MINNESOTA AREA II POTATO RESEARCH AND PROMOTION COUNCIL

AND

NORTHERN PLAINS POTATO GROWERS ASSOCIATION

2016

RESEARCH REPORTS

Table of Contents

The Boards of The Minnesota Area II Potato Growers Association and The Northern Plains Potato Growers Association

would like to thank the following business associates for their support.

Thank you!

AgStar
Financial Services, ACA

Mark Koch
Financial Svcs Exec
MN License 20334748

806 3rd Street South
PO Box 608
Waite Park, MN 56387
(866) 577.1831
direct (320) 203.4616
cell (320) 241.9470
fax (320) 258.2980
Mark.Koch@AgStar.com
AgStar.com

AgStar Financial Services is an equal opportunity employer, lender and provider.

Harriston

Dexter Sitzer
General Manager
701.360.3286

✉ dsitzer@invisimax.com
☎ 800.437.8205 | 701.248.3286
harriston-mayo.com

500 Ordway Ave.
Minto, ND 58261
Division of Harriston - Mayo

JOHN DEERE

Andy Schwinghammer
Location Manager

MIDWEST MACHINERY CO

Midwest Machinery Co.
1035 35th Ave. NE • Sauk Rapids, MN 56379
Phone: 320-252-2010
Mobile: 320-492-1864
Email: aschwinghammer@mmcjd.com
www.midwestmachineryco.com

MINNESOTA DRIVELINE INC.

POWER COMPONENTS, INC.
" The Driveline Experts"

John Polikowsky
President
powcompinc@hotmail.com

328-28th Avenue South • Waite Park, MN 56387
320-255-1688 • Fax-255-1143 • 800-825-4569

ST. CLOUD
REFRIGERATION INC.

MARK FITCH
mark.fitch@scr-mn.com

toll free 800-827-1692
direct 320-258-5176
fax 320-251-9390

CENTRAL | METRO DIVISION
604 Lincoln Ave. NE
St. Cloud, MN 56304
scr-mn.com

Centra Sota

Adam Johnson
Sales Agronomist

Cell: 320-980-2188
Office: 763-662-2285
Fax: 763-662-2364

PO Box 36
2168 - 165th Avenue
Santiago, MN 55377
www.centrasota.com
ajohnson@centrasota.com

Rapid Packaging
Right Packaging. Right Now!

BERG BAG

Marty Gilbert
marty.gilbert@rapidpackaging.com

Direct: 763.404.8932
Cell: 612.802.8748
Main: 763.404.8900
800.422.0538
Fax: 763.404.8910

8700 109th Avenue North
Suite 300
Minneapolis, MN 55316

www.rapidpackaging.com • www.bergbag.com

PAUL B. OMANN
Lic # 494124

Omann
Insurance Agency

1091 2ND STREET SOUTH
SUITE #500
SARTELL, MN 56377-0100

OFFICE 320-253-6822
FAX 320-253-8270
E-MAIL pbo@omannins.com
HOME 320-251-3395

P.E.C.
Park Equipment Company

KIFCO/AG-RAIN
Water Reel Irrigation

T-L
IRRIGATION

DOUG ROBERTSON
Phone: (763) 263-6595
Fax: (763) 263-8373

20104 Highway 10 West
Big Lake, MN 55309
Res. Phone (763) 263-2621

TRIPLE H AVIATION INC.

17674 Cty. Rd. 14 • Big Lake, MN 55309

Phone **763-263-6161**
Toll Free **1-877-873-2511**

George Hook 763-360-4581
Matt Hook 763-370-5149
Robb Hook 612-819-3592

WINFIELD™

Joe Nagel
Specialty Crops Account Manager

janagel@landolakes.com
C 715-347-0411
D 715-544-0313
F 715-544-0315

1559 HOLIDAY COURT
STEVENS POINT WISCONSIN 54482

SHIP TO 1559 HOLIDAY COURT
STEVENS POINT WISCONSIN 54482

WINFIELD.COM | WINFIELD SOLUTIONS, LLC
A LAND O'LAKES COMPANY

PRO AG CROP CONSULTANTS, INC.
"Professional Advice for Profitable Agriculture"

Rick Gilbertson
President

(320) 251-0523
Fax (320) 203-0213
E-Mail: rgilbertson@charter.net

1926 East Highview Drive
Sauk Rapids, MN 56379-2631

RED'S Auto Electric, Inc.
www.RedsAutoElectric.com

East
Steve Blommer
625 E. St. Germain
St. Cloud, MN 56304
(320) 251-3911
Fax: (320) 253-3986

West
Tom Blommer
49 2nd Ave. S. P.O. Box 367
Waite Park, MN 56387
(320) 253-8765
Fax: (320) 253-8651

- Factory-trained Valley service technicians
- Fully stocked service trucks & parts department ready to service any brand
- Committed to keeping your Irrigation equipment on the job 'round the clock

VALLEY®

Grand Irrigation, Inc.

320-743-3000
7551 State St. P.O. Box 247
Clear Lake, MN 55319

Crop Production Services

Jerry Langmade
Senior Sales

Office: (763)263-2518
Toll free: (800)770-4693
Fax: (763)263-8381
Moble: (612) 747-5683

20190 Hwy 10 W
PO Box 337
Big Lake, MN 55309

jerry.langmade@cpsagu.com

www.cpsagu.com

Brent Petersen, Ph.D.
President

CROPWISE
RESEARCH LLC

852 1st Street N
Sartell, MN 56377

Phone: 320-267-6380
Fax: 320-230-4190
brentpetersen@cropwise.net

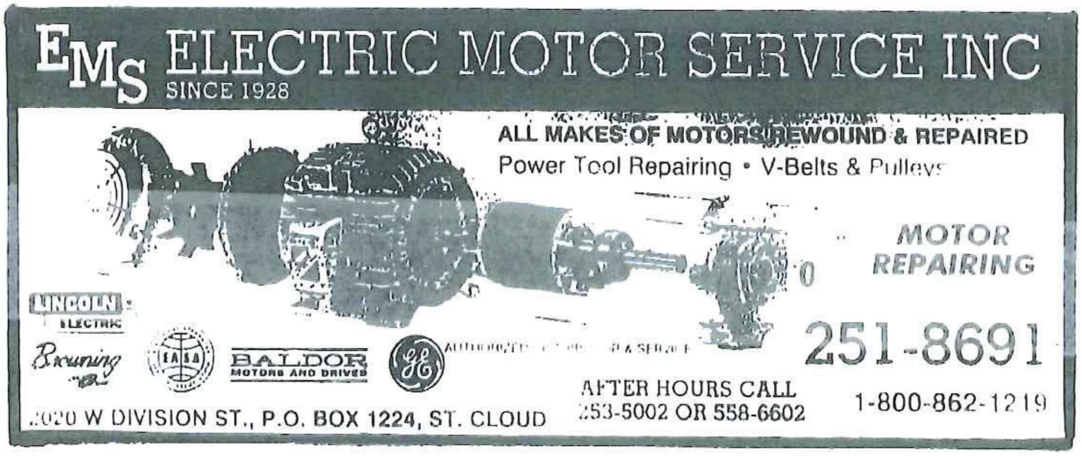
320-251-6861

Potato Associates
of the Northern Plains Potato Growers Association

Randy	Boushey	A & L POTATO COMPANY
Charles	Gunnerson	ADA PRODUCE CO.
Doug	Coleman	AG ENGINEERING & DEV. CO.
Chip	Steckler	AG WORLD SUPPORT SYSTEMS
Lisa	Peters	AG WORLD SUPPORT SYSTEMS
Warren	Henninger	AG WORLD SUPPORT SYSTEMS
Tim	Friez	AG WORLD SUPPORT SYSTEMS
Chris	Burgess	AGCOUNTRY FARM CREDIT SRVS
Michele	Sorenson	AGCOUNTRY FARM CREDIT SRVS
Randy	Skjerven	AGCOUNTRY FARM CREDIT SRVS
Craig	Hanson	AGCOUNTRY FARM CREDIT SRVS
Kevin	Fetsch	AGCOUNTRY FARM CREDIT SRVS
Stacey	Sem	AGCOUNTRY FARM CREDIT SRVS
Jeremy	Johnson	AGCOUNTRY FARM CREDIT SRVS
Renae	Fayette	AGCOUNTRY FARM CREDIT SRVS
Jennifer	Lee	AGCOUNTRY FARM CREDIT SRVS
Roger	Twedt	AGCOUNTRY FARM CREDIT SRVS
Kyle	Froslie	AGCOUNTRY FARM CREDIT SRVS
Seth	Twedt	AGCOUNTRY FARM CREDIT SRVS
Marlene	Nelman	AGCOUNTRY FARM CREDIT SRVS
Bill	Hunt	AGCOUNTRY FARM CREDIT SRVS
Bob	Bahl	AGCOUNTRY FARM CREDIT SRVS
Linda	Sauer	AGCOUNTRY FARM CREDIT SRVS
Brad	Kallenbach	AGCOUNTRY FARM CREDIT SRVS
Craig	Magnusson	AGRIMAX
John	Lee	AGVISE LABORATORIES
Allan	Nipstad	ALERUS FINANCIAL
Brad	Costello	ALERUS FINANCIAL
Curt	Scheevel	AMERICAN TIRE
Ralph	Frederick	AMVAC CHEMICAL CORP.
Greg	Anderson	ANDERSON POTATO COMPANY
Paul	Dolan	ASSOCIATED POTATO GROWERS
Greg	Holtman	ASSOCIATED POTATO GROWERS
Jeff	Lazur	ASSOCIATED POTATO GROWERS
Chris	Thompson	ASSOCIATED POTATO GROWERS
Don	Augustin	AUGIE'S CHEMICAL CO.
Chris	Wharam	BASF
Kevin	Thorsness	BAYER CROPSCIENCE
Mark	Haugland	BAYER CROPSCIENCE
Jeremy	Frieze	BAYER CROPSCIENCE
John	Martin	BAYER CROPSCIENCE
Mitch	Bloms	BAYER CROPSCIENCE
John	Christianson	BAYER CROPSCIENCE
Gordon	Delano	BEAVER CREEK AG SERVICE INC
Rick	Berg	BERG BAG COMPANY
Al	Bergstrom	BERGSTROM ELECTRIC
Jim	Hiebert	BIG JIM'S TIRE
Danielle	Golden	BLACK GOLD FARMS
Jason	Vasichek	BOBCAT OF GRAND FORKS, INC.
Phil	Ray	BREMER BANK
Keith	Zikmund	BREMER BANK
Nick	Osowski	BREMER BANK
Rick	Robinson	BREMER BANK
Russell	Carignan	BREMER BANK
Mark	Yahna	BREMER BANK
Nicholas	Skjerven	BREMER BANK
Jeff	Calillier	BREMER BANK
Lloyd	Kuster	BREMER INSURANCE
Jim	Stockeland	BRITTON TRANSPORT
Trevor	Horton	BRITTON TRANSPORT
Scott	Greenhalgh	BRITTON TRANSPORT
Tom	Hurtt	BUTLER MACHINERY CO.
Kristie	Steffen	CAVENDISH FARMS
Alan	Pranke	CAVENDISH FARMS
Mark	Urquhart	CAVENDISH FARMS
Warren	Wahl	CAVENDISH FARMS
Henry	Fietsek	CAVENDISH FARMS
Krysten	Perkins	CAVENDISH FARMS
Maurel	Mattson	CENTRAL PRODUCE
Andrew	Petersen	CHOICE FINANCIAL
Tony	Gudajtes	CHOICE FINANCIAL
Val	Walker	CHOICE FINANCIAL
Denny	Schneider	CHOICE FINANCIAL
Dale	Ommodt	CROP & LIVESTOCK NUTRITION
Brad	Mitchell	DOUBLE L
Clay	Allen	DOUBLE L
Jerry	Nolte	DREES, RISKEY & VALLAGER, LTD
Levi	Otis	ELLINGSON COMPANIES
Roger	Ellingson	ELLINGSON COMPANIES
Derrick	Ellingson	ELLINGSON COMPANIES
Dustin	Lundeby	ELLINGSON COMPANIES
Max	Fuxa	ELLINGSON COMPANIES
Jason	Abbot	ELLINGSON COMPANIES
Brad	Erickson	ERICKSON FINANCIAL ADVISORS
Terry	Longtin	FARMERS NATIONAL CO.
Kyle	Nelson	FARMERS NATIONAL CO.
Barry	Medd	FIRST STATE BANK
Julie	Byron	FIRST UNITED BANK
Howard	Ray	FIRST UNITED BANK
Matt	Beneda	FIRST UNITED BANK
Steve	Rehovsky	FIRST UNITED BANK
Dan	Johnson	FIRST UNITED BANK
Chris	Midgarden	FIRST UNTED BANK
Alex	Simonson	FREIGHT EX FREIGHT SERVICES
Matt	Swanson	FREIGHT EX FREIGHT SERVICES
Scott	Burkel	FREIGHT EX FREIGHT SERVICES
Jim	Carlson	FREIGHT EX FREIGHT SERVICES
Tyler	Dechant	GOWAN CO.
Dave	Schuurman	GYPSOIL
Dexter	Sitzer	HARRISTON INDUSTRIES
Mike	Hills	HILLS INC.
Scott	Hills	HILLS INC.
Dave	Hills	HILLS INC.
Andy	Gullickson	HOOPLE FARMERS GRAIN CO.
Mike	Brown	HOOPLE FARMERS GRAIN CO.
Bennett	Olson	HOOPLE FARMERS GRAIN CO.
Guy	Phelps	HOOPLE FARMERS GRAIN CO.
Robbie	Markel	HOOPLE FARMERS GRAIN CO.
Chris	Brown	HOOPLE FARMERS GRAIN CO.
Kristi	Magnuson-Nelson	HUGOS
Dave	Wylot	J R SIMPLOT CO
Craig	Holcombe	J R SIMPLOT CO
Leslie	Lzicar	J R SIMPLOT CO

Heather	Baerwald	J R SIMPLOT CO
Gary	Deziel	J R SIMPLOT CO
Alan	Twedt	J R SIMPLOT CO
Dave	Anderson	J R SIMPLOT CO
Harley	Leake	J R SIMPLOT CO
Amy	Wigestrand	J R SIMPLOT CO
Bret	Nedrow	J R SIMPLOT CO
Nicole	Dvorak	J R SIMPLOT CO
Scott	Lund	J R SIMPLOT CO
Michael	Johnston	J R SIMPLOT CO
Steve	Paget	J R SIMPLOT CO
Bonnie	Larson	J R SIMPLOT CO
Casey	Byram	J R SIMPLOT CO
Chris	Beneda	J R SIMPLOT CO.
Tal	Elseth	J R SIMPLOT CO.
Darryl	Solberg	J R SIMPLOT CO.
Jason	Coates	J R SIMPLOT CO.
Ken	Storm	K & T IRRIGATION INC.
James	Wolsky	K & T IRRIGATION, INC.
Cathy	Spicer	KAPSTONE CONTAINER
Joe	Dahlen	LOCKWOOD MFG.
Tom	Tallackson	LOCKWOOD MFG.
Dennis	Biliske	MAIN RESOURCE EQUIP. AUCTIONS
Allen	Merrill	MAIN RESOURCE LAND SALES
Michael	Delisle	MAYO MANUFACTURING
Carla	Pederson	MAYPORT INSURANCE & REALTY
Roger	Brakke	MIDWEST POTATO SERVICES
Duwayne	Grinolds	MIDWEST POTATO SERVICES
Clark	Piepkorn	MIDWEST POTATO SERVICES
Mark	Fischer	MIDWEST POTATO SERVICES
Todd	Brakke	MIDWEST POTATO SERVICES
Jaden	Disher	MIDWEST POTATO SERVICES
Barry	Woinarowicz	MIDWEST POTATO SERVICES
Mark	Yozamp	MIDWEST REFRIGERATION
Jim	Johnston, Jr.	MORTON BUILDINGS
Bob	Ruebel	NACHURS
Kevin	Crandall	NACHURS
Mike	Paulson	NACHURS
Vic	Hoffman	NACHURS
Max	Dietrich	NACHURS
Ole	Velde	NACHURS
Greg	Tullis	NCTC FARM BUSINESS MGMT
Ron	Dvergsten	NCTC FARM BUSINESS MGMT
Jerod	Hanson	NCTC FARM BUSINESS MGMT
Greg	Kalinoski	NCTC FARM BUSINESS MGMT
Betsy	Jensen	NCTC FARM BUSINESS MGMT
Greg	Dvergsten	NCTC FARM BUSINESS MGMT
Diane	Peycke	ND POTATO COUNCIL
Willem	Schrage	ND STATE SEED DEPT.
Ken	Bertsch	ND STATE SEED DEPT.
Susie	Thompson	NDSU- DEPT. OF PLANT SCIENCES
Andy	Robinson	NDSU/UMN
Todd	Villars	NICHINO AMERICA
John	Dusek	NODAK MUTUAL INSURANCE CO
Ryan	Wernsman	NOFFSINGER MFG CO INC
Ron	Gjelsness	NOKOTA PACKERS
Tim	Lee	NOKOTA PACKERS
Steve	Tweten	NOKOTA PACKERS
Mike	Moen	NOKOTA PACKERS
Mike	Rerick	NOKOTA PACKERS
Steve	Johnson	NOKOTA PACKERS
Carissa	Olsen	NOKOTA PACKERS
Don	Hollam	NORTH VALLEY EQUIPMENT
Larry	Salinas	NORTH VALLEY EQUIPMENT
John	Golden	NORTHERN PLAINS TRACK
Terry	Schlieve	NUFARM
John	Bergman	1,4 GROUP, INC.
Justin	Miller	OSTARA
Steve	Severson	PARK RIVER IMPLEMENT
John	Blair	PARK RIVER IMPLEMENT.
Paul	Dozenrod	PAUL'S ELECTRIC
Doug	Peterson	PETERSON FARMS, INC
Rocky	Schumacher	PETERSON SEED FARM
Jerry	Shern	PRO AG EQUIPMENT, INC.
Del	Shern	PRO AG EQUIPMENT, INC.
Ken	Vaneps	PRO AG EQUIPMENT, INC.
Frank	Gowan	PRO AG EQUIPMENT, INC.
Pat	Callahan	PRO AG EQUIPMENT, INC.
Rod	Kroocmo	PRO AG EQUIPMENT, INC.
Robert	Dunnigan	R M D POTATO SALES
Jason	Peterson	RABO AGRIFINANCE
Mike	Hergert	RED RIVER FARM NETWORK
John	Botsford	RED RIVER LAND COMPANY
Lyle	Hangsleben	REYNOLDS UNITED CO-OP
Richie	Schumacher	SCHUMACHER & SONS
Heidi	Coe	SECOND HARVEST HEARTLAND
Tony	Mans	SECOND HARVEST HEARTLAND
Bob	Branham	SECOND HARVEST HEARTLAND
Steve	Helgaard	SIMPLOT GROWER SOLUTIONS
Shawn	Kasprick	SIMPLOT GROWER SOLUTIONS
Dale	Novak	SIMPLOT GROWER SOLUTIONS
Kevin	Misialek	SIMPLOT GROWER SOLUTIONS
Korey	Sundby	SIMPLOT GROWER SOLUTIONS
Tony	Lorentz	SIMPLOT GROWER SOLUTIONS
Trent	Johnson	SIMPLOT GROWER SOLUTIONS
Scott	Cameron	SIMPLOT GROWER SOLUTIONS
Ryan	Van Eps	SIMPLOT GROWER SOLUTIONS
Steve	Weberg	SIMPLOT GROWER SOLUTIONS
Nate	Medbery	SIMPLOT GROWER SOLUTIONS
Gene	O'toole	SIMPLOT GROWER SOLUTIONS
Brian	Sondeland	SIMPLOT GROWER SOLUTIONS
Tim	Unke	SIMPLOT GROWER SOLUTIONS
Kevin	Shephard	SIMPLOT GROWER SOLUTIONS
Corey	Steidley	SPUDNIK
Joe	Pic	SPUDNIK
Jamison	Potter	SPUDNIK
Duane	Day	SPUDNIK
Jeremy	Dvorak	SPUDNIK
Clay	Swanson	SWANSON MOTORS
Marc	Rinke	SYNGENTA CROP PROTECTION
Kyle	Whittenburg	SYNGENTA CROP PROTECTION
Mike	Geelan	SYNGENTA CROP PROTECTION
Robbie	Holthusen	SYNGENTA CROP PROTECTION
Ben	Nesseth	SYNGENTA CROP PROTECTION
Nathan	Berdal	SYNGENTA CROP PROTECTION
Todd	Forbush	TECHMARK, INC.
Patrick	Morris	TECHMARK, INC.
Bob	Blomquist	THE INSULATION PLACE

Ryan	Alme	TLB AIR
Brian	Baglien	TOBIASON POTATO COMPANY
athan	Deyle	RIEST AG GROUP
Mike	Mccall	TRIEST AG GROUP
Wayne	Ausk	TRIEST AG. GROUP
Chad	Hutchinson	TRIEST AG. GROUP
Scott	Homstad	TRI-STEEL MFG CO
Tom	Gullickson	TRUE NORTH EQUIPMENT
Gary	Shields	VALLEY BAG COMPANY
Ron	Anderson	VALLEY PLAINS EQUIPMENT
Todd	Phelps	VALLEY POTATO GROWER
Cristina	Aakre	VALLEY TISSUE CULTURE, INC
Charles	Aarestad	VALLEY TISSUE CULTURE, INC.
Sandi	Aarestad	VALLEY TISSUE CULTURE, INC.
Alexandra	Bare	VALLEY TISSUE CULTURE, INC.
Dan	Schanilec	WARNER & WARNER, INC
Doug	Sigurdson	WILBUR-ELLIS
		WILLISTON AREA DEVELOPMENT
Dennis	Anderson	
Carmen	Gravning	
Joseph	Sowokinos	
Duane	Preston	
Joel	Midgarden	



Bacterial Pathogens Associated with Potato Soft Rot and Black Leg In Minnesota and North Dakota

Research Report February 1, 2016

Principal Investigator: Carol Ishimaru, Professor, Department of Plant Pathology, UMN
Research Technician: Rebecca Curland, Department of Plant Pathology, UMN
Collaborator: Andrew Robinson, Extension Potato Agronomist, Department of Plant Sciences, NDSU and UMN

Summary

Several different pathogens cause soft rot diseases of potato. In the U.S., the most commonly found are *Pectobacterium carotovorum, P. wasabiae*, and *P. atrosepticum*. This project is providing baseline information on the species associated with soft rot diseases in the Northern Plains potato-growing region. In 2014-2015 the Ishimaru lab in St. Paul received a number of stem, tuber and water samples (n=38) from various locations in Minnesota and North Dakota. Of these, presumptive soft rot bacteria were obtained from 26 samples, yielding a total of 55 isolates, which were characterized further. Identity of isolates was determined through biochemical and physiological tests and by PCR amplification and sequencing of 16S rRNA genes. Of those definitely identified, all belonged to the genus *Pectobacterium*. None of the isolates belonged to the genus *Dickeya*.

Background

Soft rot diseases are found most years in the Northern Plains. In some years, like 2013, excessive rains and prolonged wet periods create ideal conditions. Soft rot symptoms in potato can take several forms. Black leg, non-emergence, tuber soft rots, and stem and leaf blights can develop depending on when and where the infection occurred. The specific bacteria causing the disease also influence the types and severities of symptoms. There are several common types of bacteria that cause soft rot diseases. Most common are *Pectobacterium carotovorum, P. wasabiae*, and *P. atrosepticum.* In 2014-15, a particularly aggressive type of soft rot bacteria belonging to the genus *Dickeya* caused losses in the seed industry in Northeastern U.S. Surprisingly, there isn't much information on the specific types of soft rot bacteria present in Minnesota and North Dakota. The goal of this project, initiated in 2014, was to isolate and characterize soft rot bacteria from commercial potato fields in the Northern Plains.

Research progress

Bacterial isolation

Isolates of soft rot bacteria were obtained by culture-dependent methods. Samples were submitted to NDSU or UMN by growers or were collected from fields by Andy Robinson and C. Ishimaru (Table 1). Briefly, a small piece of infected plant tissue was suspended in phosphate buffer and serial dilutions spread on an improved semi-selective crystal violet pectate (CVP) medium containing AG366 pectin, as described by Helias *et al.* (2012). For all samples, representative colonies causing pits on CVP were purified by repeated sub-culturing and retested for pectolytic activity on CVP. All isolates were catalogued and stored in glycerol stocks at -80C.

Biochemical and physiological characterization

A combination of seven tests was conducted to determine the identity of each isolate in the soft rot collection. Initially, isolates were tested for Gram reaction by a KOH test and for ability to fluoresce on King's medium B, a medium used to differentiate fluorescent pseudomonads from

Pectobacterium. Most were non-fluorescent. Isolates were tested for facultative anaerobic growth on Hugh Leifson media; a positive reaction of this test is characteristic of *Pectobacterium* and *Dickeya* species. Additional tests included growth at 37° C (negative reaction is specific to *Pectobacterium atrosepticum* and *Pectobacterium wasabiae*), color on YDC medium (*Pectobacterium* and *Dickeya* are buff-colored), sensitivity to erythromycin (sensitivity differentiates *Dickeya* from *Pectobacterium*), and ability to macerate potato slices.

PCR and DNA sequencing

DNA was extracted from each isolate using the DNeasy Blood and Tissue kit (Qiagen). PCR amplification of the 16S rRNA gene was completed and the products sequenced (ACGT Inc). DNA from *Pectobacterium carotovorum* subsp*. carotovorum*, *Pectobacterium wasabiae*, *Dickeya dadantii* and *Dickeya dianthicola* provided by Amy Charkowski (UW Madison) was included in PCR and sequencing reactions and used as reference sequences. Sequences were compared using NCBI's BLAST tool. The sequencing results provided initial identification of the isolates to at least the genus level. The majority of the sequence matches was in agreement with the results of the biochemical/physiological tests and supported an initial classification of our isolate collection (Tables 2 and 3). Five isolates (listed in Tables 2 and 3 as *Pectobacterium* spp.) could not be identified to the species level. These will require further molecular diagnostics to infer specific/sub-specific identification.

Major findings

- The majority of the sequence matches was in agreement with the results of the biochemical/physiological tests and supported an initial classification of isolates (Tables 2 and 3).
- Five isolates (listed in Tables 2 and 3 as *Pectobacterium* spp.) could not be identified to the species level. These will require further molecular diagnostics to infer specific/sub-specific identification.
- In Minnesota and North Dakota, the common causes of potato soft rot are *Pectobacterium carotovorum subsp. carotovorum, P. carotovorum* subsp. *brasiliensis*, and *P. wasabiae*.
- *Dickeya* was not found in the any of the samples collected in 2014-2015.

Further studies

While 16S rRNA PCR and sequencing is a useful tool to group isolates at the genus and occasionally species level, further molecular studies can improve confidence in specific isolate identity. Multi-locus sequence analysis based on several housekeeping genes has been used to differentiate soft rot isolates and could be easily pursued by our group (*Ma et al*., 2007; Kim *et al.,* 2008), as we routinely use MLST in other projects. Additionally, the methods described above depend on pure cultures of bacteria. Such approaches limit the information to only those isolates that can be grown in culture. Ideally, it would be valuable to be able to identify the presence of soft rot bacteria in samples in a culture-independent method, e.g. directly from soil, infected plant tissues, water, etc. DNA-based approaches that allow detection directly from samples could provide a more rapid and economic identification of soft rot bacteria. This could be especially useful for samples containing very few numbers of soft rot bacteria.

Potato diseases caused by soft rot bacteria remain a concern in the Northern Plains. Continued monitoring could help in alerting growers to introductions or the spread of new forms of soft rot bacteria, such as *Dickeya* spp. in the region.

Table 1. Description of soft rot samples collected in 2014-2015

Location	Sample type	Number of samples
Osage, MN	stem	1
Ottertail, MN	stem	1
Karlsrue, MN	stem	1
Candoo, ND	stem	1
Becker, MN	tuber	4
Becker, MN	stem	11
Inkster, ND	tuber	1
Inkster, ND	stem	3
Big Lake, MN	stem	3
Big Lake, MN	water[a]	2
Hubbard, MN	stem	1
Park Rapids, MN	stem	1
Clear Lake, MN	stem	4
Clear Lake, MN	water[a]	2
Grand Forks, ND	stem	2
Total		38

[a]ditch and standing water adjacent to heavily infected fields

Table 2. Number and identification of soft rot bacteria obtained from samples collected in Minnesota and North Dakota

	Number of isolates	
Species	Minnesota	North Dakota
Pectobacterium carotovorum subsp. *carotovorum*	18	1
P. wasabiae	12	2
P. carotovorum subsp. *brasiliensis*	6	0
Pectobacterium species	1	4
Dickeya species	0	0
Other[a]	6	5
Total	43	12

[a]pectolytic bacteria other than *Pectobacterium* or *Dickeya*

Table 3. Sources of soft rot bacteria found in Minnesota and North Dakota

	Number of isolates		
Species	Stem	Tuber	Ditch water
Pectobacterium carotovorum subsp. *carotovorum*	17	2	0
P. wasabiae	12	2	0
P. carotovorum subsp. *brasiliensis*	6	0	0
Pectobacterium species	5	0	0
Other[a]	3	6	2
Total	43	10	2

[a]pectolytic bacteria other than *Pectobacterium* or *Dickeya*

Can we maintain or increase tuber production and minimize nitrogen losses with Enhanced Efficiency Fertilizers?

Upasana Ghosh[a], Harlene Hatterman-Valenti[b], Collin Auwarter[c] and Amitava Chatterjee[d]

[a] Graduate research assistant, Department of Soil Science, North Dakota State University

[b] Professor, Department of Plant Science, North Dakota State University

[c] Research Technician, Department of Plant Science, North Dakota State University

[d] Assistant Professor, Department of Soil Science, North Dakota State University

Corresponding Author – Upasana Ghosh (upasana.ghosh@ndsu.edu)

Summary

Increasing demand for food supply and concerns about environmental and soil health created a compulsion for sustainable management for the most limiting and loss prone nutrient, nitrogen (N). Enhanced efficiency fertilizers (EEFs) are believed to have a potential to reduce nutrient loss and environmental impact while maintaining or increasing yield. A field study was conducted to evaluate if enhanced efficiency fertilizers and split application can reduce N loss with profitable yield compared to conventional fertilization practices in three potato cultivars at Northern Plains Potato Growers' Association Irrigation site near Inkster, ND in 2015. The experiment was laid out with eighteen treatment combinations comprised of six N treatments [Growers' standard, Urea @ 200 lb N/acre, UreaSplit @ 250 lb N/acre, ESN @ 250 lb N/ acre, SuperU@ 250 lb N/ acre and Control (no fertilizer N)] and three cultivars [Russet Burbank, Dakota Trailblazer, ND8068-5 Russ] in factorial RCBD with four replications. Losses of N through ammonia (NH_3) volatilization, nitrous oxide (N_2O) emission and nitrate (NO_3^-) leaching were measured throughout the growing season. After harvest, tuber yield and quality, above ground biomass and plant N uptake were determined. Overall, higher N application rate i.e. above 200 lb N/acre and split application did not significantly increase yield. Highest tuber yields were achieved with Urea @ 200 lb N/ acre and ESN @ 250 lb N/acre. Considering N loss mitigation ESN @ 250 lb N/acre performed very well as it reduced N loss through NH_3 volatilization and NO_3^- leaching compared to other N treatments as well as increased yield significantly over the control and conventional practices in all varieties. SuperU @ 250 lb N/acre reduced N_2O emission significantly, but increased NO_3 leaching and NH_3 volatilization enormously. SuperU @ 250 lb N/acre failed to increase yield significantly compared to control in all varieties because the slower mineralization and split application could not supply sufficient

N to the plant according to demand. Our study opened several important scopes for further investigations. The performance of the EEFs while complete doses are applied at planting can be evaluated. A recalibration for N rate recommendation for potatoe is also required as the N release patterns of EEFs are different from the conventional fertilizers and several studies including ours could not find any yield advantage with higher N application rate.

Rationale

Potato (*Solanum tuberosum*) is a high N demand crop that requires around 200 lb N/acre throughout the growth period for a yield goal of 450 cwt/acre. Potato N use efficiency is significantly low particularly under irrigated sandy soils. Increasing N fertilizer prices and environmental health concerns associated with N losses are forcing the growers and researchers to better manage N fertilizers and improve N use efficiency. The efficiency of fertilizer N management is primarily influenced by source, form, placement, application rate and timing of application in addition to soil environmental conditions. Enhanced efficiency N fertilizers like polymer coated urea and urea blended with urease and nitrification inhibitor showed promising results with respect to yield increase and minimization of N loss in several studies (Halvorson, 2010; Rosen et al., 2014). Growers in Minnesota successfully use ESN (polymer coated urea) in potato production when applied at shoot emergence. However, not much research have been conducted in ND to evaluate the efficiency of different improved fertilizers in reducing N loss with profitable production of potatoes.

Researchers are starting to investigate alternative N formulations for efficient N management practices in specific varieties of a crop. However, the physiological and genotypic variation in N use efficiency of potato is poorly understood. Although plant breeders seldom select for nutrient use efficiency, understanding N uptake and partitioning differences may assist in the selection of genotypes that uses nutrient more efficiently.

Our experiment examined the efficiency of ESN, SuperU (Urea blended with nitrification and urease inhibitor) and split application in reducing N loss with successful production of three potato cultivars i.e. Russet Burbank, Dakota Trailblazer and ND8068-5 Russ. The main objectives of our research were

1. To evaluate if EEFs (ESN and SuperU) and split application of N fertilizers can increase potato tuber yield and N uptake as well as improve quality

2. To examine the efficiency of EEFs (ESN and SuperU) and split application of N fertilizers in reducing N losses through NH_3 volatilization, N_2O emission and NO_3^- leaching below root zone.

Materials and Methods

A field research was conducted to evaluate if enhanced efficiency fertilizers i.e. ESN, SuperU and split application of N fertilizers can reduce N loss from soil as well as increase yield over conventional practices, at the Northern Plains Potato Growers' Association irrigation site near Inkster, ND in 2015. The initial basic properties of the soil of the study site are listed in Table 1.

Russet Burbank, Dakota Trailblazer and ND8068-5 Russ were planted with six N treatments in a 3 (varieties) × 6 (N treatments) factorial randomized complete block design with four replications on 10th June, 2015. The N treatments were

1. Grower's Standard (10-34-0 @ 30 gallon/acre at planting+ Urea @ 150 lb N/acre at hilling + UAN @ 70 lb N /acre at tuber initiation)
2. Urea @ 200 lb N/ acre at planting
3. Urea @ 100 lb N/ acre at planting and @ 150 lb N/ acre at hilling
4. SuperU @ 100 lb N/ acre at planting and @ 150 lb N/ acre at hilling
5. ESN @ 100 lb N/ acre at planting and @ 150 lb N/ acre at hilling
6. Control (No fertilizer N)

Parameters

1. *Yield and tuber quality*- Middle two rows of each plot were harvested using single row potato harvester. Potato yield and grades were determined by an optical grader.
2. *Plant N uptake*- Above ground plant samples and tuber samples were collected, dried at 60°C, grinded and total N concentration in tissue were determined through micro Kjeldahl process. Plant N uptake was calculated from tissue N concentration, tuber yield and above ground biomass.
3. *Ammonia volatilization*- NH_3 emission was measured weekly (early in the season) and biweekly (later in the season) using semi static acid trap chamber to estimate the N loss through volatilization.

4. *Nitrous oxide emission*- Headspace air samples were collected weekly (early in the season) and biweekly (later in the season) using static chamber method. Samples were analyzed for N_2O concentration using gas chromatograph fitted with a 63Ni electron capture detector (ECD).
5. *Residual nitrate-N in soil profile (0- 3 feet)*- Profile soil samples were collected from each plot at 0-12”, 12-24” and 24-36” depths after harvest to determine the residual NO_3^- leached down and deposited in the profile. Soil samples were extracted with 2.0 M KCl to estimate NO_3^- using diffusion conductivity membrane apparatus (Timberline 2800).

Results

Table 1: Initial physical and chemical properties of the soil of study site

Parameters	Estimates
Texture	Sandy loam
Bulk density	1.16 g cm^{-3}
pH	6.0
Electrical conductivit	0.17 dS m^{-1}
Cation exchange capacity	10.6 cmol kg^{-1}
Available N (0-2 feet)	23 lb $acre^{-1}$
Organic matter	3.31 %

Table 2: Effect of N treatments on tuber yield and grades of Russet Burbank potato

	Size grade						
Treatments	0-4 Oz	4-6 Oz	6-12 Oz	>12 Oz	Culls	Total	Marketable
	Cwt / acre						
Grower's	70.2 ab	92.0 ab	209 a	43.0 c	20.3 c	434 abc	344 bc
Urea@200lb	53.0 c	77.6 bc	219 a	86.4 ab	25.0 bc	461 a	383 a
UreaSplit@250lb	48.5 cd	71.0 c	207 a	77.2 b	23.6 bc	427 bc	355 ab
SuperU@250lb	77.1 a	106 a	164 a	44.5 c	23.8 bc	415 c	314 bc
ESN@250lb	60.6 bc	67.4 cd	223 a	64.1 bc	32.8 ab	448 ab	355 ab
Control	38.9 d	48.5 d	169 b	110 a	43.9 a	409 c	327 c

Table 3: Effect of N treatments on tuber yield and grades of Dakota Trailblazer potato

	Size grade						
Treatments	0-4 Oz	4-6 Oz	6-12 Oz	>12 Oz	Culls	Total	Marketable
	Cwt/acre						
Grower's	45.9 a	54.7 a	121 c	149 a	23.7 a	395 b	325 b
Urea@200lb	456 a	65.3 a	192 a	112 b	9.64 b	425 ab	369 a
UreaSplit@250lb	43.2 a	66.8 a	184 a	82.3 c	18.2 ab	394 b	333 b
SuperU@250lb	38.4 a	64.6a	196 a	93.0 bc	21.5 a	414 ab	354 ab
ESN@250lb	43.9 a	64.9 a	158 b	154 a	22.9 a	444 a	377 a
Control	28.6 b	57.2 a	197 a	88.4 bc	14.9 ab	386 b	343 ab

Table 4: Effect of N treatments on tuber yield and grades of ND8068-5 Russ potato

	Size grade						
Treatments	0-4 Oz	4-6 Oz	6-12 Oz	>12 Oz	Culls	Total	Marketable
	Cwt/ acre						
Grower's	60.7 ab	84.0 cd	228 ab	84.8 a	16.9 b	474a	396 a
Urea@200lb	60.2 ab	106 a	245 a	29.8 cd	23.2 a	464 ab	381 ab
UreaSplit@250lb	52.3 ab	98.9 abc	207 b	56.2 b	15.9 b	431 bc	362 b
SuperU@250lb	50.5 b	81.4 d	233 ab	40.9 bc	15.2 b	421 c	356 b
ESN@250lb	51.0 b	87.6 bcd	209 b	86.1 a	12.1 bc	445 ab	382 ab
Control	62.6 a	102 ab	177 c	17.9 d	7.23 c	367 d	297 c

Yields

Total yield, marketable yield and all grades were significantly influenced by treatment × variety interactions. Urea @ 200 lb N/acre and ESN @ 250 lb N/acre produced highest total tuber in Russet Burbank potato (Table 2). Total marketable yield was significantly higher with Urea @ 200 lb N/ acre, ESN @ 250 lb N/ acre and UreaSplit @ 250 lb N/acre compared to control (Table 2). Maximum total yield and marketable yield were obtained with Urea @ 200 lb N/acre (Table 2). Only ESN @ 250 lb N/ acre could increase the total tuber yield compared to control in Dakota Trailblazer variety (Table 3). In Dakota Trailblazer, marketable yield was significantly higher with Urea @ 200 lb N/acre and ESN @ 250 lb N/ acre (Table 3). In ND8068-5 Russ all the N treatments produced significantly higher amount of total tuber compared to control (Table 4). The maximum total yield and marketable yield were obtained with Grower’s standard, but the results were not significantly different than that of Urea @ 200 lb N/ acre and ESN @ 250 lb N/ acre (Table 4).

Nitrogen Uptake

Nitrogen uptake in tubers, shoots and total N uptake were significantly influenced by N treatments (Table 5). Across all varieties, all N treatments except for Urea @ 200 lb N/ acre significantly increased total N uptake compared to control, but the treatment effects were not significantly different from each other (Table 5). Tuber N uptake were significantly higher in Growers' standard, UreaSplit @ 250 lb N/ acre and SuperU @ 250 lb N/acre compared to control. Shoot N uptake was significantly higher in Grower's standard, SuperU @ 250 lb N/ acre and ESN @ 250 lb N/ acre (Table 5). Variety did not have any effect on tuber N uptake or total N uptake, but significantly influenced shoot N uptake. Shoot N uptake was maximum in Dakota Trailblazer and minimum in ND8068-5 Russ.

Table 5: Effect of N treatments and varieties on tuber, shoot and total N uptake

Sources of Variation	N uptake (lb/acre)		
	Tuber	Shoot	Total
N Treatment			
Growers'	161 a	11.6 a	172 a
Urea@200lb	145 ab	6.75 bc	152 ab
UreaSplit@250lb	171a	6.41 bc	177 a
SuperU@250lb	155 a	11.3 a	166 a
ESN@250lb	148 ab	8.45 b	157 a
Control	118 b	4.78 c	122 b
Significance	*	***	*
Variety			
Russet Burbank	151	6.61 b	157
Dakota Trailblazer	140	12.2 a	152
ND8068-5 Russ	158	5.81 c	164
Significance	NS	*	NS
Interaction			
Treatment × Variety	NS	NS	NS

N Losses

Nitrogen loss through NH_3 volatilization from UreaSplit@250lb N/acre was maximum and significantly higher than other treatments across all varieties (Table 6). Cumulative NH_3 volatilization from growers' standard and SuperU @ 250 lb N/ acre were significantly higher than that of control, but not significantly different from each other. ESN @ 250 lb N/ acre and

Urea @ 200 lb N/ acre did not increase cumulative NH_3 volatilization significantly over control (Table 6). Averaged across all N treatments, cumulative NH_3 volatilization was highest from Dakota trailblazer variety and significantly higher than that of ND8068-5 (Table 6).

Table 6: Effect of N treatments and varieties on NH_3 volatilization, N_2O emission and residual NO_3-N in soil profile (0-3 feet)

Sources of Variation	Cumulative emissions (lb/acre)		Profile (0-3 ft) NO_3-N (lb/acre)
N Treatment	NH_3-N	N_2O-N	NO_3-N
Grower's	5.41 b	2.04 c	38.6 b
Urea@200lb	3.16 c	2.62 a	23.2 c
UreaSplit@250lb	**17.8 a**	2.43 ab	35.4 b
SuperU@250lb	5.33 b	1.22 d	66.2 a
ESN@250lb	3.15 c	2.11 bc	19.8 cd
Control	2.19 c	0.61 e	13.1 d
Significance	***	***	***
Variety			
Russet Burbank	6.22 ab	2.13 a	26.3 b
Dakota trailblazer	7.23 a	1.90 a	36.8 a
ND8068-5 Russ	5.08 b	1.49 b	35.1a
Significance	**	***	***
Treatment × Variety	NS	NS	**

Table 7: Effect of significant treatment × variety interaction on residual NO_3-N in soil profile (0-3 feet)

N Treatment	NO_3-N lb/acre		
	Russet Burbank	Dakota Trailblazer	ND8068-5 Russ
Growers'	33.8 b	43.2 b	38.8 b
Urea@200lb	16.1 c	31.0 bc	22.5 c
UreaSplit@250lb	36.4 ab	27.1 bc	42.6 b
SuperU@250lb	46.0 a	81.1 a	71.5 a
ESN@250lb	14.0 c	22.1 bc	23.4 c
Control	11.3 c	16.2 c	11.8 c

Cumulative N_2O-N emission from all the N treatments were significantly higher than control (Table 6). Averaged across all varieties, N_2O emission was highest from Urea @ 200 lb N/acre, closely followed by ESN @ 250 lb N/ acre. Nitrous oxide emission from SuperU @ 250 lb N/ acre was significantly lower than all other N treatments.

Interaction between variety and N treatment significantly influenced residual NO_3-N in soil profile (0-3 feet) (Table 6). In all varieties, highest residual NO_3-N in soil profile (0- 3 feet) was observed in treatment SuperU @ 250 lb N/acre (Table 7). Besides that, in Russet Burbank and ND 8068-5 Russ, Growers' standard and UreaSplit @ 250 lb N/acre and in Dakota Trailblazer only Growers' standard resulted into significantly higher residual NO_3-N in soil profile over control (Table 7). In all varieties ESN @ 250 lb N/acre was successful in reducing leaching and accumulation of NO_3-N in soil profile.

Discussion

Averaged across all varieties total yield increased with all N treatments and the highest productions were obtained with Urea @ 200 lb N/acre followed by ESN @ 250 lb N/acre. The yield obtained from Urea @ 200 lb N/acre and ESN@ 250 lb N/acre were not significantly different. Many researchers ((Rosen, 1992; Scherer et al, 1992, Robinson et al, 2014) showed that higher rate of N application (>180-200 lb N/acre) might not result into significant yield increase in potatoes. Split application of SuperU might have been restricted N availability during tuber initiation and tuber bulking by slowing down the nitrification and resulting a huge amount of residual N in soil profile through leaching later in the season. Although Robinson et al. (2014) reported ND8068-5 Russ as least profitable followed by Dakota Trailblazer and finally Russet Burbank, in our experiment ND8068-5Russ had the highest marketable yield followed by Russet Burbank and finally Dakota Trailblazer. The reason behind it might be the delay in harvesting ND8068-5 Russ, an early maturing variety because of our field design (factorial RCBD). Further investigations can confirm if ND8068-5 Russ have a potential of producing profitable yield as much as or more than the popular established cultivar Russet Burbank. Dakota Trailblazer has been reported to have a lower N requirement, so the high rate of N application might have been affected its tuber yield by increasing the vegetative growth.

Both tuber and plant N uptake in Urea @ 200 lb N/acre did not increase significantly over control, because higher yield with lower N application rate resulted into a dilution in tissue N concentration. The same dilution effect was observed in case of tuber N uptake in treatment ESN @ 250 lb N/acre. Significantly higher shoot N uptake in Dakota Trailblazer compared to other two varieties was due to excessive vegetative growth which in turn reduced tuber yield.

Between two enhanced efficiency fertilizers ESN and SuperU, ESN reduced NH_3 volatilization successfully (no excess NH_3 emission over control) by slow release of N, while

SuperU increased NH_3 volatilization significantly over control and ESN by restricting nitrification and increasing NH_3 accumulation. This result also suggests that the urease inhibition mechanism of SuperU was less effective than the nitrification inhibition. An opposite trend was observed in case of N_2O emission where ESN produced significantly higher amount of N_2O compared to SuperU. As ESN do not slow down nitrification, N_2O production through both nitrification and denitrification in an irrigated system is quite explainable.

As plants could not utilize N in SuperU treatment properly due slow mineralization and split application, the unutilized mineralized NO_3-N leached down the profile and resulted into a huge amount of residual NO_3-N. The split application in Growers' standard also caused significant leaching and residual NO_3-N accumulation. The lower N loss through NH_3 volatilization and N_2O emission in ND 8068-5 Russ compared to the other two varieties suggests a higher N requirement of the variety and which actually corresponds to the maximum total N uptake in this short duration variety (Table 5).

Conclusion

Higher rate of N application (>200 lb N/acre) and split application did not have any tuber yield advantage. Considering environmental concerns, ESN performed promisingly as it significantly reduced NH_3 volatilization and NO_3^- leaching with profitable production. The enhanced efficiency fertilizers could have been performed better if full doses were applied prior to planting. Further investigation is required with time of application of the EEFs and the yield potential of ND8068-5 Russ regarding growing period.

References

Halvorson, A.D.; Grosso, S.J.D.; Alluvione, F. 2010. Nitrogen source effects on nitrous oxide emissions from irrigated no till corn. Journal of Environmental Quality 39, 1554-1562.

Robinson, A.P.; Larsen, R.;Thompson, A.; Gudmestad, N. 2014. Sustainable production of Dakota Trailblazer. Northern Plains Potato Growers Association Research Report, 83-91.

Rosen, C.J.; Crants, J.; McNearney, M. 2014. Irrigated potato response to rate and application timing of two controlled release nitrogen fertilizers. Northern Plains Potato Growers Association Research Report, 115- 130.

Scherer, T.F.; Weigel, J.; Grabanski, R.; Preston, D.A. 1992. Growing irrigated potatoes. AE 1040 NDSU Extension service.

Defining glyphosate and dicamba drift injury thresholds in potatoes - Oakes. Hatterman-Valenti, Robinson, Auwarter, Crook, and Brandvik.

A field study was conducted to correlate plant injury in potatoes to results a producer would receive from lab analysis of leaf tissue when off-target movement of glyphosate, dicamba, or the combination of both herbicides is suspected. Russet Burbank seed pieces were planted May 22. Simulated drift doses of glyphosate at 0.2, 0.04, 0.007 lb ae/A, dicamba at 0.09, 0.02, 0.004 lb ae/A, and glyphosate + dicamba at 0.2+0.09, 0.04+0.02, 0.007+0.004 lb ae/A were applied to plants at the tuber initiation stage (July 7) using a CO2 sprayer equipped with 8002 nozzles at 40 psi and an output of 20 GPA. Visual injury ratings and tissue sample collection occurred 10 and 20 days after application. Tissue samples were sent to South Dakota Agricultural Laboratories for residue analysis. Two of the four treated rows were harvested and graded to evaluate herbicide effect on potato yield and grade.
Summary: The highest dicamba dose (0.02 lb) alone or with glyphosate caused the most visible injury. The highest dicamba dose alone or with glyphosate reduced the total and marketable yield compared to the untreated. More undersized tubers (< 4 oz) were formed when plants received dicamba (0.09 or 0.02 lb) alone or with glyphosate.

Table 1.

No.	Treatment	Rate (lb ae/A)	Injury (20 DAA)	No. 2 < 4 oz	No. 1 < 4 oz	No. 1 4-6 oz	No. 1 6-10 oz	No. 1 10-14 oz	No. 1 > 14 oz	No. 1 Total	No. 1 > 4 oz	No. 2 > 4 oz
			--- % ---	CWT/A								
1	Untreated		0	5	48	79	152	50	14	403	294	57
2	Glyphosate	0.2	10	37	44	65	93	30	7	455	196	178
3	Glyphosate	0.04	0	5	56	108	139	43	7	421	297	63
4	Glyphosate	0.007	0	3	56	84	140	41	17	413	283	71
5	Dicamba	0.09	49	119	16	16	5	0	0	321	21	165
6	Dicamba	0.02	31	73	32	30	22	4	1	396	57	235
7	Dicamba	0.004	30	15	63	89	109	40	6	426	244	104
8	Glyphosate Dicamba	0.2 0.09	50	148	12	5	4	1	0	306	10	137
9	Glyphosate Dicamba	0.04 0.02	28	65	36	32	29	3	0	400	64	236
10	Glyphosate Dicamba	0.007 0.004	30	11	60	81	127	42	7	431	257	103
	LSD (0.05)		4	24	20	28	49	20	7	63	87	66

Defining glyphosate and dicamba drift injury thresholds in potatoes - Inkster. Hatterman-Valenti, Robinson, Auwarter, Crook, and Brandvik.

A field study was conducted to correlate plant injury in potatoes to results a producer would receive from lab analysis of leaf tissue when off-target movement of glyphosate, dicamba, or the combination of both herbicides is suspected. Russet Burbank seed pieces were planted June 10. Simulated drift doses of glyphosate at 0.2, 0.04, 0.007 lb ae/A, dicamba at 0.09, 0.02, 0.004 lb ae/A, and glyphosate + dicamba at 0.2+0.09, 0.04+0.02, 0.007+0.004 lb ae/A were applied to plants at the tuber initiation stage (July 30) using a CO2 sprayer equipped with 8002 nozzles at 40 psi and an output of 20 GPA. Visual injury ratings and tissue sample collection occurred 10 and 20 days after application. Tissue samples were sent to South Dakota Agricultural Laboratories for residue analysis. Two of the four treated rows were harvested and graded to evaluate herbicide effect on potato yield and grade.
Summary: Visible injury was much lower at Inkster compared to Oakes. The highest glyphosate dose (0.2 lb) and all treatments with dicamba caused more injury compared to the untreated, but the highest amount of injury was less than 20%. Tuber grade was quite variable and no response pattern was evident, which was in contrast to Oakes. The highest dicamba dose alone reduced the total and marketable yield compared to the untreated. Investigation of maximum and minimum air temperatures following the herbicide applications suggest that non-stressful day and night temperatures immediately after plant contact with sublethal doses of glyphosate and/or dicamba can help plants recover and metabolize the herbicides and greatly change tuber yield and grade responses. More research under controlled environmental conditions are needed in order to define the role environmental conditions play in the recovery from sublethal doses of glyphosate and/or dicamba to potato.

Table 1.

No.	Treatment	Rate (lb ae/A)	Injury (20 DAA)	No. 2 < 4 oz	No. 1 < 4 oz	No. 1 4-6 oz	No. 1 6-10 oz	No. 1 10-14 oz	No. 1 > 14 oz	No. 1 Total	No. 1 > 4 oz	No. 2 > 4 oz
			--- % ---	CWT/A								
1	Untreated		0	5	103	117	92	23	6	378	238	32
2	Glyphosate	0.2	14	2	105	108	90	19	10	351	227	17
3	Glyphosate	0.04	0	4	78	91	105	22	9	335	226	28
4	Glyphosate	0.007	0	85	74	58	42	10	1	353	112	82
5	Dicamba	0.09	13	7	90	93	99	19	5	351	217	37
6	Dicamba	0.02	14	106	25	27	23	5	1	289	57	102
7	Dicamba	0.004	14	92	40	44	61	10	2	311	117	62
8	Glyphosate Dicamba	0.2 0.09	16	8	89	91	80	21	8	320	200	22
9	Glyphosate Dicamba	0.04 0.02	11	53	68	74	91	31	4	362	200	41
10	Glyphosate Dicamba	0.007 0.004	9	86	49	63	75	15	2	351	155	61
	LSD (0.05)		4	96	54	58	74	21	NS	69	147	57

Northern Plains Potato Growers Association
Research Proposal Application

Title: Developing a qPCR Assay to Determine Population Densities of Root-lesion Nematodes (*Pratylenchus penetrans*) in Soils to Be Planted to Potato

Investigator name: Dr. Guiping Yan**,** Assistant Professor of Nematology
Address: Dept. Plant Pathology #7660, NDSU**,** PO Box 6050, Fargo, ND 58108-6050
Email: guiping.yan@ndsu.edu
Phone: 701-231-7069

Cooperators: Drs. Neil Gudmestad, Gary Secor and Andy Robinson

Executive summary

Pratylenchus penetrans is the most economically damaging root-lesion nematode species affecting potato. Accurate identification and quantification of *P. penetrans* in fields are critical for designing effective measures to control this nematode. It is difficult to identify and count *P. penetrans* in a large number of field samples based on morphological features when other nematodes are also present. We proposed to develop a qPCR assay (DNA-based) to detect and quantify *P. penetrans* directly in DNA extracts from soil. The research project was proposed for three years. During the first year of the project, we collected 50 soil samples from five counties in ND and MN. Eight groups (genera) of plant-parasitic nematodes were detected. Twenty-three of the samples were found to contain root-lesion nematodes. Eleven of the 23 soil samples were infested with *P. penetrans*. Carrot disk cultures were used to rear the nematodes to obtain pure populations of *P. penetrans* with mixed life stages. Three of the eight carrot disks successfully produced large numbers of *P. penetrans* that will be used to construct the standard curves for the qPCR assay. To discern the sequence variation and genetic diversity among the *P. penetrans* populations, seven populations from four farms in MN were selected for DNA extraction and sequencing. Much sequence variation was found in a genomic region (ITS rDNA) among these isolates. The consensus sequence from these populations will be used in year two of the project to design qPCR primers and probes that are specific to all the tested populations. Sensitive and accurate detection and quantification of *P. penetrans* is important to help growers preform risk assessment and make the best management strategies for controlling the disease to increase potato yield and quality.

Rationale for conducting the research

Root-lesion nematodes (*Pratylenchus* spp.) are the most common nematode pests of potato. Several species in this group are detrimental to potato (Mahran et al. 2010). In the Midwest, the important species include *P. penetrans*, *P. neglectus*, *P. scribneri*, *P. thornei*, and *P. crenatus*. Among the species, *P. penetrans* is the most economically damaging species (Waeyenberge et al. 2009). Potato plant growth was negatively correlated with densities of *P. penetrans* and the yield of potatoes was reduced up to 50% in an affected field in Norway (Holgado et al. 2009). In northeastern USA and Canada, *P. penetrans* causes economic losses on potato when acting alone, but even more severe losses by interacting with *Verticillium* wilt fungi, causing the Potato Early Dying disease. This disease complex causes significant reduction in tuber size and total marketable yield and therefore can become a limiting factor in potato production (Mahran et al. 2010).

Accurate identification of *P. penetrans* and awareness of population densities in fields are critical for designing effective measures to control this nematode. It is quite often difficult to separate *P. penetrans* from other *Pratylenchus* species based on their morphology. It is a challenge to count *P. penetrans* using the traditional microscopic method from a large number of field soil samples when other closely related nematodes are also present. Molecular technologies provide a rapid and accurate alternative to the microscopic method. A number of molecular techniques have been developed to detect and identify *P. penetrans* (Sato et al. 2007, Waeyenberge et al. 2009, Mokrini et al. 2013). However, there are no published procedures in the USA for identifying and quantifying *P. penetrans* using DNA extracted directly from field soil. We aim to develop a real-time quantitative PCR (qPCR) assay to determine population densities of *P. penetrans* in soils to be planted to potato. Sensitive and accurate detection and quantification of *P. penetrans* is important to help growers perform risk assessment and make the best management strategies for controlling the disease to increase potato yield and quality.

The research project was proposed for three years. The objectives for year one of the project are to 1) assay soil samples collected from potato-producing areas of ND and MN to identify potato fields infested with *P. penetrans*; 2) utilize pure nematode cultures to increase the populations of *P. penetrans* from various locations; and 3) sequence genomic regions of *P. penetrans* from diverse regions to design qPCR primers and probes.

Procedures, Results and Discussions

The procedures and results for year one of the project are described as follows.

Objective 1. Assay soil samples collected from potato-producing areas to identify potato fields infested with *P. penetrans*. Fifty soil samples were collected from four counties (Dickey, Grand Forks, Sargent, Walsh) in ND and one county (Sherburne) in MN. Sampling date, current crop, plant growth stage, and GPS location were recorded. Nematodes were extracted from these samples using the sugar centrifugal flotation method, and were identified to genus under a microscope. Eight groups (genera) of plant-parasitic nematodes were detected including root-lesion, pin, spiral, stunt, stubby root, dagger, lance, and ring nematodes. Among the 50 samples, twenty-three were found to contain root-lesion nematodes ranging from 75 to 1,690 per kg of soil (Table 1). DNA was extracted from the root-lesion nematodes. PCR amplification, cloning and sequencing were conducted to identify the root-lesion nematodes to species. The 12 samples from Sargent County, ND were identified as *Pratylenchus scribneri*. Morphological measurements were performed and the resulting data supported the presence of *P. scribneri*, which led to the first report of *P. scribneri* infecting potato in North Dakota (Yan et al. 2016). The 11 samples from Sherburne County, MN were all identified as *P. penetrans* (Table 1, Figure 1). The fields with *P. penetrans* were recorded and the nematode materials will be used for developing the qPCR assay.

DNA standards of nematode control species from other states and countries were acquired from USDA-ARS Nematology Laboratory (Beltsville, MD). A total of 19 isolates of root-lesion nematodes were provided by this lab, including four isolates of *P. penetrans*, three isolates of *P.*

neglectus, two isolates of *P. scribneri*, two isolates of *P. thornei*, two isolates of *P. agilis*, four isolates of *P. hexincisus*, and two isolates of *P. zeae*. These *P. penetrans* isolates and closely related *Pratylenchus* spp. are necessary for designing species-specific primers to develop the qPCR assay.

Table 1. Root-lesion nematode density (nematodes/kg soil) and species identity in infested potato fields in MN and ND

Sample No.	Sampling Date	County/State	Root-lesion Nematodes/kg soil	Species ID
P1	4/22/2015	Sargent, ND	150	*P. scribneri*
P2	4/22/2015	Sargent, ND	500	*P. scribneri*
P3	4/22/2015	Sargent, ND	350	*P. scribneri*
P4	4/22/2015	Sargent, ND	160	*P. scribneri*
P5	4/22/2015	Sargent, ND	175	*P. scribneri*
P6	9/18/2015	Sherburne, MN	233	*P. penetrans*
P7	9/18/2015	Sherburne, MN	380	*P. penetrans*
P8	9/18/2015	Sherburne, MN	612	*P. penetrans*
P9	9/18/2015	Sherburne, MN	607	*P. penetrans*
P10	9/18/2015	Sherburne, MN	311	*P. penetrans*
P11	9/18/2015	Sherburne, MN	239	*P. penetrans*
P12	9/18/2015	Sherburne, MN	82	*P. penetrans*
P13	9/18/2015	Sherburne, MN	244	*P. penetrans*
P14	9/18/2015	Sherburne, MN	1,021	*P. penetrans*
P15	9/18/2015	Sherburne, MN	81	*P. penetrans*
P16	9/18/2015	Sherburne, MN	75	*P. penetrans*
P17	10/1/2015	Sargent, ND	1,690	*P. scribneri*
P18	10/1/2015	Sargent, ND	574	*P. scribneri*
P19	10/1/2015	Sargent, ND	594	*P. scribneri*
P20	10/1/2015	Sargent, ND	1,112	*P. scribneri*
P21	10/1/2015	Sargent, ND	993	*P. scribneri*
P22	10/1/2015	Sargent, ND	869	*P. scribneri*
P23	10/1/2015	Sargent, ND	479	*P. scribneri*

Figure 1. The root-lesion nematode *Pratylenchus penetrans* isolated from a potato field in MN.

Objective 2. Utilize pure nematode cultures to increase the populations of *P. penetrans*. Root-lesion nematode may exist in the same field with other plant-parasitic and non-plant parasitic nematodes. Juveniles, eggs, adult females and males are the common structures present in soil. To obtain pure populations of *P. penetrans* with mixed life stages, carrot disk cultures were used to rear the nematodes (Figure 2). Juveniles, adult females and males identified as *P. penetrans* were placed onto sterilized carrot disks to establish pure cultures. The nematodes were isolated from infested soil collected from Sargent County, MN. Carrot cultures were incubated at a constant temperature (22°C) for 5 months for nematode multiplication. Nematodes were then extracted from carrot by cutting the disks into thin slices and floating the carrot pieces in distilled water in a petri dish. Nematodes were recovered using a sieve (20 µm).

Eighteen surface-sterilized carrot disks were prepared and inoculated with one to four *P. penetrans* nematodes on August 17, 2015. Eight of the disks were examined on January 21, 2016 for nematode reproduction. Nematodes were extracted and eggs, females, males and juveniles were counted separately. The numbers of nematodes in three disks (carrot disk no. 1-3) inoculated with 2-4 nematodes were found to have increased substantially after 5 months incubation compared to the initial inoculation (Table 2). However, the nematodes in other disks inoculated with one nematode has no increase (carrot disk no. 5-8) except the nematode in the disk no. 4 increased slightly (Table 2). This suggested that more than one nematode should be used to inoculate a carrot disk to obtain a large population of *P. penetrans*. A large number of *P. penetrans* with the mixed life stages will be needed to construct the standard curves for the qPCR assay. The pure nematode suspensions from the carrot cultures are kept in a refrigerator (4°C) for further DNA and qPCR work.

Table 2. Numbers of *P. penetrans* nematodes recovered from carrot disk cultures after 5 months incubation compared to initial inoculation rates.

Carrot Disk No.	Inoculation Rate	Nematodes Recovered After 5 Months Incubation					Multiplication Rate [a]
		Egg	Female	Male	Juvenile	Total	
1	1 male + 3 females	13,000	620	520	780	14,920	3,730
2	1 male + 2 females	9,680	420	140	800	11,040	3,680
3	1 juvenile + 1 female	8,440	400	240	720	9,800	4,900
4	1 female	360	20	20	40	440	440
5	1 female	0	0	0	0	0	0
6	1 female	0	0	0	0	0	0
7	1 female	0	0	0	0	0	0
8	1 female	0	0	0	0	0	0

[a] Multiplication rate = final nematode count divided by initial nematode number in a carrot disk

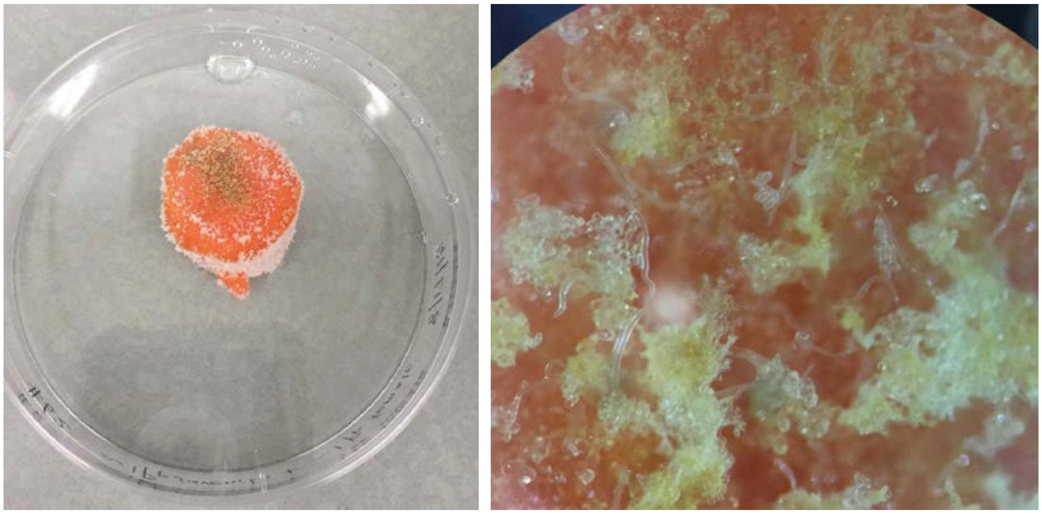


Figure 2. Carrot disk culture used for increasing the population of *Pratylenchus penetrans* isolated from a potato field in MN. Left (a carrot disk infected with *P. penetrans* showing brown lesions on the carrot surface), and right (abundant nematodes observed in the carrot disk).

Objective 3. Sequence genomic regions of *P. penetrans* from diverse regions to design qPCR primers and probes. To discern the sequence variation and genetic diversity among the *P. penetrans* populations, seven populations from four farms in MN were selected for DNA extraction. PCR amplifications were performed with primers targeting at two genomic regions (ITS of rDNA, D2/D3 of 28S rRNA). PCR products were cloned (using pGEM-T easy vector) and sequenced. Sequences were compared among these populations and also with those of known isolates of *P. penetrans* from other states and countries that were available in a public sequence database (GenBank).

Comparison of DNA sequences from D2/D3 genomic region

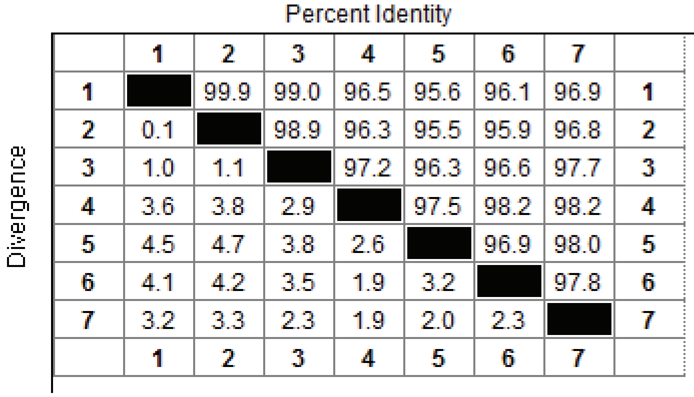
The D2-D3 region of 28S rRNA was sequenced in three isolates of *P. penetrans* from two farms in MN. The length of PCR products were 769-773 bp and 12 nucleotides were different from each other. The three isolates had 96 to 99% sequence similarity with the published sequences of *P. penetrans* in GenBank. The sequence identity among these three isolates ranged from 99.1 to 99.5%. No much sequence variation was found in this genomic region among the three isolates.

Comparison of DNA sequences from ITS region

The ITS region was sequenced in seven isolates of *P. penetrans* from four farms in MN (Table 3). The length of PCR products were 707-719 bp. Compared with the published sequences of *P. penetrans* in GenBank, the seven isolates had the similarity of 92 to 99% (Table 3). The percentage of identity from each other ranged from 95.5 to 99.9 (Figure 3). Much sequence variation was found in ITS region among the seven isolates. The consensus sequence from these populations will be used in year two of the project to design qPCR primers and probes that are specific to all the tested populations.

Table 3. Sequence comparison with published *P. penetrans* in GenBank

Sample ID	Identity with published *P. penetrans*	Identity with other *Pratylenchus* spp.
MN-PT-1	98%-92%	< 92%
MN-PT-2	97%-94%	< 91%
MN-PT-3	99%-95%	< 92%
MN-PT-4	99%-94%	< 91%
MN-PT-5	99%-94%	< 91%
MN-PT-6	99%-94%	< 91%
MN-PT-7	99%-94%	< 91%



Percent Identity

Divergence

	1	2	3	4	5	6	7	
1	■	99.9	99.0	96.5	95.6	96.1	96.9	1
2	0.1	■	98.9	96.3	95.5	95.9	96.8	2
3	1.0	1.1	■	97.2	96.3	96.6	97.7	3
4	3.6	3.8	2.9	■	97.5	98.2	98.2	4
5	4.5	4.7	3.8	2.6	■	96.9	98.0	5
6	4.1	4.2	3.5	1.9	3.2	■	97.8	6
7	3.2	3.3	2.3	1.9	2.0	2.3	■	7
	1	2	3	4	5	6	7	

1: MN-PT-4
2: MN-PT-5
3: MN-PT-6
4: MN-PT-7
5: MN-PT-1
6: MN-PT-2
7: MN-PT-3

Figure 3. Percentage of nucleotide identity among the seven *P. penetrans* isolates from MN in ITS region.

Literature Cited:

Holgado, R., Oppen, K. A., Skau, O., and Magnusson, C. 2009. Field damage in potato by lesion nematode *Pratylenchus penetrans*, its association with tuber symptoms and its survival in storage. Nematologia Mediterranea 37:25-29.

Mahran, A., Tenuta, M., Shinners-Carenelly, T., Mundo-Ocampo, M., and Daayf, F. 2010. Prevalence and species identification of *Pratylenchus* spp. in Manitoba potato fields and host suitability of "Russet Burbank". Canadian Journal of Plant Pathology 32:272-282.

Mokrini, F., Waeyenberge, L., Viaene, N., Abbad Andaloussi, F., and Moens, M. 2013. Quantitative detection of the root-lesion nematode, *Pratylenchus penetrans*, using qPCR. European Journal of Plant Pathology DOI 10.1007/s10658-013-0252-1.

Sato, E., Min, Y. Y., Shirakashi, T., Wada, S., and Toyota, K. 2007. Detection of the root-lesion nematode, *Pratylenchus penetrans* (Cobb), in a nematode community using real-time PCR. Japanese Journal of Nematology 37:87-92.

Waeyenberge, L., Viaene, N., and Moens, M. 2009. Species-specific duplex PCR for the detection of *Pratylenchus penetrans*. Nematology 11:847-857.

Yan, G. P., Plaisance, A., Huang, D., Gudmestad, N. C., and Handoo, Z. A. 2016. First report of the root-lesion nematode *Pratylenchus scribneri* infecting potato in North Dakota. *Plant Disease* 100: (in press).

Evaluation of Crystal Green/MAP blends as Phosphate Sources for Irrigated Potatoes

Carl Rosen, James Crants, and Matt McNearney
Department of Soil, Water, and Climate, University of Minnesota
crosen@umn.edu

Summary

Struvite is a P_2O_5-rich mineral byproduct of wastewater treatment with high potential as a fertilizer in potato production. This potential may be limited, however, by struvite's high production costs, relative to conventional P_2O_5 sources such as monnoammonium phosphate (MAP). These higher costs may be at least partially offset by a lower required application rate. Struvite's solubility properties (poor solubility in water; high solubility in citrate) are predicted to result in less loss of P_2O_5 to precipitation than occurs with conventional P_2O_5 sources. We conducted a field study at the Sand Plain Research Station in Becker, MN, to evaluate the effectiveness of two blends of a struvite product (Crystal Green, Ostara) with MAP, relative to 100% MAP, as sources of P_2O_5 for Russet Burbank potato production. MAP was banded or broadcast at planting at a rate of 100 $lbs \cdot ac^{-1}$ P_2O_5, and two different blends of Crystal Green and MAP (1:3 or 1:1 ratios of Crystal Green to MAP) were broadcast at 100 or 75 $lbs \cdot ac^{-1}$ P_2O_5. These treatments were compared to a zero-P_2O_5 control treatment. Tuber yield increased, while tuber size decreased, with P_2O_5 application rate. Tuber yield and size were not related to the proportion of P_2O_5 provided by Crystal Green, nor to whether 100% MAP was broadcast-applied or banded. Plant stand and tuber quality were not meaningfully related to the treatment applied. These results indicate that the use of blends of MAP and Crystal Green provide neither advantages nor disadvantages, in terms of tuber yield and quality, compared to 100% MAP.

Background

Struvite is a phosphate-rich mineral ($NH_4MgPO_4 \cdot 6H_2O$) that precipitates from waste water when anaerobic digestion releases ammonium, magnesium, and phosphate. To prevent struvite scale from fouling infrastructure in treatment plants, it can be precipitated in chemical reactors to remove it from the wastewater stream after digestion. Ostara Nutrient Recovery Technologies, Inc., uses fluid bed reactors to precipitate struvite in a relatively pure, granular form (Crystal Green®). Crystal Green has demonstrated value as a phosphate fertilizer (5-28-0-10Mg), but additional research is needed to determine optimum management for its use on a wider variety of crops.

The solubility of struvite is thought to be enhanced in the root zone because struvite has low water solubility but is more soluble in citrate, which is known to be exuded by plant roots. The solubility properties of struvite could be beneficial to farmers because the phosphate in struvite may be released into the soil solution more readily in proximity to plant roots, preventing it from precipitating in much less plant-available forms before it can be taken up. If this hypothetical advantage holds, less fertilizer should be required to meet crop requirements because less is lost to precipitation. This would be particularly valuable in crops with high phosphate demands such as potatoes.

A second predicted advantage of struvite's solubility properties is that it may reduce the advantage of banding over broadcast application that pertains to other, more water-soluble phosphate fertilizers. The advantage of banding is that it places phosphate close to plants, where plants are more likely to take it up before it precipitates, but this advantage would be diminished if struvite's phosphate is less likely to precipitate in unavailable forms over the course of weeks or months after application.

At this time, struvite cannot be produced as cheaply as conventional phosphate sources such as monoammonium phosphate (MAP), making the application of pure struvite economically noncompetitive. However, if blends of struvite and conventional sources improve yield over conventional sources alone, the use of such blends may be a good investment for growers.

The objectives of this study were to: (1) evaluate the responses of Russet Burbank potato tuber yield, size distribution, and quality to fertilization with blends of Crystal Green and MAP relative to MAP alone; (2) to determine whether Crystal Green /MAP blends applied at 75% of the recommended rate of phosphate per acre perform as well as MAP alone at 100% of the recommended rate; and (3) to determine whether the performance of Crystal Green/MAP blends relative to MAP alone depends on whether MAP is banded at planting or broadcast before planting (as all the blends were).

Methods

This study was conducted in 2015 at the Sand Plain Research Farm in Becker, Minnesota, on a Hubbard loamy sand soil. The previous crop was rye. Selected characteristics for the top six inches of soil in the study field at the beginning of the season (April 16) are shown in Table 1.

The study field received 200 $lbs \cdot ac^{-1}$ KCl (0-0-60) 200 $lbs \cdot ac^{-1}$ Sul-Po-Mag (0-0-22-22S-11Mg) on April 28, providing 164 $lbs \cdot ac^{-1}$ K, 44 $lbs \cdot ac^{-1}$ S, and 22 $lbs \cdot ac^{-1}$ Mg. These fertilizers were broadcast and incorporated with a chisel plow.

Plots were laid out in a randomized complete block design with five replicates. Potatoes were planted by hand on April 30 with three-foot spacing between rows and one-foot spacing within. Each plot consisted of four, 20-foot rows, the middle two rows being used for sampling and harvest. One red seed potato was planted at each end of each harvest row, so that each harvest row contained 18 Russet Burbank seed potatoes at planting, while each non-harvest row contained 20. The field was surrounded by a buffer strip of Russet Burbank one row (three feet) wide along either side and five feet wide at either end, with red potatoes replacing Russet Burbank in the harvest rows. Whole ("B") seed was used for Russet Burbank, while the red seed potatoes were cut ("A") seed.

Seven fertilizer treatments were applied (Table 2). Except for a control treatment that received no supplemental P_2O_5, each treatment received 75 or 100 $lbs \cdot ac^{-1}$ P_2O_5 as MAP or a blend of MAP and Crystal Green prills. In one treatment (treatment 7), P_2O_5 was banded at planting (April 30) during row closure, three inches to each side and two inches below the seed piece, using a metered, drop-fed applicator incorporated into the planter. In the remaining treatments (treatments 2 - 6), P_2O_5 was hand-broadcast prior to planting, on April 29.

Non-P fertilizers were banded at row closure (Table 2). The composition of the non-P_2O_5 fertilizers varied among treatments to maintain consistent total application rates of nutrients other than P_2O_5. However, the application rate of S varied among treatments (Table 2).

At shoot emergence, on May 22, 211 $lbs \cdot ac^{-1}$ N were applied as Environmentally Smart Nitrogen (ESN: 44-0-0), and the plots were hilled.

Belay was applied in-furrow at planting for beetle control, along with the systemic fungicide Quadris. Weeds, diseases, and other insects were controlled using standard practices. Rainfall was supplemented with sprinkler irrigation using the checkbook method of irrigation scheduling. The nitrate and ammonium concentrations of irrigation water were monitored throughout the year. Plant stand and the number of stems per plant were assessed on June 10 and again on June 18.

Leaf petioles were sampled on June 18, June 29, July 13, July 22, and August 3. Petiole P and Mg concentrations will be determined on a dry-weight basis by the Research Analytical Laboratory of the University of Minnesota using inductively coupled plasma analysis.

Vines were chopped on September 17. Tubers were harvested on October 6. One harvest row from each plot was sorted by the research team at Becker, and the second was sorted by Ag World (Jamestown, ND). The data from both sorting teams were pooled for analysis.

The data were analyzed using the GLM procedure in SAS 9.4. Dependent variables were modeled as functions of treatment and block. Significant differences between treatments at alpha = 0.10 were determined with Waller-Duncan k-ratio t tests. Four contrasts were performed for each variable analyzed: (1) a comparison of the control treatment with all treatments receiving P_2O_5 (treatment 1 vs. treatments 2 – 7); (2) a linear contrast on application rate that included all 7 treatments; (3) a comparison of banded versus broadcast application including all treatments receiving 100 $lbs\cdot ac^{-1}$ P_2O_5 (treatment 2 vs. treatment 7); and (4) a linear contrast on the proportion of P_2O_5 provided by Crystal Green at an application rate of 100 $lbs\cdot ac^{-1}$ P_2O_5 (treatments 2-4).

Results:

Plant stand and number of stems per plant

Results for plant stand and the number of stems per plant are presented in Table 3. Neither variable was significantly related to treatment. The significant contrast on the proportion of P_2O_5 provided by Crystal Green for plant stand is due to the relatively low stand in the treatment receiving 100% MAP by broadcast application (treatment 2).

Tuber yield and size distribution

The results for tuber yield are presented in Table 4. Treatment had significant effects on total yield, with yield increasing with phosphate application rate. Marketable yield did not vary significantly with treatment in the GLM, but it was significantly related to phosphate application rate in the linear contrast.

The proportion of yield represented by tubers over 6 ounces was significantly affected by treatment, with the control treatment (treatment 1) having a significantly higher mean proportion than any other treatment. There was also a tendency for treatments receiving 75 $lbs\cdot ac^{-1}$ P_2O_5 to have a larger proportion of yield in tubers over 6 ounces than those receiving 100 $lbs\cdot ac^{-1}$ P_2O_5, producing a significant linear contrast. The proportion of yield in tubers over 10 ounces also tended to decrease with increasing P_2O_5 application rate, resulting in a significant linear contrast and a significant contrast of the control treatment with the other treatments (treatment 1 vs. treatments 2 – 6). However, the effect of treatment in the analysis was not significant.

The higher proportion of yield in large size classes for treatments receiving less P_2O_5 was due more to low yield in the smaller size classes than to high yield in larger size classes, as indicated by the tendency of marketable yield to increase with P_2O_5 application rate.

The linear contrasts of yield on the proportion of P_2O_5 provided by Crystal Green were in no case significant, indicating that blends of Crystal Green and MAP have neither advantages nor disadvantages relative to pure MAP, in terms of yield, when broadcast-applied. The contrasts of broadcast versus banded MAP were also never significant.

Tuber quality
Results for tuber quality are presented in Table 5. Treatment had no significant effects on the prevalence of hollow heart, scab, dry-matter content, or specific gravity. There was a significant effect of treatment on the prevalence of brown center; this condition only occurred in one tuber in each of two plots, and those plots received the control treatment (treatment 1). Hollow heart occurred in the same tubers, as well as one in the treatment receiving banded MAP (treatment 7). As a result, both conditions had significant linear contrasts on rate and significant contrasts of the control treatment against the other treatments.

Conclusions

Total and marketable yield both increased with increasing P_2O_5 application rate, though the relationship was only strong enough to produce a significant effect of treatment for total yield. This increase in yield occurred in the two smaller tuber size classes (< 6 oz), and the opposite trend was seen in the largest size class (> 10 oz), with the result that the percentage of yield represented by large tubers tended to decrease with increasing P_2O_5 application rate, especially for tubers over 6 oz.

The proportion of the applied phosphorus represented by Crystal Green had no meaningful effect on any measured variable with the possible exception of plant stand, which was lower for the treatment receiving broadcast MAP (treatment 2) than for any other treatment. Similarly, the contrast between banded and broadcast application was not significant for any variable, aside from a marginally significant effect on the prevalence of scab, which was relatively rare in the treatment receiving banded MAP (treatment 7). These results are not consistent with the hypothesis that Crystal Green/MAP blends or banded MAP lose less P_2O_5 to precipitation than broadcast MAP by releasing a larger percentage of their P_2O_5 in proximity to plant roots.

In summary, fertilization with P_2O_5 promoted tuber yield in this system, but decreased mean tuber size. Fertilization with blends of Crystal Green and MAP provided neither advantages nor disadvantages, in terms of tuber yield, size, or quality, relative to fertilization with pure MAP.

Table 1. Characteristics of the top six inches of soil collected from the study site in Becker, MN, on April 16, 2015 (initial soil properties).

Primary macronutrients			Secondary macronutrients			Micronutrients					Other characteristics	
NO_3-N (ppm)	Bray P (ppm)	NH_4OAc-K (ppm)	NH_4OAc-Ca (ppm)	NH_4OAc-Mg (ppm)	SO_4-S (ppm)	Hot Water B (ppm)	DTPA-Cu (ppm)	DTPA-Fe (ppm)	DTPA-Mn (ppm)	DTPA-Zn (ppm)	Water pH	O.M. LOI (%)
2.00	11	46	555	123	2.0	0.152	0.323	37.7	9.50	0.72	5.7	1.3

Table 2. Application rates and method of MAP and MAP/Crystal Green blends for each treatment applied to Russet Burbank potato plants at the Sand Plain Research Farm in Becker, MN, in 2015. Phosphate fertilizers were either hand-broadcast on April 29 or banded at row closure on April 30, at tuber planting.

Treatments			Nutrient application rates at planting (lbs·ac^{-1})							Fertilizer application rates at planting (lbs·ac^{-1})							
Treatment #	Phosphate source[1]	Application method	N	P_2O_5	K	S	Mg	Zn	B	CG (5-28-0-10Mg)	MAP (11-50-0)	Urea (46-0-0)	Sul-Po-Mag (0-0-22-22S-11Mg)	K_2SO_4 (0-0-50-17S)	KCl (0-0-60)	EZ20 (2-0-0-14S-20Zn)	Granubor (14.3% B)
1	None	None	30	0	58.8	40.7	20.0	1.0	0.5	0	0	65	182	0	31	5.0	3.5
2	MAP	Broadcast preplant	30	100	58.8	40.7	20.0	1.0	0.5	0	200	17	182	0	31	5.0	3.5
3	25% CG : 75% MAP	Broadcast preplant	30	100	58.8	22.8	20.0	1.0	0.5	89	150	20	101	0	61	5.0	3.5
4	50% CG : 50% MAP	Broadcast preplant	30	100	58.8	20.7	20.0	1.0	0.5	179	100	22	19	92	14	5.0	3.5
5	25% CG : 75% MAP	Broadcast preplant	30	75	58.8	27.3	20.0	1.0	0.5	67	113	31	121	0	54	5.0	3.5
6	50% CG : 50% MAP	Broadcast preplant	30	75	58.8	20.7	20.0	1.0	0.5	134	75	33	60	40	43	5.0	3.5
7	MAP	Band at planting	30	100	58.8	40.7	20.0	1.0	0.5	0	200	17	182	0	31	5.0	3.5

[1] Crystal Green (CG: Ostara Nutrient Recover Technologies, Inc.): 5-28-0-10Mg. MAP: 18-46-0.

Table 3. The effect of phosphate source and method and rate of application on Russet Burbank plant stand and stems per plant at the Sand Plain Research Farm in Becker, MN, in 2015.

Treatment			Percent plant stand, June 2	Stems per plant, June 10
Treatment	Phosphate rate (P_2O_5 lbs·ac^{-1})	Phosphate source[1]		
1	0	None	98	3.0
2	100	MAP	92	2.9
3	100	25% CG : 75% MAP	99	3.0
4	100	50% CG : 50% MAP	99	3.0
5	75	25% CG : 75% MAP	99	2.9
6	75	50% CG : 50% MAP	98	3.0
7	100	MAP, banded	97	2.6
Significance of treatment[2]			NS	NS
MSD (0.1)			--	--
Contrasts	Control vs. others (1 vs. 2-7)[2]		NS	NS
	Linear (1, 5&6, 2-4&7; 0, 75, 100)[2]		NS	NS
	Banded vs. broadcast (@ 100; 2 vs. 7)[2]		NS	NS
	Proportion CG (2 - 4; 0, 0.25, 0.5)[2]		*	NS

[1] **Crystal Green** (CG: Ostara Nutrient Recover Technologies, Inc.): 5-28-0-10Mg. **MAP**: 18-46-0. Fertilizer broadcast one day before planting (treatments 1 - 6) or banded at planting (treatment 7).

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

Table 4. The effect of phosphate source and method and rate of application on Russet Burbank tuber yield and size distribution at the Sand Plain Research Farm in Becker, MN, in 2015.

Treatment			Tuber Yield									
Treatment	Phosphate rate (P_2O_5 lbs·ac^{-1})	Phosphate source[1]	0-4 oz	4-6 oz	6-10 oz	> 10 oz	Total	#1s > 3 oz.	#2s > 3 oz	Total Marketable	> 6 oz	> 10 oz
			cwt·ac^{-1}								%	
1	0	None	39	105	182	89	416	265	112	377	65	21
2	100	MAP	90	174	173	60	497	267	140	407	47	12
3	100	25% CG : 75% MAP	79	206	163	49	498	285	133	418	42	10
4	100	50% CG : 50% MAP	84	198	150	57	489	268	136	405	41	11
5	75	25% CG : 75% MAP	88	165	160	74	488	249	151	399	47	15
6	75	50% CG : 50% MAP	79	169	169	61	477	254	144	398	48	13
7	100	MAP, banded	88	176	172	74	510	280	143	422	48	14
Significance of treatment[2]			**	**	NS	NS	**	NS	NS	NS	**	NS
MSD (0.1)			17	33	--	--	30	--	--	--	8	--
Contrasts	Control vs. others (1 vs. 2-7)[2]		**	**	++	++	**	NS	NS	++	**	**
	Linear (1, 5&6, 2-4&7; 0, 75, 100)[2]		**	**	NS	++	**	NS	NS	*	**	**
	Banded vs. broadcast (@ 100; 2 vs. 7)[2]		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Proportion CG (2 - 4; 0, 0.25, 0.5)[2]		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1] **Crystal Green** (CG: Ostara Nutrient Recover Technologies, Inc.): 5-28-0-10Mg. **MAP**: 18-46-0. Fertilizer broadcast one day before planting (treatments 1 - 6) or banded at planting (treatment 7).

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

Table 5. The effect of phosphate source and method and rate of application on Russet Burbank tuber quality (prevalences of hollow heart, brown center, and scab; percent dry matter; and specific gravity) at the Sand Plain Research Farm in Becker, MN, in 2015.

Treatment			Tuber Quality				
Treatment	Phosphate rate (P_2O_5 lbs·ac^{-1})	Phosphate source[1]	Hollow heart	Brown center	Scab	Dry matter	Specific gravity
			%				
1	0	None	1.6	1.6	14.8	20.8	1.0747
2	100	MAP	0.0	0.0	14.1	20.8	1.0753
3	100	25% CG : 75% MAP	0.0	0.0	12.8	21.2	1.0774
4	100	50% CG : 50% MAP	0.0	0.0	5.6	21.0	1.0755
5	75	25% CG : 75% MAP	0.0	0.0	6.4	21.1	1.0765
6	75	50% CG : 50% MAP	0.0	0.0	10.1	20.5	1.0745
7	100	MAP, banded	0.8	0.0	1.6	21.2	1.0778
Significance of treatment[2]			NS	*	NS	NS	NS
MSD (0.1)			--	1.1	--	--	--
Contrasts	Control vs. others (1 vs. 2-7)[2]		*	**	NS	NS	NS
	Linear (1, 5&6, 2-4&7; 0, 75, 100)[2]		*	**	NS	NS	NS
	Banded vs. broadcast (@ 100; 2 vs. 7)[2]		NS	NS	++	NS	NS
	Proportion CG (2 - 4; 0, 0.25, 0.5)[2]		NS	NS	NS	NS	NS

[1] **Crystal Green** (CG: Ostara Nutrient Recover Technologies, Inc.): 5-28-0-10Mg. **MAP**: 18-46-0. Fertilizer broadcast one day before planting (treatments 1 - 6) or banded at planting (treatment 7).

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

Evaluation of Polyhalite as a Potash, Sulfur, Magnesium, and Calcium Source for Irrigated Potato Production

Carl Rosen, Matt McNearney, and James Crants
Department of Soil, Water, and Climate
University of Minnesota
crosen@umn.edu

Abstract: Polyhalite is a naturally occurring mineral consisting of sulfate forms of potassium, magnesium, and calcium with a chemical formula of $K_2SO_4 \cdot MgSO_4 \cdot 2CaSO_4 \cdot 2H_2O$ and an approximate fertilizer value from one known mineral deposit of 0-0-14-19(S)-3.6(Mg)-12.1(Ca). Because of relatively large deposits worldwide, there is interest in whether polyhalite can be used as an economical nutrient source for crop production. The overall objective of this study was to determine the effectiveness of polyhalite as a nutrient source for potato production in Minnesota. This study was conducted in 2014 at the Sand Plain Research Farm in Becker, Minnesota on an acid, low organic matter Hubbard loamy sand soil with low soil test K, Ca, Mg and S. Six treatments varying in fertilizer source were tested: 1) control (no K, S, Mg Ca application); 2) 400 lb K_2O/A as polyhalite (Sirius Minerals, Plc), which also supplied 543 lb/A S, 83 lb/A Mg and 389 lb/A Ca; 3) 400 lb K_2O/A as KCl (Muriate of Potash – MOP); 4) 400 lb K_2O/A as KCl plus gypsum and Epsom salts; 5) 300 lb K_2O/A as polyhalite and 100 lb K_2O/A as KCl; and 6) 100 lb K_2O/A as polyhalite and 300 lb K_2O/A as KCl. Russet Burbank was the cultivar tested. Irrigation water and rainwater supplied 134.6 lb Ca/A, 51.5 lb Mg/A and 13.8 lb S/A. Loading of Ca and Mg with irrigation/rainfall inputs exceeded the recommendations for Ca and Mg and loading of S provided over 1/3 of the S recommended. Marketable yields were significantly higher with polyhalite than the control or with 100% MOP. Blends of polyhalite with MOP were as effective as polyhalite as the sole source of K. Because of the high inputs of Ca and Mg from irrigation/rainwater, yield increases with polyhalite were likely due to the added S. Based on yield response as well as tissue and soil tests, polyhalite appears to be an effective source of K and S and is comparable to a combined application of MOP, gypsum, and Epsom salts. This study was repeated in 2015 and results are still pending.

Background

Polyhalite is a naturally occurring mineral consisting of sulfate forms of potassium, magnesium, and calcium with a chemical formula of $K_2SO_4 \cdot MgSO_4 \cdot 2CaSO_4 \cdot 2H_2O$ and an approximate fertilizer value from known deposits of 0-0-14-19(S)-3.62(Mg)-12.15(Ca). Because of relatively large deposits worldwide, there is interest in whether polyhalite can be used as an economical nutrient source for crop production. Once mined, the mineral is granulated and suitable for spreading with conventional fertilizer spreaders. The lower K content relative to S compared to sulfate of potash means that high rates of S would be applied when the product is used to meet the K demands of a crop like potatoes. Soils that might benefit from a polyhalite application would likely be low organic matter, acidic sandy soils with low basic cation content. The overall objective of this study was to determine the effectiveness of polyhalite as a nutrient source for potato production in Minnesota.

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. Selected soil chemical properties before planting were as follows (0-6“): pH, 5.2; organic matter, 1.4%; Bray P1, 37 ppm; ammonium acetate extractable K, Ca, and Mg, 100, 330, and 48 ppm, respectively; Ca-phosphate extractable SO_4-S, 3 ppm; hot water extractable B, 0.1 ppm; and DTPA extractable Fe, Mn, Cu, and Zn, 55, 15, 0.4, and 0.5 ppm, respectively. Extractable nitrate-N in the top 2 ft of soil was 15 lb/A. Soil samples from the 0-6 inch depth were collected from each plot prior to fertilizer application and then again following harvest and analyzed for ammonium acetate extractable K, Ca, and Mg, and Ca-phosphate extractable SO_4-S.

Four, 20-ft rows were planted for each plot with the middle two rows used for sampling and harvest. Whole "B single drop" seed of Russet Burbank potatoes were hand planted in furrows on May 7, 2014. Row spacing was 12 inches within each row and 36 inches between rows. Each treatment was replicated four times in a randomized complete block design. Belay for beetle control and the systemic fungicide Quadris were banded at row closure. Weeds, diseases, and other insects were controlled using standard practices. Rainfall was supplemented with sprinkler irrigation using the checkbook method of irrigation scheduling.

Six treatments varying in fertilizer source were tested: 1) control (no K, S, Mg, Ca application); 2) 400 lb K_2O/A as polyhalite (Sirius Minerals, Plc), which also supplied 543 lb/A S, 83 lb/A Mg and 389 lb/A Ca; 3) 400 lb K_2O/A as KCl (muriate of potash – MOP); 4) 400 lb K_2O/A as KCl plus gypsum and Epsom salts to provide the same amount of Ca and Mg per acre as treatment 2. Because of a calculation error, the amount of Ca applied with the gypsum was 45% lower than desired; 5) 300 lb K_2O/A as polyhalite and 100 lb K_2O/A as KCl; and 6) 200 lb K_2O/A as polyhalite and 200 lb K_2O/A as KCl. A summary of the amount of K2O, SO4-S Mg and Ca applied is as follows:

Nutrient Source	K_2O	SO_4-S	Mg	Ca
	-------------------- lb/A			---------------------
1. Control	0	0	0	0
2. Polyhalite	400	543	102	344
3. KCl	400	0	0	0
4. KCl + Gypsum* + Epsom salts	400	287	102	188
5. 75% Polyhalite + 25% KCl	400	407	76	258
6. 50% Polyhalite + 50% KCl	400	271	51	172

On May 5, 2014 one half of the amount for each treatment was broadcast applied followed by incorporation to a depth of about 6 inches with a field cultivator. At planting, all plots received fertilizer that was banded 3 inches to each side and 2 inches below the seed piece, including 30 lbs N/A, 136 lbs P_2O_5/A, 1.5 lbs S/A, 1.0 lb B/A, and 2 lbs Zn/A, applied as a blend of monoammonium phosphate (MAP), EZ20, and Granubor. At emergence (June 5), the other half of each treatment was applied by hand as a sidedress and then hilled in. All treatments received a total of 240 lb N/A, which included 30 lb N/A at planting and 170 lb N/A as ESN applied at emergence/hilling on June 5 and two applications of UAN at the rate of 20 lb N/A on July 1 and July 16.

Plant stands and stem counts were measured on June 26. Petiole samples were collected from the 4th leaf from the terminal on four dates: July 2, July 16, July 30, and Aug. 6. Petioles were analyzed for N, S, K, Mg, and Ca on a dry weight basis. In addition, on Aug. 6 SPAD readings were recorded on the terminal leaflet of 4th leaf from the terminal. Vines were killed with two applications of Reglone on Sept. 12 and 17. Tubers were machine harvested on Sept. 24. Two, 18-ft sections of row were harvested from each plot. Total tuber yield and graded yield were measured. Sub-samples of tubers were collected to determine tuber specific gravity, tuber dry matter and K, S, Mg and Ca concentration, and the incidence of hollow heart, brown center, and scab. In addition, subsamples of tubers were sent to the USDA/ARS, Potato Research Worksite in East Grand Forks for sugar analysis and frying quality.

Results

Rainfall and irrigation water nutrient concentrations and load: Nutrient concentrations and calculated loads are presented in Table 1. Rainfall totaled 20.4 inches and this was supplemented with 10.65 inches of water during the growing season with the first irrigation occurring 47 days after planting (approximately 27 days after emergence). Concentrations of S in rainwater averaged 0.2 ppm and contributed 1.1 lb S/A. Rainwater K, Ca, and Mg concentrations were below detection limits. Irrigation water Ca, Mg and S concentrations were 55.8, 21.3, and 5.3 ppm, respectively. Irrigation water K concentrations were below detection limits. Combining contributions of irrigation water and rainwater, the total loads of Ca, Mg, and S were 134.6, 51.5 and 13.8 lbs/ac, respectively. Based on the soil test for this site, the fertilizer recommendations for Ca, Mg and S are 100, 50, and 30 lb/ac respectively. Loading of Ca and Mg with irrigation/rainfall inputs exceeded the fertilizer recommendations for Ca and Mg and loading of S provided over 1/3 of the S fertilizer recommended.

Tuber yield and quality and stand count, and stems per plant: Tuber yield and size distribution is provided in Table 2. The control treatment with no K, S, Ca, or Mg added resulted in the lowest total and marketable yields and lowest amounts of tubers greater than 6 oz. The addition of K as MOP increased yield slightly, but with MOP alone, yields were still lower than those plots that were supplied with polyhalite, polyhalite blends, or MOP plus gypsum and Epsom salts. These results indicate that in this acid soil with low nutrient levels, addition of the nutrients contained in polyhalite provided a yield benefit. Treatments had no effect on stand count, stems per plant hollow heart, or brown center (Table 3). Tuber scab incidence was highest with the 100% polyhalite treatment followed by the 75% polyhalite treatment and then the 25% polyahalite treatment. Scab incidence in the 100% MOP treatment was statistically the same as all other treatments tested. The control and gypsum plus Epsom salt treatments had numerically the lowest incidence of scab. Additional studies are needed to determine whether these treatment effects are consistent over years. Tubers from the control treatment had significantly higher specific gravity than those from all other treatments. Tubers from the 100% polyhalite treatment had numerically higher specific gravity than those from the polyhalite blends and the 100% MOP treatment with and without gypsum and Epsom salts. Tuber dry matter was not affected by treatment although the control had numerically the highest dry matter. Treatments had minimal effects on tuber sugars and frying quality (Table 4); although glucose readings tended to be highest in the control (zero K) treatment.

Soil K, Mg, Ca and S: Changes in soil test K, Mg, Ca and S are presented in Table 5. As expected, differences between extractable K in the spring before fertilizer application and after harvest were greatest in the control treatment, where K was not applied. In that treatment, soil test K dropped from 97 ppm to 56 ppm, reflecting the large amounts of K taken up by the plant. When K was applied with polyhalite or MOP there was a slight increase or decrease in soil test K with no significant difference between sources. There was a slight trend for a greater drop in soil test K with polyhalite than with MOP. Soil test Ca increased with gypsum and with increasing rate of polyhalite application. As expected, the largest decrease in soil test Ca was with the 100% MOP application (310 ppm down to 276 ppm Ca). Surprisingly, soil test Mg increased in all treatments including the control suggesting that there was some Mg added with the irrigation water. Soil test Mg increased with Epsom salts and with increasing rate of polyhalite application. The smallest increase in soil test Mg was with the 100% MOP treatment. Similar to Mg, soil test S increased in all treatments including the control suggesting that there was some S added with the irrigation water. Soil test S increased with gypsum and Epsom salts and with increasing rate of polyhalite application. The smallest increase in soil test S was with control and the 100% MOP treatment.

Petiole N, S, K, Mg and Ca: Petiole S and N concentrations are presented (Table 6) and petiole K, Mg, and Ca concntratiosn are presented in Table 7. Petiole S concentrations were lowest in the control and MOP treatments at all sampling dates and MOP had lower petiole S concentrations than the control on July 30. When MOP was balanced with Ca, Mg, and S, petiole S concentrations increased but were often lower than the 100% polyhalite treatment at all but the July 26 sampling date. The critical value for petiole S during tuber bulking is 0.20%. Petioles from the control and 100% MOP treatment were at or below this level on some of the sampling dates. Petiole N (note: this is total N not nitrate-N) was highest in the control plants at all four sampling dates with the exception of petiole N concentrations in the polyhalite and the 75/25% polyhalite/MOP blend fertilizer treatments on the June 26 sampling date. Treatments with 100% MOP had lower petiole N concentrations than those with 100% polyhalite on June 26 and August 6 with blends of polyhalite and MOP intermediate in petiole N concentrations. Because color differences were visually noticeable on Aug. 6, SPAD readings were taken and they confirm the darker green color of the control treatment on this date. These results suggest that chloride and to a lesser extent sulfate applied with K competes with N uptake. Alternatively, it was observed on Aug. 5 that the canopy of the control treatment was much more upright with less biomass than all the fertilized treatments (which had already started to lodge) suggesting that the higher N concentrations in the control may due to a dilution effect. Additional vine measurements are needed to determine the exact cause of higher N concentrations in petioles of the control treatment. Petiole K concentrations were significantly higher with 100% MOP than 100% polyhalite on the first two sampling dates and numerically higher with 100% MOP than 100% polyhalite on the last two sampling dates. Comparisons of polyhalite with gypsum/Epsom salts plus MOP suggest lower availability of K on the first two sampling dates with polyhalite and higher availability at the last two sampling dates. Petiole K concentrations with the polyhalite/MOP blends were higher than 100% polyhalite on the first sampling date, but similar on the last three sampling dates. The critical concentration for petiole K during tuber bulking 8%. The petioles from the zero K control had a concentration below this value on the second sampling date at 7.9% and well below the critical value on the last two sampling dates ranging from 4.1 to 4.9%. For the K fertilized plots, petiole K concentrations on the first two sampling dates were all above 8%. Petiole K concentrations on the third sampling date for the K fertilized treatments ranged from 7.5 to 9.0%. Petiole K concentrations on the last sampling date for the K fertilized treatments ranged from 7.2 to 8.3%. Petiole Mg concentrations for all treatments were below the critical value of 0.3% on the first sampling, which occurred before the first irrigation treatment. On the second sampling date only petioles from the MOP treatment had a concentration lower than 0.3%. On the last two sampling dates petioles from all treatments had Mg concentrations above 0.3% reflecting the added Mg from irrigation water. On the last two sampling dates petiole Mg concentrations were highest in the zero K fertilizer plots and lowest in the MOP fertilized plots suggesting there was some competition between Mg and K from K fertilized plots. Petiole Ca concentrations were highest in the zero K fertilized plots at all sampling dates. Addition of Ca with polyhalite or gypsum did not result in higher petiole Ca concentrations. On the first two sampling dates petiole Ca concentrations were generally below the critical value of 0.6% and above this value on the last two sampling dates. As with Mg, added Ca with the irrigation water likely contributed to the high petiole Ca concentrations at the later sampling dates.

Tuber N, S, K, Mg, and Ca: Tuber N, S, K, Ca, and Mg results are presented (Table 8). Unlike petiole N, tuber N was not significantly affected by treatment; although tuber N tended to be lowest in the control treatment. Tuber S was lowest in the control and 100% MOP treatment. As expected, tuber S increased with gypsum and Epsom salts and with increasing rate of polyhalite application. Tuber K increased with K fertilizer application, but was not affected by K source. Because total K fertilizer applied was the same for all K fertilized treatments at relatively high rates (400 lb K_2O/ac), these results are not too surprising. Tuber Mg concentration was lowest in the zero K control plots. An unexpected result was that application of MOP alone resulted in numerically the highest tuber Mg concentrations and significantly higher than the 300 lb K_2O/ac polyhalite/100 K_2O/ac MOP blend. It is likely that the Mg applied with the irrigation water influenced these results. Tuber Ca concentrations were not significantly affected by treatment although there was a slight trend for high tuber Ca with polyhalite and polyhalite blends.

Conclusions

Use of polyhalite as a K, Ca, Mg, and S source in the acid, low organic matter soil evaluated in this study resulted in an increase in marketable yields of Russet Burbank potato over the control and 100% MOP treatment. Blends of polyhalite with MOP were as effective as polyhalite as the sole source of K. Irrigation water and rainwater supplied 134.6 lb Ca/A, 51.5 lb Mg/A and 13.8 lb S/A. Loading of Ca and Mg with irrigation/rainfall inputs exceeded the recommendations for Ca and Mg and loading of S provided over 1/3 of the S recommended. Based on yield response as well as tissue and soil tests, polyhalite appears to be an effective source of K and S and is comparable to a combined application of MOP, gypsum, and Epsom salts.

Table 1. Nutrient concentrations and content of rainfall and irrigation water based on 20.4 inches of rainfall and 10.65 inches of irrigation water.

Water Source	Unit	K	Ca	Mg	S
Irrigation water	ppm	<0.3	55.8	21.3	5.3
Irrigation water	lb/A	0	134.6	51.5	12.7
Rain water	ppm	<0.3	<0.43	<0.18	0.2
Rain water	lb/A	0	0	0	1.1
Total	lb/A	0	134.6	51.5	13.8

Table 2. Effects of polyhalite and MOP (with or without S, Ca, and Mg) on Russet Burbank tuber yield and size distribution.

Treatment				Tuber yield										
Treatment #	lbs K_2O/ac as Polyhalite	lbs K_2O/ac as KCl	Other amendments	0-3 oz	3-6 oz	6-10 oz	10-14 oz	> 14 oz	Total yield	#1s > 3 oz.	#2s > 3 oz	Marketable yield	> 6 oz	> 10 oz
				cwt / ac									%	
1	0	0	None	30	117	140	90	67	444	266	149	415	67	35
2	400	0	None	24	96	146	107	119	493	275	194	468	75	45
3	0	400	None	32	92	138	105	89	456	285	139	424	73	42
4	0	400	Gypsum & $MgSO_4$	28	100	144	116	121	509	325	157	481	75	46
5	300	100	None	26	92	143	114	121	495	295	175	469	76	46
6	200	200	None	33	104	146	119	137	538	295	210	505	75	47
Treatment significance[1]				NS	NS	NS	NS	++	**	NS	++	**	++	++
Treatment MSD (P < 0.1)				--	--	--	--	52	42	--	51	35	6	9

[1] **, *, ++ significant at 1%, 5%, and 10% respectively.

Table 3. Effects of polyhalite and MOP (with or without S, Ca, and Mg) on plant stand, stems per plant, and tuber hollow heart, brown center, scab incidence, dry matter, and specific gravity.

Treatment				Tuber quality						
Treatment #	lbs K_2O/ac as Polyhalite	lbs K_2O/ac as KCl	Other amendments	Hollow heart	Brown center	Scab	Dry matter	Specific gravity	Stems per Plant	Plant Stand
				%						%
1	0	0	None	0	0	16	19.9	1.0843	2.4	98.6
2	400	0	None	3	3	36	18.7	1.0793	2.6	97.9
3	0	400	None	1	1	22	19.4	1.0767	2.2	95.1
4	0	400	Gypsum & $MgSO_4$	1	1	13	19.7	1.0759	2.5	97.2
5	300	100	None	2	2	27	19.6	1.0746	2.2	97.2
6	200	200	None	0	0	14	19.7	1.0784	2.5	97.2
Treatment significance[1]				NS	NS	++	NS	**	NS	NS
Treatment MSD (P < 0.1)				--	--	16	--	0.0036	--	--

[1] **, *, ++ significant at 1%, 5%, and 10% respectively.

Table 4. Effects of polyhalite and MOP (with or without S, Ca, and Mg) on chip color, Agtron score, and sucrose and glucose concentrations - stem end versus bud end.

Treatment				Stem end				Bud end			
Treatment #	lbs K_2O/ac as Polyhalite	lbs K_2O/ac as KCl	Other amendments	Chip color	Agtron score	Sucrose (mg/g)	Glucose (mg/g)	Chip color	Agtron score	Sucrose (mg/g)	Glucose (mg/g)
1	0	0	None	2.0	58	0.677	2.052	1.3	65	1.273	0.577
2	400	0	None	2.3	58	0.791	1.663	1.3	67	1.388	0.245
3	0	400	None	1.8	61	0.728	1.906	1.0	66	1.236	0.308
4	0	400	Gypsum & $MgSO_4$	1.8	61	0.768	1.581	1.3	65	1.316	0.132
5	300	100	None	2.0	59	0.731	1.720	1.0	68	1.262	0.204
6	200	200	None	2.0	59	0.769	1.876	1.3	66	1.343	0.281
Treatment significance[1]				NS	NS	NS	NS	NS	NS	NS	*
Treatment MSD (P < 0.1)				--	--	--	--	--	--	--	0.216

[1] **, *, ++ significant at 1%, 5%, and 10% respectively.

Table 5. Effects of polyhalite and MOP (with or without S, Ca, and Mg) on soil test K, Ca, Mg and SO_4-S. Soil tests in the spring were taken before treatments were applied. Soil tests in the fall were taken after harvest.

Treatment				Soil Test											
Treatment #	lbs K_2O/ac as Polyhalite	lbs K_2O/ac as KCl	Other amendments	K Spring	K Fall	K Difference[2]	Ca Spring	Ca Fall	Ca Difference[2]	Mg Spring	Mg Fall	Mg Difference[2]	SO_4-S Spring	SO_4-S Fall	SO_4-S Difference[2]
				ppm											
1	0	0	None	97.3	56.8	-40.5	356.6	363.9	7.2	50.5	62.1	11.6	3.0	3.8	0.8
2	400	0	None	101.8	93.0	-8.8	345.2	406.2	61.0	50.7	72.5	21.8	3.0	68.5	65.5
3	0	400	None	105.8	108.0	2.3	309.5	276.2	-33.3	43.4	47.0	3.7	2.8	4.3	1.5
4	0	400	Gypsum & $MgSO_4$	111.3	115.3	4.0	301.0	334.2	33.2	44.3	74.3	30.0	3.0	61.0	58.0
5	300	100	None	93.8	83.3	-10.5	343.6	415.4	71.8	49.0	66.0	17.0	2.5	43.8	41.3
6	200	200	None	92.8	84.0	-8.8	322.0	335.3	13.3	50.0	65.7	15.7	2.5	21.5	19.0
Treatment significance[1]				NS	**	**	NS	++	++	NS	*	**	NS	**	**
Treatment MSD (P < 0.1)				--	15.1	19.3	--	88.6	66.7	--	12.7	11.2	--	27.8	27.9

[1] **, *, ++ significant at 1%, 5%, and 10% respectively.

[2] Difference = Spring values subtracted from fall values

Table 6. Effects of polyhalite and MOP (with or without S, Ca, and Mg) on petiole S and N concentrations and leaflet SPAD readings.

Treatment				Petiole S				Petiole N				SPAD 8/06/14
Treatment #	lbs K_2O/ac as Polyhalite	lbs K_2O/ac as KCl	Other amendments	June 26	July 16	July 30	Aug 6	June 26	July 16	July 30	Aug 6	
				%								
1	0	0	None	0.20	0.25	0.23	0.20	5.51	5.38	4.92	4.17	45.6
2	400	0	None	0.39	0.33	0.32	0.30	5.48	4.76	4.36	3.81	40.3
3	0	400	None	0.24	0.23	0.18	0.21	5.06	4.56	4.31	3.49	39.4
4	0	400	Gypsum & $MgSO_4$	0.29	0.31	0.28	0.26	4.78	4.71	3.92	3.29	39.1
5	300	100	None	0.36	0.32	0.29	0.29	5.29	4.85	4.21	3.77	41.3
6	200	200	None	0.32	0.28	0.26	0.26	5.03	4.72	4.16	3.55	38.5
Treatment significance[1]				**	**	**	**	*	**	*	**	*
Treatment MSD ($P < 0.1$)				0.04	0.04	0.03	0.02	0.38	0.20	0.46	0.30	4.2

[1] **, *, ++ significant at 1%, 5%, and 10% respectively.

Table 7. Effects of polyhalite and MOP (with or without S, Ca, and Mg) on petiole K, Mg, and Ca concentrations.

Treatment				Petiole K				Petiole Mg				Petiole Ca			
Treatment #	lbs K_2O/ac as Polyhalite	lbs K_2O/ac as KCl	Other amendments	June 26	July 16	July 30	Aug 6	June 26	July 16	July 30	Aug 6	June 26	July 16	July 30	Aug 6
				%											
1	0	0	None	8.33	7.93	4.91	4.06	0.20	0.45	0.78	1.14	0.57	0.63	0.79	0.94
2	400	0	None	9.41	9.77	8.43	7.94	0.21	0.34	0.66	0.76	0.28	0.48	0.67	0.76
3	0	400	None	11.33	10.60	9.00	8.34	0.18	0.25	0.40	0.53	0.47	0.48	0.63	0.81
4	0	400	Gypsum & $MgSO_4$	12.37	10.44	8.02	7.73	0.26	0.40	0.70	0.83	0.33	0.41	0.62	0.71
5	300	100	None	11.90	10.22	8.70	8.28	0.23	0.33	0.57	0.66	0.35	0.46	0.64	0.69
6	200	200	None	11.35	9.75	7.54	7.21	0.22	0.36	0.69	0.84	0.36	0.51	0.74	0.83
Treatment significance[1]				**	**	**	**	*	**	**	**	**	*	++	*
Treatment MSD ($P < 0.1$)				1.49	0.76	1.02	0.99	0.04	0.06	0.10	0.15	0.10	0.09	0.13	0.13

[1] **, *, ++ significant at 1%, 5%, and 10% respectively.

Table 8. Effects of polyhalite and MOP (with or without S, Ca, and Mg) on tuber N, S, K, Mg, and Ca concentrations.

Treatment				**Elemental concentration**				
Treatment #	**lbs K_2O/ac as Polyhalite**	**lbs K_2O/ac as KCl**	**Other amendments**	**Nitrogen**	**Sulfur**	**Potassium**	**Magnesium**	**Calcium**
				---------------------------- % -------------------------------				
1	0	0	None	1.198	0.130	1.271	0.059	0.029
2	400	0	None	1.213	0.185	1.756	0.078	0.033
3	0	400	None	1.328	0.140	1.795	0.083	0.029
4	0	400	Gypsum & $MgSO_4$	1.390	0.175	1.765	0.082	0.028
5	300	100	None	1.215	0.178	1.732	0.073	0.034
6	200	200	None	1.328	0.168	1.710	0.076	0.032
Treatment significance[1]				NS	**	**	**	NS
Treatment MSD ($P < 0.1$)				--	0.012	0.21	0.007	--

[1] **, *, ++ significant at 1%, 5%, and 10% respectively.

A Field Evaluation of Aspire as a Potassium and Boron Source for Irrigated Russet Burbank Potato

Carl Rosen, James Crants, and Matt McNearney
Department of Soil, Water, and Climate, University of Minnesota
crosen@umn.edu

Summary

Potassium and boron are both essential nutrients for potato production, promoting tuber yield, internal quality, and storability. However, because the range between deficient and toxic soil concentrations of boron is narrow, and because only small quantities are required to meet the needs of potato plants, even application of boron is both important and difficult. Aspire (Mosaic Co.; 0-0-58-0.5B) is a fertilizer intended to facilitate even application of boron by incorporating it with a macronutrient (potassium) at a ratio at which these two nutrients are typically required. In a field study conducted at the Sand Plain Research Farm in Becker, MN, we evaluated the effectiveness of Aspire as a source of potassium and boron for Russet Burbank potato plants. In five treatments, potassium was applied at 300 lbs lbs·ac^{-1} K_2O as KCl or Aspire. Two treatments, one receiving KCl and one receiving Aspire, were fertilized in two applications, one at planting and one at hilling. The other three were fertilized in a single application at emergence, with two receiving KCl and the third receiving Aspire. One of the two treatments receiving a single application of KCl also received boron in the form of Granubor. A sixth treatment received neither potassium nor boron. Tuber yield, size, and quality were evaluated at the end of the season. The treatment that received no potassium or boron had lower yield, smaller tubers, and higher tuber dry matter content than the treatments that did, demonstrating a clear impact of potassium fertilization in this system. Responses to boron were more complex, as they depended on whether fertilizer was applied in a single application or two applications. Among the three treatments receiving a single application, the treatment receiving Aspire had larger tubers than the one receiving KCl without boron, and the treatment receiving KCl with boron was intermediate between the two. In contrast, there was little difference in tuber size distribution between the two treatments receiving split applications of fertilizer. Thus, the results for the single-application treatments suggest that boron fertilization was beneficial in this study system, and boron in the form of Aspire was more effective than granular boron, while the results for the split-application treatments suggest that the boron in Aspire had less of an effect on tuber size, yield, or quality.

Background

Potatoes have a very high demand for potassium, relative to other vegetable crops. Potassium can influence the yield and size distribution of potato tubers, as well as their specific gravity and storage characteristics. Boron is important in the integrity of the plant cell wall, where it binds pectins together, and in calcium absorption. In both these roles, boron availability is vital to tuber internal quality and storability, as well as yield. Boron also can increase the concentration of vitamin C in potato tubers.

The importance of these nutrients to potatoes as an agricultural crop is clear. However, because boron is a micronutrient and is therefore applied in very small quantities, even application of this nutrient can be difficult to achieve. Uneven application is a potential problem because the range between deficient and toxic soil concentrations of boron is very narrow. Aspire (0-0-58-0.5B) manufactured by Mosaic Co., is a product devised to facilitate even application of boron by combining it in fertilizer granules with potassium, which, being required in high quantities, is easier to distribute evenly.

The objectives of this study were to: (1) evaluate Russet Burbank potato response to Aspire relative to potassium without boron (KCl), (2) evaluate the effectiveness of Aspire relative to KCl blended with supplementary granular boron (Granubor), and (3) compare the effectiveness of a single pre-planting application of K to split pre-planting / emergence applications for both Aspire and KCl without boron.

Materials and Methods

The study was conducted at the Sand Plain Research Farm in Becker, MN, on a Hubbard loamy sand soil. The previous crop was rye. Selected characteristics for the top six inches of soil in the study field at the beginning of the season (March 30) are presented in Table 1.

Plots were laid out in a randomized complete block design with four replicates. Potatoes were planted by hand on April 28 with three-foot spacing between rows and one-foot spacing within. Each plot consisted of four, 20-foot rows, with the middle two rows used for sampling and harvest. One red seed potato was planted at each end of each harvest row, so that each harvest row contained 18 Russet Burbank seed potatoes at planting, while each non-harvest row contained 20. The field was surrounded by a buffer strip of Russet Burbank one row (three feet) wide along either side and five feet wide at either end, with red potatoes replacing Russet Burbank in the harvest rows. Whole ("B") seed was used for Russet Burbank, while the red seed potatoes were cut ("A") seed.

Six treatments were applied (Table 2). One treatment received no supplementary KCl or B. All other treatments received 300 lbs·ac^{-1} K, as either KCl (treatments 2, 3, and 5) or Aspire (treatments 4 and 6). K was applied in either a single application banded at row opening (treatments 2 – 4) or as two equal applications, one banded at row opening and one banded at shoot emergence (May 19; treatments 5 – 6). One treatment receiving KCl (treatment 3) also received 2.5 lbs·ac^{-1} B as Granubor, equivalent to the B received by the treatments receiving Aspire.

All treatments received 30 lbs·ac^{-1} N and 136 lbs·ac^{-1} P as MAP (11-52-0) and 1 lbs·ac^{-1} Zn and 0.5 lbs·ac^{-1} S as Blu-Min Granular Zinc Sulfate (Kronos Micronutrients; 35.5% Zn; 17.5% S) at planting, 141 lbs·ac^{-1} N as Environmentally Safe Nitrogen (Agrium, Inc.; 44-0-0) and 30 lbs·ac^{-1} N and 30 lbs·ac^{-1} S as ammonium sulfate (21-0-0-24S) at hilling; and 40 lbs·ac^{-1} N as 28% UAN in two applications, on July 1 and 20.

Belay was applied in-furrow at planting for beetle control, along with the systemic fungicide Quadris. Weeds, diseases, and other insects were controlled using standard practices. Rainfall was supplemented with sprinkler irrigation using the checkbook method of irrigation scheduling. The nitrate and ammonium concentrations of irrigation water were monitored throughout the year.

Plant stand among the 36 plants in the harvest rows was assessed on June 2, and the number of stems per plant for 10 harvest-row plants was determined on June 10.

Leaf petioles were sampled on June 16 and 25, July 13 and 22, and August 6. Petiole K and B concentration will be determined on a dry-weight basis by the Research Analytical Laboratory of the University of Minnesota using inductively coupled plasma analysis. Vines were chopped on September 17. Tubers were harvested on October 6.

The data were analyzed using the GLM procedure in SAS 9.4. Dependent variables were modeled as functions of treatment and block. Significant differences between treatments at alpha = 0.10 were determined with Waller-Duncan k-ratio t tests. Three contrasts were performed for each variable analyzed: (1) a comparison of the zero-K treatment (treatment 1) with those receiving KCl without B (treatments 2 and 5); (2) a comparison of treatments receiving KCl with those receiving Aspire at the same times and rates (treatments 2 and 5 versus 4 and 6); and (3) a comparison of treatments receiving K in a single application versus two (treatments 2 and 4 versus 5 and 6).

Results

Tuber yield and size distribution

The results for tuber yield and size distribution are presented in Table 3. There were significant effects of treatment for all yield variables except for the yield of U.S. No. 1 tubers.

The control treatment (treatment 1) had lower total and marketable yield and a smaller percentage of yield represented by tubers over 6 or 10 ounces than any treatment receiving K (treatments 2 – 6). This indicates that K availability limited tuber yield in the study field, as expected given the low soil K in this field at the beginning of the season (Table 1). There was no effect of single versus split application of K on any yield variable.

Treatments fertilized with Aspire (treatments 4 and 6) had similar total and marketable yields to treatments receiving KCl without B (treatments 2 and 5). However, the contrast between the Aspire and KCl treatments was significant for yield in most size categories, yield of U.S. No. 2 tubers, and the proportion of yield represented by tubers over 6 or 10 ounces. Overall, treatments receiving Aspire had larger tubers than those receiving KCl without B. The effect was clearly evident in comparing the treatments receiving a single large application of K at emergence (treatment 2 vs. 4), but much less so in the treatments receiving split applications of K (treatments 5 and 6).

The treatment receiving KCl with Granubor at planting (treatment 3) showed a tuber size distribution intermediate between those of the treatment receiving a single application of Aspire at planting (treatment 4) and the treatment receiving KCl without B (treatment 2). This suggests that application of B had an effect on tuber size distribution in this study, which is consistent with the low concentration of B in the study field's soil (Table 1).

Tuber quality

The results for tuber quality are presented in Table 2. There was a significant effect of treatment on tuber dry matter concentration, with the control treatment (treatment 1) having a higher percentage of dry matter than any treatment receiving K (treatments 2 – 6).

The contrast of single versus split application was significant for the prevalence of scab, with the split-application treatments (treatment 5 and 6) having higher mean prevalence than their single-application counterparts (treatments 2 and 4, respectively). This is the result of a small difference in scab prevalence between the treatment receiving KCl as a single application (treatment 2; 0% ± 0% scab prevalence) and that receiving KCl in two applications (treatment 5; 3% ± 2% scab prevalence), and the statistical significance of this contrast is probably not biologically meaningful.

Conclusions

Both K and B had effects on tuber yield, though the effects of B were complex. The control treatment (treatment 1), which received no K or B, had lower yield and smaller tubers, as well as higher tuber dry matter content, than the remaining treatments (treatments 2 – 6), all of which received 300 lbs·ac^{-1} K_2O. The value of K in the low-K soils of the study field is unambiguous in these results.

The treatment receiving Aspire in a single application at planting (treatment 4) had larger tubers than the corresponding treatment receiving KCl (treatment 2), though its yield was not significantly greater. The treatment receiving a single application of KCl supplemented with B (treatment 3) had a tuber size distribution intermediate between the two, though somewhat more similar to the treatment receiving Aspire (treatment 3), suggesting that the presence of B in Aspire explains the difference in outcome between Aspire and KCl.

Curiously, the difference in tuber size distribution produced by Aspire versus KCl was negligible when the fertilizers were applied in split applications, one at planting and one at emergence. Both of these treatments (treatments 5 and 6) had similar tuber size distributions to the treatment receiving KCl with B at planting (treatment 3). These results are not consistent with the conclusion that B is important for tuber size. However, split applications of K alone can sometimes increase tuber size compared with single preplant K applications. Therefore, the K split alone may have negated or minimized the tuber size effect due to added B.

Table 1. Characteristics of the top six inches of soil collected from the study site at the Sand Plain Research Farm in Becker, MN, on March 30, 2015.

Primary macronutrients			Secondary macronutrients			Micronutrients					Other characteristics	
NO_3-N (ppm)	Bray P (ppm)	NH_4OAc-K (ppm)	NH_4OAc-Ca (ppm)	NH_4OAc-Mg (ppm)	SO_4-S (ppm)	Hot Water B (ppm)	DTPA-Cu (ppm)	DTPA-Fe (ppm)	DTPA-Mn (ppm)	DTPA-Zn (ppm)	Water pH	O.M. LOI (%)
2.33	17	58	555	123	2.0	0.058	0.323	37.7	9.50	0.72	6.1	1.1

Table 2. Amount, form, and timing of potassium and boron applied to Russet Burbank potato plants at the Sand Plain Research Farm in Becker, MN, in 2015. All fertilizers were banded in at row opening ("pre-planting," April 28) or hilling ("emergence," May 19).

Treatment	K sources[1]	Pre-planting	Emergence	Total applied
		K rates (lbs·ac^{-1} K_2O)		
1	None	0	0	0
2	KCl	300	0	300
3	KCl + B	300	0	300
4	Aspire	300	0	300
5	KCl	150	150	300
6	Aspire	150	150	300

[1] KCl: 0-0-60; Aspire: 0-0-58-0.5B

Table 3. Effect of amount, form, and timing of application of potassium and boron on Russet Burbank tuber yield and size distribution at the Sand Plain Research Farm in Becker, MN, in 2015.

Treatment	K sources[1]	Pre-planting	Emergence	Total applied	Tuber Yield										
					0-3 oz	3-6 oz	6-10 oz	10-14 oz	>14 oz	Total	#1s > 3 oz.	#2s > 3 oz	Total Marketable	> 6 oz	> 10 oz
		K rates (lbs·ac^{-1} K_2O)			cwt · ac^{-1}									%	
1	None	0	0	0	68 a	169 a	181 ab	67 d	15 d	500 b	309	123 b	432 c	53 c	16 d
2	KCl	300	0	300	71 a	137 b	202 a	114 c	73 c	597 a	377	149 b	526 b	65 b	31 c
3	KCl + B	300	0	300	48 bc	112 c	177 bc	126 bc	133 ab	596 a	364	183 a	547 ab	73 a	43 ab
4	Aspire	300	0	300	43 c	115 c	156 c	155 a	142 a	611 a	368	199 a	567 a	74 a	48 a
5	KCl	150	150	300	60 ab	130 bc	195 ab	138 ab	103 bc	627 a	384	182 a	566 a	70 ab	39 b
6	Aspire	150	150	300	49 bc	125 bc	187 ab	135 b	118 ab	613 a	376	188 a	564 a	72 a	41 b
Treatment significance[2]					*	**	*	**	**	**	NS	**	**	**	**
Minimum significant difference (0.1)					16	21	22	19	33	33	--	33	31	5	5
Contrasts	No K vs. K (1 vs. 2&5)[2]				NS	**	NS	**	**	**	**	*	**	**	**
	KCl vs. Aspire (2&5 vs. 4&6)[2]				**	NS	**	*	**	NS	NS	*	NS	*	**
	Single vs. split (2&4 vs. 5&6)[2]				NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1] KCl: 0-0-60; Aspire: 0-0-58-0.5B

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

Table 4. Effect of amount, form, and timing of application of potassium and boron on Russet Burbank tuber quality at the Sand Plain Research Farm in Becker, MN, in 2015.

Treatment	K sources[1]	Pre-planting	Emergence	Total applied	Tuber Quality				
					Hollow Heart	Brown Center	Scab	Dry matter	Specific Gravity
		K rates (lbs·ac^{-1} K_2O)			%				
1	None	0	0	0	0	0	0 b	22.1 a	1.0796 a
2	KCl	300	0	300	0	0	0 b	20.9 b	1.0784 ab
3	KCl + B	300	0	300	0	0	0 b	21.1 b	1.0795 a
4	Aspire	300	0	300	0	0	1 b	20.8 b	1.0763 b
5	KCl	150	150	300	1	1	3 a	20.8 b	1.0764 b
6	Aspire	150	150	300	0	0	1 b	20.9 b	1.0766 b
Treatment significance[2]					NS	NS	++	*	++
Minimum significant difference (0.1)					--	--	2	0.8	0.0029
Contrasts	No K vs. K (1 vs. 2&5)[2]				NS	NS	++	**	++
	KCl vs. Aspire (2&5 vs. 4&6)[2]				NS	NS	NS	NS	NS
	Single vs. split (2&4 vs. 5&6)[2]				NS	NS	*	NS	NS

[1] KCl: 0-0-60; Aspire: 0-0-58-0.5B

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

Identification of Specific Starch Profiles in NDSU Potato Germplasm

Leah Krabbenhoft*, Susan Raatz[3], Senay Simsek[1],
Julie Garden-Robinson[2], and Asunta Thompson[1]

[1]Dept. of Plant Sciences, [2]Extension Food and Nutrition, North Dakota State University, Fargo, ND, [3]USDA-ARS Human Nutrition Laboratory, Grand Forks, ND

As an economically important staple crop across the world, the potato (*Solanum tuberosum* L.) has large-scale production, consumption, and affordability. Potato is the most important non-cereal crop eaten in more countries than any other crop produced for consumption. North Dakota ranked fourth in the United States for potato production in 2013 at 2.3 billion pounds, while Minnesota ranked seventh with 1.7 billion pounds (National Potato Council 2015). According to a recent review by Zaheer and Akhtar (2014), potatoes range in size, color, shape, starch content, and flavor. There are over 4,000 cultivars of potato worldwide (International Potato Center).

Potatoes are popularly processed in a variety of forms including French fries, chips, baked, and mashed. As no single potato cultivar has been shown to be appropriate for all food applications, screening of cultivars is needed for specific end use and for their ability to provide optimum processing performance and product quality (Singh et al. 2005). Growing conditions, genetic attributes, and aging during postharvest storage affect potato quality for processing (Arvanitoyannis et al. 2008).

The starch contained within potato is also used in industrial applications such as, but not limited to, adhesives, paper, textiles, and biodegradables. Starch has traditionally been used in functions of thickening and adhesion; however, as the demand for bio-sustainable products is on the rise, crops, including potato, are important (Kraak 1993). Heating of dilute aqueous potato starch above the gelatinization temperature induces the starch granules to swell and results in a highly viscous and transparent solution (Kraak 1993). This results in a lack of necessary properties that are desirable for many industrial applications. The instability associated with heating past the gelatinization temperature is due to the crystallization tendency of the amylose fraction contained within the starch polymer composition (Kraak 1993). Modified starches have focused attention on other properties including stability, shelf-life, expansion, and texture (Light, 1990).

Amylopectin typically makes up 70-80% of the available starch in the potato tuber (Zeeman et al. 2010), with the rest consisting of amylose. Amylose is considered a slowly digested starch, or resistant starch, while amylopectin is rapidly digested and is considered a soluble form of starch (Birt et al. 2013). Potatoes cultivars with a reduced level of amylopectin are considered more desirable from a glycemic point of view, in that they will not elicit as much of an insulin response compared to cultivars with an increase in amylopectin concentration. Raw potato starch consists of large amounts of resistant starch that is converted to digestible starch after cooking (Birt et al. 2013). Foods high in rapidly digested starch have a high glycemic index (GI) and elicit high insulin demand (Augustin et al. 2002). The effect of cooling of cooked potatoes was shown to differ among potato selections (Kinnear et al. 2011). Genotype and environment have been shown to be the most significant factors contributing to variations in starch profiles among different genotypes (Bach et al. 2013).

The North Dakota State University (NDSU) potato improvement team has developed clones with high levels of starch and associated quality characteristics for French fry and chip processing. However, specific starch profiles of this germplasm have not been explored. The objectives of this research were to 1) evaluate parental genotypes and advancing potato selections from the NDSU potato breeding program for starch attributes, focusing on the genetic diversity contained within this germplasm collection, and 2) to assess fine starch chemistry for unique potato genotypes based upon the initial evaluation. Our evaluation of parental genotypes and advancing potato selections has been completed, while our next focus is to begin fine starch chemistry assessments for unique potato genotypes. The experimental approach consisted of testing steamed tuber material with the Megazyme® resistant starch assay for the determination of resistant and soluble starch content. The results of the study indicate clones have significantly different levels of resistant and/or soluble starch.

A recent study compared cooking method and service temperature to the levels of resistant, soluble, and total starch (Jackson et al. 2013). This study examined tubers that were baked or boiled, as well as three service temperatures (hot, 60°C; chilled, 4°C for 6 days and chilled prior to reheating to 60°C). In order to examine a large number of potato clones, the baking and boiling method is inefficient. A new method not previously used in studies was desired in order to increase the number of potato clones that could be cooked at once and within a shorter period of time, such as the Ziploc® Zip'n Steam bag method. In an effort to compare the baking and boiling cooking methods with steaming using the Ziploc® Zip'n Steam bags, we conducted a study which included three potato cultivars commercially produced in North Dakota (Red Norland, Russet Burbank, and Yukon Gold), three cooking methods (baked, boiled, and steamed with Ziploc® Zip'n Steam), and two service temperatures (hot, 60°C and chilled overnight at 4°C).

A factorial model was used with three levels of clone, three levels of treatment (cooking method), and two levels of temperature. Clone, treatment, treatment x temperature, and clone x treatment x temperature were all significant factors for both soluble and resistant starch. Temperature was only a significant factor for resistant starch. The data suggested that the cooking method did not impact the levels of both soluble and resistant starch levels when factored by clone, indicating that the Ziploc® Zip'n Steam bags could be used for cooking potato tuber material more efficiently for starch evaluation.

Based on the preliminary experiment, Ziploc® Zip'n Steam bags were used as a cooking method for our study that examined 225 potato clones from the North Dakota State University potato breeding program. The clones were grown in two locations (Absaraka, ND and Baker, MN) in 2014. From Baker, 202 genotypes were evaluated, and 46 genotypes from Absaraka were examined. Of the clones assessed from Absaraka, 23 were also examined from Baker. An augmented design was used with three control cultivars (Red Norland, Russet Burbank, and Yukon Gold). An augmented design is used to compare control cultivars with new genotypes that have limited or no replication. For soluble starch across both locations, all sources of variation were significant except for the control cultivars, which were expected. Since different genotypes were tested within the blocks (ie. 9 per run, with 3 controls), significance was expected between the blocks and between genotypes. For resistant starch across both locations, all sources of variation were significant, including the controls, indicating that there must be factor(s) influencing resistant starch levels, such as enzymes degrading starch molecules during prolonged storage. Further analysis is required to determine the factor(s) involved in the significant control value. Soluble starch from clones grown at Baker had non-significant differences for the control cultivars, while resistant starch levels were significant for control varieties. However, all sources of variation were significant for clones grown at Absaraka, possibly due to the low number of entries analyzed from this location. The highest and lowest five clones for soluble and resistant starch levels among clones from Baker are reported in Table 1. These clones, among others that are not significantly different in their soluble or resistant starch value, can be further examined for their applicability in various products (ie. food products, bioplastics, pharmaceutical use, etc.) based on their starch profiles.

Table 1: A comparison of the highest and lowest levels of soluble and resistant starch (reported as mg/g dry matter) among clones, from Baker, MN, 2014.

	Clone	**Soluble starch**	**Clone**	**Resistant starch**
		(mg/g)		(mg/g)
Highest 5	ND113256C-2R	365.6	ND113517ABC-9	148.8
	ND102687AB-1Russ	359.0	ND102822CAB-1	139.0
	Lenape	353.4	ND113163-1	137.2
	ND102735CB-4R	338.5	ND102549TB-	130.9
	ND113508C-4	335.3	ND113517ABC-6	124.4
Lowest 5	ND113438CB-8R	176.7	ND113438CB-8R	54.7
	ND113497B-1Russ	174.0	ND102990B-3R	42.6
	ND113487c-1	168.1	ND113060-1	40.9
	Inca Dawn	165.0	ND102903-1R	39.5
	ND113438CB-8R	160.3	ND102921C-3	34.4
Controls	Red Norland	230.6	Red Norland	75.0
	Russet Burbank	224.5	Russet Burbank	81.4
	Yukon Gold	226.6	Yukon Gold	91.2
	Mean	246.6	Mean	85.8
	CD at 5%	25.4	CD at 5%	9.8

Although the potato is often under scrutiny for high glycemic index levels, the potato provides individuals with a variety of other health benefits, including a variety of essential nutrients such as carbohydrates, proteins, vitamin C, vitamin B6, magnesium, potassium, and fiber (Willet et al. 2002). Improved cultivars for chip processing, frozen processing, and the fresh market are continuously being developed by the North Dakota State University (NDSU) potato improvement team. Measuring and comparing the differences in starch content within the various NDSU potato genotypes may provide for new and improved potato products for consumers, along with industrial applications.

This project was supported by the U.S. Department of Agriculture's (USDA) Agricultural Marketing Service through grant 14-SCBGP-ND-0038. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA.

Literature Cited

Arvanitoyannis, I., O. Vaitsi, and A. Mavromatis. 2008. Potato: A comparative study of the effect of cultivars and cultivation conditions and genetic modification on the physico-chemical properties of potato tubers in conjunction with multivariate analysis towards authenticity. *Critical Reviews in Food Science and Nutrition* 48:799-823.

Augustin, L. S., S. Franceschi, D. J. Jenkins, C.W. Kendall, and C. La Vecchia. 2002. Glycemic index in chronic disease: a review. *European Journal of Clinical Nutrition* 56:1049-1171.

Bach, S., R. Yada, B. Bizimungu, M. Fan, and J. Sullivan. 2013. Genotype by environment interaction effects on starch content and digestibility in potato (*Solanum tuberosum* L.). *Journal of Agricultural and Food Chemistry* 61:3941-3948.

Birt, D.F., T. Boylston, S. Hendrich, J. Jane, J. Hollis, L. Li, J. McClelland, S. Moore, G.J. Phillips, M. Rowling, K. Schalinske, M.P. Scott, and E. Whitley. 2013. Resistant starch: promise for improving human health. *Advances in Nutrition* 4:587-601.

International Potato Center. http://cipotato.org/potato/facts/ Verified February 3, 2016.

Jackson, I.M., L. Idso, G. Combs, K. Beals, and S. Raatz. 2013. A standardized method for preparation of potatoes and analysis of their resistant starch content: Variation by cooking method and service temperature. *The FASEB Journal* 27:1074.2.

Kinnear, T., T. Wolever, A. Murphy, J. Sullivan, Q. Liu, and B. Bizimungu. 2011. Effect of preparation method on the glycemic index of novel potato clones. *Food and Function* 2:438–444.

Kraak, A. 1993. Industrial applications of potato starch products. *Industrial Crops and Products* 1:107-112.

Light, J.M. 1990. Modified food starches: why, what, where, and how. *Cereal Foods World* 35:1081-1092.

National Potato Council. 2015. Potato Statistical Yearbook, 2015.

Singh, N., L. Kaur, R. Ezekiel, and H. Guraya. 2005. Microstructural, cooking and textural characteristics of potato (*Solanum tuberosum* L) tubers in relation to physicochemical and functional properties of their flours. *Journal of the Science of Food and Agriculture* 85:1275-1284.

Willet, W. C., J. Manson, and S. Liu. 2002. Glycemic index, glycemic load and risk of type 2 diabetes. *The American Journal of Clinical Nutrition* 76:S274-S280.

Zeeman, S. C., J. Kossmann, and A.M. Smith. 2010. Starch: its metabolism, evolution, and biotechnological modification in plants. *Annual Review of Plant Biology* 61:209-234.

Management of Colorado Potato Beetle in Minnesota and North Dakota – Annual Report 2015

Dr. Ian MacRae,
Nathan Russart
Dept. of Entomology,
U. Minnesota Northwest
Research & Outreach Center
2900 University Ave.
Crookston, MN 56716
imacrae@umn.edu
218 281-8611 Office
218 281-8603 Fax

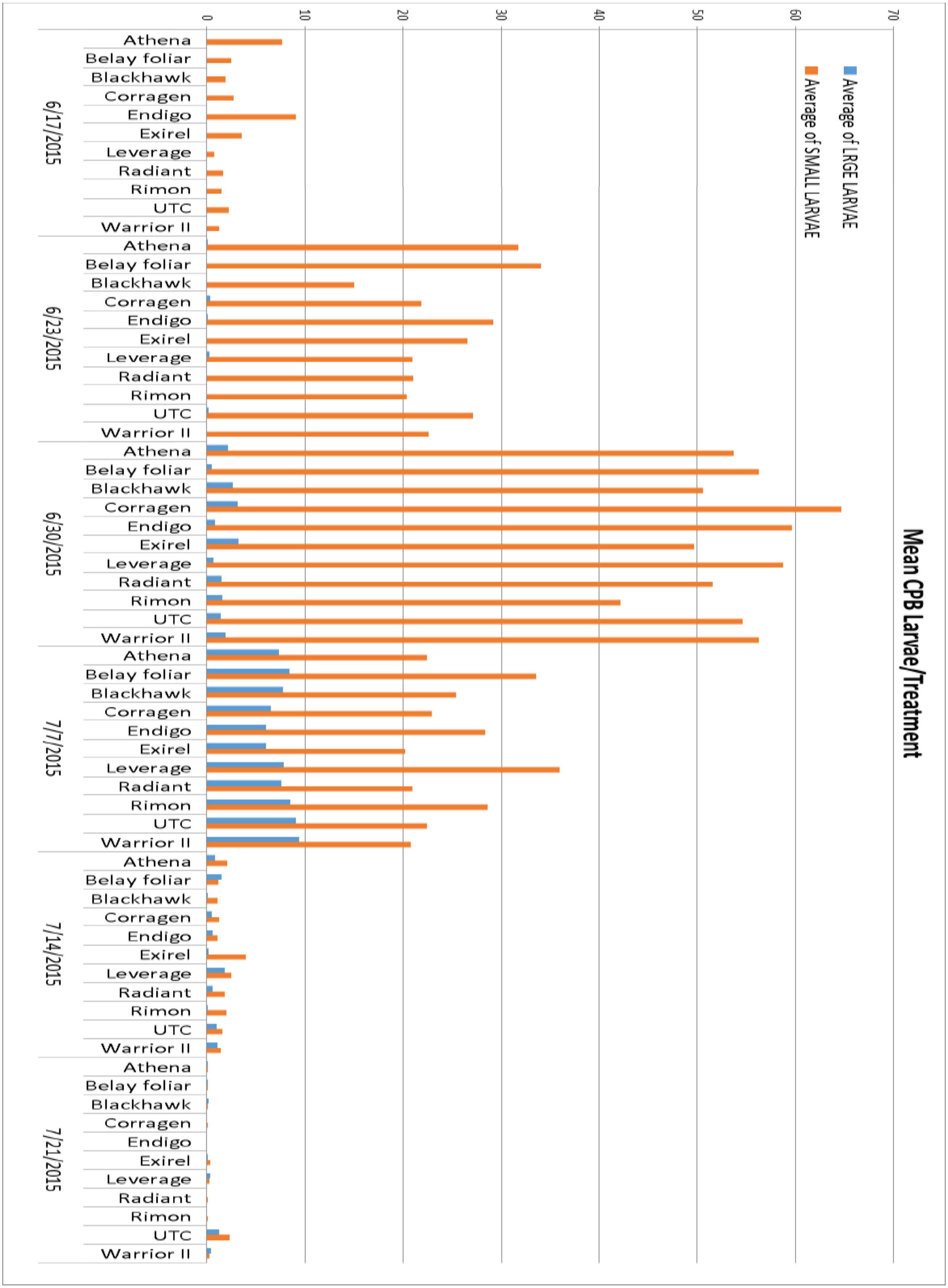
Executive Summary – This is a continuing project designed to management tactics for Colorado Potato Beetles (**CPB**) in Minnesota and North Dakota. This proposal will focus on assessing foliar control methods in anticipation of the potential loss of neonicotinoid insecticides as at-plant treatments, determining changes in the emergence patterns of adult Colorado potato beetle in Minnesota and North Dakota and the influence this plays in resistance management, and the remote sensing of canopy defoliation.

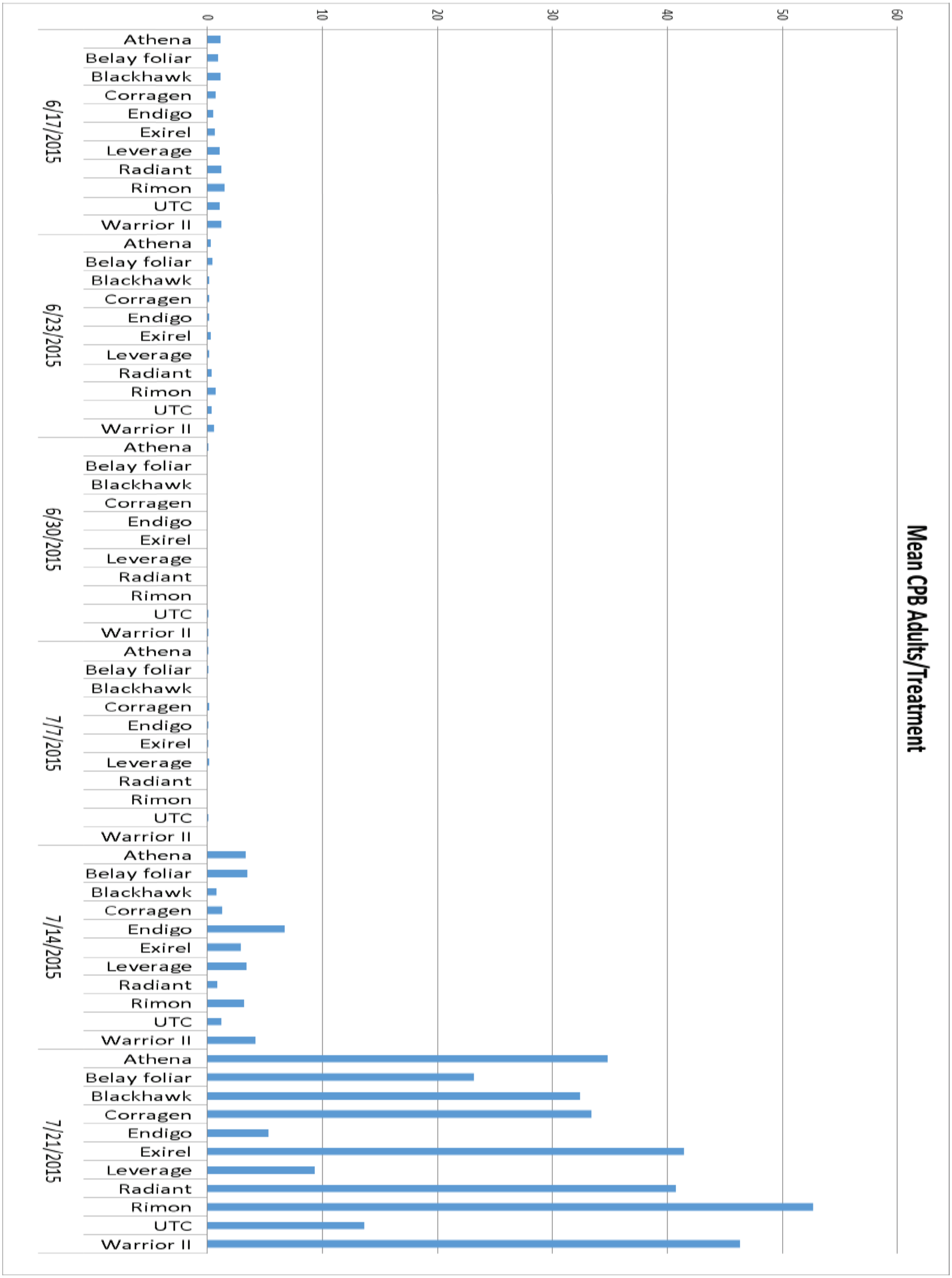
i) CPB Management in a Post-Neonicotinoid World...

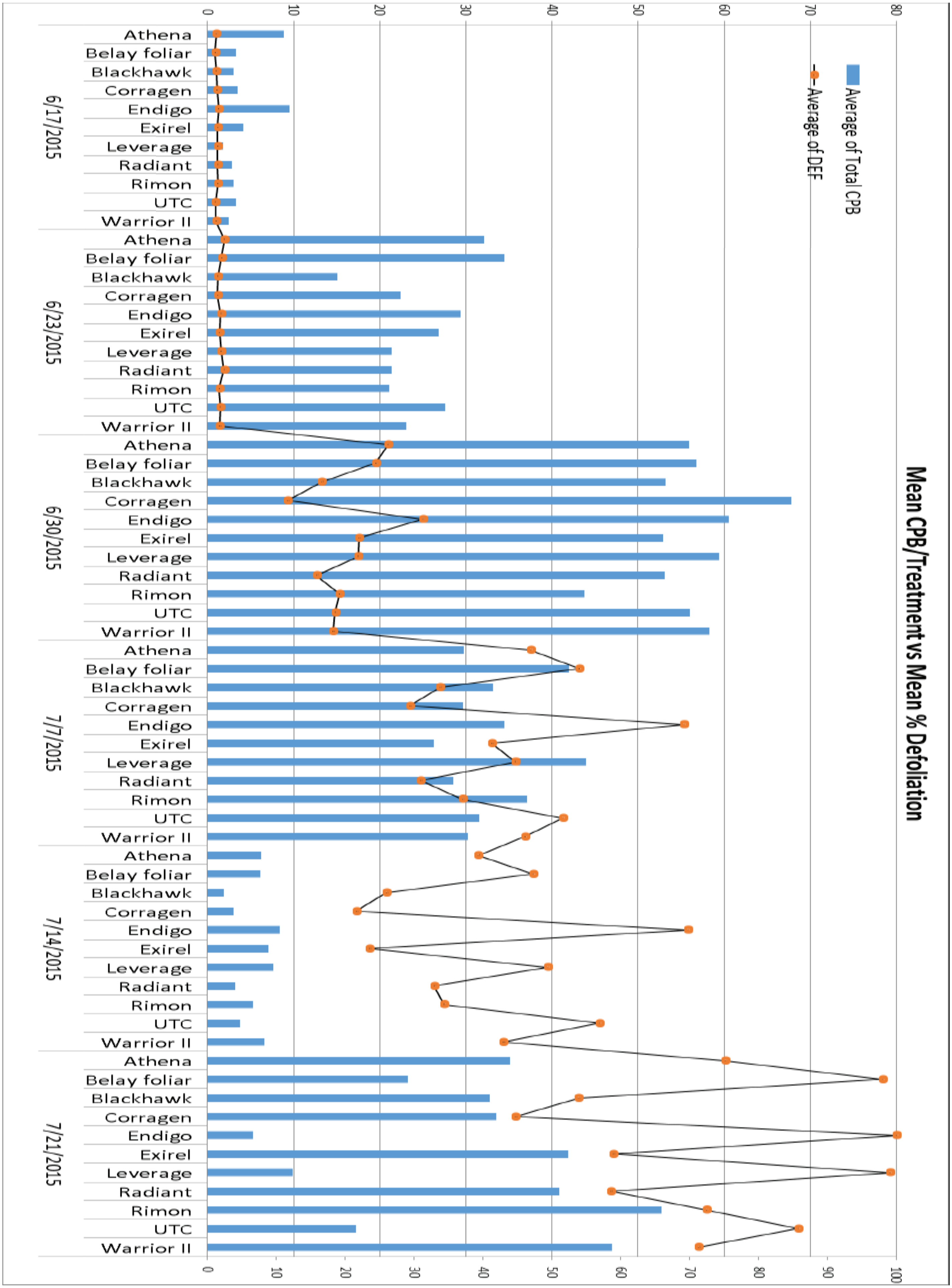
Plots were established at the UMN Sand Plains Research Farm in Becker, MN. Replicated treatments consisted of different rotated, foliar applications of insecticides (different modes of action). Published information and local experience was used to formulate regimes based on expected efficacy and cost. Efficacy was assessed by CPB population suppression and yield. Beetle populations and % defoliation were monitored weekly and applications made when the mean values in a set of treatment plots reached treatment threshold (30% defoliation pre-bloom or 50% egg hatch). Consequently, not all treatments were sprayed at the same date or as often through the season. Economic analyses of treatment costs (cost of insecticide * rate * number of seasonal applications) is still underway.

1st Foliar Treatment	2nd Foliar Treatment
Agri-Mek 0.15EC @ 16oz/ac	**Blackhawk @ 3.5oz/ac**
Athena @ 17oz/ac	**Blackhawk @ 3.5oz/ac**
Blackhawk @ 3.5oz/ac	**Exirel @ 13.5oz/ac**
Exirel @ 13.5oz/ac	**Agri-Mek 0.15EC @ 16oz/ac**
Rimon 0.83EC @ 12oz/ac	**Blackhawk @ 3.5oz/ac**
Radiant SC @ 8oz/ac	**Exirel @ 13.5oz/ac**
Corragen @5oz/ac	**Blackhawk @ 3.5oz/ac**
Warrior II @1.92oz/ac	**Blackhawk @ 3.5oz/ac**
Belay @12oz/ac	**Blackhawk @ 3.5oz/ac**
Admire Pro @ 1.3oz/ac	**Blackhawk @ 3.5oz/ac**
UTC	**UTC**

In addition, a number of industry trials were conducted evaluating both registered and unregistered products. Results are under analysis and review.


Mean CPB Larvae/Treatment
Average of LRGE LARVAE
Average of SMALL LARVAE
0
10
20
30
40
50
60
70
6/17/2015
6/23/2015
6/30/2015
7/7/2015
7/14/2015
7/21/2015
Athena
Belay foliar
Blackhawk
Corragen
Endigo
Exirel
Leverage
Radiant
Rimon
UTC
Warrior II


Mean CPB Adults/Treatment
0
10
20
30
40
50
60
6/17/2015
6/23/2015
6/30/2015
7/7/2015
7/14/2015
7/21/2015
Athena
Belay foliar
Blackhawk
Corragen
Endigo
Exirel
Leverage
Radiant
Rimon
UTC
Warrior II


Mean CPB/Treatment vs Mean % Defoliation
Average of Total CPB
Average of DEF
0
10
20
30
40
50
60
70
80
0
10
20
30
40
50
60
70
80
90
100
6/17/2015
6/23/2015
6/30/2015
7/7/2015
7/14/2015
7/21/2015
Athena
Belay foliar
Blackhawk
Corragen
Endigo
Exirel
Leverage
Radiant
Rimon
UTC
Warrior II

ii) Emergence patterns of CPB

Overwintered adult Colorado Potato Beetle. Note the red flight wings, found under the hard, striped outer wings.

CPB were collected weekly throughout the growing season from treatment plots at the UMN Sandhills Research Farm. Beetles were checked to ascertain if they are overwintered individuals or summer generation adults.

Adult CPB were checked for 'red wings' as collected throughout the summer. Overwintered adults were recovered on the July 07 date, summer adults began to be recovered on the July 14 sample date. This indicates that in Area II, the tail end of the distribution of the overwintered adults (i.e. the last emerging overwintered adults) now overlaps the distribution of the earliest emerging summer produced adults. This indicates there will potentially be an overlap of eggs and larvae resulting in a more continuous distribution of beetles through the summer. This was somewhat seen in the foliar trials this summer and resulted in extremely high mid-late season defoliation pressure.

Difficulties in obtaining a susceptible adult colony for laboratory procedures prevented valid assessment of neonicotinoid resistance in 2015 but will be conducted in 2016.

iii) Remote sensing of CPB Defoliation

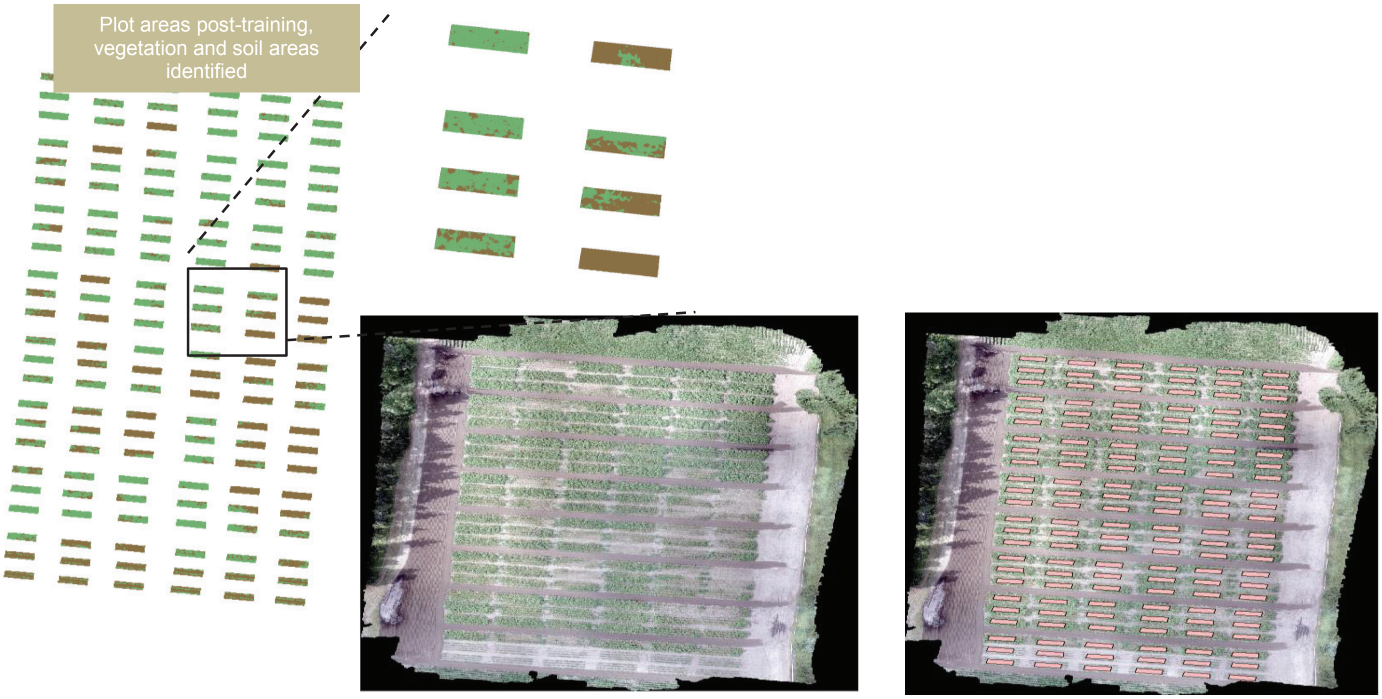
Insecticide treatment plots at the UMN Sand Plains Research Farm and at the UMN NWROC were flown weekly using a small unmanned aerial system (UAS) and imagery obtained from both visible (VIS) and near-infrared (NIR) cameras. The percent defoliation and CPB population was assessed weekly for each plot. Flights were conducted 40m above ground, between the hours of 10 a.m. and 2 p.m., ensuring the amount of reflected light was comparable across dates.

We used both VIS and NIR images in analysis but the following reports on the use of VIS data obtained from a GoPro camera. Individual images were obtained from the video using VLC Media player to capture TIFF images from video, resultant TIFF images were then stitched using AgiSoft PhotoScan (Agisoft LLC, St Petersburg, RU) into a single image of all the plots. Stitched image was uploaded into ArcGIS 10.3 and plot centers were described and bounded by polygons. Using polygons representing the plot centers, the stitched image was then clipped to produce a raster with only the plots to be analyzed. Supervised classification was used wherein the software is 'trained' to recognize areas of interest. Training data was obtained that represented both soil and vegetated areas and used in the maximum likelihood classification tool. Maximum likelihood image classification was conducted using plot centers clipped from the stitched image. All pixels were included in the classification, i.e., no values remained unclassified due to low probability. Resulting raster image displaying derived areas of vegetation and soil then converted to a polygon shapefile and intersected with the plot centers in order to retain plot numbers. Total area for soil was then calculated and then divided by the total plot area to calculate a percentage of area covered by soil (assumed to be defoliated areas). Calculated defoliation per plot was correlated with the ground-based defoliation estimates to estimate comparative accuracy of the method using the statistical software R v.3.2.2.

The supervised classification produced defoliation estimates for all plots. Pearson's Correlation Coefficient was highly significant (r = 0.8929917). ***The estimates of defoliation calculated from UAS visible imagery were at least as accurate as ground observations.***

This project will complement an ongoing remote sensing of PVY project already being conducted collaboratively between my laboratory and that of Dr. Asunta Thompson of NDSU.

This project was partially supported by a Minnesota Dept. of Agriculture Crops Research Proposal. The results were so successful that we have submitted an additional proposal to develop techniques using commercially available equipment.



Organic Foliar Trial – Potato (Colorado Potato Beetle)

Trial Information – Trials were conducted at the Univesity of Minnesota Northwest Research & Outreach Center in Crookston, MN. This facility has Hegne-Fargo complex soils (silty-clay loams). The field was prepped with an appropriate fertilizer regime for potatoes. Plots were 4 row X 25' long with 36" row spacing, plant spacing was 12". Plots were separated by a 10' alley at the ends and 2 blank rows between plot edges. This is a dryland production center and plots relied on precipitation for water (growing season weather records included in Appendix), plots were treated weekly from emergence with fungicide and had standard weed control. Plots were planted with Red Norland seed potatoes June 4, vines were killed Sept 04 and harvested Sept 22.

Table 1. Treatments in Colorado Potato Beetle foliar trial.

Treatment No.	Product	Rate (/ac)
1	PyGanic 5.0EC	9 fl.oz.
2	PyGanic 5.0EC + MGK (F-3110)	9fl.oz. + 2.0% v/v
3	X-M15-1D	10 lbs
4	X-M15-1D	25 lbs
5	X-M15-1D	50 lbs
6	Entrust SC (22.5% AI)	6 fl.oz.
7	Azera	32 fl.oz.
8	Azera + MGK (F-3110)	32 fl.oz + 2.0% v/v
9	X-7476-14	3.4 lb
10	UTC	N/A

This trial was designed to assess the impact of several insecticides (Table 1) on the first seasonal generation of Colorado Potato Beetle (CPB). Insecticides were first applied 7/02/15 and weekly thereafter until 7/22/15 (a total of 4 applications). At 7/29 the majority of the population were adult stage beetles. The mean number of CPB per plant were assessed weekly by counting the number of beetles (separating by stage) from 4 sample randomly selected plants per plot. Weekly defoliation rates in plots was visually assessed using visual estimates of the same 4 plants. The mean number of beetles per plant and the mean defoliation rate by treatment were then calculated and the total annual population and defoliation rates compared using GLM ANOVA. Beetle population data was collected until 7/29. On 7/30 All plots were sprayed with Blackhawk Naturalyte insecticide (Spinosyn A&D, Dow AgriScience, Indianapolis, IN). No yield limiting populations of insects other than Colorado Potato Beetle were observed in the plots (aphids and potato leafhopper were relatively absent, even in UTC plots). No disease symptoms were noted and no phytotoxicity was recorded in any plot.

Toxicity trials were conducted on both larval and adult stages of CPB using three different dosages of X-M15-1D. A micro-applicator was used to deposit 0.1µl drops of insecticide approximately mixed to titre mirroring exposure rates equivalent to individual field exposure at 10 lbs/ac, 25 lbs/ac, and 50 lbs./ac product. Replicate treatments consisted of 10 individuals in a petri plate, maintained for 4 days (larvae) or 7 days (adults) post application. Survivorship was calculated and compared using GLM ANOVA.

Yields (mean kg/Ha and converted to 100wt/ac) were assessed by counting and weighing all tubers from a linear 10' strip within either of the two center rows of each plot. Mean tuber weight and size was calculated by treatments and compared using GLM ANOVA.

Both ground level and aerial imagery of plots was obtained. Ground photos of plots were obtained 8/02/15 and aerial photos on 7/31/15.

Population dynamics were calculated and weekly levels are presented graphically.

Population Dynamics – Colonization by Colorado Potato Beetle was delayed in 2015, resulting in an extended period of oviposition. 30% egg hatch (the threshold used for application in this trial) (Figure A4 occurred 7/01 and initial insecticide application occurred 7/02. Insecticides were re-applied every week until 7/22. On 7/29, populations were assessed and because the majority of beetles in plots were adult insects, it was decided to terminate the trial as the majority of the first seasonal generation of larvae had completed development. The plots were then used in a separate experiment to assess the efficacy of many of the same insecticides on potato aphid species (see separate report).

Weekly population dynamics of total CPB per plant (Fig. A1) indicate the population had a late but extended development. There were few adults initially but summer generation adults were comparatively numerous by 7/29 (Fig A2). Larval presence extended throughout the growing season due to the oviposition period (Fig A3). This also led to small (i.e. younger) and large (i.e. older) larval stages co-occurring through much of the first summer generation (Fig A4). This is not typical. Given the seasonal distribution of eggs and adults, the later appearing younger larvae probably arose from eggs laid by overwintering adult CPB. While this may be due to climatic variables, it may also arise from an avoidance behavior observed in other areas of the North Central states. Later emerging CPB adults, while susceptible to neonicotinoid insecticides, avoid the higher titre of insecticide found in younger plants, thus having increased survivorship in fields seed treated with those insecticides. Eggs laid by overwintered adults were present at least until 7/15 (Fig A4).

An Analysis of Variance indicated that there were significant treatment effects in the seasonal total number of feeding CPB stages (Fig. Table A1). While plots treated with Entrust were the only plots to have significantly fewer CPB than did the UTC treated plots, a Fisher's LSD means comparison test indicated there were several other differences between treatments (Table A2). Generally, plots treated with X-M15-1D at 10 lbs/ac and 50 lbs/ac had the highest total CPB numbers totaled over the season.

Defoliation - An Analysis of Variance indicated there was a significant treatment effect on the mean % defoliation (P = 0.000) (Table 2). While there was considerable variation in the data, a Fisher's LSD test indicated there were significant differences between treatments

Table 2. ANOVA table for % Defoliation in Colorado Potato Beetle foliar trial.

Analysis of Variance

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
TREATMENT$	3,426.087	9	380.676	5.680	0.000
Error	63,673.708	950	67.025		

Table 3. Separation of significantly different mean % defoliation (all significantly different at α=0.10, highlighted significantly different at α=0.05)

Fisher's Least-Significant-Difference Test

TREATMENT$(i)	TREATMENT$(j)	Difference	p-Value	95% Confidence Interva	
				Lower	Upper
Azera	PyGanic	-2.698	0.023	-5.017	-0.379
Azera	UTC	-3.021	0.011	-5.340	-0.702
Azera	X-M15-1D10	-3.406	0.004	-5.725	-1.087
Azera	X-M15-1D50	-4.865	0.000	-7.184	-2.546
Azera+MGKF-3110	Entrust	1.990	0.093	-0.329	4.309
Azera+MGKF-3110	PyGanic	-2.250	0.057	-4.569	0.069
Azera+MGKF-3110	UTC	-2.573	0.030	-4.892	-0.254
Azera+MGKF-3110	X-M15-1D10	-2.958	0.012	-5.277	-0.639
Azera+MGKF-3110	X-M15-1D50	-4.417	0.000	-6.736	-2.098
Entrust	PyGanic	-4.240	0.000	-6.559	-1.921
Entrust	PyGanic+MGKF-3110	-2.948	0.013	-5.267	-0.629
Entrust	UTC	-4.562	0.000	-6.881	-2.244
Entrust	X-M15-1D10	-4.948	0.000	-7.267	-2.629
Entrust	X-M15-1D50	-6.406	0.000	-8.725	-4.087
PyGanic	X-M15-1D25	2.625	0.027	0.306	4.944
PyGanic	X-M15-1D50	-2.167	0.067	-4.486	0.152
PyGanic	X-7476-14	2.740	0.021	0.421	5.059
PyGanic+MGKF-3110	X-M15-1D10	-2.000	0.091	-4.319	0.319
PyGanic+MGKF-3110	X-M15-1D50	-3.458	0.004	-5.777	-1.139
UTC	X-M15-1D25	2.948	0.013	0.629	5.267
UTC	X-7476-14	3.062	0.010	0.744	5.381
X-M15-1D10	X-M15-1D25	3.333	0.005	1.014	5.652
X-M15-1D10	X-7476-14	3.448	0.004	1.129	5.767
X-M15-1D25	X-M15-1D50	-4.792	0.000	-7.111	-2.473
X-M15-1D50	X-7476-14	4.906	0.000	2.587	7.225

Yields –Although yields were within expected ranges for dryland potato production (Fig 2), there were no significant treatment effects on total mean harvested yields (P = 0.536) (Table 2).

There was, however, a significant treatment effect on tuber size (P = 0.035)(Table 3). Generally, tubers harvested from either Azera treatment plots were largest, followed by those treated with Entrust, either PyGanic treatment, the untreated plots and finally by those from X-M15-1D plots (Table 4). Means calculated to be significantly different (according to Fishers LSD) are presented on Table 5.

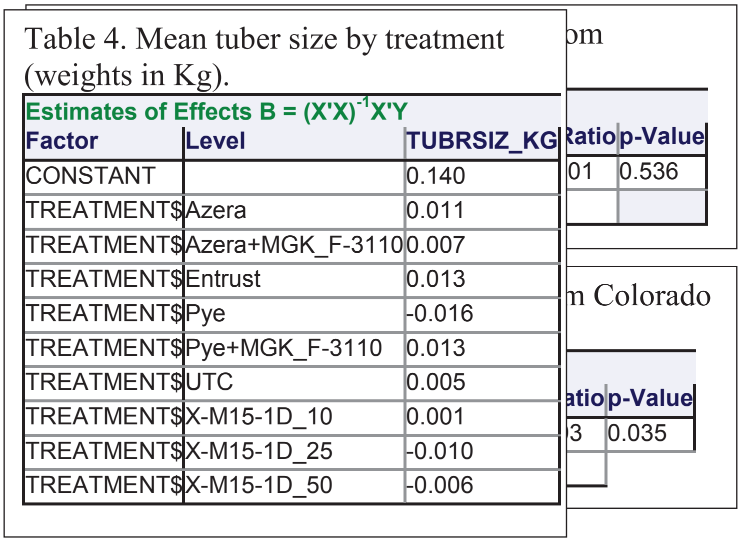


Table 4. Mean tuber size by treatment (weights in Kg).

Estimates of Effects B = $(X'X)^{-1}X'Y$

Factor	Level	TUBRSIZ_KG
CONSTANT		0.140
TREATMENT$	Azera	0.011
TREATMENT$	Azera+MGK_F-3110	0.007
TREATMENT$	Entrust	0.013
TREATMENT$	Pye	-0.016
TREATMENT$	Pye+MGK_F-3110	0.013
TREATMENT$	UTC	0.005
TREATMENT$	X-M15-1D_10	0.001
TREATMENT$	X-M15-1D_25	-0.010
TREATMENT$	X-M15-1D_50	-0.006

om

Ratio	p-Value
01	0.536

n Colorado

atio	p-Value
3	0.035

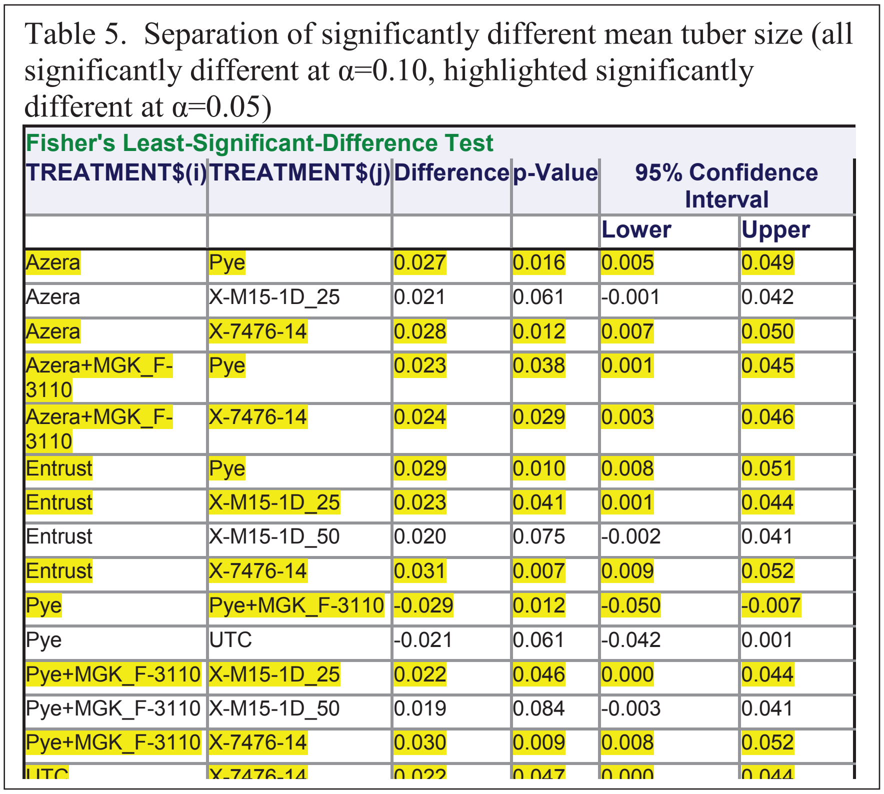


Table 5. Separation of significantly different mean tuber size (all significantly different at α=0.10, highlighted significantly different at α=0.05)

Fisher's Least-Significant-Difference Test

TREATMENT$(i)	TREATMENT$(j)	Difference	p-Value	95% Confidence Interval	
				Lower	Upper
Azera	Pye	0.027	0.016	0.005	0.049
Azera	X-M15-1D_25	0.021	0.061	-0.001	0.042
Azera	X-7476-14	0.028	0.012	0.007	0.050
Azera+MGK_F-3110	Pye	0.023	0.038	0.001	0.045
Azera+MGK_F-3110	X-7476-14	0.024	0.029	0.003	0.046
Entrust	Pye	0.029	0.010	0.008	0.051
Entrust	X-M15-1D_25	0.023	0.041	0.001	0.044
Entrust	X-M15-1D_50	0.020	0.075	-0.002	0.041
Entrust	X-7476-14	0.031	0.007	0.009	0.052
Pye	Pye+MGK_F-3110	-0.029	0.012	-0.050	-0.007
Pye	UTC	-0.021	0.061	-0.042	0.001
Pye+MGK_F-3110	X-M15-1D_25	0.022	0.046	0.000	0.044
Pye+MGK_F-3110	X-M15-1D_50	0.019	0.084	-0.003	0.041
Pye+MGK_F-3110	X-7476-14	0.030	0.009	0.008	0.052
UTC	X-7476-14	0.022	0.047	0.000	0.044

Appendix A – Weekly Population Dynamics

Figure A1 – Weekly mean number of Colorado Potato Beetle Adults / plant vs mean % defoliation by treatment.

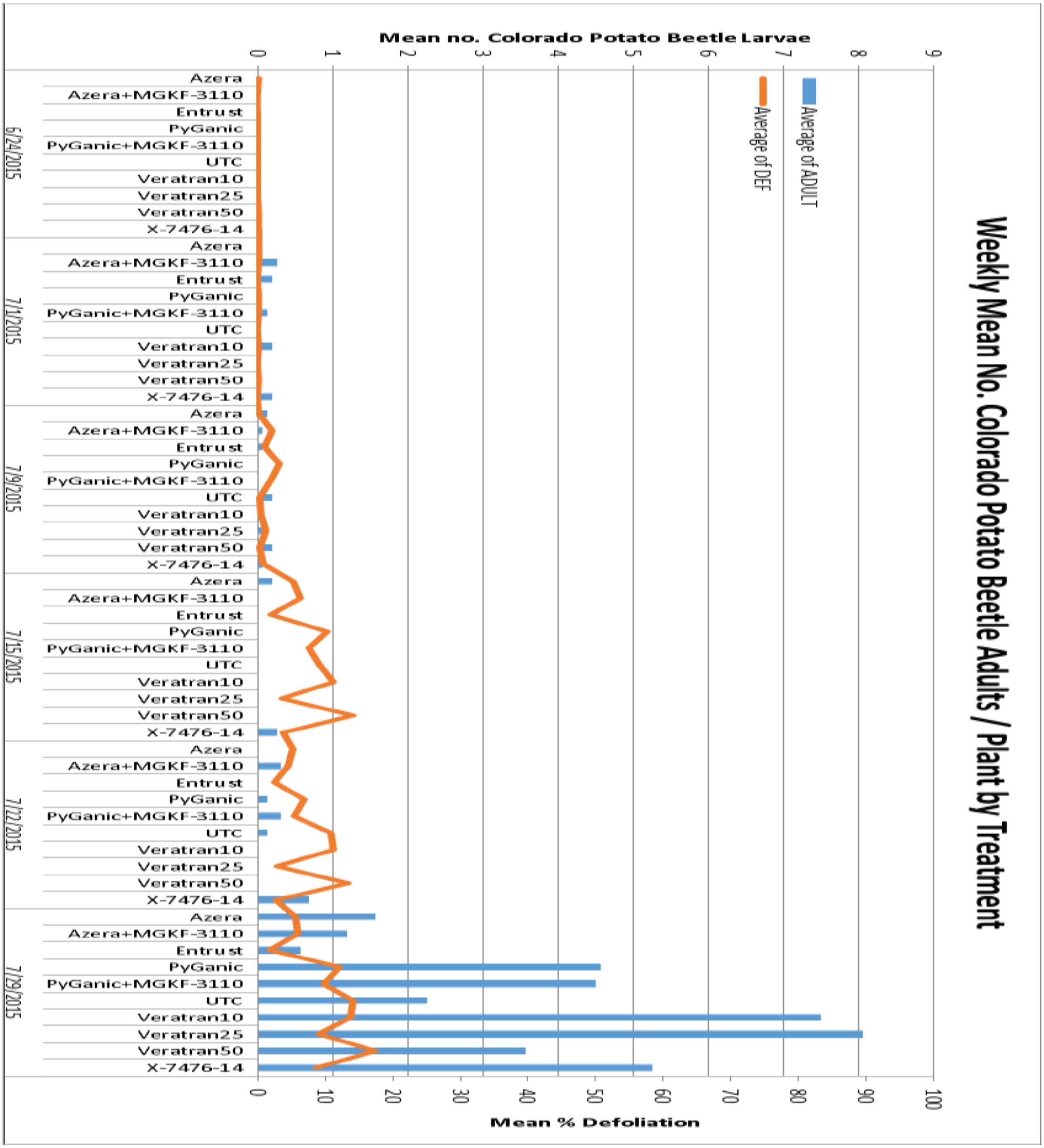


Figure A2 – Weekly mean number of total Colorado Potato Beetle larvae / plant by treatment.

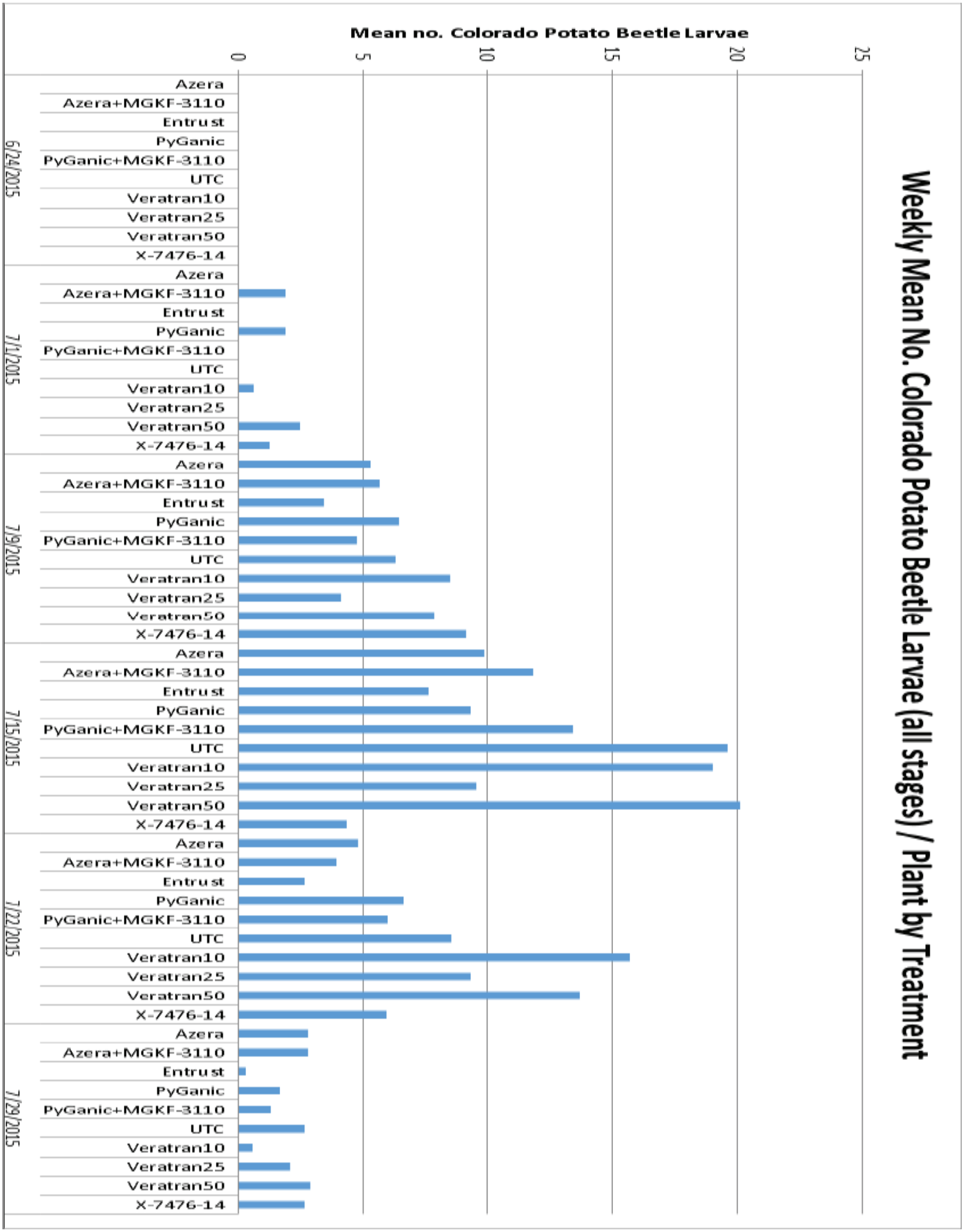


Figure A3 – Weekly mean number of Colorado Potato Beetle larval stages (small vs large) by treatment.

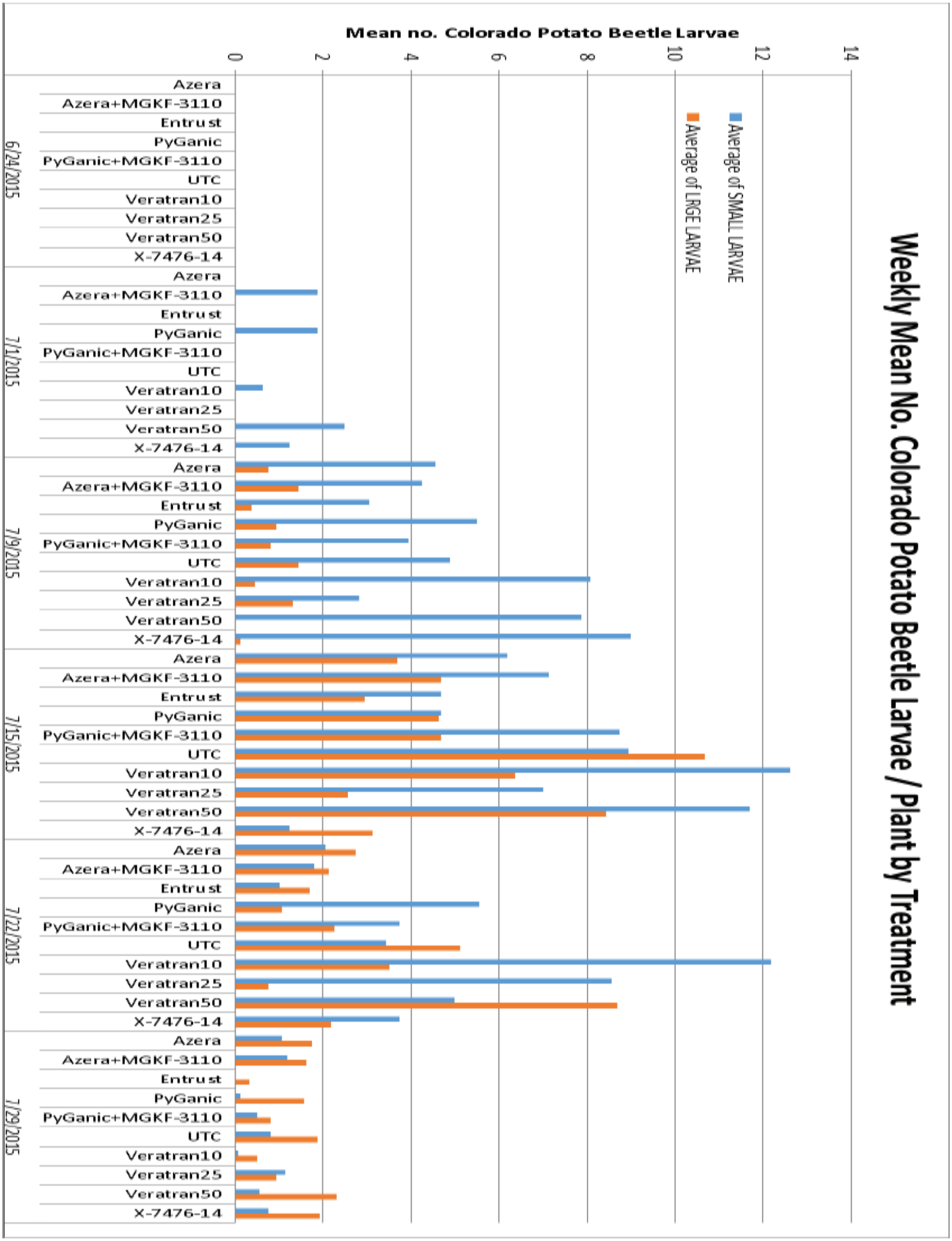


Figure A4 – Weekly mean number of Colorado Potato Beetle eggs per plant by treatment.

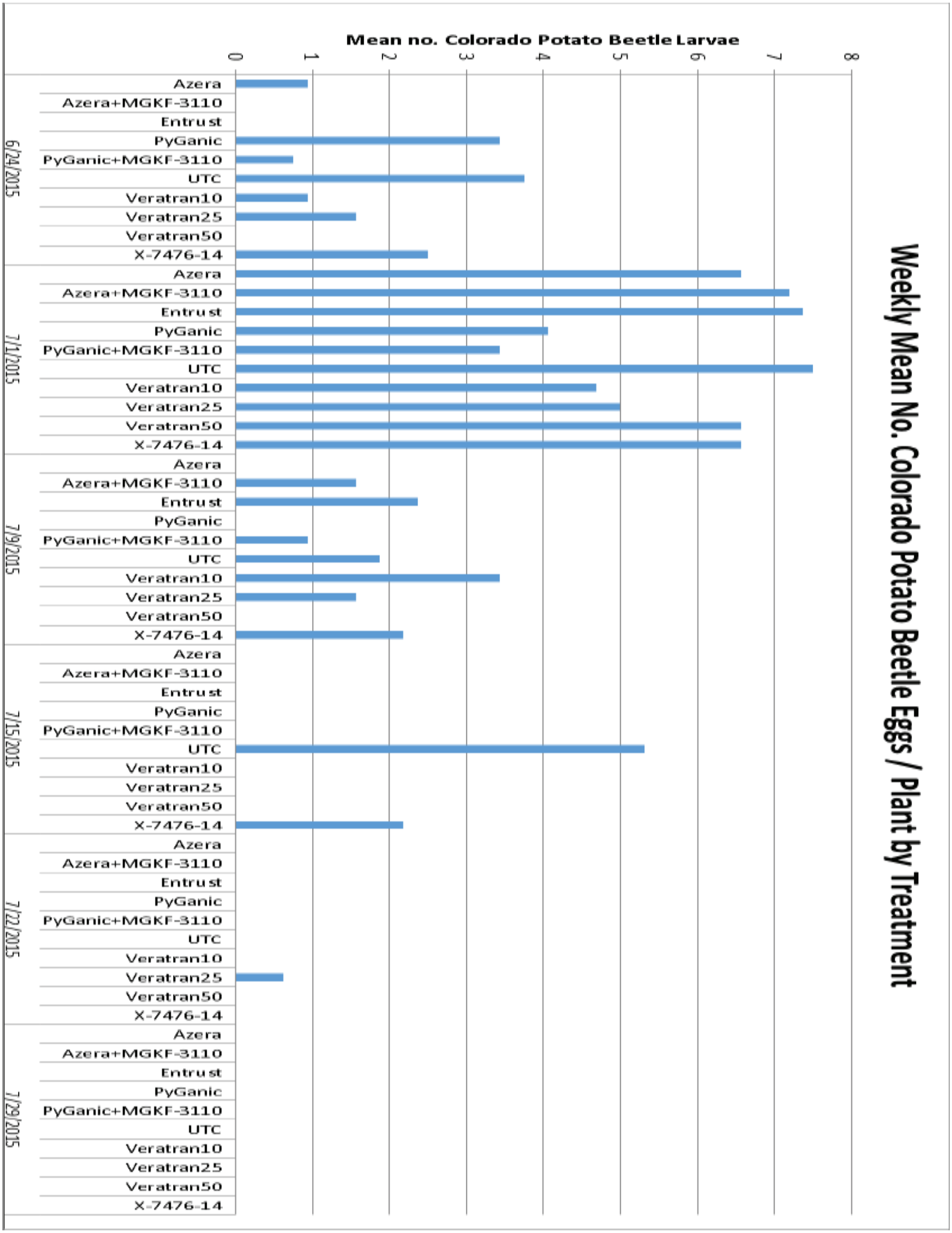
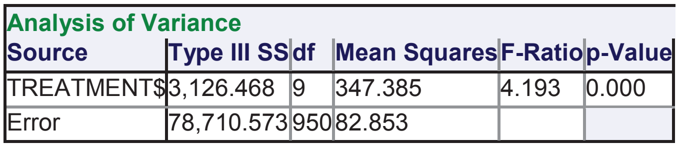


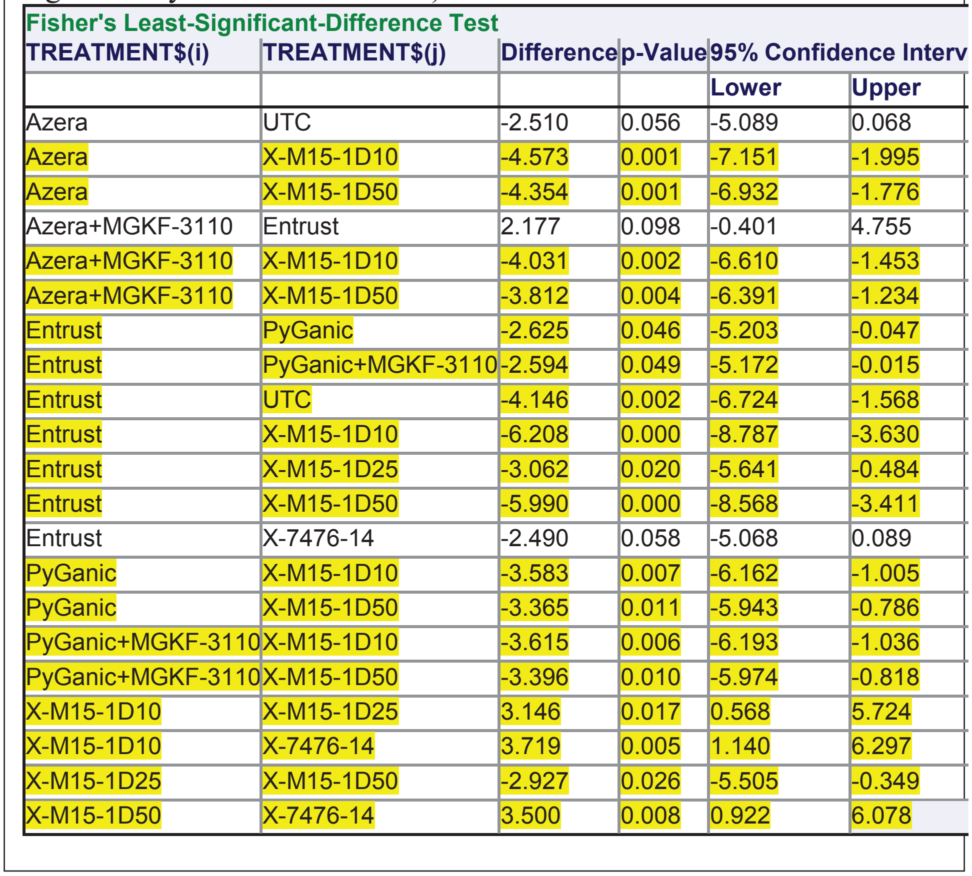
Table A1 – ANOVA table for to seasonal total Colorado Potato Beetle per plant by treatment.



Analysis of Variance

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
TREATMENT$	3,126.468	9	347.385	4.193	0.000
Error	78,710.573	950	82.853		

Table A2 - Separation of significantly different seasonal total CPB means by treatment (all significantly different at α=0.10, highlighted significantly different at α=0.05)



Fisher's Least-Significant-Difference Test

TREATMENT$(i)	TREATMENT$(j)	Difference	p-Value	95% Confidence Interv	
				Lower	Upper
Azera	UTC	-2.510	0.056	-5.089	0.068
Azera	X-M15-1D10	-4.573	0.001	-7.151	-1.995
Azera	X-M15-1D50	-4.354	0.001	-6.932	-1.776
Azera+MGKF-3110	Entrust	2.177	0.098	-0.401	4.755
Azera+MGKF-3110	X-M15-1D10	-4.031	0.002	-6.610	-1.453
Azera+MGKF-3110	X-M15-1D50	-3.812	0.004	-6.391	-1.234
Entrust	PyGanic	-2.625	0.046	-5.203	-0.047
Entrust	PyGanic+MGKF-3110	-2.594	0.049	-5.172	-0.015
Entrust	UTC	-4.146	0.002	-6.724	-1.568
Entrust	X-M15-1D10	-6.208	0.000	-8.787	-3.630
Entrust	X-M15-1D25	-3.062	0.020	-5.641	-0.484
Entrust	X-M15-1D50	-5.990	0.000	-8.568	-3.411
Entrust	X-7476-14	-2.490	0.058	-5.068	0.089
PyGanic	X-M15-1D10	-3.583	0.007	-6.162	-1.005
PyGanic	X-M15-1D50	-3.365	0.011	-5.943	-0.786
PyGanic+MGKF-3110	X-M15-1D10	-3.615	0.006	-6.193	-1.036
PyGanic+MGKF-3110	X-M15-1D50	-3.396	0.010	-5.974	-0.818
X-M15-1D10	X-M15-1D25	3.146	0.017	0.568	5.724
X-M15-1D10	X-7476-14	3.719	0.005	1.140	6.297
X-M15-1D25	X-M15-1D50	-2.927	0.026	-5.505	-0.349
X-M15-1D50	X-7476-14	3.500	0.008	0.922	6.078

Progress Report: Managing Fusarium Dry Rot of Stored Potatoes

Gary Secor, Department of Plant Pathology, NDSU, Fargo, ND 58102
gary.secor@ndsu.edu

Introduction and Background. Fusarium dry rot has been a consistent problem of stored potatoes for over 100 years, and in recent years has again become a serious disease of both stored seed potatoes and commercial potatoes grown in ND and MN. The major cause of dry rot in our region is *Fusarium sambucinum*, but in 2005 *Fusarium graminearum* was identified for the first time as a cause of dry rot. Both *F. sambucinum* and *F. graminiearum* continue to be major dry rot pathogens. Fusarium is a wound pathogen that requires an injury to infect. Fusarium infests soil by planting infected seed which rots and releases spore into the soil, and the Fusarium in the soil infects harvested potato tubers through harvest wounds, and dry rot develops slowly in storage. Planting Fusarium infected seed results in weak plants and premature seed decay, and Fusarium infection sites in seed act as entry sites for Erwinia seed decay and blackleg, resulting in poor stands due to seed decay after planting. Fusarium is spread during the cutting process and can cause also serious losses in pre-cut seed if not stored properly prior to planting. Fusarium can persist in the soil for many years and neither crop rotation nor fumigation is effective in reducing Fusarium populations in the soil.

Injury management programs and post-harvest application of thiabendazole (Mertect) at ultra-low volumes effectively managed dry rot in storage for about 20 years, but widespread resistance to thiabendazole developed the 1990's in *F. sambucinum* which remains today. F. graminearum is sensitive to thiabendazole. No other post-harvest chemicals were available until Stadium, a combination of azoxystrobin, fludioxonil and difenoconazole, was registered in 2012. Seed treatment fungicides containing fludioxonil provided some control of Fusarium as a seed treatment, but Fusarium resistance to fludioxanil has developed in some areas in the US and Canada. In 2014, we identified resistance to fludioxonil (Maxim) *F. sambucinum* isolates from seed potatoes with dry rot collected from ND, MN, NE and CO. Few other compounds are active against Fusarium. Mancozeb has some activity, but in not available in liquid formulation, and dusts are being phased out of the industry for worker safety considerations. The stobilurin compounds, including azoxystrobin, have limited activity against Fusarium. We tested three SDHI fungicides, Vibrance (sedaxane), Emesto Silver (penflufen + prothioconazole) and Vertisan (penthiopyrad), for activity against Fusarium in laboratory trials, and they do not have good activity against Fusarium. The compound with the best activity against Fusarium in post-harvest trials and in laboratory tests is the DMI fungicide difenoconazole. There are few varieties with good genetic resistance to Fusarium dry rot, although some differences do exist.

Treating potato seed with fungicides can reduce Fusarium seed decay, but except for fludioxonil, most registered compounds have little or moderate activity against Fusarium. However, resistance to fludioxonil is prevalent in *F. sambucinum* from seed potatoes produced in several areas. Seed treatments containing difenoconazole can be effective based on preliminary data, but may be limited in availability.

Due to the increase in dry rot of stored potatoes, the increase in *Fusarium/Pectobacterium* seed decay, the paucity of fungicides with good activity for managing Fusarium, and the lack of Fusarium management for potatoes, we are reporting on work conducted to more completely understand and manage Fusarium decay of seed and stored potatoes.

Objectives.

1. Compare wound healing of selected processing cultivars as an indicator of susceptibility to decay by inoculating tuber slices with *Pectobacterium* and *Pectobacterium* plus *Fusarium sambucinum* at 45F and 50F daily over a two week period and monitoring decay.

2. Determine efficacy of commonly used seed treatments for managing Fusarium decay of cut seed after inoculation of cut seed with fludioxonil resistant *F. sambucinum* of three processing cultivars, Umatilla, Shepody and Russet Burbank.

3. Test selected processing varieties for susceptibility/resistance to *F. sambucinum* and Pectobacterium soft rot.

4. Determine the effect of Emesto Silver + NuBark MZ and Emesto Silver + Serenade Opti on wound healing of cut seed or Russet Burbank and Red Norland.

Impact. The results of this work can be used a model to understand and manage Fusarium dry rot and secondary bacterial soft rot by all growers in our region. This data will be used to develop a fungicide seed treatment program to reduce infection of seed potatoes by *F. sambucinum*, which will reduce Fusarium soil inoculum and dry rot of commercial potatoes in storage, and indirectly reduce Pectobacterium seed decay and soft rot of cut seed potatoes.

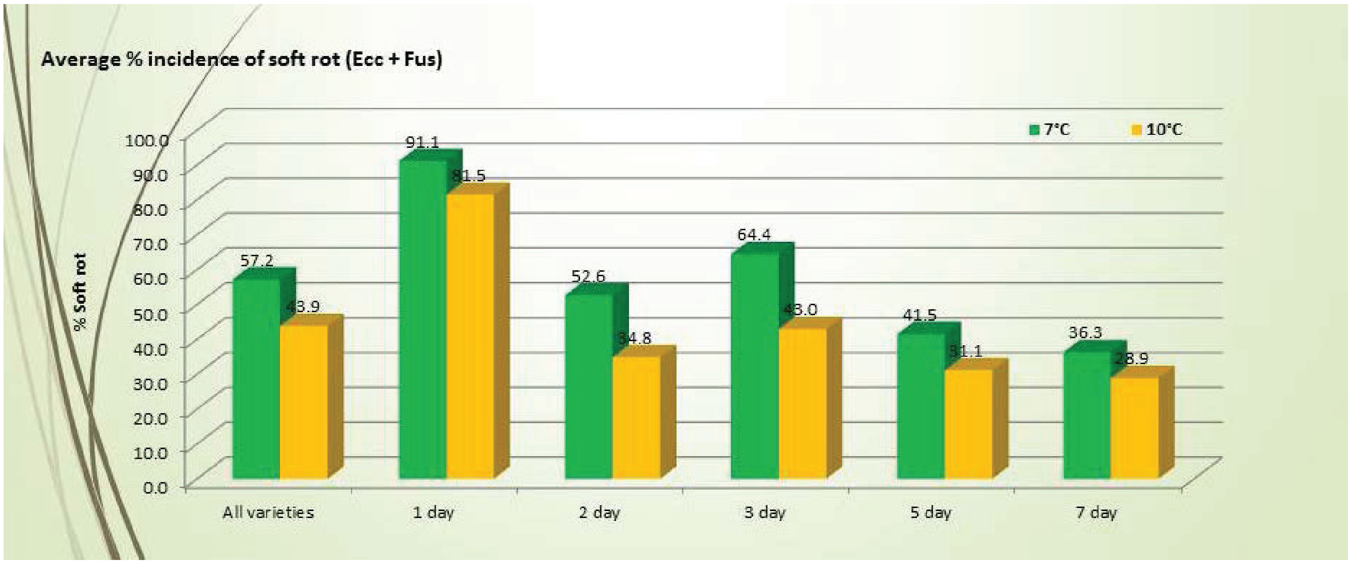
Results. 1. Wound Healing of processing cultivars. Hockey puck size tubers slices were cut from nine processing cultivars and used for trials to determine the effect of wound healing (days) on rot after inoculation with the soft rot bacteria, *Pectobacterium carotovora* + the dry rot fungus*, Fusarium sambucinum*. Pucks were cut, wound healed for 1, 3, 5, and 7 days before inoculation and decay rated five and 21 days after inoculation. The trial was conducted at 45 and 50°F. The results can be seen in Figures 1-6. In general, across all cultivars, there was less disease at 50 v. 45°F (Fig 1). Decay was highest when inoculated one day after cutting and decreased from two to seven days after cutting, with differences among varieties (Figures 2-6). Differences in lesion size were also evident 21 days after inoculation (Figure 7). The differences in decay could be attributed to differences in wound healing among cultivars. Figure 8 shows wound healing five days after cutting Shepody, Umatilla and Dakota Russet seed. Note the weaker wound healing of Dakota Russet and Umatilla compared to Shepody.

Conclusions.

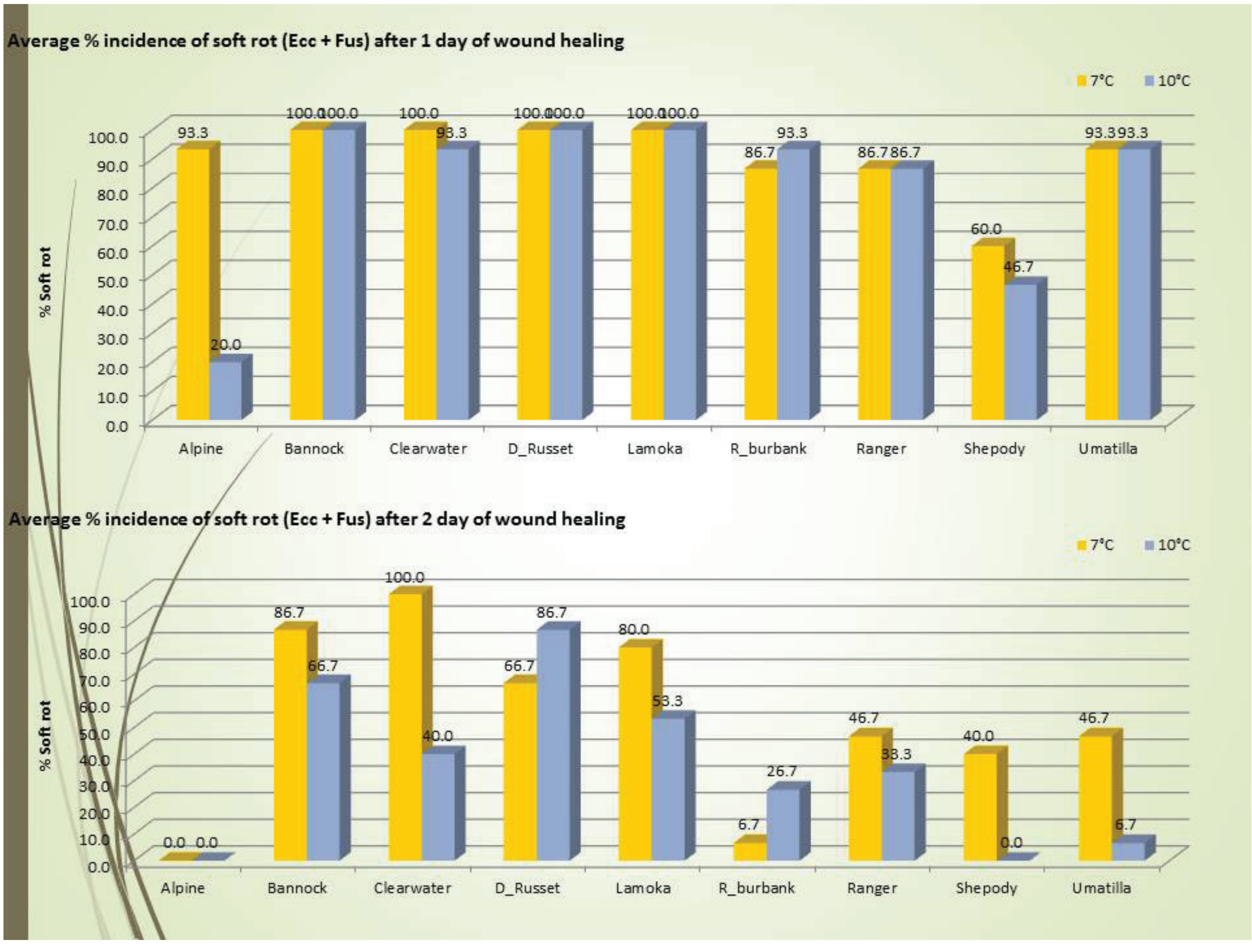
1. Decay caused by PCC + F. sambucinum was less at 50F compared to 45F. Growers should consider cutting seed at the warmer temperature.
2. There are differences among processing potato cultivars for susceptibility to decay caused by PCC + F. sambucinum.

3. Differences in wound healing, especially delayed wound healing, may explain in part, why some varieties are more susceptible to seed decay than others.

Figure 1. Average incidence of soft rot across nine potato cultivars after inoculation with PCC + Fusarium at two temperatures over seven days



Figures 2 and 3. Percent decay of nine potato cultivars inoculated with PCC + Fusarium after one day and two days of wound healing at two temperatures



Figures 4 and 5. Percent decay of nine potato cultivars inoculated with PCC + Fusarium after three days and five days of wound healing at two temperatures

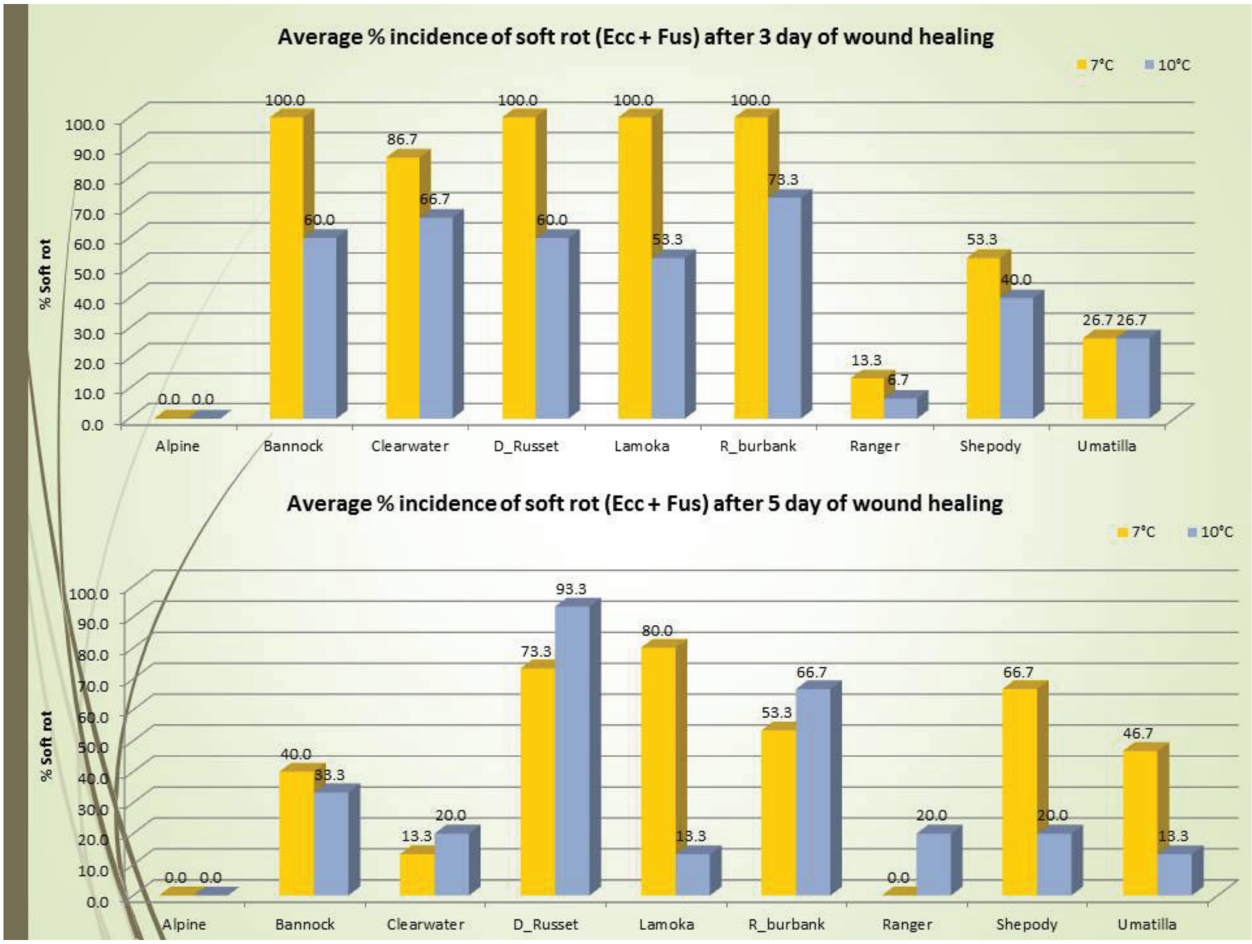


Figure 6. Percent decay of nine potato cultivars inoculated with PCC + Fusarium after seven days of wound healing at two temperatures

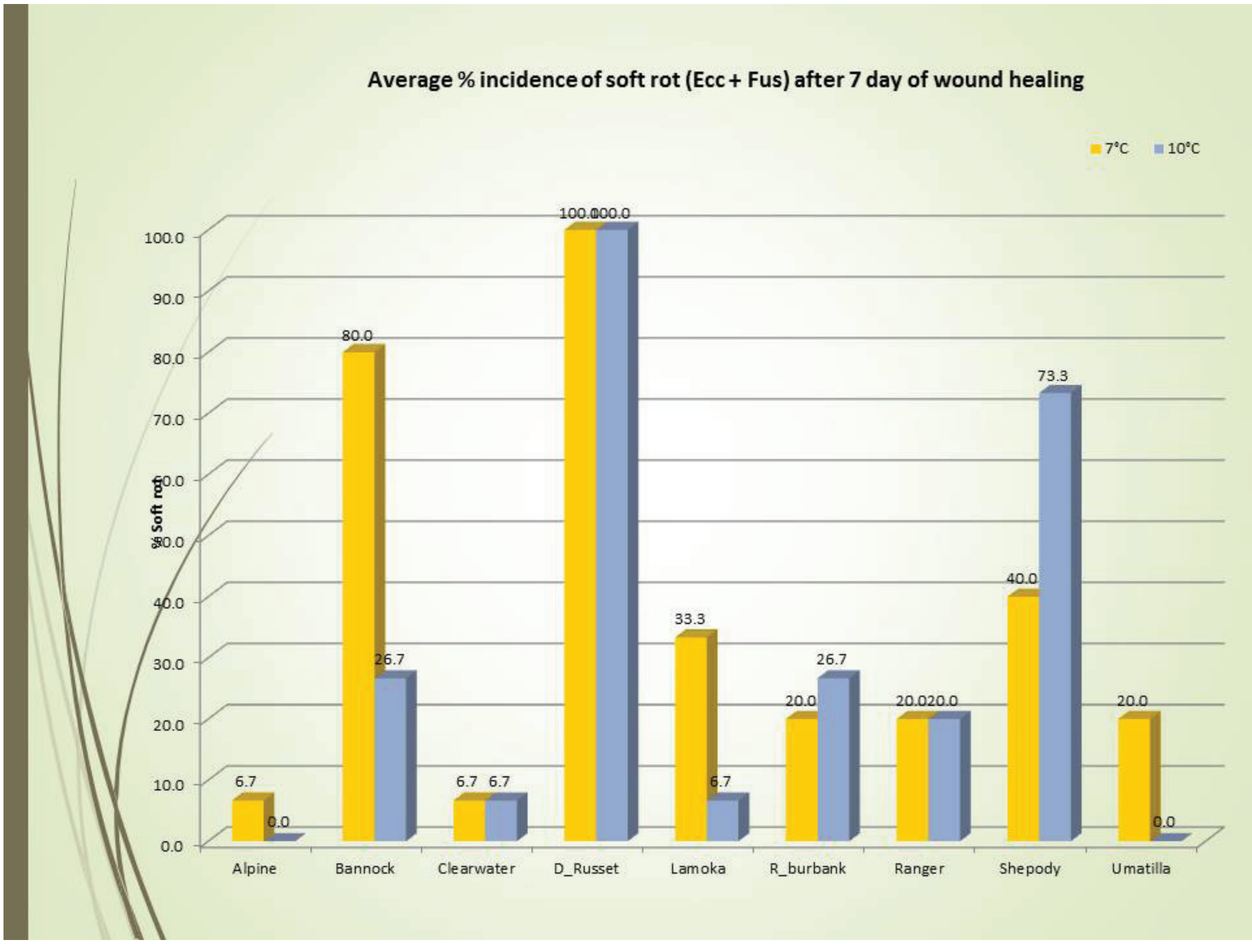


Figure 7. Decay lesion size of nine potato cultivars inoculated with PCC + Fusarium 21 days after inoculation at two temperatures

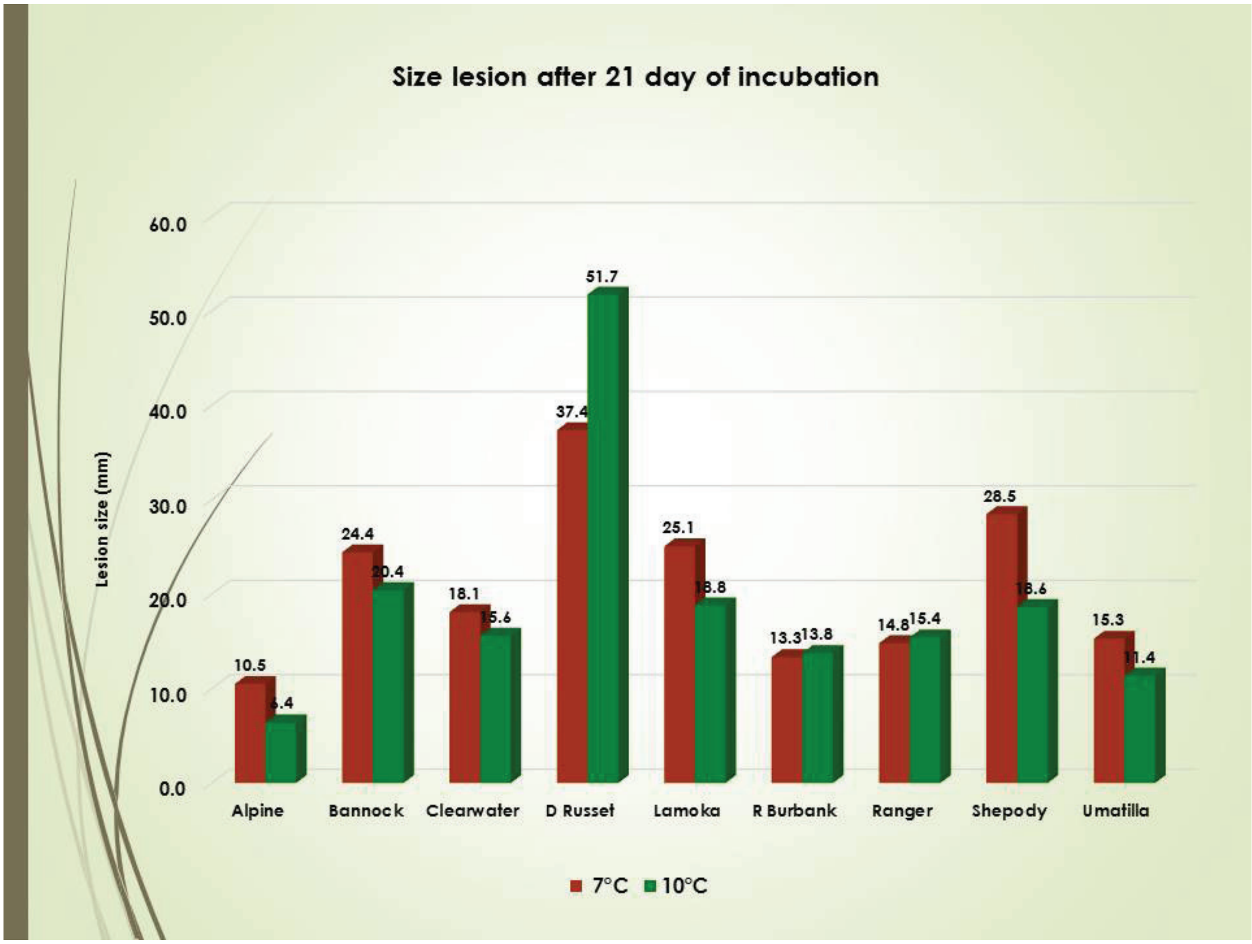
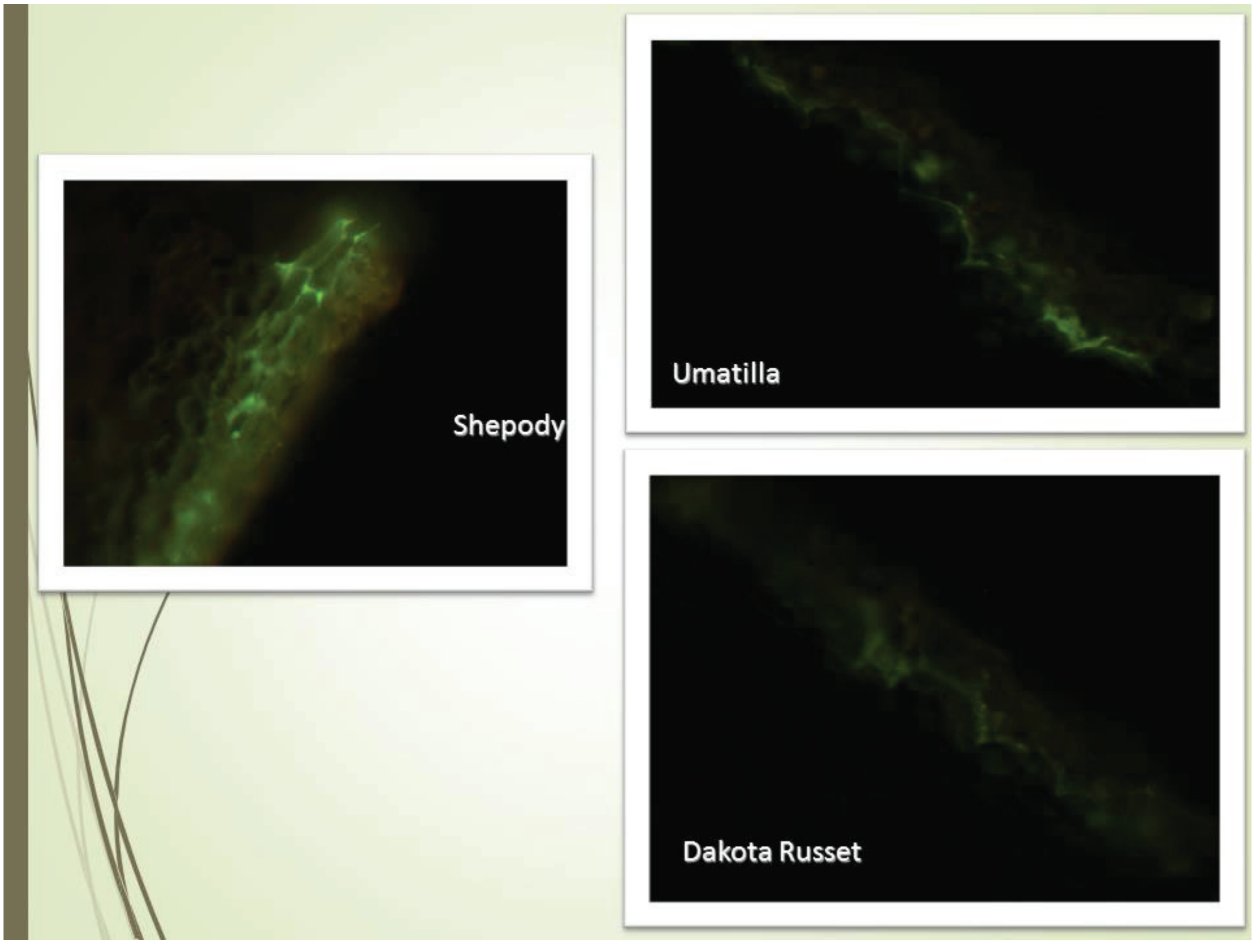


Figure 8. Microscope photos ofwound healing response of three potato cultivars after five days of wound healing. Note the robust wound healing of Shepody compared to less robust wound healing in Umatilla and Dakota Russet



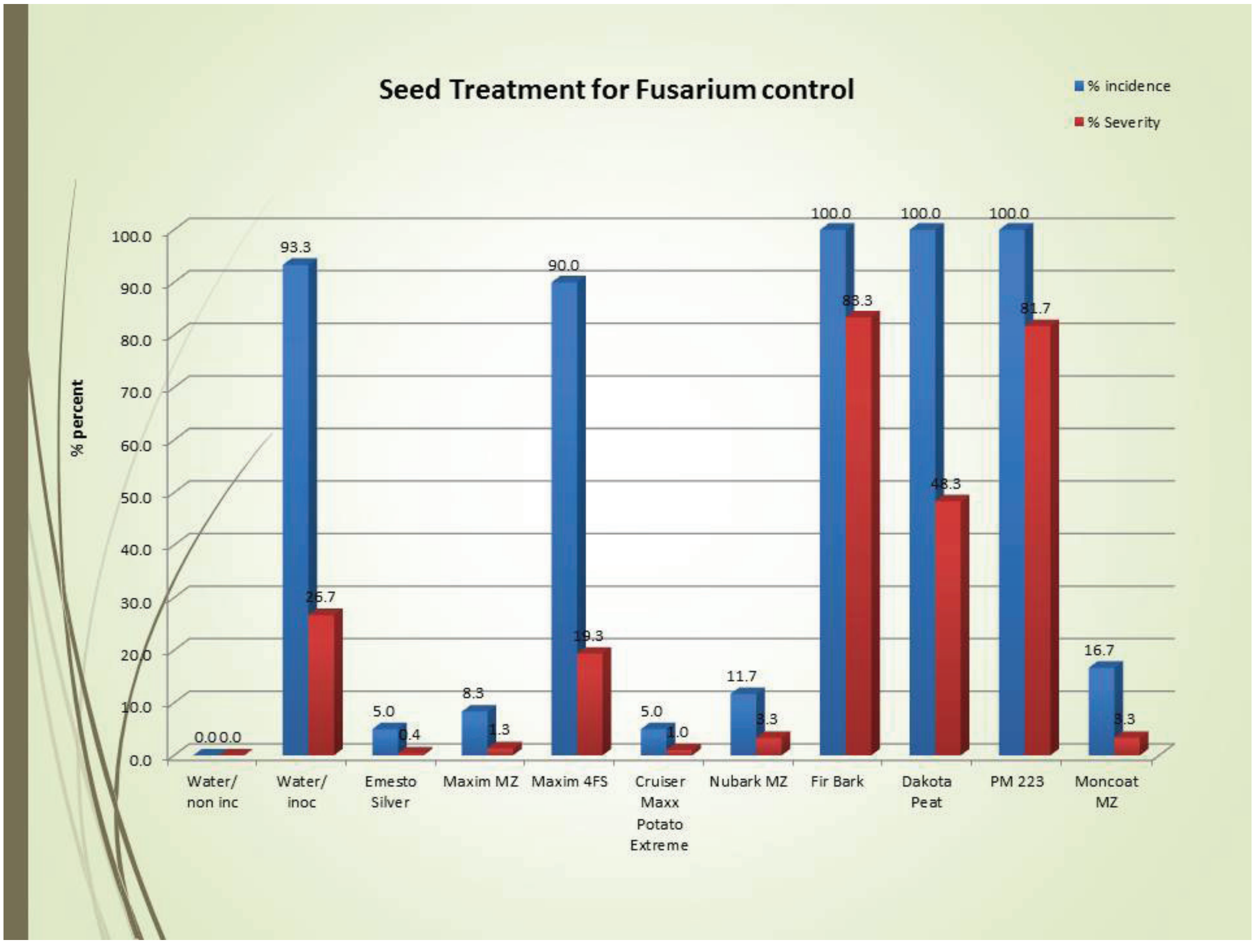
2. Impact of managing Fusarium decay by various seed treatment after inoculation with fludioxonil resistant F. sambucinum. Twenty freshly cut seed pieces of three potato cultivars, Umatilla, Shepody and Russet Burbank, were inoculated with a spore mixture from three fludioxonil resistant isolates of F. sambucinum. Seed was treated with various seed treatment products and incubated for three weeks at 50°F in plastic garbage containers. After incubation, seed was evaluated for incidence and severity of decay (wet plus dry). Figure 9 shows the treatments and rates. Figure 10 shows the results of the study. Maxim MZ gave good control of decay compared to Maxim alone which gave poor control of decay. MZ gave good control of Fusarium decay, as all treatments containing MZ provided the lowest incidence of disease. As expected, three non-fungicide products, fir bark, Dakota Peat and PM223 did not provide any control of Fusarium decay.

Conclusions.

1. Fludioxonil resistant isolates are not controlled by fludioxonil alone.

2. Seed treatment products with fludioxonil must contain an MZ partner to manage Fusarium
3. Other seed treatment products that contain a DMI fungicide can manage Fusarium decay of cut potato seed
4. Seed treatment products that do not contain a fungicide do not reduce Fusarium seed decay

Figure 10. Incidence and severity of cut potato seed decay three weeks after inoculation with fludioxanil resistant Fusarium sambucinum followed by various seed treatments and stored at 50F



3. Assessing resistance of potato processing cultivars to *Fusarium sambucinum.* Seven potato processing cultivars and two advanced selections grown under irrigation at the NNPGA Inkster Irrigated Potato Research site were harvested and tested for susceptibility to infection caused by two Fusarium species, *F. sambucinum* and *F. solani*. *F. sambucinum* is the leading cause of storage dry rot and *F. solani* is the leading cause of Fusarium decay in many areas. Testing with F. sambucinum was not successful due to and tubers will be tested again this year but results are not available for this report. Most of the cultivars tested were susceptible decay caused by F. solani, with the exception of Clearwater that had zero decay (Figure 11. Umatilla and Russet Burbank were the most susceptible to f. solani decay (Figure 11).

Figure 11. Susceptibility of potato cultivars and selections to decay after inoculation with *Fusarium solani*

	Selection	Rot area (mm)
5601	PORO6V12-3	604.9
5602	AO2507 - 2LB	505.1
5603	Sage	585.3
5604	Clearwater	0.0
5605	Bannock	627.7
5606	Umatilla	761.2
5607	Shepody	453.7
5608	Russet Burbank	936.1
5609	Prospect	608.6
LSD $_{p>0.05}$		220.10

4. Determine the effect of Emesto Silver + NuBark MZ and Emesto Silver + Serenade Opti on wound healing of cut seed. Tubers from 2 cultivars (cv. Russet Burbank and Red Norland, Inkster) were washed and allowed to air-dry. After drying the tubers were quartered so each seed piece contained 2 cut sides. Three treatments were applied to cut seed pieces of each cultivar.

1. Seed was treated with water alone at an equivalent rate of 0.31.fl oz/cwt
2. Seed was sprayed with a slurry of Emesto Silver and water at an equivalent of 0.31 fl oz. / cwt to each of the seed piece samples plus Nubark Mancozeb dust applied after the Emesto Silver at an equivalent rate of 16 oz. / cwt.
3. Seed was sprayed with a slurry of Emesto Silver and water at an equivalent of 0.31 fl oz. / cwt to each of the seed piece samples plus Serenade Opti liquid applied after the Emesto Silver at an equivalent rate of 8 oz. / cwt.

The treated seed pieces were then tumbled for 20 seconds to evenly apply the fungicide mixture to all of the seed pieces.

After tumbling each of the treatments, the seed pieces were separated into groups of 10 and placed into pots with mesh screen placed in the bottom. These pots were then placed in double paper bags, which had a Ziploc bag with a wet paper towel placed in the bottom to provide humidity for suberization of the tubers. The bags were then folded at the top and stapled to help maintain the humidity of the tuber samples. The paper bags were then placed in a large plastic garbage can and stored at 50° F and 95% humidity until assessment.

At 1, 3, 5, 7, and 14 days after cutting and treating, 10 seed pieces were removed from each treatment and evaluated for wound healing (suberization). A block of tissue approximately 1cm x 3 cm x 0.5cm was cut from the juncture of the two cut planes of each seed piece to be evaluated. Under a dissecting microscope, freehand serial section approximately 1mm thick were cut from the block of tissue and mounted in water on a microscope slide. Sections were pre-viewed and the best section selected for suberin measurement.

Cut sections were evaluated for suberin deposition and suberin quality as measures of wound healing. Cut sections were viewed using a Zeiss Axiostar HBO 50 microscope using the fluorescent light source. The ultraviolet light source is a high pressure mercury lamp with excitation wavelengths of 450-490 and barrier filter BA520. Suberin is comprised of both aliphatic and phenolic compounds, and the phenolic compounds fluoresce in the presence of ultraviolet light. Suberin thickness was measured using an ocular micrometer which is calibrated to a stage micrometer. All of the measurements are taken at 10x magnification, at which one ocular unit equals to 10 microns. For each section observed, the thinnest and thickest suberin was measured and an average of the two measurements calculated. A total of ten data points were recorded for each treatment/date/variety. Data were reported in ocular units.

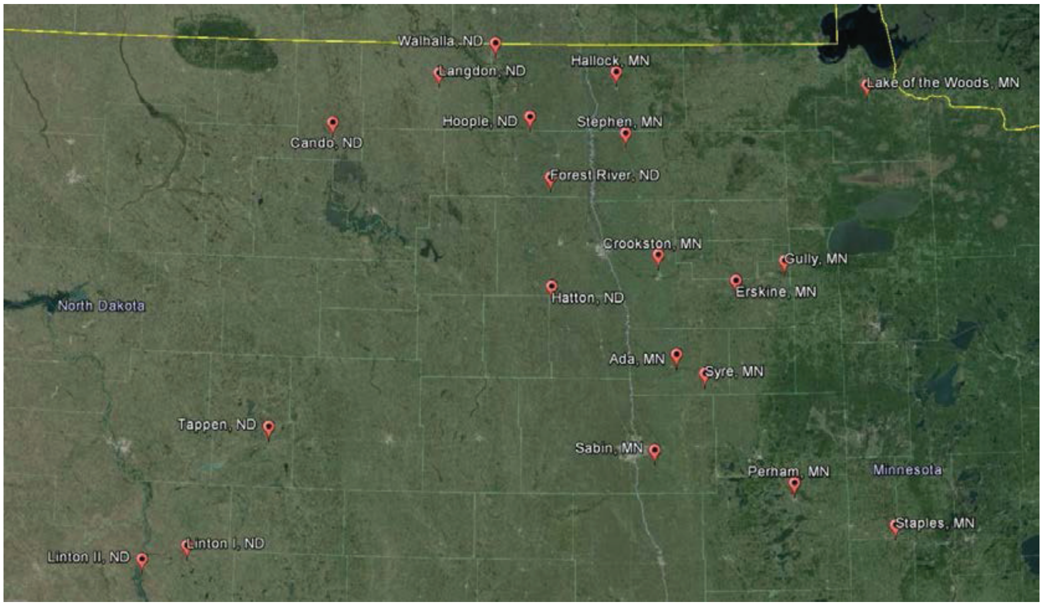
Data was analyzed using SAS ANOVA and reported as box plots or treatment means separated by LSD or Duncan’s Multiple Range Test.

Results. In Russet Burbank, both treatments significantly reduced the thickness of the suberin layer at 3, 7 and 14 days compared to the water only control, but suberin layer thickness was significantly increased by both treatments at five days. In Red Norland, suberin thickness was significantly reduced by both products compared to the water control at three days and by Emesot Silver plus NuBark MZ at seven days, but there were no significant differences between fungicide treatments and the water control at five and 14 days or for Emesto Silver plus Serenade Opti at seven days. It is important to provide favorable condition to maximize wound healing after cutting and treatment of cut seed with these products.

Managing PVY Vectors, Annual Report 2015

Dr. Ian MacRae,
Dept. of Entomology, U. Minnesota
Northwest Research & Outreach Center
2900 University Ave.
Crookston, MN 56716
imacrae@umn.edu
218 281-8611 Office
218 281-8603 Fax

A) A network of 20 - 2m tall suction traps were established in the seed potato production areas of Minnesota and North Dakota, 19 of which were able to consistently provide data through the season. These traps consist of a fan drawing air down in through the trap and trapping the incoming aphids in a sample jar which is changed weekly. Sample jars are sorted, aphids identified to species and aphid population dynamics at sample locations are determined. Maps were prepared weekly showing these dynamics.

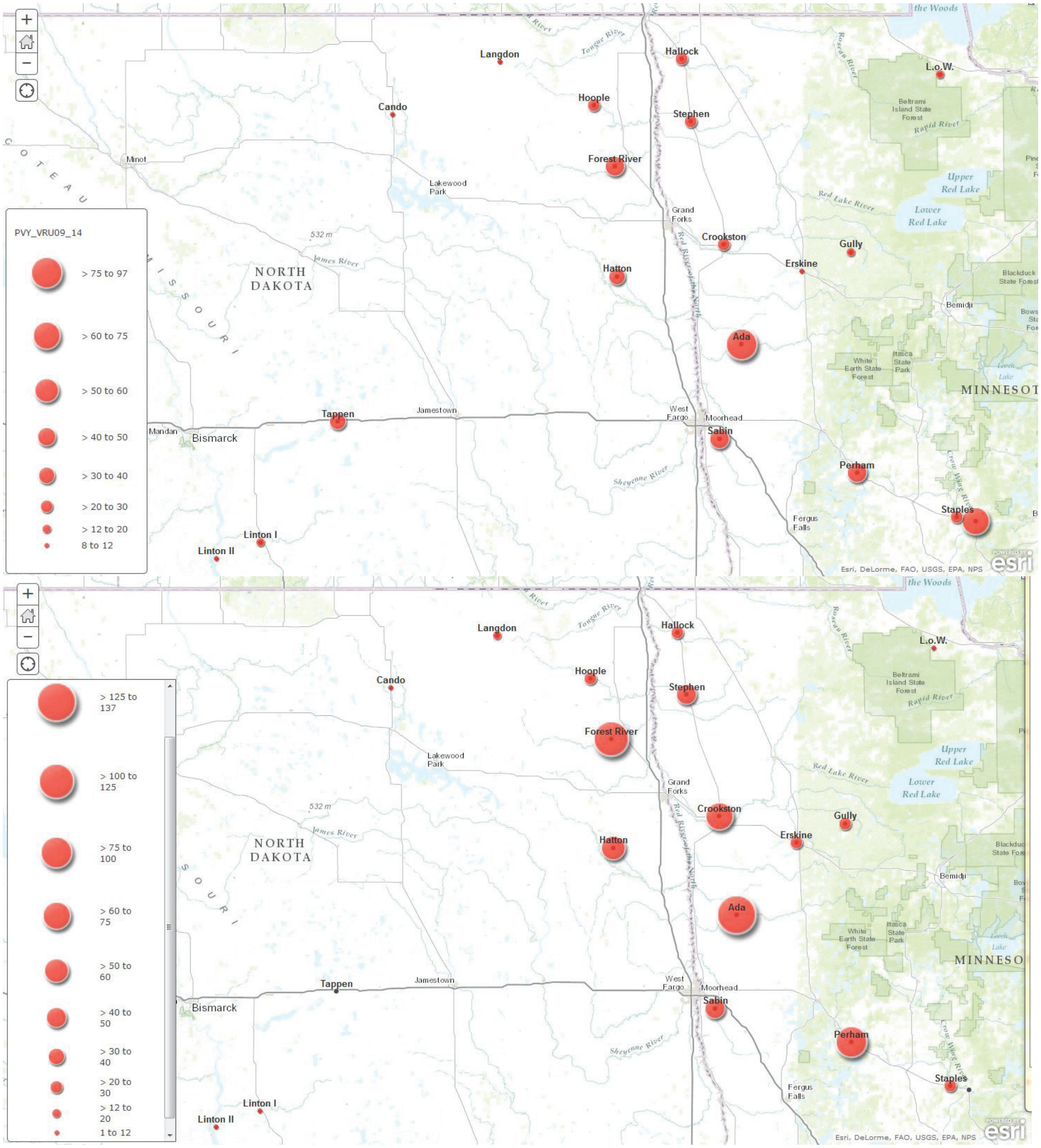


Aphid Alert suction trap locations, 2015.

In 2015, we also implemented the PVY Vector Risk Index. This measurement standardized the amount of vector pressure being encountered at a trap location. All vectors are not created equally, some vector PVY more efficiently than others; therefore the same number of aphids of different species may not cause the same potential of PVY transmission to fields in the area. The relative efficiencies of aphid vectors to transmit PVY has been investigated and published, green peach aphid is the most efficient vector and the vector efficiency of other species is generally compared to it. We used values from the literature to calculate relative cumulative vector pressure at a location based on the relative efficiencies and numbers present (e.g. soybean aphid is 10% as efficient as green peach, so a catch of 5 soybean aphids and 1 green peach at a location would total a PVY Vector Index value of 1.5 for that location. We presented the cumulative yearly PVY Vector Index values and the total PVY Vector Index value from 2014 to provide producers with an insight into what vector pressure they were experiencing compared to last year.

In 2014, 2 traps at the MN Dept. of Agriculture winter grow-out site at Waialua HI. These traps are used to monitor for the presence of aphid virus vectors at the site; the absence of vectors ensures virus is not being transmitted to plants in the grow-out. For next season, we will be attempting to develop a risk potential map for the seed producing areas based on aphid numbers and vector efficiencies (how effectively a particular species can transmit the PVY virus). In 2015, we added two additional traps in Hawaii and are trapping for the MN, MT, CO and ID programs. Vector numbers will be made available to the state seed certification departments of those states.

Aphid population information was made available to growers on two websites (aphidalert.blogspot.com and aphidalert.umn.edu), via NPPGA weekly email, linked to on the NDSU Potato Extension webpage (http://www.ag.ndsu.edu/potatoextension), and posted on the AgDakota and Crops Consultants List Serves. Growers could make decisions on beginning oil treatments or targeted edge applications could be



Seasonal cumulative PVY Vector Risk Index for 2015 (upper map) and the total cumulative PVY Vector Risk Index for 2014 (bottom map). PVY Vector pressure was higher in 2015 and there were differences in PVY Vector Index values at specific locations between the two years. The total cumulative values for the PVY Vector Risk Index in 2014 = 258.57, and in 2015 = 569.87.

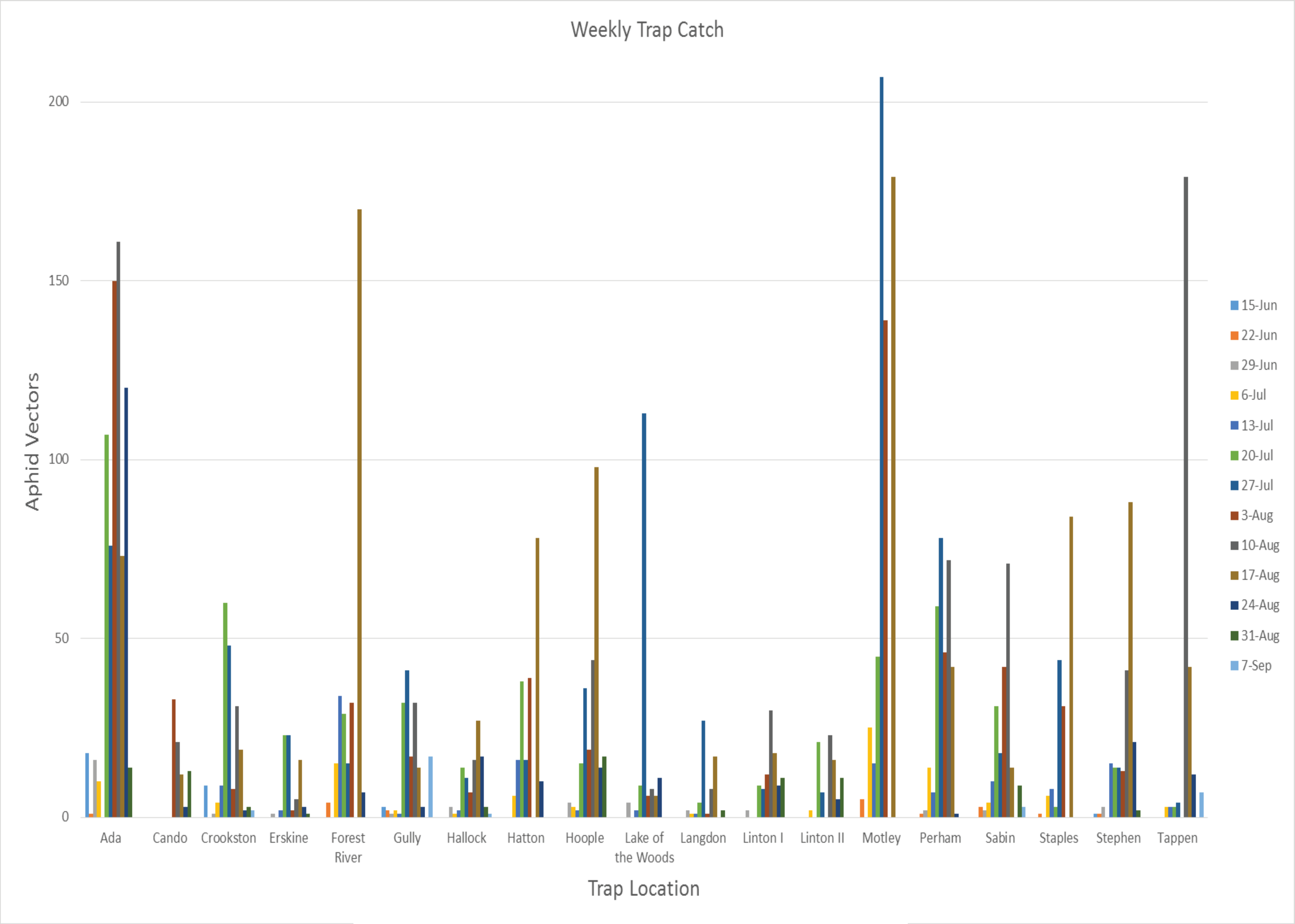
made based on the information obtained from the regional monitoring system. Partial funding for this project was obtained from a Minnesota State Specialty Crops Block Grant in collaboration with the Minnesota Dept. of Agriculture and the Sugarbeet Research and Education Board (we established 3 sites to monitor Sugarbeet Root Aphid but they are in geographic locations that add to our regional picture of aphid vector distributions). Additional funding will be sought from other commodity groups to further expand the network if possible. Traps were established in early June and maintained until the seed field hosting the trap was vine-killed/harvested. At that point a field is no longer attractive to aphids.

Location	**PVY Vector Index 2014**	**PVY Vector Index 2015**
Ada	45.3	93.04
Cando	1.32	8.13
Crookston	16.76	21.82
Erskine	7.27	10.44
Forest River	33.06	40.61
Gully	11.23	15.6
Hallock	15.73	22.05
Hatton	18.36	31.06
Hoople	7.9	26.86
Lake of the Woods	2.22	19.21
Langdon	10.42	8.43
Linton I	5.11	14.07
Linton II	3.89	9.89
Motley		73.33
Perham	21.56	49.26
Sabin	6.88	44.42
Staples	16.51	20.31
Stephen	22.01	25.66
Tappen		35.68
Total PVY Risk	258.57	569.87

A total of 4205 aphids, representing 16 potential PVY vector species, were recovered from traps in 2015. Rather than the raw vector numbers at each location, the comparison of the risk of virus transmission is better represented by the PVY Vector Risk Index maps. The cumulative total values for the PVY Vector Index were higher in 2015 than in 2014 (258.57 vs 569.87 respectively) but there were differences at individual sites (see above table). This reflects total number of vectors captured in the two years as well (2509 in 2014 and 4205 in 2015)

Again in 2015, the use of data from the Aphid Alert network was used to address the flight dynamics of sugarbeet root aphid. This demonstrated the potential application of the network to other cropping systems. We received funding from the Sugarbeet Research & Education Board to facilitate this trapping effort. In addition to providing information on sugarbeet root aphid, these extra traps provided a greater resolution to our regional estimation of all potato vector populations.

We will be using Aphid Alert data from the past 4 years to construct predictive models of aphid arrival and distribution in MN and ND. This will facilitate a more timely application of management tactics. This work is ongoing.



Seasonal trap catch by week and location

Location	Week of	Green peach aphid	Soybean aphid	Bird cherry oat aphid	Corn leaf aphid	English grain aphid	Green bug	Potato aphid	Sunflower aphid	Thistle aphid	Turnip aphid	Cotton/melon aphid	Pea aphid	Cowpea aphid	Black bean aphid	Buckthorn aphid	Sugarbeet root aphid	Identified non-vector	Total # captured	Total Vectors	PVY Risk Index
Forest River	20-Jul	0	11	4	0	7	0	0	0	0	0	0	0	1	6	0	0	10	39	29	2.46
Hatton	20-Jul	0	21	1	0	12	0	0	0	0	1	0	2	0	1	0	2	79	119	38	3.6
Ada	27-Jul	0	45	12	0	13	0	0	0	0	3	0	0	3	0	0	2	20	98	76	7.28
Cando	27-Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crookston	27-Jul	0	38	5	0	4	0	0	1	0	0	0	0	0	0	0	2	12	62	48	4.51
Erskine	27-Jul	0	17	2	0	2	0	0	0	0	2	0	0	0	0	0	1	4	28	23	2.6
Forest River	27-Jul	0	6	0	0	1	0	2	2	0	3	0	0	0	1	0	1	3	19	15	1.87
Gully	27-Jul	0	24	0	0	13	0	0	0	0	2	0	0	0	2	0	0	3	44	41	3.85
Hallock	27-Jul	1	2	0	0	5	0	0	0	0	0	0	1	2	0	0	0	3	14	11	1.67
Hatton	27-Jul	0	7	0	0	4	0	0	0	0	3	0	1	0	1	0	2	24	42	16	2.1
Hoople	27-Jul	0	11	16	0	4	0	0	2	0	0	0	2	1	0	0	1	22	59	36	3.33
Lake of the Woods	27-Jul	0	105	1	0	2	0	0	0	0	5	0	0	0	0	0	0	15	128	113	12.2
Langdon	27-Jul	1	0	1	0	15	0	1	1	0	0	0	0	0	7	1	0	10	37	27	3.16
Linton I	27-Jul	0	0	1	0	6	0	0	0	0	1	0	0	0	0	0	1	1	10	8	0.7
Linton II	27-Jul	0	0	1	0	0	0	0	0	0	3	0	3	0	0	0	1	2	10	7	1.6
Motley	27-Jul	0	169	14	0	8	0	0	1	0	11	0	0	4	0	0	0	4	211	207	22.05
Perham	27-Jul	0	53	3	0	4	0	1	0	0	10	3	0	4	0	0	0	7	85	78	9.09
Sabin	27-Jul	0	11	0	0	5	0	0	0	0	0	0	1	0	1	0	4	5	27	18	1.65
Staples	27-Jul	0	23	17	0	0	0	0	0	0	3	0	0	1	0	0	0	1	45	44	4.91
Stephen	27-Jul	0	4	1	0	3	0	0	1	0	3	0	0	0	0	2	1	11	26	14	2.56
Tappen	27-Jul	0	0	0	0	1	0	0	0	0	3	0	0	0	0	0	0	3	7	4	0.95

Weekly trap catch at winter grow-out location.

Metam Sodium Control of Verticillium Wilt in High OM and Fine-Textured Soils
Submitted to MN Area II and NPPGA

Neil C. Gudmestad
Department of Plant Pathology
North Dakota State University

Executive Summary

Verticillium wilt, caused by *Verticillium dahliae* Kleb, is the principle pathogen involved in the early dying syndrome and is arguably the most economically damaging disease of potato in the USA when considering direct and indirect losses due to the disease and the cost of control. Soil fumigation with metam sodium is the primary means by which irrigated potato producers manage this disease. Approximately 34 million pounds of the active ingredient metam sodium are applied by the potato industry each year for the control of *Verticillium* wilt at cost of nearly $200 million, not including the cost of application. Metam sodium recently has been re-registered by the Environmental Protection Agency (EPA), but with considerable restrictions placed on its use. The increased scrutiny by EPA and environmental groups on the application of metam sodium for soil-borne pathogen control increases the need to establish best management practices for sub-surface shank applications of this soil fumigant. The purpose of the research proposed here is to fine-tune recommendations for shank applications of metam sodium based on soil propagule numbers of *V. dahliae,* soil temperature, injection depth and rate of chemical to improve disease control while also potentially reducing the amount of fumigant applied. An indirect result of this research will be an improvement in the sustainability of irrigated potato production. Previous research established parameters for proper fumigation of soils with a loamy sand texture and organic matter (OM) contents less than 1.3%. However, many potato production soils in North Dakota and Minnesota have a sandy loam to silt loam texture (a finer texture than our previous research) and OM contents of >2%. The proposed research will be directed at improving soil fumigation under these types of soils.

Research Objectives

1) Determine the efficacy of metam sodium based on rate, soil temperature and inoculum level of *V. dahliae* in irrigated sandy loam/silt loam soils with OM >2%.
2) Develop guidelines for sub-surface metam sodium applications at different soil temperatures that effectively control *V. dahliae* while also complying with more restrictive impending EPA mandates

Current Research

MN Area II and the NPPGA previously funded research on soil fumigation in 2010 and 2011. This research concentrated on developing effective metam sodium use strategies for improving efficacy in controlling *V. dahliae* populations in a low OM soils with a sandy texture (Pasche et al., 2014). The variables studied were metam sodium rate (0, 40, 50, 60, & 70 gal/a), depth of shank injection (two depths at 6” & 10” vs. single injection at 10”) and soil temperature at the time of application (39F vs 55-59F). In the light soil where these studies were conducted we found no rate response among the metam sodium rates used. A rate of 40 gal/a reduced Verticillium wilt and increased total and marketable yields to the same degree as rates of 50 to 70 gal/a. Control of Verticillium wilt was significantly better when metam sodium was applied at 39F compared to 55 or 59F. Finally, there was no significant difference in Verticillium wilt control or yield of potatoes when metam sodium was injected at a single depth of 10” compared to traditional split applications at 6” & 10” (Pasche, et al., 2014). This research has dramatically changed the recommendations we make regarding how, what time, and the rate of metam sodium for Verticillium wilt control.

While it is apparent that the shank injection of metam sodium at cold soil temperatures (39F), at a single depth (10”) at a relatively low rate (40 gal/a) in light soils with relatively low OM will optimize Verticillium wilt control at the lowest possible cost to the grower, we were asked many times by potato growers if these application parameters are also ideal for fine textured soils with higher OM levels (>2%). These growers have asked if similar studies as those discussed here be performed on silt loam type soils with higher OM levels. A finer soil texture and higher OM levels may impede the movement of MITC gas through the soil profile thus reducing fumigation efficacy.

The first year of this two year study was initiated in the fall of 2014. All of the treatments were established in a field in the Ponsford Prairie near Osage, MN in a field with 2.3% OM. Site specific soil samples were taken before and after soil fumigation to determine metam sodium efficacy for each soil temperature at application, metam sodium rate, and injection depth combination. The field was be planted to Russet Burbank in the spring of 2015 and data such as Verticillium propagule reduction, stand, weekly wilt development, total and marketable yield, was collected throughout the season.

Results and Discussion

Levels of *V. dahliae* in the field were very high and averaged nearly 69 vppg in the non-fumigated plots which is over 8-fold higher than the economic threshold for Russet Burbank (Table 1). Previous research by our research group has demonstrated that high levels of Vd such as this cannot be completely ameliorated by soil fumigation (Pasche, et al. 2014; Taylor, et al. 2005). However, shank injection of metam sodium, regardless of injection depth, significantly reduced Vd propagules at both the 0-4” and 4-8” soil depths and all rates of the soil fumigant significantly reduced vppg although there was no rate response due to metam sodium (Table 1). Soil temperature at the time of shank injection had no effect on metam sodium efficacy which is in direct contrast to previous research on sandy soils with low organic matter (Pasche, et al. 2014). In previous studies soil temperatures of 39F at the time of fumigation significantly improved metam sodium efficacy compared to temperatures of 55-59F. Improvement of metam sodium efficacy when injected at 38F compared to 54F was not evident in the silt loam soil type used in the current study.

Reductions of Verticillium propagules ranged from 49 to 61% in the 0-4” soil depth and from 73 to 80% in the 4-8” depth across all rates of metam sodium, however, there was no increased reduction observed with higher rates of the fumigant (Table 2). Injection of metam sodium at 6 and 10” depths, compared to injection at a single 10” depth, significantly improved metam sodium efficacy in reducing Verticillium propagules in the 0-4” depth, but not in the 4-8” depth. This is in direct contrast of previous research in a low organic matter sandy soil in which there were no differences in efficacy of metam sodium due to injection depth. It is likely that the finer textured silt loam soil used in this study slowed the movement of metam sodium to the upper 0-4” soil profile when the fumigant is injected at a single 10” depth thereby not allowing enough MITC to reach the soil surface to kill the Verticillium propagules.

Due to the high levels of Vd in the soil prior to soil fumigation, there was no significant reduction of Verticillium wilt observed with any rate of metam sodium compared to the non-fumigated control (Table 3). Likewise, soil temperature at the time of soil fumigation did not significantly affect efficacy. Interestingly, however, injection of metam sodium at two depths of 6 and 10” significantly decreased Verticillium wilt compared to the non-fumigated control and the injection of the fumigant at a single 10” depth. Once again, this suggests that splitting the injection of metam sodium when fumigating finer textured soils with >2% organic matter may improve efficacy of the fumigant.

Despite the high levels of Verticillium in the soil, soil fumigation with metam sodium significantly improved both total and marketable yields regardless of injection depth and rate of fumigant (Table 4). Percentages of tubers in each size category were also significantly increased due to soil fumigation. There were no significant differences in yield parameters due to soil temperature at the time of soil fumigation, however, and there were no differences in the percentages of US No. 1 or US No. 2 potatoes due to soil fumigation (Tables 4 & 5). The percentages of total unusables was significantly reduced with the use of metam sodium compared to the non-fumigated control (Table 5).

Summary

Results of the first year of this study suggest that the method by which a fine-textured soil with >2% organic matter is fumigated with metam sodium may be significantly different than what is recommended for coarse to medium textured sandy soils with <2% OM. In other words, with more coarse textured soils, metam sodium fumigation at a single depth of 10" in relatively cold soils (<40F) will significantly improve efficacy. However, in finer textured soils, such as a silt loam, movement of metam sodium vertically and horizontally may be much slower suggesting that split applications at 6 and 10" may still be warranted to improve efficacy. Additionally, soil temperature at the time of fumigation may be less of a factor to improve efficacy in a finer textured silt loam soil compared to a sandy loam soil. It is interesting to note that in the previous studies we found there to be no rate response of metam sodium in low organic matter soils with a medium 'sandy' texture. In other words, a relatively low rate of 40 gal/a was as efficacious as higher rates of the soil fumigant. Based on a first year of this study, the same trend appears to be true for a finer textured soil.

Literature Cited

Hamm, P. B., Ingham, R. E., Jaeger, J. R., Swanson, W. H., and Volker, K. C. 2003. Soil fumigant effects on three genera of potential soilborne pathogenic fungi and their effect on potato yield in the Columbia Basin of Oregon. Plant Dis. 87:1449-1456.

Nicot, P. C. and Rouse, D. I. 1987. Relationship between soil inoculum density of *Verticillium dahliae* and systemic colonization of potato stems in commercial fields over time. Phytopathology 77:1346-1355.

Pasche, J.S., Taylor, R.J., David, N., and Gudmestad, N.C. 2014. Effect of soil temperature, injection depth, and metam sodium rate on the management of Verticillium wilt of potato. Am. J. Potato Res. 91:277-290.

Taylor, R. J., Pasche, J. S. and Gudmestad, N. C. 2005. Influence of tillage and method of metam sodium application on distribution and survival of *Verticillium dahliae* in the soil and the development of potato early dying disease. Am. J. Potato Res. 82:451-461.

Table 1. Verticillium propagules per gram of soil (Vppg) at two depths as impacted by metam sodium.

Injection Depth	Rate	Soil Temp.	Vppg					
			Fall 2014			Spring 2015		
			0-4"	4-8"	0-8"	0-4"	4-8"	0-8"
Control	0 gal / a	54 F	90.2	60.8	151.0	105.0	86.0	191.0
10 in	40 gal / a	54 F	77.8	59.0	136.8	47.0	10.0	57.0
10 in	50 gal / a	54 F	114.2	82.2	196.4	61.4	22.0	83.4
10 in	60 gal / a	54 F	91.8	76.8	168.6	55.8	30.2	86.0
10 in	70 gal / a	54 F	86.6	46.4	133.0	46.8	11.6	58.4
Control	0 gal / a	38 F	103.2	61.4	164.6	81.0	60.6	141.6
10 in	40 gal / a	38 F	68.4	39.0	107.4	39.0	11.4	50.4
10 in	50 gal / a	38 F	52.6	31.8	84.4	40.6	18.8	59.4
10 in	60 gal / a	38 F	89.6	55.2	144.8	34.4	6.4	40.8
10 in	70 gal / a	38 F	91.2	34.6	125.8	35.8	18.4	54.2
Control	0 gal / a	54 F	85.6	63.2	148.8	35.6	37.6	73.2
6 in +10 in	40 gal / a	54 F	71.8	67.6	139.4	25.0	9.6	34.6
6 in +10 in	50 gal / a	54 F	96.8	51.6	148.4	29.2	6.6	35.8
6 in +10 in	60 gal / a	54 F	95.8	61.8	157.6	22.6	9.8	32.4
6 in +10 in	70 gal / a	54 F	95.4	49.2	144.6	37.4	3.2	40.6
Control	0 gal / a	38 F	84.8	40.0	124.8	53.6	36.2	89.8
6 in +10 in	40 gal / a	38 F	80.4	40.4	120.8	22.2	7.0	29.2
6 in +10 in	50 gal / a	38 F	77.8	44.6	122.4	20.2	4.0	24.2
6 in +10 in	60 gal / a	38 F	67.4	32.6	100.0	22.2	8.6	30.8
6 in +10 in	70 gal / a	38 F	53.8	38.8	92.6	13.0	5.8	18.8
LSD$_{P = 0.05}$			NS	NS	NS	NS	32.4	72.7
Control			91.0	56.4	147.3	68.8	55.1	123.9
10 in			84.0	53.1	137.2	45.1	16.1	61.2
6 in +10 in			79.9	48.3	128.2	24.0	6.8	30.8
LSD$_{P = 0.05}$			NS	NS	NS	17.6	12.9	29.0
	0 gal / a		91.0	56.4	147.3	68.8	55.1	123.9
	40 gal / a		74.6	51.5	126.1	33.3	9.5	42.8
	50 gal / a		85.4	52.6	137.9	37.9	12.9	50.7
	60 gal / a		86.2	56.6	142.8	33.8	13.8	47.5
	70 gal / a		81.8	42.3	124.0	33.3	9.8	43.0
LSD$_{P = 0.05}$			NS	NS	NS	24.4	16.9	39.4
		54 F	90.6	61.9	152.5	46.6	22.7	69.2
		38 F	76.9	41.8	118.8	36.2	17.7	53.9
LSD$_{P = 0.05}$			NS	10.3	20.7	NS	NS	NS

Early = 1st Fumigation on 10/15/2014 Late = 2nd Fumigation on 11/5/2014

Table 2. Percentage reduction of Verticillium propagules per gram of soil (Vppg at two depths as impacted by metam sodium.

Injection Depth	Rate	Timing	Vppg			
			Percentage Reduction (decimalized)			
			0-4"	t Grouping	4-8"	t Grouping
Control	0 gal / a	54 F	-0.14	D	-0.40	D
10 in	40 gal / a	54 F	0.33	ABCD	0.83	A
10 in	50 gal / a	54 F	0.43	ABCD	0.74	A
10 in	60 gal / a	54 F	0.39	ABCD	0.59	A
10 in	70 gal / a	54 F	0.46	ABCD	0.70	A
Control	0 gal / a	38 F	0.12	BCD	-0.11	BCD
10 in	40 gal / a	38 F	0.25	ABCD	0.70	A
10 in	50 gal / a	38 F	-0.05	CD	0.42	ABC
10 in	60 gal / a	38 F	0.61	AB	0.85	A
10 in	70 gal / a	38 F	0.58	ABC	0.53	ABC
Control	0 gal / a	54 F	0.60	AB	0.39	ABCD
6 in +10 in	40 gal / a	54 F	0.67	AB	0.86	A
6 in +10 in	50 gal / a	54 F	0.68	AB	0.87	A
6 in +10 in	60 gal / a	54 F	0.77	A	0.84	A
6 in +10 in	70 gal / a	54 F	0.61	AB	0.93	A
Control	0 gal / a	38 F	0.37	ABCD	-0.23	CD
6 in +10 in	40 gal / a	38 F	0.72	AB	0.83	A
6 in +10 in	50 gal / a	38 F	0.71	AB	0.91	A
6 in +10 in	60 gal / a	38 F	0.65	AB	0.75	A
6 in +10 in	70 gal / a	38 F	0.76	A	0.83	A
LSD$_{P = 0.05}$			NS		NS	
Control			0.24	B	-0.09	B
10 in			0.38	B	0.67	A
6 in +10 in			0.69	A	0.85	A
LSD$_{P = 0.05}$			0.24		0.27	
	0 gal / a		0.24	B	-0.09	B
	40 gal / a		0.49	AB	0.80	A
	50 gal / a		0.44	AB	0.73	A
	60 gal / a		0.61	A	0.76	A
	70 gal / a		0.60	A	0.75	A
LSD$_{P = 0.05}$			NS		0.35	
		54 F	0.48	A	0.48	A
		38 F	0.47	A	0.47	A
LSD$_{P = 0.05}$			NS		NS	

Early = 1st Fumigation on 10/15/2014 Late = 2nd Fumigation on 11/5/2014

Table 3. Impact of metam sodium on Verticillium wilt development.

Injection Depth	Rate	Soil Temp.	Wilt (% Severity)								AUDPC	RAUDPC
			7/23	7/30	8/6	8/12	8/20	8/26	9/2	9/8		
Control	0 gal / a	54 F	1.10	2.46	6.99	45.96	56.96	89.45	99.57	.	780.8	0.16613
10 in	40 gal / a	54 F	0.29	0.53	5.13	11.79	14.90	41.18	82.60	98.42	961.04	0.20448
10 in	50 gal / a	54 F	0.42	0.49	3.98	20.55	21.78	51.14	88.92	98.25	646.35	0.13752
10 in	60 gal / a	54 F	1.28	0.58	4.19	21.51	21.50	46.63	77.50	.	229.36	0.0488
10 in	70 gal / a	54 F	0.23	0.42	3.81	15.05	18.03	30.36	66.94	91.63	1035.88	0.2204
Control	0 gal / a	38 F	2.36	2.01	13.33	53.97	83.71	97.17	100.00	100.00	1418.07	0.30172
10 in	40 gal / a	38 F	0.31	0.81	3.98	15.68	22.93	32.19	77.00	95.97	1140.14	0.24258
10 in	50 gal / a	38 F	0.23	0.65	3.75	11.23	17.90	37.29	71.89	89.36	1064.58	0.22651
10 in	60 gal / a	38 F	0.40	0.37	3.51	13.65	14.54	27.43	70.33	93.75	467.72	0.09951
10 in	70 gal / a	38 F	0.45	0.55	3.86	18.51	25.29	37.62	62.86	84.55	851.82	0.18124
Control	0 gal / a	54 F	1.63	1.16	11.71	34.29	34.80	84.82	.	.	295.85	0.06295
6 in +10 in	40 gal / a	54 F	0.86	0.66	3.55	12.79	21.62	27.71	75.00	.	193.92	0.04126
6 in +10 in	50 gal / a	54 F	0.40	0.68	3.43	15.32	26.75	39.43	87.74	98.27	799.5	0.17011
6 in +10 in	60 gal / a	54 F	0.29	0.52	4.80	16.97	21.18	47.72	85.09	97.25	915.93	0.19488
6 in +10 in	70 gal / a	54 F	0.21	0.35	3.85	11.93	15.04	30.66	73.21	97.08	601.55	0.12799
Control	0 gal / a	38 F	0.34	1.07	4.80	16.70	17.93	73.33	98.00	.	197.77	0.04208
6 in +10 in	40 gal / a	38 F	0.27	0.41	3.14	17.81	17.15	38.99	83.13	96.25	612.32	0.13028
6 in +10 in	50 gal / a	38 F	0.35	0.37	2.43	11.17	15.03	24.72	38.25	75.05	477.58	0.10161
6 in +10 in	60 gal / a	38 F	0.19	0.29	2.43	10.54	12.24	23.22	59.70	86.31	476.77	0.10144
6 in +10 in	70 gal / a	38 F	0.21	0.38	3.88	17.06	16.13	26.83	62.73	89.43	452.9	0.09636
LSD$_{P = 0.05}$			0.32	0.31	1.56	5.90	7.96	12.37	13.51	5.58	448.50	0.09540
Control			1.35	1.69	9.58	42.91	54.94	89.84	99.57	100.00	673.12	0.14322
10 in			0.45	0.55	4.02	15.63	19.84	37.06	73.42	92.75	799.61	0.17013
6 in +10 in			0.35	0.46	3.47	14.88	18.12	34.02	70.60	90.47	566.31	0.12049
LSD$_{P = 0.05}$			0.24	0.19	1.11	4.46	6.77	8.03	12.02	NS	209.50	0.04460
	0 gal / a		1.35	1.69	9.58	42.91	54.94	89.84	99.57	100.00	673.13	0.14322
	40 gal / a		0.44	0.61	3.98	14.63	18.99	36.59	79.91	96.80	726.86	0.15465
	50 gal / a		0.35	0.54	3.45	15.02	20.00	37.90	70.22	88.86	747.01	0.15894
	60 gal / a		0.73	0.51	4.33	17.23	21.11	44.48	76.82	92.96	599.87	0.12763
	70 gal / a		0.28	0.40	3.59	15.25	17.56	30.52	66.92	90.62	640.04	0.13618
LSD$_{P = 0.05}$			0.30	0.24	1.41	5.50	8.18	9.64	12.48	8.95	NS	NS
		54 F	0.66	0.78	5.02	20.17	23.25	46.87	80.06	96.04	646.02	0.13745
		38 F	0.51	0.69	4.55	18.94	24.73	40.77	69.42	89.38	715.97	0.15233
LSD$_{P = 0.05}$			NS	NS	NS	NS	NS	NS	7.30	3.92	NS	NS

Early = 1st Fumigation on 10/15/2014 Late = 2nd Fumigation on 11/5/2014

Table 4. Impact of metam sodium on potato yield and grade.

Injection Depth	Rate	Soil Temp.	Total Yield (cwt/a)	Market Yield (cwt/a)	Total >10 oz. (%)	Total 6 - 9 oz. (%)	Total >6 oz. (%)	Total 3 - 6 oz (%)	Specific Gravity
Control	0 gal / a	54 F	302.15	278.52	8.67	35.79	44.46	47.75	1.078
10 in	40 gal / a	54 F	443.02	422.51	23.48	42.67	66.15	29.21	1.083
10 in	50 gal / a	54 F	424.13	393.82	17.82	42.92	60.74	32.22	1.084
10 in	60 gal / a	54 F	402.79	374.45	12.35	44.99	57.34	35.52	1.085
10 in	70 gal / a	54 F	460.47	428.33	20.12	43.42	63.54	29.23	1.086
Control	0 gal / a	38 F	342.56	312.02	8.40	36.95	45.35	45.68	1.083
10 in	40 gal / a	38 F	431.92	395.43	23.85	38.16	62.01	29.21	1.084
10 in	50 gal / a	38 F	459.77	428.45	22.89	38.57	61.46	31.75	1.084
10 in	60 gal / a	38 F	465.29	420.48	18.31	38.99	57.30	33.02	1.087
10 in	70 gal / a	38 F	429.77	394.74	19.25	40.37	59.62	32.05	1.087
Control	0 gal / a	54 F	292.79	246.24	7.24	32.52	39.76	43.24	1.080
6 in +10 in	40 gal / a	54 F	404.59	376.08	16.11	41.59	57.70	35.02	1.085
6 in +10 in	50 gal / a	54 F	467.04	434.26	23.78	40.68	64.45	28.58	1.085
6 in +10 in	60 gal / a	54 F	424.54	393.53	21.08	39.63	60.71	31.91	1.085
6 in +10 in	70 gal / a	54 F	481.11	454.96	18.01	46.31	64.32	30.22	1.086
Control	0 gal / a	38 F	377.56	344.32	15.72	36.46	52.17	38.99	1.081
6 in +10 in	40 gal / a	38 F	487.33	464.07	23.12	43.44	66.56	28.66	1.088
6 in +10 in	50 gal / a	38 F	481.46	444.11	25.53	40.85	66.38	25.86	1.087
6 in +10 in	60 gal / a	38 F	512.33	482.30	24.83	42.66	67.49	26.65	1.087
6 in +10 in	70 gal / a	38 F	480.93	439.76	16.09	39.62	55.70	35.75	1.089
LSD$_{P = 0.05}$			97.23	104.08	NS	NS	NS	NS	NS
Control			328.76	295.28	10.00	35.43	45.43	43.91	1.080
10 in			439.64	407.27	19.76	41.26	61.02	31.52	1.085
6 in +10 in			467.41	436.13	21.07	41.85	62.91	30.33	1.086
LSD$_{P = 0.05}$			37.59	39.27	5.85	3.03	6.86	5.54	0.002
	0 gal / a		328.76	295.28	10.00	35.43	45.43	43.91	1.080
	40 gal / a		441.72	414.52	21.64	41.46	63.10	30.52	1.085
	50 gal / a		458.10	425.16	22.50	40.75	63.25	29.60	1.085
	60 gal / a		451.24	417.69	19.14	41.57	60.71	31.77	1.086
	70 gal / a		463.07	429.44	18.37	42.43	60.79	31.81	1.087
LSD$_{P = 0.05}$			48.77	51.26	7.22	3.80	8.63	6.97	0.003
		54 F	410.26	380.27	16.87	41.05	57.92	34.29	1.083
		38 F	446.89	412.57	19.80	39.61	59.40	32.76	1.086
LSD$_{P = 0.05}$			NS	NS	NS	NS	NS	NS	NS

Early = 1st Fumigation on 10/15/2014 Late = 2nd Fumigation on 11/5/2014

Table 5. Impact of metam sodium on potato yield and grade.

Injection Depth	Rate	Soil Temp.	>10 oz. (%)		6 - 9 oz. (%)		3 - 6 oz (%)		Unusables (%)			
			US No. 1	US No. 2	US No. 1	US No. 2	US No. 1	US No. 2	Total	Under-size	Hollow Heart	Other
Control	0 gal / a	54 F	7.85	0.82	33.34	2.46	43.50	4.26	7.79	7.40	0.00	0.40
10 in	40 gal / a	54 F	22.37	1.11	39.98	2.69	27.15	2.06	4.65	4.49	0.00	0.16
10 in	50 gal / a	54 F	17.05	0.77	40.61	2.31	30.29	1.94	7.04	4.97	1.93	0.15
10 in	60 gal / a	54 F	12.11	0.24	42.88	2.11	33.83	1.69	7.15	6.82	0.17	0.16
10 in	70 gal / a	54 F	19.05	1.08	41.90	1.52	27.62	1.61	7.23	4.74	2.25	0.24
Control	0 gal / a	38 F	8.10	0.30	34.98	1.97	43.69	1.99	8.98	8.04	0.65	0.29
10 in	40 gal / a	38 F	21.90	1.95	36.97	1.19	27.81	1.40	8.80	7.04	1.31	0.46
10 in	50 gal / a	38 F	21.79	1.10	36.50	2.08	29.85	1.90	6.81	5.65	0.88	0.28
10 in	60 gal / a	38 F	15.79	2.52	36.76	2.24	31.43	1.59	9.69	6.87	2.43	0.39
10 in	70 gal / a	38 F	16.33	2.92	37.92	2.46	30.09	1.96	8.33	4.70	3.26	0.37
Control	0 gal / a	54 F	6.84	0.40	29.99	2.54	41.33	1.91	17.01	14.27	0.00	2.74
6 in +10 in	40 gal / a	54 F	14.05	2.07	39.24	2.35	33.39	1.63	7.30	5.90	1.29	0.12
6 in +10 in	50 gal / a	54 F	20.46	3.32	38.76	1.92	26.91	1.68	6.98	4.98	1.47	0.53
6 in +10 in	60 gal / a	54 F	18.60	2.48	37.84	1.80	30.15	1.76	7.39	5.24	1.85	0.30
6 in +10 in	70 gal / a	54 F	17.03	0.98	44.09	2.22	28.21	2.02	5.45	5.15	0.00	0.30
Control	0 gal / a	38 F	14.29	1.43	34.42	2.04	36.95	2.04	8.84	7.35	1.39	0.10
6 in +10 in	40 gal / a	38 F	21.75	1.37	40.97	2.47	26.62	2.04	4.78	4.57	0.00	0.21
6 in +10 in	50 gal / a	38 F	23.84	1.70	38.34	2.51	24.50	1.37	7.76	4.47	2.99	0.30
6 in +10 in	60 gal / a	38 F	23.20	1.63	39.94	2.72	25.07	1.58	5.88	4.44	1.16	0.28
6 in +10 in	70 gal / a	38 F	15.77	0.32	37.90	1.72	34.08	1.67	8.56	6.91	0.40	1.26
$\text{LSD}_{P\,=\,0.05}$			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Control			9.27	0.74	33.18	2.25	41.36	2.55	10.65	9.26	0.51	0.88
10 in			18.30	1.46	39.19	2.07	29.76	1.77	7.46	5.66	1.53	0.27
6 in +10 in			19.34	1.73	39.63	2.21	28.61	1.72	6.76	5.21	1.14	0.41
$\text{LSD}_{P\,=\,0.05}$			5.37	NS	2.93	NS	5.46	0.55	2.47	2.44	3.08	NS
	0 gal / a		9.27	0.74	33.18	2.25	41.36	2.55	10.65	9.26	0.51	0.88
	40 gal / a		20.02	1.62	39.29	2.18	28.74	1.78	6.38	5.50	0.65	0.24
	50 gal / a		20.78	1.72	38.55	2.20	27.88	1.72	7.15	5.02	1.82	0.31
	60 gal / a		17.43	1.72	39.35	2.22	30.12	1.65	7.52	5.84	1.40	0.28
	70 gal / a		17.04	1.32	40.45	1.98	30.00	1.81	7.39	5.37	1.48	0.54
$\text{LSD}_{P\,=\,0.05}$			6.61	NS	3.65	NS	6.86	0.69	3.11	NS	NS	NS
		54 F	15.54	1.33	38.86	2.19	32.24	2.05	7.80	6.39	0.90	0.51
		38 F	18.27	1.52	37.47	2.14	31.01	1.75	7.84	6.00	1.45	0.39
$\text{LSD}_{P\,=\,0.05}$			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Early = 1st Fumigation on 10/15/2014 Late = 2nd Fumigation on 11/5/2014

Minimizing Phytotoxicity and Quantify Efficacy of Phosphorous Acid

Submitted to the MN Area II and NPPGA

Andrew P. Robinson
Department of Plant Sciences
North Dakota State University/University of Minnesota

Neil Gudmestad
Department of Plant Pathology
North Dakota State University

Executive Summary

Phosphorous acid is commonly used as a method to reduce pink rot of potatoes in storage. Some of the challenges of using this product are that it burns leaves when foliar applied. Data indicate that this foliar damage can be reduced by adjuvants, but injury is still too high for grower acceptance. Additional data indicate that foliar applications likely increase the amount of phosphites in tubers. This study evaluated the effects of various phosphorous acid products on plant injury, but no injury was observed. Another study found differences in timing and rates of phosphorous acid treatments applied foliar on Russet Burbank. From these studies, the data suggestions that multiple applications of 5-7 pt/a of phosphoric acid with one application occurring during bulking will provide the least injury and best protection from pink rot.

Research Objectives

1) Determine how injury can be reduced with foliar phosphorous acid treatments
2) Quantify the amount of phosphonic acid needed in tubers to provide disease protection by application rate and timing
3) Validate the efficacy of phosphorous acid by surveying potato growers

Current Research

Injury Study

Previous work on phosphorous acid has examined the effectiveness of adding surfactants to phosphorous acid to reduce foliar injury. It was found that silicone surfactants were able to reduce injury when tank mixed with 4.2 lb ai/a phosphorous acid (5 pt/a Phostrol), but not at 8.4 lb ai/a phosphorous acid (10 pt/a Phostrol). In the current study Reveille and Phostrol were applied at various rates to test for injury differences with and without Silkin (Table 1). Phostrol at 5 and 10 pt/a has 4.2 and 8.4 lb ai/a phosphorous acid, respectively. Reveille was applied at 5, 8, and 16 pt/a which represents 2.4, 4.2, and 8.4 lb ai/a phosphorous acid, respectively. Treatments were applied on July 14, 2015 with a 9-foot handheld boom pressurized with CO_2 and calibrated to deliver 10 gal/a. Plots were rated for visual injury symptoms and estimated for biomass loss on 20 and 27 July and 11 August (1, 2 and 4 weeks after treatment). There were no significant differences in crop injury or biomass loss. This is one of the challenge working with this product is the inconsistent results. The environment, plant health, or timing before the next irrigation may effect phosphorus acid injury.

Rate Study

A trial was established near Park Rapids, MN in a commercial planted Russet Burbank field that would not receive any phosphorous acid treatments during the season. A randomized complete block design was utilized with 4 replicates and 12 treatments (Table 2). Plots measured 12 by 30. Emergence was on May 28 and row closure in June 28. Treatments were applied from hooking (June 18) through mid bulking (July 23). Plants in plots were visually evaluated for injury and biomass loss. Harvest was completed on September 25 by digging 25 row feet with a small plot harvester. All tubers were subsequently graded into <4, 4-6, 6-10, 10-14, and >14 oz size categories (Table 3)

Pink rot control differed between treatments (Table 2). Treatments 1 through 7 were used to determine if an early treatment of phosphorous acid could be applied at high rates with a ground sprayer to reduce injury and provide sufficient control of pink rot in storage. The severity of pink rot declined as the rate increased from 5 to 20 pt/a, but rates higher than 20 pt/a caused less control of pink rot than 20 pt/a. Multiple treatments of phosphorous acid were more effective than a single early treatment, except for treatment 11 which had 10 pt/a of Phostrol applied on 18 and 25 June. When Phostrol was applied in multiple treatments and had at least one treatment applied on or after July 9th, pink rot control was the best.

There were differences in graded yield, but differences were somewhat inconsistent between treatments (Table 3) Thus, it is difficult to tell from this one-year study what is causing some of these differences in yield. The non-treated check had the highest numerical yield. The 3 applications of 7 pt/a Phostrol (treatment 8) had a similar yield to the non-treated check, the treatment with four applications of 5 pt/a Phostrol (treatment 9) and 2 applications of 10 pt/a Phostrol later in the season (treatment 10) had a reduction in yield. There doesn't appear to be enough of information to determine why these yield differences occurred.

The first year of this study did indicate that early treatments did reduce pink rot incidence, but rates of 10-25 pt/a were needed. A more effective way of loading tubers with phosphites would be to make multiple applications of 5-7 pt/a starting at dime sized tubers. Multiple applications of low amounts (5-7 pt/a) of phosphoric acid at the right time with a surfactant/silicone will provide the least injury and best protection from pink rot.

Grower Survey

Samples were taken from 11 fields from growers. These fields had received foliar phosphorus acid treatments. Tubers were challenge inoculated and sent to laboratories for phosphite testing. Pink rot severity varied somewhat between fields (Table 4). Samples are still being testing the for phosphite content. Differences in pink rot severity were found in the challenge inoculation. Depth ranged from 5.3 to 15.9 mm. Differences may be attributed to total active ingredient applied, cultivar, environmental conditions, and plant growth stage.

Table 1. Phosphorous acid injury treatments applied at Lisbon, ND in 2015.

Treatment		Rate
1	Non-treated	0
2	Reveille	5 pt/a
3	Phostrol	5 pt/a
4	Reveille	8 pt/a
5	Phostrol	10 pt/a
6	Reveille	16 pt/z
7	Phostrol + Silkin	10 pt/a + 0.06% v/v
8	Phostrol + Silkin	10 pt/a + 0.13% v/v
9	Phostrol + Silkin	10 pt/a + 0.25% v/v
10	Reveille + Silkin	16 pt/a + 0.06% v/v
11	Reveille + Silkin	16 pt/a + 0.13% v/v
12	Reveille + Silkin	16 pt/a + 0.25% v/v
13	Sysstem-Ready + Agrobest Liquid + Micro-Mix	2.5 qt/a + 1 gal/a + 1 qt/a
14	Sysstem-K + Sysstem-Cal + Micro-Mix DL	1 qt/a + 2 qt/a + 1 qt/a

Table 2. Treatments applied near Park Rapids, MN 2015 and severity of pink rot on Russet Burbank tubers tested. Least significant difference determined at P=0.05.

Treatment		Rate (pt/a)	Treatment date	Pink rot severity (penetration depth in mm)
1	Non-treated	0		26.6
2	Phostrol	5	18-Jun	23.1
3	Phostrol	10	18-Jun	20.4
4	Phostrol	15	18-Jun	16.0
5	Phostrol	20	18-Jun	11.8
6	Phostrol	25	18-Jun	16.5
7	Phostrol	30	18-Jun	22.2
8	Phostrol	7	9-Jul	1.4
	Phostrol	7	16-Jul	
	Phostrol	7	23-Jul	
9	Phostrol	5	9-Jul	0.0
	Phostrol	5	16-Jul	
	Phostrol	5	23-Jul	
	Phostrol	5	30-Jul	
10	Phostrol	10	9-Jul	0.6
	Phostrol	10	23-Jul	
11	Phostrol	10	18-Jun	13.0
	Phostrol	10	25-Jun	
12	Phostrol	10	18-Jun	2.9
	Phostrol	10	25-Jun	
	Phostrol	10	9-Jul	
	LSD			*7.6*

Table 3. Graded yield of Russet Burbank potato after receiving foliar phosphorous acid treatments near Park Rapids, MN 2015. Least significant difference determined at P=0.05, ns=not significant.

Treatment		Rate (pt/a)	Treatment Date	<4 oz	4-6 oz	6-10 oz	10-14 oz	> 14 oz	Total	Total marketable	#1s > 4 oz	#2s > 4 oz	> 6 oz	> 10 oz
				cwt/a									%	
1	Non-treated	0		52	99	218	89	53	511	460	433	26	71	28
2	Phostrol	5	18-Jun	54	96	176	79	60	467	413	391	22	68	30
3	Phostrol	10	18-Jun	59	123	209	72	33	496	438	424	14	63	21
4	Phostrol	15	18-Jun	49	103	191	87	37	469	420	400	20	67	27
5	Phostrol	20	18-Jun	55	100	194	80	37	466	411	405	7	67	25
6	Phostrol	25	18-Jun	62	117	174	84	32	468	407	391	16	62	25
7	Phostrol	30	18-Jun	51	104	223	80	43	502	452	422	30	69	25
8	Phostrol	7	9-Jul	57	123	214	96	20	510	454	438	16	65	23
	Phostrol	7	16-Jul											
	Phostrol	7	23-Jul											
9	Phostrol	5	9-Jul	61	113	170	68	39	450	392	369	23	61	23
	Phostrol	5	16-Jul											
	Phostrol	5	23-Jul											
	Phostrol	5	30-Jul											
10	Phostrol	10	9-Jul	66	112	188	62	26	453	388	373	14	61	19
	Phostrol	10	23-Jul											
11	Phostrol	10	18-Jun	58	113	203	91	39	503	445	437	8	66	26
	Phostrol	10	25-Jun											
12	Phostrol	10	18-Jun	62	111	204	71	27	475	414	395	19	64	21
	Phostrol	10	25-Jun											
	Phostrol	10	9-Jul											
	LSD			*ns*	*ns*	*31.1*	*ns*	*ns*	*40.8*	*42.6*	*44.8*	*ns*	*ns*	*ns*

Table 4. Grower field survey pink rot challenge following foliar phosphorous acid treatments. Samples are from North Dakota and Minnesota. Least significant difference determined at P=0.05.

Sample	Treatment	Total product applied	Pink rot severity
		pt/a	penetration depth, mm
1	7 pt/a air 3x	21	10.1
2	10 pt/a ground rig + 7 pt/a air + 4 pt/a air	21	15.3
3	10 pt/a ground rig + 7 pt/a air 2x	24	5.3
4	5 pt/a air 4x	20	7.2
5	10 pt/a ground + 5 pt/a air	15	14.5
6	5 pt/a air 4x	20	14.1
7	5 pt/a air 3x	15	14.4
8	4 pt/a air 3x	12	6.5
9	4 pt/a air 3x	12	15.9
10	4 pt/a air 4x	16	7.5
11	4 pt/a air 4x	16	9.1
LSD			*6.9*

Nitrogen Response of New Potato Varieties Selected for Low Tuber Reducing Sugars

Na Sun, Carl Rosen, James Crants, and Matt McNearney
Department of Soil, Water, and Climate
University of Minnesota

Abstract: Acrylamide, a known neurotoxin and potential carcinogen, is formed in fried potato products from reducing sugars and asparagine precursors. Since its discovery in 2002, decreasing the acrylamide concentration in fries and chips has been a high priority for the potato industry. Cultivar and nitrogen (N) fertilizer management have been shown to affect acrylamide forming potential by influencing the concentration of tuber reducing sugars and asparagine. The objective of this study was to evaluate the agronomic performance and acrylamide forming potential of new potato cultivars developed for low tuber reducing sugar concentrations. New cultivars, Dakota Russet and Easton (AF3001-6), were compared with Russet Burbank under five N rates (120, 180, 240, 300 and 360 lb/A), at the Sand Plain Research Farm in Becker, Minnesota in 2014 and 2015. Tuber yield and size distribution were evaluated after harvest. Reducing sugar (glucose) concentrations were determined at harvest and following 16 and 32 weeks of storage at the USDA-ARS Potato Research Worksite in East Grand Forks, Minnesota. In 2014, cultivar and N rate effects were significant for yield and sugar concentration. The N rate by cultivar interaction was not significant for yield in either year indicating that N response was similar among the varieties. Easton had larger tubers (greater than 6 oz), and higher yields than the other two varieties. Dakota Russet had lower yields but larger tubers than Russet Burbank. Marketable yield and tuber size increased quadratically with N rate up to 240 lb/A in 2014, but increased linearly to 360 lb N/A in 2015. Glucose concentrations in the stem end were much higher than in the bud end for all varieties. At the harvest and 32 week storage dates in 2014 and the harvest date in 2015, the effect of N rate on tuber glucose concentrations depended on variety. Glucose concentrations of Russet Burbank tubers in the stem end decreased linearly with increasing N rate in 2014 whereas the N rate effect was not significant in the other two varieties. In 2015, there was a trend for increasing stem end glucose with N rate, although the effect was most pronounced in Russet Burbank. Dakota Russet and Easton tubers had significantly lower glucose concentrations than Russet Burbank tubers in both the stem and bud ends. In general, variety selection is a more effective and consistent approach to lower tuber reducing sugar than N management.

Background

Acrylamide is a compound formed during the Maillard reaction when potato products are fried and has been identified as a neurotoxin and possible carcinogen. Reducing acrylamide content in fried potato products has therefore become a priority in the potato industry. Acrylamide concentrations can be deceased by reducing the two precursors in the raw tubers: reducing sugars (mainly fructose and glucose) and the amino acid, asparagine. Both variety selection and cultural practices such as nitrogen management can affect reducing sugars and asparagine. While nitrogen management can affect tuber reducing sugars and asparagine concentrations, the limiting factor in acrylamide formation during potato frying in most cases is reducing sugars. In other words, asparagine concentrations are generally high in all conventionally bred potato varieties and not limiting. In contrast, reducing sugars can vary widely and if kept low, acrylamide concentrations in fried products will also be low. Therefore, identifying varieties with low reducing sugar forming potential and nitrogen practices that optimize yield and result in low reducing sugar levels will help to reduce acrylamide formation in fried products.

In 2012, a national research project was funded by the USDA/NIFA Specialty Crop Research Initiative. This project led by the University of Wisconsin, involved potato researchers from the University of Maine, University of Idaho, Washington State University, and the University of Minnesota. One of the goals of this research was to identify promising varieties from breeding programs around the US that have low acrylamide concentrations when fried. For the first two years of the project a variety trial was conducted to identify promising selections. Fourteen new genotypes from five states (Colorado, Idaho, Maine, Oregon and Wisconsin) in

2013, and eleven new genotypes/varieties from five states (Idaho, Maine, Wisconsin, North Dakota and Minnesota) in 2014 were evaluated for tuber yield and quality and glucose concentrations in five locations in the U.S. Following these variety trials, two promising selections were identified for further agronomic evaluation relative to Russet Burbank, the industry standard. The two varieties selected for further study in Minnesota were Easton (AF3001-6, a Maine variety) and Dakota Russet (ND8229-3, a North Dakota variety).

The objectives of this study were to (1) determine the effects of variety and N rate on tuber quality, yield and size distribution; (2) characterize variety and N rate effects on glucose concentrations at harvest and storage over 32 weeks.

Materials and Methods

This study was conducted at the Sand Plain Research Farm in Becker, Minnesota, on a Hubbard loamy sand soil in 2014 and 2015. The previous crop was winter rye. Average soil chemical properties before planting were as follows (0-6") in 2014 and 2015 were: pH, 6.0, 6.3; organic matter, 6.0, 6.3 %; Bray P1, 35, 31 ppm; ammonium acetate extractable K, Ca and Mg, 118, 94; 882, 919; and 150, 174ppm respectively; Ca-phosphate extractable SO_4-S, 3, 2 ppm; hot water extractable B, 0.3, 0.2 ppm; DTPA-Fe, DTPA-Mn, DTPA-Zn and DTPA-Cu, 39, 28;11, 8;1.8, 1.5; and 0.7, 0.7 ppm respectively. Extractable nitrate-N in the top 2 feet was 29 lb/A in 2014 and 13 lb/A in 2015.

Two new varieties (Dakota Russet and Easton) and Russet Burbank were subjected to five N fertilizer treatments, 120, 180, 240, 300 and 360 lb/A. Prior to planting, 200 lb/A 0-0-60, 200 lb/A 0-0-22 and 90 lb N/A Environmentally Smart Nitrogen (ESN) per plot were broadcasted and incorporated by chisel plow. At planting, 30 lb N/A, 130 lb/A P_2O_5, 181 K_2O, 44 lb/A S, 20 lb/A Mg, 1 lb/A Zn, 0.5 lb/A B were banded 3 inches to each side and 2 inches below the seed piece in all plots. The rest of the N for each treatment was applied at emergence (0, 60, 120, 180, and 240 lb N/A).

A randomized complete block design with four replications in a factorial treatment arrangement of N rate and variety was used. Each plot consisted of seven rows with row five and six as harvest rows. Spacing between rows was 36'' and seeds were spaced 12" apart within each row. Harvest rows of each plot had two red potato plants at both ends as markers. Whole "B" seed of Russet Burbank, and cut "A" seed of Dakota Russet and Easton were hand planted in furrows. Belay insecticide was applied in-furrow for beetle control, along with the systemic fungicide Quadris. Weeds, diseases, and other insects were controlled using standard practices. Rainfall was supplemented with sprinkler irrigation using the checkbook method of irrigation scheduling.

Due to varying weather conditions, the growing season length differed each year. Tubers were planted on 6 May in 2014 and 21 April in 2015. All plots were machine harvested on 2 October in 2014 and 28 September in 2015. Tuber yield and size distribution were graded after harvesting. Following tuber grading, tuber subsamples were collected to determine hollow heart and specific gravity. Tubers were stored at 48^{o}F for 32 weeks. Glucose concentrations were measured in tuber bud and stem ends at the USDA-ARS Potato Research Worksite in East Grand Forks, MN using a YSI-2700 industrial sugar analyzer at harvest and after 16 and 32 weeks storage.

Results

Tuber yield and size distribution

In both years, the variety by N rate interaction was generally not significant for tuber yield and size distribution (Tables 1 and 2). Exceptions included percentage of tubers greater than 6 oz in 2015, and No.2 > 4 oz and 4-6 oz tubers in both years. The main effects of variety and N rate were significant for yield and most tuber size categories. In general, yields were 13-14% higher in 2015 compared to 2014, which was likely due to an earlier planting date and longer growing season in 2015.

In 2014, the variety effect was significant for all yield and tuber size categories (Table 1). Total and marketable yields ranked as follows: Easton > Russet Burbank > Dakota Russet. Russet Burbank had significantly higher yields in the categories of tubers < 10 oz and No.2 tubers > 4 oz than Dakota Russet and Easton. For No.1 tubers, tuber > 10 oz and percentage of tubers greater than 6 and 10 oz, Easton had the significantly higher yield than Dakota Russet and Russet Burbank. Similar results for tuber yield and size distribution response to variety were obtained in 2015, except that the 6-10 oz tuber size was not affected by variety and Easton had significantly higher No.2 tubers than the other varieties (Table 2).

In 2014, the N rate effect was significant for all yield and tuber size categories except for 0-4 oz tubers (Table 1). Yields increased quadratically (up to 240 lb N/A) for No.1 tubers, large tubers (> 10 oz, % > 6 oz and % > 10 oz), total and marketable yields and linearly for No.2 tubers. Yield decreased quadratically (4-6 oz tubers) and linearly (6-10 oz) with increasing N rate. In 2015, the N rate effect was not significant for 0-4 oz and 6-10 oz tubers (Table 2). Unlike 2014 which was generally a quadratic response to N, yields of No.1 tubers, No.2 tubers, large tubers (> 10 oz, % > 6 oz and % > 10oz), total and marketable yields increased linearly with increasing N rate, up to 360 lb N/A. Yield decreased linearly with increasing N rate for 4-6 oz tubers.

Over the two year period, the trends for total and marketable yields were as follows: Easton > Russet Burbank > Dakota Russet. For undersize tubers < 4 oz): Russet Burbank > Dakota Russet = Easton. For misshapen tubers (#2s > 4 oz): Russet Burbank > Easton > Dakota Russet in 2014; and Easton > Russet Burbank > Dakota Russet in 2015. The effect of increasing N rate on increasing misshapen tubers was more pronounced for Russet Burbank and Easton than Dakota Russet both years.

Tuber quality and glucose concentration

The variety by N rate interaction was not significant for hollow heart in either year, but was significant for specific gravity in 2015 (Tables 3 and 4). The variety effect was significant for hollow heart and specific gravity in both years. Easton and Dakota Russet had less hollow heart, with same or higher level of specific gravity than Russet Burbank. The N rate effect for hollow heart and specific gravity were not consistent over the two years. Specific gravity responded to N rate in 2014, decreasing linearly with increasing N rate. In 2015, the effect of N rate on specific gravity depended on variety. For Russet Burbank and Easton, specific gravity slightly increased with increasing N rate, while for Dakota Russet, specific gravity tended to decrease with increasing N rate. The percentage of tubers with hollow heart was not consistently affected by N rate in 2014. In 2015, the response to N rate was quadratic with higher incidence at the 180 lb N/A rate. Overall the incidence of hollow heart was much lower in 2015 compared to 2014 for all varieties.

Glucose concentrations at the stem and bud end over 32 weeks of storage are only available for 2014; although concentrations at harvest are available for both years (Tables 3 and 4). The stem end had higher glucose concentrations than the bud end at all sampling times. In 2014, glucose concentrations in both the stem and bud ends decreased during storage. Stem end glucose concentrations at harvest and after 32 weeks storage depended on the interaction of variety by N rate. At harvest, stem end glucose decreased linearly for Russet Burbank and Dakota Russet, but the N rate effect was not consistent and actually tended to increase with increasing N rate for Easton. The bud end at harvest tended to increase with N rate and the effect was more pronounced with Easton than the other two varieties. At 16 weeks only the variety effect was significant with Russet Burbank having higher glucose concentrations that Easton and Dakota Russet. After32 weeks, glucose concentrations in the stem end decreased with increasing N rate in Russet Burbank but the N rate effect was inconsistent for the newer varieties. In general and over the entire storage period, the new varieties Dakota Russet and Easton had significantly lower glucose concentrations at both ends of the tuber than Russet Burbank regardless of N rate.

In 2015, the effect of variety on glucose concentrations was consistent with the previous year. New varieties had significantly lower glucose concentrations than Russet Burbank, with Dakota Russet having the lowest concentrations in the stem end and Easton having the lowest concentrations in the bud end. The N rate effect and the interaction of variety by N rate were significant for stem end glucose, but had no effect on bud end glucose. In contrast to 2014, stem end glucose tended to increase linearly with increasing N, with the effect being more pronounced in Russet Burbank and Easton than Dakota Russet.

Conclusions

Generally, the interaction of variety by N rate was not significant for tuber yield and size distribution. However, the main effects of variety and N rate were significant and consistent. Increased N supply increased larger tubers and total and marketable yields, although the response to N rate depended on year. A quadratic response to N rate up to 240 lb N/A was obtained in 2014, while a linear response up to 360 lbs N/A was obtained in 2015. Dakota Russet and Easton had significantly more No.1 tubers and larger tubers than Russet Burbank. In contrast, total and marketable yields were highest for Easton followed by Russet Burbank, and lowest for Dakota Russet. Easton also had more No.2 tubers in 2015 than Russet Burbank and Dakota Russet. Overall, higher yields were obtained in 2015 than in 2014, most likely due to a longer growing season. As for tuber quality and glucose concentrations, the effect of N rate was inconsistent. In contrast, the variety effect was highly consistent for tuber quality and glucose content. Easton and Dakota Russet had significantly less hollow heart and lower glucose concentrations than Russet Burbank.

Table 1. Variety and N rate effect on tuber yield and size distribution in 2014.

Variety	N Rate (lb/A)	Tuber Yield (CWT/A)								% > 6 oz	% > 10 oz
		Total	MKT	1s > 4 oz	2s > 4 oz	0-4 oz	4-6 oz	6-10 oz	>10 oz		
Russet Burbank	120	488.7	419.4	302.4	117.0	69.3	172.9	195.0	51.5	50.0	10.3
Russet Burbank	180	540.9	484.9	366.1	118.8	56.1	109.6	212.3	162.9	69.2	29.9
Russet Burbank	240	529.6	487.0	385.1	103.4	42.6	96.2	181.4	209.5	74.4	40.2
Russet Burbank	300	513.0	468.1	350.8	117.2	45.0	88.6	171.0	208.5	74.1	40.8
Russet Burbank	360	564.8	507.5	363.6	143.9	57.3	101.8	178.9	226.8	71.8	40.1
Dakota Russet	120	367.6	338.8	301.5	37.4	28.7	60.0	154.7	124.1	75.8	33.7
Dakota Russet	180	445.9	423.1	372.2	50.9	22.8	46.9	133.7	242.5	84.7	54.8
Dakota Russet	240	492.1	462.5	395.3	67.2	29.7	51.2	132.3	278.9	83.6	56.8
Dakota Russet	300	478.7	453.4	386.8	66.6	25.3	65.9	139.1	248.5	80.9	51.3
Dakota Russet	360	471.7	450.1	375.5	74.6	21.6	52.9	120.6	276.7	84.3	58.8
Easton	120	495.1	470.2	417.8	52.4	24.9	73.5	185.1	211.5	80.3	43.2
Easton	180	619.9	603.9	553.0	50.9	16.0	53.3	172.9	377.7	88.7	60.9
Easton	240	600.5	587.5	503.4	84.1	13.0	46.7	130.5	410.2	90.1	68.3
Easton	300	575.2	560.0	458.4	101.7	15.2	46.8	119.3	393.9	89.2	68.5
Easton	360	623.7	605.7	469.2	136.5	18.0	44.0	121.0	440.8	90.0	70.8
Main Effect											
Variety	Russet Burbank	527.7 b	473.7 b	353.6 b	120.1 a	54.0 a	113.8 a	187.7 a	171.8 c	67.94 c	32.24 c
	Dakota Russet	451.2 c	425.6 c	366.3 b	59.3 c	25.6 b	55.4 b	136.1 b	234.2 b	81.84 b	51.07 b
	Easton	582.9 a	565.5 a	480.4 a	85.1 b	17.4 b	52.9 b	145.7 b	366.8 a	87.67 a	62.36 a
Significance		**	**	**	**	**	**	**	**	**	**
N rate	120 lb/A	450.4 c	409.5 c	340.6 d	68.9 d	41.0	102.1 a	178.3 a	129.1 c	68.69 b	29.07 c
	180 lb/A	535.6 ab	504.0 ab	430.4 a	73.5 cd	31.6	70.0 b	173.0 a	261.1 b	80.88 a	48.55 b
	240 lb/A	541.3 ab	512.8 ab	427.9 ab	84.9 bc	28.4	64.7 b	148.1 b	299.54 a	82.74 a	55.08 a
	300 lb/A	522.3 b	493.9 b	398.7 c	95.2 b	28.4	67.1 b	143.1 b	283.6 ab	81.39 a	53.52 ab
	360 lb/A	553.4 a	521.1 a	402.8 bc	118.4 a	32.3	66.2 b	140.2 b	314.8 a	82.05 a	56.56 a
Significance		**	**	**	**	NS	**	**	**	**	**
Interaction	Variety *N Rate	NS	NS	NS	*	NS	++	NS	NS	NS	NS
Linear N		**	**	*	**	NS	**	**	**	**	**
Quadratic N		**	**	**	NS	NS	**	NS	**	**	**

NS = non-significant; ++ = significant at 10%; * = significant at 5%; ** = significant at 1%

Table 2. Variety and N rate effect on tuber yield and size distribution in 2015.

Variety	N Rate (lb/A)	Tuber Yield (CWT/A)								% > 6 oz	% > 10 oz
		Total	MKT	1s > 4 oz	2s > 4 oz	0-4 oz	4-6 oz	6-10 oz	>10 oz		
Russet Burbank	120	573.5	476.6	397.5	79.1	96.9	189.1	186.9	100.6	50.2	17.6
Russet Burbank	180	598.2	513.6	446.0	67.6	84.6	148.0	218.8	146.8	61.0	24.7
Russet Burbank	240	614.9	531.9	460.7	71.2	83.0	130.6	211.0	190.3	65.2	30.9
Russet Burbank	300	619.8	548.2	463.4	84.8	71.6	115.5	187.0	245.6	69.3	39.4
Russet Burbank	360	653.1	578.4	476.5	101.8	74.8	110.1	201.1	267.1	71.2	40.2
Dakota Russet	120	491.7	460.0	445.8	14.2	31.7	78.3	218.0	163.7	77.6	33.2
Dakota Russet	180	498.6	472.9	461.4	11.5	25.7	95.2	208.0	169.7	76.0	34.6
Dakota Russet	240	521.8	494.4	490.0	4.3	27.5	94.9	195.6	203.8	76.5	39.1
Dakota Russet	300	528.1	493.1	488.0	5.1	35.1	101.0	199.8	192.2	74.0	36.1
Dakota Russet	360	545.0	508.7	499.8	8.9	36.3	99.6	193.1	216.0	75.0	39.5
Easton	120	592.8	557.2	493.6	63.7	35.6	98.0	208.4	250.8	77.5	42.3
Easton	180	649.3	622.3	539.6	82.7	27.0	81.2	214.4	326.7	83.3	50.2
Easton	240	666.9	638.4	499.6	138.8	28.5	76.8	190.0	371.6	84.2	55.7
Easton	300	699.5	665.7	498.4	167.3	33.8	72.8	172.6	420.3	84.7	60.1
Easton	360	707.9	665.1	547.9	117.3	42.7	74.9	186.1	404.1	83.5	57.2
Main Effect											
Variety	Russet Burbank	611.9 b	529.7 b	448.8 c	80.9 b	82.2 a	138.7 a	201.0	190.1 b	63.4 c	30.6 c
	Dakota Russet	517.1 c	485.8 c	477.0 b	8.8 c	31.2 b	93.8 b	203.0	189.1 b	75.8 b	36.5 b
	Easton	663.3 a	629.8 a	515.8 a	113.9 a	33.5 b	80.7 c	194.3	354.7 a	82.7 a	53.1 a
	Significance	**	**	**	**	**	**	NS	**	**	**
N rate	120 lb/A	552.7 d	497.9 c	445.6 b	52.3 c	54.8	121.8 a	204.4	171.7 d	68.4 b	31.0 c
	180 lb/A	582.0 c	536.3 b	482.4 a	53.9 bc	45.8	108.1 b	213.7	214.4 c	73.5 a	36.5 b
	240 lb/A	601.2 bc	554.9 ab	483.4 a	71.4 abc	46.3	100.8 bc	198.9	255.2 b	75.3 a	41.9 a
	300 lb/A	615.8 ab	569.0 a	483.2 a	85.7 a	46.8	96.4 bc	186.5	286.0 ab	76.0 a	45.2 a
	360 lb/A	635.3 a	584.1 a	508.1 a	76 ab	51.2	94.9 c	193.5	295.8 a	76.6 a	45.7 a
	Significance	**	**	++	++	NS	**	NS	**	**	**
Interaction	Variety *N Rate	NS	NS	NS	*	NS	**	NS	NS	**	NS
Linear N		**	**	*	*	NS	**	NS	**	**	**
Quadratic N		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = non-significant; ++ = significant at 10%; * = significant at 5%; ** = significant at 1%

Table 3. Variety and N rate effect on tuber quality and storage glucose concentration in 2014.

Variety	N Rate (lb/A)	Hollow Heart (%)	Specific Gravity	0 Week		16 Weeks		32 Weeks	
				Stem	Bud	Stem	Bud	Stem	Bud
Russet Burbank	120	22.5	1.0798	6.54	0.82	4.32	0.52	3.94	0.51
Russet Burbank	180	22.5	1.0823	5.31	1.06	5.95	0.91	3.60	0.40
Russet Burbank	240	30	1.0795	3.59	1.12	4.14	0.86	3.90	0.83
Russet Burbank	300	37.5	1.0756	3.91	0.75	3.32	0.45	2.47	0.35
Russet Burbank	360	22.5	1.0782	3.36	1.24	3.18	0.66	2.58	0.44
Dakota Russet	120	10	1.0833	1.35	0.39	0.33	0.25	0.32	0.13
Dakota Russet	180	17.5	1.0848	1.08	0.41	0.59	0.12	0.66	0.13
Dakota Russet	240	12.5	1.0814	1.02	0.30	0.64	0.15	0.39	0.18
Dakota Russet	300	7.5	1.0801	0.84	0.19	0.57	0.19	0.42	0.32
Dakota Russet	360	20	1.0782	0.87	0.35	0.63	0.31	0.42	0.14
Easton	120	5	1.0884	1.31	0.11	1.11	0.03	0.39	0.06
Easton	180	2.5	1.0881	2.35	0.20	1.26	0.02	0.25	0.08
Easton	240	7.5	1.0832	1.70	0.30	0.77	0.15	0.36	0.03
Easton	300	0	1.0824	1.96	0.32	0.72	0.23	0.66	0.03
Easton	360	2.5	1.0795	2.56	0.85	0.89	0.08	0.27	0.06
Main Effect									
Variety	Russet Burbank	27.0 a	1.0791 c	4.54 a	1.00 a	4.18 a	0.69 a	3.30 a	0.49 a
	Dakota Russet	13.5 b	1.0816 b	1.03 c	0.33 b	0.55 b	0.20 b	0.44 b	0.18 b
	Easton	3.5 c	1.0843 a	1.98 b	0.36 b	0.95 b	0.10 b	0.39 b	0.05 c
	Significance	**	**	**	**	**	**	**	**
N rate	120 lb/A	12.5	1.0839 a	3.07 a	0.44 b	1.92	0.24	1.55 a	0.24
	180 lb/A	14.2	1.0851 a	2.91 a	0.56 b	2.60	0.30	1.50 a	0.19
	240 lb/A	16.7	1.0814 b	2.10 b	0.57 b	1.85	0.39	1.55 a	0.35
	300 lb/A	15.0	1.0794 bc	2.24 b	0.42 b	1.53	0.27	1.18 b	0.22
	360 lb/A	15.0	1.0786 c	2.26 b	0.81 a	1.56	0.35	1.09 b	0.21
	Significance	NS	**	*	++	NS	NS	*	NS
Interaction	Variety *N Rate	NS	NS	**	NS	NS	NS	**	NS
Linear N		NS	**	**	++	NS	NS	**	NS
Quadratic N		NS	NS	NS	NS	NS	NS	NS	NS

NS = non-significant; ++ = significant at 10%; * = significant at 5%; ** = significant at 1%

Table 4. Variety and N rate effect on tuber quality and storage glucose concentration in 2015.

Variety	N Rate (lb/A)	Hollow Heart (%)	Specific Gravity	0 Week	
				Stem	Bud
Russet Burbank	120	2.0	1.0765	2.35	0.97
Russet Burbank	180	5.0	1.0761	2.41	0.64
Russet Burbank	240	8.0	1.0768	2.47	0.65
Russet Burbank	300	5.1	1.0779	2.09	0.90
Russet Burbank	360	3.1	1.0770	3.72	0.84
Dakota Russet	120	1.0	1.0818	0.63	0.46
Dakota Russet	180	4.0	1.0768	0.76	0.49
Dakota Russet	240	1.0	1.0733	0.76	0.52
Dakota Russet	300	1.0	1.0768	0.69	0.48
Dakota Russet	360	0.0	1.0745	0.84	0.34
Easton	120	0.0	1.0789	1.14	0.28
Easton	180	3.0	1.0790	1.92	0.32
Easton	240	0.0	1.0798	1.94	0.27
Easton	300	0.9	1.0785	1.70	0.14
Easton	360	0.0	1.0793	1.67	0.09
Main Effect					
Variety	Russet Burbank	4.6 a	1.0769 b	2.62 a	0.80 a
	Dakota Russet	1.4 b	1.0767 b	0.75 c	0.46 b
	Easton	0.8 b	1.0791 a	1.67 b	0.21 c
	Significance	**	*	**	**
N rate	120 lb/A	1.0 b	1.0791	1.43 b	0.57
	180 lb/A	4.0 a	1.0773	1.70 ab	0.50
	240 lb/A	3.0 ab	1.0766	1.72 ab	0.48
	300 lb/A	2.4 ab	1.0778	1.47 b	0.51
	360 lb/A	1.0 b	1.0769	2.08 a	0.42
	Significance	++	NS	++	NS
Interaction	Variety *N Rate	NS	*	++	NS
Linear N		NS	NS	*	NS
Quadratic N		*	NS	NS	NS

NS = non-significant; ++ = significant at 10%; * = significant at 5%; ** = significant at 1%

On-Farm Evaluation of Potato Response to Nitrogen Source and Rate and Length of History of Potato Cultivation

Carl Rosen, James Crants, and Matt McNearney
Department of Soil, Water, and Climate, University of Minnesota
crosen@umn.edu

Summary

A field experiment was conducted near Park Rapids, MN, in adjacent center pivot fields planted with Russet Burbank potatoes, to evaluate N fertilization strategies. The objectives of the study were (1) to find the optimum N application rate for this site (2) to evaluate different sources of N (3) to determine the effect of DCD, a nitrification inhibitor, on the value of uncoated urea as a N source for potatoes, and (4) to determine the effect of field planting history on the response of potato yield and tuber quality to N source and application rate. The response variables included tuber yield and size distribution, tuber quality, plant stand in mid July, and soil water NO_3-N concentration throughout the season. Ten treatments were applied in a randomized complete block design with four replicates. The effect of N application rate was evaluated by applying Environmentally Smart Nitrogen (ESN, Agrium, Inc.) at six rates at hilling just prior to emergence (0, 80, 120, 160, 200, and 240 lbs·ac^{-1} N). In addition to ESN, four other N sources were applied in treatments receiving 120 lbs·ac^{-1} N at hilling: urea, ammonium sulfate, SuperU (Koch Agronomic Services), and urea with dicyandiamide (DCD), a nitrification inhibitor. The study design was applied to adjacent fields under center-pivot irrigation. The old field was in its 15th year of potato cultivation, while the new field was in its second. In addition to the N applied at hilling, all treatments received 110 lbs·ac^{-1} N at other times in the old field and 108 lbs·ac^{-1} N in the new field. Soil water NO_3-N concentration tended to increase with N application rate in the new field, but not in the old field. N application rate significantly affected tuber yield, which peaked at rates of 160 – 200 lbs·ac^{-1} N as ESN at emergence (270 – 310 lbs·ac^{-1} N total) in both fields. The proportion of yield represented by larger size classes (over 6 or 10 ounces) increased with application rate across the range of rates tested. Tuber specific gravity decreased with increasing N application rate in the new field, but not in the old, and the same was true of plant stand. The source of N applied was less consequential than the application rate. SuperU produced higher soil water NO_3-N than urea in mid June, but there were no other effects of N source on any variable measured. The new field had a higher mean soil water NO_3-N concentration than the old in early to mid June, but a lower concentration from late June onward. There was a tendency for the old field to produce more very large tubers (> 14 oz) and fewer unusable tubers than the new field. Among the treatments used to evaluate the effect of N rate, the old field also had a higher mean tuber specific gravity than the new field. Overall, the effect of N application rate was much stronger than the effects of N source or field age, and we found no evidence that adding DCD to urea had any significant effect on its performance as a fertilizer. In previous years, the effects of field age have been more pronounced. The "new fields" used in those years were in their first seasons of potato cultivation, and it is possible that the effects of planting in a new field fade rapidly after the first year in potato production.

Background

Polymer coated ureas (PCUs) are controlled-release N fertilizers with a polymer coating that slows the diffusion of water into and urea out of urea granules. This reduces the risk of damaging seedlings with excessive ammonia (to which urea is initially converted by soil microbes) and losing N to volatilization of ammonia and leaching of nitrate (produced from ammonia by nitrification) before can take it up. In ten years of study at the Sand Plain Research Farm in Becker, Minnesota, Environmentally Smart Nitrogen (ESN, Agrium, Inc.: 44-0-0) has been found to be an effective N source for potatoes. It is not known, however, how relevant results at this site are to potato agriculture in other places.

In this study, we evaluated ESN in a field near Park Rapids, MN, approximately 120 miles NNW of Becker. ESN was tested at six different rates (0, 80, 120, 160, 200, and 240 lbs·ac^{-1} N) and compared with four other N sources at one of these rates (120 lbs·ac^{-1} N). The other sources were uncoated urea, ammonium sulfate, SuperU, and urea with dicyandiamide (DCD), a nitrification inhibitor. The products were applied at hilling, in addition to approximately 110 lbs·ac^{-1} N at planting and post-hilling.

A field's agricultural history potentially affects crop performance and the optimum rates and sources of N. To examine these effects, this study was conducted on in two adjacent center pivot fields. The "old field" had a 14-year history of potato cultivation, while the "new field" was in its second year of potato cultivation.

The objectives of this study were (1) to find the optimum application rate of N for Russet Burbank potatoes in fields near Park Rapids, MN, (2) to evaluate different N sources, including ESN, in these fields (3) to determine the effect of DCD on the value of uncoated urea as a N source for potatoes, and (4) to determine the effect of field planting history on the response of potato yield and tuber quality to N source and application rate.

Materials and Methods

The study was conducted in 2015 in two adjacent center-pivot-irrigated fields (Wade Kemper and Lil Wade) near Park Rapids, MN, in a Verndale-Nymore soil complex, using the potato cultivar Russet Burbank. The "new field" was planted on soil with a sandy texture (Verndale sandy loam) in an area that had had 1 previous potato crop. The "old field" was planted on similar soil (Verndale sandy loam and Nymore loamy sand) in an area that had had 14 previous potato crops. Characteristics of the top 10 inches of soil at planting are presented for each field in Table 1.

Within each field, ten treatments, as shown in Table 2, were established in a randomized complete block design with four replicates (40 plots per field). Russet Burbank B seed with an average size of 2.1 oz was planted on April 28 with 3-foot spacing between rows and 14-inch spacing within rows. Plots 50 feet long and 18 feet (6 rows) wide were marked on May 8. The fields were hilled on May 23 just prior to emergence. Shoot emergence occurred around May 28. Tubers harvested for analysis were collected from the central 20 feet of the middle two rows of each plot.

The new and old fields received, respectively, 675 and 418 lbs·ac^{-1} KCl (0-0-60) in the fall of 2014 (405 and 251 lbs·ac^{-1} K, respectively). At planting (April 28), the new field received 68 lbs·ac^{-1} N, 52 lbs·ac^{-1} P, 33 lbs·ac^{-1} S, and 1.1 lbs·ac^{-1} B as a mixture of urea (60 lbs·ac^{-1}), AMS (138 lbs·ac$^{-1)}$, MAP (100 lbs·ac^{-1}), and 15% boron (7 lbs/ac). The old field received 67 lbs·ac^{-1} N, 24 lbs·ac^{-1} S, and 1.1 lbs·ac^{-1} B as a mixture of urea (100 lbs·ac^{-1}), ammonium sulfate (100 lbs·ac^{-1}), and 15% boron (7 lbs/ac). Each field received N as fertigations with UAN (32-0-0) on June 22 and 29. The new field received 5.4 gal·ac^{-1} (19 lbs·ac^{-1} N) on June 22 and 6.1 gal·ac^{-1} (21 lbs·ac^{-1} N) on June 29. The old field received 7.0 gal·ac^{-1} (25 lbs·ac^{-1} N) on June 22 and 5.4

gal·ac^{-1} (19 lbs·ac^{-1} N) on June 29. In total, the new field received 108 lbs·ac^{-1} N and the old field received 110 lbs·ac^{-1} N as a baseline rate.

Study treatments differed in the amount and form of N applied at emergence hilling (May 22). Five treatments received 80, 120, 160, 200, or 240 lbs·ac^{-1} N as ESN, and four treatments received 120 lbs·ac^{-1} N as urea, ammonium sulfate, Super U, or urea with dicyandiamide (DCD), a nitrification inhibitor. A control treatment received no fertilizer at hilling.

Suction tube lysimeters were installed on May 8 and 13 in the new and old fields, respectively, to sample soil water at a depth of 4 feet. In each of the two fields, the lysimeters were placed in each plot in treatments 1, 3, and 6 – 10. Samples were collected on May 22 and 27, June 3, 10, 17, and 24, July 1, 8, 15, 22, and 29, August 10 and 19, and September 22. The samples were stored frozen and then tested for NO_3-N concentration. Lysimeters were installed in plots receiving 0, 120, or 240 lbs·ac^{-1} N at hilling as ESN (treatments 1, 3, and 6) and those receiving 120 lbs·ac^{-1} N at hilling as urea, ammonium sulfate, SuperU, or urea with DCD (treatments 7-10).

From May 27 through September 24, rainfall was monitored on-site, and overhead irrigation was applied as needed. Daily precipitation in this period is presented in Figure 1. Precipitation data from May 6 through May 26 was collected on-site by the grower (R. D. Offutt Company). Data from April 28 through May 5 come from the National Weather Service weather station in Park Rapids. Plant stand counts were conducted on the central 20 feet of the two harvest rows in each plot on July 10, 48 days after hilling. Petioles were collected on July 1, July 10, July 20, July 29, and August 7. The petiole of the 4th leaf from the end of a shoot was sampled from 25 plants per plot. Samples will be analyzed for NO_3-N concentration on a dry-weight basis with a Wescan N analyzer.

Tubers were harvested on September 23 and 24, and cleaned, sorted, and graded as soon as possible afterward. About 2.1% of harvested tubers were classified as "unusable," including those with serious internal defects. These were included in total yield, but not in other summary variables. Specific gravity was determined for a subset of marketable tubers from each plot.

To assess residual soil NO_3-N and NH_4-N concentrations after harvest, 12-inch soil cores were collected from each plot on October 13. These were analyzed for NO_3 and NH_4 concentrations using a Wescan N analyzer.

ANOVA tests were performed using the GLM procedure in SAS 9.4. To evaluate the effect of ESN application rate at hilling, analyses were performed on treatments 1 – 6, using field, ESN rate, replicate, and field*rate as independent variables. The effect of rate was also evaluated using linear and quadratic contrasts. To evaluate the effect of N source, analyses were performed that included only treatments 3 and 7-10, with field, N source, replicate, and field*source as independent variables. Where the field*rate or field*source interaction was not significant, Waller-Duncan k-ratio t-tests were performed on all significant results for the main effect of rate or source to determine the minimum significant difference between treatments.

Results:

Soil water NO_3-N

Results for soil water NO_3-N concentration 4 feet below the soil surface are presented in Table 3. Soil water NO_3-N concentration increased over time from May 22 to June 10 (new field) or June 24 (old field).

The relationship of soil water NO_3-N to N application rate (treatments 1, 3, and 6, Table 3a) differed between the two fields. In the new field, soil water NO_3-N increased with application rate on most sampling dates, though this relationship was not consistently significant and was not always evident. In the old field, there was rarely a significant relationship between N application rate and soil water NO_3-N, and on the only three dates when a relationship was present (July 8, July 15, and August 10), the treatment receiving the intermediate application rate (120 lbs·ac^{-1} N; treatment 3) had the highest soil water NO_3-N concentration.

N source (treatments 3, 7 – 10, Table 3b) was not generally related to soil water NO_3-N. Only on June 10 and 17, and only when both fields were considered together, was there a relationship. On those dates, the treatment receiving Super U (treatment 9) had higher soil water NO_3-N than the treatment receiving urea (treatment 7). On June 17, it also had higher soil water NO_3-N than the treatments receiving ESN (treatment 3) or urea with DCD (treatment 10). Field age was often a significant factor in soil water NO_3-N concentration, with the old field generally having higher concentrations than the new field. Only among the treatments receiving different N sources at a constant rate (treatments 3, 7 – 10) on June 3 did the new field have higher soil water NO_3-N than the old field.

Tuber yield and size

Results for tuber yield in the study plots are presented in Table 4. Outside of the study plots, the new field yielded 517.3 cwt·ac^{-1} and the old field yielded 500.2 cwt·ac^{-1}. In the analyses of the effects of N application rate (Table 4a), there were significant effects of the rate*field interaction term for total yield, usable yield, yield of U.S. No. 1 tubers, and marketable yield (all of which were closely related to each other). The significance of this interaction is attributable to high yield at 160 lbs·ac^{-1} N as ESN and low yield at 200 lbs·ac^{-1} N as ESN in the old field relative to the new. The two fields had very similar yield at all other application rates.

For treatments in the N rate study (treatments 1 – 6, Table 4a), the old field had higher yield of tubers over 14 ounces than the new. N application rate significantly influenced multiple tuber yield variables (Table 4a). The percentage of yield in tubers over 6 or 10 ounces increased steadily with application rate, as did the absolute yield of tubers over 14 ounces. In both the new and old fields, total yield, marketable yield, and yield of U.S. No. 1 tubers were low in the control treatment (treatment 1) and not consistently responsive to application rate among the treatments receiving any amount of ESN at hilling (treatments 2 – 6).

Among the treatments included in evaluating the effect of N source (treatments 3 and 7 – 10, Table 4b), there were almost no significant effects of N source, field age, or their interaction. The only exception was an effect of field age on the yield of unusable tubers, which was higher in the new field. (Unusable tubers are tubers of low quality, discussed further in the following section.)

Plant stand and tuber quality
The tuber quality results are shown in Table 5. Plant stand on July 10 was weakly negatively related to the application rate of ESN ($0.05 < P < 0.10$; treatments 1 – 6, Table 5a), with a significant linear contrast of stand against application rate ($p < 0.05$). This trend was evident in the new field (linear contrast $P < 0.05$), but not in the old field ($P > 0.10$). Plant stand was not related to N source (treatments 3, 7-10, Table 5b).

Among the treatments receiving different rates of ESN at hilling (treatments 1-6), tuber specific gravity was higher in the old field than the new, and it decreased with increasing N application rate. A larger proportion of the yield was unusable for reasons other than hollow heart or brown center in the new field, and this proportion tended to decrease with increasing N application rate.

Among the treatments receiving different sources of N at a uniform rate (treatments 3, 7 – 10), a larger proportion of yield was unusable for reasons other than hollow heart or brown center in the new field than the old, and the new field also had somewhat higher prevalences of both hollow heart and brown center. The greater proportion of unusable yield in the new field is probably not attributable to a higher prevalence of disease, since the two soil pathogens tested for (*Verticillium* and lesion nematodes) were much less abundant in the new field (Table 1).

Conclusions

The N application rate had significant effects on multiple yield variables. Total and marketable yield peaked at a total application rate of 270 – 310 $\text{lbs}\cdot\text{ac}^{-1}$ N (160 – 200 $\text{lbs}\cdot\text{ac}^{-1}$ N as emergence applied ESN) in both fields. The proportion of yield in tubers over 6 or 10 ounces increased with application rate across the range of rates tested, though with diminishing returns at higher rates. In contrast, the source of N used and the age of the field had few significant effects on yield variables in this season of the study.

The lack of any effect of N source is similar to results obtained from this study in 2013, when the sources evaluated were urea, ammonium sulfate, ESN, and a blend of ESN and Duration (a slower-release PCU than ESN). However, in 2014, N source influenced tuber yield (low for urea and Agrocote, which was 100% 44-0-0 that year, relative to ammonium sulfate, ESN, and ESN with Duration, with ESN producing especially high marketable yield), tuber size (low for urea), and the prevalence of hollow heart (low for ESN, but high for ESN with Duration). The cause of the inconsistency in the effect of N source from year to year is unclear, particularly since the two sources producing the most divergent results in 2014 (urea and ESN) were included in the study in all three seasons.

The effects of field age on tuber size and quality were less pronounced in 2015 than they have been in previous seasons. This may be a reflection of the age of the "new" field. In 2013 and 2014, the new field was in its first year of potato production. In 2015, the new field was in its second year of potato production. It is possible that the some of the effects of field age seen in previous years are very short-lived.

Table 1. Initial soil characteristics in each of the two study fields near Park Rapids, MN, in 2015.

Field	OM (%)	pH	CEC	Bray P (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)	S (ppm)	Zn (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)	B (ppm)	Sand (%)	Silt (%)	Clay (%)	*Verticillium* propagules per g soil	Lesion nematodes per g soil
New	1.8	5.8	8.8	63	130	169	1045	16.0	2.1	11.3	54	0.57	0.33	80	15	5	1	21
Old	1.7	6.1	9.0	107	175	226	1070	19.7	3.6	6.3	68	0.60	0.43	84	13	3	24	162

Table 2. N treatments tested on irrigated Russet Burbank potatoes near Park Rapids, MN, in 2015.

Treatment	Nitrogen source[1] at emergence	Nitrogen application rate at emergence ($lbs \cdot ac^{-1}$)	Total nitrogen application rate ($lbs \cdot ac^{-1}$)
1	Control	0	110
2	ESN	80	190
3	ESN	120	230
4	ESN	160	270
5	ESN	200	310
6	ESN	240	350
7	Urea	120	230
8	AS	120	230
9	SuperU	120	230
10	Urea + DCD	120	230

[1] Ammonium sulfate: 21-0-0. ESN (Environmentally Smart Nitrogen; Agrium, Inc.): 44-0-0. Urea, SuperU (Koch Agronomic Services): 46-0-0.

Figure 1. Inches of precipitation received as rainfall and irrigation between April 28 and September 24, 2015, in the study fields near Park Rapids, MN. Data for April 28 to May 5 were obtained from the National Weather Service weather station in Park Rapids. Data were collected by RD Offutt from May 6 to May 27. Data from May 27 to September 24 come from a weather station in the new field.

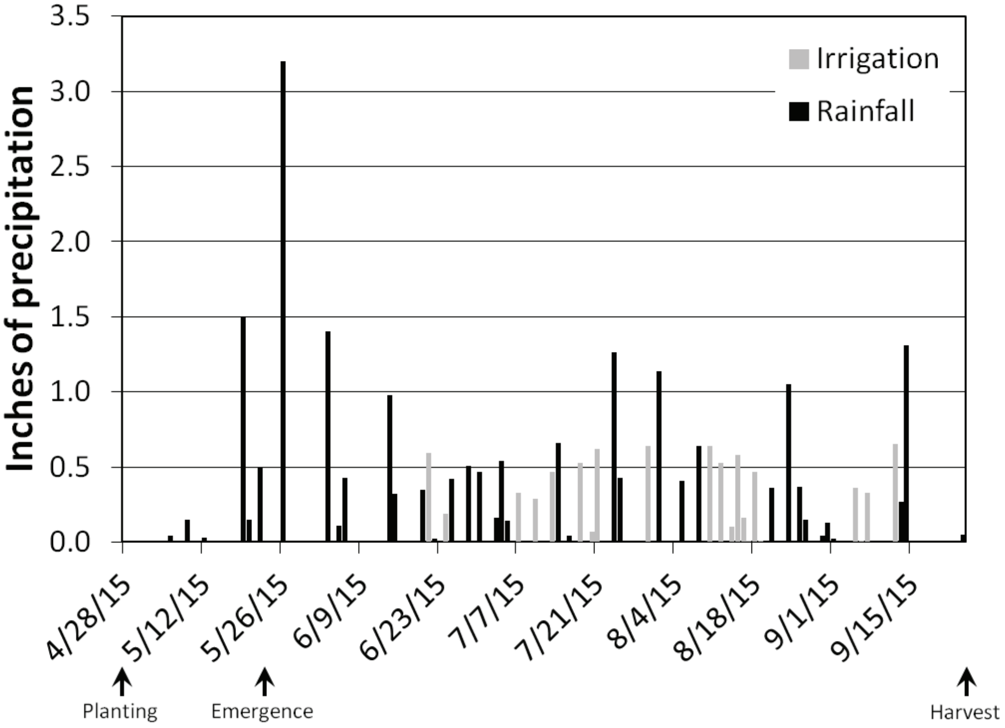


Table 3a. Effects of N application rate on soil water NO_3-N concentrations 4 feet below the soil surface of Russet Burbank potato fields in Park Rapids, MN, in 2015.

Nitrogen Treatments					Soil water NO_3-N (ppm)													
Field	Treatment	Nitrogen source[1]	Nitrogen application rate at emergence (lbs·ac^{-1})	Total nitrogen application rate (lbs·ac^{-1})	May 22	May 27	June 03	June 10	June 17	June 24	July 01	July 08	July 15	July 22	July 29	August 10	August 19	September 22
New	1	Control	0	110	15	23	44	85	70	40	50	54	48	48	49	55	43	31
	3	ESN	120	230	24	38	61	81	87	65	70	73	70	95	54	77	60	43
	6	ESN	240	350	29	47	82	98	104	97	87	83	70	72	67	73	70	57
Significance of application rate[2]					NS	*	*	NS	NS	++	++	NS	++	NS	NS	NS	NS	NS
Minimum significant difference ($P < 0.1$)					--	17	21	--	--	34	26	--	17	--	--	--	--	--
Contrasts[3]				Linear	NS	*	**	NS	NS	*	*	NS	++	NS	NS	NS	++	NS
				Quadratic	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Old	1	Control	0	110	25	45	74	84	84	120	120	87	84	78	99	73	90	96
	3	ESN	120	230	28	39	70	97	78	120	125	122	137	75	127	113	118	114
	6	ESN	240	350	31	42	68	97	78	117	125	88	127	89	112	110	88	78
Significance of application rate[2]					NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	++	NS	NS
Minimum significant difference ($P < 0.1$)					--	--	--	--	--	--	--	--	30	--	--	34	--	--
Contrasts[2]				Linear	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS
				Quadratic	NS	NS	NS	NS	NS	NS	NS	++	*	NS	NS	++	NS	NS
Both	1	Control	0	110	21	36	64	84	79	72	85	84	79	65	77	79	74	68
	3	ESN	120	230	26	39	66	90	97	102	101	98	103	88	103	101	89	73
	6	ESN	240	350	30	52	76	97	91	103	102	86	93	79	85	88	77	65
Significance of application rate[2]					NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Minimum significant difference ($P < 0.1$)					--	--	--	--	--	--	--	--	--	--	--	--	--	--
Contrasts[2]				Linear	NS	++	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
				Quadratic	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
New	All treatments				23	42	66	88	89	71	67	69	62	74	57	67	60	44
Old	All treatments				28	42	71	93	90	119	123	109	129	80	113	106	101	98
Significance of field age[2]					NS	NS	++	NS	NS	**	**	*	**	NS	**	*	*	**
Significance of rate*field interaction[2]					NS	++	*	NS	NS	++	NS	NS	NS	NS	NS	NS	NS	NS

[1] ESN (Environmentally Smart Nitrogen; Agrium, Inc.): 44-0-0.

[2] NS: not significant. ++, *, **: significant at 10%, 5%, and 1%, respectively.

Table 3b. Effects of N source on soil water NO_3-N concentrations 4 feet below the soil surface of Russet Burbank potato fields in Park Rapids, MN, in 2015.

Nitrogen Treatments					Soil water NO_3-N (ppm)													
Field	Treatment	Nitrogen source[1]	Nitrogen application rate at emergence ($lbs \cdot ac^{-1}$)	Total nitrogen application rate ($lbs \cdot ac^{-1}$)	May 22	May 27	June 03	June 10	June 17	June 24	July 01	July 08	July 15	July 22	July 29	August 10	August 19	September 22
New	3	ESN	120	230	24	38	61	81	87	65	70	73	70	95	54	77	60	43
	7	Urea	120	230	21	45	72	81	85	87	82	91	89	97	75	67	74	51
	8	AS	120	230	32	36	73	94	98	78	73	116	128	107	77	68	68	57
	9	SuperU	120	230	28	60	88	139	131	102	97	113	105	90	76	71	83	72
	10	Urea + DCD	120	230	21	26	57	109	97	110	100	98	94		57	86	78	74
Significance of nitrogen source[2]					NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Minimum significant difference (P < 0.1)					--	--	--	--	--	--	--	--	--	--	--	--	--	--
Old	3	ESN	120	230	28	39	70	97	78	120	125	122	137	75	127	113	118	114
	7	Urea	120	230	18	35	44	58	70	99	113	85	107	89	86	90	92	81
	8	AS	120	230	22	26	46	79	90	111	93	80	85	80	49	86	82	69
	9	SuperU	120	230	13	32	55	95	89	111	112	109	123	78	112	110	99	99
	10	Urea + DCD	120	230	28	29	36	69	78	109	97	106	114		109	75	83	65
Significance of nitrogen source[2]					NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Minimum significant difference (P < 0.1)					--	--	--	--	--	--	--	--	--	--	--	--	--	--
Both	3	ESN	120	230	26	39	66	90	82	102	101	98	103	88	103	101	89	73
	7	Urea	120	230	20	41	60	73	80	91	92	88	95	93	80	78	83	64
	8	AS	120	230	27	31	59	90	93	89	83	92	96	91	60	76	74	62
	9	SuperU	120	230	22	44	71	117	110	106	105	111	114	83	94	91	91	85
	10	Urea + DCD	120	230	25	28	44	92	88	110	99	102	104	--	88	79	80	69
Significance of nitrogen source[2]					NS	NS	NS	++	*	NS	NS	NS	NS	NS	NS	NS	NS	NS
Minimum significant difference (P < 0.1)					--	--	--	36	22	--	--	--	--	--	--	--	--	--
New	All treatments				25	41	72	102	101	89	86	94	92	96	70	72	72	59
Old	All treatments				22	32	51	84	82	112	109	102	116	81	98	96	97	85
Significance of field age[2]					NS	NS	*	NS	*	++	*	NS	NS	NS	*	*	**	**
Significance of source*field interaction[2]					NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	++

[1] Ammonium sulfate: 21-0-0. ESN (Environmentally Smart Nitrogen; Agrium, Inc.): 44-0-0. Urea, SuperU (Koch Agronomic Services): 46-0-0.

[2] NS: not significant. ++, *, **: significant at 10%, 5%, and 1%, respectively.

Table 4a. Effects of N application rate on Russet Burbank tuber yield, grade, and size distribution in Park Rapids, MN, in 2015.

Field	Nitrogen Treatments				Tuber yield											
	Treatment	Nitrogen source[1]	Nitrogen application rate at emergence (lbs·ac^{-1})	Total nitrogen application rate (lbs·ac^{-1})	Unusable	0-3 oz	3-6 oz	6-10 oz	> 10 oz	Total yield	Usable yield	#1s > 3 oz.	#2s > 3 oz	Marketable yield	> 6 oz	> 10 oz
					cwt·ac^{-1}										% of usable yield	
New	1	Control	0	110	7	46	175	145 c	19 d	392 c	385 d	313 c	26	339 c	43 c	5 c
	2	ESN	80	190	7	52	207	213 ab	61 c	540 b	533 ab	455 ab	26	481 ab	51 b	11 b
	3	ESN	120	230	17	41	178	207 ab	94 b	537 b	520 bc	455 ab	25	479 ab	58 ab	18 a
	4	ESN	160	270	19	38	168	188 b	98 b	511 b	492 c	423 b	31	453 b	58 ab	20 a
	5	ESN	200	310	26	50	168	223 a	127 a	594 a	568 a	490 a	28	518 a	62 a	22 a
	6	ESN	240	350	5	46	153	190 ab	110 ab	506 b	500 bc	428 b	26	454 b	60 a	22 a
Significance of application rate[2]					NS	NS	NS	**	**	**	**	**	NS	**	**	**
Minimum significant difference (P < 0.1)					--	--	--	34	24	49	38	43	--	42	7	6
Contrasts[3]				Linear	NS	NS	++	*	**	**	**	**	NS	**	**	**
				Quadratic	NS	NS	NS	**	*	**	**	**	NS	**	++	NS
Old	1	Control	0	110	8	48	195 a	165 c	32 d	448 c	440 c	370 c	22	392 c	45 d	7 d
	2	ESN	80	190	4	55	209 a	212 a	72 c	552 ab	548 ab	464 ab	29	493 ab	52 c	13 c
	3	ESN	120	230	5	42	185 a	185 bc	101 bc	518 b	513 b	443 b	27	471 b	56 bc	20 b
	4	ESN	160	270	10	47	192 a	205 ab	137 a	591 a	581 a	508 a	26	534 a	59 ab	23 ab
	5	ESN	200	310	15	41	145 b	197 ab	115 ab	513 b	498 bc	426 b	31	457 b	63 a	23 ab
	6	ESN	240	350	10	46	143 b	188 b	145 a	531 ab	521 ab	442 b	33	475 b	64 a	28 a
Significance of application rate[2]					NS	NS	**	*	**	*	*	**	NS	**	**	**
Minimum significant difference (P < 0.1)					--	--	26	22	30	62	62	51	--	47	6	5
Contrasts[2]				Linear	NS	NS	**	NS	**	*	*	*	NS	**	**	**
				Quadratic	NS	NS	*	*	NS	*	*	**	NS	**	NS	NS
Both	1	Control	0	110	7	47	185 b	155 c	26 d	420 b	413 b	342 b	24	366 b	44 d	6 e
	2	ESN	80	190	6	53	208 a	213 a	67 c	546 a	541 a	460 a	28	487 a	52 c	12 d
	3	ESN	120	230	11	41	182 b	196 ab	98 b	528 a	516 a	449 a	26	475 a	57 b	19 c
	4	ESN	160	270	15	42	178 b	195 ab	115 ab	545 a	530 a	459 a	28	488 a	59 ab	21 bc
	5	ESN	200	310	20	46	157 c	210 a	121 a	553 a	533 a	458 a	30	487 a	62 a	23 ab
	6	ESN	240	350	8	46	148 c	189 b	128 a	519 a	511 a	435 a	30	465 a	62 a	25 a
Significance of application rate[2]					NS	NS	**	**	**	**	**	**	NS	**	**	**
Minimum significant difference (P < 0.1)					--	--	21	19	18	38	34	32	--	31	4	3
Contrasts[2]				Linear	NS	NS	**	**	**	**	**	**	NS	**	**	**
				Quadratic	NS	NS	**	**	*	**	**	**	NS	**	NS	NS
New	All treatments				14	46	175	194	85	513	500	427	27	454	55	17
Old	All treatments				9	46	177	191	99	523	514	440	28	468	56	19
Significance of field age[2]					NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	++
Significance of rate*field interaction[2]					NS	NS	NS	NS	NS	*	*	*	NS	*	NS	NS

[1] ESN (Environmentally Smart Nitrogen; Agrium, Inc.): 44-0-0.

[2] NS: not significant. ++, *, **: significant at 10%, 5%, and 1%, respectively.

Table 4b. Effects of N source on Russet Burbank tuber yield, grade, and size distribution in Park Rapids, MN, in 2015.

Field	Nitrogen Treatments				Tuber yield											
	Treatment	Nitrogen source[1]	Nitrogen application rate at emergence (lbs·ac^{-1})	Total nitrogen application rate (lbs·ac^{-1})	Unusable	0-3 oz	3-6 oz	6-10 oz	> 10 oz	Total yield	Usable yield	#1s > 3 oz.	#2s > 3 oz	Marketable yield	> 6 oz	> 10 oz
					cwt·ac^{-1}										% of usable yield	
New	3	ESN	120	230	17	41	178	207	94	537	520	455	25	479	58	18
	7	Urea	120	230	9	57	170	210	91	538	528	437	35	471	57	17
	8	AS	120	230	10	50	202	213	70	545	534	462	22	485	53	13
	9	SuperU	120	230	15	45	188	206	82	536	521	451	25	476	55	16
	10	Urea + DCD	120	230	16	56	184	207	73	535	519	444	20	464	54	14
Significance of nitrogen source[2]					NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Minimum significant difference (P < 0.1)					--	--	--	--	--	--	--	--	--	--	--	--
Old	3	ESN	120	230	5	42	185	185	101	518	513	443	27	471	56	20
	7	Urea	120	230	3	56	184	179	76	498	495	420	20	439	52	15
	8	AS	120	230	6	59	176	207	98	545	539	451	29	480	56	18
	9	SuperU	120	230	2	55	217	194	73	541	538	459	24	484	50	14
	10	Urea + DCD	120	230	5	49	178	206	72	509	504	424	31	455	55	14
Significance of nitrogen source[2]					NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Minimum significant difference (P < 0.1)					--	--	--	--	--	--	--	--	--	--	--	--
Both	3	ESN	120	230	11	41	182	196	98	528	516	449	26	475	57	19
	7	Urea	120	230	6	56	177	195	83	518	512	428	27	455	54	16
	8	AS	120	230	8	54	189	210	84	545	537	456	26	482	55	16
	9	SuperU	120	230	9	50	202	200	78	538	530	455	25	480	53	15
	10	Urea + DCD	120	230	11	53	181	206	72	524	513	435	25	460	54	14
Significance of nitrogen source[2]					NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Minimum significant difference (P < 0.1)					--	--	--	--	--	--	--	--	--	--	--	--
New	All treatments				14	50	184	208	83	538	524	449	26	474	55	16
Old	All treatments				4	52	189	193	84	522	518	440	26	466	53	16
Significance of field age[2]					**	NS	NS	++	NS	NS	NS	NS	NS	NS	NS	NS
Significance of source*field interaction[2]					NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1] Ammonium sulfate: 21-0-0. ESN (Environmentally Smart Nitrogen; Agrium, Inc.): 44-0-0. Urea, SuperU (Koch Agronomic Services): 46-0-0.

[2] NS: not significant. ++, *, **: significant at 10%, 5%, and 1%, respectively.

Table 5a. Effects of N source on Russet Burbank tuber quality in Park Rapids, MN, in 2015.

(a)

Field	Nitrogen Treatments				Plant stand, July 10	Tuber Quality			
	Treatment	Nitrogen source[1]	Nitrogen application rate at emergence (lbs·ac^{-1})	Total nitrogen application rate (lbs·ac^{-1})		Specific Gravity	Hollow heart	Brown center	Other unusable
							% of usable yield		
New	1	Control	0	110	93	1.088 a	0.00	0.24	1.48
	2	ESN	80	190	95	1.082 bc	0.00	0.00	0.82
	3	ESN	120	230	93	1.085 ab	2.05	0.21	0.68
	4	ESN	160	270	86	1.081 c	2.27	0.00	1.06
	5	ESN	200	310	88	1.083 bc	3.20	0.00	0.51
	6	ESN	240	350	83	1.083 bc	0.10	0.00	0.23
Significance of application rate[2]					NS	*	NS	NS	NS
Minimum significant difference (P < 0.1)					--	0.004	--	--	--
Contrasts[2]				**Linear**	*	*	NS	NS	++
				Quadratic	NS	++	NS	NS	NS
Old	1	Control	0	110	93	1.087	0.48	0.00	0.34
	2	ESN	80	190	90	1.088	0.00	0.16	0.26
	3	ESN	120	230	94	1.088	0.26	0.00	0.35
	4	ESN	160	270	89	1.086	1.40	0.00	0.07
	5	ESN	200	310	93	1.086	1.45	0.62	0.21
	6	ESN	240	350	92	1.084	0.84	0.00	0.09
Significance of application rate[2]					NS	NS	NS	NS	NS
Minimum significant difference (P < 0.1)					--	--	--	--	--
Contrasts[2]				**Linear**	NS	NS	NS	NS	NS
				Quadratic	NS	NS	NS	NS	NS
Both	1	Control	0	110	93	1.088 a	0.24	0.12	0.91
	2	ESN	80	190	93	1.085 ab	0.00	0.08	0.54
	3	ESN	120	230	93	1.086 ab	1.15	0.11	0.51
	4	ESN	160	270	88	1.083 b	1.90	0.00	0.64
	5	ESN	200	310	90	1.085 b	2.33	0.31	0.36
	6	ESN	240	350	88	1.084 b	0.47	0.00	0.16
Significance of application rate[2]					++	++	NS	NS	NS
Minimum significant difference (P < 0.1)					6	0.003	--	--	--
Contrasts[2]				**Linear**	*	**	NS	NS	*
				Quadratic	NS	NS	NS	NS	NS
New	All treatments				90	1.084	1.27	0.08	0.80
Old	All treatments				92	1.087	0.71	0.13	0.23
Significance of field age[2]					NS	**	NS	NS	**
Significance of rate*field interaction[2]					NS	NS	NS	NS	NS

[1] ESN (Environmentally Smart Nitrogen; Agrium, Inc.): 44-0-0.

[2] NS: not significant. ++, *, **: significant at 10%, 5%, and 1%, respectively.

Table 5b. Effects of N source on Russet Burbank tuber quality in Park Rapids, MN, in 2015.

(b)

Field	Nitrogen Treatments				Plant stand, July 10	Tuber Quality			
	Treatment	Nitrogen source[1]	Nitrogen application rate at emergence (lbs·ac^{-1})	Total nitrogen application rate (lbs·ac^{-1})		Specific Gravity	Hollow heart	Brown center	Other unusable
							% of usable yield		
New	3	ESN	120	230	93	1.085	2.05	0.21	0.68
	7	Urea	120	230	95	1.087	1.14	0.00	0.38
	8	AS	120	230	86	1.088	0.51	0.32	0.71
	9	SuperU	120	230	89	1.085	0.54	0.37	1.34
	10	Urea + DCD	120	230	96	1.084	0.95	0.59	1.09
Treatment significance					NS	NS	NS	NS	NS
Treatment MSD (P < 0.1)					--	--	--	--	--
Old	3	ESN	120	230	94	1.088	0.26	0.00	0.35
	7	Urea	120	230	92	1.087	0.00	0.00	0.33
	8	AS	120	230	93	1.087	0.77	0.00	0.21
	9	SuperU	120	230	89	1.088	0.00	0.13	0.30
	10	Urea + DCD	120	230	94	1.088	0.57	0.00	0.31
Treatment significance					NS	NS	NS	NS	NS
Treatment MSD (P < 0.1)					--	--	--	--	--
Both	3	ESN	120	230	93	1.086	1.15	0.11	0.51
	7	Urea	120	230	93	1.087	0.57	0.00	0.36
	8	AS	120	230	90	1.088	0.64	0.16	0.46
	9	SuperU	120	230	89	1.087	0.27	0.25	0.82
	10	Urea + DCD	120	230	95	1.086	0.79	0.34	0.76
Treatment significance, both fields combined					NS	NS	NS	NS	NS
Treatment MSD (P < 0.1)					--	--	--	--	--
New	All treatments				92	1.086	1.06	0.30	0.85
Old	All treatments				92	1.088	0.28	0.03	0.30
Field significance					NS	NS	++	++	*
Field * Treatment significance					NS	NS	NS	NS	NS

[1] Ammonium sulfate: 21-0-0. ESN (Environmentally Smart Nitrogen; Agrium, Inc.): 44-0-0. Urea, SuperU (Koch Agronomic Services): 46-0-0.

[2] NS: not significant. ++, *, **: significant at 10%, 5%, and 1%, respectively.

Optimizing Potassium Management for Irrigated Potato Production Russet Burbank

Carl Rosen, Matt McNearney, James Crants, and Peter Bierman
Department of Soil, Water, and Climate, University of Minnesota
crosen@umn.edu

Summary: A field experiment was conducted at the Sand Plain Research Farm in Becker, MN to evaluate the effect of potassium (K) application rate and timing on Russet Burbank yield and quality, petiole K concentrations, and changes in soil test K at different depths in the soil. Twelve K treatments were tested: rates of 0, 90, 180, 270, and 360 lb K_2O/A applied in the fall, and a split application of 180 lb K_2O/A in the fall + 180 lb K_2O/A at emergence the following spring; and rates of 0, 90, 180, 270, and 360 lb K_2O/A applied in the spring preplant, and a split application of 180 lb K_2O/A preplant + 180 lb K_2O/A at emergence. Both total and marketable yields increased significantly as K rate increased to 270 lb K_2O/A, before leveling off at the higher K rates. Yield increases were due to significant increases in tuber size as K rate increased. When applied at the same total K rate, split-application treatments also tended to increase tuber size compared to single-application treatments. Application season (fall vs. spring) had no effect on total or marketable tuber yield, but fall application significantly increased the yield of #1 tubers > 3 oz in size and decreased yield of #2's in that size class. Scab increased significantly as K application rate increased, but incidence of hollow heart and brown center were very low and not affected by any treatment. Both specific gravity and dry matter were significantly greater when 360 lb K_2O/A was applied in a single rather than a split application, although the difference was greater for specific gravity. Tuber dry matter responded quadratically to K rate and was greatest at 180 lb K_2O/A. Petiole K was not affected by season of K application, but was significantly affected by K application rate. As K rate increased, petiole K concentrations increased significantly on three of the four sampling dates. All K treatments had sufficient petiole K on the 1st date. Concentrations were variable but not significantly different on the 2nd date, and on the 3rd date, only the zero K control was K deficient. By the 4th date only the 270- and 360-lb K_2O/A treatments had petiole K above the 8.0% sufficiency level, which was consistent with the fact that yields and tuber size peaked at the 270 lb K_2O/A treatment and then leveled off for the two 360-lb K_2O/A treatments. In the 0-6 in. soil depth, fall samples after harvest showed a significant linear increase in soil K as the K fertilizer rate increased. Single-application treatments also significantly increased soil K compared to split-application treatments applied at the same total K rate. The magnitude of changes in soil K between pre-fertilizer application and post- harvest levels reflected the same patterns among treatments as the post-harvest K levels themselves. For the zero K control, a 9 ppm decrease in soil K in the 0-6 in. soil depth over the growing season corresponded to the drawdown in soil K from a total tuber yield of 426 cwt/A. The 8 ppm soil K increase at 180 lb K_2O/A suggests that slightly less than this K rate is sufficient to maintain soil K in the 0-6 in. depth and provide a total yield of 539 cwt/A. The 564 cwt/A maximum yield occurred with 270 lb K_2O/A and increased soil test K 33 ppm, so the K requirement to both sustain K fertility and achieve maximum yield was greater than 180 lb K_2O/A, but possibly less than 270 lb K_2O/A. The current recommendation to obtain this yield at the average pre-application soil test K level of 50 ppm in this experiment is 400 lb K_2O/A. This recommendation is greater than the amount required for top yields and to sustain soil test K. However, it would increase soil K from a Low to Medium level, which could be beneficial in improving K fertility to a more desirable maintenance range. Soil samples collected before K application in the fall and pre-application in the spring both had K levels similar to the overall 50 ppm K average, so would both give the same K fertilizer recommendation and show that there would be no agronomic advantage to collecting samples for K in the fall vs. spring. Movement of fertilizer K below the zone of application is indicated by a significant linear increase in soil K as the K application rate increased in the post-harvest samples collected in the 6-12 in. soil depth. Increases were smaller than in the 12-24 in. depth, which could have been due to greater K uptake from this soil layer and/or deeper K leaching below 12 in. In the 12-24 in. soil depth, there was also a significant linear increase in soil K in the post-harvest fall samples as the K application rate increased. Soil K concentrations were actually greater in the 12-24 in. depth than in the 6-12 in. depth for all K treatments. There were several potential leaching events during the growing season, including 6.2 in. of rain over a 4 d period in August.

Background: Numerous questions about soil test potassium (K) levels and potential leaching losses of K were asked over several recent growing seasons. Agronomists noted lower petiole K levels than normal, which prompted questioning of when the soil should be tested for K. The currently recommended times are in the fall or early spring prior to planting. However, in some cases samples are taken in June of the previous season while soybeans are being grown. Research is needed to determine when soil test K provides a reasonable measure of K availability, how much K might be leaching below the crop root zone, and how much soil K drops after growing a crop of potatoes fertilized at various K rates.

The objectives of this study were to: 1) evaluate potato response to K fertilizer rate and timing, 2) determine K drawdown following a crop of potatoes, and 3) determine the extent of K movement through the growing season. This is the fourth year of the study and the second year that includes fall-applied K treatments.

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 soybean. Selected soil chemical properties before planting were as follows (0-6“): pH, 5.7; organic matter, 1.3%; Bray P1, 11 ppm; ammonium acetate extractable K, Ca, and Mg, 42, 474, and 109 ppm, respectively; Ca-phosphate extractable SO_4-S, 2.5 ppm; hot water extractable B, 0.13 ppm); and DTPA extractable Fe, Mn, Cu, and Zn, 33, 17.0, 0.4, and 0.7 ppm, respectively. Extractable nitrate-N in the top 2 ft of soil was 21.3 lb/A. The preplant extractable K level did not include samples from plots that received K fertilizer in the fall of 2014.

Four, 20-ft rows were planted for each plot with the middle two rows used for sampling and harvest. Whole “B” seed of Russet Burbank potatoes were hand planted in furrows on April 27, 2015. Row spacing was 12 inches within each row and 36 inches between rows. Each treatment was replicated four times in a randomized complete block design. Belay for beetle control and the systemic fungicide Quadris were banded in-furrow at row closure. Weeds, diseases, and other insects were controlled using standard practices. Rainfall was supplemented with sprinkler irrigation using the checkbook method of irrigation scheduling.

Twelve K treatments were tested as described in Table 1 below: 0, 90, 180, 270, and 360 lb K_2O/A applied in the fall of 2014 and a split application of 180 lb K_2O/A in the fall + 180 lb K_2O/A at crop emergence in 2015; and 0, 90, 180, 270, and 360 lb K_2O/A applied preplant in the spring of 2015 and a split application of 180 lb K_2O/A preplant + 180 lb K_2O/A at emergence. Fall K was broadcast and incorporated to a depth of 3 to 4 inches with a field cultivator on Nov 7, 2014. Preplant K was broadcast and incorporated to a depth of 3 to 4 inches with a field cultivator on April 14, 2015. Emergence K was sidedressed on May 19 and mechanically incorporated during hilling. Potassium chloride (0-0-60) was the K source for all treatments.

All treatments received a total of 240 lb N/A applied at planting (30 lb N/A), at emergence/hilling (170 lb N/A), and post-hilling (two applications of 20 lb N/A). Nitrogen at planting (April 27) was supplied as monoammonium phosphate (MAP) and was banded 3 inches to each side and 2 inches below the seed piece using a metered, drop fed applicator. Emergence N applications were supplied as a combination of ESN (140 lb N/A) and ammonium sulfate (30 lb N/A + 34 lb S/A), which was mechanically incorporated during hilling on May 19 (along with the emergence K treatment). Post-hilling N was applied over the row with a tractor-mounted sprayer as a 28% UAN solution in 25 gal of water/A. The tractor traveled in the irrigation alleys to prevent damage to the crop. Irrigation was applied immediately following application of UAN to simulate fertigation with an overhead irrigation system. Post-hilling N was applied on July 1 and July 20. In addition to N, banded fertilizer at planting (for all treatments) included 136 lb P_2O_5/A, 1.5 lb S/A, 2.0 lb Zn/A, and 1.0 lb

B/A applied as a blend of MAP, zinc sulfate and zinc oxide (EZ 20), and sodium tetraborate (Granubor 2).

Plant stands were measured on June 2 and stem numbers per plant on June 10. Petiole samples were collected from the 4th leaf from the terminal on four dates: June 16, June 25, July 13, and July 22. Petioles were analyzed for K on a dry weight basis. Vines were killed by mechanical beating on Sept 17 and tubers were machine harvested on Oct 6. Two, 18-ft sections of row were harvested from each plot. Total tuber yield and graded yield were measured. Sub-samples of tubers were collected to determine tuber specific gravity, tuber dry matter, and the incidence of hollow heart, brown center, and scab.

Soil samples from three soil depths (0-6 in., 6-12 in., and 12-24 in.) were collected from treatments 1-6 in the fall of 2014, from treatments 7-12 in the spring of 2015, and from all plots in the fall of 2015 and analyzed for ammonium acetate extractable K. Fall 2014 samples were collected on Oct 30, after soybean harvest and before K fertilizer application. Spring 2015 samples were collected on April 2, before preplant K fertilizer application and planting. Fall 2015 samples were collected after harvest on Oct 27.

Table 1. Potassium treatments[1] tested on irrigated Russet Burbank potatoes.

Treatment #	Timing and rate of potassium application			Total potassium
	Fall	Spring preplant	Emergence	
	lbs K_2O/A			
1	0	0	0	0
2	90	0	0	90
3	180	0	0	180
4	270	0	0	270
5	360	0	0	360
6	180	0	180	360
7	0	0	0	0
8	0	90	0	90
9	0	180	0	180
10	0	270	0	270
11	0	360	0	360
12	0	180	180	360

[1] All K fertilizer was applied as potassium chloride (0-0-60).

Results

Rainfall and Irrigation. Rainfall from planting to tuber harvest was 28.2 in. This was supplemented by 9.1 in. of irrigation for a total of 37.3 in. of water during the growing season. Fig. 1 shows the distribution of rainfall and irrigation throughout the season.

Tuber Yield and Size Distribution: Table 2 shows the effects of K treatment and application season on tuber yield and size distribution. K rate significantly affected total and marketable yields and distribution of yield across all size classes. Single vs. split application timing and application season (fall vs. spring) had some significant effects on yield distribution among tuber size classes, but there were no significant rate x season interactions.

Significant increases in both total and marketable yield occurred as K rate increased to 270 lb K_2O/A, before leveling off at the highest K rate. Yield increases were due to increases in tuber size. Greatest yields in the three largest size classes, as well as the largest yield percentages of >6 oz and >10 oz tubers, occurred at the 270 lb K_2O/A rate. Yield of tubers in the 3-6 oz size class decreased as K rate increased to 270 lb K_2O/A and yield of non-marketable tubers <3 oz was much greater for the zero K control than for any other treatment.

When applied at the same total K rate of 360 lb K_2O/A, split-application treatments increased tuber size compared to single-application treatments. Split application resulted in significantly lower yields of 0-3 and 3-6 oz tubers and a significantly greater percentage of tubers in both the >6 oz and >10 oz size classes. Application season (fall vs. spring) had no effect on total or marketable tuber yield, but fall application significantly increased the yield of #1 tubers > 3 oz in size and spring application had greater yields of #2 tubers > 3 oz in size.

Tuber Quality: Due to very limited incidence of hollow heart and no occurrence of brown center, there were no treatment effects on either of these tuber disorders. Incidence of scab increased significantly as K application rate increased, but neither single vs. split application nor application season had any effect on scab (Table 3).

Significant differences among some treatments occurred for specific gravity and tuber dry matter, although there was a significant interaction between K treatment and application season for specific gravity (Table 3). Both specific gravity and dry matter were significantly greater when 360 lb K_2O/A was applied in a single rather than a split application. The difference for specific gravity was much greater than for dry matter, which was due to the fall + emergence split application (Treatment #6) having the lowest specific gravity of any treatment. The difference between the fall vs. spring split application treatments was the only comparison between similar fall and spring treatments that showed a significant difference in specific gravity.

Tuber dry matter increased quadratically as K application rate increased to 180 lb K_2O/A, before decreasing at higher rates. It was lowest for the zero and 360 lb K_2O/A rates. Dry matter was also significantly greater when K fertilizer was applied in the fall than when it was spring applied.

Plant Stand and Stems per Plant: The only significant treatment effect on stand percentage and the number of stems per plant was that stem number was slightly greater when fertilizer was applied in the fall than in the spring (Table 4). Total and marketable yields were numerically a little greater for fall treatments, but the difference was not statistically significant (Table 2). Fall treatments did have significantly greater yield of #1 tubers > 3 oz in size and lower yield of #2's > 3 oz.

Petiole K Concentrations: Petiole K concentrations on four dates during the growing season are presented in Table 5. Petiole K was significantly affected by K application rate, but was not affected by season of K application or single vs. split application of 360 lb K_2O/A, and the K treatment X application season interaction was not significant.

As K rate increased, petiole K concentrations increased significantly on three of the four sampling dates. The increases were larger and more regular on the 3rd and 4th dates than on the 1st date. On the 2nd date, the two lowest K rates had the highest petiole K concentrations, although these differences were not statistically significant.

The sufficiency range for petiole K in potatoes is 8.0-10.0% K. This range has been established for the time period 40 to 50 days after emergence and may be less accurate before and after that 10 d interval. The sampling dates in Table 5 are 28, 35, 50, and 59 days after emergence. On the 1st sampling date, all K treatments had petiole K concentrations above 10%. On the 2nd date, the 0-, 90-, and single application 360-lb K_2O/A rates were in the sufficiency range and the other three treatments were 1-2% lower and between 7.0 and 7.7% K. It is possible that the reason the two lowest K rates had the highest petiole K concentrations was that greater vegetative growth for the higher K treatments caused a dilution in tissue K. On the 3rd date, only the zero K control was K deficient, but by the 4th date only the 270- and 360-lb K_2O treatments had petiole K above 8.0%. Petiole K concentrations on the 4th date were consistent with the fact that yields and tuber size generally peaked at the 270 lb K_2O treatment and leveled off for the two 360-lb K_2O treatments.

Soil Test K: Table 6 provides soil K concentrations at three soil depths. Samples for Treatments #1-6 were collected in the fall of 2014 after soybean harvest, but before fall K fertilizer application, and in the fall of 2015 after potato harvest. Samples for Treatments #7-12 were collected in the spring of 2015, before K application and potato planting, as well as after harvest in the fall of 2015. Changes in soil K between the two sampling dates are also calculated for all treatments at all soil depths. In all three soil depths, soil test K before application of any K fertilizer was statistically similar for all plots, showing that this was an area with uniform K fertility suitable for the study. It was also an area with a low level of plant-available K, making it a site with a high likelihood of response to fertilizer K.

0-6 in. depth

In the 0-6 in. soil depth, fall samples after harvest showed a significant linear increase in soil K as the K fertilizer rate increased. Single-application treatments significantly increased soil K compared to split-application treatments applied at the same total K rate, although most of this difference was accounted for by the difference between the single application spring treatment compared to the split spring + emergence K treatment (#11 vs. #12). Application season had no effect on soil test K in the fall at this soil depth and there was no significant K treatment X application season interaction.

Changes in soil test K in the 0-6 in. soil depth between the sampling dates before K fertilizer application and after harvest reflected the same patterns among treatments as the post-harvest K levels themselves. The magnitude of changes in soil test K increased significantly as K rate increased and there was no significant K treatment X application season interaction. There was also a greater numerical change in soil K from single-application treatments compared to split-application treatments, but this difference was not significant.

For the zero K control, there was a 9 ppm decrease in soil K in the 0-6 in. soil depth between the pre-fertilization and post-harvest soil tests. This corresponds to the drawdown in soil K from a Russet Burbank potato crop with a total yield of 426 cwt/A (Table 2). There was a 4 ppm soil K drawdown at the 90 lb K_2O/A rate, but increases in soil K at all higher rates of K application. The 8 ppm soil K increase at 180 lb K_2O/A suggests that slightly more than this K rate is sufficient to maintain soil K in the 0-6 in. soil depth and provide a total yield of about 539 cwt/A. The 564 cwt/A maximum yield occurred with 270 lb K_2O/A and increased soil test K 33 ppm. The actual K requirement to both sustain K fertility at current levels and provide for maximum yield under the conditions of this experiment were greater than 180 lb K_2O/A, but probably somewhat less than 270 lb K_2O/A.

The average pre-application soil test K level across all treatments in the 0-6 in. soil depth was 49.9 ppm (Table 6). The current recommendation to obtain a potato yield greater than 500 cwt/A at this soil test level is 400 lb K_2O/A. Under 2015 growing conditions in this field, this recommendation overestimates the minimum amount required for top yields. However, the recommendation would increase soil test K from a Low to Medium level at the end of the growing season, which could be beneficial in improving K fertility to a more desirable maintenance range.

For Treatments #1-6, samples for the pre-application soil test for K were collected in the fall after soybean harvest. For Treatments #7-12, samples for the pre-application soil test for K were collected in the spring before fertilizer application and planting. Fall samples averaged 49.5 ppm K, whereas spring samples averaged 50.2 ppm. These very similar levels would both give the same K fertilizer recommendation of 400 lb K_2O/A as the overall average of 49.9 ppm. On the basis of these results in 2015, there would be no agronomic advantage to collecting samples for K in the fall vs. spring, and other factors such as relative seasonal workloads or differences in turnaround times at soil testing labs could be useful for such decisions.

6-12 in. depth

In the 6-12 in. soil depth, there was a significant linear increase in soil K as the K application rate increased in the post-harvest samples collected in the fall of 2015. This indicates movement of fertilizer K below the zone of K application. The increase was relatively small, so even though there was a trend for greater changes in soil test K from pre-application to post-harvest levels as K application increased, this change difference was not significant. The changes in K at this soil depth were also probably affected by differences in K uptake. Because yield increased with increasing K rate (Table 2), K uptake from this depth probably increased as well, which could have masked the extent to which K moved from the point of application into the 6-12 in. soil depth. Deeper leaching below 12 in. could also have masked K movement into and through this soil depth. Single vs. split application, application season, and K treatment X season had no effects on soil K at this depth.

12-24 in. depth

In the 12-24 in. soil depth, there was also a significant linear increase in soil K as the K application rate increased in the post-harvest fall samples, as well as a significantly greater change in soil test K from pre-application to post-harvest levels as K application increased. Soil K concentrations in the fall of 2015 were greater in the 12-24 in. depth than in the 6-12 in. depth for all K treatments, including the zero K control. This shows that widespread K movement downward through the measured soil profile occurred, and indicates that at least some deeper leaching of K probably also took place. Fig. 1 shows five growing season precipitation events greater than 1.5 in., one greater than 2 in., and one greater than 2.5 in. During one 4-day period (Aug 6-9), total precipitation was 6.2 in.

Increases in soil K in the 12-24 in. soil depth were significantly greater when 360 lb K_2O/A was applied in a single rather than a split application. This reduction in K movement with split application indicates that there was probably reduced K leaching below the 12-24 in. depth as well. Differences in K accumulation in the 12-24 in. soil depth between single- and split-applications were greater when the initial K application was made in the spring. When the initial application was in the fall, there was a numerical difference between single and split (Treatment #5 vs. 6), but when the initial application was made in the spring, there was a significant difference (Treatment #11 vs. 12).

This could have been due to greater leaching below 24 in. with the single fall application and therefore a lower residual K level after harvest.

Conclusions

Total and marketable yields increased significantly as K rate increased to 270 lb K_2O/A, before leveling off at the higher K rates. Yield increases were due to significant increases in tuber size as K rate increased. These results were similar to last year, except that 2014 yields were lower and increases leveled off at 180 lb K_2O/A. Higher K requirements for maximum yield in 2015 than 2014 were probably related lower initial levels of soil K in 2015. In both years, tuber size increased up to the 270 lb K_2O/A rate. Application season (fall vs. spring) and single vs. split application of 360 lb K_2O/A had no effect on total yield in either year. Single vs. split application had mixed results on tuber size. In 2015, split application significantly increased tuber size, but in 2014 tuber size was greatest for single application.

Petiole K was not affected by season of K application, but was significantly affected by K application rate. As K rate increased, petiole K concentrations increased on all four sampling dates in 2014 and three of the four dates in 2015. Despite these similar patterns, petiole K concentrations were much higher in 2015 than 2014. Only the 270 and 360 lb K_2O/A rates ever reached the minimum sufficiency level in 2014, whereas in 2015 even the zero K control was in the sufficiency range on two of the four sampling dates. Petiole K was not affected by season of application in either year. The only significant difference for single vs. split application was higher K with split application on the first sampling date in 2014.

In the 0-6 in. soil depth, fall samples after harvest showed a significant linear increase in soil K as the K fertilizer rate increased in both 2014 and 2015. Single-application treatments also significantly increased fall soil K compared to split-application treatments applied at the same total K rate in 2015, but not in 2014. Application season had no effect on soil K in post-harvest samples in 2015. The season effect was not tested on soil data in 2014.

For the zero K control in 2015, a 9 ppm decrease in soil K in the 0-6 in. soil depth over the growing season corresponded to the drawdown in soil K from a total tuber yield of 426 cwt/A. The 8 ppm soil K increase at 180 lb K_2O/A suggests that slightly less than this K rate is sufficient to maintain soil K and provide a total yield of 539 cwt/A. The 564 cwt/A maximum yield occurred with 270 lb K_2O/A and increased soil test K 33 ppm, so the K requirement to both sustain K fertility and achieve maximum yield was somewhere between 180- and 270-lb K_2O/A.

The current recommendation to obtain this yield at the average pre-application soil test K level of 50 ppm in this experiment is 400 lb K_2O/A. This recommendation is greater than the amount required for top yields and to sustain soil test K. However, it would increase soil K from a Low to Medium level, which could be beneficial in improving K fertility to a more desirable maintenance range. Soil samples collected before K application in the fall and pre-application in the spring both had K levels similar to the overall 50 ppm K average, so they would both give the same K fertilizer recommendation. Based on these 2015 data, there would be no agronomic advantage to collecting samples for K in the fall vs. spring.

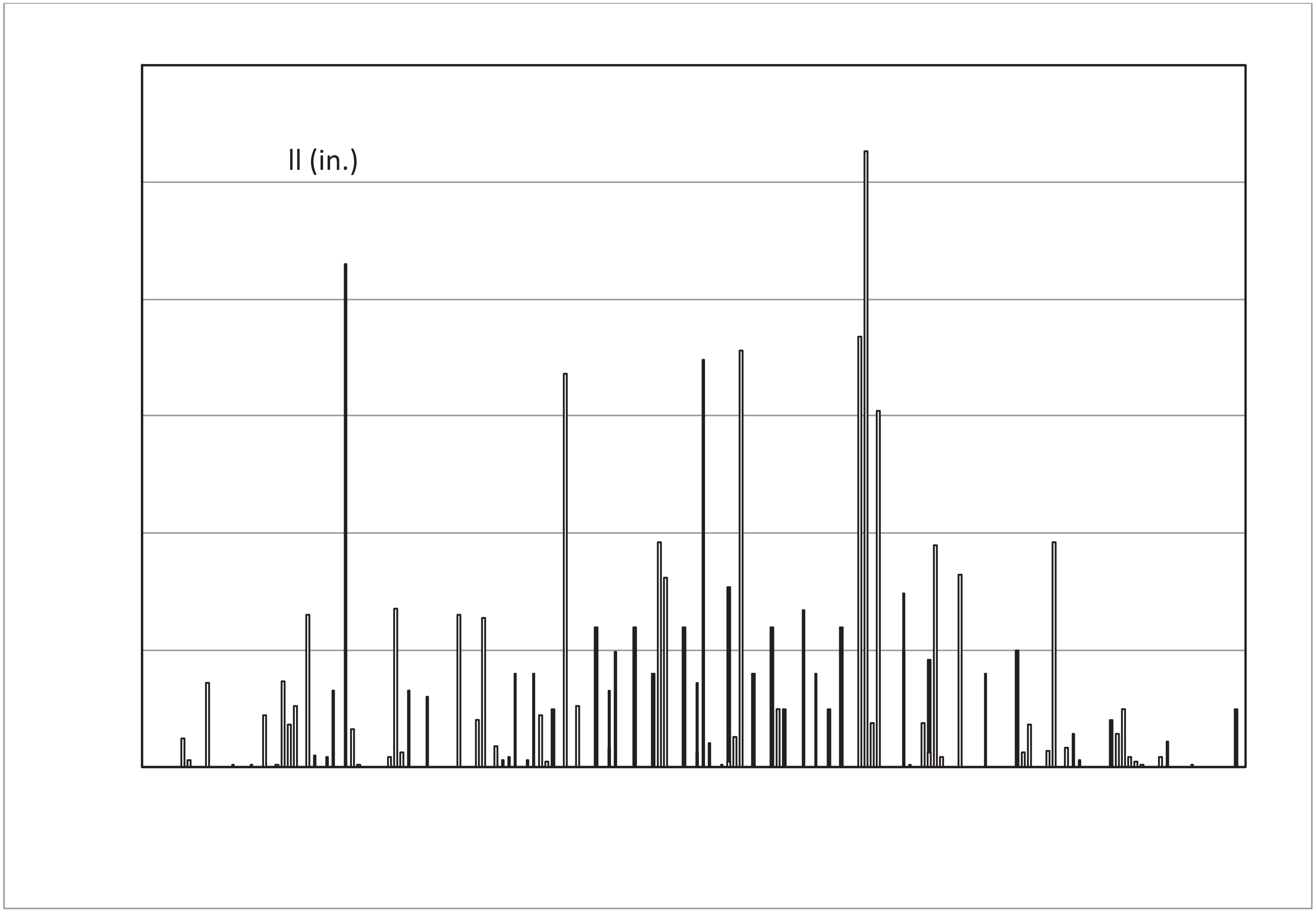


Fig. 1. Distribution of rainfall and irrigation during the growing season.

Table 2 Effect of potassium application rate and timing on Russet Burbank tuber yield and size distribution.

Treatments				Tuber yield										
	Treatment #	Application timing[1]	Total K applied	0-3 oz	3-6 oz	6-10 oz	10-14 oz	> 14 oz	Total	#1s > 3 oz.	#2s > 3 oz	Total marketable	> 6 oz	> 10 oz
		K2O lbs·ac-1		cwt·ac^{-1}									%	
Overall treatment effect	1	0, 0, 0	0	72	192	126	25	5	420	265	83	348	37	7
	2	90, 0, 0	90	46	184	181	67	21	499	316	137	453	54	17
	3	180, 0, 0	180	43	145	206	111	54	558	401	114	515	66	29
	4	270, 0, 0	270	46	133	224	106	51	559	375	139	513	67	27
	5	360, 0, 0	360	48	143	203	103	64	560	403	109	512	66	29
	6	180, 0, 180	360	39	114	197	124	85	559	390	130	520	72	37
	7	0, 0, 0	0	71	176	139	33	12	431	259	102	361	43	10
	8	0, 90, 0	90	54	175	183	71	34	518	316	147	464	55	20
	9	0, 180, 0	180	51	163	190	91	25	520	320	148	468	59	22
	10	0, 270, 0	270	48	146	204	105	66	568	365	155	521	66	30
	11	0, 360, 0	360	55	139	195	102	46	538	341	142	483	64	27
	12	0, 180, 180	360	41	107	221	112	63	544	347	156	503	72	32
			Overall treatment significance[2]	**	**	**	**	**	**	**	++	**	**	**
			MSD (α = 0.10)	17	25	27	32	31	41	51	55	47	7	8
Main effects	K treatment		0 K	71	184	133	29	8	426	262	93	354	40	9
			90 K	50	180	182	69	28	508	316	142	458	54	19
			180 K	47	154	198	101	40	539	360	131	492	62	26
			270 K	47	139	214	105	58	564	370	147	517	66	29
			360 K	51	141	199	102	55	549	372	126	498	65	28
			360 K split	40	111	209	118	74	552	369	143	512	72	34
			K treatment significance[2]	**	**	**	**	**	**	**	*	**	**	**
			MSD (α = 0.10)	10	17	18	21	20	28	34	34	32	5	6
			Single vs. split application[2]	++	**	NS	NS	NS	NS	NS	NS	NS	*	++
			Linear effect of application rate[2]	**	**	**	**	**	**	**	*	**	**	**
			Quadratic effect of application rate[2]	*	NS	**	**	NS	**	**	*	**	**	*
	Season		Fall	49	152	189	89	47	526	358	119	477	60	25
			Spring	53	151	189	86	41	520	325	142	467	60	23
			Application season significance[2]	NS	NS	NS	NS	NS	NS	**	*	NS	NS	NS
Interaction effect			K treatment * season significance[2]	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1] Fall 2014, spring 2015, emergence 2015

[2] NS: not significant. ++, *, **: statistically significant at 10%, 5%, and 1%, respectively.

Table 3. Effect of potassium application rate and timing on Russet Burbank tuber quality.

Treatments				Tuber Characteristics				
	Treatment #	Application timing[1]	Total K applied	Tuber Quality			Specific Gravity	Dry Matter %
				HH	BC	Scab		
		(K2O lbs·ac-1)		%				
Overall treatment effect	1	0, 0, 0	0	0	0	4	1.0788	20.6
	2	90, 0, 0	90	0	0	7	1.0747	20.9
	3	180, 0, 0	180	0	0	6	1.0787	21.0
	4	270, 0, 0	270	0	0	12	1.0773	21.0
	5	360, 0, 0	360	0	0	19	1.0773	20.5
	6	180, 0, 180	360	0	0	17	1.0718	19.7
	7	0, 0, 0	0	0	0	6	1.0752	20.2
	8	0, 90, 0	90	0	0	8	1.0762	20.4
	9	0, 180, 0	180	0	0	11	1.0769	20.6
	10	0, 270, 0	270	1	0	4	1.0762	20.1
	11	0, 360, 0	360	0	0	12	1.0799	19.9
	12	0, 180, 180	360	0	0	9	1.0757	19.4
	Overall treatment significance[2]			NS	NS	NS	*	*
	MSD (α = 0.10)			--	–	--	0.0039	1.0
Main effects	K treatment	0 K		0	0	5	1.0770	20.4
		90 K		0	0	8	1.0754	20.6
		180 K		0	0	9	1.0777	20.8
		270 K		1	0	8	1.0767	20.6
		360 K		0	0	16	1.0784	20.2
		360 K split		0	0	13	1.0738	19.5
		K treatment significance[2]		NS	NS	NS	*	**
		MSD (α = 0.10)		--	–	--	0.0025	0.6
		Single vs. split application[2]		NS	NS	NS	**	++
		Linear effect of application rate[2]		NS	NS	*	NS	*
		Quadratic effect of application rate[2]		NS	NS	NS	NS	**
	Season	Fall		0	0	11	1.0763	20.6
		Spring		0	0	8	1.0766	20.1
		Application season significance[2]		NS	NS	NS	NS	*
Interaction effect	**K treatment * season significance[2]**			NS	NS	NS	++	NS

[1] Fall 2014, spring 2015, emergence 2015

[2] NS: not significant. ++, *, **: statistically significant at 10%, 5%, and 1%, respectively.

Table 4. Effect of potassium application rate and timing on Russet Burbank stand percentage and stems per plant .

Treatments				Plant Stand	Stems
	Treatment #	Application timing[1]	Total K applied	June 2	June 10
		K2O lbs·ac-1		%	per plant
Overall treatment effect	1	0, 0, 0	0	100	3.0
	2	90, 0, 0	90	100	2.6
	3	180, 0, 0	180	99	3.1
	4	270, 0, 0	270	99	2.9
	5	360, 0, 0	360	98	3.1
	6	180, 0, 180	360	99	2.9
	7	0, 0, 0	0	100	2.8
	8	0, 90, 0	90	97	2.8
	9	0, 180, 0	180	98	2.7
	10	0, 270, 0	270	98	2.5
	11	0, 360, 0	360	100	2.6
	12	0, 180, 180	360	100	2.5
			Overall treatment significance[2]	NS	NS
			MSD (α = 0.10)	--	--

Main effects	**K treatment**	0 K	100	2.9
		90 K	99	2.9
		180 K	99	2.7
		270 K	99	2.8
		360 K	100	2.7
		360 K split	98	2.7
		K treatment significance[2]	NS	NS
		MSD (α = 0.10)	--	--
		Single vs. split application[2]	NS	NS
		Linear effect of application rate[2]	NS	NS
		Quadratic effect of application rate[2]	NS	NS
	Season	Fall	99	2.9
		Spring	99	2.7
		Application season significance[2]	NS	++
Interaction effect		**K treatment * season significance[2]**	NS	NS

[1] Fall 2014, spring 2015, emergence 2015.

[2] NS: not significant. ++, *, **: statistically significant at 10%, 5%, and 1%, respectively.

Table 5. Effect of potassium application rate and timing on Russet Burbank petiole potassium concentration.

Treatments				Petiole sampling date			
	Treatment #	Application timing[1]	Total K applied	16-Jun	25-Jun	13-Jul	22-Jul
		K2O lbs·ac-1		%K			
Overall treatment effect	1	0, 0, 0	0	12.6	9.0	4.9	2.6
	2	90, 0, 0	90	10.7	8.8	8.2	5.1
	3	180, 0, 0	180	12.4	7.3	9.0	7.2
	4	270, 0, 0	270	10.2	7.8	10.5	8.8
	5	360, 0, 0	360	12.3	10.4	11.8	9.9
	6	180, 0, 180	360	15.1	6.8	11.2	9.4
	7	0, 0, 0	0	11.0	8.8	5.9	2.9
	8	0, 90, 0	90	13.8	10.7	7.5	4.7
	9	0, 180, 0	180	11.7	6.7	9.6	6.7
	10	0, 270, 0	270	11.6	7.6	10.2	7.5
	11	0, 360, 0	360	15.9	6.5	11.3	9.7
	12	0, 180, 180	360	14.2	8.3	11.3	9.3
	Overall treatment significance[2]			NS	NS	**	**
	MSD (α = 0.10)			–	–	1.1	1.1
Main effects	K treatment		0 K	11.8	8.9	5.4	2.8
			90 K	12.3	9.7	7.9	4.9
			180 K	12.1	7.0	9.3	7.0
			270 K	10.9	7.7	10.3	8.1
			360 K	13.8	8.4	11.6	9.8
			360 K split	14.6	7.5	11.2	9.4
		K treatment significance[2]		NS	NS	**	**
		MSD (α = 0.10)		–	–	0.8	0.8
		Single vs. split application[2]		NS	NS	NS	NS
		Linear effect of application rate[2]		++	NS	**	**
		Quadratic effect of application rate[2]		NS	NS	*	++
	Season		Fall	12.2	8.4	9.3	7.2
			Spring	12.9	8.1	9.3	6.8
		Application season significance[2]		NS	NS	NS	NS
Interaction effect	K treatment * season significance[2]			NS	NS	NS	NS

[1] Fall 2014, spring 2015, emergence 2015

[2] NS: not significant. ++, *, **: statistically significant at 10%, 5%, and 1%, respectively.

Table 6. Effect of potassium application rate and timing on soil potassium concentrations at three soil depths and changes in soil potassium between potassium fertilization and potato harvest.

		Treatments			Soil K ppm								
					0 - 6" soil sample depth			6 - 12" soil sample depth			12 - 24" soil sample depth		
		Treatment #	Application timing[1]	Total K applied	Pre-application soil K	Fall 2015 soil K	Change in Soil K	Pre-application soil K	Fall 2015 soil K	Change in Soil K	Pre-application soil K	Fall 2015 soil K	Change in Soil K
			K2O lbs·ac-1										
Overall treatment effect		1	0, 0, 0	0	45	35	-10	31	24	-6	30	30	0
		2	90, 0, 0	90	56	48	-8	32	25	-7	29	32	3
		3	180, 0, 0	180	51	58	8	30	25	-5	26	37	11
		4	270, 0, 0	270	46	85	39	30	29	-1	32	48	16
		5	360, 0, 0	360	51	92	41	33	27	-6	30	54	24
		6	180, 0, 180	360	48	90	43	29	25	-4	31	43	12
		7	0, 0, 0	0	46	38	-8	29	25	-5	32	29	-3
		8	0, 90, 0	90	50	50	-1	30	27	-3	31	32	1
		9	0, 180, 0	180	50	58	8	31	28	-4	34	33	-1
		10	0, 270, 0	270	52	78	27	29	25	-4	35	37	3
		11	0, 360, 0	360	55	113	58	32	33	1	33	69	35
		12	0, 180, 180	360	48	81	33	32	30	-3	28	39	11
				Overall treatment significance[2]	NS	**	**	NS	NS	NS	NS	**	**
				MSD (α = 0.10)	–	15	16	--	--	–	--	16	14
Main effects	K treatment			0 K	45	36	-9	30	24	-5	31	30	-2
				90 K	53	49	-4	31	26	-5	30	32	2
				180 K	50	58	8	31	26	-4	30	35	5
				270 K	49	82	33	29	27	-3	33	43	9
				360 K	53	103	50	33	30	-3	31	61	30
				360 K split	48	86	38	30	27	-3	30	41	12
				K treatment significance[2]	NS	**	**	NS	NS	NS	NS	**	**
				MSD (α = 0.10)	–	10	11	--	--	–	--	10	9
				Single vs. split application[2]	NS	*	NS	NS	NS	NS	NS	**	**
				Linear effect of application rate[2]	NS	**	**	NS	*	NS	NS	**	**
				Quadratic effect of application rate[2]	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Season			Fall	49	68	19	31	26	-5	30	41	11
				Spring	50	70	20	30	28	-3	32	40	8
				Application season significance[2]	NS	NS	NS	NS	NS	NS	++	NS	NS
Interaction effect				**K treatment * season significance[2]**	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1] Fall 2014, spring 2015, emergence 2015

[2] NS: not significant. ++, *, **: statistically significant at 10%, 5%, and 1%, respectively.

Potato Improvement for the Northern Plains
2015 Summary

Asunta (Susie) L. Thompson, Ph.D.
Department of Plant Sciences
North Dakota State University
Fargo, North Dakota 58108
asunta.thompson@ndsu.edu
701.231.8160 (office)

Potato is a leading vegetable and horticultural crop produced in North Dakota and Minnesota. Potatoes are grown on about 31,970 ha in ND, and in 2014 had a farmgate value of more than $221.9 mil (NASS, 2015). Approximately 60% of potatoes produced in ND and MN are for processing (French fries/frozen and chip), with the remainder used for tablestock and certified seed. The NDSU potato breeding program, as part of the North Dakota Agricultural Experiment Station, actively evaluates potato genotypes and releases improved cultivars for producer, industry and consumer adoption, addressing shortcomings of industry standards; the most recent is Dakota Ruby (2014). Northern Plain's producers require early maturing cultivars across all market types, with stringent quality standards existing within each market class. Improved potato cultivars possessing resistance to abiotic and biotic stresses, and with enhanced quality attributes, may reduce input costs for producers, provide high quality raw material for chip and frozen/French fry processing, and provide healthy and flavorful choices for consumers.

In 2015, more than 50% of hectares eligible for certification by the North Dakota State Seed Department were planted to cultivars (and/or selections thereof) and promising advancing selections developed by the NDSU potato breeding program (NDSSD). Similarly, more than 34% of hectares eligible in Minnesota for certification by the Minnesota Department of Agriculture were developed by the NDSU potato breeding program (MDA). North Dakota is the second largest producer of seed potatoes, second only to Idaho, and Minnesota ranks eighth. Combined the two states account for just under 20% of all certified seed produced in the US. In 2014 dollars, sale of certified seed potatoes produced in North Dakota exceeded $22 million (NASS, 2015). Certified seed production is an indirect measure of commercial adoption, as it is estimated that one hundredweight of certified seed potatoes results in a 10 fold increase, or 10 hundred weight of subsequent seed or commercial (use for fresh/tablestock, processed in to chips or French fries, or other products) production. Dakota Crisp, Dakota Diamond, Dakota Trailblazer, Dakota Russet, and Dakota Ruby are finding niches in potato production, with increases in adoption by producers and industry across North America.

Utilizing conventional breeding, the NDSU potato improvement team conducts germplasm enhancement, breeding, selection, evaluation and development of superior genotypes addressing shortcomings of industry standards and emerging stresses faced by producers, industry and consumers. Traits emphasized include high yield, durable resistance to pests and environmental stresses, and advancement in nutrient and water use efficiency, as well as nutritional and quality attributes.

To meet the needs of NPPGA/MN Area II potato producers and our associated industry, the following research objectives were established:
1. Develop potato (*Solanum tuberosum* Group Tuberosum L.) cultivars for North Dakota, the Northern Plains, and beyond, using traditional hybridization that are genetically superior for yield, market-limiting traits, and processing quality.
2) Identify and introgress into adapted potato germplasm, genetic resistance to major disease, insect, and nematode pests causing economic losses in potato production in North Dakota and the Northern Plains.
3) Identify and develop enhanced germplasm with resistance to environmental stresses and improved quality characteristics for adoption by consumers and the potato industry.

Dedicated crossing blocks were used in hybridizing in the winter greenhouse; in 2015, 378 families were created. In the seedling nursery at Langdon, 25,481 individual genotypes representing 166 families were evaluated; 187 selections were retained for subsequent evaluation in 2016 and beyond. Unselected seedling tubers were shared with breeding programs in Colorado (3,905), Idaho (5,922), Maine (4,085), and Texas (5,161). Unselected seedling tubers received from these cooperating programs were grown at Larimore, ND, with 130 selections being retained for further evaluation. In maintenance plots and increase lots produced at Baker, MN, 475 second, 1094 third year, and 203 fourth year and older genotypes were produced; 49, 39, and 169 were retained, respectively.

In order to address these objectives, yield and evaluation trials were grown at eight sites, five irrigated and three non-irrigated, in North Dakota and Minnesota in 2015. Non-irrigated sites included Crystal, Hoople and Grand Forks, ND. Trials at Crystal included the North Central Regional Potato Variety Trial (NCRPVT) focusing on fresh market types. NDSU entries included ND6961B-21PY, ND7818-1Y, ND7834-2P, ND7882b-7Russ, ND7982-1R, and ND113300-3RSY. Several of these clones have colored flesh equating to a potential improvement in antioxidant content. ND7882b-7Russ has performed well and has medium-early maturity, but under northern plains conditions often has hollow heart; it will be dropped from further consideration unless another potato producing region finds it to be suitable. The Fresh Trial included 30 entries, 17 advanced selections and 13 cultivar checks. The Preliminary Fresh Market Trial had 80 entries, 67 selections (primarily red skinned and white fleshed) compared to 13 industry standards. Standouts from these two trials included AND00272-1R, AND99331-2PintoY, ND4659-5R, ND6002-1R, ND7982-1R, ND102663B-3R, ND102733Cb-1R, ND113113B-2PSY, ND113207-1R, ND113338C-3R, and ND113460C-PS. Many of these genotypes combine early maturity, beautiful skin and flesh colors (including several with deep yellow flesh), high yield of desirable sizes for the fresh market, in addition to late blight and Colorado Potato Beetle resistance breeding.

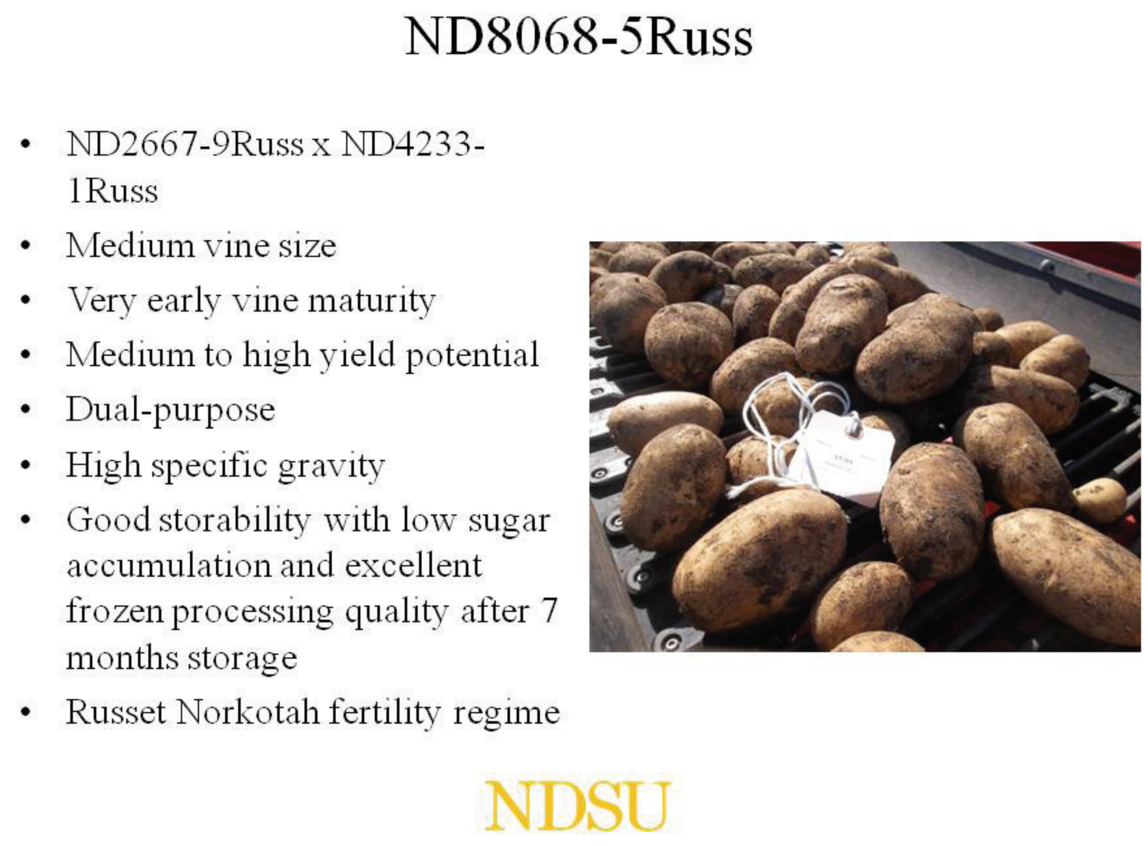
Trials at Hoople focus on chip processing. The Advanced Chip Trial had 14 advancing selections compared to nine chip industry standards, and the Preliminary Chip Processing Trial included 82 entries. Promising selections included ND7519-1 and ND7799c-1. Previous releases Dakota Pearl, Dakota Crisp and Dakota Diamond also performed very well for yield and grade, specific gravity, as well as chip color. Additionally, the National Chip Processing Trials (NCPT), which include 102 unreplicated selections and 61 replicated entries from US potato breeding programs, were grown at this site. The NCPT has goals of rapidly identifying replacements for Snowden with long-term chip processing potential, and Atlantic, primarily to address its susceptibility to internal heat necrosis, while providing high yield potential and high specific gravity, and that can withstand production environments in the south. Nine NDSU clones were included with several identified across the nine US sites as having potential for further evaluation in 2016. Two defoliation trials focusing on Colorado Potato Beetle (CPB) resistance breeding efforts were planted at the NPPGA Research Farm south of Grand Forks. Forty-three seedling families and more than 200 individual genotypes with CPB resistance breeding were evaluated for defoliation. Information was used during selection of single hills at Langdon, and also during selection of maintenance and increase lots at Baker. A second year of the trial addressing vine kill options using dessicant rate and timing to achieve optimum skin set for Dakota Ruby was conducted. Appropriate fertility regimen accompanied by timely vine kill prior to harvest minimized skinning and marketability of tubers.

Irrigated trials were grown at Inkster, Larimore, Oakes, and Williston, ND, and at Park Rapids, MN. At Larimore the focus is the Processing Trial which included 24 selections, cultivars and industry standards, the preliminary processing trial (68 entries), maintenance of out-of-state selections, and out-of-state seedlings. Several advancing selections with potential resistance to Corky Ringspot disease looked promising in terms of agronomics, yield and grade, specific gravity, and French fry color. These selections will be evaluated for resistance 2017. ND8068-5Russ is a very early selection with promise for both the fresh and French fry processing markets due to excellent size and yield mid-summer, as well high specific gravity and low sugar levels from the field and storage. Tables 1-3 provide results of the Processing Trial. The National French Fry Processing trial (NFPT), supported by the USPB, was also conducted at this site, with the goal of identifying russet selections with French Fry processing potential with low acrylamide levels. In 2015, the irrigated NCRPVT fresh market trial (30 entries including the NDSU lines listed above) and the irrigated Chip Processing Trial (17 advancing selections and seven industry checks) were planted at this site due to space limitations at Inkster. Trials at Inkster included a replicated screening trial for Verticillium wilt resistance, conducted in collaboration with Dr. Neil Gudmestad's program. Twenty-one clones across market types were evaluated. Additionally, in collaboration with Dr. Harlene Hatterman-Valenti and Collin Auwarter, we conducted a metribuzin sensitivity screening trial, evaluating 16 cultivars and selections. Information from these two trials is important for developing cultivar management information for new and potential cultivar releases. The processing trial at Oakes included 18 entries, nine advancing NDSU dual-purpose russet selections and nine industry standards. Finally, a processing trial with 18 entries and a scab evaluation trial with 95 entries were planted at Park Rapids. Dakota Russet, Dakota Trailblazer and ND8068-5Russ looked very promising in regard to yield and processing quality attributes, though ND8068-5Russ will not compete with full-season cultivars for yield or grade. Results from yield trials (including the Larimore Processing Trial results presented below) will be submitted to the Valley Potato Grower magazine for publication, as in past years.

From storage, all yield trial entries were evaluated for blackspot and shatter bruise potential, while processing (chip and frozen) entries were also evaluated for color from 3.3C (38F), 5.5C (42F) and 7.2C (45F, French fry genotypes only) following eight week storage; additionally they will be evaluated from long-term (approximately seven months) storage. Collaborative screening trials included screening for late blight resistance and resistance to silver scurf, blackdot and other cosmetic diseases impacting tuber appearance with Dr. Secor. Screening for resistance to powdery scab, PMTV, pink rot, *Pythium* leak and *Phytophthora nicotianae* was conducted by Dr. Gudmestad's program.

The NDSU potato breeding program is supported by Mr. Richard (Dick) Nilles and currently has three graduate students pursuing their MS degrees, working on starch attribute screening, elucidation of late blight resistance, and remote sensing of PVY in seed potato production. The NDSU potato breeding program is very grateful for funding, hosting of trials, seed and other resources that are provided to the program and the potato improvement team by the NPPGA, MN Area II, and individual growers and potato industry personnel.

Four selections were highlighted at the recent National Potato Council's Potato Expo in Las Vegas. They are summarized here:



ND8068-5Russ

- ND2667-9Russ x ND4233-1Russ
- Medium vine size
- Very early vine maturity
- Medium to high yield potential
- Dual-purpose
- High specific gravity
- Good storability with low sugar accumulation and excellent frozen processing quality after 7 months storage
- Russet Norkotah fertility regime

NDSU

ND7799c-1

- Dakota Pearl x NY115
- Medium vine size
- Medium-late maturity
- High yield potential
  - Nice tuber type and tuber size profile
- Medium to high specific gravity (1.086 average)
- Chips from 42F storage

NDSU

ND113113-2PSY

- Yagana x ND028742b-12PEY
- Suited for the specialty market
- Medium early maturity
- Medium to small, but vigorous vine size
- Medium to high yield potential
- Attractive purple splashed, oval, smooth tubers with bright yellow flesh and shallow eyes
- Very uniform tuber size profile
- High specific gravity (1.090 average)

ND113207-1R

- T10-12 x Dakota Ruby
- Medium and vigorous vine
- Medium early maturity
- Medium to high yield potential
- Uniform oval tuber type and tuber size profile
- Very smooth
- High set
- Low specific gravity (1.075 average across irrigated and non-irrigated sites)
- White flesh

NDSU

Table 1. Agronomic and quality evaluations for advanced processing selections and cultivars, full season, Larimore, 2015.

Clone	% Stand	Vine Size[1]	Vine Maturity[2]	Stems per Plant	Specific Gravity[3]	% Hollow Heart[4]	Black-spot Bruise[5]
1. AND97279-5Russ	98	3.8	2.3	1.9	1.1041	6	4.7
2. ND8068-5Russ	96	1.5	1.0	2.1	1.0962	3	5.0
3. ND039194AB-1Russ	96	3.5	3.0	1.4	1.0911	2	3.8
4. ND049251B-9Russ	90	4.0	2.8	1.7	1.0895	3	3.6
5. ND049546b-10Russ	96	3.0	1.5	1.3	1.0885	11	4.2
6. ND060761B-3Russ	91	3.3	2.3	1.4	1.0899	3	4.7
7. ND081764B-4Russ	90	3.3	3.3	1.2	1.0917	9	4.2
8. ND091933ABCR-7Russ	91	1.3	1.0	1.7	1.0896	10	4.0
9. ND091938BR-2Russ	96	4.0	3.5	1.8	1.0933	1	3.0
10. ND102647-3Russ	95	1.5	1.8	2.0	1.0836	33	3.8
11. ND102719B-1Russ	96	4.3	4.0	1.3	1.1030	3	4.2
12. ND113100-1Russ	93	4.5	2.0	1.8	1.0888	1	3.9
13. ND113174B-2Russ	99	5.0	4.3	1.4	1.0940	5	4.3
14. WND8624-2Russ	89	2.8	2.5	1.4	1.0912	4	4.0
15. WND8625-2Russ	91	3.8	1.1	1.6	1.0920	9	4.2
16. Alpine Russet	96	4.3	3.0	1.6	1.0942	0	4.4
17. Bannock Russet	100	4.0	3.9	1.8	1.0928	28	3.5
18. Dakota Russet	94	3.8	3.3	1.1	1.0976	13	3.2
19. Dakota Trailblazer	96	4.8	4.0	1.3	1.1112	20	3.6
20. Ranger Russet	96	4.0	3.5	1.9	1.0993	3	4.9
21. Russet Burbank	99	4.0	2.9	1.8	1.0850	21	4.2
22. Russet Norkotah	99	2.8	1.0	1.8	1.0875	11	4.4
23. Shepody	96	3.8	2.3	1.8	1.0893	8	3.7
24. Umatilla Russet	98	3.5	2.5	1.9	1.0968	8	3.2
Mean	95	3.5	2.6	1.6	1.0933	9	4.0
LSD (∝=0.05)	7	0.9	0.7	0.3	0.0078	10	1.6

[1] Vine size – scale 1-5, 1 = small, 5 = large.

[2] Vine maturity – scale 1-5, 1 = early, 5 = late.

[3] Determined using weight-in-air, weight-in-water method.

[4] Hollow heart includes brown center.

[5] Blackspot bruise determined by the abrasive peel method, scale 1-5, 1=none, 5=severe.

Table 2. Yield and grade for advanced processing selections and cultivars, full season, Larimore, 2015.

Clone	Total Yield Cwt./A	US No. 1 Cwt./A	US No. 1 %	0-4 oz. %	4-6 oz. %	6-12 oz. %	>12 oz. %	US No. 2 %	Culls %
1. AND97279-5Russ	347	276	79	16	19	50	10	2	3
2. ND8068-5Russ	259	211	81	17	23	56	2	1	1
3. ND039194AB-1Russ	375	338	90	6	11	46	33	4	0
4. ND049251B-9Russ	313	272	87	9	14	48	25	3	1
5. ND049546b-10Russ	222	200	88	10	21	51	17	2	0
6. ND060761B-3Russ	361	303	85	5	8	42	34	9	2
7. ND081764B-4Russ	332	299	90	10	13	49	28	0	0
8. ND091933ABCR-7Russ	289	202	69	30	32	37	0	1	0
9. ND091938BR-2Russ	391	339	87	3	7	41	39	7	2
10. ND102647-3Russ	281	225	80	17	32	43	4	2	0
11. ND102719B-1Russ	371	316	84	5	8	48	28	7	4
12. ND113100-1Russ	310	243	78	7	10	47	21	14	1
13. ND113174B-2Russ	404	290	71	2	6	31	35	12	14
14. WND8624-2Russ	263	243	92	6	16	51	25	1	0
15. WND8625-2Russ	275	248	90	5	9	50	31	3	1
16. Alpine Russet	488	446	91	3	9	38	45	5	1
17. Bannock Russet	309	279	90	9	13	45	32	0	0
18. Dakota Russet	335	311	92	6	8	59	25	1	1
19. Dakota Trailblazer	321	268	84	6	9	42	32	6	4
20. Ranger Russet	390	310	79	7	11	42	27	5	9
21. Russet Burbank	423	315	74	10	14	35	25	7	8
22. Russet Norkotah	345	296	86	14	18	47	20	0	1
23. Shepody	358	230	65	4	7	29	29	15	16
24. Umatilla Russet	394	297	75	12	11	44	21	8	5
Mean	340	282	83	9	14	45	25	5	3
LSD (∝=0.05)	79	76	9	5	5	10	11	5	5

Table 3. Shatter bruise potential and French fry evaluations following harvest and after 8 weeks storage at 45F, full season trial, Larimore, 2015.

Clone	Shatter Bruise[1]	Fry Color[2]	Stem-end Color	% Sugar End[3]	Fry Color[2]	Stem-end Color	% Sugar End[3]
		Field Fry			Following 8 wks. at 45F		
1. AND97279-5Russ	1.5	1.0	2.2	75	1.0	1.8	58
2. ND8068-5Russ	1.7	0.6	1.1	50	0.5	0.9	33
3. ND039194AB-1Russ	2.4	1.3	2.0	75	1.4	2.0	59
4. ND049251B-9Russ	2.5	1.0	2.2	75	1.1	2.4	84
5. ND049546b-10Russ	1.4	0.5	1.2	83	0.9	1.8	58
6. ND060761B-3Russ	1.4	0.6	1.7	59	0.6	1.7	59
7. ND081764B-4Russ	2.0	0.9	2.6	83	1.6	2.9	50
8. ND091933ABCR-7Russ	1.7	0.5	0.8	33	1.4	1.8	25
9. ND091938BR-2Russ	1.6	0.8	1.2	42	1.2	1.5	25
10. ND102647-3Russ	1.3	0.5	1.1	25	0.4	1.2	33
11. ND102719B-1Russ	1.4	0.5	1.1	46	0.6	1.4	50
12. ND113100-1Russ	1.2	0.7	2.0	83	0.6	2.3	67
13. ND113174B-2Russ	1.7	1.4	3.2	67	1.0	3.8	88
14. WND8624-2Russ	2.5	2.3	2.6	17	2.6	2.9	17
15. WND8625-2Russ	1.9	1.0	1.7	50	2.0	2.4	33
16. Alpine Russet	2.0	1.0	1.6	42	1.0	1.8	42
17. Bannock Russet	1.4	0.8	2.0	75	1.3	2.1	75
18. Dakota Russet	1.5	0.7	0.9	25	0.7	0.8	17
19. Dakota Trailblazer	1.3	0.7	1.6	67	0.6	1.1	50
20. Ranger Russet	1.8	0.9	2.4	100	1.1	2.4	67
21. Russet Burbank	1.3	1.3	3.3	84	1.0	3.1	84
22. Russet Norkotah	1.4	1.6	2.2	50	1.9	2.4	42
23. Shepody	2.0	1.6	2.5	42	1.0	2.3	67
24. Umatilla Russet	1.3	1.3	2.9	67	1.0	2.0	75
Mean	1.6	1.0	1.9	59	1.1	2.0	52
LSD (∝=0.05)	1.6	0.6	0.9	45	0.7	0.8	43

[12] Shatter bruise is evaluated using a bruising chamber with digger chain link baffles. Tubers are stored at 45F prior bruising. Shatter bruises are rated on a scale of 1-5, with 1 = none and 5 = many and severe.

[2] Fry color scores: 0.1 corresponds to 000, 0.3 corresponds to 00, 0.5 corresponds to 0, 1.0 equals 1.0; subsequent numbers follow French fry rating scale 000 to 4.0. Scores of 3.0 and above are unacceptable because adequate sugars cannot be leached from the tuber flesh to make an acceptable fry of good texture.

[3] Any stem end darker than the main fry is considered a sugar end in these evaluations, thus mirroring the worst case scenario. The processing industry defines a sugar end as a 3.0 or darker.

Title: Predictive biochemical markers for cold-induced sweetening (CIS) resistance to complement potato breeding programs.

Sanjay K. Gupta
University of Minnesota, Department of Soil, Water and Climate, 175 Borlaug Hall, 1991 Upper Buford Circle, St. Paul, MN 55108. Tel. (612) 625-1244: Email: gupta020@umn.edu

Cooperators:
Dr. Thomas Michaels, University of Minnesota, Dept. of Horticultural Science, St. Paul, MN 55108
Tel. (612) 624-7711: Email: michaels@umn.edu

Executive Summary: Processing and nutritional quality of the potatoes during long term cold storage is the most important trait that determines potato variety acceptability for potato processing. Reliable biochemical markers have been developed to predict a potato clones ability to accumulate reducing sugar during long term cold storage. Analysis of data revealed that potato clones with low levels of AcInv, invertase inhibitor and A-II protein demonstrated best CIS resistance. Selection of parents based on biochemical markers had a significant effect on breeding efficiency. Both the parents from class A yielded 93% clones with desirable glucose level and chip color, which drops to 52% when one parent was from class A and other from class B. Parents like MN99380 and NY138 demonstrated low AcInv and inhibitor levels.

Potato clones classified as class A accumulated low concentrations of reducing sugar glucose during cold storage. The markers were stable over years. It is suggested that these biochemical markers can be used for selection of parents and progenies having high CIS resistance.

Rationale: Biochemical markers to predict cold sweetening resistance in stored potatoes are reliable selection tools for potato breeding because they have the capacity to predict a clone's ability to process from long term cold storage. Analyzing segregating breeding populations from crosses between high and low cold sweetening resistant parents would enable us to better understand the genetic interaction of these biochemical factors related to Cold Induced Sweetening (CIS) resistance.

The overall goal of this project is to increase the ultimate efficiency of the potato breeding by precise selection of parents and progenies that can be applied for future potato selection to increase their storage-life. Potato breeders can be expected to make increasing use of biochemical markers in their programs. The information generated through this study will directly contribute to state, regional and national potato potato breeding programs by elucidating the role and function of these factors in CIS resistance. This research, in the short-term, will lead to improved potato breeding methods by developing better screening tools for this trait; and lead to, in the long-term improved potato varieties for processing.

Current Research:

Material and Methods: In order to have better understanding of how these biochemical markers can be used to predict chip processing from cold storage, breeding clones used in the Minnesota Potato Breeding program were sampled and subsequently divided into 3 main categories (category A, B, or C) based on AcInv activity. Category A- best CIS resistance, B - intermediate CIS resistance, and C - very low CIS resistance. (Figure 1). Crosses among these parents were made resulting in 39 families and 1124 progeny that were categorized as per their cold-sweetening resistance category. In the year 2015, six families representing various CIS class combination were selected for further study. Six families were evaluated for specific gravity (SG), chip color (CC), and sugars (glucose and sucrose). Ten gram fresh tuber sample from each sample was ground under liquid nitrogen and stored at -80°C for biochemical analysis. All the six families were stored at 42°F storage for evaluations after cold storage to study the inheritance of biochemical markers for cold induced sweetening trait.

Results: Chip color and reducing sugar (97%) levels were significantly high in families with both the parents from class A (Table 1) than in the families with only one parent from class A. After 3 months storage at 42°F the pattern remains similar with slight decrease in the total percentage.

In family 142 (MN99380-1Y X MN02696) represented by class A- X A-, none of the clones demonstrated presence of A-II isozymes of UGPase enzyme. However, family 148 with similar parent combination demonstrated 50% clones with A-II isozymes of UGPase. Families with both parents having A-II isozymes (#126 and 127) demonstrated higher percentage of clones with A-II isozymes of UGPase (Table 1).

Families (#142 and 138) demonstrated higher number of clones with low levels of acid invertase activity and more clones in class A. Family #148 with both parents from Class A demonstrated slightly different pattern (Fig 2). This pattern need to be further explored. However, families with one parent from class A and one from class B demonstrated dominance of clones with higher acid invertase activity and more clones in class C with very low or no resistance to CIS (Fig 2). High levels of AcInv enzyme activity mask the effect of A-II isozyme of UGPase. The biochemical analysis after 3 months storage at 42°F cold storage was good indicator of CIS resistance in potato clones. Interestingly clones in families 142, 148 and 138 demonstrated low levels of acid invertase inhibitor protein as compared to clones in families 161, 126 and 127. This is due to the fact that at least one parent in these families had low levels of acid invertase inhibitor protein.

Discussion: The concentration of reducing sugars following long term cold storage is a primary determinant of the acceptability of potato cultivars for processing. Potatoes with excessive amount of reducing sugars (glucose and fructose) when fried or roasted at high temperature produce unacceptably brown to black pigmented processed products, which have an off-taste and higher levels of the carcinogen acrylamide. Presence of acrylamide in processed food has become a serious public health concern (Halford *et al*. 2012; Medeiros et al. 2012).

Two key enzymes, UGPase and vacuolar Acid Invertase (AcInv) responsible for high levels of reducing sugars accumulation during long term cold storage have been identified (Gupta and Sowokinos 2003; McKenzie et al. 2005). In recent years research has been focused on the AcInv enzyme activity (Zhu et al. 2014; Mckenzie et al 2013; Lin et al. 2013, Liu et al 2013). Xu et al. (2009) found that potato clones with lower levels of AcInv accumulate less reducing sugars. AcInv activity controls the glc:Suc ratio (Zrenner et al., 1993) and AcInv activity is determined by the balance between the enzyme and inhibitor proteins (McKenzie et al., 2013). The regulation of AcInv activity by invertase inhibitor protein is not clear (Chen et al., 2008). Studies have shown that AcInv activity increase during long term storage. The fold increase in AcInv activity during long term storage depends on the genotype, storage temperature and amount of inhibitor protein present. There could be several biochemical and genetic factors contributing to the observed high AcInv activity and the variable glucose concentrations. Therefore, it is imperative to study the regulation of AcInv activity by its regulatory protein.

Analysis of preliminary data revealed the significance of acid invertase inhibitor protein. Potato clones with low levels of AcInv and low invertase inhibitor protein demonstrated best CIS resistance. Parents like MN99380 and NY138 demonstrated low AcInv and low invertase inhibitor levels and yielded higher percentage of clones with low reducing sugar level.

A thorough understanding of AcInv activity and its interaction with inhibitor proteins after long term cold storage will enable us to better understand the accumulation of reducing sugar during long term storage, with associated reductions in acrylamide levels in processed potato products.

Conclusion: The preliminary data clearly suggests that by identifying appropriate parents, progeny can be obtained with a much higher frequency of desirable sugar levels and chip color. Potato clones containing A-II isozymes of UGPase, reduced vacuolar acid invertase (AcInv) enzyme and inhibitor protein demonstrated higher resistance to CIS. Acid invertase inhibitor protein plays crucial role in CIS resistance.
For successful breeding of new potato variety for high CIS resistance, parents should be selected for low levels of AcInv and invertase inhibitor and high levels of A-II protein of UGPase enzyme.
These biochemical markers could be successfully used to screen large number of clones for their CIS resistance in various potato breeding programs, NCR, NFPT and SCRI projects.

These markers are available for use through University of Minnesota office of technology commercialization.

http://license.umn.edu/technologies/20130267_assessing-cold-induced-sweetening-of-potato-varieties.

Literature Cited:

Chen S, MR Hajirezafi, MI Zanor, C Hornyik, S Debast, C Lacomme, AR Fernie, U Sonnewald, F Bornke 2008. Plant, Cell and Environ. **31**:165-176.

Gupta SK, Sowokinos, JR 2003. J Plant Physiol 160:589-600.

Halford NG, TY Curtis, N Muttucumaru, J Postles, JS Elmore, DS Mottram 2012. Journal of Experimental Botany **63:**2841–2851.

Lin Y, Liu J, Liu X, Ou YB, Li M, Zhang HL, Song BT, Xie CH. 2013. Plant Physiology and Biochemistry. 73: 237-244.

Liu X, Cheng SH, Liu J, Ou YB, Song BT, Zhang C, Lin Y, Li XQ, Xie CH. 2013. Postharvest Biology and Technology. 86:265-271.

Medeiros VR, F Mestdagh, B De Meulenaer 2012. Food Chemistry **133:**1138–1154.

McKenzie MJ, JR Sowokinos, IM Shea, SK Gupta, RR Lindlauf, JAD Anderson 2005. Am J Potato Res **82**:231-239.

Mckenzie MJ, Chen RKY, Harris JC, Ashworth MJ, Brummell, DA. 2013. Plant Cell and Environment. 36(1):176-185

Xu C, Coleman WK, Meng FR, Bonierbale M, Li XQ. 2009.

Zhu XB, Richael C, Chamberlain P, Busse JS, Bussan AJ, Jiang JM, Bethke PC. 2014. PLOS ONE. 9(4)

Zrenner R, L Willmitzer, U Sonnewald. 1993. Planta. 190:247-252.

APPENDIX 1:

Table 1. Cold-Induced Sweetening (CIS) resistance in various class combination families.

Family	Female	Male	Class	n[1]	CC[2] Harvest (%)	Glc[3] Harvest (%)	CC[2] After 3 Months (%)	A-II Isozymes % clones	CIS Resistance Class[4] (%) – 3 Months 42°F			AcInv Inhibitor[5] – 3 Months 42°F	
									A	B	C	Min	Max
142	MN99380-1Y	MN02696	A - * A-	35	97	97%	74	0	43	40	17	0.654	13.837
148	ND860-2	MN99380-1Y	A- * A-	16	73	73%	63	50	7	47	47	0.61	15.602
138	MN02696	Waneta	A- * A+	19	100	69%	83	32	59	35	6	0.605	25.317
161	W6609-3	Snowden	A- * B+	16	75	65%	31	63	6	50	44	5.64	31.528
126	Atlantic	Waneta	B+ * A+	26	60	60%	33	73	19	50	31	0.803	25.602
127	Atlantic	Lamoka	B+ * A+	23	52	52%	26	78	0	43	57	2.708	23.157

n[1] **Number of clones**

CC[2] **Chip Color 2/5 or less**

Glc[3] **Glucose (1 mg/g Fresh Weight or less)**

CIS Resistance Class[4] - A = 1< units, B = 1-3 units, C = >3 Units

AcInv Inhibitor[5] - Total Acid Invertase Units

Figure1: CIS resistance marker classes based on the expression of marker enzymes.

A. Clones with up to 1 unit of Acid Invertase Activity

a.	Clones with A-II isozyme of UGPase	(A+)
b.	Clones without A-II isozyme of UGPase	(A-)

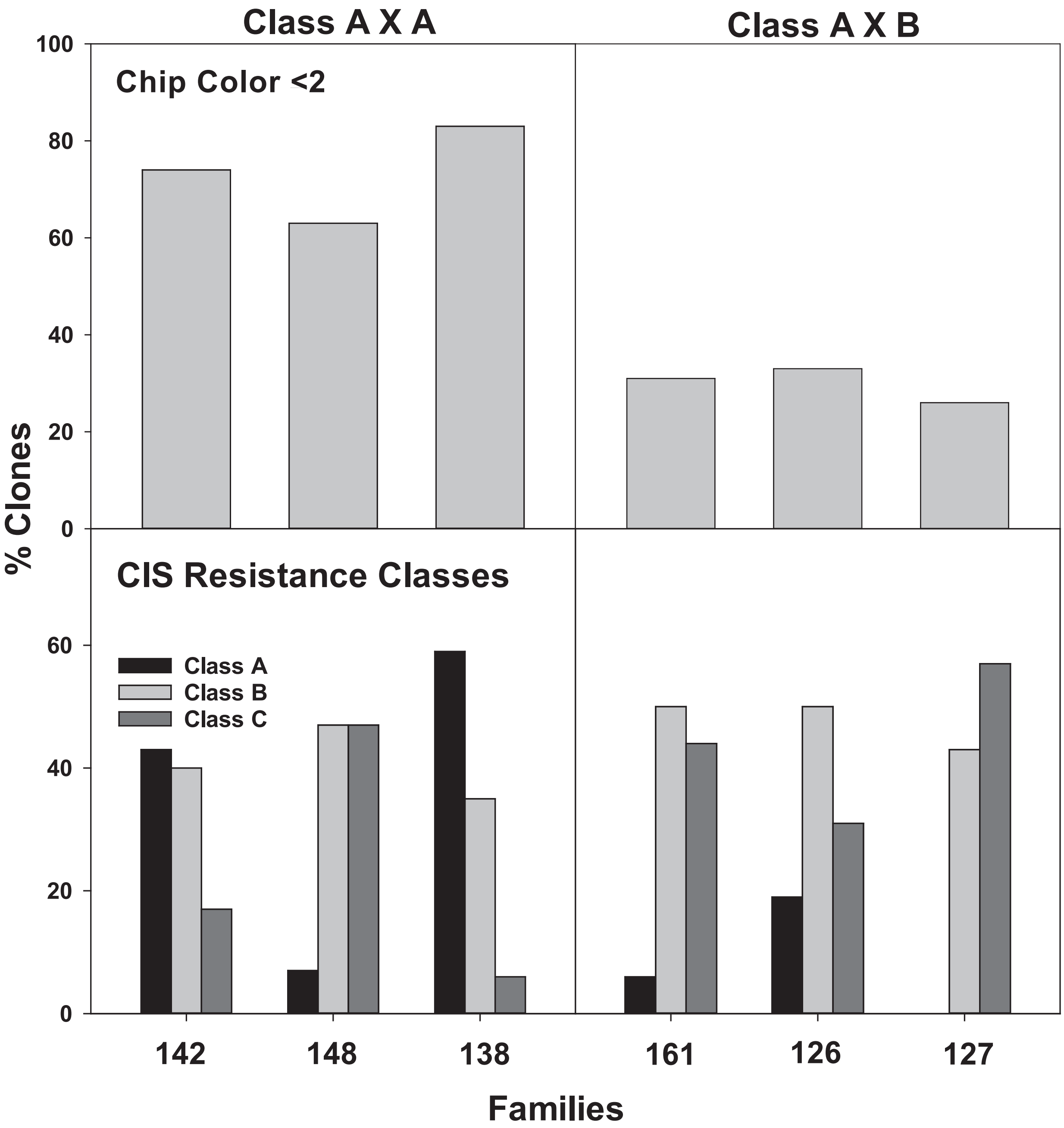
B. Clones with 1 – 3 Units of Acid Invertase Activity

a.	Clones with A-II isozyme of UGPase	(B+)
b.	Clones without A-II isozyme of UGPase	(B-)

C. Clones with more than 3 units of Acid Invertase Act.

a.	Clones with A-II isozyme of UGPase	(C+)
b.	Clones without A-II isozyme of UGPase	(C-)

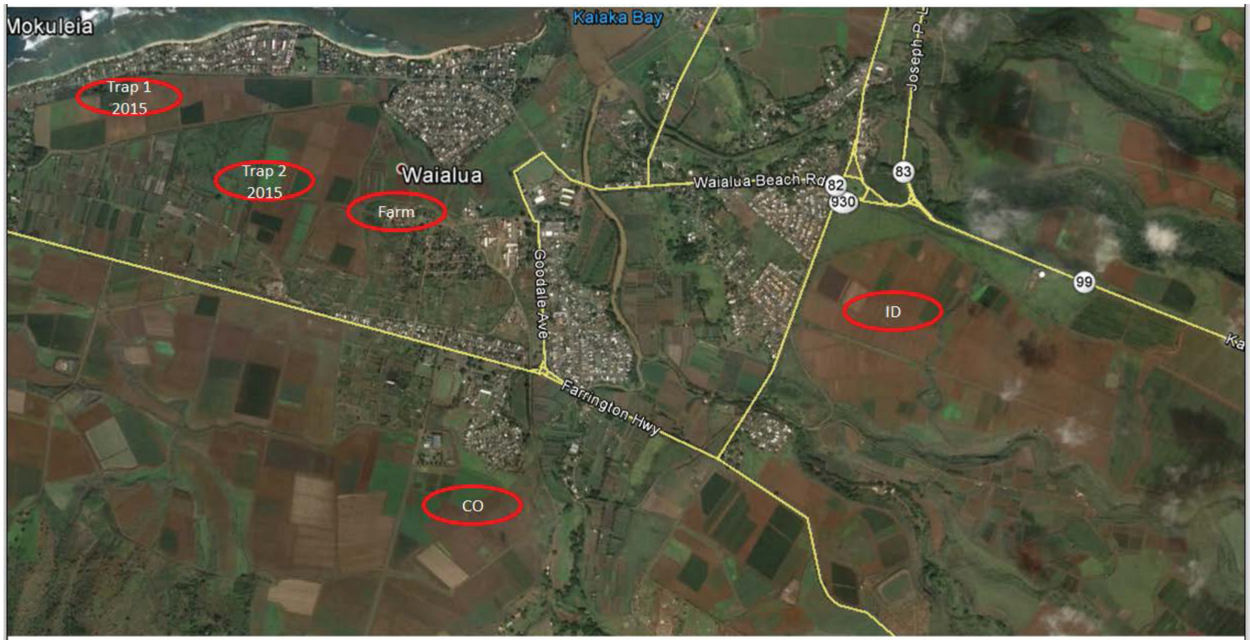
Figure 2: CIS resistance after 3 months storage at 42°F.



PVY Vector Monitoring, Winter Grow-Out 2015/16

Dr. Ian MacRae,
Nathan Russart
Dept. of Entomology, U. Minnesota
Northwest Research & Outreach Center
2900 University Ave.
Crookston, MN 56716
imacrae@umn.edu
218 281-8611 Office
218 281-8603 Fax

In 2015/16, PVY vectors were again monitored at the winter grow-out site at Waialua HI. These traps are used to monitor for the presence of aphid virus vectors at the site; the absence of vectors ensures virus is not being transmitted to plants in the grow-out. The traps monitored plots for the MN, MT, CO and ID programs (fig. 1). Vector numbers and PVY Risk Index values were be made available to the state seed certification departments of those states.



Minnesota and Montana Traps are in the vicinity of Traps 1 and 2 from last year. These had not yet been planted when we were there.

Figure 1. PVY vector monitoring trap locations at the Hawaii winer grow-out site, 2015/16.

Traps were established on Nov 30 and traps were monitored and trap jars changed weekly. Trap jars were sent to the entomology lab at UMN 's Northwest Research & Outreach Center where the contents were sorted aphid species identified.

The total PVY Vector Risk Index for the grow-out period was low (fig. 2). Very few aphids were caught over the 7 week grow-out season (fig. 3), most of which were bird cherry oat aphids (not uncommon for this site). Only one green peach aphid was recovered in the traps and that was in the last week of trapping. Consequently, the potential for movement of PVY inoculum within the grow-out season was very low.

This work was funded by MN, MT, ID and Co state seed certification services.

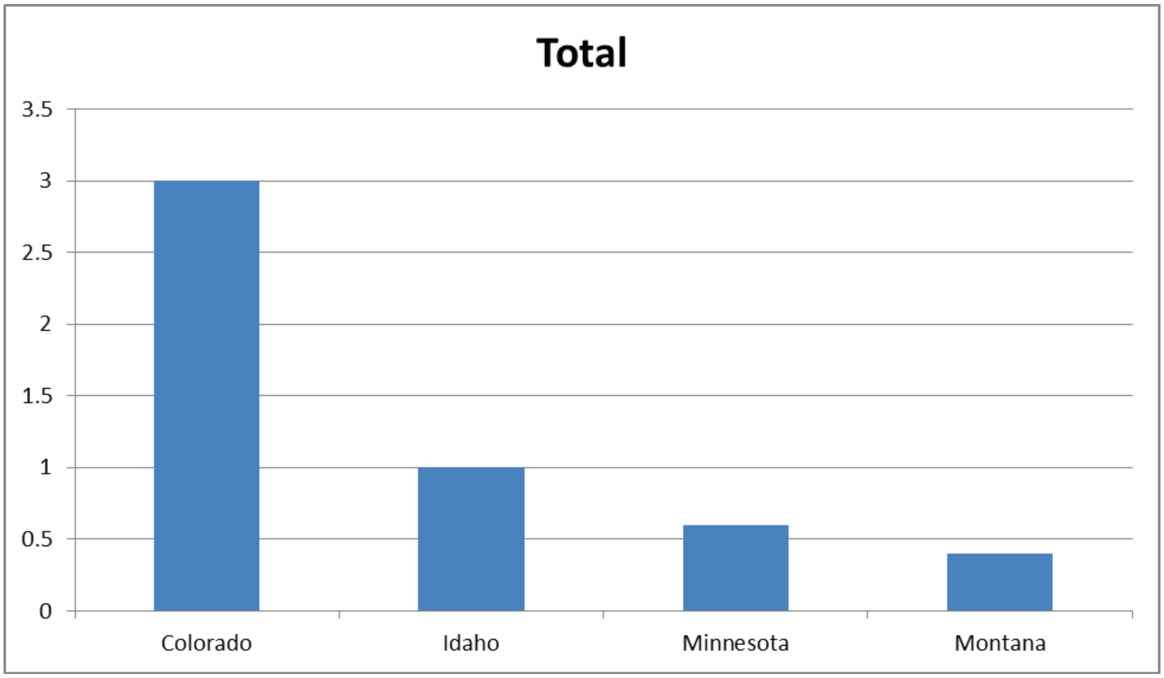


Figure 2. Cumulative PVY Vector Risk Index values for the 4 traps at the Hawaii winter grow-out site, 2015/16.

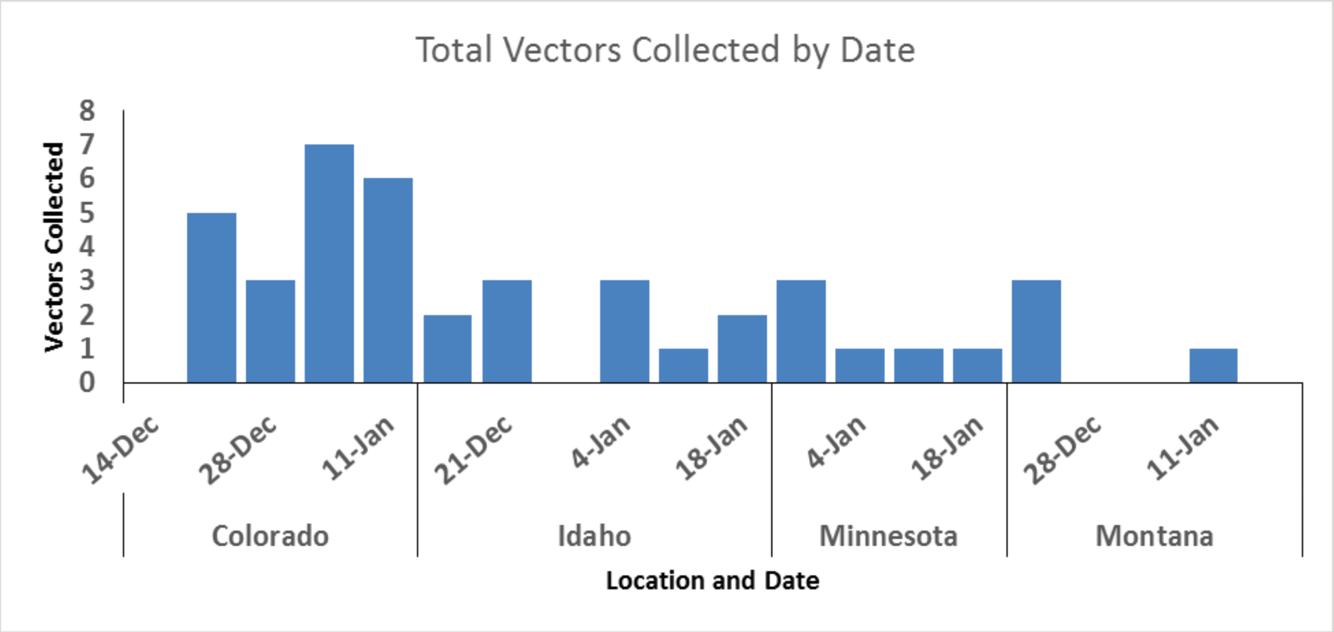


Figure 3. Total PVY vectors recovered by trap location.over the winter grow-out trial at Hawaii site, 2015/16.

Response of Irrigated Russet Burbank Potatoes to Nitrogen Rate, Polymer-Coated Urea Sources, and a Microbial Additive

Carl Rosen, James Crants, and Matt McNearney
Department of Soil, Water, and Climate, University of Minnesota
crosen@umn.edu

Summary

A field experimented was conducted at the Sand Plain Research Farm in Becker, MN, to evaluate the effects of the form, rate, and timing of nitrogen (N) application on a crop of Russet Burbank potatoes, and the effectiveness of MicroAZ-ST Liquid, a formulation of *Azospirillum* intended to stimulate root growth. Two polymer-coated ureas (PCUs), Environmentally Smart Nitrogen (ESN; Agrium, Inc.; 44-0-0) and Agrocote (Everris; 25% 44-0-0, 75% 43-0-0), were compared to urea/UAN, at total N application rates of 120, 180, and 240 lbs·ac^{-1} N. Urea/UAN was also evaluated at 150, 210, and 270 lbs·ac^{-1} N total, and there was a control treatment receiving no N after planting (at which time all treatments received 30 lbs·ac^{-1} N). In addition to single applications at emergence, both ESN and Agrocote were applied at 150 lbs·ac^{-1} N at emergence with 60 lbs·ac^{-1} N added in five applications of UAN later in the season (240 lbs·ac^{-1} N total, including the planting application), similar to the application schedule of the urea/UAN treatment at the same total N rate. MicroAZ-ST Liquid was applied at emergence in a urea/UAN treatment receiving 180 lbs·ac^{-1} N total and at planting in two urea/UAN treatments receiving 180 and 240 lbs·ac^{-1} N total. N application rate was found to be positively related to terminal leaflet SPAD readings, tuber yield, and tuber size. In contrast, N source was only related to early-season SPAD readings and tuber size, with urea/UAN producing higher SPAD readings than Agrocote and larger tubers than either PCU. For both ESN and Agrocote, the use of a modest application of PCU at emergence with post-hilling UAN applications slowed the decline in leaflet SPAD throughout the season relative to a single large N application of PCU at emergence, but had no effect on tuber yield, size, or quality. The use of MicroAZ-ST Liquid had no significant effects on potato plants. Marketable yield was maximized at an application rate of 210 to 240 lbs·ac^{-1} N total.

Background

The nitrogen (N) fertilizer urea has a high N density (46% by weight), which minimizes transportation and application costs. Its other benefits include its versatility (it can be applied in granular or liquid forms), its handling safety (relative to ammonium nitrate and anhydrous ammonia), and its fairly low cost of production. Because of these factors, urea is among the more popular N sources for agricultural crops worldwide.

Urea is rapidly converted to plant-available forms of N (ammonium and nitrate) through the enzymatic activities of soil microorganisms. These compounds are rapidly lost (through volatilization and leaching, respectively) if not taken up by plants, and ammonium is phytotoxic in high concentration, especially to seedlings. For these reasons, a single application of urea at planting to meet the crop's annual N requirements is not advisable. Instead, it is common practice to use a modest application of granular urea at planting with multiple applications of aqueous urea and ammonium nitrate (UAN) after hilling.

The use of multiple applications increases urea's application costs, diminishing one of its advantages. An alternative is to extend the release period of urea using polymer-coated urea products (PCUs). The use of PCUs both reduces the concentration of urea (and nitrate and ammonium) in the soil immediately after application and extends the period over which N is supplied to the crop.

Studies on PCUs as N sources for potato plants have been conducted over twelve years at the Sand Plain Research Farm (SPRF) in Becker, MN. Environmentally Smart Nitrogen (ESN; 44-0-0, Agrium, Inc.) has received particular attention and has been found to be a viable alternative to urea/UAN. There are other PCU products on the market that may also be effective alternatives to urea/UAN, and one goal of the PCU studies at SPRF has been to evaluate some of these other products.

In 2015, in addition to ESN, we evaluated a blend of Agrocote products (25% 44-0-0, 75% 43-0-0; Everris) as an N source for Russet Burbank potato plants. We applied these N sources, as well as urea/UAN, at rates of 120, 180, and 240 lbs·ac^{-1} N, with urea/UAN also being applied at 150, 210, and 270 lbs lbs·ac^{-1} N. For ESN and Agrocote, the full application was given at emergence, while the applications of urea/UAN were divided between 60 to 150 lbs·ac^{-1} N as urea at emergence and 30 – 130 lbs·ac^{-1} N applied as urea/UAN in 3 – 5 applications later in the season. In addition to the single-application treatments for both ESN and Agrocote, N was also applied at 150 lbs·ac^{-1} N as PCU at emergence and 90 lbs·ac^{-1} N in 5 applications of UAN later in the season (similar to the urea/UAN treatment receiving 240 total lbs·ac^{-1} N). A check treatment receiving 0 lbs·ac^{-1} N at emergence was also included. All treatments received 30 lbs·ac^{-1} N at planting as DAP.

The overall objective of PCU studies at SPRF is to evaluate methods of improving N use efficiency (tuber yield and N uptake per pound of N applied) and the economic efficiency of N fertilizer application (tuber yield per dollar invested in fertilization) in irrigated potato production. In 2015, this involved an evaluation of different sources of N (urea/UAN, ESN, and Agrocote) at different rates, with a comparison of a single large PCU application at emergence to a smaller emergence PCU application with subsequent applications of UAN at the expected optimum rate (240 lbs·ac^{-1} N total). In addition, we tested the effectiveness of TerraMax MicroAZ-ST Liquid, a formulation of *Azospirillum* intended to stimulate root growth and improve stand development in wheat. Its effectiveness in potato agriculture has not been previously assessed.

Materials and Methods

The study was conducted in 2015 at the Sand Plain Research Farm in Becker, MN, on a Hubbard loamy sand soil. The previous crop was rye. Selected characteristics of the top six inches of soil in the study field, collected on March 30, 2015, are shown in Table 1.

The study was replicated four times in a randomized complete block design. The four blocks were planted, two to a field, in two adjacent fields. Russet Burbank potatoes were planted by hand with three feet between rows and one-foot spacing within rows. Each of the two fields was surrounded by a buffer strip of Russet Burbank potatoes one row wide along either side and five feet long at either end. Each plot had four, 20-foot rows, the middle two being used for sampling and harvest. One red seed potato (cv. Chieftain) was planted at the end of each harvest row, so that each harvest row held 18 Russet Burbank seed potatoes at planting. In the buffer strips at each end of each field, red potatoes were also planted in place of Russet Burbanks for each harvest row. Whole B seed was used for Russet Burbank, and cut “A” seed was used for the red potatoes.

Eighteen different N fertilizer treatments were applied (Table 2). A check treatment received no N fertilizer after planting. Fourteen treatments were designed to evaluate the effects of N source (urea/UAN, ESN, or Agrocote) and rate, as well as the effect of using a single large application of ESN or Agrocote compared to a smaller application supplemented with subsequent UAN applications. The remaining three treatments evaluated the effects of MicroAZ-ST Liquid (TerraMax) applied at planting or emergence, with urea/UAN as the N source, applied at two N rates.

Belay was applied in-furrow for beetle control, along with the systemic fungicide Quadris. Weeds, diseases, and insect pests were controlled using standard practices. Rainfall was supplemented with sprinkler irrigation using the checkbook method of irrigation scheduling. The nitrate and ammonium concentrations of irrigation water were monitored throughout the year.

Two hundred $\text{lbs}\cdot\text{ac}^{-1}$ 0-0-60 and 200 $\text{lbs}\cdot\text{ac}^{-1}$ 0-0-22 (164 $\text{lbs}\cdot\text{ac}^{-1}$ K total) were broadcast on April 13 and 14, respectively, and incorporated with a chisel plow on April 15. Potatoes were planted on April 22. Planting fertilizer was applied to all plots at row closure, banded three inches to each side and two inches below the seed piece using a metered, drop-fed applicator incorporated into the planter. The planting fertilizer included 30 $\text{lbs}\cdot\text{ac}^{-1}$ N, 77 $\text{lbs}\cdot\text{ac}^{-1}$ P, 181 $\text{lbs}\cdot\text{ac}^{-1}$ K, 20 $\text{lbs}\cdot\text{ac}^{-1}$ Mg, 41.5 $\text{lbs}\cdot\text{ac}^{-1}$ S, 1 $\text{lbs}\cdot\text{ac}^{-1}$ B, and 1 $\text{lb}\cdot\text{ac}^{-1}$ Zn, as a blend of diammonium phosphate (DAP), potassium chloride, potassium magnesium sulfate, Granubor 2, and Blu-Min granular zinc sulfate.

N applications at emergence (May 21) were hand-broadcast and mechanically incorporated during hilling. Post-hilling UAN was applied with a tractor-mounted sprayer as 28% UAN at 25 $\text{gal}\cdot\text{ac}^{-1}$. The tractor traveled in the irrigation alleys to prevent damage to the crop. Irrigation was applied immediately following fertilizer application to simulate fertigation with an overhead irrigation system. Post-hilling N applications were administered on June 25, July 6, July 16, July 23, and August 3. Treatments receiving 30 $\text{lbs}\cdot\text{ac}^{-1}$ N post-hilling did not receive UAN on July 6 or July 23.

WatchDog weather stations (Spectrum Technologies) were used to monitor soil moisture and temperature. Two pairs of soil moisture and temperature sensors were in two plots, one receiving 150 $\text{lbs}\cdot\text{ac}^{-1}$ N as ESN (treatment 10, in rep 4) and the second receiving 150 $\text{lbs}\cdot\text{ac}^{-1}$ N as Agrocote at emergence (treatment 14, in rep 1). The probes were installed after hilling, four inches below the surface of the hill. Air temperature and precipitation were also recorded by the station in the plot receiving ESN. Soil moisture and soil and air temperature data are presented in Figure 1, and precipitation is presented in Figure 2.

Plant stands were measured in each plot on June 4, and stems per plant were determined for the harvest rows on June 10.

The petiole of the 4th leaf from the shoot tip was collected from 25 harvest-row plants per plot on five dates: June 15, June 24, July 9, July 22, and August 3. Petioles will be analyzed for NO_3-N concentration with a Wescan N analyzer. The chlorophyll concentration of the terminal leaflet of the 4th leaf from the shoot tip was measured for 40 harvest-row plants per plot using a SPAD meter on the same dates, except that the fourth reading was taken on July 23.

Vines were harvested on September 2 from one 10-ft section of each harvest row in each plot. Vines were chopped on September 4. Plots were machine harvested on September 8, and tubers were sorted and graded on September 10-11. Subsamples of vines and tubers were collected to determine moisture percentage and N concentration, which will be used to calculate N uptake and distribution within the plant. Tuber sub-samples were also used to determine tuber specific gravity and dry matter content and the prevalences of hollow heart, brown center, and scab.

Samples from the top two feet of soil were collected on October 26. Their concentrations of NH_4-N and NO_3-N will be determined with a Wescan N analyzer.

Measured amounts of ESN or Agrocote Max fertilizer were placed in plastic mesh bags and buried at the depth of fertilizer placement on May 21. Bags were collected on 9 dates: May 26, June 3, June 12, June 18, June 29, July 9, July 23, August 12, and September 2. The dry weight of the remaining fertilizer (minus the mean prill coat weight) will be determined for each collection date to track urea release over time.

Plant response data were analyzed using the GLM procedure in SAS 9.4. Dependent variables were modeled as functions of treatment and block. Results for a subset of the treatments (treatments 2, 4, 6, 8-10, and 12-14) were modeled as functions of N source, application rate, and their interaction, in a second set of GLMs. Significant differences between treatments at alpha = 0.10 were determined with Waller-Duncan k-ratio t tests.

Results

Plant stand and stems per plant

Results for plant stand and the number of stems per plant are presented in Table 3. Plant stand was very high for all plots, and no treatment had less than 98.6% average stand. The number of stems per plant also varied little among treatments, ranging from 2.5 to 3.1 stems/plant. Consequently, there was no significant effect of treatment on either variable. However, the number of stems per plant was significantly related to the source*rate interaction. The number of stems per plant tended to increase with application rate for treatments receiving urea/UAN, to decrease with rate for treatments receiving Agrocote, and to decrease and then increase for those receiving ESN.

Terminal leaflet SPAD readings

Results for terminal leaflet SPAD readings are presented in Table 3. N treatment had highly significant effects on SPAD readings on all five sampling dates. The control treatment (treatment 1) consistently had a significantly lower mean chlorophyll concentration than any other treatment.

In general, treatments receiving more total N had higher SPAD readings. N source had little to no effect on SPAD, except that treatments receiving urea/UAN (treatments 2, 4, and 6) consistently had higher SPAD values on June 15 than those receiving Agrocote at the same N rates (treatments 12, 13, and 14, respectively).

There was a tendency for the treatments receiving a PCU with post-hilling UAN (treatments 11 and 15) to have higher late-season SPAD readings than those receiving the same amount of N from the PCU applied at emergence alone (treatments 10 and 14, respectively).

SPAD readings for the treatments receiving MicroAZ-ST Liquid (treatments 16 – 18) did not differ from those of the treatments receiving urea/UAN at the same rates without MicroAZ-ST Liquid (treatments 4 and 6).

Tuber yield

Tuber yield results are presented in Table 4. The zero-N check treatment (treatment 1) had significantly lower total and marketable yield, and a smaller portion of its yield in large size classes, than all other treatments.

Total and marketable yield and the proportion of yield in large size classes all tended to increase with application rate, with stronger responses between 120 and 180 lbs·ac^{-1} N total than between 180 and 240 lbs·ac^{-1} N total. Yield in the smallest two size classes (0 to 3 oz and 3 to 6 oz) decreased with increasing application rate, while yield in the largest two classes (10 to 14 oz and greater than 14 oz) increased.

N source did not have a significant effect on total or marketable yield, but Agrocote and ESN had significantly higher yields of 3- to 6-oz tubers and significantly lower yields of tubers over 14 oz than urea-UAN. As a result, Agrocote had a significantly lower percentage of tubers over 6 oz, and both PCUs had significantly lower percentages of tubers over 10 oz, than urea/UAN, averaged across the three rates at which all three N sources were applied (120, 180, and 240 lbs·ac^{-1} N).

The treatment receiving 210 lbs·ac^{-1} N at emergence as ESN (treatment 10) had the highest total and marketable yield of all treatments, and its marketable yield and yield of U.S. No. 1 tubers were significantly greater than those of the treatment receiving 150 lbs·ac^{-1} N at emergence as ESN and 60 lbs·ac^{-1} N post-hilling as UAN (treatment 11). In no other respect did applying 210 lbs·ac^{-1} N as a PCU at emergence produce a significantly different yield result than applying 150 lbs·ac^{-1} N at emergence as that PCU with subsequent applications of UAN.

There was a significant source*rate interaction in the yield of U.S. No. 1 tubers. While the yield for the treatments receiving a single emergence application of ESN (treatments 8-10) or Agrocote (treatments 12-14) increased with application rate, especially between 120 and 180 lbs·ac^{-1} N, the yield for treatments receiving urea/UAN at the same rates (treatments 2, 4, and 6) did not respond to application rate. The same lack of response to application rate was observed for yield of U.S. No. 1 tubers across the full range of application rates of urea/UAN (treatments 2 – 7). The positive response of marketable yield to application rate observed among the urea/UAN treatments, especially between 150 and 270 lbs·ac^{-1} N total (treatments 3 – 7), was largely due to a response in the yield of U.S. No. 2 tubers.

By no measure of yield did the application of MicroAZ-ST impart a significant advantage or disadvantage relative to no application (comparing treatments 16 and 17 to treatment 4 and treatment 18 to treatment 6).

Tuber quality

Tuber quality results are presented in Table 5. No tuber quality variable was significantly related to the treatment applied.

Conclusions

Overall, the application rate of N in this study had a much greater effect on potato plants than the form or timing of its application. Leaflet SPAD, tuber yield, and tuber size all increased with application rate. The only clear effect of N source on leaflet SPAD was higher SPAD values on the first sampling date (June 15) for treatments receiving urea/UAN (treatments 2, 4, and 6) than those receiving Agrocote without UAN at the same total application rates (treatments 12-14). There were also source effects on tuber size, with treatments receiving urea/UAN having larger tubers than those receiving either PCU without UAN, averaged across the three shared application rates (120, 180, and 240 lbs·ac^{-1} N total).

Applying 150 lbs·ac^{-1} N as a PCU at emergence and 60 lbs·ac^{-1} N as multiple applications of UAN later in the season produced higher late-season leaflet SPAD readings than applying the same total amount of N as a single emergence application of PCU. However, this effect of late-season UAN on late-season leaflet SPAD did not translate into an effect on tuber yield, size distribution, grade, or quality.

Based on the response of marketable yield to N application rate, whether considering all 18 treatments together or the control and urea/UAN treatments alone (treatments 1 – 7), marketable yield peaked at an application rate of between 210 and 240 lbs·ac^{-1} N total. ESN and Agrocote applied at emergence both performed approximately the same as urea/UAN applied at the same rate, in terms of tuber yield and quality, though urea/UAN tended to produce larger tubers than the PCUs. We found no evidence that MicroAZ-ST Liquid had any impact on any of the response variables measured.

Table 1. Soil characteristics of the study site at the beginning of the season (March 30, 2015).

Primary macronutrients			Secondary macronutrients			Micronutrients					Other characteristics	
NO_3-N (ppm)	Bray P (ppm)	NH_4OAc-K (ppm)	NH_4OAc-Ca (ppm)	NH_4OAc-Mg (ppm)	SO_4-S (ppm)	Hot Water B (ppm)	DTPA-Cu (ppm)	DTPA-Fe (ppm)	DTPA-Mn (ppm)	DTPA-Zn (ppm)	Water pH	O.M. LOI (%)
4.22	37	118	940	160	2.5	0.294	0.685	37.8	10.16	2.15	6.2	2.3

Table 2. N treatments applied to irrigated Russet Burbank potatoes at the Sand Plain Research Farm in Becker, MN, in 2015.

Treatment	Planting	Emergence	Post-hilling[1]	Total N, planting and later (lbs·ac^{-1})
	Nitrogen sources[2] and N rates (lbs·ac^{-1})			
1	30 DAP	0	0	30
2	30 DAP	60 Urea	10, 0, 10, 0, 10	120
3	30 DAP	90 Urea	10, 0, 10, 0, 10	150
4	30 DAP	120 Urea	10, 0, 10, 0, 10	180
5	30 DAP	150 Urea	10, 0, 10, 0, 10	210
6	30 DAP	150 Urea	12, 12, 12, 12, 12	240
7	30 DAP	150 Urea	24, 24, 20, 12, 10	270
8	30 DAP	90 ESN	0	120
9	30 DAP	150 ESN	0	180
10	30 DAP	210 ESN	0	240
11	30 DAP	150 ESN	12, 12, 12, 12, 12	240
12	30 DAP	90 Agrocote	0	120
13	30 DAP	150 Agrocote	0	180
14	30 DAP	210 Agrocote	0	240
15	30 DAP	150 Agrocote	12, 12, 12, 12, 12	240
16	30 DAP	120 Urea + MicroAZ-ST[3]	10, 0, 10, 0, 10	180
17	30 DAP + MicroAZ-ST[3]	120 Urea	10, 0, 10, 0, 10	180
18	30 DAP + MicroAZ-ST[3]	150 Urea	12, 12, 12, 12, 12	240

[1] Post-hilling N applied as 28% UAN on each of five application dates: 6/25, 7/6, 7/16, 7/23, 8/3

[2] DAP (diammonium phosphate): 18-46-0. ESN (Environmentally Smart Nitrogen, Agrium, Inc.): 44-0-0. Agrocote (Everris): 25% 44-0-0, 75% 43-0-0. UAN (urea + ammonium nitrate): 28-0-0. Urea: 46-0-0.

[3] TerraMax MicroAZ-ST Liquid, 12.8 oz·ac^{-1}

Figure 1. Air temperature and soil moisture and temperature between emergence (May 21) and five days before harvest (September 3) at the Sand Plain Research Farm in Becker, MN, in 2015.

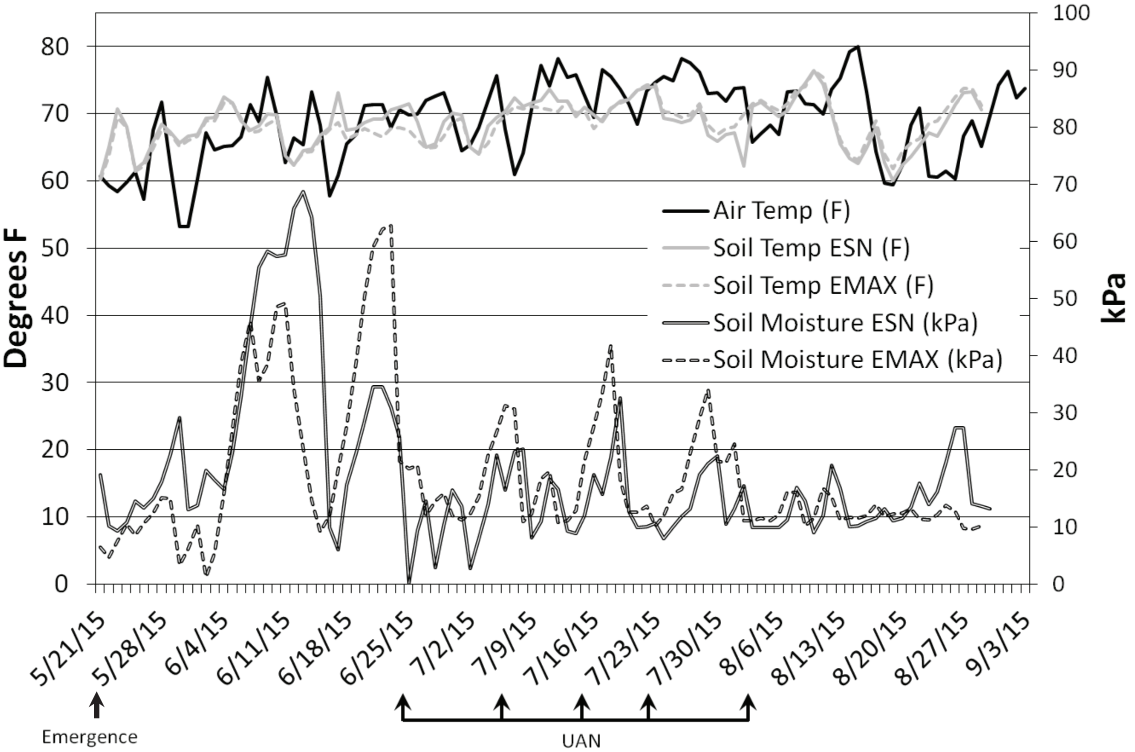


Figure 2. Precipitation as rainfall or irrigation between planting (April 22) and harvest (September 8) at the Sand Plain Research Farm in Becker, MN, in 2015.

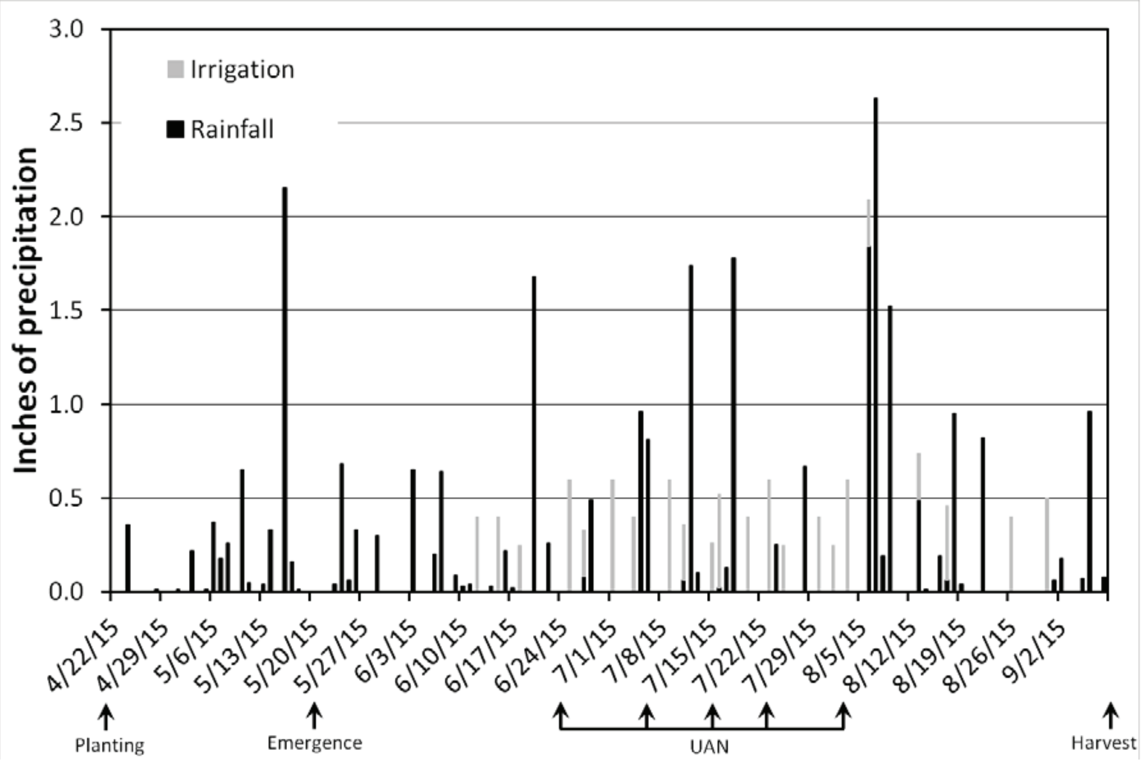


Table 3. Effect of N treatment on plant stand, stems per plant, and leaflet SPAD readings (chlorophyll concentration) of Russet Burbank potato plants grown at the Sand Plain Research Farm in Becker, MN, in 2015.

Treatment	Planting	Emergence	Post-hilling[1]	Total N, planting and later (lbs·ac^{-1})	Stand and stems		Leaflet SPAD				
	Nitrogen sources[2] and N rates (lbs·ac^{-1})				June 4 plant stand (%)	June 10 stems per plant	15-Jun	24-Jun	9-Jul	23-Jul	3-Aug
1	30 DAP	0	0	30	100	2.7	38.5	35.5	29.2	24.4	19.8
2	30 DAP	60 Urea	3 x 10 UAN	120	100	2.5	41.9	38.3	33.4	29.7	25.7
3	30 DAP	90 Urea	3 x 10 UAN	150	100	2.7	44.1	40.4	34.5	31.5	28.0
4	30 DAP	120 Urea	3 x 10 UAN	180	100	2.6	43.9	42.3	35.4	32.9	28.7
5	30 DAP	150 Urea	3 x 10 UAN	210	99	2.7	43.9	41.9	36.1	34.8	31.6
6	30 DAP	150 Urea	5 X 12 UAN	240	99	3.1	44.7	42.5	37.2	37.1	34.1
7	30 DAP	150 Urea	24, 24, 20, 12, 10	270	100	3.0	43.4	42.6	37.0	37.4	36.6
8	30 DAP	90 ESN	0	120	99	2.8	42.2	40.0	34.1	29.2	26.3
9	30 DAP	150 ESN	0	180	100	2.8	43.0	42.5	35.7	33.2	29.6
10	30 DAP	210 ESN	0	240	100	2.9	42.6	42.8	38.4	36.1	33.7
11	30 DAP	150 ESN	5 X 12 UAN	240	100	2.8	42.7	43.3	37.9	38.0	37.7
12	30 DAP	90 Agrocote	0	120	100	2.9	40.5	38.5	33.4	29.1	25.7
13	30 DAP	150 Agrocote	0	180	100	2.7	41.7	40.3	36.0	32.1	29.4
14	30 DAP	210 Agrocote	0	240	100	2.6	43.8	42.3	36.7	36.0	33.8
15	30 DAP	150 Agrocote	5 X 12 UAN	240	100	2.9	41.3	39.4	37.0	35.7	35.5
16	30 DAP	120 Urea + MicroAZ-ST[3]	3 x 10 UAN	180	99	2.7	44.3	41.7	35.3	32.9	29.6
17	30 DAP + MicroAZ-ST[3]	120 Urea	3 x 10 UAN	180	100	2.9	43.4	42.1	35.1	32.4	29.7
18	30 DAP + MicroAZ-ST[3]	150 Urea	5 X 12 UAN	240	100	2.9	44.7	42.6	37.5	35.9	34.8
Treatment significance[4]					NS	NS	**	**	**	**	**
Minimum significant difference (0.1)					--	--	1.0	1.1	1.3	1.2	2.0

[1] Post-hilling N applied as 28% UAN on each of five application dates: 6/25, 7/6, 7/16, 7/23, 8/3

[2] DAP (diammonium phosphate): 18-46-0. ESN (Environmentally Smart Nitrogen, Agrium, Inc.): 44-0-0. Agrocote (Everris): 25% 44-0-0, 75% 43-0-0. UAN (urea + ammonium nitrate): 28-0-0. Urea: 46-0-0.

[3] TerraMax MicroAZ-ST Liquid, 12.8 oz·ac^{-1}

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

Table 4. Effect of N treatment on tuber yield, size, and grade for Russet Burbank potato plants grown at the Sand Plain Research Farm in Becker, MN, in 2015.

Treatment	Planting	Emergence	Post-hilling[1]	Total N, planting and later	Tuber Yield										
					0-3 oz	3-6 oz	6-10 oz	10-14 oz	>14 oz	Total	#1s > 3 oz.	#2s > 3 oz	Total Marketable	> 6 oz	> 10 oz
	Nitrogen sources[2] and N rates (lbs·ac^{-1})			(lbs·ac^{-1})	cwt · ac^{-1}									%	
1	30 DAP	0	0	30	166	199	39	1	0	406	214	25	239	10	0
2	30 DAP	60 Urea	3 x 10 UAN	120	65	198	216	69	21	569	439	65	504	53	16
3	30 DAP	90 Urea	3 x 10 UAN	150	75	162	199	82	28	546	418	54	471	56	20
4	30 DAP	120 Urea	3 x 10 UAN	180	72	141	210	90	54	566	432	62	494	62	25
5	30 DAP	150 Urea	3 x 10 UAN	210	66	157	182	124	70	598	447	85	532	63	33
6	30 DAP	150 Urea	5 X 12 UAN	240	58	127	214	114	68	580	430	92	522	68	31
7	30 DAP	150 Urea	24, 24, 20, 12, 10	270	67	146	197	115	74	598	452	79	532	64	31
8	30 DAP	90 ESN	0	120	84	196	215	51	7	554	417	52	469	49	10
9	30 DAP	150 ESN	0	180	60	185	230	95	29	599	478	61	539	59	20
10	30 DAP	210 ESN	0	240	68	164	236	108	40	616	462	85	548	62	24
11	30 DAP	150 ESN	5 X 12 UAN	240	73	147	221	89	46	575	417	85	502	62	23
12	30 DAP	90 Agrocote	0	120	85	236	159	48	5	533	374	74	448	39	10
13	30 DAP	150 Agrocote	0	180	69	178	231	70	29	577	444	64	508	57	17
14	30 DAP	210 Agrocote	0	240	62	162	219	103	32	577	444	71	515	61	23
15	30 DAP	150 Agrocote	5 X 12 UAN	240	67	176	242	75	40	600	439	94	533	59	19
16	30 DAP	120 Urea + MicroAZ-ST[3]	3 x 10 UAN	180	58	135	220	120	50	583	450	75	525	66	29
17	30 DAP + MicroAZ-ST[3]	120 Urea	3 x 10 UAN	180	72	154	190	94	58	568	431	65	496	60	26
18	30 DAP + MicroAZ-ST[3]	150 Urea	5 X 12 UAN	240	55	119	215	147	89	625	473	97	570	72	38
Treatment significance[4]					**	**	**	**	**	**	**	*	**	**	**
Minimum significant difference (0.1)					12	34	35	27	23	41	33	35	43	7	6

[1] Post-hilling N applied as 28% UAN on each of five application dates: 6/25, 7/6, 7/16, 7/23, 8/3

[2] DAP (diammonium phosphate): 18-46-0. ESN (Environmentally Smart Nitrogen, Agrium, Inc.): 44-0-0. Agrocote (Everris): 25% 44-0-0, 75% 43-0-0. UAN (urea + ammonium nitrate): 28-0-0. Urea: 46-0-0.

[3] TerraMax MicroAZ-ST Liquid, 12.8 oz·ac^{-1}

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

Table 5. Effect of N treatment on Russet Burbank tuber quality (prevalences of hollow heart, brown center, and scab; percent dry matter; and specific gravity) at the Sand Plain Research Farm in Becker, MN, in 2015.

Treatment	Planting	Emergence	Post-hilling[1]	Total N, planting and later	Tuber Quality				
					Hollow Heart	Brown Center	Scab	Dry matter	Specific Gravity
	Nitrogen sources[2] and N rates (lbs·ac^{-1})			(lbs·ac^{-1})	%				
1	30 DAP	0	0	30	0	0	11	20.8	1.0745
2	30 DAP	60 Urea	3 x 10 UAN	120	7	7	0	20.8	1.0729
3	30 DAP	90 Urea	3 x 10 UAN	150	8	8	5	21.1	1.0808
4	30 DAP	120 Urea	3 x 10 UAN	180	3	3	4	20.2	1.0753
5	30 DAP	150 Urea	3 x 10 UAN	210	4	4	3	20.7	1.0804
6	30 DAP	150 Urea	5 X 12 UAN	240	1	1	4	20.4	1.0787
7	30 DAP	150 Urea	24, 24, 20, 12, 10	270	2	2	1	21.0	1.0757
8	30 DAP	90 ESN	0	120	4	4	0	20.7	1.0805
9	30 DAP	150 ESN	0	180	0	0	6	21.3	1.0837
10	30 DAP	210 ESN	0	240	3	3	5	21.0	1.0768
11	30 DAP	150 ESN	5 X 12 UAN	240	1	1	1	20.1	1.0768
12	30 DAP	90 Agrocote	0	120	1	1	0	21.5	1.0815
13	30 DAP	150 Agrocote	0	180	11	11	3	21.3	1.0904
14	30 DAP	210 Agrocote	0	240	1	1	5	20.3	1.0770
15	30 DAP	150 Agrocote	5 X 12 UAN	240	2	2	7	21.0	1.0774
16	30 DAP	120 Urea + MicroAZ-ST[3]	3 x 10 UAN	180	4	4	2	20.9	1.0769
17	30 DAP + MicroAZ-ST[3]	120 Urea	3 x 10 UAN	180	1	1	6	20.6	1.0776
18	30 DAP + MicroAZ-ST[3]	150 Urea	5 X 12 UAN	240	4	4	4	20.6	1.0783
				Treatment significance[4]	NS	NS	NS	NS	NS
				Minimum significant difference (0.1)	--	--	--	--	--

[1] Post-hilling N applied as 28% UAN on each of five application dates: 6/25, 7/6, 7/16, 7/23, 8/3

[2] DAP (diammonium phosphate): 18-46-0. ESN (Environmentally Smart Nitrogen, Agrium, Inc.): 44-0-0. Agrocote (Everris): 25% 44-0-0, 75% 43-0-0. UAN (urea + ammonium nitrate): 28-0-0. Urea: 46-0-0.

[3] TerraMax MicroAZ-ST Liquid, 12.8 oz·ac^{-1}

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

Starter Fertilizer for Dryland Potato - Hatterman-Valenti and Auwarter.

Field research was conducted at the Northern Plains Potato Growers Association research site near Grand Forks, ND to evaluate Redline as a starter and foliar fertilizer application on Red Norland potatoes compared to standard grower recommendations. Soil tests at 0-8" showed 88# N, 7 ppm P (low), and 183 ppm K (high). On June 12, furrows were opened with the planter and treatments were applied to both sides of where the seed piece is going to be placed. Seed pieces were planted on 36" rows and 12" spacing with a Harriston Double-Row planter. Prior to planting (Time A) the field received 150# N.

Time B = Planting
Time C = 2nd application of Redline (also treatment 9, WC 101) on treatments 6-8. Treatments 6-9 received 25 gal/A 10-34-0 + 5 gal/A Redline @ planting.

Starter fertilizer increased yield in the dryland study (Table 1). The lowest yielding treatment was treatment 1 (179 cwt/a), which only received 150# N at planting. Treatments 3 and 8 were the highest yielding treatments (260 cwt/a). The grower standard (treatment 2) had the 3rd lowest yield with 227 cwt/a, and received 119 # P (the most of any treatment). Foliar Redline applications were beneficial as treatments 6, 7, and 8 had the 5th, 3rd, and 1st highest yields, respectively, and increased as the amount of Redline applied at timing C increased.
Tuber counts showed significant differences as well (Table 2), with treatment 1 having the fewest marketable tubers (>4 oz). Treatments 3 and 8 had the greatest number of tubers (65).

Table 1. Potato yield and grade.

			Row A			Row B			Market-
Treatment	Rate	Time	Total	< 4 oz	4-6 oz	6-10 oz	> 10 oz	Total	able
			CWT/A						
1 Urea	152 lb/a	A	189	32	76	34	32	179	147
2 Urea	320 lb/a	A	225	28	102	50	46	227	199
10-34-0	30 lb/a	B							
3 Urea	320 lb/a	A	226	32	99	49	79	260	229
10-34-0	27 lb/a	B							
Redline	3 gal/a	B							
4 Urea	320 lb/a	A	223	24	103	56	45	229	206
10-34-0	25 lb/a	B							
Redline	5 gal/a	B							
5 Urea	320 lb/a	A	246	26	90	53	65	234	208
10-34-0	20 lb/a	B							
Redline	10 gal/a	B							
6 Urea	320 lb/a	A	200	23	98	53	56	232	209
10-34-0	25 lb/a	B							
Redline	5 gal/a	B							
Redline	1 gal/a	C							
7 Urea	320 lb/a	A	222	25	106	53	57	243	218
10-34-0	25 lb/a	B							
Redline	5 gal/a	B							
Redline	3 gal/a	C							
8 Urea	320 lb/a	A	252	28	104	60	64	260	232
10-34-0	25 lb/a	B							

Redline	5 gal/a	B							
Redline	5 gal/a	C							
9 Urea	320 lb/a	A	240	26	90	38	54	208	182
10-34-0	25 lb/a	B							
Redline	5 gal/a	B							
WC101	1 pt/a	C							
LSD P=.05			73	12	16	14	30	41	45

Table 2. Tuber count per 20 ft of row.

Treatment	Rate	Time	< 4 oz	4-7 oz	6-10 oz	> 10 oz	Total	Marketable
			Number					
1 Urea	152 lb/a	A	32	28	10	5	78	44
2 Urea	320 lb/a	A	26	38	14	9	88	62
10-34-0	30 lb/a	B						
3 Urea	320 lb/a	A	29	35	15	15	95	65
10-34-0	27 lb/a	B						
Redline	3 gal/a	B						
4 Urea	320 lb/a	A	23	35	16	8	83	60
10-34-0	25 lb/a	B						
Redline	5 gal/a	B						
5 Urea	320 lb/a	A	25	32	15	11	84	58
10-34-0	20 lb/a	B						
Redline	10 gal/a	B						
6 Urea	320 lb/a	A	18	35	15	10	79	60
10-34-0	25 lb/a	B						
Redline	5 gal/a	B						
Redline	1 gal/a	C						
7 Urea	320 lb/a	A	23	38	15	10	87	64
10-34-0	25 lb/a	B						
Redline	5 gal/a	B						
Redline	3 gal/a	C						
8 Urea	320 lb/a	A	25	36	17	11	92	65
10-34-0	25 lb/a	B						
Redline	5 gal/a	B						
Redline	5 gal/a	C						
9 Urea	320 lb/a	A	25	34	11	9	80	55
10-34-0	25 lb/a	B						
Redline	5 gal/a	B						
WC101	1 pt/a	C						
LSD P=.05			9	6	4	5	12	10

Starter Fertilizer for Irrigated Potato – Hatterman-Valenti and Auwarter.

Field research was conducted at the Northern Plains Potato Growers Association irrigation research site near Inkster, ND to evaluate Redline as a starter and foliar fertilizer application on Russet Burbank potatoes compared to standard grower recommendations. Soil tests at 0-6" showed 11# N, 27 ppm P (high), and 214 ppm K (high). On June 10, furrows were opened with the planter and treatments were applied to both sides of where the seed piece was going to be placed. Seed pieces were planted on 36" rows and 12" spacing with a Harriston Double-Row planter. Prior to planting (Time A) the field received 67.76# N and 124# K.

Time B = Planting
Time C = Nitrogen prior to Hilling (70#)
Time D = 2nd application of Redline (also treatment 9, WC 101) on treatments 6-8. Treatments 6-9 received 25 gal/A 10-34-0 + 5 gal/A Redline @ planting.
Time E = Fertigated Nitrogen (30#)
Time F = Fertigated Nitrogen (30#)

Treatment 2 was the grower standard, while treatments 1 and 10 did not receive a starter fertilizer. There were no significant differences between treatments for yield, grade, or tuber production. However, given the rain delays and planting finally on June 10, all treatments performed well with total yields between 411 and 485 cwt/a. The lowest yielding treatment was treatment 8 and the second lowest yielding treatment was treatment 1. Treatment 8 also had the fewest tubers. The highest yielding treatment was treatment 6 with a total yield of 485 cwt/a, and a marketable yield of 393cwt/a. This treatment did not have the highest total tuber count, but did have the greatest number of tubers in the 6 – 12 oz. grade range. The benefits of a starter fertilizer have been previously observed and would have been expected if planting would not have been delayed more than a month in 2015.

Table 1. Potato yield and grade.

			Row A			Row B			Market-
Treatment	Rate	Time	Total	< 4 oz	4-6 oz	6-12 oz	> 12 oz	Total	able
			CWT/A						
1 Urea	152 lb/a	C	495	98	115	195	33	441	343
Nitrogen	107 lb/a	E							
Nitrogen	107 lb/a	F							
2 10-34-0	30 gal/a	B	498	83	112	196	73	463	381
Urea	152 lb/a	C							
Nitrogen	107 lb/a	E							
Nitrogen	107 lb/a	F							
3 10-34-0	27 gal/a	B	502	114	118	182	35	452	337
Redline	3 gal/a	B							
Urea	152 lb/a	C							
Nitrogen	107 lb/a	E							
Nitrogen	107 lb/a	F							
4 10-34-0	25 gal/a	B	514	100	132	180	72	484	384
Redline	5 gal/a	B							
Urea	152 lb/a	C							
Nitrogen	107 lb/a	E							
Nitrogen	107 lb/a	F							
5 10-34-0	20 gal/a	B	501	91	123	208	51	475	384

Redline	10 gal/a	B							
Urea	152 lb/a	C							
Nitrogen	107 lb/a	E							
Nitrogen	107 lb/a	F							
6 10-34-0	25 gal/a	B	479	92	116	220	53	485	393
Redline	5 gal/a	B							
Urea	152 lb/a	C							
Redline	1 gal/a	D							
Nitrogen	107 lb/a	E							
Nitrogen	107 lb/a	F							
7 10-34-0	25 gal/a	B	466	96	120	205	32	455	359
Redline	5 gal/a	B							
Urea	152 lb/a	C							
Redline	3 gal/a	D							
Nitrogen	107 lb/a	E							
Nitrogen	107 lb/a	F							
8 10-34-0	25 gal/a	B	507	85	84	192	48	411	326
Redline	5 gal/a	B							
Urea	152 lb/a	C							
Redline	5 gal/a	D							
Nitrogen	107 lb/a	E							
Nitrogen	107 lb/a	F							
9 10-34-0	25 gal/a	B	505	98	117	213	44	478	380
Redline	5 gal/a	B							
Urea	152 lb/a	C							
WC101	16 fl oz/a	D							
Nitrogen	107 lb/a	E							
Nitrogen	107 lb/a	F							
10 Urea	152 lb/a	C	524	101	125	206	27	468	367
Nitrogen	107 lb/a	E							
Nitrogen	107 lb/a	F							
LSD P=.05			73	39	34	45	37	87	78

Table 2. Tuber count per 20 ft of row.

Treatment	Rate	Time	< 4 oz	4-7 oz	6-12 oz	> 12 oz	Total	Marketable
			--			Number	--	
1 Urea	152 lb/a	C	93	51	54	5	209	110
Nitrogen	107 lb/a	E						
Nitrogen	107 lb/a	F						
2 10-34-0	30 gal/a	B	92	49	53	11	206	113
Urea	152 lb/a	C						
Nitrogen	107 lb/a	E						
Nitrogen	107 lb/a	F						
3 10-34-0	27 gal/a	B	113	52	51	5	226	108
Redline	3 gal/a	B						

	Urea	152 lb/a	C						
	Nitrogen	107 lb/a	E						
	Nitrogen	107 lb/a	F						
4	10-34-0	25 gal/a	B	97	59	49	10	214	117
	Redline	5 gal/a	B						
	Urea	152 lb/a	C						
	Nitrogen	107 lb/a	E						
	Nitrogen	107 lb/a	F						
5	10-34-0	20 gal/a	B	96	54	58	8	216	121
	Redline	10 gal/a	B						
	Urea	152 lb/a	C						
	Nitrogen	107 lb/a	E						
	Nitrogen	107 lb/a	F						
6	10-34-0	25 gal/a	B	92	51	60	8	213	119
	Redline	5 gal/a	B						
	Urea	152 lb/a	C						
	Redline	1 gal/a	D						
	Nitrogen	107 lb/a	E						
	Nitrogen	107 lb/a	F						
7	10-34-0	25 gal/a	B	95	53	56	4	212	115
	Redline	5 gal/a	B						
	Urea	152 lb/a	C						
	Redline	3 gal/a	D						
	Nitrogen	107 lb/a	E						
	Nitrogen	107 lb/a	F						
8	10-34-0	25 gal/a	B	90	37	52	7	187	97
	Redline	5 gal/a	B						
	Urea	152 lb/a	C						
	Redline	5 gal/a	D						
	Nitrogen	107 lb/a	E						
	Nitrogen	107 lb/a	F						
9	10-34-0	25 gal/a	B	96	52	58	6	217	117
	Redline	5 gal/a	B						
	Urea	152 lb/a	C						
	WC101	16 fl oz/a	D						
	Nitrogen	107 lb/a	E						
	Nitrogen	107 lb/a	F						
10	Urea	152 lb/a	C	102	55	56	3	221	116
	Nitrogen	107 lb/a	E						
	Nitrogen	107 lb/a	F						
LSD P=.05				30	16	12	5	41	23

Project Title: **University of Minnesota** Potato Breeding and Genetics

Project Leader: Dr. Thomas Michaels, University of Minnesota, Department of Horticulture
456 Alderman Hall 1970 Folwell Ave, St. Paul, MN 55108 612-624-7711 michaels@umn.edu

Research Scientist: Spencer Barriball, University of Minnesota, USDA Potato Research Worksite,
311 5th Avenue NE, East Grand Forks, MN 56721 218-773-2473 barri059@umn.edu

GOALS OF THIS RESEARCH

The objective of this research is to develop and release potato varieties adapted to Minnesota and North Dakota. Selection will emphasize lines having superior yield, quality, and host plant resistance to biotic and abiotic stress.

2015 RESEARCH OBJECTIVES

OBJECTIVE 1	BREEDING, EVALUATION, AND SELECTION FOCUSED ON FRY AND CHIP PROCESSING AND FRESH MARKET RUSSET, RED AND YELLOW VARIETIES
OBJECTIVE 2	TISSUE CULTURE BANK MANAGEMENT, VIRUS CLEAN-UP RESEARCH
OBJECTIVE 3	OUTREACH

SUMMARY

Research emphasized the development, evaluation and release of potato varieties with improved yield, quality, and resistance to biotic and abiotic stress.

Objective 1

SELECTION AND CLONAL ADVANCEMENT: Breeding lines advance through the UM program in generations. Early generations are Single-hills, and Generation 1 (G1); Mid-generations are G2, G3, and G4; Late- generations are G5 and up. By the time a selected clone moves to G2 and beyond, sufficient breeder's seed is available for multi-location evaluations.

Single-hills: Represent selected clones from new hybrid crosses. After a cross and sowing of new hybrid seed, seedlings are first grown in the greenhouse to produce mini-tubers. These minitubers are planted to the field as *single-hills*.

Generation1: Single-hills selected from the previous year are planted for the first time in the field using normal plant spacing and production practices as *G1*. Typically, only 4 to 8-hills of each clone are available for planting.

Early Generations Planted in 2015

Market	G1	G2	G3
Reds	20	18	8
Yellows	1	11	2
Russets	24	15	26
Chip	16	3	21
Total	61	47	57

Generation 2-6: Selected *G1* clones are moved to the next year as *G2* selections. Typically, sufficient seed is available to evaluate the clones from multiple locations using replicated plots. Additionally, the clones are segregated into market-type and planted as *Fresh, Processing, or Chipping Trials.* Selected *G2 clones and beyond* are evaluated at multiple locations using replicated plots, and more comprehensive data is collected including yield, size and grade, internal and external physiological defects, specific gravity and processing quality. In 2015 the *G3's and beyond* were planted at Becker Early harvest and Becker Late harvest.

Locations	2015 Number of Clones Tested by Generation*								
	Total	G2	G3	G4	G5	G6	G8	G11	G13
Fresh Market									
Becker Early	59	27	10	4	13	-	1	1	3
Processing									
Becker Late	61	15	26	8	10	2	-	-	-
Chippers									
Becker Late	30	3	21	6	-	-	-	-	-

***Totals include dual purpose clones**

Generation 7 and beyond – Advanced Regional Trial, Advanced Yield and processing trials:

After *G6,* advanced clones are evaluated in *Advanced Regional Trial, Advanced Yield and processing trials.* The North Central Region Potato Variety Trial is a cooperative trial with Canada, Minnesota, North Dakota, Wisconsin, and Michigan Potato Breeding programs. UMN entered 1 selection for 2015, MN10003PLWR-06R, for its second year. For 2016, UMN will enter 4 new selections. In 2016, trials will also be conducted in the Red River Valley for fresh, chip and processing lines.

Objective 2

TISSUE CULTURE AND VIRUS ELIMINATION IN UM BREEDING LINES

In 2015 UMN Clones were put into tissue culture for clonal preservation and virus elimination. Genotypes are tissue cultured by taking sprouts from tubers and after introduction into a sterile environment, each genotype undergoes sub-culturing 3 times to produce healthy plantlets from which virus testing can be done.

Breeding for Disease Resistance

The focus of this program is to develop cultivars resistant to the major diseases of potato. Disease screening for foliar and tuber late blight, common scab, PVY resistance and PVY symptom expression, are performed. UMN hosts a common scab screening nursery with entries from all National breeding programs. In 2015, 336 individual clones were screened from Colorado State University, USDA Idaho, University of Maine, Michigan State University, North Carolina State University, Cornell University, Oregon State University, Texas A&M, USDA Beltsville, and University of Wisconsin.

Objective 3

EXTENSION / OUTREACH / COMMUNICATION:

1. MN Area II: Reporting Conference & Field-day @ Becker
2. NPPGA: Reporting Conference / Expo & Twilight Field Tour
3. NPC EXPO: Las Vegas, NV

FUNDING: NPPGA, MN Area II Research and Promotion Council, USPB, NIFA, Minnesota Ag Experiment Station. We appreciate the funding that these organizations provide to this program. **THANK YOU.**

Promising Clones

(26) MN100054BW-01Rus

(AC97306-1RU x A93157-6LS)

Early to Mid maturing fresh market russet with cream flesh and uniform medium to large tubers and a low 1.064 specific gravity.

(25) MN10053BW-01Rus

(AC96052-1RU x CO98067-7RU)

Mid to late maturing dual purpose russet with white flesh, uniform large tubers, and low to mid specific gravity 1.076.

(140) MN13085PLWR-01Rus

(MonDak Gold x AOMN03178-2Rus)

Mid season russet with white flesh, produces very white fries, uniform tuber profile, and target specific gravity of 1.085.

(5) MN07112WB-01W/P

Late maturing round specialty potato with mottled purple and white flesh, medium to large very round tubers, zero internal defects, and makes bright purple and gold chips.

(121) MN13039PLWR-03

(AF0338-17 x MN99380-1Y)

Early maturing white, round, fresh market potato with pink eyes and yellow flesh, specific gravity of 1.072 and excellent culinary properties

Runestone Gold

Medium to Late Season red skinned yellow flesh potato with moderate to low specific gravity and excellent culinary qualities.

Fresh Market Red Skin Breeding Yield and Quality Evaluation Trial, Becker, MN

Summary

Fresh Market (FM) clones were grown in Becker, MN on Hubbard loamy sand soil with sprinkler irrigation. The Trial is a replicated with 20 hill plots spaced in row at 12 inches and between row at 36 inches. Planting date was May 4th and 1st vine kill was July 24th for a total of 82 days. The trial is split into two groups, **advanced FM** and **1st and 2nd year FM selections**. Agronomic, quality, and yield data are reported in tables 1 and 2 for **advanced FM** and tables 3 and 4 for **1st and 2nd year FM selections**. Unique ID #'s have been given to all clones in the program to help report yearly clone data from multiple tables. A breakdown by generation can be seen on page 1 of this report under *Objective 1.*

Agronomic Quality

In Table 1, stand counts after 51 days after planting (DAP) ranged from very low at 60% for MN10006PLWR-06R to 100% for 15 of the 42 entries. Low stands were most likely seed piece rot and not overall environment as the average stand percentage was 92.6. Plant vigor was also measured the same day with an average of 3.5 out of 5 (excellent) for all clones.

Internal and External Quality

Hollow heart was present in only 8 clones ranging from 5 to 75%. Overall hollow heart had a very low presence with 80% of the clones showing zero. Color intensity, flesh color, tuber shape, and appearance were rated after harvest. Tuber and plant appearances were evaluated using Plant Variety Protection standards. Skin Color rating based on a Red 1-5 (e.g. R1) and Pink 1-5 (e.g.P1). R1 is most desired full color red and P5 is least desired faded pink skin. Shape was evaluated using a 1-5 scale. 1 = compressed, 2 = round, 3 = oblong, and 4 = long. Appearance was evaluated using a 1-9 scale. 1 = very poor, 3 = poor, 5 = fair, 7 = good, 9 = excellent. The majority of clones showed comparable or better red intensity color to that of Red Lasoda and Red Norland.

Yield

In Table 2, Yield data is represented in total marketable hundred weight per acre and % ounce profile. Tubers per plant is also shown. Average marketable yield was 325 cwt with a range of 150 to 483 cwt. 6 red clones had yield above 400 cwt while Red Norland and Red Lasoda yielded 479 cwt and 483 cwt respectively.

Preliminary Trial

Tables 3 and 4 are similar to 1 and 2 and show **early selections** grown for either only the 1st or 2nd season. Planting date is the same as above but plots are **non-replicated** 20 hill units. 14 of the 24 selections had a stand of 95% or greater and many had above average plant vigor. Red skin color was also excellent in the majority of clones. Yield ranged from 145 to 641 cwt with an average of 313. Internal quality was excellent with only 1 selection having hollow heart at 10%.

Conclusion

Selections that performed well will be advanced another year while poor performing selections will be dropped. Selection is focused on early bulking and early vine maturity to compete with early season varieties grown in the Becker region. The most outstanding selections will be entered into the 2016 North Central Potato Variety Trial which focuses on Fresh Market variety development across multiple states.

Promising **advanced** clones include, (11)MN10003PLWR-06R, (55)MN12028WW-01R/Y, (99)MN10001PLWR-03R, (116)MN13032PLWR-08R, and (123)MN13040PLWR-01. Promising **early** selections include (110)MN13025PLWR-08R, (113)MN13026PLWR-02R, (114)MN13026PLWR-06R, (121)MN13039PLWR-03, (142)MN13097PLWR-02R, and (148)MN14001W-01R. 55 is a red with yellow flesh and 121 and 123 are white skin yellow flesh with pink eyes. Elite Clones available for commercial use include Runestone Gold (MN02616R/Y) and (5)MN07112WB-01W/P and (162)MonDak Gold.

Table 1. Agronomic and quality evaluations for **Advanced Fresh Market** selections

ID#	Clone	Female	Male	Skin	Int[1]	Flesh	Shape[2]	APP[3]	Specific Gravity	% HH[4]	% Stand[5]	Vigor[6]
1	MN02467Rus/Y	MN Family #51	OP	Rus		Y	5	9	1.063	30	100	2.5
2	MN02586	MN Family #133	OP	W		Y	2	9	1.080	0	100	5
3	MN02616R/Y	Minnesota Family #149	OP	Red	1	Y	4	9	1.077	0	95	5
4	MN04844-07	W 2257-2	Dakota Pearl	W		Y	1	9	1.073	20	100	4
5	MN07112WB-01W/P	CO97227-2P/PW	CO97216-3P/PW	W/P		P	2	9	1.067	0	100	5
8	MN10001PLWR-14R	CO98012-5R	MN99460-14	Red	2	W	2/3	7	1.059	0	95	2.5
9	MN10003PLWR-02R	CO98012-5R	Colorado Rose	Red	1	W	1/3	9	1.059	0	90	2.5
10	MN10003PLWR-03R	CO98012-5R	Colorado Rose	Red	1	W	2	7	1.056	0	100	2
11	MN10003PLWR-06R	CO98012-5R	Colorado Rose	Red	1	W	3	7	1.059	0	95	4
12	MN10003PLWR-07R	CO98012-5R	Colorado Rose	Red	1	W	3	7	1.054	0	87.5	2
13	MN10008PLWR-06R	ND6002-2R	Dakota Rose	Red	1	W	2/3	7	1.064	0	92.5	4
15	MN10020PLWR-04R	MN 96072-4	Colorado Rose	Red	1	W	3	9	1.049	0	100	3
16	MN10020PLWR-05R	MN 96072-4	Colorado Rose	Red	1	W	3	9	1.062	0	100	4
17	MN10020PLWR-08R	MN 96072-4	Colorado Rose	Red	1	W	2	5	1.055	0	97.5	4
20	MN10024PLWR-09R	ND 4659-5R	Dakota Rose	Red	1	W	2	9	1.060	0	82.5	3
21	MN10024PLWR-11R	ND 4659-5R	Dakota Rose	Red	2	W	3	5	1.051	5	90	3
22	MN10025PLWR-07R	NDTX 4271-5	Dakota Rose	Red	1	W	2	7	1.057	0	100	3.5
23	MN10025PLWR-20R	NDTX 4271-6	Dakota Rose	Red	3	W	3	1	1.051	0	95	3.5
34	MN11035PLWRGR-01R	MN03021-1R	Dakota Rose	Red	1	W	3/4	5	1.055	0	97.5	4.5
36	MN11037PLWRGR-04R	MN03021-1R	MN06030-1R	Red	1	W	3	9	1.055	0	100	2
39	MN11042PLWRGR-03R	MN03505-3R	CO99076-6R	Red	1	W	3/4	5	1.064	0	95	4
44	MN11059PLWRGR-07R	ND8555-8R	MN96013-1R	Red	2	W	1	5	1.061	0	95	4
51	MN12004WB-01R	CO99076-6R	MN03505-3R	Red	1	W	2/3	7	1.059	0	95	1
52	MN12004WW-01R	CO99076-6R	MN03505-3R	Red	1	W	2/3	7	1.056	0	100	2.5
53	MN12006WW-01R	Dakota Rose	CO99076-6R	Red	1	W	2/4	7	1.065	0	100	5
55	MN12028WW-01R/Y	MN96013-1R	CO99076-6R	Red	2	Y	1/2	9	1.064	0	100	3.5
99	MN13001PLWR-03R	ATMN03505-3	Dakota Rose	Red	1	W	2	9	1.056	0	92.5	4
100	MN13001PLWR-04R	ATMN03505-3	Dakota Rose	Red	1	W	1	9	1.069	0	95	2
101	MN13001WW-01R	ATMN03505-3	Dakota Rose	Red	1	W	1/2	9	1.055	0	97.5	2
104	MN13006PLWR-06R	CO99076-6R	Dakota Rose	Red	1	W	2/3	9	1.055	0	60	1.5
105	MN13006PLWR-09R	CO99076-6R	Dakota Rose	Red	1	W	2/3	9	1.058	0	65	2
107	MN13007PLWR-04R	Dakota Jewel	ND4659	Red	1	W	2	7	1.054	0	95	3.5
108	MN13007PLWR-06R	Dakota Jewel	ND4659	Red	1	W	1/2	9	1.063	15	77.5	3.5
109	MN13007PLWR-10R	Dakota Jewel	ND4659	Red	1	W	2	7	1.055	0	92.5	3.5
112	MN13026PLWR-01R	MN96013-1	ND8555-8R	Red	1	W	2	9	1.067	20	67.5	2.5
115	MN13029PLWR-01R	ND8555-5R	DAKOTA ROSE	Red	1	W	1/2	5	1.057	0	97.5	3.5
116	MN13032PLWR-08R	ND8555-5R	MN96013-1R	Red	1	W	2	3	1.064	0	92.5	4
122	MN13039PLWR-04	AF0338-17	MN99380-1Y	W/Y		Y	2/3	7	1.058	75	97.5	4.5
123	MN13040PLWR-01	AO0286-3Y	MSJ126-9Y	W/Y		Y	1/2	9	1.071	0	87.5	4
128	MN13044PLWR-01R	CO99045-1Y	ND8555-8R	Red	3	Y	5	9	1.064	0	60	2.5
161	MN18747	ND 2264-7	MN 47.82-6 (MN 14489)	LW		W	4	9	1.065	0	92.5	5
162	MonDak Gold	MN 1006.81-4	MN 5.80-12	LR		Y	4	9	1.075	0	100	5
	Red Lasoda			Red	2	W	1/3	7	1.064	0	90	4.5
	Red Norland			Red	2	W	3	5	1.067	0	100	5
	Russet Norkotah			Rus		W	5	9	1.070	30	100	5
	Yukon Gold			W		Y	3/2	9	1.080	5	97.5	5
								Mean	1.062	4.3	92.6	3.5

1-Red Color Intensity 1-5

2-Shape1=compressed 2=round 3=oval 4= oblong 5=long

3-Tuber Appearance 1=very poor 3=poor 5=fair 7=good 9=excellent

4-Hollow Heart

5-20 Hills Rated 51 Days After Planting

6-Plant Vigor 1=poor 5=Excellent

Table 2. Yield and Grade for **Advanced Fresh Market** Selections

				Yield						
ID	Clone	% Stand	Tubers per plant	Marketable Cwtyld	0-4 oz %	4-6 oz %	6-12 oz %	>12 oz %	Cull %	Total Cwtyld
1	MN02467Rus/Y	100	6.6	228.1	41.1	27.2	29.3	2.4	0.0	228.1
2	MN02586	100	15.5	435.3	60.3	28.3	11.4	0.0	0.0	435.3
3	MN02616R/Y	95	12.9	425.3	39.1	37.8	23.0	0.0	0.0	425.3
4	MN04844-07	100	9.2	284.9	48.9	34.0	17.0	0.0	0.0	284.9
5	MN07112WB-01W/P	100	14.5	224.7	96.8	3.2	0.0	0.0	0.0	224.7
8	MN10001PLWR-14R	95	7.2	245.7	34.9	33.7	30.7	0.0	0.7	247.5
9	MN10003PLWR-02R	90	12.1	261.4	70.0	13.7	16.3	0.0	0.0	261.4
10	MN10003PLWR-03R	100	7.9	150.1	86.0	7.3	6.8	0.0	0.0	150.1
11	MN10003PLWR-06R	95	9.0	277.3	47.3	39.8	12.9	0.0	0.0	277.3
12	MN10003PLWR-07R	87.5	10.7	203.1	77.9	13.6	7.5	0.0	0.9	205.0
13	MN10008PLWR-06R	92.5	17.1	400.2	68.6	19.9	11.4	0.0	0.0	400.2
15	MN10020PLWR-04R	100	10.1	334.1	44.2	36.6	19.2	0.0	0.0	334.1
16	MN10020PLWR-05R	100	11.0	356.6	42.4	36.0	21.6	0.0	0.0	356.6
17	MN10020PLWR-08R	97.5	10.9	387.2	37.4	32.9	29.7	0.0	0.0	387.2
20	MN10024PLWR-09R	82.5	16.4	324.6	75.6	16.7	7.6	0.0	0.0	324.6
21	MN10024PLWR-11R	90	12.1	282.1	68.0	22.4	9.5	0.0	0.0	282.1
22	MN10025PLWR-07R	100	8.5	366.3	20.1	33.7	40.2	2.4	3.7	380.3
23	MN10025PLWR-20R	95	15.0	319.5	75.9	20.0	4.2	0.0	0.0	319.5
34	MN11035PLWRGR-01R	97.5	11.1	396.2	30.5	25.7	37.6	3.0	3.2	409.4
36	MN11037PLWRGR-04R	100	12.6	298.9	76.1	17.8	6.1	0.0	0.0	298.9
39	MN11042PLWRGR-03R	95	14.6	339.3	75.6	16.2	8.3	0.0	0.0	339.3
44	MN11059PLWRGR-07R	95	13.1	330.2	64.5	26.2	9.3	0.0	0.0	330.2
51	MN12004WB-01R	95	6.7	165.2	58.9	21.4	19.7	0.0	0.0	165.2
52	MN12004WW-01R	100	5.9	155.5	67.8	23.0	9.2	0.0	0.0	155.5
53	MN12006WW-01R	100	14.4	437.3	48.8	31.5	19.1	0.0	0.5	439.5
55	MN12028WW-01R/Y	100	13.4	363.5	67.0	21.1	11.9	0.0	0.0	363.5
99	MN13001PLWR-03R	92.5	11.5	387.6	35.3	38.4	26.3	0.0	0.0	387.6
100	MN13001PLWR-04R	95	14.7	289.2	86.8	11.7	1.5	0.0	0.0	289.2
101	MN13001WW-01R	97.5	6.8	198.4	50.1	36.5	13.4	0.0	0.0	198.4
104	MN13006PLWR-06R	60	6.8	202.9	14.9	20.1	42.0	16.4	6.7	217.4
105	MN13006PLWR-09R	65	10.8	229.6	42.8	36.9	20.4	0.0	0.0	229.6
107	MN13007PLWR-04R	95	13.9	393.6	52.8	36.1	11.0	0.0	0.0	393.6
108	MN13007PLWR-06R	77.5	17.1	451.8	39.6	33.0	27.4	0.0	0.0	451.8
109	MN13007PLWR-10R	92.5	15.0	393.5	57.4	30.5	12.1	0.0	0.0	393.5
112	MN13026PLWR-01R	67.5	9.4	210.7	42.0	38.0	20.0	0.0	0.0	210.7
115	MN13029PLWR-01R	97.5	10.8	342.4	42.6	43.3	13.2	0.0	0.9	345.6
116	MN13032PLWR-08R	92.5	15.4	309.5	88.8	9.2	2.0	0.0	0.0	309.5
122	MN13039PLWR-04	97.5	11.3	466.9	24.8	32.3	33.5	9.3	0.0	466.9
123	MN13040PLWR-01	87.5	16.9	351.8	76.8	16.8	6.4	0.0	0.0	351.8
128	MN13044PLWR-01R	60	21.8	288.0	82.8	16.2	1.0	0.0	0.0	288.0
161	MN18747	92.5	7.9	364.0	18.8	26.0	45.4	9.8	0.0	364.0
162	MonDak Gold	100	14.8	348.1	82.0	15.8	2.2	0.0	0.0	348.1
	Red Lasoda	90	9.5	483.4	12.6	19.9	56.8	10.7	0.0	483.4
	Red Norland	100	10.8	479.5	22.5	33.6	42.1	1.8	0.0	479.5
	Russet Norkotah	100	10.2	390.1	30.5	38.6	29.4	1.4	0.0	390.1
	Yukon Gold	97.5	8.6	375.8	21.8	26.7	48.1	3.4	0.0	375.8
	Mean	92.6	11.8	325.0	53.3	26.1	19.0	1.3	0.4	326.1

Planted: May 4th, 2015
Vine Killed: July 24th, 2015
Harvested: August 11th, 2015

Table 3. Agronomic and quality evaluations for **1st and 2nd year Fresh Market** selections

ID#	Clone	Female	Male	Skin	Int[1]	Flesh	Shape[2]	APP[3]	Specific Gravity	% HH[4]	% Stand[5]	Vigor[6]
56	MN12054PLWR-02R	MN06030-1R	MN06030-1R	Red	1	W	1/2	7	1.052	0	100	3
57	MN12054PLWR-03R	MN06030-1R	MN06030-1R	Red	1	W	2/3	7	1.058	0	100	2
58	MN12057PLWR-04R	ND8555-8R	Dakota Rose	Red	1	W	1/2	7	1.062	0	95	3
59	MN12063PLWR-02R	ND8555-8R	MN06030-1R	Red	1	W	3	5	1.067	0	100	2
102	MN13005WW-01R	CO99076-6R	COMN03021-1	Red	1	W	1/2	5	1.057	0	95	3
103	MN13006PLWR-03R	CO99076-6R	Dakota Rose	Red	1	W	3	7	1.063	0	85	1
106	MN13007PLWR-02R	Dakota Jewel	ND4659	Red	2	W	2	5	1.044	0	75	4
110	MN13025PLWR-08R	MN96013-1	Dark Red Norland	Red	1	Y	3	7	1.065	0	100	4
113	MN13026PLWR-02R	MN96013-1	ND8555-8R	Red	1	Y	3/4	7	1.070	0	100	5
114	MN13026PLWR-06R	MN96013-1	ND8555-8R	Red	1	W	2	3	1.064	0	95	5
117	MN13032WW-01R	ND8555-8R	MN96013-1R	Red	1	W	3	5	1.060	0	95	2
118	MN13037WW-01R	WIMN06030-1R	CO99076-6R	Red	1	W	1/2	9	1.055	0	90	1
121	MN13039PLWR-03	AF0338-17	MN99380-1Y	W		Y	2	9	1.072	0	100	4
142	MN13097PLWR-02R	ND4659	MN08122BW-1R	Red	1	W	1/2	9	1.077	0	100	4
148	MN14001W-01R	OP	OP	Red	1	W	2	9	1.056	0	100	4
149	MN14001W-02R	OP	OP	Red	1	W	3	5	1.047	0	80	3
150	MN14001W-03R	OP	OP	Red	2	W	2	7	1.055	0	85	2
151	MN14003W-01R	OP	OP	Red	1	W	1/2	5	1.062	0	90	2
152	MN14006W-01R	OP	OP	Red	1	W	3	7	1.060	0	85	3
153	MN14011W-01R	OP	OP	Red	1	W	2/3	7	1.051	10	60	2
154	MN14012W-01R	OP	OP	Red	1	W	2	7	1.063	0	65	3
156	MN14019W-01R	OP	OP	Red	1	W	3/4	3	1.068	0	95	3
157	MN14022W-01R	OP	OP	Red	1	W	2	9	1.068	0	95	3
158	MN14025W-01R	OP	OP	Red	1	W	2	9	1.061	0	80	4
								Mean	1.061	0.4	90.2	3.0

1-Red Color Intensity 1-5

2-Shape1=compressed 2=round 3=oval 4= oblong 5=long

3-Tuber Appearance 1=very poor 3=poor 5=fair 7=good 9=excellent

4-Hollow Heart

5-20 Hills Rated 51 Days After Planting

6-Plant Vigor 1=poor 5=Excellent

Table 4. Yield and Grade for **1st and 2nd Year Fresh Market selections**

				Yield						
ID	**Clone**	**% Stand**	**Tubers Per plant**	**Marketable Cwtyld**	**0-4 oz %**	**4-6 oz %**	**6-12 oz %**	**>12 oz %**	**Cull %**	**Total Cwtyld**
56	MN12054PLWR-02R	100	7.8	300.1	26.7	37.1	29.1	1.7	5.3	317.0
57	MN12054PLWR-03R	100	9.0	219.1	75.0	25.0	0.0	0.0	0.0	219.1
58	MN12057PLWR-04R	95	10.3	291.6	61.6	33.5	4.9	0.0	0.0	291.6
59	MN12063PLWR-02R	100	9.2	179.1	99.0	1.0	0.0	0.0	0.0	179.1
102	MN13005WW-01R	95	12.5	336.7	67.7	21.0	11.4	0.0	0.0	336.7
103	MN13006PLWR-03R	85	5.4	185.9	49.1	39.4	11.5	0.0	0.0	185.9
106	MN13007PLWR-02R	75	9.8	342.2	66.8	27.6	5.6	0.0	0.0	342.2
110	MN13025PLWR-08R	100	14.8	411.8	66.5	28.8	4.7	0.0	0.0	411.8
113	MN13026PLWR-02R	100	13.1	461.1	38.7	48.5	11.9	0.0	0.9	465.2
114	MN13026PLWR-06R	95	17.9	276.5	98.5	1.5	0.0	0.0	0.0	276.5
117	MN13032WW-01R	95	10.4	324.0	58.5	30.3	8.8	2.5	0.0	324.0
118	MN13037WW-01R	90	6.7	184.4	77.3	19.2	1.9	0.0	1.6	187.3
121	MN13039PLWR-03	100	19.0	356.8	90.4	8.9	0.8	0.0	0.0	356.8
142	MN13097PLWR-02R	100	16.9	641.9	30.6	35.5	33.9	0.0	0.0	641.9
148	MN14001W-01R	100	13.8	383.1	64.9	28.2	6.9	0.0	0.0	383.1
149	MN14001W-02R	80	10.3	375.8	56.5	33.4	10.1	0.0	0.0	375.8
150	MN14001W-03R	85	5.4	292.4	18.4	37.6	44.0	0.0	0.0	292.4
151	MN14003W-01R	90	8.8	257.6	71.9	24.3	3.8	0.0	0.0	257.6
152	MN14006W-01R	85	8.4	397.9	29.7	30.5	39.8	0.0	0.0	397.9
153	MN14011W-01R	60	2.6	145.8	45.8	25.6	24.0	4.6	0.0	145.8
154	MN14012W-01R	65	6.8	262.1	77.0	21.7	1.3	0.0	0.0	262.1
156	MN14019W-01R	95	7.7	237.3	55.8	32.7	10.8	0.0	0.7	239.0
157	MN14022W-01R	95	14.6	334.2	83.7	15.3	1.1	0.0	0.0	334.2
158	MN14025W-01R	80	8.3	322.7	51.0	32.7	16.3	0.0	0.0	322.7
	Mean	90.2	10.4	313.3	60.9	26.6	11.8	0.4	0.4	314.4

Planted: May 4th, 2015

Vine Killed: July 24th, 2015

Harvested: August 11th, 2015

Process Russet Breeding Yield and Quality Evaluation Trial, Becker, MN

Summary

Processing russet clones were grown in Becker, MN on Hubbard loamy sand soil with sprinkler irrigation. The Trial is a replicated with 20 hill plots spaced in row at 12 inches and between row at 36 inches. Planting date was May 4th and 1st vine kill was August 28th for a total of 117 days. The trial is split into two groups, **advanced processing** and **1st and 2nd year processing selections**. Agronomic, quality, and yield data are reported in tables 5 and 6 for **advanced processing** and tables 7 and 8 for **1st and 2nd year processing selections**. Unique ID #'s have been given to all clones in the program to help report yearly clone data from multiple tables.

Agronomic Quality

In Table 5, stand counts after 51 days after planting (DAP) ranged from 87.5% for MN13101PLWR-02Rus to 100% for 15 of the 42 entries. Low stands were most likely seed piece rot and not overall environment as the average stand percentage was 98.8. Plant vigor was also measured the same day with an average of 4.0 out of 5 (excellent) for all clones. Average maturity after 96 days was 2.5. The length of the season was 117 days.

Internal Quality

Hollow heart was present in only 20 clones ranging from 6 to 38%. Average hollow heart was 5.2%. Specific Gravity (SG) target range is 1.080-1.095. SG ranged from 1.064 to 1.103 with an average of 1.075. Fry scores were taken after sampling direct from harvest, blanched for 4 minutes at 165F, and fried for 3 minutes at 365F. Scores were from 000 as the lightest and 4 as the darkest. The data is presented in a modified format from Susie Thompson were 000 equals .1, 00= .3, 0 = .5, and 1=1, etc. to obtain averages of each replication. Fry scores ranged from 0.4 to 4.0 with an average of 1.7. Russet Burbank had a SG of 1.074, no presence of hollow heart, and a fry score of 0.5. 24 clones had a specific gravity in the target range of 1.080 to 1.095, 13 of those had zero Hollow Heart and an average fry score 1.6. Overall, 17 clones averaged a score of .8 or less.

Yield

In Table 6, Yield data is represented in total marketable hundred weight per acre and % ounce profile. Tubers per plant is also shown. Average marketable yield was 508 cwt with a range of 294 to 812 cwt. Russet Burbank had a yield of 476 cwt per acre and a maturity rating of 2 after 96 days. There were 8 clones that had a higher yield than Russet Burbank and a maturity of 2.5 or less with target specific gravity from 1.080 – 1.095. Clones with earlier maturation will be advanced and evaluated for early season French fries.

Preliminary Trial

Tables 7 and 8 are similar to 5 and 6 and show **early selections** grown for either only the 1st or 2nd season. Planting date is the same as above but plots are **non-replicated** 20 hill units. All 19 selections had a stand of 95% or greater and 16 had a vigor rating of 4 or higher after 51 days. SG average was 1.077 with 8 in the target range of 1.080 to 1.095. Average fry score was 1.3 with 7 clones at 0.5. Maturity was mostly early to mid season with average yields of 508 cwt. Yield ranged from 299 to 713 cwt. Internal quality was excellent with 14 selections having no presence of Hollow Heart.

Conclusion

Promising clones include (7)MN09152BW-01Rus, (25)MN10053BW-01Rus, (26)MN10054BW-01Rus, and (140)MN13085PLWR-01Rus. These have shown good internal and fry qualities for several years as well as good yield. Virus was present in 25 and 26 in the field and is likely the cause of the lower yields in 2015. All lines will be also be fried after storage in 42F. Selections that performed well will be advanced another year while poor performing selections will be dropped.

Table 5. Agronomic and quality evaluations for **Advanced Processing** selections

ID#	Clone	Female	Male	Skin	Flesh	Specific Gravity	% HH[1]	Fry[2]	% Stand[3]	Vigor[4]	Maturity[5]
6	MN09107BB-01Rus	SH Bulk	OP	Rus	W	1.075	0	0.4	100	3.5	3
7	MN09152BW-01Rus	SH Bulk	OP	Rus	W	1.082	13	0.5	100	4.5	1.5
14	MN10010WW-06Rus	AOA95154-1	AC97306-1RU	Rus	W	1.069	0	1.8	95	3.5	2
18	MN10023BB-01Rus	AC00395-2RU	AO96164-1	Rus	W	1.067	0	3.0	97.5	3	2.5
19	MN10023BW-01Rus	AC00395-2RU	AO96164-1	Rus	C	1.075	0	2.0	97.5	4	3.5
24	MN10030WB-04Rus	PA99N12-1	AC97306-1RU	Rus	W	1.073	13	0.8	100	4	3.5
25	MN10053BW-01Rus	AC96052-1RU	CO98067-7RU	Rus	W	1.076	13	0.5	100	4	4
26	MN10054BW-01Rus	AC97306-1RU	A93157-6LS	Rus	W	1.064	6	0.8	100	4	2.5
27	MN10056WB-10Rus	Summit Russet	Canela Russet	Rus	C	1.068	6	1.5	100	4	3
28	MN10056WW-05Rus	Summit Russet	Canela Russet	Rus	C	1.072	6	2.5	100	3.5	3
29	MN10056WW-10Rus	Summit Russet	Canela Russet	Rus	W	1.064	11	2.0	100	4	3.5
30	MN10064BW-01Rus	AC00395-2RU	A96104-2	Rus	W	1.076	5	0.7	100	5	2
31	MN11026WB-07Rus	MN18710	Russet Norkotah	Rus	C	1.069	0	0.7	100	4.5	1.5
32	MN11027WW-06Rus	85038	Russet Norkotah	Rus	C	1.067	6	3.0	100	5	3
35	MN11035WB-06LW	Chipeta	Shepody	Rus	C	1.076	6	4.0	97.5	4	1.5
37	MN11040WB-04Rus	MN02419	Stampede Russet	Rus	W	1.067	0	2.5	97.5	4.5	4
38	MN11040WB-12Rus	MN02419	Stampede Russet	Rus	W	1.078	0	3.0	100	5	2.5
40	MN11048WW-04Rus	Russet Norkotah	19012	Rus	C	1.080	0	3.5	100	5	1.5
41	MN11057WB-03Rus	W1151	Russet Norkotah	Rus	W	1.064	0	3.5	100	3.5	3.5
42	MN11057WB-04Rus	W1151	Russet Norkotah	Rus	C	1.065	0	4.0	100	4.5	2.5
43	MN11057WW-04Rus	W1151	Russet Norkotah	Rus	W	1.064	0	2.3	97.5	3	3
54	MN12028WB-01Rus	MN96013-1R	CO99076-6R	Rus	W	1.083	0	0.5	100	4	2
63	MN12088WW-01Rus	AC99375-1RUS	AF3362-1RUS	Rus	C	1.075	0	1.3	100	5	2
77	MN12124WB-01Rus	SHEPODY	MN03178-2RUS	Rus	W	1.084	6	0.4	100	3.5	2
78	MN12124WW-01Rus	SHEPODY	MN03178-2RUS	Rus	W	1.087	19	0.7	95	4	2
129	MN13046PLWR-08Rus	MN07011GFB-1	AOND95249-1	Rus	C	1.089	19	1.0	92.5	4	1.5
133	MN13063PLWR-04Rus	AF3362-1	AOND95249-1	Rus	W	1.103	6	1.5	100	4	1
134	MN13064PLWR-01LW	AF3362-1	MN18747	LW	C	1.065	6	2.0	100	3.5	3.5
136	MN13064PLWR-11Rus	AF3362-1	MN18747	Rus	C	1.068	6	1.5	100	4	3.5
137	MN13069PLWR-01Rus	AOND95249-1	MN18747	Rus	W	1.084	6	0.8	97.5	4	1
138	MN13070PLWR-02Rus	KRANTZ	AOMN03178-2RUS	Rus	W	1.075	6	0.4	95	4	3
140	MN13085PLWR-01Rus	MN15620	AOMN03178-2RUS	Rus	W	1.085	0	1.2	100	4.5	2.5
144	MN13101PLWR-02Rus	RUSSET BURBANK	AOMN03178-2RUS	Rus	W	1.081	0	1.3	87.5	1	1.5
145	MN13109PLWR-01Rus	SolCap346	AOND95249-1	Rus	W	1.082	38	0.5	100	4.5	3
147	MN13117PLWR-02Rus	Shepody	AOMN03178-2RUS	Rus	W	1.082	38	2.3	100	3	4
163	NDMN120013WB-01Rus	ND060564C-3Russ	ND060761B-3Russ	Rus	C	1.066	0	4.0	100	5	3.5
164	NDMN120013WW-01Rus	ND060564C-3Russ	ND060761B-3Russ	Rus	C	1.065	0	2.2	100	4	3
166	NDMN120022WB-01Rus	ND060618CB-9	ND060761B-3Russ	Rus	C	1.077	0	0.7	97.5	3	2
167	NDMN120024WW-02Rus	ND060625Cb-1Russ	ND070927-2Russ	Rus	W	1.072	0	2.5	100	4.5	2
168	NDMN120029WW-01Rus	ND060761B-3Russ	Ranger Russet	Rus	W	1.075	0	3.5	97.5	4	2.5
169	NDMN120048WW-01Rus	M1	Dakota Trailblazer	Rus	C	1.082	0	1.7	100	4	2
170	NDMN120053WW-01Rus	ND4382-17	ND049289B-1Russ	Rus	C	1.070	0	0.7	100	4.5	3
171	NDMN120058WW-01Rus	ND4382-52	Dakota Trailblazer	Rus	W	1.082	0	1.0	100	5	3
172	NDMN120063WW-01Rus	ND5873-53	AND97279-5Russ	Rus	C	1.079	0	0.8	100	4.5	1
	Russet Burbank			Rus	W	1.074	0	0.5	100	4	2
					Mean	1.075	5.2	1.7	98.8	4.0	2.5

1-% Hollow Heart

2-Fry color scores: 0.1 corresponds to a 000, 0.3 corresponds to 00, 0.5 to 0, 1.0 to 1 and subsequent numbers follow French Fry rating scale 000 to 4.0

3-% stand of 20 hills

4-Plant Vigor 1=poor 5=Excellent

5-Maturity 1=very early (<100 DAP) 2=early (100-110 DAP) 3=mid-season (111-120 DAP) 4=late (121-130 DAP) 5=very late (>130 DAP)

Table 6. Yield and Grade for **Advanced Processing selcetions**

				Yield						
ID	**Clone**	**% Stand**	**Tubers Per plant**	**Marketable Cwtyld**	**0-4 oz %**	**4-6 oz %**	**6-12 oz %**	**>12 oz %**	**Cull %**	**Total Cwtyld**
6	MN09107BB-01Rus	100	12.8	524.9	29.7	30.4	35.5	4.4	0.0	524.9
7	MN09152BW-01Rus	100	13.4	802.9	11.9	14.0	55.2	18.0	0.8	809.6
14	MN10010WW-06Rus	95	8.4	517.2	11.8	15.6	48.2	22.9	1.5	524.9
18	MN10023BB-01Rus	98	4.9	307.3	11.6	14.4	44.0	28.8	1.1	310.8
19	MN10023BW-01Rus	98	6.0	342.3	14.5	19.5	45.2	20.7	0.0	342.3
24	MN10030WB-04Rus	100	8.8	360.6	28.2	18.6	45.0	5.1	3.1	372.3
25	MN10053BW-01Rus	100	12.5	642.5	16.0	21.3	49.8	11.8	1.1	649.5
26	MN10054BW-01Rus	100	8.0	486.8	10.2	17.0	54.4	18.4	0.0	486.8
27	MN10056WB-10Rus	100	9.9	386.0	33.3	24.3	35.0	5.7	1.6	392.2
28	MN10056WW-05Rus	100	9.4	400.1	26.0	29.8	34.4	9.8	0.0	400.1
29	MN10056WW-10Rus	100	8.2	387.2	18.7	26.7	42.5	11.3	0.9	390.6
30	MN10064BW-01Rus	100	14.6	477.1	42.9	27.5	25.3	4.2	0.0	477.1
31	MN11026WB-07Rus	100	7.6	502.3	9.5	15.1	37.6	37.1	0.6	505.1
32	MN11027WW-06Rus	100	7.8	471.7	10.4	11.7	44.9	25.5	7.4	509.5
35	MN11035WB-06LW	98	10.8	591.5	13.8	19.1	48.3	15.6	3.2	610.8
37	MN11040WB-04Rus	98	14.4	384.3	60.6	26.0	13.4	0.0	0.0	384.3
38	MN11040WB-12Rus	100	12.2	577.9	18.1	24.4	46.8	6.8	4.0	602.0
40	MN11048WW-04Rus	100	11.4	570.2	16.4	27.4	47.6	8.0	0.6	573.9
41	MN11057WB-03Rus	100	9.3	432.2	20.4	22.0	50.4	7.3	0.0	432.2
42	MN11057WB-04Rus	100	10.6	539.2	16.9	19.2	41.7	19.4	2.9	555.1
43	MN11057WW-04Rus	98	9.4	520.4	15.6	19.6	40.9	24.0	0.0	520.4
54	MN12028WB-01Rus	100	8.8	548.5	9.7	15.7	51.9	21.4	1.4	556.0
63	MN12088WW-01Rus	100	15.4	748.2	19.5	20.6	40.8	19.2	0.0	748.2
77	MN12124WB-01Rus	100	9.7	420.3	25.8	26.9	37.6	9.7	0.0	420.3
78	MN12124WW-01Rus	95	9.7	533.0	15.0	24.0	50.5	10.5	0.0	533.0
129	MN13046PLWR-08Rus	93	6.1	580.0	3.4	6.7	35.7	51.0	3.3	599.5
133	MN13063PLWR-04Rus	100	12.2	557.8	19.5	32.7	42.2	4.6	1.1	564.1
134	MN13064PLWR-01LW	100	6.8	552.2	3.7	8.0	39.9	42.6	5.8	586.2
136	MN13064PLWR-11Rus	100	5.7	464.6	5.4	7.2	35.2	47.0	5.2	490.1
137	MN13069PLWR-01Rus	98	10.6	812.2	5.5	9.8	40.7	40.9	3.2	838.7
138	MN13070PLWR-02Rus	95	8.6	489.5	12.7	23.3	50.7	12.7	0.5	492.1
140	MN13085PLWR-01Rus	100	11.7	733.9	10.6	13.2	48.7	27.0	0.4	736.7
144	MN13101PLWR-02Rus	88	6.0	294.0	24.7	26.1	42.4	5.2	1.6	298.9
145	MN13109PLWR-01Rus	100	7.5	408.3	13.1	21.8	52.3	11.1	1.7	415.5
147	MN13117PLWR-02Rus	100	6.9	439.0	8.7	14.0	51.6	23.4	2.4	449.8
163	NDMN120013WB-01Rus	100	13.3	750.6	9.3	19.0	58.1	10.5	3.1	774.9
164	NDMN120013WW-01Rus	100	11.2	677.4	7.4	17.6	60.4	12.3	2.3	693.4
166	NDMN120022WB-01Rus	98	11.4	396.8	40.7	31.8	25.4	2.2	0.0	396.8
167	NDMN120024WW-02Rus	100	13.5	490.3	36.5	31.4	26.3	5.2	0.6	493.4
168	NDMN120029WW-01Rus	98	9.0	422.1	22.9	20.4	37.4	15.2	4.1	440.0
169	NDMN120048WW-01Rus	100	8.3	331.6	30.8	25.5	36.2	5.6	1.8	337.8
170	NDMN120053WW-01Rus	100	14.8	372.5	60.8	23.4	14.3	1.6	0.0	372.5
171	NDMN120058WW-01Rus	100	12.4	612.0	17.8	19.4	52.4	7.5	2.9	630.1
172	NDMN120063WW-01Rus	100	14.0	541.9	31.3	23.4	37.5	5.6	2.1	553.6
	Russet Burbank	100	12.0	476.6	29.5	21.8	34.7	10.2	3.8	495.2
	Mean	98.8	10.1	508.4	20.0	20.6	42.0	15.7	1.7	517.6

Planted: May 4th, 2015
Vine Killed: August 28th, 2015
Harvested: September 16th, 2015

Table 7. Agronomic and quality evaluations for **1st and 2nd year Processing** selections

ID#	Clone	Female	Male	Skin	Flesh	Specific Gravity	% HH[1]	Fry[2]	% Stand[3]	Vigor[4]	Maturity[5]
60	MN12088PLWR-02Rus	AC99375-1RUS	AF3362-1RUS	Rus	W	1.078	0	1.0	100	5	1
61	MN12088PLWR-03Rus	AC99375-1RUS	AF3362-1RUS	Rus	W	1.075	0	0.5	100	5	4
62	MN12088PLWR-04Rus	AC99375-1RUS	AF3362-1RUS	Rus	W	1.078	0	0.5	100	5	1
64	MN12091PLWR-01Rus	AF3317-15RUS	MN18747	Rus	W	1.089	13	0.5	100	4	1
65	MN12091PLWR-02Rus	AF3317-15RUS	MN18747	Rus	W	1.077	0	2.0	95	2	3
66	MN12092PLWR-01Rus	AF3317-15RUS	MN03178-2RUS	Rus	W	1.068	0	4.0	100	4	2
67	MN12101PLWR-01Rus	MN15620	MN18747	LR	W	1.065	0	0.5	100	3	1
70	MN12112PLWR-03Rus	MN18747	MN02696	Rus	C	1.082	13	1.0	95	4	3
72	MN12115PLWR-01Rus	MN18747	ND8229-3RUS	Rus	C	1.074	0	0.3	100	4	1
73	MN12115PLWR-02Rus	MN18747	ND8229-3RUS	Rus	W	1.084	0	0.5	100	4	3
75	MN12122PLWR-04Rus	SHEPODY	MN18747	Rus	C	1.065	0	1.0	100	4	4
76	MN12124PLWR-02Rus	SHEPODY	MN03178-2RUS	Rus	C	1.080	13	2.0	100	4	3
132	MN13063PLWR-01Rus	AF3362-1	AOND95249-1	Rus	W	1.076	0	1.0	100	5	2
135	MN13064PLWR-04LW	AF3362-1	MN18747	LW	W	1.081	0	0.5	100	5	2
139	MN13072PLWR-01Rus	MN07051BB-1	AOND95249-1	Rus	C	1.090	13	2.0	100	4	1
143	MN13101PLWR-01Rus	RUSSET BURBANK	AOMN03178-2RUS	Rus	C	1.068	13	3.0	100	4	4
146	MN13111PLWR-01Rus	SolCap68	AF3008-3	Rus	W	1.079	0	0.5	100	3	3
159	MN14029W-01Rus	OP	OP	Rus	C	1.086	0	1.0	100	4	1
165	NDMN120015WW-02Rus	ND060607B-4	AND01804-3Russ	Rus	W	1.072	0	2.0	100	4	4
					Mean	1.077	3.3	1.3	99.5	4.1	2.3

1-% Hollow Heart

2-Fry color scores: 0.1 corresponds to a 000, 0.3 corresponds to 00, 0.5 to 0, 1.0 to 1 and subsequent numbers follow French Fry rating scale 000 to 4.0

3-% stand of 20 hills

4-Plant Vigor 1=poor 5=Excellent

5-Maturity 1=very early (<100 DAP) 2=early (100-110 DAP) 3=mid-season (111-120 DAP) 4=late (121-130 DAP) 5=very late (>130 DAP)

Table 8. Yield and Grade for **1st and 2nd Year Processing selections**

				Yield						
ID	**Clone**	**% Stand**	**Tubers Per Plant**	**Marketable Cwtyld**	**0-4 oz %**	**4-6 oz %**	**6-12 oz %**	**>12 oz %**	**Cull %**	**Total Cwtyld**
60	MN12088PLWR-02Rus	100	11.4	690.4	12.9	14.0	45.5	27.6	0.0	690.4
61	MN12088PLWR-03Rus	100	9.4	602.9	8.1	11.4	44.0	27.3	9.1	663.5
62	MN12088PLWR-04Rus	100	8.3	713.2	5.6	5.6	32.9	55.9	0.0	713.2
64	MN12091PLWR-01Rus	100	5.5	421.1	5.4	9.8	44.1	40.8	0.0	421.1
65	MN12091PLWR-02Rus	95	8.4	419.7	16.7	27.8	40.6	14.9	0.0	419.7
66	MN12092PLWR-01Rus	100	6.2	313.7	14.4	20.4	35.2	18.8	11.2	353.5
67	MN12101PLWR-01Rus	100	7.5	395.3	16.1	22.9	39.4	21.6	0.0	395.3
70	MN12112PLWR-03Rus	95	10.3	424.2	25.8	32.8	41.4	0.0	0.0	424.2
72	MN12115PLWR-01Rus	100	8.7	466.6	11.6	24.6	58.0	5.8	0.0	466.6
73	MN12115PLWR-02Rus	100	9.2	484.1	17.5	22.7	42.1	16.1	1.6	491.8
75	MN12122PLWR-04Rus	100	8.4	508.9	11.4	16.0	52.9	19.7	0.0	508.9
76	MN12124PLWR-02Rus	100	6.7	455.2	4.9	16.4	58.1	20.5	0.0	455.2
132	MN13063PLWR-01Rus	100	9.1	687.5	6.6	6.3	38.8	40.1	8.1	748.4
135	MN13064PLWR-04LW	100	7.2	679.9	2.9	3.4	34.4	59.4	0.0	679.9
139	MN13072PLWR-01Rus	100	6.8	522.6	1.8	11.6	51.6	31.3	3.7	542.6
143	MN13101PLWR-01Rus	100	12.0	505.0	26.6	32.7	37.1	3.6	0.0	505.0
146	MN13111PLWR-01Rus	100	5.8	441.6	2.7	10.2	54.7	27.6	4.8	463.6
159	MN14029W-01Rus	100	11.0	622.6	12.3	15.7	58.2	13.8	0.0	622.6
165	NDMN120015WW-02Rus	100	9.6	299.0	44.7	25.5	26.7	0.0	3.1	308.5
	Mean	99.5	8.5	508.1	13.0	17.4	44.0	23.4	2.2	519.7

Planted: May 4th, 2015
Vine Killed: August 28th, 2015
Harvested: September 16th, 2015

Chip Market Breeding Yield and Quality Evaluation Trial, Becker, MN

Summary

Chipping clones were grown in Becker, MN on Hubbard loamy sand soil with sprinkler irrigation. The Trial is a replicated with 20 hill plots spaced in row at 12 inches and between row at 36 inches. Planting date was May 4th and 1st vine kill was August 28th for a total of 117 days. The trial is split into two groups, **advanced chippers** and **1st and 2nd year chipping selections**. Agronomic, quality, and yield data are reported in tables 9 and 10 for **advanced chippers** and tables 11 and 12 for **1st and 2nd year chipping selections**. Unique ID #'s have been given to all clones in the program to help report yearly clone data from multiple tables.

Agronomic Quality

In Table 9, stand counts after 51 days after planting (DAP) ranged from 97.5% to 100% for 15 of the 20 entries. Plant vigor was also measured the same day with an average of 4.0 out of 5 (excellent) for all clones. Average maturity after 96 days was 2.7. The length of the season was 117 days.

Internal Quality

Hollow heart was present in only 5 clones ranging from 5 to 11%. Average hollow heart was 2.2%. Specific Gravity (SG) target range is 1.080-1.095. SG ranged from 1.063 to 1.087 with an average of 1.078. Chip scores were taken after sampling and storage at 38F for 2 weeks to apply heavy pressure on the population for evidence of resistance to cold induced sweeting. Chips were fried for 90 seconds at 365F. Scores were based on the Snack Food Association scale of 1.0-5.0 light to dark. 2.5 is considered unacceptable for commercial processing. Scores ranged from 2.0 (MN13041PLWR-03 and MN13089PLWR-01) to 5.0. Check varieties included Atlantic, Norvalley, and Snowden. Hollow heart was 11% in Atlantic and not present in either Norvalley or Snowden. SG was 1.086, 1.082, and 1.087 respectively with average chip scores of 4.0, 3.0, and 2.8. 11 clones had a specific gravity in the range of 1.078 to 1.095, 7 of those had zero Hollow Heart and an average chip score 2.8. Overall, 7 clones averaged a score of 2.5 or less, the threshold for commercial processing.

Yield

In Table 10, Yield data is represented in total marketable hundred weight per acre and % ounce profile. Tubers per plant is also shown. Average yield was 539 cwt with a range of 348 to 819 (Snowden). Atlantic, Norvalley, and Snowden had yields of 582, 698, and 819 cwt, and maturities of 3.5, 2, and 2.5 after 96 days. There were 7 clones that had yields of 500 or greater.

Preliminary Trial

Tables 11 and 12 are similar to 9 and 10 and show **early selections** grown for either only the 1st or 2nd season. Planting date is the same as above but plots are **non-replicated** 20 hill units. All 20 of 21 selections had a stand of 100% and 16 had a vigor rating of 4 or higher after 51 days. Average SG was 1.079 with 4 in the target range of 1.080 to 1.095. Average chip score was 3.5 with 5 clones at 2.5. Maturity was mostly mid season after 96 days with average yields of 525 cwt. Yield ranged from 176 to 787 cwt. Internal quality was excellent with 14 selections having no presence of Hollow Heart.

Conclusion

Promising clones include (71) MN12113WW-01, (85) MN12132PLWR-02, (86) MN12134PLWR-02, (126)MN13041PLWR-03, and (141) MN13089PLWR-01, All lines will be also be chipped after storage in 42F. Selections that performed well will be advanced another year while poor performing selections will be dropped.

Table 9. Agronomic and quality evaluations for **Advanced Chipping** selections

ID#	Clone	Female	Male	Skin	Flesh	Specific Gravity	% HH[1]	Chip[2]	% Stand[3]	Vigor[4]	Maturity[5]
33	MN11031WW-01	Calwhite	Chipeta	W	W	1.066	0	4.5	100	4	3.5
45	MN11136PLWRGR-10	B1992-106	Dakota Pearl	W	W	1.083	0	2.5	97.5	4.5	3
46	MN11136PLWRGR-11	B1992-106	Dakota Pearl	W	W	1.078	6	2.5	100	4.5	3.5
47	MN11142PLWRGR-01	Dakota Pearl	Atlantic	W	W	1.071	0	3.5	100	4	4
48	MN11153PLWRGR-03	MN00467-4	Dakota Pearl	W	W	1.066	0	3.0	97.5	3.5	3.5
49	MN11189PLWRGR-02	QSW06-03	MN00467-4	W	W	1.063	0	2.5	100	4.5	3.5
71	MN12113WW-01	MN18747	MN03178-2RUS	W	W	1.081	0	2.5	100	4.5	3.5
90	MN12138WB-01	B1992-106	MN00467-4	W	W	1.081	5	4.0	100	2	2
91	MN12138WW-01	B1992-106	MN00467-4	W	W	1.078	11	4.5	100	3	1
119	MN13039PLWR-01	AF0338-17	MN99380-1Y	W	Y	1.080	0	3.8	100	4.5	2
120	MN13039PLWR-02	AF0338-17	MN99380-1Y	W	Y	1.078	0	4.5	100	4	2
124	MN13040PLWR-02	AO0286-3Y	MSJ126-9Y	W	Y	1.071	0	5.0	100	4	3.5
125	MN13041PLWR-01	AO1143-3c	MN99380-1Y	W	Y	1.071	0	2.3	97.5	3	2
126	MN13041PLWR-03	AO1143-3c	MN99380-1Y	W	Y	1.085	0	2.0	100	3.5	1
127	MN13042PLWR-02	CO99045-1Y	DAKOTA PEARL	W	Y	1.080	10	4.5	100	3.5	2
130	MN13048PLWR-01	MN99380-1Y	ATLANTIC	W	C	1.078	0	3.8	97.5	4.5	3
141	MN13089PLWR-01	MN15620	AOMN03178-2RUS	W	C	1.086	0	2.5	95	3.5	2
	Atlantic			W	W	1.086	11	4.0	100	5	3.5
	Norvalley			W	W	1.082	0	3.0	100	4.5	2
	Snowden			W	W	1.087	0	2.8	100	4.5	2.5
					Mean	1.078	2.2	3.4	99.3	4.0	2.7

1-% Hollow Heart

2-Chip color 1.0 to 5.0 (light to dark). Chips made after samples were stored at 38F for 2 Weeks

3-% stand of 20 hills

4-Plant Vigor 1=poor 5=Excellent

5-Maturity 1=very early (<100 DAP) 2=early (100-110 DAP) 3=mid-season (111-120 DAP) 4=late (121-130 DAP) 5=very late (>130 DAP)

Table 10. Yield and Grade for **Advanced Chipping** selections

				Yield						
ID	**Clone**	**% Stand**	**Tubers Per Plant**	**Marketable Cwtyld**	**0-4 oz %**	**4-6 oz %**	**6-12 oz %**	**>12 oz %**	**Cull %**	**Total Cwtyld**
33	MN11031WW-01	100	11.2	764.2	7.4	11.0	51.2	30.3	0.0	764.2
45	MN11136PLWRGR-10	97.5	9.6	523.9	15.7	15.8	45.5	23.0	0.0	523.9
46	MN11136PLWRGR-11	100	13.5	389.5	55.1	29.5	15.5	0.0	0.0	389.5
47	MN11142PLWRGR-01	100	8.7	348.2	27.9	20.7	37.3	14.1	0.0	348.2
48	MN11153PLWRGR-03	97.5	12.9	469.6	34.8	27.9	32.0	5.4	0.0	469.6
49	MN11189PLWRGR-02	100	11.5	511.2	25.0	21.7	43.9	8.9	0.6	514.2
71	MN12113WW-01	100	7.3	395.2	14.4	21.0	41.7	22.9	0.0	395.2
90	MN12138WB-01	100	8.1	471.0	12.5	14.3	52.8	20.3	0.0	471.0
91	MN12138WW-01	100	7.6	401.1	15.9	15.5	50.9	17.6	0.0	401.1
119	MN13039PLWR-01	100	8.2	489.9	9.7	20.7	49.2	18.8	1.5	497.5
120	MN13039PLWR-02	100	12.2	578.0	19.5	22.9	49.9	7.7	0.0	578.0
124	MN13040PLWR-02	100	10.8	492.1	23.1	29.8	42.0	5.1	0.0	492.1
125	MN13041PLWR-01	97.5	18.6	504.4	58.9	29.1	10.8	1.2	0.0	504.4
126	MN13041PLWR-03	100	14.8	753.7	15.9	23.2	54.4	6.5	0.0	753.7
127	MN13042PLWR-02	100	11.2	448.6	27.9	35.2	34.9	0.0	0.0	448.6
130	MN13048PLWR-01	97.5	11.6	698.3	10.4	16.0	53.6	20.0	0.0	698.3
141	MN13089PLWR-01Rus	95	10.8	453.1	25.3	26.8	40.5	7.2	0.2	454.2
	Atlantic	100	9.4	582.0	11.3	15.3	42.9	30.5	0.0	582.0
	Norvalley	100	13.5	698.1	18.4	16.8	42.0	22.8	0.0	698.1
	Snowden	100	15.5	819.0	14.4	25.6	51.4	8.7	0.0	819.0
	Mean	99.3	11.3	539.6	22.2	21.9	42.1	13.5	0.1	540.1

Planted: May 4th, 2015
Vine Killed: August 28th, 2015
Harvested: September 16th, 2015

Table 11. Agronomic and quality evaluations for **1st and 2nd year Chipping** selections

ID#	Clone	Female	Male	Skin	Flesh	Specific Gravity	% HH[1]	Chip[2]	% Stand[3]	Vigor[4]	Maturity[5]
69	MN12108PLWR-05	MN18747	Dakota Pearl	W	W	1.070	0	4.0	100	3	2
74	MN12116PLWR-05	MN18747	SUPERIOR	W	C	1.066	0	5.0	100	4	4
79	MN12125PLWR-01	ATLANTIC	FL1533	W	W	1.071	38	5.0	100	5	3
80	MN12127PLWR-02	ATLANTIC	MN18747	W	W	1.073	0	4.0	100	3	3
81	MN12127PLWR-03	ATLANTIC	MN18747	W	W	1.068	0	4.0	100	5	3
82	MN12128PLWR-02	ATLANTIC	MN00467-4	W	W	1.072	0	3.5	100	3	3
83	MN12128PLWR-06	ATLANTIC	MN00467-4	W	W	1.086	38	4.0	100	4	3
84	MN12131PLWR-01	ATLANTIC	NY138	W	C	1.085	0	4.5	100	5	2
85	MN12132PLWR-02	ATLANTIC	NY139	W	C	1.078	40	2.5	100	3	2
86	MN12134PLWR-02	ATLANTIC	QSW06-03	W	W	1.093	0	2.5	100	4	3
87	MN12134PLWR-05	ATLANTIC	QSW06-03	W	C	1.091	0	4.0	100	4	3
88	MN12136PLWR-03	B1992-106	DAKOTA PEARL	W	W	1.079	0	3.0	100	4	3
89	MN12136PLWR-06	B1992-106	DAKOTA PEARL	W	Y	1.084	0	3.0	100	3	3
92	MN12142PLWR-03	DAKOTA PEARL	ATLANTIC	W	Y	1.076	0	3.5	100	4	3
93	MN12143PLWR-02	DAKOTA PEARL	MN99380-1Y	W	W	1.086	50	2.5	100	4	2
94	MN12152PLWR-01	MN99380-1Y	SNOWDEN	W	W	1.077	60	2.5	100	4	2
95	MN12166PLWR-01	NORVALLEY	NORVALLEY	W	W	1.085	25	3.5	100	5	4
96	MN12171PLWR-02	NORVALLEY	MN00467-4	W	W	1.072	38	3.5	100	5	3
97	MN12179PLWR-04	SNOWDEN	B1992-106	W	W	1.082	40	3.0	95	3	4
98	MN12181PLWR-02	SNOWDEN	DAKOTA PEARL	W	W	1.081	30	2.5	100	5	3
131	MN13052PLWR-01	MSJ126-9Y	MN99380-1Y	W	W	1.073	0	3.5	100	4	2
					Mean	1.079	17.0	3.5	99.8	4.0	2.9

1-% Hollow Heart

2-Chip color 1.0 to 5.0 (light to dark). Chips made after samples were stored at 38F for 2 Weeks

3-% stand of 20 hills

4-Plant Vigor 1=poor 5=Excellent

5-Maturity 1=very early (<100 DAP) 2=early (100-110 DAP) 3=mid-season (111-120 DAP) 4=late (121-130 DAP) 5=very late (>130 DAP)

Table 12. Yield and Grade for **1st and 2nd Year Chipping** selections

				Yield						
ID	**Clone**	**% Stand**	**Tubers Per Plant**	**Marketable Cwtyld**	**0-4 oz %**	**4-6 oz %**	**6-12 oz %**	**>12 oz %**	**Cull %**	**Total Cwtyld**
69	MN12108PLWR-05	100	8.1	421.6	14.6	22.9	44.4	18.1	0.0	421.6
74	MN12116PLWR-05	100	9.0	560.7	9.4	17.3	50.7	22.5	0.0	560.7
79	MN12125PLWR-01	100	8.3	787.1	5.1	5.7	29.3	59.8	0.0	787.1
80	MN12127PLWR-02	100	10.8	489.9	18.6	30.2	44.2	7.0	0.0	489.9
81	MN12127PLWR-03	100	7.1	617.4	4.4	4.4	41.6	49.7	0.0	617.4
82	MN12128PLWR-02	100	8.2	386.5	19.7	18.0	47.7	14.5	0.0	386.5
83	MN12128PLWR-06	100	8.6	394.7	22.8	18.9	44.8	13.5	0.0	394.7
84	MN12131PLWR-01	100	11.8	537.2	22.8	19.9	48.7	8.6	0.0	537.2
85	MN12132PLWR-02	100	8.5	298.3	36.8	18.3	42.8	2.1	0.0	298.3
86	MN12134PLWR-02	100	5.8	329.6	12.3	15.4	56.9	15.5	0.0	329.6
87	MN12134PLWR-05	100	8.5	351.6	19.0	26.6	44.9	3.1	6.4	375.8
88	MN12136PLWR-03	100	9.4	640.5	9.4	6.1	49.8	34.7	0.0	640.5
89	MN12136PLWR-06	100	14.7	642.6	23.7	22.8	45.9	7.6	0.0	642.6
92	MN12142PLWR-03	100	15.7	650.6	25.6	26.4	43.6	4.4	0.0	650.6
93	MN12143PLWR-02	100	12.6	668.1	14.7	20.4	53.9	11.0	0.0	668.1
94	MN12152PLWR-01	100	12.2	775.1	9.4	16.6	41.8	32.1	0.0	775.1
95	MN12166PLWR-01	100	7.3	348.3	21.0	17.5	42.9	18.6	0.0	348.3
96	MN12171PLWR-02	100	11.0	677.4	10.0	17.4	50.2	21.5	0.9	683.3
97	MN12179PLWR-04	95	7.1	176.3	56.3	20.9	22.9	0.0	0.0	176.3
98	MN12181PLWR-02	100	12.2	681.8	11.0	12.6	50.6	21.0	4.7	715.5
131	MN13052PLWR-01	100	16.5	597.9	37.4	34.0	25.2	3.4	0.0	597.9
	Mean	100	10.1	525.4	19.2	18.7	44.0	17.6	0.6	528.4

Planted: May 4th, 2015

Vine Killed: August 28th, 2015

Harvested: September 16th, 2015

Weed control in irrigated potatoes with Aceto EPTC. Hatterman-Valenti and Auwarter.

A study was initiated at the Northern Plains Potato Growers Association Irrigation Research site near Inkster, ND to evaluate a new formulation of EPTC on Russet Burbank for efficacy and material handling/application characteristics. Herbicides were applied with a CO_2 backpack sprayer equipped with 11002 XR flat-fan nozzles and operated at 40 psi with an output of 20 GPA. Application timing codes were:
A – preplant
B – just before hilling
C – immediately after hilling

Table 1. Weed control 28 days after application (DAA) (9 days after hilling), and 61 DAA (42 days after hilling).

Treatment	Rate	Applic	28DAA				61DAA			
	oz ai/A	timing	Injury	Colq	Rrpw	Grft	Injury	Colq	Rrpw	Grft
Untreated			0	0	0	0	0	0	0	0
Aceto EPTC	4.8	A	10	88	91	100	0	99	100	100
Eptam	4.8	A	8	93	96	100	0	98	96	100
Aceto EPTC	9.6	A	18	95	99	100	0	96	100	100
Eptam	9.6	A	14	96	99	100	0	96	100	100
Aceto EPTC	4.8	B	19	90	91	100	0	90	93	100
Eptam	4.8	B	13	90	95	100	0	91	93	100
Matrix+Sencor	0.38+0.67	C	8	88	93	100	0	95	95	100
LSD 0.05			8	9	7	0	0	7	9	0

Summary: Potatoes quickly outgrew initial injury and all treatments generally provided excellent season-long weed control.

Table 2. Potato yield and grade.

Treatment	Rate lb ai/A	Applic timing	< 4 oz	4-6 oz	6-12 oz	> 12 oz	Total	Market	% Market
			-------------------------------		CWT/A	-------------------------------			
Untreated			24	27	42	7	391	298	76
Aceto EPTC	4.8	A	21	23	41	14	411	325	79
Eptam	4.8	A	19	22	49	9	431	348	81
Aceto EPTC	9.6	A	21	25	42	11	437	347	79
Eptam	9.6	A	22	25	43	9	393	305	77
Aceto EPTC	4.8	B	27	28	37	7	355	260	73
Eptam	4.8	B	23	22	46	7	371	283	77
Matrix+Sencor	0.38+0.38	C	25	21	43	9	408	305	75
LSD 0.05			6	6	9	8	60	7	9

Summary: Weed pressure was light and the lack of weed pressure contributed to similarity in grade and yield among all treatments. EPTC is readily lost through volatilization when the soil surface is moist at time of application if not incorporated immediately. This study showed that the two application timings performed statistically similarly even though there was a slight trend for less yield when applied immediately before hilling.