2008 Research reports — NPPGA & MN Area Two

SUBMITTED BY	TITLE
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Gudmestad, Neil	*Effective Pink Rot Disease Control & Management of Mefenoxam Resistance in Phytophthora erythroseptica*
Gudmestad, Neil	*Quantification of soilborne pathogens of potato using real-time PCR*
Gudmestad, Neil & Gary Secor	*Support of Irrigated Potato Research in North Dakota 2007*
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University of Minnesota
Department of Plant Pathology

2007
Potato Disease Report

Potato Pathology and Genomics
http://ppg.cfans.umn.edu/

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The financial support of the Minnesota Area II Potato Research and Promotion Council is gratefully acknowledged.

Section I. Evaluating Potato Germplasm for Disease Resistance

SUMMARY: Disease screening plots were established at two locations (Rosemount and Becker, MN) in 2007. Entries were screened for resistance to late blight (caused by the Oomycete *Phytophthora infestans*; UMore Park, Rosemount, MN) and common scab (caused by the Actinomycete *Streptomyces scabies;* Sand Plain Research Farm, Becker, MN). In total, 198 wild potatoes populations and genotypes, including the entire USDA Potato Genebank holding of *Solanum cardiophyllum* and *S. chacoense* were screened for late blight resistance at UMore park. Cultivated potato germplasm was produced by the University of Minnesota Potato Breeding Program (489 entries tested for late blight, 692 entries tested for common scab), the University of Minnesota Potato Pathology and Genomics Program (208 entries tested for common scab), or was contributed by researchers throughout the North Central Region (30 entries tested for late blight and common scab). Eighty-four entries were tested as part of the National Late Blight Trial (Rosemount) and 72 entries were tested as part of the National Scab Trial (Becker). Late blight testing of 19 lines from the University of Minnesota Potato Entomology Program and 23 lines from the USDA-ARS, Aberdeen, ID was also completed. Modifications to late blight inoculation methods were implemented in 2007, enhancing screening capacity.

Table 1. Source and number of entries screened at the late blight and common scab nurseries in 2006.

Source	**Late Blight** (UMore Park, Rosemount, MN)	**Common Scab** (Sand Plain Research Farm, Becker, MN)
UMN Potato Breeding	489	692
UMN Potato Pathology & Genomics	198 wild potato populations and genotypes	208
North Central Trial	30	30
National Late Blight and Scab Trial	84	72
UMN Potato Entomology	19	
USDA-ARS, Aberdeen, ID	23	

(A) Late Blight – Rosemount, MN

Late blight, caused by the fungus *Phytophthora infestans*, was responsible for the Irish Potato Famine of the mid-1800's. The disease is characterized by brown to black water-soaked lesions on potato leaves and stems. Under cool, humid conditions, late blight can destroy an entire field within 10-14 days. When sporangia or zoospores are washed into the soil, they can infect potato tubers. Tuber infection is characterized by a dry, brown, granular rot. Secondary pathogens, such as *Erwinia carotovora* (soft rot), *Phytophthora erythroseptica* (pink rot), and *Pythium* spp. (leak) frequently follow. Late blight is currently managed by intensive fungicide applications. This approach is expensive and not environmentally sustainable. Genetic resistance derived from cultivated or wild potato is a promising means to reduce pesticide dependency, risk to the environment, and costs to potato growers.

Resistance to late blight is evaluated at UMore Park (Rosemount, MN) in cooperation with James Rowe (Administrative Professional), Jim Karelis (Sr. Research Plot Technician) and Kimon Karelis (Research Plot Coordinator). The UMore Park is geographically isolated from commercial potato farms allowing intentional inoculation with the late blight pathogen. Because the spores of the pathogen are air-borne, inoculations and late blight screening is restricted to non-production areas. To further protect regional growers, the Late Blight Nursery is planted 4 to 8 weeks later than commercial production fields in Minnesota and Wisconsin.

After careful comparisons of direct vs. indirect inoculation methods in 2005 and 2006, direct inoculations, in which the pathogen is directly applied to experimental lines, were adopted in 2007. This modification to historic research methods reduced land usage and enhanced screening capacity. Disease screening methods are detailed in Appendix A. Complete results for individual entries from the University of Minnesota Potato Breeding Program, University of Minnesota Potato Pathology and Genomics Program, National Late Blight, and North Central Region for 2007 are listed in Appendix B. Table 2 summarizes our findings.

Table 2. Number of entries in each late blight resistance class based on infection 39 days after inoculation with the potato late blight pathogen at Rosemount, MN 2007

Sources of entries	No. (percent) of entries 28 DAI
UM Potato Breeding	
Resistant	0 (0%)
Moderately Resistant	2 (0.4%)
Moderately Susceptible	11 (2.2%)
Susceptible	476 (97.3%)
National Late Blight Trial	
Resistant	0 (0%)
Moderately Resistant	4 (4.8%)
Moderately Susceptible	12 (14.3%)
Susceptible	68 (81.0%)
North Central Trial	
Resistant	0 (0%)
Moderately Resistant	0 (0%)
Moderately Susceptible	0 (0%)
Susceptible	30 (100.0%)
UM Potato Entomology	
Resistant	7 (36.8%)
Moderately Resistant	1 (5.3%)
Moderately Susceptible	0 (0%)
Susceptible	11 (57.9%)
USDA-ARS, Aberdeen, ID	
Resistant	6 (26.1%)
Moderately Resistant	13 (56.5%)
Moderately Susceptible	4 (17.4%)
Susceptible	0 (0%)
All Entries	
Resistant	13 (2.0%)
Moderately Resistant	20 (3.1%)
Moderately Susceptible	27 (4.2%)
Susceptible	585 (90.7%)

(B) Common Scab

Common scab, caused predominantly by the ubiquitous soil-borne bacterium *Streptomyces scabies*, is a disease of several root crops. In potato, symptoms include the development of corky lesions on the tuber that significantly reduce tuber quality and marketability, particularly for table stock varieties. In severe cases, common scab appears as deep sunken lesions ("pit scab") that invite secondary infection. Alkaline and dry soils exacerbate disease development. Genetic tolerance is sought after by potato breeders in Minnesota and throughout the US. The Sand Plain Research Farm is an ideal location for germplasm screening for resistance to common scab. As in previous years, in 2007 the Potato Pathology and Genomics program cooperated with the UM Potato Breeding Program and potato breeding programs at Michigan State University, University of Wisconsin, and North Dakota State University to screen breeding materials for tolerance to common scab. We also served as a test site for the replicated National Scab Trial. In 2007 we continued efforts to characterize heirloom potato cultivars as sources of resistance to common scab.

Resistance to common scab is evaluated at the Sand Plain Research Farm located in Becker, MN in cooperation with Ronald Faber (Farm Manager) and Scott Garvin (Research Plot Technician). Detailed disease screening methods are listed in Appendix A. Severity and coverage ratings for all entries are listed in Appendix B. Table 3 summarizes our findings.

All 'Red Pontiac' plots that were planted next to test plots developed high levels of common scab, indicating disease pressure was fairly uniform throughout the plot. Coverage evaluations did not always correlate well with severity evaluations. Any tuber that received a 0 for severity also was scored with a 0 for coverage. However, scab lesions could range from superficial (severity = 1) to very deep (e.g. severity = 5) and only have 5% or less of the tuber surface covered (coverage = 2). Therefore, several entries that received a severity rating of 3 or 4 had coverage ratings of only 1 or 2. Since tubers can be rejected for sale when common scab lesions are severe, regardless of the degree of coverage, severity is a better measure of resistance in processing-type potatoes. Coverage may be the better assessment for fresh market reds.

Table 3. Number of entries in each common scab resistance class based on Severity and Coverage Ratings at Becker, MN 2007

Sources of entries	Severity Rating (%)
UM Potato Pathology & Genomics	
Resistant	11 (5.3%)
Moderately Resistant	19 (9.1%)
Moderately Susceptible	17 (8.2%)
Susceptible	161 (77.4%)
UM Potato Breeding	
Resistant	6 (0.9%)
Moderately Resistant	46 (6.6%)
Moderately Susceptible	53 (7.7%)
Susceptible	587 (84.8%)
National Scab Trial	
Resistant	2 (2.8%)
Moderately Resistant	17 (23.6%)
Moderately Susceptible	11 (15.3%)
Susceptible	42 (58.3%)
North Central Trial	
Resistant	0 (0%)
Moderately Resistant	10 (33.3%)
Moderately Susceptible	4 (13.3%)
Susceptible	16 (53.3%)
All Entries	
Resistant	19 (1.9%)
Moderately Resistant	92 (9.2%)
Moderately Susceptible	85 (8.5%)
Susceptible	806 (80.4%)

References

Davis, J. R., and Garner, J. 1978. Common scab of potato. University of Idaho Agricultural Experiment Station current information series No. 386. University of Idaho, Moscow, Idaho.

Henfling, J. W. 1987 Late blight of potato: *Phytophthora infestans*. Technical Information Bulletin 4. International Potato Center, Lima, Peru.

King, R. R., and Lawrence, C. H., and Clark, M. C. 1991. Correlation of phytotoxin production with pathogenicity of *Streptomyces scabies* isolates from scab infected potato tubers. Am. Potato J. 68:675-680.

Appendix A: Disease Screening Methods

(A) Late Blight

Tubers were planted on June 6. Entries were submitted by the University of Minnesota Potato Pathology and Genomics Program, the University of Minnesota Potato Breeding Program, the National Late Blight Trial (conducted by Dr. Kathleen Haynes, USDA/ARS, Beltsville, MD), the North Central Region trials, the University of Minnesota Potato Entomology Program, and the USDA-ARS at Aberdeen, ID. Admire 2F insecticide was applied in furrow at a rate of 16 fl. oz./acre to all planted potatoes. No fungicides were applied to the field at any time during the season.

All experimental were directly inoculated with a suspension of *P. infestans* (US-8 strain) zoospores and sporangia at a concentration of 1000 sporangia /ml in the late evening of August 6. Inoculum was applied with a CO_2 sprayer at 20 psi using a single nozzle (6502 tip) wand. Plots were irrigated for 1 hour prior to inoculation. Sprinkler irrigation was applied the next morning and thereafter, 4 to 6 times per week depending upon weather conditions for 1 hour to prolong natural dew periods. All irrigation was accomplished using a low-volume, overhead mist-type sprinkler system.

Evaluations were initiated 18 days after inoculation and were made approximately every 3 to 5 days until 39 days after inoculation (6 readings total). Each entry was visually scored for disease severity using the CIP scale (Henfling, 1987). The CIP rating system is as follows:

CIP	% Late Blight	
Rating	Mean	Limits
1	0	0
2	2.5	Trace to 5
3	10	5 to <15
4	25	15 to <35
5	50	35 to <65
6	75	65 to <85
7	90	85 to <95
8	97.5	95 to <100
9	100	100

After all disease ratings were made, the CIP ratings were categorized based on readings taken 39 DAI as follows:

Resistance Class	Score
Resistant	<2.5
Moderately Resistant	2.5-4.99
Moderately Susceptible	5-7.49
Susceptible	>7.5

(B) Common Scab

Potato seed pieces were planted on May 1 by hand and Admire 2F insecticide was applied in furrow at a rate of 16 fl. oz./acre. Each entry consisted of 4 seed pieces spaced 12 inches apart, followed by a four-foot space, then two seed pieces of 'Red Pontiac' 12 inches apart, followed by another four-foot space. The 'Red Pontiac' was used as a susceptible check, to measure disease pressure throughout the plot.

For evaluation, all potato hills were lifted from the ground and dropped back on the ground using a one-row potato harvester. Evaluations were made on September 25, after a natural rainfall had washed much of the soil from the harvested tubers. All tubers from the four hills were rated as a group using the following scale:

Rating	Severity	Coverage
0	No scab visible	No scab visible
1	Scab <= 1 mm deep	Trace or 1-2 lesions less than 1 cm^2
2	Scab 2-3 mm deep	1 to 5 % tuber surface covered
3	Scab 3-4 mm deep	>5 to 50% tuber surface covered
4	Scab 4-5 mm deep	Over 50% tuber surface covered
5	Scab over 5 mm deep	---

Entries were considered resistant if the severity and coverage ratings were 0, moderately resistant for severity and coverage ratings of 1-2, moderately susceptible for severity and coverage ratings of 3, and susceptible for severity ratings of 4-5 or a coverage rating of 4.

Appendix B. Field Plot Data

(A) Late Blight: Disease resistance scores for entries in the (1) University of Minnesota Potato Breeding Program, (2) the North Central Region, and (3) the National Late Blight Trial.

1. UM Potato Breeding Program (Dr. Christian Thill)

Trial	Clone	Final Reading	Class
Adv	AOMN 03102-5	9	S
Adv	AOMN 03102-5	9	S
Adv	ATMN 03527-1	6	MS
Adv	ATMN 03527-1	9	S
Adv	COMN 03016-4	9	S
Adv	COMN 03016-4	9	S
Adv	COMN 03019-4	9	S
Adv	COMN 03019-4	9	S
Adv	COMN 03020-2	9	S
Adv	COMN 03020-2	9	S
Adv	COMN 03020-3	9	S
Adv	COMN 03020-3	9	S
Adv	COMN 03021-1	9	S
Adv	COMN 03021-1	9	S
Adv	COMN 03021-2	9	S
Adv	COMN 03021-2	9	S
Adv	COMN 03027-1	9	S
Adv	COMN 03027-1	9	S
Adv	COMN 03030-1	9	S
Adv	COMN 03030-1	9	S
Adv	MN(DE) 03 14-4	9	S
Adv	MN(DE) 03 14-4	9	S
Adv	MN(DE) 03 8-2	9	S
Adv	MN(DE) 03 8-2	9	S
Adv	MN(DM) 03 1-4	9	S
Adv	MN(DM) 03 1-4	9	S
Adv	MN(DM) 03 5-1	9	S
Adv	MN(DM) 03 5-1	8	S
Adv	NDMN 03308-1	9	S
Adv	NDMN 03308-1	9	S
Adv	NDMN 03316-3	9	S
Adv	NDMN 03316-3	9	S
Adv	NDMN 03324-4	9	S
Adv	NDMN 03324-4	9	S
Adv	NDMN 03406-1	9	S

Adv	NDMN 03406-1	9	S
Adv	NDMN 03407-7	9	S
Adv	NDMN 03407-7	9	S
Adv	NDMN 03410-2	9	S
Adv	NDMN 03410-2	9	S
DE Accepts	DE02-137-05	9	S
DE Accepts	DE02-137-05	9	S
DE Accepts	DE02-153-02	9	S
DE Accepts	DE02-153-02	9	S
DE Accepts	DE02-156-15	9	S
DE Accepts	DE02-156-15	9	S
DE Accepts	DE02-159-30	9	S
DE Accepts	DE02-159-30	9	S
DE Accepts	DE02-205-13	9	S
DE Accepts	DE02-205-13	9	S
DE Selections	DEM 15	9	S
DE Selections	DEM 15	9	S
DE Selections	DEM 21	9	S
DE Selections	DEM 21	9	S
DE Selections	DEM 63	9	S
DE Selections	DEM 63	9	S
E2	MN 05001-002	9	S
E2	MN 05001-002	9	S
E2	MN 05001-004	9	S
E2	MN 05001-004	9	S
E2	MN 05001-007	9	S
E2	MN 05001-007	9	S
E2	MN 05001-011	9	S
E2	MN 05001-011	9	S
E2	MN 05001-014	9	S
E2	MN 05001-014	9	S
E2	MN 05001-016	-	
E2	MN 05001-016	-	
E2	MN 05001-017	9	S
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E2	MN 05001-018	9	S
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E2	MN 05001-031	9	S
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E2	MN 05001-036	9	S
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E2	MN 05001-043	9	S
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E2	MN 05001-083	9	S
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Elite	MN 00177-5	7	MS
Elite	MN 00177-5	9	S
Elite	MN 00467-4	9	S
Elite	MN 00467-4	9	S
Elite	MN 02 419	9	S
Elite	MN 02 419	9	S
Elite	MN 02 586	9	S
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Elite	MN 02 696	-	
Elite	MN 15620	9	S
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Int	AOMN 041101-01	7	MS
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Int	AOMN 041123-01	9	S

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Int	AOMN 041138-01	9	S
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Int	COMN 04651-01	9	S
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Int	COMN 04702-03	9	S
Int	COMN 04702-03	9	S

Int	COMN 04702-07	9	S
Int	COMN 04702-07	9	S
Int	COMN 04702-08	9	S
Int	COMN 04702-08	9	S
Int	COMN 04702-09	9	S
Int	COMN 04702-09	9	S
Int	COMN 04702-11	9	S
Int	COMN 04702-11	9	S
Int	COMN 04702-14	9	S
Int	COMN 04702-14	9	S
Int	COMN 04702-16	9	S
Int	COMN 04702-16	9	S
Int	COMN 04702-18	9	S
Int	COMN 04702-18	9	S
Int	COMN 04703-02	9	S
Int	COMN 04703-02	9	S
Int	COMN 04704-01	9	S
Int	COMN 04704-01	9	S
Int	COMN 04712-01	9	S
Int	COMN 04712-01	9	S
Int	COMN 04712-05	9	S
Int	COMN 04712-05	9	S
Int	COMN 04713-03	9	S
Int	COMN 04713-03	9	S
Int	COMN 04723-01	6	MS
Int	COMN 04723-01	6	MS
Int	COMN 04732-01	9	S
Int	COMN 04732-01	9	S
Int	COMN 04733-01	9	S
Int	COMN 04733-01	9	S
Int	COMN 04733-02	9	S
Int	COMN 04733-02	9	S
Int	COMN 04733-03	9	S
Int	COMN 04733-03	9	S
Int	COMN 04744-01	9	S
Int	COMN 04744-01	9	S
Int	COMN 04747-05	9	S
Int	COMN 04747-05	9	S
Int	COMN 04756-02	9	S
Int	COMN 04756-02	9	S
Int	COMN 04756-04	9	S
Int	COMN 04756-04	9	S
Int	COMN 04759-01	9	S
Int	COMN 04759-01	9	S
Int	COMN 04759-02	9	S

Int	COMN 04759-02	9	S
Int	COMN 04759-03	9	S
Int	COMN 04759-03	9	S
Int	COMN 04760-01	9	S
Int	COMN 04760-01	9	S
Int	COMN 04773-04	9	S
Int	COMN 04773-04	9	S
Int	COMN 04776-01	9	S
Int	COMN 04776-01	9	S
Int	COMN 04776-02	9	S
Int	COMN 04776-02	9	S
Int	COMN 04777-02	9	S
Int	COMN 04777-02	9	S
Int	COMN 04777-04	9	S
Int	COMN 04777-04	9	S
Int	COMN 04779-01	9	S
Int	COMN 04779-01	9	S
Int	COMN 04780-01	9	S
Int	COMN 04780-01	9	S
Int	COMN 04781-02	9	S
Int	COMN 04781-02	9	S
Int	COMN 04781-04	9	S
Int	COMN 04781-04	9	S
Int	COMN 04787-04	9	S
Int	COMN 04787-04	9	S
Int	COMN 04788-02	9	S
Int	COMN 04788-02	9	S
Int	COMN 04788-03	9	S
Int	COMN 04788-03	9	S
Int	COMN 04788-04	9	S
Int	COMN 04788-04	9	S
Int	COMN 04788-05	9	S
Int	COMN 04788-05	9	S
Int	COMN 04788-06	9	S
Int	COMN 04788-06	9	S
Int	COMN 04788-07	9	S
Int	COMN 04788-07	9	S
Int	COMN 04788-09	9	S
Int	COMN 04788-09	9	S
Int	COMN 04788-10	9	S
Int	COMN 04788-10	9	S
Int	MN 04yyyy-01	9	S
Int	MN 04yyyy-01	9	S
Int	NDMN 04870-03	9	S
Int	NDMN 04870-03	9	S

Int	NDMN 04871-01	9	S
Int	NDMN 04871-01	9	S
Int	NDMN 04883-01	9	S
Int	NDMN 04883-01	9	S
Int	NDMN 04885-01	9	S
Int	NDMN 04885-01	9	S
Int	NDMN 04893-02	9	S
Int	NDMN 04893-02	9	S
Int	NDMN 04899-01	9	S
Int	NDMN 04899-01	9	S
Int	NDMN 04905-02	9	S
Int	NDMN 04905-02	9	S
Int	NDMN 04905-04	9	S
Int	NDMN 04905-04	9	S
Int	NDMN 04905-06	9	S
Int	NDMN 04905-06	9	S
Int	NDMN 04905-09	9	S
Int	NDMN 04905-09	9	S
Int	NDMN 04905-11	9	S
Int	NDMN 04905-11	9	S
Int	NDMN 04905-13	9	S
Int	NDMN 04905-13	9	S
Int	NDMN 04905-14	9	S
Int	NDMN 04905-14	9	S
Int	NDMN 04910-01	9	S
Int	NDMN 04910-01	9	S
Int	NDMN 04911-02	9	S
Int	NDMN 04911-02	9	S
Int	NDMN 04913-01	9	S
Int	NDMN 04913-01	9	S
Int	NDMN 04916-01	9	S
Int	NDMN 04916-01	9	S
Int	NDMN 04917-02	9	S
Int	NDMN 04917-02	9	S
Int	NDMN 04943-01	5	MS
Int	NDMN 04943-01	6	MS
Int	NDMN 04948-01	8	S
Int	NDMN 04948-01	-	
Int	NDMN 04960-01	9	S
Int	NDMN 04960-01	9	S
Int	NDMN 04962-01	9	S
Int	NDMN 04962-01	9	S
Int	NDMN 04964-01	9	S
Int	NDMN 04964-01	9	S
Int	NDMN 04964-03	9	S

Int	NDMN 04964-03	9	S
Int	NDMN 04968-01	9	S
Int	NDMN 04968-01	9	S
Int	NDMN 04971-05	9	S
Int	NDMN 04971-05	9	S
Int	NDMN 04979-02	9	S
Int	NDMN 04979-02	9	S
Int	USDAWIMN 04007-1	9	S
Int	USDAWIMN 04007-1	9	S
Int	USDAWIMN 04020-1	9	S
Int	USDAWIMN 04020-1	8	S
Int	USDAWIMN 04053-1	3	MR
Int	USDAWIMN 04053-1	4	MR
Int	USDAWIMN 04063-1	8	S
Int	USDAWIMN 04063-1	8	S
Int	USDAWIMN 04103-1	9	S
Int	USDAWIMN 04103-1	9	S
Int	WIMN 04799-01	9	S
Int	WIMN 04799-01	9	S
Int	WIMN 04823-01	9	S
Int	WIMN 04823-01	9	S
Int	WIMN 04836-01	8	S
Int	WIMN 04836-01	9	S
Int	WIMN 04837-01	9	S
Int	WIMN 04837-01	9	S
Int	WIMN 04837-02	8	S
Int	WIMN 04837-02	9	S
Int	WIMN 04837-03	9	S
Int	WIMN 04837-03	9	S
Int	WIMN 04844-06	9	S
Int	WIMN 04844-06	9	S
Int	WIMN 04844-07	9	S
Int	WIMN 04844-07	9	S
Int	WIMN 04844-16	9	S
Int	WIMN 04844-16	8	S

Int	WIMN 04854-04	9	S
Int	WIMN 04854-04	9	S
Int	WIMN 04854-05	9	S
Int	WIMN 04854-05	9	S
Int	WIMN 04854-07	9	S
Int	WIMN 04854-07	9	S
Int	WIMN 04855-02	9	S
Int	WIMN 04855-02	9	S
Int	WIMN 04860-01	8	S
Int	WIMN 04860-01	8	S
Int	WIMN 04862-02	9	S
Int	WIMN 04862-02	9	S
Int	WIMN 04866-02	9	S
Int	WIMN 04866-02	9	S
LB	AND 99362B-1Russ	5	MS
LB	AND 99362B-1Russ	5	MS
LB	ND 039051B-1R	8	S
LB	ND 039051B-1R	9	S

2. North Central Region (University of Minnesota, North Dakota State University, University of Wisconsin, and Michigan State University)

Trial	Clone	Final Reading	Class
NCR	AND 98324-1Rus	9	S
NCR	AND 98324-1Rus	9	S
NCR	ATND 98459-1RY	9	S
NCR	ATND 98459-1RY	9	S
NCR	CV97065-1	9	S
NCR	CV97065-1	9	S
NCR	CV98112-3	9	S
NCR	CV98112-3	9	S
NCR	MSA8254-2BRUS	9	S
NCR	MSA8254-2BRUS	9	S
NCR	MSI005-20Y	9	S
NCR	MSI005-20Y	9	S
NCR	MSJ316-A	8	S
NCR	MSJ316-A	8	S
NCR	ND 4659-5R	9	S
NCR	ND 4659-5R	9	S
NCR	ND 5002-3R	9	S
NCR	ND 5002-3R	9	S
NCR	VHB0950-2	9	S
NCR	VHB0950-2	9	S
NCR	W1879-1Rus	9	S
NCR	W1879-1Rus	9	S
NCR	W2133-1	9	S
NCR	W2133-1	9	S
NCR	W2324-1	9	S
NCR	W2324-1	9	S
NCR	W2683-2Rus	9	S
NCR	W2683-2Rus	8	S
NCR	WV4298-1	9	S
NCR	WV4298-1	8	S

3. National Late Blight Trial

Trial	Clone	Final Reading	Class
NLB	A95109-1	9	S
NLB	A95109-1	9	S
NLB	A95109-1	9	S
NLB	A95109-1	9	S
NLB	A97066-42LB	5	MS
NLB	A97066-42LB	5	MS
NLB	A97066-42LB	7	MS
NLB	A97066-42LB	6	MS
NLB	AC96052-1RU	9	S
NLB	AC96052-1RU	9	S
NLB	AC96052-1RU	9	S
NLB	AC96052-1RU	9	S
NLB	B0718-3	3	MR
NLB	B0718-3	3	MR
NLB	B0718-3	4	MR
NLB	B0718-3	3	MR
NLB	B1992-106	9	S
NLB	B1992-106	9	S
NLB	B1992-106	9	S
NLB	B1992-106	9	S
NLB	B2152-17	9	S
NLB	B2152-17	9	S
NLB	B2152-17	9	S
NLB	B2152-17	9	S
NLB	B2327-2	9	S
NLB	B2327-2	9	S
NLB	B2327-2	9	S
NLB	B2327-2	9	S
NLB	B2445-6	6	MS
NLB	B2445-6	7	MS
NLB	B2445-6	7	MS
NLB	B2445-6	8	S
NLB	B2448-2	5	MS
NLB	B2448-2	8	S
NLB	B2448-2	9	S
NLB	B2448-2	8	S
NLB	CO95172-3RU	9	S
NLB	CO95172-3RU	9	S
NLB	CO95172-3RU	9	S
NLB	CO95172-3RU	9	S
NLB	CO97043-14W	9	S

NLB	CO97043-14W	9	S
NLB	CO97043-14W	9	S
NLB	CO97043-14W	9	S
NLB	CO97065-7W	9	S
NLB	CO97065-7W	9	S
NLB	CO97065-7W	9	S
NLB	CO97065-7W	9	S
NLB	CO97087-2 RU	9	S
NLB	CO97087-2 RU	9	S
NLB	CO97087-2 RU	9	S
NLB	CO97087-2 RU	9	S
NLB	LBR1R2R3R4	6	MS
NLB	LBR1R2R3R4	6	MS
NLB	LBR1R2R3R4	6	MS
NLB	LBR1R2R3R4	6	MS
NLB	LBR5	9	S
NLB	LBR5	9	S
NLB	LBR5	9	S
NLB	LBR5	9	S
NLB	LBR9	9	S
NLB	LBR9	9	S
NLB	LBR9	9	S
NLB	LBR9	9	S
NLB	Priemier Russet	9	S
NLB	Priemier Russet	8	S
NLB	Priemier Russet	8	S
NLB	Priemier Russet	8	S
NLB	W 1836-3Rus	9	S
NLB	W 1836-3Rus	9	S
NLB	W 1836-3Rus	9	S
NLB	W 1836-3Rus	9	S
NLB	W 2133-1	9	S
NLB	W 2133-1	9	S
NLB	W 2133-1	9	S
NLB	W 2133-1	9	S
NLB	W 2683-2Rus	9	S
NLB	W 2683-2Rus	9	S
NLB	W 2683-2Rus	9	S
NLB	W 2683-2Rus	9	S
NLB	Yukon Gem	9	S
NLB	Yukon Gem	9	S
NLB	Yukon Gem	9	S
NLB	Yukon Gem	8	S

Common Scab: Disease severity and coverage scores for entries in the (1) University of Minnesota Potato Pathology and Genomics Program, (2) University of Minnesota Potato Breeding Program, (3) North Central Region, and (4) National Scab Trial. Resistance classes are based on severity ratings.

(1) UM Potato Pathology and Genomics (Dr. James Bradeen)

Trial	Clone	Severity	Coverage	Class
PPG	213#	2	1	MR
PPG	213#	3	2	MS
PPG	213#	5	2	S
PPG	AC Blue Pride	3	1	MS
PPG	AC Blue Pride	5	4	S
PPG	AC Blue Pride	5	4	S
PPG	AC Brador	4	2	S
PPG	AC Brador	5	4	S
PPG	AC Brador	5	4	S
PPG	AC Brador	5	4	S
PPG	AC Domino	5	4	S
PPG	AC Domino	5	3	S
PPG	AC Red Island	3	1	MS
PPG	AC Red Island	5	4	S
PPG	AC Red Island	5	3	S
PPG	AK FROSTLESS	2	4	MR
PPG	AK FROSTLESS	5	3	S
PPG	AK FROSTLESS	5	3	S
PPG	Albys Gold	4	4	S
PPG	Albys Gold	5	4	S
PPG	Albys Gold	5	4	S
PPG	All Blue	5	4	S
PPG	All Blue	5	4	S
PPG	All Blue	5	4	S
PPG	All Blue	5	4	S
PPG	All Blue	5	4	S
PPG	All Blue	5	2	S
PPG	All Blue	5	3	S
PPG	Alturas	4	4	S
PPG	Alturas	5	3	S
PPG	Alturas	5	3	S
PPG	ARRAN CONSUL	5	4	S
PPG	ARRAN CONSUL	5	4	S
PPG	ARRAN PILOT	4	4	S
PPG	ARRAN PILOT	5	3	S
PPG	ARRAN	4	4	S

	VICTORY			
PPG	ARRAN VICTORY	5	3	S
PPG	ARRAN VICTORY	5	3	S
PPG	Atzimba	5	3	S
PPG	Atzimba	5	3	S
PPG	Atzimba	5	0	S
PPG	Augsburg Gold	4	3	S
PPG	Augsburg Gold	5	3	S
PPG	Beauty of Hebron	3	3	MS
PPG	Beauty of Hebron	5	4	S
PPG	Beauty of Hebron	5	4	S
PPG	Belle de Fontany	4	4	S
PPG	Belle de Fontany	4	4	S
PPG	BINTJE	4	2	S
PPG	BINTJE	5	4	S
PPG	BINTJE	5	4	S
PPG	Bison	3	4	MS
PPG	Bison	3	2	MS
PPG	Bison	5	2	S
PPG	Butte	0	0	R
PPG	Butte	1	1	MR
PPG	Butterfinger	5	4	S
PPG	Butterfinger	5	4	S
PPG	Candy Cane	5	4	S
PPG	Candy Cane	5	2	S
PPG	Candy Cane	5	3	S
PPG	Caribe	2	1	MR
PPG	Caribe	4	2	S
PPG	Carola / Ronigers	3	2	MS
PPG	Carola / Ronigers	5	4	S
PPG	Carola / Ronigers	5	3	S
PPG	Corne de Moutan	4	2	S
PPG	Corne de Moutan	4	2	S
PPG	Corne de Moutan	5	3	S
PPG	Dakchip	4	4	S
PPG	Dakchip	5	4	S
PPG	Dakchip	5	3	S
PPG	Denali	5	4	S
PPG	Denali	5	4	S
PPG	Denali	5	4	S
PPG	Elba	5	4	S
PPG	Elba	5	4	S
PPG	Elba	5	3	S

PPG	Epicure	5	4	S
PPG	Epicure	5	4	S
PPG	Epicure	5	3	S
PPG	Fortyfold	5	4	S
PPG	Fortyfold	5	4	S
PPG	Fortyfold	5	4	S
PPG	French Fingerling	4	4	S
PPG	French Fingerling	4	3	S
PPG	Garnet Chile	5	4	S
PPG	Garnet Chile	5	4	S
PPG	Garnet Chile	5	4	S
PPG	German Butterball	0	0	R
PPG	German Butterball	0	0	R
PPG	German Butterball	4	3	S
PPG	German Butterball/Hancock	2	4	MR
PPG	German Butterball/Hancock	2	2	MR
PPG	German Butterball/Hancock	3	2	MS
PPG	Gold Nugget	0	0	R
PPG	Gold Nugget	3	2	MS
PPG	Gold Nugget	5	2	S
PPG	Green Mountain	5	4	S
PPG	Green Mountain	5	4	S
PPG	Green Mountain	5	4	S
PPG	Inca Gold	5	4	S
PPG	Inca Gold	5	3	S
PPG	Inca Gold	5	3	S
PPG	Jac. Lee	4	3	S
PPG	Jac. Lee	5	4	S
PPG	Jac. Lee	5	3	S
PPG	Kathadin	1	1	MR
PPG	Kathadin	2	1	MR
PPG	Kathadin	5	4	S
PPG	King Edward	2	1	MR
PPG	King Edward	5	4	S
PPG	King Edward	5	2	S
PPG	King Edward	5	3	S
PPG	Krantz	0	0	R
PPG	Krantz	2	2	MR
PPG	Krantz	5	1	S
PPG	La Ratte	2	2	MR
PPG	La Ratte	3	3	MS
PPG	La Ratte	4	2	S

PPG	Lumpers	1	1	MR
PPG	Lumpers	4	4	S
PPG	Lumpers	4	3	S
PPG	Mrs. Moehlers	3	2	MS
PPG	Mrs. Moehlers	4	4	S
PPG	Mrs. Moehlers	5	4	S
PPG	Nooksack	0	0	R
PPG	Nooksack	5	3	S
PPG	Norchief	5	4	S
PPG	Norchief	5	4	S
PPG	Norchief	5	4	S
PPG	Nordak	5	4	S
PPG	Nordak	5	4	S
PPG	Nordak	5	4	S
PPG	Norgleam	4	4	S
PPG	Norgleam	5	4	S
PPG	Norgleam	5	4	S
PPG	NorKing	0	0	R
PPG	NorKing	1	1	MR
PPG	NorKing	1	1	MR
PPG	NorQueen	0	0	R
PPG	NorQueen	1	1	MR
PPG	NorQueen	1	1	MR
PPG	Ozzete	5	4	S
PPG	Ozzete	5	3	S
PPG	Ozzete	5	3	S
PPG	Pimpernel	5	4	S
PPG	Pimpernel	5	4	S
PPG	Pimpernel	5	4	S
PPG	Pimpernel	5	4	S
PPG	Pimpernel	5	4	S
PPG	Pimpernel	5	4	S
PPG	Pink Pearl	4	4	S
PPG	Pink Pearl	4	4	S
PPG	Pink Pearl	5	4	S
PPG	Princess Laratte	3	3	MS
PPG	Princess Laratte	4	4	S
PPG	Princess Laratte	4	3	S
PPG	Purple Majesty	5	4	S
PPG	Purple Majesty	5	4	S
PPG	Purple Majesty	5	4	S
PPG	Purple Perivian	5	4	S
PPG	Purple Perivian	5	4	S
PPG	Purple Perivian	5	3	S
PPG	Purple Viking	5	4	S

PPG	Purple Viking	5	4	S
PPG	Purple Viking	5	4	S
PPG	Red Beauty	5	4	S
PPG	Red Beauty	5	4	S
PPG	Red Beauty	5	4	S
PPG	Red Thumb	4	4	S
PPG	Red Thumb	5	4	S
PPG	Red Thumb	5	3	S
PPG	Red Warba	5	4	S
PPG	Red Warba	5	4	S
PPG	Red Warba	5	4	S
PPG	Reda	2	1	MR
PPG	Reda	4	3	S
PPG	Reda	5	4	S
PPG	Reddalle	5	4	S
PPG	Reddalle	5	4	S
PPG	Reddalle	5	3	S
PPG	Rose Gold	3	3	MS
PPG	Rose Gold	5	4	S
PPG	Rose Gold	5	4	S
PPG	Ruby Crescent	1	1	MR
PPG	Ruby Crescent	2	2	MR
PPG	Ruby Crescent	5	4	S
PPG	Ruby Crescent	5	4	S
PPG	Russian Banana	0	0	R
PPG	Russian Banana	0	0	R
PPG	Russian Banana	4	1	S
PPG	Saqinaw Gold	4	3	S
PPG	Sharlotte	3	2	MS
PPG	Sharlotte	3	3	MS
PPG	Sharlotte	4	4	S
PPG	Snow Flake	5	4	S
PPG	Snow Flake	5	4	S
PPG	Snow Flake	5	4	S
PPG	Viking	4	4	S
PPG	Viking	4	4	S
PPG	Viking	5	2	S
PPG	Yellow Finn	5	3	S
PPG	Yukon Gold	0	0	R
PPG	Yukon Gold	5	4	S
PPG	Yukon Gold	5	3	S
PPG	Zarevo	3	2	MS
PPG	Zarevo	3	3	MS

(2) UM Potato Breeding Program (Dr. Christian Thill)

Trial	Clone	Severity	Coverage	Class
Adv	AOMN 03102-5	5	3	S
Adv	AOMN 03102-5	5	4	S
Adv	AOMN 03178-2	3	3	MS
Adv	AOMN 03178-2	4	3	S
Int	AOMN 041006-01	5	4	S
Int	AOMN 041006-01	5	4	S
Int	AOMN 041014-03	5	4	S
Int	AOMN 041014-03	5	4	S
Int	AOMN 041022-01	5	4	S
Int	AOMN 041022-01	5	4	S
Int	AOMN 041022-02	5	3	S
Int	AOMN 041022-02	5	4	S
Int	AOMN 041033-01	5	4	S
Int	AOMN 041033-01	5	3	S
Int	AOMN 041040-01	4	4	S
Int	AOMN 041040-01	5	4	S
Int	AOMN 041044-01	5	4	S
Int	AOMN 041044-01	5	4	S
Int	AOMN 041047-01	5	3	S
Int	AOMN 041047-01	5	4	S
Int	AOMN 041047-02	4	2	S
Int	AOMN 041047-02	4	4	S
Int	AOMN 041048-01	5	4	S
Int	AOMN 041048-01	5	4	S
Int	AOMN 041050-02	3	4	MS
Int	AOMN 041050-02	4	3	S
Int	AOMN 041056-01	4	4	S
Int	AOMN 041056-01	5	4	S
Int	AOMN 041060-02	5	3	S
Int	AOMN 041060-02	5	3	S
Int	AOMN 041060-20?	4	4	S
Int	AOMN 041060-20?	5	4	S
Int	AOMN 041070-01	1	1	MR
Int	AOMN 041070-01	2	1	MR
Int	AOMN 041093-01	2	3	MR
Int	AOMN 041093-01	3	3	MS
Int	AOMN 041100-01	2	2	MR
Int	AOMN 041100-01	4	1	S
Int	AOMN 041101-01	2	3	MR
Int	AOMN 041101-01	4	3	S
Int	AOMN 041101-03	5	3	S

Int	AOMN 041101-03	5	3	S
Int	AOMN 041113-02	2	1	MR
Int	AOMN 041113-02	5	3	S
Int	AOMN 041113-03	5	4	S
Int	AOMN 041113-03	5	4	S
Int	AOMN 041115-02	2	2	MR
Int	AOMN 041115-02	2	1	MR
Int	AOMN 041122-01 (filler)	5	4	S
Int	AOMN 041122-01 (filler)	5	4	S
Int	AOMN 041123-01	5	4	S
Int	AOMN 041123-01	5	4	S
Int	AOMN 041124-02?	2	2	MR
Int	AOMN 041124-02?	3	1	MS
Int	AOMN 041127-01	5	4	S
Int	AOMN 041127-01	5	3	S
Int	AOMN 041138-01	3	4	MS
Int	AOMN 041138-01	5	2	S
Int	AOMN 041140-01	5	3	S
Int	AOMN 041140-01	5	3	S
Adv	ATMN 03505-3	4	3	S
Adv	ATMN 03505-3	5	4	S
Adv	ATMN 03527-1	5	3	S
Adv	ATMN 03527-1	5	4	S
Adv	COMN 03016-4	5	3	S
Adv	COMN 03016-4	5	2	S
Adv	COMN 03019-4	5	4	S
Adv	COMN 03019-4	5	4	S
Adv	COMN 03020-2	5	3	S
Adv	COMN 03020-2	5	4	S
Adv	COMN 03020-3	5	4	S
Adv	COMN 03020-3	5	4	S
Adv	COMN 03021-1	5	4	S
Adv	COMN 03021-1	5	4	S
Adv	COMN 03021-2	4	3	S
Adv	COMN 03021-2	5	3	S
Adv	COMN 03024-6	4	4	S
Adv	COMN 03024-6	5	3	S
Adv	COMN 03027-1	4	2	S
Adv	COMN 03027-1	5	3	S
Adv	COMN 03032-2	2	3	MR
Adv	COMN 03032-2	5	3	S
Adv	COMN 03032-3	5	4	S
Adv	COMN 03032-3	5	4	S

Adv	COMN 03035-5	5	3	S
Adv	COMN 03035-5	5	4	S
Adv	COMN 03039-1(Filler)	5	4	S
Adv	COMN 03039-1(Filler)	5	4	S
Adv	COMN 03049-5	5	4	S
Adv	COMN 03049-5	5	4	S
Int	COMN 04650-01	4	2	S
Int	COMN 04650-01	5	4	S
Int	COMN 04650-02 (filler)	5	4	S
Int	COMN 04650-02 (filler)	5	4	S
Int	COMN 04651-01	3	4	MS
Int	COMN 04651-01	4	4	S
Int	COMN 04651-03	4	4	S
Int	COMN 04651-03	5	2	S
Int	COMN 04652-01	4	4	S
Int	COMN 04652-01	5	4	S
Int	COMN 04653-01	5	4	S
Int	COMN 04653-01	5	4	S
Int	COMN 04654-01(filler)	5	4	S
Int	COMN 04654-01(filler)	5	4	S
Int	COMN 04654-02	5	4	S
Int	COMN 04654-02	5	4	S
Int	COMN 04654-03	4	4	S
Int	COMN 04654-03	4	4	S
Int	COMN 04659-02	3	4	MS
Int	COMN 04659-02	4	4	S
Int	COMN 04659-03	5	4	S
Int	COMN 04659-03	5	3	S
Int	COMN 04659-05	5	4	S
Int	COMN 04659-05	5	4	S
Int	COMN 04659-06	5	3	S
Int	COMN 04659-06	5	2	S
Int	COMN 04668-01	5	4	S
Int	COMN 04668-01	5	4	S
Int	COMN 04670-01	4	3	S
Int	COMN 04670-01	5	4	S
Int	COMN 04670-02	5	4	S
Int	COMN 04670-02	5	4	S
Int	COMN 04684-01	2	1	MR

Int	COMN 04684-01	4	2	S
Int	COMN 04685-01	2	1	MR
Int	COMN 04685-01	4	3	S
Int	COMN 04686-01	5	3	S
Int	COMN 04686-01	5	4	S
Int	COMN 04686-02 (Filler)	5	4	S
Int	COMN 04686-02 (Filler)	5	4	S
Int	COMN 04689-03	0	0	R
Int	COMN 04689-03	5	1	S
Int	COMN 04692-01	4	3	S
Int	COMN 04692-01	5	3	S
Int	COMN 04692-02	5	4	S
Int	COMN 04692-02	5	4	S
Int	COMN 04692-03	5	4	S
Int	COMN 04692-03	5	4	S
Int	COMN 04692-05	5	4	S
Int	COMN 04692-05	5	4	S
Int	COMN 04692-07	3	4	MS
Int	COMN 04692-07	5	4	S
Int	COMN 04692-10	4	4	S
Int	COMN 04692-10	5	4	S
Int	COMN 04692-11	5	4	S
Int	COMN 04692-11	5	4	S
Int	COMN 04696-01	5	4	S
Int	COMN 04696-01	5	4	S
Int	COMN 04697-02	5	3	S
Int	COMN 04697-02	5	4	S
Int	COMN 04698-01	5	4	S
Int	COMN 04698-01	5	4	S
Int	COMN 04698-02	4	4	S
Int	COMN 04698-02	5	4	S
Int	COMN 04699-03	4	4	S
Int	COMN 04699-03	5	4	S
Int	COMN 04699-05	3	3	MS
Int	COMN 04699-05	5	3	S
Int	COMN 04702-01	4	1	S
Int	COMN 04702-01	4	3	S
Int	COMN 04702-03	3	3	MS
Int	COMN 04702-03	4	4	S
Int	COMN 04702-05 (Filler)	5	4	S
Int	COMN 04702-05 (Filler)	5	4	S

Int	COMN 04702-06	4	3	S
Int	COMN 04702-06	5	4	S
Int	COMN 04702-07	5	2	S
Int	COMN 04702-07	5	4	S
Int	COMN 04702-08	4	3	S
Int	COMN 04702-08	5	2	S
Int	COMN 04702-09	4	4	S
Int	COMN 04702-09	4	4	S
Int	COMN 04702-10	4	3	S
Int	COMN 04702-10	5	4	S
Int	COMN 04702-12	5	4	S
Int	COMN 04702-12	5	4	S
Int	COMN 04702-14	5	4	S
Int	COMN 04702-14	5	4	S
Int	COMN 04702-16	0	0	R
Int	COMN 04702-16	3	2	MS
Int	COMN 04702-18	5	4	S
Int	COMN 04702-18	5	4	S
Int	COMN 04703-02	5	3	S
Int	COMN 04703-02	5	3	S
Int	COMN 04704-01	4	4	S
Int	COMN 04704-01	5	3	S
Int	COMN 04712-01	5	4	S
Int	COMN 04712-01	5	4	S
Int	COMN 04712-05	5	3	S
Int	COMN 04712-05	5	4	S
Int	COMN 04713-02	0	0	R
Int	COMN 04713-02	2	1	MR
Int	COMN 04713-03	4	4	S
Int	COMN 04713-03	5	4	S
Int	COMN 04723-01	1	2	MR
Int	COMN 04723-01	2	3	MR
Int	COMN 04732-01	5	3	S
Int	COMN 04732-01	5	3	S
Int	COMN 04733-01	5	4	S
Int	COMN 04733-01	5	4	S
Int	COMN 04733-02	5	4	S
Int	COMN 04733-02	5	4	S
Int	COMN 04733-03	5	4	S
Int	COMN 04733-03	5	4	S
Int	COMN 04739-01	5	3	S
Int	COMN 04739-01	5	4	S
Int	COMN 04744-01	5	4	S
Int	COMN 04744-01	5	4	S
Int	COMN 04747-01	1	1	MR

Int	COMN 04747-01	1	1	MR
Int	COMN 04747-04	5	4	S
Int	COMN 04747-04	5	4	S
Int	COMN 04747-05	5	4	S
Int	COMN 04747-05	5	4	S
Int	COMN 04756-02	4	4	S
Int	COMN 04756-02	5	4	S
Int	COMN 04756-04	2	1	MR
Int	COMN 04756-04	3	4	MS
Int	COMN 04759-01	5	4	S
Int	COMN 04759-01	5	4	S
Int	COMN 04759-02	2	3	MR
Int	COMN 04759-02	3	1	MS
Int	COMN 04759-03	1	1	MR
Int	COMN 04759-03	5	4	S
Int	COMN 04760-01	2	3	MR
Int	COMN 04760-01	4	4	S
Int	COMN 04773-03	5	4	S
Int	COMN 04773-03	5	4	S
Int	COMN 04773-04	5	4	S
Int	COMN 04773-04	5	4	S
Int	COMN 04773-05	4	4	S
Int	COMN 04773-05	5	4	S
Int	COMN 04776-01	2	2	MR
Int	COMN 04776-01	3	3	MS
Int	COMN 04776-02	5	2	S
Int	COMN 04776-02	5	4	S
Int	COMN 04777-02	5	2	S
Int	COMN 04777-02	5	2	S
Int	COMN 04777-04	5	4	S
Int	COMN 04777-04	5	4	S
Int	COMN 04778-02	5	4	S
Int	COMN 04778-02	5	4	S
Int	COMN 04779-01	3	2	MS
Int	COMN 04779-01	5	4	S
Int	COMN 04779-02	5	3	S
Int	COMN 04779-02	5	4	S
Int	COMN 04780-01	4	3	S
Int	COMN 04780-01	4	3	S
Int	COMN 04780-02 (filler)	5	4	S
Int	COMN 04780-02 (filler)	5	4	S
Int	COMN 04780-05	5	3	S
Int	COMN 04780-05	5	4	S

Int	COMN 04780-06	5	4	S
Int	COMN 04780-06	5	3	S
Int	COMN 04781-02	5	3	S
Int	COMN 04781-02	5	4	S
Int	COMN 04781-04	3	4	MS
Int	COMN 04781-04	5	4	S
Int	COMN 04782-01	5	3	S
Int	COMN 04782-01	5	3	S
Int	COMN 04782-04	4	2	S
Int	COMN 04782-04	5	3	S
Int	COMN 04787-04	5	4	S
Int	COMN 04787-04	5	4	S
Int	COMN 04788-02	4	4	S
Int	COMN 04788-02	5	4	S
Int	COMN 04788-03	3	4	MS
Int	COMN 04788-03	4	4	S
Int	COMN 04788-04	2	3	MR
Int	COMN 04788-04	4	4	S
Int	COMN 04788-05	5	4	S
Int	COMN 04788-05	5	4	S
Int	COMN 04788-06	3	4	MS
Int	COMN 04788-06	4	4	S
Int	COMN 04788-07	4	4	S
Int	COMN 04788-07	4	4	S
Int	COMN 04788-09	3	4	MS
Int	COMN 04788-09	4	4	S
Int	COMN 04788-10	4	4	S
Int	COMN 04788-10	4	4	S
DE Accepts	DE02-108-03	4	2	S
DE Accepts	DE02-108-03	5	4	S
DE Accepts	DE02-137-05	5	4	S
DE Accepts	DE02-137-05	5	4	S
DE Accepts	DE02-156-15	2	3	MR
DE Accepts	DE02-156-15	3	4	MS
DE Accepts	DE02-205-12	5	3	S
DE Accepts	DE02-205-12	5	4	S
DE Accepts	DE02-205-13	5	4	S
DE Accepts	DE02-205-13	5	4	S
DE Selections	DEM 15	5	4	S
DE Selections	DEM 15	5	4	S
DE Selections	DEM 63	5	4	S
DE Selections	DEM 63	5	3	S
Elite	MN 00177-5	4	3	S
Elite	MN 00177-5	5	3	S
Elite	MN 02 419	5	4	S

Elite	MN 02 419	5	4	S
Elite	MN 02 529	5	4	S
Elite	MN 02 529	5	4	S
Elite	MN 02 586	5	4	S
Elite	MN 02 586	5	4	S
Elite	MN 02 587	5	4	S
Elite	MN 02 587	5	4	S
Elite	MN 02 588	5	4	S
Elite	MN 02 588	5	4	S
Elite	MN 02 678	5	3	S
Elite	MN 02 678	5	2	S
Elite	MN 02 696	5	4	S
Elite	MN 02 696	5	4	S
Int	MN 04yyyy-01	5	4	S
Int	MN 04yyyy-01	5	4	S
E2	MN 05001-007	5	3	S
E2	MN 05001-007	5	3	S
E2	MN 05001-011	5	3	S
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E2	MN 05001-014	3	3	MS
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E2	MN 05001-051	5	3	S
E2	MN 05001-054	5	3	S
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E2	MN 05001-074	5	4	S
E2	MN 05001-074	5	4	S

E2	MN 05001-083	4	3	S
E2	MN 05001-083	5	4	S
E2	MN 05001-088	3	1	MS
E2	MN 05001-088	5	3	S
E2	MN 05001-090	5	4	S
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E2	MN 05001-092	5	4	S
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E2	MN 05001-105	5	2	S
E2	MN 05001-107	0	0	R
E2	MN 05001-107	3	4	MS
E2	MN 05001-110	5	4	S
E2	MN 05001-110	5	4	S
E2	MN 05001-112	4	3	S
E2	MN 05001-112	5	3	S
E2	MN 05001-114	4	3	S
E2	MN 05001-114	5	4	S
E2	MN 05001-115	0	0	R
E2	MN 05001-115	2	2	MR
E2	MN 05001-116	5	4	S
E2	MN 05001-116	5	3	S
E2	MN 05001-117	4	4	S
E2	MN 05001-117	5	4	S
E2	MN 05001-119	4	4	S
E2	MN 05001-119	5	3	S
E2	MN 05001-120	5	4	S
E2	MN 05001-120	5	4	S
E2	MN 05001-125	4	4	S

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E2	MN 05001-128	4	2	S
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E2	MN 05001-130	4	4	S
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E2	MN 05001-148	3	2	MS
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E2	MN 05001-168	5	4	S
E2	MN 05001-170	4	4	S
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E2	MN 05001-171	4	4	S
E2	MN 05001-171	5	3	S

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E2	MN 05001-173	5	4	S
E2	MN 05001-175	4	4	S
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E2	MN 05001-176	5	2	S
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E2	MN 05001-180	3	3	MS
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E2	MN 05001-182	5	4	S
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E2	MN 05001-183	5	2	S
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E2	MN 05001-184	5	4	S
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E2	MN 05001-186	5	4	S
E2	MN 05001-186	5	4	S
E2	MN 05001-189	1	2	MR
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E2	MN 05001-196	5	4	S
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E2	MN 05001-197	4	4	S
E2	MN 05001-198	3	4	MS
E2	MN 05001-198	3	4	MS
E2	MN 05001-199	3	2	MS
E2	MN 05001-199	5	2	S
E2	MN 05001-202	5	3	S
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E2	MN 05001-203	4	3	S
E2	MN 05001-203	4	4	S
E2	MN 05001-204	5	3	S
E2	MN 05001-204	5	4	S
E2	MN 05001-206	5	4	S

E2	MN 05001-206	5	4	S
E2	MN 05001-207	2	3	MR
E2	MN 05001-207	5	3	S
E2	MN 05001-208	1	1	MR
E2	MN 05001-208	5	2	S
E2	MN 05001-209	3	1	MS
E2	MN 05001-209	5	4	S
Elite	MN 15620	5	3	S
Elite	MN 15620	5	3	S
Elite	MN 19470	5	4	S
Elite	MN 19470	5	4	S
Elite	MN 96013-1	5	4	S
Elite	MN 96013-1	5	4	S
Elite	MN 99380-1	5	4	S
Elite	MN 99380-1	5	4	S
Elite	MN 99460-14	5	4	S
Elite	MN 99460-14	5	4	S
Adv	MN(DE) 03 14-4	5	4	S
Adv	MN(DE) 03 14-4	5	4	S
Adv	MN(DE) 03 8-2	5	4	S
Adv	MN(DE) 03 8-2	5	4	S
Adv	MN(DM) 03 1-4	5	2	S
Adv	MN(DM) 03 1-4	5	4	S
Adv	MN(DM) 03 42-1	5	4	S
Adv	MN(DM) 03 42-1	5	4	S
Adv	MN(DM) 03 5-1	5	4	S
Adv	MN(DM) 03 5-1	5	4	S
Adv	NDMN 03308-1	4	4	S
Adv	NDMN 03308-1	5	3	S
Adv	NDMN 03316-3	4	2	S
Adv	NDMN 03316-3	5	4	S
Adv	NDMN 03324-4	5	4	S
Adv	NDMN 03324-4	5	3	S
Adv	NDMN 03333-1	5	4	S
Adv	NDMN 03333-1	5	4	S
Adv	NDMN 03333-2	5	4	S
Adv	NDMN 03333-2	5	4	S
Adv	NDMN 03339-4	1	1	MR
Adv	NDMN 03339-4	3	2	MS
Adv	NDMN 03376-1	5	4	S
Adv	NDMN 03376-1	5	4	S
Adv	NDMN 03378-12	3	2	MS
Adv	NDMN 03378-12	4	4	S
Adv	NDMN 03406-1	4	4	S
Adv	NDMN 03406-1	5	3	S

Adv	NDMN 03407-7	5	4	S
Adv	NDMN 03407-7	5	4	S
Adv	NDMN 03410-2	5	2	S
Adv	NDMN 03410-2	5	4	S
Int	NDMN 04870-03	2	2	MR
Int	NDMN 04870-03	4	3	S
Int	NDMN 04871-01	4	3	S
Int	NDMN 04871-01	5	3	S
Int	NDMN 04874-01	5	4	S
Int	NDMN 04874-01	5	4	S
Int	NDMN 04883-01	4	2	S
Int	NDMN 04883-01	5	4	S
Int	NDMN 04885-01	2	3	MR
Int	NDMN 04885-01	5	3	S
Int	NDMN 04893-02	5	3	S
Int	NDMN 04893-02	5	4	S
Int	NDMN 04899-01	0	0	R
Int	NDMN 04899-01	2	1	MR
Int	NDMN 04905-02	5	3	S
Int	NDMN 04905-02	5	4	S
Int	NDMN 04905-04	5	4	S
Int	NDMN 04905-04	5	4	S
Int	NDMN 04905-06	4	3	S
Int	NDMN 04905-06	4	3	S
Int	NDMN 04905-09	5	4	S
Int	NDMN 04905-09	5	4	S
Int	NDMN 04905-11	2	4	MR
Int	NDMN 04905-11	5	4	S
Int	NDMN 04905-13	3	4	MS
Int	NDMN 04905-13	5	3	S
Int	NDMN 04905-14	5	4	S
Int	NDMN 04905-14	5	4	S
Int	NDMN 04908-01	4	2	S
Int	NDMN 04908-01	5	4	S
Int	NDMN 04910-01	5	4	S
Int	NDMN 04910-01	5	2	S
Int	NDMN 04911-01	4	4	S
Int	NDMN 04911-01	5	4	S
Int	NDMN 04911-02	5	3	S
Int	NDMN 04911-02	5	3	S
Int	NDMN 04913-01	2	2	MR
Int	NDMN 04913-01	5	3	S
Int	NDMN 04916-01	3	3	MS
Int	NDMN 04916-01	4	4	S
Int	NDMN 04917-02	1	1	MR

Int	NDMN 04917-02	3	3	MS
Int	NDMN 04917-03	3	4	MS
Int	NDMN 04917-03	3	4	MS
Int	NDMN 04917-04	5	4	S
Int	NDMN 04917-04	5	4	S
Int	NDMN 04938-01	5	3	S
Int	NDMN 04938-01	5	4	S
Int	NDMN 04943-01	5	3	S
Int	NDMN 04943-01	5	4	S
Int	NDMN 04948-01	5	4	S
Int	NDMN 04948-01	5	4	S
Int	NDMN 04953-01	5	4	S
Int	NDMN 04953-01	5	4	S
Int	NDMN 04960-01	5	4	S
Int	NDMN 04960-01	5	4	S
Int	NDMN 04961-01	5	4	S
Int	NDMN 04961-01	5	4	S
Int	NDMN 04962-01	5	3	S
Int	NDMN 04962-01	5	3	S
Int	NDMN 04964-01	5	3	S
Int	NDMN 04964-01	5	4	S
Int	NDMN 04964-03	5	4	S
Int	NDMN 04964-03	5	3	S
Int	NDMN 04964-04	5	4	S
Int	NDMN 04964-04	5	4	S
Int	NDMN 04968-01	5	3	S
Int	NDMN 04968-01	5	3	S
Int	NDMN 04971-01	5	3	S
Int	NDMN 04971-01	5	3	S
Int	NDMN 04971-05	5	4	S
Int	NDMN 04971-05	5	4	S
Int	NDMN 04977-01	4	2	S
Int	NDMN 04977-01	4	4	S
Int	NDMN 04978-01	2	3	MR
Int	NDMN 04978-01	5	3	S
Int	NDMN 04979-02	4	3	S
Int	NDMN 04979-02	5	3	S
Chk	NorValley	5	4	S
Chk	NorValley	5	4	S
Chk	R. Norkotah	5	3	S
Chk	R. Norkotah	5	4	S
Chk	Red Norland	5	4	S
Chk	Red Norland	5	4	S
Chk	Red Pontiac	5	4	S
Chk	Red Pontiac	5	4	S

Chk	Shepody	5	4	S
Chk	Shepody	5	4	S
Chk	Snowden	5	2	S
Chk	Snowden	5	2	S
Int	USDAWIMN 04005-1	5	3	S
Int	USDAWIMN 04005-1	5	3	S
Int	USDAWIMN 04007-1	5	2	S
Int	USDAWIMN 04007-1	5	2	S
Int	USDAWIMN 04020-1	5	4	S
Int	USDAWIMN 04020-1	5	4	S
Int	USDAWIMN 04048-1?	4	2	S
Int	USDAWIMN 04048-1?	4	3	S
Int	USDAWIMN 04053-1	3	4	MS
Int	USDAWIMN 04053-1	4	4	S
Int	USDAWIMN 04060-1	5	3	S
Int	USDAWIMN 04060-1	5	3	S
Int	USDAWIMN 04063-1	5	4	S
Int	USDAWIMN 04063-1	5	4	S
Int	USDAWIMN 04081-2	5	3	S
Int	USDAWIMN 04081-2	5	4	S
Int	USDAWIMN 04082-1	2	3	MR
Int	USDAWIMN 04082-1	4	2	S
Int	USDAWIMN 04086-1	5	3	S
Int	USDAWIMN 04086-1	5	3	S
Int	USDAWIMN 04103-1	2	1	MR

Int	USDAWIMN 04103-1	4	4	S
Int	WIMN 04799-01	4	4	S
Int	WIMN 04799-01	5	4	S
Int	WIMN 04823-01	5	4	S
Int	WIMN 04823-01	5	4	S
Int	WIMN 04824-01	5	4	S
Int	WIMN 04824-01	5	4	S
Int	WIMN 04836-01	2	3	MR
Int	WIMN 04836-01	3	3	MS
Int	WIMN 04836-02	5	4	S
Int	WIMN 04836-02	5	4	S
Int	WIMN 04837-01	4	4	S
Int	WIMN 04837-01	5	3	S
Int	WIMN 04837-02	4	4	S
Int	WIMN 04837-02	4	4	S
Int	WIMN 04837-03	5	4	S
Int	WIMN 04837-03	5	4	S
Int	WIMN 04844-01	2	4	MR
Int	WIMN 04844-01	3	4	MS
Int	WIMN 04844-03	3	4	MS
Int	WIMN 04844-03	4	4	S
Int	WIMN 04844-04	3	3	MS
Int	WIMN 04844-04	5	3	S
Int	WIMN 04844-06	4	4	S
Int	WIMN 04844-06	5	2	S
Int	WIMN 04844-07	5	3	S
Int	WIMN 04844-07	5	4	S
Int	WIMN 04844-08	3	2	MS
Int	WIMN 04844-08	4	4	S
Int	WIMN 04844-12	2	4	MR
Int	WIMN 04844-12	4	3	S
Int	WIMN 04844-16	2	4	MR
Int	WIMN 04844-16	3	2	MS
Int	WIMN 04846-01	5	4	S
Int	WIMN 04846-01	5	4	S
Int	WIMN 04851-01	5	4	S
Int	WIMN 04851-01	5	3	S
Int	WIMN 04854-01	4	4	S
Int	WIMN 04854-01	5	4	S
Int	WIMN 04854-04	5	4	S
Int	WIMN 04854-04	5	3	S
Int	WIMN 04854-05	5	3	S
Int	WIMN 04854-05	5	4	S
Int	WIMN 04854-07	5	4	S

Int	WIMN 04854-07	5	2	S
Int	WIMN 04855-02	4	3	S
Int	WIMN 04855-02	5	4	S
Int	WIMN 04860-01	5	4	S
Int	WIMN 04860-01	5	4	S
Int	WIMN 04862-02	5	4	S
Int	WIMN 04862-02	5	3	S
Int	WIMN 04866-02	5	4	S
Int	WIMN 04866-02	5	4	S
Chk	Y. Gold	5	4	S
Chk	Y. Gold	5	4	S

(3) North Central Region (University of Minnesota, North Dakota State University, University of Wisconsin, and Michigan State University)

Trial	Clone	Severity	Coverage	Class
NCR	MSA8254-2BRUS	1	1	MR
NCR	W2683-2Rus	1	1	MR
NCR	W2683-2Rus	1	1	MR
NCR	W1879-1Rus	1	3	MR
NCR	ND 5002-3R	2	1	MR
NCR	W2133-1	2	3	MR
NCR	CV97065-1	2	4	MR
NCR	W1879-1Rus	2	2	MR
NCR	ND 5002-3R	2	3	MR
NCR	CV98112-3	2	3	MR
NCR	ND 4659-5R	3	1	MS
NCR	CV98112-3	3	3	MS
NCR	WV4298-1	3	4	MS
NCR	MSA8254-2BRUS	3	2	MS
NCR	MSJ316-A	4	3	S
NCR	ND 4659-5R	4	4	S
NCR	CV97065-1	4	3	S
NCR	W2133-1	4	3	S
NCR	MSJ316-A	4	4	S
NCR	WV4298-1	4	4	S
NCR	VHB0950-2	4	4	S
NCR	W2324-1	5	4	S
NCR	ATND 98459-1RY	5	4	S
NCR	VHB0950-2	5	4	S
NCR	MSI005-20Y	5	4	S
NCR	AND 98324-1Rus	5	4	S
NCR	AND 98324-1Rus	5	4	S
NCR	W2324-1	5	4	S
NCR	MSI005-20Y	5	4	S
NCR	ATND 98459-1RY	5	4	S

(4) National Scab Trial

Trial	Clone	Severity	Coverage	Class
Natl Scab	A95409-1	0	0	R
Natl Scab	A95409-1	2	2	MR
Natl Scab	A95409-1	5	3	S
Natl Scab	A97066-42LB	4	4	S
Natl Scab	A97066-42LB	5	4	S
Natl Scab	A97066-42LB	5	4	S
Natl Scab	AOA95154-1	1	1	MR
Natl Scab	AOA95154-1	2	2	MR
Natl Scab	AOA95154-1	4	3	S
Natl Scab	AOA95155-7	1	1	MR
Natl Scab	AOA95155-7	2	2	MR
Natl Scab	AOA95155-7	3	3	MS
Natl Scab	Atlantic	5	3	S
Natl Scab	Atlantic	5	4	S
Natl Scab	Atlantic	5	3	S
Natl Scab	B2152-17	3	3	MS
Natl Scab	B2152-17	3	4	MS
Natl Scab	B2152-17	5	3	S
Natl Scab	B2327-2	4	3	S
Natl Scab	B2327-2	4	4	S
Natl Scab	B2327-2	5	4	S
Natl Scab	B2445-6	3	3	MS
Natl Scab	B2445-6	3	3	MS
Natl Scab	B2445-6	4	3	S
Natl Scab	B2451-6	5	2	S
Natl Scab	B2451-6	5	4	S
Natl Scab	B2451-6	5	3	S
Natl Scab	B2486-4	2	2	MR
Natl Scab	B2486-4	4	4	S
Natl Scab	B2486-4	5	2	S
Natl Scab	BNC41-8	2	3	MR
Natl Scab	BNC41-8	3	4	MS
Natl Scab	BNC41-8	3	3	MS
Natl Scab	BNC48-3	3	1	MS
Natl Scab	BNC48-3	5	4	S
Natl Scab	BNC48-3	5	3	S
Natl Scab	BNC49-1	4	4	S
Natl Scab	BNC49-1	4	4	S
Natl Scab	BNC49-1	5	4	S
Natl Scab	BNC49-2	5	3	S
Natl Scab	BNC49-2	5	3	S

Natl Scab	BNC49-2	5	4	S
Natl Scab	MN00307-1	1	3	MR
Natl Scab	MN00307-1	2	1	MR
Natl Scab	MN00307-1	3	3	MS
Natl Scab	MN00467-4	2	2	MR
Natl Scab	MN00467-4	3	2	MS
Natl Scab	MN00467-4	4	3	S
Natl Scab	MN18710	0	0	R
Natl Scab	MN18710	2	1	MR
Natl Scab	MN18710	5	2	S
Natl Scab	Ranger Russet	5	4	S
Natl Scab	Ranger Russet	5	4	S
Natl Scab	Ranger Russet	5	4	S
Natl Scab	Russet Burbank	1	1	MR
Natl Scab	Russet Burbank	5	4	S
Natl Scab	Russet Burbank	5	4	S
Natl Scab	Superior	5	4	S
Natl Scab	Superior	5	4	S
Natl Scab	Superior	5	3	S
Natl Scab	W1836-3rus (Freedom Russet)	1	1	MR
Natl Scab	W1836-3rus (Freedom Russet)	2	2	MR
Natl Scab	W1836-3rus (Freedom Russet)	2	1	MR
Natl Scab	W2133-1	4	1	S
Natl Scab	W2133-1	5	3	S
Natl Scab	W2133-1	5	3	S
Natl Scab	W2324-1	5	4	S
Natl Scab	W2324-1	5	4	S
Natl Scab	W2324-1	5	3	S
Natl Scab	W2683-2rus	1	1	MR
Natl Scab	W2683-2rus	2	1	MR
Natl Scab	W2683-2rus	3	2	MS

Advanced potato breeding clones: storage and processing evaluation

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The concentration of reducing sugars (glucose and fructose) that accumulate in a potato cultivar during storage determines its marketing potential for chips, fries, or fresh markets (Sowokinos and Glynn, 2000). The darkening undesirable effect that reducing sugars have on the color of chip and fry products is well known. Potatoes that resist sweetening when cold-stressed generally have a greater ability to resist sweetening when subjected to field stresses such as temperature, moisture, fertility and early dying (Sowokinos et al., 2000).

Potato breeding is an expensive and labor-intensive process. Tens of thousands of potato clones are grown annually by breeders in an effort to find a "single clone" that may meet all of the horticultural requirements necessary to make a successful cultivar (i.e., high yield and solids, disease resistance, etc.). Once a new clone has undergone several years of field trials, it often fails because of storage- and marketing-related problems. This report describes the storage characteristics of advanced potato clones provided by state and federal breeders and is funded, in part, by the Northern Plains Potato Growers Association.

Materials and Methods:
Seventy-four advanced clones from Idaho, Maine, Michigan, Minnesota, New York, North Dakota, Oregon, Texas, Wisconsin and Alberta Canada were grown under irrigation south of Larimore, ND. All potatoes were harvested mid-September, suberized two weeks at room temperature and then placed into 45 F, 42 F and 38 F storage. Several tubers of each clone were evaluated for sugar content, Agtron color values and chip appearance at three intervals (i.e., harvest, three and seven month's storage). Potatoes were also reconditioned at 55 F for two months following storage at 42 F for five months. All storage and processing evaluations were conducted at the USDA/ARS Potato Research Worksite.

Results
The individual clones demonstrated a wide range of sugar accumulation when subjected to cold stress. At 42 F storage, the concentration of glucose ranged from 0.06 mg/g in W 2982-1 (Table 1) to 6.81 mg/g in Red Pontiac (Table 3). These glucose values represented a greater than 100-fold difference in their ability to sweeten in storage.

Based on sugar content and chip appearance the clones were categorized into three classes.

- Class A: Clones that can be chipped directly from 42 F storage (Table 1).
- Class B: Clones that chip from 45 F but not from 42 F storage (Table 2).
- Class C: Clones that chip from neither 45 F nor 42 F storage (Table 3).

Table 1 show the 'Class A' clones that chipped successfully from 42 F without reconditioning. Reconditioning, however, did improve most of the Agtron scores (data not shown). Four of the top 10 performers were from North Dakota, (ND 8304-2, ND 7519-1, ND Sport 860 and Dakota Pearl). Wisconsin also had four clones in the top ten (W 2982-1, W 4013-1, W 2717-5 and W 2310-3). The top clone was from Minnesota (MN 02 582) and Michigan placed one in the top 10 (MSJ 147-1). Other named cultivars in the Class A group were Snowden (WI), Norvalley (ND) Ivory Crisp (ND), Dakota Crisp (ND) and Dakota Diamond (ND),

Table 2 shows the 'Class B' clones that chip from 45 F but not from 42 F. Only nine clones were in Class B. They were from North Dakota, Wisconsin, Idaho, USDA, Maine, Michigan and Minnesota. Although these clones do not have the low glucose-forming potential (GFP) of clones listed in Table 1 (Class A), their level of performance is still considerably better than the original chipping standard, Norchip. Consequently, the clones listed in Table 2, still play an important role in meeting grower and industry needs.

Table 3 lists 'Class C' clones that chip neither from 42 F or 45 F storage. Cultivars such as Russet Burbank and Russet Norkotah fall into this class. Their higher inherent 'basal level' of sugars serves to direct their end use more towards the fry and fresh markets. Chieftain and Red Pontiac with high glucose values of 5.67 and 6.81 mg/g, respectively, are fresh market clones..

Summary

The Class A' clones listed in Table 1 provide the quality advantages from storage as listed below**.**

- Decreased microbial spoilage.
- Retention of dry matter
- Reduced shrinkage
- Decreased need for sprout inhibition
- Decreased physiological aging
- Increased marketing window.

For a new potato cultivar to be successful, it must also demonstrate a variety of other horticultural and marketing qualities that are required by the producer and consumer. Contact the respective potato breeder (listed below) if you are interested in any additional quality traits demonstrated by the potato clones listed.

References

Sowokinos, J. R. and M. Glynn 2000 Marketing potential of advanced potato breeding clones. *Valley Potato Grower*. 65(110):6-8

Sowokinos, J. R., S. K. Gupta and M. Glynn. 2000. Potato clones with a new anti-sweetening gene (Asgene) Valley Potato Grower, 65(115):4-6

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<u>Table 1. 2005-06 Class A Cones</u>: Potato clones that chip following six months storage at 42 F. Clones are aligned in order of decreasing Agtron value from 42 F.

Clone	Source	42 F			45 F		
		CC[2]	AGT[3]	GLC[1] (mg/g)	CC[2]	AGT[3]	GLC[1] (mg/g)
MN 02 582	MN	1	70	0.07	1	75	0.02
W 2982-1	WI	1	69	0.06	1	70	0.02
W 4013-1	WI	1	68	0.42	1	70	0.16
ND 8304-2	ND	1	65	0.29	1	70	0.15
ND 7519-1	ND	1	65	0.20	1	73	0.05
W 2717-5	WI	1	64	0.18	1	73	0.04
MSJ 147-1	MI	2	62	0.42	1	70	0.17
Sport 860	ND	2	62	0.42	1	73	0.06
Dakota Pearl	ND	2	62	0.29	1	69	0.20
W 2310-3	WI	2	62	0.31	1	74	0.01
MSJ 126-9Y	MI	2	61	0.29	***	***	***
W 2324-1	WI	2	60	0.58	1	70	0.09
MN 02 586	MN	2	60	0.32	1	65	0.24
ND 8-14	ND	2	60	0.55	1	66	0.12
ND 860-2-8	ND	2	60	0.54	1	73	0.06
Snowden	WI	2	60	0.31	2	62	0.46
W 2133-1	WI	2	60	0.52	1	70	0.08
ND 7818-1Y	ND	2	60	0.28	1	73	0.03
NDA 5507-3Y	ND/ID	2	60	0.41	2	60	0.53
MN 02 587	MN	2	59	0.66	2	64	0.23

Norvalley	ND	2	59	0.62	2	69	0.25
ATTX 8823-2W	ID/TX	2	59	0.51	***	***	***
A 93157-6LS	ID	2	59	0.32	2	64	0.10
CO 95051-7W	CO/OR	2	59	0.37	2	64	0.14
Ivory Crisp	ND/OR/ID/USDA	2	58	0.74	1	70	***
MN 02 678	MN	2	58	0.30	1	73	0.05
MN 02 696	MN	2	58	0.23	1	67	0.02
MSK 061-4	MI	2	58	0.23	1	75	0.02
Dakota Crisp	ND	2	58	0.82	2	61	0.42
W 2438-3	WI	2	58	0.68	2	60	0.30
Dakota Diamond	ND	2	58	0.80	2	62	0.30
W 2683-2 RUS	WI	2	58	0.67	***	***	***
ND 5775-3	MD	2	57	***	***	***	***
MSM 051-3	MI	2	57	0.84	2	63	0.31

[1]CC = Represents chip color relating to the Potato Chip/Snack Food Association five-code color chart: 1 and 2 are acceptable, 3 is marginal, 4 and 5 are unacceptable.
[2]Agtron values of 60 or greater yield acceptable colored chips.
[3]Desirable values for Glc (glucose) are 0.50 mg/g or less
***** Denotes no data**

<u>Table 2. 2005-06 Class B clones</u>: Potato clones that chip following 6 months storage at 45 F, but not 42 F. Clones are aligned in order of decreasing Agtron values from 45 F storage.

Clone	Source	42 F CC[2]	42 F AGT[3]	42 F GLC[1] (mg/g)	45 F CC[2]	45 F AGT[3]	45 F GLC[1] (mg/g)
ND 6095-1	ND	3	54	0.70	2	61	0.32
MN 02 510	MN	3	54	0.67	2	56	0.62
AF 2172-56	MA	3	53	1.33	2	58	0.47
A 91814-5	ID	3	53	0.79	2	59	0.72
MN 02 524	MN	3	52	***	2	59	***
AF 2215-1	MA	3	51	1.31	2	59	0.29
ND 5255-59	ND	3	50	1.28	***	***	***
W 2309-7	WI	3	50	***	2	63	0.11
MSJ 316-A	MI	3	49	0.92	2	55	0.17

[1]CC = Represents chip color relating to the Potato Chip/Snack Food Association five-code color chart: 1 and 2 are acceptable, 3 is marginal, 4 and 5 are unacceptable.
[2]Agtron values of 60 or greater yield acceptable colored chips.
[3]Acceptable values for Glc (glucose) are 0.50 mg/g or less
***** Denotes no data**

Table 3. 2005-2006 Class C Clones: Potato clones that do not chip following six months storage from either 45 F or 42 F storage. Clones are aligned in order of decreasing Agtron values from 42 F storage.

Clone	Source	42 F			45 F		
		CC[2]	AGT[3]	GLC[1] (mg/g)	CC[2]	AGT[3]	GLC[1] (mg/g)
TX 1475-3W	TX	3	49	1.91	3	54	0.64
TXA 549-1 RU	TX/ID	3	47	***	3	54	1.97
MN 02 515	MN	3	47	1.24	***	***	***
MSJ 461-1	MI	3	45	2.48	3	54	1.17
AF 2393-7	MA	3	45	2.34	***	***	***
MN 15620	MN	3	45	2.20	3	47	2.15
AF 2314-1	MA	4	44	***	***	***	***
AF 2916-1	MA	4	44	1.02	3	50	0.74
Atlantic	USDA	4	44	1.01	2	57	0.76
MSJ 036-A	MI	4	44	0.94	3	54	0.60
Russet Burbank	CO	4	43	3.96	3	50	2.97
AF 2376-5	MA	4	42	3.69	3	53	1.44
Norchip	ND	4	42	1.57	3	47	0.88
A 9305-10	ID	4	41	2.87	3	47	2.14
ATX 91137-1 RU	ID/TX	4	40	2.80	3	49	2.41
A 97066-42LB	ID	4	40	1.11	3	51	0.53
AOTX 95295-3RU	ID/OR/TX	4	40	2.74	4	43	2.63
Dark Red Norland	ND	4	40	3.41	3	45	3.05
A 9045-7	ID	4	39	3.36	3	45	2.77
Shepody		4	38	3.96	3	48	3.15
ATTX 95490-2W	ID/TX/TX	4	38	3.72	4	40	3.42
Russet Norkotah	ND	4	38	3.77	3	45	1.87
Yukon Gold		4	37	3.73	3	51	2.29
A 95109-1	ID	4	36	2.71	4	44	2.64
MWTX 2609-4 RU	MN/WI/TX	4	35	3.93	3	45	2.48
ATTX 98466-5R/W-Y/R	ID/TX/TX	5	34	3.00	4	44	1.78
AOTX 95265-3RU	ID/OR/TX	5	33	3.94	3	45	2.13
Chieftain	ND	5	32	5.67	5	34	-------
Red Pontiac	USDA/MI/FL	5	32	6.81	5	34	4.18

[1]CC = Represents chip color relating to the Potato Chip/Snack Food Association five-code color chart: 1 and 2 are acceptable, 3 is marginal, 4 and 5 are unacceptable.
[2]Agtron values of 60 or greater yield acceptable colored chips.
[3]Acceptable values for Glc (glucose) are 0.50 mg/g or less
***** denotes no data**

Effective Pink Rot Disease Control and Management of Mefenoxam Resistance in *Phytophthora erythroseptica*

Research Supported by MN Area II and NPPGA

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Introduction:

Pink rot and leak, collectively referred to as 'water rots', are caused primarily by the soilborne fungi *Phytophthora erythroseptica* and *Pythium ultimum*, respectively. These two diseases cause problems with tuber quality and integrity of the stored potato crop. One could argue that in the United States, these two tuber rots are economically more important on a yearly basis than any other disease affecting tuber quality. Although late blight tuber rot infections tend to be acute and spectacularly devastating when they occur, in most production years few growers experience economic loss from this phase of the disease. Pink rot and leak are chronic and endemic diseases, present every year in nearly every potato production region. Storage rot surveys conducted in each of the past nine years in ND and MN indicate that pink rot is generally more prevalent, however leak can be important also, particularly at the beginning of harvest when tuber pulp temperatures are higher and skin set is poor (Taylor and Gudmestad, unpublished data). More recent observations suggest that the pink rot pathogen is gaining entry into potato tubers through pink eye affected areas causing the disease to develop quite late in storage. Disease management tactics that provide more residual control in storage are needed.

Background and Justification:

Differences in etiology of pink rot and leak are significant which ultimately affects disease management (Taylor et al. 2004). Infections of pink rot typically occur in the field, prior to harvest, when zoospores of *P. erythroseptica* infect stolons, tuber eyes or lenticels (rare) (Lambert and Salas, 2001). Infection by *P. ultimum* is strictly through wounds made at harvest (Salas and Secor, 2001). However, research by our research group determined that pink rot also has a post-harvest phase and that *P. erythroseptica* is capable of high infection rates in storage depending on the severity of wounding, tuber pulp temperature and inoculum pressure (Salas, et al., 2000). Field infections, and those that occur during harvest, usually appear in storage within one month of being placed into storage. More recently, the physiological disorder called pink eye, characterized by aberrant wound and incomplete wound healing (Lulai, et al., 2006), also appears to be an infection court for the pink rot pathogen after potatoes are placed into storage (Gudmestad, unpublished). These post-harvest infections of pink rot appear much later, from November through January, and are changing the dynamics of the disease and making disease control more challenging.

Most potato cultivars in production in the USA are susceptible to both pink rot and leak (Salas et al., 2003), although a few cultivars have moderate levels of resistance to one, but not both, of these diseases. We have recently developed a source of resistance to both pink rot and leak, resulting from a somatic hybrid backcross clone derived from *Solanum* *berthaultii* and *S. etuberosum* (Thompson et al., 2006). It will be some time before this source of resistance is reflected in commercially accepted potato cultivars.

Cultural practices alone are frequently inadequate to manage pink rot and leak and since most potato cultivars are susceptible to pink rot and leak, the industry has depended on the fungicide mefenoxam for disease management. Mefenoxam provides excellent control of pink rot, and fair control of leak when applied in furrow (Taylor et al., 2004). The advantage of in furrow, at planting applications of mefenoxam compared to foliar applications for pink rot control has been demonstrated in Australia as well (Wicks et al., 2000). The difference in the level of disease control of pink rot relative to leak is directly related to differences in etiology between the two diseases (Taylor et al. 2004). After the application of mefenoxam to potato plants, it is known to concentrate in the periderm of tubers (Bruin et al., 1982), a phenomenon made possible only with phenylamide fungicides since they are symplastically mobile in plants and capable of movement in the phloem. Wounds made at harvest breech the barrier to infection afforded by mefenoxam, thereby reducing efficacy in leak control relative to pink rot (Taylor et al., 2004), since *P. ultimum* is a strict wound pathogen. The level of leak control provided by mefenoxam is not economic, therefore, we recommend potato growers not use this fungicide solely for this purpose. Wounds made at harvest can also negate the effects of mefenoxam with the control of pink rot as well (Figure 1). Therefore, cultural practices that encourage skin set and minimize wounds at harvest are important in preserving the level of control afforded by the application of mefenoxam.

Disease control is further exacerbated by the occurrence of mefenoxam resistance in both the pink rot and the leak pathogen (Taylor et al., 2002). Mefenoxam resistance in *P. erythroseptica* appears to be widespread in the states of Maine, Idaho, and Colorado We first detected mefenoxam resistance in the pink rot pathogen in Minnesota in 2000 (Taylor et al., 2002). From 2001-2004, approximately 20% of the *P. erythroseptica* we have recovered from potato storages were resistant to mefenoxam, however, resistance in the pink rot pathogen spike to nearly 60% in 2005. Mefenoxam-resistant isolates of the pathogen have also been found in North Dakota, Wisconsin and Michigan. Based on data generated by our research group, it is clear that mefenoxam resistance in the pink rot pathogen renders this fungicide useless for disease control (Figure 2). Understanding the impact of mefenoxam resistance on disease management in addition to the development of alternative and effective management strategies is of utmost importance for the control of water rots.

Phosphorous acid-based fungicides have been shown to provide suppression of pink rot, but have no effect on leak (Johnson et al, 2004). Phosphorous acid-based fungicides, which belong to the group of fungicides referred to as ‘phosphonates’, are unique in that they have two modes of action. These types of fungicide not only kill the pathogen on contact, but they also stimulate the plants own defense mechanisms, thereby providing additional control. We feel it will be useful to determine if the potato plant’s stimulation of defense mechanisms would provide residual pink rot control, superior to mefenoxam in the presence of post-harvest wounds in storage. Unfortunately, multiple applications of phosphorous acid are required to achieve this level of control is very expensive, approximately 2-3X the cost of mefenoxam-based fungicides. Post-harvest infections of *P. erythroseptica* can also be reduced with the application of phosphorous acid onto tubers being placed into storage (Miller et al., 2006).

The overall objective of the work proposed here is to determine how mefenoxam resistance can be managed in MN and to identify control strategies that will provide residual control of pink rot in storage.

Research Objectives:

1. Determine the prevalence of mefenoxam-resistance in the *P. erythroseptica* population in Minnesota and North Dakota.
2. Determine the impact of an alternative fungicide, phosphorous acid, on the management of mefenoxam resistance.
3. Determine if phosphorous acid provides residual control of pink rot in storage that is not currently provided by mefenoxam.

Procedures:

Field plots and mefenoxam application. Fungicide application trials will be conducted under center pivot irrigation over two consecutive growing seasons. Fungicide treatments will be established each year to provide different levels of pink rot control in treated versus non-treated tubers (Table 1). At planting, a 50:50 blend of mefenoxam sensitive and insensitive isolates of the pink rot pathogen will be applied in the seed piece zone. Fungicide treatments will be applied at the recommended label rate. Mefenoxam (Ridomil Gold 4EC or Ultrafluorish) as an in-furrow application of 200 g a.i./ha at planting followed by an additional side-dress application of 100 g a.i./ha 21 days later (Table 1). This split application of mefenoxam at these rates previously has been demonstrated to provide the highest level of pink rot control (Taylor et al., 2004). Another mefenoxam treatment will be two foliar applications of 100 g a.i./ha when tubers are approximately 10 mm in diameter and 14 days later. One, two and three phosphorous acid (Phostrol) treatments will all be made at a rate of 11.65 L/ha (Table 1). No in furrow treatments will be used since these have been demonstrated to ineffective in controlling pink rot (Johnson, et al., 2004). The foliar phosphorous acid treatments will be applied when tubers are 10mm in diameter and 14 days later (2 applications) and the same treatment regime with a third application 14 days after the second application (total of three foliar applications). An additional phosphorous acid treatment will include a post-harvest application simulating tubers going into storage. Two treatments of cyazofamid (Ranman) will be used in this experiment (Table 1). The first will be an in furrow, at planting application at a rate of 450 mL/ha. The second treatment will be an in furrow treatment of 450 mL/ha followed by a sidedress application of 225 mL/ha.

Disease evaluations at harvest. Pink rot tubers will be obtained at harvest from all non-treated and all fungicide (2 treatments each of mefenoxam, 4 phosphorous acid and 2 cyazofamid) treated plots. These pink rot infected tubers will be taken to the laboratory and isolations for *P. erythroseptica* will be performed. All isolates obtained will be maintained on a treatment X replication basis and tested for their sensitivity to mefenoxam based on the methods previously described. The purpose of this portion of the proposed research is to determine the effect of non-mefenoxam fungicides on the mefenoxam sensitive and insensitive populations of *P. erythroseptica*.

Post-harvest pink rot inoculations. Plants will be killed by mechanical flailing 2 to 3 weeks prior to maturity to insure the availability of a sufficient quantity of tubers of the desired size and adequate skin set. After harvest, tubers were stored for 2 weeks at 15ºC and 90% relative humidity to facilitate wound healing. However, because levels of mefenoxam in tubers will decline over time, test tubers used in this study were stored at 10ºC for no longer than 4 months prior to testing. We do not know the length of residual control for phosphorous acid, but the experiments conducted here will provide that information and determine if this fungicide provides control of pink rot beyond harvest.

The level of residual, post-harvest control of pink rot will be determined using challenge inoculations conducted at 30 day intervals after harvest. Residual pink rot control studies will focus on the phosphorous acid treatments and comparing this to the known residual control provided by mefenoxam. We will not test the residual control potential of cyazofamid, since it is not a systemic fungicide (Table 1). Wounded and non-wounded tubers will be placed in plastic moist chamber boxes and inoculated with 10 µl of the zoospore suspension of *P. erythroseptica*. Inoculated tubers will be covered with four layers of paper towels moistened to saturation with deionized water. The chamber boxes will be sealed to establish high humidity to promote infection and incubated in the dark at ambient temperature at 20 to 22ºC for 10 days.

Disease assessment. Inoculated tubers will removed from the moist chambers and infection will be determined by cutting each tuber in half through the axis from the sites of inoculation on the apical bud end to the basal stem end. Split tubers will be covered with moist paper towels and incubated at ambient temperatures of 20 to 24ºC for approximately 30 min to enhance the development of the discoloration diagnostic of pink rot. Infected tubers will be counted and disease incidence calculated as (number of diseased tubers/number of inoculated tubers) × 100. To determine pink rot severity, the maximum width of rot (W) and the depth (D) of rot from the inoculation point will be measured and penetration (P) of rot was calculated as $P = (W/2 + [D - 5])/2$. Disease incidence will be transformed to percent disease control using the formula ([disease incidence of untreated control – disease incidence of treatment]/disease incidence of non-treated control) × 100.

Pink rot survey. *P. erythroseptica* isolates will be collected by transferring small pieces of infected tissue, approximately 25 mm3 in size, to culture dishes containing water agar amended with ampicillin (100 µg/ml) and incubated in the dark at 17 to 20ºC for 3 to 5 days. Colonies with mycelia resembling that of *P. erythroseptica* will be selected and purified by hyphal tipping.

Mefenoxam sensitivity testing. Mefenoxam (Ridomil Gold 4EC) sensitivity will be determined using an in vitro screening method. Tests will be conducted on modified V8 juice agar amended with fungicide in a 10-fold dilution series ranging from 0.01 to 100 µg/ml and control plates not amended with mefenoxam. A 5-mm-diameter disk containing mycelium and agar from the margin of actively growing colonies of 4- to 6-day-old cultures will be positioned in the center of a culture dish. Isolate growth will be determined by measuring colony diameters in two perpendicular directions after 6 days of incubation in the dark at 20 ± 1ºC. Measurements were averaged, the diameter of the mycelial plug will be subtracted, and relative growth reduction for each rate of fungicide will be calculated as follows: (100 – [growth with fungicide/growth in control plate] × 100). The EC_{50} relative to the control will be estimated by plotting the percentage inhibition against the log-scale of fungicide concentration.

Results:
Field Trials. Mefenoxam (Ridomil) and phosphorous acid (Phostrol) were applied at several rates and application methods to evaluate residual efficacy for the control of pink rot. Tubers harvested from this trial were challenge inoculated every 30 days following harvest to determine residual activity of each fungicide. The field in which this trial was planted had a very low level (<1%) of pink rot at harvest and 60 days after harvest (Table 1). Foliar applications of Phostrol provided excellent control of pink rot in tubers challenge inoculated with either a mefenoxam resistant or sensitive isolate of *P. erythroseptica* (Table 2). Ridomil provided control of pink rot when tubers were challenge inoculated with a sensitive isolate but not when inoculated with a resistant isolate of *P. erythroseptica* (Table 2, Figure 1). Phostrol appears to provide residual excellent control of pink rot in storage when applied two or three times to the foliage or post-harvest when tubers are going into storage (Table 2, Figure 1). Phostrol also provides excellent control of both mefenoxam sensitive and resistant isolates of *P. erythroseptica.*

Field Survey. The *P. erythroseptica* population in North Dakota continues to be largely sensitive to mefenoxam (Figure 2). From this we conclude that fungicide resistance is not the primary cause of the pink rot issues in storage in 2007.

The population of *P. erythroseptica* in Minnesota is also predominantly sensitive to mefenoxam although to a lesser degree (Figure 2 & 3). There is considerable year to year variability in the frequency of mefenoxam resistance in Minnesota (Figure 3), an indication that the population is in flux and trending towards the development of resistance to this fungicide. The data also suggest that the frequency of fields with mefenoxam resistance are increasing in Minnesota. Approximately 2/3 of the potato fields sampled in Minnesota have a resistant population or a mixed population of sensitive and resistant populations (Figure 4). Field studies that determine the level of mefenoxam resistance that is tolerable, before fungicide failure occurs, are warranted.

Additional Research Results (data not shown): Our field and storage observations suggest that pink eye lesions can act as important infection courts for the pink rot pathogen (see introduction). Controlled inoculation studies have confirmed this. Additional studies have also confirmed that mefenoxam applications do not provide control of pink rot infections that occur through pink eye lesions, conversely phosphorous acid does control this phase of the pink rot disease. It also appears from other studies we have conducted that once the frequency of mefenoxam resistance is 25% in a field, the use of mefenoxam should cease.

Additional studies are planned. This research has been supported by R.D. Offutt, Co., Simplot Inc., and Lamb-Weston.

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Table 1. Percentage tuber rot among treatments evaluated at harvest and 60 days after harvest (DAH). Mean separation based on Fisher's protected least significant difference (LSD) test (P = 0.05).

Treatment		Rate	Application Timing	Percent Tuber Rot	
				At Harvest (9/10)	60 DAH
3301	Non-treated	-	-	0.6	0.1
3302	Ridomil 4EC	6.1 oz / a	in-furrow	0.1	0.1
3303	Ridomil 4EC	12.2 oz / a	in-furrow	0.7	0.7
3304	Ridomil 4EC	6.1 oz / a	in-furrow	0.2	0.2
	Ridomil 4EC	6.1 oz / a	sidedress		
3305	Ridomil 4EC	6.1 oz / a	in-furrow	0.2	0.1
	Ridomil MZ	2.0 lb / a	tuber set		
3306	Ridomil MZ	2.0 lb / a	tuber set	0.8	0.5
	Ridomil MZ	2.0 lb / a	tuber set + 14 days		
3307	Phostrol	10.0 pt / a	tuber set	0.2	0.2
3308	Phostrol	10.0 pt / a	tuber set	0.9	1.3
	Phostrol	10.0 pt / a	tuber set + 14 days		
3309	Phostrol	10.0 pt / a	tuber set	0.4	0.7
	Phostrol	10.0 pt / a	tuber set + 14 days		
	Phostrol	10.0 pt / a	tuber set + 28 days		
3310	Phostrol	12.8 fl oz / ton	post-harvest	0.7	0.4
$LSD_{P = 0.05}$				NS	0.7

P. erythroseptica isolations from infected tubers at harvest and 60 days after harvest, isolates tested for sensitivity to mefenoxam.

Data: Percent tuber infection at harvest and 60 days after harvest.

Post harvest challenge inoculations 30, 60, 90 and 120 days post-harvest.

Table 2. Percentage tuber rot among treatments challenge inoculated with a mefenoxam resistant and sensitive isolate of *Phytophthora erythroseptica* 30 and 38, 65 and 99 days after harvest (DAH). Mean separation based on Fisher's protected least significant difference (LSD) test (P = 0.05).

Treatment	Rate	Application Timing	*P. erythroseptica* isolate	*P. erythroseptica* challenge inoculation (% incidence)		
				30 and 38 DAH	65 DAH	99 DAH
Non-treated	-	-	Mefenoxam Resistant	26.3	32.5	30.0
Ridomil 4EC	6.1 oz / a	in-furrow	Mefenoxam Resistant	20.0	22.5	47.5
Ridomil 4EC	12.2 oz / a	in-furrow	Mefenoxam Resistant	28.8	25.0	42.5
Ridomil 4EC Ridomil 4EC	6.1 oz / a 6.1 oz / a	in-furrow sidedress	Mefenoxam Resistant	32.5	20.0	52.5
Ridomil 4EC Ridomil MZ	6.1 oz / a 2.0 lb / a	in-furrow tuber set	Mefenoxam Resistant	28.8	22.5	42.5
Ridomil MZ Ridomil MZ	2.0 lb / a 2.0 lb / a	tuber set tuber set + 14 days	Mefenoxam Resistant	32.5	25.0	35.0
Phostrol	10.0 pt / a	tuber set	Mefenoxam Resistant	6.3	22.5	17.5
Phostrol Phostrol	10.0 pt / a 10.0 pt / a	tuber set tuber set + 14 days	Mefenoxam Resistant	6.3	0.0	7.5
Phostrol Phostrol Phostrol	10.0 pt / a 10.0 pt / a 10.0 pt / a	tuber set tuber set + 14 days tuber set + 28 days	Mefenoxam Resistant	1.3	2.5	7.5
Phostrol	12.8 fl oz / ton	10 days post-harvest	Mefenoxam Resistant	0.0	0.0	0.0
$LSD_{P = 0.05}$				8.8	20.9	17.0
Non-treated	-	-	Mefenoxam Sensitive	12.5	17.5	37.5
Ridomil 4EC	6.1 oz / a	in-furrow	Mefenoxam Sensitive	5.0	2.5	12.5
Ridomil 4EC	12.2 oz / a	in-furrow	Mefenoxam Sensitive	6.3	17.5	15.0
Ridomil 4EC Ridomil 4EC	6.1 oz / a 6.1 oz / a	in-furrow sidedress	Mefenoxam Sensitive	2.5	10.0	12.5
Ridomil 4EC Ridomil MZ	6.1 oz / a 2.0 lb / a	in-furrow tuber set	Mefenoxam Sensitive	2.5	15.0	17.5
Ridomil MZ Ridomil MZ	2.0 lb / a 2.0 lb / a	tuber set tuber set + 14 days	Mefenoxam Sensitive	5.0	22.5	12.5
Phostrol	10.0 pt / a	tuber set	Mefenoxam Sensitive	3.8	10.0	10.0
Phostrol Phostrol	10.0 pt / a 10.0 pt / a	tuber set tuber set + 14 days	Mefenoxam Sensitive	0.0	0.0	5.0
Phostrol Phostrol Phostrol	10.0 pt / a 10.0 pt / a 10.0 pt / a	tuber set tuber set + 14 days tuber set + 28 days	Mefenoxam Sensitive	0.0	2.5	0.0
Phostrol	12.8 fl oz / ton	10 days post-harvest	Mefenoxam Sensitive	0.0	0.0	0.0
$LSD_{P = 0.05}$				5.5	13.4	14.0

Table 2. Con't

Treatment	Rate	Application Timing	*P. erythroseptica* isolate (Avg. of sensitive and resistant isolate)	*P. erythroseptica* challenge inoculation (% incidence)		
				30 and 38 DAH	65 DAH	99 DAH
Non-treated	-	-		19.4	25.0	33.8
Ridomil 4EC	6.1 oz / a	in-furrow		12.5	12.5	30.0
Ridomil 4EC	12.2 oz / a	in-furrow		17.5	21.3	28.8
Ridomil 4EC Ridomil 4EC	6.1 oz / a 6.1 oz / a	in-furrow sidedress		17.5	15.0	32.5
Ridomil 4EC Ridomil MZ	6.1 oz / a 2.0 lb / a	in-furrow tuber set		15.6	18.8	30.0
Ridomil MZ Ridomil MZ	2.0 lb / a 2.0 lb / a	tuber set tuber set + 14 days		18.8	23.8	23.8
Phostrol	10.0 pt / a	tuber set		5.0	16.3	13.8
Phostrol Phostrol	10.0 pt / a 10.0 pt / a	tuber set tuber set + 14 days		3.1	0.0	3.3
Phostrol Phostrol Phostrol	10.0 pt / a 10.0 pt / a 10.0 pt / a	tuber set tuber set + 14 days tuber set + 28 days		0.6	2.5	3.8
Phostrol	12.8 fl oz / ton	10 days post-harvest		0.0	0.0	0.0
$LSD_{P = 0.05}$				5.1	12.3	11.0
			Mefenoxam Resistant	18.3	17.3	28.3
			Mefenoxam Sensitive	3.8	9.8	12.3
$LSD_{P = 0.05}$				2.3	5.5	4.9

NOTE: Incidence at 30 and 38 days after harvest (DAH) could be combined via Levenes test of HOV (P = 0.05).

No significant difference in incidence was observed between 30 and 38 DAH (P = 0.05).

The interaction of the main effects of treatment and mefenoxam resistance were significant for incidence at 30/38 and 99 DAH but not at 65 DAH (P = 0.05).

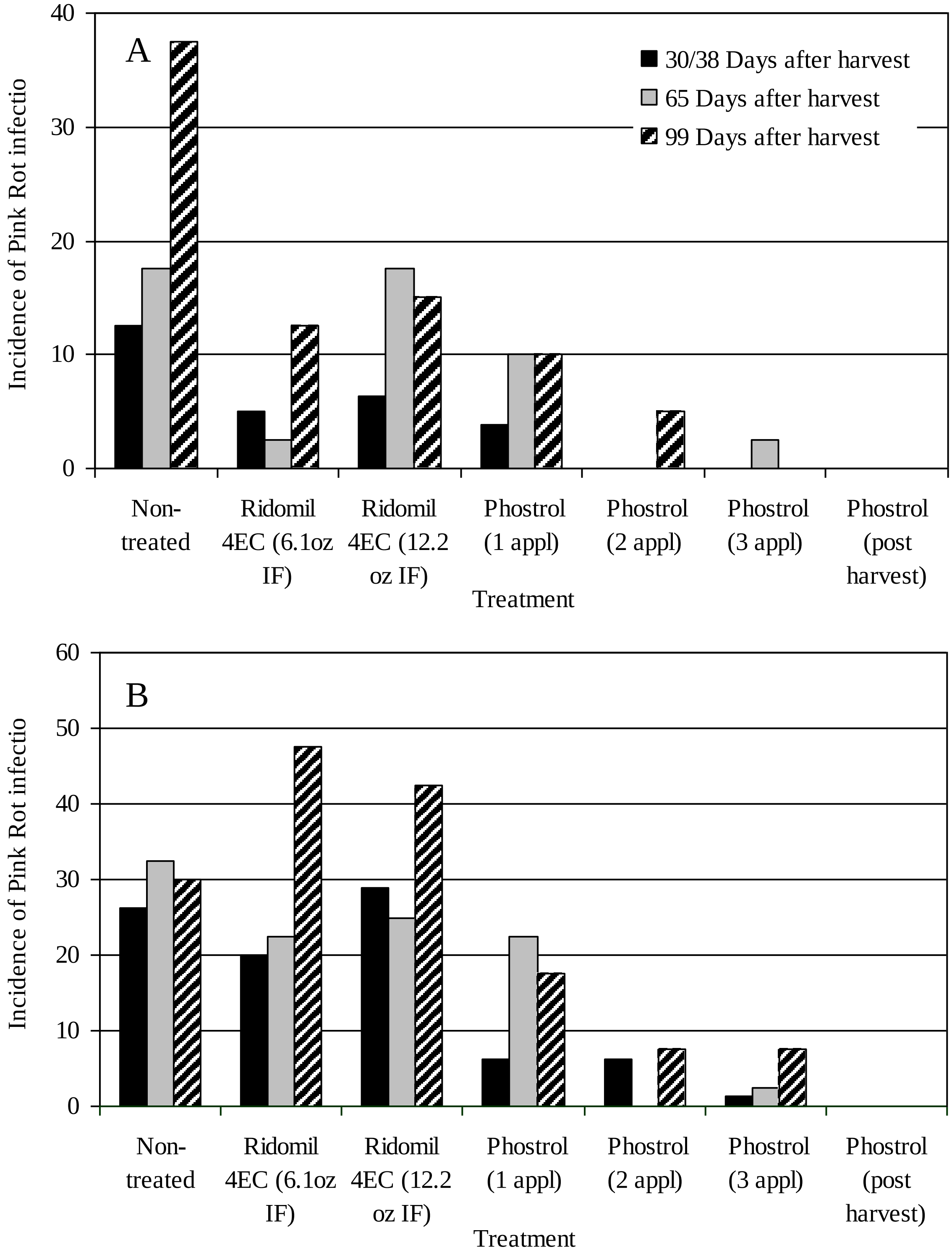

Figure 1. Incidence of pink rot caused by mefenoxam sensitive (A) and resistant (B) isolates of *Phytophthora erythrosetpica* in potato tubers treated with mefenoxam or phosphorus acid.

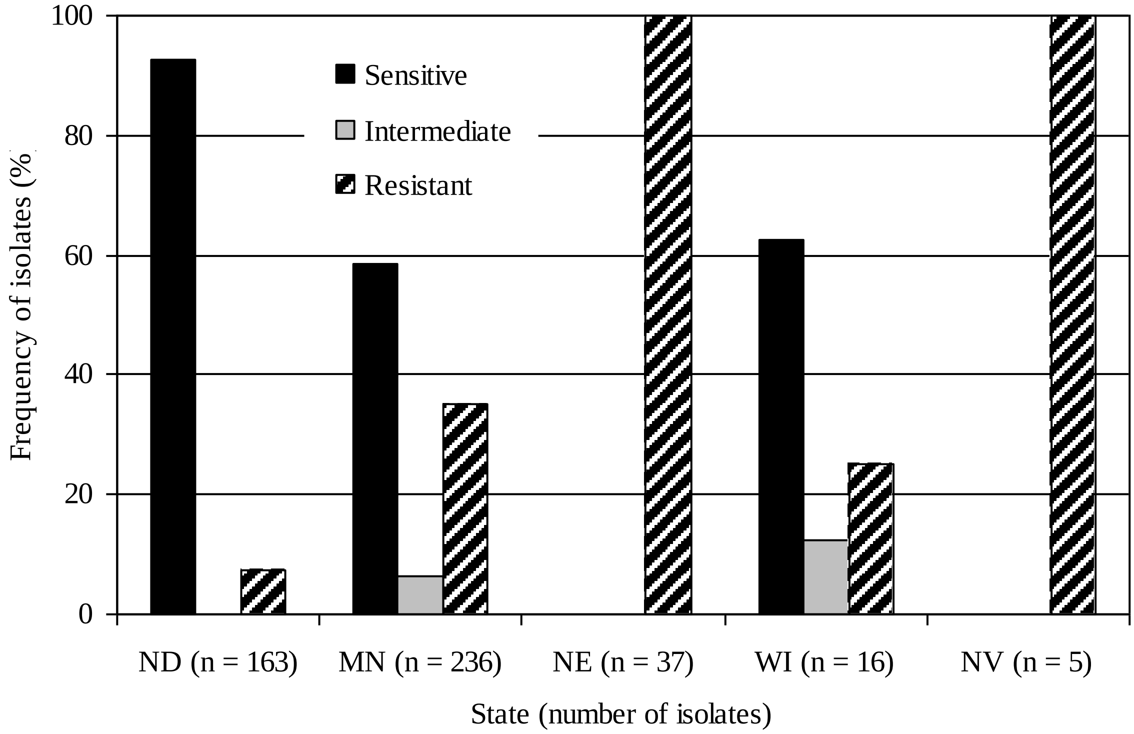

Figure 2. Frequency of mefenoxam resistance and sensitivity in *Phytophthora erythrospetica* in four states in 2007.

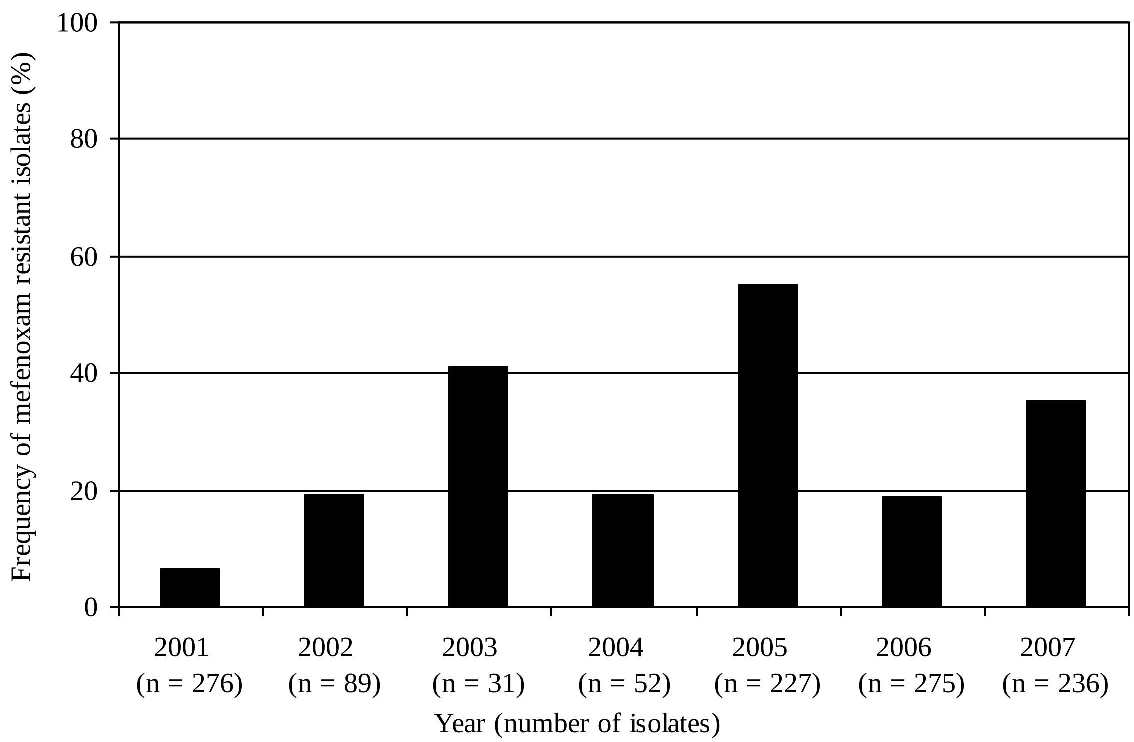

Figure 3. Frequency of mefenoxam resistance in *Phytophthora erythroseptica* in Minnesota from 2001to 2007.

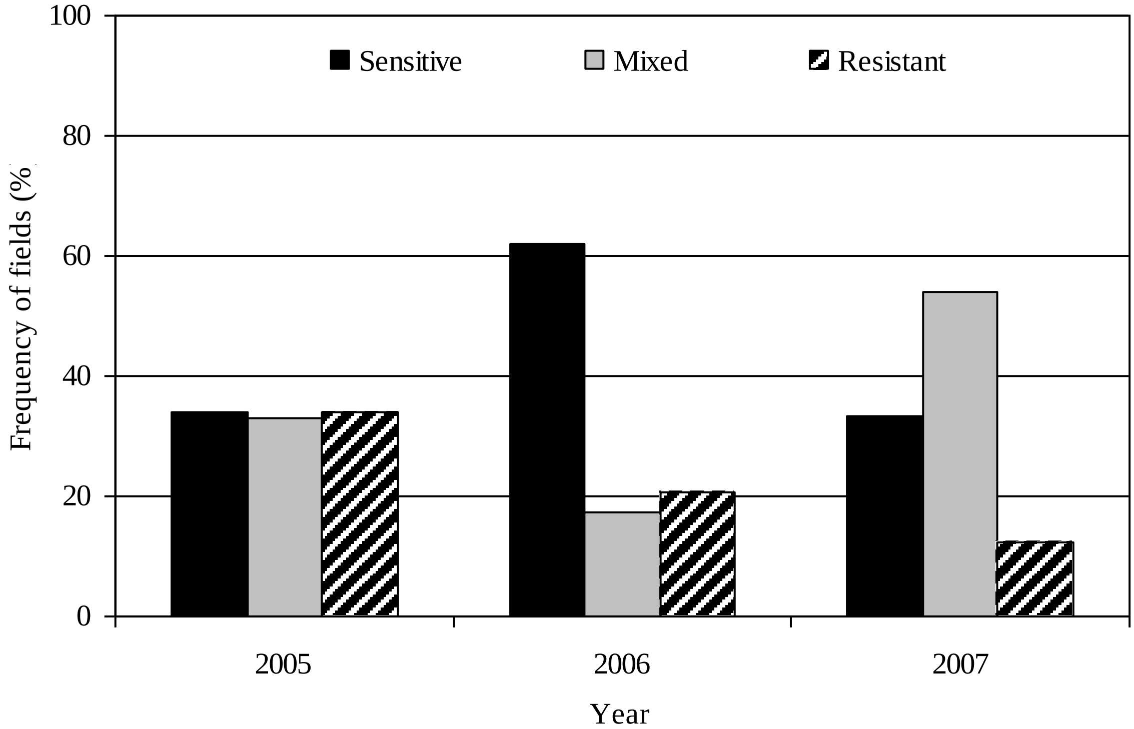

Figure 4. Frequency of potato fields with mefenoxam sensitive, resistant or mixed populations of *Phytophthora erythroseptica*.

Quantification of soilborne pathogens of potato using real-time PCR

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Funded by Minnesota Area II Potato Growers & NPPGA

Introduction:

A number of important soilborne pathogens affect potato development and tuber quality. These diseases include powdery scab, caused by *Spongospora subterranea*, Verticillium wilt, caused by *Verticillium dahliae,* and black dot, caused by *Colletotrichum coccodes*.

Powdery scab can affect crop development by infecting roots and negatively impacting nutrient and water uptake but this disease also affects tuber quality. The powdery scab pathogen is also the vector of the potato mop top virus. *V. dahliae* and *C. coccodes* affect crop development and are components of the early dying complex, although the former is generally acknowledged as the primary pathogen (Davis and Johnson, 2001; Johnson, 1994; Tsror et al., 1999). Vegetative group 4 is the most important group of *V. dahliae* affecting potato. *C. coccodes* also affects tuber quality, particularly as it affects the fresh market and the chip processing sectors of the potato industry (Read and Hide, 1988).

Disease management of these diseases usually involved the implementation of various agrochemicals, which are expensive and in some cases, such as with metam sodium used to control Verticillium wilt, can potentially harm the environment. Diseases such as powdery scab cannot be controlled chemically leaving growers with the option of avoiding the disease by not planting a field or using less susceptible cultivars.

Soil population levels of a pathogen usually impacts disease development and severity. In the Midwestern US, soil populations of *V. dahliae* >8 microsclerotia/g of soil are generally regarded as economically damaging. Preliminary studies on *C. coccodes* suggest soil populations >70 microsclerotia are yield limiting (Gudmestad et al., 2005). Soil population studies on these two pathogens were performed using classical soil dilution and culture plating in the laboratory. These types of studies are very difficult or impossible to do with pathogens such as *S. subterranea,* a pathogen that cannot be cultured. Additional studies on the relationships between populations of soilborne pathogens and yield and quality losses would be aided by methods of detection and quantification that are precise, rapid and relatively inexpensive.

Quantification of soilborne pathogen inocula has been recently facilitated by the implementation of polymerase chain reaction (PCR) technology, either in classical or in real-time format (Cullen, et al., 2002; Gudmestad, et al., 2007; Qu, et al., 2006). Real-time PCR has proven to be useful in quantifying *C. coccodes* resulting in a relationship being detected between soil population of the pathogen and the number of potato crops in a given field (Figure 1). This work was funded by MN Area II in 2006. Similar studies have been performed using *S. subterranea* (Qu et al., 2006).

The goal of the research proposed here is to develop a multiplex real-time PCR method that will allow quantification of several soilborne pathogens simultaneously within the same sample. The target pathogens include *V. dahliae, C. coccodes, S. subterranea* and *R. solani.* PCR primers have been previously described for these pathogens, but the studies proposed here will multiplex these primers into a single assay.

Studies on soil sampling and soil processing will also be performed to optimize DNA extraction for the PCR detection protocol.

Research Objectives:

1) Develop a multiplex real-time PCR method for the detection and quantification of *V. dahliae, C. coccodes,* and *S. subterranea* from field soil.
2) Develop soil sampling and soil processing procedures to optimize DNA extraction from soilborne pathogens.

Research Plan:

The real-time PCR method for the black dot pathogen, *C. coccodes*, has been successfully developed by our laboratory with funding from MN Area II in 2006 and was used on a trial basis during the last growing season (see MN Area II research report submitted in November, 2006). We have developed a real-time PCR method for *V. dahliae* that must be validated with field samples collected in 2007. If successful, we will combine the *C. coccodes* and *V. dahliae* PCR methods into a duplex reaction that will permit the quantification of these two pathogens in a single reaction. Further studies will be undertaken to use the powdery scab PCR method of Qu et al. (2006) with the methods already developed in our laboratory. The detailed methodology to accomplish this is discussed below.

DNA will be extracted from axenic cultures of *V. dahliae,* and *C. coccodes* grown in potato dextrose broth, and from spore balls of *S. subterranea* using the FastPrep DNA extraction kit (MoBio Inc.). DNA will be quantified with a fluorometer and diluted to 10 ng/µL in ddH_2O. *S. subterannea* will be amplified using the forward primer $PF18Sd2_{100}$ (19 bp), the reverse primer $PR18Sd2_{176}$ (26 bp), and the Taqman™ probe $PT18Sd2_{121}$ (28 bp). *C. coccodes* will be amplified using the forward primer CcTqF1, reverse primer CcTqR1, and the Taqman probe CcTqP1 (Cullen et al. 2002). *R. solani* will be amplified using the forward primer RsTqF1, reverse primer RsTqR1, and the Taqman probe RQP1 (Lees et al. 2002). A real-time PCR assay for *V. dahliae* will be developed by analyzing a DNA sequence corresponding to the *V. dahliae* ITS1-5.8srDNA-ITS2 domain (GENEBANK Accession EF015891) domain with Primer Express Software. The species specificity of each real-time assay will be confirmed by amplifying target DNA and non-target DNAs including the three other fungi and purified potato DNA. Real-time PCR reactions and thermocycling conditions will be as described by Vandemark et al. (2000).

In order to develop multiplex real-time PCR assays that can detect all possible combinations of the four pathogens (*V. dahliae* x *C. coccodes*, *V. dahliae* x *S. subterranea*, *C. coccodes* x *S. subterranea*), two Taqman probes will be synthesized for each pathogen, with one being labeled at the 5' terminus with the fluorochrome 6-carboxyfluorescein (FAM), and the other labeled at the 5' terminus with the fluorochrome VIC (Applied Biosystems). Initial real-time PCR assays will include purified DNA (25 ng) of each pathogen in all six pair-wise combinations. Primer and probe limiting experiments will be performed according to manufacturer's recommendations (Applied Biosystems) to determine the minimum, most cost effective amount of primers and Taqman probe that can be used in multiplex reactions.

After verifying the sensitivity and specificity of the multiplex real-time PCR assays with purified pathogen DNAs, soil will be collected from potato fields. Mycelia of

V. dahliae and *C. coccodes*, along with spore balls of *S. subterannea*, will be added in known quantities to the soil samples. DNA will be extracted from 5 g soil samples with the MegaPrep DNA extraction kit (Mo Bio Inc.) and multiplex real-time PCR will be performed using 10 μL of the soil DNA extract in a 50 μL reaction volume. The amount of each respective pathogen detected in the soil sample will be determined based on standard curves using purified pathogen DNA as template. Serial dilutions of the DNA extracts from pathogen infested soil will be made and examined by real-time PCR to determine threshold levels for reliable detection of each pathogen. DNA extracted from the original soil sample prior to infestation by the four respective pathogens will also be amplified by real-time PCR to examine baseline levels of detection from non-infested soil.

Results

The real time PCR method has been fully optimized for the detection of *C. coccodes* microsclerotia (ms) and is capable of detecting 0.8 ms/g of soil when diluted in 1 ml of water (Figure 1). A curvilinear relationship exists between the threshold detection level and the number of microsclerotia per gram of soil, thus providing a regression formula that can be utilized to quantify the black dot pathogen in soil (Figure 2).

Soils from several locations in Minnesota have been tested for the population of *C. coccodes* present. Approximately 200 fields have been tested the past two years. A few interesting trends have been noted. First, the black dot pathogen could not detected in any non-potato field. (Figure 3), indicating that it is not an indigenous pathogen but one that is introduced into soils with potato seed. Second, the interval between crops is inversely related to the *C. coccodes* population that can be detected (Figure 3A). In other words, we detected higher populations of the black dot fungus in fields four years removed from the last potato crop then in fields where potato is grown every other year. An explanation for this is that the potato debris left in the soil from the previous crop must decompose before the pathogen can be detected. Lastly, as the total number of potato crops in a field increases, so does the population of *C. coccodes* (Figure 3B) and this relationship is statistically significant (Figure 4).

We have designed a PCR primer based on the extracellular trypsin protease gene that is specific for *V. dahliae* (Figure 5). This primer is very sensitive, capable of detecting 1 pg of DNA from the pathogen (Figure 6). We are continuing to optimize the real time PCR format so that it can be duplexed with the C. coccodes primers described above. The powedery scab pathogen primers (Qu, et al., 2006) have not been optimized at this point in our studies.

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Read, P.J. and Hide, G.A. 1988. Potato Res. 31:493-500.

Tsror (Lahkim) L., Erlich, O. and Hazanovsky, M. 1999. Plant Dis. 83:561-565.

Vandemark, G. J., B. M. Barker and M. A. Gritsenko. 2002. Phytopathology 92:265-272.

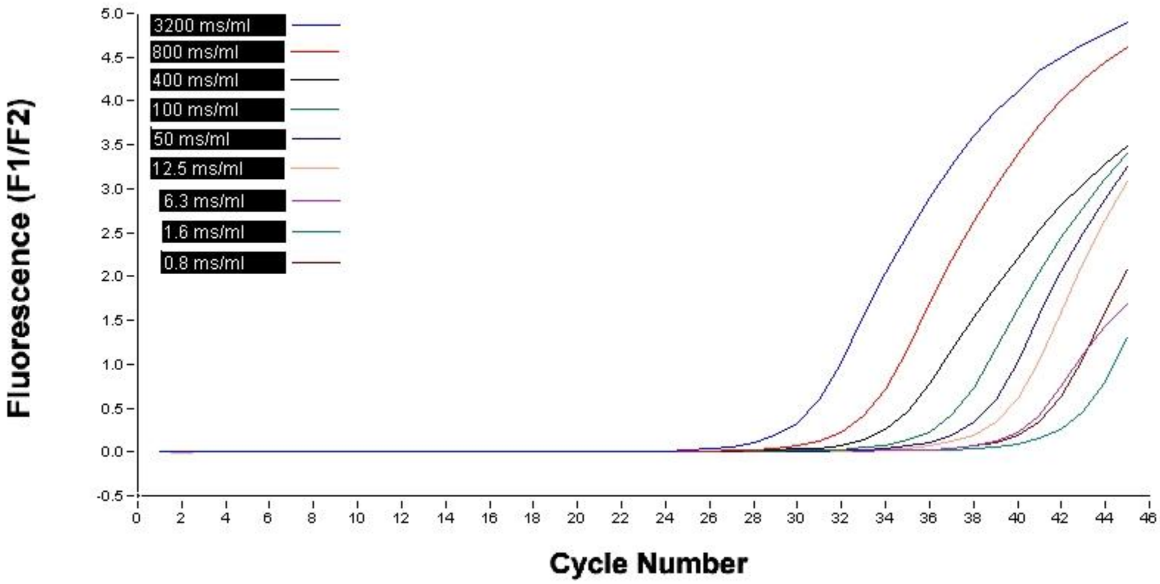

Figure 1. Real-time PCR standard curves demonstrating the number of cycles required to detect microsclerotia of *Colletotrichum coccodes* at several concentrations.

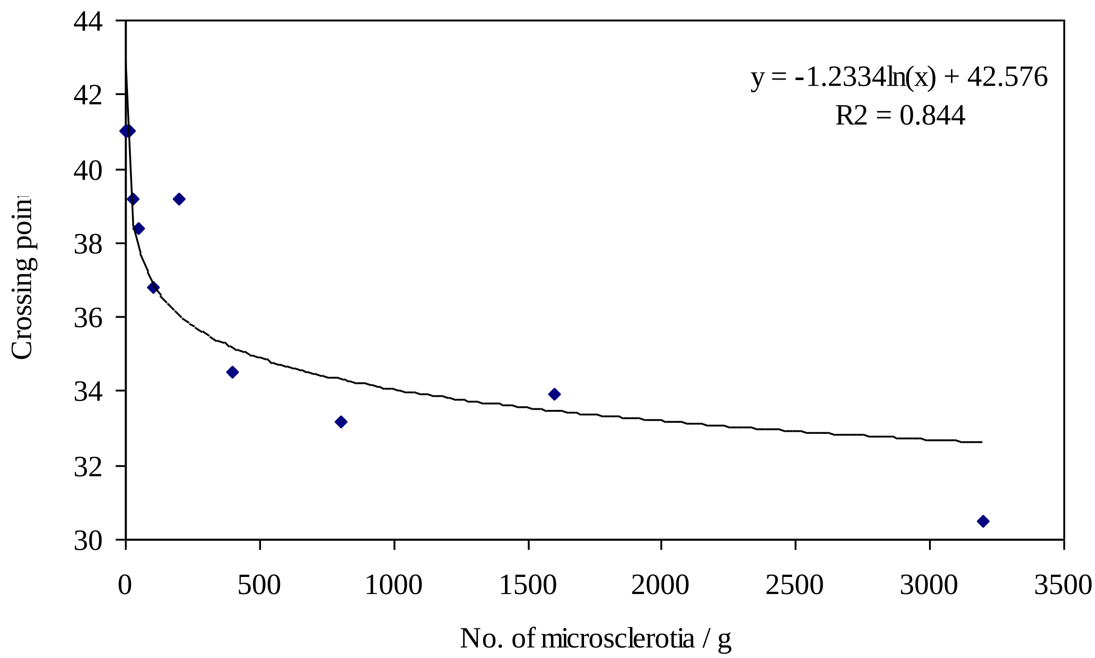

Figure 2. Relationship of fluorescence (F1/F2 crossing point) to microsclerotia of *Colletotrichum coccodes* detected from artificially infested field soil.

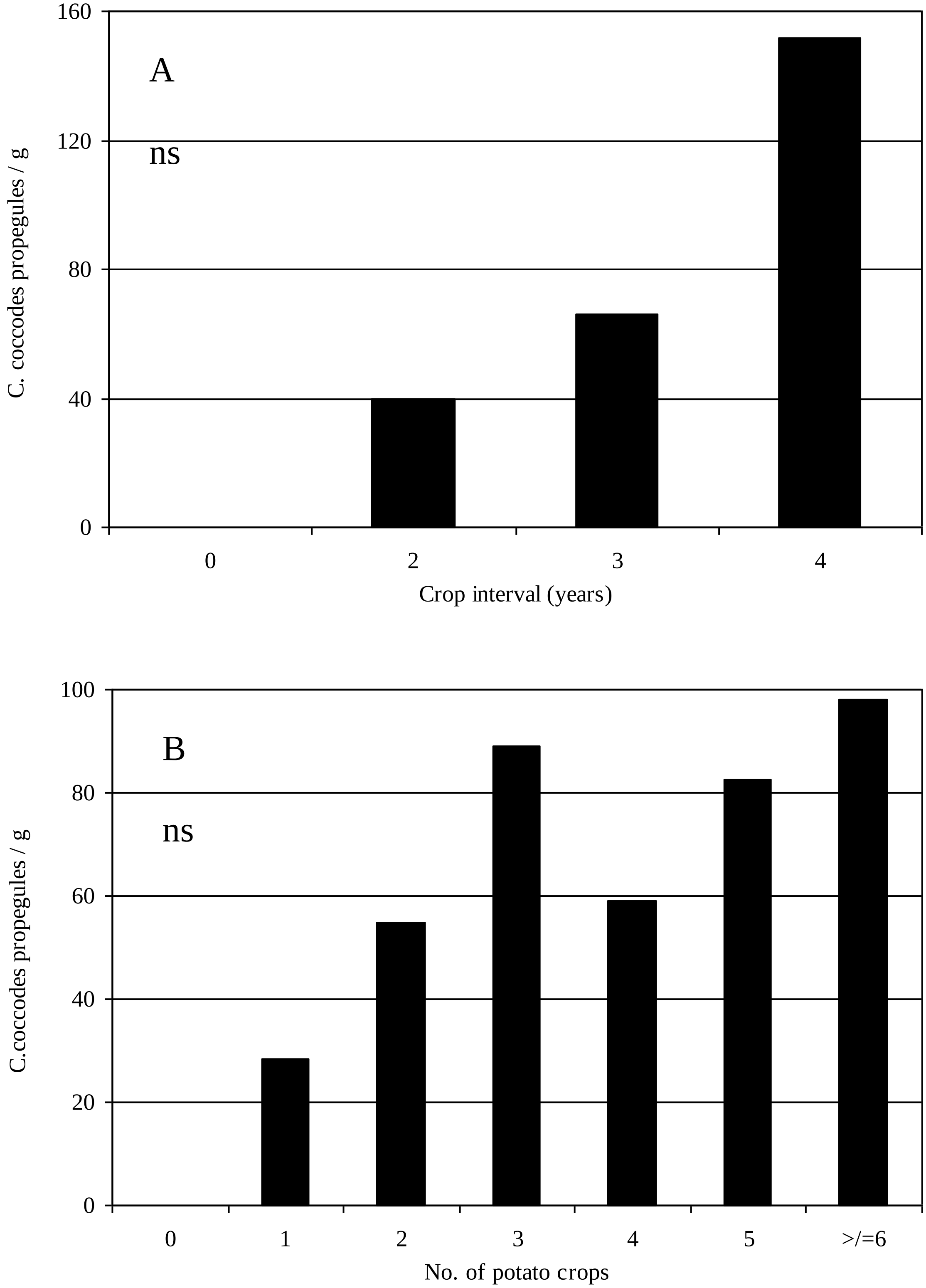

Figure 3. The population of *Colletotrichum coccodes* is influenced by the crop rotation or the number of years between potato crops (A) and the total number of potato crops that have been planted (B).

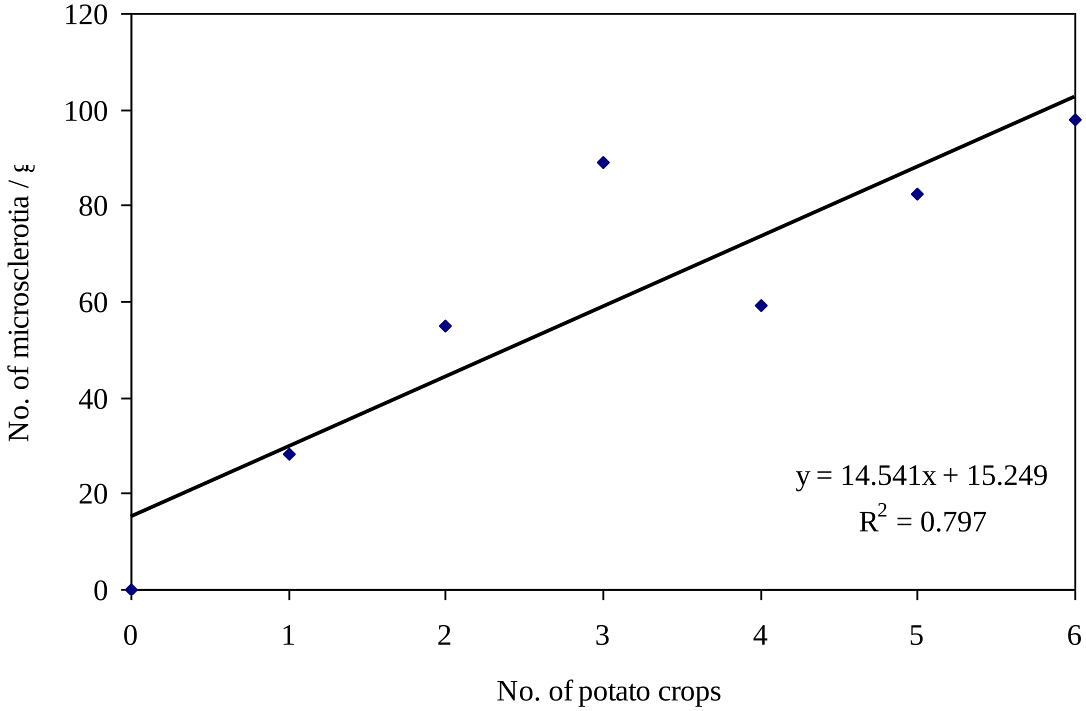

Figure 4. Relationship between the number of potato crops and population of *Colletotrichum coccodes* in fields (n=45) tested using real-time PCR.

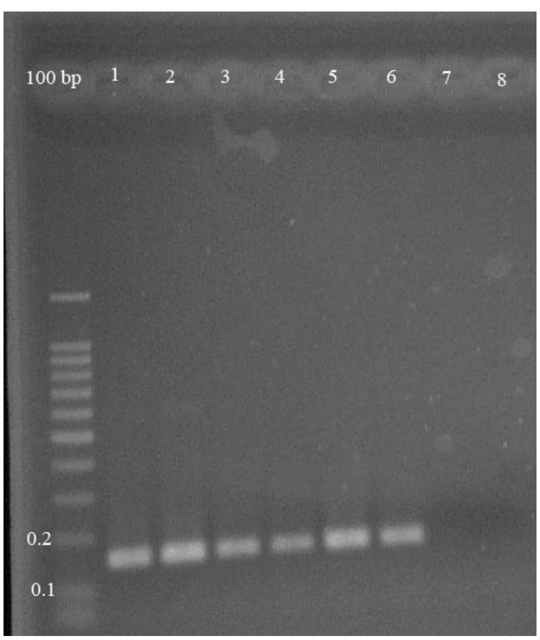

Figure 5. PCR amplification of *Verticillium dahliae* isolates with primer sets, VTP1-2F andVTP1-2R (expected band size is 155bp). The primers are designed based on *Verticillium dahliae* extracellular trypsin protease (VTP1) gene. Lane1, 100bp ladder; lanes 1-4, isolates from Minnesota; lane 5, isolate from North Dakota; lanes 6-7, isolates from Nebraska.

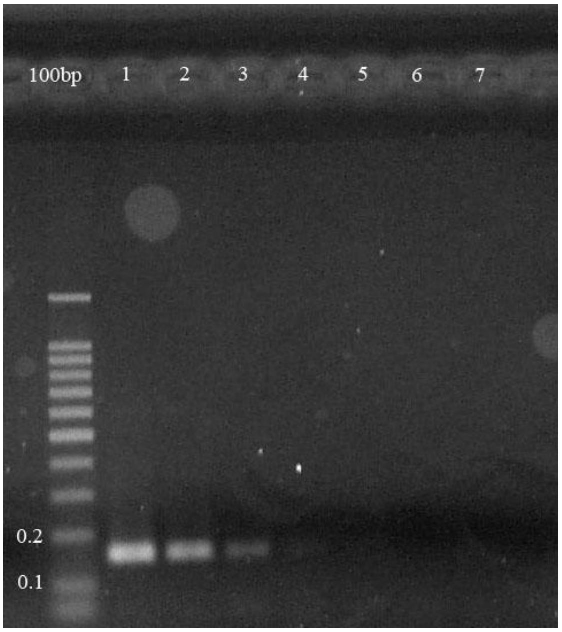

Figure6. PCR amplification of a *Verticillium dahliae* isolate at different DNA concentrations using the primer set, VTP1-2F andVTP1-2R. Lane 1, DNA concentration of 1ng; Lane 2, DNA concentration of 0.1ng; Lane 3, DNA concentration of 0.01ng; Lane 4, DNA concentration of 1pg; Lane 5, DNA concentration of 0.1pg; Lane 6, DNA concentration of 0.01pg; Lane7 water blank.

Support of Irrigated Potato Research in North Dakota-2007
Submitted to NPPGA

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Executive Summary
Irrigated potato production accounts for approximately one half or more of the state's total potato production. Irrigated potato production differs significantly from non-irrigated production. Since most of the irrigated potato production is used in the production of French fries, the spectrum of cultivars grown under irrigation differs significantly from those produced under non-irrigated production. In addition, the pressure of potato diseases, insect and weed pests and use of fertilizer all differ significantly in potatoes produced under irrigation than those produced under non-irrigated conditions. Therefore, it is important to perform potato research under irrigated conditions.

Rationale
North Dakota State University has been involved in irrigated potato research for the past 18 years. Potato disease research trials performed under irrigated conditions were done on a very limited basis from 1988 to 1994 with small trials being conducted near Lisbon, ND (1988-1991) and Park Rapids, MN (1991-present). During the mid-1990's potato cultivar, physiology and nitrogen management trials were performed under irrigation near Oakes and Carrington, ND. Irrigated potato research trials performed by the NDSU were expanded considerably after 1995 with funding from the Minnesota Area II. This funding allowed potato disease research to be conducted near Staples, Hollandale Browerville, and Long Prairie MN, in addition to irrigated potato research trials that were being conducted near Park Rapids, MN and near Dawson/Tappen, ND.

In 1998, the Red River Valley Potato Growers Association (RRVPGA) supported irrigated potato research trials in the area of cultivar improvement, potato physiology, nitrogen management along with considerable efforts in disease and insect management. The support, in the amount of $20,000, allowed irrigated potato research to be conducted near McCleod, ND in 1998 and near Glyndon, MN in 1999; irrigated research locations very near to NDSU at Fargo, ND. In 2000 through 2002, irrigated potato research was moved to central North Dakota, near Dawson, ND. In 2006, total costs of performing irrigated potato research near Dawson, ND at the NPPGA research site was nearly $40,094 (see itemized expenses below). These costs involved general maintenance (tillage, cultivation, irrigation, fertility management, application of all herbicides, fungicides and insecticides, etc.) in addition to assisting in planting and harvest operations.

Procedures

Irrigated potato research will be performed near Tappen, ND, at the NPPGA irrigated research site. Research trials to be conducted include cultivar improvement, factors affecting sugar end disorder, nutrient management, weed control, tuber disease management, and seed piece decay. In addition, the funding for the Tappen plot coordinator and additional labor facilitates the use of the NPPGA site by all potato research projects by coordinating and performing soil tillage, irrigation management, making all herbicide and fungicide applications for weed and foliar disease control , as well as providing the much needed labor during harvest operations.

The specific potato research projects performed at the NPPGA site are listed below. Results from many of these trials can be found elsewhere in this report or online at North Dakota State University (disease control trials at: http://www.ndsu.nodak.edu/instruct/gudmesta/lateblight/)

Research Projects Conducted at NPPGA Site in 2007:

Plant Pathology

Acc #	Trial Name	Investigator
600	Seed Increase- disease screening	Gudmestad
1500	Foliar Fungicides - Standard	Gudmestad
1600	Foliar Fungicides - Experimental	Gudmestad
1900	Sugar End / Water Volume Evaluation	Gudmestad
G-2200	Phytotoxicity	Gudmestad
S-2300	Red Norland Increase	Secor
S-2500	Pinkeye	Secor
S-2600	Skinning	Secor
2700	Seed Treatment	Secor
3000	Stem End Evaluation	Gudmestad
3400	Pink Rot Fungicide screening	Gudmestad
4600	Advanced Clone Disease Screening	Secor
G-5500	NDSU Pink Rot / Pythium Leak	Gudmestad

Plant Sciences

	Trial Name	Investigator
	North Central Region - Reds	Thompson
	North Central Region - Chips	Thompson
	North Central Region - Processing	Thompson
	Tappen Chip	Thompson
	Tappen Processing	Thompson
	Tappen Specialty	Thompson
	Tappen Red Norland	Thompson
	Agzyme	Thompson
	Out of State Maintenance	Thompson
	Out of State Seedlings	Thompson
	Simulated Glyphosate Drift	Hatterman-Valenti
	Simulated Hail on Russet Norkotah	Hatterman-Valenti
	Herbicide Timing	Hatterman-Valenti
	Herbicide # 1	Hatterman-Valenti
	Herbicide # 2	Hatterman-Valenti
	Herbicide # 3	Hatterman-Valenti
	Micronutrients	Hatterman-Valenti
	Hill Geometry	Hatterman-Valenti

Proposed Budget:

Labor (1/2 time technician)	$19,407.00
Fringe Benefits	$6,98600
Total Labor	$26,393.00
Travel	$7,750.00
Materials and Supplies	$1,857.00
Total Proposed Budget	**$36,000.00**

Itemized Expenses Incurred in 2007:

Expenses incurred while performing potato research at the research farm in Tappen, ND during the 2007 growing season.

Labor		
	Salary	$18,783.78
	Hourly	$9,765.87
	Overtime	$3,829.81
	Labor Total	**$32,379.46**
Travel		
	Meals/Lodging	$1,609.50
	Vehicle Expenses (total miles = 16,716)	$9,428.90
	Travel Total	**$11,038.40**
Materials & Supplies		
	Winter wheat (estimated)	$50.00
	Diesel fuel (no charge)	$0.00
	Spring tillage (no charge)	$0.00
	Fall tillage (no charge)	$0.00
	Soil test (no charge)	$0.00
	Pre-plant fertilizer & spreader (estimated)	$2,600.00
	Liquid starter fertilizer	$0.00
	Equipment Rent	$6,000.00
	Telephone (weather station 12 months)	$400.00
	Materials & Supplies Total	**$9,050.00**
	Grand Total	**$52,467.86***

* Total expenses incurred in 2007 do not include expenditures for fungicide trials 1500 and 1600 conducted by Gudmestad and Secor.

Dryland potato desiccation with Aim (Carfentrazone-ethyl). Harlene Hatterman-Valenti and Collin Auwarter.

A study was conducted to evaluate adjuvants for use with Aim or a tank-mix of Aim and Reglone. Red Norland seed pieces (2 oz) were planted May 29, 2007 at the NDSU research site near Prosper, ND. The trial was conducted on clay loam soil with 3.4% organic matter and 6.9 pH. Plots were 4 rows by 25 ft arranged in a randomized complete block design with 4 replicates. Potato seed pieces were planted in 36 inch rows and 12 inch plant spacing. A fungicide maintenance program was utilized throughout the growing season. The desiccant treatments were applied September 7, using a CO2 pressurized sprayer equipped with 8002 flat fan nozzles with a spray volume of 20 GPA and a pressure of 40 psi.

Application Date:	9/7	9/14
Application Timing	'A'	'B'
Time of Day	8:00 AM	6:00 PM
Air Temp. °F	61	56
% Rel. Hum.	81	35
Wind Velocity (mph)	7	5
% Cloud Cover	10	0

Potato desiccation with carfentrazone-ethyl

	Rating date				9/11	9/11	9/14	9/14	9/21	9/21	10/1	10/1
	Rating data type: Desiccation				Stem	Lvs	Stem	Lvs	Stem	Lvs	Stem	Lvs
	DAA: 'A'-'B'				4	4	7	7	14-7	14-7	24-17	24-17
No.	Treatment Name	Rate	Unit	Appl Code								
1	AIM	3.2	fl oz/a	AB	15ab	28b	21b	40c	45c	94b	94b	100a
	N-Tense	1	qt/a									
2	AIM	2	fl oz/a	AB	10bc	31b	18b	58b	73b	99a	100a	100a
	Reglone	1	pt/a									
	MSO	1	qt/a									
3	AIM	2	fl oz/a	AB	20a	53a	34a	78a	79a	100a	100a	100a
	Reglone	1.5	pt/a									
	MSO	1	qt/a									
4	AIM	3.2	fl oz/a	AB	8c	18c	13b	29d	39d	90c	94b	100a
	MSO	1	qt/a									
5	Untreated				0d	0d	0c	0e	0e	0d	0c	0b

Means followed by same letter do not significantly differ (P=.05, LSD)
Mean comparisons performed only when AOV Treatment P(F) is significant at mean comparison OSL.

Treatments of Aim mixed with Reglone performed best. The treatment of Aim at 2 oz/A with Reglone at 1.5 pt/a showed greater stem and leaf desiccation at 4 and 7 days after application than other treatments. At 24 DAA, treatments with only Aim (no Reglone) showed complete death of leaves but slightly less necrosis of the stems.

Influence of growth stage on potato injury from simulated glyphosate drift. Harlene Hatterman-Valenti and Collin Auwarter.

A study was conducted at the Northern Plains Potato Grower's Association Irrigation Research site near Tappen, ND to evaluate simulated glyphosate drift applied to Russet Burbank potato. The study was conducted on loamy sand soil with 1.8 % organic matter and 7.7 pH. Onions were grown during 2006. Plots were 4 rows by 25 ft arranged in a randomized complete block design with four replicates. Seed pieces (2 oz) were planted on 36 inch rows and 12 inch spacing on May 10, 2007. The objective of this study was to compare the injury from glyphosate applied at the tuber hooking (TH), tuber initiation (TI), early tuber bulking (EB), and late tuber bulking/early senescence stage (LB). Glyphosate was applied at rates one-third, one-sixth, one-twelfth, and one-twenty-forth the standard use rate (0.25, 0.125, 0.0625, and 0.0313 lb ae/A) on July 6, July 26, and August 23 on the TI, EB, and LB stages, and at 0.25 lb ae/A on June 20 for the TH stage with a CO_2 pressurized sprayer equipped with 8002 flat fan nozzles with a spray volume of 20 GPA and a pressure of 40 psi. The amount of AMS added to the spray solution was reduced accordingly. Potatoes were machine harvested September 25 and graded a few weeks later. Application, environmental, crop, and yield data are listed below:

Date:	6/20/07	7/6/07	7/26/07	8/23/07
Treatment:	TH	TI	EB	LB
Air temperature (F):	75	81	70	64
Rel. hum. (%):	48	40	97	77
Wind (mph):	3	10	3	7
Soil moisture:	adequate	above normal	above normal	above normal
Cloud cover (%):	0	0	100	25

Potatoes treated with glyphosate at the TH stage had significantly lower yield of tubers >4 oz than the untreated, 51 cwt/A compared to 451 cwt/A. Potatoes treated with 0.25 lb/A glyphosate earlier in the growing season (TH or TI) had >70% cull tubers (<4 oz). Potatoes treated at the EB stage showed little total yield effects compared to the untreated, however potatoes treated at the EB stage yielded higher at the 0-4, 4-6, and 6-10 oz and yielded lower at the 10-12, 12-14, and >14 oz sizes. Potatoes treated with 0.25 and 0.125 lb/A glyphosate at the LB stage showed a significant yield loss compared to the untreated. Potatoes treated with 0.25 lb/A at the LB stage had a yield loss of 200 cwt/A and potatoes treated with 0.125 lb/A at the LB stage had a yield loss of 100 cwt/A compared to the untreated. Daughter tubers are being stored throughout the winter to determine if daughter tubers from plants treated with glyphosate show any affects compared to daughter tubers from plants not treated with glyphosate.

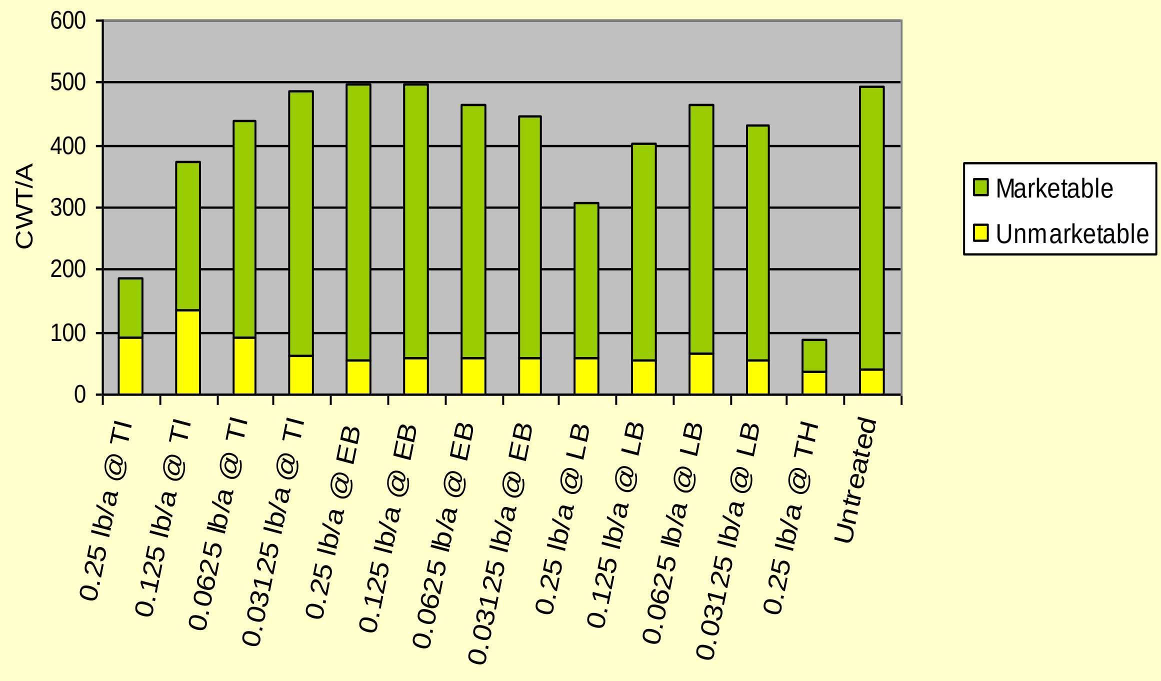


Figure 1. Yield of marketable and unmarketable tubers

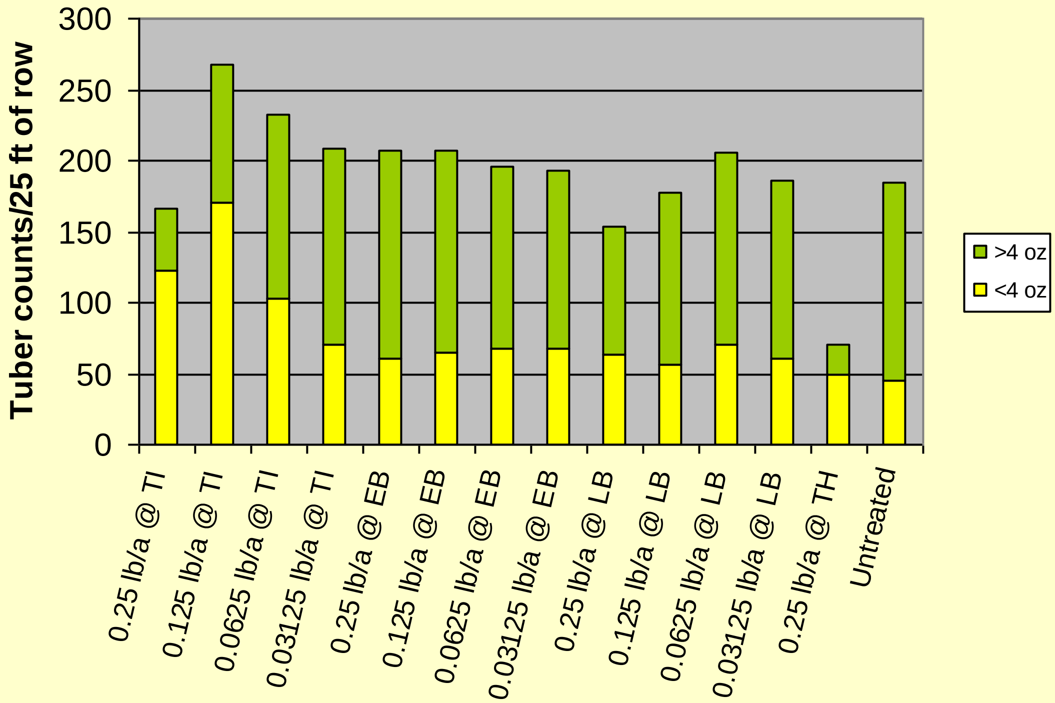


Figure 2. Effect of glyphosate on total count of tubers

<u>Influence of hill geometry on irrigated potato yield</u> – Harlene Hatterman-Valenti and Collin Auwarter.

A field trial was conducted at the Northern Plains Potato Grower's Association Irrigation Research site near Tappen, ND to evaluate the effect of various hill shapes on Russet Burbank potato yield. The study was conducted on loamy sand soil with 1.8% organic matter and 7.7 pH. The previous crop was onion. Individual plots were four 50-ft long rows arranged in a randomized complete block design with 4 replicates. Seed pieces (2oz) were planted May 8, 2007 with a 36-inch row spacing and 12 inches between seed pieces. Treatments consisted of: 1) No hill, 2) Regular hill, 3) Furrow planting, 4) "M" shaped hill, and 5) Flat top hill. Every 2 weeks throughout the growing season starting shortly after tuber initiation (July 13-September 6) 5 plants (shoots, tubers, and roots) per treatment in each rep were measured, counted, and weighed. A maintenance program was conducted throughout the growing season to apply pesticides. Potatoes were roto-beaten September 26, and harvested September 27. Tubers sat in storage until mid-December, when they were graded for yield.

Table 1. Total tuber counts at harvest after 5 seasonal digs:

Trt.	Name	<4oz	4-6oz	6-10oz	10-12oz	12-14oz	>14oz	Total
		-------------------Counts of Tubers in 37.5 rowft.--------------------						
1	Flat Top Hill	96a	60ab	90a	22ab	15abc	18bc	301a
2	No Hill	93a	70a	84a	18b	10c	10c	285ab
3	Furrow	61b	47c	80a	26a	19a	30a	263b
4	Regular Hill	81ab	58b	83a	17b	12bc	12c	262b
5	‘M’ Shaped Hill	86a	57bc	95a	26a	16ab	22ab	301a

Table 2. Potato yield and grade:

Trt.	Name	<4oz	4-6oz	6-10oz	10-12oz	12-14oz	>14oz	Total	>4oz
		-----------------------------------Cwt/A-----------------------------------							
1	Flat Top Hill	60a	72ab	170a	58ab	48abc	76bc	483a	423a
2	No Hill	56a	85a	158a	47b	32c	44c	422b	366b
3	Furrow	37b	58c	152a	68a	60a	126a	500a	463a
4	Regular Hill	48ab	71b	155a	45b	37bc	49c	406b	358b
5	‘M’ Shaped Hill	54a	69bc	181a	68a	51ab	90ab	512a	458a

The furrow treatment generally produced fewer total tubers. However, it had the least amount in categories <4, 4-6, and 6-10 oz, and the most in 10-12, 12-14, and >14 oz. When comparing the furrow treatment against the others in overall yield, similar results occurred, less cwt/a for the small grades (<4, 4-6), and 6-10 but greater in 10-12, 12-14, and >14 oz grades. In the >14 oz cwt/a category, the furrow treatment had 126 cwt/a compared to the second highest, 'M' shaped hill with 90 cwt/a. Overall, the 'M' shaped hill had the highest yield with 512 cwt/a, followed by the furrow with 500 cwt/a, and the flat top hill with a yield of 483 cwt/a. Regular hill had the lowest yield with 406 cwt/a, which was worse than the no hill with 422 cwt/a. Results were attributed to weather and possibly to row marking prior to planting. 'M' shaped hill had the highest overall yield, however the furrow treatment generated the highest marketable yield (>4 oz), with a cwt/a of 463. The furrow treatment only had a 7% reduction from overall weight to marketable whereas the next highest yielding treatments averaged reduction was 12%.

Plant sampling throughout the growing season did not show a lot of differences. One thing noticed at every dig the furrow treatment had the least amount of below ground stem and root weight due to the shallow planting depth. Early samples from the furrow treatment indicated that the tuber weights and the largest tuber weight lagged behind the other treatments, however by the forth sampling period (August 23) the furrow treatment had the largest weight in tubers. This was similar to the final sampling and carried on into the overall yield.

<u>Season-long weed control in irrigated potatoes –</u> Harlene Hatt.erman-Valenti and Collin Auwarter.

A field trial was conducted at the Northern Plains Potato Grower's Association Irrigation Research site near Tappen, ND to evaluate various herbicides and herbicide combinations for season-long weed control in Russet Burbank potato. The study was conducted on loamy sand soil with 1.8% organic matter and 7.7 pH. Onion was the previous crop. Plots were four 3 ft wide rows that were 25 ft long with 5 ft of red spacer potatoes between replicates. Treatments were arranged in a randomized complete block design with 4 replicates. Seed pieces (2oz) were planted May 10, 2007 with 12-inch spacing between seed pieces. Treatments were sprayed directly after hilling (pre) and/or when plants were 8-12 inches in height (post) using a CO_2-pressurized sprayer equipped with 8002 flat-fan nozzles with a spray volume of 20 GPA and a pressure of 40 psi on June 5 and June 20. Potatoes were machine harvested September 18 and graded in December.

Application, environmental, crop, and weed data are listed below:

Date:	6/5/07	6/20/07
Treatment:	PRE(A)	POST(B)
Air Temperature (F):	52	75
Rel Hum. (%):	63	48
Wind (mph):	5	3
Soil Moisture:	adequate	adequate
Cloud Cover (%):	0	0

Table 2. Potato injury and weed control:

Trt.	Name	Rate	App	------------6/29------------ ---------% Control---------			6/29	--------------9/6--------------- ----------% Control----------		
			Code	LQ	RRPW	GF	Injury	LQ	RRPW	GF
1	Untreated			0c	0c	0c	0c	0c	0c	0b
2	Chateau	1.5oz	A	99a	99a	100a	3c	91a	94ab	99a
	Outlook	13.5floz	A							
3	Chateau	1.5oz	A	98a	100a	99a	13a	90ab	94ab	100a
	Dual Magnum	1pt	A							
4	Chateau	1.5oz	A	95a	96a	96a	10ab	81b	89b	98a
	Prowl	2.4pt	A							
5	Chateau	1.5oz	A	98a	100a	97a	4bc	91a	98a	100a
	Eptam	3.4pt	A							
6	Dual Magnum	2pt	A	89a	94ab	100a	0c	99a	100a	100a
	Reflex	1pt	A							
7	Dual Magnum	2pt	A	90a	98a	100a	0c	96a	98a	98a
8	Reflex	1pt	A	35b	94ab	96a	0c	93a	100a	100a
9	Matrix	1.5oz	B	94a	100a	99a	0c	98a	100a	100a
	MSO	1pt	B							
10	Sencor	0.5lb	A	88a	88b	99a	0c	95a	94ab	100a
	Dual Magnum	1pt	A							
11	Prowl	2.4pt	A	95a	98a	98a	0c	93a	98a	100a
	Sencor	0.5lb	A							
12	Sencor	0.5lb	B	100a	100a	100a	0c	99a	100a	100a
	Select	10floz	B							
	Outlook	21floz	B							
	MSO	1pt	B							

Table 3. Effect of herbicides on potato yield and grade:

Trt.	Name	Rate	App Code	<4oz	4-6oz	6-10oz	10-12oz	12-14oz	>14oz	Total	>4oz
				---------------	---------------	---------------	---------------	CWT/A	---------------	---------------	---------------
1	Untreated			78a	118a	191a	45cd	34b-e	34a	499abc	421b
2	Chateau	1.5oz	A	70a-d	111a	173a	51bcd	26de	47a	478cd	409bc
	Outlook	13.5floz	A								
3	Chateau	1.5oz	A	66a-d	103a	184a	55a-d	37b-e	40a	486bcd	419b
	Dual Magnum	1pt	A								
4	Chateau	1.5oz	A	73abc	105a	170a	39d	24e	38a	448d	376c
	Prowl	2.4pt	A								
5	Chateau	1.5oz	A	65a-d	105a	197a	54a-d	33cde	31a	485bcd	420b
	Eptam	3.4pt	A								
6	Dual Magnum	2pt	A	61cd	98a	206a	60abc	40a-d	56a	522ab	461a
	Reflex*	1pt	A								
7	Dual Magnum	2pt	A	72abc	108a	198a	63abc	29cde	42a	512abc	440ab
8	Reflex*	1pt	A	57d	94a	190a	64ab	49ab	46a	500abc	442ab
9	Matrix	1.5oz	B	64bcd	103a	194a	65ab	54a	47a	527a	463a
	MSO	1pt	B								
10	Sencor	0.5lb	A	75ab	94a	202a	67ab	35b-e	40a	512abc	437ab
	Dual Magnum	1pt	A								
11	Prowl	2.4pt	A	57d	101a	195a	70a	43abc	51a	517ab	460a
	Sencor	0.5lb	A								
12	Sencor	0.5lb	B	66a-d	108a	199a	55a-d	34b-e	49a	511abc	445ab
	Select	10floz	B								
	Outlook	21floz	B								
	MSO	1pt	B								

* Reflex currently is not labeled for use on potatoes

All treatments showed good weed control throughout the season. There was some injury in the Chateau treatments (1.5 oz/a + additional herbicide) as emerging stems were less than 2" below soil surface after hilling. This had an effect on yield as all Chateau treatments had lower yields compared with the other treatments, including the untreated. Weed pressure was not heavy due to the heavy rainfall shortly after hilling, which washed out emerging weed seedlings. Thus, the untreated yielded comparatively well to others. The highest yielding treatment was Matrix @ 1.5 oz/a + MSO @ 1 pt/a applied post.

Adjuvant effect on dryland potato desiccation with Reglone. Harlene Hatterman-Valenti and Collin Auwarter.

A study was conducted to evaluate adjuvants for use with Reglone. Red Norland seed pieces (2 oz) were planted May 29, 2007 at the NDSU research site near Prosper, ND. The trial was conducted on clay loam soil with 3.4% organic matter and 6.9 pH. Plots were 4 rows by 25 ft arranged in a randomized complete block design with 4 replicates. Potato seed pieces were planted in 36 inch rows and 12 inch plant spacing. A fungicide maintenance program was utilized throughout the growing season. The desiccant treatments were applied September 7, using a CO2 pressurized sprayer equipped with 8002 flat fan nozzles with a spray volume of 20 GPA and a pressure of 40 psi. Environmental conditions at the time of application included: 61°F air temp., 81% Rel. Hum., 7 mph wind velocity, and 10% cloud cover.

Effect of adjuvant on potato desiccation using Reglone.

	Rating date			9/11	9/11	9/14	9/14	9/21	9/21	10/1	10/1
	Rating data type:										
	Desiccation			Stem	Lvs	Stem	Lvs	Stem	Lvs	Stem	Lvs
	DAA			4	4	7	7	14	14	24	24
No.	Treatment Name	Rate	Unit								
1	Reglone	2	pt/a	33.8a	60.0b	40.0b	85.0b	91.3a	98.8a	98.8a	100.0a
2	Reglone	2	pt/a	32.5a	67.5ab	41.3b	92.5a	95.0a	100.0a	100.0a	100.0a
	Preference	0.25	%v/v								
	Interlock	2	fl oz/a								
3	Reglone	2	pt/a	40.0a	71.3ab	52.5a	91.3a	95.0a	100.0a	100.0a	100.0a
	AG 06011	6	fl oz/a								
4	Reglone	2	pt/a	30.0a	68.8ab	40.0b	85.0b	93.8a	100.0a	100.0a	100.0a
	AG 05006	0.5	% v/v								
	Interlock	2	fl oz/a								
5	Reglone	2	pt/a	35.0a	67.5ab	42.5b	88.8ab	95.0a	100.0a	100.0a	100.0a
	AG 07042	0.5	% v/v								
	Interlock	2	fl oz/a								
6	Reglone	2	pt/a	37.5a	75.0a	42.5b	91.3a	95.0a	100.0a	100.0a	100.0a
	AG 07042	0.5	% v/v								
	Interlock	2	fl oz/z								
7	Untreated			0.0b	0.0c	0.0c	0.0c	0.0b	0.0b	0.0b	0.0b

Means followed by same letter do not significantly differ (P=.05, LSD)
Mean comparisons performed only when AOV Treatment P(F) is significant at mean comparison OSL.

The treatments were applied when the plants were beginning to senescence. All provided good results at both 14 and 24 DAA. Reglone with AG06011 showed slightly better desiccation early after application and provided greater stem necrosis at 7 DAA compared with others, but all were equivalent at 14 DAA.

Annual Report, 2007: Entomology, University of Minnesota

Ted Radcliffe and Jeff Davis

1. Host Plant Resistance to Aphids and Viruses:

The University of Minnesota Potato Program has for years had the goal of developing potato breeding lines incorporating durable resistances to PVY, PLRV, late blight and aphids through introgression of genes from wild potato species using traditional breeding practices. In previous research, we identified numerous sources of resistance to aphids in wild potato germplasm, e.g., *Solanum etuberosum*, *S. bulbocastanum* and *S. stoloniferum*, but only recently have we begun to understand the genetic bases of these resistances.

Among our advanced breeding lines, we have identified two unique sources of resistance to aphids and viruses. One potato clone (HPR24) consistently expressed field and greenhouse resistance to PLRV and all strains of PVY (resistance was quantified using visual identification, poly- and monoclonal DAS-ELISA and RT-PCR). HPR24 has also shown extreme resistance to green peach aphid and potato aphid, reducing reproduction of both aphids 84% when compared to cv. Russet Burbank. HPR24 was identified as containing two PVY resistance genes, Ry_{adg} and Ry_{sto}, as well as *PLRV.1*, a marker for PLRV resistance. HPR24 was crossed with susceptible cv. Chieftain, producing an F_1 population.

A second source of resistance was derived from a set of somatic fusions between *Solanum bulbocastanum* (PI 245310) and *Solanum tuberosum* created by Dr. J.P. Helgeson (USDA, U. Wis.) to impart late blight resistance. Crosses between one of the BC1s and the BC2, made by Dr. Christian Thill to introgress this source of late blight resistance into current Minnesota breeding material created two separate populations; 40 new BC2s and 20 BC3s. These populations have also been screened for aphid and virus resistance. In addition, these lines contain the *RB* gene, a durable broad-spectrum late blight resistance gene from *S. bulbocastanum*. Forty-four plant lines were resistant to aphids and resistance levels were equal to or less than *S. bulbocastanum*, reducing green peach aphid and potato aphid population growth rates by 76% and 80%, respectively, when compared to susceptible cultivars. One line (K7G-319) was resistant to both aphid species in the greenhouse and to green peach aphid in the field. Twenty-five lines were resistant to both PVY and PLRV, both in the field and greenhouse. No plant lines were asymptomatic expressers. Thirty-four plant lines contain *RB* and nine of those were resistant to green peach aphid.

We have pyramided resistances to PVY, PLRV, green peach aphid, potato aphid and late blight into one potato clone which can be used as a breeding source for multiple resistance factors.

2.1 Marker Assisted Selection

Over the past five years, we have identified several novel sources of resistance to PVY, PLRV, to two key virus vectors, green peach aphid, potato aphid, and to late blight among two advanced potato breeding lines (one from the MN breeding program, one from the USDA, Univ. Wis. Program). Both lines have wild potato species in their parental backgrounds. These resistances have since been pyramided into several potato clones providing sources for incorporation of multiple resistance factors into future breeding lines. Durable sources of resistance to PVY, PLRV, green peach aphid, potato aphid and late blight now exist in our program. These sources of resistance need to be incorporated into commercially acceptable cultivars. We are testing the hypothesis that MAS can be used to accelerate development of potato cultivars that pyramid sources of aphid, virus and late blight resistance. We hope that through the possibility of accelerated selection and directed breeding made possible by MAS we can hasten delivery of cultivars incorporating these resistance traits. Use of MAS could enable us to screen and select progeny for resistance genes prior to their being field tested for resistance expression. If this approach proves successful it could reduce the expense and time needed to produce cultivars with acceptable tuber quality.

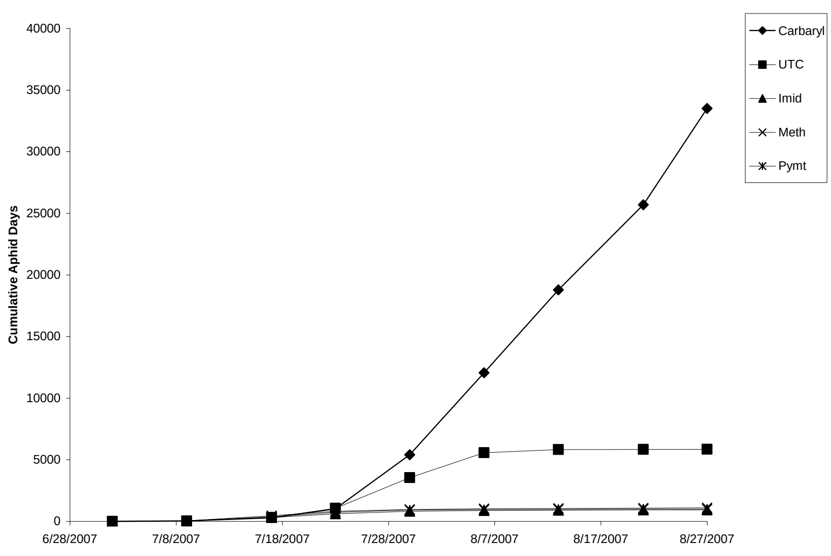
Among two of our advanced potato breeding lines, we have identified novel sources of resistance to aphids (green peach aphid and potato aphid) and viruses (PVY and PLRV), and a source of resistance to late blight. We have identified molecular markers for each of these resistances which can be used in MAS. The markers available for PVY and late blight are for independent, major resistance genes; Ry_{adg}, Ry_{sto}, $Ry_{f\text{-}sto,}$, and *RB*. Potato leafroll resistance is known to be quantitatively inherited with a single marker, *PLRV.1,* accounting for 60% of phenotypic variance. The markers we have identified for green peach aphid and potato aphid resistance are also quantitative (Davis 2006).

Marker assisted selection has been used in potato breeding for single major resistance genes, but only a single recent instance for multiple (four) major resistance genes. No program has reported the use of both major resistance gene markers and quantitative trait loci (QTLs) for MAS in potato. In our program we are using MAS to introgress four major resistance genes and three QTLs. We have crossed commercial cultivars with resistant breeding lines to pyramid multiple resistances with acceptable production characteristics. These clones will be placed into tissue culture to preserve and maintain them for future research and potato breeders.

2. Moderate Host Plant Resistance

Comprehensive field and greenhouse studies were undertaken to assess 49 commercial potato cultivars for resistance to green peach aphid and potato aphid. In greenhouse life table studies, the intrinsic rate of increase (r_m) of green peach aphid was lowest (0.167) on cv. Russet Norkotah and highest (0.350) on cv. Red La Soda. Aphid/predator population models indicated that green peach aphid populations would remain stable for 20 days on Russet Norkotah (resistant) whereas on Red La Soda (susceptible) aphid density would exceed 54,000 per plant. Simulation models combining insecticides with host plant resistance indicated three insecticide applications would be necessary to maintain green peach aphid below the Minnesota recommended action threshold on Red La Soda for 21 days whereas just one application would provide equal control on Russet Norkotah. In 2007 field trials, however, we found no significant differences in green peach aphid numbers between these cultivars (ANOVA, *P*-value = 0.8603). Insecticides were effective in reducing aphid populations (see Fig. 1.). In the untreated control, aphid populations were brought below threshold by predators two weeks after carbaryl (Sevin XLR) applications to flare aphids ceased. Tubers were sent to Hawaii for virus indexing this winter, but the results of serological tests of leaves for virus are not yet available.

Fig. 1. Cumulative green peach aphid days (model simulation)



3. Row Spacing Experiment

Experiments were conducted summer 2007 to determine the effects in-row spacing (i.e., simulating stand gaps) would have on aphid landing rates and virus transmission. Previous experiments had shown that gaps of as little as 6.5 square feet significantly increased spread of PVY. Russet Burbank potatoes were planted 23 May in plots 8 rows wide, 50 ft long, with 36 in between rows. Treatments in 2007 consisted of five different in-row spacings; 8, 12, 18, 27, and 40 in. Treatments were arranged in a randomized complete block design with five replications each. All plots received weekly applications of Bravo Zn at 1-2 pt/acre for late blight control and Sevin XLR at 2 qt/acre to control potato leafhoppers. Two applications of SpinTor 2SC at 4.5 oz/acre were made to control Colorado potato beetle. 100 tubers from each plot were harvested 15 September and sent to Hawaii for winter grow-out. Leaves were sampled for virus indexing by ELISA. These assays will be completed in February 2008.

4. Potato virus survey in Minnesota winter trial and comparison of results of visual and serological virus indexing, 2005-2007

Jeff Davis and Ted Radcliffe

Virus management in seed potato production is becoming increasingly challenging worldwide, with PVY presenting the greatest problem. What presently appears to be the greatest obstacle to managing PVY is the increasing prevalence of viruses that do not express obvious visual symptomology.

PVY^N was first detected in North America in 1990. In response, Canada and the U.S. implemented a PVY^N Management Plan and declared PVY^N to be a quarantine regulated disease. However, by 2004, it was evident that quarantine had failed to prevent spread and that PVY^N and $PVY^{N:O}$ recombinants (i.e. variants of PVY sharing the pathotype of PVY^N and serotype of PVY^O) were distributed widely across North America..

The prevalence in North America of PVY^N and $PVY^{N:O}$, alone or as mixed infections with PVA or PVS, has called into question the effectiveness of visual virus indexing for purposes of seed certification. A number of studies by other researchers have shown that visual indexing often fails to correctly identify PVY-infected plants. Error rates of 20-30% are were typical. By contrast, serological assay (ELISA) were >95% accurate.

In North America, as in Europe, $PVY^{N:O}$ recombinants appear to have a high rate of spread In Eastern Europe, $PVY^{N:O}$ has been reported predominant over PVY^N by 9:1. In Manitoba, incidence of $PVY^{N:O}$ recombinants increased from 0.7 percent in 1996, to 64 percent in 2002. In 2005 and 2007, we sampled potato seed lots entered by Minnesota seed potato growers into the Minnesota Department of Agriculture Seed Potato Certification Program winter grow-out on Oahu, Hawaii for PVY and other viruses.

Purposes of this research was to:(1) ascertain prevalence of PVY strains in Minnesota potato seed lots and, (2) determine how well results of visual virus indexing correlated with results of serological testing. In Hawaii, plants were visually indexed by MDA seed potato inspectors for expression of virus symptoms shortly after full stand emergence. Each year, leaflets were collected from two subsets of plants: (1) plants scored as visually positive for PVY and (2) plants scored as visually negative for PVY. Leaflets were transported on ice to Minnesota for serologically testing

Results obtained using PVY^{all} showed reasonable agreement with visual positives both in 2005 (71 percent) and 2007 (74 percent)(Table 1). However, visual indexing failed to detect many of the PVY positives indicated by DAS-ELISA. Of the plants scored as visually negative for PVY, 23 percent were ELISA positive in 2005 and 57 percent were ELISA positive in 2007. PVY strain identification by RT-PCR indicated a concurrent shift from PVY^{O} to $PVY^{N/NTN}$ variants. PVY^{O} accounted for 32 percent of total PVY in 2005, but only 18 percent in 2007. $PVY^{N:O}$ increased from 56 percent to 75 percent over the same time.

Table 1 Comparison of visual indexing and ELISA for detection of total virus

	2004-2005		**2006-2007**	
	Visual +ve	**ELISA +ve**	**Visual +ve**	**ELISA +ve**
Virus +ve	1129	795(70%)	118	309
Virus -ve	971	670 (69%)	40	136
Totals	2100		158	445

Another unexpected result of the DAS-ELISA testing of Minnesota seed lots entered in the winter grow-out was the high frequency of other viruses, particularly in 2007 (Table 2). Most surprising was the 67 percent level of PLRV-positives found in 2007, compared to just 1 percent PLRV-positives in 2005. The significance of such high levels of PLRV is unclear since only a handful of plants in the 2007 MDA winter grow-out expressed visual symptoms of PLRV, and no seed lot was rejected for recertification because of PLRV and no increase in PLRV was observed in the 2007 Minnesota seed potato crop. It is possible that the PLRV detected in the 2007 winter test represented current season spread.

Table 2 Virus types detected by ELISA in leaves visually scored as virus positive or

virus negative				
	2004-2005		**2006-2007**	
	Visual +ve ELISA +ve	**Visual -ve ELISA +ve**	**Visual +ve ELISA +ve**	**Visual -ve ELISA +ve**
PVY^{all}	565 (71%)	68 (23%)	87 (74%)	175 (57%)
PVS	185 (23%)	194 (66%)	25 (21%)	69 (22%)
PVA	27 (3%)	11 (4%)	5 (4%)	11 (6%)
PVM	12 (2%)	18 (6%)	41 (35%)	135 (44%)
PLRV	4 (1%)	5 (2%)	71 (60%)	216 (70%)
PVX	4 (1%)	5 (2%)	46 (39%)	84 (27%)
Total	797	301	118	309

Among plants PVY-positive by DAS-ELISA in the 2005 winter grow-out, RT-PCR showed 32 percent had PVY^{O}, 56 percent had $PVY^{N:O}$ and 12 percent had PVY^{NTN} (Table 3). Among PVY-positive plants in the 2007 winter grow-out, 19 percent had PVY^{O}, 75 percent had $PVY^{N:O}$ and 5 percent had PVY^{NTN}. Some seed lots in the 2007 winter grow-out had many missing plants suggesting the possibility that PVY^{NTN} incidence in the tubers may have been higher than leaf testing indicated.

Table 3 PVY strain and isolate as determined by RT-PCR		
	2005	**2007**
PVYO	32%	19%
PVYN	0%	1%
PVYN:O	56%	75%
PVYNTN	12%	5%

For purposes of seed potato certification PVY and PLRV are the viruses of primary concern. In Minnesota, seed lots are rarely failed due to any other virus. Accuracy of identification of these viruses in the winter grow-out is critical in two respects. False positives can cause rejection of a seed lot that should be recertified. False negatives can permit seed lots that are actually over tolerance to be recertified. The latter defeats the purpose of recertification because it fails to remove virus inoculums from the seed production system and can serve to perpetuate virus epidemics.

With PVY^{N} and $PVY^{N:O}$ recombinants now prevalent in North America, visual virus indexing may be unable to achieve the level of diagnostic accuracy required for a seed potato certification to be effective. Molecular testing (RT-PCR) is the only method that can provide absolute assurance that a potato seedling is free of virus. Serological testing (DAS-ELISA) is a more realistic alternative, but even that is time consuming and expensive compared to visual virus indexing. Serological testing of foliage from all the plants grown in a state seed potato certification program winter grow-out would be a formidable task and is perhaps impractical because of the handling time required to collect and process such a high volume of samples. Moreover, no single serological test is certain to detect all strains of PVY. For this reason, most U.S. and international seed potato certification regulations continue to specify visual indexing as the standard to be used.

5. Soybean aphid (*Aphis glycines* Matsumura) is a vector of PLRV

Experiments were undertaken to (i) determine if soybean aphid, *Aphis glycines* Matsumura, could acquire, retain, and transmit *Potato leafroll virus* (PLRV) and (ii) compare its feeding behavior with that of green peach aphid, *Myzus persicae* (Sulzer), on potato. Soybean aphid acquired PLRV 78% of the time, 73% and 70% retaining infectivity 72 h and 144 h, respectively. Soybean aphid transmitted PLRV at 9% efficiency. Electrical penetration graphs (EPG) showed no significant differences between the aphid species in pre-probe, xylem phase, sieve element salivation and phloem sap ingestion durations on potato. Prior to invasion of soybean aphid, soybean crop borders were commonly used by Minnesota and North Dakota seed potato growers to protect against *Potato virus Y* spread. Experiments were done to determine if soybean aphid infested soybean borders would increase PLRV spread. Cumulative soybean aphid days (CSBAD) on insecticide-treated borders were 636 in 2002, 3 in 2004, and 160 in 2005. Untreated borders had CSBAD of 15,139 in 2002, 708 in 2004, and 28,170 in 2005. PLRV spread in potatoes was not different with insecticide-treated and untreated borders in 2002 and 2004 ($\chi 2=0.034$, 1.085; df=1, 1; $P=0.8545$, 0.2977; respectively). In 2005, with extreme soybean aphid pressure, untreated borders had significantly greater PLRV spread ($\chi 2=8.385$; df=1; $P=0.0038$). This is the first indication that soybean aphid can transmit PLRV.

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Evaluation of Several Controlled Release Fertilizers for Irrigated Potato Production -2007-

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Summary: Field experiments were continued and expanded at the Sand Plain Research Farm in Becker, Minn. to evaluate the effects of controlled release fertilizers (CRFs) on yield and quality of 'Russet Burbank' potato. Fertilizers included two types of polymer coated urea (PCU), ESN and Kingenta; a Kingenta sulfur coated urea (Kingenta SCU); a blended fertilizer by Kingenta; and Nutrisphere Nitrogen (NSN). The CRF fertilizers applied at 40, 120, 200 and 280 lb N/A were compared with equivalent rates of urea. An additional 40 lb N/A was applied as diammonium phosphate in the starter to all treatments except the zero N control. All ESN was applied at emergence and hilling except for two treatments at the 200 lb N/A rate where ESN was applied preplant (6 days) or applied at planting. NSN was also applied at emergence and hilling. The other CRFs were applied at 160 or 240 lbs N/A and either preplant or at planting. All urea was split-applied between emergence and post-hilling, except two treatments were split applied at preplanting and emergence. In addition, one split post-hilling treatment was included to simulate fertigation. In general, differences in leaching were small, but urea applied preplant leached significantly more nitrate-N than some CRFs. However, CRFs applied at excessive N rates did not reduce leaching, but overall, when used at realistic N rates, CRFs do appear to reduce nitrate-N leaching compared with equivalent rates of soluble N applied in three applications. Soluble N applied in five applications was similar to CRFs in one application. Leaching with NSN (which is reported to be a urease inhibitor) tended to be lower than three splits of soluble N. Kingenta PCU and SCU applied at preplanting produced significantly higher total yields than conventional urea. Marketable yields with urea were similar to those with preplant Kingenta PCU, but lower than those with preplant Kingenta SCU. Yields with Kingenta PCU applied at planting at the 200 lb N/A rate had significantly higher total and marketable yield than treatments with soluble urea N. At equivalent N rates, significant differences in total and marketable yield were not seen between urea and ESN, Kingenta SCU applied at planting, NSN or the Kingenta Blend. ESN had the highest total yield with 160 lb N/A and the highest marketable yield at 240 lbs N/A applied at emergence. Applications of ESN preplant and at planting resulted in numerically lower yields than when applied at emergence, suggesting a more optimum N program when applied at emergence. ESN and NSN applied at emergence had similar yields to five splits of soluble N. Release of N from ESN generally followed the N uptake pattern for potato, although the release rate for Kingenta PCU was much slower. Residual inorganic N (nitrate-N + ammonium-N) was highest with the 5 split urea treatment and Kingenta treatments.

Improving nitrogen (N) use efficiency in potato is important both from a production/quality standpoint as well as an environmental perspective. One approach towards improving N use efficiency is to provide a source of N that is available during the times of high plant demand. Fertigation is one approach used to supply N in smaller doses through the season. One draw back of fertigation, however, is that N application is often needed after a rainfall when additional water is not. An alternate approach is the use of controlled release fertilizers. Previous studies have shown that potato yields are higher and nitrate-N leaching lower with polymer coated urea fertilizer (controlled release) compared with uncoated urea (quick release). However, because of the high cost of the controlled release fertilizer evaluated in those studies, its use could not be justified from an economic standpoint. Several more economical controlled release fertilizers have recently been manufactured that can be formulated to release N over various time intervals depending on the type of coating as well as soil temperature and moisture. The companies making these products include Agrium, Inc. which produces a polymer coated urea (PCU) called Environmentally Smart Nitrogen (ESN); Shandong Kingenta Ecological Engineering CO.,LTD. produces a PCU, a sulfur coated urea (Kingenta SCU) and a blend that incorporates both of these products plus micronutrients; and finally, Specialty Fertilizer Products which produces NutriSphere Nitrogen, which has been reported to be a urease inhibitor. These products may hold promise for improving potato yields on soils vulnerable to nitrate-N losses; however, specific effects of this fertilizer on potato yield and quality need to be evaluated.

The specific objectives of this study were to: 1) determine N release characteristics of ESN and Kingenta polymer coated urea (PCU) fertilizer in Minnesota sandy soils used for potato production, 2) characterize the yield and quality response of Russet Burbank potato to these fertilizers and additional CRFs (Kingenta SCU and NSN) applied at various N rates and timing, and 3) compare these fertilizers to urea applied at the same rates and at various times of application.

MATERIALS AND METHODS

The 2007 study is a continuation and expansion of previous studies on controlled release fertilizers for potato. The study was conducted at the Sand Plain Research Farm in Becker, Minnesota on a Hubbard loamy sand. Russet Burbank was the cultivar used for the study and the previous crop was rye. Selected soil chemical properties before planting were as follows (0-6"): pH, 6.8; organic matter, 1.5%; Bray P1, 31 ppm; ammonium acetate extractable K, Ca, and Mg, 87, 718, and 141 ppm, respectively; and DTPA extractable Zn, 0.7 ppm. Extractable nitrate-N and ammonium-N in the top 2 ft prior to planting were 11 lb/A and 15 lb/A, respectively. Prior to planting 250 lb/A 0-0-22-11-18 and 250 lb/A 0-0-60 were broadcast and incorporated with a moldboard plow.

Four, 20 ft rows were planted for each plot with the middle two rows used for sampling and harvest. Whole "B" seed was hand planted in furrows on April 26, 2007. Spacing was 36 inches between rows and 12 inches within each row. Each treatment was replicated 5 times in a randomized complete block design. Admire Pro was applied in-furrow for beetle control. Weeds, diseases, and other insects were controlled using standard practices.

Preweighed starter fertilizer was banded 3 inches to each side and 2 inches below the seed piece using a belt type applicator. The starter fertilizer was applied to all plots except for the control and consisted of 40 lb N/A and 102 lb P_2O_5/A as diammonium phosphate (DAP), 200 lb K_2O/A as potassium chloride and potassium magnesium sulfate, 30 lb Mg/A as potassium magnesium sulfate, 60 lb S/A as potassium magnesium sulfate, 2 lb Zn/A as zinc oxide, and 0.5 lb B/A as boric acid. For the control plots a modified starter without N was used and consisted of the same amount of P as triple superphosphate along with the same amounts of K_2O, Mg, S, B, and Zn.

There were five types of controlled release fertilizers along with uncoated urea (46-0-0) tested in this study. Shandong Kingenta Ecological Engineering CO.,LTD. manufactures a polymer coated urea (referred to as Kingenta PCU) (42-0-0), a sulfur coated urea (Kingenta SCU) (35-0-0), and a blended fertilizer (Kingenta Blend) (17-7.5-16) that incorporates Kingenta PCU, Kingenta SCU and several other micro-elements. Agrium, Inc., produces Environmentally Smart

Nitrogen (ESN) (44-0-0) which is also a polymer coated urea. NutriSphere Nitrogen (NSN) (46-0-0), produced by Specialty Fertilizer Products, has been reported as a urease inhibitor.

Twenty four treatments were tested and listed in Table 1.

Table 1. Treatments tested in the controlled release fertilizer study.

	Preplanting	Planting	Emergence & Hilling	Post-hilling	Total
	----------	----------lb N/A	----------	----------	
1.	0	0	0	0	0
2.	0	40 DAP	20 Urea	1 x 20 Urea	80
3.	0	40 DAP	60 Urea	1 x 60 Urea	160
4.	0	40 DAP	100 Urea	1 x 100 Urea	240
5.	0	40 DAP	140 Urea	1 x 140 Urea	320
6.	0	40 DAP	100 Urea	5 x 20 Urea	240
7.	60 Urea	40 DAP	60 Urea	0	160
8.	100 Urea	40 DAP	100 Urea	0	240
9.	0	40 DAP	40 ESN	0	80
10.	0	40 DAP	120 ESN	0	160
11.	0	40 DAP	200 ESN	0	240
12.	0	40 DAP	280 ESN	0	320
13.	200 ESN	40 DAP	0	0	240
14.	0	40 DAP+200 ESN	0	0	240
15.	120 ESN	40 DAP	0	0	160
16.	120 Kingenta PCU	40 DAP	0	0	160
17.	200 Kingenta PCU	40 DAP	0	0	240
18.	0	40 DAP+200 Kingenta PCU	0	0	240
19.	200 Kingenta SCU	40 DAP	0	0	240
20.	0	40 DAP+200 Kingenta SCU	0	0	240
21.	0	240 Kingenta Blend	0	0	240
22.	100 Urea	40 DAP	100 NSN	0	240
23.	0	40 DAP	120 NSN	0	160
24.	0	40 DAP	200 NSN	0	240

For the urea plots (treatments 2-8), plant emergence N applications were sidedressed as urea and mechanically incorporated. Preplant N applications for treatments 7 and 8 were preweighed and broadcast by hand six days before planting on April 20. Post-hilling N for treatment 6 was applied by hand as 50% granular urea and 50% granular ammonium nitrate and watered-in with overhead irrigation to simulate fertigation with 28% N. The five post-hilling applications took place on June 4, June 19, July 2, July 12, and July 25.

For the controlled release fertilizer plots, preplant N applications were also preweighed and broadcast by hand on April 20. For treatments with N applications at planting, the required amount of controlled release fertilizer was mixed in with the starter fertilizer and the treatments applied at emergence and hilling were sidedressed with the required amount of N. Preplanting fertilizer was applied on April 20, planting fertilizer on April 26, and emergence fertilizer was applied and hilled in on May 15.

Petiole samples were collected from the 4th leaf from the terminal on June 12, June 25, July 9, July 24, and August 6. Petioles were analyzed for nitrate-N on a dry weight basis. Vines were harvested from two, 10-ft sections of row, followed by mechanically beating the vines over the entire plot area on September 19. On September 28, plots were machine-harvested and total tuber yield, graded yield, tuber specific gravity, the incidence of hollow heart, and frying quality was measured. Sub-samples of vines and tubers were collected to determine moisture percentage and N concentrations, which were then used to calculate N uptake and distribution.

Release of N from the two types of polymer coated urea (ESN and Kingenta PCU) was determined by burying 3 grams of fertilizer in plastic mesh containers to the approximate depth of the fertilizer band. The plastic mesh containers were buried at preplant on April 20 and at planting on April 26. To simulate release from sidedress applications the mesh bags were buried about 2-3 inches below the surface of the hill on May 15. The mesh bags were retrieved at periodic times through the growing season, placed in paper bags, and then air dried. Prills were removed by hand and then weighed on a scale. The amount of weight loss was assumed to be equivalent to the amount of N released. NSN is a water soluble polymer and release rates using the mesh bag method are not possible. Similarly, SCU breaks apart slowly on contact with water, making it difficult to assess release rates with the mesh bag method.

A WatchDog weather station from Spectrum Technologies was used to monitor rainfall, air temperature, and soil temperature at the fertilizer band depth, approximately 10 inches below the top of the hill. At least three lysimeters were installed per treatment to collect soil water samples at the 4 foot depth (beyond the root zone) to determine the amount of inorganic N that could potentially be lost to the groundwater. Samples were taken at least once a week throughout the growing season and analyzed for nitrate-N and ammonium-N.

Two midseason soil samples were taken on June 15 and July 18 in all plots and consisted of 5 cores in one harvest hill to the 1 foot depth to determine inorganic N levels. After harvest, six soil cores to the 2 ft depth were collected in all plots to determine residual inorganic N levels. Soils were air dried, extracted with 2 N KCl, and then analyzed for nitrate-N and ammonium-N.

RESULTS

Weather

Rainfall and irrigation for the 2007 growing season (April 26-Sept 19) are provided in Figure 1. Approximately 14 inches of rainfall was supplemented with 19 inches of irrigation. In general, there were many small leaching events throughout the season, with several large events near the end or after harvest. Three major leaching events (greater than 1 inch of water leached) occurred at 107, 145, and 162 days after planting. Air and soil temperature measurements are provided in Figure 2.

Nitrogen Release from ESN and Kingenta PCU in Relation to Potato N Uptake

A generalized N uptake curve for potato grown at Becker is shown in Figure 3. Maximum N uptake rates occur between 40 and 80 days after planting. Figure 4 shows release of N from the coated fertilizers over the growing season based on ESN and Kingenta PCU applied at preplanting and planting as well as ESN at emergence.

ESN

Release of N from ESN tended to follow the demand of N by potato with maximum release between 20 – 90 days after planting. About 40% of the N had been released by the time the potato N uptake rate was starting to increase. Approximately 90% of the N was released by 80 days after planting for preplant fertilizer and by 90 days after planting for ESN applied at planting and emergence.

Kingenta PCU

Release of N from Kingenta PCU did not follow the same path as the uptake curve for potatoes; instead it followed a more linear path. At 40 days after planting, both applications had released about 35% of N, and only about 50% at 80 days after planting. Kingenta PCU applied preplant did not release 90% of its N until approximately 160 days after planting (vine harvest occurred on day 147) and Kingenta PCU applied at planting had not reached 90% released by day 169.

Tuber Yield and Quality

Urea

Table 2 shows the effects of N application rate, source, and timing on tuber yield and size distribution. Total and marketable yields increased with addition of N above the zero N control for both urea and controlled release N sources. The highest total and marketable yields for uncoated urea occurred with the simulated fertigation treatment of 240 lbs N/A. For the urea treatments applied at emergence and posthilling, increasing N rates did not necessarily increase total yield, but it did increase marketable yields. Timing of urea application did not make a difference in yields, but 160 lbs N/A applied at preplant and emergence had higher total yields but smaller tubers than 240 lbs N/A applied at the same time. In general, tuber size increased with increasing N rate.

Table 3 shows treatment effects on tuber quality. Increasing urea N rates showed an increase in the percent of potatoes disqualified by hollow heart, which coincides with an increase in large tubers over 10 ounces. The highest specific gravity and lightest chip colors for urea treatments occurred at 240 lbs N/A applied at emergence and posthilling (3 splits). It should be noted that chip color at harvest was high for all treatments and would have resulted in poor fry color.

ESN

For ESN, the highest total yields occurred at 160 lbs N/A applied at emergence or preplanting. The highest marketable yield, however, occurred at the 240 lb N/A emergence application due to an increase in tuber size. The 320 lb N/A rate typically resulted in decreased total and marketable yields; although tuber size was larger. There was no significant difference between total and marketable yields for urea and ESN. ESN, however, did have significantly higher yields of #2 potatoes.

N rate for ESN did not have a clear effect on tuber quality, but there was a trend due to timing for chip color. Applications at preplanting and planting tended to produce tubers that fried to lighter colors. When fried, ESN treatments produced a significantly darker bud end chip color than urea treatments, but the stem end colors were not different.

Kingenta PCU

Kingenta PCU applied at 240 lbs N/A at planting produced the highest total and marketable yields of this study. When Kingenta PCU was applied preplant, it resulted in significantly higher total yields than equivalent rates of urea, although marketable yields were not significantly different. Kingenta PCU had significantly more tubers from the less than 10 ounce categorey and higher yields of #2 potatoes, while urea produced more tubers in the 10 to 14 and greater than 14 ounce categories, which explains why marketable yields were the same. N timing and rate did not have an effect on tuber quality, except that Kingenta PCU applied at planting had a lower percent of disqualified potatoes from hollow heart. The preplant Kingenta PCU treatments had a significantly lower specific gravity than the tubers from the urea treatments.

Kingenta SCU & Kingenta Blend

The preplant Kingenta SCU produced higher total and marketable yields than Kingenta SCU applied at planting, and both Kingenta SCU treatments resulted in higher yields than urea treatments at equivalent rates. The Kingenta blend produced the lowest total and marketable yields of all the Kingenta products, but the yields were similar or slightly higher than comparable urea treatments. The only difference between urea, Kingenta SCU and Kingenta Blend with respect to tuber quality is seen in percent of hollow heart. Only Kingenta SCU and Kingenta Blend applied at planting resulted in less than 10% of tubers with hollow heart.

NSN

The NSN + Urea treatment produced the lowest total yield compared with the other NSN treatments, but this combination of fertilizers also produced a higher marketable yield than with NSN alone; however, differences were small and not statistically significant. The NSN + Urea treatment produced higher total and marketable yields than when urea alone was applied at preplant and at emergence (although differences were not statistically significant). This suggests that NSN was able to allow N to be available to the plants longer in the season. The NSN only treatments had a significantly higher amount of tubers over 14 ounces, but they also had a significantly lower stand count and stem count than urea treatments, which likely promoted the larger growth of tubers. These treatments were not significantly different from comparable urea treatments in total or marketable yields. Hollow heart and specific gravity generally did not differ between NSN and urea treatments, but the stem end chip color was significantly lighter with the NSN treatments.

Petiole Nitrate-N Concentrations

Petiole NO_3-N concentrations as affected by N rate, N source, and N timing are displayed in Table 4. As expected, petiole NO_3-N generally increased with increasing N rate for all N sources and decreased as the season progressed. Petiole NO_3-N levels with the 320 lb N/A rate applied at planting were generally the highest of any treatment, especially later in the season, and may explain the decrease in yield at this rate compared with lower rates if they stimulated vine growth at the expense of tuber bulking.

Differences between urea and ESN treatments were significant throughout the sampling dates, but the differences depended on the time of the season. Petiole NO_3-N was significantly higher with urea than with ESN on the first and second sampling dates. This pattern had reversed itself by the third date with petiole NO_3-N higher with ESN and continued on into the season, illustrating the slow release nature of ESN.

Petiole NO_3-N was typically lower with Kingenta PCU than urea treatments, although this was only significant on the second and third dates. This may be due to the very slow release of the Kingenta PCU, as seen in the release curves. Kingenta SCU and Kingenta Blend applied at planting were approximately the same for the first two dates and higher for the last three dates compared with urea, again displaying the slower release of these fertilizers. Kingenta SCU applied preplant followed a pattern similar to that of urea applied at planting, with an early spike that had decreased by over half of the petiole NO_3-N on the second date. No significant differences were seen between NSN only treatments and urea treatments in petiole NO_3-N.

Soil Nitrate-N and Ammonium-N Levels

Inorganic N levels as affected by treatment are shown in Table 5. As expected, the soil inorganic N levels tended to decrease as the season went on. Increasing N rates tended to increase soil nitrate-N levels, with 320 lbs N/A having the highest levels for both urea and ESN. Treatments had no effect on ammonium-N in July, otherwise N treatments did influence soil inorganic N. The two samples taken midseason showed that ammonium-N levels were typically higher than nitrate-N levels, but this pattern had reversed post-season.

Timing of N application did not seem to affect soil inorganic N for urea treatments, but 240 lbs N/A applied at planting for ESN and Kingenta PCU had consistently higher ammonium-N levels than when applied at preplant or emergence (for ESN). Kingenta SCU did not show this pattern. Both Kingenta PCU and ESN had significantly lower nitrate-N levels than urea in June, but at no other sampling date. Kingenta PCU did, however, have significantly higher residual nitrate-N levels than urea, due to the slow release nature of the fertilizer. This pattern is also seen with Kingenta SCU and Kingenta Blend, but was not significant. At equivalent N rates, NSN did not have significantly different soil inorganic-N levels compared with urea at any time during the season.

Nitrate-N Leaching

Soil water nitrate-N concentrations at the four foot depth for the control and 240 lb N/A treatments (40 lbs applied as DAP and the remaining 200 lb N/A either as ESN or urea/28%) are presented in Figure 5. The pattern shown is typical of all treatments and nitrate-N concentrations peaked between 50 and 100 days after planting, then declined, and increased again after vine harvest. The 5 split urea treatment peaked much later than the other fertilizers, most likely in response to the later post-hilling application.

Total nitrate-N leached beyond four feet over the growing season is seen in Figure 6. Overall, there were very few major leaching events in 2007, and since nitrate-N leaching is highly dependent on water percolation past the root zone, there were few significant differences seen between treatments. The major events that did occur happened later in the season, when nitrate-N concentrations were already on the decline.

In general, nitrate-N leaching increased with higher N rates, but significant differences in N rates were only seen with ESN. ESN applied at 320 lbs N/A had significantly more nitrate-N leaching than ESN applications of 160 lbs N/A applied at emergence. Timing of ESN application did not affect nitrate-N leaching.

The urea treatments appeared to have the highest amount of leaching, with the highest amount occurring at 160 lbs N/A of urea applied at preplant and emergence, but this was not significantly different than 240 lbs N/A urea applied at preplant and emergence nor 320 lbs N/A of urea applied at emergence and posthilling. Urea applied at preplant and emergence did, however, have significantly more leaching than ESN or Kingenta PCU applied at preplant at 240 lbs N/A. At equivalent rates, urea applied at preplant and emergence was not significantly different than Urea + NSN.

CONCLUSIONS

Based on four years of data with ESN on potatoes, the results show that this controlled release fertilizer has the potential to result in yields equal to or greater than those with conventional urea. Emergence appeared to be the best time for ESN application to optimize yields, and 160 -240 lbs N/A will produce the highest yields. Kingenta controlled release fertilizers in this study also show promise in producing yields similar to or greater than traditional urea, although timing of application to produce the best yields depends on the product. NSN appeared to perform similarly to equivalent rates of N from urea. Because this was a low leaching year, differences in leaching due to N source were small, although the controlled release fertilizers appear to reduce nitrate-N leaching, except when excessive (320 lb N/A) N rates are used.

Figure 1. Rainfall and irrigation over the 2007 growing season.

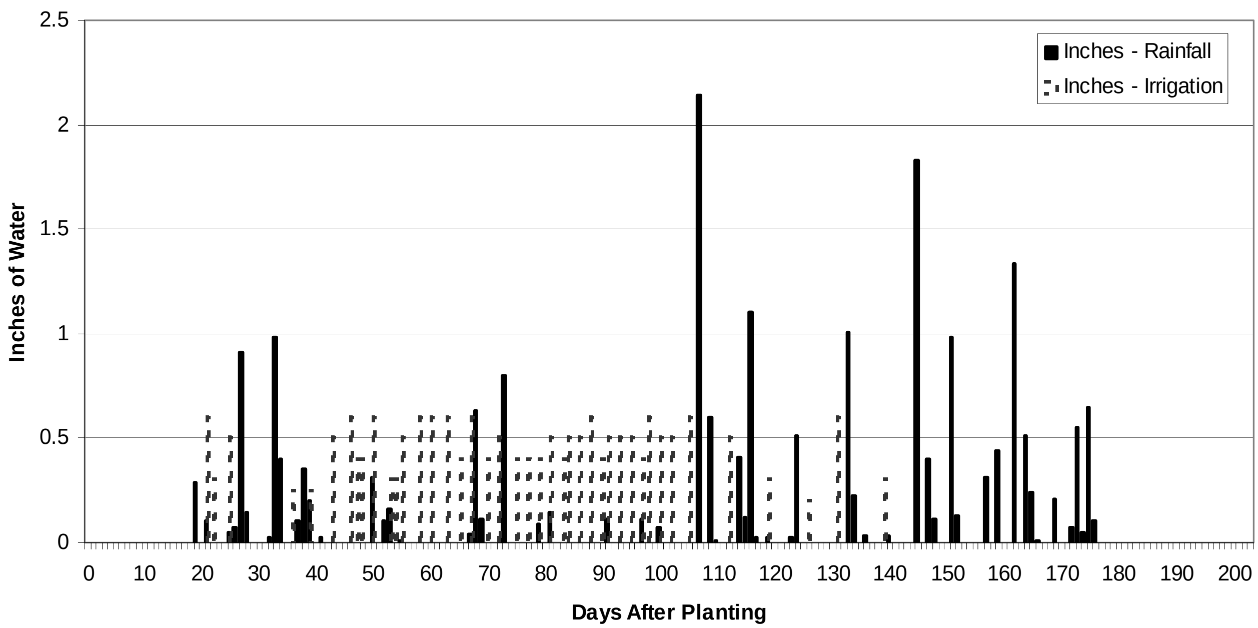

Figure 2. Average daily soil moisture and air and soil temperature at 10 inch depth below the top of the hill over the growing season.

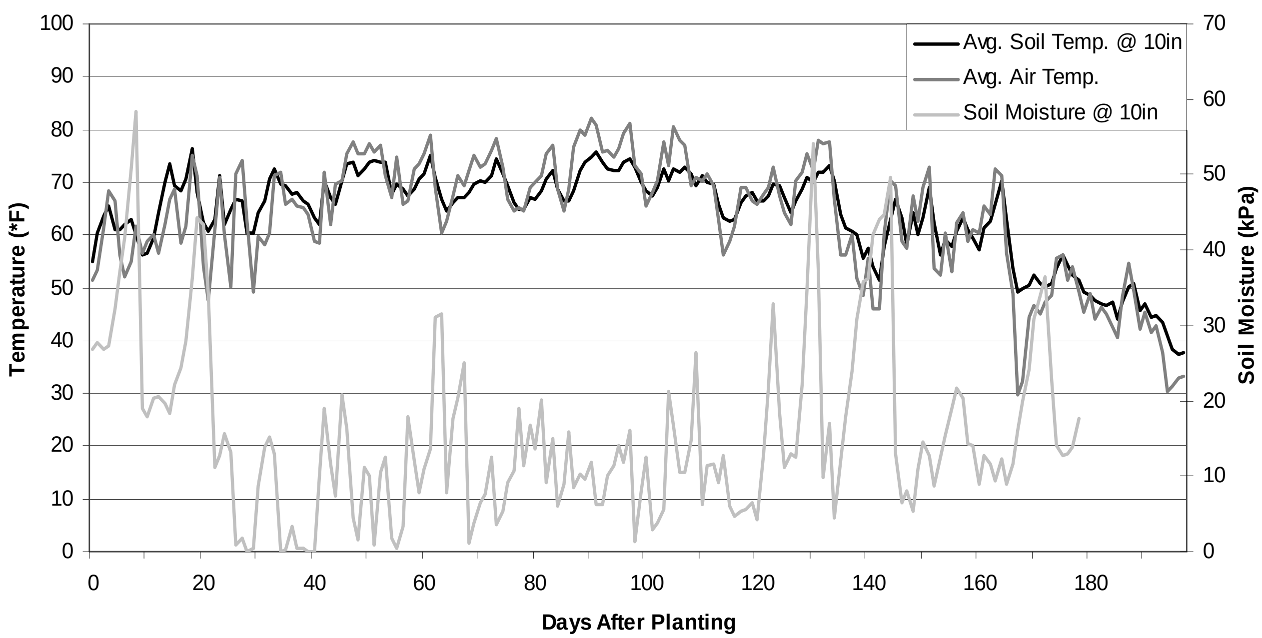

Figure 3. Generalized potato N uptake and growth – Russet Burbank, based on data collected from Becker, MN.

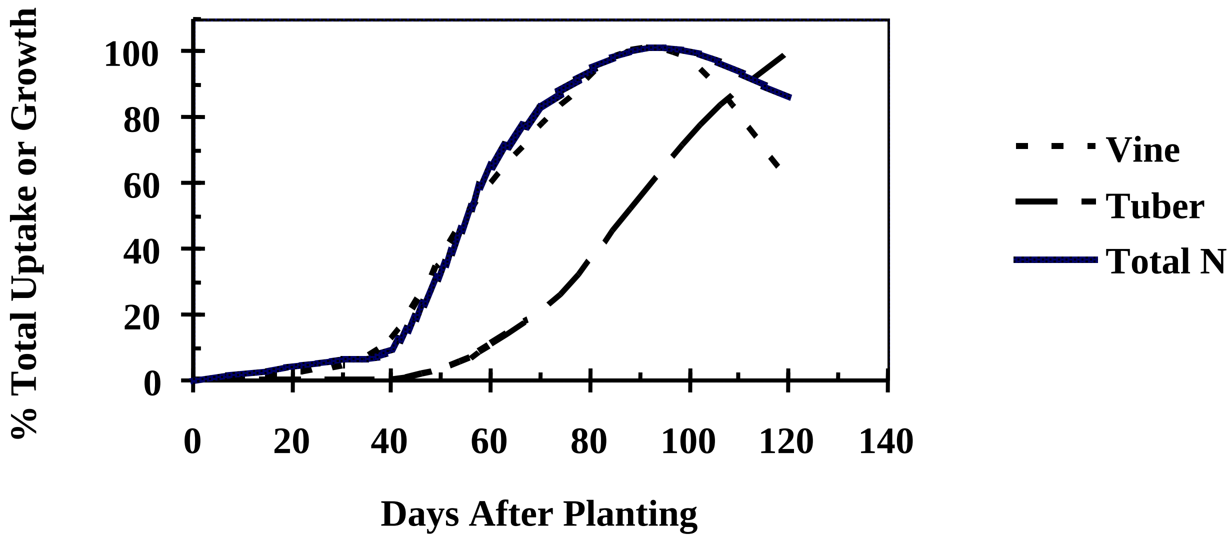

Figure 4. N released from ESN and Kingenta PCU at Becker, 2007.

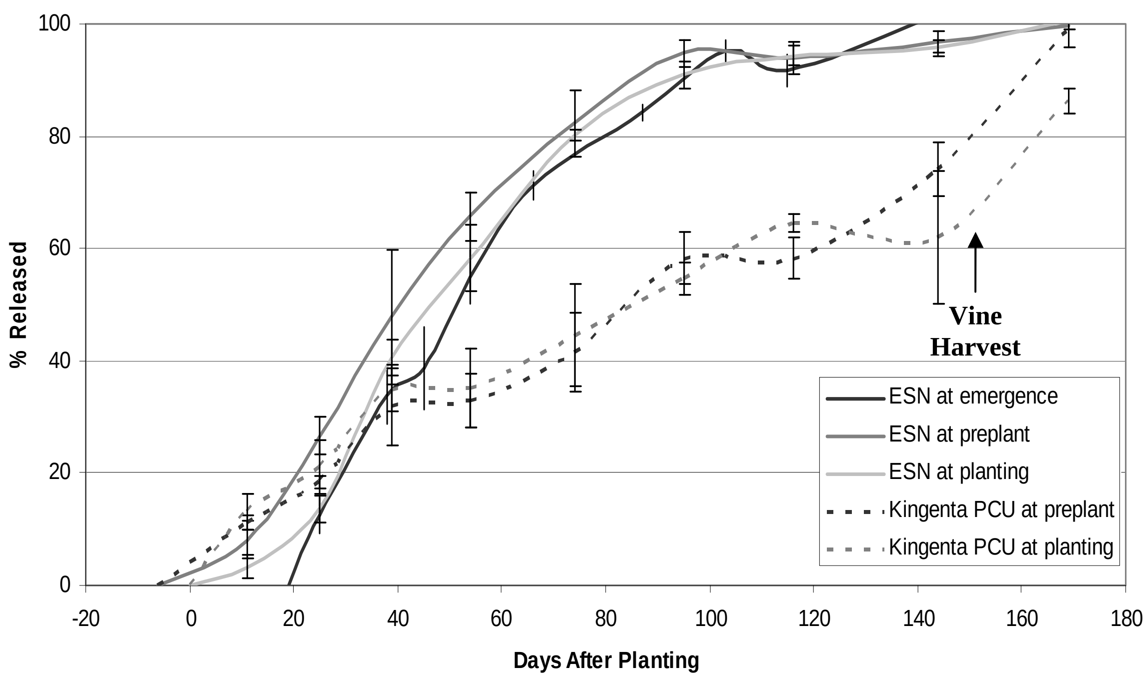

Figure 5. Soil water nitrate-N concentrations at the four foot depth for the control and 240 lb N/A treatments (40 lbs applied as DAP and the remaining 200 lb/A either as a controlled release fertilizer or urea/28%).

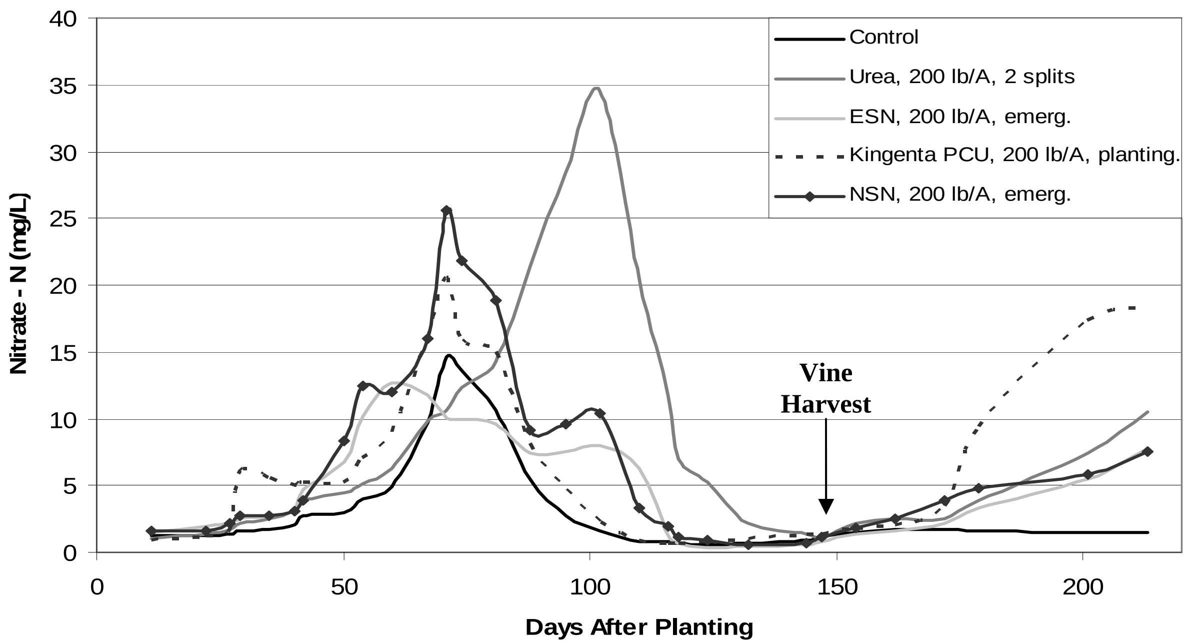

Figure 6. Total nitrate-N leached over the 2007 growing season until ground freeze at Becker.

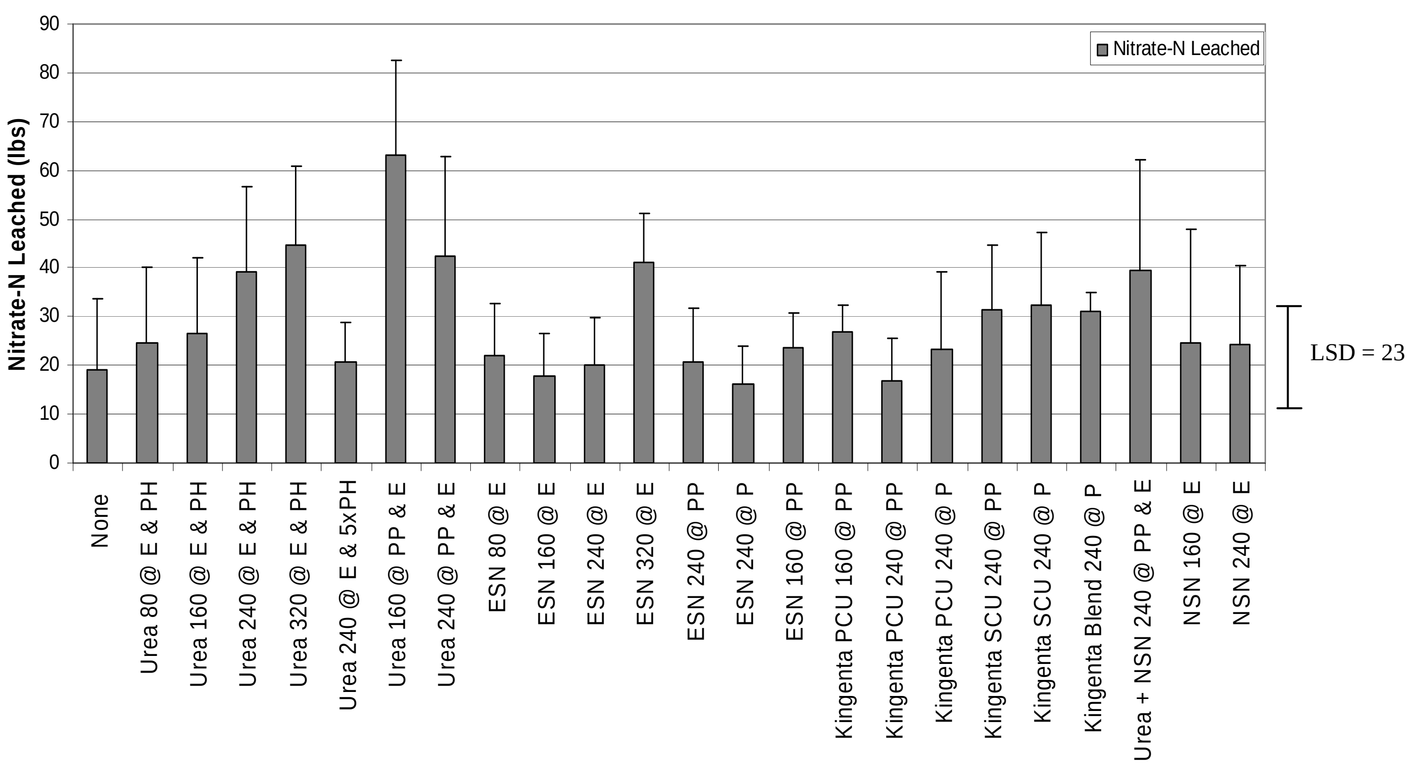

Table 2. Effect of nitrogen source, rate, and timing on Russet Burbank yield and size distribution, Becker, 2007.

Treatments				Tuber Yield, cwt/A											Number	%
Trmt #	Nitrogen Source	Nitrogen Rate	Timing PP, P, EH, PH[1]	0-4 oz	4-6 oz	6-10 oz	10-14 oz	>14 oz	Total	#1 >4 oz	#2 >4 oz	Total Marketable	% >6 oz	% >10 oz	of Stems	Stand Count
1	None	0	0, 0, 0, 0	107.5	183.8	135.0	33.2	13.4	473.0	94.3	271.1	365.4	38.6	9.7	2.9	100.0
2	Urea	80	0, 40, 20, 20	140.3	213.6	246.4	76.1	23.9	700.3	264.5	295.5	560.0	49.3	14.2	2.9	100.0
3	Urea	160	0, 40, 60, 60	95.3	164.3	252.1	126.6	60.1	698.4	326.7	276.4	603.1	62.8	26.8	3.0	99.4
4	Urea	240	0, 40, 100, 100	69.2	116.5	216.5	175.4	125.8	703.4	408.5	225.8	634.3	73.6	42.9	3.0	96.7
5	Urea	320	0, 40, 140, 140	70.4	95.3	199.1	184.5	156.8	706.3	446.2	189.7	635.9	76.5	48.3	2.9	98.9
6	Urea	240	0, 40, 100, 5x20	83.1	122.0	196.4	177.0	155.5	734.0	389.7	261.2	650.9	72.2	45.4	2.9	99.4
7	Urea	160	60, 40, 60, 0	93.9	163.9	236.7	134.1	82.7	711.2	405.5	211.8	617.4	63.8	30.5	2.8	98.9
8	Urea	240	100, 40, 100, 0	70.4	125.8	217.0	157.7	111.5	682.4	430.0	182.0	612.0	71.2	39.6	2.9	98.9
9	ESN	80	0, 40, 40, 0	125.5	200.3	243.4	83.7	33.4	686.2	214.4	346.3	560.7	52.5	16.9	3.1	100.0
10	ESN	160	0, 40, 120, 0	118.4	183.8	249.8	131.8	73.2	757.0	351.5	287.0	638.6	60.1	27.0	3.0	100.0
11	ESN	240	0, 40, 200, 0	97.3	153.0	229.9	137.6	125.3	743.2	360.8	285.1	645.9	66.4	35.4	2.9	99.4
12	ESN	320	0, 40, 280, 0	87.5	118.5	192.5	169.0	129.7	697.2	405.7	203.9	609.6	70.1	42.5	3.0	99.4
13	ESN	240	200, 40, 0, 0	83.5	149.5	234.7	136.0	114.8	718.4	415.6	219.4	635.0	67.6	34.9	2.9	100.0
14	ESN	240	0, 240, 0, 0	64.2	104.0	211.3	170.0	148.7	698.2	402.4	231.5	633.9	76.0	45.7	2.9	99.4
15	ESN	160	120, 40, 0, 0	121.8	198.3	264.9	119.0	52.8	757.0	355.1	280.1	635.1	57.2	22.2	3.2	99.4
16	Kingenta PCU	160	120, 40, 0, 0	125.6	210.3	275.6	107.2	34.6	753.2	252.9	374.7	627.6	55.4	18.8	3.1	99.4
17	Kingenta PCU	240	200, 40, 0, 0	122.4	183.9	257.8	129.9	54.5	748.5	296.0	330.1	626.1	59.0	24.4	3.2	100.0
18	Kingenta PCU	240	0, 240, 0, 0	101.2	154.1	271.2	173.6	101.2	801.3	338.3	361.8	700.1	68.1	34.2	3.1	99.4
19	Kingenta SCU	240	200, 40, 0, 0	102.8	167.5	247.6	171.9	94.8	784.5	406.8	275.0	681.8	65.5	33.8	3.2	100.0
20	Kingenta SCU	240	0, 240, 0, 0	63.8	109.8	206.2	185.8	174.5	740.0	407.6	268.7	676.3	76.5	48.5	3.2	100.0
21	Kingenta Blend	240	0, 240, 0, 0	75.9	102.7	222.3	172.0	155.7	728.5	409.2	243.4	652.5	75.8	45.3	2.9	99.4
22	Urea + NSN	240	100, 40, 100, 0	66.7	129.4	218.5	163.4	142.4	720.5	446.4	207.4	653.8	72.8	42.3	2.7	97.8
23	NSN	160	0, 40, 120, 0	87.0	150.5	236.8	151.9	97.7	723.9	357.8	279.1	636.9	67.5	34.8	2.6	91.1
24	NSN	240	0, 40, 200, 0	75.1	124.0	185.0	173.9	168.7	726.7	427.9	223.6	651.6	73.1	47.6	2.8	91.1
Significance[2]				**	**	**	**	**	**	**	**	**	**	**	NS	++
LSD (0.10)				22.3	32.1	32.1	31.9	37.2	45.7	73.9	65.0	44.5	6.3	7.5	0.6	6.8
Contrasts																
Control vs rest, trmt 1 vs. 2-24				NS	*	**	**	**	**	**	NS	**	**	**	NS	NS
Urea vs ESN, trmts 2,3,4,5 vs. 9, 10, 11, 12				*	++	NS	NS	NS	NS	NS	++	NS	NS	NS	NS	NS
Urea 3 splits vs 7 splits, trmt 4 vs. 6				NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Urea vs Kingenta, trmts 3,4 vs. 16,17				**	**	*	*	**	*	**	**	NS	**	**	NS	NS
Urea vs NSN, trmts 3,4 vs. 23, 24				NS	NS	++	NS	*	NS	NS	NS	NS	NS	++	++	**

[1]PP, P, EH, PH= Preplanting, Planting, Emergence & Hilling, and Post-Hilling, respectively

[2]NS = Non significant; ++,*,** = Significant at 10%, 5% and 1% respectively

Table 3. Effect of nitrogen source, rate, and timing on Russet Burbank tuber quality- Becker, 2007.

Treatments				% with Hollow Heart	Specific Gravity	Visual Chip Color[2] 0 month	
Trmt #	Nitrogen Source	Nitrogen Rate	Timing PP, P, EH, PH[1]			bud	stem
1	None	0	0, 0, 0, 0	1.6	1.068	5.0	7.7
2	Urea	80	0, 40, 20, 20	7.0	1.074	4.9	7.7
3	Urea	160	0, 40, 60, 60	13.6	1.075	5.0	7.7
4	Urea	240	0, 40, 100, 100	14.4	1.079	4.8	7.4
5	Urea	320	0, 40, 140, 140	17.6	1.075	4.9	7.3
6	Urea	240	0, 40, 100, 5x20	16.1	1.073	5.2	7.6
7	Urea	160	60, 40, 60, 0	13.8	1.075	4.9	7.4
8	Urea	240	100, 40, 100, 0	12.8	1.077	5.0	7.5
9	ESN	80	0, 40, 40, 0	16.2	1.075	5.2	7.5
10	ESN	160	0, 40, 120, 0	15.9	1.076	5.4	7.6
11	ESN	240	0, 40, 200, 0	11.2	1.076	5.4	7.6
12	ESN	320	0, 40, 280, 0	16.0	1.074	5.5	7.4
13	ESN	240	200, 40, 0, 0	14.3	1.075	4.9	7.4
14	ESN	240	0, 240, 0, 0	10.4	1.074	4.8	7.4
15	ESN	160	120, 40, 0, 0	14.5	1.076	4.6	7.4
16	Kingenta PCU	160	120, 40, 0, 0	16.0	1.075	5.1	7.7
17	Kingenta PCU	240	200, 40, 0, 0	15.2	1.072	5.0	7.8
18	Kingenta PCU	240	0, 240, 0, 0	8.0	1.073	5.2	7.6
19	Kingenta SCU	240	200, 40, 0, 0	14.0	1.077	4.9	7.4
20	Kingenta SCU	240	0, 240, 0, 0	8.0	1.075	4.7	7.4
21	Kingenta Blend	240	0, 240, 0, 0	6.4	1.074	4.6	6.9
22	Urea + NSN	240	100, 40, 100, 0	14.3	1.077	5.0	7.5
23	NSN	160	0, 40, 120, 0	19.2	1.077	5.1	7.3
24	NSN	240	0, 40, 200, 0	17.1	1.075	5.1	7.3
			Significance[3]	++	**	NS	++
			LSD (0.10)	11.9	0.003	1.2	0.5
			Contrasts				
			Control vs rest, trmt 1 vs. 2-24	**	**	NS	++
			Urea vs ESN, trmts 2,3,4,5 vs. 9, 10, 11, 12	NS	NS	**	NS
			Urea 3 splits vs 7 splits, trmt 4 vs. 6	NS	**	NS	NS
			Urea vs Kingenta, trmts 3,4 vs. 16,17	NS	**	NS	NS
			Urea vs NSN, trmts 3,4 vs. 23, 24	NS	NS	NS	++

[1]PP, P, EH, PH= Preplanting, Planting, Emergence & Hilling, and Post-Hilling, respectively

[2]1=white, 10=very dark

[3]NS = Non significant; ++,*,** = Significant at 10%, 5% and 1% respectively

Table 4. Effect of nitrogen source, rate and timing on nitrate-N in petioles.

Treatments				Petiole Nitrate- N				
Trmt #	Nitrogen Source	Nitrogen[1] Rate	Timing PP, P, EH, PH[2]	12-Jun	25-Jun	9-Jul	24-Jul	6-Aug
				ppm				
1	None	0	0, 0, 0, 0	595	418	943	421	399
2	Urea	80	0, 40, 20, 20	11814	1016	805	553	224
3	Urea	160	0, 40, 60, 60	15333	6387	4118	1116	340
4	Urea	240	0, 40, 100, 100	15305	13261	6449	2652	949
5	Urea	320	0, 40, 140, 140	18010	14086	12152	5037	2413
6	Urea	240	0, 40, 100, 5x20	15636	9757	8532	2549	1964
7	Urea	160	60, 40, 60, 0	19269	4533	6279	654	281
8	Urea	240	100, 40, 100, 0	21671	10968	7085	1731	1254
9	ESN	80	0, 40, 40, 0	10630	1389	806	724	204
10	ESN	160	0, 40, 120, 0	11231	6386	6530	2161	559
11	ESN	240	0, 40, 200, 0	14218	10471	12227	6306	3166
12	ESN	320	0, 40, 280, 0	15998	10662	15210	10787	7795
13	ESN	240	200, 40, 0, 0	22085	8209	8085	2575	1107
14	ESN	240	0, 240, 0, 0	18475	15815	13836	8401	4086
15	ESN	160	120, 40, 0, 0	18233	3543	4613	1474	796
16	Kingenta PCU	160	120, 40, 0, 0	16948	1561	1181	809	190
17	Kingenta PCU	240	200, 40, 0, 0	15452	2503	2412	1033	551
18	Kingenta PCU	240	0, 240, 0, 0	15970	3651	2694	1509	1009
19	Kingenta SCU	240	200, 40, 0, 0	20296	7102	7032	2227	774
20	Kingenta SCU	240	0, 240, 0, 0	18416	10994	10588	5581	3309
21	Kingenta Blend	240	0, 240, 0, 0	21797	12591	10048	5037	3026
22	Urea + NSN	240	100, 40, 100, 0	18304	9377	10367	2661	1328
23	NSN	160	0, 40, 120, 0	16616	7458	4272	1335	350
24	NSN	240	0, 40, 200, 0	17553	11701	8540	1869	614
			Significance[3]	**	**	**	**	**
			LSD (0.10)	2816	2457	3143	1458	1042
			Contrasts					
			Control vs rest, trmt 1 vs. 2-24	**	**	**	**	*
			Urea vs ESN, trmts 2,3,4,5 vs. 9, 10, 11, 12	*	++	**	**	**
			Urea 3 splits vs 7 splits, trmt 4 vs. 6	NS	*	NS	NS	NS
			Urea vs Kingenta, trmts 3,4 vs. 16,17	NS	**	*	NS	NS
			Urea vs NSN, trmts 3,4 vs. 23, 24	NS	NS	NS	NS	NS

[1]40 lbs/A of nitrogen at planting is from diammonium phosphate

[2]PP, P, EH, PH= Preplanting, Planting, Emergence & Hilling, and Post-Hilling, respectively

[3]NS = Non significant; ++,*,** = Significant at 10%, 5% and 1% respectively

Table 5. Effect of nitrogen source, rate and timing on midseason (0-1 ft) and residual (0 - 2ft) soil inorganic N - Becker, 2007.

Treatments				**Soil Inorganic - N**								
				June			**July**			**Residual**		
Trmt #	**Nitrogen Source**	**Nitrogen[1] Rate**	**Timing PP, P, EH, PH[2]**	**Total**	**NH_4-N**	**NO_3-N**	**Total**	**NH_4-N**	**NO_3-N**	**Total**	**NH_4-N**	**NO_3-N**
				-0-1 ft lbs / A-						**-0-2 ft lbs / A-**		
1	None	0	0, 0, 0, 0	56.5	47.5	9.0	43.4	32.3	11.1	31.0	14.3	17.6
2	Urea	80	0, 40, 20, 20	79.9	57.7	22.2	44.8	35.0	9.8	35.3	16.2	20.1
3	Urea	160	0, 40, 60, 60	81.8	53.5	28.4	51.3	40.7	10.6	34.0	17.4	18.1
4	Urea	240	0, 40, 100, 100	122.3	70.7	51.5	49.9	37.1	12.8	33.6	15.0	18.6
5	Urea	320	0, 40, 140, 140	192.3	94.7	97.6	59.3	42.1	17.2	39.7	18.1	21.7
6	Urea	240	0, 40, 100, 5x20	76.6	48.2	28.4	58.9	43.4	15.5	66.0	39.0	27.0
7	Urea	160	60, 40, 60, 0	95.6	53.6	42.0	56.7	44.7	11.9	36.2	19.5	16.7
8	Urea	240	100, 40, 100, 0	117.0	61.2	55.8	55.4	43.8	11.6	32.0	15.5	16.5
9	ESN	80	0, 40, 40, 0	70.2	52.1	18.1	49.6	37.8	11.8	36.7	19.1	17.6
10	ESN	160	0, 40, 120, 0	67.3	47.2	20.1	62.4	50.1	12.3	35.8	17.3	18.6
11	ESN	240	0, 40, 200, 0	87.8	62.9	24.9	51.7	38.0	13.7	38.7	18.5	20.3
12	ESN	320	0, 40, 280, 0	100.5	62.3	38.2	53.1	37.9	15.3	42.9	17.6	25.3
13	ESN	240	200, 40, 0, 0	139.9	66.0	74.0	54.5	43.2	11.2	36.0	17.5	18.5
14	ESN	240	0, 240, 0, 0	171.1	125.6	45.5	60.5	46.8	13.7	44.8	22.0	24.2
15	ESN	160	120, 40, 0, 0	81.0	52.1	28.9	48.9	37.2	11.7	34.0	16.4	17.6
16	Kingenta PCU	160	120, 40, 0, 0	68.2	53.2	15.0	49.3	39.0	10.2	41.5	18.9	22.6
17	Kingenta PCU	240	200, 40, 0, 0	72.5	49.8	22.7	47.6	36.0	11.6	55.2	27.3	29.6
18	Kingenta PCU	240	0, 240, 0, 0	68.7	50.8	17.9	52.3	42.2	10.1	67.2	30.0	37.3
19	Kingenta SCU	240	200, 40, 0, 0	99.0	57.2	41.9	55.1	42.6	12.4	46.2	22.0	24.3
20	Kingenta SCU	240	0, 240, 0, 0	129.9	81.6	48.3	54.1	41.3	12.8	54.5	27.0	29.2
21	Kingenta Blend	240	0, 240, 0, 0	147.1	78.5	68.5	62.6	43.4	19.2	47.8	20.8	26.9
22	Urea + NSN	240	100, 40, 100, 0	118.8	61.6	57.2	57.2	46.8	10.5	34.9	17.0	19.3
23	NSN	160	0, 40, 120, 0	80.2	54.0	26.1	54.7	42.0	12.7	33.3	16.4	16.9
24	NSN	240	0, 40, 200, 0	127.6	82.0	45.6	50.5	40.9	9.5	35.6	17.6	18.0
Significance[3]				**	*	**	NS	NS	**	**	*	**
LSD (0.10)				0.0	0.0	0.0	0.0	--	0.0	15.7	14.7	5.2
Contrasts												
Control vs rest, trmt 1 vs. 2-24				*	NS	*	*	*	NS	++	NS	++
Urea vs ESN, trmts 2,3,4,5 vs. 9, 10, 11, 12				*	NS	**	NS	NS	NS	NS	NS	NS
Urea 3 splits vs 7 splits, trmt 4 vs. 6				NS	NS	NS	NS	NS	NS	**	**	**
Urea vs Kingenta, trmts 3,4 vs. 16,17				NS	NS	++	NS	NS	NS	*	NS	**
Urea vs NSN, trmts 3,4 vs. 23, 24				NS	NS	NS	NS	NS	NS	NS	NS	NS

[1] 40 lbs/A of nitrogen at planting is from diammonium phosphate

[2] PP, P, EH, PH= Preplanting, Planting, Emergence & Hilling, and Post-Hilling, respectively

[3] NS = Non significant; ++,*,** = Significant at 10%, 5% and 1% respectively

Effects of Potassium Fertilizer Sources, Timing, and Rates On Tuber Specific Gravity

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Summary: Tuber specific gravity was affected by variety, K rate, K source, and K timing. 'Umatilla' had significantly higher specific gravity than 'Russet Burbank', but this effect was not consistent across all sampling dates. The K treatment with 400-lb K_2O/A applied preplant had significantly lower tuber specific gravity on most sampling dates, and when averaged across all dates, than the group of 300-lb K_2O/A treatments. The early split application of 300-lb K_2O/A as 0-0-60 had significantly lower specific gravity at harvest, and the comparable late split application was numerically lower, than the treatment with 300-lb K_2O/A applied preplant. Applying all of the K as potassium chloride reduced specific gravity at harvest compared with applying all or ½ of the K in non-chloride form. Tuber K concentrations were not significantly affected by K fertilizer treatment. Split K application increased petiole K compared with equivalent amounts of preplant K and petiole K also increased as preplant K rate increased from 300-lb K_2O/A to 400-lb K_2O/A. Umatilla had higher tuber and petiole K concentrations than Russet Burbank. Potassium treatments did not significantly affect total tuber yield, but marketable yield was lower with 400-lb K_2O/A than 300-lb K_2O/A due to an increase in unmarketable tubers less than 4 oz in size. Split K applications had lower yields of small tubers than applying all K preplant and late split application resulted in fewer small tubers than early split application. Applying 400-lb K_2O/A preplant reduced the number of stems per plant compared with 300-lb K_2O/A preplant or split. Hollow heart and brown center were not affected by K treatment. The only significant effect of K on chip color was that stem end chips were slightly lighter with 400-lb K_2O/A than 300-lb K_2O/A.

Background

Specific gravity is a parameter that affects the processing quality of potato. Too low a specific gravity causes an increase in frying time, the need for more product, and too much fat to be absorbed by the fries. On the other hand, too high a specific gravity causes an increase in bruising and shattering, which in turn reduces fry quality. In recent years, the specific gravity of potatoes growing in the upper Midwest has been high (>1.090). Previous studies with 'Russet Burbank' have shown that in-season applications of potassium chloride can reduce specific gravity. There is some question as to whether the effect is due to the chloride, the potassium or both. Therefore, a need exists to evaluate the effects of various potassium sources applied as a sidedress on the quality of potato tubers. 'Umatilla' was included in this trial because this cultivar has been shown to have even higher specific gravity than Russet Burbank.

This study is the second year of a study initiated in 2006. The overall objective was to determine the effects of various K sources, application timing, and rates on specific gravity of Russet Burbank and Umatilla potatoes.

Materials and Methods

This study was conducted at the Sand Plain Research Farm in Becker, Minnesota on a Hubbard loamy sand soil. The field was fallowed the previous year and selected soil chemical properties before planting were as follows (0-6"): pH, 5.9; organic matter, 1.4%; Bray P1, 32.3 ppm; ammonium acetate extractable K, Ca, and Mg, 85, 479, and 80 ppm, respectively; hot water extractable B, 0.2 ppm; and DTPA extractable Zn, Cu, Fe, and Mn, 1.8, 0.6, 38.0, and 9.6 ppm, respectively. Extractable NO_3-N and NH_4-N in the top 2 ft of soil were 11.3 and 13.0 lb/A, respectively.

Russet Burbank and Umatilla were the cultivars grown. Five, 20-ft rows were planted for each plot. Two of the middle three rows were used for petiole sampling and tuber harvest and the third was used for specific gravity sampling. Cut "A" seed treated with NuBark was hand planted in furrows on April 20, 2007. Row spacing was 12 inches within each row and 36 inches between rows. Each treatment was replicated four times for each cultivar in a randomized complete block design. Admire was applied in-furrow for beetle control. Weeds, diseases, and other insects were controlled using standard practices. Rainfall was supplemented with sprinkler irrigation using the checkbook method of irrigation scheduling.

Each cultivar was subjected to six potassium treatments with different K sources, application timing, and rates as described below:

Cultivar	**Preplant K**	**Emergence K**	**2nd Sidedress K**	**Total K_2O**
	---------- lb. K_2O/A ----------			
Russet Burbank	300 as 0-0-60	0	0	300
Russet Burbank	150 as 0-0-60	150 as 0-0-60	0	300
Russet Burbank	150 as 0-0-60	150 as 0-0-22	0	300
Russet Burbank	0	150 as 0-0- 60	150 as 0-0-60	300
Russet Burbank	0	150 as 0-0-50	150 as 0-0-50	300
Russet Burbank	400 as 0-0-60	0	0	400
Umatilla	300 as 0-0-60	0	0	300
Umatilla	150 as 0-0-60	150 as 0-0-60	0	300
Umatilla	150 as 0-0-60	150 as 0-0-22	0	300
Umatilla	0	150 as 0-0- 60	150 as 0-0-60	300
Umatilla	0	150 as 0-0-50	150 as 0-0-50	300
Umatilla	400 as 0-0-60	0	0	400

No banded K was applied at planting. Ammonium sulfate was used as one of the N sources for the emergence N application to the non-sulfate treatments (those not receiving 0-0-22-18S or 0-0-50-18S) to eliminate any treatment effect due to sulfur.

Preplant K fertilizer was broadcast and incorporated with a moldboard plow to a 6-in depth on April 18. Emergence K was sidedressed and mechanically incorporated in the hilling operation on May 10 and 2nd sidedress K was applied and mechanically incorporated on May 25. For Treatment 3, 0-0-60 was applied preplant and 0-0-22 was applied at emergence.

Starter fertilizer was banded at planting 3 inches to each side and 2 inches below the seed piece using a belt type applicator. All treatments received 50-lb N/A and 125-lb P_2O_5/A as diammonium phosphate, 2-lb Zn/A as zinc oxide, and 0.5-lb B/A as boric acid at planting. Total N application was 250-lb N/A for all treatments. At plant emergence, 100-lb N/A was sidedressed and mechanically incorporated. It was applied in conjunction with K in treatments receiving K at that time. Treatments 3 and 5 received their entire emergence N as urea. The other treatments received 53-lb N/A as urea and 47-lb N/A as ammonium sulfate, which equalized the S applied with the K sources used for Treatments 3 and 5. An additional 100-lb N/A was applied to all treatments in three equal, split applications as 50% granular urea and 50% ammonium nitrate. At the 2nd sidedress on May 25, N was mechanically incorporated and was applied in conjunction with K in treatments receiving K at that time. On June 7 and June 20, sidedressed N was watered-in with overhead irrigation.

Stand counts were made on May 25 and stem counts on June 6. Petiole samples were collected from the 4th leaf from the terminal on July 11 and analyzed for K on a dry weight basis. Tuber samples for specific gravity measurements were collected on five dates. On Aug 1, Aug 13, Sept 4, and Sept 14 samples were collected by hand digging all the tubers from two representative plants. Vines were mechanically beaten over the entire plot area on Sept 21 and on Sept 26 sub-samples for specific gravity were collected from tubers that were machine harvested for final yield and quality measurements. Specific gravity was measured by the weight-in-air/weight-in-water method using tubers greater than 4 oz in size. Total tuber yield, graded yield, internal disorders, K concentrations, and visual ratings of stem and bud end chip color after frying were also determined for the tubers harvested on Sept 26.

Results and Discussion

Tuber specific gravity: Table 1 shows the effects of variety and K rate, source, and timing on tuber specific gravity on five sampling dates. Umatilla had significantly higher specific gravity than Russet Burbank on all five sampling dates, although it was also more variable. The average for Umatilla across all dates was 1.0787 vs. 1.0757 for Russet Burbank. Higher specific gravity for Umatilla than Russet Burbank is consistent with results from other studies. However, in this study significant variety x K treatment interactions occurred at harvest and for the average specific gravity across sampling dates. At harvest the early split application of 300-lb K_2O/A as 0-0-60 and the 400-lb K_2O/A preplant treatment had lower specific gravities for Umatilla than Russet Burbank. The average specific gravities for the 400-lb K_2O/A preplant treatment were also similar for Umatilla and Russet Burbank, whereas Umatilla had much higher average specific gravities for all of the other treatments.

Specific gravities were similar for all sampling dates except Aug. 13, which averaged significantly lower than all other dates. This effect was due to lower specific gravity for Russet Burbank on Aug. 13 compared with other dates, but it did not occur for Umatilla. The relatively stable pattern in specific gravity over the season differed from 2006 results, when it increased steadily over the two months prior to harvest. The different pattern in 2007 compared with 2006 was likely due to the relatively dry and hot growing period through July followed by a wetter August and September.

The majority of the specific gravity differences among treatments in 2007 occurred on the last three sampling dates and for the overall average across dates. The 400-lb K_2O/A preplant application had the lowest specific gravity on the last four sampling dates, as well as when averaged across all dates. It was significantly lower for the last three dates and for the overall average than the group of 300-lb K_2O/A applications considered collectively. On the third and fifth dates and when averaged across all dates, 400-lb K_2O/A preplant was also significantly lower than 300-lb K_2O/A preplant when the two were compared directly. These results are consistent with the idea that increased K application and availability can reduce tuber specific gravity.

The early split application of 300-lb K_2O/A as 0-0-60 resulted in significantly lower specific gravity at harvest than applying 300-lb K_2O/A preplant. The late split application of 300-lb K_2O/A as 0-0-60 also had numerically lower specific gravity at harvest than the equivalent preplant treatment. These results supported the concept that in-season K application reduces tuber specific gravity. Preplant and split applications had similar specific gravities on other dates, except on Sept 14 when applying 300-lb K_2O/A preplant resulted in significantly lower specific gravity compared with the group of 300-lb K_2O/A treatments receiving in-season, split applications.

Specific gravity on Aug 1, at the final harvest, and when averaged across all sampling dates was significantly lower for the late split application of 0-0-60 (potassium chloride) than the late split application of 0-0-50 (potassium sulfate). Specific gravity was also significantly lower at final harvest for the early split application of 0-0-60 than the early split application where ½ of the total K was in chloride form and the other ½ was supplied as 0-0-22 (potassium-magnesium sulfate). These results are consistent with chloride playing a role in reducing specific gravity.

Tuber and petiole K concentrations: Table 2 shows the effects of variety and K rate, source, and timing on K concentrations in tubers and petioles. Tuber samples were collected on the Sept. 26 harvest date. Petiole samples were collected on July 11, which was 82 days after planting and during the tuber bulking growth phase.

Umatilla had significantly higher K concentrations in both tubers and petioles than Russet Burbank. This tendency to accumulate higher amounts of K in tubers was not associated with a decrease in specific gravity, since Umatilla had significantly higher tuber specific gravity than Russet Burbank (Table 1). In 2006 Umatilla also had significantly higher tuber K than Russet Burbank, but petiole K was significantly lower.

Potassium fertilizer treatments had no significant effects on tuber K. Trends were generally consistent with K application rates and timing, but results differed from 2006 when in-season K applications significantly increased tuber K concentrations compared with applying all of the fertilizer K preplant and there was also a significant rate effect. Split application of 300-lb K_2O/A did increase petiole K concentration compared with the same amount of preplant K, and late split applications increased petiole K more than early split applications, but higher amounts of K in aboveground plant tissue did not translate into significantly higher amounts of K in tubers. Petiole K concentrations ranged from 7.3 to 8.1%, so most treatments were slightly below the sufficiency range of 8 to 10%.

Tuber yield: Table 3 shows the effects of variety and K rate, source, and timing on tuber yield, tuber size distribution, plant stand, and the number of stems per plant. Both total and marketable yield were significantly higher for Russet Burbank than Umatilla. Yield differences were due to larger tuber size for Russet Burbank, although Umatilla had significantly higher yields of #1 tubers greater than 4 oz in size. Plant stands were 8% higher for Russet Burbank, but the number of stems per plant was 23% higher for Umatilla. In a nitrogen study this year at the same location, plant stands were 9% higher for Russet Burbank and the number of stems per plant was 12% higher for Umatilla.

Potassium treatments had no significant effects on total yield, but marketable yield was significantly lower and yield of tubers less than 4 oz in size was significantly higher for 400-lb K_2O/A preplant compared with the group of treatments receiving 300-lb K_2O/A. This was somewhat similar to tuber size effects in 2006 when yield of tubers greater than 10 oz in size was significantly lower for 400-lb K_2O/A preplant, but comparable differences in total marketable yield with the group of treatments receiving 300-lb K_2O/A did not occur.

Late split K applications had significantly more large tubers and significantly less small tubers than early split applications. Split K applications also had significantly lower yields of tubers less than 4 oz in size than preplant applications. Late split application of 0-0-60 resulted in significantly more tubers less than 4 oz in size than the comparable late split application of 0-0-50, which was contrary to 2006 results where 0-0-60 resulted in significantly more large tubers. The early split application that included 0-0-22 had larger yields of 10-14 oz tubers and #1 tubers greater than 4 oz than the early split application of 100% 0-0-60. Similar results did not occur in 2006. Plant stands were not affected by K treatment. Applying 400-lb K_2O/A preplant reduced the number of stems per plant compared with 300-lb K_2O/A preplant or split.

Tuber quality: Table 4 shows the effects of variety and K rate, source, and timing on chip color and the incidence of hollow heart and brown center. Chip color was significantly darker for Russet Burbank than Umatilla for both stem end and bud end chips. The only significant K treatment effects were that stem end chips were slightly lighter with 400-lb K_2O/A preplant than with the 300-lb K_2O/A applications. Stem end chips tended to be darker than bud end chips, although the two chip types were not statistically compared.

Hollow heart and brown center were both significantly higher for Russet Burbank than Umatilla. K treatment had no significant effects on either parameter, although both tended to be higher with 400-lb K_2O/A applied preplant ($p = 0.11$ for hollow heart and 0.14 for brown center).

Conclusions: Umatilla had higher specific gravity than Russet Burbank, but this effect was not consistent across all sampling dates. The K treatment with 400-lb K_2O/A applied preplant had significantly lower tuber specific gravity on most sampling dates, and when averaged across all dates, than the group of 300-lb K_2O/A treatments. Early split application of 300-lb K_2O/A as 0-0-60 had significantly lower specific gravity at harvest than 300-lb K_2O/A applied preplant. The equivalent late split application of 0-0-60 was numerically lower than 300-lb K_2O/A preplant. These results support the involvement of K in tuber specific gravity. Applying all of the K as potassium chloride reduced specific gravity at harvest compared with applying all or ½ of the K in non-chloride form. These results support the involvement of chloride in tuber specific gravity.

Tuber K concentrations were not significantly affected by K fertilizer treatment. Trends were consistent with application rates and timing, but differences in tuber K were not well correlated with differences in specific gravity. Split K application increased petiole K compared with equivalent amounts of preplant K and petiole K also increased as preplant K rate increased, but these differences did not lead to differences in tuber K. Umatilla had higher tuber and petiole K concentrations than Russet Burbank. Potassium treatments did not significantly affect total tuber yield, but marketable yield was lower with 400-lb K_2O/A than 300-lb K_2O/A due to an increase in unmarketable tubers less than 4 oz in size. Split K applications had lower yields of small tubers than all K preplant and late split application had fewer small tubers than early split application. Applying 400-lb K_2O/A preplant reduced the number of stems per plant compared with 300-lb K_2O/A preplant or split.

Russet Burbank had higher stand counts than Umatilla, but the number of stems per plant was higher for Umatilla. Chip color was significantly darker for Russet Burbank than Umatilla. The only significant effect of K on chip color was that stem end chips were slightly lighter with 400-lb K_2O/A than 300-lb K_2O/A. Hollow heart and brown center were not affected by K treatment, but both were significantly higher for Russet Burbank than Umatilla.

Table 1. Effect of variety and potassium rate, source, and timing on tuber specific gravity over five sample dates.

Treatments					Sample Date					
Treatment #	Variety	K Rate lbs. K_2O / A	K Source	K Timing PP, E, S2[2]	8/1	8/13	9/4	9/14	9/26	Average[1]
					Specific Gravity					
1	Russet Burbank	300	0-0-60	300, 0, 0	1.0780	1.0719	1.0786	1.0759	1.0777	1.0764
2	Russet Burbank	300	0-0-60	150, 150, 0	1.0764	1.0709	1.0773	1.0759	1.0770	1.0755
3	Russet Burbank	300	0-0-60 and 0-0-22	150, 150, 0	1.0773	1.0722	1.0760	1.0780	1.0770	1.0761
4	Russet Burbank	300	0-0-60	0, 150, 150	1.0736	1.0692	1.0758	1.0778	1.0772	1.0747
5	Russet Burbank	300	0-0-50	0, 150, 150	1.0788	1.0719	1.0759	1.0778	1.0778	1.0764
6	Russet Burbank	400	0-0-60	400, 0, 0	1.0771	1.0721	1.0744	1.0744	1.0769	1.0750
7	Umatilla	300	0-0-60	300, 0, 0	1.0784	1.0802	1.0790	1.0772	1.0800	1.0790
8	Umatilla	300	0-0-60	150, 150, 0	1.0816	1.0841	1.0791	1.0802	1.0767	1.0801
9	Umatilla	300	0-0-60 and 0-0-22	150, 150, 0	1.0803	1.0742	1.0831	1.0819	1.0817	1.0804
10	Umatilla	300	0-0-60	0, 150, 150	1.0787	1.0779	1.0777	1.0779	1.0785	1.0781
11	Umatilla	300	0-0-50	0, 150, 150	1.0834	1.0843	1.0794	1.0819	1.0823	1.0822
12	Umatilla	400	0-0-60	400, 0, 0	1.0779	1.0720	1.0777	1.0774	1.0745	1.0759
Main Effects										
Variety	Russet Burbank				1.0769	1.0714	1.0763	1.0766	1.0773	1.0757
	Umatilla				1.0800	1.0788	1.0792	1.0794	1.0789	1.0793
				Significance[3]	*	**	**	**	*	**
K Treatment	0-0-60, 300 lb. / A Preplant				1.0782	1.0761	1.0788	1.0765	1.0789	1.0777
	0-0-60, 300 lb. / A Early Split				1.0790	1.0765	1.0782	1.0780	1.0768	1.0777
	0-0-60 + 0-0-22, 300 lb. / A Early Split				1.0788	1.0731	1.0791	1.0800	1.0793	1.0781
	0-0-60, 300 lb. / A Late Split				1.0761	1.0729	1.0767	1.0778	1.0779	1.0764
	0-0-50, 300 lb. / A Late Split				1.0811	1.0781	1.0776	1.0799	1.0800	1.0793
	0-0-60, 400 lb. / A Preplant				1.0775	1.0720	1.0761	1.0759	1.0757	1.0754
				Significance	NS	NS	NS	NS	**	**
				LSD (0.10)	--	--	--	--	0.0021	0.0015
Sample Date	August 1				1.0784	--	--	--	--	1.0784
	August 13					1.0748	--	--	--	1.0748
	September 4				--	--	1.0777	--	--	1.0777
	September 14				--	--	--	1.0780	--	1.0780
	September 26				--	--	--	--	1.0781	1.0781
				Significance	--	--	--	--	--	**
				LSD (0.10)	--	--	--	--	--	0.0013
Interactions	Variety x K Treatment				NS	NS	NS	NS	*	++
	Variety x Sample Date				--	--	--	--	--	*
	K Treatment x Sample Date				--	--	--	--	--	NS
	Variety x K Treatment x Sample Date				--	--	--	--	--	NS
				Contrasts						
				300 K vs. 400 K (1-5, 7-11 vs. 6,12)	NS	NS	*	++	**	**
				Early Split vs. Late Split (2,3,8,9 vs. 4,5,10,11)	NS	NS	++	NS	NS	NS
				300 K Preplant vs. 300 K Split (1,7 vs. 2-5, 8-11)	NS	NS	NS	++	NS	NS
				300 K Preplant vs. 400 K Preplant (1,7 vs. 6,12)	NS	NS	*	NS	*	*
				0-0-60 vs. 0-0-60 + 0-0-22 (2,8 vs. 3,9)	NS	NS	NS	NS	*	NS
				0-0-60 vs. 0-0-50 (4,10 vs. 5,11)	*	NS	NS	NS	++	**

[1]Averages for Variety and K treatment across Sample Dates and Averages for Sample Dates across Variety and K Treatment.

[2]PP, E, S2 = Preplanting, Emergence, and Second Sidedress, respectively.

[3]NS = Non significant; ++, *, ** = Significant at 10%, 5%, and 1%, respectively.

Table 2. Effect of variety and potassium rate, source, and timing on tuber K at harvest and petiole K during tuber bulking.

Treatments						
Treatment #	**Variety**	**K Rate lbs K_2O/A**	**K Source**	**K Timing PP, E, S2[3]**	**Tuber[1] K**	**Petiole[2] K**
					---------- % ----------	
1	Russet Burbank	300	0-0-60	300, 0, 0	2.01	6.96
2	Russet Burbank	300	0-0-60	150, 150, 0	2.02	7.22
3	Russet Burbank	300	0-0-60 and 0-0-22	150, 150, 0	2.12	7.16
4	Russet Burbank	300	0-0-60	0, 150, 150	2.02	7.8
5	Russet Burbank	300	0-0-50	0, 150, 150	1.97	7.57
6	Russet Burbank	400	0-0-60	400, 0, 0	2.10	7.47
7	Umatilla	300	0-0-60	300, 0, 0	2.08	7.6
8	Umatilla	300	0-0-60	150, 150, 0	2.18	7.68
9	Umatilla	300	0-0-60 and 0-0-22	150, 150, 0	2.14	7.9
10	Umatilla	300	0-0-60	0, 150, 150	2.22	8.34
11	Umatilla	300	0-0-50	0, 150, 150	2.05	8.02
12	Umatilla	400	0-0-60	400, 0, 0	2.16	7.73
Main Effects						
Variety	Russet Burbank				2.04	7.36
	Umatilla				2.14	7.88
				Significance[4]	*	**
K Treatment	0-0-60, 300 lb/A Preplant				2.05	7.28
	0-0-60, 300 lb/A Early Split				2.10	7.45
	0-0-60 + 0-0-22, 300 lb/A Early Split				2.13	7.53
	0-0-60, 300 lb/A Late Split				2.12	8.07
	0-0-50, 300 lb/A Late Split				2.01	7.79
	0-0-60, 400 lb/A Preplant				2.13	7.58
				Significance	NS	*
				LSD (0.10)	--	0.48
Interaction	Variety X K Treatment				NS	NS
				Contrasts		
				300 K vs. 400 K (1-5, 7-11 vs. 6, 12)	NS	NS
				Early Split vs. Late Split (2, 3, 8, 9 vs. 4, 5, 10, 11)	NS	*
				300 K Preplant vs. 300 K Split (1, 7 vs. 2-5, 8-11)	NS	*
				300 K Preplant vs. 400 K Preplant (1, 7 vs. 6, 12)	NS	NS
				0-0-60 vs. 0-0-60 + 0-0-22 (2, 8 vs. 3, 9)	NS	NS
				0-0-60 vs. 0-0-50 (4, 10 vs. 5, 11)	NS	NS

[1]Tuber samples were from the Sept 26 harvest date.

[2]Petiole samples were collected on July 11 during tuber bulking (82 days after planting).

[3]PP, E, S2 = Preplanting, Emergence, Second Sidedress, respectively; for treatments 3 and 9, 0-0-60 was applied preplant and 0-0-22 after emergence.

[4]NS = Non significant; ++, *, ** = Significant at 10%, 5%, and 1%, respectively

Table 3. Effect of variety and potassium rate, source, and timing on tuber yield, tuber size distribution, stand count, and number of stems per plant.

Treatments					Tuber Yield											Stand count	Number of stems per plant
Treatment #	Variety	K Rate lbs. K_2O / A	K Source	K Timing PP, E, S2[1]	0-4 oz	4-6 oz	6-10 oz	10-14 oz	> 14 oz	Total	#1 > 4 oz	# 2 > 4 oz	Total marketable	> 6 oz	> 10 oz		
					cwt / A									%			
1	Russet Burbank	300	0-0-60	300, 0, 0	131.7	162.1	207.1	140.5	134.1	775.5	300.9	342.9	643.8	62.1	35.4	100.0	3.0
2	Russet Burbank	300	0-0-60	150, 150, 0	143.3	185.5	224.6	115.1	90.6	759.0	254.0	361.7	615.7	56.6	26.9	100.0	2.9
3	Russet Burbank	300	0-0-60 and 0-0-22	150, 150, 0	126.4	175.2	214.0	139.7	127.8	783.0	304.5	352.2	656.6	61.5	34.1	100.0	3.4
4	Russet Burbank	300	0-0-60	0, 150, 150	113.5	155.0	221.2	155.5	124.5	769.7	328.6	327.6	656.2	65.3	36.6	100.0	3.3
5	Russet Burbank	300	0-0-50	0, 150, 150	104.0	142.3	221.2	158.8	154.0	780.2	338.8	337.5	676.3	68.7	40.7	99.3	3.3
6	Russet Burbank	400	0-0-60	400, 0, 0	137.9	169.6	207.0	122.9	100.0	737.3	269.9	329.6	599.4	58.2	30.0	100.0	3.0
7	Umatilla	300	0-0-60	300, 0, 0	134.6	164.6	217.5	84.3	63.1	664.1	404.8	124.8	529.5	54.5	21.8	92.4	4.0
8	Umatilla	300	0-0-60	150, 150, 0	127.5	173.9	244.5	87.2	31.7	664.7	385.7	151.6	537.2	54.6	17.9	93.1	4.0
9	Umatilla	300	0-0-60 and 0-0-22	150, 150, 0	131.3	169.4	225.3	108.0	42.0	675.9	431.6	113.0	544.6	55.5	22.1	92.4	3.8
10	Umatilla	300	0-0-60	0, 150, 150	115.3	150.7	217.5	96.6	79.9	660.0	382.5	162.2	544.7	59.7	26.9	89.6	3.8
11	Umatilla	300	0-0-50	0, 150, 150	88.5	135.0	203.7	109.6	74.2	611.0	411.3	111.3	522.5	63.7	30.5	88.9	3.6
12	Umatilla	400	0-0-60	400, 0, 0	141.0	149.3	216.9	95.4	66.4	668.9	405.3	122.7	528.0	56.6	24.1	94.4	3.3
Main Effects																	
Variety	Russet Burbank				126.1	165.0	215.8	138.7	121.8	767.4	299.4	341.9	641.3	62.1	33.9	99.9	3.1
	Umatilla				123.0	157.1	220.9	96.9	59.5	657.4	403.5	130.9	534.4	57.4	23.8	91.8	3.8
				Significance[2]	NS	NS	NS	**	**	**	**	**	**	**	**	**	**
K Treatment	0-0-60, 300 lb. / A Preplant				133.1	163.3	212.3	112.4	98.6	719.8	352.8	233.8	586.6	58.3	28.6	96.2	3.5
	0-0-60, 300 lb. / A Early Split				135.4	179.7	234.5	101.1	61.1	711.8	319.9	256.6	576.5	55.6	22.4	96.5	3.5
	0-0-60 + 0-0-22, 300 lb. / A Early Split				128.8	172.3	219.6	123.8	84.9	729.4	368.0	232.6	600.2	58.5	28.1	96.2	3.6
	0-0-60, 300 lb. / A Late Split				114.4	152.9	219.4	126.1	102.2	714.8	355.5	244.9	600.5	62.5	31.7	94.8	3.6
	0-0-50, 300 lb. / A Late Split				96.2	138.6	212.5	134.2	114.1	695.6	375.1	224.4	599.4	66.2	35.6	94.1	3.4
	0-0-60, 400 lb. / A Preplant				139.5	159.5	211.9	109.2	83.2	703.1	337.6	226.1	563.7	57.4	27.0	97.2	3.2
				Significance	**	*	NS	*	NS	NS	NS	NS	NS	**	*	NS	NS
				LSD (0.10)	19.0	25.6	--	21.2	--	--	--	--	--	4.7	7.2	--	--
Interaction	Variety x K Treatment			**Significance**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
				Contrasts													
				300 K vs. 400 K (1-5, 7-11 vs. 6,12)	*	NS	NS	NS	NS	NS	NS	NS	++	NS	NS	NS	*
				Early Split vs. Late Split (2,3,8,9 vs. 4,5,10,11)	**	**	NS	*	*	NS	NS	NS	NS	**	**	NS	NS
				300 K Preplant vs. 300 K Split (1,7 vs. 2-5, 8-11)	++	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
				300 K Preplant vs. 400 K Preplant (1,7 vs. 6,12)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*
				0-0-60 vs. 0-0-60 + 0-0-22 (2,8 vs. 3,9)	NS	NS	NS	*	NS	NS	*	NS	NS	NS	NS	NS	NS
				0-0-60 vs. 0-0-50 (4,10 vs. 5,11)	++	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1]PP, E, S2 = Preplanting, Emergence, and Second Sidedress, respectively.

[2]NS = Non significant; ++, *, ** = Significant at 10%, 5%, and 1%, respectively.

Table 4. Effect of variety and potassium rate, source, and timing on chip color and the incidence of hollow heart and brown center.

Treatments								
Treatment #	Variety	K Rate lbs K_2O/A	K Source	K Timing PP, E, S2[2]	Chip Color[1] Stem end	Bud end	Hollow Heart (%)	Brown Center (%)
1	Russet Burbank	300	0-0-60	300, 0, 0	7	4.3	6.9	7.9
2	Russet Burbank	300	0-0-60	150, 150, 0	7.2	4.3	6.0	6.0
3	Russet Burbank	300	0-0-60 and 0-0-22	150, 150, 0	6.9	4.1	4.0	4.0
4	Russet Burbank	300	0-0-60	0, 150, 150	7.1	4.1	5.0	6.0
5	Russet Burbank	300	0-0-50	0, 150, 150	7	4.1	1.0	1.0
6	Russet Burbank	400	0-0-60	400, 0, 0	6.8	3.9	5.0	5.0
7	Umatilla	300	0-0-60	300, 0, 0	4.6	3.2	1.0	1.0
8	Umatilla	300	0-0-60	150, 150, 0	4.3	3.2	0.0	0.0
9	Umatilla	300	0-0-60 and 0-0-22	150, 150, 0	4.8	3.3	0.0	0.0
10	Umatilla	300	0-0-60	0, 150, 150	4.8	3.5	0.0	0.0
11	Umatilla	300	0-0-50	0, 150, 150	4.7	3.6	1.0	1.0
12	Umatilla	400	0-0-60	400, 0, 0	4.1	3.6	5.0	5.0
Main Effects								
Variety	Russet Burbank				7.0	4.1	4.6	5.0
	Umatilla				4.5	3.4	1.2	1.2
				Significance[3]	**	**	**	**
K Treatment	0-0-60, 300 lb/A Preplant				5.8	3.7	3.9	4.4
	0-0-60, 300 lb/A Early Split				5.8	3.8	3.0	3.0
	0-0-60 + 0-0-22, 300 lb/A Early Split				5.9	3.7	2.0	2.0
	0-0-60, 300 lb/A Late Split				5.9	3.8	2.5	3.0
	0-0-50, 300 lb/A Late Split				5.8	3.9	1.0	1.0
	0-0-60, 400 lb/A Preplant				5.5	3.8	5.0	5.0
				Significance	NS	NS	NS	NS
				LSD (0.10)	--	--	--	--
Interaction	Variety X K Treatment				NS	NS	NS	NS
				Contrasts				
				300 K vs. 400 K (1-5, 7-11 vs. 6, 12)	*	NS	NS	NS
				Early Split vs. Late Split (2, 3, 8, 9 vs. 4, 5, 10, 11)	NS	NS	NS	NS
				300 K Preplant vs. 300 K Split (1, 7 vs. 2-5, 8-11)	NS	NS	NS	NS
				300 K Preplant vs. 400 K Preplant (1, 7 vs. 6, 12)	++	NS	NS	NS
				0-0-60 vs. 0-0-60 + 0-0-22 (2, 8 vs. 3, 9)	NS	NS	NS	NS
				0-0-60 vs. 0-0-50 (4, 10 vs. 5, 11)	NS	NS	NS	NS

[1]Scale of 1 (white) to 10 (dark brown).

[2]PP, E, S2 = Preplanting, Emergence, Second Sidedress, respectively; for treatments 3 and 9, 0-0-60 was applied preplant and 0-0-22 after emergence.

[3]NS = Non significant; ++, *, ** = Significant at 10%, 5%, and 1%, respectively

Effects of Liquid Fertilizer Sources and Avail on Potato Yield and Quality

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Summary: A field experiment at the Sand Plain Research Farm in Becker was conducted to evaluate the effects of several liquid fertilizer formulations as well as P fertilizer (MAP or 10-34-0) with and without Avail on yield and quality of Russet Burbank potato. The study compared 12 treatments including a zero P control. Specialty liquid treatments NRG-N and eN and one conventional liquid treatment were applied at lower N rates than the other nine treatments. In general, the only significant effects on tuber yield were lower yields and smaller tubers associated with specialty and conventional liquid treatments when applied at lower N rates. At equivalent N rates, P rate did not significantly affect total or marketable yield; although, there were fewer small tubers and proportionally more larger sized tubers in the zero P treatment than with treatments receiving P. This effect is consistent with previous research showing that starter P fertilizer increases tuber set and sometimes reduces tuber size. There were no significant differences in yield or tuber size between conventional dry and liquid fertilizers applied at the standard N and P rate of 240 lb N/A and 120 lb P_2O_5/A. In general, use of Avail did not statistically affect marketable yield, although MAP at 120 lb P_2O_5/A with Avail tended to have proportionally larger tubers than MAP or 10-34-0 without Avail. This effect was not observed when Avail was used with 10-34-0. Avail tended to increase petiole P concentrations at tuber set and early tuber bulking, but these effects were not observed during mid and late bulking periods. Treatments tested had inconsistent effects on petiole micronutrient concentrations.

Background

Liquid fertilizers such as 10-34-0 have become more popular as starter fertilizers for potato production in recent years. In addition, new types of liquid formulations are being promoted by various companies with claims of increased fertilizer use efficiency, suggesting that they can be used at lower rates compared with conventional dry or liquid sources. Studies comparing conventional dry fertilizers with the various liquid fertilizers for potato production are lacking. These types of studies are needed to allow growers to make informed decisions about their use. In addition to liquid formulations, various methods of enhancing the efficiency of phosphorus (P) fertilizers have recently been developed. One such product is called Avail manufactured by Specialty Fertilizers. Avail is a water soluble polymer with a very high cation exchange capacity. The idea behind using Avail with P fertilizers is that within a small zone around the P fertilizer, the polymer will bind iron, aluminum and calcium and prevent precipitation of insoluble P compounds. Avail can be used with both granular and liquid P sources. The effects of Avail on potato yield and quality have not yet been examined in Minnesota.

The objective of this study was to evaluate the effects of several liquid fertilizer formulations and Avail on yield and quality of ‘Russet Burbank’ potato.

Materials and Methods

This study was conducted at the Sand Plain Research Farm in Becker on a Hubbard loamy sand soil. The previous crop was rye and selected soil chemical properties before planting were as follows (0-6"): pH, 5.9; organic matter, 2.3%; Bray P1, 29 ppm; ammonium acetate extractable K, Ca, and Mg, 103, 814, and 161 ppm, respectively; hot water extractable B, 0.3 ppm; Ca-phosphate extractable SO_4-S, 5 ppm; and DTPA extractable Zn, Cu, Fe, and Mn, 1.2, 0.5, 36.7, and 12.4 ppm, respectively. Extractable NO_3-N and NH_4-N in the top 2-ft of soil were 16 and 13 lb/A, respectively.

Treatments compared conventional dry fertilizer formulations and rates with conventional liquid 10-34-0 at equivalent rates as well as monoammonium phosphate (MAP) and 10-34-0 with and without Avail. Newer types of liquid formulations, NRG-N and eN (added to 28% UAN) manufactured by Agro-Culture (St. Johns, Michigan), were also evaluated. The Agro-Culture fertilizers have chelating compounds and slower release N formulations, which theoretically allow the use of lower nutrient rates. A liquid micronutrient fertilizer was also tested in combination with NRG-N. An additional Agro-Culture compound was used called eN, a urease inhibitor, which was added to 28% N. A conventional liquid fertilizer treatment at reduced N and P rates which was supposed to be equivalent to the Agro-Culture treatment was included for comparison, along with a dry fertilizer treatment that contained no phosphate. Because of an error in application, the Agro-Culture treatment at the low rate ended up with lower N than planned and the conventional liquid comparison ended up with a higher N rate than planned.

The following 12 specific treatments were evaluated (Note: all plots were preplant broadcast with 180-lb K_2O/A as 0-0-60 plus 37-lb K_2O/A and 30-lb S/A as 0-0-22-18):

1. **Dry fertilizer without phosphate at N rates equivalent to Treatment #5: 240 lb N/A**
    a. Planting: 35 lb N/A as urea
    b. Emergence sidedress: 100 lb N/A as urea
    c. Remainder:105 lb N/A as urea-ammonium nitrate granular (split into 3 post-hilling applications) and irrigated in
2. **Agro-Culture Liquid (High NRG-N): 115 lb N/A + 32 lb P_2O_5/A + 4 lb K_2O/A**
    a. Planting: 5 gal/A High NRG-N + 12 gal/A Pro-Germinator 9-24-3 + 2 qt/A Micro 500 = 27 lb N/A + 32 lb P_2O_5/A + 4 lb K_2O/A
    b. Emergence sidedress: 15 gal/A NRG-N = 44 lb N/A
    c. Second sidedress: 15 gal/A NRG-N = 44 lb N/A
3. **Conventional liquid program: 176 lb N/A and 32 lb P_2O_5/A**
    a. Planting: 8 gal/A 10-34-0 + 15.5 gal/A 28% urea-ammonium nitrate solution = 56 lb N/A + 32 lb P_2O_5/A
    b. Emergence sidedress: 20 gal/A 28% urea-ammonium nitrate solution = 60 lb N/A
    c. Second sidedress: 20 gal/A 28% urea-ammonium nitrate solution = 60 lb N/A
4. **Agro-Culture Liquid #2: (28% + eN) plus micronutrients: 203 lb N/A + 60 lb P_2O_5/A**
    a. Planting: 5 gal 28% + eN + 22.5 gal/A Pro-Germinator 9-24-3 + 2 qt/A Micro 500 = 38 lb N/A + 60 lb P_2O_5/A + micronutrients
    b. Emergence sidedress: 25 gal/A 28%+eN = 75 lb N/A
    c. Second sidedress: 30 gal/A 28%+eN = 90 lb N/A
5. **Dry fertilizer: 240 lb N/A + 60 lb P_2O_5/A**
    a. Planting: 120 lb/A MAP + 50 lb/A Urea = 35 lb N/A + 60 lb P_2O_5/A
    b. Emergence: 217 lb Urea/A = 100 lb N/A
    c. Remainder:105 lb N/A as urea-ammonium nitrate granular (split into 3 post-hilling applications) and irrigated in

6. **Dry fertilizer: 240 lb N/A + 60 lb P_2O_5/A + Avail**
    a. Planting: 120 lb/A MAP+Avail + 50 lb/A Urea = 35 lb N/A + 60 lb P_2O_5/A
    b. Emergence: 217 lb Urea/A = 100 lb N/A
    c. Remainder:105 lb N/A as urea-ammonium nitrate granular (split into 3 post-hilling applications) and irrigated in
7. **Dry fertilizer: 240 lb N/A + 120 lb P_2O_5/A**
    a. Planting: 240 lb/A MAP + 24 lb/A Urea = 35 lb N/A + 120 lb P_2O_5/A
    b. Emergence: 217 lb Urea/A = 100 lb N/A
    c. Remainder:105 lb N/A as 28% urea-ammonium nitrate granular (split into 3 post-hilling applications) and irrigated in
8. **Conventional liquid fertilizer: 240 lb N/A + 120 lb P_2O_5/A**
    a. Planting: 30 gal/A 10-34-0 = 35 lb N/A + 120 lb P_2O_5/A
    b. Emergence: 33.3 gal/A 28% = 100 lb N/A
    c. Remainder:105 lb N/A as urea-ammonium nitrate granular (split into 3 post-hilling applications) and irrigated in
9. **Dry fertilizer: 240 lb N/A + 120 lb P_2O_5/A + Avail**
    a. Planting: 240 lb/A MAP+Avail + 24 lb/A Urea = 35 lb N/A + 120 lb P_2O_5/A
    b. Emergence: 217 lb Urea/A = 100 lb N/A
    c. Remainder:105 lb N/A as urea-ammonium nitrate granular (split into 3 post-hilling applications) and irrigated in
10. **Conventional liquid fertilizer: 240 lb N/A + 120 lb P_2O_5/A + Avail**
    a. Planting: 30 gal/A 10-34-0 + Avail = 35 lb N/A + 120 lb P_2O_5/A
    b. Emergence: 33.3 gal/A 28% = 100 lb N/A
    c. Remainder:105 lb N/A as urea-ammonium nitrate granular (split into 3 post-hilling applications) and irrigated in
11. **Conventional liquid fertilizer: 240 lb N/A + 120 lb P_2O_5/A (split)**
    a. Planting: 15 gal/A 10-34-0 = 17 lb N/A + 60 lb P_2O_5/A
    b. Emergence: 33.3 gal/A 28% + 15 gal 10-34-0/A = 118 lb N/A + 60 lb P_2O_5/A
    c. Remainder:105 lb N/A as urea-ammonium nitrate granular (split into 3 post-hilling applications) and irrigated in
12. **Dry fertilizer: 240 lb N/A + 120 lb P_2O_5/A (preplant)**
    a. Preplant: 240 lb/A MAP + 24 lb/A Urea = 35 lb N/A + 120 lb P_2O_5/A
    b. Planting - None
    c. Emergence: 217 lb Urea/A = 100 lb N/A
    d. Remainder:105 lb N/A as 28% urea-ammonium nitrate granular (split into 3 post-hilling applications) and irrigated in

Preplant MAP (treatment 12) was applied and incorporated on April 23, 2007. Four, 20-ft rows were planted for each plot with the middle two rows used for sampling and harvest. 'Russet Burbank' "B" seed was hand planted in furrows on April 24, 2007. Spacing was 12 inches within each row and 36 inches between rows. Each treatment was replicated 4 times in a randomized complete block design. Admire was applied in-furrow for beetle control. Weeds, diseases, and other insects were controlled using standard practices. Rainfall was supplemented with sprinkler irrigation using the checkbook method of irrigation scheduling.

Fertilizer applications at planting were banded 3 inches to each side and 2 inches below the seed piece. Pre-weighed dry fertilizer was applied using a belt type applicator and liquid fertilizer was metered through drop hoses using the same banding equipment. Emergence fertilizer, both dry and liquid, was sidedressed on May 14 and mechanically incorporated in the hilling operation. The second sidedress application was on June 4. This included 100% of the post-hilling fertilizer for treatments 2, 3, and 4, and 1/3 of the post-hilling fertilizer for treatments 1 and 5 through 12. The remainder for treatments 1 and 5 through 12 was sidedressed in equal applications on June 19 and June 28. Post-hilling fertilizer as granular urea + ammonium nitrate was hand applied over the rows and then watered in with overhead irrigation.

Petiole samples were collected from the 4^{th} leaf from the terminal on four dates: June 12, June 26, July 11, and July 24. Petioles were analyzed for nitrate-N and multiple ICP elements on a dry weight basis. Vines were killed by chopping on September 14 and plots were machine harvested on September 24. Total tuber yield, graded yield, tuber specific gravity, and incidence of hollow heart and brown center were measured after harvest. A subsample of tubers was stored at 45 F for about one month and then fried for chip color.

Results and Discussion

Tuber yield and size distribution: Table 1 shows the effects of fertilizer treatment on tuber yield and size distribution. In general, the only significant effects were lower yields and smaller tubers associated with specialty and conventional liquid treatments when lower N rates were used. The dry fertilizer treatment with no phosphate applied was numerically lower in total yield than the treatments that included phosphate (except for the lowest N rate with NRG-N). Significant differences among treatments in total marketable yield were due to the lower yield at the lowest N rate with NRG-N. All other treatments were statistically the same.

The dry fertilizer treatment with no phosphate applied had significantly lower yields of smaller-sized tubers (< 4 oz) than the treatments that included phosphate. This response suggests that the no phosphate treatment produced fewer tubers, which consequently grew to larger size due to reduced competition. This is consistent with previous research showing that the application of P in starter fertilizer promotes increased tuber set, even in soils testing high in P. The percent of tubers greater than 6 and 10 ounces was affected by both P rate and N rate. The proportion of tubers greater than 6 oz and 10 oz was highest when no P fertilizer was applied and lowest when reduced N rates were used. The 120 lb P_2O_5/A as MAP plus Avail treatment resulted in the highest proportion of tubers greater than 6 oz among the treatments that received P and was statistically the same as the zero P control.

In general, no significant differences occurred in any yield category between the conventional dry fertilizer and conventional liquid full rate fertilizer treatments, with or without Avail, which had equivalent N and P application rates. The exception was for MAP plus Avail at the 120 lb P_2O_5/A rate, which resulted in larger amounts of tubers greater than 14 oz and smaller amounts of tubers in the 4-6 oz category. As mentioned above, differences due to NRG-N and eN were due to lower N rates.

Tuber quality: Table 2 shows the effects of fertilizer source and rate on tuber quality. There were no significant differences among treatments in specific gravity, the incidence of hollow heart and brown center or chip color due to treatment.

Petiole nutrient concentrations: Tables 3, 4, 5, and 6 show the effects of fertilizer source and rate on petiole nutrient concentrations on four sampling dates from mid-June to late-July. On the first two sampling dates, petiole nitrate was highest with the zero P control treatment, suggesting that low P reduced the capacity of the leaf to assimilate the nitrate. Lowest petiole nitrate was associated with lower rates of N application on the first three sampling dates and carried over into lower yields. There were no differences in petiole nitrate due to treatment on the fourth sampling date. Petiole P on the first sampling date was significantly affected by treatment. Lowest petiole P was with the zero P control and then it increased with increasing P rate. One exception was that the preplant MAP treatment at 240 lb P2O5/A resulted in significantly lower petiole P than banded MAP. While not significantly different, petiole P with MAP+Avail tended to be higher than with MAP alone. Petiole-P with 10-34-0 + Avail was slightly lower than with 10-34-0 without Avail. Treatment did not significantly affect petiole P at any of the later sampling dates, although there was a trend for petiole P to be higher when Avail was used on the second sampling date. Petiole P was not deficient in any treatment or sampling date, yet tuber set appeared to be lower when P was not applied.

Petiole K was not affected by treatment on any of the sampling dates. The lack of K differences was not surprising, because all plots received essentially the same K fertilizer applications. While treatment affected petiole Ca and Mg levels on some dates, they were not consistent from one date to the next. These inconsistent differences do not suggest a strong treatment effect on Ca and Mg nutrition.

Petiole Zn and B were not affected by treatment on any of the sampling dates. Petiole Cu concentrations increased on the third sampling date, which was due to the use of Cu containing fungicides. Significant differences in Fe, Mn and Cu occurred on some of the sampling dates, but there was no pattern that appeared to be related to fertilizer treatment.

Conclusions: The results of this study indicate that liquid fertilizers can be used to achieve equivalent yields to dry fertilizers when applied at equivalent rates. Reduced rates of N and P in liquid fertilizers (Pro germinator+NRGN, pro germinator+eN, 10-34-0+28%) resulted in lower yields and reduced tuber size compared with standard rates of dry or liquid fertilizer during the growing conditions of 2007. Most of the differences were due to N deficiency as shown by lower petiole nitrate levels. The zero P treatment had significantly lower petiole P than all the other treatments on the first sampling date, but not on the next three. Avail+MAP tended to result in higher petiole P than MAP alone although differences were not significant. Total yields were numerically lower when P was not applied, but tuber size was larger due to lower set. Therefore marketable yields were not affected by P rate. Consistent treatment effects on petiole micronutrient levels were not found.

Table 1. Effect of fertilizer treatment on tuber yield and tuber size distribution.

Treatment	N Rate lb N/A	N Timing[1] PP, P, E, S1-S3	P Rate lb P_2O_5/A	P Timing PP, P, E	Tuber Yield 0-4 oz	4-6 oz	6-10 oz	10-14 oz	>14 oz	Total	#1 > 4 oz	#2 > 4 oz	Total mrktble	> 6oz %	> 10 oz %
					----	----	----	----	cwt/A	----	----	----	----		
Control - 0 P	240	0, 35, 100, 35x3	0	0, 0, 0	82.3	134.4	234.6	133.1	102.3	686.6	426.4	177.9	604.3	68.3	34.2
ACLF NRG + micros	115	0, 27, 44, 44	32	0, 32, 0	144.2	239.0	198.8	51.6	18.8	652.4	258.0	250.3	508.2	40.1	10.5
Conventional Liquid	176	0, 56, 60, 60	32	0, 32, 0	129.9	234.7	205.2	88.4	44.6	702.8	323.0	249.9	572.9	48.2	18.9
ACLF #2 + micros	203	0, 38, 75, 90	60	0, 60, 0	125.5	221.5	235.8	71.8	61.1	715.7	345.5	244.8	590.2	51.5	18.5
MAP Conventional	240	0, 35, 100, 35x3	60	0, 60, 0	116.5	165.4	207.6	138.7	92.7	720.9	361.2	243.2	604.4	60.9	32.0
MAP + Avail	240	0, 35, 100, 35x3	60	0, 60, 0	118.1	182.4	202.7	137.7	96.3	737.1	356.6	262.4	619.0	59.4	31.9
MAP Conventional	240	0, 35, 100, 35x3	120	0, 120, 0	123.9	184.3	212.5	117.9	96.9	735.6	367.2	244.5	611.7	58.0	28.9
10-34-0 Conventional	240	0, 35, 100, 35x3	120	0, 120, 0	127.7	190.1	245.6	128.5	60.1	752.0	327.8	296.5	624.3	58.0	25.2
MAP + Avail	240	0, 35, 100, 35x3	120	0, 120, 0	112.3	152.5	197.9	127.2	123.3	713.1	343.0	257.8	600.9	62.7	35.0
10-34-0 + Avail	240	0, 35, 100, 35x3	120	0, 120, 0	131.6	199.6	200.6	109.3	77.6	718.7	325.4	261.8	587.1	54.0	26.0
10-34-0 Split	240	0, 17, 118, 35x3	120	0, 60, 60	115.0	179.3	203.6	136.5	99.4	733.7	378.2	240.5	618.8	59.7	32.0
MAP Preplant	240	35, 0, 100, 35x3	120	120, 0, 0	124.0	204.2	243.6	97.0	60.4	729.2	358.9	246.4	605.2	54.9	21.6
Significance[2]					*	**	NS	**	**	NS	**	*	++	**	**
LSD (0.1)					25.3	29.5	--	32.6	32.6	--	55.8	55.5	72.1	6.3	6.5

[1]PP=preplant, P=planting, E=emergence, S1-S3= sidedress on June 4, 19, & 28.

[2]NS=not significant; **, *, ++ = significant at P=0.01, 0.05, and 0.1, respectively.

Table 2. Effect of fertilizer treatment on specific gravity, incidence of hollow heart and brown center, and chip color.

Treatment	N Rate lb N/A	N Timing[1] PP, P, E, S1-S3	P Rate lb P_2O_5/A	P Timing PP, P, E	Hollow Heart %	Brown Center %	Specific Gravity	Chip Color[3] Stem End	Chip Color Bud End
Control - 0 P	240	0, 35, 100, 35x3	0	0, 0, 0	4.0	3.0	1.0789	7.8	5.2
ACLF NRG + micros	115	0, 27, 44, 44	32	0, 32, 0	1.0	1.0	1.0797	7.8	5.0
Conventional Liquid	176	0, 56, 60, 60	32	0, 32, 0	3.1	3.1	1.0802	7.8	5.1
ACLF #2 + micros	203	0, 38, 75, 90	60	0, 60, 0	2.1	2.1	1.0823	7.9	5.0
MAP Conventional	240	0, 35, 100, 35x3	60	0, 60, 0	4.1	4.1	1.0797	7.7	5.4
MAP + Avail	240	0, 35, 100, 35x3	60	0, 60, 0	2.0	3.0	1.0797	7.6	5.5
MAP Conventional	240	0, 35, 100, 35x3	120	0, 120, 0	5.0	5.0	1.0804	7.8	5.5
10-34-0 Conventional	240	0, 35, 100, 35x3	120	0, 120, 0	5.0	5.0	1.0816	7.8	5.3
MAP + Avail	240	0, 35, 100, 35x3	120	0, 120, 0	2.0	2.0	1.0788	7.3	5.3
10-34-0 + Avail	240	0, 35, 100, 35x3	120	0, 120, 0	4.0	4.0	1.0802	7.7	5.5
10-34-0 Split	240	0, 17, 118, 35x3	120	0, 60, 60	9.7	9.7	1.0824	7.8	5.6
MAP Preplant	240	35, 0, 100, 35x3	120	120, 0, 0	2.0	2.0	1.0816	7.8	5.1
Significance[2]					NS	NS	NS	NS	NS
LSD (0.1)					--	--	--	--	--

[1]PP=preplant, P=planting, E=emergence, S1-S3= sidedress on June 4, 19, & 28.
[2]NS=not significant; **, *, ++ = significant at P=0.01, 0.05, and 0.1, respectively.
[3]1=light; 10=dark.

Table 3. Effect of fertilizer treatment on petiole nutrient concentrations on June 12.

	N	N	P	P	6/12/2007									
Treatment	**Rate**	**Timing[1]**	**Rate**	**Timing**	NO_3-N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	lb N/A	**PP, P, E, S1-S3**	**lb P_2O_5/A**	**PP, P, E**	ppm	%				ppm				
Control - 0 P	240	0, 35, 100, 35x3	0	0, 0, 0	24278	0.32	9.92	0.96	0.63	128	80	60	6	72
ACLF NRG + micros	115	0, 27, 44, 44	32	0, 32, 0	15702	0.45	9.65	1.09	0.67	133	50	51	5	79
Conventional Liquid	176	0, 56, 60, 60	32	0, 32, 0	19404	0.44	9.40	1.17	0.76	157	65	56	5	79
ACLF #2 + micros	203	0, 38, 75, 90	60	0, 60, 0	19722	0.40	9.08	0.99	0.69	114	42	50	5	71
MAP Conventional	240	0, 35, 100, 35x3	60	0, 60, 0	20253	0.46	9.23	1.19	0.86	110	63	55	5	72
MAP + Avail	240	0, 35, 100, 35x3	60	0, 60, 0	19665	0.52	9.27	1.03	0.71	128	60	56	6	76
MAP Conventional	240	0, 35, 100, 35x3	120	0, 120, 0	19443	0.57	9.33	1.17	0.83	131	60	55	5	74
10-34-0 Conventional	240	0, 35, 100, 35x3	120	0, 120, 0	18587	0.58	9.07	1.11	0.65	140	58	56	5	76
MAP + Avail	240	0, 35, 100, 35x3	120	0, 120, 0	21333	0.61	9.30	1.22	0.84	136	62	58	6	78
10-34-0 + Avail	240	0, 35, 100, 35x3	120	0, 120, 0	20390	0.56	9.35	1.17	0.75	138	54	60	5	74
10-34-0 Split	240	0, 17, 118, 35x3	120	0, 60, 60	18293	0.59	8.72	1.13	0.68	135	47	57	5	70
MAP Preplant	240	35, 0, 100, 35x3	120	120, 0, 0	19327	0.40	8.95	1.13	0.73	110	54	56	5	67
Significance[2]					**	**	NS	NS	NS	++	**	NS	*	NS
LSD (0.1)					2013	0.08	--	--	--	30	11	--	1	--

[1]PP=preplant, P=planting, E=emergence, S1-S3= sidedress on June 4, 19, & 28.

[2]NS=not significant; **, *, ++ = significant at P=0.01, 0.05, and 0.1, respectively.

Table 4. Effect of fertilizer treatment on petiole nutrient concentrations on June 26.

	N	N	P	P	6/26/2007									
Treatment	**Rate**	**Timing[1]**	**Rate**	**Timing**	NO_3-N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	lb N/A	**PP, P, E, S1-S3**	**lb P_2O_5/A**	**PP, P, E**	ppm	%				ppm				
Control - 0 P	240	0, 35, 100, 35x3	0	0, 0, 0	21547	0.42	9.17	0.78	0.57	78	56	52	10	99
ACLF NRG + micros	115	0, 27, 44, 44	32	0, 32, 0	4378	0.34	9.28	0.78	0.45	77	46	44	7	100
Conventional Liquid	176	0, 56, 60, 60	32	0, 32, 0	11797	0.37	8.89	0.77	0.54	77	49	47	6	93
ACLF #2 + micros	203	0, 38, 75, 90	60	0, 60, 0	16471	0.36	8.96	0.81	0.59	77	53	51	6	91
MAP Conventional	240	0, 35, 100, 35x3	60	0, 60, 0	18143	0.37	8.23	0.92	0.71	82	58	53	5	89
MAP + Avail	240	0, 35, 100, 35x3	60	0, 60, 0	19460	0.41	8.98	0.80	0.59	74	54	50	6	93
MAP Conventional	240	0, 35, 100, 35x3	120	0, 120, 0	18366	0.41	8.55	0.96	0.73	79	52	48	4	91
10-34-0 Conventional	240	0, 35, 100, 35x3	120	0, 120, 0	17366	0.31	8.46	1.05	0.70	74	56	38	4	72
MAP + Avail	240	0, 35, 100, 35x3	120	0, 120, 0	19788	0.44	8.70	0.94	0.74	83	60	52	5	96
10-34-0 + Avail	240	0, 35, 100, 35x3	120	0, 120, 0	17804	0.36	8.33	0.99	0.71	80	49	38	4	82
10-34-0 Split	240	0, 17, 118, 35x3	120	0, 60, 60	17017	0.39	8.23	1.04	0.72	72	46	37	4	78
MAP Preplant	240	35, 0, 100, 35x3	120	120, 0, 0	17155	0.39	8.72	0.92	0.70	79	51	48	6	94
Significance[2]					*	NS	NS	*	**	NS	NS	NS	**	NS
LSD (0.1)					7214	--	--	0.19	0.13	--	--	--	1.8	--

[1]PP=preplant, P=planting, E=emergence, S1-S3= sidedress on June 4, 19, & 28.

[2]NS=not significant; **, *, ++ = significant at P=0.01, 0.05, and 0.1, respectively.

Table 5. Effect of fertilizer treatment on petiole nutrient concentrations on July 11.

Treatment	N Rate lb N/A	N Timing[1] PP, P, E, S1-S3	P Rate lb P_2O_5/A	P Timing PP, P, E	7/11/2007 NO$_3$-N ppm	P %	K %	Ca %	Mg %	Fe ppm	Mn ppm	Zn ppm	Cu ppm	B ppm
Control - 0 P	240	0, 35, 100, 35x3	0	0, 0, 0	9287	0.38	6.84	1.06	0.81	85	73	46	16	99
ACLF NRG + micros	115	0, 27, 44, 44	32	0, 32, 0	926	0.36	7.62	0.96	0.68	120	64	46	17	37
Conventional Liquid	176	0, 56, 60, 60	32	0, 32, 0	2117	0.35	8.00	1.06	0.55	94	69	45	38	89
ACLF #2 + micros	203	0, 38, 75, 90	60	0, 60, 0	3118	0.37	7.12	0.91	0.67	119	60	49	15	80
MAP Conventional	240	0, 35, 100, 35x3	60	0, 60, 0	10764	0.35	7.61	0.91	0.62	89	60	48	34	118
MAP + Avail	240	0, 35, 100, 35x3	60	0, 60, 0	11283	0.37	7.34	1.04	0.78	75	61	45	20	69
MAP Conventional	240	0, 35, 100, 35x3	120	0, 120, 0	12710	0.39	7.37	0.88	0.58	79	72	49	22	72
10-34-0 Conventional	240	0, 35, 100, 35x3	120	0, 120, 0	10064	0.42	7.54	0.86	0.61	73	63	51	23	41
MAP + Avail	240	0, 35, 100, 35x3	120	0, 120, 0	8574	0.39	7.00	1.02	0.70	89	59	43	15	55
10-34-0 + Avail	240	0, 35, 100, 35x3	120	0, 120, 0	13749	0.47	7.37	0.94	0.67	116	55	53	14	93
10-34-0 Split	240	0, 17, 118, 35x3	120	0, 60, 60	9530	0.51	7.17	0.93	0.67	100	51	47	15	94
MAP Preplant	240	35, 0, 100, 35x3	120	120, 0, 0	10500	0.43	7.21	0.95	0.69	135	65	52	16	82
Significance[2]					**	++	NS	NS	**	NS	NS	NS	*	NS
LSD (0.1)					3357	0.12	--	--	0.12	--	--	--	14	--

[1]PP=preplant, P=planting, E=emergence, S1-S3= sidedress on June 4, 19, & 28.
[2]NS=not significant; **, *, ++ = significant at P=0.01, 0.05, and 0.1, respectively.

Table 6. Effect of fertilizer treatment on petiole nutrient concentrations on July 24.

Treatment	N Rate lb N/A	N Timing[1] PP, P, E, S1-S3	P Rate lb P_2O_5/A	P Timing PP, P, E	7/24/2007 NO$_3$-N ppm	P %	K %	Ca %	Mg %	Fe ppm	Mn ppm	Zn ppm	Cu ppm	B ppm
Control - 0 P	240	0, 35, 100, 35x3	0	0, 0, 0	6671	0.37	8.21	0.82	0.70	108	63	50	9	170
ACLF NRG + micros	115	0, 27, 44, 44	32	0, 32, 0	3048	0.33	8.27	0.93	0.67	85	71	34	8	156
Conventional Liquid	176	0, 56, 60, 60	32	0, 32, 0	missing	0.30	8.31	1.22	0.68	128	69	79	10	181
ACLF #2 + micros	203	0, 38, 75, 90	60	0, 60, 0	3016	0.25	8.10	0.85	0.74	74	64	71	8	164
MAP Conventional	240	0, 35, 100, 35x3	60	0, 60, 0	5617	0.35	8.03	1.04	0.67	70	64	45	8	154
MAP + Avail	240	0, 35, 100, 35x3	60	0, 60, 0	4511	0.26	8.11	0.84	0.67	120	59	56	7	153
MAP Conventional	240	0, 35, 100, 35x3	120	0, 120, 0	3595	0.36	8.53	0.98	0.63	66	64	72	9	171
10-34-0 Conventional	240	0, 35, 100, 35x3	120	0, 120, 0	2177	0.33	8.33	0.73	0.68	62	55	84	10	153
MAP + Avail	240	0, 35, 100, 35x3	120	0, 120, 0	5451	0.38	8.41	0.85	0.71	71	70	59	7	172
10-34-0 + Avail	240	0, 35, 100, 35x3	120	0, 120, 0	3299	0.32	8.16	0.91	0.74	89	62	48	7	157
10-34-0 Split	240	0, 17, 118, 35x3	120	0, 60, 60	1690	0.39	8.41	0.94	0.77	65	52	61	6	172
MAP Preplant	240	35, 0, 100, 35x3	120	120, 0, 0	5865	0.34	8.81	0.94	0.72	116	67	55	11	153
Significance[2]					NS	NS	NS	++	NS	NS	NS	NS	++	NS
LSD (0.1)					--	--	--	0.23	--	--	--	--	3	--

[1]PP=preplant, P=planting, E=emergence, S1-S3= sidedress on June 4, 19, & 28.
[2]NS=not significant; **, *, ++ = significant at P=0.01, 0.05, and 0.1, respectively.

Evaluation of Specialty Phosphorus Fertilizer Formulations for Potatoes

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Abstract: Field experiments were conducted at the Sand Plain Research Farm in Becker, Minn. to evaluate the effects of MAP-based fertilizer, MicroEssentials S15 (MES15) and MicroEssentials SZ (MESZ) manufactured by Mosaic Co., on yield, quality, and P nutrition of Russet Burbank potato. Treatments included MAP, MES15, and MESZ fertilizer applied at 60 and 120 lb P_2O_5/A and a zero P control. Phosphorus fertilization increased total yield, marketable yield, tuber set, and P uptake. The lower tuber set in the zero P control plots did result in larger tuber size at harvest, although tuber size was more than adequate in all treatments. At equivalent P rates, the specialty P fertilizers used in this study tended to increase marketable yield and P uptake compared with conventional MAP, although the effect was not statistically significant for marketable yield. The MESZ formulation in particular performed well at the 60 lb P_2O_5/A rate for P uptake and marketable yield. Improved early season P availability was also suggested by higher petiole P levels with specialty formulations than with conventional MAP. Tuber specific gravity, hollow heart and brown center were not significantly affected by treatment. While further studies are needed, the results suggest a possible advantage to using these specialty P fertilizer formulations for potatoes on medium P testing soils.

Backgound: One of the challenges associated with improving P use efficiency in plants is maintaining an available form of P following application of P fertilizer. All soils tend to fix P making it less available for plant uptake. Phosphorus fixation is highest in highly acidic and alkaline soils due insoluble aluminum and iron P compounds in acid soils and insoluble calcium P compounds in alkaline soils. Use of elemental sulfur in the formulation has an acidifying effect and may help keep P in solution for a longer period of time, particularly on neutral to alkaline soils. Specialties fertilizers have recently been developed (US patent #6544313) that blend sulfur and zinc into a MAP-based product. MicroEssentials S15 (MES15) is a 13-33-0 product that contains 7.5% elemental S and 7.5% sulfate-S as ammonium sulfate. MicroEssentials SZ is a 12-40-0 product that contains 5% elemental S, 5% sulfate-S as ammonium sulfate, and 1% Zn as Zn oxide. The overall objective of this study was to determine potato response to specialty P products (MES15 and MESZ) manufactured by The Mosaic Company.

Materials and Methods: This study was conducted at the Sand Plain Research Farm in Becker, Minnesota on a Hubbard loamy sand soil. The previous crop was rye and selected soil chemical properties before planting were as follows (0-6"): pH, 6.7; organic matter, 1.3%; Bray P1, 19 ppm; ammonium acetate extractable K, Ca, and Mg, 79, 744, and 141 ppm, respectively; hot water extractable B, 0.2 ppm; Ca-phosphate extractable SO_4-S, 6 ppm; and DTPA extractable Zn, Cu, Fe, and Mn, 1.0, 0.4, 24, and 11 ppm, respectively.

Four, 20-ft rows were planted for each plot with the middle two rows used for sampling and harvest. Whole "B" Russet Burbank potato seed was hand planted in furrows on May 4, 2007. Row spacing was 12 inches within each row and 36 inches between rows. Each treatment was replicated 4 times in a randomized complete block design. Admire was applied in-furrow for beetle control. Weeds, diseases, and other insects were controlled using standard practices.

Rainfall was supplemented with sprinkler irrigation using the checkbook method of irrigation scheduling.

The following seven fertilizer treatments were tested:

1. Control (N, K & 15S; no P applied)
2. Conventional MAP (11-52-0) + 15S at 60 lb P_2O_5/A
3. Conventional MAP (11-52-0) + 15S at 120 lb P_2O_5/A
4. MicroEssentials S15 (13-33-0, 15S) at 60 lb P_2O_5/A
5. MicroEssentials S15 (13-33-0, 15S) at 120 lb P_2O_5/A
6. MicroEssentials SZ (12-40-0, 10S, 1Zn) at 60 lb P_2O_5/A
7. MicroEssentials SZ (12-40-0, 10S, 1Zn) at 120 lb P_2O_5/A

The amount of product applied per plot (based on a 240 sq ft area) @ 60 lb & 120 P_2O_5/A:
<u>60 lb/A P_2O_5 rate</u>:
MAP: ((60/43560)*240)/0.52 = 0.636 lb per plot (N = 12.7 lb/A)
Microessentials S15: ((60/43560)*240)/0.33 = 1.002 lb per plot (N = 23.6 lb/A; S = 27.5 lb/A)
Microessentials SZ: ((60/43560)*240)/0.40 = 0.826 lb per plot (N = 18.0 lb/A; S = 15 lb/A)

<u>120 lb/A P_2O_5 rate</u>
MAP: ((120/43560)*240)/0.52 = 1.272 lb per plot (N = 25.4 lb/A)
Microessentials S15: ((120/43560)*240)/0.33 = 2.004 lb per plot (N = 47.2 lb/A; S = 55 lb/A)
Microessentials SZ: ((120/43560)*240)/0.40 = 1.652 lb per plot (N = 36.0 lb/A; S = 30 lb/A)

The fertilizer was applied in a band 3 inches to the side and two inches below the seed piece using a belt type applicator. A preplant application of 40 lb N/A as 33-0-0 had been made in the first week of April for the rye before it was decided to use the field for this study. Potassium was broadcast applied as 0-0-60 (potassium chloride) at a rate of 150 lbs K_2O/A before planting to all plots. An additional 150 lb K_2O/A was applied as either 0-0-60 or 0-0-50 (potassium sulfate) depending on treatment to equalize the S rate to all treatments at 55 lb S/A, which was the amount of S applied with the high rate of MES15. In other words, the amount of K applied as 0-0-50 was subtracted from the 150 lb K_2O/A rate applied as a band at planting. Total N applied was 247 lb N/A. The rate of N applied at planting was adjusted with urea to the amount applied with the high rate of MES15 (47 lb N/A). The sidedress N applications were made with urea at the rate of 80 lb N/A at emergence on May 30 and two post hilling applications as urea-ammonium nitrate at 40 lb N/A on June 11 and June 28. Plots were irrigated immediately after posthilling N application to minimize volatilization.

Petiole samples were collected at initial tuber set (June 25) and at early (July 12) and mid tuber bulking (July 30). Total tuber yield, graded yield, tuber specific gravity, sugar end evaluation, and internal disorders were recorded at final harvest. A subsample of vines and tubers was collected for moisture determination. Dried tissues were weighed and then ground to pass through a 1 mm screen. Elemental concentrations in plant tissue were determined by AgVise laboratories. Nutrient uptake was calculated by multiplying tissue nutrient concentration by the total dry matter.

Each treatment was replicated 4 times in a randomized complete block design giving a total of 28 plots for the study (4x7). The experiment was statistically analyzed using ANOVA procedures on SAS and means were separated using a Waller-Duncan LSD test at P = 0.10.

Results:

Tuber Yield: Treatment effects on tuber yield and size distribution are presented in Table 1. Total tuber yield increased with P fertilizer addition regardless of source. In general, the greatest response was with conventional MAP with total yields increasing as P rate increased from 0 to 120 lb P_2O_5/A. In contrast, when MESZ specialty fertilizer was used, potato yield increased up to 60 lb P_2O_5/A. The response to P with MES15 was similar to the conventional MAP, but the yield increase between 60 and 120 lb P_2O_5/A was less with MES15 than with conventional MAP. The control was statistically the same as 60 lb P_2O_5/A with conventional MAP, but significantly lower than 60 lb P_2O_5/A with specialty formulations and 120 lb P_2O_5/A with both specialty formulations and conventional MAP. While trends were similar for marketable yield, there were no significant differences at the 10% probability level. Of interest is that tuber size (% > 10 oz) was significantly higher when no P fertilizer was applied and the yield of less than 4 oz tubers was significantly higher when P fertilizer was applied regardless of source.

The number of tubers per plant was counted on five plants prior to mechanical harvest. The results show that final tuber set was about 30 to 40% lower when P fertilizer was not applied (Table 2). The larger tuber size without the application of P fertilizer is directly related to the lower set. This study is consistent with previous research at Becker showing that P fertilizer is important for increasing tuber set. While larger tuber size is important for processing, the size obtained during the 2007 growing season was high enough so that the premium would be the same for all treatments. Thus, differences in economic return for 2007 would primarily be related to total and marketable yield.

Tuber quality: Treatment effects on hollow heart, brown center, specific gravity, and chip color are presented in Table 3. In general, P fertility had minor effects on tuber quality. While not significantly difference, tuber specific gravity was numerically lowest when P fertilizer was not applied. Hollow heart and brown center were variable with no discernable trends due to P rate or source. Chip color was quite dark for all treatments, most likely due to some periods of water stress during the hot growing season. Stem end color tended to be lighter with the specialty fertilizers, but the trend was inconsistent with P rate.

Petiole nutrient concentrations: Petiole NO_3-N, P, S and Zn in samples collected on June 25 are presented in Table 4. Petiole NO_3-N decreased with increasing P rate regardless of source, suggesting a dilution effect when P fertilizer is applied. Petiole P increased with increasing P rate. At equivalent P rate, petiole P was generally higher with specialty formulations than conventional MAP, particularly at the 60 lb P_2O_5/A rate. While significant differences were detected for petiole S, treatment effects were not consistent with P rate or source. Petiole Zn was not affected by treatment. On July 12, trends for petiole P were not as consistent as on the first sampling date (Table 5). The only significant increase over the control for petiole P was with MESZ fertilizer at the highest rate. Petiole S and Zn were not affected by treatment. On July 30, petiole S was highest in the control and surprisingly lowest with the specialty fertilizers (Table 6). Petiole NO_3-N, P, and Zn were not affected by treatment.

Tuber and vine nutrient concentrations: Tuber P concentration increased with P fertilizer application but there were no significant differences among P sources (Table 7). Tuber N, S and Zn concentrations were not significantly affected by treatment. Vine S concentrations were highest in the control with generally no effect due to fertilizer source (Table 7). Vine P, N and Zn were not significantly affected by treatment.

Tuber and vine dry matter accumulation and P uptake: Tuber dry matter accumulation and P uptake are presented in Table 8. Tuber dry matter increased with P fertilizer application with the highest dry matter accumulation occurring with the MESZ treatment at 60 lb P_2O_5/A. Fertilizer treatment did not significantly affect vine dry matter accumulation, therefore total dry matter accumulation (vines plus tubers) generally followed the same trends as tuber dry matter. P uptake by tubers increased with P fertilizer application for conventional MAP and MES15. For MESZ, highest tuber P uptake was at the 60 lb P_2O_5/A rate and was significantly higher than tuber P uptake with conventional MAP at both 60 lb P_2O_5/A and 120 lb P_2O_5/A. Vine P uptake was not affected by treatment. Total P uptake (vines plus tubers) followed the same trends as tuber P uptake.

General Conclusions: Results from this study clearly show that potatoes responded to P in a soil with a Bray P of 19 ppm. Fertilization with P improved tuber set and increased marketable yield. The lower tuber set in the zero P control plots did result in larger tuber size at harvest, presumably due to less competition for nutrients. At equivalent P rates, the specialty P fertilizers used in this study tended to increase marketable yield and P uptake compared with conventional MAP. The MESZ formulation in particular performed well at the 60 lb P_2O_5/A rate. Improved early season P availability was also suggested by higher petiole P levels with specialty formulations than with conventional MAP. Surprisingly, the added Zn with the MESZ formulation did not result in an increase in Zn concentrations in petioles, vines, or tubers. The results suggest a possible advantage to using specialty P fertilizer formulations such as MES15 or MESZ for potatoes on medium P testing soils.

Table 1. Effect of MES15 and MESZ on tuber yield and size distribution.

Treatments			Total tuber yield (cwt/A)										
#	P_2O_5 Source	P_2O_5 Rate (lb/A)	< 4 oz	4-6 oz	6-10 oz	10-14 oz	> 14 oz	Total	> 4 oz #1	> 4 oz #2	Total Marketable	% > 6 oz	% > 10 oz
1	Control	0	28.0	67.5	123.7	138.2	180.1	537.2	405.4	104.0	509.3	82.6	59.6
2	MAP	60	57.8	112.7	168.6	137.0	114.0	590.0	401.8	130.4	532.2	70.7	42.0
3	MAP	120	56.4	121.9	192.4	147.4	101.3	619.4	403.6	159.4	563.1	70.9	39.8
4	MES15	60	45.9	99.5	164.6	144.3	158.8	613.1	410.1	157.1	567.2	76.3	49.4
5	MES15	120	51.9	111.0	192.1	148.0	120.6	623.7	409.6	162.2	571.7	73.8	42.9
6	MESZ	60	47.8	99.4	168.8	145.9	164.8	626.7	444.3	134.6	578.9	76.5	49.6
7	MESZ	120	53.0	99.1	168.6	138.1	156.5	615.4	386.6	175.8	562.4	75.0	47.5
		Significance	++	NS	*	NS	NS	++	NS	NS	NS	NS	*
		LSD (0.10)	18.6	-	32.2	-	-	61.4	-	-	-	-	11.4

[1]NS = Non significant; ++, *, ** = Significant at 10%, 5%, and 1%, respectively.

Table 2. Effect of MES15 and MESZ on number of stems per plant in June and tubers per plant at harvest.

Treatments			Stems per plant	Tubers per plant				
#	P_2O_5 Source	P_2O_5 Rate (lb/A)		< 4 oz	4-6 oz	6-10 oz	> 10 oz	Total
1	Control	0	3.3	1.4	1.7	2.2	2.3	7.5
2	MAP	60	3.1	3.5	3.6	3.4	1.5	12.0
3	MAP	120	4.1	4.4	2.8	3.6	1.1	11.8
4	MES15	60	3.5	2.4	3.3	3.3	1.1	10.0
5	MES15	120	3.7	3.2	3.3	4.8	1.4	12.6
6	MESZ	60	3.2	3.2	2.7	3.5	1.3	10.6
7	MESZ	120	3.4	3.1	1.8	3.0	1.9	9.7
		Significance	++	*	++	**	++	*
		LSD (0.10)	0.6	1.6	1.4	0.9	0.8	2.6

[1]NS = Non significant; ++, *, ** = Significant at 10%, 5%, and 1%, respectively.

Table 3. Effect of MES15 and MESZ on tuber quality.

Treatments			% Hollow Heart	% Brown Center	Specific Gravity	Chip Color[2] Stem End	Chip Color[2] Bud End
#	P_2O_5 Source	P_2O_5 Rate (lb/A)					
1	Control	0	4.6	4.6	1.0792	7.2	4.2
2	MAP	60	12.6	12.6	1.0803	7.3	4.3
3	MAP	120	4.0	4.0	1.0811	7.0	4.4
4	MES15	60	2.2	2.2	1.0802	6.6	4.4
5	MES15	120	7.0	7.0	1.0806	6.9	4.2
6	MESZ	60	5.1	5.1	1.0807	7.2	4.3
7	MESZ	120	11.0	11.0	1.0802	6.8	4.1
		Significance[1]	NS	NS	NS	*	NS
		LSD (0.10)	-	-	-	0.4	-

[1]NS = Non significant; ++, *, ** = Significant at 10%, 5%, and 1%, respectively. [2]Color: 1= light; 10 = very dark.

Table 4. Effect of MES15 and MESZ on petiole nitrate-N, P, S, and Zn on June 25.

Treatments			6/25/2007			
#	P_2O_5 Source	P_2O_5 Rate (lb/A)	ppm NO_3-N	% P	% S	ppm Zn
1	Control	0	22048	0.32	0.23	60
2	MAP	60	21843	0.38	0.22	46
3	MAP	120	18737	0.43	0.26	60
4	MES15	60	18787	0.46	0.24	56
5	MES15	120	16564	0.51	0.24	54
6	MESZ	60	19335	0.45	0.21	59
7	MESZ	120	18922	0.46	0.23	51
		Significance[1]	**	**	**	NS
		LSD (0.10)	2550	0.06	0.02	-

[1]NS = Non significant; ++, *, ** = Significant at 10%, 5%, and 1%, respectively.

Table 5. Effect of MES15 and MESZ on petiole nitrate-N, P, S, and Zn on July 12.

Treatments			7/12/2007			
#	P_2O_5 Source	P_2O_5 Rate (lb/A)	ppm NO_3-N	% P	% S	ppm Zn
1	Control	0	ND	0.36	0.24	60
2	MAP	60	ND	0.44	0.26	46
3	MAP	120	ND	0.35	0.24	48
4	MES15	60	ND	0.37	0.24	54
5	MES15	120	ND	0.45	0.22	51
6	MESZ	60	ND	0.47	0.22	61
7	MESZ	120	ND	0.52	0.24	57
		Significance[1]	-	++	NS	NS
		LSD (0.10)	-	0.12	-	-

[1]NS = Non significant; ++, *, ** = Significant at 10%, 5%, and 1%, respectively. ND = not determined due to insufficient sample

Table 6. Effect of MES15 and MESZ on petiole nitrate-N, P, S, and Zn on July 30.

Treatments			7/30/2007			
#	P_2O_5 Source	P_2O_5 Rate (lb/A)	ppm NO_3-N	% P	% S	ppm Zn
1	Control	0	8289	0.22	0.25	33
2	MAP	60	6495	0.28	0.23	37
3	MAP	120	8028	0.20	0.24	34
4	MES15	60	7078	0.20	0.19	31
5	MES15	120	6651	0.25	0.20	29
6	MESZ	60	5411	0.25	0.21	35
7	MESZ	120	6458	0.26	0.20	32
		Significance[1]	NS	NS	++	NS
		LSD (0.10)	-	-	0.04	-

[1]NS = Non significant; ++, *, ** = Significant at 10%, 5%, and 1%, respectively.

Table 7. Effect of MES15 and MESZ on tuber and vine P, N, S, and Zn concentrations.

Treatments			Elemental concentration							
#	P_2O_5 Source	P_2O_5 Rate (lb/A)	% P		%N		%S		ppm Zn	
			Tubers	Vines	Tubers	Vines	Tubers	Vines	Tubers	Vines
1	Control	0	0.18	0.08	1.20	1.13	0.12	0.15	16	110
2	MAP	60	0.20	0.08	1.30	1.08	0.12	0.13	15	73
3	MAP	120	0.20	0.08	1.28	1.28	0.12	0.14	15	98
4	MES15	60	0.20	0.07	1.35	1.15	0.11	0.11	15	85
5	MES15	120	0.21	0.09	1.33	1.13	0.12	0.11	15	68
6	MESZ	60	0.20	0.08	1.28	1.20	0.11	0.12	16	101
7	MESZ	120	0.21	0.08	1.30	1.05	0.11	0.10	22	71
		Significance[1]	++	NS	NS	NS	NS	**	NS	NS
		LSD (0.10)	0.02	-	-	-	-	0.03	-	-

[1]NS = Non significant; ++, *, ** = Significant at 10%, 5%, and 1%, respectively.

Table 8. Effect of MES15 and MESZ on vine and tuber dry matter accumulation and P uptake.

Treatments			Dry Matter			P uptake		
#	P_2O_5 Source	P_2O_5 Rate (lb/A)	lb/A			lb/A		
			Tubers	Vines	Total	Tubers	Vines	Total
1	Control	0	11465	3176	14641	20.8	2.5	23.2
2	MAP	60	12180	3304	15484	24.5	2.5	27.0
3	MAP	120	13172	2945	16117	26.4	2.2	28.6
4	MES15	60	12574	3494	16067	24.5	2.5	27.0
5	MES15	120	13409	2707	16116	28.2	2.4	30.6
6	MESZ	60	14938	3315	18253	30.2	2.7	32.9
7	MESZ	120	13124	3356	16481	27.8	2.5	30.3
		Significance[1]	++	NS	++	**	NS	**
		LSD (0.10)	2080	-	2000	3.6	-	3.4

[1]NS = Non significant; ++, *, ** = Significant at 10%, 5%, and 1%, respectively.

Umatilla and Russet Burbank
Response to Nitrogen Fertilizer Rate and Timing

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Summary: A field experiment at the Sand Plain Research Farm in Becker was conducted to characterize the response of 'Umatilla' and 'Russet Burbank' potatoes to nitrogen (N) rate and timing of application. Total and marketable yields of Russet Burbank were greater than Umatilla, but Russet Burbank had more small tubers and a significantly lower yield of #1 tubers greater than 4 oz in size than Umatilla. Nitrogen rate affected both yield and tuber size, but Russet Burbank responded to higher rates of N than Umatilla. Russet Burbank had its highest marketable yield with 240-lb N/A and part of the N applied post-hilling. Umatilla had its highest marketable yield with 180-lb N/A. Russet Burbank had its greatest amount of tubers 10-14 oz in size and highest percentage of tubers greater than 6 oz with 300-lb N/A. Umatilla had its greatest amount of 10-14 oz tubers with 120-lb N/A and its highest percentage of tubers greater than 6 oz with 180-lb N/A. Vine dry matter increased significantly as N rate increased and averaged 40% more for Russet Burbank than Umatilla. Post-hilling N application had no significant effect on tuber yield, tuber size, or vine dry matter. Stand counts were higher for Russet Burbank, but Umatilla had more stems per plant. Tuber specific gravity was significantly higher for Umatilla, while Russet Burbank had a significantly higher incidence of hollow heart and significantly darker chip color. Nitrogen rate and timing had no effect on specific gravity or chip color. Hollow heart tended to increase with increasing N rate for Russet Burbank, but the opposite trend occurred for Umatilla. Both hollow heart and brown center increased significantly when part of the N was applied post-hilling. Umatilla had higher petiole nitrate-N concentrations than Russet Burbank, but this effect was not consistent at all N rates. Petiole nitrate-N increased as N rate increased for both varieties on all sampling dates and was with consistent similar increases in vine dry matter production. Applying part of the N post-hilling had no effect on petiole nitrate-N compared with applying all of the N before hilling.

Background

This study was a modification of research conducted in 2004 and 2005 that compared N responses of the potato varieties 'Alturas' and 'Russet Burbank' and 2006 research that compared N responses of the varieties 'Umatilla' and 'Russet Burbank'. Alturas is a recently released cultivar from the Northwest breeding program with a lower N requirement than Russet Burbank, which led to its use in wellhead protection areas to protect water quality. Further evaluation of Alturas has been abandoned, because it was found to have undesirable processing and storage qualities. 'Umatilla' is another cultivar released in the mid 1990's from the Northwest breeding program. It has more desirable processing and storage attributes than Alturas, but has not been extensively evaluated for N response under Midwest conditions. The 2007 year of this study was conducted to compare N responses of Umatilla and Russet Burbank, which will provide growers with data to more efficiently manage N for this new cultivar. It will also be useful to those concerned about the effects of potato production on groundwater quality.

The objective of this study was to determine the effects of N rate and timing on Russet Burbank and Umatilla yield and quality.

Materials and Methods

This study was conducted at the Sand Plain Research Farm in Becker, Minnesota on a Hubbard loamy sand soil. The previous crop was cereal rye and selected soil chemical properties before planting were as follows (0-6"): pH, 6.2; organic matter, 1.8%; Bray P1, 48 ppm; ammonium acetate extractable K, Ca, and Mg, 92, 646, and 129 ppm, respectively; hot water extractable B, 0.2 ppm; and DTPA extractable Zn, Cu, Fe, and Mn, 0.5, 0.2, 22.5, and 4.7 ppm, respectively. Extractable NO_3-N and NH_4-N in the top 2 ft of soil were 11.6 and 11.0 lb/A, respectively.

Four, 20-ft rows were planted for each plot with the middle two rows used for sampling and harvest. Cut "A" 'Umatilla' seed treated with NuBark and "B" 'Russet Burbank' seed was hand planted in furrows on April 19, 2007. Row spacing was 12 inches within each row and 36 inches between rows. Each treatment was replicated four times for each variety in a randomized complete block design. Admire was applied in-furrow for beetle control. Weeds, diseases, and other insects were controlled using standard practices. Rainfall was supplemented with sprinkler irrigation using the checkbook method of irrigation scheduling.

Each cultivar was subjected to six N treatments with different rates and application timing as described below. Treatment 5 was modified from a treatment used in the three previous years of the study where emergence and initial post-hilling applications were 45 lb N/A (increased to 75 lb N/A in 2007) and total N was 180 lb N/A (increased to 240 lb N/A in 2007). Treatment 6 was modified from a treatment used in the three previous years of the study where emergence and initial post-hilling applications were 75 lb N/A (increased to 105 lb N/A in 2007) and total N was 240 lb N/A (increased to 300 lb N/A in 2007).

Treatment	Planting	Emergence	Hilling + Post-hilling	Total
	-------------------------------- lb. N/A --------------------------------			
1	30	0	0	30
2	30	45	45	120
3	30	75	75	180
4	30	105	105	240
5	30	75	75 + 30 + 30	240
6	30	105	105 + 30 + 30	300

The 30-lb N/A application at planting was banded 3 inches to each side and 2 inches below the seed piece using a belt type applicator. It was supplied as 750 lb/A of 4-18-26 and was supplemented with 2-lb Zn/A as zinc oxide and 0.5-lb B/A as boric acid. Emergence and hilling N applications were supplied as urea and mechanically incorporated. Post-hilling N was applied by hand as 50% granular urea and 50% ammonium nitrate, which was watered-in with overhead irrigation to simulate fertigation with a 28% UAN solution. Emergence fertilizer was applied on May 10, hilling application was on May 29, and post-hilling N was applied on June 11 and June 28 (½ of the total amount on each date). A complete factorial arrangement was used with cultivar and N rate/timing as main effects.

Plant stands were measured on May 29 and the number of stems per plant was counted on June 6. Petiole samples were collected from the 4th leaf from the terminal on four dates: June 12, June 27, July 12, and July 25. Petioles were analyzed for nitrate-N on a dry weight basis. Vines were harvested on Sept 14 from two, 10-ft sections of row, followed by mechanically beating the vines over the entire plot area. Plots were machine harvested on Sept 24 and total tuber yield and graded yield were measured. Sub-samples of vines and tubers were collected to determine moisture percentage and N concentrations, which were then used to calculate N uptake and distribution within the plant. Tuber sub-samples were also used to determine tuber specific gravity, the incidence of hollow heart and brown center. Visual ratings of stem and bud end chip color after frying were determined following about one month of storage at 45 F.

Results and Discussion

Tuber yield: Table 1 shows the effects of variety, N rate, and N timing on tuber yield, size distribution, stand count, and number of stems per plant. Total and marketable yields of Russet Burbank were 20 to 25% greater than for Umatilla. Russet Burbank had significantly higher yields of tubers between 10 and 14 oz in size, but also greater amounts less than 6 oz in size. Umatilla had a 33% greater total yield of #1 tubers larger than 4 oz and a greater percentage of its marketable yield in this category (64% for Umatilla compared with 38% for Russet Burbank).

For the two varieties combined, total tuber yield was highest with 120-lb N/A and marketable yield was highest with 180-lb N/A, but rates from 120- to 300-lb N/A were not significantly different from one another in either yield category. Russet Burbank had its highest marketable yield and highest yield of #1 tubers greater than 4 oz with 240-lb N/A (some of the N applied post-hilling). Umatilla had its highest yield in both of these categories with 180-lb N/A. Applying part of the N post-hilling had no effect on yield compared with applying all of the N before hilling.

Nitrogen fertilizer rate affected all but one tuber size category, but there were significant differences between the two varieties and overall Russet Burbank size was more affected by N rate. Russet Burbank had its largest amount of 10-14 oz tubers and highest percentage of tubers greater than 6 oz with 300-lb N/A. Umatilla had its largest amount of 10-14 oz tubers with 120-lb N/A and its highest percentage of tubers greater than 6 oz with 180-lb N/A. Russet Burbank had its smallest amount of 4-6 oz tubers with 300-lb N/A, while Umatilla had its smallest amount with 120-lb N/A. Averaged across both varieties, the amount of tubers greater than 14 oz increased with increasing N rate and the largest amount of #1 tubers greater than 4 oz in size occurred with 180-lb N/A. The percentage of tubers greater than 10 oz increased with increasing N rate for both varieties. Nitrogen application timing had no effect on tuber size.

Stand count, stem number, and vine dry matter. Stand count was 9% higher for Russet Burbank than Umatilla and decreased slightly for Umatilla as N rate increased. The number of stems per plant was 12% higher for Umatilla than Russet Burbank, but was not affected by N rate. In a potassium study this year at the same location, stand counts were 8% higher for Russet Burbank and the number of stems per plant was 23% higher for Umatilla.

Averaged across treatments Russet Burbank produced 40% greater vine growth than Umatilla, but this difference was not consistent at all N rates. Vine dry matter increased significantly with increasing N rate for both varieties, except that for Russet Burbank the treatments receiving 240- and 300-lb N/A and part of their N post-hilling were equivalent. Nitrogen application timing had no significant effect on stand count, stem number, or vine dry matter.

Tuber quality: Table 2 shows the effects of variety, N rate, and N timing on tuber quality. Tuber specific gravity was significantly higher for Umatilla than for Russet Burbank, which is consistent with previous research. Nitrogen rate and timing had no effect on specific gravity. Russet Burbank had a significantly higher incidence of hollow heart, and tended to be higher in brown center, than Umatilla. Hollow heart tended to increase with increasing N rate for Russet Burbank, but tended to decrease for Umatilla. A similar N rate pattern occurred with brown center. Hollow heart and brown center both increased significantly when part of the N was applied post-hilling. Color of both stem and bud end chips was significantly darker for Russet Burbank than Umatilla. Nitrogen rate and timing had no significant effect on chip color but Russet Burbank had its darkest chips, and Umatilla had its lightest chips, at the lowest N rate. Stem end chips were consistently darker than bud end chips, although they were not statistically compared.

N uptake and distribution: Data on N uptake and distribution between vines and tubers was not available at the time of this report.

Petiole nitrate concentrations: Table 3 shows the effects of variety, N rate, and N timing on petiole nitrate-N concentrations on four sampling dates. When averaged across treatments, Umatilla had significantly higher nitrate-N concentrations than Russet Burbank on the first and fourth sampling dates and was numerically higher on the middle two dates. However, this pattern was not consistent for all N rates. Petiole nitrate-N increased as N rate increased for both varieties on all four sampling dates. These increases were similar to the increases in vine dry matter as N rate increased (Table 1). Nitrogen application timing had no effect on petiole nitrate-N.

Conclusions: Total and marketable yields of Russet Burbank were greater than Umatilla, but Russet Burbank had more small tubers and a significantly lower yield of #1 tubers greater than 4 oz in size than Umatilla. Nitrogen rate affected yield, tuber size, and vine dry matter of both varieties, but Russet Burbank responded to higher rates of N than Umatilla. Nitrogen application timing had no effect on yield, tuber size or vine dry matter production. Stand counts were higher for Russet Burbank, but Umatilla had more stems per plant. Tuber specific gravity was significantly higher and chip color was significantly lighter for Umatilla than Russet Burbank, but neither quality was affected by N rate or timing. Hollow heart and brown center tended to increase with increasing N rate for Russet Burbank, but not Umatilla. Petiole nitrate-N increased as N rate increased for both varieties, but was not affected by N application timing.

Table 1. Effect of variety, N rate, and N timing on tuber yield, tuber size distribution, stand count, number of stems per plant, and vine dry matter.

Treatments				Tuber Yield													Vine
Treatment #	Variety	N Rate lbs. N / A	N Timing P, E, H, PH[1]	0-4 oz	4-6 oz	6-10 oz	10-14 oz	> 14 oz	Total	#1 > 4 oz	# 2 > 4 oz	Total marketable	> 6 oz	> 10 oz	Stand Count	Number of Stems per plant	Dry Matter lb/A
				cwt / A									%				
1	Russet Burbank	30	30, 0, 0, 0	181.1	251.7	146.2	46.9	7.0	632.9	157.9	294.0	451.8	31.4	8.5	99.3	3.4	0.44
2	Russet Burbank	120	30, 45, 45, 0	153.9	232.4	212.3	78.4	23.3	700.4	256.6	289.9	546.5	44.8	14.5	100.0	3.3	0.48
3	Russet Burbank	180	30, 75, 75, 0	118.3	162.0	204.9	123.0	54.6	662.8	276.3	268.2	544.6	57.9	27.3	100.0	3.2	1.22
4	Russet Burbank	240	30, 105, 105, 0	120.9	162.7	161.4	112.5	65.6	623.1	254.4	247.9	502.3	54.9	29.0	100.0	3.2	1.36
5	Russet Burbank	240	30, 75, 75, 60	127.0	154.3	198.0	123.5	89.0	691.9	306.7	258.1	564.8	59.5	30.9	100.0	3.2	1.58
6	Russet Burbank	300	30, 105, 105, 60	122.8	130.0	163.9	133.7	99.2	649.6	269.6	257.2	526.8	61.3	36.2	100.0	3.3	1.54
7	Umatilla	30	30, 0, 0, 0	105.0	129.9	142.9	42.5	17.1	437.4	277.8	54.6	332.4	46.1	13.6	93.7	3.9	0.15
8	Umatilla	120	30, 45, 45, 0	102.3	109.5	179.5	108.8	42.2	542.3	352.1	87.9	440.0	60.9	27.8	93.1	3.5	0.56
9	Umatilla	180	30, 75, 75, 0	80.6	109.8	200.0	97.3	65.1	552.8	377.6	94.6	472.2	65.4	29.2	88.2	3.7	0.65
10	Umatilla	240	30, 105, 105, 0	92.7	122.1	179.3	100.6	58.8	553.5	343.6	117.2	460.8	61.2	29.0	91.0	4.0	0.88
11	Umatilla	240	30, 75, 75, 60	89.0	113.0	172.5	97.9	55.4	527.9	324.9	114.0	438.9	61.4	28.5	91.7	3.6	1.04
12	Umatilla	300	30, 105, 105, 60	104.6	119.6	169.0	104.6	66.4	564.1	343.8	115.7	459.5	60.5	30.5	93.1	3.6	1.45
Main Effects																	
Variety	Russet Burbank			137.3	182.2	181.1	103.0	56.5	660.1	253.6	269.2	522.8	51.6	24.4	99.9	3.3	1.11
	Umatilla			95.7	117.3	173.9	92.0	50.8	529.7	336.6	97.3	434.0	59.2	26.4	91.8	3.7	0.79
			Significance[2]	**	**	NS	*	NS	**	**	**	**	**	NS	**	**	**
N Rate	30			143.0	190.8	144.5	44.7	12.1	535.2	217.8	174.3	392.1	38.8	11.1	96.5	3.6	0.30
	120			128.1	171.0	195.9	93.6	32.7	621.3	304.3	188.9	493.2	52.9	21.2	96.5	3.4	0.52
	180			99.4	135.9	202.4	110.2	59.8	607.8	327.0	181.4	508.4	61.6	28.2	94.1	3.4	0.94
	240[3]			106.8	142.4	170.4	106.6	62.2	588.3	299.0	182.5	481.5	58.0	29.0	95.5	3.6	1.12
	240[4]			108.0	133.7	185.3	110.7	72.2	609.9	315.8	186.1	501.8	60.4	29.7	95.8	3.4	1.31
	300			113.7	124.8	166.4	119.2	82.8	606.8	306.7	186.4	493.1	60.9	33.3	96.5	3.5	1.50
			Significance	**	**	**	**	**	*	**	NS	**	**	**	NS	NS	**
			LSD (0.10)	15.2	20.9	25.4	14.5	19.0	54.3	35.4	--	45.6	4.0	4.1	--	--	0.19
Interaction	Variety x N Rate			*	**	NS	*	NS	NS	NS	++	NS	*	*	++	NS	++
			Contrasts														
			Linear N (trmts 1-4 and 7-10)	**	**	*	**	**	++	**	NS	**	**	**	++	NS	**
			Quadratic N (trmts 1-4 and 7-10)	**	**	++	**	**	NS	**	NS	*	**	**	*	NS	**
			Post-Hill vs No Post-Hill (trmts 4,10 vs 5,11)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1]P, E, H, PH = Planting, Emergence, Hilling, and Post-Hilling, respectively.

[2]NS = Non significant; ++, *, ** = Significant at 10%, 5%, and 1%, respectively.

[3]No post-hill N applied.

[4]Post-hill N applied.

Table 2. Effect of variety, N rate, and N timing on tuber specific gravity, hollow heart, brown center, and chip color.

Treatments							Chip Color[1]	
Treatment #	Variety	Nitrogen Rate lbs/A	Nitrogen Timing P, E, H, PH[2]	Specific Gravity	Hollow Heart	Brown Center	Stem end	Bud end
					---------- % ----------			
1	Russet	30	30, 0, 0, 0	1.0704	0.0	0.0	8.1	6.3
2	Russet	120	30, 45, 45, 0	1.0733	1.0	0.0	8.0	6.5
3	Russet	180	30, 75, 75, 0	1.0738	4.3	4.3	7.8	5.8
4	Russet	240	30, 105, 105, 0	1.0712	3.1	1.0	7.5	5.9
5	Russet	240	30, 75, 75, 60	1.0738	8.4	7.1	7.8	5.9
6	Russet	300	30, 105, 105, 60	1.0717	6.6	6.6	7.4	5.9
7	Umatilla	30	30, 0, 0, 0	1.0776	3.2	3.2	5.9	5.0
8	Umatilla	120	30, 45, 45, 0	1.0785	2.1	2.1	6.9	5.2
9	Umatilla	180	30, 75, 75, 0	1.0795	1.0	1.0	6.6	4.7
10	Umatilla	240	30, 105, 105, 0	1.0793	0.0	0.0	6.8	5.3
11	Umatilla	240	30, 75, 75, 60	1.0766	2.1	1.1	6.6	4.8
12	Umatilla	300	30, 105, 105, 60	1.0801	3.3	3.3	6.7	5.0
Main Effects								
Variety	Russet Burbank			1.0724	3.9	3.2	7.8	6.0
	Umatilla			1.0786	1.9	1.8	6.6	5.0
			Significance[3]	**	*	NS	**	**
N Rate	30			1.0740	1.6	1.6	7.0	5.6
	120			1.0760	1.5	1.0	7.5	5.8
	180			1.0767	2.6	2.6	7.2	5.2
	240[4]			1.0753	1.6	0.5	7.2	5.6
	240[5]			1.0752	5.2	4.1	7.2	5.4
	300			1.0759	4.9	4.9	7.1	5.4
			Significance	NS	++	NS	NS	NS
			LSD (0.10)	--	3.4	--	--	--
Interaction	Variety X N Rate			NS	++	NS	*	NS
			Contrasts					
			Linear N (trmts 1-4 and 7-10)	NS	NS	NS	NS	NS
			Quadratic N (trmts 1-4 and 7-10)	NS	NS	NS	NS	++
			Post-Hill vs No Post-Hill (trmts 4,10 vs 5,11)	NS	*	*	NS	NS

[1]Scale of 1 (white) to 10 (dark brown).

[2]P, E, H, PH = Planting, Emergence, Hilling, and Post-Hilling, respectively.

[3]NS = Nonsignificant; ++, *, ** = Significant at 10%, 5%, and 1%, respectively.

[4]No post-hilling N applied.

[5]Part of the N applied post-hilling.

Table 3. Effect of variety, N rate, and N timing on petiole nitrate-N on four sampling dates.

Treatments				Petiole Nitrate-N			
Treatment #	Variety	N Rate lbs/A	N Timing P, E, H, PH[1]	Sampling Date 6/12	6/27	7/12	7/25
				---------- ppm ----------			
1	Russet	30	30, 0, 0, 0	2302	438	325	351
2	Russet	120	30, 45, 45, 0	12752	4080	595	508
3	Russet	180	30, 75, 75, 0	18796	7736	3507	1410
4	Russet	240	30, 105, 105, 0	22372	13816	6759	3739
5	Russet	240	30, 75, 75, 60	18862	8367	7500	2879
6	Russet	300	30, 105, 105, 60	19460	11990	9430	4577
7	Umatilla	30	30, 0, 0, 0	9687	542	200	489
8	Umatilla	120	30, 45, 45, 0	21620	5597	1457	1245
9	Umatilla	180	30, 75, 75, 0	25890	10119	3387	1725
10	Umatilla	240	30, 105, 105, 0	26329	10271	5771	3356
11	Umatilla	240	30, 75, 75, 60	26184	10825	7006	6329
12	Umatilla	300	30, 105, 105, 60	25105	14826	13854	9518
Main Effects							
Variety	Russet Burbank			15757	7738	4686	2244
	Umatilla			22469	8697	5279	3777
			Significance[2]	**	NS	NS	**
N Rate	30			5995	490	262	420
	120			17186	4838	1026	877
	180			22343	8928	3447	1568
	240[3]			24351	12043	6265	3547
	240[4]			22523	9596	7253	4604
	300			22283	13408	11642	7048
			Significance	**	**	**	**
			LSD (0.10)	1866	2981	1382	1332
Interaction	Variety X N Rate			NS	NS	*	*
			Contrasts				
			Linear N (trmts 1-4 and 7-10)	**	**	**	**
			Quadratic N (trmts 1-4 and 7-10)	**	**	**	**
			Post-Hill vs No Post-Hill (trmts 4,10 vs 5,11)	NS	NS	NS	NS

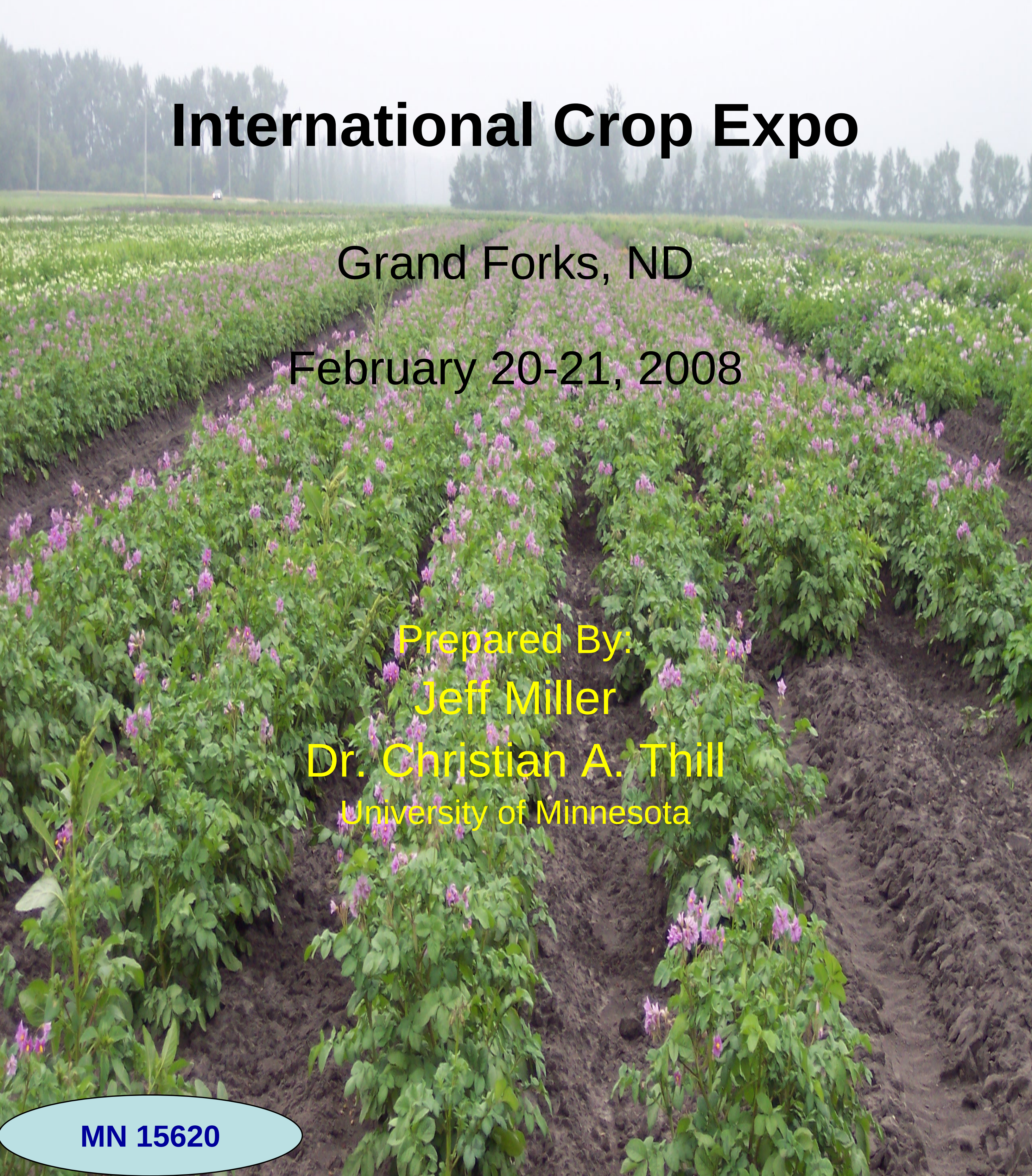
[1]P, E, H, PH = Planting, Emergence, Hilling, and Post-Hilling, respectively.

[2]NS = Nonsignificant; ++, *, ** = Significant at 10%, 5%, and 1%, respectively.

[3]No post-hilling N applied.

[4]Part of the N applied post-hilling.

Virus Free Clones
University of Minnesota - 2008



International Crop Expo

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Prepared By:

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Minnesota Potato Breeding and Genetics 2007

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Breeding Objectives

Objective 1: Develop and evaluate enhanced potato germplasm for resistance to potato diseases and having improved yield, yield stability, and marketing quality. Deliverables include Red skin and yellow flesh, Round white chip processing, and Long russet FF processing and fresh market cultivars.

Objective 2: Determine post-harvest storage requirements and subsequent processing characteristics for sugar ends and cold induced sweetening resistance of breeding lines and development of novel breeding procedures to increase the breeding efficiency for these traits.

Objective 3: Determine the occurrence of symptom-less expression to potato viruses $PVY^{O/N}$ in breeding populations, and breed for host plant resistance to potato viruses.

Report Contents

The scope of this report is to focus on the clones that have gone through tissue and are virus free.

Yield, Grade and Quality Evaluations – Breeding selections advancing in our program were compared to commercial cultivars in field trials at irrigated locations in Minnesota and North Dakota.
Typical yield, grade, and quality information were collected at harvest. These data include plant maturity, stand, total and US #1 marketable and size distribution yield, percentage of U.S. No. 1 yield and graded defect weights (malformed tubers, severe growth cracking, etc.), specific gravity, incidence and type of internal and external defects, and processing color. Then, evaluations for storability and processing were determined after 1-, 3-months storage at 40 and 45F.

Minnesota Table A. 2007. Location, planting, vine kill (Days after planting, DAP), and harvest (DAP) dates of MN research trials at irrigated and non-irrigated locations.

Location	Irrigation	Planted	Kill DAP	Harvest DAP
Grand Forks, ND – (Seed increase)	Non irrigated	26 June	100	110
Grand Forks, ND – (Single hills)	Non irrigated	26 June	100	110
Becker, MN				
Late	Irrigated	30 April	120	130
Single Hills & E1's	Irrigated	18 May	115	125
Williston, ND	Irrigated	10 May	120	140
Single Hills	Irrigated	11 May	120	140
Late Blight – Rosemount, MN	Irrigated	20 June	90	110
C. Scab – Becker, MN	Irrigated	1 May	120	140
Expr - PLRV / PVY – Rosemount, MN	Non irrigated	6 June	100	120
Vert. – Grand Forks	Non irrigated	27 June		

Clonal Evaluations and Procedures

Minnesota Table B. 2007. Number of MN clonal selections and cultivars at replicated yield trial and disease resistance trial locations.

	Number of MN Clonal selections and cultivars					
	Stages of development [1]					
Clonal Market type	**Elite**	**Intermediate**	**Early**		**Checks**	**Total**
Chipping	61	65	26	3	Atlantic, NorValley, Snowden	152
Processing	13	105	43	2	R. Burbank, Shepody	161
Fresh	24	44	26	4	R. Norkotah, Red Norland, Red Pontiac, Yukon Gold	94
NCR	**FF**	**Chip**	**Fresh**			
North Dakota	1		3			4
Wisconsin	2	2				4
Michigan	1	2				4
Canada	2	1	1			4
Other Germplasm Enhancement	2	673	23			
Disease Screening Trials	Clones Screened					
Late Blight - Natl	23					23
Late Blight - Breeding	409					409
Late Blight - Family selection	518					518
PVY expression	280					280
C. Scab - Natl	24					24
C. Scab - Breeding	409					409
Vert	409					409
New hybrid generation (Single-hills)			70,000			

Project Description

The University of Minnesota potato breeding research is emphasizing the development, evaluation, and distribution of potato cultivars and germplasm with improved yield, quality, and disease resistance by developing new hybrid progenies and evaluating them in multiple dryland and irrigated locations. Post harvest storage and quality characterizations are performed from 40, 42, 45, and 48F throughout the 7 month storage season; focusing on sugar end and cold induced sweetening. The most advanced selections will be evaluated for Nitrogen use efficiency, N timing and spacing. Novel breeding methods and germplasm enhancement strategies are pursued to increase the efficiency of determining disease and pest resistance characterization early in the breeding effort. A focus is on foliar and tuber late blight, common scab, PVY and PLRV symptom expression, common scab, CPB, aphids, *Verticillium* wilt, and sugar end and cold induced sweetening.

Grand Forks, ND – Evaluate (~30,000) and select new hybrids from breeding crosses for marketing potential. Evaluate enhanced potato germplasm for improved yield, yield stability, and marketing quality. Characterize germplasm for resistance sugar end, cold induced sweetening and to *Verticillium* wilt.

Becker, MN – Evaluate (~30,000) and select new hybrids from breeding crosses for marketing potential. Evaluate enhanced potato germplasm for improved yield, yield stability, and marketing quality. Characterize germplasm for resistance sugar end, cold induced sweetening and to common scab. Determine the Nitrogen use efficiency, N-timing, and spacing requirements of potato breeding lines advancing from the potato breeding program.

Rosemount, MN – Determine the occurrence of symptom-less expression to potato viruses $PVY^{O/N}$ in breeding populations, and breed for host plant resistance to potato viruses. Exploit novel breeding methods for determining genetic gain for late blight resistance earlier in breeding, and develop foliar and tuber late blight resistance germplasm. Determine genomic differences, identifying genes involved in the reproductive biology of potato, and analyze post-zygotic crossing barriers that inhibit gene introgression between wild *Solanum* species and cultivated potato for late blight resistance.

Williston, ND – Evaluate (~30,000) and select new hybrids from breeding crosses for marketing potential. Evaluate enhanced potato germplasm for improved yield, yield stability, and marketing quality. Characterize germplasm for resistance sugar end, and cold induced sweetening.

Breeding for host plant resistance to potato pests and diseases

A breeder should not focus heavily first on disease and pest resistance, then marketability traits, or the reverse. A balanced approach is necessary since varieties having superior disease and pest resistance lacking marketability traits will be limited in commercial use, and varieties lacking disease and pest resistance will likely not sustain the viability of our industry. Most notable are susceptibilities to multiple diseases, pests, and viruses such as *Verticillium* wilt, late and early blight, storage rots *Fusarium* and *Erwinia*, common scab, Colorado potato beetle, green peach aphids, potato leafhoppers, and all common viruses. In the UM potato breeding program evaluations are made for resistance to multiple diseases and pests. We also evaluate germplasm from north central and other US breeding programs. In UM breeding populations we apply EGS procedures to our screened populations.

Promising New Potato Varieties

This report is focusing on the most advanced & some of the more promising University of Minnesota clones. All of these clones have gone through tissue culture to rid the clones of disease & are available as virus free tissue culture plantlets.

			Color	
Sort	**Clone**	**Mkt**	**Skin**	**Flesh**
1	MN 99460-21	FF	Rus	W
2	MN 99460-14	FM	Red	W
3	MN 99380-1	Chip/FM	W	Yel-dk
4	MN 96072-4	FM	Red	W
5	MN 96013-1	FM	Red	W
6	MN 19470	FF	LW	W
7	MN 19350	FF	W	W
8	MN 19298	FM	Red	Yel
9	MN 18747	P	LW	W
10	MN 18710	FF/FM	Rus	W
11	MN 15620	FF	Red	Yel
12	MN 02 616	FM	Red	Yel-dk
13	MN 02 589	Chip/FM	W	Yel-lt
14	MN 02 588	Chip	W	W
15	MN 02 586	Chip/FM	W	Yel-lt
16	MN 02 574	Chip/FM	White	Yel
17	MN 02 467	FM	Rus	Yel-lt
18	MN 02 419	FF	LW	Cream
19	MN 00177-5	FM	Red	W
20	COMN 04712-05	FF	Rus-lt	x

2008 University of Minnesota Potato Breeding & Genetics

MN 15620

Parentage: MN 1006.81-4 x MN 5.80-12

Developers: University of Minnesota, Minnesota Agricultural Experiment Statior

Incentives for production: 89% of MN 15620 are US No. 1. French fry processing color is excellent from 45F. Tuber set averages 7 tubers per plant with >60% over 6oz. Specific gravity of MN 15620 = Russet Burbank. Smaller tubers may be marketed for fresh market due to their

Strengths: MN 15620 is a seedling selected by F. Lauer having a smooth red to pink color skin, light yellow flesh, oblong to oval tuber shape, and excellent cooking qualities that make it suitable for tablestock and French fry processing use. Internal quality is excellent. In addition, MN 15620 has moderate field tolerance to CPB, and *Verticillium* wilt, and is resistant to PVY

MN 15620

***Morphological Characteristics*:**

Plant: Dark to medium green foliage; Semi-erect vine medium to tall in height; small to medium size leaflets with visible stems providing good bed cover. Vigor is excellent. Stems, leaf veins, and petioles have anthocyanin pigmentation.

Flower: Dark Red Violet

Tubers: The tubers have a smooth skin, red to pink in color, light yellow flesh, and an oblong tc oval tuber shape.

***Agronomic Characteristics*:**

Maturity: Medium-late

Yield: High yield under irrigated conditions.

Specific Gravity: About 1.080 in Minnesota irrigated and non-irrigated.

Storability: Long dormancy, i.e. no sprouting at 6 months 40F with CIPC.

Diseases: moderate field tolerance to CPB, and *Verticillium* wilt, and is resistant to PVY and PLRV.

Weaknesses: Susceptibility to common scab and late blight.

6 Year Performance

		Tubers	Total Yld	US # 1's			B's	A's	Culls			Internal Defects (%)			
Clone	Loc	/Plant	Cwtyld	Cwtyld	%	%< 2 oz.	%	%	%	Sp. Gr.	Chip	HH	IN	VD	BC
MN 15620	BE	7	229.0	188.8	83.7	13.7	37.2	63.2	0.0	1.059	5.1	0	0	11	4
	BL	9	408.7	349.6	85.1	8.2	23.1	75.5	1.4	1.072	5.2	2	3	5	1
	H	5.9	408.7	370.2	90.6	1.3				1.075	2.3	0	0	17	0
	W	5	429.4	384.3	91.1	2.2	17.6	74.3	8.1	1.086	4.7	0	0	0	0
Late harvest: Avg.		6.6	415.6	368.0	88.9	3.9	20.4	74.9	4.8	1.078	4.0	0.7	0.8	7.1	0.2

2008 University of Minnesota Potato Breeding & Genetics

MN 99380-1

Parentage: Atlantic x MSA091-1

Developers: University of Minnesota, Minnesota Agricultural Experiment Station

Incentives for production: MN 99380-1 has a high yield of uniformly smooth tubers with ~ 86% US No. 1; tuber flesh color is dark yellow. Specific gravity is moderate ~ 1.078. Chip processing is excellent from 40F where low glucose content from storage is observed. Tuber set averages 9 tubers per plant with ~ 52% of the tubers > 6 oz.

Strengths: MN 99380-1 is a seedling selected in 1999 having white skin, dark yellow flesh, smooth uniform tubers, and an excellent internal quality. MN 99380-1 has low glucose content from storage and chips directly from 40F. Tubers have moderate to high specific gravity and good culinary characteristics. MN 99380-1 has some resistance to late blight, low incidence of pink rot.

***Morphological Characteristics*:**

Plant: Light green foliage; Semi-erect vine medium in height; Small to medium size somewhat open leaflets .

Flower: Pale Red Violet White Tips, Fades White

Tubers: The tubers are white skinned, dark yellow flesh, and are round to oval in shape, medium

***Agronomic Characteristics*:**

Maturity: Medium

Yield: Medium yield under irrigated conditions.

Specific gravity: Moderate: ~ 1.078

Storability: Short dormancy period

Diseases: low incidence to pink rot.

Weaknesses: Susceptible to Verticillium wilt, CPB, and slight susceptibility to common scab.

5 Year Performance

		Tubers	Total Yld	US # 1's			B's	A's	Culls			Internal Defects (%)			
Clone	**Loc**	**/Plant**	**Cwtyld**	**Cwtyld**	**%**	**%< 2 oz.**	**%**	**%**	**%**	**Sp. Gr.**	**Chip**	**HH**	**IN**	**VD**	**BC**
MN 99380-1	BE	10.0	309.3	256.9	82.7	13.4	49.2	50.5	0.4	1.064	2.2	1	1	8	1
	BL	10.1	389.7	337.4	86.7	6.0	22.2	72.8	5.0	1.070	3.7	3	3	6	0
	H	6.0	294.4	265.8	90.3	3.1				1.085	2.0	0	0	0	0
	W	10.3	290.3	235.0	80.5	7.2	32.5	61.3	6.2	1.080	2.9	0	0	4	0
Late harvest:	Avg.	8.8	324.8	279.4	85.8	5.4	27.4	67.1	5.6	1.078	2.9	1.1	1.1	3.4	0.0

2008 University of Minnesota Potato Breeding & Genetics

MN 18710

Parentage: AC91.9 x MN 14489

Incentives for production: MN 18710 is a dual purpose russet with a high yield of uniformly smooth and oblong shaped tubers with ~ 95% US No. 1; tuber flesh color is white. Specific gravity is medium-high ~ 1.077. French fry processing is excellent from 50F. Tuber set averages 9 tubers per plant with ~ 75% of the tubers > 6 oz. In 2004 dryland production ~ 86% of the tubers were > 6 oz.

Strengths: MN 18710 is a seedling selected by F. Lauer having a light russet skin, white flesh, smooth uniform tubers, and an excellent internal quality. MN 18710 processes into French fries from 50F and has a good fresh market appearance. Tubers have moderate to high specific gravity ~1.083 and good culinary characteristics. MN 18710 has resistance to common scab.

***Morphological Characteristics*:**

Plant: Light to medium green foliage, medium height, medium sized closed leaflets providing excellent bed cover. Profusion of white flowers.

Flower: White

Tubers: The tubers are a blocky oval-oblong russeted tuber with shallow eyes, an attractive appearance & having white flesh.

***Agronomic Characteristics*:**

Maturity: Medium late

Yield: Moderate to high yield producing very few under 2 oz. & cull potatoes compared to Russet Burbank. Yield is comparable to Russet Norkotah.

Weaknesses: Susceptible to *Verticillium* wilt, CPB, pink rot, and susceptibility to late blight.

5 Year Performance

		Tubers	Total Yld	US # 1's			B's	A's	Culls			Internal Defects (%)			
Clone	**Loc**	**/Plant**	**Cwtyld**	**Cwtyld**	**%**	**%< 2 oz.**	**%**	**%**	**%**	**Sp. Gr.**	**Chip**	**HH**	**IN**	**VD**	**BC**
MN 18710	BE	11	295	257	87.5	10.8	35.9	64.1	0.5	1.060	6.4	2	0	3	3
	BL	12	516	496	96.1	3.9	11.1	88.3	0.7	1.069	7.1	0	0	3	1
	H	6.6	598	552	92.3	0.9				1.079	6.3	0	0	0	0
	W	7	396	379	97.2	1.8	9.9	87.4	2.7	1.082	6.3	0	0	0	0
Late harvest:	Avg	8.5	503.5	476.0	95.2	2.2	10.5	87.8	1.7	1.077	6.5	0.0	0.0	1.0	0.2

2008 University of Minnesota Potato Breeding & Genetics

MN 18747

Parentage: ND 2264-7 x MN 47.82-6 (MN 14489)

Developers: University of Minnesota, Minnesota Agricultural Experiment Station

Incentives for production: The tubers of MN 18747 have a uniform shape with a smooth white skin and white flesh; >95% of the tubers are US No. 1. Early French fry processing color is excellent as is from 48F storage. Tuber set averages 6 tubers per plant with >55 and 80% over 6oz. at early and late harvest, respectively. Specific gravity of MN 18747 = Shepody.

Strengths: MN 18747 is a seedling selected by C. Thill having a smooth white color skin, white flesh, blocky-oblong uniform tuber shape, and excellent French fry quality. Its use is for early French fry processing since internal quality is excellent, and yield is superior to Shepody. MN 18747 expresses normal symptoms of PVY and PLRV infection unlike Shepody. In addition, MN 18747 is resistant to common scab.

***Morphological Characteristics*:**

Plant: Dark green foliage; erect vine and tall in height; intermediate to stemmy, large oblong leaflets that provide good bed cover. Vigor is excellent.

Flowers: Flowers are red violet with prominent white tips that fade to white.

Tubers: The tubers are long and smooth with a white color skin, white flesh, and a blocky-oblong uniform tuber shape.

***Agronomic Characteristics*:**

Maturity: Medium-early.

Tubers: Smooth white color skin, white flesh, blocky-oblong uniform tuber shape, and excellent internal quality.

Yield: Early yield is high > Shepody under irrigated conditions; late yield ≥ Shepody.

Specific Gravity: About 1.075-1.080 in Minnesota irrigated and non-irrigated.

Culinary Quality: MN 18747 tubers can be used for fresh market baking, mashing, and microwave cooking and for processing into French fries.

Foliage: Dark green foliage with large oblong leaflets.

Diseases: Normal symptoms of PVY and PLRV infection unlike Shepody, resistant to common scab.

Storability: Medium dormancy, i.e. slight sprouting at 5 months 40F with CIPC.

Weaknesses: Susceptibility to CPB, *Verticillium* wilt, and late blight.

3 Year Performance

		Tubers	Total Yld	US # 1's			B's	A's	Culls			Internal Defects (%)			
Clone	**Loc**	**/Plant**	**Cwtyld**	**Cwtyld**	**%**	**%< 2 oz.**	**%**	**%**	**%**	**Sp. Gr.**	**Chip**	**HH**	**IN**	**VD**	**BC**
MN 18747	BE	7	288	276	96	3.8	18.8	81.2	0.0	1.059	4.8	0	0	0	0
	BL	6	449	441	98	2.1	15.6	84.4	0.0	1.065	2.9	0	0	2	0
	H	4.2	301	285	95	1.0				1.070	2.3	0	0	0	0
	W	6	365	357	98	1.0	13.3	86.7	0.0	1.076	3.6	3	0	0	1
Late harvest:	Avg.	5.4	371.8	360.9	96.7	1.4	14.4	85.6	0.0	1.070	2.9	1.1	0.0	0.6	0.3

2008 University of Minnesota Potato Breeding & Genetics

MN 99460-21

Parentage: OP

Developers: University of Minnesota, Minnesota Agricultural Experiment Station

Incentives for production: The tubers of MN 99460-21 have a uniform shape with a smooth russeted skin and white flesh. 90% of the tubers are US No. 1. Tuber set averages 7 tubers/plant. Specific gravity of MN 99460-21 = that of R. Burbank.

Strengths: MN 99460-21 is an attractive uniform shaped dual purpose russet with 74% of tubers over 6 oz. and very few undersize potatoes.

Morphological Characteristics:

Plant: Dark green foliage; erect vine and tall in height; intermediate to stemmy. Vigor is

Flowers: Pale Red Violet, Prominent White Tips, Fades to White

Agronomic Characteristics:

Maturity: Medium-early.

Tubers: The tubers are long and smooth with a russeted skin, white flesh, and a blocky-oblong tuber shape.

Yield: Lower than both Russet Burbank & Russet Norkotah.

Specific Gravity: About 1.075-1.080 in Minnesota irrigated and non-irrigated.

Foliage: Dark green foliage with large oblong leaflets.

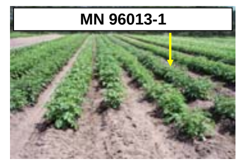
Diseases: Susceptible to commom scab.

Weaknesses: Susceptibility to common scab and late blight. Some incidence of hollow heart.

5 Year Performance

			Total Yld	US # 1's			B's	A's	Culls			Internal Defects (%)			
Clone	**Loc**	**#/Plant**	**Cwtyld**	**Cwtyld**	**%**	**%< 2 oz.**	**%**	**%**	**%**	**Sp. Gr.**	**Chip**	**HH**	**IN**	**VD**	**BC**
MN 99460-21	BE	4	215.9	195.9	91.0	7.3	41.8	58.2	0.0	1.062	5.9	4	3	8	5
	BL	7	392.5	366.2	93.1	2.4	9.6	86.0	4.4	1.074	6.1	11	0	4	0
	H	4.0	294.7	238.5	80.9	0.3				1.070	4.3	0	0	0	0
	W	8.6	351.9	334.9	96.2	2.3	20.2	77.8	2.0	1.085	6.2	0	0	0	0
Late harvest:	Avg.	6.5	346.4	313.2	90.1	1.7	14.9	81.9	3.2	1.076	5.5	3.7	0.0	1.3	0.0

MN 96013-1



Parentage: MN 15622 x ND 2050-1

Developers: University of Minnesota, Minnesota Agricultural Experiment Station

Incentives for production: MN 96013-1 has a medium high yield of uniformly dark red smooth skinned tubers with a specific gravity of 1.074. Tuber set averages 7 tubers/plant. 50% of the tubers are in the 4-10 oz size range with 34% over 10 oz. Flesh color is dark yellow.

Strengths: MN96013-1 is a seedling selected in 1996 having dark red skin, dark yellow flesh, smooth uniform tubers, and an excellent internal quality. Tubers have low to moderate specific gravity with excellent skin set. MN96013-1 has moderate resistance to common scab. Little fading

Morphological Characteristics:

Plant: Medium tall semi-procumbant stemmy plant. Dark green foliage. Medium to large closed leaflets. Provides good bed cover. Anthocyanins in petiole, petioluole, leaf vein, stems, rachii & pedicle.

Flower: Dark Red Violet, Slight White Tips

Tubers: Round-oval with dark red color, shallow eyes. Very good skin set. Dark yellow flesh.

Agronomic Characteristics:

Maturity: Medium

Yield: Slightly less than Red Norland (5%)

Specific gravity: low to moderate ~ 1.074.

Diseases: Susceptible to Verticillium wilt, CPB, and susceptibility to late blight, silver scurf, and pink rot.

Weaknesses: Not for long term storage.

5 Year Performance

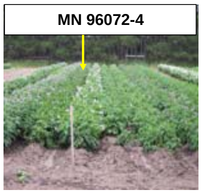
			Total Yld	US # 1's			B's	A's	Culls			Internal Defects (%)			
Clone	**Loc**	**#/Plant**	**Cwtyld**	**Cwtyld**	**%**	**%< 2 oz.**	**%**	**%**	**%**	**Sp. Gr.**	**Chip**	**HH**	**IN**	**VD**	**BC**
MN 96013-1	BE	9	225	197	87.4	12.6	56.7	43.3	0.0	1.059		2	0	5	1
	BL	10	398	347	87.6	5.4	19.6	77.2	3.1	1.069	5.8	0	0	6	1
	H	4	255	207	81.0	2.3				1.074	3.5	0	0	0	0
	W	8	325	304	95.1	4.9	30.6	62.7	6.7	1.080	5.9	0	0	1	0
Late harvest:	Avg.	7.3	326.0	286.0	87.9	4.2	25.1	69.9	4.9	1.074	5.1	0.0	0.0	2.3	0.2

MN 96072-4

Parentage: 84505 x ND 225-1

Developers: University of Minnesota, Minnesota Agricultural Experiment Station

Incentives for production: MN 96072-4 has a medium yield of uniformly dark red smooth skinned tubers with a specific gravity of 1.066. Tuber set averages 11 tubers/plant. > 50% of the tubers are in the 4-10 oz size range with fewer than 10% over 10 oz. Flesh color is white.



Strengths: MN 96072-4 is an attractive uniform shaped round red with excellent internal qualities and very few oversized potatoes. Skin set is excellent. Color does not fade in storage

Morphological Characteristics:

Plant: Dark green foliage. Medium to large closed leaflets. Provides excellent bed & row coverage

Flower: Red violet with slight white tips

Tubers: Round-oval with deep red coloration. Little fading through storage.

Agronomic Characteristics:

Maturity: Medium

Yield: Less than both Red Norland & Red Pontiac

Specific gravity: Low to Medium ~ 1.055 -1.070

Diseases: Susceptible to Verticillium wilt, CPB, LB & Common Scab.

Storability: Excellent long term storage.

Weaknesses: Susceptible to *Verticillium* wilt, CPB, and susceptibility to late blight.

5 Year Performance

			Total Yld	US # 1's			B's	A's	Culls			Internal Defects (%)			
Clone	**Loc**	**#/Plant**	**Cwtyld**	**Cwtyld**	**%**	**%< 2 oz.**	**%**	**%**	**%**	**Sp. Gr.**	**Chip**	**HH**	**IN**	**VD**	**BC**
MN 96072-4	BE	13	242	166	69.0	26.9	63.3	36.4	0.5	1.055	6.8	1	0	14	3
	BL	14	376	325	86.2	11.1	22.1	76.3	1.7	1.060	7.8	2	0	3	2
	H	8.0	307	207	67.5	6.8				1.067	5.5	0	0	0	0
	W	12	286	216	78.0	7.8	34.4	63.0	2.6	1.070	7.8	0	0	0	0
Late harvest:	Avg.	11.3	322.8	249.5	77.3	8.6	28.3	69.7	2.1	1.066	7.1	0.7	0.0	1.0	0.5

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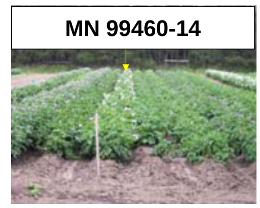
MN 99460-14

Parentage: OP

Developers: University of Minnesota, Minnesota Agricultural Experiment Station

Incentives for production: MN 99460-14 has a high yield of uniformly smooth dark red tubers with ~ 90% US No. 1; Tuber flesh color is white. Specific gravity is moderate to high ~ 1.071 - 1.086.

Strengths: MN 99460-14 is a uniformly shaped round dark red with a smooth skin that doesn't fade through long term storage. ~ 60 - 70% of the tubers are in the 4-10 oz. size class.



***Morphological Characteristics*:**

Plant: Tall, erect plant with dark green foliage. Medium to large closed leaflets. Provides excellent bed cover.

Flower: Red violet with slight white tips

Tubers: Round-oval with deep red coloration, shallow eyes. Little fading through storage. Very good skin set.

***Agronomic Characteristics*:**

Maturity: Later maturing red.

Yield: Less than both Red Norland & Red Pontiac

Specific gravity: Moderate to high ~ 1.071 -1.086.

Diseases: Susceptible to Verticillium wilt, CPB, and susceptibility to late blight, silver scurf, pink rot and common scab.

Storability: Excellent long term storage with little to no fading.

Weaknesses: Susceptible to *Verticillium* wilt, CPB, and susceptibility to late blight, silver scurf, and pink rot.

6 Year Performance

		Tubers	Total Yld	US # 1's			B's	A's	Culls			Internal Defects (%)			
Clone	**Loc**	**/Plant**	**Cwtyld**	**Cwtyld**	**%**	**%< 2 oz.**	**%**	**%**	**%**	**Sp. Gr.**	**Chip**	**HH**	**IN**	**VD**	**BC**
MN 99460-14	BE	8	250.9	215.0	86.1	8.8	47.4	53.2	0.0	1.058	5.8	3	1	12	8
	BL	8	384.8	353.2	91.2	4.7	16.1	82.2	1.7	1.071	6.5	4	2	3	0
	H	4.7	283.2	253.5	89.5	1.9				1.080	5.0	10	0	0	0
	W	4.9	298.4	270.2	93.3	2.9	18.2	76.0	5.8	1.086	6.8	0	0	0	0
Late harvest:	Avg.	5.8	322.1	292.3	91.4	3.2	17.2	79.1	3.7	1.079	6.1	4.5	0.7	0.8	0.0

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MN 19298

Parentage: Unknown

Developers: University of Minnesota, Minnesota Agricultural Experiment Station

Incentives for production: MN 19298 has a high yield of dark red tubers with ~ 85% US No. 1. Tuber flesh color is yellow. Specific gravity is moderate to low ~ 1.072. Tuber set averages 10 tubers per plant with ~ 60% of the tubers between 4 - 10 oz.

Strengths: MN 19298 is a seedling selected F. Lauer having dark red skin, yellow flesh, uniform round to slightly oval tubers with slight eye depth, and an excellent internal quality.Tubers have moderate to low specific gravity and good culinary characteristics.MN 19298 has partial resistance to late blight and is resistant to PLRV.

***Morphological Characteristics*:**

Plant: Light to medium green foliage, semi-erect plant with medium size closed leaflets providing excellent bed coverage. Vigor is excellent.

Flower: Red Violet with White Tips

Tubers: Round-oval with dark red color, shallow eyes. Very good skin set. Dark yellow flesh.

***Agronomic Characteristics*:**

Maturity: Early

Yield: > Red Norland on the sands of Becker, MN; Similar to Red Norland on the peat soils of Hollandale, MN.

Specific Gravity: low to medium. About 1.060-1.071 under irrigated conditions.

Weaknesses: Susceptible to *Verticillium* wilt, CPB, silver scurf, pink rot & LB. Not a long term storage potato.

5 Year Performance

		Tubers	Total Yld	US # 1's			B's	A's	Culls			Internal Defects (%)			
Clone	**Loc**	**#/Plant**	**Cwtyld**	**Cwtyld**	**%**	**%< 2 oz.**	**%**	**%**	**%**	**Sp. Gr.**	**Chip**	**HH**	**IN**	**VD**	**BC**
MN 19298	BE	9	252	186	73.8	21.7	67.9	32.5	0.0	1.054	4.0	1	0	5	3
	BL	13	448	400	88.9	10.0	26.7	71.8	1.5	1.062	5.4	2	1	2	3
	H	5.8	289	242	83.8	4.2				1.066	3.3	0	0	0	0
	W	11	314	277	88.0	8.8	42.0	52.9	5.1	1.071	6.3	2	0	3	0
Late harvest	Avg.	9.9	350.4	306.4	86.9	7.6	34.4	62.4	3.3	1.066	5.0	1.1	0.3	1.5	1.1

2008 University of Minnesota Potato Breeding & Genetics

MN 00177-5

Parentage: MN 19298 x MN 96013-1

Developers: University of Minnesota, Minnesota Agriculture Experiment Station

Incentives for production: MN 00177-5 is a round oval dark red potato with a high yield of smooth skinned tubers with ~ 83% US No. 1. Tuber flesh color is white. Tuber set averages 10 tubers per plant with ~ 57% of the tubers in the 4-10 oz. categories..

Strengths: MN 00177-5 was selected in 2000 having a dark red skin and white flesh. It has excellent skin set with little or no skinning and uniform round tubers.Tubers have good internal quality.

***Morphological Characteristics*:**

Plant: Light to medium green foliage, vigorous vine growth with dark red violet flowers; some anthocyanin pigmentation.

Flower: Dark red violet

Tubers: Dark red, round to slightly oval, shallow eyes, excellent skin set, white flesh.

***Agronomic Characteristics*:**

Maturity: Medium

Yield: Very high yield on Becker, MN sands; > Red Norland but < Red Pontiac.

Specific Gravity: Similar to Red Norland & Red Pontiac; ~ 1.056 - 1.062.

Weaknesses: Moderately susceptible to early blight. Susceptible to late blight and common scab.

3 Year Performance

		Tubers	Total Yld	US # 1's			B's	A's	Culls			Internal Defects (%)			
Clone	**Loc**	**#/Plant**	**Cwtyld**	**Cwtyld**	**%**	**%< 2 oz.**	**%**	**%**	**%**	**Sp. Gr.**	**Chip**	**HH**	**IN**	**VD**	**BC**
MN 00177-5	BE	13.0	369	308	83.4	11.5	25.2	71.2	3.6	1.053	5.0	0	0	13	8
	BL	14	484	435	87.6	4.1	6.2	80.1	13.6	1.062	4.9	0	1	1	7
	W	5.4	278	236	78.8	2.8	10.7	78.8	10.5	1.056	6.5	0	0	0	0
Late harvest:	Avg.	9.7	381.2	335.2	83.2	3.4	8.5	79.4	12.1	1.059	5.7	0.0	0.6	0.6	3.3

MN 19350

Parentage: MN 623.87-1 (MN 16191) x MN 3002.92-3 (MN 85673)

Developers: University of Minnesota, Minnesota Agriculture Experiment Station

Incentives for production: MN 19350 is a round white potato with a moderate yield of lightly netted tubers with ~ 97 % US No. 1. Tuber flesh color is white. Tuber set averages 8 tubers per plant with ~ 85% of the tubers in the > 4 oz. categories. Internal qualities are excellent. Specific gravity = that of Atlantic & Snowden & > Norvalley.

Weaknesses: Susceptible to late blight and moderately susceptible to common scab.

4 Year Performance

		Tubers	Total Yld	US # 1's			B's	A's	Culls			Internal Defects (%)			
Clone	**Loc**	**#/Plant**	**Cwtyld**	**Cwtyld**	**%**	**%< 2 oz.**	**%**	**%**	**%**	**Sp. Gr.**	**Chip**	**HH**	**IN**	**VD**	**BC**
MN 19350	BE	12	342	320	93.6	6.4	37.3	62.7	0.0	1.068	5.5	1	0	4	3
MN 19350	BL	11	476	451	94.3	4.0	24.2	72.3	3.5	1.078	5.8	3	0	3	0
MN 19350	H	3.3	225	223	99.0	1.0				1.091	4.0	0	0	0	0
MN 19350	W	8	349	328	97.1	2.9	31.7	61.1	7.2	1.091	4.8	1	0	1	0
Late harvest:	Avg.	7.4	349.9	333.8	96.8	2.6	28.0	66.7	5.3	1.087	4.9	1.3	0.0	1.1	0.0

MN 19470

Parentage: Unknown

Developers: University of Minnesota, Minnesota Agriculture Experiment Station

Incentives for production: MN 19470 is a long white potato with a high yield of uniformly shaped tubers. 93 % are US No. 1. Tuber flesh color is white. Tuber set averages 8 tubers per plant. ~ 71% of the tubers are in the > 6 oz. categories. Specific gravity is > Shepody. Tubers are resistant to common scab.

Weaknesses: Susceptible to late blight. Hollow heart has been noted in larger tubers.

4 Year Performance

		Tubers	Total Yld	US # 1's			B's	A's	Culls			Internal Defects (%)			
Clone	**Loc**	**#/Plant**	**Cwtyld**	**Cwtyld**	**%**	**%< 2 oz.**	**%**	**%**	**%**	**Sp. Gr.**	**Chip**	**HH**	**IN**	**VD**	**BC**
MN 19470	BE	6	234	208	89.1	10.9	46.9	53.1	0.0	1.073	7.0	5	0	6	2
MN 19470	BL	11	562	525	92.1	2.6	13.2	83.4	3.4	1.086	6.3	8	3	2	6
MN 19470	H	6.6	411	368	89.6	1.9				1.096	4.5	0	0	0	0
MN 19470	W	7	410	383	97.7	2.3	29.4	62.3	8.3	1.101	5.6	1	1	1	0
Late harvest:	Avg.	8.2	461.0	425.3	93.1	2.3	21.3	72.8	5.9	1.094	5.5	3.1	1.5	1.1	1.9

MN 02 419

Parentage: Unknown

Developers: University of Minnesota, Minnesota Agriculture Experiment Station

Incentives for production: MN 02 419 is a long white potato that has a yield comparable to Shepody. ~ 91% of its yield is US #1 with 70% being 6 oz. or greater. Specific gravity = Shepody. Flesh color is white.

Weaknesses: Some hollow heart in larger tubers. Susceptible to common scab.

4 Year Performance

		Tubers	Total Yld	US # 1's			B's	A's	Culls			Internal Defects (%)			
Clone	**Loc**	**#/Plant**	**Cwtyld**	**Cwtyld**	**%**	**%< 2 oz.**	**%**	**%**	**%**	**Sp. Gr.**	**Chip**	**HH**	**IN**	**VD**	**BC**
MN 02 419	BE		306	245	79.5	6.6	47.4	53.3	0.0	1.066	5.8	8	0	9	0
	BL		476	435	90.2	2.2	10.6	86.1	3.4	1.079	5.8	7	3	0	0
	W		426	391	91.0	0.8	11.6	86.7	2.1	1.088	6.8	0	0	0	0
Late harvest:	Avg.		450.7	412.9	90.6	1.5	11.1	86.4	2.7	1.084	6.3	3.3	1.3	0.0	0.0

MN 02 467

Parentage: Unknown

Developers: University of Minnesota, Minnesota Agriculture Experiment Station

Incentives for production: MN 02 467 is an attractive yellow fleshed fresh market russet potato that has a specific gravity = Russet Norkotah. 92 % of the tubers are US #1. The majority of the US #1 are in the 6 - 10 oz size. MN 02 467 is resistant to common scab.

Weaknesses: Hollow heart has been noted in larger tubers.

4 Year Performance

		Tubers	Total Yld	US # 1's			B's	A's	Culls			Internal Defects (%)			
Clone	**Loc**	**#/Plant**	**Cwtyld**	**Cwtyld**	**%**	**%< 2 oz.**	**%**	**%**	**%**	**Sp. Gr.**	**Chip**	**HH**	**IN**	**VD**	**BC**
MN 02 467	BE		248	211	88.5	4.7	32.7	67.3	0.0	1.061	5.4	15	0	13	10
	BL		463	422	91.4	4.0	9.4	88.9	1.7	1.068	6.8	12	0	0	0
	W		377	329	93.0	1.4	9.9	83.1	7.0	1.081	6.0	8	0	0	0
Late harvest:	Avg.		419.7	375.5	92.2	2.7	9.6	86.0	4.4	1.074	6.4	9.6	0.0	0.0	0.0

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MN 02 574

Parentage: Unknown

Developers: University of Minnesota, Minnesota Agriculture Experiment Station

Incentives for production: MN 02 574 is a dual purpose white chipping/fresh market potato with yellow flesh. ~ 80% are US # 1 with the majority in the 4 - 8 oz. size. Very few oversize potatoes. It has moderate to high specific gravity.

Weaknesses: Susceptible to late blight. Moderate susceptibility to common scab.

4 Year Performance

		Tubers	Total Yld	US # 1's			B's	A's	Culls			Internal Defects (%)			
Clone	**Loc**	**#/Plant**	**Cwtyld**	**Cwtyld**	**%**	**%< 2 oz.**	**%**	**%**	**%**	**Sp. Gr.**	**Chip**	**HH**	**IN**	**VD**	**BC**
MN 02 574	BE		294	180	61.9	32.6	72.2	27.8	0.0	1.059	4.3	5	2	17	6
	BL		523	429	80.6	12.5	31.7	66.2	2.1	1.074	4.1	0	2	8	3
	W		479	371	78.3	6.9	33.8	62.9	3.2	1.088	4.8	0	0	0	0
Late harvest:	Avg.		501.1	399.8	79.4	9.7	32.8	64.5	2.7	1.081	4.4	0.0	0.8	4.2	1.7

MN 02 586

Parentage: Unknown

Developers: University of Minnesota, Minnesota Agriculture Experiment Station

Incentives for production: MN 02 586 is an attractive white light yellow fleshed dual purpose potato that has a moderate to very high specific gravity. 80% of the tubers are US #1. The majority of the US #1 are in the 4 - 8 oz size (~ 60%). Internals are

Weaknesses: Susceptible to late blight. Moderately susceptible to common scab.

4 Year Performance

		Tubers	Total Yld	US # 1's			B's	A's	Culls			Internal Defects (%)			
Clone	**Loc**	**#/Plant**	**Cwtyld**	**Cwtyld**	**%**	**%< 2 oz.**	**%**	**%**	**%**	**Sp. Gr.**	**Chip**	**HH**	**IN**	**VD**	**BC**
MN 02 586	BE		317	228	71.5	19.9	69.2	30.9	0.0	1.064	5.3	3	0	5	0
	BL		627	502	80.2	10.4	28.0	70.9	1.1	1.079	4.6	0	1	0	0
	W		423	330	79.5	6.2	25.3	72.7	2.0	1.101	4.0	0	0	0	0
Late harvest:	Avg.		524.8	416.0	79.8	8.3	26.7	71.8	1.5	1.090	4.3	0.0	0.6	0.0	0.0

MN 02 588

Parentage: Unknown

Developers: University of Minnesota, Minnesota Agriculture Experiment Station

Incentives for production: MN 02 588 is a round white chipping potato that has a high yield of uniformly sized 4 - 10 oz. tubers. There are very few oversize tubers. Specific gravity = that of Atlantic, NorValley, & Snowden.

Weaknesses: Susceptible to late blight & common scab.

4 Year Performance

		Tubers	Total Yld	US # 1's			B's	A's	Culls			Internal Defects (%)			
Clone	**Loc**	**#/Plant**	**Cwtyld**	**Cwtyld**	**%**	**%< 2 oz.**	**%**	**%**	**%**	**Sp. Gr.**	**Chip**	**HH**	**IN**	**VD**	**BC**
MN 02 588	BE		249	169.2	70.9	18.5	57.0	43.0	0.0	1.064	4.5	23	0	17	5
	BL		434	362.8	80.5	12.2	22.2	77.2	1.2	1.076	3.4	6	3	4	0
	W		433	371.6	86.6	2.6	16.0	81.0	3.6	1.084	4.3	0	0	0	0
Late harvest:	Avg.		433.3	367.2	83.5	7.4	19.1	79.1	2.4	1.080	3.8	3.1	1.7	1.9	0.0

MN 02 589

Parentage: Unknown

Developers: University of Minnesota, Minnesota Agriculture Experiment Station

Incentives for production: MN 02 589 is an attractive white light yellow fleshed dual purpose potato that has a moderate to high specific gravity. Excellent yield with 90% US #1's. The majority of the US #1 are in the 4 - 10 oz size (~ 75%). Internals are

Weaknesses: Susceptible to late blight & common scab.

4 Year Performance

		Tubers	Total Yld	US # 1's			B's	A's	Culls			Internal Defects (%)			
Clone	**Loc**	**#/Plant**	**Cwtyld**	**Cwtyld**	**%**	**%< 2 oz.**	**%**	**%**	**%**	**Sp. Gr.**	**Chip**	**HH**	**IN**	**VD**	**BC**
MN 02 589	BE		315	215	71.7	14.5	64.0	35.9	0.0	1.061	4.4	9	5	12	7
	BL		587	544	92.8	5.4	18.8	81.2	0.8	1.073	4.0	0	0	2	0
	W		476	415	90.0	2.7	16.4	82.4	3.7	1.084	4.9	0	0	0	0
Late harvest:	Avg.		531.7	479.8	91.4	4.1	15.9	81.8	2.2	1.079	4.4	0.0	0.0	0.8	0.0

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MN 02 616

Parentage: Unknown

Developers: University of Minnesota, Minnesota Agriculture Experiment Station

Incentives for production: MN 02 616 is an oval-oblong dark red smooth skinned potato that is an excellent yielder (~510 cwt). It has dark yellow flesh. It's specific gravity is better than Red Norland & Red Pontiac. ~ 88% are US # 1's.

Weaknesses: Susceptible to late blight. Moderately susceptible to common scab.

4 Year Performance

		Tubers	Total Yld	US # 1's			B's	A's	Culls			Internal Defects (%)			
Clone	**Loc**	**#/Plant**	**Cwtyld**	**Cwtyld**	**%**	**%< 2 oz.**	**%**	**%**	**%**	**Sp. Gr.**	**Chip**	**HH**	**IN**	**VD**	**BC**
MN 02 616	BE		376	320	85.6	6.1	42.7	56.9	0.0	1.060	1.8	0	0	14	0
	BL		600	537	89.7	4.2	11.2	89.2	3.4	1.066	6.5	0	3	5	0
	W		420	359	86.7	3.0	22.0	75.6	3.0	1.079	6.1	0	0	0	0
Late harvest:	Avg.		509.8	447.8	88.2	3.6	16.6	82.4	3.2	1.073	6.3	0.0	1.7	2.5	0.0

COMN 04712-05

Parentage: A93004-3RU x CO94084-12RU

Developers: University of Minnesota, Minnesota Agriculture Experiment Station

Incentives for production: COMN 04712-05 is an oblong light russet potato with white flesh. Internals are excellent.

Weaknesses: Susceptible to late blight & common scab. Low Specific gravity in Becker, MN.

1st Year Performance

		Tubers	Total Yld	US # 1's			B's	A's	Culls			Internal Defects (%)			
Clone	**Loc**	**#/Plant**	**Cwtyld**	**Cwtyld**	**%**	**%< 2 oz.**	**%**	**%**	**%**	**Sp. Gr.**	**Chip**	**HH**	**IN**	**VD**	**BC**
COMN 04712-05	BL	5.0	224	154	68.6	5.8	21.7	68.6	9.7	1.039	6.0	0	0	0	0
COMN 04712-05	W	6.1	445	416	93.6	0.6	6.4	93.6	0.0	1.074		0	0	0	0
Late harvest:	Avg.	5.5	334.8	285.2	81.1	3.2	14.1	81.1	4.8	1.056	6.0	0.0	0.0	0.0	0.0

Potato Breeding and Cultivar Development for the Northern Plains
North Dakota State University
2007 Summary

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Potato Breeding, Selection, Cultivar Development, and Germplasm Enhancement
The North Dakota State University (NDSU) potato breeding program, as part of the North Dakota Agricultural Experiment Station, has been active for more than 75 years. During this time, twenty three cultivars have been named and released. NDSU releases have traditionally been widely adapted and accepted, thus have significantly impacted production in North Dakota, Minnesota, the Northern Plains, and across North America. As a leader in breeding, selection, and cultivar development, our aim is to identify and release superior, multi-purpose cultivars that are high yielding, possess multiple resistances to diseases, pests and stresses, have excellent processing and consumer quality, and that are adapted to production conditions in North Dakota, Minnestoa, and the Northern Plains. In order to meet specific needs of producers and industry in the Northern Plains, we have established the following research objectives:

1. Develop potato (*Solanum tuberosum* L.) cultivars that are genetically superior for yield, disease and pest resistance, marketing, processing ability and consumer quality adapted to North Dakota, the Northern Plains and other areas, through the use of traditional and molecular techniques.
2. Screen and develop germplasm incorporating genetic resistance to major diseases, pests and environmental stresses that cause economic losses in potato production in North Dakota and North America.
3. Evaluate advanced selections and cultivars for improved culinary quality.

In 2007, our research activities ranged from Park Rapids in Minnesota to Langdon, Tappen and Wyndmere in North Dakota. The procedures used in potato breeding, selection and cultivar development are summarized in the schematic attached to this report. Potato breeding is a long, arduous process, involving interdisciplinary teams which evaluate multiple facets. The potato is highly influenced by seed quality, cultural practices, and the environment. The NDSU potato improvement team is highly involved with the North Dakota State Seed Department and in continuing certification of our materials. The following narrative reviews our research efforts designed to help us attain our objectives.

In 2007, 545 families were created in the greenhouse and approximately 100,000 seedlings from true botanical seed were planted in the summer and fall crops in greenhouses at NDSU. Harvest of the summer and fall crops of seedlings were completed and counts obtained. Our primary foci for breeding continue to be cold processing ability (chip and frozen products); late blight, Colorado Potato Beetle, sugar end, pink rot and *Pythium* leak, aphid and virus resistance; and other emerging areas of importance for regional producers and industry, including *Verticillium* wilt, PVY and *Fusarium* resistance, in addition to enhanced nutritional quality. Our breeding efforts continue to include germplasm enhancement as a means of developing durable and long-term resistance to these diseases, pests, and stresses.   We continue to exploit wild species and wild species hybrids, in addition to released cultivars and advanced germplasm from around the globe, in order to introgress these important resistances and quality traits. At Langdon, more than 86,439 ND seedlings, representing 528 families were evaluated. Unselected seedling tubers from cooperating programs in Colorado, Idaho, and Texas were grown at Hoople, Langdon, Tappen and Wyndmere. Unselected seedling tubers totally about 100,000, were shared with the breeding programs in CO, ID, MI, MN, TX and WI. Approximately 1,007 second, 147 third year, and 321fourth year and older selections, were maintained and/or increased in our seed fields at Absaraka and Wyndmere; additional selections with late blight resistance and for several genetic studies were also maintained and increased at Wyndmere.

Yield and evaluation trials were grown at four locations in Minnesota and North Dakota, three irrigated and one non-irrigated site. Seventy one advancing selections and named cultivars were evaluated in replicated yield trials at Hoople, including the North Dakota state red and chip trials, and North Central Regional red and chip trials. A location of the Norland selection trial was also grown at Hoople. Irrigated sites were at Park Rapids, MN, Larimore, and Tappen, ND, with 15, 23 and 86 genotypes evaluated, respectively, in the replicated trials. Trials at Larimore included the NCRPVT processing trial and our state processing trial. At Tappen, the NCRPVT red, processing and chip trials were grown. Additionally, we had the state processing trial, an irrigated locale of the state chip trial and the Norland selection trial. Additionally, 367 second year and 29 third and fourth year selections from out- of-state programs were maintained and increased at Tappen. A graduate student is comparing conventional production to organic production practices and the effect on antioxidant capacity following several cooking methods for specialty genotypes. These trials were grown at the Tappen site (irrigated, conventional) and an organic grower's field nearby.

Four entries from NDSU were evaluated in the North Central Regional Potato Variety Trial (NCRPVT), including ND4659-5R, ND5002-3R, and ATND98459-1RY, three bright red skinned selections suitable for the fresh market. ATND98459-1RY has yellow flesh. Determination will be made regarding release of ND4659-5R and ND5002-3R, with possible release in 2008. AND98324-1Russ, a dual-purpose russet, suitable for tablestock and frozen processing, was included in the russet/long white trial. Due to hollow heart at many sites in the NCRPVT, determination has been made to cease advancement of this selection. It will be retained in our clone bank and may be used as parental material due to its excellent processing qualities. NDSU had no entries in the NCRPVT chip trial. We also did not have an entry in the 2007 United States Potato Board/Snack Food Association (USPB/SFA) Chip Trial. ND7519-1, a high yielding selection with cold chipping ability, will be entered in the 2008 trial.

We continue our efforts to identify germplasm for cultivar release that will reliably and consistently process from long term cold storage. As we graded, chip and frozen processing selections were sampled, and stored at 42F and 38F (5.5C and 3.3C) for eight weeks. Additional samples from 5.5C will be processed after seven months storage in June. Trial entries have been evaluated for blackspot and shatter bruise potential. Storage profiles for AOND95249-1Russ and ND7818-1Y, an advanced dual-purpose russet and a yellow fleshed specialty selection with cold chipping ability, respectively, including sugar development and processing quality are being conducted cooperatively with Marty Glynn at the USDA-ARS Potato Worksite in East Grand Forks. Appropriate industry checks have been included. We hope to conduct sensory evaluation of frozen fries and flakes in early March.

Late blight resistance breeding efforts continued in 2007. Dr. Gary Secor's program evaluated seedling families using a detached leaf assay in the greenhouse. Resistant selections have been retained for field evaluation in 2008. Several field trials were grown at Prosper, ND to evaluate field resistance of materials identified in previous years as being resistant. Work by a graduate student in Plant Pathology is focused on evaluation for tuber resistance. In 2007, we had several selections with commercial potential (ie. appearance and processing/tablestock quality) in our red and processing trials. These selections were all identified in previous years detached leaf assay evaluations or field evaluations.

Nineteen selections were evaluated for disease reaction to bacterial ring rot in the field by Dr. Neil Gudmestad's research group. Drs. Neil Gudmestad and Ray Taylor are evaluating clones for resistance to pink rot and *Pythium* leak. We have an extensive collaborative project on breeding for resistance to *Phytophthora erythroseptica* and *Pythium ultimum*, including developing molecular markers and determining the heritability of resistance. Evaluation for tuber blemish diseases is being conducted by Dr. Secor's program for 20 selections. Seedling families were evaluated for defoliation levels in a Colorado potato beetle (CPB) resistance screening nursery by Dr. Janet Knodel and Don Carey. Defoliation data for families was used in determining selection intensity of these families at Langdon. A replicated trial included advancing selections which previously demonstrated resistance to feeding by Colorado potato beetle. Additional collaboration includes the sucrose rating and serial chipping of chip and frozen processing selections by Dr. Joseph Sowokinos (UMN) and Marty Glynn (USDA-ARS) at the USDA-ARS Potato Worksite in East Grand Forks, MN. NDSU submitted entries in cooperative trials in FL, MI, MN, NC, TX and WI, amongst others. These trials included collaborations with producers, industry, and research groups.

Promising advanced selections include red tablestock selections ND4659-5R, ND5002-3R and ND8555-8R. Dual-purpose russet selections, AOND95249-1Russ, ND8229-3 and AOND95292-3Russ possess excellent appearance and processing quality. Several cold chipping selections look very promising, including ND5775-3, ND8304-2, ND8305-1, and ND7818-1Y. Information for plant variety protection and cultivar release was collected for several of these selections in 2007, with the anticipation of release consideration in 2008. Please see descriptions of our most advanced genotypes following the breeding schematic.

Goals for 2008 include continued breeding, evaluation and development efforts of superior genotypes with multiple resistances, high yield potential and important quality attributes; to improve our seed increase procedures working with the NDSSD; and to further expand the long-term storage evaluations. We are excited by the opportunity to conduct cooperative and interdisciplinary research projects with members of the NDSU potato improvement team, the North Dakota State Seed Department, the USDA-ARS programs in Fargo and East Grand Forks, and other U.S. research programs.

Finally, we are extremely grateful for the support of potato producers and industry personnel in Minnesota and North Dakota, the Northern Plains and across North America, without whom our work would be difficult and without meaning. We are very thankful for the funding received from the NPPGA and the Minnesota Area II Research Council, particularly in light of federal funding cuts which had provided significant funds toward our breeding efforts in recent years.

Potato Breeding and Cultivar Development
Breeding and Selection Schematic

North Dakota State University

Year	Procedure
1	Parental selection, hybridization, and true seed production in the greenhouse. Produce seedling tubers from the true potato seed in the greenhouse. Initiate late blight screening of seedling families.
2	100,000+ North Dakota seedlings are planted in the field (Langdon, ND) as single hills. Up to 100,000 from out-of state programs are also planted at ND and/or MN locations. Initial selection takes place at harvest; 1,000-1,500 are typically retained. This is the first cycle of field selection. Initial decisions regarding seed increase are begun.
3	Two-four hill units are planted at Absaraka for seed maintenance. Typically 200-250 selections are retained at harvest based primarily on phenotypic selection. This is the second cycle of field selection. Colorado potato beetle (CPB) resistant (potential) selections are entered into replicated trials and evaluated for defoliation. Selections are evaluated for specific gravity and internal defects. Chipping and russet selections are evaluated for sucrose rating and are chipped from storage (42 and 45F). Replicated late blight screening evaluations occur.
4 and/or 5	Two-four hill units are planted at Absaraka and 10 hills are planted at Wyndmere for seed maintenance. Decisions regarding increase are made at harvest and following quality evaluations during the winter. This is the third cycle of field selection. Selections are evaluated for specific gravity and internal defects. Chipping evaluations, late blight and CPB resistance screenings continue. Cleanup and micropropagation are initiated for exceptional genotypes. Selected lines are increased for trial seed. Entry into state yield trials for up to three years. Sensory evaluations are conducted. Decision is made after grading, or during the winter, determining which selections to continue with.
6	Second year of state trials. Promising selections continue to be increased. Additional selections are entered into micropropagation. Cultural management and disease/pest (field and post-harvest reaction) evaluation trials begin. Promising selections continue to be increased. To growers for evaluation and increase.
7	Third year in State Trials or exceptional selections to North Central Regional Potato Variety Trial. Cultural management and disease/pest evaluation trials continue. Processing selections are evaluated for flake production.
8-11	Enter in Regional Trial for up to 3 years and Snack Food Association Trial if it is a chipper. Grower evaluation and increase continue. Cultural management and disease/pest reaction evaluations continue.
10-15+	Consider for release as a named cultivar.

February 2008

ND4659-5R

- NorDonna x ND2842-3R
- Tablestock; medium specific gravity
- Medium maturity
- Medium yield potential
- Medium vine with red-purple flowers
- Bright red, round, smooth tubers with white flesh and shallow eyes.
- No outstanding disease or pest resistances or susceptibilities.
- Stores well

ND5002-3R

- ND3504-3R x NorDonna
- Tablestock; medium specific gravity
- Medium to late maturity
- Medium yield potential
- Medium vine with red-purple flowers
- Smooth, round to oblong tubers, with bright red skin, very white flesh, and shallow eyes
- Susceptible to silver scurf, PVY (expresses typical symptoms), and sensitive to metribuzin applications

ND8555-8R

- ND8555-8R
  - ND7188-4R x ND5256-7R
  - Early maturity
  - Medium vine

AOND95249-1Russ

- A89163-3LS x A8914-4
- Medium-late maturity
- High yield potential
- Good storability and low sugar accumulation in storage.
- High specific gravity
- Resistance to late blight, *Vertillium* wilt, and sugar ends in field evaluations. Hollow heart and blackspot bruise occasionally noted.
- Tolerant of metribuzin applications.

ND8229-3

- Marcy x AH66-4
- Medium maturity
- Medium vine size
- Medium to high yield potential
- Good storability and excellent fry color from 45F storage

Chip Selections

- ND5775-3
  - ND2471-8 x Brodick
  - Medium maturity
  - High yield potential
- ND7818-1Y
  - Morene x Marcy
  - Medium maturity
  - Medium yield potential
- ND8304-1
  - ND860-2 x ND7083-1
  - Medium early maturity
  - Medium yield potential
- ND8305-1
  - ND2471-8 x White Pearl
  - Early maturity
  - Medium to high yield potential