spacing in	Size Class (in) <2	2-3.3	>3.3	Pick outs <3.3	Pick outs >3.3	Total Yield
		cwt/acre					
Conv.	6	25.8	320.2	15.1	8.0	.9	369.3
	8	21.4	294.3	14.3	8.0	.9	339.0
BHS	6	25.8	306.8	14.3	8.0	.9	355.0
	8	25.8	296.1	20.5	9.8	.9	352.3
PTS	6	27.6	299.7	18.7	12.5	1.8	360.3
	8	22.3	278.3	24.1	24.1	.9	337.2

	Plant Population	Yield/ Plant	#1's	#1	Specific Gravity
	plants/acre	lbs	cwt/acre	%	
Conv.	29079	1.323	335.4	90.7	1.071a
	21617	1.610	308.6	91.1	1.069b
BHS	28817	1.191	321.1	90.3	1.070a
	20663	1.698	316.7	89.9	1.069b
PTS	28232	1.323	318.4	88.2	1.071a
	21048	1.610	302.4	89.9	1.069b

Table 8. Yield and quality of Atlantic potatoes as affected by tillage and seeding rate.

Tillage	Seed Spacing in	Size Class(in) <2	2-3.3	>3.3	Pick Outs <3.3	>3.3	Total
		cwt/acre					
Conv.	6	35.7	302.4	21.4	15.1	1.8	376.4
	8	31.2	304.2	25.9	11.6	.9	372.8
BHS	6	33.9	306.8	16.0	16.0	.9	372.8
	8	33.9	300.6	20.5	8.9	.9	364.8
PTS	6	30.3	303.8	20.5	18.7	.9	373.7
	8	26.8	291.7	25.9	22.3	2.7	369.3

	Hollow Heart	Plant Population	Yield/ Plant	#1	#1	Specific Gravity
	#/10	Plant/acre	lbs	cwt/acre	%	
Conv.	2.0	28817	1.301	323.8	86.0	1.084
	0.8	21002	1.808	330.0	88.4	1.086
BHS	1.5	27740	1.301	322.9	86.7	1.086
	0.8	20694	1.808	322.0	88.2	1.086
PTS	1.3	28002	1.301	323.8	86.6	1.085
	2.0	20817	1.808	317.5	85.8	1.087

Funding: MPIC

COLORADO POTATO BEETLE MANAGEMENT

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Summary: Research in 1988 included: 1) analysis of inheritance of insecticide resistance, 2) preliminary investigations of the effect of different potato cultivars on larval growth and survival, 3) development of an insecticide-resistance test kit for use by growers, and 4) evaluation and registration of new insecticides for Colorado potato beetle control.

1) Results indicate that resistance to both Guthion and Furadan is inherited as dominant genes. Both resistance genes are also probably carried on autosomal (non-sex) chromosomes. Resistance genes appear to already exist in nature at very low levels (approximately .001%).

2) Growth and survival of beetle larvae is influenced by the particular potato cultivar they feed on. The degree of insecticide resistance may also affect the probability of larval survival on different cultivars, with insecticide-resistant larvae more likely to survive to pupation.

3) Resistance tests of beetle populations collected from Michigan potato fields show that approximately half of all populations tested are resistant to Furadan that resistance to Imidan may be very widespread, and that moderate to high levels of Asana resistance are present in many populations.

4) Some of the new insecticides evaluated in 1988 were: Trident (a bacterial spore preparation), and Trigard (an insect growth regulator).

Practical applications: The dominant inheritance of resistance indicates that resistance can increase very rapidly in the field. Since resistance to Guthion, Furadan and Asana usually result from different mechanisms, alternation of these chemicals will help slow resistance development. PBO (piperonyl butoxide) is effective as a synergist for Guthion (and other organophosphates, such as Imidan) and for some types of Asana resistance. PBO was widely used in the field in 1988 and was very effective.

New labels were obtained in 1988 for PBO, Rotenone & PBO, and M-1 (a new bacterial product). Emergency labeling was obtained for Kryocide/cryolite in 1988 and will be pursued again in 1989.

Results from petri dish test kits indicate that roughly half of the fields tested had very high levels of Furadan resistance. Asana and Imidan resistance was also widespread.

1) Inheritance of Insecticide Resistance in Colorado Potato Beetle

Studies were conducted to determine: the mode of inheritance of resistance to different insecticides (i.e., the extent of dominance or recessiveness), whether the resistance genes are associated with sex-linked or autosomal chromosomes, and whether resistance is controlled by one gene or is polygenic.

Guthion (an organophosphate) and Furadan (a carbamate) were used in the studies. These insecticides are widely used in Colorado potato beetle control programs. In Michigan they have been effective, although there are some instances where beetles have developed more than a 500-fold resistance to these insecticides (Table 1).

TABLE 1. RESISTANCE LEVELS OF DIFFERENT STRAINS OF COLORADO POTATO BEETLES.

BEETLE STRAIN	INSECTICIDE	LD_{50} (μg/beetle)	RESISTANCE RATIO[b]
Long Island (Resistant)	Guthion	556	448
	Furadan	>200	---
Montcalm (Resistant)	Guthion	18.4	14.8
	Furadan	93.9	521
Vestaburg (Susceptible)	Guthion	1.24	----
	Furadan	0.18	----

[a] LD_{50} = That dose of the insecticide that kills 50% of the beetles.

[b] Resistance ratio = LD_{50} of the resistant strain / LD_{50} of the susceptible strain

The Colorado potato beetle strains used in these studies were originally collected from field populations, and later selected in the laboratory.

VESTABURG SUSCEPTIBLE STRAIN (S): This strain is of Michigan origin and has been under continuous culture in our laboratory for about two years.

LONG ISLAND STRAIN (R): This field collected strain was heterogeneous resistant to Guthion when it was collected two years ago. After repeated backcrossing, selection at 80 % mortality, and intercrossing for five generations, a (RR) homozygote has been produced. This gave rise to a steeper log probit-dose line. This is clearly demonstrated by comparing the slopes and the X^2 values in the following regression evaluations. After the selections, b=3.01 (steeper slope) and X^2 = 0.625 (very small)--strong indication for homogeneity.

Before selection:

Heterogeneous (SS, RS, RR) y=1.80 +1.18x (X^2=7.14 D.F. 5), LD_{50}= 489μg/beetle

After selection:

Homogeneous (RR) y=-3.26+3.01x, (X^2=0.625 D.F 5)
LD_{50}=556 µg/beetle

MONTCALM-C STRAIN (R TO FURADAN): This strain has been selected four times. Before the selection the beetles were heterogeneous susceptible with LD50 = 0.63 µg/beetle. The first selection was made by spraying the field with Furadan 4F at the recommended field rate. Approximately 40 to 50 larvae, out of an original 300,000 survived (99.9% selection), and were returned to the laboratory. Progeny from these original larvae have been selected four times with Furadan (80% mortality selection). In an extremely short time the beetles showed a steep dose-mortality line, and an 147-fold increase in resistance to Furadan (Table 2). These results support the preadaptive theory for development of resistance. Resistant genes preexist in the field in very low frequencies. Selection must act on the supply of genetic variants already in the population at the time the selection program begins, not on mutations that occur during the process of selection. The speed by which resistance to Furadan has occurred is characteristic of monogenic inheritance, compared with polygenic inheritance, which takes more time to develop. It is interesting that selection with Furadan also gives cross-resistance to Guthion.

TABLE 2. INCREASE IN RESISTANCE OF THE MONTCALM STRAIN OF CPB TO FURADAN AND GUTHION DURING FOUR GENERATIONS OF SELECTION WITH FURADAN

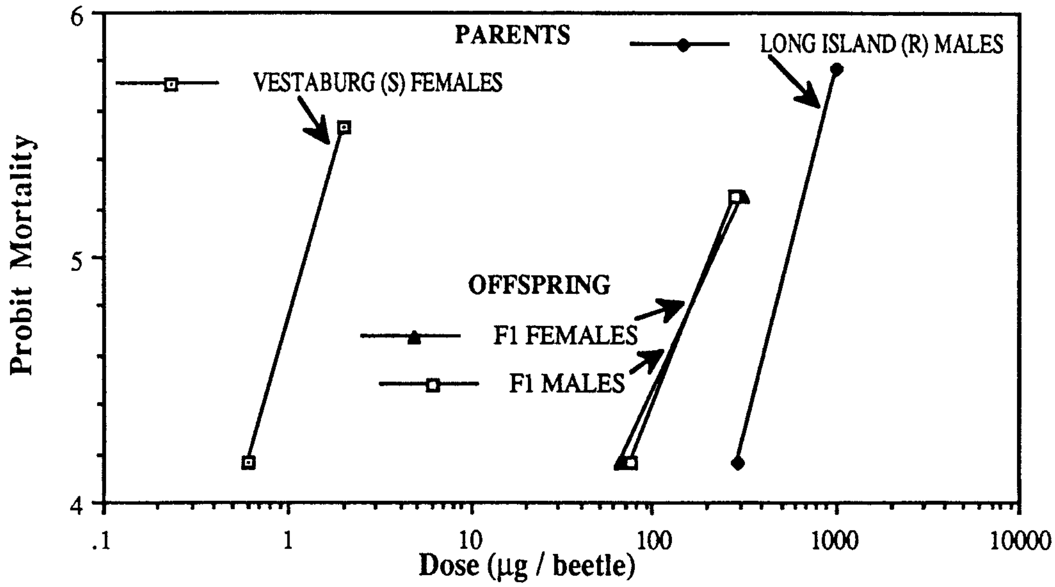
GENERATION		LD_{50} (µg/beetle) FURADAN	GUTHION
Before Selection	P	0.6	1.4
Selection (in field) (mortality = 99.9%--- larvae)	F_1	34.8	-.-
Selection (in lab) (mortality = 80%---adults)	F_2	93.9	9.2
Selection (in lab) (mortality = 80%---adults)	F_3	> 100.0	18.1

The two resistant strains include major resistance genes isolated from field collected populations that already have had extensive exposure to the specific pesticide. At this time the levels of resistance are very high and ranges of the dosage-mortality lines for the R and S strains are not overlapping.

The successful identification of resistant genotypes and phenotypes depends, to a large extent, on the proper choice of a sensitive bioassay method. The FAO standard bioassay techniques for Colorado potato beetle were used. Insecticide toxicity was estimated by topical application, applying 2 microliters of a solution of technical compound in acetone. Probit analysis was used to estimate the LD50's (amount of the insecticide that kills 50% of the population). The beetles were maintained, and the tests conducted, at 25 °C. Mortality was estimated after 3 days.

The mass-cross technique, with about 20 pairs of beetles, was used. The reciprocal crosses between strains susceptible and resistant to Guthion gave almost identical results for the F1 progeny, confirming that resistance to Guthion is inherited as incompletely dominant, and appears to be carried on autosomal (non-sex) chromosomes (Figure 1).

VESTABURG FEMALES (SUSCEPTIBLE) X LONG ISLAND MALES (RESISTANT)



VESTABURG MALES (SUSCEPTIBLE) X LONG ISLAND FEMALES (RESISTANT)

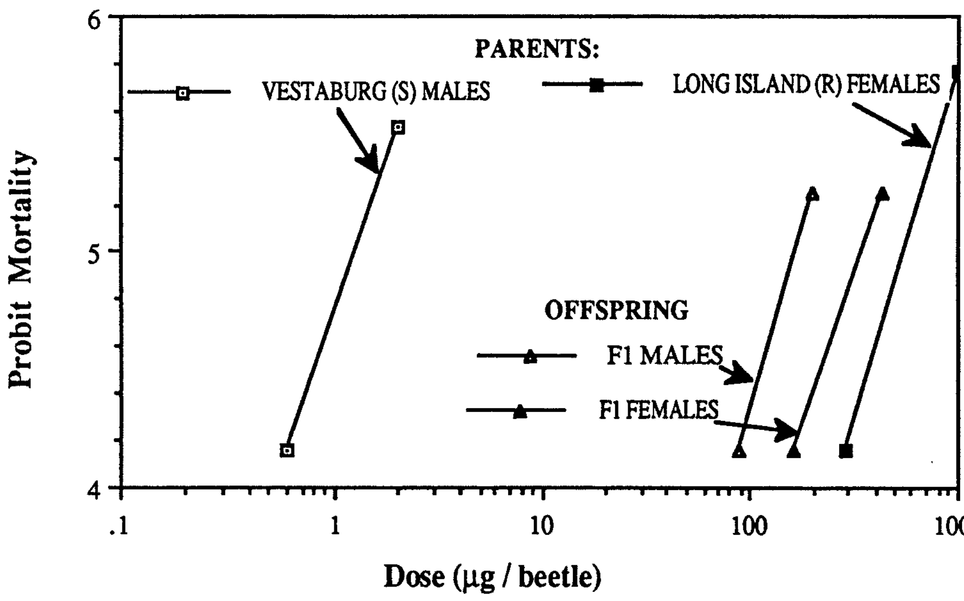


FIGURE 1. LEVELS OF RESISTANCE TO GUTHION IN OFFSPRING (F1) AND PARENTS OF A CROSS OF SUSCEPTIBLE (VESTABURG STRAIN) AND RESISTANT (LONG ISLAND--LI STRAIN) COLORADO POTATO BEETLES.

We repeated the crosses and applied a synergist, piperonyl butoxide (a specific inhibitor of mixed-function oxidase enzymes), with the Guthion to the F1 progeny. We got very good synergistic ratios, almost returning the resistant F1 progeny to the susceptible level (Figure 2).

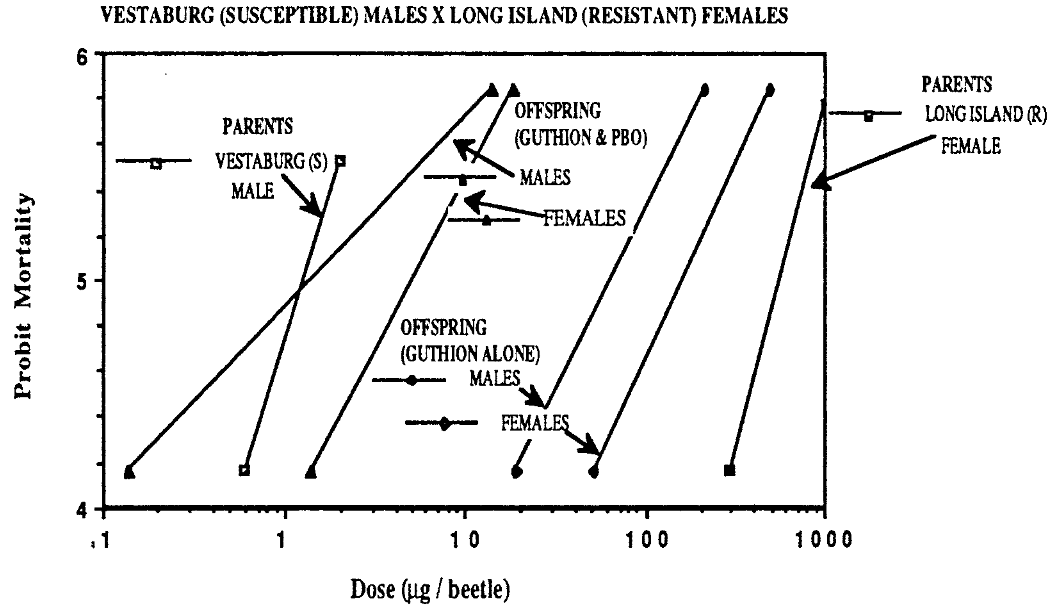
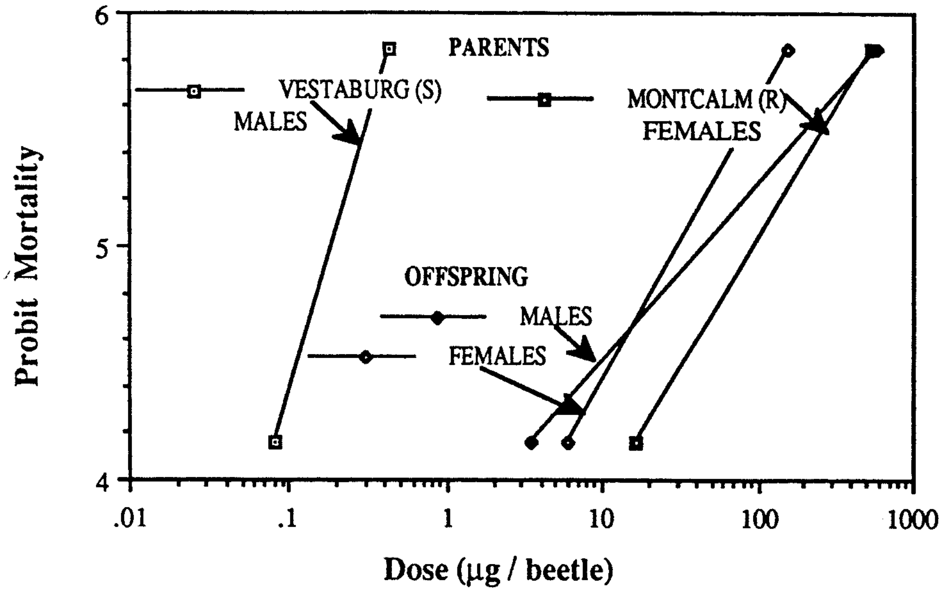


FIGURE 2. **LEVELS OF RESISTANCE TO GUTHION ALONE, AND TO A COMBINATION OF GUTHION AND PBO IN OFFSPRING (F1) OF A CROSS OF SUSCEPTIBLE (VESTABURG STRAIN) AND RESISTANT (LONG ISLAND STRAIN) COLORADO POTATO BEETLES.**

Extensive synergistic and physiological studies using both the Long Island and Macomb County resistant strains of beetle have shown that mixed-function oxidases are the main mechanism responsible for Guthion resistance.

Reciprocal crosses between carbofuran-selected resistant beetle strains (Montcalm), and the Vestaburg susceptible strain showed that Furadan resistance was incompletely dominant, and appeared to autosomal (Figure 3). Our work on Furadan resistance is under progress and we expect to complete very soon the studies involving backcrossing and analysis of the F2 progeny. This will give us a more precise picture of the inheritance of Furadan resistance.

MONTCALM FEMALES (RESISTANT) X VESTABURG MALES (RESISTANT)



VESTABURG FEMALES (SUSCEPTIBLE) X MONTCALM MALES (RESISTANT)

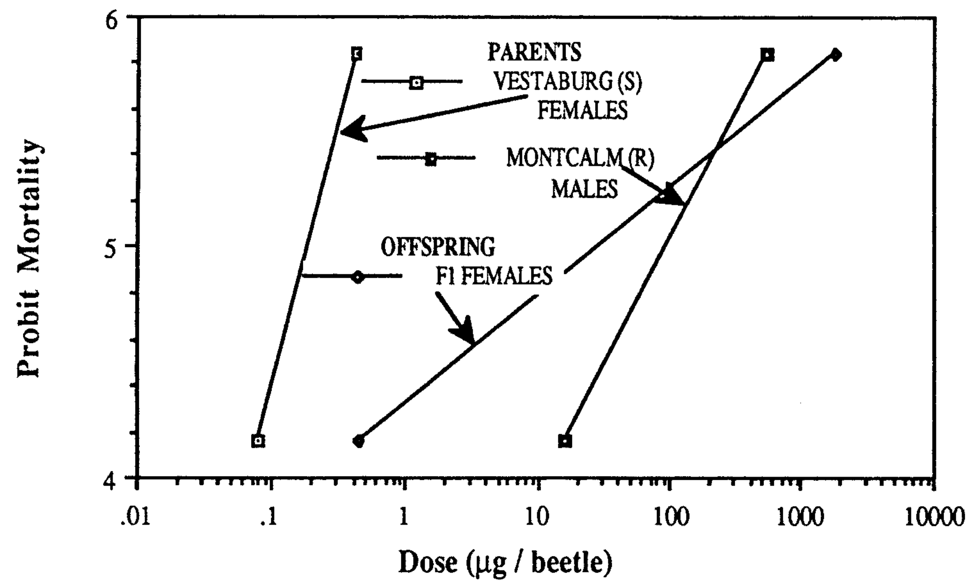


FIGURE 3. LEVELS OF RESISTANCE TO FURADAN IN OFFSPRING (F1) AND PARENTS OF A CROSS OF SUSCEPTIBLE (VESTABURG STRAIN) AND RESISTANT (MONTCALM STRAIN) COLORADO POTATO BEETLES.

From the practical standpoint, accumulation of knowledge of formal genetics of resistance in the Colorado potato beetle will provide essential background on recommendations for control, and the design of an appropriate integrated pest management program for this very serious pest.

2) Effect of Potato Cultivar on Larval Growth and Survival Rate

The growth and survival of Colorado potato beetle larvae when fed on three different potato cultivars were compared. Both insecticide-resistant and susceptible strains of beetle were used to assess whether there is a relationship between resistance to insecticides and to plant chemicals present in potato foliage. Larvae were kept in petri dishes, fed daily on freshly-excised potato foliage, and weighed every day or two.

Survival rates of resistant beetle larvae were higher on the cultivar Conestoga than on Onaway or Superior (Figure 4). Survival of the insecticide-suceptible strain of Colorado potato beetle was very poor on all cultivars (Figure 5).

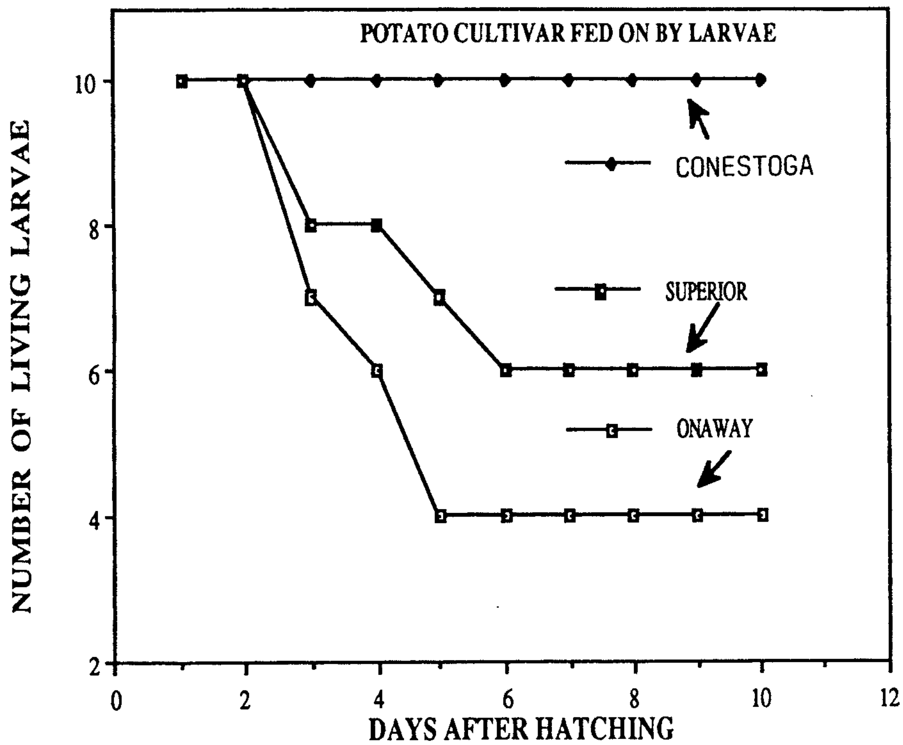


FIGURE 4. DAILY SURVIVAL OF INSECTICIDE-RESISTANT COLORADO POTATO BEETLE LARVAE (JP STRAIN) WHEN FED ON THREE DIFFERENT POTATO CULTIVARS.

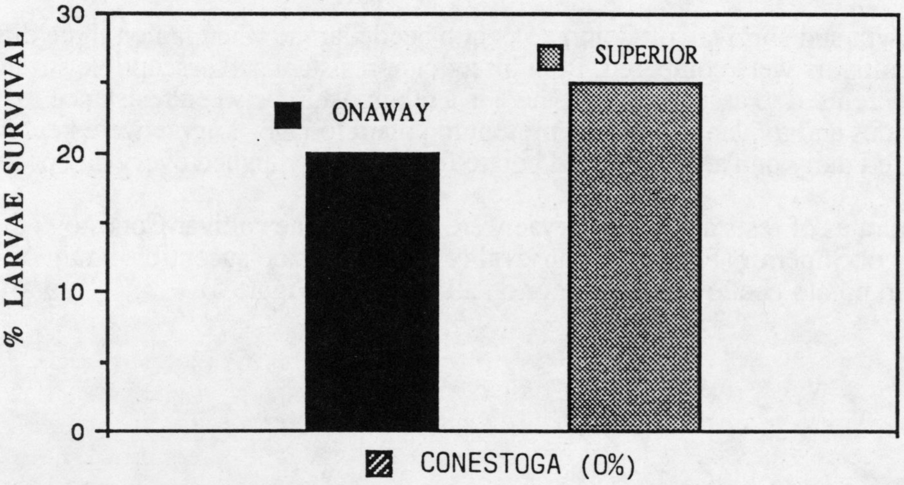


FIGURE 5. PERCENT SURVIVAL OF INSECTICIDE-SUSCEPTIBLE COLORADO POTATO BEETLE LARVAE (ANTRIM STRAIN) AFTER FEEDING FOR 10 DAYS ON THREE DIFFERENT POTATO CULTIVARS.

Beetle larvae fed on the potato cultivar Superior were heavier than larvae fed on Onaway or Conestoga cultivars early in the larval period (Figure 6). Weights of beetle larvae fed on the Onaway cultivar were, at first, comparable to those of larvae fed on other cultivars, and then increased dramatically in comparison. Larvae fed Conestoga grew at a moderate rate for the first four days, and never grew very rapidly. Comparison of growth rates of susceptible and resistant strains of beetle were not directly possible because of the poor survival rates of the susceptible strains. However, the susceptible individuals that did survive attained the heaviest prepupal weights. Survival rate, therefore, may not be related to mature larval weight.

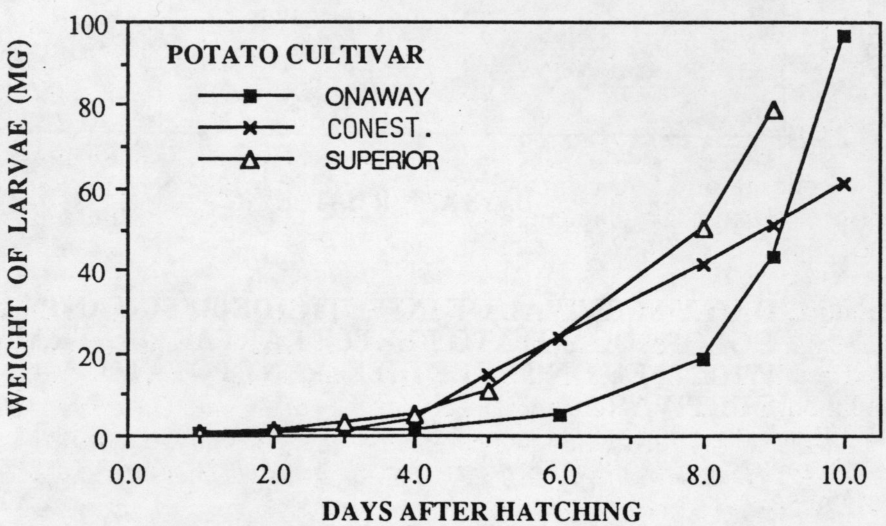


FIGURE 6 WEIGHT OF INSECTICIDE-RESISTANT COLORADO POTATO BEETLE LARVAE WHEN FED ON THREE DIFFERENT POTATO CULTIVARS.

In sum, both survival rate and growth rate of beetle larvae appear to be affected by potato cultivar. Although the low survival rate of insecticide-susceptible beetles prevents definitive conclusions, the resistance status of the beetle does appear to influence at least survival on different potato cultivars. Future plans for this work include comparisons of rates of larval growth, feeding, and survival between russet-type potatoes and small white potatoes, and comparisons between white varieities and colored varieties. The results of these and future studies will be useful in the future for developing Colorado potato beetle management recommendations and for consideration in future potato variety development.

3) Development of an Insecticide-Resistance Test Kit

Test "kits" to enable growers to test Colorado potato beetles for resistance prior to insecticide application were developed and distributed in 1988. Each "kit" included separate tests to detect resistance to Furadan, Imidan (results also an indicator of Guthion resistance), Asana, and an Asana and piperonyl butoxide (PBO) combination. Each resistance test was composed of a petri dish containing a filter paper that had been dipped into a discriminating concentration of the insecticide (i.e., the insecticide concentration that killed susceptible beetles, but not resistant ones), and subsequently dried. When placed in the petri dish, adult beetles walked over the insecticide-treated filter paper and picked up the dried residue on their tarsi. Although some of the insecticide may have been ingested when the beetles groomed their tarsi, the primary method of insecticide exposure was through direct contact.

Discriminating concentrations for each insecticide were determined by preliminary tests using laboratory and field-collected beetle populations of known resistance levels. For each insecticide, both resistant and suceptible strains were tested in petri dishes containing filter papers treated with a range of different concentrations of the insecticide. The range of concentrations usually included the field rate of the insecticide (assuming 30 gallons per acre application rate), but the discriminating concentration was not necessarily the same as the field application rate (beetles in the petri dish test were constantly exposed to the insecticide residue, unlike the situation in the field).

In addition to resistance tests for the four insecticides listed above, each resistance test "kit" contained a thermometer (since temperature affects insecticide toxicity, this was to help growers keep the tests within the required temperature range of 70 - 80 ^{o}F), a 3-part carbonless form to record data and background information, a self-addressed, stamped envelope for mailing back the data, and instructions. Growers were instructed to collect beetles from their field, maintain them for about 24 hours on potato foliage, then add 20 beetles to each petri dish and record mortality 24 hours later. The instruction sheet explained how to interpret test results in terms of insecticide recommendations.

Approximately 200 test kits were distributed to growers, to pest-control consultants, to extension agents, and to chemical company representatives during the summer of 1988. We received results from 51 of these tests. These results show that the vast majority of beetle populations tested were either very suceptible, or almost totally resistant to Furadan 4F (Figure 7). Only one population (out of 51 tested) showed mixed levels of resistance. This result agrees with our previous finding that resistance to Furadan can develop very rapidly in beetle populations.

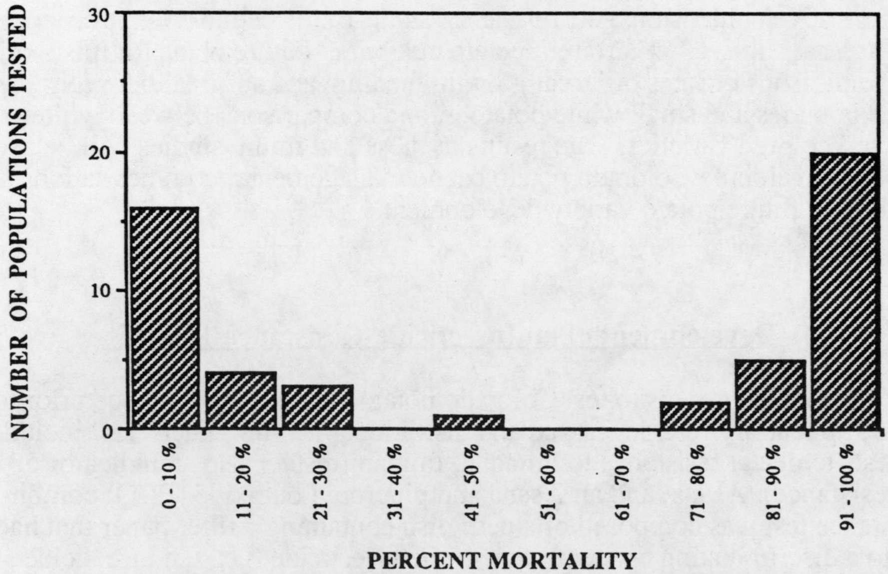


FIGURE 7. FIELD POPULATIONS OF COLORADO POTATO BEETLE TESTED WITH FURADAN 4F RESISTANCE TEST (8.0 G AI/L)

Additional results show that resistance to Imidan may be very widespread in Michigan beetle populations (Figure 8). Of the 31 populations tested, only one showed a mortality of greater than 50% .

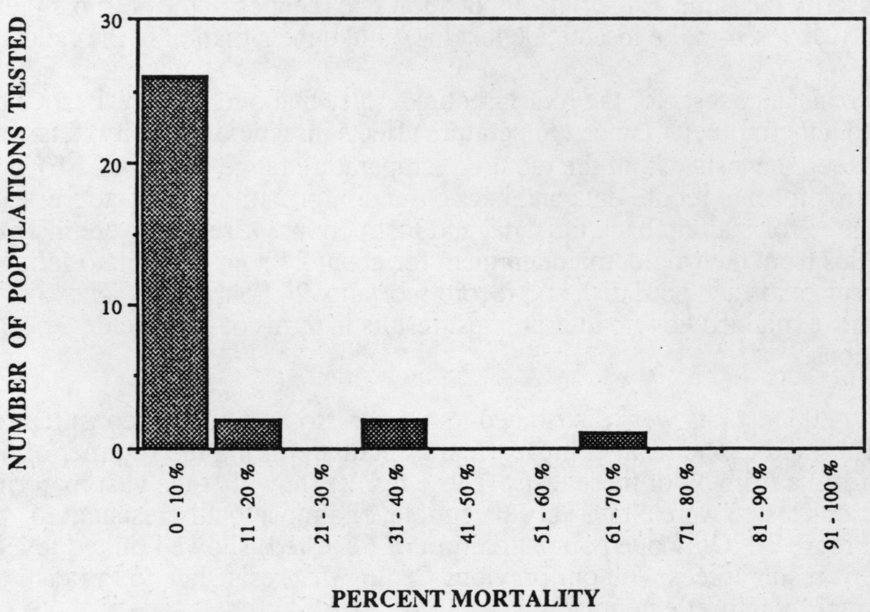


FIGURE 8. FIELD POPULATIONS OF COLORADO POTATO BEETLE TESTED WITH IMIDAN 50 WP RESISTANCE TEST (1.6 G AI/L)

Most field populations exhibited moderate to high levels of resistance to Asana (Figure 9), although a few of the populations were very susceptible. The addition of the mixed-function oxidase inhibitor, piperonyl butoxide (PBO) increased the suceptibility of most beetle populations to Asana. For a few populations, however, the addition of PBO had little effect.

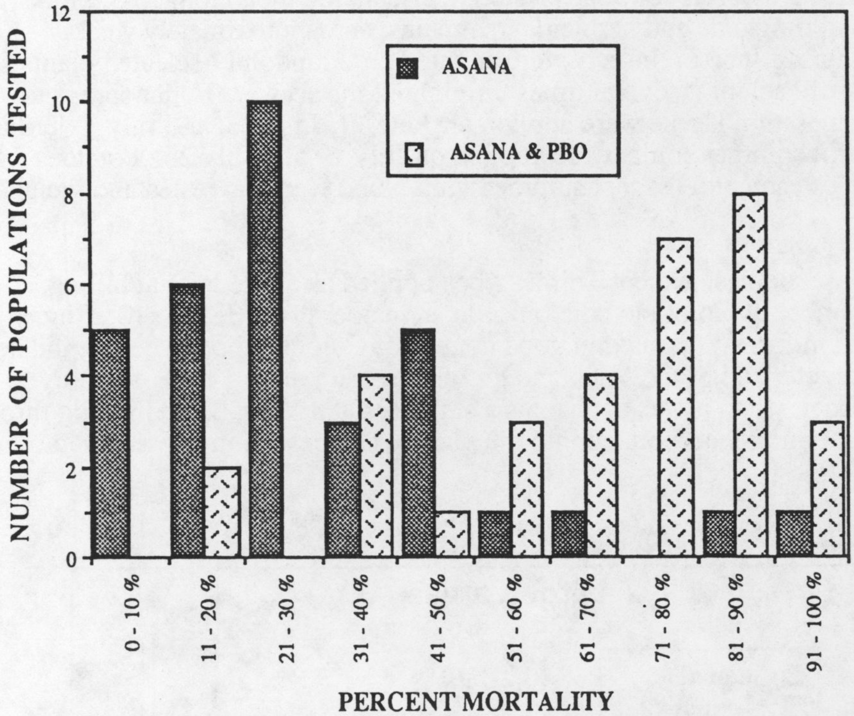


FIGURE 9. FIELD POPULATIONS OF COLORADO POTATO BEETLE TESTED WITH ASANA 1.9 EC RESISTANCE TEST (0.9 G AI/L) AND ASANA 1.9 EC & PBO 8 EC RESISTANCE TEST.

The resistance test kit has proved valuable in two ways. First, the kit has provided growers, and others involved in Colorado potato beetle control, with an easy-to-use tool to help identify effective insecticides prior to application, and to assess reasons for control failure (for example, insecticide resistance vs poor spray coverage). Second, data generated from the use of this test has helped us document the extent and distrubution of insecticide resistance in Michigan beetle populations.

Future development plans for the insecticide resistance test "kits" include additional insecticides, and field demonstrations. We plan to include more chemicals in the kit, especially an organochlorine insecticide (Thiodan) and an Imidan and PBO combination (To assess furthur the extent of and mechanism of Imidan resistance in Michigan beetle populations). Complete kits will be available early in the 1989 season so growers' insecticide decisions can be based on a knowledge of the resistance status of their particular beetles.

In addition, we are planning field demonstrations in the summer of 1989. The purpose of these demonstrations will be to show the relationship between test kit results, and field effectiveness of an insecticide.

4) Evaluation and Registration of New Insecticides

Insecticide-evaluation trials in 1988 were conducted at the MSU Montcalm Potato Research Farm in Entrican, MI. Trials included: evaluation of systemic insecticides, evaluation of foliar sprays to control first generation larvae, and evaluation of foliar sprays to control summer adults.

Potatoes were planted on May 13, 1988. Plots were 3 rows wide (34" row spacing) and 40 ft (foliar spray plots) or 50 ft (systemic insecticide plots) long. All plots received normal fungicide and herbicide treatments, and approximately weekly irrigation beginning June 6. Insects were counted on 2 randomly-selected plants from the center row of each plot several times throughout the season. Foliar sprays to control first generation larvae were applied on June 17, June 23, and July 1. Foliar sprays to control summer adults were applied on July 19 and July 26. Potatoes from the center row of each plot (except summer adult plots) were harvested and weighed on October 5.

All systemic insecticides, except Thimet when applied as a sidedress at hilling, reduced the number of Colorado potato beetle larvae per plant (Figure 10). Since Thimet applied in furrow resulted in good control of Colorado potato beetle, the hot dry conditions characteristic of the Michigan growing season during 1988 probably prevented Thimet, when it was applied as a sidedress at hilling, from moving through the soil and becoming incorporated into the plant. The best control was given by Temik.

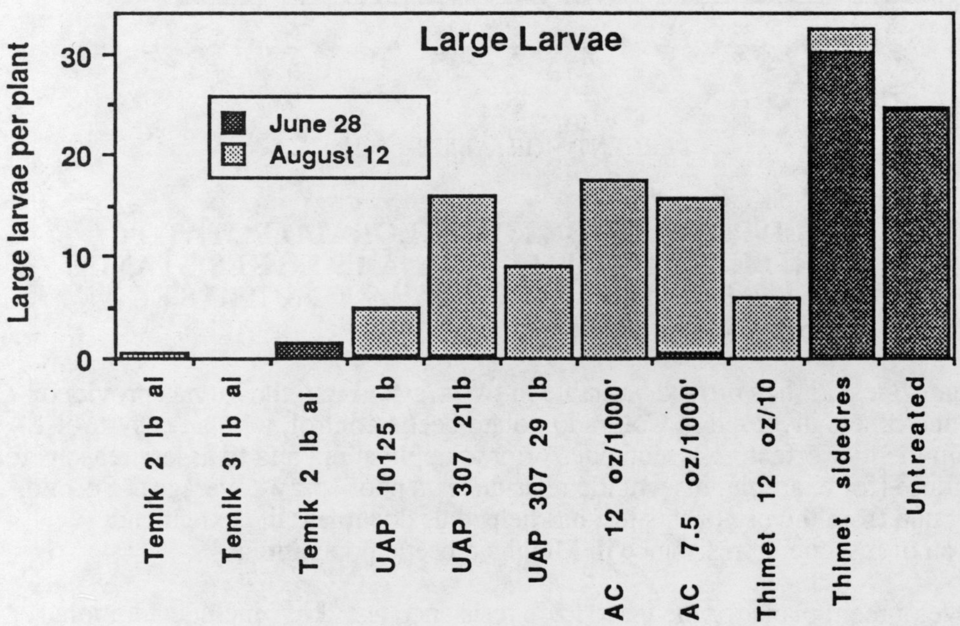


FIGURE 10. NUMBER OF LARGE COLORADO POTATO BEETLE LARVAE PER PLANT ON 2 SAMPLING DATES IN 1988 FOR DIFFERENT SYSTEMIC INSECTICIDE TREATMENTS

All foliar sprays reduced the number of first generation large Colorado potato beetle larvae per plant (Figure 11). The best control was given by: Imidan, a combination of a pyrethroid (Capture or Asana) and PBO, and the growth regulator Trigard. There were no significant differences in the number of beetles per plant among foliar treatments applied to control summer adults.

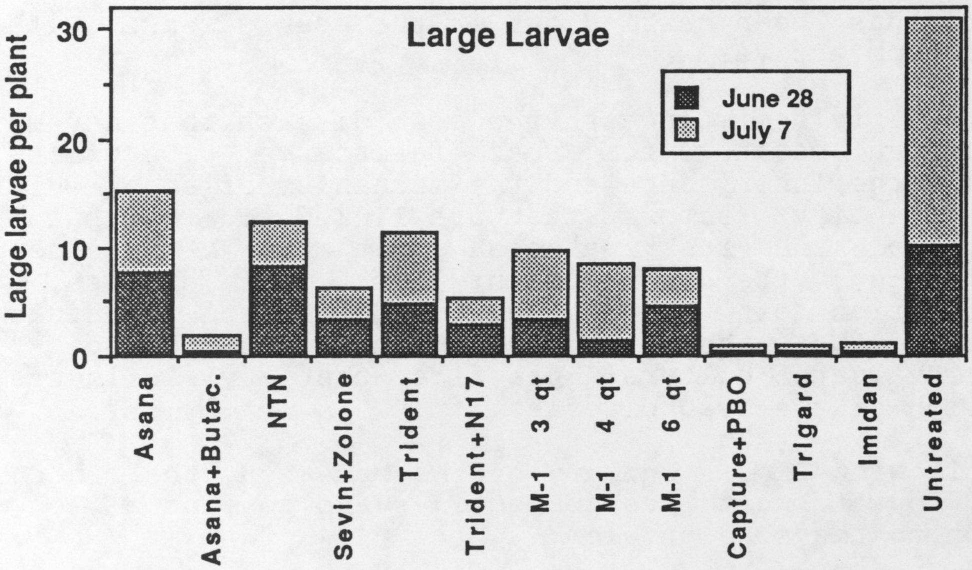


FIGURE 11. NUMBER OF LARGE COLORADO POTATO BEETLE LARVAE PER PLANT ON 2 SAMPLING DATES IN 1988 FOR DIFFERENT FOLIAR INSECTICIDE TREATMENTS

In addition to testing new insecticides in 1988, data from previous years research was used to obtain a section 18 emergency registration was obtained for Kryocide (cryolite). Also, M-1 was, for the first time, registered for use on potatoes in Michigan.

RESEARCH REPORT ON ARS/USDA COOPERATIVE AGREEMENT FOR SCAB RESEARCH

R. Hammerschmidt, D. Douches, M.L. Lacy, L. Hanson, K. Ludlam
F. Spooner and C. Wallace

Research has been carried out on the scab disease with the following objectives:

1.Identify resistance to the scab disease that may be used in breeding potatoes for scab resistance. Determine the nature of the inheritance and the mechanism of scab resistance

2. Identify factors that are linked to the pathogenic ability of the scab pathogen that may be of help in understanding the development of the disease, the identification of the pathogen and in the mechanism of survival of the pathogen in the absence of the potato.

3. Evaluate cultural practices that may influence the expression of the scab disease.

The following is a summary of the research that has been carried out to meet these objectives and to find a long-term solution to the scab problem.

DISEASE RESISTANCE RESEARCH

During the summer of 1987, named and numbered potato varieties were screened for scab resistance at a site on the MSU Soils Research Farm in East Lansing. The results of this trial is given in table 1. Several lines were shown to have some resistance to the disease based on a low number of infected tubers.

A greenhouse screen was developed to help augment the screening process. In this screen, greenhouse potting mixture is mixed with a slurry of the pathogen. The mixture is placed into pots and seed pieces are planted in the soil mixture. After emergence of the plants, the pots are watered from the bottom to maintain the dryer conditions in the tuber zone needed for good infection. The results of two trials are presented in tables 2 and 3. This assay is relatively rapid and has the potential to allow screening of a large number of plants with a very uniform inoculum level. We are now working to develop a screen for plants at the seedling stage.

Genetic studies are being carried out to determine the heritability of scab resistance using the greenouse screen. A diallel mating design using tetraploid genotypes, is currently being used to determine the heritability of resistance. Haploid plants will be extracted from the tetraploid clones that are being identified as having a high degree of resistance. These lines will be used to determine how many genes control resistance.

We have prepared part of the greenhouse for photoperiod control. This will allow us to screen wild species of potato, which have a strict photoperiod requirement for tuberization, for resistance to scab. Identifying resistance in these wild species could provide valuable new sources of scab resistance.

We have initiated studies on the biochemical and physiological basis for resistance to potato scab. We have been determining the levels of the antibiotic phenolic compound, chlorogenic acid, in the epidermis and periderm of young tubers. We have found that there is a correlation between the content of chlorogenic acid and the level of resistance to scab (Table 4). The correlation is not completely without exception, and this may represent the fact that scab resistance may be composed of several components. Understanding the mechanisms of resistance will enable us to use biochemical markers to help select for resistant varieties. This information may also be of great help in improving the control strategies. Understanding how resistance works may enable us to enhance the expression of resistance by genetic means or even cultural practices.

Scanning electron microscopy of young tubers being infected by S. scabies has been used to try to determine when infections do take place and if there are any obvious differences between resistant and susceptible varieties. For this work, the varieties Shepody (susceptible) and Krantz (resistant) were used. The surface of young (ca. 0.5 inches in diameter), infected tubers were observed via SEM. The apex of the tuber and the zone where stomata differentiate into lenticels appear to be the areas where most infections take place in the susceptible variety. The part of the tuber where the periderm is beginning to suberize and the lenticels are maturing did not appear to harbor any infections. In the resistant variety, the stomata appeared to close in response to the presence of the pathogen (thus physically blocking its invasion). The colonization of lenticels in the area where stomates are differentiated into young stomates was found to be reduced when compared to the susceptible plants. Although these results are very prel;iminary, they do support the role of a preformed toxic compound in resistance as well as physical barriers in preventing invasion of the young tuber tissue.

STUDIES ON THE BIOLOGY OF THE PATHOGEN

Understanding the biology and physiology of the pathogen is needed to aid the development of resistant varieties as well as in finding better means to identify the pathogen (unfortunately, when grown in culture, the pathogen looks vary much like non-pathogenic Streptomycetes). This work is also carried out to determine if the pathogen may exist in different forms that have different levels of virulence on potatoes.

Twenty-four single spore isolates of Streptomyces were collected form disease tubers from several locations in the state. The isolates were tested for pathogenicity on three varieties of potato (monona, atlantic and shepody). The isolates were also tested for their ability to produce pigments on peptone-yeast-iron agar, growth on various carbohydrates and their ability to degrade pectin. The latter was done since the invasion of tuber tissue by the pathogen appears to require the degradation of pectin in the tuber tissue by the pathogen. One trial was also run directly comparing several pathogenic isolates for differences in pathogenicity on the same variety.

Many, but not all of the isolates from scab lesions were pathogenic. We found that there was a good correlation between the ability of an isolate to cause scab disease and its ability to produce pigments on PYI media. We found an even better correlation between the ability of the pathogenic isolates to use sucrose as a carbon source. The non-pathogens grew very poorly, or not at all, on this sugar. This observation is of interest, since sugars are tranlocated to the tuber in the form of sucrose before they are converted to starch. Although it is too early to draw firm conclusions, the ability to use sucrose may help explain why the pathogen may try to infect the tuber as it develops. These results will be of use in developing a screen for pathogenic isolates as well as in the understanding of how the pathogen initiates disease.

Pathogenic variability was also observed. Simultaneous comparison of eleven pathogenic isolates on the Atlantic variety showed that symptoms ranged from superficial scabs through severe pitting (Table 5). Development of more virulent isolates of the pathogen may explain, in part, why some varieties (e.g. Onaway) are exhibiting more scab than previously observed.

Since variation does appear to occur, we have begun to study the genetics of virulnce and pathogenicity. Using DNA isolated from several isolates of S. scabies and non-pathogenic Streptomycetes, we have carried out restriction enzyme digestions of the DNA. Analysis of the digested DNA by agarose gel electrophoresis has shown that there are some major differences between the pathogens and saprophytic non-pathogens. The pathogens, however, appear to show similar patterns. These results suggest that we can easily distinguish pathogens from non-pathogens at the molecular level. This work will also help us determine which genes make the pathogen a pathogen and not a saprophyte, how virulence may change and if pathogenicity can be transferred from the pathogen to a saprophyte.

EFFECT OF SELECTED CULTURAL PRACTICES ON SCAB

Over the last sveral years, we have shown that the use of the acid forming N source, ammonium sulfate, and use of proper soil moisture during tuber initiation and expansion leads to the expression of less scab on the tubers. During the last year, an experiment to examine the effect of the preceding crop on sdcab development. Due to timing, plots were seeded with various crops one month before planting potatoes. Just prior to planting potatoes, these cover crops were plowed into the soil. Even this short period of growth markedly influenced the xpression of thedisease. The most severe scab was observed in the plots where red clover had been planted. In decreasing severity from red clover was corn, fallow control, rye, alfalfa and oriental mustard. The latter crop was included since it is known that toxic compounds in mustards can decrease the population of some soil pathogens as well as the potential use of another mustard, canola, as a cash crop in michigan. Similar severity with red clover was observed in the legume rotation plots we analyzed for Hesterman and Griffin. This is also in agreement with other studies on rotation and scab disease as well as observations by growers. The results are presented in Table 6. Current work also involves trying to determine why some of these crops enhance the level of scab while others appear to lessen the severity.

CONCLUSIONS

The work carried out thus far has been a combined effort from several approaches to attempt to find a solution to the scab problem. We have identified sveral good sources of resistance that may be useful in the breeding program. We have also made some progress into understanding the nature of disease resistance and the mechanism of infection and pathogenicity by S. scabies.
We have also demonstrated that certain crops that precede potatoes can have a positive or negative influence on the severity of scab in the following potato crop. This is the first major effort to try to control scab by the simultaneous study of a number of factors that are important in this disease and its development.

At present we can recommend that scab severity can be reduced through the use of several measures when used together: these include maintainting soil moisture levels below 50 cb from emergence until 6-8 weeks after emergence, the use of ammonium sulfate as the N source, using the most resistant variety of potato availabe, and using a rye cover crop. It is very clear that red clover should not be a part of the rotation. Alternate legumes, such as alflafa, appear to be better with regard to scab severity.

TABLE 1
1987 FIELD EVALUATION FOR SCAB RESISTANCE

VARIETY	%TUBERS 0 SCAB	%TUBERS 5%SCAB
NY 72	53	84
D195-24	60	95
TND22-5	45	80
BR7093-24	46	92
TC 582-1	100	
D191-2	73	96
ND 2109-7	45	100
A7691-1	57	100
A7411-2	83	94
NY 79	42	90
A 79141-3	89	97
NY 81	41	100
WNC 521-12	53	92
WNC 672-2	56	100
NY 71	58	96
CO 81103-1	46	94
NORGOLD RUSSET	65	94
WIS 848	72	100
MS 401-2	72	100
MS 402-6	76	97
HILITE RUSSET	95	100
NORCHIP	26	94
SANGRE	82	100
SHEPODY	60	76
RUSSET NORKOTAH	75	100
LAO0-38	63	93
ERAMOSA	62	99
A79341-3	68	94
MS 401-3	58	94
SAGINAW GOLD	75	80
MS 401-1	25	86
MS 402-7	41	93
KRANTZ	88	100
ONAWAY	96	100
MS 401-8	71	98
ATLANTIC	73	95
MS 401-4	83	100
MS 716-15	69	97
A 76147-2	84	100
MICHIGOLD	68	100
MN 10874	67	98
MS 401-7	96	100
MS 700-83	71	100
MS 702-80	70	98
ROSEGOLD	80	92
MS 401-6	81	100
MS 401-5	65	88
NORKING RUSSET	83	97
MS 402-8	86	100

MS 402-2	85	96
CONESTOGA	85	95
WIS 855	40	80
MS 402-4	48	100
FL 657	85	88
A7414-4CP	97	100
ND 1859-4	100	100
ND671-4R	100	100
SH-1	76	100
AF236-1	60	88
MS 402-1	98	100
A76147-2	100	100
(THE FOLLOWING ARE ONE OBSERVATION ONLY)		
9972-2B	80	100
B0045-6	25	85
AF875-16	60	100
BO237-1	17	100
BO178-14	16	72
B9792-8B	30	82
B0238-4	60	100
AF875-17	60	100
CS7639-1	75	100
B0256-15	25	63
B9792-15B	30	100
B0032-40	83	100
5470	86	100
D43	100	100
5452	57	100
W231	82	100
W879	33	100
W760	33	76
AF465-2	79	100
ALLAGASH RUSSET	13	100
MN2331	67	100
B9569-2	75	100
MN12838	67	100
MN82328	95	100
TOLAAS	95	100
ATD63-7	84	100
ATD63-2	96	100

TABLE 2
GREENHOUSE SCREEN FOR RESISTANCE

VARIETY	RATING*	COMMENTS**
KRANTZ	0.0	NONE
NY71	11.0	PITTING
716-15	18.0	SURFACE
W855	3.6	SURFACE
SAG.GOLD	4.3	SURFACE
LA01-38	9.3	SURFACE
MONONA	15.2	SURFACE
RIDEAU	0.6	SUPERFICIAL
702-80	1.7	SUPERFICIAL
ATLANTIC	4.4	PITTING
NDD 277-2	17.0	PITTING
SUPERIOR	2.0	SUPERFICIAL
PUNGO	8.0	SURFACE
MICHIGOLD	17.3	PITTING
700-83	8.3	PITTING
NY81	9.3	SURFACE
ONTARIO	1.0	SUPERFICIAL
NORCHIP	10.3	SURFACE
ND651-9	25.0	SURFACE

*Average per cent coverage of tubers
**Most severe type of scab noted on tubers

TABLE 3
GREENHOUSE SCAB RESISTANCE SCREEN

VARIETY	LESION TYPE
MONONA	COMMON, SURFACE
Y245.7	NONE
LEMHI	NONE
PUNGO	COMMON, SURFACE
NOOKSAK	COMMON, SURFACE
SAG.GOLD.	RAISED LESIONS
ONAWAY	COMMON, SURFACE
ONTARIO	SUPERFICIAL SURFACE
RIDEAU	COMMON (IF PRESENT)
MICHIGOLD	RAISED
SUPERIOR	SUPERFICIAL SURFACE
716-15	RAISED, PITTED
LA01-38	RAISED
84S10	VERY SMALL, SUPERFICIAL
ND860-2	PITTED
W5337.3	PITTED
702-80	NONE
700-83	COMMON, SURFACE
NORCHIP	COMMON, SURFACE
NDD277-2	RAISED

Of these varieties tested, Y245.7, Lemhi and 84S10 have the highest level of resistance. Superior, Rideau, and Ontario fall into the next group. Onaway, 702-80 (from past experience) are in the last group. All of the others are susceptible.

TABLE 4
RELATIVE CHLOROGENIC ACID CONTENT OF TUBER APICAL TISSUE

VARIETY	CGA VALUE*
LEMHI RUSSET	0.225
RIDEAU	0.243
MICHIGOLD	0.121
ONAWAY	0.070
ATLANTIC	0.076
MS 700-83	0.048

*A320/MG FR WT

TABLE 5
EFFECT OF ISOLATE ON SCAB SEVERITY ON ATLANTIC

ISOLATE	SEVERITY	LESION TYPE
3S	+	SUPERFICIAL
CON2	+	SURFACE
ONAWAY925	++	SURFACE
RPF	++	PITTED
RP	+++	SURFACE/PITTED
DP2	+++	PITTED
F945	+++	PITTED
CON1	++++	PITTED
ATLANTIC	++++	PITTED
DPW	++++	PITTED
FIELD2	++++	PITTED

TABLE 6

EFFECT OF PRE-PLANTING COVER CROPS ON SCAB INCIDENCE IN ATLANTIC POTATOES

COVER CROP*	SCAB RATING**
RED CLOVER (7lb/A)	12.9A
CORN (7 lb/A)	11.4AB
FALLOW CONTROL	9.1 BC
RYE (20 lb/A)	8.9 BC
ALFALFA (7 lb/A)	7.9 C
ORIENTAL MUSTARD (20 LB/A	6.8 C

*All plots seeded to rye the previous fall. Cover crops were planted on May 14 following plowing in of rye. Covers were plowed in on June 14 and immediately planted to potatoes.

**0=no scab, 1=1-4%, 5=5-9%, 10=10-20%, 25=20-25% or above.

Funding Federal Grant

INFLUENCE OF ENVIRONMENTAL FACTORS ON WOUND HEALING OF POTATO TUBERS IN RELATION TO STORAGE DISEASES

INVESTIGATORS: R. HAMMERSCHMIDT AND A.C. CAMERON

OBJECTIVES:

A. Evaluate the effect of elevated CO_2 on the development of soft and dry rot diseases.
B. Determine the effect of elevated CO_2 levels on the expression of suberization-related enzymes and other biochemical changes in wounded tuber tissue.
C. Evaluate changes in disease development by *Erwinia carotovora* and *Fusarium solani* 'coeruleum' as a function of time in storage.
D. Examine the effect of preharvest, in-field treatments, on the wound healing ability and susceptibility of tuber tissue.
E. Examine the influence of temperature on the rapidity of suberization in relation to disease resistance development.
F. Examine the reaction of selected varieties to dry and soft rot infections.

JUSTIFICATION

Improper wound repair can lead to economic losses due to shrinkage (water loss) of the tuber and pathogen mediated decay. Wounds and bruises that occur during harvesting and handling can act as the sites for water loss and pathogen entry if these injuries are not properly suberized. Since the suberization process is known to produce an effective barrier to both water loss and infection, understanding the biology of this process in relation to the storage environment as well as to pre-harvest treatments of the plants is needed to improve the storability of the tubers. Our current knowledge in all of the objective areas is incomplete.

PROCEDURES

Biochemical and chemical methods

Suberization studies were carried out using 2.1 cm diameter X 1.0 cm thick slices of tuber tissue prepared from surface sterilized tuber tissue. The slices were placed into chambers (20'C) and humididfied air or humidified air containing 4% CO_2 were passed through at a constant flow rate. Samples were taken at daily intervals for the measurement of suberization or for the assay of suberization related enzyme activity. Suberization was measure by the thioglycolic acid assay detailed in the last report. Two enzymes believed to be involved in suberization (an acidic cell wall peroxidase [PO] and the cytoplasmic enzyme phenylalanine ammonia lyase [PAL]) were measured out of buffer extracts of acetone powder preparations of tuber tissue. The enzymes were both assayed spectrophotometrically or via isozyme staining in polyacrylamide gels (PO only).

Infection and suberization studies

Infection of wounds by *Fusarium solani* 'coeruleum' (Fsc) was monitored in relation to temperature and rate of wound healing. Wounded surfaces of tuber tissue were inoculated with a spore suspension of Fsc at intervals after wounding and holding at 18'C, after wounding and holding at 5'C, and various combinations of time and temperatures.

Whole tubers were screened for resistance to soft and dry rots by injection of the tubers with a spore suspension of Fsc or with a cell suspension of *Erwinia carotovora* (Ec).For general screening, the tubers were held in air (Fsc screen) or under near anaerobic conditions (Ec screen). In some experiments, the whole tubers were placed in sealed containers through which humidified air or humidified air containing 4% CO_2 were passed.

Field treatments of plants which are thought to have positive effects of the storability of potato included calcium applications and foliar sprays with Metalaxyl. Tubers from calcium treated plants were obtained from R.W. Chase and G. Silva. These tubers were used in the types of assays described above.

Studies on the effect of storage duration on disease development were carried out on whole tubers at monthly intervals for 9 months from the date of storage. Tubers were incoulated as described above for Ec and Fsc.

RESULTS AND DISCUSSION

Effect of elevated CO_2 levels on soft rot and dry rot development

Four per cent CO_2 was found to increase the severity of soft rot development when compared to disease development in air. Tubers, which had been in storage less than four months, exhibited large spreading decay areas by four days after inoculation when incubated in 4% CO_2. Soft rot inoculated tubers incubated in air showed little or no decay. Tubers that had been stored over six months were equally susceptible to soft rot regardless of the atmosphere. These results are in agreement with other observations that show the ability to heal wound and resist infection declines while in storage. Preliminary studies on older tubers incoculated with Fsc also showed no differential response to CO_2 vs. air. These results support our previous findings that elevated CO_2 in a storage, such as that generated by respiration during suberization, can promote development of soft rot.

Effect of elevated CO_2 levels on expression of suberization related enzyme induction

Incubation of wounded tuber tissue in 4% CO_2 was previously shown to inhibit the rate of suberization as shown by suberin deposition and other factors. Two enzymes needed for the synthesis of suberin were studied to evaluate the effect of CO_2 on the regulation of suberization. PAL activity was found to be delayed in time of induction and the magnitude of the induction by alowing the tissues to incubate in the presence of CO_2. The induction of the suberization specific peroxidase, the last enzymatic step in the synthesis of the major part of suberin, was delayed in the presence of CO_2 as was the magnitude of induction. This is being pursued further as this particular enzyme appears to be a key factor in suberization rates. These studies have shown that the slowing of suberization by CO_2 can be traced back, in part, to the expression of two enzymes that are involved in the synthesis of the suberin polymer.

Effect of storage duration on disease expression

Tubers of the Atlantic and Russet Burbank varieties were shown to gradually increase in the level of susceptibility over a period of six months with greater increases in the loss of resistance to infection between 7 and 9 months. Wound repair rates also slowed during storage, with the greatest decline in rate occurring after six months in storage. This work has demonstrated that the tubers, while in storage, gradually lose their ability to defend against disease and to induce the process of suberization when wounded.

Effect of in-field treatments and genetic background on wound healing and disease response

These experiments are in progress at the time of writing. Preliminary evidence suggests that additional calcium in the tubers will increase their resistance to soft rot decay. Similarly, metalaxyl appears to increase the resistance to infection by Fusarium through mechanisms not directly related to fungicidal activity of metalaxyl. This work suggests that in-field treatment of the plants may improve the storage characteristics of the tubers.

Influence of temperature on suberization and disease development rates

Inoculation of wounded tuber tissues at 18'C with Fsc has demonstrated that suberization is complete enough to effectively protect the tissue from infection by 4 days after wounding. Shifting the tubers from 18'C to 5'C prior to four days at 18'C also prevents infection but also greatly slows suberization. Decay, however, will proceed if the infected tissue is returned to the higher tissue. Infection of tissue at 5'C also results in little to no infection if the tissues are held at 5'C. Transfer of the infected tissues incubated initially at 5'C to the higher temperature after sevral weeks at 5'C will also allow disease to proceed agressively. These results suggest that although rapid lowering of the temperature will stop development of the disease, more disease may develop when the tubers are warmed to more ambient temperatures due, in part, to a slowing of the wound healing mechanisms.

Funding Federal Grant

What Consumers Want in Fresh Potatoes...Know-How Producers Can Use to Increase Market Share and Profitability

Investigator: Mary D. Zehner, Department of Agricultural Economics

Objectives: While the overall goal of the study was to suggest how the Michigan potato industry might best recover its share of the fresh potato market, specific objectives included:

* Identify how Michigan white potatoes are positioned in the minds of consumers; i.e., positive and negative perceptions.
* Discover underlying reasons for consumers' purchase patterns.
* Learn what, if any, consumer needs exists which could provide the Michigan fresh potato industry with new opportunities to regain market share.

Justification:

The fresh fruit and vegetable industry in the U.S. has been experiencing significant growth during the last decade due to consumers' changing lifestyles and a desire for more healthful, natural foods. However, Michigan potatoes have not benefited from the increase "fresh" demand to the extent they could have.

Today's consumers are increasingly demanding higher and higher quality merchandise in smaller packages or in bulk displays from which they can select any number items. Why do Idaho potatoes consistently command a higher price than their Michigan counterparts? Are Michigan producers of potatoes providing a less desirable product and/or packaging from the consumers' point of view? Competitors in other states have been continually upgrading the quality aspects of their products. Their product lines and packaging have been extended to meet consumers' demands for variety. Over time, this has enabled them to capture a greater share of the household and institutional markets. Michigan producers need to know what product characteristics and packaging options are most important to consumers, and then make appropriate changes.

Methodology:

Four focus groups were held with consumers of fresh potatoes, two with heavy users and two with light users. In this study, a heavy user was defined as someone who purchased ten or more pounds of fresh potatoes in an average month. A light user was defined as someone who purchased less than ten pounds of fresh potatoes in an average month.

Respondents were recruited by telephone. Selected participants were adults most responsible for menu planning and meal preparation in their households. The groups were recruited to include a representation of age, employment patterns, household income and race. One heavy user and one light user focus group were held in Lansing and then duplicated in Detroit. The sessions were conducted by Bonnie J. Knutson, PhD. and were audio taped. The groups began at 5:30 and 7:30 p.m. and lasted between one and one-and-a-half hours. Members of Michigan Potato Industry Commission observed the sessions from behind a one way mirror.

Focus group interviewing consists of bringing together a small group of people, normally 8 to 10 at a time. Then let them talk about a topic, idea product or concept. The unique advantage of focus group interviewing is the dialogue between participants. Members of the group listen and react to each other. Focus group interviews are not projectable in the statistical sense. They provide a base for designing a quantitative study.

Conclusions and Recommendations:

Findings from the four focus groups clearly demonstrate that there is no one single target market for Michigan potatoes. Instead, a wide spectrum of opportunities exist to address the varying needs and wants of consumers. While the question of how to most effectively address the specific interests of each segment needs to be further investigated, this study suggests that there are several common threads which can be utilized through all strategies.

The Positive Image of Michigan Potatoes

Promotion of fresh Michigan potatoes should incorporate the three aspects which consumers view as the product's strengths. First, potatoes, in general are associated with "home, hearth and good food." National trends point to a return to the home (sometimes called "cocooning") fueled by the baby boom generation being in the family formation stage. Additionally, interest in American and regional cuisines, freshness of food products and food as an art is on the rise.

The Michigan potato industry should build on the homey image with the Michigan potato's positive position of high price-value and good all-purpose product. Recent successful examples of similar efforts for other food product are Kellogg's Corn Flakes ("Taste corn flakes again for the very first time") and Campbell's Soups ("Soup is good food").

The Need and Desire for Information

Secondly there is an opportunity for an intensive educational program for consumers. People not only need, but want information that will teach them:

> More and new ways to prepare potatoes that stress (1) variety, (2) ease and convenience (time) in the preparation process, and (3) utilizing the microwave for more than just baking.
>
> Methods of storing potatoes in the home to prolong freshness and shelf life, including where to best store and the advantages and disadvantages of various locations.
>
> How to retain/enhance the nutritional value and the desireable taste characteristics without have to add on what consumers clearly recognize as high-calorie, low nutrition items.
>
> The part that greening of potatoes plays in the entire ground-to-table process.

In this regard, the industry might also consider developing a more "market-friendly" term to identify the greening process. When many people think about vegetation greening, it is usually in a positive light, i.e., the trees are getting green, the tomatoes and apples are getting ripe (losing their green). But in the potato industry, greening is a negative process. This may cause confusion in the consumers' minds. Therefore, while the industry may continue to use and understand the term, a more effective name may be desirable in the marketplace.

The most effective vehicles for informational materials seem to be at the point-of-purchase locations. Most participants indicated that small tear off sheets/cards placed places by the potatoes would be good. Some information if presented clearly and attractively could also be placed on the (paper) bag or on a paper insert in the bag. All educational materials must, of course, invite attention by suggesting that reading will be quick, easy and valuable.

Improved Bagging Alternatives

Thirdly, the Michigan potato industry should investigate the need for increasing bagging alternatives. Of particular appeal to light users would be the availability of a smaller (three pound) bag. In addition, development of a better potato bag should be explored. Characteristics of a superior bag would include (1) expanded visibility of all contents, (2) enhancement of the products shelf life and freshness and (3) prevention of any dirt present on the potatoes from escaping.

Funding MPIC and PPG

THE INFLUENCE OF CHLOROPROPHAM (CIPC) ON POTATO CARBOHYDRATES DURING COMMERCIAL PRODUCTION AND STORAGE

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Good sprout inhibition, in stored potatoes, can be achieved with proper Chloropropham (CIPC) application. CIPC influences many aspects of tuber metabolism, although, its effects on potato carbohydrates has not been fully investigated. This effort was directed at determining changes in glucose, fructose, sucrose and fried chip color of CIPC treated Atlantic potatoes during storage.

Atlantic potatoes were grown at the Montcalm Research Farm (Montcalm County, Michigan) and harvested late in September 1987. Potatoes given regular irrigation (approx. 9 in. of irrigation water), over the course of the growing season, were compared to highly irrigated (approx. 14 in. of irrigation water) potatoes during the study. Thirty pound samples from both regular and high irrigation treatments were placed in double mesh bags and buried three feet deep in a commercial storage bin at the Wayne Lennard & Son's Farm in Samaria, Michigan along with 15,000 hundred weight of Atlantic potatoes. Samples were arranged in the bin to give four replicates, with seven bags per replication. Five pound bags of Russet Burbanks, to be used only for CIPC analysis, were also buried with the Atlantic potato samples. After filling into the storage bin, potatoes were held for three weeks at environmental temperatures to allow for suberization. Potatoes were then treated with CIPC and storage was maintained at 50°F (10°C) and 90% relative humidity for the duration of storage.

Sampling was done 24 hours prior to CIPC application and 2, 30, 60 and 150 days after CIPC application. At each sampling, 4-5 tubers were analyzed for glucose, fructose and sucrose using a YSI Model 27 analyzer. Color of the processed potato chips, prepared from 4-5 tubers, was determined at each sample time, using an Agtron Colorimeter. Specific gravity was determined by a standard weight in water method (PC/SFA Procedure) and CIPC analyses were done by PPG Industries, Inc. (Barberton, OH).

SUGAR ANALYSIS

Figures 1 and 2 show glucose, fructose and sucrose changes of the Atlantic samples during storage. The glucose content in both regular and high irrigation was very low at the outset and remained almost unchanged throughout the study. However, the sucrose content increased by almost 25% during storage of both treatments. The fructose content, which was moderate at the time of storage in both treatments, decreased by 36% for the regular irrigation treatment and 26% for the high irrigation treatment. The sucrose content was higher in the regular irrigation samples than in the high irrigation tubers.

The changes in glucose do not appear to be significant in this study. However, the concentration of fructose and sucrose was consistently higher. Further study is required to determine if increased fructose and sucrose concentration is due to stress during storage or specifically due to CIPC application.

The accumulation of sugars (especially the reducing sugars, glucose and fructose) in chipping potatoes, can result in dark colored chips and a loss in chip quality. Reducing sugars react with amino acids to produce undesirable dark compounds during cooking. It is these dark compounds which produce an unacceptable darkening of chips during frying.

COLOR & SPECIFIC GRAVITY

Table 1 shows the chip color and specific gravity values obtained. Color of chips made from the tuber samples reflected the low to moderate reducing sugar concentration. The regular irrigation samples gave excellent to acceptable chip color. High irrigation samples also gave acceptable chip color except in one case. The average specific gravity over the storage period was slightly higher for regular irrigation (1.087) than for high irrigation (1.083) samples but the treatments were not different.

CIPC RESIDUES

Comparisons of 1986 and 1987 CIPC residues, as determined by PPG Industries, are shown in Table 2. It can be seen that the beginning residue levels varied somewhat between the two years. The initial concentration was almost twice as high in 1986 as in 1987. By 30 days of storage residues were approximately the same for both years and continued to be comparable at 150 days. However, active sprouting had begun by 120 days of storage in 1986 but sprouting was not present at 150 days of storage in 1987.

TABLE 1. AGTRON CHIP COLOR AND SPECIFIC GRAVITY OF ATLANTIC POTATOES IN STORAGE, LENNARD FARM, 1987

	REGULAR IRRIGATION		HIGH IRRIGATION	
SAMPLE TIME	AGTRON[1]	SPECIFIC GRAVITY[2]	AGTRON	SPECIFIC GRAVITY
24 Hours Before CIPC	62 [3]	1.086	55	1.084
2 Days After CIPC	56	1.087	56	1.085
30 Days After CIPC	56	1.086	53	1.082
60 Days After CIPC	64	1.086	66	1.081
150 Days After CIPC	62	1.088	60	1.084

1 Agtron Color > 60 = Excellent; 56-60 = Acceptable; 50-55 = Marginal

2 All specific gravity values are averages of 3 samples

3 Average of 3 values

TABLE 2. COMPARISON OF CIPC RESIDUES FROM 1986 AND 1987 ATLANTIC POTATOES IN STORAGE, LENNARD FARM

DAYS AFTER CIPC APPLICATION	1987 REGULAR IRRIGATION	1987 HIGH IRRIGATION	1986 REGULAR IRRIGATION
2	6.0 PPM [1]	5.6 PPM	11.0 PPM
30	4.6 PPM	3.9 PPM	4.1 PPM
60	4.1 PPM	2.8 PPM	3.5 PPM
150	1.8 PPM	1.6 PPM	1.5 PPM

1 Average of 4 values

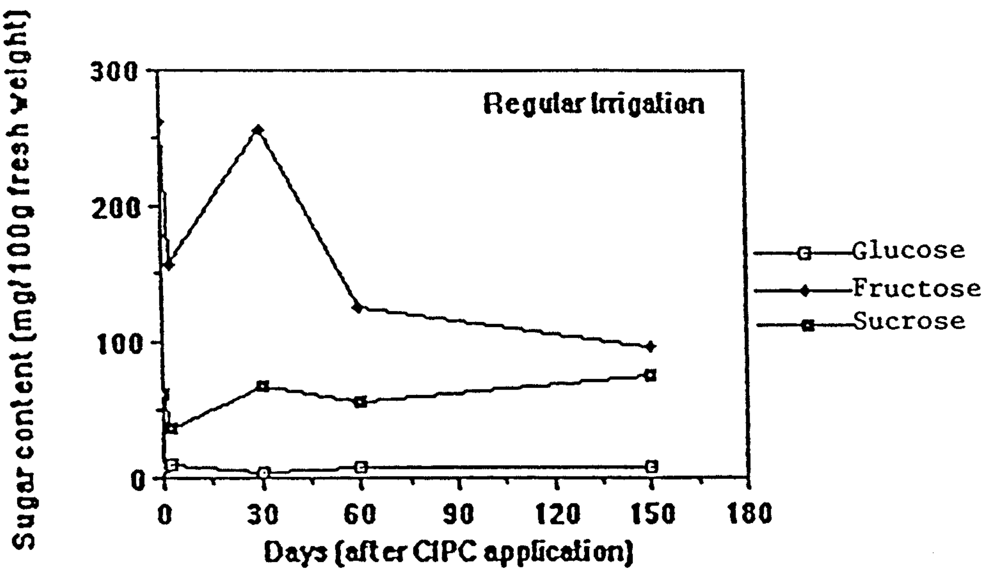

Figure 1. Carbohydrate Content of Atlantic Potatoes in Storage, Lennard Farm, 1987.

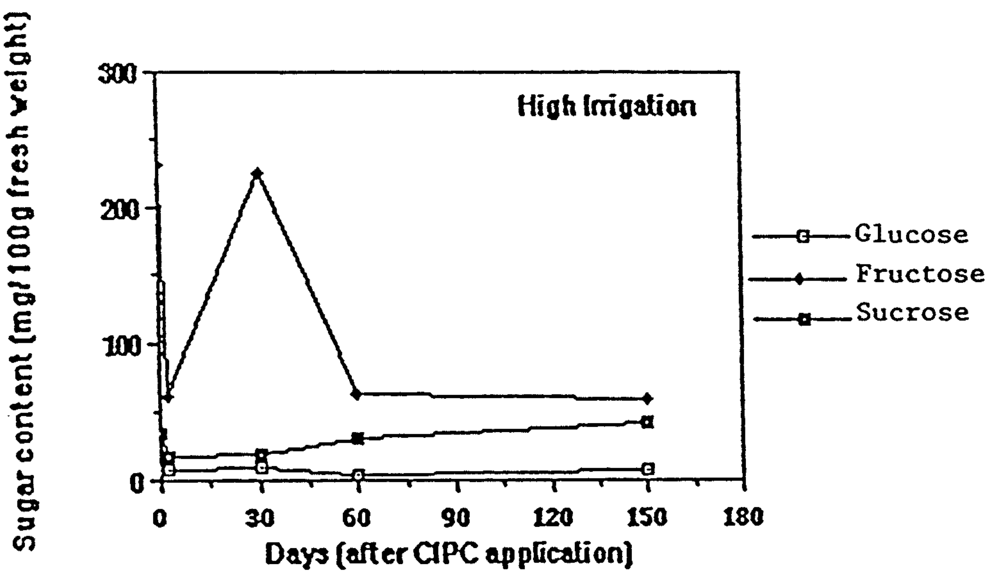

Figure 2. Carbohydrate Content of Atlantic Potatoes in Storage, Lennard Farm, 1987.

Bisulfite Alternatives for Fresh, Peeled Potatoes

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For many years, bisulfites have been used to reduce enzymatic browning and extend the shelf life of many processed food products. However, bisulfites have recently been implicated as harmful compounds for certain individuals with steroid-dependent asthma. Because of this, current and pending legislation is attempting to protect sensitive individuals by restricting the use of sulfiting agents and requiring warning labels on treated foods. Legislation may soon prevent commercial potato processors from treating whole, peeled and refrigerated potatoes with bisulfites. This action would seriously affect processors who depend on these compounds for control of product quality.

Ascorbic acid is an acceptable reducing agent for the prevention of enzymatic browning in fruits and vegetables although it does not exert the same kind of long term control as the bisulfites. Recently, researchers have substituted L-ascorbic acid with the less expensive isomer, D-araboascorbic acid (erythorbic acid), in the commercial processing of frozen apple slices. Research has also shown that combinations of ascorbic, citric and sorbic acid can be used in conjunction with oxygen impermeable packaging to prolong shelf life of horticultural products.

The objectives of this study were to identify alternatives to bisulfite treatment which a) maintain product quality; and b) can be implemented with existing commercial processing equipment.

Whole, abrasion-peeled Russet Burbank potatoes were collected for three trials from a commercial processing line at Pellerito Foods, Inc. Potatoes were treated as follows:

Treatment I: Dipped in water for 2 min., drained packaged in water and metal clipped in Cryovac B540 plastic bags.

Treatment II: Dipped in water for 2 min., drained, packaged in a solution of 0.2% sorbic acid (potassium salt) + 0.2% citric acid (+ 0.25% calcium chloride was added during Trial 2 & 3 only) and sealed in plastic bags.

Treatment III: Dipped in a solution of 3% araboascorbic acid (erythorbic acid) + 2% sodium chloride + 0.25% sodium acid pyrophosphate ($Na_2H_2P_2O_7$) for 2 min., drained, packaged in 0.2% sorbic acid (potassium salt) + 0.2% citric acid (+ 0.25% calcium chloride in Trial 2 & 3 only) and metal clipped in plastic bags.

Treatment IV: Dipped in a 2000 ppm bisulfite solution (sodium metabisulfite) for 1.5 min., drained and metal clipped in plastic bags.

Potatoes were transported to Michigan State University and placed in cold storage (39°F; 3.8^{o}C) for evaluation of color and microbial load.

Color was measured using the Hunter Color Difference Meter (Model D25-2) standardized with a white tile (L_L=92.3; a_L= -1.2; b_L= 0.5). Reflectance measurements were made on slices taken from the surface of two potatoes from each treatment.

Microbial analyses were done using a plate count method. Prepared plates were held at 86°F (30°C) for 24 hours to check for contamination and then inoculated with samples taken from whole peeled potatoes. These swab samples were spread on the surface of the plates, which were incubated at 86^{o}C (30°C) for 48 hours, after which counts were determined using Quebec Colony Counter.

Texture analyses were done using a Food Technology Co., TR-5 Texture Recorder. Weighed equatorial slices from peeled potatoes (1.3 cm thickness) were sheared horizontally in a 10 blade shear-extrusion attachment.

Sensory evaluations were conducted using a triangle test taste panel. Russet Burbank potatoes were removed from cold storage (45°F); 7.2°C), abrasion-peeled and dipped in; (1) water for 2 min., or (2) 3% erythorbic acid + 2% sodium chloride + 0.25% sodium acid pyrophosphate for 2 min., drained, and held in 0.2% sorbic acid (potassium salt) + 0.25% citric acid for 10 days. Potatoes were diced and placed in approximately 5 L boiling water in a steam heated kettle and cooked for 15 min, drained, and mashed.

Sensory evaluations were performed in the Michigan State University, Food Science, Sensory Evaluation Facility. Warm (80°F; 26.6°C) samples (approx. 100 g) were presented to twenty-seven untrained, college-aged men and women panelists in three small dishes identified by three random digit codes. Panelists were requested to choose the odd sample based on flavor and texture, and then requested to give comments. Panelists were also requested to note if the flavor and texture differences detected were objectionable. No information was provided to panelists regarding potato treatments. The data was statistically analyzed using standard statistical methods and statistical tables which were developed for the sensory tests performed.

The color of non-sulfited potatoes was acceptable during the 18 day storage interval for trials 1 & 2 (Table 1 & 2). Potatoes packaged in solutions maintained lightness and were comparable to sulfited potatoes. Potatoes dipped in the erythorbic acid mixture (Treatment III) appeared to be lighter than sulfited potatoes which acquired a yellow tint. Potatoes from all treatments in trial 3, were subjectively determined to have acceptable color after 18 days of storage.

Earlier attempts to control enzymatic browning by dipping potatoes in an erythorbic acid mixture and packing without solution in oxygen-barrier bags following an air evacuation and flush with carbon dioxide or nitrogen were unsuccessful. This may have been caused by a low vacuum or by a poor plastic bag seal. Regardless, incorporation of a packaging system in a commercial facility would be expensive and a significant expense would be added to processed products due to the cost of oxygen-barrier bags. Also, the modified atmosphere package may provide an acceptable growth environment for anaerobic microbial pathogens. Results from this study, indicated that a significant improvement in color was achieved when potatoes were packaged in solution without oxygen-barrier bags being used.

During the preparation of potatoes for sensory evaluation, it was observed that potatoes dipped in the erythorbic and citric acid mixtures prior to cooking remained very light, whereas, the potatoes dipped in water turned grey. The grey metallic tint is due to an "after-cooking" darkening which requires iron cations. For the antioxidant treated potatoes, the iron is chelated by sodium acid pyrophosphate and citric acid and the darkening reaction is inhibited. In addition, the antioxidant solutions reduce the enzymatic browning reactions which occur during the initial warming of the potatoes.

The microbial load for potatoes packaged in the citric acid mixture (Treatments II & III) were generally lower at 6 days of storage than water packed or bisulfite treated. The elevated microbial load for Treatment I indicates that spoilage renders the product unacceptable long before the color changes. A strong aroma was observed due to spoilage for all the Treatment I samples by 6 days of storage. The sulfited potatoes (Treatment IV) did not have a strong spoilage aroma until 9 days of storage during the 3 trials. Commercial processors expect sulfited potatoes to maintain acceptable quality for 5 to 7 days prior to further processing. The lower microbial loads for Treatments II & III compared to Treatments I & IV, appear to be due to the acidification and microbial static properties of citric acid and sorbic acid, respectively. Incorporation of further additives may further extend the shelf life of refrigerated potatoes.

Sensory analysis of mashed potatoes indicated that only 8 out of 27 panelists were able to correctly identify the odd sample. Statistically, this means that no apparent differences (p=0.05) for texture and flavor were detected between potatoes dipped in water and potatoes dipped in erythorbic acid and citric acid mixtures. Only one panelist who correctly selected the odd sample noted an objectionable flavor while one other panelist noted an objectionable texture.

In this work, potatoes were packaged in 30 pound plastic pails. The citric/sorbic acid solution needed to fill the pail added 10-15 pounds to the shipping weight. This is a major consideration in light of shipping and handling charges. However, it is felt that the amount of solution can be drastically reduced without increasing enzymatic browning. Further work is needed to determine the minimum amount of packing solution required.

The alternatives to bisulfite suggested here have several advantages. First there is greater consumer perception of safety for potatoes treated with the erythorbic acid and citric acid mixtures as compared to sulfiting agents. Second, the procedure for treating potatoes with erythorbic acid dip permits the reuse of the solution. It is likely that this solution will need to be recharged with erythorbic acid during the course of a processing day because oxidation of erythorbic acid during processing of potatoes reduces the effectiveness of the antioxidant to 'scavange oxygen' and reduce the o-quinone product of enzymatic browning. Third, the proposed system increases the storage life of potatoes by several days. The storage life of potatoes from Treatment II & III was between 6 and 9 days based on microbial spoilage. Fourth, this process can be implemented with existing equipment and processing procedure. Packaging systems preently in use would require minimal modifications for packing potatoes in solution.

Table 1. Mean Hunter Color Measurements (L_L-value[a]) for Trial 1.

	Storage Time (Days; n=3)				
Treatment	Day 3	Day 6	Day 9	Day 12	Day 18
I[b]	62.3	65.5	62.4	65.7	66.9
II[c]	66.4	68.5	67.0	68.9	69.0
III[d]	65.0	67.5	67.0	66.2	68.8
IV[e]	64.1	66.4	62.9	65.1	66.2

[a]Hunter L_L-values range from 0=black to 100=white.

[b]Potatoes dipped in H_2O and packaged in H_2O.

[c]Potatoes dipped in H_2O and packaged in citric acid and sorbic acid.

[d]Potatoes dipped in erythorbic acid, sodium acid pyrophosphate and sodium chloride, then packaged in citric acid and sorbic acid.

[e]Potatoes dipped in bisulfite, drained and packaged.

Table 2. Mean Hunter Color Measurements (L_L-value[a]) for Trial 2.

	Storage Time (Days; n=3)				
Treatment	Dav 3	Day 6	Day 9	Day 12	Day 18
I[b]	61.1	60.7	59.2	60.1	62.8
II[c]	65.2	65.0	63.8	64.0	65.8
III[d]	66.2	65.1	63.3	63.5	64.6
IV[e]	64.5	64.3	64.3	62.4	62.9

[a]Hunter L_L-values range from 0=black to 100=white.

[b]Potatoes dipped in H_2O and packaged in H_2O.

[c]Potatoes dipped in H_2O and packaged in citric acid and sorbic acid and calcium chloride.

[d]Potatoes dipped in erythorbic acid, sodium acid pyrophosphate and sodium chloride, then packaged in citric acid and sorbic acid.

[e]Potatoes dipped in bisulfite, drained and packaged.

Table 3. Microbiological Load (CFU[a]/cm^2) for Trials 1 & 2.

Treatment	Storage Time (Trial 1) Day 6	Storage Time (Trial 1) Day 12	Storage Time (Trial 2) Day 6	Storage Time (Trial 2) Day 12
I[b]	1.4×10^5	3.4×10^5	3.4×10^5	106
II[c]	$< 10^2$	$< 10^2$	$< 10^2$	10^6
III[d]	$< 10^2$	3.7×10^3	$< 10^2$	10^6
IV[e]	4.5×10^3	9.2×10^6	4.1×10^4	10^6

[a]CFU - Colony Forming Units.

[b]Potatoes dipped in H_2O and packaged in H_2O.

[c]Potatoes dipped in H_2O and packaged in citric acid and sorbic acid and calcium chloride.

[d]Potatoes dipped in erythorbic acid, sodium acid pyrophosphate and sodium chloride, then packaged in citric acid and sorbic acid.

[e]Potatoes dipped in bisulfite, drained and packaged.

Table 4. Microbiological Load (CFU[a]/cm^2) for Trial 3.

Storage Time (Days; n=3)

Treatment	Day 3	Day 6	Day 9	Day 12
I[b]	6.6×10^4	2.7×10^5	$>10^6$	$> 10^6$
II[c]	$< 10^2$	$< 10^3$	3.8×10^5	$> 10^6$
III[d]	$< 10^2$	5.3×10^3	$>10^6$	$> 10^6$
IV[e]	$< 10^3$	3.8×10^3	$>10^6$	$> 10^6$

[a]CFU - Colony Forming Units.

[b]Potatoes dipped in H_2O and packaged in H_2O.

[c]Potatoes dipped in H_2O and packaged in citric acid and sorbic acid and calcium chloride.

[d]Potatoes dipped in erythorbic acid, sodium acid pyrophosphate and sodium chloride, then packaged in citric acid and sorbic acid.

[e]Potatoes dipped in bisulfite, drained and packaged.

POTATO STORAGE RESEARCH — PHASE C (THIRD YEAR)

INVESTIGATORS Roger Brook And Todd Forbush

OBJECTIVE

The general goal of this project is to develop and validate an improved MSU Simulated Storage system in which the environmental conditions can be controlled, monitored, and replicated to study potatoes over an extended storage season.

Specific objectives of this year's research include:

- to expand the instrumentation of the MSU Simulated Storage to include monitoring of carbon dioxide and oxygen levels at several points in the storage,
- to continue monitoring of the MSU Simulated Storages for environmental effects on potato quality at several airflow levels, and to compare this data with the results of related ongoing research on potato quality,
- to evaluate existing simulation models of potato storage as compared to the current MSU Simulated Storages for their usefulness in evaluating storage options and management practices.

METHODS/PROCEDURES

Storage System

Three Simulated Storages were placed within a commercial potato storage facility at Sandyland Farms Inc. (Howard City MI). The storage system has been described in more detail in previous reports and in technical research papers.[1] The bins were reduced in size to result in 64 $ft.^2$ cross-sectional area. This gave a storage capacity of roughly 360 cwt. per bin. A floor plan of the facility is shown in Figure 1.

Ventilation System

Each Simulated Storage is equipped with a ventilation system which is independent of the other storages. Bins #1 and #2 are equipped with ventilation systems designed at 1.5 and 3.0 cfm/cwt, respectively. Bin #3 is equipped with a variable speed fan that is capable of delivering up to 3 cfm/cwt.

The intake air is drawn from the attic of the commercial building. It is distributed to the three Simulated Storages through a common "fresh air manifold" so that these bins have access to the same intake air. In previous years, the ventilation systems of the Simulated Storages exhausted into the commercial bin via pressure louvers. The ventilation system was modified by the addition of an exhaust air duct. This duct reduced the effect of the pressure in the commercial bin on the exhausting of fresh air. Additional modifications to the exhaust system were made on November 10, 1987, which involved the addition of a small exhaust fan to each bin. The fans were controlled by the signal for fresh air from the computer, and were run any time the bins required fresh air.

Control System

The ventilation system was controlled using a 1056 FANCOM environmental control computer developed in The Netherlands by FANCOM Computers Inc. (commercially available at Techmark Inc., Lansing MI).[2] The fans ran to correct pile temperature differentials and any time fresh air was required. In bins #1 and #2 with single speed fans, the fan came on full speed if any air movement was requested by the computer. In bin #3 with the variable speed fan, the computer determined the volume of air required to resolve the temperature problems.

Data Collection

Changes to the data collection system included the following items:

- expanding the gas sampling to include the sensing of four gas levels within each bin;
- ability to determine the amount of oxygen and the amount of carbon dioxide, present within the pile during the storage season;
- additional relative humidity sensors (aspirated wet bulb/dry bulb psychrometer) to determine the humidity of the air above the pile;
- increase the resolution of the in-pile temperature sensors from 0.5 °C to 0.1 °C;
- change room temperature control to read from the relative humidity sensor above the pile (this change eliminated the problem of a quick response experienced when controlling via the plenum temperature);
- install air volume sensors in the fresh air and recirculation air louvers to determine the amount of air moving, and the source of the air.

Potato Samples

Sample bags (25 lb.) were placed within each of the Simulated Storages at levels of 4 ft., 8 ft., and 12 ft. from the floor of the storage (4 bags per level). Upon removal from storage, these samples were evaluated for weight loss and for changes in sugar content during storage. Each bin was also evaluated by Frito-Lay (Allen Park, MI) at the time of removal for its value to the potato chipping industry.

RESULTS AND DISCUSSION

Management of Storages

The potatoes for the Simulated Storages were harvested on October 5, 1987. Potato variability into storage was reduced by filling the three Simulated Storages from one field in one day. The pulp temperature of the potatoes was 50.5 °F. The potato piles were allowed to rise in temperature without ventilation to 60 °F. This took between 5 and 8 days; bins #1 and #2 took five days, and bin #3 took 8 days.

When the potatoes had obtained the 60 °F temperature level, the ventilation system was programmed to maintain this temperature for "pre-conditioning". The potatoes were treated with CIPC sprout inhibitor on November 13, 1987, to reduce the possibility of sprouting in long term storage. The pile temperature was held at 60°F until November 16, 1987. Then, the management scheme was to lower the desired temperature 1 °F per week until the potatoes reached a temperature of 50°F, or until marketing them. The relative humidity of the storage was maintained as close to 92% RH as possible with a small humidifier in the main air plenum of each bin.

Condensation was noted on the surface of Bin #1 on December 29, 1987. The humidifier was then turned off, but the fan was left to the control of the computer until January 4, 1988, when the fan was put on continuous circulation. The bin was marketed on January 27, 1988.

Bin #2 was marketed on February 16, 1988. Bin #3 was marketed on February 23, 1988.

Fan Operation

An analysis of data from the storage season yielded the data in Table 1 for air volume and reason for fan operation. The length of season varied for each bin because of staggered unloading. The data shows that the fan in the high airflow volume bin (bin #2) ran nearly the same amount of time as the low airflow volume bin (bin #1). This resulted in just over twice the total volume of air, since the specific volume of air flow was twice as large.

The average operation period for the maintenance of uniform pile temperature ranged from 6.4 hr. for bin #2 to 20 hr. for bin #1 (around December 29, 1987). The increased operation time in bin #1 was due to increased fan operation to counteract the

TABLE 1: Fan time operation analysis for the Simulated Storages, 1987-1988 storage season.

Bin Number	1	2	3
Time, days	114	134	142
Airflow, cfm/cwt	1.5	3.0	1.4[x]
Fan Time			
hours	1077	1381	2352
%	39	43	69
Number of Cycles			
pile temperature diff	46	92	126
fresh air required	68	146	238
Cycle Time, hr			
pile temperature diff	2.4	6.4	12.0
fresh air required	2.3[xx]	5.4	3.5
Cycle Reason, %			
pile temperature diff	85	43	64
fresh air required	15	57	36

[x] Variable airflow, value is average airflow for season
[xx] Season until Dec. 29 only

natural convection which occurred within the pile during extended periods without ventilation. If this period of operation for bin #1 is taken out of the season, the average period for maintenance was 2.3 hr. per cycle.

The high cycle time for correction of pile temperature for the high airflow bin (5.4 hr. for bin #2) may have resulted from a temperature fluctuation within the pile from the "blast" of cool air used to cool the pile. Such a "blast" would then require additional ventilation to complete the required temperature correction. The fans cycled 68, 146, and 238 times for temperature correction throughout the season.

On the average, the fans cycled 1, 1.8 and 2.6 times per day, with periods without ventilation ranging from a few hours to nearly a week. The reason for the increased cycling in bin #3 (variable airflow) may have been the low airflow that was used. On the average the airflow was 1.4 cfm/cwt, with volumes as high as 3 cfm/cwt. Long periods of low volume air (.0 cfm/cwt) were recorded for pile temperature maintenance ventilation. This would suggest that the influences may need to be changed to increase the volume of airflow for different problems. In bin #2, the high airflow rate may have resulted in the high frequency of fan cycling. High airflow rates cause sudden changes, which may over compensate for small troubles.

Environment Control

Table 2 presents the data for temperature and relative humidity control in the Simulated Storages. The data show an adequate control of pile temperature in all three bins, as compared to the criteria of an allowed temperature differential within the pile of 1.1°F, and allowed control range on average temperature of 0.5°F. The average temperatures for bins #1, #2 and #3 are shown in Figure 2. Representative temperature and airflow data for bin #2 are shown in Figure 3. Representative carbon dioxide, oxygen and airflow data for bin #3 are shown in Figure 4.

The data also show good control of the relative humidity within less than 5% (Bins #1 and #3) and 7.5% (Bin #2) of the desired value of 92%, as measured by an aspirated psychrometer.

Potato Quality

Table 3 presents the data generated by Frito-Lay on the usefulness of the potatoes from the Simulated Storages for sale as chipping potatoes, plus the weight loss observed for the sample bags within the pile. Note that the higher solids in bin #3 correlated roughly with the increased weight loss observed. Table 4 presents the results of the sugar analysis before harvest, and for the sample bags within the pile. The percent glucose readings before harvest suggest that some reducing sugars must be burned off in storage before acceptable chip colors are obtained. Chip color was initially

TABLE 2: Temperature and relative humidity control for the simulated storage bins during the 1987-1988 storage season.

Bin	#1	#2	#3
Difference between highest and lowest measured pile temperatures			
Average difference, °F	1.1	1.2	1.5
Lowest difference, °F	0.0	0.0	0.0
Highest difference, °F	1.8	2.9	3.5
Difference between desired and measured pile temperature			
Average difference, °F	0.4	0.3	0.4
Lowest difference, °F	0.0	0.0	0.0
Highest difference, °F	1.3	1.8	2.5
Difference between desired and measured relative humidity			
Average difference, %	3.6	6.4	3.3
Lowest difference, %	0.0	0.0	0.0
Highest difference, %	14.0	14.0	11.0

unacceptable. However, as time progressed from the October 5 loading data into early November, the chip color problem cleared up. This would suggest that potato respiration cleared the pool of glucose (reducing sugar).

COMPUTER SIMULATION

Methods and Procedures

A computer simulation model[3] which predicts heat generation and condensation due to tuber surface temperature differences, was modified and used for this study. The temperature difference problem studied was that of having 6.5 ft. of 70°F potatoes in the lower portion of the pile, and 6.5 ft. of 50°F potatoes in the upper half of the pile. This condition could occur when a bin has been partially filled one day, and then opened on the next day to continue filling. The problem with this condition is the possibility of condensation forming on the cooler potatoes due to the warm, moist air rising from the warmer potatoes. The resulting condensation could cause spoilage of potatoes along the temperature interface.

The ventilation management schemes investigated were as follows:

- No Ventilation
- Complete Recirculation with 1.5 cfm/cwt ventilation
- Fixed Inlet Conditions of:
  - 60°F, 65 % RH, with 0.75 cfm/cwt ventilation
  - 60°F, 65 % RH, with 1.5 cfm/cwt ventilation
  - 60°F, 65 % RH, with 3.0 cfm/cwt ventilation
  - 60°F, 80 % RH, with 0.75 cfm/cwt ventilation
  - 60°F, 80 % RH, with 1.5 cfm/cwt ventilation
  - 60°F, 80 % RH, with 3.0 cfm/cwt ventilation

The tubers were subjected to specific inlet conditions. The temperature value was chosen as the mean temperature of the two lots of potatoes, and the humidity and ventilation rate were varied. These conditions were chosen to agree with the typical fall weather conditions in Michigan.

Results and Discussion

Weight Loss

The simulation results suggests that the weight loss percentage increases with the ventilation rate. However this is a function of the water on the tuber surface. The amount of water removed from within the tuber is negligible until the surface moisture is removed. Therefore, the longer the tubers are covered with moisture, the lower the weight loss will be. The lowest predicted weight loss was with the recirculation run. However, this type of ventilation did not remove moisture satisfactorily, as explained below. The weight loss values or the 0.75 cfm/cwt, 65% RH and the 1.5 cfm/cwt, 80% RH were predicted to be similar.

TABLE 3: Frito-Lay cook tests and weight loss for samples from simulated storages, 1987-1988 storage season.

Pile Level	4'	8'	12'
Bin #1			
Color	62	63	63
% Solids	16.2	16.5	15.9
Appearance	0	0	0
% Weight Loss	4.4	5.3	6.7
Bin #2			
Color	63	63	62
% Solids	17.4	16.5	17.8
Appearance	3	0	1
% Weight Loss	7.8	7.9	8.0
Bin #3			
Color	63	60	63
% Solids	18.8	18.0	17.4
Appearance	2	0	0
% Weight Loss	9.2	10.4	8.2

Condensation

Running the ventilation system in a complete recirculation mode slowly moved the condensation layer through the top of the pile, and placed this moisture into the lower regions of the pile. Thus, condensation at all levels of the pile was predicted. Once the air that is present in a tightly sealed building is at the saturation point, additional water cannot be absorbed by the air. This pattern is expected to continue until some moisture is removed from the structure, or the air is heated to a sufficient level to absorb this moisture. This may occur by heat generation within the pile. However these high temperatures would detrimental to the tuber in terms of soft rot infestation.

From this simulation, the tubers were subjected to specific inlet conditions. The temperature value was chosen as the mean temperature of the two lots of potatoes, and the humidity and ventilation rate were varied.

As the ventilation rate was increased, the time required to remove surface condensation decreased (see Table 5). Increasing the ventilation from 0.75 cfm/cwt to 1.5 cfm/cwt decreased the time to remove the surface condensation by 44%. The increase from 1.5 to 3.0 cfm/cwt decreased the time for removal of condensation by 56%. The effect of decreasing inlet relative humidity was to decrease the time required to remove the surface moisture. At the 1.5 cfm/cwt a decrease of the inlet relative humidity from 80% to 65% decreased the time required to remove surface condensation by 56%.

Temperature

The simulation results suggest that the time required to obtain a uniform temperature gradient (+_2°C) within the potato pile is 20 to 30 hours for both the 1.5 and 3.0 cfm/cwt ventilation rates at both relative humidity levels (see Table 5). The uniform pile temperature was not obtained within the same limits with the low ventilation rate, or recirculation simulations.

TABLE 4: Sugar content analysis for samples from Simulated Storages, 1987-1988 storage season.

Date or location	Sample No.	Glucose	Sucrose	Total Sugars
Pre-harvest samples				
8-15-87	1	0.04	0.52	0.56
8-25-87	2	0.05	0.22	0.27
8-29-87	3	0.05	0.15	0.20
9-08-87	4	0.05	0.45	0.50
9-16-87	5*	0.04	0.40	0.44
9-18-87	6	0.05	0.39	0.44
10-02-87	7	0.05	0.47	0.52
10-07-87	8	0.06	0.79	0.85
Bin #1				
4'	56	0.010	0.08	0.09
8'	B65	0.006	0.06	0.06
12'	52	0.016	0.08	0.10
Bin #2				
4'	59	0.010	0.15	0.16
8'	B60	0.006	0.10	0.10
12'	B73	0.006	0.09	0.10
Bin #3				
4'	57	0.022	0.56	0.58
8'	B77	0.027	0.61	0.63
12'	B79	0.027	0.41	0.43

* Vine kill

The temperature change within any single layer of the pile over a period of time was also calculated (see Table 5). A sudden decrease in temperature may cause the potato respiration to decrease, therefore causing an imbalance of the sugar content in the potato. If this imbalance continues to exist into the storage season, the potatoes may be unsuitable for the process industry.

The largest temperature decrease took place within the 1.5 ft. depth of the recirculation simulation, where the potato temperature decreased 16.2°F (70 °F to 53.8°F) in 10 hours. This type of temperature stress could be expected to reduce respiration rate, which may result in reducing sugar build-up within the tuber. The temperature decrease was not as sever in the 80 % RH simulations with ventilation temperature set at 60°F. This was due to a reduction in evaporative surface cooling in the tubers from a lower vapor pressure differential.

Management Suggestions

The following management suggestions are made with the results of the above simulations in mind:

- Avoid the condition of placing cool potatoes in contact with warm potatoes when filling a potato storage bin.
- If cool potatoes are placed in contact with warm potatoes, run the fans at 1.5 cfm/cwt. Set the inlet air at the average of the pulp temperatures of the two lots and 80% RH.
- Observe the top of the pile, when condensation (a water film on the lower side of the potato tubers) appears, continue ventilation until it is removed, then return to normal management practices.
- Market these potatoes as soon as possible.

TABLE 5: Time requirements and temperature change information for different siumlation conditions.

	Time to Remove Condensation	Time to Uniform Temperature	Maximum Temperature Change
Recirculation	280	100	16.4 (70 - 53.6)
65%, 0.75 cfm/cwt	100	300	10.8 (70 - 59.2)
80%, 0.75 cfm/cwt	160	110	10.6 (70 - 59.4)
65%, 1.5 cfm/cwt	40	30	11.7 (70 - 58.3)
80%, 1.5 cfm/cwt	90	30	10.8 (70 - 59.2)
65%, 3.0 cfm/cwt	- 20	30	12.4 (70 - 57.6)
80%, 3.0 cfm/cwt	40	20	11.3 (70 - 58.7)

[1] Trade names are used in the paper solely to provide specific information. Mention of a trade name does not constitute a warranty of the product by Michigan State University or the United States Department of Agriculture or an endorsement of the product to the exclusion of other products not mentioned.

[2] For more details on the control system, see the following:

Forbush, T.D., Cargill, B.F. and Brook, R.C. Sensing, monitoring and controlling potato storage environments - a progress report. Tech. Paper 87-4067. ASAE, St. Joseph, MI.

[3] For more details on the computer simulation model, see the following:

Lerew, L. E., 1978. Development of a temperature- weight loss model for bulk stored potatoes. Unpubl. Ph.D. thesis, Michigan State Univ., E. Lansing MI.

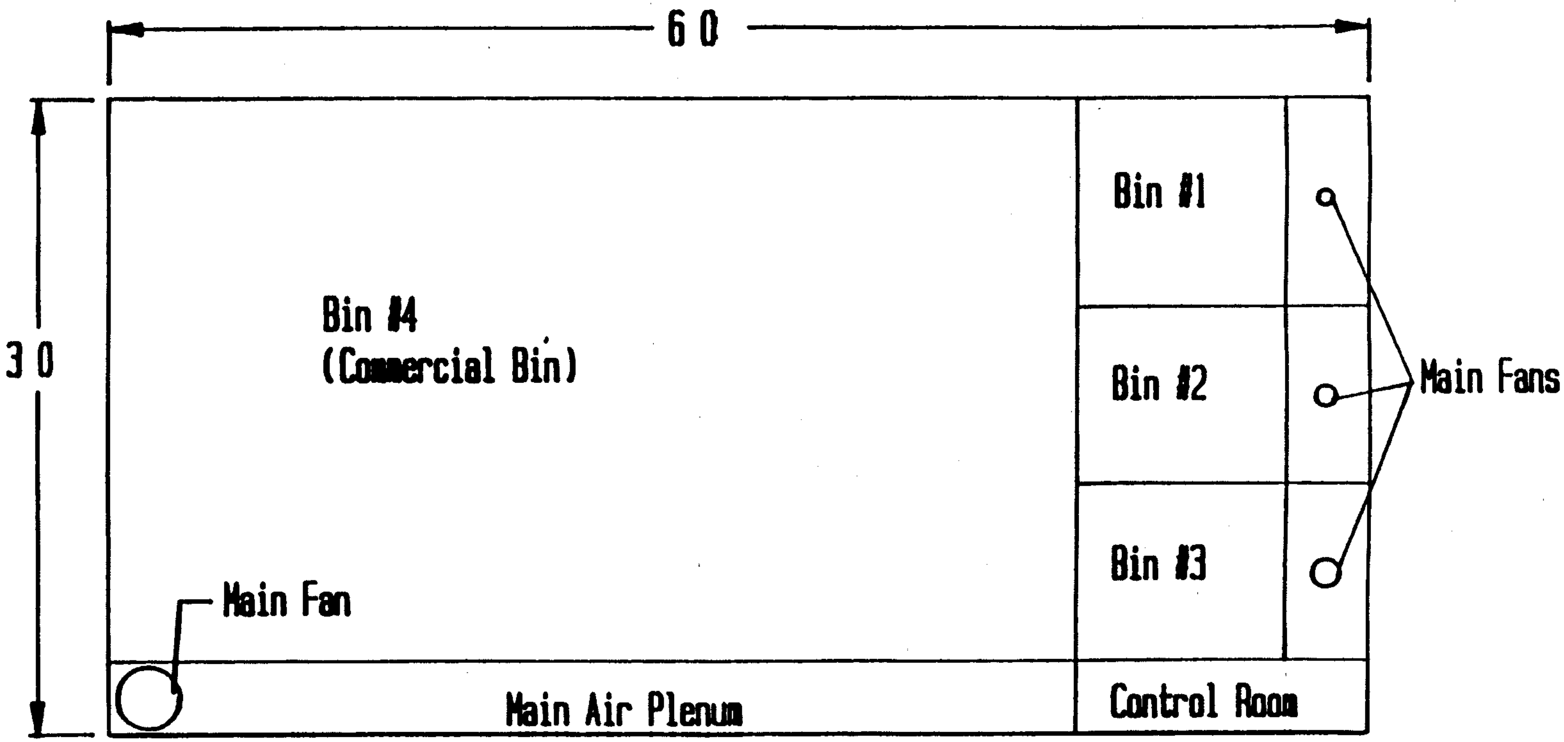

FIGURE 1: Floor plan of the Simulated Storage research facility (scale 1:10)

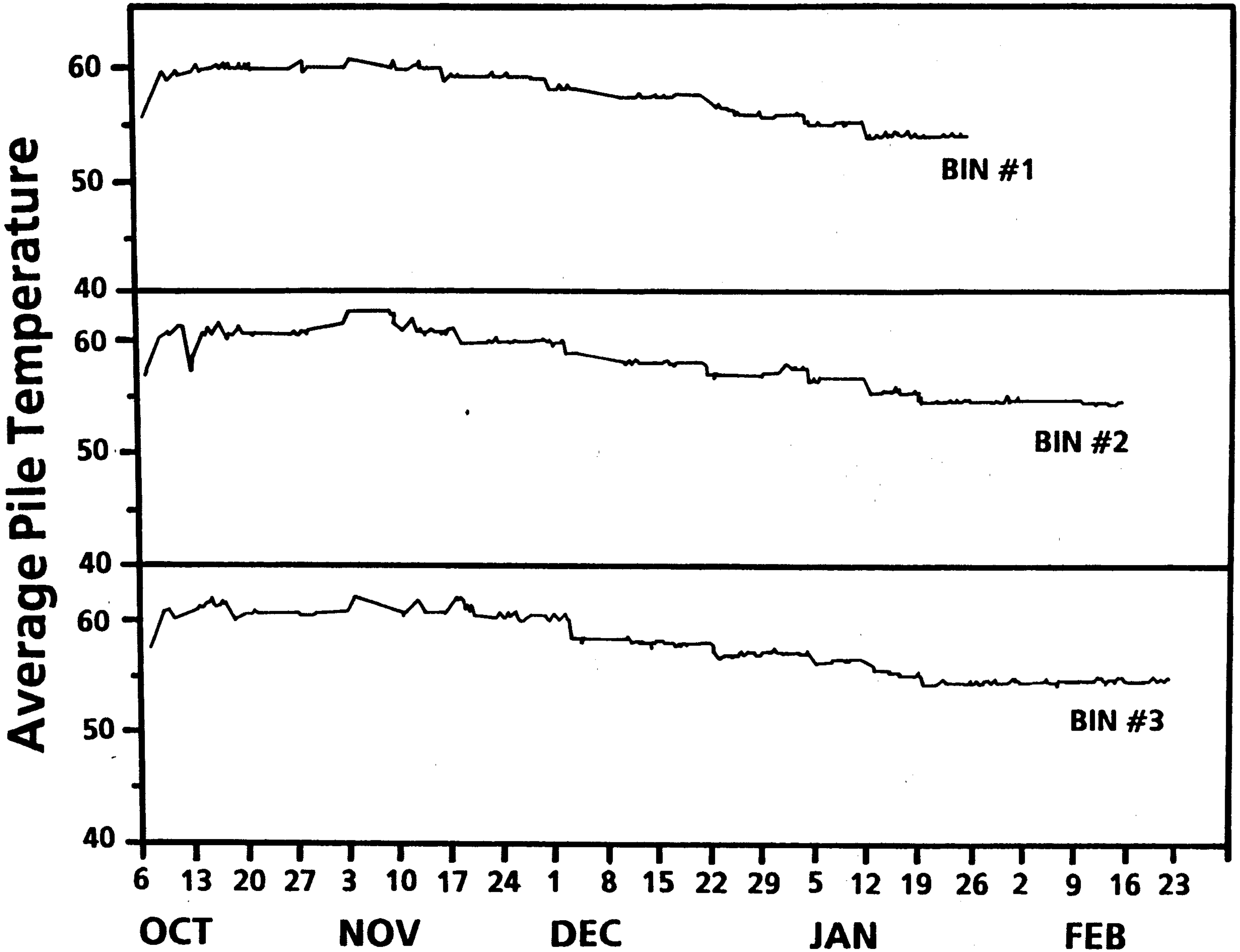

FIGURE 2: Average potato pile temperature for the 1987-1988 storage season.

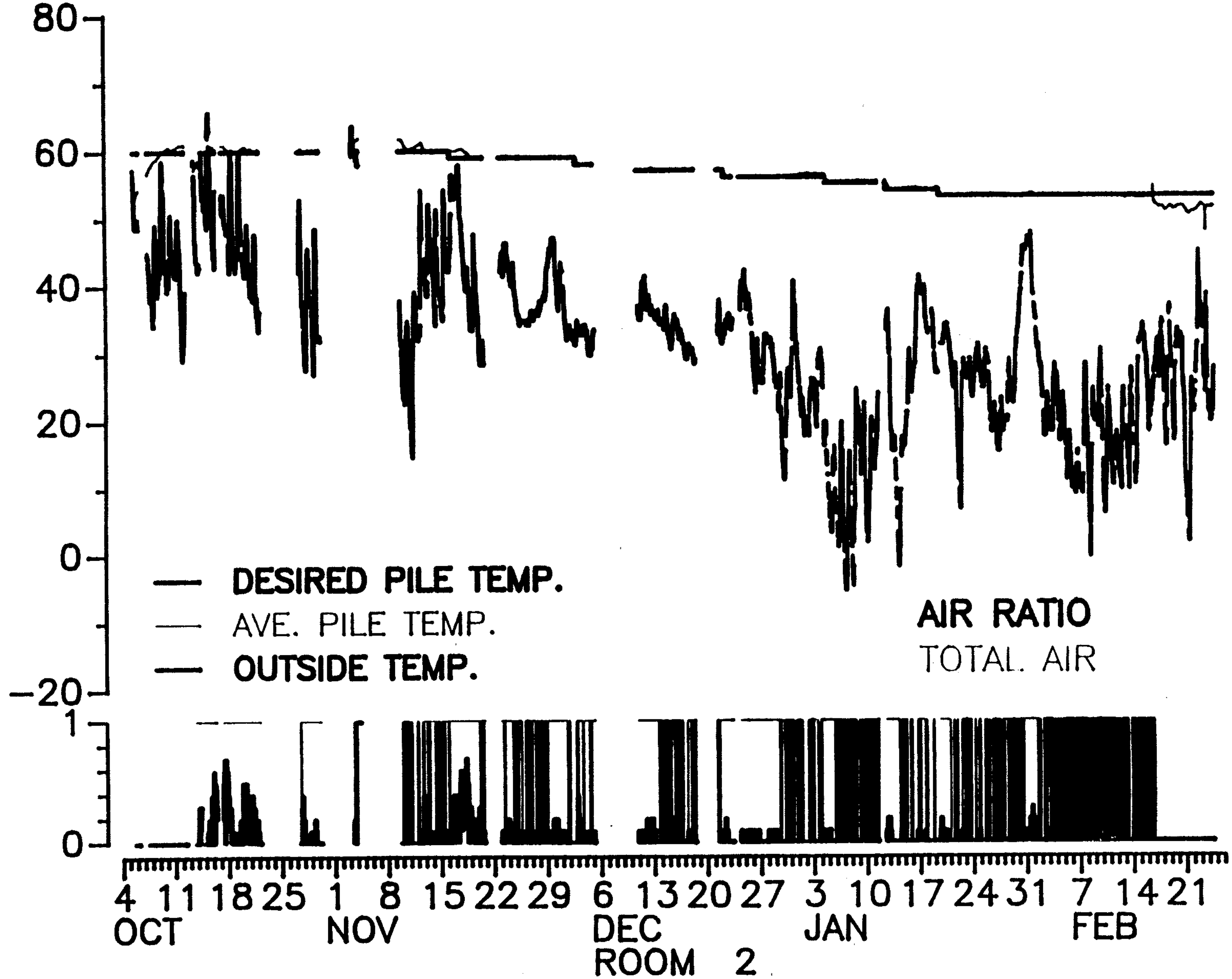

FIGURE 3: Representative temperature and airflow data for bin #2 for the 1987-1988 storage season.

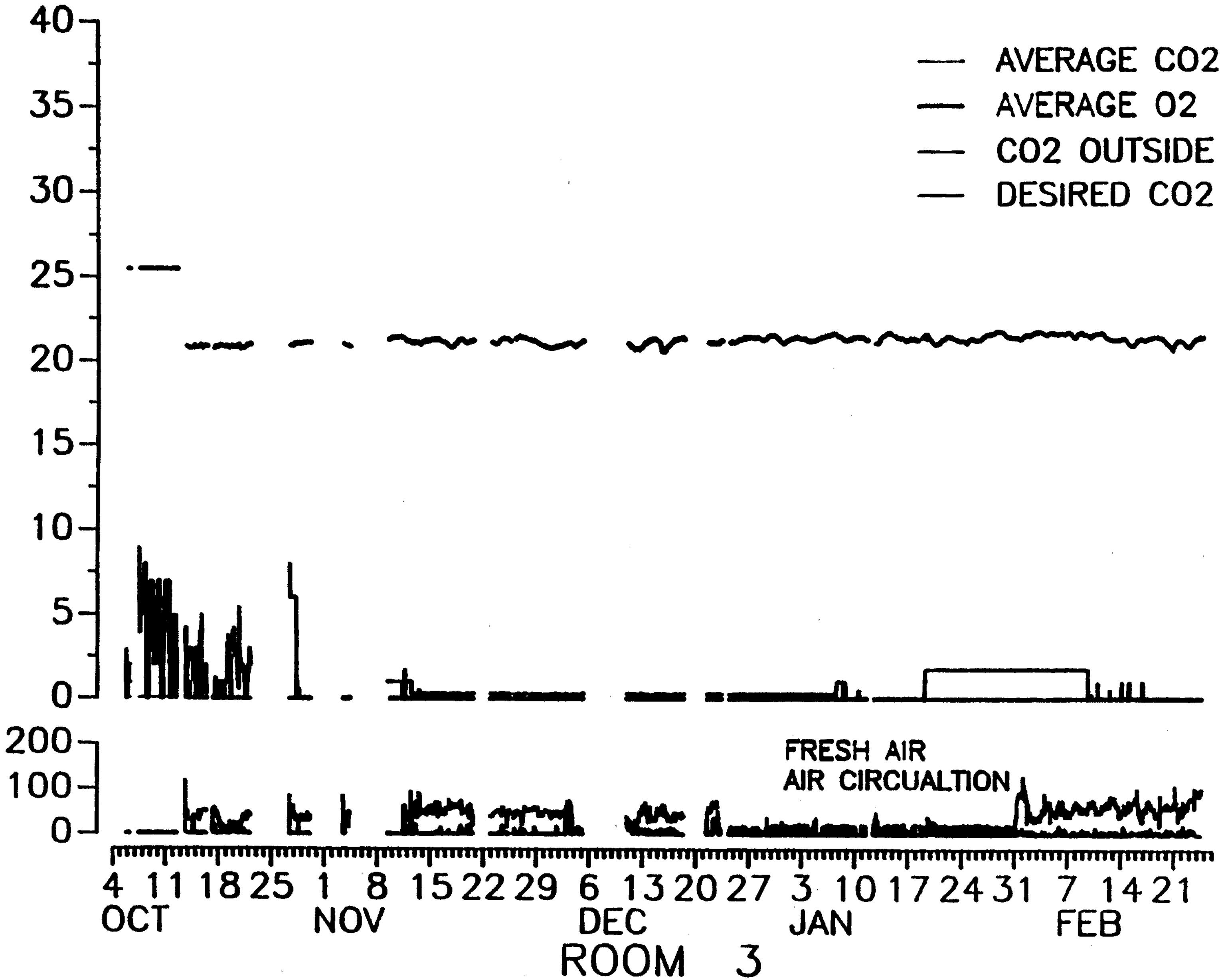

FIGURE 4: Representative oxygen, carbon dioxide and airflow datao for bin #2 for the 1987-1988 storage season.

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