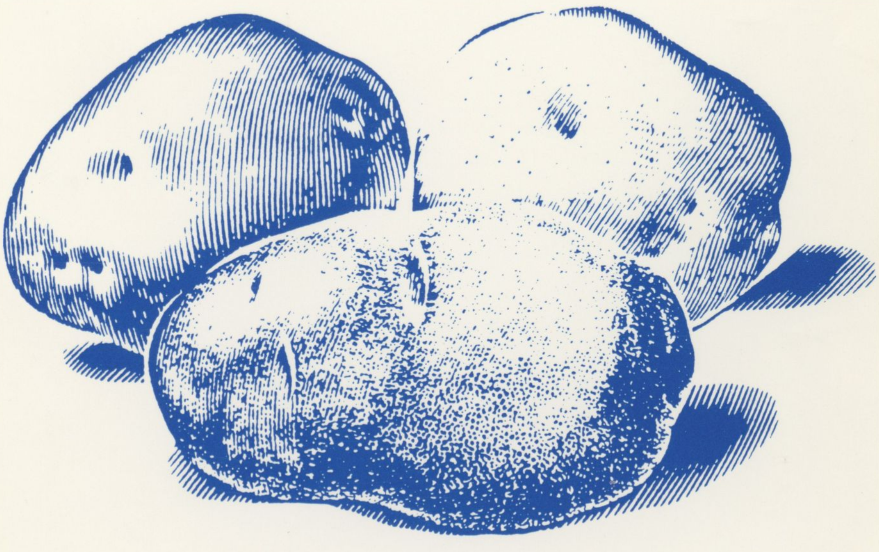
1992
MICHIGAN POTATO RESEARCH REPORT

VOLUME 24



Michigan State University
Agricultural Experiment Station

In Cooperation With

The Michigan Potato Industry Commission

THE MICHIGAN POTATO INDUSTRY COMMISSION

February 12, 1993

To All Michigan Potato Growers & Shippers:

The Michigan Potato Industry Commission, Michigan State University's Agricultural Experiment Station and Cooperative Extension Service are pleased to provide you with a copy of the results from the 1992 potato research projects.

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

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

Best wishes for a prosperous '93 season,

The Michigan Potato Industry Commission

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

TABLE OF CONTENTS

Page

1992 MSU POTATO RESEARCH REPORT

R.W. Chase, Coordinator

Introduction and Acknowledgements

The 1992 Potato Research Report contains reports of potato research projects conducted by MSU potato researchers at several different locations. The 1992 report is the 24th report which has been prepared annually since 1969. This volume includes research projects funded by the Special Federal Grant 88-34141-3372, the Michigan Potato Industry Commission and numerous other sources. The principal source of funding for each project has been noted at the beginning of each report.

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

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

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

Thanks go to Dick Crawford, for the day-to-day operations at the Research Farm; Jeff Smeenk, CSS Potato Technician and Dr. Kazimierz Jastrzebski, visiting scientist from Poland. Also, a special thanks to Jodie Schonfelder for the typing and preparation of this report.

Weather

The 1992 growing season was almost a direct contrast to 1991 which was noted in the 1991 Report as a "quick" season. Tables 1 and 2 summarizes the temperatures and rainfall for the 1992 growing season along with the 15 year average. A month by month comparison between 1991 and 1992 shows the overall temperature difference.

Since 1991, heat unit terminology has been more common. Using a base 50 degree day calculation at the Vestaburg weather station, the number of degree days as of September 8, 1992 were 1,810. At the same date in 1991, there were 2,477 degree days, a reduction of 27%. In 1992 there were only eight days when the temperature exceeded 85°F and only one of these exceeded 90°F. A hard frost occurred on May 25 and a lighter one on June 22.

Rainfall totals for April-September, 1992 were 15.33 inches, 6 inches below 1991 and 4¼ inches below the 15 year average. May and June were the driest months and both were below the 15 year average, particularly May.

Soil Tests

Soil tests for the general plot area were:

	lbs/A				Cation Exchange Capacity
pH	P_2O_5	K_2O	Ca	Mg	
5.6	383	152	610	124	5.8 me/100 g

Previous Crops and Fertilizers

The general plot area was planted to drilled soybeans in 1991 which were disked in late summer and seeded to winter rye at 1½ bushels/A. Except in fertilizer trials, where the amounts of fertilizers applied are specified in the individual project reports, the following fertilizers were used in the potato trials:

	Analysis		Nutrients
plowdown	0-0-50	350 lbs/A	0-0-175
banded at planting	20-10-10	200 lbs/A	40-20-20
broadcast at emergence	34-0-0	150 lbs/A	51-0-0
sidedress at hilling	46-0-0	100 lbs/A	46-0-0
irrigation	28-0-0	15 gals/A	42-0-0
irrigation (RB ranges)	28-0-0	15 gals/A	42-0-0

Herbicides

A tank mix of metolachlor (Dual) at 2 lbs/A plus metribuzin (Sencor) at ½ lb/A was applied preemergence. Hilling was completed when plants were 10-12" tall (mid June). Wild buckwheat has become a significant weed problem in recent years and this treatment has not provided adequate control.

Irrigation

Irrigation was initiated on May 26 and 12 applications were made during the growing season with the last application on August 25, 1992. Approximately 9 inches of irrigation water was applied. The MSU Irrigation Scheduling program was monitored by Don Smucker, Montcalm County Extension Director and these data were used to determine the timing for irrigation applications.

Insect and Disease Control

Phorate was applied at planting at 11.3 ounces/1,000 ft. of row. For nematode control, Mocap 10G was banded with the planter at 30 lbs/A. Problems with potato early die did develop in certain plot locations and it was very severe on Superior and Russet Norkotah.

The incidence of Colorado potato beetle was greatly reduced in comparison with 1991. Foliar insecticide sprays were initiated on June 17 with M-trak. Later applications of Imidan plus PBO were made as needed. Dimethoate (Cygon) was used for aphid control. The primary fungicide used was Penncozeb which was initiated on July 1.

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
1978	50	31	67	45	78	50	81	56	82	57	75	52	72	49
1979	50	33	66	44	74	55	82	57	77	55	76	47	71	49
1980	49	31	69	42	73	50	81	58	81	58	70	49	71	48
1981	56	35	64	39	73	50	77	51	78	53	67	47	69	46
1982	53	28	72	46	70	44	80	53	76	48	66	44	70	44
1983	47	28	60	38	76	49	85	57	82	57	70	46	70	46
1984	54	34	60	39	77	54	78	53	83	55	69	45	70	47
1985	58	38	70	44	71	46	81	55	75	54	70	50	71	48
1986	60	36	70	46	77	50	82	59	77	51	72	50	73	49
1987	61	36	77	46	80	56	86	63	77	58	72	52	76	52
1988	52	31	74	46	82	53	88	60	84	61	71	49	75	50
1989	56	32	72	34	81	53	83	59	79	55	71	44	74	46
1990	NA	NA	64	43	77	55	79	58	78	57	72	47	NA	NA
1991	60	40	71	47	82	59	81	60	80	57	69	47	74	52
1992	51	34	70	42	76	50	76	54	75	51	69	46	69	46
15-YR. AVG.	54	33	68	43	76	52	81	57	79	55	71	48	72	48

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

Year	April	May	June	July	August	September	Total
1978	2.34	1.35	2.55	1.89	5.90	2.77	16.80
1979	2.58	1.68	3.77	1.09	3.69	0.04	12.85
1980	3.53	1.65	4.37	2.64	3.21	6.59	21.99
1981	4.19	3.52	3.44	1.23	3.48	3.82	19.68
1982	1.43	3.53	5.69	5.53	1.96	3.24	21.38
1983	3.47	4.46	1.19	2.44	2.21	5.34	19.11
1984	2.78	5.14	2.93	3.76	1.97	3.90	20.48
1985	3.63	1.94	2.78	2.58	4.72	3.30	18.95
1986	2.24	4.22	3.20	2.36	2.10	18.60	32.72
1987	1.82	1.94	0.84	1.85	9.78	3.32	19.55
1988	1.82	0.52	0.56	2.44	3.44	5.36	14.14
1989	2.43	2.68	4.85	0.82	5.52	1.33	17.62
1990	1.87	4.65	3.53	3.76	4.06	3.64	21.51
1991	4.76	3.68	4.03	5.73	1.75	1.50	21.45
1992	3.07	0.47	1.18	3.51	3.20	3.90	15.33
15-YR. AVG.	2.80	2.76	2.99	2.77	3.80	4.44	19.56

MICHIGAN STATE UNIVERSITY POTATO BREEDING PROGRAM

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Department of Crop and Soil Sciences

Cooperators: K. Jastrzebski, J. Smeenk, R. Freyre, R.W. Chase, R. Hammerschmidt, D. Maas, J. Cash and G. Bird

The MSU program has a multi-faceted approach to variety development. We have the capacity to conduct variety trials of advanced selections, develop new genetic combinations in the breeding program and identify exotic germplasm that will enhance the varietal breeding efforts. With each cycle of crossing and selection we expect to see directed improvement towards improved varieties. In addition, our program has the capacity to utilize new biotechnologies such as genetic mapping and genetic engineering to improve varieties. We feel that these in-house capacities (both conventional and biotechnological) put us in a position to respond and focus upon the most promising directions. The breeding goals at MSU are based upon current and future needs of the Michigan potato industry. Traits of importance include yield potential, disease resistance (scab and early die), chipping and cooking quality, storability, along with shape, internal quality and appearance. We report upon the on-going potato breeding program which is divided into three integrated directions: 1) breeding and varietal development, 2) germplasm enhancement, and 3) genetics studies to understand the inheritance of key traits.

I. VARIETAL DEVELOPMENT

In the winter of 1992 approximately 250 successful crosses were made between 70 cultivars and advanced breeding lines. These seeds are being used as the current breeding base for the program in 1992 and 1993. In the summer 1992, approximately 27,000 seedlings, derived from 225 populations, were grown and visually evaluated at the Montcalm and Lake City Research Farms as part of the first year selection process of this germplasm. Twenty-five percent of the crosses were between long types, seventy percent between round whites, and five percent each were crosses to select red and yellow-flesh varieties.

A total of 800 single-hill selections were made (3% selection intensity) and they are currently being evaluated for specific gravity, cold chip-processing (45 and 40F), and storability. When chipped directly out of 45F storage, about 15% of the single-hill selections had acceptable chip color. These selections will be evaluated as 8-hill selections in 1993. Of the 8-hill selections from 1992, 39 out of 85 clones chip-processed with acceptable color. These good chippers will be chipped out of 40F storage later this storage season. In addition to the single-hill selections, 85 8-hill plots, 20 twenty-hill plots, and 21 2x20-hill plots will be advanced for further evaluation in 1993. Approximately 25% of the 2x20-hill selections will be advanced to replicated trials under standard commercial practices for 1993 at the Montcalm Research Farm.

In the Adaptation trial (table shown in Variety Report) 38 lines from North American breeding programs including Michigan were tested. Round-white selections from Purdue University, 84-9-8, yielded well along with B083-1 and B076-2 (Michigan) which may have potential in the chip-processing market. B007-1 (Michigan), a long russet type, may fit the fresh count-pack market. These selections will be further tested in 1993.

II. Progress in Breeding "Cold-Chipping" Varieties

One of the critical objectives is to develop potato varieties that will not accumulate reducing sugars in cold storage (40F). We commonly call these varieties "cold chippers". During the 1991 harvest, approximately 650 selections were made from the 20,000 seedlings grown at the Montcalm Research Farm. Following harvest, specific gravity was measured and chip-processing (from 45F storage) was tested January 15, 1992 directly out of storage. This storage period allowed enough time for reducing sugars to accumulate in these selections.

There is a question as to which temperature is most appropriate to screen for cold-chipping. We have chosen, as our initial screen, to chip-process directly out of 45F storage. We feel there is no long-term value in 2-4 week reconditioning out of 40F storage, and we do not want to reduce the number of selections too quickly in the breeding program. If we do select too hard and too soon, we may lose the opportunity to combine other important traits (ie. yield, specific gravity, disease resistance, etc.) along with cold-chipping. As desirable cold-chipping genes accumulate in the breeding program, we will reduce the storage temperature for screening to 40F.

Of the 650 single-hill selections, 120 were identified as having acceptable chip color and minimal internal defects when chip-processed directly out of 45F storage. These selections were advanced for further evaluation in 1992. Approximately 80 selections were made at the 8-hill stage. Of those, 25% had acceptable specific gravity and chip color directly out of 45F storage. Atlantic (unacceptable) and Snowden (excellent) were chipped as checks. We further tested these acceptable selections for chip-processing directly out of 40F storage. Results showed that genetic variation exists among these selections for sugar accumulation, however, none were rated to have acceptable chip color directly out of 40F.

Fifty-five 4-hill, eleven 20-hill, and 19 2x20-hill selections were also sampled for post-harvest evaluation in 1991. About 20% of these selections had acceptable cold-chipping ability out of 45F storage. Some of these selections were tested in replicated trials at the Montcalm Research Farm in 1992 for more intensive agronomic and chipping evaluations. We are currently evaluating the current storage season chip-processing ability.

The 1991-92 chip data also feeds information back to the crossing program. When we examined the pedigrees of these selections, a number of parents were identified that contribute to cold-chipping out of 45F storage. These were ND860-2, ND2008-2, W877, S440, MS702-80 and Lemhi Russet. For 1992 we continued to use these parents in the MSU crossing block to breed superior chip-processing potatoes. Snowden was not included in this list because it is difficult to get this variety to flower. It also does not produce many flowers per cluster. Based upon 1991 greenhouse observations, we enhanced the flowering ability of Snowden in the 1992 crossing block and obtained numerous cross combinations. We had these populations in the field for fall 1992 evaluation and selections were made.

From an initial population of 3,500 seedlings from 62 crosses, 80 diploid selections have been made. Selection criteria was based upon tuber appearance, size, dormancy, and internal quality, along with maturity, specific gravity, and chip quality. Of these selections 22 had chip color as good as Snowden when chipped directly out of 45F storage. These selections have been crossed and the progeny were in the field for 1992 selection. The diploid germplasm is the basis for long-term genetic improvement of the potato varieties in the MSU breeding program.

III. Germplasm Enhancement

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

In 1991 many of the interspecific crosses yielded unacceptable genotypes for varietal consideration. This indicates prebreeding with these species at the 2x level may produce more successful results. Seventy-five diploid populations were generated from the best-performing species hybrids and were then grown and selected at the Montcalm Research Farm. About 10% of the 3,000 seedlings were selected for further evaluation in 1993. About 60 advanced selections from the first cycle of crosses are currently being evaluated for specific gravity, cold chip-processing, and dormancy and disease resistances. Twenty-five percent of these best lines formed the crossing block to generate new populations in 1993. From this material we expect to find improved diploid *Solanum* species parents to be used in crosses to select new varieties.

We added to the germplasm enhancement program a number of genetic lines that are derivatives of cell (protoplast) fusions between *S. brevidens* (from Argentina) and the cultivated potato. These lines were developed by J. Helgeson at the University of Wisconsin and have been noted for their *Erwinia* and PLRV resistance. Through further crossing and evaluation we hope to incorporate these resistances into the breeding populations.

IV. Assessment of Potato Breeding Progress in the U.S.

Replicated field trials were conducted at Montcalm, Michigan in 1990, 1991 and 1992 to compare 21 potato varieties that have or have had importance over the past century. The varieties were evaluated for total yield, marketable yield, maturity, internal defects, specific gravity, chip-processing quality, visual merit, tuber dormancy and scab resistance. A number of trends were observed over the three years. The many of the older varieties have a greater yield potential; however, the more recent varieties have improved appearance. The round white varieties have been improved for chip-processing ability and specific gravity. The long type varieties have shown an increase in the percent U.S. #1 yield. This study will help us develop breeding strategies to improve potatoes for Michigan.

V. Use of Molecular Markers for the Study and Analyses of Quantitative Trait Loci in Diploid Potato

DNA (restriction fragment length polymorphisms or RFLPs) and protein markers (isozymes) have excellent prospects for the rapid development of new breeding methodologies that can take advantage of current molecular biology techniques. Analysis of RFLPs has recently become feasible in potato and provides a genetic map with sufficient resolution to indicate the numbers, types, and distributions of genes influencing quantitatively inherited traits (traits controlled by many genes). The most important traits in potato are quantitatively inherited. With a detailed genetic map we are developing and applying a new approach to breeding quantitatively inherited traits, (ie. chip-processing ability, specific gravity and tuber dormancy) in potato, which is referred to as quantitative trait loci analysis or QTL analysis. The objective of this research is to identify genetic associations (or linkages) between genetic markers (isozymes, RAPDs and RFLPs) and genes controlling specific gravity, tuber dormancy and chip color in diploid potatoes. The identification of these genetic linkages will make it more efficient to breed in the traits from the diploid breeding program to the cultivated gene pool.

The objective of the quantitative trait loci analysis was to identify associations between isozymes and RFLPs and quantitative trait variation for specific gravity and tuber dormancy in 2x potato. The two populations used (TRP132 and TRP133) are derived from 2 (tbr-chc x phu) crosses and have 143 and 110 individuals respectively. In 1990 they were planted at 2 locations with 3 replications, evaluated for the tuber traits and characterized with 11 isozyme loci. For specific gravity association was found with 6-Pgdh-3, Got-2 and Pgm-1 for TRP133, results being consistent in both locations. For dormancy association was found with 6-Pgdh-3, Got-1, Got-2 and Prx-3. In TRP132, association was found for specific gravity with 6Pgdh-3 and Got-2 over both locations, and with Pgm-1 and Dia-2 on only one location. In 1991 the populations were planted in 1 location with 2 replications, and evaluated for specific gravity. For TRP133, there was high correlation with data from 1990, and significant association was found with 6-Pgdh-3 and Got-2. Twenty-seven RFLPs have been examined, two of these have shown significant association with specific gravity while other four have shown significant association with dormancy. Linkage analysis indicates that QTLs for this trait are localized on chromosomes 2, 5, 7 and 8.

Future plans include further survey of the genome with other probes to identify more QTLs and also fine-map those already identified. Also, progenies derived from 4x-2x crosses and segregating for some of the markers that show significant association with the QTLs will be studied. Ultimately we hope to be able to breed in these valuable genes by tracking with these genetic markers.

Funding Fed. Grant/MPIC

1992 POTATO VARIETY EVALUATIONS

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

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

Both round and long variety groups were harvested at two dates. The yield was graded into four size classes, incidence of external and internal defects was recorded, and samples for specific gravity, chipping, bruising, disease and cooking tests were taken. Chip quality was assessed on 25-tuber samples, taking two slices from each tuber. Chips were fried at 365°F. The color was measured with an M-35 Agtron colorimeter and visually with the SFA 1-5 color chart. Prior to chipping, the tubers were stored at 45 or 50°F.

Results

A. Round white varieties

Thirteen varieties and nine breeding lines were compared at two harvest dates. Atlantic, Snowden, Onaway, and Superior were used as checks. The average yield was much below the two recent years and results are presented in Tables 1 and 2.

Variety Characteristics

Onaway - medium-early fresh market variety with excellent yield potential and a low specific gravity. Tubers are round to oblong, large, deep eyes, susceptible to growth cracks and early blight. It has very good internal quality, but the storability is poor.

Atlantic - medium-late, chipping variety of high specific gravity and good yield potential. Susceptible to scab, soft rot, white knot, and to internal defects (hollow heart, vascular discoloration, internal brown spot).

Superior - medium-early, fresh market variety. Tubers are well-shaped, medium size with a medium specific gravity. Resistant to scab but very susceptible to *Verticillium* wilt.

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

Mainechip - medium-late variety of excellent chipping quality. It is comparable to Atlantic in specific gravity, lower yield potential, but better internal quality. Tubers are rather small.

Norwis - medium-late, high yielding variety. Tubers are large but in 1992 some hollow heart and quite frequent brown centers were present. The specific gravity is low and it is susceptible to scab.

Snowden - late maturing variety of excellent chipping quality. Specific gravity high. Tubers are round, small to medium size, well shaped with excellent internal quality. It is not resistant to scab, but has some resistance to *Fusarium* dry rot.

Castile - very late variety of very high yield potential. Tubers are well-shaped, oblong and, very large, yet do not hollow. Tubers have a white skin and attractive appearance. Specific gravity is medium, and internal defects are few. Susceptibility to blackspot and some incidence of *Altenaria solani* was noted on tubers during 1991-92 storage.

Chipeta - very late variety of high yield potential. Chip color was good, but specific gravity is low to medium at early harvest.

Prestile - new tablestock variety from Maine and tested for the first time in Michigan. In 1992, it showed very high yield potential, tubers were round and very attractive. Textural quality was good, but scab infection was heavy. Reported to be susceptible to heat necrosis and air checks.

Portage - previously tested as CS7697-24. Early to medium early fresh market variety. Yield potential is good. Tubers were round, well shaped, with low specific gravity. It was severely infected with scab.

Niska - medium-early, fresh market variety. It has medium to high yield potential. Specific gravity is too low for chipping. Vascular discoloration was common in oversize tubers.

Chaleur - medium-early, fresh market variety from New Brunswick, Canada tested for the first time. Yield and specific gravity were very low in 1992. Round, well shaped tubers and very good flesh color were observed.

NY78 - late season tablestock variety which sets tubers early. Has excellent yield potential with large tubers. Vascular discoloration was quite frequent. Resistant to GN, early blight and scab.

E55-35 - late maturity, medium yielding with high specific gravity and good chip quality. Tubers well-shaped, medium large and uniform in size. Few internal defects were noted and reported to have scab tolerance. Has a good potential in Michigan. The performance in 1992 was average.

E55-44 - medium-early variety. Chipping quality is good but specific gravity is below 1.080. Tubers are medium large, uniform, well-shaped and of excellent general appearance. Good potential in Michigan. The performance in 1992 was poor.

AF1060-2 - first year tested in Michigan. Maturity is medium-late with high yield and the tubers were round and well shaped. A selection from Maine with fresh market potential.

NY85 - medium-early variety. The performance in 1992 much below average.

NY88 - medium-early variety. The performance in 1992 much below average. Chip color very good, but specific gravity rather low. Selection is being dropped by Cornell.

W870 - medium-late, chipping variety. Medium yield potential and high specific gravity. Tubers are medium-large and slightly flat. Few internal defects. The performance in 1992 was well below average. It is susceptible to scab.

W877 - medium late variety of excellent chipping quality and high specific gravity. Average yield potential. It has good internal quality but is susceptible to scab.

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

B. Long Varieties

Five varieties and three breeding lines were tested. A78242-5 was comparable to Russet Burbank in total yield, but significantly higher in the US No. 1 yield. W1005 performed much below average. W1005 and Goldrush (ND1538-1) (also tested in North Central Region trial) are the only russet lines of some potential in Michigan. The results are presented in Tables 3 and 4.

Variety Characteristics

Ranger Russet (A7411-2) - late, medium yielding, high specific gravity variety. Tubers are large and have good appearance. Few internal defects and excellent potential for processing but susceptible to blackspot and scab.

Frontier Russet is a medium-late variety with average yields. Specific gravity medium. Tuber appearance and cooking quality are good. Shows some resistance to scab but some tendency to hollow heart. Tubers develop purplish cast when exposed to light.

Russet Burbank - used as a standard in the trial. Late maturity, average yields. Specific gravity good for processing and baking. Has a tendency to form off-shape and undersize tubers and is resistant to scab.

Goldrush - medium early, fresh market variety. It has good yield potential. Tubers are russet, oblong to long, and well shaped. Low specific gravity, good internal quality was noted. Similar in maturity and specific gravity to Russet Norkotah but fewer internal defects, more tolerance to Verticilium wilt and better flesh color.

Russet Norkotah - early to mid-season variety. Yield potential and specific gravity are rather low. Tubers are oblong to long and well shaped with some resistant to scab. After cooking darkening was recorded in some years as well as susceptibility to Verticilium wilt.

A78242-5 - medium-late, average to high yield potential, medium specific gravity. Tubers are well-shaped, blocky and attractive. Tendency for hollow heart and brown centers was recorded in 1991, but not in 1992.

W1005 - late variety of high yield potential, although it performed poorly in 1992. Tubers are long and rather thin. Specific gravity high. Resistant to scab but susceptible to black spot in 1992.

W1099 - medium early variety, tested first year in Michigan. It has a dark russet skin. Yield and specific gravity were low.

C. Adaptation

The Michigan adaptation trial serves as a screen for advanced breeding lines from various states. The best lines from this trial will enter the dates of harvest experiment the following year. Thirty-two lines were tested in 1992. Steuben, Snowden, Spartan Pearl and Superior were used as checks. The results are presented in Table 5.

Among the check varieties, the best yielder was Steuben, followed by Snowden and Spartan Pearl. The 1992 growing season was disastrous for Superior because of Verticilium wilt. Also LA12-59 (named Fontenot in 1992) performed below its average in previous years. Six lines yielded better than Snowden: MN12823, NYE11-45, MSB083-1, NY84, P84-9-8, and MSB076-2. MN12823 was the top yielder however it has very large and rather irregular tubers and its specific gravity was low. Chipping quality was fair. NYE11-45 has round and smooth tubers with low specific gravity. It may have a potential as fresh market variety.

MSB083-1, NY84 and P84-9-8 will be tested for fresh market potential, while MSB076-2 might also be an out-of-field chipper. B0256-3, P83-11-5, MSB007-1 and B0257-12 yielded on the level of Snowden and should be further tested in Michigan. Since the 1992 growing season was so untypical, most of the lines will be tested again for adaptation in Michigan in 1993.

D. North Central Regional Trial

The North Central Trial is conducted in a wide range of environments, in 14 states and provinces, to provide adaptability data for the release of new varieties. In 1992, eight breeding lines were compared to five standard varieties of various tuber type. The results are presented in Table 6.

As in other experiments, the level of yield in 1992 was much lower than usual. Red Pontiac, known for its high yield potential, produced only about 65% of the 1991 level. Only one breeding line, MN12823, produced more than Red Pontiac, while W887 and LA12-59 yielded on the level of Red Pontiac. MN12823 had very large tubers of somewhat irregular shape, low specific gravity, and is susceptible to internal defects. W887 had high specific gravity and internal quality was good. Some susceptibility to shatter wounds was noted and its dormancy is very short. LA12-59, a red-skin fresh market variety, has been released as Fontenot in 1992. The specific gravity is low. ND1871-3R yielded less than Red Pontiac and LA12-59. Its specific gravity was very low. W1100R produced total yield on the level of Red Pontiac, but its tubers were very small. Its specific gravity was also very low. Its yield was average, but had a high specific gravity, excellent chipping quality and a good internal quality. ND2224-5R and MN14489 produced a small yield of very low specific gravity.

E. Disease Evaluation

As part of the postharvest evaluation, resistance to *Fusarium sambucinum* (fusarium dry rot) was assessed by inoculating whole tubers post harvest. The tubers were held at 68°F for three weeks and then scored for disease by measuring the diameter of the decayed tissue. No absolute resistance was detected in the 114 varieties and advanced lines that were screened (Table 7). Some lines did, however, exhibit a lesser degree of rot than others. These included W887, Snowden, 86SD19-10Y, MS401-2Y, P83-6-18, and Frontier Russet. We will be repeating this evaluation on the lines that showed the greatest promise to confirm these results of our initial study.

Following the fusarium dry rot testing, Altenaria solani and Erwinia soft rot were evaluated. The low levels of infection observed in these studies did not discriminate between resistant and susceptible clones. We will be conducting further tests to optimize environmental conditions that will promote infection levels that discriminate between clones.

F. Blackspot Susceptibility

An integral component of the variety evaluation program has been an assessment of blackspot susceptibility. Check samples (CK) were 25 tuber samples collected from the normal harvest process. Bruised (BR) samples were also collected at harvest and placed in a hexagon plywood drum and tumbled 10 times to provide a simulated bruise. Both samples were peeled in an abrasive peeler in November and individual tubers were assessed for the numbers of blackspot bruise on each potato. These results are shown in Table 8. The advanced seedlings and varieties showing the least effect from the simulated bruise damage were Chipeta, E55-35, NY88, Portage, Onaway, Prestile, E55-44, Superior and Chaleur. The incidence of blackspot injury is related to environmental conditions at harvest time, however cultivars do have inherent characteristics which influences the degree of injury.

G. Upper Peninsula Variety Trial

A potato variety trial was conducted by Dr. Rich Leep and Jim Lempke on the Paul/Mike Van Damme Farm. The plots were planted on May 14 and harvested on September 25. Overall yields were very good. Table 9. Ranger Russet and W1005 exceeded Russet Burbank in yields of US No. 1 and specific gravity.

Table 1.

ROUND WHITES
FIRST DATE OF HARVEST
MONTCALM RESEARCH FARM
AUGUST 6, 1992 (92 DAYS)

	CWT/Acre		Percent of Total[1]				Spec.	Tuber Quality[2]					3+ Year
Variety	US#1	Total	B	A	OV	PO	Grav.	HH	VD	BC	IBS	#	US#1 Ave
ATLANTIC	304	330	7	86	6	2	1.084	12				17	320
ONAWAY	304	345	11	80	8	2	1.068	0				21	375
PRESTILE	298	331	9	83	8	1	1.067	1				7	---
PORTAGE	293	344	12	79	7	3	1.067	0				19	---
AF1060-2	277	304	8	80	12	1	1.069	0				34	---
NORWIS	273	324	13	82	3	3	1.062	6				7	330
E55-44	271	307	10	80	8	3	1.076	0				18	339
NY78	259	300	13	84	3	1	1.064	0				6	---
CASTILE	247	317	22	77	1	1	1.069	0				2	445*
NY88	232	303	22	75	2	2	1.075	0				4	---
E55-35	231	284	19	79	2	1	1.077	0				9	283*
CHALEUR	228	261	12	83	4	1	1.068	0				7	---
W870	226	282	19	80	1	1	1.084	0				2	318*
MAINECHIP	226	278	17	80	1	3	1.084	0				1	283
CHIPETA	218	258	13	84	0	3	1.071	0				0	---
W887	210	250	16	84	1	0	1.082	1				1	283
NY85	208	277	24	75	0	0	1.075	0				2	---
NISKA	202	282	26	72	1	2	1.073	0				1	335*
W877	194	244	20	78	2	1	1.093	1				4	---
GEMCHIP	174	218	19	80	0	2	1.070	0				0	278
SNOWDEN	167	259	36	64	0	0	1.082	0				0	265*
SUPERIOR	151	207	26	71	2	2	1.074	0				3	265
AVERAGE	236	287					1.074						
$LSD_{(.05)}$	44	38											

Planted May 5, 1992
* Two year average

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

[2] Quality
HH - Hollow Heart
VD - Vascular Discoloration
BC - Brown Center
IBS - Internal Brown Spots
- Number of oversize tubers cut

Table 2.

ROUND WHITE
SECOND DATE OF HARVEST
MONTCALM RESEARCH FARM
SEPTEMBER 10, 1992 (127 DAYS)

	CWT/Acre		Percent of Total[1]				Spec.	Tuber Quality[2]					3+ Year
Variety	US#1	Total	B	A	OV	PO	Grav.	HH	VD	BC	IBS	#	US#1 Ave
PRESTILE	454	476	3	75	21	1	1.082				2	40	---
ATLANTIC	404	429	4	69	25	2	1.093	14		9		40	415
NY78	400	432	7	80	12	1	1.073		20			35	---
CHIPETA	396	445	4	60	29	7	1.083	1	4			40	---
CASTILE	372	423	9	83	5	3	1.084					16	507*
NORWIS	358	414	4	76	10	9	1.073	4		13		33	428
PORTAGE	356	411	7	74	12	6	1.073		9			34	---
AF1060-2	356	400	7	61	28	5	1.075		6			40	---
W887	332	361	5	79	13	3	1.095	2	1	2	1	37	409*
SNOWDEN	320	394	17	80	2	1	1.089		1			6	342*
NISKA	288	358	14	76	4	5	1.080		6			10	---
E55-35	281	314	8	82	8	2	1.089		1		3	20	400
ONAWAY	277	320	10	81	6	4	1.068		1			14	428
GEMCHIP	275	323	6	70	15	9	1.079	5	1			33	424
W870	247	291	12	82	3	3	1.087					7	---
NY88	235	292	18	77	3	1	1.082					8	---
NY85	219	276	18	78	1	2	1.084					2	---
MAINECHIP	206	246	13	79	5	4	1.089					11	312
CHALEUR	204	237	12	80	6	2	1.069			1		10	---
E55-44	186	223	16	79	5	0	1.074	1				8	352
W877	147	184	17	77	3	3	1.094					5	306
SUPERIOR	88	138	35	64	0	1	1.072						290
AVERAGE	291	336					1.081						
Lsd $_{(0.05)}$		60											

Planted May 5, 1992
* Two year average

[1] Size

A - 2-3.25"
B - < 2"
OV - > 3.25"
PO - Pick outs

[2] Quality

HH - Hollow Heart
VD - Vascular Discoloration
BC - Brown Center
IBS - Internal Brown Spots
\# - Number of oversize tubers cut

Table 3.

LONG RUSSETS
FIRST DATE OF HARVEST
MONTCALM RESEARCH FARM
AUGUST 6, 1992 (92 DAYS)

Variety	CWT/Acre US#1	CWT/Acre Total	Percent of Total[1] B	A	OV	PO	Spec. Grav.	Tuber Quality[2] HH	VD	BC	IBS	#	3+ Year US#1 Ave
A78242-5	160	271	42	58	0	1	1.073	0				3	258
R. NORKOTAH	135	238	42	51	3	4	1.070	0				0	249
R. BURBANK	133	250	40	51	1	7	1.070	0				2	214
RANGER R.	122	228	45	50	2	4	1.073	0				0	243
GOLDRUSH	118	243	50	45	3	3	1.067	0				11	---
FRONTIER R.	117	226	48	50	1	2	1.069	0				1	236
W1005	114	235	47	48	0	4	1.075	0				1	279
W1099	111	224	49	47	2	3	1.068	0				6	---
AVERAGE	126	240					1.071						
$LSD_{(.05)}$	77	67											

Table 4.

LONG RUSSETS
SECOND DATE OF HARVEST
MONTCALM RESEARCH FARM
SEPETEMBER 10, 1992 (127 DAYS)

Variety	CWT/Acre US#1	CWT/Acre Total	Percent of Total[1] B	A	OV	PO	Spec. Grav.	Tuber Quality[2] HH	VD	BC	IBS	#	3+ Year US#1 Ave
A78242-5	387	452	13	64	21	1	1.079					30	349
RANGER R.	313	399	13	52	27	9	1.086	1				40	357
R. BURBANK	298	428	15	54	15	16	1.082					35	322
GOLDRUSH	264	341	19	60	17	3	1.069					34	386
FRONTIER R.	247	315	20	60	18	1	1.078				1	35	316
W1099	210	297	25	65	5	4	1.068					13	---
W1005	167	261	34	62	2	2	1.081					15	376
R. NORKOTAH	153	225	30	62	6	2	1.069	1				12	273
AVERAGE	255	340					1.077						
$Lsd_{(0.05)}$	74	67											

Planted May 5, 1992
* Two year average

[1] Size
- A - 4-10 oz
- B - < 4 oz
- OV - > 10 oz
- PO - Pick outs

[2] Quality
- HH - Hollow Heart
- VD - Vascular Discoloration
- BC - Brown Center
- IBS - Internal Brown Spots
- # - Number of oversize tubers cut

Table 5.

1992 ADAPTATION
MONTCALM RESEARCH FARM
SEPTEMBER 14, 1992 (130 DAYS)

Variety	Typ[1]	CWT/Acre US#1	CWT/Acre Total	Percent of Total[2] B	A	OV	PO	Spec. Grav.	Tuber Quality[3] HH	VD	BC	IBS	#
MN12823	L	509	599	2	52	34	13	1.079	5		8	1	40
STEUBEN		488	510	3	56	40	2	1.082		2			40
E11-45		470	523	9	84	6	1	1.072		1	3		29
BO83-1		460	525	8	66	22	5	1.080	1	11		3	40
NY84		418	470	10	74	14	2	1.071		2	1	2	31
P84-9-8		408	527	6	72	6	17	1.086	7	1	5		25
BO76-2		402	434	7	84	9	1	1.095					29
SNOWDEN		360	409	11	77	11	2	1.088		6		2	30
B2750		346	374	5	67	26	2	1.089					36
P83-11-05		343	515	10	67	2	21	1.086	2		1		8
S. PEARL		336	362	6	78	15	1	1.081	1				34
BOO7-1	L	327	375	9	72	15	5	1.070		1			31
B2753		323	380	8	71	15	8	1.080	1		3		34
R. CLOUD	Rd	309	337	5	64	28	3	1.071				1	40
P83-6-18		306	398	18	74	3	5	1.075					10
MS401-2	Y	290	330	11	79	9	2	1.089			4		18
BO42-1	Ru	284	322	31	51	16	2	1.082			2	1	20
E57-13		268	316	14	76	9	2	1.069			1		23
AO91-1		263	310	13	76	8	3	1.083		3	1		17
LA12-59	Rd	259	281	5	62	30	3	1.081	2	2			40
A84180-8	Ru	254	305	12	60	23	6	1.071	8			2	35
MS402-7		247	266	5	77	16	2	1.075					33
NY91		236	274	11	67	19	3	1.087	4	1	6		23
B9922-11	Ru	225	276	16	66	16	2	1.078	2			4	26
BO952-1		208	257	19	78	2	1	1.076					5
B110-3		206	256	16	76	4	4	1.089			1		10
B2751		206	248	17	81	2	1	1.089				2	4
W178-R	Rd	197	278	30	67	2	1	1.062					3
BO27-1R	Ru	193	250	20	70	7	4	1.071	4		2		14
P84-13-12		184	222	19	78	4	0	1.092					9
BO95-2		153	213	28	71	1	0	1.086					1
B111-4Y	Y	151	194	26	61	11	2	1.066		3			16
A1161-1		142	182	21	74	3	2	1.069			1	1	6
MN13540	L	98	167	42	55	3	1	1.071					3
SUPERIOR		84	148	43	54	1	2	1.093		1			12
84-75R	Rd	82	199	58	40	0	2	1.064		3	2		9
B2752		75	100	25	73	2	1	1.065					1
B0899-1	Rd	70	111	40	57	0	4	1.063					0

Planted May 6, 1992

[1] Type

Rd - Red
Ru - Russet
Y - Yellow
L - Long

[2] Size

A - 2-3.25" or 4-10 oz
B - < 2" or < 4 oz
OV - > 3.25"or > 10 oz
PO - Pick outs

[3] Quality

HH - Hollow Heart
VD - Vascular Discoloration
BC - Brown Center
IBS - Internal Brown Spots
- Number of oversize tubers cut

Table 6.

NORTH CENTRAL REGIONAL TRIAL
MONTCALM RESEARCH FARM
SEPTEMBER 12, 1992

Variety	CWT/Acre		Percent of Total[1]				Spec. Grav.	Tuber Quality[2]				
	US#1	Total	B	A	OV	PO		HH	VD	BC	IBS	#
MN12823	465	518	3	45	45	8	1.074	14	6	3	-	40
R. PONTIAC	384	429	4	51	38	7	1.062	19	-	-	-	40
W887	376	396	4	88	7	2	1.090	-	1	-	-	26
LA12-59	372	416	9	80	9	2	1.075	1	-	-	-	31
ND1871-3R	322	351	9	79	13	0	1.068	1	1	-	3	29
W1100R	255	382	33	66	1	1	1.062	-	-	-	1	3
W870	252	299	15	82	2	1	1.085	-	-	-	-	5
R. BURBANK	217	302	23	65	6	7	1.078	-	-	-	-	18
ND2224-5R	217	256	15	79	6	1	1.061	-	-	-	1	10
NORGOLD R.	207	272	18	63	14	6	1.063	-	-	-	-	21
NORCHIP	186	237	15	76	3	7	1.073	-	1	1	-	4
MN14489	185	219	13	76	8	3	1.068	2	-	-	-	9
NORLAND	171	209	16	78	4	3	1.059	-	-	-	-	7
LSD (0.05)	54	54										

Planted May 6, 1992

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

[2] Quality
HH - Hollow Heart
VD - Vascular Discoloration
BC - Brown Center
IBS - Internal Brown Spots
\# - Number of oversize tubers cut

Table 7. **1992 FUSARIUM DRY ROT EVALUATION**

VARIETY	BUD INFECTION RATING
W887	0.8
Snowden	1.3
P83-6-18	2.4
86SD19-10Y	2.4
Frontier R.	2.6
A84180-8	2.9
B107-2	3.1
86SD19-8Y	3.3
R. Norkotah	3.3
Norgold	3.4
ND1871-3R	3.5
W877	3.5
Steuben	3.6
White Rose	3.6
B0257-3	3.7
E57-13	3.7
Kennebec	3.7
P83-11-5	3.8
A116-2	3.9
Chipeta	4.0
MN14489	4.2
Superior	4.2
Desiree	4.3
B111-1Y	4.4
W870	4.4
Red Pontiac	4.5
W1005	4.5
Yukon Gold	4.5
B106-7	4.6
Norland	4.6
B027-1R	4.8
P84-13-12	4.9
B106-8	5.1
MS402-7	5.1
NY78	5.1
Atlantic	5.2
MS404-1	5.2
B040-3	5.3
Onaway	5.3
Ontario	5.3
A091-1	5.4
Eramosa	5.4
B027-2	5.5
B076-2	5.5
B110-13	5.5
E55-35	5.5
Gemchip	5.5
B0952-1	5.6
Red Cloud	5.6
Sangre	5.6
B110-3	5.7
Katahdin	5.7
Bliss Triumph	5.8
W1100	5.8
A119-1(red)	6.0
B083-1	6.0
Chieftian	6.0
Early Rose	6.0
MN13540	6.0
Red LaSoda	6.1
Reddale	6.1
A116-1	6.2
A78242-5	6.2
B007-1	6.2
B101-2	6.2
B0256-1	6.2
Norchip	6.2
B0257-9	6.3
Portage	6.3
Mainechip	6.3
W1099	6.4
B076-1	6.5
I. Cobbler	6.5
NY-88	6.5
AF1060-2	6.6
A071-2	6.7
LemhiR	6.7
P84-9-8	6.8
Goldrush	6.8
NY-84	6.8
Ranger R.	6.8
84-75R	6.9
B073-2	6.9
G. Mountain	6.9
B123-1	7.0
Niska	7.0
A129-1	7.1
E55-44	7.2
NY85	7.2
Saginaw Gold	7.2
LA12-59	7.3
MS402-2	7.3
R. Burbank	7.4
B095-2	7.5
Castile	7.5
Norwis	7.8
Prestile	7.9
W178R	7.9
A125-1	8.0
Hilite	8.0
B107-1	8.2
B042-1	8.3
B0257-12	8.6
B9922-11	8.6
E11-45	8.6
Chaleur	8.7
Nooksack	8.7
Shepody	8.7
A097-1	8.8
MN12823	8.8
NY91	8.9
Sebago	8.9
MS401-2	9.0

0 = no infection
9 = severe infection

Table 8. **1992 BRUISE TRIAL**

ROUND WHITES FROM DATES OF HARVEST

Variety		Percent Bruise Free	Number of Tubers: 0	1	2	3	4	5+ Bruises per tuber
Castile	CK[a]	92	23	2				
	BR[b]	16	4	4	9	5	1	2
Niska	CK	92	23	1	1			
	BR	40	10	8	5	2		
NY87	CK	88	22	3				
	BR	44	11	6	6	2		
Atlantic	CK	88	22	3				
	BR	48	12	6	4	2		1
Snowden	CK	88	22	3				
	BR	48	11	8	3		1	
NY85	CK	100	25					
	BR	48	12	7	6			
W877	CK	92	23	2				
	BR	52	13	9	2	1		
W887	CK	100	25					
	BR	63	15	5	4			
Mainechip	CK	96	24	1				
	BR	64	16	5	3	1		
AF1060-2	CK	100	25					
	BR	64	16	3	5	1		
W870	CK	96	24	1				
	BR	68	17	7	1			
Gemchip	CK	100	25					
	BR	68	17	4	1	3		
Norwis	CK	100	25					
	BR	68	17	6	1	1		
Chipeta	CK	88	22	3				
	BR	76	19	5	1			
E55-35	CK	100	25					
	BR	80	20	5				
NY88	CK	92	23	2				
	BR	84	21	3	1			
Portage	CK	96	24	1				
	BR	84	21	2	2			
Onaway	CK	100	25					
	BR	84	21	3	1			
Prestile	CK	92	23	2				
	BR	88	22	2	1			
E55-44	CK	96	24	1				
	BR	96	24	1				
Superior	CK	96	24	1				
	BR	100	22					
Chaleur	CK	100	25					
	BR	100	25					

[a] CK - Check, no additional bruising

[b] BR - Bruising was simulated at harvest

Table 9. TUBER YIELD, SIZE DISTRIBUTION, AND SPECIFIC GRAVITY OF FOURTEEN POTATO VARIETIES IN THE UPPER PENINSULA OF MICHIGAN

Variety	CTW/Acre		Percent of Total[1]					Spec.
	US#1	Total	US#1	B	A	OV	PO	Grav.
Castile	557	581	96	4	66	30	0	1.085
Prestile	530	553	96	4	67	29	0	1.081
Ranger Russet	487	553	88	11	68	20	1	1.092
NY78	459	489	94	6	70	24	0	1.076
A78242-5	453	481	94	6	69	25	0	1.082
Gemchip	422	472	90	9	79	10	2	1.086
W1005	397	487	81	19	75	6	0	1.091
E55-35	393	441	89	10	81	8	1	1.091
Frontier Russet	389	428	91	9	67	23	1	1.084
W1099	368	397	93	7	76	16	1	1.078
Norwis	366	397	92	8	75	17	0	1.075
Russet Burbank	353	462	75	7	63	12	18	1.089
Russet Norkotah	302	362	84	16	78	6	0	1.079
ND1538-1	277	324	85	13	76	9	2	1.078

Farm Cooperator: Mike VanDamme

Planted: May 14, 1992 (20 seed pieces - 1 foot apart)

Harvested: September 25, 1992

[1] Size

A - 2-3.25"
B - < 2"
OV - > 3.25"
PO - Pick outs

Funding: Federal Grant/MPIC

FRESH PACK VARIETY TRIALS

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

Introduction

Grower-cooperator potato variety trials of varieties and advanced seedlings for the tablestock market were initiated in 1991. The objective is to identify the most promising varieties which would enhance the Michigan tablestock industry. Michigan, Ohio and states in the Northeast and along the east coast have traditionally marketed round white, all-purpose type potatoes. Although Superior is the major variety grown for this market, there are many other round white varieties which are also grown. Unfortunately, varieties do vary in their culinary qualities which does affect the consistency that a consumer can expect in repeat purchases because the variety in the pack is not specified.

From a national perspective, the most popular fresh market potato type is the long-russet and by far, the most popular variety is Russet Burbank. In 1987 the Russet Norkotah, a long-russet, fresh market variety was released by North Dakota. This variety produces a high percentage of U.S. No. 1 potatoes and has allowed many states, including Michigan, to increase their market share of the long-russet type potato. In order to at least stabilize, and hopefully enhance Michigan's fresh market share, the search for well adapted long-russet varieties must be pursued. The future of the round white, all purpose market could be enhanced if the number of varieties produced were substantially reduced and perhaps labelled by variety.

Procedure

In 1991, a grower-cooperator in four different counties were selected for these trials. The cooperators are: Styma Farms, Presque Isle County; Pleasant Valley Farms of Lakeview, Inc., Montcalm County; Duyck Farms, Bay County and Smith Bros. Farm, Monroe County. The extension agents in each of these counties (Dick Long, Presque Isle; Don Smucker, Montcalm; Mike Staton, Bay and Paul Marks, Monroe) have all played a significant role in this project.

In 1991, the varieties selected for trials on each farm were Gemchip, Steuben, Spartan Pearl, Norwis, Kanona and Eramosa. Onaway and Superior were included as check varieties. In 1992, the varieties selected were expanded to include long russets and reds. The entries were Castile, Steuben, Gemchip, Ranger Russet, Norwis, Goldrush, La12-59 (red), Dark Red Norland, Eramosa and two locations of E55-44. Onaway, Superior and Russet Norkotah were included as reference varieties.

Fifty pound samples of each variety were provided to each grower for planting in single rows. Observations on emergence, stand and growth were made. Planting dates and harvest dates were typical for the area. In

December of each year the cooperators meet to discuss results and determine the entries for the following year. Whereas 1991 was entirely round-white types, it was decided to include long russets and reds in 1992.

Results

Tables 1 and 2 summarize the performance results for the 1991 and 1992 seasons. The two growing seasons were in many regards direct contrasts. 1991 was a more rapid season in that heat units accumulated more readily with earlier maturities. On the other hand, 1992 was characterized as a slower accumulation of heat units with cooler temperatures throughout the season. 1992 was a very favorable growth season for potatoes as reflected in the yields.

Gemchip was judged to have good general appearance in 1991. Tubers are round to oval, smooth skin and medium to shallow eyes. Some incidence of a slight skin spotting may be characteristic of the variety. In 1992, scab was noted at three of the four locations with some scored as severe. Hollow heart and some greening were also noted. It does have above average yields and may have some tolerance to Verticillium wilt.

Kanona was included in 1991 only. It was judged to be irregular in shape with a medium to deep eye and in Bay County it had severe pitted scab.

Castile was first tested in 1992 and has a high yield potential. Tubers are oblong to long in shape with a bright white skin and shallow eyes. Scab was noted at three locations and some hollow heart in the larger tubers. Greening was also noted in Montcalm and Presque Isle Counties. Castile is late maturing and produced very high yields at Montcalm and Presque Isle county locations.

Steuben has been tested for two years and has a high yield potential. The seed planted in 1991 did have Fusarium dry rot which did affect stands. Steuben is a late maturing variety with round to oval shape tubers. The skin is flaky and may have some scalely areas. It does set and size tubers early and a close spacing (6-7") would help control over size where hollow heart could be a problem. It is very susceptible to blackspot bruising. Hollow heart was reported at Montcalm and Monroe. There was a trace of scab in the Bay and Monroe locations.

Spartan Pearl was tested in 1991 only. Yields were good and it produced uniformly sized potatoes. Growth cracks were noted at the Montcalm location. Some concern expressed about ability to maintain good condition in storage.

Norwis is a late maturing variety with a blocky to oval and flattened tuber appearance. Skin color is buff and flesh color is an off-white. The quality in 1991 was very good, however, in 1992, scab was very prevalent and hollow heart was noted in the larger tubers at all locations.

Eramosa was tested both years, however, yields have been very low. Early season growth has been erratic and not vigorous and tubers have shown a severe scab problem. It has also been observed that the tubers are very susceptible to silver scurf. This variety will not be tested any further.

E55-44 is an advanced seedling from New York which has a mid August maturity in Michigan. It has a vigorous early growth, an upright plant and appears to set and size tubers early. Due to limited seed, it was tested at Montcalm and Bay locations only in 1992. It does have an attractive tuber appearance and is a potential chip or fresh market variety. Although specific gravity is often below 1.080, it does produce a very desirable chip color from the field and from storage. Scab susceptibility is similar to Atlantic and a trace of pitted scab was noted in Bay County.

Ranger Russet is a long russet variety released in 1991. In comparison with Russet Burbank, it is more susceptible to surface scab. On the other hand, it does have a higher percentage of U.S. No. 1 potatoes, a higher specific gravity and fewer internal defects when compared with Russet Burbank. In 1992, at the four locations, it yielded very well with a low percentage of pick outs. Surface scab was noted at all locations. It does offer prospects for frozen processing as well as for the long russet fresh market. It is susceptible to blackspot bruising.

Goldrush is a long russet from North Dakota which was tested as ND1538-1. Yields were about average. It is a dark russet and only slight surface scab was noted. Maturity and specific gravity are very similar to Russet Norkotah. Tuber appearance may be better in Russet Norkotah, however, internal defects in Goldrush are minimal, particularly hollow heart. Cooked flesh color is reported to be better than Russet Norkotah and in both cases, they are primarily long russet, fresh pack varieties.

Russet Norkotah yields were below average and scab was reported at all four locations. Hollow heart was noted at three locations whereas none was noted with Goldrush.

La12-59 is an advanced red skin seedling from the Louisiana breeding program. It is late maturing and does have a good dark red color. The seed was badly bruised and had excessive Fusarium dry rot which did result in poor stands. Yields were good considering stands, however, skinning was noted at all locations which does detract from the red market quality. At the Montcalm location, the yield of tubers over 3¼" was 69% of the yield and hollow heart was recorded in 50% of the sample cut from these large potatoes. This seedling will not be included in 1993.

Dark Red Norland is essentially a line selection which has been made from Norland and does have an improved skin color. General appearance was noted as good at all locations with a good skin color.

Summary

Plans for 1993 are to continue testing of Castile, Steuben, Gemchip, E55-44, Ranger Russet, Goldrush, Russet Norkotah and Dark Red Norland. Onaway and Superior will continue as check varieties, and Prestile (University of Maine) and Chaleur will be added as new round-white entries.

Table 1. 1991 Fresh Pack Potato Variety Trial Summary[1/].

Variety	Yield (cwt/A) No. 1	Yield (cwt/A) Total	Percent Distribution No. 1	<2"	2-3¼"	>3¼"	Pick Outs	Specific Gravity
Onaway	365	393	93	3	68	25	3	1.071
Gemchip	342	378	90	5	73	17	5	1.070
Steuben	331	348	95	3	71	24	2	1.076
Spartan Pearl	307	333	92	6	85	7	2	1.072
Norwis	290	313	93	3	59	34	5	1.068
Kanona	252	297	82	2	59	23	16	1.070
Superior	223	243	92	7	88	3	2	1.067
Eramosa	162	232	70	7	55	11	27	1.058
Overall Average	284	317	89					1.069

[1/]Three location average: Bay, Montcalm, Presque Isle Counties.

Table 2. 1992 Fresh Pack Potato Variety Trial Summary[1/].

Variety	Yield (cwt/A) No. 1	Yield (cwt/A) Total	Percent Distribution No. 1	<2"	2-3¼"	>3¼"	Pick Outs	Specific Gravity
Castile	500	572	87	10	70	17	3	1.082
Steuben	460	502	92	5	64	27	4	1.082
Onaway	415	471	88	7	66	22	5	1.071
Ranger Russet	405	469	86	9	60	26	5	1.088
Norwis	374	412	91	5	65	26	4	1.071
Gemchip	371	458	81	9	64	18	9	1.073
E55-44[2/]	337	379	89	7	75	14	4	1.079
Goldrush	321	402	80	14	67	14	5	1.071
La12-59[3/]	316	360	88	11	56	32	1	1.080
Dark Red Norland[4/]	301	355	85	14	81	2	3	1.060
Superior	289	327	88	11	82	6	1	1.075
Russet Norkotah	286	363	79	16	66	13	5	1.075
Eramosa	222	253	88	7	73	15	5	1.068
Overall Average	354	409	86					1.075

[1/]Four location average.

[2/]Montcalm and Bay Counties only.

[3/]Bay, Montcalm and Monroe Counties only.

[4/]Bay, Montcalm and Presque Isle Counties only.

Funding: Federal Grant/NPC

1992 POTATO SCAB RESEARCH

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A. Breeding and genetics

Each year a replicated field trial is conducted to assess resistance to common and pitted scab. In 1992, 114 varieties and advanced breeding lines were planted in a scab inoculated field at the MSU Soils Farm. These data are summarized in Table 1. The varieties are ranked on a 1-4 scale based upon a combined score for scab coverage and lesion severity. Examining one year's data does not indicate which varieties are resistant but should begin to identify ones that can be classified as susceptible to scab. This year's trial had high soil moisture levels due to abundant rainfall. This may have attributed to the overall low scab infection levels. Our goal is to evaluate important advanced selections and varieties in the study at least three years to obtain a valid estimate of the level of resistance in each line. The varieties that have been tested at least three years out of the last four are summarized in Table 2. We are conducting additional greenhouse tests to assess the resistance levels in some of the advanced lines (i.e. E55-35, B076-2, Portage, Prestile, etc.).

To have a higher probability of breeding scab resistant round white varieties, scab assessment must be initiated early in a breeding program. A greenhouse test was developed to assess scab resistance at the seedling stage (described in previous progress reports). We have conducted a study to determine the correlation between this seedling test and greenhouse pot and field tests and found a high correlation between the seedling and greenhouse pot tests. The 1991 field test had limited levels of infection, therefore it did not correlate well with the greenhouse results. Additional greenhouse and field tests will be conducted to study this relationship. We have incorporated this seedling screen into the breeding program so that we can identify the most susceptible seedlings. These plants are then eliminated from the breeding program before more intensive evaluation of agronomic traits is initiated. This should increase the probability that scab resistant round white varieties can be bred for Michigan.

A genetic study was conducted to evaluate the potential to breed scab resistant varieties from the cultivated germplasm. In greenhouse seedling and pot tests, the most resistant parent (Lemhi Russet) transferred the highest level of resistance to its progeny, and the most susceptible parent (ND860-2) produced the lowest family means for resistance. Surprisingly, Atlantic was a better parent to transmit scab resistance than the more resistant varieties Superior and Onaway.

We are also in the process of identifying scab resistance in the related *Solanum* species. We hope these sources will offer greater levels of resistance than those we currently find in the cultivated potato. At this time we are intensively examining collections of two species, *Solanum phureja* and *S.*

chacoense, which show higher levels of scab resistance. We are focusing on these species because some selections have been noted to carry high specific gravity and chip-processing potential. The best 5% of the selections from these species accessions are being further assessed in greenhouse pot tests for scab resistance levels. Concurrently, we are assessing scab resistance in a number of haploids derived from Atlantic, Saginaw Gold and Superior. The most resistant haploids will be crossed with the species selections to combine good tuber quality and scab resistance. These haploid/species hybrids will then be used as parents in 4x-2x crosses in the breeding program.

A study was initiated using a diploid population, in conjunction with a saturated genetic map (based upon RFLPs, RAPDs and isozyme genetic markers) to identify chromosome segments that may contain genes controlling scab resistance. A replicated greenhouse pot test was used to assess scab resistance in the population. Isozyme, RFLP and RAPD analyses were used to characterize the population. Statistical analyses were conducted to determine linkage between genetic markers and scab resistance, however, no linkages were detectable. The difficulty in this study may have been the limited genetic variation within the population. We plan to continue this study using a population that more ideally suits this analysis.

B. Mechanisms of resistance

As part of the grant, we are also trying to determine the nature of resistance of the potato tuber to scab infection. By knowing how the plant defends itself it is possible that new strategies for control of the disease can be developed.

We have found that infection of tuber tissue that is resistant to scab reacts differently than does susceptible tissue. Histological and chemical analyses of resistant tuber tissue after inoculation with S. scabies revealed a higher amount of lignin at the infection site that what is observed in the inoculated susceptible tissues. The deposition of lignin, which acts as a barrier against infection, begins at the time of penetration of the pathogen into the tissue. Tissue of the susceptible varieties also exhibited visible necrosis and growth of the pathogen that was not observed in the resistant tissue. Resistance to infection has also been correlated with an enhanced accumulation of chlorogenic acid. However, the levels that accumulate are lower than that seen in wounded controls. This suggests that in the resistant interaction, more of the phenols are used to make lignin for resistance. Thus, it is possible that resistance my be based on the potential to synthesize phenols rather than just have high levels in the tuber tissue.

Use of in vitro produced tubers are now being used to more carefully study the interaction between young, developing tubers and resistance or susceptibility to scab. We have found, at the ultrastructural level, that the scab pathogen is able to easily penetrate through the cell walls of the tissue. Preliminary evidence also suggests that the pathogen is able to directly penetrate through the young epidermis prior to the development of a periderm.

The ability to enhance the level of resistance to disease has been observed in a number of plant species, including potato. We have investigated the use of 2,6-dichloroisonicotinic acid (Ciba-Geigy, CGA-41396) in the control of scab. This material, which is not directly toxic to fungi or bacteria, has been shown to induce resistance to disease in other Solanaceous plants. The compound was applied as a soil treatment in pots just prior to the initiation of tuber formation. Preliminary tests indicated that there was no significant effect on the amount of scab. However, because of our success with this compound inducing resistance in other plants are reducing the level of dry rot infection in potato tubers, further study is underway.

Table 1.

1992 Scab Evaluation
MSU Soils Farm
East Lansing, MI

1*	2	3	4
84-75R	86SD19-10Y	P83-11-5	P83-6-18
A091-1	A071-2	P84-13-12	P84-9-8
A097-1	A11601	A116-2	86SD19-8Y
A129-1	A125-1	A78242-5	B007-1
A84180-8	Chaleur	AF1060-2	B027-2
Chipeta	E57-13	Atlantic	B095-2
B027-1R	Eramosa	B076-2	B110-3
B040-3	Kennebec	B107-1	B2750
B042-1	Fontenot	B123-1	B2751
B073-2	MN12823	Bliss T.	B2753
B076-1	MN13540	Castile	Portage
B083-1	MS402-2	Early Rose	Desiree
B0952-1	Niska	Hilite	E11-45
B101-2	Norgold Rus.	Katahdin	Gemchip
B106-7	Norwis	NY85	Green Mt.
B106-8	NY78	Prestile	T. Cobbler
B111-4Y	Onaway	Sebago	MS401-2
B2752	Ranger R	White Rose	NY94
B9922-11	Red Pontiac		Red LaSoda
Chieftain	Reddale		Shepody
E55-35	Red Cloud		W870
E55-44	Russet Burbank		W877
Frontier R	Sangre		W887
Lemhi R	Sp. Pearl		
Mainechip	W1100		
MN14489	Yukon Gold		
Goldrush			
ND1871-3R			
Nooksack			
Norchip			
Norland			
NY84			
NY88			
Ontario			
R Norkotah			
Sag. Gold			
Snowden			
Steuben			
Superior			
W1005			
W1099			
W178R			

*1 = very little infection
4 = greater incidence of infection

Table 2.

Scab Field Test Summary **Variety Ranking**

	90	91	92	Ave.
R. Norkotah	1.3	1.0	1.0	1.1
W1005	1.3	1.0	1.0	1.0
Frontier	1.5	1.0	1.0	1.2
Lemhi R.	1.5	-	1.0	1.2
Ontario	2.3	1.0	1.0	1.4
Norchip	2.3	1.3	1.0	1.5
Norgold	1.5	1.0	2.0	1.5
Superior	2.8	1.0	1.0	1.6
Snowden	2.5	1.3	1.0	1.6
RB	1.7	1.0	1.0	1.6
Norland	2.7	1.0	1.0	1.6
Mainechip	2.8	1.3	1.0	1.7
Steuben	2.5	1.7	1.0	1.7
Saginaw G.	2.7	1.3	1.0	1.8
Chipeta	3.5	1.0	1.0	1.8
MS401-1	3.3	1.3	1.0	1.9
Early Rose	1.8	1.3	3.0	2.0
Segago	3.3	1.0	3.0	2.1
E55-35	3.5	1.7	1.0	2.1
Spartan Pearl	3.0	1.3	2.0	2.1
Onaway	3.3	1.3	2.0	2.2
White Rose	2.8	1.0	3.0	2.3
A78242-5	2.8	1.3	3.0	2.4
Castile	1.8	2.3	3.0	2.4
Kathadin	2.5	1.7	3.0	1.4
Eramosa	3.0	2.5	2.0	2.6
Red Pontiac	3.8	2.0	2.0	2.6
Gemchip	2.5	1.3	4.0	2.6
Norwis	4.0	2.0	2.0	2.7
Atlantic	4.0	2.3	3.0	3.1
B2753	3.7	2.0	4.0	3.2
Red LaSoda	3.2	2.3	4.0	3.2
B2751	3.7	2.3	4.0	3.3
Shepody	4.2	1.7	4.0	3.3

*Resistant: <2
Moderately resistant: 2.0-2.5
Susceptible: 2.6-3.0
Very susceptible: >3.0

Funding: MPIC

THE EFFECT OF SEED CLASS ON THE YIELD OF ATLANTIC, SNOWDEN AND YUKON GOLD

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Introduction

Tissue culture technology combined with limited generation seed potato production has dramatically increased throughout the U.S. during the past decade. Seed stocks of known disease freedom can now be rapidly propagated and increased. From a commercial growers perspective, very little research has been conducted to determine the true yield potential that can be expected. A study was initiated in 1991 to assess the yield characteristics of selected classes of seed of Yukon Gold, Atlantic and Snowden.

Procedure

In the spring of 1991, greenhouse tubers, nuclear and generation 1 seed stocks were obtained for Atlantic, Snowden and Yukon Gold. The seed was prepared and hand planted at the Lake City Experiment Station for increase. The growing crop was monitored for any visual symptoms of diseases. The vines were top killed in mid August and the crop was harvested on September 4, 1991. Just prior to top kill, leaf samples were collected and tested for PVX, PVY, PVLR and PVS. The seed was suberized for three weeks and then uniformly stored at 40°F until preparation for planting at the Montcalm Research Farm in 1992. The seed was cut and hand planted on May 6 at 8 inches for Yukon Gold and Atlantic and 12 inches for Snowden with 34 inches between rows. Each variety was planted as a separate, randomized complete block with six replications. Each plot was 23 feet in length.

Observations and notes were taken on plant stands, vigor and evidence of foliar disease expression. The Yukon Gold and Atlantic plots were harvested on September 2 and the Snowden on September 15. Yields, size distribution and specific gravity were determined.

Results

The 1991 ELISA tests of the seed prior to harvest showed 2 plants of PVS in the nuclear, 4 plants of PVS in 25 in generation I and 6 plants of PVS in 30 for generation II for Yukon Gold. No PVS was determined in Atlantic and 1 plant of PVS in each of nuclear and generation I and 4 plants of PVS in generation II of Snowden.

Visual observations of the plantings at the Montcalm Research Farm in 1992 showed no marked differences in stand or plant vigor. There was no evidence of any visual disease symptoms in any of the varieties during the growing season.

The yield and size distribution results for the three varieties are presented in Table 1. Overall yields for Atlantic were very good, fairly good for Yukon Gold but were below expectations for Snowden which had a high percentage of undersized potatoes. Specific gravity values are not shown as there was no effect noted.

There were 12% higher yields of Yukon Gold No. 1 potatoes from the generation I and II seed when compared with a planting of nuclear seed. For Atlantic, generation I seed produced 7% less yield than nuclear and 12% less yield for generation II seed when compared with the planting of nuclear. For Snowden, the generation I seed yielded 7% less than nuclear and generation II seed was reduced by 10%.

These one year results suggest that there may be a difference in varieties in terms of the generation level which produces the best yields. For Atlantic and Snowden, these data suggest that the earlier generation seed does have a greater yield potential. To fully evaluate the true effect of generation production potential, the study must be continued for at least three years.

Table 1. The yield and size distribution of Yukon Gold, Atlantic and Snowden when planted to different seed classes.

	Yield (cwt/A)		Percent Distribution				
Seed Class Planted	No. 1	Total	No. 1	<2"	2-3¼"	>3¼"	Pick Outs
			Yukon Gold				
Nuclear	231	261	88	11	86	2	1
G I	270	294	92	7	87	5	1
G II	273	293	93	6	88	5	1
			Atlantic				
Nuclear	416	438	95	4	78	17	1
G I	395	408	97	3	76	21	0
G II	366	386	95	4	76	19	1
			Snowden				
Nuclear	214	285	75	24	74	1	1
G I	198	261	76	23	74	2	1
G II	193	253	76	24	75	1	0

Funding: Federal Grant

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

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Introduction

Management profile studies have been conducted on selected varieties and advanced seedlings since 1986 in order to evaluate the effect of plant spacing and nitrogen levels. Ranger Russet, Gemchip and E55-35 have demonstrated potential adaptability to Michigan for processing and fresh market use.

Procedure

Three levels of nitrogen (100, 150 and 200 lbs/A) and three in-row spacings (6, 9 and 12 inches) were studied with Gemchip and E55-35. For Ranger Russet spacings of 9, 12 and 15 inches were evaluated with nitrogen levels of 150, 200 and 250 lbs/A. All three cultivars were hand planted with cut seed on May 6, 1992. Before plowing 350 lbs/A of 0-0-50 (potassium sulfate) was broadcast. At planting, 200 lbs/A of 20-10-10 was applied to all plots. Each variety was a separate study in a randomized split plot design with four replications. The main plot was the nitrogen level and the sub plot consisted of the three plant spacings, each planted in a single row of 23 feet. Two border rows were planted between each plot with one row fertilized the same as the adjacent plot. Individual plots were hand fertilized with nitrogen at emergence (June 3) and at hilling (June 17) to provide the various nitrogen levels.

Soybeans were grown as a plowdown crop in 1991 and rye was planted in the fall. Phorate was used as the systemic insecticide and a banded application of Mocap 10G at 30 lb/A was applied just ahead of the opening shoe on the planter. The studies were irrigated and foliar insecticides and fungicides were applied as needed.

Results

Ranger Russet

The yields, percent size distribution, specific gravity and internal defects are summarized in Table 1. The range in yields from highest to lowest were less than 50 cwt/A and there was very little delay in maturity noted with the highest levels of nitrogen. Internal defects were minimal and the most noted defect was vascular discoloration.

The lower portion of Table 1 summarizes the effects of the three nitrogen levels regardless of spacing. These data show the greatest yield of U.S. No. 1 potatoes occurred with 200 lbs/A of nitrogen. The percentage of tubers over 10 ounces was greater with the 200 lbs/A rate and there was a trend of a slight reduction of specific gravity. The data summarizing the effects of spacing only and disregarding the nitrogen level shows an 8% reduction in yield with the 12 and 15 inch spacings. The percentage of tubers over 10 ounces was greatest with the wider spacings and there was no effect from spacing on specific gravity. Ranger Russet has shown potential for frozen processing and fresh market and spacings may vary depending on the desired tuber size.

Gemchip

Table 2 summarizes the performance data for Gemchip. The range in yield response was from 359 to 233 cwt/A of U.S. No. 1's. Internal defects were minimal with vascular discoloration the most noted defect.

Comparing the three nitrogen levels, the greatest yield of U.S. No. 1's resulted from the 150 lbs/A level and there was no effect on specific gravity. There was only a minimal effect on size distribution.

The close plant spacing of 6 inches produced the greatest marketable yield and again, there were no noted differences among the spacings on size distribution. There was a 39% greater yield with the closer spacing when compared with the 12 inch space. There has been some interest in Gemchip for the fresh market.

E55-35

Table 3 summarizes the yield and performance data for E55-35. In contrast to Gemchip and Ranger Russet, there were no internal defects noted in any of the samples that were scored. The response to nitrogen was very small with only an 11% yield increase between the 100 and 200 lbs/A levels. It may be that E55-35 is similar to Atlantic in its response to nitrogen.

As noted with Gemchip, the closer spacing produced the greatest yield of marketable yield. E55-35 does have scab resistance equal to Superior and it does have some favorable chip prospects.

Summary

These results represent only one year results and it is planned at this time that these studies will be repeated in 1993.

Table 1. Management Profiles

Ranger Russet

Variety	Lbs N	Sp	CTW per Acre US#1	CTW per Acre Total	Percent of Total[1] #1	Bs	As	OV	PO	Spec. Grav.	Tuber Quality[2] HH	VD	IBS	BC/T
Ranger	200	9	283	345	82	12	58	24	6	1.087	2	2	0	0/36
Ranger	250	9	281	348	81	12	50	31	8	1.088	0	7	0	0/40
Ranger	200	12	275	340	81	10	43	38	9	1.086	0	1	1	1/40
Ranger	200	15	270	319	85	8	51	34	7	1.087	0	2	0	0/40
Ranger	150	9	265	342	77	13	61	17	9	1.088	0	2	0	0/36
Ranger	150	15	254	313	81	11	50	31	8	1.089	2	0	0	0/40
Ranger	150	12	248	321	77	15	52	26	7	1.089	0	4	1	0/36
Ranger	250	15	244	305	80	11	47	33	9	1.088	0	4	2	0/38
Ranger	250	12	235	300	78	14	50	28	8	1.086	0	2	1	0/40
LSD (0.05)			30	26										

Variety	Lbs N	Sp	CTW per Acre US#1	CTW per Acre Total	Percent of Total #1	Bs	As	OV	PO	Spec. Grav.
	150		256	325	78	13	54	25	8	1.089
	200		276	334	83	10	51	32	7	1.087
	250		253	318	80	12	49	31	8	1.087
		9"	276	345	80	12	56	24	8	1.088
		12"	253	320	79	13	48	31	8	1.087
		15"	256	312	82	10	49	33	8	1.088

[1] Size
A - 4 -10 oz
B - < 4 oz
OV - > 10 oz
PO - Pick out

[2] Quality
HH - Hollow Heart
VD - Vascular Discoloration
IBS - Internal Brown Spots
- Number of oversize tubers cut

Table 2. Management Profile

Gemchip

Variety	Lbs N	Sp	CTW per Acre US#1	CTW per Acre Total	Percent of Total[1] #1	Bs	As	OV	PO	Spec. Grav.	Tuber Quality[2] HH	VD	IBS	BC/T
Gemchip	200	6	359	399	90	7	81	10	3	1.084	1	0	1	0/24
Gemchip	150	6	347	390	89	8	79	9	3	1.084	0	7	1	0/26
Gemchip	100	6	325	371	88	8	78	10	4	1.084	0	3	0	0/27
Gemchip	200	9	313	346	90	6	81	9	3	1.087	0	7	0	0/26
Gemchip	150	9	309	346	89	7	79	10	3	1.084	0	4	3	1/27
Gemchip	100	9	293	335	88	9	77	10	3	1.085	1	2	2	0/24
Gemchip	150	12	270	295	91	5	83	8	3	1.084	0	2	0	0/19
Gemchip	200	12	236	268	88	8	76	12	4	1.083	0	4	1	0/23
Gemchip	100	12	233	269	87	9	72	14	5	1.085	2	4	3	0/29
LSD (0.05)			43	45										

Variety	Lbs N	Sp	CTW per Acre US#1	CTW per Acre Total	Percent of Total #1	Bs	As	OV	PO	Spec. Grav.
	100		283	325	88	9	76	11	4	1.085
	150		308	343	90	7	80	9	3	1.084
	200		303	338	89	7	79	10	3	1.085
		6"	343	387	89	8	79	10	3	1.084
		9"	305	342	89	7	79	10	3	1.085
		12"	246	277	89	7	77	11	4	1.084

[1] Size
A - 2 - 3.25"
B - < 2"
OV - > 3.25"
PO - Pick out

[2] Quality
HH - Hollow Heart
VD - Vascular Discoloration
IBS - Internal Brown Spots
- Number of oversize tubers cut

Table 3. Management Profile

E55-35

Variety	Lbs N	Sp	CTW per Acre US#1	CTW per Acre Total	Percent of Total[1] #1	Bs	As	OV	PO	Spec. Grav.	Tuber Quality[2] HH	VD	IBS	BC/T
E55-35	200	6	280	318	88	11	84	4	1	1.092	0	0	0	0/11
E55-35	150	6	259	298	87	12	84	3	1	1.092	0	0	0	0/8
E55-35	100	6	246	288	86	14	83	2	0	1.087	0	0	0	0/6
E55-35	200	9	236	259	91	8	81	10	1	1.091	0	0	0	0/21
E55-35	200	12	220	241	92	8	80	12	1	1.090	0	0	0	0/25
E55-35	150	12	217	239	90	9	82	8	1	1.090	0	0	0	0/16
E55-35	150	9	215	243	89	10	86	2	1	1.089	0	0	0	0/5
E55-35	100	9	207	245	84	15	82	2	0	1.089	0	0	0	0/5
E55-35	100	12	206	231	89	10	81	8	1	1.089	0	0	0	0/14
LSD (0.05)			35	38										

Variety	Lbs N	Sp	CTW per Acre US#1	CTW per Acre Total	Percent of Total #1	Bs	As	OV	PO	Spec. Grav.
	100		220	255	86	13	82	4	0	1.088
	150		230	260	89	10	84	4	1	1.090
	200		245	272	90	9	82	9	1	1.091
		6"	262	301	87	12	84	3	1	1.090
		9"	219	249	88	11	83	5	1	1.090
		12"	214	237	90	9	81	9	1	1.090

[1] Size
A - 2 - 3.25"
B - < 2"
OV - > 3.25"
PO - Pick out

[2] Quality
HH - Hollow Heart
VD - Vascular Discoloration
IBS - Internal Brown Spots
- Number of oversize tubers cut

Funding: MPIC

Processing and Quality Evaluation of Fresh Peeled and Canned Potatoes from the MSU Variety Trials

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

INTRODUCTION

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

PROCEDURE

Tubers from approximately 6-8 cultivars and/or selections grown in Michigan and the MSU variety trials were used for processing as fresh peeled and canned. Tubers from each processing lot were assessed for specific gravity and black spot. Samples were abrasion peeled to approximately 10-12% peel loss and divided into lots for holding as fresh peeled or diced for canning. Fresh peeled samples were held at 38°F after treating with 0.5% citric + 0.5% ascorbic + 0.1% $NaCl_2$ or after dipping in water (control). These samples were evaluated at 0, 3, 5, 7 and 10 days for color (visual rating and Hunter CDM) and texture (shear press or Instron). Canned samples were diced and canned under commercial conditions. These samples were removed from storage and evaluated at 0, 3, 6 and 9 months for drained weight, color (visual and Hunter CDM), and texture (shear press or Instron). Processing for fresh peeled and canned product were done at harvest and again after 6 months storage.

RESULTS AND DISCUSSION

Results of the 10 day storage regime for fresh peeled potatoes are shown in Table 1. Changes in color and overall acceptability took place slowly during the first 3 days of refrigerated storage and there were no significant differences between the control and ascorbic acid treated samples. By day 5 the only control samples that had acceptable quality were Kanona, Superior and Viking but all of the ascorbic acid treated samples except Eramosa were still acceptable. By day 7 only the ascorbic acid treated sample of Onaway still had acceptable color and by the tenth day of storage none of the samples was acceptable. Table 2 shows the results of peeling on tubers which were stored at 45°F for 6 months prior to peeling. All samples treated with ascorbic acid had very good quality (ie., color) 1 day after peeling and the water dipped control samples were all acceptable. By the third day of refrigerated storage, the control samples were all rated as unacceptable, while the ascorbic acid treated samples were showing definite discoloration. By the seventh day of refrigerated storage all the samples were unacceptable.

Tables 3, 4 and 5 show the results of evaluation of the canned samples after 3, 6 and 9 months. As expected, all samples gained weight in the can, with Superior, Atlantic and Russet Burbank showing the greatest gains. Viking, Eramosa, Superior and Onaway all had excellent color while Stueben and Atlantic exhibited very poor color. Visual assessment of texture was related to the wholeness and integrity of the diced potato pieces. Atlantic and Stueben scored lowest but all of the samples had very acceptable attributes in this category. The Kramer Shear data indicates that the samples were very similar in their shear characteristics. Shear values relate to the force necessary to move one or more shear cell blades through a given volume of sample inside a cell of defined size. Compression refers to the force exerted by elastic deformation of the sample against the blades as the sample is forced through the grid of a shear cell. Compression values were highest for Russet Burbank, Kanona, Atlantic and Stueben. It is likely that this is an indirect reflection of the starch content of these tubers and the changes which the starch granules have undergone during processing. Based on these data Atlantic, Stueben and Kanona were dropped from the processing trials which were conducted on potatoes from the 1992 harvest.

Table 1 - Quality Evaluation of Fresh Peeled Potatoes, 1991.

	Day 1		Day 3		Day 5		Day 7		Day 10	
Cultivar	w/Asc	CK[1]	w/Asc	CK	w/Asc	CK	w/Asc	CK	w/Asc	CK
Russet Burbank	8[2]	8	8	6	5	2	4	-	3	-
Onaway	8	8	8	6	5	4	5	2	2	-
Kanona	8	8	8	7	6	5	4	3	2	-
Superior	9	9	8	8	6	6	3	4	2	-
Viking	8	8	8	7	5	6	2	3	1	-
Eramosa	7	7	6	6	4	4	2	2	1	-
Atlantic	8	8	8	6	6	3	4	-	3	-
Stueben	7	7	6	3	5	0	1	-	0	-

[1] w/Asc = with ascorbic acid; CK = control without ascorbic acid

[2] 1 to 10; 1 = poorest, 10 = best

Table 2 - Quality Evaluation of Fresh Peeled Potatoes from Tubers Which Were Stored 6 Months Before Peeling, 1991.

Cultivar	Day 1		Day 3		Day 7	
	w/Asc	Ck[1]	w/Asc	Ck	w/Asc	Ck
Russet Burbank	10[2]	7	6	0		
Kanona	10	7	5	0		
Superior	10	5	5	0		
Viking	10	10	7	0		
Atlantic	10	6	6	0		
Stueben	10	2	2	0		

[1] w/Asc = with ascorbic acid; Ck - control without ascorbic acid
[2] 1 to 10; 1 = poorest, 10 = best

Table 3 - Quality Evaluation of Canned Potatoes After 3 Months Storage, 1991.

Cultivar	Drained wt (g)[1]	Visual Color[2]	Visual Texture[2]	Force in lbs/100g[3] Shear	Compression
Russet Burbank	438.6	6	7	36	87
Onaway	395.9	9	9	30	63
Kanona	419.2	8	8	33	87
Superior	462.9	9	8	33	76
Viking	405.7	10	7	30	66
Eramosa	370.5	10	8	30	63
Atlantic	433.0	5	6	36	87
Stueben	428.0	4	5	36	81

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

Table 4 - Quality Evaluation of Canned Potatoes After 6 Months Storage, 1991.

Cultivar	Drained Wt(g)[1]	Visual Color[2]	Visual Texture[3]	Force lbs/100g Shear	Force lbs/100g Compression
Russet Burbank	480	6	7	34	74
Onaway	465	9	8	22	60
Kanona	460	6	8	32	84
Superior	470	10	9	25	65
Viking	475	10	9	28	68
Eramosa	460	10	8	18	52
Atlantic	475	5	5	30	76
Stueben	470	3	4	32	76

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

Table 5 - Quality Evaluation of Canned Potatoes After 9 Months Storage, 1991.

Cultivar	Drained Wt(g)[1]	Visual Color[2]	Visual Texture[3]	Force lbs/100g Shear	Force lbs/100g Compression
Russet Burbank	482	7	8	34	78
Onaway	460	9	8	20	65
Kanona	460	6	8	32	81
Superior	475	10	8	28	65
Viking	465	9	9	20	65
Eramosa	465	9	9	20	50
Atlantic	480	4	4	28	70
Stueben	470	1	4	25	72

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

Funding: MPIC, MECP, PPI

UNDERSTANDING THE RESPONSE OF POTATOES TO PHOSPHORUS

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Understanding the response of potato cultivars to applied phosphorus is important for efficient utilization of monetary and phosphorus resources. Many soils used for potato production have very high levels of available phosphorus as indicated by conventional soil tests. In soils subject to erosion of the surface soil considerable phosphorus may be carried into surface drainage waters. Elevated phosphorus levels in streams and lakes stimulates eutrophication and reduces water quality. Studies over the years, primarily with Russet Burbank, have shown band application of phosphate fertilizer to increase tuber yields even when available soil phosphorus levels are high. An understanding of why potatoes respond this way is needed.

Studies were established in 1992 to further the understanding of the phosphorus nutrition of potatoes. Seven cultivars, Onaway, Superior, Atlantic, Snowden, Kennebec, Russet Burbank and Russet Norkotah were grown with four amounts of band applied phosphorus, 0, 75, 150 and 225 lb P_2O_5 per acre. The cultivars selected represent the major types of potatoes grown in Michigan, except Kennebec. Kennebec was included because there are indication it has a more extensive root system than most commonly grown cultivars. A more vigorous and extensive root system should improve a plants ability to acquire phosphorus from the soil. All seven cultivars were grown in a McBride sandy loam at the Montcalm Research Farm and in a Metea sandy loam at the MSU Soils Research Farm. All cultivars except Russet Burbank were grown on an Essexville loamy sand in Bay county. The Bray-Kurtz P1 phosphorus test values for the three sites were 406, 370 and 202 lb P/A for the McBride, Essexville and Metea soils, respectively. The band fertilizer was placed two inches from both sides of the seed piece and contained 70 lb N, 50 lb K_2O and the treatment amount of P_2O_5 per acre. Thimet was applied to aide in control of Colorado potato beetles and other insects. The potatoes were planted on May 11 at the MSU Research Farm, May 12 in Bay county, May 15 in Montcalm county. About 80 lb N/A was sidedressed at hilling time. Labeled fungicide and insecticide materials were applied during the season as necessary.
The cool soil temperatures during the 1992 growing season provided conditions favorable for early season response to applied phosphorus. Petioles samples were collected from all plots on July 1 in Montcalm county, July 8 at MSU and July 22 in Bay county and analyzed for total phosphorus. Data on phosphorus contents of the petioles are presented in Tables 1, 2 and 3. On the McBride sandy loam the phosphorus concentration in the petioles of all cultivars except Kennebec reflected the amount of phosphate applied. With no phosphorus applied the P concentration in the Kennebec petioles was as high or higher than P concentration of the petioles of the other cultivars with 225 lb P_2O_5/A applied. And the petiole P concentration did not increase significantly with the application of phosphate. This indicates that the root system of Kennebec is more effective in accumulating P than are the other cultivars. For Onaway, Superior, Atlantic and Snowden the petiole P concentration did not increase above 150 lb P_2O_5/A. With the two russet varieties the highest petiole P concentration occurred with the highest applied amount of phosphate. There are significant differences among the cultivars in the amounts of P they accumulate. Atlantic and Snowden, being genetically similar, had the lowest petiole P concentrations. Petiole P concentrations in the two round white table stock cultivars, Onaway and Superior, were similar. And the petiole P concentrations in the two russet cultivars were also similar.

Trends in petiole P concentrations found in the six cultivars grown in the Essexville loamy sand (Table 2) were similar to those found on the Mc Bride sandy loam. Kennebec accumulated significantly more P in the petioles than the other cultivars and the applied phosphate rate had no effect on the petiole P concentration. In the other five cultivars petiole P concentration increased with amount of phosphate applied up to 150 lb P_2O_5/A. The genetically similar cultivars Onaway and Superior, and Atlantic and

Snowden had similar P concentrations and responses. However, in this soil the Onaway and Superior had lower petiole P levels than did Atlantic and Snowden. This was the reverse of what occurred in the McBride soil.

When grown in the Metea sandy loam the petiole P concentration in each of the cultivars, including Kennebec, increased with the amount of phosphate applied (Table 3). The petiole P concentrations were much more similar among the seven cultivars grown in this soil than in the McBride and Essexville soils. Kennebec had the highest P concentrations and Onaway had the lowest. With the petiole P concentrations reflecting the phosphate application tuber yield responses to applied phosphate were anticipated.

Each of the cultivars were harvested after they were mature and the vines had senesced. Development and maturity of the potatoes was delayed this year because of the cool temperatures and well below normal growing degree days. Total and marketable tuber yields for each of the cultivars growing in the McBride sandy loam are given in Tables 4 and 5. Total tuber yields of all cultivars except Kennebec were increased by the band application of phosphate. With Kennebec the average total tuber yield was higher with 75 lb P_2O_5/A compared with no phosphate applied, but the difference is not significant. With the other six cultivars the main increase in total tuber yield resulted from 75 lb P_2O_5/A. Applying more phosphate fertilizer than this produced smaller non-significant increases in total yield. Snowden benefitted the most from the application of phosphate. Visible growth differences could be seen between the no phosphorus and the phosphorus plots of Snowdens. Russet Burbank and Russet Norkotah were also quite responsive to phosphate application. The stands of Superior were thin and variable resulting in low and variable yields. Increases in marketable potato yields (greater than 2 inch diameter or 4 ounces) in relation to phosphorus treatment were similar to those of total yields. The relative petiole P concentrations associated with each phosphorus treatment for each cultivar would have been a good predictor of the yield benefit from phosphate application on the McBride sandy loam.

In contrast to the yield benefits from phosphate application in the McBride soil, tuber yield responses to phosphate application were limited on the Essexville loamy sand and the Metea sandy loam. Russet Norkotah was the only cultivar to give a significant response to phosphorus application in the Essexville soil (Tables 6 and 7). Tuber yields of Superior were increased with the application of 75 lb P_2O_5/A but this was not significant due to large variability. With some cultivars yields appear to have been decreased by the highest amount of phosphate. In the Metea sandy loam Onaway and Superior gave significant yield responses to phosphate application (Tables 8 and 9). Yields of Russet Norkotah increased with increasing phosphorus rate, but the increases were not significant. Unlike the potatoes grown in the McBride soil petiole P concentrations were not a good indicator of tuber yield response to applied phosphorus in the Essexville and Metea soils.

Specific gravities of marketable tubers in relation to the phosphorus treatments are presented in Tables 10, 11 and 12 for the three locations. For potatoes grown in the McBride sandy loam only tubers of Snowden and Russet Burbank showed a significant increase in specific gravity in relation to amount of phosphate applied. When grown in the Essexville loamy sand and in the Metea sandy loam phosphorus application had no consistent effect on specific gravity.

Tubers from each of the cultivar - phosphorus treatment combinations were analyzed for the P concentration. Two cores were taken from 10 of the tubers used in the specific gravity determinations. Results of the analyses are given in Tables 13, 14 and 15. Tubers produced in the McBride sandy loam had considerably lower P concentrations than did tubers grown in the Essexville and Metea soils for all cultivars. This may be an indicator as to why yield responses to applied phosphate occurred in the McBride soil and not in the other two soils. At all three sites phosphate application had little effect on tuber P content of Kennebec. The more vigorous and extensive root system of the Kennebec plants were apparently better able to supply phosphorus for the plant and developing tubers. Tubers of Kennebec also tended to have the highest P contents. With the other cultivars phosphorus application did result in higher tuber P concentrations although these increases were not always significant.

At the MSU Research Farm single plants were harvested four times during the growing season for each cultivar - phosphorus treatment to follow biomass and phosphorus accumulation in the various plant parts. At each harvest there was considerable variation among replicates. There were no discernible differences in biomass accumulation related to the amount of phosphate applied at planting time. Hence, the plant measurements taken are summarized across all phosphorus amounts for each sampling date (Table 16). Hence, the data in Table 16 simply shows a comparison of the development of the seven cultivars at each sampling date. Table 17 shows the phosphorus content of the stems and the leaves for all phosphorus rates and sampling dates. At the late June sampling date the stems and leaves of potato plants receiving 75 or 150 lb P_2O_5/A at planting had higher P concentrations than plants not receiving phosphorus. When the plant samples were collected 10 days later the P concentrations in the stem and leaf tissues were relatively unchanged in all cultivars, except Russet Norkotah. By the end of July the phosphorus levels had decreased significantly in the stems and to a lesser extent in the leaves of the early maturing cultivars, Onaway and Superior. Apparently phosphorus was being translocated from these plant parts to the developing tubers. As tuber development progressed in the other cultivars the P concentration in the stems decreased markedly while the levels in the leaves decreased only slightly. With Kennebec the stem tissue maintained a good P level through the last sampling, especially relative to Russet Burbank. Again, the more vigorous and extensive root system of Kennebec was apparently better able to supply phosphorus.

Data presented indicate that there are differences among potato cultivars in their response to applied phosphorus in terms of accumulation in various plant parts and yield. When tubers begin to size rapidly the P concentration in the stem tissue decreases markedly whereas loss of P from the leaf tissue including the petiole occurs more slowly. The decline in P content of the stem tissue is most dramatic in Russet Burbank. With Kennebec the P concentration in the stem and leaf tissue remained fairly stable throughout the sampling period. This difference in P status over time is likely related to the more extensive and vigorous root system reported for Kennebec. Even though petiole P concentrations generally reflected the amount of P applied at planting, the higher petiole P levels corresponded to higher tuber yields in only one soil, the McBride sandy loam. In all soils petioles of Kennebec had the highest P levels.

Differences in yield response to phosphorus also occurred between soils. All cultivars except Kennebec benefitted from band application of phosphate in the McBride sandy loam, but responses were limited in the Essexville loamy sand and Metea sandy loam. The reasons for this differential response are not well understood at this time, and this is an area requiring further study. The response difference may be related to differences in phosphorus chemistry or differences in the physical condition of the soil. Table 18 shows the levels of extractable P in 27 soils used for potato production as determined with four different chemical extractants. Each of these extractants indicate the same relative amounts of available phosphorus in these soils. However they have not given a good indication as to the potential benefit from applied phosphate. The 0.01 M $CaCl_2$ reflects the readily soluble P status of the soil and tends to give some indication as to whether or not phosphate application may be beneficial for potatoes on a given soil. However more field yield data is needed. The Essexville soil in Bay county was loosen to a depth of 14 inches in the row area prior to planting. This provided a favorable environment for good root development whereas the McBride sandy loam was more compact and restrictive to root development. The lack of response from Kennebec which has a vigorous root system points toward the need for better root systems to improve utilization of soil phosphorus.

Table 1. Petiole phosphorus content of seven potato cultivars in relation to band applied phosphorus when grown in a McBride sandy loam.[a]

Phosphorus Applied	Onaway	Superior	Atlantic	Snowden	Kennebec	Russet Burbank	Russet Norkotah
lb P_2O_5/A	- - - - - - - - - - - - - -	% P in Petiole	- - - - - - - - - - - - - -				
0	.28	.31	.23	.22	.43	.30	.27
75	.36	.38	.25	.26	.48	.36	.33
150	.47	.45	.30	.35	.49	.42	.38
225	.46	.44	.31	.33	.49	.45	.44
LDS .10	.028	.056	.028	.040	NS	.028	.040
CV	4.9	11.0	7.5	9.1	12.6	4.5	8.0

[a] Sampling date 7-1-92

Table 2. Petiole phosphorus content of six potato cultivars in relation to band applied phosphorus when grown in an Essexville loamy sand.[a]

Phosphorus Applied	Onaway	Superior	Atlantic	Snowden	Kennebec	Russet Norkotah
lb P_2O_5/A	- - - - - - - - - - - - - -	% P in Petiole	- - - - - - - - - - - - - -			
0	.26	.21	.27	.28	.51	.22
75	.25	.25	.37	.29	.51	.21
150	.28	.26	.40	.37	.52	.33
225	.29	.27	.40	.37	.52	.31
LSD .10	NS	NS	.08	NS	NS	NS
CV	18.8	19.3	14.1	28.7	21.0	32.9

[a] Sampling date 7-22-92.

Table 3. Petiole phosphorus content of seven potato cultivars in relation to band applied phosphorus when grown in a Metea sandy loam.[a]

Phosphorus Applied	Onaway	Superior	Atlantic	Snowden	Kennebec	Russet Burbank	Russet Norkotah
lb P_2O_5/A	- - - - - - - - - - - - - -	% P in Petiole	- - - - - - - - - - - - - -				
0	.25	.29	.28	.27	.38	.26	.26
75	.25	.30	.31	.31	.39	.28	.29
150	.27	.32	.36	.35	.41	.30	.32
225	.30	.35	.37	.37	.45	.33	.32
LSD .10	.016	.053	.032	.030	.044	.028	.040
CV	4.4	13.7	7.8	7.7	8.8	7.8	10.5

[a] Sampling date 7-8-92.

Table 4. Response of seven potato cultivars to band applied phosphorus when grown in a McBride sandy loam. Total yield.

Phosphorus Applied	Onaway	Superior	Atlantic	Snowden	Kennebec	Russet Burbank	Russet Norkotah
lb P_2O_5/A	cwt/A						
0	366	234	333	205	495	285	277
75	386	230	346	278	532	351	350
150	381	224	338	326	529	369	388
225	342	274	366	325	513	381	364
LSD .10	27	43	28	30	NS	36	30
CV (%)	5.8	14.4	6.6	8.6	7.0	8.2	6.7

Table 5. Response of seven potato cultivars to band applied phosphorus when grown in a McBride sandy loam. Marketable yield.

Phosphorus Applied	Onaway	Superior	Atlantic	Snowden	Kennebec	Russet Burbank	Russet Norkotah
lb P_2O_5/A	cwt/A						
0	328	163	290	158	461	200	196
75	352	153	301	233	499	248	258
150	348	163	300	286	499	275	298
225	302	198	321	285	473	283	267
LSD .10	31	NS	26	29	NS	35	30
CV (%)	7.5	22.1	6.9	9.6	7.9	11.2	9.3

Table 6. Total tuber yields of six potato cultivars in relation to band application of phosphorus when grown in an Essexville loamy sand.

Phosphorus Applied	Onaway	Superior	Atlantic	Snowden	Kennebec	Russet Norkotah
lb P_2O_5/A			cwt/A			
0	396	224	353	368	458	244
75	405	284	336	374	455	294
150	405	282	363	367	466	332
225	434	210	335	368	434	281
LSD .10	NS	NS	NS	NS	NS	42
CV	10.2	36.2	6.7	3.8	14.1	9.6

Table 7. Marketable tuber yields of six potato cultivars in relation to band application of phosphorus when grown in an Essexville loamy sand.

Phosphorus Applied	Onaway	Superior	Atlantic	Snowden	Kennebec	Russet Norkotah
lb P_2O_5/A			cwt/A			
0	343	151	289	292	392	149
75	346	195	259	303	396	173
150	348	204	302	316	408	209
225	380	182	270	299	376	184
LSD .10	NS	NS	NS	NS	NS	50
CV	10.6	26.8	11.8	7.6	15.6	18.5

Table 8. Total tuber yield of seven potato cultivars in relation to band applied phosphorus when grown in a Metea sandy loam.

Phosphorus Applied	Onaway	Superior	Atlantic	Snowden	Kennebec	Russet Burbank	Russet Norkotah
lb P_2O_5/A				cwt/A			
0	371	258	447	381	491	374	307
75	394	267	420	382	495	388	327
150	396	287	425	369	473	356	353
225	435	265	449	380	498	375	359
LSD .10	54	NS	NS	NS	NS	NS	NS
CV (%)	10.7	8.4	9.6	8.7	12.0	8.3	13.4

Table 9. Marketable tuber yield of seven potato cultivars in relation to band applied phosphorus when grown in a Metea sandy loam.

Phosphorus Applied	Onaway	Superior	Atlantic	Snowden	Kennebec	Russet Burbank	Russet Norkotah
lb P_2O_5/A				cwt/A			
0	322	186	416	339	452	247	214
75	345	192	391	334	456	249	232
150	341	204	387	322	424	240	248
225	391	187	413	336	451	254	258
LSD .10	52	39	NS	NS	NS	NS	NS
CV (%)	11.8	11.5	10.2	9.6	12.0	7.7	17.1

Table 10. Specific gravity of tubers of seven potato cultivars in relation to band applied phosphorus in a McBride sandy loam.

Phosphorus Applied	Onaway	Superior	Atlantic	Snowden	Kennebec	Russet Burbank	Russet Norkotah
lb P_2O_5/A							
0	1.071	1.075	1.095	1.090	1.075	1.079	1.075
75	1.070	1.076	1.096	1.091	1.078	1.080	1.074
150	1.072	1.077	1.096	1.094	1.076	1.081	1.076
225	1.073	1.077	1.096	1.095	1.077	1.083	1.073
CV	.09	.15	.12	.12	.13	.14	.12

Table 11. Specific gravity of tubers of six potato cultivars in relation to band application of phosphorus when grown in an Essexville loamy sand.

Phosphorus Applied	Onaway	Superior	Atlantic	Snowden	Kennebec	Russet Norkotah
lb P_2O_5/A						
0	1.069	1.071	1.097	1.091	1.076	1.070
75	1.069	1.073	1.090	1.090	1.076	1.073
150	1.068	1.072	1.092	1.091	1.080	1.073
225	1.070	1.071	1.089	1.090	1.077	1.070
CV	0.19	0.26	0.47	0.19	0.19	0.39

Table 12. Specific gravity of tubers of seven potato cultivars in relation to band applied phosphorus in a Metea sandy loam.

Phosphorus Applied	Onaway	Superior	Atlantic	Snowden	Kennebec	Russet Burbank	Russet Norkotah
lb P_2O_5/A							
0	1.075	1.083	1.100	1.096	1.083	1.089	1.079
75	1.076	1.083	1.099	1.095	1.083	1.091	1.078
150	1.075	1.082	1.097	1.095	1.084	1.091	1.078
225	1.074	1.082	1.099	1.096	1.086	1.093	1.081
CV	0.20	0.11	0.23	0.17	0.19	0.11	0.17

Table 13. Tuber phosphorus content of seven potato cultivars in relation to band applied phosphorus when grown in a McBride sandy loam.

Phosphorus Applied	Onaway	Superior	Atlantic	Snowden	Kennebec	Russet Burbank	Russet Norkotah
lb P_2O_5/A				% P in Tuber			
0	.20	.21	.17	.17	.28	.16	.20
75	.22	.23	.18	.19	.28	.19	.22
150	.23	.25	.20	.20	.29	.21	.24
225	.25	.27	.20	.23	.28	.23	.26
LDS .10	.020	.016	.011	.016	NS	.016	.016
CV	6.8	5.1	5.6	6.1	3.4	5.9	4.8

Table 14. Tuber phosphorus content of six potato cultivars in relation to band applied phosphorus when grown in an Essexville loamy sand.

Phosphorus Applied	Onaway	Superior	Atlantic	Snowden	Kennebec	Russet Norkotah
lb P_2O_5/A			% P in Tuber			
0	.24	.25	.25	.24	.28	.29
75	.24	.25	.28	.24	.29	.30
150	.27	.25	.29	.25	.28	.31
225	.26	.27	.28	.26	.29	.31
LSD .10	NS	.01	NS	NS	NS	NS
CV	10.3	3.0	15.8	9.7	6.9	9.6

Table 15. Tuber phosphorus content of seven potato cultivars in relation to band applied phosphorus when grown in a Metea sandy loam.

Phosphorus Applied	Onaway	Superior	Atlantic	Snowden	Kennebec	Russet Burbank	Russet Norkotah
lb P_2O_5/A				% P in Tuber			
0	.25	.23	.25	.23	.31	.22	.24
75	.27	.24	.25	.24	.31	.22	.25
150	.28	.26	.26	.25	.31	.25	.26
225	.28	.28	.25	.25	.31	.26	.27
LSD .10	.011	.011	NS	.016	NS	.032	.020
CV	3.8	4.4	8.4	8.2	5.4	11.0	6.6

Table 16. Development of seven potato cultivars grown in a Metea sandy loam.

Cultivar	Sampling Date	Stolon		Tuber		Stem		Leaf & Petiole	
		Number	Fresh Weight	Number	Fresh Weight	Number	Fresh Weight	Fresh Weight	Area
			g		g		g	g	cm^2
Onaway	6-26	23	4.3	11	104	5	112	254	3267
	7-6	24	6.6	12	257	5	116	255	4070
	7-27	22	3.8	12	719	5	188	300	5308
	8-7	25	4.2	11	966	5	192	424	6517
Superior	6-26	25	5.6	9	92	5	77	199	2704
	7-6	23	4.3	9	219	5	106	225	3172
	7-27	26	4.8	12	758	6	120	279	4515
	8-7	26	3.7	12	899	5	125	254	5263
Atlantic	6-26	24	7.9	11	117	5	161	235	3842
	7-6	23	7.1	12	322	5	241	408	4863
	7-27	21	7.7	10	834	5	274	431	8227
	8-7	28	7.7	15	1146	6	385	511	9665
Snowden	6-26	27	10.7	12	73	5	96	203	2708
	7-6	29	10.7	14	168	6	169	329	4931
	7-27	27	17.3	12	568	6	218	337	7075
	8-7	27	8.4	14	1000	6	446	408	-
Kennebec	6-26	19	6.5	7	43	5	84	219	-
	7-6	21	10.0	6	207	4	150	327	4876
	7-27	18	8.3	8	517	4	223	376	8082
	8-7	23	8.8	10	960	4	497	585	9867
Russet Burbank	6-26	23	2.4	10	108	5	93	153	2670
	7-6	25	3.4	12	201	5	169	305	4411
	7-27	25	2.8	13	713	4	292	312	8618
	8-7	20	2.7	13	778	4	290	387	8548
Russet Norkotah	6-16	24	2.5	14	105	5	107	194	2824
	7-6	25	2.7	14	410	6	136	235	4290
	7-27	24	2.5	13	791	5	149	270	5847
	8-7	24	2.6	13	826	5	174	262	-

Table 17. Temporal changes in P concentration in stems and leaves of seven potato cultivars in relation to band applied phosphate when grown in a Metea sandy loam.

Cultivar	P_2O_5 Applied	Stems 6/26	Stems 7/6	Stems 7/27	Stems 8/7	Leaves and Petioles 6/26	Leaves and Petioles 7/6	Leaves and Petioles 7/27	Leaves and Petioles 8/7
		- - - - - - - % P - - - - -				- - - - - - - % P - - - - - -			
Onaway	0	.21	.20	.14	.15	.33	.29	.24	.20
	75	.20	.18	.14	.13	.36	.32	.27	.22
	150	.32	.29	.14	.13	.50	.40	.24	.24
	225	.35	.22	.17	.12	.51	.35	.31	.19
Superior	0	.18	.24	.12	.12	.30	.40	.20	.23
	75	.27	.22	.12	.14	.36	.35	.24	.24
	150	.32	.35	.11	.13	.41	.42	.23	.21
	225	.35	.29	.20	.16	.45	.35	.24	.24
Atlantic	0	.31	.27	.20	.15	.38	.35	.24	.23
	75	.38	.32	.23	.21	.40	.38	.29	.24
	150	.33	.29	.32	.19	.42	.38	.31	.23
	225	.39	.35	.25	.15	.48	.42	.37	.28
Snowden	0	.22	.27	.18	.17	.37	.34	.33	.32
	75	.24	.30	.15	.16	.46	.33	.33	.30
	150	.36	.29	.17	.16	.49	.35	.36	.27
	225	.37	.36	.26	.13	.42	.38	.31	.27
Kennebec	0	.29	.30	.20	.28	.38	.35	.36	.33
	75	.37	.32	.26	.23	.49	.49	.38	.27
	150	.39	.37	.35	.18	.44	.42	.36	.32
	225	.36	.33	.34	.28	.52	.42	.43	.32
Russet Burbank	0	.20	.17	.10	.10	.34	.32	.23	.24
	75	.30	.20	.13	.11	.41	.32	.27	.24
	150	.25	.22	.16	.12	.41	.34	.30	.24
	225	.24	.22	.16	.14	.41	.40	.28	.26
Russet Norkotah	0	.26	.19	.18	.13	.49	.29	.32	.24
	75	.23	.18	.15	.15	.40	.34	.30	.28
	150	.37	.20	.14	.13	.42	.33	.30	.27
	225	.35	.21	.17	.15	.49	.37	.32	.25

Table 18. Extractable phospohrus in twenty-seven soils used for potato production using four chemical extractants.

Soil Texture	Source County	Extractant 0.01 M $CaCl_2$	0.05 M $NaHCO_3$	Bray P1	Mechlich 3
		- - - - - - - - μg P/g soil	- - - - -		
Muck	Allegan	1.5	83	106	190
Muck	Allegan	4,4	65	160	218
Muck	Allegan	4.2	86	177	225
Loamy sand	Arenac	1.5	33	80	83
Muck	Arenac	75.4	160	233	337
Sand	Arenac	7.3	71	190	212
Sandy loam	Bay	3.9	88	248	257
Loamy sand	Bay	9.4	122	320	435
Sandy loam	Delta	1.5	54	109	141
Sandy loam	Delta	1.3	53	126	150
Sandy loam	Delta	1.2	52	150	190
Sandy loam	Dickinson	2.3	92	171	266
Muck	Eaton	6.5	65	83	137
Loam	Lenawee	1.7	33	75	101
Loam	Lenawee	1.2	47	83	101
Sandy loam	Lenawee	2.6	52	146	171
Sandy loam	Monroe	1.4	49	122	165
Sandy loam	Monroe	2.3	56	155	177
Loamy sand	Monroe	1.5	73	184	225
Clay loam	Monroe	2.2	49	212	218
Loamy sand	Monroe	1.7	71	219	275
Sandy loam	Montcalm	2.6	75	240	322
Sandy loam	Montcalm	1.3	53	141	206
Sandy loam	Montcalm	1.7	46	231	240
Loamy sand	Presque Isle	2.8	92	297	375
Fine sandy loam	Presque Isle	1.7	55	184	275
Fine sandy loam	Presque Isle	5.6	98	225	275

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NITROGEN MANAGEMENT TO IMPROVE POTATO YIELD, QUALITY AND GROUNDWATER QUALITY

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INTRODUCTION

An adequate supply of nitrogen (N) is essential for sustaining high potato yields. Under most conditions, the soil N supply is not entirely sufficient for potatoes and supplemental N from fertilizer sources is added. When N is applied at rates that exceed crop requirements, the excess N is susceptible to leaching and may potentially reach groundwater. This constitutes an environmental risk. On the other hand, application rates that are insufficient to meet the crop demand, leads to an economic risk. The N available from soil reserves can be substantial, depending on N left-over from previous year and N mineralization from organic matter and decomposing crop residues. Because of the transitory nature of N in the soil, predictions of soil N availability on a site-specific basis are not entirely reliable at present.

Our approach to N management research is based on increasing the efficiency of both soil N and applied fertilizer N to ultimately achieve an overall reduction in N fertilizer use on potatoes. The management strategy is to reduce at-planting or early season N application rates and rely more on petiole sap testing to determine fertilizer N needs during the season. We have also introduced the concept of 'window plots' to monitor the N status of potatoes. These plots would ideally receive 60-80 lbs/A less N than the conventional rate and provide both a visual and quantitative comparison of potatoes growing under two N management systems.

The petiole sap testing procedure developed at MSU is being tested for use as an effective and practical on-farm management strategy. Sap nitrate levels have shown to increase in proportion to the N availability from the soil and decreases progressively with the age of plants. Based on weekly sap testing and yield data, a critical level of 1000 ppm has been established as an adequate mid-season nitrate level for several potato varieties. If the sap nitrate N level is found to be below the critical N range, then in-season corrective fertilizer can be applied, thereby increasing the N use efficiency and minimizing the risk of yield loss and N leaching.

OBJECTIVES

1. To calibrate a petiole sap nitrate test to accurately assess the N requirement for high quality potato yields;

2. To determine the relationship between petiole sap nitrate concentration with soil N availability.

3. To establish N 'window plots' for visual comparison of potato growth and sap nitrate levels at two N fertilizer rates.

MATERIALS AND METHODS

Field research trials were conducted at the Montcalm Research Farm, MSU soils farm, E. Lansing, and in the Upper Peninsula. At Montcalm, the treatments included 3 N fertilizer rates and 2 potato varieties, Snowden and R. Norkotah. At MSU, only Snowden was used. The N rates were 0, 120, and 240 lbs N/A (Table 1). For treatments 2 and 3, 60 lbs of N were applied at planting (May 5), and the balance was sidedressed as ammonium nitrate at tuber initiation (June 10). At the UP site, 4 N rates, 0, 60, 120, 180 lbs/A were tested on Russet Burbank (Table 2). Treatments 2-4 received 60 lbs N at planting (May 14). Treatments 3-4 were sidedressed on June 25. Preplant application of P and K were made according to soil test recommendation at each site. The plots were 50 feet long and spaced 34" apart. Treatments were evaluated in a randomized complete block design with 4 replications.

A. Soil Sampling for Nitrate N

A random preplant soil sample (0-12" deep) from each site was taken just prior to planting. The zero N plots were sampled for 10 weeks to study N mineralization. During the season, all N plots at Montcalm and MSU were sampled (avoiding the fertilizer band as much as possible) at emergence, tuber initiation, and 2 weeks after tuber initiation. Immediately after harvest all N plots at Montcalm and MSU were sampled to a depth of 2 feet in 1 foot increments to assess the residual soil N.

B. Petiole sampling for nitrate N analysis.

All plots were sampled once a week starting on June 23 at Montcalm, June 24 at MSU, and July 8 in the UP, and continued for 5 consecutive weeks. The sap nitrate concentration was determined by the procedure developed at MSU. Each sample was taken in the morning hours and consisted of 15-20 petioles taken randomly from the entire plot from the fourth or fifth fully expanded leaf. The sap was squeezed into a zip lock bag and mixed with an extraction solution consisting of aluminum sulfate and boric acid. The nitrate N concentration of the extract was then determined with a nitrate ion specific electrode.

The influence of time of day on the sap nitrate level was studied by consecutively sampling the same plots at 3-hour intervals on a given day. On July 10, petioles from 240 lb N plots at the MSU site were sampled at 8 AM, 11 AM, 2 PM, and 5 PM. This study was repeated on July 30, and the sampling time was extended until 8 PM.

C. N Window Plots

On a larger scale, seven window plots (approximately 100 x 100 ft) were established, six at Montcalm and one in Bay Co. Ideally these plots were to receive 60-80 lb/A less N than the conventional rate. These trials were done with the active participation of the growers. To establish these trials, growers were advised to skip the last sidedress N application in the window area. The N rates used on the inside and outside of window plots are presented in Table 3. The N status of these plots were monitored weekly by sap testing beginning at tuber initiation. Tuber yields, size distribution and specific gravity were evaluated at harvest. Soil samples were taken to estimate the soil N residue at harvest.

RESULTS AND DISCUSSION

The Montcalm and MSU trials were harvested on Sept 3 and Sept 29 respectively. The UP trial was harvested on Sept 24. Tubers were graded according to size. Total yield and percent of US # 1 tubers were determined. Specific gravity was measured by weighing samples in air and water.

Petiole sap N level in response to N application rate and sampling date

The combined effects of N fertilizer rate and sampling date on petiole sap nitrate concentration at Montcalm, MSU, and UP are presented in Figs 1, 2 and 3, respectively. The sap nitrate level increased with N fertilizer rate but response was less pronounced at Montcalm. At Montcalm, the sap nitrate level for the zero N rate (check plot) was consistently higher than other locations, indicating a higher soil N availability. In general, the nitrate level was higher at the beginning of the season and decreased as the season progressed. This pattern was interrupted only if supplemental N was applied during the sampling period. The sap nitrate concentration in the check plots decreased steadily with time. At 240 lbs/A, the sap nitrate concentration remained steady and showed only a small decrease with time.

Soil N Mineralization

The soil N mineralization in the zero N plots at Montcalm and MSU are shown in Fig. 4. At Montcalm, a substantial quantity of nitrate N (greater than 60 lbs N/A-1ft) was available for potatoes from the soil N pool on June 19. The nitrate level peaked about 40 days after planting which corresponds to the time of tuber initiation. This coincides with the period of greatest N need to potatoes. In the following weeks, the crop demand for N increased and began to deplete the soil available N. Because potato roots utilize a soil depth of about 2 feet, it was estimated that the check plots at Montcalm provided as much as 100 lbs nitrate N/A-2ft. This data substantiate the fact that N mineralization is crucial in determining the optimum fertilizer N rate for potatoes. In contrast, soil N derived from mineralization at MSU was very low (less than 20 lbs/A) and did not peak at any time during the season. In the UP (Fig 5), the soil N mineralization was similar to Montcalm.

Tuber Yield, Quality and Critical Nutrient Level

The tuber yield, percent US # 1 and specific gravity of potatoes at Montcalm, MSU and UP, are presented in Tables 4-11. At Montcalm, both Snowden and R. Norkotah succumbed to early die disease and most of the vines senesced by the middle of August. The disease did not seem to be affected by the N rate, however, yields were reduced substantially. Despite the disease, snowden showed a significant yield increase to N fertilizer (Table 4). Specific gravity tended to decrease with high N rates but the mean values are not significantly different. Increased N rates increased the percent of oversized (>$3^1/_2$")tubers (Table 5). R. Norkotah performed best at 120 lbs N/A (Tables 6 and 7). This treatment produced the highest US #1 tubers. The US #1 yield declined at 240 lbs/A. Nitrogen influenced tuber size and increased the percent US#1 tubers. Because of the heavy early die disease infestation, true N effects on tuber yield and quality must be tempered before making any conclusions from this trial.

The seasonal variations of the sap nitrate level of Snowden and R. Norkotah are presented in Figs. 6 and 7. Based on previous research, we established a critical level of 1000 ppm as an adequate mid-season nitrate level. In Snowden, the Zero N (check plot) was the only treatment where the sap nitrate level dipped below the critical level starting on July 14. This treatment also produced significantly lower tuber yields compared to N treated plots. In R. Norkotah, the sap nitrate level of check plots reached the critical level on July 21. Again the check plots produced significantly lower US #1 yields compared to N treated plots.

At MSU, Snowden showed a marked yield increase to N fertilizer, even 240 lbs/A (Tables 8 and 9). At 240 lbs N, the total, US#1, and oversized tuber yields was significantly higher than the 120 lbs/A. Specific gravity was not significantly different for the 2 N treated plots. The check plots produced significantly lower yield and specific gravity. The sap nitrate data (Fig. 8) showed that 240 lbs N was the only treatment that maintained a sap nitrate concentration above the critical level (1000 ppm) during most of the growing period.

In the UP, the total potato yields produced by the 3 N treated plots were significantly greater than the check plots (Tables 10 and 11). Among the N treated plots, however, no significant yield or specific gravity differences were evident. The sap nitrate level at 120 and 180 lb N was above the 1000 ppm during critical periods of growth (Fig. 9).

The residual soil N measured at harvest for the 2 potato varieties at Montcalm are presented in Tables 12 and 13. The residual N increased in proportion to the N fertilizer rate. At the 240 lbs N/A rate, about 100 lbs N/A/2ft ($N0_3$-N and NH_4-N) were present in the soil. This leftover N is susceptible to leaching during winter months. Nitrogen residues observed at Montcalm may be higher than in a normal year because of early senescence of potatoes. At MSU (Table 14), increased N rates increased the amount of nitrate N in the surface foot. The total N residue of the top 2 feet, however, did not show substantial differences among N fertilizer rates.

Petiole sap N level in response to sampling time

The sap nitrate data from the sampling time study is presented in Fig. 9a. On July 10, the sap nitrate level showed a gradual increase from 8 AM to 5 PM. These changes, although small, were statistically significant. On July 30, the sap nitrate level peaked at 2 PM and started to decrease thereafter. These differences were not statistically significant. The changes in the sap nitrate level during the day may be related to the leaf water potential. We speculate that increased transpiration rates during mid-day could concentrate the sap and increase the nitrate concentration. These differences, taken in the context of total nitrate levels in the sap, were not considered large enough to specify time limitations for sampling. In order to keep samples homogeneous, however, we prescribed the morning hours for field sampling.

Tuber Yield and Sap Nitrate data from Window Plots

The yield and the sap nitrate data for the window plots are presented in Tables 15-27 and Figs. 10-15. In 1992, we were unable to establish ideally suited N rates in several locations. This was due to the widely different N application rates, application times and application methods utilized on each farm. Nonetheless, in fields where the N differences between the inside and outside window plot was between 60-80 lbs (Sackett Acres, Sackett Ranch, and Duyck's farm), no significant yield differences were evident. In 3 out of 4 farms where the N differences were greater than 90 lbs (Crooks, Crawford, and Townview), the yields were significantly different. No significant differences in specific gravity were observed at any of the locations. Residual soil N at harvest is presented in Table 28. As expected, the levels of residual N were higher outside the window plot compared to the inside.

We feel that these data provide some evidence to support that the conventional N rate may be reduced by up to 60-70 lbs, without incurring yield or economic losses to growers. The critical mid-season level of 1000 ppm was still applicable on many farms to determine the N requirements. These window plots also provided an opportunity to monitor petiole sap nitrate levels as affected by N application through irrigation and spray programs.

FUTURE RESEARCH

Future research will focus on further field testing and validating the petiole sap nitrate test. This test offers great potential as a decision support mechanism for growers who are concerned with possible late season N deficiencies or excessive N residues in the soil. Further research on the expanded use the sap test in conjunction with soil N tests, would enable one to manipulate fertilizer application rates to improve N use efficiency and leave as little N residue as possible after harvest to safeguard against groundwater contamination. With the growing public concern about water quality and other environmental issues, there is increased pressure to regulate fertilizer and pesticide use in agriculture. Michigan potato growers will need to demonstrate that they are willing to adapt new technology and use chemicals in an environmentally sensitive manner.

Table 1. Nitrogen rates (lbs/A) and time of application at Montcalm and MSU in 1992.

Treatment #	At-planting	Tuber initiation	Total
1	0	0	0
2	60	60	120
3	60	180	240

Table 2. Nitrogen rates (lbs/A) and time of application at Upper Peninsula in 1992

Treatment #	At-planting	Tuber initiation	Total
1	0	0	0
2	60	0	60
3	60	60	120
4	60	120	180

Table 3. Nitrogen fertilizer rates (lbs/A) used on inside and outside window plots at Montcalm 1992.

Farm	Variety	N inside	N Outside	N Diff.	Plant date	Harvest Date
Crooks	Snowden	55	242	187	5/12	9/11
Crawford	Snowden	175	260	95	5/20	9/24
Hansen	R.Nork.	142	280	138	5/15	9/11
Sackett Acres	Snowden	154	223	69	5/6	9/11
Sackett Ranch	Snowden	170	245	75	5/20	9/24
Townview	Snowden	161	261	100	5/20	9/24

Table 4. The effects of nitrogen fertilizer rate on tuber yield (cwt/A) and specific gravity of Snowden potatoes. Montcalm Research Station 1992.

N Rate lbs/A	< 2"	2-3 1/2"	>3 1/2"	PO	US#1	Total	Sp.Gr
0	21.4	178.5 b	6.5 b	1.0	185.0 b	207.4 b	1.090
120	26.2	227.8a	9.9 b	0.3	237.7a	264.2a	1.089
240	21.4	240.0a	25.5a	0	265.5a	286.9a	1.088

Table 5. The effects of nitrogen fertilizer rate on percent size distribution of Snowden potatoes. Montcalm Research Station 1992.

N Rate lbs/A	< 2"	2-3 1/2"	>3 1/2"	PO	US#1
0	10	86	3	0	89
120	10	86	4	0	90
240	7	83	9	0	92

Table 6. The effects of nitrogen fertilizer rate on tuber yield (cwt/A) and specific gravity of R. Norkotah potatoes. Montcalm Research Station 1992.

N Rate lbs/A	<4oz	4-10oz	>10 oz	PO	US#1	Total	Sp.Gr
0	42.2	108.1 b	7.1	7.1	115.2 c	164.5 b	1.072
120	36.0	161.8a	14.3	4.1	176.1a	216.2a	1.073
240	38.4	139.4a	7.5	4.1	146.9 b	189.4ab	1.070

Table 7. The effects of nitrogen fertilizer rate on percent size distribution of R. Norkotah potatoes. Montcalm Research Station 1992.

N Rate lbs/A	< 2"	2-3 1/2"	>3 1/2"	PO	US#1
0	26	66	4	4	70
120	17	75	6	2	81
240	19	74	5	2	79

Table 8. The effects of nitrogen fertilizer rate on tuber yield (cwt/A) and specific gravity of Snowden potatoes. MSU Soil Research Farm 1992.

N Rate lbs/A	< 2"	2-3 1/2"	>3 1/2"	PO	US#1	Total	Sp.Gr
0	41.6	113.5c	2.1c	0	115.7c	157.3c	1.077b
120	41.1	316.5b	29.1b	0	345.6b	386.7b	1.090a
240	33.4	388.1a	81.4a	0	469.5a	502.9a	1.089a

Table 9. The effects of nitrogen fertilizer application rate on percent size distribution of Snowden potatoes. MSU Soil Research Farm 1992.

N Rate lbs/A	< 2"	2-3 1/2"	>3 1/2"	PO	US#1
0	26	72	1	0	74
120	11	82	8	0	89
240	7	77	16	0	93

Table 10. The effects of nitrogen fertilizer rate on tuber yield (cwt/A) and specific gravity of R. Burbank potatoes. UP 1992.

N Rate lbs/A	US#1	Total	Sp.Gr
0	211	264 b	1.088
60	252	333 a	1.085
120	247	351 a	1.087
180	266	365 a	1.087

Table 11. The effects of nitrogen fertilizer rate on percent size distribution of R. Burbank potatoes : UP 1992.

N Rate lbs/A	<4oz	4-10 oz	>10 Oz	PO	US#1
0	7	75	6	13	80
60	5	67	8	20	75
120	5	59	10	26	69
180	3	60	13	24	72

Table 12. Residual soil nitrogen at harvest in relation to N rate applied to Snowden. Montcalm 1992.

N Rate	Soil depth -inches				
	0-12		13-24		0-24
	NO_3-N	NH_4-N	NO_3-N	NH_4-N	Total
	----------------------lb N/A--------------------				
0	9.0 b*	22.0	10.1 b	20.9 a	62.0 b
120	19.4 ab	25.7	20.2 ab	16.9 ab	82.7 ab
240	29.9 a	18.7	38.5 a	11.5 b	98.6 a

* Mean separation within columns by LSD test (P=0.05).

Table 13. Residual soil nitrogen at harvest in relation to N rate applied to R. Norkotah. Montcalm 1992.

N Rate	Soil depth -inches				
	0-12		13-24		0-24
	NO_3-N	NH_4-N	NO_3-N	NH_4-N	Total
	----------------------lb N/A--------------------				
0	7.9 b*	18.0	7.6 b	14.8	48.3 b
120	26.3 a	18.7	28.1 a	18.4	91.5 a
240	34.9 a	17.3	37.4 a	11.5	101.1 a

* Mean separation within columns by LSD test (P=0.05).

Table 14. Residual soil nitrogen at harvest in relation to N rate applied to Snowden. MSU 1992.

N Rate	Soil depth -inches				
	0-12		13-24		0-24
	NO_3-N	NH_4-N	NO_3-N	NH_4-N	Total
	----------------------lb N/A--------------------				
0	9.4 b*	15.1	5.4	11.7	41.6
120	13.7 a	14.8	6.5	10.8	45.8
240	15.1 a	14.8	7.6	10.8	48.3

* Mean separation within columns by LSD test (P=0.05).

Table 15. The effects of N rate on tuber yield (cwt/A) and specific gravity of Snowden potatoes (Crooks Farm).

Window	N rate lbs/A	<2"	2-3$^{1}/_{2}$"	>3$^{1}/_{4}$	PO	US#1*	Total*	Sp.Gr
Inside	55	75.0	297.7	1.8	0	299.5	374.5	1.088
Outside	242	26.0	401.8	46.7	0	448.5	474.5	1.087

* The oversized, US #1, and total tuber yields were significantly higher outside the window plot compared to inside at 1% level of significance
Some color differences in the foliage was evident on 7/14/92

Table 16. The effects of low N window plots on percent size distribution of Snowden potatoes (Crooks Farm).

Window	< 2"	2-3$^{1}/_{4}$"	>3$^{1}/_{4}$"	PO	US#1
Inside	20	79	1	0	80
Outside	5	85	10	0	95

Table 17. The effects of N rate on tuber yield (cwt/A) and specific gravity of Snowden potatoes (Crawford Farm).

Window	N rate lbs/A	<2"	2-3$^{1}/_{2}$"	>3$^{1}/_{4}$	PO	US#1*	Total*	Sp.Gr
Inside	175	16.2	261.6	28.1	0	289.7	305.9	1.087
Outside	260	17.0	304.1	105.2	0	409.3	426.3	1.087

* The US #1, and total tuber yields were significantly higher outside the window plot compared to inside at the 10% level of significance. The oversized tuber yield was significant at 5% level.
No color differences in the foliage evident on 7/17/92

Table 18. The effects of low N window plots on percent size distribution of Snowden potatoes (Crawford Farm).

Window	< 2"	2-3$^{1}/_{4}$"	>3$^{1}/_{4}$"	PO	US#1
Inside	5	86	9	0	95
Outside	4	71	25	0	96

Table 19. The effects of N rate on tuber yield (cwt/A) and specific gravity of R. Norkotah potatoes (Hansen Farm).

Window	N rate lbs/A	<4oz	4-10oz	>10 oz	PO	US#1	Total	Sp.Gr
Inside	142	46.2	252.4	100.5	17.4	352.9	416.6	1.070
Outside	280	37.0	251.4	137.5	33.9	388.9	459.6	1.070

Slight color differences in the foliage observed on 7/17/92

Table 20. The effects of N rate on percent size distribution of R. Norkotah potatoes (Hansen Farm).

Window	< 4oz	4-10 oz	>10 Oz	PO	US#1
Inside	11	61	24	4	85
Outside	8	55	30	7	85

Table 21. The effects of N rate on tuber yield (cwt/A) and specific gravity of Snowden potatoes (Sackett Acres).

Window	N rate lbs/A	<2"	2-3 1/2"	>3 1/4"	PO	US#1	Total	Sp.Gr
Inside	154	51.3	325.2	24.6	0	349.9	400.1	1.091
Outside	223	40.0	310.0	69.8	0	379.6	418.6	1.090

No color differences in the foliage evident on 7/17/92

Table 22. The effects of N rate on percent size distribution of Snowden potatoes (Sackett Acres).

Window	< 2"	2-3 1/4"	>3 1/4"	PO	US#1
Inside	13	81	6	0	87
Outside	10	74	17	0	91

Table 23. The effects of N rate on tuber yield (cwt/A) and specific gravity of Snowden potatoes (Sackett Ranch).

Window	N rate lbs/A	<2"	2-3 1/2"	>3 1/4	PO	US#1*	Total*	Sp.Gr
Inside	170	59.5	475.0	13.4	0	488.4	548.0	1.087
Outside	245	60.8	466.3	29.4	0	495.7	556.5	1.086

* The US #1 and total yield differences are not statistically significant.
Color differences in the foliage was evident on 7/17/92

Table 24. The effects of N rate on percent size distribution of Snowden potatoes (Sackett Ranch).

Window	< 2"	2-3 1/4"	>3 1/4"	PO	US#1
Inside	11	87	2	0	89
Outside	11	84	5	0	89

Table 25. The effects of N rate on tuber yield (cwt/A) and specific gravity of Snowden potatoes (Townview Farm).

Window	N rate lbs/A	<2"	2-3 1/2"	>3 1/4	PO	US#1*	Total*	Sp.Gr
Inside	161	54.6	284.6	13.2	0	297.8	352.4	1.092
Outside	261	40.7	361.9	57.5	0	419.4	460.2	1.087

* The oversized, US #1, and the total tuber yields were significantly higher outside the window plot at the 1% level of significance
No color differences in the foliage evident on 7/17/92

Table 26. The effects of N rate on percent size distribution of Snowden potatoes (Townview Farm).

Window	< 2"	2-3 1/4"	>3 1/4"	PO	US#1
Inside	15	81	4	0	85
Outside	9	79	12	0	91

Table 27. The effects of N rate on tuber yield (cwt/A) of Onaway potatoes (Duyck's Farm) 1992.

Window	N rate lbs/A	<2"	2-3$^1/_2$"	>3$^1/_4$	PO	US#1	Total
Inside	40	54	198	8	0	205	259
Outside	121	36	192	7	0	199	235

Table 28. Residual soil N in the window plots. Montcalm 1992.

Name	Window	Soil depth -inches					
		0-12		13-24		0-24	
		NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N
		lb N/A					
Sackett Acres	Inside	4.4	15.8	5.8	13.5	10.2	29.3
	Outside	7.7	15.8	4.3	12.1	12.0	27.9
Townview Farms	Inside	11.7	12.9	6.1	19.8	17.8	32.7
	Outside	14.9	17.0	10.3	7.3	25.2	24.3
Crooks Farms	Inside	13.6	14.3	9.2	13.7	22.8	28.0
	Outside	28.0	11.2	55.7	11.9	83.7	23.1
Hansen Farms	Inside	11.2	21.8	7.8	14.3	19.0	36.1
	Outside	11.7	24.8	12.8	8.9	24.5	33.7
Crawford Farms	Inside	8.2	9.3	27.6	8.0	35.8	17.3
	Outside	14.7	9.3	21.1	9.7	35.8	19.0
Sackett Ranch	Inside	6.4	13.1	4.0	14.2	10.4	27.3
	Outside	12.9	19.7	5.8	7.0	18.7	26.7

Fig. 1. Petiole sap Nitrate in response N rate and sampling week: Montcalm 1992

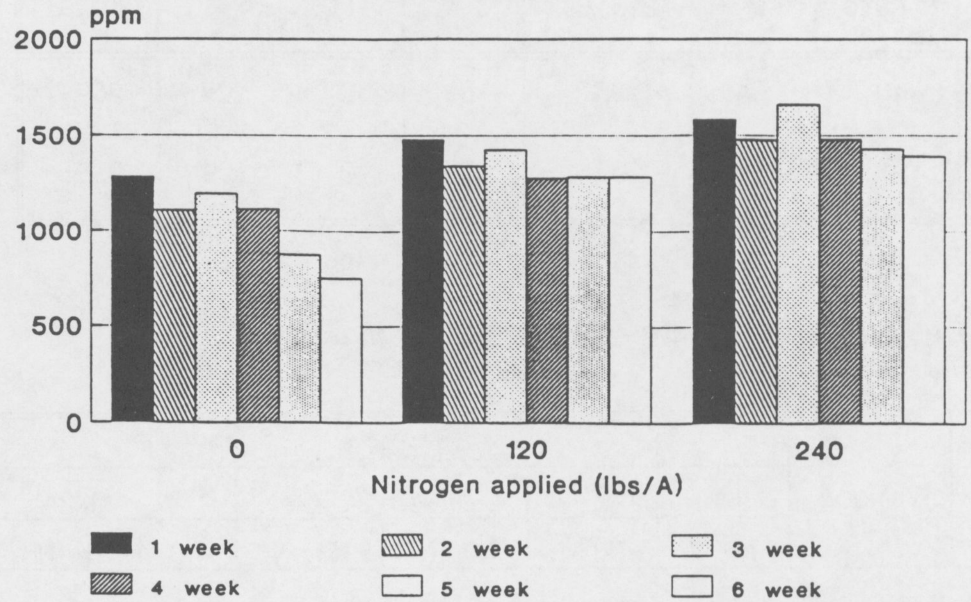


Fig. 2. Petiole Sap Nitrate in response N rate and sampling week : MSU 1992

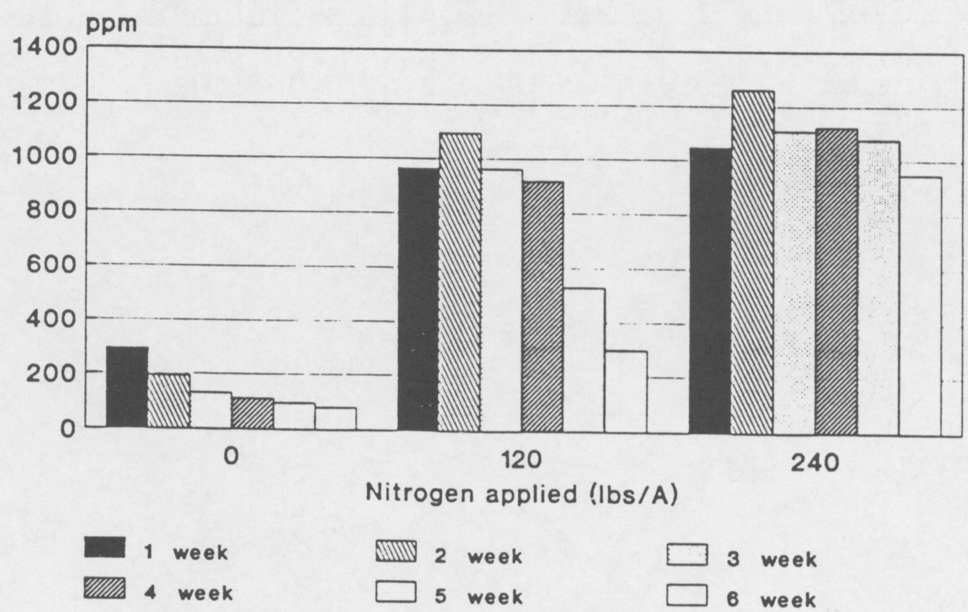


Fig. 3. Petiole Sap Nitrate in response N rate and sampling week : UP 1992

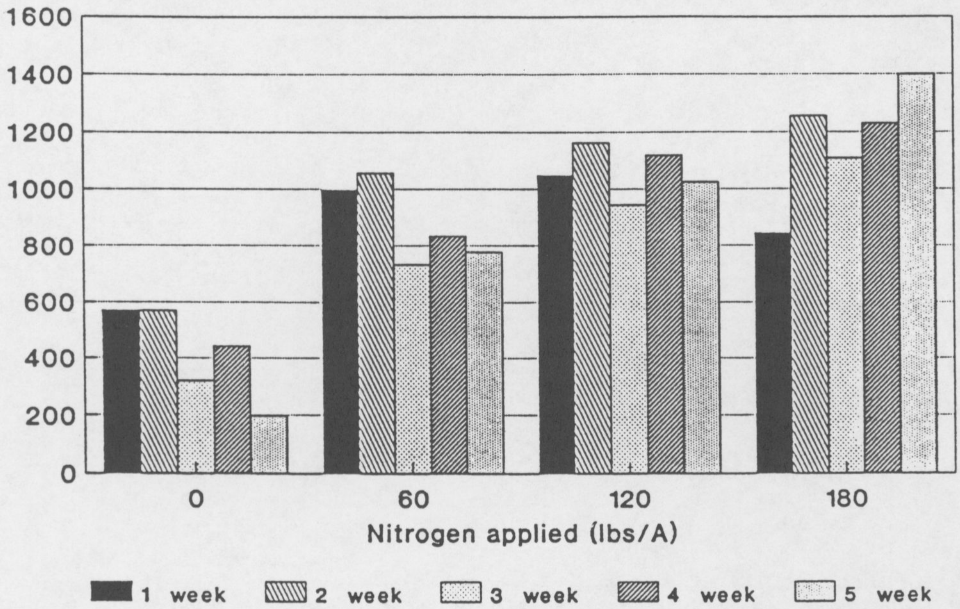


Fig. 4. N mineralization for Montcalm and MSU : 1992

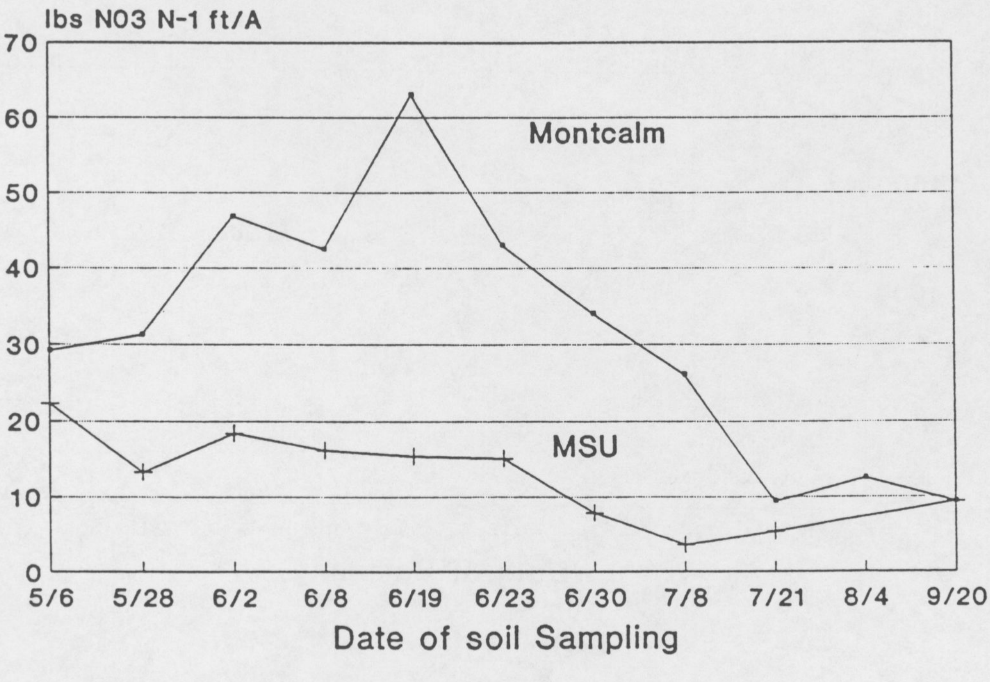


Fig 5. N mineralization at UP : 1992

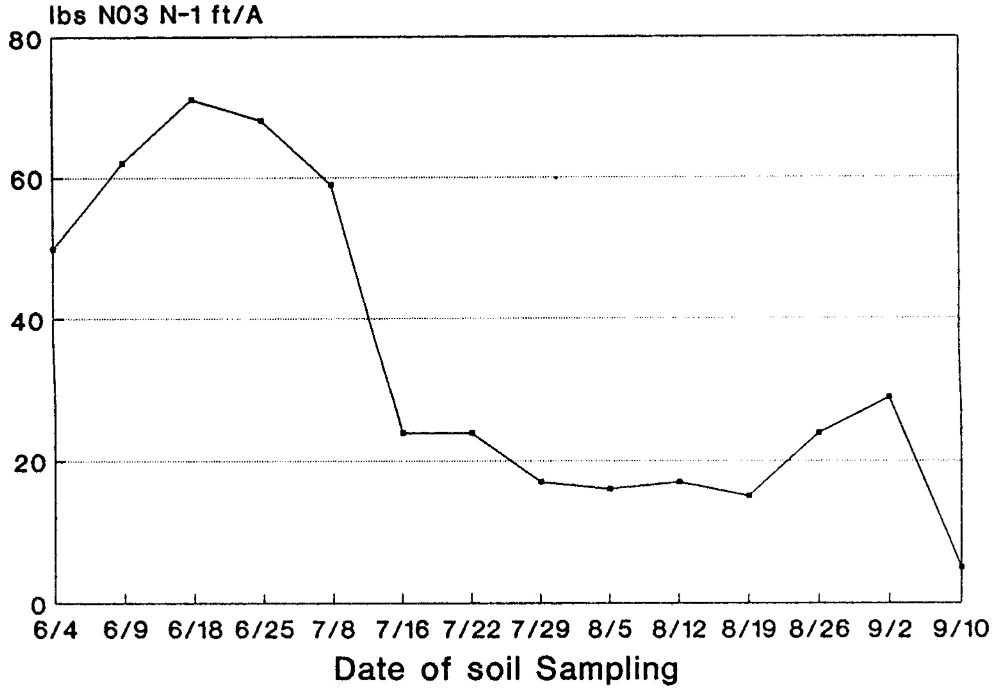


Fig 6. Sap Nitrate N Concentration
With Time. Snowden : Montcalm 1992

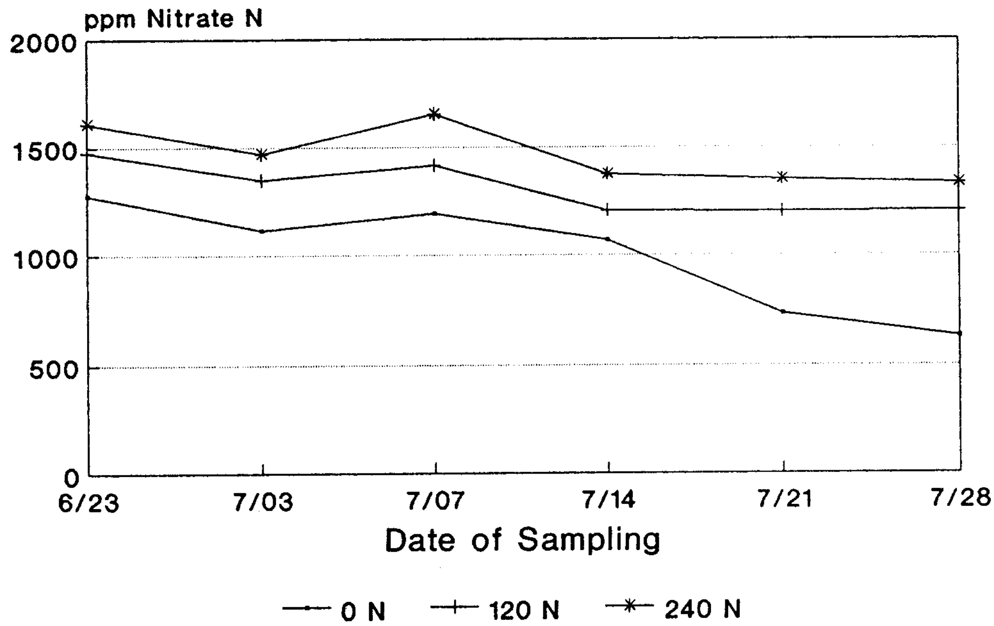


Fig 7. Sap Nitrate N Concentration
With Time. R.Norkotah : Montcalm 1992

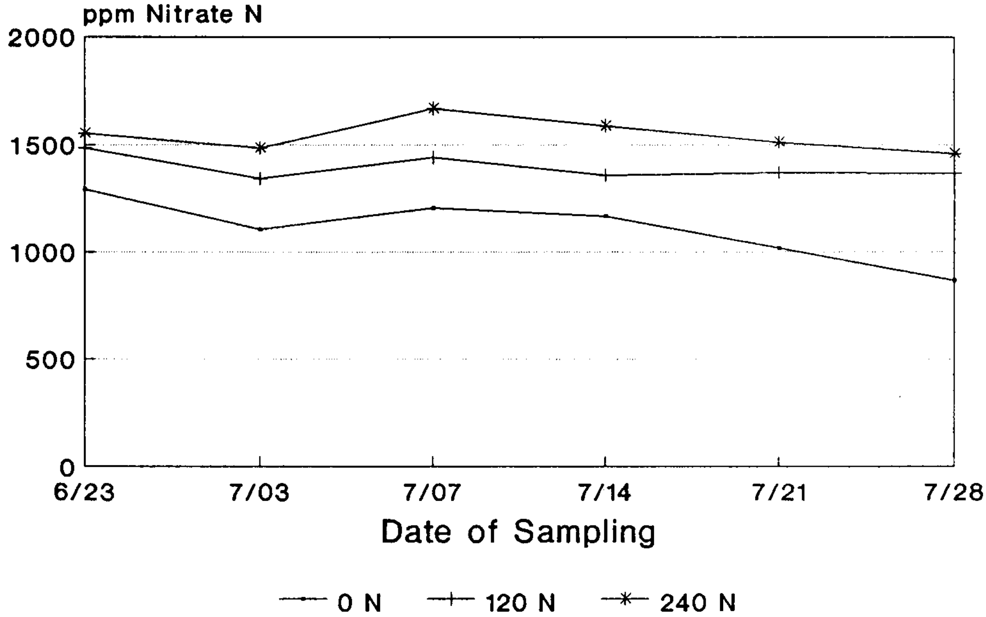


Fig 8. Sap Nitrate N Concentration
With Time. MSU Potatoes 1992

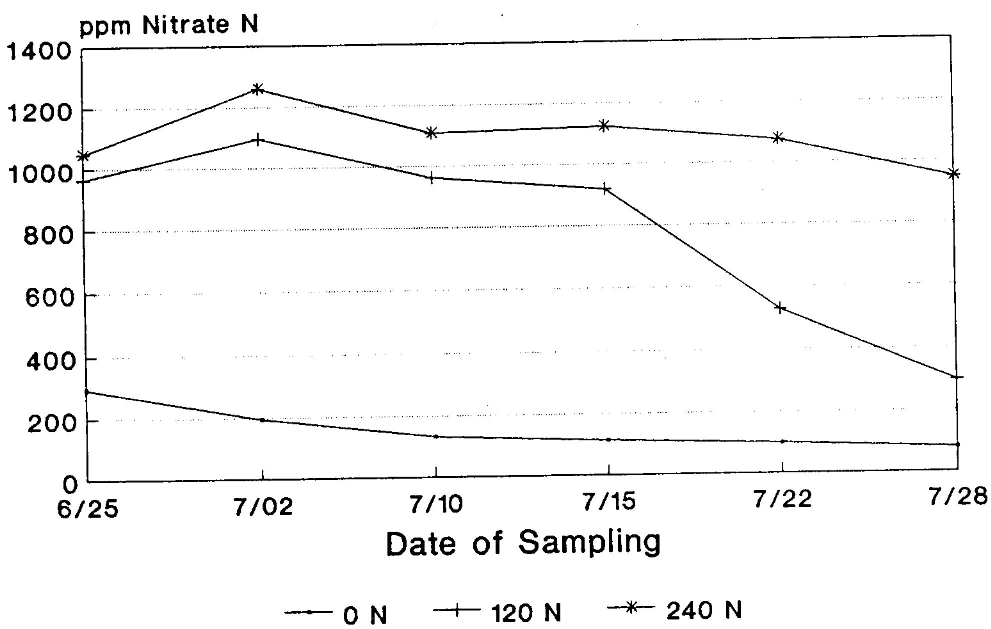


Fig. 9. Sap Nitrate N Concentration
With Time. UP 1992

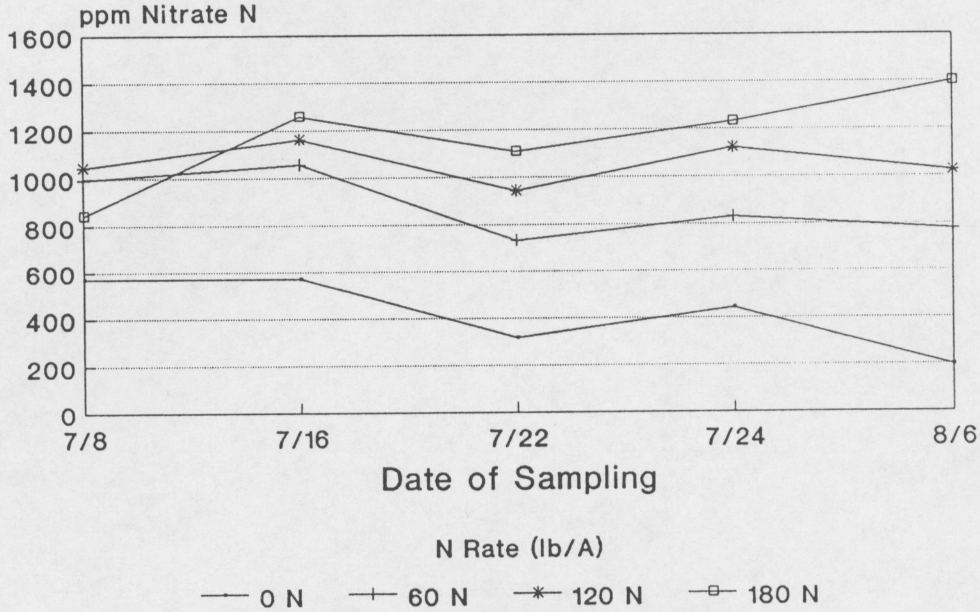


Fig. 9a. Changes in sap nitrate level
with time of day. MSU 1992

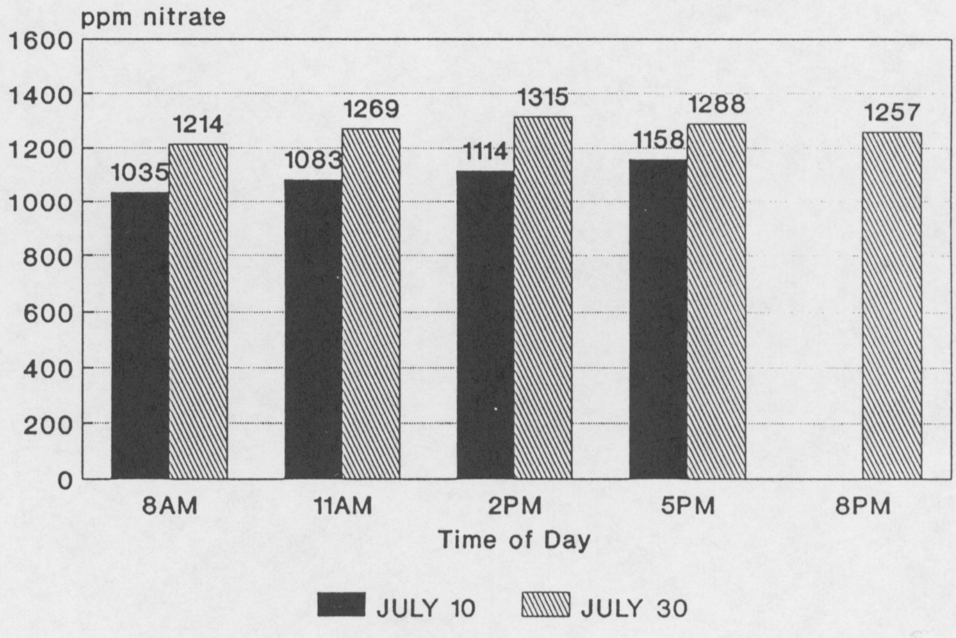


Fig 10. Sap Nitrate in the Window Plot
Crooks Potato Farm, 1992

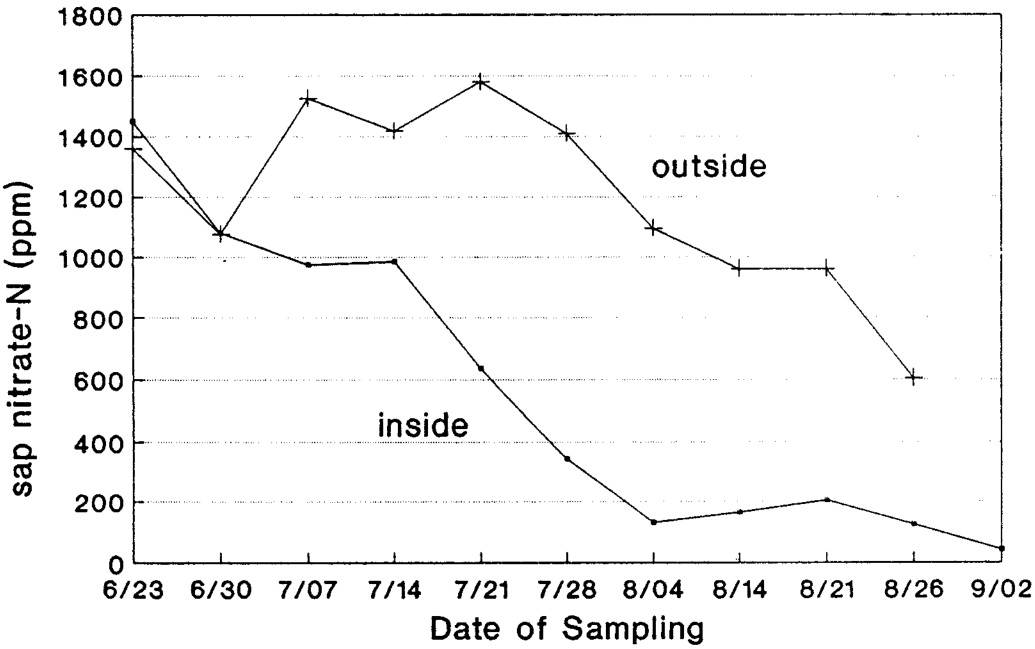


Fig. 11. Sap Nitrate in the Window Plot
Crawford Farm, 1992

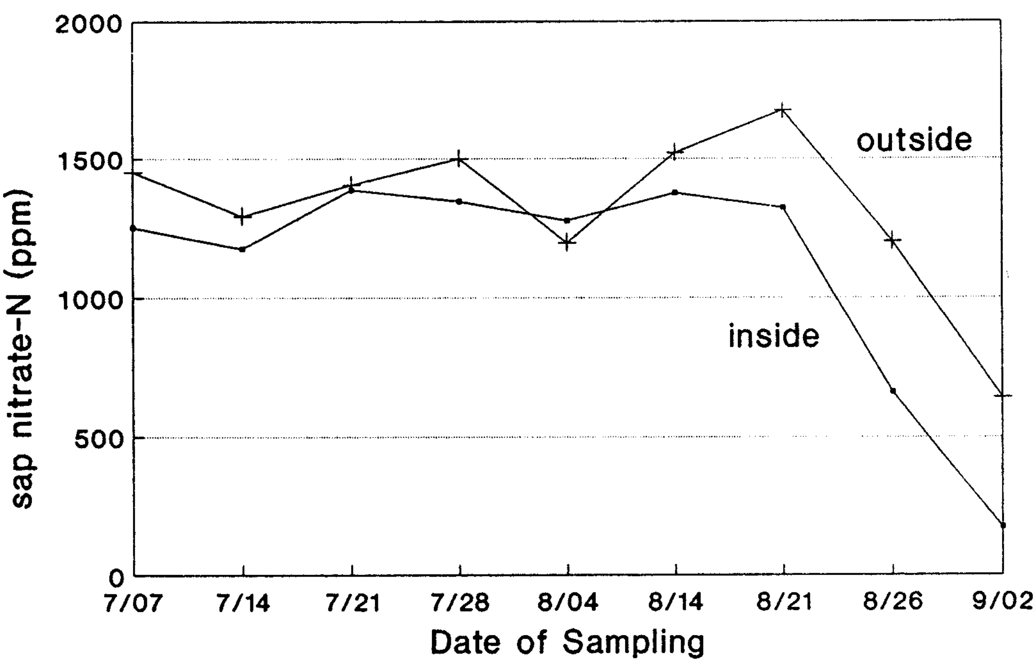


Fig. 12. Sap Nitrate in the Window Plot
Hansen Potato Farm, 1992

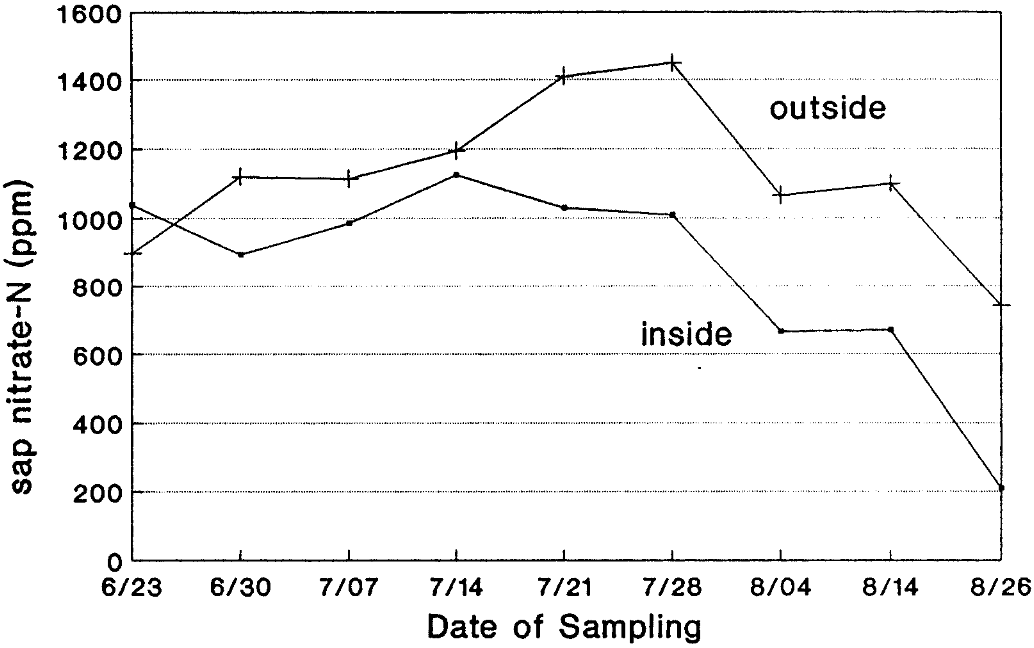


Fig 13. Sap Nitrate in the Window Plot
Sackett Acres, 1992

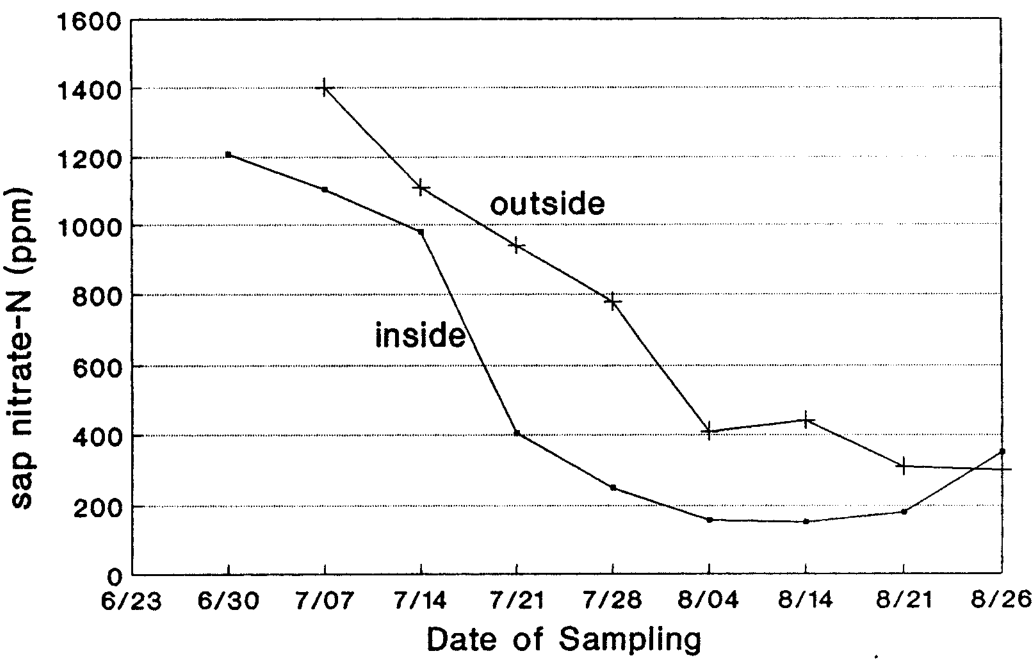


Fig 14. Sap Nitrate in the Window Plot
Sackett Ranch, 1992

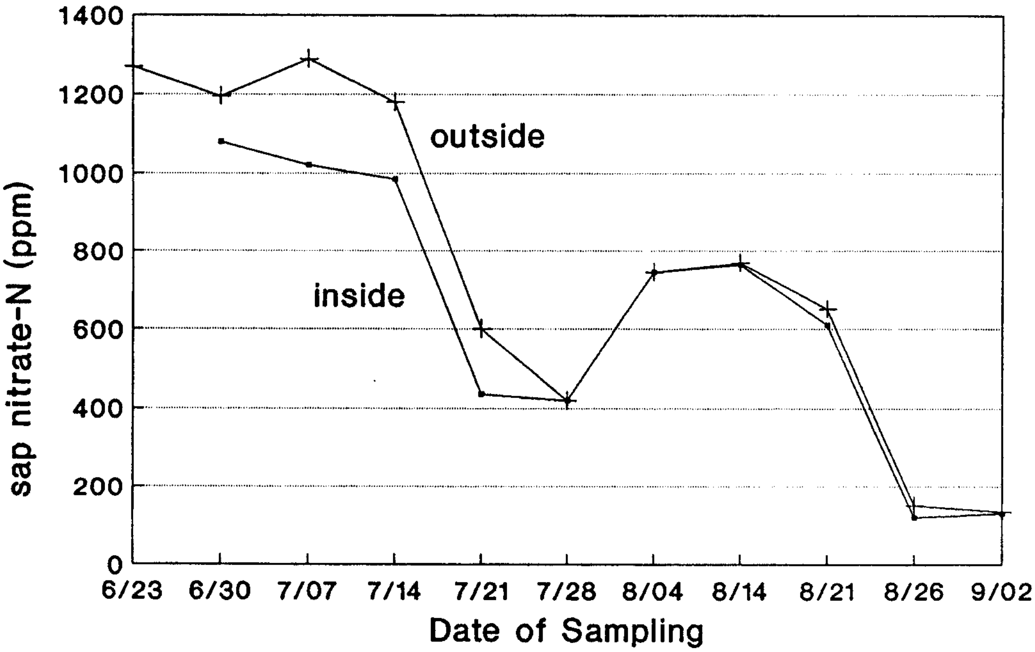
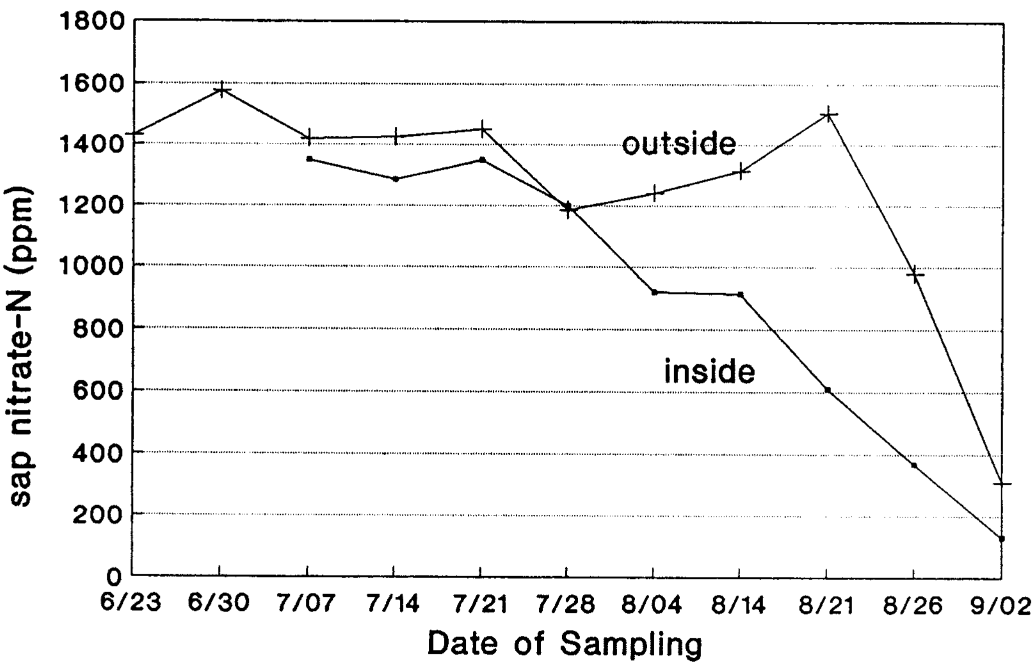


Fig 15. Sap Nitrate in the Window Plot
Townview Farm, 1992



Funding: MPIC

ON FARM VALIDATION OF CRITICAL NITRATE LEVELS IN POTATO PETIOLES

M. L. Vitosh, G. H. Silva, D. R. Smucker and M. Staton

A highly successful series of potato nitrate testing clinics were held in 1992 in Montcalm and Bay counties with excellent response from potato growers. A free nitrate testing service was offered to growers who were interested in the sap nitrate test to monitor the N status of their potato crop during the season. Seven clinics were held at Montcalm and five in Bay county. A total of 540 petiole samples from 36 participating growers were tested (Table 1). The sap nitrate data obtained from Montcalm and Bay county are summarized in Figs. 1 and 2.

Growers were asked to bring petiole samples to the clinics for testing. Instructions on how and when to sample petioles were published in a brochure and distributed to growers. Growers also filled out an information sheet for each sample giving background data on field practices, fertilizers, variety, etc. The effort that growers put in to sampling petioles on a weekly basis, despite cool and wet growing conditions, was greatly appreciated. The test results and recommendations were returned to the grower either on the day of the clinic or sent out by mail that night. In most fields tested, the crop N status, as determined by sap nitrate test, was adequate. Several fields showed excessive sap nitrate levels. These growers were advised not to add more N fertilizer. Fields that showed borderline N levels, growers were asked to re-test samples in the following week before supplemental N applications were recommended. When the early season N levels and the amount of N fertilizer added was minimal, growers were advised to add more N fertilizer.

The clinics provided valuable test data from a broad range of growing conditions and potato varieties. Nitrate test values varied from week to week, field to field and grower to grower but generally declined throughout the season as expected. Some values which changed dramatically from one week to the next were difficult to explain, however, much of the concern lead us to conclude that the variability was probably due to sampling errors rather than analysis or equipment errors. Some sudden increases in nitrate values from one week to the next could be explained by the addition of nitrogen fertilizer. Input from growers, consultants, and county extension agents who sampled the fields or who knew the history of the field was extremely valuable.

In Bay county, most potatoes are grown for early tablestock and harvested in late July and August. During this limited growing period, potatoes are not likely to manifest serious N deficiencies. In Montcalm, however, where many late season varieties are grown, the sap test appeared to have the greatest practical value. We believe that the sap nitrate technology should be integrated with other best management practices to manage N in such a way to increase fertilizer efficiency and minimize N losses due to leaching.

Table 1. Potato Sap testing clinics at Montcalm and Bay county in 1992

MONTCALM CO		BAY CO.	
Date	# samples tested	Date	# samples tested
June 23	35	June 24	26
June 30	32	July 1	28
July 7	42	July 8	10
July 14	53	July 15	23
July 21	62	July 22	26
July 28	55		
August 4	46		

Fig. 1. Average Weekly Sap Nitrate in Montcalm Grower Fields

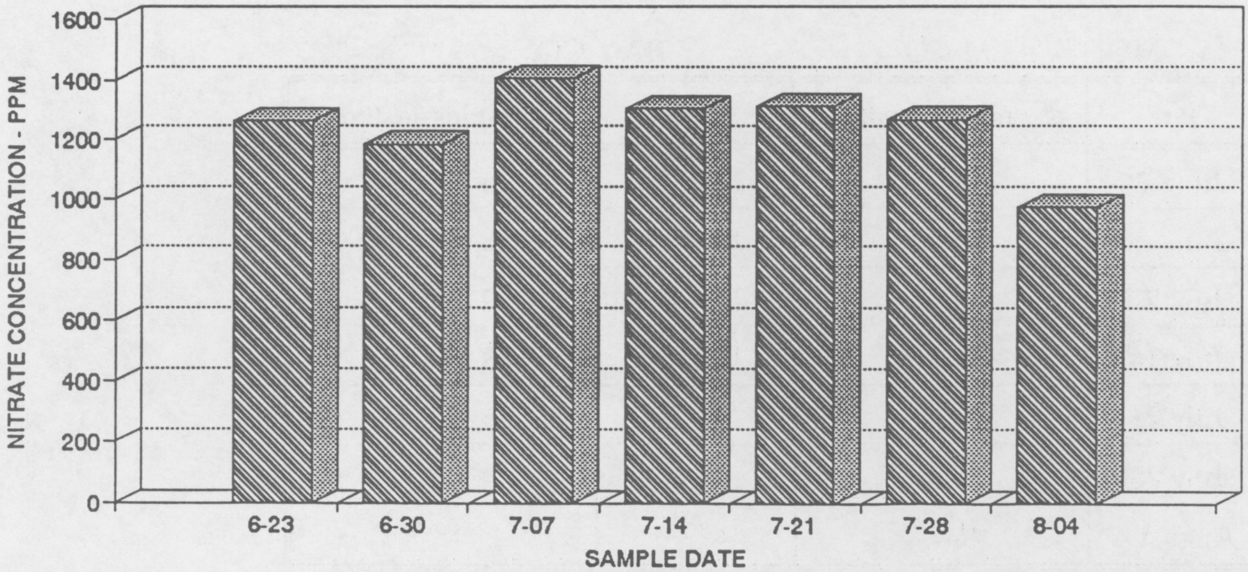
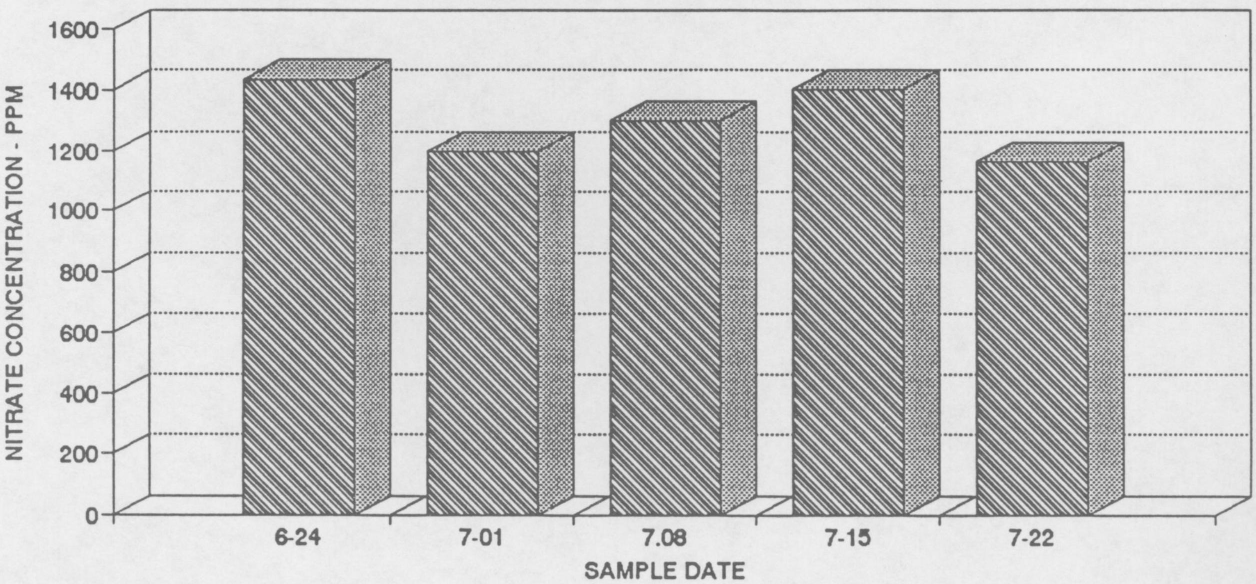


Fig. 2. Average Weekly Sap Nitrate in Bay County Grower Fields



Funding: MPIC

EFFECTS OF NITROGEN FERTILIZER MANAGEMENT ON NITRATE LEACHING

J.T. Ritchie and M. McNabnay
Department of Crop and Soil Sciences

The goal of this study is to develop nitrogen fertilization strategies that minimize nitrate leaching to groundwater while still maintaining acceptable profitability. The use of permanently installed drainage lysimeters allows the direct measurement of nitrate leached. The permanent installation of the lysimeters also allows long term tracking of nitrate leaching. This study provides direct evidence of the impact of nitrogen management on potential groundwater contamination and the results of long term management decisions. As scrutiny of agricultural practices increases this type of data will become more and more important.

METHODOLOGY

The lysimeters used in this study are steel boxes that are 48 inches wide, 68 inches long and 6 feet tall. The boxes have open tops and are installed so that their tops are about 1.5 feet belowground allowing normal tillage operations. The bottoms of the lysimeters are closed except for a small opening through which the drainage water is channeled. The volume of outflow is automatically measured and samples are taken whenever 0.25 inches of water has passed through the profile. These samples are then analyzed for nitrate concentration which allows the calculation of the amount of nitrate lost to leaching. The lysimeters are separated into two treatments, a conventional (CON) with somewhat high nitrogen input and a better management system (BMS), with lower input nitrogen scheduled according to plant needs. Each year since 1988, the BMS plot has received about half the nitrogen fertilizer compared to the CON plot.

Corn was planted in 1992 as a part of the rotation with potatoes. Potatoes had been grown on the lysimeter field for the past two years. Both plots were planted with hybrid field corn on May 13, 1992, at which time a starter fertilizer containing 30 lbs N/acre was banded two inches beside and two inches below the seed. The corn was planted with 34" row spacing and 6" seed spacing yielding a plant population of approximately 30,900 plants/acre.

To schedule nitrogen on the BMS plots, a plant response fertilization (PRF) strategy was used. In PRF the plants which were being scheduled were compared in size and color to an area that was known to have adequate nitrogen. When a difference was observed between the two plots, the BMS plots were fertilized. In this study both height to top collar measurements and leaf chlorophyll contents were used. A regular meter stick was used for top collared leaf measurements and a Minolta SPAD 502 leaf chlorophyll meter was used for leaf chlorophyll measurements.

Nitrogen was applied at a rate of 200 lbs/acre on 1 July to the CON plot to be certain that enough nitrogen was available for the plant's growth. On 27 July, a measureable difference was present between the plants of the two plots. The corn could potentially take up 60 lbs/acre of nitrogen during the remainder of the season. This amount was applied to the BMS plots.

Yield measurements were taken from a carefully controlled area directly over the top of each lysimeter and from 2 randomly chosen areas in each of the larger areas of the plots.

RESULTS

Yield 1992

The entire 1992 summer growing season was unseasonably cool and wet and corn yields were low in much of the state. The yields from this experiment were not exceptional but the comparison between them is instructional. Table 1 shows the yield results for the two plots. On the lysimeters, a yield reduction was found with the BMS management. The lysimeter area is small and the differences might be due to natural variation but it could represent a response to the mild nitrogen deficit as compared to the well fertilized CON plants. The lysimeter area also received considerable foot-traffic to service the lysimeters so that the area seemed to constantly have somewhat lower yields than the main plot area. In the main area of the plots outside the lysimeter the yield was slightly higher for the BMS indicating that there is probably no difference in yield response to the two treatments.

TABLE 1. Measured results for the lysimeter and field plots, Montcalm Research Farm, 1992.

CORN YIELDS BUSHELS PER ACRE - 1992			
CONVENTIONAL (CON)		BETTER MANAGEMENT (BMS)	
Lysimeter	Field	Lysimeter	Field
109	118	95	121

Leaching 1992

Drainage data from the two lysimeters for 1992 is shown in Figure 1. Throughout the year the lysimeters drained nearly identically, they are situated in very similar soil profiles and receive equal irrigation. Overall they seem to replicate one another very well. Much of the drainage occurred in April and May was when rainfall rates were high and the irrigation rates were low

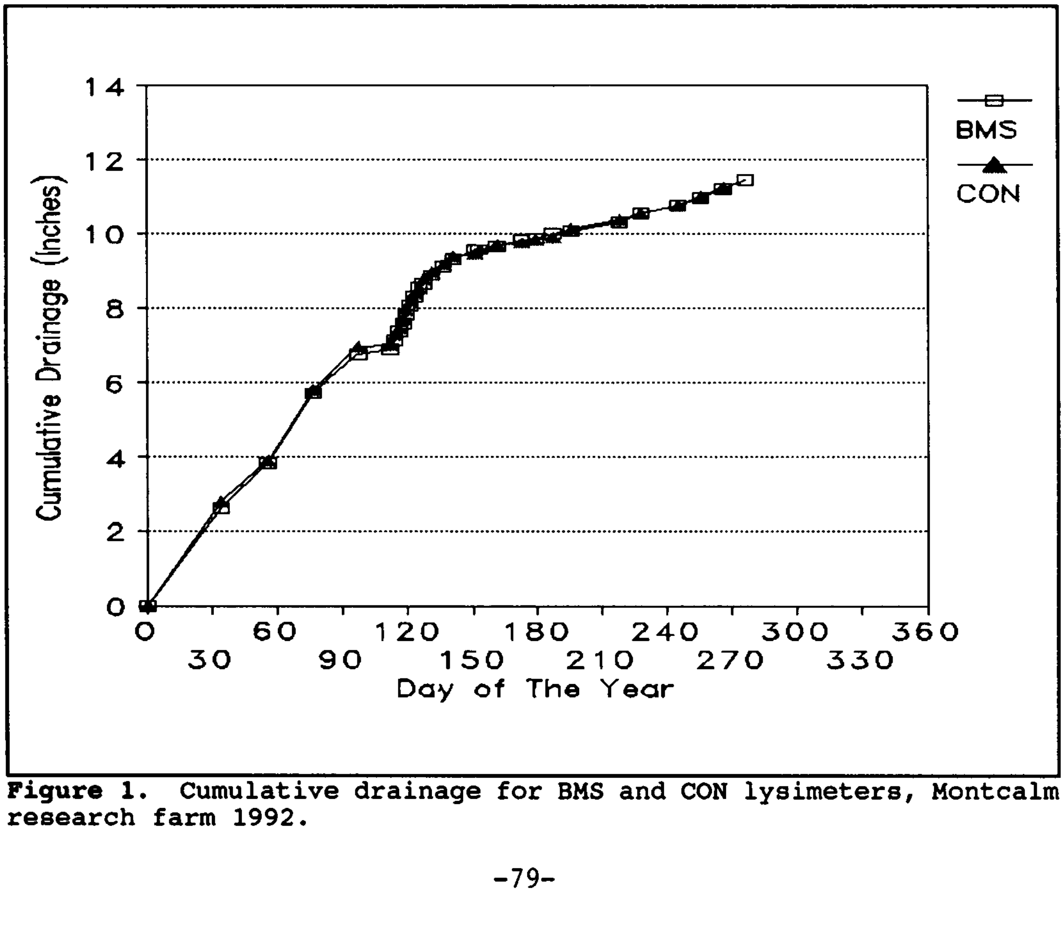


Figure 1. Cumulative drainage for BMS and CON lysimeters, Montcalm research farm 1992.

Nitrate concentrations in the leachate are shown in Figure 2. During the course of the study the concentration of nitrate in the BMS drainage water has steadily decreased. During 1992 it seems to have stabilized at approximately one half of the CON amount. Nitrate N concentrations in drainage water fluctuate considerably during the season.

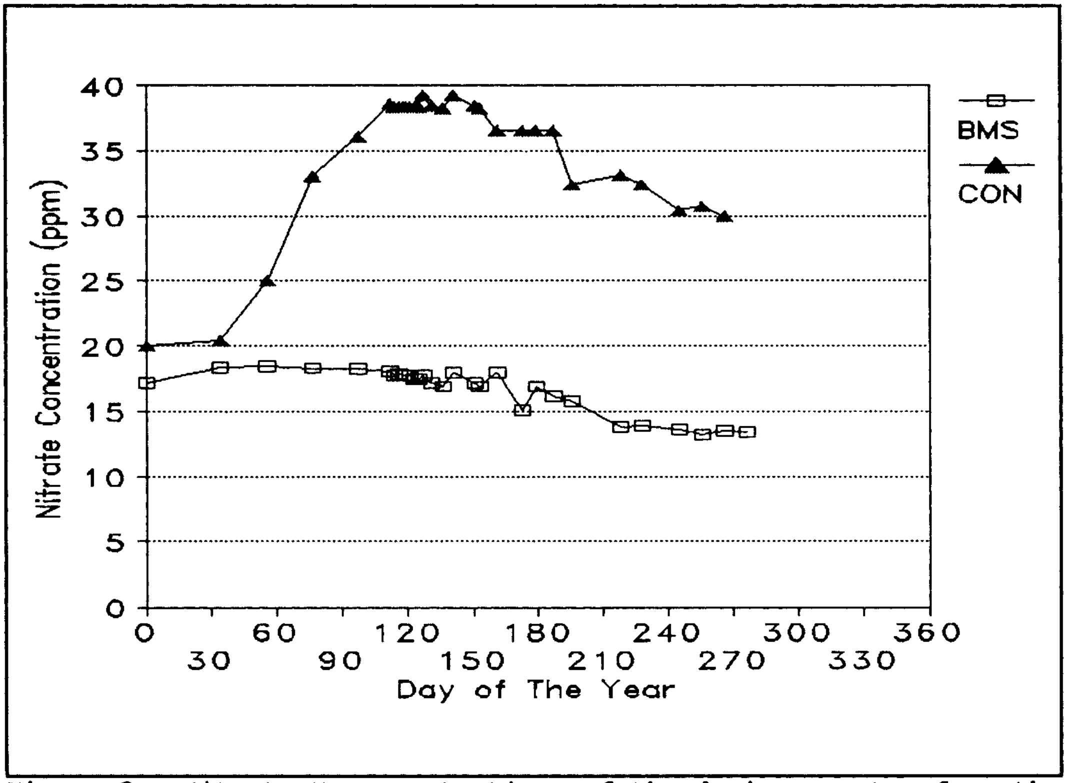


Figure 2. Nitrate-N concentrations of the drainage water from the BMS and CON lysimeters. Montcalm research farm 1992.

Nitrate leaching is the product of the drainage amount and concentration of the leachate. Since the drainage for both treatments are practically identical it follows that the CON treatment would lose more N to leaching due to its higher nitrate concentration. The leaching results are shown in Figure 3 and reflect this. Both treatments lose nitrate during the year, especially during the spring, but the CON treatment does so at a greater rate.

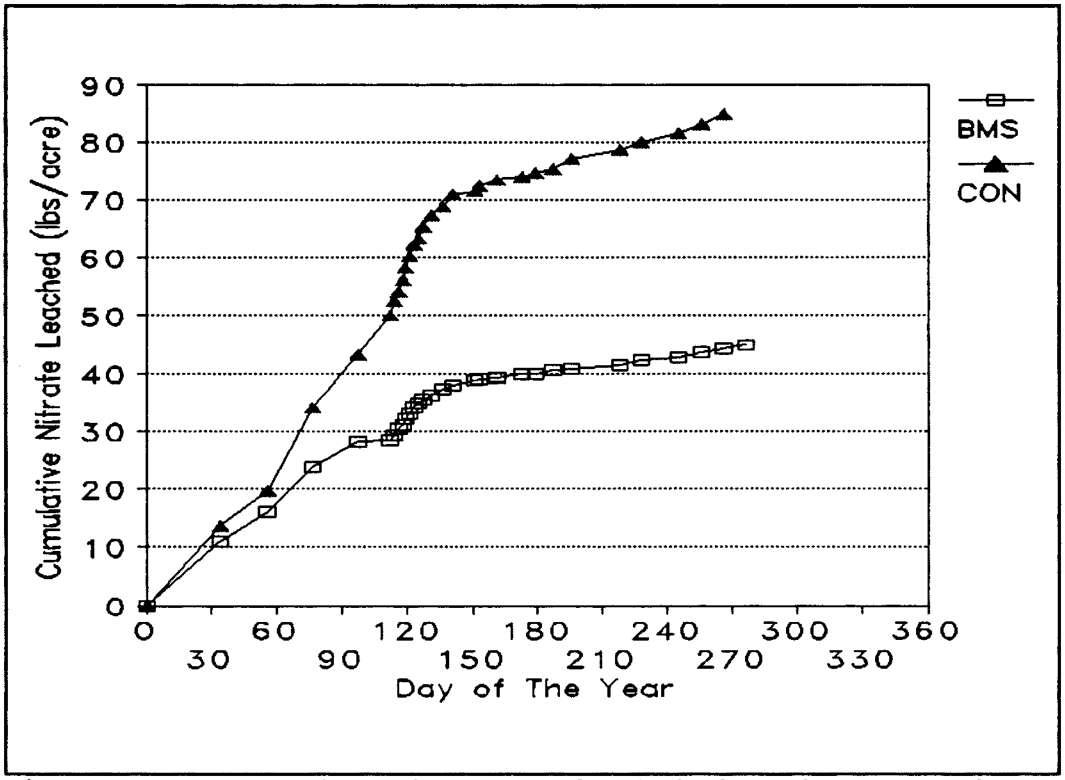


Figure 3. Cumulative nitrate N leached for the BMS and CON lysimeters. Montcalm research farm 1992.

Yield and Leaching: 1988-1992
Data compiled over a long period of time gives a better perspective on long term trends and impacts than a single year study. The goal of this study has always been to reduce nitrate leaching by implementing better fertilizer management. The study has been successful in that we have been able to significantly reduce nitrate leaching. However, maintenance of yield has been variable. The strategy of PRF or plant response fertilization has been successful on corn and has shown a capacity to significantly reduce nitrate leaching. Unfortunately, more work needs to be done to solidify a symptom and a strategy that will allow better success on managing potatoes with a plant response fertilization strategy.

TABLE 2. Percent reduction in crop yield due to reduced nitrogen fertilizer application in the BMS treatment for the years 1988 through 1992. Montcalm Research Farm.

YEAR	CROP TYPE	Percent Reduction of Yield in BMS Treatment
1988	Potatoes	1.2
1989	Corn	5.4
1990	Potatoes	33.8
1991	Potatoes	33.5
1992	Corn	12.8

TABLE 3. Cumulative nitrogen inputs and outputs for both the RES and CON treatments for the years 1988 through 1992. Montcalm Research Farm.

Year	Crop Type	CUMULATIVE NITROGEN (LBS/A)					
		Fertilizer N		Removed by * Harvest		Leached	
		BMS	CON	BMS	CON	BMS	CON
1988	Potatoes	110	200	80	81	58#	73#
1989	Corn	240	400	180	187	258	288
1990	Potatoes	350	593	248	289	368	448
1991	Potatoes	475	793	299	368	442	532
1992	Corn	565	1023	392	474	487	617

* N uptake calculated assuming 0.33 lbs N/cwt of potatoes and 1.5% nitrogen concentration in the corn grain.
# Leaching measurements began in July, 1988.

Cumulative drainage and leaching data are shown in Figures 4 and 5. Figure 4 shows cumulative drainage, drainage has been largely the same with the exception of the end of the 1991 season. At the end of this season early death of the BMS vines seems to have increased its drainage and produced the separation seen.

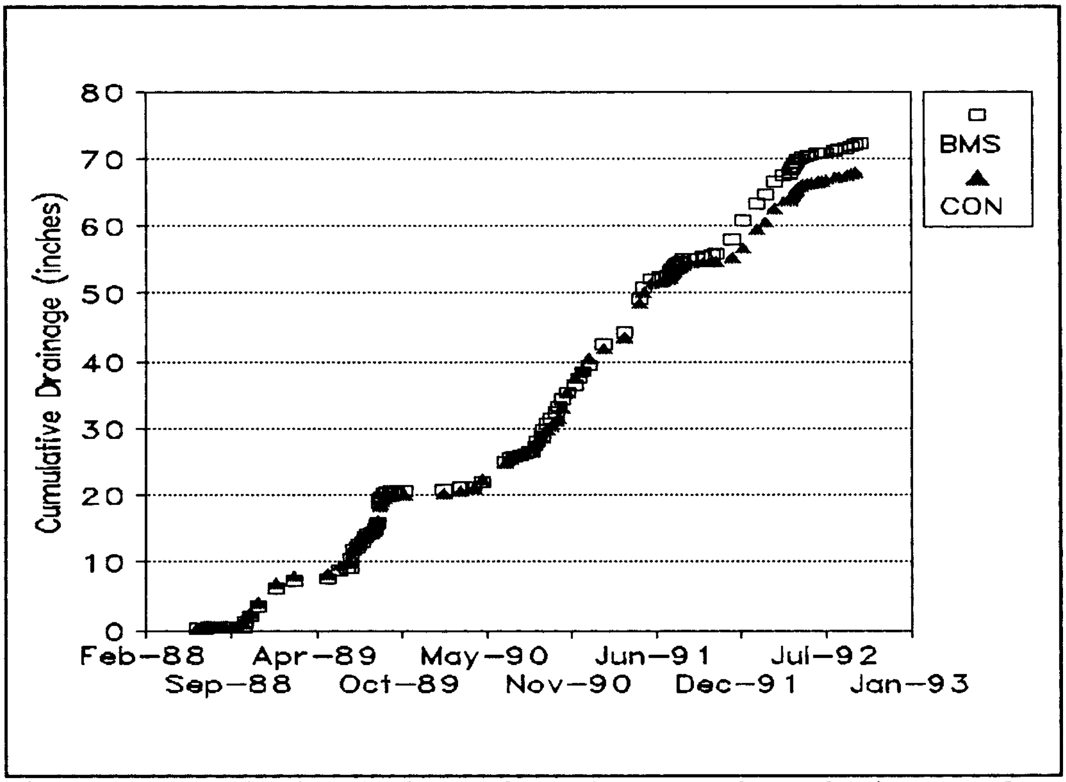


Figure 4. Cumulative drainage from the BMS and CON lysimeters from 7/88 through 10/92. Montcalm research farm.

Cumulative Nitrate lost is shown in Figure 5. Early in the study nitrate leaching seems to be a function of management of the soil in the four years prior to 1988, indicating a certain amount of "momentum" in leaching losses. However, response to management can be seen during 1990 and the trend for the rest of the study appears to be reduced losses.

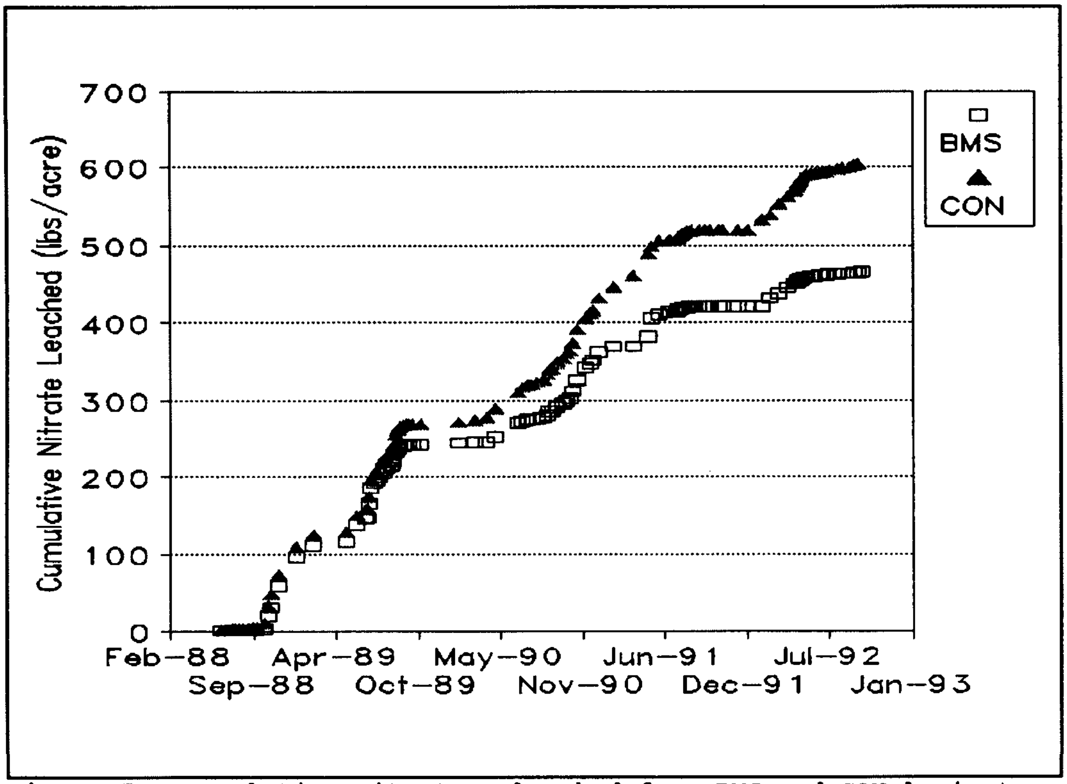


Figure 5. Cumulative nitrate N leached from BMS and CON lysimeters from 7/88 through 10/92. Montcalm research farm.

The most effective way of demonstrating nitrate loss is presented in Figure 6. This graph plots nitrogen loss against total drainage. The more or less constant slope of the CON line indicates that this treatment continues to lose nitrogen at a more or less constant rate. The decreasing slope of the BMS line indicates that its nitrogen loss is slowing.

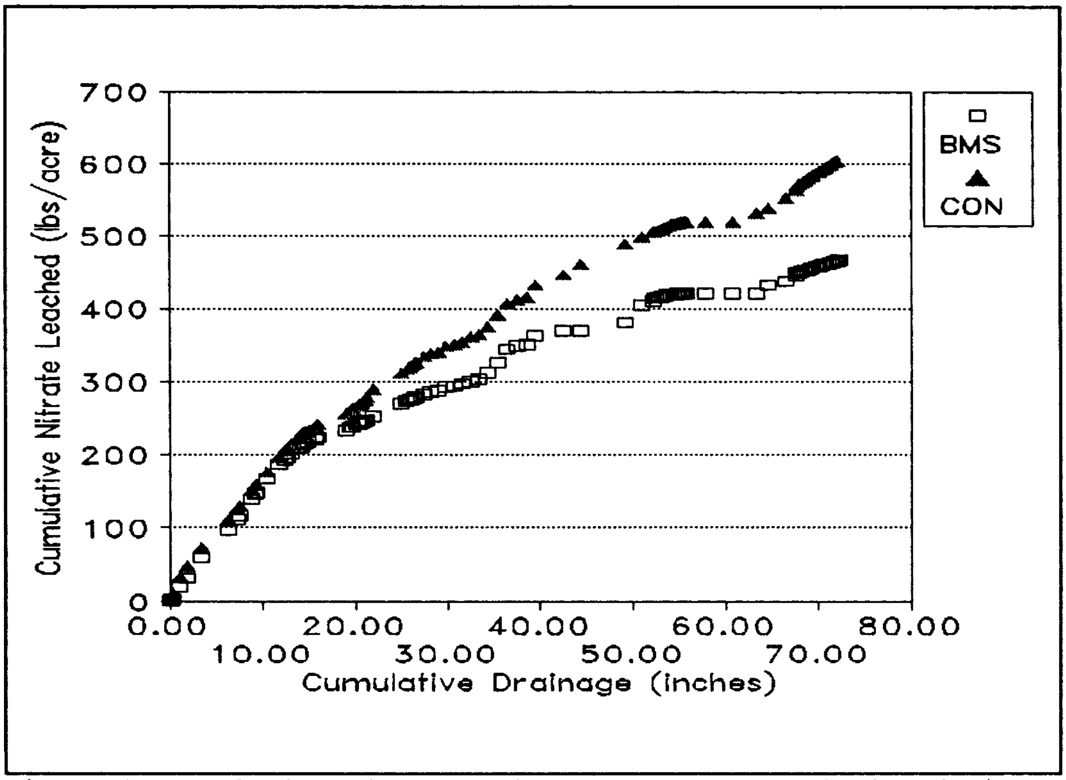


Figure 6. Cumulative nitrate N leached versus cumulative drainage for the BMS and CON lysimeters from 7/88 through 10/92. Montcalm Research Farm.

The results of this study indicate that better nitrogen management can reduce nitrate leaching. BMS management has produced a marked decrease in both nitrate concentration and total losses. PRF has also worked well on corn. What remains is to implement PRF effectively on potatoes and continue to reduce nitrate leaching while being able to maintain yield.

Funding: Federal Grant

Colorado Potato Beetle Management
1992 Potato Research Report

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Summary

Colorado potato beetle (CPB) research in 1992 focused on 1) The effectiveness of propane burners and crop vacuums for control of CPB, 2) Factors influencing dispersal of CPB out of rotated fields after overwintering, 3) Feeding behavior of susceptible and *Bacillus thuringiensis* (Bt) -resistant CPB larvae on untreated and Bt-treated potatoes, 4) Insecticide efficacy test for CPB control, and 5) control of CPB with Trigard.

Research showed that mechanical methods (burners and crop vacuums) could control CPB adults and affect egg hatch, especially in the early season when plants are small. Preliminary analysis of factors influencing dispersal of CPB after overwintering, indicate that crop type and crop size have an effect on the movement of CPB. The presence of volunteer potatoes, in fields rotated from potatoes (1991) to carrots (1992), had an effect on the dispersal of CPB. It appears that beetles disperse out of carrot plots less readily if volunteer potatoes are present. Laboratory trials examining the feeding behavior of susceptible and Bt-resistant CPB larvae on untreated and Bt-treated potatoes shows that neither, susceptible nor, Bt-resistant CPB larvae detected a difference between treated and untreated foliage. This suggests that avoidance is not a significant part of the resistance developed in our Bt-resistant CPB strain. Insecticide evaluation studies showed that several insecticides, including AC 303,630, Confidor (NTN33893), and Asana + PBO gave good control of CPB larvae, reduced defoliation, and resulted in highest yields. The control of CPB with Trigard studies showed no significant differences between treatments in the number of egg masses, small larvae or adults for any sampling date. Also, no significant differences were found in yield between treatments.

Introduction

1992 was one of the coldest summers recorded in Michigan. These cool temperatures delayed and prolonged the emergence of overwintered CPB. Consequently, all stages of CPB (adults, eggs, and larvae) were found in potato fields during the first half of the growing season. Cool temperatures also delayed potato development and a late freeze damaged early planted potatoes.

Research in 1992 focused on traditional (insecticide) methods to control CPB as well as nontraditional methods (propane burners and crop vacuums). Two sets of insecticide evaluation trials were conducted. One set evaluated standard and new insecticides for the control of CPB. The other trial evaluated the insect growth regulator Trigand for CPB control.

A propane burner and crop vacuum were evaluated for their efficiency for CPB control. These studies were to incorporate a early planted trap crop (to lure emerging CPB adults) but a late freeze damaged these plants. By the time the plants recovered the entire field had emereged.

Research also focused on the dispersal behavior of overwintered CPB and the feeding behavior of Bt-resistant CPB larvae. Factors potentially affecting the dispersal behavior of postdiapause CPB included: type and size of rotational crop, presence of volunteer potatoes in the rotational crop, and timing of CPB emergence from diapause versus growth of rotational crop. Also, the potential use of feeding deterrents/repellents to confine dispersing CPB was studied.

Feeding behavior of Bt-resistant CPB larvae on Bt-treated potatoes was examined. These studies tested whether Bt-resistant larvae could detect foliage treated with Bt. Avoidance of plants treated with Bt would serve as a method of resistance for the beetle.

Funding for these studies was provided by: USDA National Potato Research Grant Program, NC Regional IPM Program, USDA special potato research grant, Agrochemical Industries, and Michigan Agricultural Experimental Station. We wish to thank Keilen Farms Inc., Clinton Co., MI, and Duyck and Sons Farms, Bay Co., MI for their cooperation, as well as, William Sutherland of Gas Production Co., Vestaburg, MI and Sukup Manufacturing Co., Sheffield, Iowa for the use of their equipment.

Propane burners and crop vacuums for the control of Colorado potato beetles. Mechanical means of CPB control (propane burners and crop vacuums) have received much attention in Michigan. At least eight Michigan growers built and used propane burners in 1992. These burners were based on the design of a unit used in Long Island, New York. Also, one crop vacuum was used by several growers in eastern Michigan in 1992. The purpose of our 1992 field study was to use a trap crop (four border rows planted early to attract CPB) to attract the emerging CPB and evaluate the effectiveness of a crop vacuum and propane burner for the controlling these beetles. In Michigan, the CPB typically over winters in the same field where it feeds and develops. In the spring the CPB emerges and begins to search for a suitable host. Our study site was planted to corn in 1991 and was adjacent to a field planted to potatoes. In 1992, we planted four rows of potatoes two weeks prior to planting the entire field. We used these four rows as a trap crop to attract the CPB that overwintered in the adjacent field (planted to soy beans in 1992). The trap crop could serve several useful purposes. The early planted trap crop (planted two weeks early, the only potatoes emerging) would not only attract the emerging CPB but would also allow us to concentrate our control efforts to a limited area. Unfortunately, a late mid-May freeze damaged our trap crop, eliminating the early effect we planned for. By the time our trap crop recovered, the entire field had emerged. In this report we will discuss the effectiveness of the propane burner and crop vacuum.

The propane burner was used on the trap crop ten times in a 14 day period. The plants ranged in size from two leaflets emerging to plants over eight inches tall with several stems. The burners were operated at ca. 30 psi with a tractor speed of 5 mph. The burners were situated 8 to 12 inches from the row center angled towards the plant approximately 4 inches above the plant. The effectiveness of the burner ranged from 50 to 85% control with a average CPB adult kill of 69%. The effect on egg hatch was examined by collecting egg masses that were flamed and counting the number hatched. Fifty percent of the observed egg masses did not hatch compared with 100% hatch of egg masses not flamed. The effects of the propane burner on the potato plants was negligible on plants less than eight inches tall. All plants took on a blue-black appearance right after flaming but their green color returned by the following morning. The propane burner had no effect on potato yield (Fig. 1).

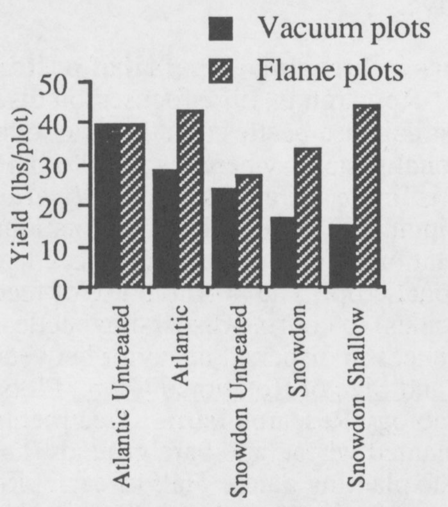

Fig. 1. Potato yield (lbs/35ft) from flame and vacuum plots.

The crop vacuum provided 70% control of adult CPB with a range of control from 50 to 95%. This large range is due to the size of the plants (larger plants with greater leaf area tend to fold up and prevent the beetles from being sucked off the plant) and to the wind conditions at time of treatment. Beetles tend to hand on tighter to the plant with increasing wind speed (Fig. 2). The vacuumed removed approximately 70% of both small and large CPB larvae. Newly emerged larvae that were still congregated with their egg mass were complete removed by vacuuming. The only effect the crop vacuum had on egg mass removal was when the leaf the egg mass was attached to was ripped from the plant. However, the wind force of the vacuum and the sandy soils had a sand-blasting effect on the egg shell and 60% of the egg masses observed after vacuuming did not hatch. The crop vacuum significantly reduced `Snowdon' potato yield. No differences were observed with the yield of `Atlantic' (Fig. 1).

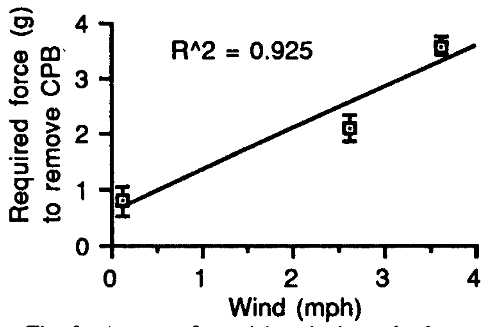

Fig. 2. Average force (g) and sd required to remove CPB at different wind speeds.

The propane burner and crop vacuum proved to be effective tools for the control of CPB. Both mechanical means provided approximately 70% control of CPB in our field study. However, there are limitations to both of the units tested. These units tend to be limited to treating 4 to 6 rows per pass (compared to spray booms treating 40-50 rows). This small number of treated rows will limit the acreage that can be treated. Also, soil compaction should be a concern when using either unit. Both units have a limited time for operation in the growing season. As plants increase in size the units become less effective.

Factors influencing dispersal of postdiapause Colorado potato beetles out of rotated fields. Research in 1992 focused on discovering how various factors influence dispersal of postdiapause beetles (beetles after overwintering). Our ultimate aim is to develop crop rotational systems where dispersal of CPB from last year's to the current year's potato fields is limited. Factors potentially affecting this dispersal that were investigated in 1992 included: type and size of rotational crop, presence of hosts (volunteer potatoes) in the rotational crop, and timing of beetle emergence from diapause vs. growth of the rotational crop. The potential use of feeding deterrents/repellents (tin and copper fungicides) to confine dispersing beetles was also studied. In addition, we looked at differences in dispersal behavior between postdiapause and summer adult CPB.
Type and Size of Rotational Crop. Plots (6 m x 12 m) were planted in a field at the Entomology Research Farm. Treatments included early and late-planted peas, early and late-planted wheat, and bare ground. There was about 2 wks difference between early and late planting dates. Half of each plot was surrounded by a 6 inch barrier of black visquine plastic painted with Fluon® (beetles are unable to climb barrier and had to fly to leave plot). The other half of each plot was surrounded by the black visquine barrier painted with white spray paint and sand (beetles were able to climb barrier). Each plot was surrounded by a row of potatoes 1.5 meter from the plot edge. Postdiapause beetles were marked and released in the center of each half plot. Plots and surrounding potatoes were searched for marked beetles at various intervals following release. Beetles found on potatoes were collected. Beetles were released into plots four times.

In general, fewer beetles released into plots with older (bigger) plants left the plots and reached the potatoes than beetles released into plots with younger (smaller) plants (Figure 3). This was true for both Fluon and non-Fluon plots. Size of plants apparently inhibits both walking and flight. For the most part, more beetles reached the potatoes when released into peas than into wheat. The exception to this was for Fluon-surrounded plots planted with young peas. Beetles were able to fly quite easily out of small peas. Finally, few beetles that were released into bare-ground plots reached the potatoes, although many left the plots. At first glance, this is an unexpected result. However, it may be that beetles in bare plots left in long-distance dispersal flight.

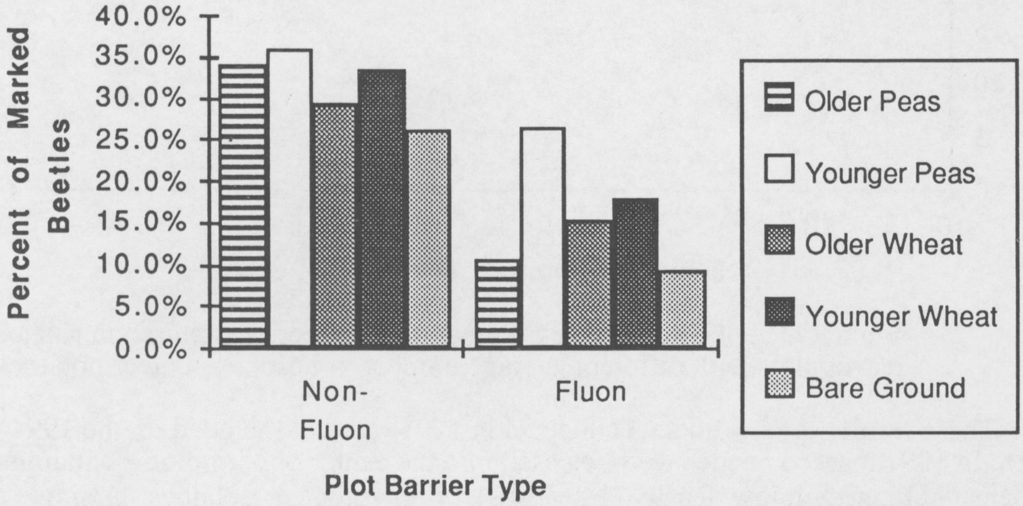

Figure 3. Cumulative percentage of marked beetles released into different plots that were recaptured by 24 hours after release in potatoes. Plot types = Peas, Wheat and Bare ground. Older plots were planted ca 2 weeks before younger plots. Plots were surrounded by barriers that prevented walking out of plot (Fluon Barriers) or did not prevent walking (Non-fluon barriers).

It must be emphasized that the above results are extremely preliminary. Data analysis is continuing. It will be especially useful to compare data for dispersal patterns over a longer time.

Effect of Hosts in Rotational Crop. Small plots (6 m x 6 m) were set up in a commercial carrot field (potatoes in 1991) that bordered a potato field in Clinton Co., MI (Keilens Farms). Plots had either sprouted potatoes planted to simulate volunteer potatoes, or no potatoes were planted. There were four replications (plots) per treatment. During the experiment, naturally-occurring volunteer potatoes grew in all plots. These were removed periodically. However, the effect of these potatoes was that the no-volunteer treatment simply had a lower number of volunteers than the volunteer treatment. Beetles were collected from the carrot and potato field, marked, and released into the center of each carrot plot. Plots were searched for marked and unmarked beetles at various intervals after release. The first three rows of the neighboring potato field were also searched for marked beetles.

Analysis of results is currently underway. It appears that beetles dispersed out of carrot plots less if hosts (volunteer potatoes) were present. Preliminary results indicate that a low density of volunteer potatoes is effective at reducing dispersal. Higher densities of potatoes do not reduce dispersal more than low densities (Figure 4).

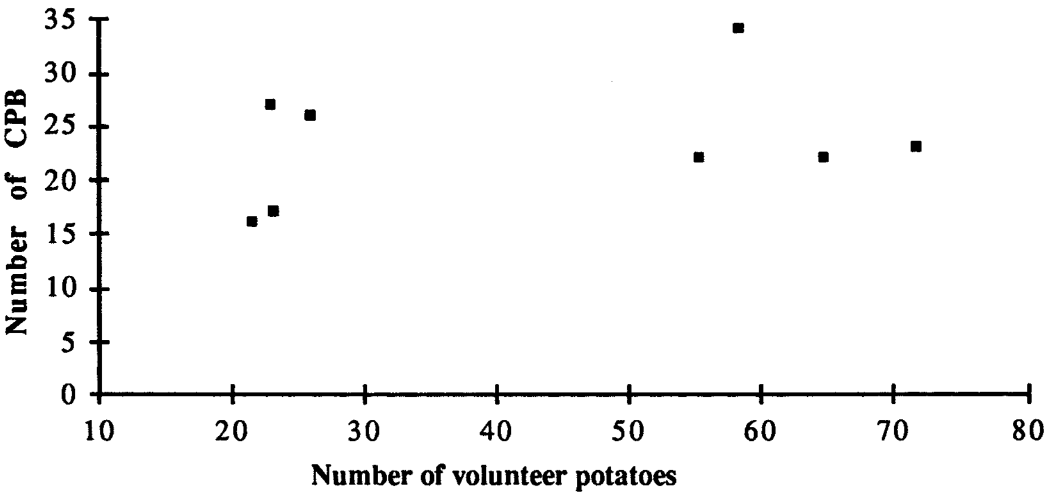

Figure 4. Total number of Colorado potato beetles captured in rotated carrot plots with different average number of hosts (volunteer potatoes).

These results agree with data collected in 1991 (but not included in the 1991 report). In 1991 marked beetles were released into the center of corn plots containing a high density (1 per m^2), low density (1 per $5m^2$), or no volunteer potatoes. A single row of nine potatoes was 1 meter from each corn plot. Both the corn plot and the row of potatoes were searched periodically for marked beetles. The total percent of marked beetles that were later recaptured was not significantly influenced by the presence, or density of volunteer potatoes in the corn (Figure 5). However, of the total number recaptured, a much higher percentage of beetles were found in the potatoes (indicating that they had left the corn) in corn plots lacking volunteer potatoes (Figure 6). The density of the volunteer potatoes did not significantly affect where the beetles were recaptured.

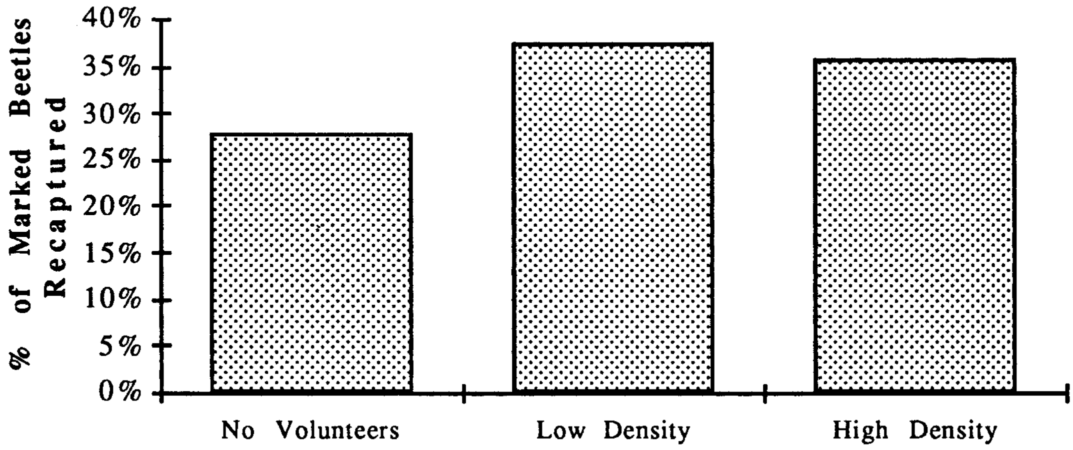

Figure 5. Percent of marked Colorado potato beetles released into corn plots with or without volunteer potatoes that were recaptured 24 hours after release.

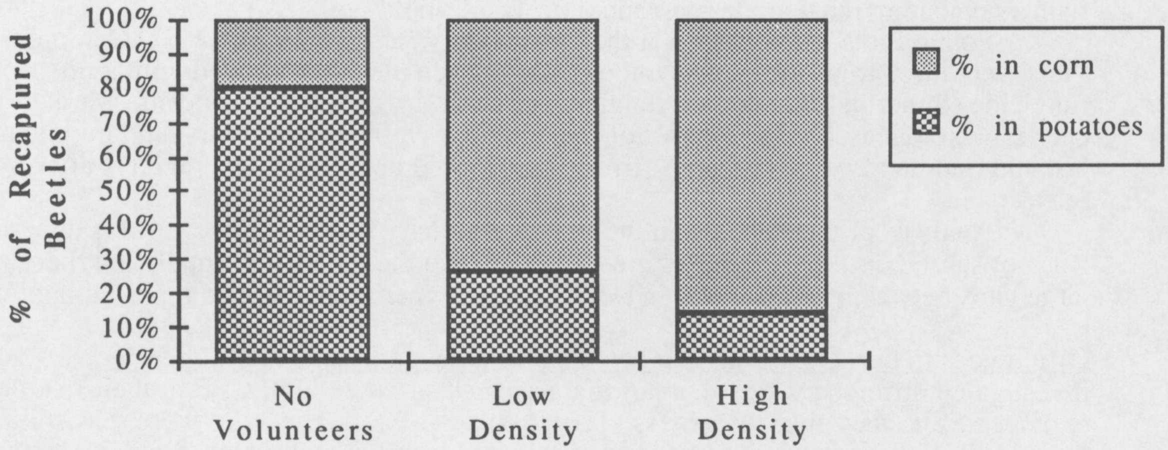

Figure 6. Percent of marked Colorado potato beetles released into corn plots with or without volunteer potatoes and were recaptured 24 hours after release that were found in the corn and in the potatoes.

Volunteer potatoes reduce dispersal of postdiapause CPB in a variety of crops. Besides carrots and corn (above) research in 1992 showed that dispersal out of plots containing volunteers is reduced in wheat, peas, and bare ground.

Collectively, these results indicate that the presence of hosts (volunteer potatoes) in a rotated field very effectively reduces dispersal of postdiapause CPB out of the field. By reducing dispersal out of the field, colonization of new potato fields is also reduced. Preliminary results also show that volunteer potatoes effectively decrease dispersal even at low densities. Increasing the density of volunteers does not reduce CPB dispersal to a corresponding degree.

<u>Timing of beetle emergence from diapause vs. growth of the rotational crop</u>. Research continued this year on predicting beetle emergence from diapause vs. crop growth on the basis of soil temperatures. Knowledge of how crop size affects dispersal of postdiapause CPB (see above) will be useful only if we are able to predict when beetle emergence from diapause will occur relative to the size of the rotational crop. Beetle emergence from diapause was monitored at the Montcalm Research Farm, Entrican MI, and at the Entomology Research Farm, MSU Campus. Soil temperatures were monitored beginning April 15, 1992. Size of corn and potatoes were measured periodically at Montcalm Research Farm. The size of wheat, and peas were measured periodically at the Entomology Research Farm. Data analysis is not complete at this time.

In addition, experiments were begun to study the effect of soil-type on beetle emergence from diapause. Large plastic trash containers were placed into holes in the ground in Sept 1992 and were filled with sandy loam soil (from Montcalm Co., MI), muck soil (from Clinton Co., MI) or sand (Martin Block Co.). Pre-diapause beetles (70 per container) were placed on top of the soil, and provided with food. Containers were covered with fiberglass screening. Beetles rapidly buried themselves in the soil.

In spring 1993, soil temperature and beetle emergence will be monitored in each container.

<u>Use of Feeding Deterrents/Repellents (tin and copper fungicides) to Confine Colonizing Beetles</u>. The focus of this research is to find methods of confining colonizing postdiapause CPB to small areas of the new potato field (e.g., field edges). Control

methods can be restricted to these areas, thus allowing the use of some methods (e.g., flamers, vacuums) that are less practical for whole-field use.

Potato Plots were planted at the Entomology Research Farm, MSU Campus. Plots were three rows wide. The middle row of each plot was sprayed with a tin fungicide (Supertin ®), a copper fungicide (Kocide®), or was not sprayed. Marked beetles were released on both sides of the middle row, between the first and middle and last and middle row. Plots were searched for marked beetles for several days after release.

Analysis of these data is in the very preliminary stages. However, this experiment was not started until late in the summer. Potatoes in the plots were small, and there were large gaps between potatoes within a row. These experiments will be repeated next year.

Differences in Dispersal Behavior between Summer and Postdiapause CPB. We investigated differences between postdiapause and summer adult CPB in their readiness to disperse and their responsiveness to potato plants. Marked beetles were released into the middle of 1.2m x 1.2 m arenas. [Arenas were surrounded by black visquine barriers 6 inches high. Four potato plants, one in each corner, were planted in each arena.] Arenas were checked every 20 minutes until 140 minutes after release. The position of marked beetles in each arena was noted.

The most striking difference was in the percentage of beetles found on plants (Figure 7). A higher percentage of summer adult CPB were always found on or near plants than were postdiapause adults. Postdiapause adults were more likely to be found near the center of the arena (where they were released) or on the soil surface not near a plant. This may indicate that summer adults are more responsive to potato plants than are postdiapause adults. Since few beetles left the arena, this experiment does not answer the question of whether postdiapause and summer adults differ in their inclination to disperse. However, results do support previous observations that potato plants reduce beetle dispersal.

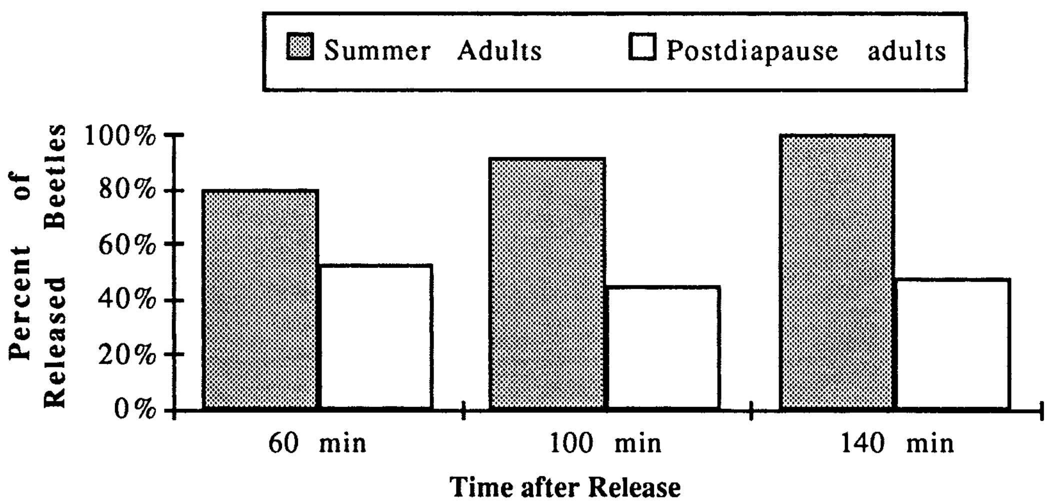

Figure 7 Percent of marked postdiapause and summer adult Colorado potato beetles released in arenas containing four potato plants that were found on potatoes at various times after release.

Data from experiments conducted in 1991, but not previously reported, agree with the above results. In 1991 beetles were released into corn plots with or without volunteer potatoes (see above). A single row of nine potatoes was planted adjacent to 1 side of the plot. Summer adults were slightly more likely to be recaptured (in corn and on potatoes) than were postdiapause adults (Figure 8). However, of the beetles recaptured, summer adults were much more likely than postdiapause adults to be recaptured on potatoes (vs.

in the corn plot). Again, this may indicate that summer adults are more responsible to hosts than postdiapause adults. Also, since a slightly lower percentage of postdiapause adults were recaptured, postdiapause beetles may be slightly more dispersive than summer adults.

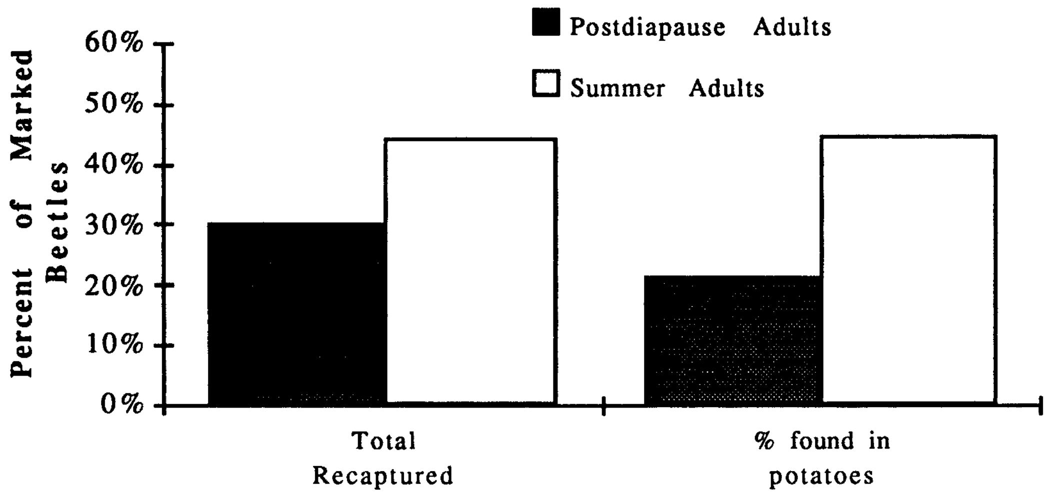

Figure 8. Percent of marked postdiapause or summer adult Colorado potato beetles released into corn plots that were recaptured 24 hours after release.

Differences in dispersal behavior between different generations of CPB adults need to be taken into account in developing management schemes that work.

Feeding behavior of susceptible and *Bacillus thuringiensis (Bt)*-resistant Colorado potato beetle larvae on untreated and Bt-treated potatoes. There is a major concern regarding the development of resistance in Colorado potato beetles to *Bacillus thuringiensis tenebrionis (=san diego).* Resistance to Bt is a concern because few insecticides other than Bt materials are available for control of insecticide-resistant larvae in southern and central Michigan. Current foliar insecticides containing Btt are: Novodor, M-Trak, Trident, and Foil. Bt resistance is also a concern because potatoes genetically-engineered for potato beetle resistance will rely on production of an identical Bt toxin.

High levels of resistance to Btt have been selected in a laboratory strain of Colorado potato beetles in Mark Whalon's laboratory. This strain was originally collected from commercial potato fields in Michigan after treatment with Bt. Surviving larvae were returned to the laboratory and reared with selection for Bt resistance by small larvae in each generation.

Feeding behavior of potato beetles is important for selection of resistance to Bt because Bt must be eaten to be toxic. If adults or larvae can detect the difference between potato foliage treated with Bt or containing Bt toxin, this may be a mechanism of resistance.

In a different view, if susceptible potato beetles could detect and avoid Bt treated foliage, they might avoid commercial fields treated with Bt or commercial fields of engineered potatoes. Avoiding the treated potatoes would be ideal because they would not injure the crop, but also would not be selected for development of resistance to Bt.

Laboratory trials were conducted to begin assessing the ability of potato beetle larvae to detect Bt in the form of a foliar spray. Bt-susceptible and Bt-resistant larvae were used. Foliage was either untreated or treated with M-Trak. M-Trak application rate was approximately equivalent to Bt expression in Monsanto resistant potato plants (about

100 fold the normal field M-Trak application rate). Larvae were placed on the foliage, allowed to acclimate to the experimental conditions for 40 minutes and then observed for feeding. The proportion of time each larva spent feeding was measured.

Both Bt-susceptible and resistant larvae spent the same amount of time feeding on untreated foliage. Bt-resistant larvae spent more time feeding on treated foliage than susceptible larvae. It appeared that even within the initial 40 minute acclimation time, Bt toxin had already begun to affect the susceptible larvae. Bt-resistant larvae spent approximately the same amount of time feeding on treated and untreated leaves.

Conclusions are that neither susceptible or resistant larvae detect a difference between treated and untreated foliage. This suggests that avoidance is not a significant part of the resistance developed in our Bt-resistant potato beetle strain. Further trials are planned to compare feeding on Monsanto's genetically engineered resistant potatoes.

Insecticide Efficacy Tests for CPB Control. Twelve insecticides were tested at the MSU Montcalm Research Farm in Entrican, MI. Potatoes were planted 10 inches apart with a 34 inch row spacing on 7 May. Plots were 45 feet long and three rows wide. Treatments were arranged in a randomized complete block design with four replications. Two rows of potatoes treated with Temik applied in 8" bands at planting, or six feet of bare ground separated plots. ASC 66824 was applied with a hand-held single nozzle CO_2 sprayer. Foliar treatments were applied with a tractor-mounted sprayer. Both methods applied solutions at 30 gal/acre and 45 psi. Applications were done on 26 June, 2 & 5 July, 15 July and 21 July. Monitor + Asana + piperonyl butoxide (PBO), Danitol, Imidan + PBO, and AC 303,630 were applied on 2 July but spraying was interrupted by wind. Remaining foliar treatments were applied on 5 July. Two randomly selected plants from the middle row of each plot were sampled for all stages of CPB on 29 June, 6-10 July, 17 July, and 24 July. A visual defoliation assessment was done on 17 July. Potatoes were harvested from the middle row of each plot on 3 September, separated by size and weighed.

Most products tested (except ASC 66824) gave good to very good control of small and large larvae. Yields were lowest in untreated and ASC66824 plots.

Control of Colorado Potato Beetle, 1992.

Treatment	Rate/acre	Egg Masses		Adults		Small Larvae[1]		Large Larvae[1]	
		Mean no. per plant (±SEM) over four sampling dates							
Untreated		0.47 ±0.13	a	1.13 ±0.24	e	6.29 ±0.07	fg	7.64 ±0.10	g
Kryocide	12 lb	0.28 ±0.16	a	0.50 ±0.05	bcd	2.24 ±0.52	bcde	1.04 ±0.39	abcde
Cryolite	12 lb	0.63 ±0.14	a	0.16 ±0.08	ab	2.65 ±0.38	cde	2.71 ±0.30	ef
AC 303,630 with crop oil	0.10 lb ai + 1 qt	0.16 ±0.03	a	0.22 ±0.06	abc	3.29 ±0.30	def	1.89 ±0.06	cde
AC 303,630 with crop oil	0.15 lb ai + 1 qt	0.32 ±0.11	a	0.19 ±0.08	ab	1.18 ±0.19	abc	0.84 ±0.11	abcd
AC 303,630 with crop oil	0.20 lb ai + 1 qt	0.41 ±0.09	a	0.13 ±0.05	a	0.45 ±0.20	a	0.42 ±0.16	a
AC 303,630	0.15 lb ai	0.42 ±0.13	a	0.42 ±0.19	abcd	1.91 ±0.23	bcd	0.66 ±0.26	abc
Monitor + Asana + PBO	0.75 lb ai + 0.05 lb ai + 8 oz	0.50 ±0.10	a	0.38 ±0.08	abcd	1.60 ±0.48	abcd	0.98 ±0.21	abcde
Danitol	0.30 lb ai	0.44 ±0.24	a	0.19 ±0.04	ab	2.49 ±0.15	cde	1.83 ±0.18	bcde
Asana + PBO	0.05 lb ai + 8 oz	0.38 ±0.14	a	0.22 ±0.06	abc	1.01 ±0.09	abc	0.52 ±0.15	ab
Imidan + PBO	1 lb ai + 8 oz	0.50 ±0.24	a	0.19 ±0.12	ab	2.35 ±0.28	cde	2.21 ±0.35	de
M-Trak	2.5 qts	0.19 ±0.08	a	0.22 ±0.03	abc	2.56 ±0.22	cde	1.38 ±0.24	abcde
Novodor	2.5 qts	0.13 ±0.05	a	0.13 ±0.09	a	2.01 ±0.32	bcde	1.31 ±0.57	abcde
ASC 66824 - broadcast[2]	8 lb ai	0.41 ±0.29	a	0.56 ±0.25	bcd	4.57 ±0.48	ef	5.59 ±0.20	fg
ASC 66824 - 8" band[2]	8 lb ai	0.63 ±0.18	a	0.78 ±0.14	de	6.78 ±0.28	fg	6.92 ±0.24	g
ASC 66824 - 8" band[2]	4 lb ai	0.69 ±0.21	a	0.78 ±0.18	de	10.09 ±0.21	g	8.07 ±0.08	g
ASC 66824 - 8" band[3]	4 lb ai	0.59 ±0.24	a	0.47 ±0.16	abcd	3.40 ±0.15	def	7.63 ±0.07	g
NTN 33893 - in furrow	8.6 oz/1000'	0.53 ±0.25	a	0.47 ±0.16	abcd	1.41 ±0.37	abcd	0.63 ±0.21	abc
NTN 33893 - in furrow	12.9 oz/1000'	0.47 ±0.19	a	0.66 ±0.26	cde	1.15 ±0.41	abc	0.86 ±0.51	abcd
NTN 33893 - foliar	2.88 oz	0.19 ±0.04	a	0.38 ±0.30	abc	0.71 ±0.38	ab	0.44 ±0.18	a

Means within a column followed by the same letter are not significantly different ($P > 0.05$, LSD on ln(x+1) tranformed data).

1 Means were retransformed from means of ln(x+1)

2 Sprayed at planting.

3 Applied at hilling on 15 June.

Control of Colorado Potato Beetle, 1992.

Treatment	Rate/acre	Yield in lbs per 45 row feet (SEM) Size A		Size B		Defoliation Rating
Untreated		61.25 ±5.88	abcde	4.38 ±0.69	a	3.2
Kryocide	12 lb	67.25 ±8.42	cde	3.75 ±0.52	a	2.3
Cryolite	12 lb	66.00 ±10.57	cde	3.75 ±0.60	a	1.8
AC303,630 with crop oil	0.1 lb ai + 1 qt	77.75 ±6.06	e	3.25 ±0.25	a	1.4
AC303,630 with crop oil	0.15 lb ai + 1 qt	67.63 ±8.79	cde	0.13 ±0.97	a	1.3
AC303,630 with crop oil	0.2 lb ai + 1 qt	64.50 +3.07	bcde	5.13 ±0.52	a	1.1
AC303,630	0.15 lb ai	77.50 ±18.64	e	5.38 ±1.07	a	1.4
Monitor + Asana + PBO	0.75 lb ai + 0.05 lb ai + 8 oz	67.00 ±2.26	cde	4.38 ±0.13	a	1.6
Danitol	0.3 lb ai	70.00 ±8.18	cde	3.50 ±0.54	a	1.4
Asana + PBO	0.05 lb ai + 8 oz	75.25 ±7.03	e	4.50 ±0.54	a	1.2
Imidan + PBO	1 lb ai + 8 oz	74.38 ±8.83	de	3.88 ±0.80	a	2.1
M-Trak	2.5 qts	66.63 ±11.27	cde	5.50 ±1.40	a	2.1
Novodor	2.5 qts	57.13 ±10.71	abcd	3.25 ±1.09	a	1.4
ASC66824 - broadcast[1]	8 lb ai	67.00 ±5.64	cde	6.00 ±1.37	a	2.9
ASC66824 - 8" band[1]	8 lb ai	44.63 ±3.67	a	4.38 ±0.63	a	3.6
ASC66824 - 8" band[1]	4 lb ai	47.13 ±2.81	ab	6.00 ±0.71	a	3.6
ASC66824 - 8" band[2]	4 lb ai	56.00 ±7.08	abc	5.63 ±0.99	a	3.8
NTN33893 - in furrow	8.6 oz/1000 row feet	67.88 ±10.18	cde	5.00 ±1.02	a	1.2
NTN33893 - in furrow	12.9 oz/1000 row feet	67.13 ±6.69	cde	4.88 ±1.39	a	1.8
NTN33893 - foliar	2.88 fl. oz	68.00 ±2.23	cde	4.25 ±0.43	a	1.3

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

1 Sprayed at planting.

2 Applied at hilling on 15 June.

Control of CPB with Trigard. The farm of Dave and Art Duyck, Bay Co., MI, was the site of a field trial using the growth regulator Trigard against CPB. Snowdon potatoes were planted on 12 May and managed by the grower. Treatments included two plots treated with Trigard; one standard plot treated with Asana + PBO, and Guthion + Imidan + PBO; and an "untreated" plot (treated on 24 July). Plots were of variable length and width (40' x 100' for the untreated plot; ca. 0.5 acre for each Trigard plot; and > 10 acres for the standard plot). A tractor mounted sprayer was used to spray the plots on 27 June and 22 July. On 11 July Trigard was applied with the ground sprayer and an aerial application was made on the standard plot. In addition, the untreated plot was sprayed with Guthion + Imidan + PBO on 24 July. Counts of all stages of CPB were made on 8 randomly selected plants per plot on 1, 7, and 21 July and 5 and 19 August. A visual defoliation assessment was done on 21 July, 5 Aug and 19 Aug. Potatoes were harvested from four 15' sections of row on 15 September, separated by size and weighed.

There were no statistically significant differences between treatments in the numbers of egg masses, adults, or small larvae for any sampling date, although the Trigard plots tended to have fewer adults and larvae than the standard or untreated plots. The Trigard South plot had the lowest number of small larvae on the first 3 sampling dates and the lowest seasonal average. There were significantly more large larvae in the standard treatment than in the Trigard or untreated plots on 21 July. Over the entire season there were fewer large larvae in the Trigard South plot than other plots. Yield was not significantly different between treatments based on four 15 ft samples (Table). However, Art Duyck reported 25 bags from a one-row sample across the standard insecticide area (1280 ft long) and approximately 30 bags from the same area in the Trigard treated areas. Because plots were not replicated, it was not possible to determine if yield differences were due to differences in treatment or differences in soil type, etc. The standard plot had the highest yield and the untreated plot the lowest yield of size A potatoes. Defoliation was never > 25% in any of the plots.

There were several factors that could have affected the results of this field trial. The lower numbers of larvae in the Trigard South plot may have been due to spatial differences in CPB pressure within the field. The South plot was farthest from the northern border of the field and therefore less prone to a "border effect." The uneven distribution of CPB in this field may be related to border effects, effects of overhead irrigation equipment, past crop history or other factors. In addition, unseasonably cool weather and timing of applications could have affected the performance of Trigard.

Control of Colorado Potato Beetle with Trigard, 1992.

Plot	Treatment	Date	Rate/acre	Method
Trigard North & South	Trigard	27 June	1/3 lb	ground
	Trigard	11 July	1/6 lb	ground
	Trigard	22 July	1/6 lb	ground
Standard				
	Asana + PBO	27 June	0.5 lb ai+ 8 oz.	ground
	Guthion + Imidan + PBO	11 July	1 lb ai + 1 lb ai + 8 oz	air
	Guthion + Imidan + PBO	24 July	1 lb ai + 1 lb ai + 8 oz	ground
	Guthion + Imidan + PBO	6 August	1 lb ai+ 1 lb ai + 8 oz	ground
Untreated				
	Guthion + Imidan + PBO	24 July	1 lb ai + 1 lb ai + 8 oz	ground

	Mean no. per plant (±SEM) over 5 dates				Mean wt of potatoes kg (±SEM)		Defoliation[2]		
Treatment	Adults[1]	Egg Masses	Small Larvae	Large Larvae[1]	Size A	Size B	21 Jul	5 Aug	19
Untreated	1.29 ±0.46 a	0.13 ±0.06 a	6.88 ±3.47 a	1.41 ±0.39 a	13.13 ±1.28 a	2.15±0.10 a	1.3	2.0	[illegible]
Standard	1.16 ±0.28 a	0.30 ±0.21 a	8.80 ±4.00 a	1.97 ±0.51 a	19.33 ±3.21 a	1.28±0.15 a	1.9	1.7	[illegible]
Trigard North	0.46 ±0.15 a	0.23 ±0.08 a	8.25 ±3.53 a	1.34 ±0.22 a	13.95 ±1.02 a	1.55±0.49 a	1.4	1.0	[illegible]
Trigard South	0.45 ±0.21 a	0.33 ±0.09 a	5.10 ±1.71 a	0.51 ±0.16 a	16.43 ±0.78 a	1.68±0.32 a	1.5	1.0	[illegible]

Means within a column followed by the same letter are not significantly different (P>0.05, LSD on ln(x+1) transformed data).
1 Means were retransformed from ln(x+1) means.
2 Rating: 1 = no damage, 2 = 0-5%, 3 = 6-25%, 4 = 26-50%, 5 = > 50%.
21 July, 8 plants evaluated; 5 & 19 Aug, 3 plants evaluated.

Funding: MPIC

Survival of *Bacillus thuringiensis* Resistant Colorado Potato Beetle on Transgenic Potatoes

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Background

Bacillus thuringiensis (B.t.) insecticides and transgenic plants represent notable emerging tools for insect pest management. Resistant strains could be useful for comparative studies to determine B.t. mode of action and to develop synergists and agonists. We have recently developed a strain of Colorado potato beetles (CPB) which is resistant to B.t. (Whalon et al. in press). This strain (Bt-R) has resulted from selection of second instars with commercially formulated B.t. (M-One or Spudcap, Mycogen Corp.). In successive selections (after the 17th generation) the resistance levels have remained high, at about 200-fold (Rahardja and Whalon, submitted).

It is our contention that by the time transgenic plants are released for commercial potato production that there will be instances of resistance to B.t. in the field. Based on our experience, we feel that field resistance will be at a fairly low level, (ca. 20-fold), but the introduction of transgenic plants will place a high selection pressure on CPB populations. This presents a major concern with the use and deployment strategy for transgenic potatoes (McGaughey and Whalon, 1992). Our goal was to assess the utility of transgenic potatoes in a situation where resistance is already present in field populations.

Methods

Bioassays were conducted on larvae and adults using excised petioles from Russet Burbank potatoes which were treated with high levels of B.t. to make them very similar to transgenic plants. Larvae were weighed and assessed for mortality daily. Effects on adults were also measured in caged potted plants (Whalon et al. in press).

Results

The Bt-R strain had about 75% survivability on simulated transgenic plants during the 4-day feeding trials (Table 1.). This is significantly higher ($P<0.01$) than the Bt-S strain. The Bt-R strain did have significantly higher ($P<0.01$) mortality when exposed to B.t. compared with feeding on foliage without B.t. For both strains, weight gain is reduced when exposed to B.t. (Figure 1). But with the Bt-S strain, the larvae have a net weigh loss, while the Bt-R strain gains weight, but at a slower rate compared to controls.

In the adult studies, the Bt-S adults had 40% mortality when feeding on simulated transgenic plants, compared with 10% mortality in control groups (Table 2.). There was no significant effect on Bt-R mortality. It appears as though B.t. may have effects on reproduction, as there was a substantial decrease in the number of eggs produced by both strains when exposed to B.t.

Discussion

These results add to our knowledge of the efficacy of B.t. and transgenic plants. In the field, no larvae have survived on a total of 20 acres planted under experimental use permits. All stages of beetles show arrested feeding on transgenic potatoes. Adults do survive, but don't feed very much, and there seems to be a notable decrease in egg laying. We have no data on effects on pupae.

In the lab, using simulated transgenic plants, there has been no significant larval survival in the Bt-S strain. and no survival of first instars in either strain. The Bt-R strain shows survival in second and later instars, survival increasing with age. With the adults, we see increased mortality, and decreased egg production, potentially an important aspect of resistance management.

Conclusions

1. Transgenic potato plants are extremely effective.
2. Bt-R larvae in second and later instars can survive significant exposure to B.t.
3. CPB resistance threatens long-term use of transgenic plants
4. We need to continue to work on strategies which reduce the development of resistance to B.t. and transgenic plants.

References

McGaughey & Whalon, Science 258: 1451 (1992).
Rahardja & Whalon, J.Econ Ent. (submitted).
Whalon et al., J. Econ. Ent. 86 (in press).

Table 1. Mortality of Colorado potato beetle larvae on normal and simulated transgenic plants during 4-day feeding trials.

	Percent Mortality
Bt-S / no B.t.	7 ± 6
Bt-S / + B.t.	95 ± 5
Bt-R / no B.t.	6 ± 3
Bt-R / + B.t.	24 ± 6

Values shown are the mean ± SEM for 3 replicates (10-20 individuals assayed per replicate).

Table 2. Mortality and reproductive effects of simulated transgenic potatoes on Colorado potato beetle adults during 15-day feeding trials.

		# Egg masses/day	
	% Mortality (Lab)	Lab	Field
Bt-S / no B.t.	0	1.2	0.6
Bt-S / + B.t.	40	0.0	0.0
Bt-R / no B.t.	10	1.1	1.3
Bt-R / + B.t.	10	0.1	0.0

Lab tests conducted on 8-12 pairs of adults

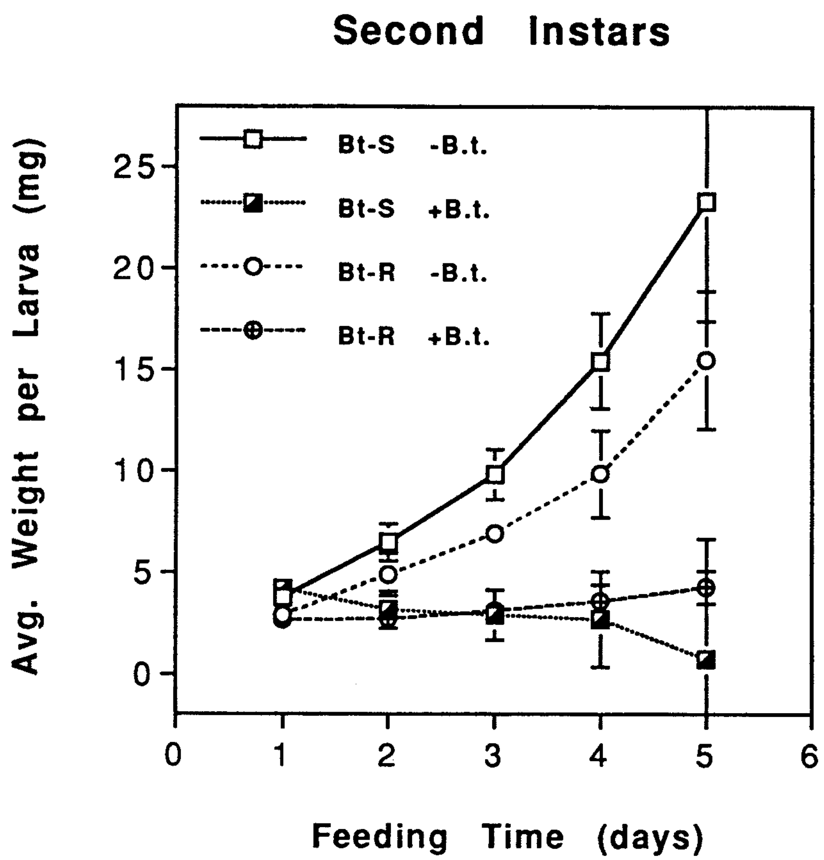

Figure 1. Average weights of Colorado potato beetle larvae feeding on normal and simulated transgenic plants.

Funding: Federal Grant/MPIC

MANAGEMENT OF ROOT-LESION NEMATODES AND THE POTATO EARLY-DYING DISEASE

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Introduction

A number of experiments were conducted in 1992 to further investigate the role of root-lesion nematodes, *Pratylenchus sp.*, in Michigan potato production. These nematodes are known to interact with the fungus, *Verticillium dahliae*, to negatively impact potato growth and yields. Nematicides are commonly used to control these 2 plant pathogens, but it is imperative that other management options are investigated. Crop rotations and the proper selection of fall cover crops are two tactics receiving more emphasis in the M.S.U. Nematology Program. Research was conducted in these two areas, in addition to a potato variety trial and nematicide trial in 1992.

Another area of interest is the use of the entomophagous nematode, *Steinernema carpocapsae*, for control of the Colorado Potato Beetle (CPB). These nematodes were found to be very effective in the laboratory, but prior to 1992 had not been applied, in Michigan, for CPB control in the field. Limited field studies were conducted at a campus site in 1992.

Crop Rotation Trial

The primary objective of this research is to evaluate crop rotation as a tactic to alleviate potato tuber yield and quality losses caused by the joint interaction of the root-lesion nematode, *Pratylenchus penetrans*, and the Verticillium wilt fungus, *Verticillium dahliae*. This is a 10-year investigation being conducted with the cooperation of Dr. Maury Vitosh. The trial was initiated in 1991 and is located at M.S.U. Potato Research Farm.

Three crops were grown at this location in 1992, potatoes (Russet Norkotah), alfalfa and soybeans. The crops were planted on May 19. Potato crops followed potato, alfalfa, and oats (1991 crops). The three potato treatments all received 400 lbs of 20-10-10 fertilizer at-planting. Soil samples were then collected *ca*. 3 weeks after planting to determine the amounts of nitrogen needed as a side-dress treatment at hilling. The side-dress rates were as follows: potatoes following alfalfa only required 5 lbs. of N; potatoes following oats, 40 lbs. and potatoes following potatoes received 50 lbs. of nitrogen. Therefore, the nitrogen credits due to the previous crops were accounted for in 1992.

Potato petiole samples were collected at weekly intervals in July for the 3 treatments (Figure 1). There were essentially no differences in the nitrate concentrations in the petiole sap over the 4 sampling dates when comparing treatments. The nitrate concentrations were considered adequate, so no additional nitrogen was applied.

Nematode samples were collected on July 10. More root-lesion nematodes were recovered from soybean roots than from roots of alfalfa or potato. Root-lesion nematode counts did not differ between the 3 potato treatments although slightly higher numbers were found in the potato monoculture plots (Table 1). Root-lesion nematode counts did not differ among the hosts (potato, alfalfa and oats) grown in 1991 in samples collected on July 2, 1991.

Potato stem tissue was collected from all the potato plots on Sept. 14. Fifteen stems were randomly selected from each plot and a piece, approximately 3 in. in length, was excised from the basal region of each stem. Each stem section was further excised in the lab, surface sterilized and plated in order to detect the presence of V. dahliae. The greatest percentage (21%) of infected stems were found in plots where potatoes followed potatoes. 17.5% of the stems were infected when potatoes followed alfalfa and 13.3% where potatoes followed oats. Furthermore, all the stems per plot were then combined, after the initial excisions, and ground in a Wiley Mill to quantify stem infection per gram of tissue. There were no differences between treatments in the number of V. dahliae colonies recovered per gram potato stem tissue (Table 1).

The potato plots were harvested on Oct. 6. Growing alfalfa or oats in 1991 prior to the 1992 potato crop resulted in significant yield increases when compared to a potato monoculture (Table 1). These differences apparently are not due to differences in nitrogen levels, root-lesion nematodes or V. dahliae infections. Therefore, it seems other undetermined factors were responsible for the observed yield increases. All the yields however fell well below our yield goal of 400 cwt/A.

Variety Trial

The objective of this study was to examine the responses of 5 potato varieties to metham (Busan 1020). The varieties selected for evaluation were Atlantic, Ranger Russet, Russet Norkotah, Snowden and Superior. Busan 1020 was applied in the spring on May 6 at 50 gal./A. The potatoes were planted on May 19 and harvested on Oct. 7. Potatoes had not been grown on this particular site for at least 6 years.

Nematode samples were collected on June 23. There were no differences observed between varieties in the numbers of root-lesion nematodes recovered per gram root tissue in the absence of soil fumigant. However, the application of Busan 1020 resulted in excellent nematode control (Table 2). The nematicide treatment apparently produced season-long control when comparing population densities of root-lesion nematodes recovered in the soil at harvest (Table 2).

Stem pieces were collected on Sept. 14 for detection and quantification of V. dahliae infections. Twenty-five stem sections were randomly selected per plot, the methodology was described in the previous section. Lower percentages of infected stems were recovered from fumigated than from untreated plots across all the varieties tested (Table 2). The same trend was apparent for the numbers of V. dahliae colonies recovered per gram potato stem tissue (Table 2). V. dahliae numbers were approximately 7 times higher in Superior stems than Ranger Russet in samples collected from the untreated plots.

Stand counts were taken on June 23 and the data are shown in Table 3. The number of plants were counted per 100 row ft. to document phytotoxicity (if any) due to the fumigation treatment. No phytotoxicity was observed based on the fact there were no significant stand reductions. Plant health measurements were taken on Aug. 13. Four individuals scored the plants for disease and a mean of the 4 ratings were used in the analysis (Table 3). No significant differences were observed between plants grown in fumigated compared to untreated soil. Not surprisingly, Superior was more chlorotic than the rest of the varieties on Aug. 13.

Fumigation resulted in significant yield increases for all 5 varieties (Table 4). The largest fumigation response was observed with Superior. Total yield was increased 171 cwt/A. The smallest increase occured with Ranger Russet, total yield was increased 65 cwt/A.

All 5 varieties tested yielded between 481 and 504 cwt/A in fumigated plots. However, based on the data obtained in this trial, Superior and Snowden are the varieties most apt to provide a fumigation response. These varieties should be utilized in fields that have been fumigated. Atlantic, Ranger Russet and Russet Norkotah did not respond nearly as well to the fumigation treatment because their yields were quite high in the untreated plots. These varieties could therefore be grown in fields that were not previously fumigated. They may not be as susceptible to early-dying as the previous 2 varieties, but these observations are based on only 1 year of field data.

Nematicide Trial

A nematicide trial was conducted at the Potato Research Farm to evaluate the efficacy of various nematicides for root-lesion nematode control. An experimental compound tested, in addition to Bioac TNA and Vapam were applied in the fall of 1991 on Oct. 17. The remaining materials were applied at-planting or just prior to planting on May 11, 1992. This trial was harvested on Sept. 1. Superior was the potato cultivar utilized in this study.

Root samples were collected on June 23 to assess the population densities of root-lesion nematodes. There were essentially no differences in the numbers of nematodes recovered on that sampling date (Table 5). Root samples were not collected at a later date. It's quite possible that more differences would have been observed at a later sampling date.

The application of Vapam at 75 gal./A was the only treatment that resulted in a significant yield increase when compared to the yield from the untreated plots (Table 5). However, the yield from the Vapam-treated plots in this trial (347 cwt/A) was not much higher than the yield of Superior from the untreated plots in the variety trial (313 cwt/A). This could possibly be due to increased disease pressure in the nematicide trial compared to the variety trial. However, although, the same seed source was utilized, it does demonstrate some of the dangers in comparing yields from 2 different trials or locations.

Cover Crop/Green Manure Study

A greenhouse study was initiated in the fall of 1992 to evaluate a number of plant species as hosts for root-lesion nematodes and to investigate the effectiveness of utilizing these same plants as green manure crops to control root-lesion nematodes and V. dahliae. The plants and cultivars used in the study were potato (cv. Superior), pea (cv. Maestro), sudax (cv. Haygrazer), oats (cv. Heritage), barley (cv. Hudson), marigold (cv. Happy Red), canola (cv. Cargill DH1) and rapeseed (cvs. Askari, Bridger, Dwarf Essex and Sollux). The study was conducted in 8 in. clay pots filled with unsterilized, sandy-loam soil collected from the check plots in the potato nematicide trial at harvest. The population density of root-lesion nematodes at planting was 80 per 100 cm^3 soil. The initial population density of V. dahliae has yet to be determined. No V. dahliae data have been obtained to date for this study, only nematode information.

Forty-five days after planting the plants were removed from the pots and root samples processed to assess root-lesion nematode populations. Peas, rapeseed and canola were found to be excellent hosts (Table 6). In addition, many nematodes were also recovered from sudax roots, a plant considered a relatively poor host for root-lesion nematodes. Marigold was the poorest host.

Entire plants (shoots and roots) were then chopped and incorporated in the soil as a green manure treatment. All the plants, including potato were investigated. Fourteen days after incorporation, one potato minituber (Plant Genetics, Inc.) was planted in each pot. Russet Burbank was used for this purpose. Sixty days later, the plants were sampled and nematodes enumerated.

Utilization of marigold as a cover (or rotational) crop and as a green manure treatment effectively controlled root-lesion nematodes in this study (Table 7). No other treatments were found to be as effective including the 4 varieties of rapeseed utilized. These results were somewhat unexpected because in a preliminary study, mixing relatively small quantities of field-collected rapeseed shoots into nematode-infested soil (5 or 10g of plant material into 100 cm^3 soil) resulted in decreases in nematode numbers of 70% or more. However, the rapeseed grown in the greenhouse may have been close to maturity (at least 1 variety was flowering) and glucosinolate concentrations in rapeseed decrease as the plant matures. Therefore, the stage of plant growth may dictate the effectiveness of its use as a soil amendmant for control of plant pathogens. Obviously, more studies are needed to better understand the potential of rapeseed as a soil amendment for Michigan potato production. Rapeseed has been demonstrated to control root-knot nematodes in Washington and its use as a soil amendment has resulted in potato yield increases in previous studies.

Nematodes for Control of the Colorado Potato Beetle

Steinernema carpocapsae was sprayed on potato plants in the field to assess its potential for Colorado potato beetle control.

A natural infestation of second generation beetles was used. Two experiments were conducted. Both experiments used five rates of nematode inoculum, ranging from 0 to 4 billion nematodes per acre. The suggested application rate is 3 billion per acre. However, this nematode is not currently labelled for CPB control.

One day prior to spraying, the field was scouted for potential plants. These plants were assessed on the basis of CPB density. Five plants were selected, and each one was caged. The next evening, at nightfall, each plant was sprayed with a hand held sprayer. Each plant received 100 ml of water containing the randomly selected concentration of nematodes (0, 1, 2, 3, or 4 b/A). The cage was taken of the plant for spraying, and then immediately replaced. The following day, all the beetles were collected from the plants and taken into the lab, given fresh leaves, and observed. Mortality was recorded each day. The second experiment was essentially identical to the first, except larval stage of the insect was recorded.

In the initial experiment, 91% of the CPB died, when the commerically suggested rate of three billion nematodes per acre was used (Table 9). At the 4 b/A nematode application rate, 94% of the CPB died. Efficiency was greatly reduced, however, at the lower rates of 1 or 2 b/A (Table 9). When the experiment was repeated, 100% of the CPB died at the 3 b/A rate, with 88% mortality at the 4 b/A (Table 10). However, it should be noted that at the 4 b/A rate, the plant had an unusually large number of 1st instar which did not respond to the treatment.

The time of application is extremely important with this nematode. The literature has shown that good results require that the nematode be applied during times of low sunlight and high relative humidity. During these two tests, both of these conditions were met. It was applied at night, in a caged environment, with relative humidity ranging from 80 to 100%.

In addition, to these experiments, several initial laboratory experiments were conducted to determine the susceptibility of the nematode to pesticides commonly used in Michigan potato production systems. Eleven different pesticides were tested, 0.7 ml of a solution was placed in a petri dish and the solutions were placed in a darkened growth chamber at 25C. Nine replications were made of 50 nematodes each. After 24 h, even the most toxic pesticides had less than 50% mortality ratings at high concentrations.

After this experiment was completed, two pesticides were chosen, Asana, and were tested with the beetle. Figures 2 and 3 show the results of these tests with four treatments; Check, nematode only, pesticide at field rate, and pesticide and nematode together. Again, under very controlled, laboratory conditions the nematode did extremely well, with at least a 70% mortality. For these experiments, leaves were dipped in a pesticide solution and placed on a filter paper. Ten replications were made. The petri dishes were placed in a darkened growth chamber at 25C.

Table 1. Crop rotation study, Potato Research Farm.

Rotation Crops		Root-lesion nematode 7/10/92 1 g root	*V. dahliae* 9/14/92 0.5 g stem	Potato Yields 10/6/92 cwt/A	
1991	1992			US No. 1	Total
Potato	Potato	92.6 cdef	314,3 a	129 a	172 a
Alfalfa	Potato	33.1 f	304.4 a	197 b	248 b
Alfalfa	Alfalfa	2.6 f	---	---	---
Oats	Alfalfa	75.4 def	---	---	---
Oats	Potato	62.5 ef	315.0 a	190 b	237 b
Oats	Soybeans	211.1 ab	---	---	---
Oats	Soybeans	177.5 abc	---	---	---
Oats	Soybeans	161.9 abcd	---	---	---
Oats	Soybeans	133.6 bcde	---	---	---
Oats	Soybeans	243.8 a	---	---	---

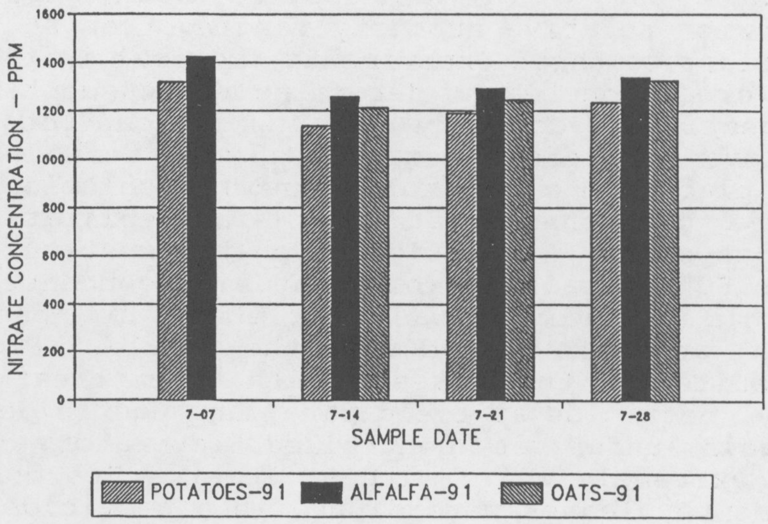


Figure 1. Petiole sap nitrate in 1992 Russet Norkotah potatoes following potatoes, alfalfa and oats.

Table 2. 1992 Potato variety trial, Potato Research Farm.

Treatment	Root-lesion nematodes		V. dahliae 9/14/92	
	1 g root tissue 6/23/92	100 cc soil 10/6/92	% stem infection	Colonies/ 0.5 g stem
Atlantic				
Untreated	55.75	151.50	24	211.25
Busan 1020*	0.00	3.00	10	105.00
Ranger Russet				
Untreated	78.75	122.00	13	115.00
Busan 1020*	0.00	0.75	4	27.50
R. Norkotah				
Untreated	61.00	186.75	32	618.75
Busan 1020*	0.25	0.00	4	47.5
Snowden				
Untreated	79.00	179.00	35	503.75
Busan 1020*	0.00	1.00	6	101.25
Superior				
Untreated	92.75	182.25	26	862.50
Busan 1020*	0.00	0.00	16	448.75

*Applied at 50 gal/A on May 6, 1992.

Table 3. 1992 potato variety trial, Potato Research Farm, plant stands and plant health ratings.

Treatment	Rating*	Stand No.
Atlantic		
Untreated	1.000	99.0
Busan 1020*	0.875	91.5
Ranger Russet		
Untreated	1.060	76.5
Busan 1020*	1.060	73.0
R. Norkotah		
Untreated	2.560	101.0
Busan 1020*	2.130	96.8
Snowden		
Untreated	1.310	80.2
Busan 1020*	1.000	89.0
Superior		
Untreated	3.380	103.5
Busan 1020*	2.500	106.8

*Plant health ratings:
- 0: all leaves green
- 1: some chlorosis, but no leaves entirely yellow
- 2: 10-25% of leaves yellow
- 3: 25-50% of leaves yellow
- 4: 50-100% of leaves yellow

Table 4. 1992 potato variety trial, yields, Potato Research Farm. Farm.

Treatment	A cwt/A	B cwt/A	J cwt/A	K cwt/A	Total cwt/A	U.S. No. 1 cwt/A
Atlantic						
Untreated	349	10	60	0	420	409
Busan 1020*	393	13	86	0	493*	480*
Ranger Russet						
Untreated	256	10	135	14	416	391
Busan 1020*	320	17	123	22	481*	443*
R. Norkotah						
Untreated	344	20	52	10	426	396
Busan 1020*	367	23	93*	21*	504*	460*
Snowden						
Untreated	318	11	35	0	365	353
Busan 1020*	411*	16	56	0	484*	468*
Superior						
Untreated	286	17	8	0	313	294
Busan 1020*	424*	24*	36*	0	484*	459*

Table 5. 1992 potato nematicide trial, Potato Research Farm.

Treatment	Plants/100 row ft 6/23/92	Root-lesion nematodes/ 1.0 g root 6/23/92	Yields (cwt/A)	
			U.S. No. 1	Total
Exp. cmpd. (1)	124	20.2	203	224
Bioac TNA (2)	116	33.6	153	174
Exp. cmpd. (3)	125	26.6	248	276
Vapam (4)	126	3.2	319	365
Untreated (5)	124	37.8	177	198
Mocap 10G (6)	16	7.6	181	202
Mocap 10G (7)	118	17.2	201	227
ASC 66824 (8)	114	42.0	178	203
ASC 66824 (9)	118	54.0	153	172
ASC 66824 (10)	127	6.0	217	244

Method of Application:

1. Exp. cmpd., 75 lbs/A, Broadcast incorporated F91
2. Bioac TNA, lbs/A, Broadcast incorporated F91, applied in 20 gal water/A
3. Exp. cmpd., 225 lbs/A, Broadcast incorporated F91
4. Vapam, 75 gal/A injected in 75 gal water/A F91
5. Untreated
6. Mocap 10G, 3.36 oz a.i./1000 row feet. Applied in 5-7 in. band behind opening disc in front of planting shoe
7. Mocap 10G, 3.36 oz a.i./1000 row feet. Applied in 5-7 in. band behind planting shoe in front of closing disc
8. ASC 66824, 4 lbs a.i./A applied in 5-7 in. band behind planting shoe in front of closing disc in 20 gal water/A.
9. ASC 66824, 8 lbs a.i./A applied in 5-7 in. band behind planting shoe in front of closing disc in 20 gal water/A.
10. ASC 66824, 8 lbs a.i./A, Broadcast P.P.I. in 12.5 gal water/A

Table 6. 1992 cover crop/green manure study, M.S.U. Greenhouse.

Treatments	Root-lesion nematodes per 1.0 g root tissue 10/15/92
Potato, 1 seed piece Superior	267
Pea, 4 seeds, Maestro	1670
Sudax, 10 seed, Haygrazer	207
Oats, 8 seeds, Heritage	172
Barley, 8 seeds, Hudson	82
Marigold, 8 seeds, Happy Red	13
Canola, 10 seeds, Cargill DH1	265
Rape, 10 seeds, Askari	417
Rape, 10 seeds, Bridger	649
Rape, 10 seeds, Sollux	485
Rape, 10 seeds, Dwarf Essex	463

Table 7. 1992 cover crop/green manure study, plant health and measurements.

Tmt.	Plant health*	Top wt. (g)	Below ground wt. (g)	Tuber wt. (g)	Stolon No.	Root- lesion nematode per 1.0 g root 12/28/92
Potato	3.25	16.78	26.80	14.82	7.88	271
Pea	2.62	25.10	34.60	18.68	7.12	404
Sudax	3.00	17.42	30.65	20.39	4.75	244
Oats	1.50	23.11	24.25	14.02	4.25	125
Barley	3.38	17.91	21.92	9.42	5.38	199
Marigold	3.25	32.88	30.10	13.08	7.50	4
Canola	3.43	18.72	29.71	15.41	5.57	168
Rape (1)	2.86	22.88	27.72	11.99	7.71	130
Rape (2)	2.88	19.10	24.40	13.19	5.12	195
Rape (3)	3.43	21.23	29.87	17.28	5.00	241
Rape (4)	2.88	28.71	26.40	11.05	5.25	171

Rape: 1) Askari, 2) Bridger, 3) Sollux, 4) Dwarf Essex

* Plant health ratings:

1. less than 10% of leaves chlorotic
2. 10-50% of the leaves chlorotic
3. 50% or more of leaves chlorotic
4. 1-50% of leaves dead or missing
5. 50% or more of leaves dead or missing

Table 8. 1992 Entomophagous nematode control of Colorado potato beetle, Experiment One; July 22, 1992.

Day	Untreated		1 b/A		2 b/A		3 b/A		4 b/A	
	Live	Dead	Live	Dead	Live	Dead	Live	Dead	Live	Dead
3	8	0	22	16	12	5	10	25	8	8
4	8	0	12	10	8	4	4	6	3	5
5	8	0	10	2	7	1	3	1	1	2
TTL	8	0	10	28	7	28	3	32	1	15
%	100	0	26	74	40	60	9	91	6	94

Table 9. 1992 Entomphagous nematode control of Colorado potato beetle, Experiment Two; July 28, 1992.

Day	Untreated		1 b/A		2 b/A		3 b/A		4 b/A	
	Live	Dead	Live	Dead	Live	Dead	Live	Dead	Live	Dead
1	44	1	25	0	13	0	21	7	44	22
2	43	1	23	2	13	0	18	3	29	15
3	43	0	21	2	10	3	2	16	13	16
4	42	1	21	0	10	3	1	1	10	3
5	38	4	20	1	10	3	1	0	8	2
6	37	1	17	3	9	1	0	1	7	1
TTL	37	8	17	8	9	4	0	28	7	59
%	82	18	68	32	69	31	0	100	12	88

Table 10. Entomophagous nematode control of Colorado potato beetle larval stages; July 28, 1992.

CPB	Untreated		1 b/A		2 b/A		3 b/A		4 b/A	
	Live	Dead	Live	Dead	Live	Dead	Live	Dead	Live	Dead
1st	6	1	2	---	---	---	---	---	5	23
2nd	13	1	---	---	1	---	---	3	---	3
3rd	1	1	2	2	1	1	---	14	---	14
4th	5	3	3	3	2	2	---	9	2	12
PP	12	2	10	3	5	1	---	2	1	6

Table 11. Mortality rates of *Steinernema carpocapsae* in dilutions of pesticides after 24 h.

Treatment	Mortality of nematode (%)					
	.01%	0.1%	1.0%	10.0%	25.0%	50.0%
Water	6%	33%	0%	10%	6%	9%
Trigard	6%	0%	25%	7%	-	-
Vydate	21%	17%	67%	16%	46%	13%
Lannate	0%	10%	19%	8%	-	-
Imidan	3%	21%	8%	13%	-	-
Centari	19%	2%	0%	9%	-	-
Dipel	0%	2%	0%	-	-	-
Safer	17%	25%	0%	10%	16%	10%
M-Pede	4%	60%	14%	13%	22%	20%
Asana	16%	2%	0%	4%	19%	9%
Bravo	6%	6%	5%	8%	9%	11%
Duel	0%	0%	0%	6%	10%	8%

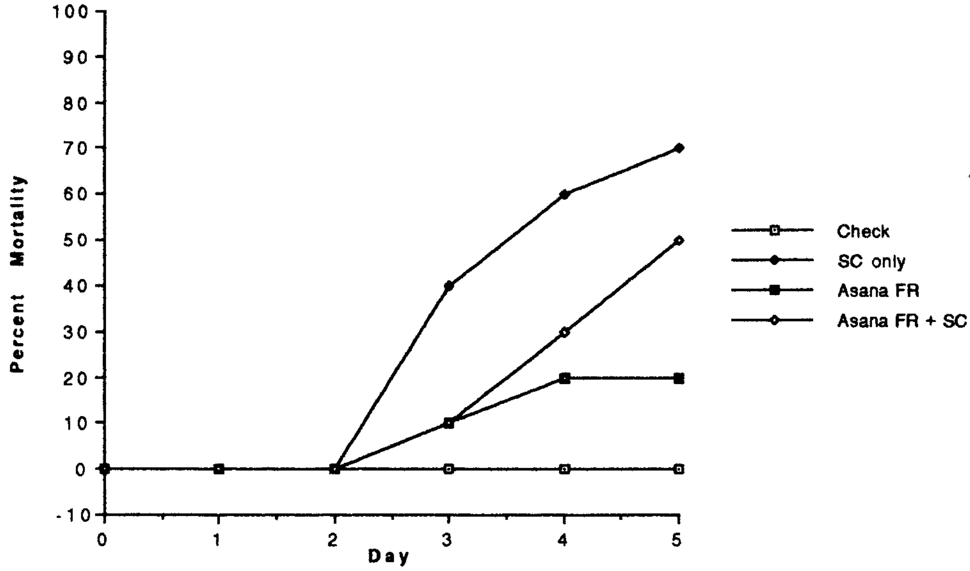


Figure 2. A comparison of Steinernema with the insecticide Asana at field rates.

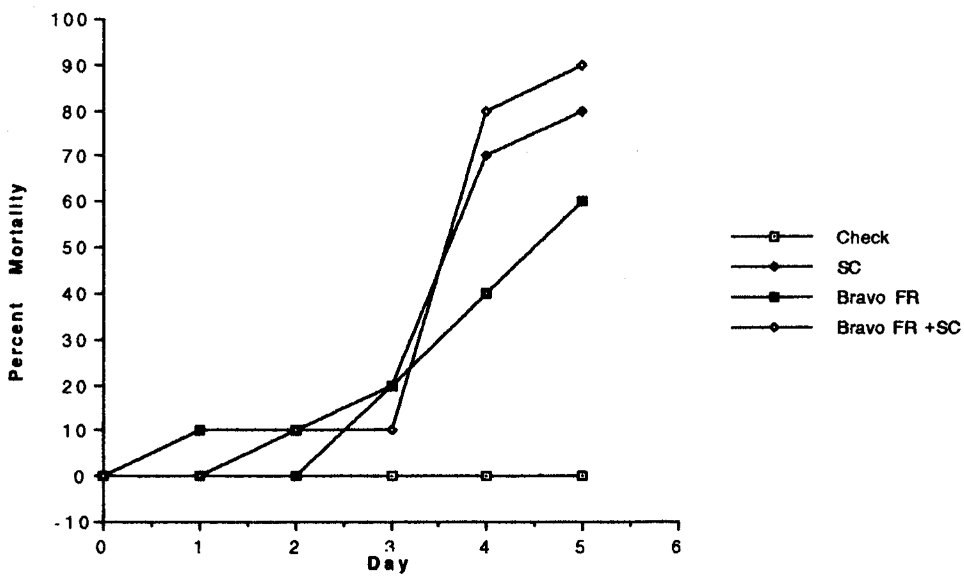
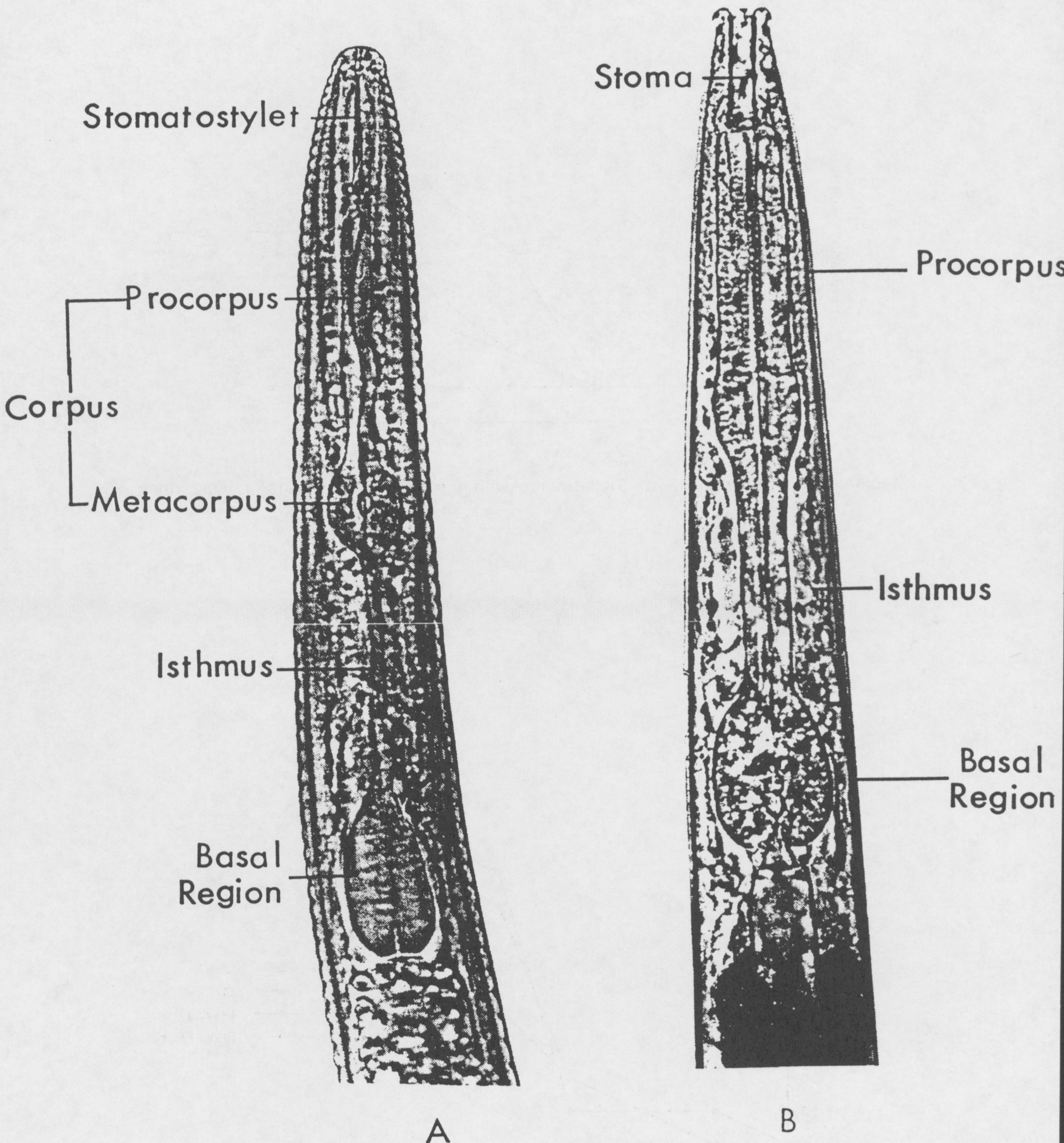


Figure 3. A comparison of Steinernema with the fungicide Bravo at field rates.


Stomatostylet
Procorpus
Corpus
Metacorpus
Isthmus
Basal Region
A
Stoma
Procorpus
Isthmus
Basal Region
B

Funding: Federal Grant

POTATO STORAGE MANAGEMENT
Cooling Rates of Snowden

Objective - Snowden potatoes harvested in the fall of 1991 were compared using different cooling rates.

Storage and Ventilation System - The MSU storage is a set of three bins, each measuring 8′ x 8′ x 18′ high. Two of the bins were installed in the fall of 1990 in a commercial potato facility at Bishop Potato Farm (Pinconning, MI) and the third was installed in the fall of 1991 in a commercial potato facility at Iott Farm (Kalkaska, MI).

Each potato storage research bin has an independent air handling system capable of maintaining a desired storage environment for that bin. The ventilation specifications for the three bins are as follows:

Capacity (cwt)	350
Ventilation rate (cfm/cwt)	1.5
Slot height (inch)	0.5
Slot area (sq. ft)	0.69
Slot velocity (ft/min)	760
Lateral size (sq. ft)	1.2
Main size (sq. ft)	24

The Intake air is drawn from the outside. The exhaust of all the bins was directed into the headspace of the pile in the commercial bin. The exhaust of the Pinconning bins was modified 1992 to exhaust directly outside.

Control System - Each ventilation system is controlled using a 656 Fancom* environmental control computer. The computer controls fresh air and recirculation air volume and humidifying and heating devices. Control changes are made based on feedback from the sensors that are placed in the ventilation system and in the pile as illustrated in Figure 1:

- temperature sensors at three foot increments within the pile
- temperature and relative humidity of ventilation air
- temperature and relative humidity of recirculation air

Storage Management - The potatoes in Bins 1 and 2 (Bishop Farm) were harvested on September 18, 1991 and Bin 3 (Iott Farm) was harvested September 13, 1991. The potatoes stored were all of the Snowden variety. Pulp temperatures at harvest were 78°F for Bins 1 and 2 and 75°F for Bin 3. A 15 tuber sample was taken weekly from the top of the pile, and from three

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*Trade names are used solely to provide specific information. Mention of a trade name does not constitute a warranty of the product by the authors or by Michigan State University or an endorsement of the product to the exclusion of other products not mentioned.

levels within the pile. Bin 3 was sampled every two weeks after December 1.

Sprout control within the bins was determined using four categories to describe sprout growth: no visible sprouts, sprouts less that 3/8 inch (peepers), sprouts between 3/8 and 1 inch, and sprouts greater than 1 inch. Very few sprouts greater than 1 inch appeared and these were include with the next smaller size in the analysis of control. The number of sprouts in the four, 15 tuber samples were counted and then the samples were analyzed for fry color and for sucrose and glucose sugar content. Samples were also taken monthly for analysis of changes in wound healing ability and resistance to decay by Fusaruim sambucinum.

Four sample bags of about 12 lbs each were placed at three levels in each bin to determine the weight loss during storage. Four bags were placed on the floor of the storage, at 5 feet and at 10 feet.

After the storages were filled, bins 1 and 2 were controlled at a temperature of 60°F for four weeks for suberization and preconditioning. Bin 3 was held for 3 weeks at 60°F.

During the cooling phase, the control systems were programmed to reduce the average potato pile temperature for bins 1, 2 and 3 by 0.2, 0.6 and 1.0°F/day, provided that the weather conditions allowed the cooling to take place. The actual cooling rates were 0.16, 0.29 and 0.48°F/day respectively. The desired end temperatures for Bins 1, 2 and 3 were 45, 42, and 39°F. Bin 1 was treated with sprout inhibitor on November 20, 1991. Bins 2 and 3 were not treated.

During the holding phase, the control system was programmed to run the fan for 3 hours of every 12 to maintain the desired storage temperatures.

On approximately January 18, 1991 the exhaust louver for the building enclosing Bins 1 and 2 malfunctioned. The building was only partially filled and was being heated by an unvented heater. The pressure in the building backed up through the exhaust fans on the research bins and the air quality and temperature were uncontrolled. The problem was detected after a couple of days but the chip color of all the potatoes in the building darkened to unacceptable levels. Attempts to improve chip color with warming of the potatoes and fresh air were unsuccessful.

Bin 3 was marketed on May 7, 1991 as seed potatoes at a temperature of 47°F. Samples were removed from the bin April 21, 1992 and were placed in storages at 47, 53 and 60°F and sugar levels and chip color were sampled weekly for one month.

Environmental Control - The controller was set to maintain the difference between any two pile temperature sensors at less that 2°F and the difference between the plenum and the pile average at no more that 4°F. A desired relative humidity was set at 95%. The average pile temperatures for the three bins are shown in Figure 2.

Potato Quality - The Agtron readings and the glucose levels for the potato samples during the storage season for bins 1, 2 and 3 are shown in Figures 3, 4 and 5. The Agtron readings were made on chips from unpeeled potatoes and readings on the high end of the scale will be lower than for chips from peeled potatoes. The lowest level for acceptable chips is an Agtron reading of approximately 50. The glucose and sucrose levels are shown in Figures 6, 7 and 8.

As of January 15 bin 1 was at 47°F and bin 2 was at 42°F. Bin 2 had just reached this holding temperature and it was not determined if this temperature would yield acceptable chips if the potatoes were held for a longer time.

The color and sugars for Bin 3 remained at acceptable levels until mid-November, when the pulp temperatures had lowered to 39°F (see Figure 8). After one week at 39°F the chips started darkening and sugar levels increased.

Visible sprouts first appeared in bins 1 and 2 the first week in November and most of the tubers had peepers within a few weeks as can be seen in Figure 9. The number of tubers with sprouts greater than 3/8 inch in bins 1 and 2 are shown in Figure 10. The potatoes in bins 1 and 2 were harvested from the same field and were stored under identical outside conditions. Even though bin 1 was treated with sprout inhibitor, better sprout control was maintained in bin 2 with faster cooling rates.

The number of tubers with sprouts in bin 3 are shown in Figure 11. The faster cooling rate provided better sprout control than either bin 1 or 2.

The weight loss for Bins 1 and 2 were not measured when the bin was emptied as much shrinkage had occurred after the bins had been warmed trying to recondition the potatoes. Bins 1 and 2 were not emptied until mid summer. The weight loss in Bin 3 was 7% on the floor, 5.4% at 5 feet and 5.6% at 10 feet.

The analysis of the Fusarium dry rot in the bins is described in the preceding report "Post-Harvest Control of Fusarium", by R. Hammerschmidt.

Reconditioning - In late April samples were removed from Bin 3 at 42°F and transferred to warmer storages for reconditioning. Three treatments were placed in storages at 47, 53 and 60°F. A forth treatment was held at 47°F for one week, 53°F for one week and then at 60°F for the remaining time. Ten tubers from each treatment were sampled weekly for fry color and sugar levels. The Agtron levels are shown in Figure 12. After 3 weeks at 60°F the sugar levels had dropped and the chips were acceptable in color. Chip from samples held at 53°F were marginally acceptable at both 3 and 4 weeks. Sugar levels dropped for all reconditioning treatments as can be seen in Figures 13 and 14. The potatoes warmed to 47°F and those in treatment 4 were still unacceptable in color after 4 weeks.

Follow up to late season storage problems - In late March a number of potato storages were experiencing unexpected chip discoloration when stored potatoes were exposed to stresses such as temperature changes or delays in shipping. Most of these problems occurred with the Snowden variety.

An experiment was set up to compare the gas exchange and the sugar and chip response of the Snowden and a Frito Lay variety when stresses were imposed on the potatoes. The stresses used were:

- reducing the airflow (slight increase in CO_2)
- sealing the potatoes (as may occur during shipping)
- rough handling and sealing
- low airflow and high CO_2

The results of this experiment were limited due to our inability to hold controls at acceptable levels. The following observations made:

- no detectable differences in gas exchange was detected between the varieties
- sealing the potatoes caused jumps in the sugar levels and chip discoloration in only a few days.
- bruising greatly accelerated the effects of sealing

The effect of the warm growing season or the number of growing degree days was cited as a major contributor to storage problems.

Recommendations - The Snowden potato can be cooled at faster rates than is normally recommended in Michigan without causing chip discoloration or rises in sugar levels. Care should be taken to assure that the difference between the pile temperatures and the plenum temperatures does not exceed 4°F. Smaller differences may be better. Uniform and gradual temperature changes are important for maintaining potato color and quality through extended storage.

Faster cooling rates can reduce the need for sprout inhibitors. Further study of cooling rates would be beneficial.

Potatoes with low temperature induced sweetening were successfully reconditioned on a laboratory scale and a larger scale study is recommended.

Methods of investigating the physiological aging of potatoes would help in the management of storing potatoes.

The weigh loss during storage can be lowered with improved humidification. Faster cooling rates increase the fresh air used and thus the need for humidification.

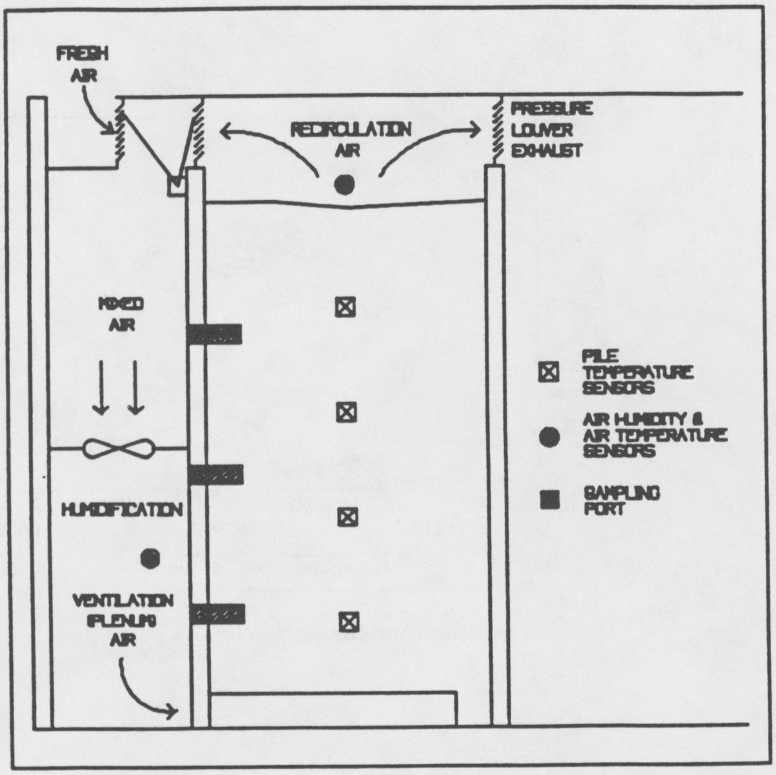

Fig. 1. Detail of ventilation system and sensor placement within the potato bins.

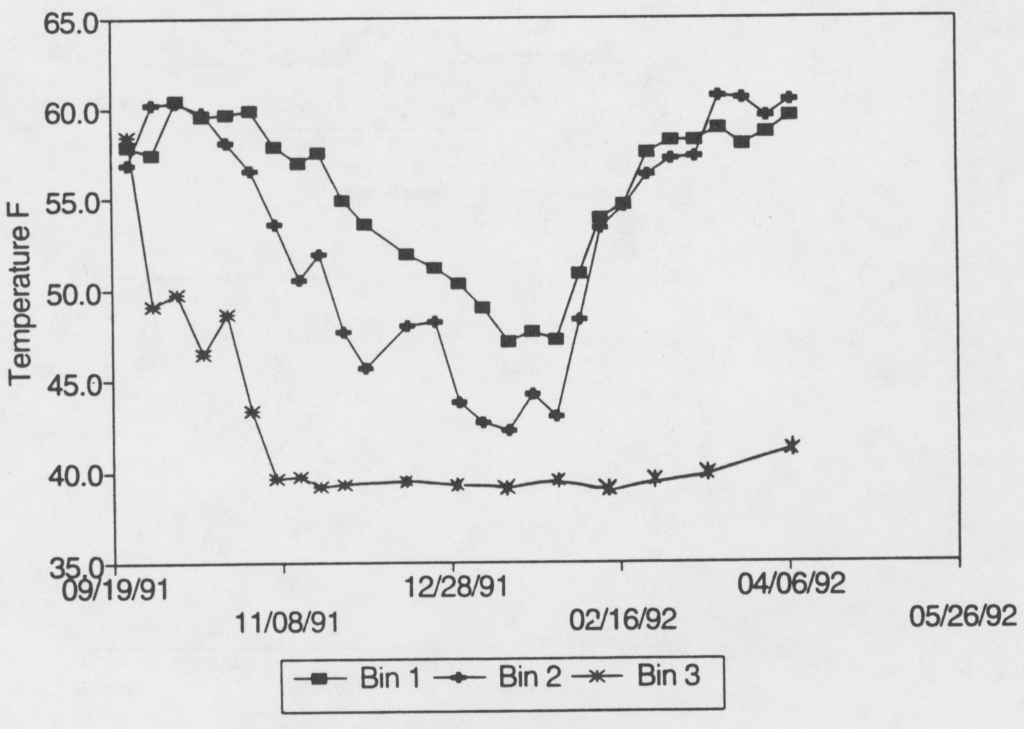

Fig. 2. Tuber pulp temperatures for bins 1, 2 and 3.

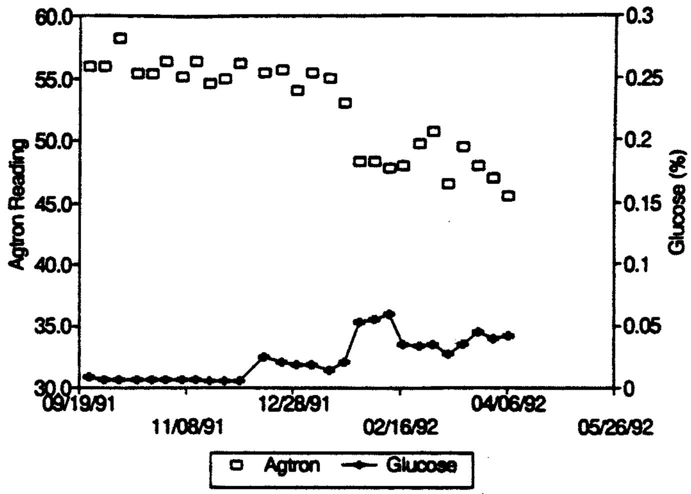

Fig. 3. Agtron Reading and Glucose % for bin 1.

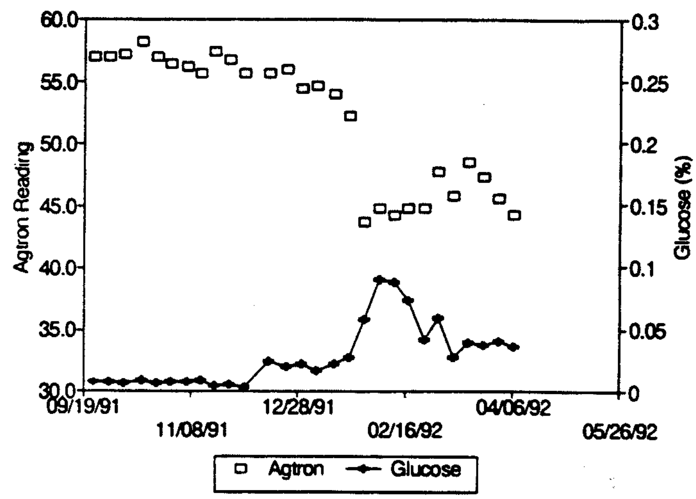

Fig. 4. Agtron Reading and Glucose % for bin 2.

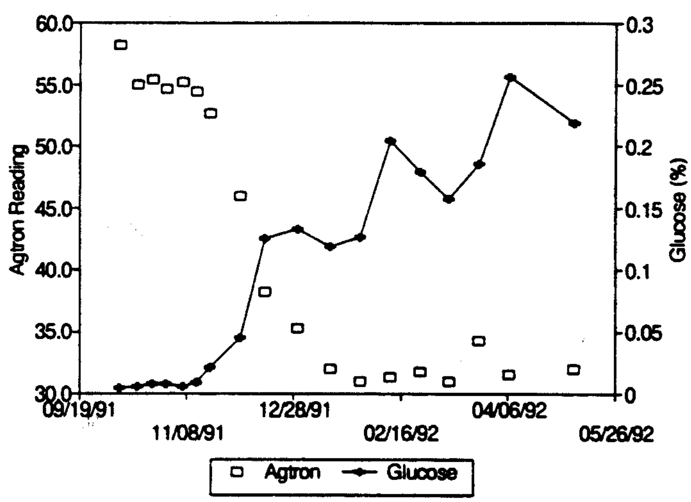

Fig. 5. Agtron Reading and Glucose % for bin 3.

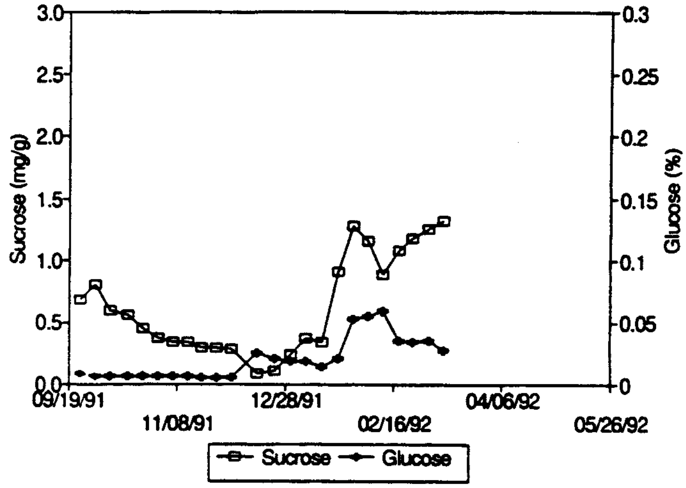

Fig. 6. Glucose and Sucrose levels for bin 1

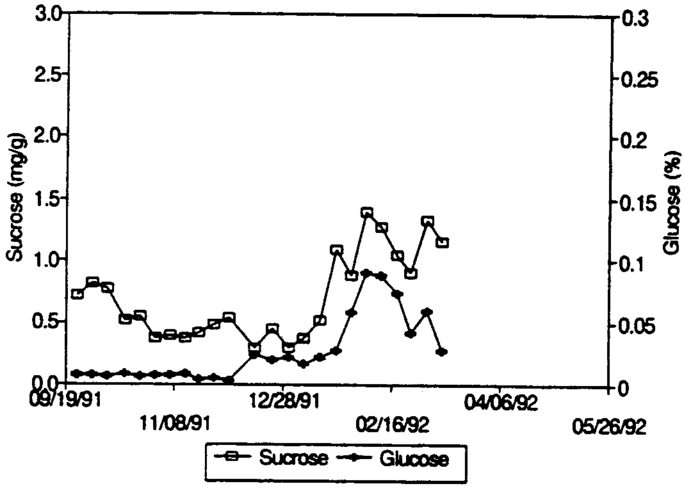

Fig. 7. Glucose and Sucrose levels for bin 2.

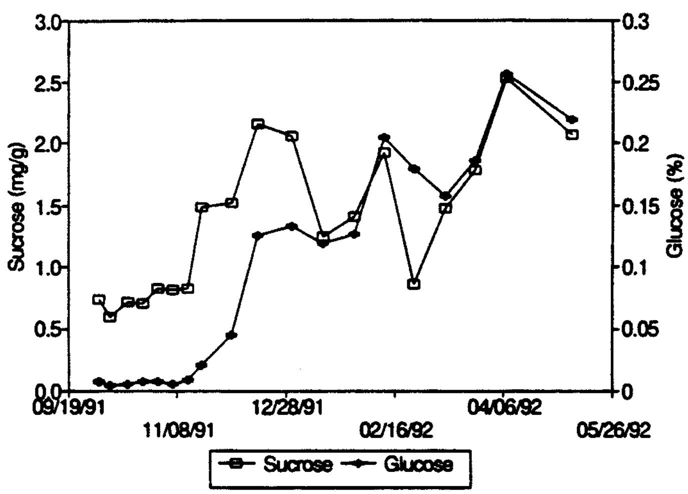

Fig. 8. Glucose and Sucrose levels for bin 3.

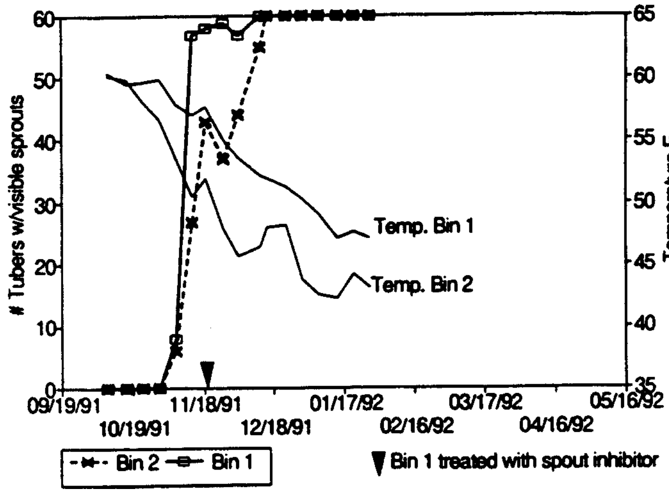

Fig. 9. Tubers w/visible sprouts. Sample of 60 tubers, 15 from each of 4 levels.

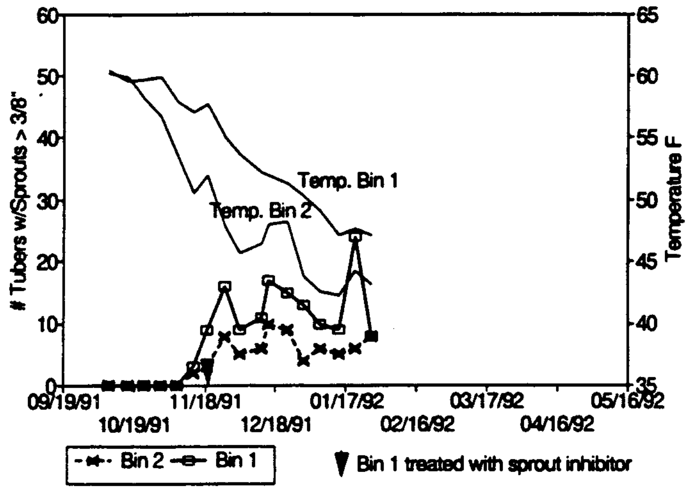

Fig. 10. Total tubers w/sprouts >3/8". Samples of 60 tubers, 15 at each of 4 levels.

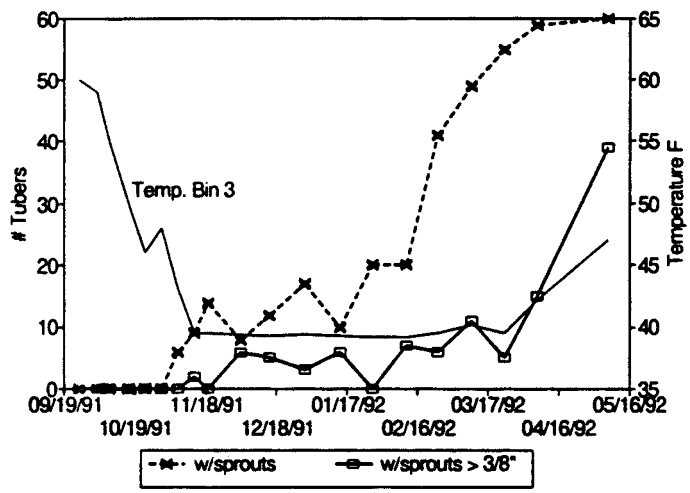

Fig. 11. Tubers w/sprouts in bin 3. Samples of 60 tubers, 15 at each of 4 levels.

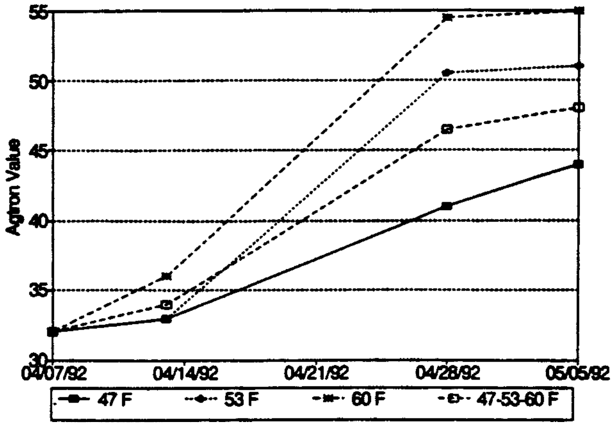

Fig. 12. Agtron Values at temperature treatments

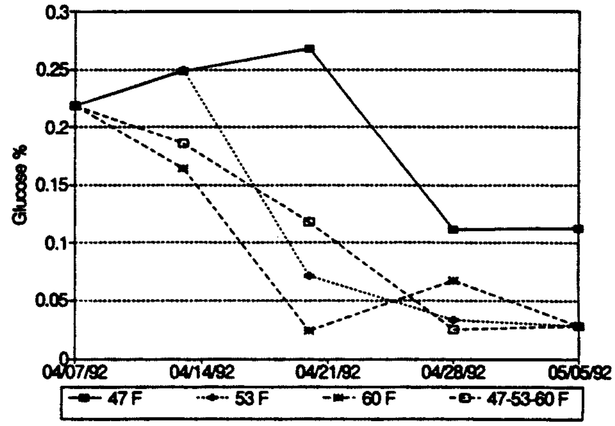

Fig. 13 Glucose % for temperature treatments.

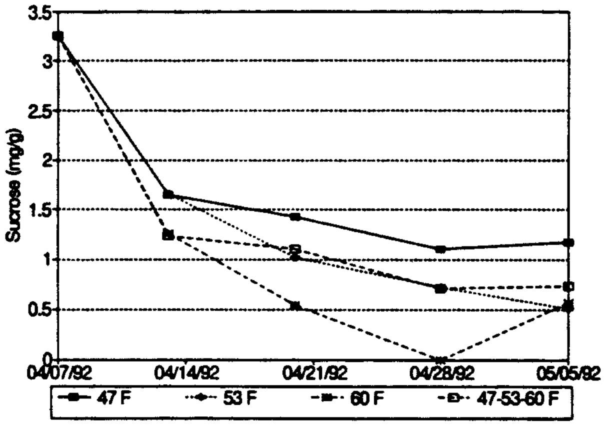

Fig. 14. Sucrose (mg/ g) for reconditioning temperatures.