MINNESOTA AREA II POTATO RESEARCH AND PROMOTION COUNCIL

AND

NORTHERN PLAINS POTATO GROWERS ASSOCIATION

2015

RESEARCH REPORTS

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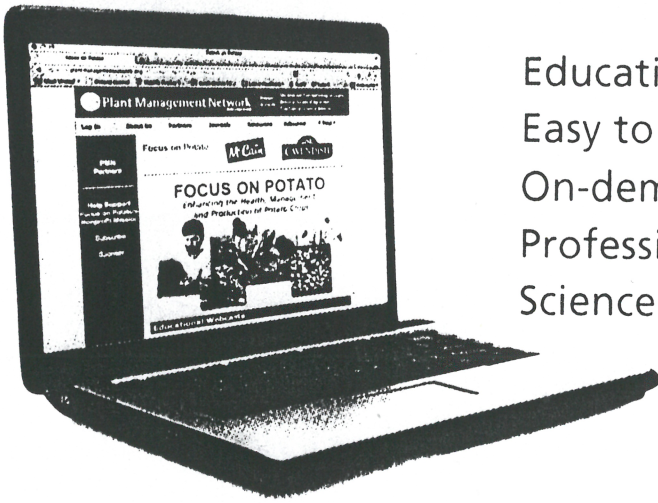

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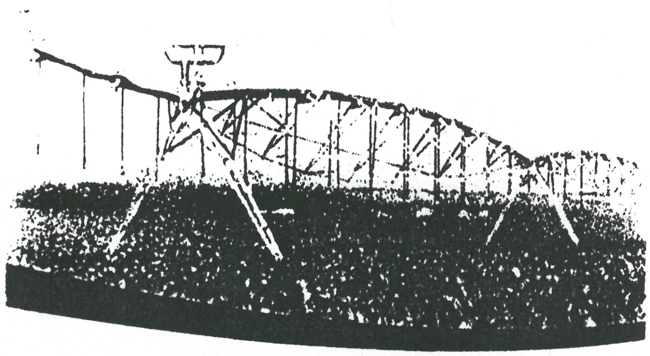


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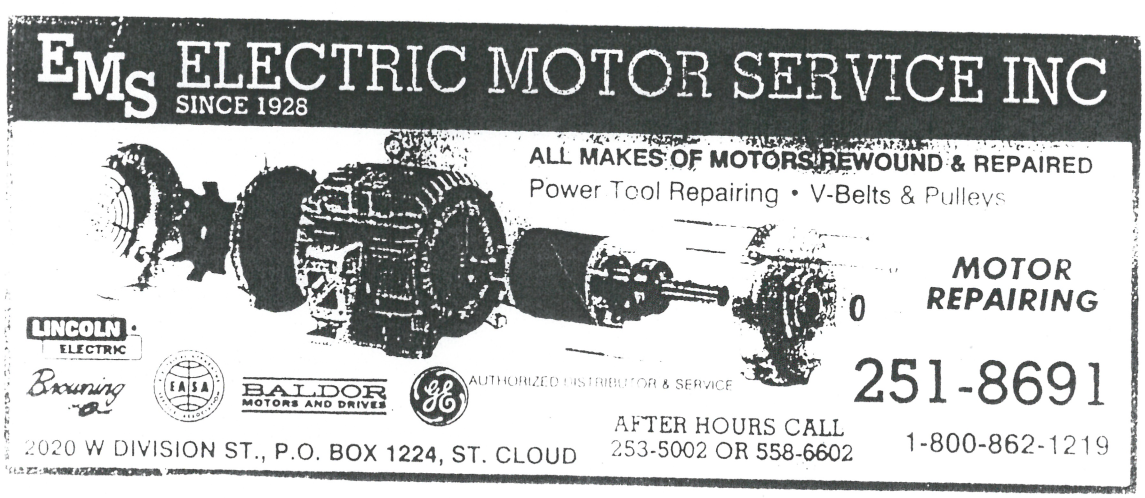
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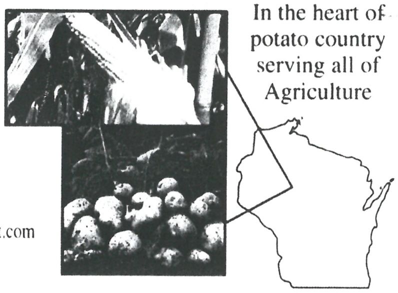

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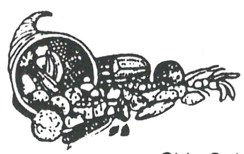

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Agnition Starter Fertilizer in Potato. Harlene Hatterman-Valenti and Collin Auwarter. Field research was conducted at the Northern Plains Potato Growers Association irrigation research site near Inkster, ND to evaluate different methods and fertilizers in addition to normal recommended fertilizer applications. Prior to planting the field received 61#N, 200#K, 30#S and 2#B. Treatment 1 received Commence potato seed treatment on May 29. On May 30, before planting, we opened the seed furrow and applied ANPOTATOIF-01-14 (treatment 2 and 3) and 10-34-0 (30 gpa) on both sides of where seed piece will be placed. We planned on planting, but rain (1.08") delayed planting. We returned June 3 and planted Russet Burbank seed pieces (2 oz) on 12" intervals with 36" row spacing using a Harriston Double Row planter. On June 16, we applied 70#N, hilled and applied herbicide. ANPOTATOFOL-01-14 was applied on July 17, early tuber, and again on July 28 with a CO2 backpack sprayer at 40 psi using 8002 flat fan nozzles and 20 gpa. Potatoes were harvested October 9 and graded December 9.

Treatments:

		5/29	5/30	5/30	6/16	7/17	7/28
Trt	**PPI**	**Commence**	**10-34-0**	**ANPOTATOIF-01-14**	**@Hilling**	**ANPOTATOFOL-01-14**	**ANPOTATOFOL-01-14**
1	61#N,200#K,30#S, 2#B	1.35oz/cwt	35#N,119#P		70#N		
2	61#N,200#K,30#S, 2#B		35#N,119#P	1 qt/a	70#N		
3	61#N,200#K,30#S, 2#B		35#N,119#P	1.5 qt/a	70#N		
4	61#N,200#K,30#S, 2#B		35#N,119#P		70#N	1 qt/a	1 qt/a
5	61#N,200#K,30#S, 2#B		35#N,119#P		70#N		

Yield Data:

Trt	Stand Count 20'		CWT/A	---------B Row Tuber Counts in 20'---------					
No.	A Row	B Row	A Row	<4oz	4-6oz	6-12oz	>12oz	Total	>4oz
1	20a	18a	478a	73a	51a	61a	10a	194a	121a
2	19a	18a	459a	85a	52a	56a	10a	203a	118a
3	18a	18a	404a	86a	60a	57a	10a	212a	126a
4	18a	18a	492a	99a	61a	63a	9a	232a	133a
5	18a	18a	470a	92a	57a	56a	6a	210a	118a
LSD (P=.05)	1.53	1.60	100.57	29.56	20.80	10.99	7.46	38.50	20.11

Trt	---------------------B Row CWT/A---------------------					
No.	<4oz	4-6oz	6-12oz	>12oz	Total	>4oz
1	79a	115a	227a	67a	487a	409a
2	91a	118a	204a	68a	481a	390a
3	97a	136a	205a	67a	505a	408a
4	107a	137a	229a	61a	534a	427a
5	102a	128a	203a	40a	474a	372a
LSD (P=.05)	31.40	46.79	34.62	53.86	43.92	47.73

We collected data at grading of tuber counts and yield in row 'B' of: 0-4 oz, 4-6 oz, 6-12 oz and >12 oz. With the limited number of treatments (less than 21 df error), it is very difficult to have significance, especially with a crop like potato. As somewhat expected, there were no significant differences among treatments. Treatment 4 in both the A row (weighed in the field) and the B row (graded) had the highest total yield of 492 and 534 cwt/a. Treatment 5, the growers standard practice treatment had a lowest marketable yield (372 cwt/a), which was approximately 15% less than the marketable yield of treatment 4 (427 cwt/a). Treatment 1 had the lowest unmarketable tubers (79 cwt/a), which was 23% less than the grower standard (102.1 cwt/a). Treatments 1 and 4 had greatest yield for tubers 6-12 oz, the grade processors want for French fries, which averaged 13% greater than the grower standard. Treatments 1, 2, 3, and 4 had 53% to 70% more tubers >12oz than the growers standard with 40 cwt/a.

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

Principal Investigator: Carol Ishimaru, Professor, 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, a small number (9) of potato samples were sent to the Ishimaru lab in St. Paul. Of these, presumptive soft rot bacteria were obtained from 7, yielding a total of 11 isolates. All isolates were Gram- negative and produced pits on crystal violet pectate medium. Most were non-fluorescent. DNA has been extracted from all isolates. PCR amplification of the 16S RNA gene has been completed and the products prepared for sequencing. The sequencing results will provide an initial identification of the isolates to at least the genus level. Funds remaining on the grant will be used to complete the identification of isolates to the species level.

Background

Soft rot diseases are found most years in the Northern Plains. In 2013, conditions were especially favorable for soft rot. Excessive rains and prolonged wet periods created ideal conditions in heavy as well as sandy soils (A. Robinson, personal communication). Information on the specific causal agents of soft rots in the region is lacking. This project, initiated in 2014, focuses on conducting a survey of soft rot pathogens present in potatoes grown in the Northern Great Plains.

Progress

In the 2014 early and mid-growing season, soft rot was not a major concern in most of the region so there were fewer samples than expected available for processing. Still, nine suspected soft rot samples were provided by Andy Robinson or by growers. These were sent to the bacteriology lab in St. Paul for analysis. Isolates of soft rot bacteria were obtained by culture-dependent methods. 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). Eight of the samples were from symptomatic, highly degraded stems or tubers. Three samples were of intact, fresh market packaged red, Yukon and russet potatoes. These were incubated in a moist chamber for about two weeks to promote soft rot development prior to processing for soft rot bacteria. For all samples, representative colonies causing pits on CVP were purified by repeated sub-culturing and retested for pectolytic activity on CVP. All isolates have been catalogued and stored in glycerol stocks at -80C. Each has been tested for Gram reaction in a KOH test and for ability to fluoresce on King's medium B, a medium used to differentiate fluorescent pseudomonas from *Pectobacterium*. Most were non-fluorescent. Table 1 presents a summary of the samples and soft rot isolates collected to date. DNA has been extracted from all isolates. PCR amplification of the 16S RNA gene has been completed and the products prepared for sequencing. The sequencing results will provide an initial identification of the isolates to at least the genus level. Future studies will use additional DNA targets to identify the isolates to the species level.

Work plan through March 2015

The identity of the 11 isolates will be confirmed by DNA analyses and by commercially available serological kits for detection of *Pectobacterium carotovorum* and *P. atrosepticum* (Agdia, Inc.). All will be re-tested for soft rot ability in tubers.

Table 1. Summary of soft rot samples processed between August 2014 and January 2015.

Sample no.	Date received	Source	Location	Sample description	No. on CVP	Phenotype of purified isolate	Date of storage	Collection #
1	8/27/14	Andy Robertson	Osage, MN	Stems in plastic bags, very mushy	<10	None pectolytic	NA	-
2	8/27/14	Andy Robertson	Ottertail, MN	Dried stems, even green tissue dried	0	None pectolytic	NA	-
3	8/27/14	Andy Robertson	Karlsrue, MN	Black leg symptoms on stems with clear margins	~10^{5-6} cfu/ml	Tan/lt. yellow on LB; non-fluorescent, pits on CVP; shallow pits; Gram -	10/7/14; three isolates	SR1 (has two colony types even after purification); SR2; SR3
4	9/5/14	Andy Robertson	Candoo, ND	Stem	~about 10^{5-6} cfu/ml	Non-fluorescent, pits on CVP; Gram -	10/7/14; one isolate	SR4
5	9/5/14	Andy Robertson	Becker, MN	Tuber	~about 10^{5-6} cfu/ml	Non-fluorescent, pits on CVP = 5b; shallow pit= 5a; yellow on LB; Gram -	10/7/14; two isolates	SR5; SR6
6	11/1/9/14	A. Robinson	Inkster, N research farm	Rotten, frozen tuber	~about 10^{7} cfu/ml	Fluorescent, pits on CVP, Gram -	12/10/14 Two isolates	6a2, 6b2
7	12/1/14	Grower		Fresh 5 lb. bag red, healthy		Pits on CVP, Gram -	1/20/15 One isolate	7
8	12/1/14	Grower		Fresh 5 lb. bag Yukon, healthy		Pits on CVP, Gram -	1/20/15 One isolate	8
9	12/1/14	Grower		Fresh 5 lb. bag Russet, healthy		Pits on CVP, Gram -	1/20/15 One isolates	9
Total = 9 Samples								**Total = 11 isolates**

Effect of Simulated Glyphosate Drift on Seed Pieces from Four Potato Processing Cultivars. Harlene Hatterman-Valenti and Collin Auwarter.

A field study was conducted to determine the carryover effect on potatoes grown for seed and planted the season following simulated glyphosate drift on four processing cultivars (Bannock Russet, Ranger Russet, Russet Burbank, and Umatilla Russet). In 2013, the four cultivars were planted on June 12 at the Northern Plains Potato Growers Association irrigation research site near Inkster, ND. Sub-lethal rates of glyphosate were applied to mother plants at one-half, one-quarter, and one-eighth the lowest labeled rate of 0.38 lb ae/A glyphosate at the tuber initiation (TI), early tuber bulking (EB), and late tuber bulking (LB) stages. Potatoes were harvested October 23, graded for yield and quality, and stored for planting in 2014. On May 28, 2014, individual seed pieces from 20 randomly selected tubers within each treatment were planted. Potato stand counts were recorded mid-July and mid-August. Plots were harvested mid-October and graded shortly after harvest.

Stand Count 42 (7/9/14) and 83 (8/19/14) DAP in 20' of row.

Trt	Trt		Rate	App	----Ranger----		---Bannock---		---Burbank---		---Umatilla---	
No.	Name	Rate	Unit	Code	7/9	8/19	7/9	8/19	7/9	8/19	7/9	8/19
1	Untreated				19.3a	19.3a	18.5a	18.5a	18.7a	18.8a	13.7ab	17.5ab
2	RU Weather Max	0.19	lb/a	TI	4.8d	6.3b	4.5bc	8.8ab	0.4f	3.5d	3.8abc	9.5bc
	Ammonium Sulfate	4	lb/100 gal	TI								
3	RU Weather Max	0.10	lb/a	TI	1.8d	9b	6.9abc	15.5ab	1.2ef	6cd	9.6ab	14ab
	Ammonium Sulfate	4	lb/100 gal	TI								
4	RU Weather Max	0.05	lb/a	TI	11c	14.8a	15.5ab	16.8ab	3.7c-f	12.5ab	10.3ab	15ab
	Ammonium Sulfate	4	lb/100 gal	TI								
5	RU Weather Max	0.19	lb/a	EB	15.8b	17.5a	0.4c	13.5ab	5.6b-f	15.5a	3.3bc	12.5b
	Ammonium Sulfate	4	lb/100 gal	EB								
6	RU Weather Max	0.10	lb/a	EB	19.5a	19.5a	6abc	16.8ab	11.9a-d	17a	18.2a	18.3a
	Ammonium Sulfate	4	lb/100 gal	EB								
7	RU Weather Max	0.05	lb/a	EB	19.5a	19.5a	16.4ab	17.8a	13.1abc	16.8a	18.2a	18.3a
	Ammonium Sulfate	4	lb/100 gal	EB								
8	RU Weather Max	0.19	lb/a	LB	2.3d	7.5b	4.1bc	6.3b	2.6def	9.3bc	0.3c	5.5c
	Ammonium Sulfate	4	lb/100 gal	LB								
9	RU Weather Max	0.10	lb/a	LB	15.3b	16.3a	4.3bc	12ab	8.2a-e	17.3a	6.5abc	12.3b
	Ammonium Sulfate	4	lb/100 gal	LB								
10	RU Weather Max	0.05	lb/a	LB	19.3a	19.3a	6.1abc	16.5ab	16.5ab	16.5a	18.7a	18.8a
	Ammonium Sulfate	4	lb/100 gal	LB								

Ranger Tuber counts in 20’ of row.

Trt	Trt		Rate	App	-----------------Tuber Counts in 20’ of row-----------------					
No.	Name	Rate	Unit	Code	<4oz	4-6oz	6-12oz	>12oz	Total	>4oz
1	Untreated				80a	45a	55ab	12ab	191a	111a
2	RU Weather Max	0.19	lb/a	TI	37b	18bc	18cd	8abc	73bc	40cd
	Ammonium Sulfate	4	lb/100 gal	TI						
3	RU Weather Max	0.10	lb/a	TI	27b	7c	10d	2c	45c	18d
	Ammonium Sulfate	4	lb/100 gal	TI						
4	RU Weather Max	0.05	lb/a	TI	35b	14bc	24bcd	9abc	81bc	47bcd
	Ammonium Sulfate	4	lb/100 gal	TI						
5	RU Weather Max	0.19	lb/a	EB	48ab	21abc	31a-d	15a	114ab	65abc
	Ammonium Sulfate	4	lb/100 gal	EB						
6	RU Weather Max	0.10	lb/a	EB	59ab	37ab	45abc	10abc	145ab	88abc
	Ammonium Sulfate	4	lb/100 gal	EB						
7	RU Weather Max	0.05	lb/a	EB	77a	36ab	56ab	8abc	175a	99ab
	Ammonium Sulfate	4	lb/100 gal	EB						
8	RU Weather Max	0.19	lb/a	LB	25b	6c	5d	3bc	41c	15d
	Ammonium Sulfate	4	lb/100 gal	LB						
9	RU Weather Max	0.10	lb/a	LB	48ab	24abc	47abc	15a	133ab	85abc
	Ammonium Sulfate	4	lb/100 gal	LB						
10	RU Weather Max	0.05	lb/a	LB	65ab	37ab	63a	13ab	177a	112a
	Ammonium Sulfate	4	lb/100 gal	LB						
				LSD (P=.05)	26.93	17.12	14.34	6.47	2.57	2.32

Ranger CWT/A.

Trt	Trt		Rate	App	---------------------------------CWT/A--------------------------------					
No.	Name	Rate	Unit	Code	<4oz	4-6oz	6-12oz	>12oz	Total	>4oz
1	Untreated				84a	102a	208ab	83abc	474a	393a
2	RU Weather Max	0.19	lb/a	TI	34bc	40bc	79bc	66abc	202bc	184bc
	Ammonium Sulfate	4	lb/100 gal	TI						
3	RU Weather Max	0.10	lb/a	TI	25bc	15c	38c	16c	94d	69c
	Ammonium Sulfate	4	lb/100 gal	TI						
4	RU Weather Max	0.05	lb/a	TI	35bc	32bc	94bc	64abc	223bc	190bc
	Ammonium Sulfate	4	lb/100 gal	TI						
5	RU Weather Max	0.19	lb/a	EB	51abc	47abc	123abc	110a	323abc	279ab
	Ammonium Sulfate	4	lb/100 gal	EB						
6	RU Weather Max	0.10	lb/a	EB	62abc	84ab	175ab	74abc	383abc	334ab
	Ammonium Sulfate	4	lb/100 gal	EB						
7	RU Weather Max	0.05	lb/a	EB	77a	81ab	209ab	49abc	413ab	338ab
	Ammonium Sulfate	4	lb/100 gal	EB						
8	RU Weather Max	0.19	lb/a	LB	21c	14c	34bc	22bc	82d	70c
	Ammonium Sulfate	4	lb/100 gal	LB						
9	RU Weather Max	0.10	lb/a	LB	52abc	55abc	186ab	101a	390abc	342ab
	Ammonium Sulfate	4	lb/100 gal	LB						
10	RU Weather Max	0.05	lb/a	LB	64ab	84ab	237a	90ab	472a	410a
	Ammonium Sulfate	4	lb/100 gal	LB						
				LSD (P=.05)	26.44	39.04	84.69	44.73	3.93	128.25

Bannock Tuber counts in 20' of row.

Trt No.	Trt Name	Rate	Rate Unit	App Code	-----------------Tuber Counts in 20' of row-----------------					
					<4oz	4-6oz	6-12oz	>12oz	Total	>4oz
1	Untreated				40a	22a	54a	35a	151a	111a
2	RU Weather Max	0.19	lb/a	TI	17ab	7bc	16b	13ab	53bc	36bc
	Ammonium Sulfate	4	lb/100 gal	TI						
3	RU Weather Max	0.10	lb/a	TI	27ab	10abc	18b	8b	63bc	36bc
	Ammonium Sulfate	4	lb/100 gal	TI						
4	RU Weather Max	0.05	lb/a	TI	38a	19ab	29b	18ab	105ab	67b
	Ammonium Sulfate	4	lb/100 gal	TI						
5	RU Weather Max	0.19	lb/a	EB	18ab	3c	6b	3b	31bc	12bc
	Ammonium Sulfate	4	lb/100 gal	EB						
6	RU Weather Max	0.10	lb/a	EB	32ab	12abc	19b	7b	74bc	41bc
	Ammonium Sulfate	4	lb/100 gal	EB						
7	RU Weather Max	0.05	lb/a	EB	27ab	15abc	31b	13ab	87bc	60bc
	Ammonium Sulfate	4	lb/100 gal	EB						
8	RU Weather Max	0.19	lb/a	LB	5b	2c	3b	2b	13c	8c
	Ammonium Sulfate	4	lb/100 gal	LB						
9	RU Weather Max	0.10	lb/a	LB	29ab	8abc	20b	10b	69bc	40bc
	Ammonium Sulfate	4	lb/100 gal	LB						
10	RU Weather Max	0.05	lb/a	LB	31ab	10abc	25b	10b	77bc	46bc
	Ammonium Sulfate	4	lb/100 gal	LB						
				LSD (P=.05)	18.42	8.80	17.45	11.66	49.16	35.75

Bannock CWT/A.

Trt No.	Trt Name	Rate	Rate Unit	App Code	----------------------------------CWT/A--------------------------------					
					<4oz	4-6oz	6-12oz	>12oz	Total	>4oz
1	Untreated				40a	49a	214a	273a	582a	541a
2	RU Weather Max	0.19	lb/a	TI	13bc	15bc	65b	109ab	206cd	195cd
	Ammonium Sulfate	4	lb/100 gal	TI						
3	RU Weather Max	0.10	lb/a	TI	25abc	23abc	67b	58b	176cd	150cd
	Ammonium Sulfate	4	lb/100 gal	TI						
4	RU Weather Max	0.05	lb/a	TI	34ab	43ab	110b	132ab	279bc	247bc
	Ammonium Sulfate	4	lb/100 gal	TI						
5	RU Weather Max	0.19	lb/a	EB	11bc	7c	22b	21b	55d	46d
	Ammonium Sulfate	4	lb/100 gal	EB						
6	RU Weather Max	0.10	lb/a	EB	25abc	27abc	77b	62b	119cd	94cd
	Ammonium Sulfate	4	lb/100 gal	EB						
7	RU Weather Max	0.05	lb/a	EB	26abc	33abc	120b	93ab	376b	343b
	Ammonium Sulfate	4	lb/100 gal	EB						
8	RU Weather Max	0.19	lb/a	LB	3c	4c	13b	15b	61d	57d
	Ammonium Sulfate	4	lb/100 gal	LB						
9	RU Weather Max	0.10	lb/a	LB	24abc	18abc	79b	74ab	144cd	127cd
	Ammonium Sulfate	4	lb/100 gal	LB						
10	RU Weather Max	0.05	lb/a	LB	27abc	22abc	100b	73ab	198cd	172cd
	Ammonium Sulfate	4	lb/100 gal	LB						
				LSD (P=.05)	16.80	20.11	69.60	5.46	130.49	118.88

Russet Burbank Tuber counts in 20’ of row.

Trt	Trt		Rate	App	-----------------Tuber Counts in 20’ of row-----------------					
No.	Name	Rate	Unit	Code	<4oz	4-6oz	6-12oz	>12oz	Total	>4oz
1	Untreated				63b	39ab	71a	20a	194a	131a
2	RU Weather Max	0.19	lb/a	TI	11d	3e	2b	0.3c	16d	5d
	Ammonium Sulfate	4	lb/100 gal	TI						
3	RU Weather Max	0.10	lb/a	TI	27cd	2e	3b	1bc	33cd	6d
	Ammonium Sulfate	4	lb/100 gal	TI						
4	RU Weather Max	0.05	lb/a	TI	47bc	11cde	11b	6abc	78bc	30cd
	Ammonium Sulfate	4	lb/100 gal	TI						
5	RU Weather Max	0.19	lb/a	EB	78b	15b-e	11b	3abc	109ab	30cd
	Ammonium Sulfate	4	lb/100 gal	EB						
6	RU Weather Max	0.10	lb/a	EB	121a	30abc	25b	4abc	181a	61abc
	Ammonium Sulfate	4	lb/100 gal	EB						
7	RU Weather Max	0.05	lb/a	EB	60b	29abc	54a	16ab	162a	100ab
	Ammonium Sulfate	4	lb/100 gal	EB						
8	RU Weather Max	0.19	lb/a	LB	46bc	6de	12b	5abc	68bc	23cd
	Ammonium Sulfate	4	lb/100 gal	LB						
9	RU Weather Max	0.10	lb/a	LB	77b	19a-d	20b	5abc	124ab	46bc
	Ammonium Sulfate	4	lb/100 gal	LB						
10	RU Weather Max	0.05	lb/a	LB	74b	43a	66a	15ab	199a	125a
	Ammonium Sulfate	4	lb/100 gal	LB						
			LSD (P=.05)		23.34	1.69	2.21	11.47	2.53	2.74

Russet Burbank CWT/A.

Trt	Trt		Rate	App	---------------------------------CWT/A--------------------------------					
No.	Name	Rate	Unit	Code	<4oz	4-6oz	6-12oz	>12oz	Total	>4oz
1	Untreated				65b	90a	276a	142a	579a	514a
2	RU Weather Max	0.19	lb/a	TI	7c	6d	7b	2c	22e	16d
	Ammonium Sulfate	4	lb/100 gal	TI						
3	RU Weather Max	0.10	lb/a	TI	19c	5d	9b	10bc	44de	24cd
	Ammonium Sulfate	4	lb/100 gal	TI						
4	RU Weather Max	0.05	lb/a	TI	36bc	25bcd	49b	44abc	155cd	119bcd
	Ammonium Sulfate	4	lb/100 gal	TI						
5	RU Weather Max	0.19	lb/a	EB	70b	33bcd	49b	23abc	175bcd	104bcd
	Ammonium Sulfate	4	lb/100 gal	EB						
6	RU Weather Max	0.10	lb/a	EB	119a	68ab	89b	34abc	319abc	200b
	Ammonium Sulfate	4	lb/100 gal	EB						
7	RU Weather Max	0.05	lb/a	EB	56b	66ab	210a	120ab	456ab	401a
	Ammonium Sulfate	4	lb/100 gal	EB						
8	RU Weather Max	0.19	lb/a	LB	35bc	13cd	45b	38abc	131cd	97bcd
	Ammonium Sulfate	4	lb/100 gal	LB						
9	RU Weather Max	0.10	lb/a	LB	68b	42abc	74b	35abc	237bc	163bc
	Ammonium Sulfate	4	lb/100 gal	LB						
10	RU Weather Max	0.05	lb/a	LB	72b	99a	253a	109ab	541a	469a
	Ammonium Sulfate	4	lb/100 gal	LB						
			LSD (P=.05)		26.03	2.57	4.52	5.04	5.52	5.83

Umatilla Tuber counts in 20' of row.

Trt	Trt		Rate	App	-----------------Tuber Counts in 20' of row-----------------					
No.	Name	Rate	Unit	Code	<4oz	4-6oz	6-12oz	>12oz	Total	>4oz
1	Untreated				84a	33ab	58a	23a	198a	113a
2	RU Weather Max	0.19	lb/a	TI	33bc	14cd	29abc	14ab	91cd	58bc
	Ammonium Sulfate	4	lb/100 gal	TI						
3	RU Weather Max	0.10	lb/a	TI	56ab	19bcd	31abc	8ab	114bc	59bc
	Ammonium Sulfate	4	lb/100 gal	TI						
4	RU Weather Max	0.05	lb/a	TI	56ab	33ab	39ab	19ab	147abc	90ab
	Ammonium Sulfate	4	lb/100 gal	TI						
5	RU Weather Max	0.19	lb/a	EB	44abc	9d	16bc	6ab	75cd	31c
	Ammonium Sulfate	4	lb/100 gal	EB						
6	RU Weather Max	0.10	lb/a	EB	61ab	29abc	44ab	14ab	147abc	86ab
	Ammonium Sulfate	4	lb/100 gal	EB						
7	RU Weather Max	0.05	lb/a	EB	81a	43a	60a	19ab	202a	122a
	Ammonium Sulfate	4	lb/100 gal	EB						
8	RU Weather Max	0.19	lb/a	LB	11c	3d	3c	6b	21d	10c
	Ammonium Sulfate	4	lb/100 gal	LB						
9	RU Weather Max	0.10	lb/a	LB	33bc	13cd	18bc	10ab	74cd	41bc
	Ammonium Sulfate	4	lb/100 gal	LB						
10	RU Weather Max	0.05	lb/a	LB	65ab	41a	57a	23a	186ab	121a
	Ammonium Sulfate	4	lb/100 gal	LB						
				LSD (P=.05)	27.69	12.94	20.32	10.39	57.18	35.57

Umatilla CWT/A.

Trt	Trt		Rate	App	----------------------------------CWT/A--------------------------------					
No.	Name	Rate	Unit	Code	<4oz	4-6oz	6-12oz	>12oz	Total	>4oz
1	Untreated				86a	75ab	225a	166a	552a	467a
2	RU Weather Max	0.19	lb/a	TI	29bc	32cd	114abc	106a	281abc	252abc
	Ammonium Sulfate	4	lb/100 gal	TI						
3	RU Weather Max	0.10	lb/a	TI	54ab	43bcd	119abc	64a	281abc	226abc
	Ammonium Sulfate	4	lb/100 gal	TI						
4	RU Weather Max	0.05	lb/a	TI	58ab	74ab	143ab	144a	419ab	361ab
	Ammonium Sulfate	4	lb/100 gal	TI						
5	RU Weather Max	0.19	lb/a	EB	38ab	20d	63bc	44a	167bc	127bc
	Ammonium Sulfate	4	lb/100 gal	EB						
6	RU Weather Max	0.10	lb/a	EB	66ab	65abc	171ab	94a	398ab	330ab
	Ammonium Sulfate	4	lb/100 gal	EB						
7	RU Weather Max	0.05	lb/a	EB	85a	97a	229a	137a	550a	463a
	Ammonium Sulfate	4	lb/100 gal	EB						
8	RU Weather Max	0.19	lb/a	LB	8c	6d	10c	35a	59bc	51c
	Ammonium Sulfate	4	lb/100 gal	LB						
9	RU Weather Max	0.10	lb/a	LB	27bc	30cd	74bc	72a	206bc	176bc
	Ammonium Sulfate	4	lb/100 gal	LB						
10	RU Weather Max	0.05	lb/a	LB	67ab	93a	214a	163a	539a	470a
	Ammonium Sulfate	4	lb/100 gal	LB						
				LSD (P=.05)	2.34	29.27	78.97	81.04	184.79	164.40

All cultivars had slower plant emergence when glyphosate was applied to mother plants, regardless of the application timing. In general, potato yield was inversely related to the glyphosate rate. The lowest 'Russet Burbank' yield occurred when glyphosate was applied at the TI stage, while the lowest yield with the other three cultivars was when glyphosate was applied later at either the EB or LB stages. 'Bannock' was the most sensitive cultivar with seed from plants receiving any sub-lethal glyphosate rate yielding ≤ 65% of the untreated. The remaining three cultivars were less sensitive to glyphosate drift and had at least one glyphosate drift treatment with similar or greater tuber yield compared to the untreated yield. Plants treated with 0.05 lb/A glyphosate at the LB stage produced seed that had the highest yields. Seed from plants receiving 0.19 lb/A glyphosate, regardless of the application timing and cultivar had lower tuber counts compared to the untreated. Results suggested that 'Ranger Russet' was the least sensitive cultivar to the carryover effect on potatoes grown for seed and planted the season following simulated glyphosate drift.

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

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Summary: Struvite is a phosphate-rich mineral that releases phosphate more rapidly in close proximity to plant roots, reducing the risk of available phosphate being lost to mineralization. This should make it possible for struvite to meet the phosphate demands of crop plants at lower application rates (lbs P_2O_5/ac) than traditional phosphate fertilizers such as monoammonium phosphate (MAP). However, because struvite is more costly to produce than MAP, and its phosphate-release dynamics may not be optimal for crops, blends of struvite and MAP may provide better return on investment than either fertilizer would on its own. We evaluated the relative effectiveness of a struvite product (Crystal Green®, Ostara), MAP, and blends of the two, as phosphate sources for Russet Burbank potatoes in Becker, MN, using a randomized complete block design with 18 treatments and four replicates. To evaluate whether struvite can meet plant phosphate demands at a lower application rate, we divided the treatments (except for the no-P_2O_5 control) between two rates: 75 lbs P_2O_5/ac, and 100 lbs P_2O_5/ac. Crystal Green, MAP, and mixtures of the two were evaluated at each rate. To evaluate the effect of application method, three treatments received pure MAP at either rate or pure Crystal Green at 100 lbs P_2O_5/ac, hand-broadcast before planting, while all other treatments received phosphate banded at row closure. The blended fertilizer treatments included either mixtures of pure MAP and Crystal Green granules or pre-blended granules that contained both of the two fertilizers. Crop performance was evaluated based on tuber yield, size, and quality. Treatment had no significant effect on total or marketable yield, the prevalence of scab, or tuber dry matter content or specific gravity. The yield of tubers under three ounces, the percentages of yield represented by tubers over six or ten ounces, and the prevalences of hollow heart and brown center were all significantly related to treatment, but not in a way that could be explained by the phosphate source used or the rate or method of its application. Mean soil Bray phosphate in the control treatment plots decreased from 28 ppm to 25 ppm throughout the season. This small change suggests that the lack of a coherent crop response to phosphate fertilization treatment may have been the result of adequate phosphate availability in the unfertilized soil. Alternatively, excessive rainfall early in the season may have stressed plants causing increased variability, and therefore making meaningful effects of phosphate source and application method and rate difficult to detect.

Background

Struvite is a phosphate-rich mineral ($NH_4MgPO_4{\cdot}6H_2O$) that precipitates from waste water after anaerobic digestion, potentially clogging pipes in treatment plants. To prevent this, struvite is intentionally precipitated in chemical reactors to remove it from the wastewater stream. 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 highly soluble in citrate, which is known to be exuded by plant roots. This should be beneficial to farmers because phosphate that is not taken up from the soil solution by plants quickly reacts with anions in the solution and precipitates in much less plant-available forms. With less loss of phosphate to mineralization, less fertilizer should be required to meet crop requirements. This advantage should be particularly valuable in crops with high phosphate demands such as potatoes.

At this time, struvite cannot be produced as cheaply as conventional phosphate sources such as monoammonium phosphate (MAP). Furthermore, it is uncertain whether the exclusive use of a slow-release phosphate fertilizer like struvite optimizes the timing of phosphate availability for crops. For these reasons, research is needed to determine whether blends of Crystal Green with conventional phosphate sources can produce better return on investment than the exclusive use of one phosphate source or another. In addition, while banded application is known to result in a lower loss of phosphate to precipitation than broadcast application, this advantage of banding may not apply to struvite, which is less subject to mineralization losses than MAP due to its lower water solubility.

The objectives of this study were to: (1) evaluate the responses of Russet Burbank potato tuber yield, size distribution, and quality to fertilization with Crystal Green as a phosphate fertilizer relative to MAP; (2) to determine the effectiveness of blends of Crystal Green and MAP relative to one or the other alone; (3) to determine whether Crystal Green or 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; (4) to evaluate the effectiveness of prills of homogenized mixtures of Crystal Green and MAP relative to physical mixtures of pure prills of each product; and (5) to compare the effectiveness of broadcast application prior to row opening to that of banded application at row closure.

Methods

This study was conducted in 2014 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 (April 14) and end (October 16) of the season are shown in Table 1.

The study field received 200 lbs/ac KCl (0-0-60) on April 15 and 200 lbs/ac Sul-Po-Mag (0-0-22-22S-11Mg) on April 21. These fertilizers were broadcast and incorporated with a chisel plow.

Plots were laid out on April 25 in a randomized complete block design with four replicates. Potatoes were planted by hand on May 20 with three-foot spacing between rows and one-foot spacing within. Each block was surrounded by a buffer strip of Russet Burbank one row (three feet) wide along either side and five feet wide at either end. 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 buffer strip had red potatoes in the harvest rows. Whole "B single drop" seed was used for Russet Burbank, while the red seed potatoes were cut "A" seed.

Eighteen fertilizer treatments were applied. The treatments are described in Table 2. Except for a control treatment that received no supplemental P_2O_5, each treatment received 75 or 100 lbs P_2O_5/ac as MAP, Crystal Green, a blend of MAP and Crystal Green prills, or prills made of a mixture of Crystal Green and MAP (hereafter, "compacted Crystal Green"). In three treatments (treatments 16 – 18), P_2O_5 was hand-broadcast prior to row opening on planting day (May 15). In the remaining treatments (treatments 2 – 15), P_2O_5 was banded at row closure three inches to each side and two inches below the seed piece using a metered, drop-fed applicator incorporated into the planter.

Non-P fertilizers were also banded at row closure. 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, particularly N and K. Application rates of S and Mg varied among treatments (Table 2).

At shoot emergence, on June 18, 210 lbs N/ac were applied as Environmentally Smart Nitrogen (ESN: 44-0-0) and the plots were hilled. Twenty lbs N/ac were applied as UAN 28% on July 23.

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. In total, approximately 23 lbs NO_3-N/ac and 8 lbs NH_4-N/ac were deposited in irrigation water, and 6 lbs NO_3-N and 34 lbs NH_4-N were deposited in rainfall.

The phosphate release dynamics of Crystal Green were measured by determining the weight loss throughout the season of fertilizer in mesh bags installed at planting depth. Two sets of bags were installed. Relatively coarse-mesh bags were installed on the same day tubers were planted, on May 15. Because a large percentage of the Crystal Green used in this study consisted of granules small enough to pass through this mesh, these bags included only larger granules. A second set of bags made of finer mesh and including the full range of granules sizes was installed on May 20. Three grams of fertilizer was placed in each bag prior to installation. Subsets of the coarse-mesh bags were collected on May 20 and 29, June 5 and 10, July 8 and 22, August 13 and 26, and September 15. Subsets of the fine-mesh bags were collected on May 29, June 5, 10, and 27, July 8 and 22, and August 13 and 26. At each collection date, the bags were dried. Their contents were weighed, and the percentage weight loss was calculated. The bags were installed in plots in which the phosphate fertilizer used was 100% Crystal Green. Two replicates were installed on each installation date.

Harvest rows within some plots were visibly damaged by excessive early-season rainfall. The two rows in each plot were assessed for damage severity on June 18. Rows judged to be severely damaged were excluded from analysis. In total, 17 of 72 plots had a row excluded. No plots had both rows excluded.

Plant stand and the number of stems per plant were assessed on June 18 and again on June 27.

Leaf petioles were sampled on June 27, July 16, July 31, and August 13. At the time of this report, determination of petiole P and Mg is still in progress.

Vines were desiccated with Reglone spray at 1 qt/ac with 0.25% LI-700 on September 17 and 22 and chopped on September 26. Tubers were harvested on October 6 and size-sorted and graded on October 9-10.

The data were analyzed using the GLM procedure in SAS 9.4, which is robust to missing data. 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.

Results:

Release dynamics of Crystal Green

Through August 13, Crystal Green installed at planting depth in coarser-mesh at planting (May 15) showed similar release dynamic to Crystal Green installed in finer-mesh bags five days after planting (May 20). The similarity between the two curves is partly the result of almost no Crystal Green being lost from the coarse-mesh bags prior to planting. In the August 26 collection, the two sets of bags appeared to diverge dramatically in their release dynamics, with the fine-mesh bags releasing three times as much (44% of their initial contents) as the coarse-mesh bags (which lost 15% of their initial contents).

Plant stand and number of stems per plant

Mean plant stand for each treatment ranged from 89% to 99% on June 18, and from 91% to 99% on June 27. Mean stem number per plant ranged from 2.5 to 3.5. Neither variable was significantly related to treatment.

Tuber yield

The results for tuber yield are presented in Table 3. There was no significant treatment effect on total or marketable yield.

Yield of tubers less than three ounces was significantly related to treatment, but P_2O_5 source and the method and rate of application did not appear to be factors in this relationship.

The percentage of yield represented by tubers over six or ten ounces varied significantly among treatments. However, this variability was not evidently related to the product used or the method or rate of application. Only the treatment receiving 100% Crystal Green at planting (treatment 2) had greater percentages of yield in tubers over six or ten ounces than the control treatment (treatment 1), and there was no general tendency for treatments having the higher application rate, having a larger percentage of Crystal Green, or receiving fertilizer at planting, to outperform those receiving lower rates, lower percentages of Crystal Green, or fertilizer pre-planting.

Tuber quality

Results for tuber quality are presented in Table 4. Treatment had no significant effects on the prevalence of scab, dry-matter content, or specific gravity. Hollow heart and brown center coincided perfectly. Their prevalences varied among treatments. The control treatment had the lowest prevalences of hollow heart and brown center, but there was otherwise no clear relationship between P_2O_5 source or the method or rate of application and the prevalences of these conditions.

Conclusions

Phosphorus fertilization treatment had no significant effect on total or marketable yield. While the yield of tubers under three ounces, the percentage of yield represented by tubers over six or ten ounces, and the percentage of tubers exhibiting hollow heart and brown center, were all significantly related to treatment, there was no evident relationship between phosphate source or the method or rate of application and any of these variables.

The inability of phosphate source and application method and rate to explain tuber yield and quality variables prevents firm conclusions from being drawn from this study. Notably, the control treatment, in which no phosphate was applied, produced results that were not significantly different from those of the vast majority of the other treatments. In addition, the Bray phosphate concentration of the soil in the control treatment plots was not markedly different on October 16 than it was on April 14, declining by 3 ppm, on average (11% of the initial mean Bray P concentration), over that period. This may indicate that available soil phosphate in these plots was sufficient or nearly sufficient, and that additional fertilization with phosphate was unlikely to have much impact on tuber yield, size, or quality.

Alternatively, the lack of significant and coherent results may have been the result of excessive rainfall early in the season. While any harvest row judged to be severely damaged by moisture on June 18 was excluded from analysis, rows showing little or no evidence of damage at that time may nevertheless have had damage sufficient to influence the yield, size, and quality of their tubers. Such damage would have changed both the means and standard deviations for the affected treatments, making meaningful effects of phosphate source or application method or timing difficult to detect.

Table 1. Characteristics of the top six inches of soil collected from the study site in Becker, MN, on April 14, 2014 (initial soil properties) and October 16 (post-harvest soil properties). The soil was collected from the control treatment plots, which received no supplemental P_2O_5.

	Replicate	Bray P (ppm)	NH_4OAc-K (ppm)	NH_4OAc-Ca (ppm)	NH_4OAc-Mg (ppm)	DTPA-Zn (ppm)	DTPA-Cu (ppm)	DTPA-Fe (ppm)	DTPA-Mn (ppm)	SO4-S (ppm)	Hot-water B (ppm)	Water pH	O.M. LOI (%)
Initial soil properties	1	38	110	-	-	-	-	-	-	-	-	6.4	1.8
	2	25	99	600	104	0.80	0.865	23.4	5.813	1	0.177	6.4	1.4
	3	26	103	-	-	-	-	-	-	-	-	6.3	1.2
	4	23	70	600	106	0.90	0.507	23.4	5.93	1	0.164	6.5	1.3
Post-harvest soil properties	1	31	79	-	-	-	-	-	-	3	-	6.1	1.6
	2	26	87	-	-	-	-	-	-	4	-	6.1	1.4
	3	23	74	-	-	-	-	-	-	4	-	6	1.1
	4	20	69	-	-	-	-	-	-	3	-	6.1	1.2

Figure 1. Percent release (mean ± S.E.) over time from Crystal Green from mesh bags installed at planting depth. The coarse-mesh bags were installed on the day tubers were planted (May 15) and contained only Crystal Green granules large enough not to pass through the mesh. The fine-mesh bags were installed five days later (May 20) and included a representative size distribution of Crystal Green granules.

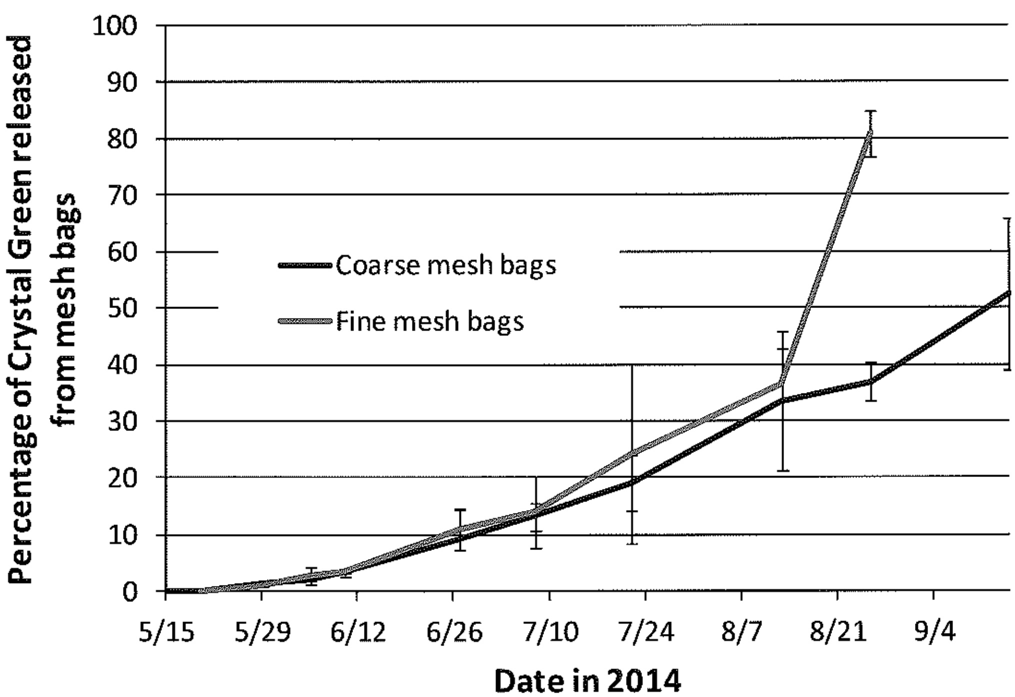

Table 2. Application rates of nutrients and fertilizers and application method of MAP, Crystal Green, and compacted Crystal Green for each treatment applied to Russet Burbank potato plants in Becker, MN, in 2014. Phosphate fertilizers were either banded with other fertilizers at row closure or hand-broadcast alone before row opening, with both methods applied on the day of tuber planting (May 15).

Treatments			Nutrient application rates on May 15 (lbs/ac)							Fertilizer application rates on May 15 (lbs/ac)								
Treatment #	Phosphate source[1]	Application method	N	P_2O_5	K	S	Mg	Zn	B	CG (5-28-0-10Mg)	MAP (11-50-0)	cpCG[2]	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% B)
1	None	None	30	0	58.8	41.4	20.0	2	1	0	0	0	65	182	0	31	10	7
2	Crystal Green	Band	30	100	58.8	21.4	35.7	2	1	357	0	0	26	0	118	0	10	7
3	MAP	Band	30	100	58.8	41.4	20.0	2	1	0	200	0	17	182	0	31	10	7
4	50% CG : 50% MAP	Band	30	100	58.8	21.4	20.0	2	1	179	100	0	22	19	92	14	10	7
5	25% CG : 75% MAP	Band	30	100	58.8	23.5	20.0	2	1	89	150	0	20	101	0	61	10	7
6	9% cpCG : 91% MAP	Band	30	100	58.8	35.2	20.0	2	1	0	0	207	20	154	0	42	10	7
7	15% cpCG : 85% MAP	Band	30	100	58.8	30.5	20.0	2	1	0	0	217	20	132	0	49	10	7
8	23% cpCG : 77% MAP	Band	30	100	58.8	25.3	20.0	2	1	0	0	229	21	109	0	58	10	7
9	Crystal Green	Band	30	75	58.8	21.4	26.8	2	1	268	0	0	36	0	118	0	10	7
10	MAP	Band	30	75	58.8	41.4	20.0	2	1	0	150	0	29	182	0	31	10	7
11	75% CG : 25% MAP	Band	30	75	58.8	21.4	20.1	2	1	201	38	0	34	0	118	0	10	7
12	50% CG : 50% MAP	Band	30	75	58.8	21.4	20.0	2	1	134	75	0	33	60	40	43	10	7
13	25% CG : 75% MAP	Band	30	75	58.8	28.0	20.0	2	1	67	113	0	31	121	0	54	10	7
14	23% cpCG : 77% MAP	Band	30	75	58.8	29.4	20.0	2	1	0	0	172	32	127	0	51	10	7
15	35% cpCG : 65% MAP	Band	30	75	58.8	22.7	20.0	2	1	0	0	188	33	97	0	63	10	7
16	MAP	Broadcast	30	100	58.8	41.4	20.0	2	1	0	200	0	17	182	0	31	10	7
17	MAP	Broadcast	30	75	58.8	41.4	20.0	2	1	0	150	0	29	182	0	31	10	7
18	Crystal Green	Broadcast	30	100	58.8	21.4	35.7	2	1	357	0	0	26	0	118	0	10	7

[1]CG = Crystal Green (Ostara Nutrient Recovery Technologies, Inc.). cpCG = Compacted Crystal Green. MAP = monoammonium phosphate.

[2]NPK-Mg of cpCG varies by treatment (Trt 6: 10-48-0-1.5Mg. Trt 7: 10-46-0-2.5Mg. Trts 8 & 14: 9-44-0-3.5Mg. Trt 15: 8-40-0-5Mg).

Table 3. The effect of phosphate source and method and rate of application on Russet Burbank tuber yield and size distribution in Becker, MN, in 2014.

Treatment				Tuber Yield										
Treatment	Phosphate rate (lbs P_2O_5/ac)	Phosphate source[1]	Application method	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
				cwt / ac									%	
1	0	None	None	25.6	66.1	121.3	115.1	114.2	442.2	330.9	85.8	416.7	79.2	51.7
2	100	Crystal Green	Band	15.3	43.7	98.4	125.4	164.9	447.7	319.2	113.3	432.5	87.0	65.3
3	100	MAP	Band	21.3	57.7	125.7	102.1	113.7	420.4	285.9	113.3	399.2	81.0	50.7
4	100	50% CG : 50% MAP	Band	11.6	41.4	105.3	101.7	138.7	398.7	282.6	104.5	387.1	85.8	59.0
5	100	25% CG : 75% MAP	Band	15.3	41.8	99.7	119.2	130.2	406.2	300.3	90.6	390.9	86.1	60.9
6	100	9% cpCG : 91% MAP	Band	18.8	50.0	109.4	119.2	143.9	441.3	342.6	79.9	422.5	84.0	59.2
7	100	15% cpCG : 85% MAP	Band	17.8	44.2	98.3	119.7	105.1	385.1	261.3	106.0	367.3	83.8	58.1
8	100	23% cpCG : 77% MAP	Band	26.3	61.8	116.0	83.1	91.9	379.1	255.4	97.4	352.8	76.8	45.9
9	75	Crystal Green	Band	21.3	58.9	119.3	110.0	121.1	430.6	292.4	116.9	409.3	80.8	52.8
10	75	MAP	Band	18.3	48.8	108.2	112.1	168.5	455.9	313.1	124.5	437.6	85.1	61.3
11	75	75% CG : 25% MAP	Band	18.0	44.0	93.3	113.9	112.9	382.0	245.8	118.2	364.0	83.8	59.7
12	75	50% CG : 50% MAP	Band	16.4	45.5	114.9	111.8	132.4	421.1	302.2	102.4	404.6	85.2	57.9
13	75	25% CG : 75% MAP	Band	30.1	58.4	113.1	96.9	94.3	392.9	274.2	88.6	362.8	76.3	47.1
14	75	23% cpCG : 77% MAP	Band	15.7	49.3	108.2	112.5	132.4	418.1	293.0	109.4	402.4	84.5	58.6
15	75	35% cpCG : 65% MAP	Band	16.7	55.7	107.9	104.3	123.5	408.0	283.1	108.3	391.4	82.2	55.4
16	100	MAP	Broadcast	32.1	80.2	137.6	111.3	80.1	441.2	295.8	113.3	409.1	74.4	42.9
17	75	MAP	Broadcast	17.8	53.4	123.1	114.5	138.8	447.6	321.0	108.8	429.8	83.9	56.2
18	100	Crystal Green	Broadcast	15.7	53.6	120.2	111.1	151.7	452.3	305.8	130.8	436.6	84.5	57.8
			Significance[2]	*	++	NS	NS	NS	NS	NS	NS	NS	*	*
			MSD (0.1)	13.0	25.8	–	–	–	–	–	–	–	7.6	12.5

[1]**Crystal Green** (CG: Ostara Nutrient Recover Technologies, Inc.): 5-28-0-10Mg. **Compacted Crystal Green** (cpCG): NPK-Mg varies by treatment (trt 6: 10-48-0-1.5Mg. Trt 7: 10-46-0-2.5Mg. Trts 8 & 14: 9-44-0-3.5Mg. Trt 15: 8-40-0-5Mg). **MAP**: 18-46-0.

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

Table 3. Effect of phosphate source and method and rate of application on Russet Burbank tuber quality in Becker, MN, in 2014.

Treatment				Tuber Quality				
Treatment	Phosphate rate (lbs P_2O_5/ac)	Phosphate source[1]	Application method	Hollow heart	Brown center	Scab	Dry matter	Specific gravity
				%				
1	0	None	None	9.3	9.3	31.0	20.4	1.0807
2	100	Crystal Green	Band	17.0	17.0	15.0	20.5	1.0787
3	100	MAP	Band	14.2	14.2	14.2	19.9	1.0775
4	100	50% CG : 50% MAP	Band	13.2	13.2	16.5	20.5	1.0799
5	100	25% CG : 75% MAP	Band	23.9	23.9	11.4	19.1	1.0815
6	100	9% cpCG : 91% MAP	Band	14.0	14.0	14.0	19.0	1.0804
7	100	15% cpCG : 85% MAP	Band	22.3	22.3	16.6	20.5	1.0797
8	100	23% cpCG : 77% MAP	Band	15.3	15.3	34.3	19.0	1.0796
9	75	Crystal Green	Band	17.2	17.2	26.2	20.6	1.0816
10	75	MAP	Band	31.1	31.1	17.4	19.3	1.0808
11	75	75% CG : 25% MAP	Band	27.3	27.3	31.5	19.5	1.0788
12	75	50% CG : 50% MAP	Band	22.0	22.0	5.0	19.5	1.0822
13	75	25% CG : 75% MAP	Band	17.5	17.5	41.8	19.3	1.0791
14	75	23% cpCG : 77% MAP	Band	17.9	17.9	19.9	19.4	1.0778
15	75	35% cpCG : 65% MAP	Band	18.0	18.0	19.0	19.6	1.0817
16	100	MAP	Broadcast	21.5	21.5	9.1	20.3	1.0791
17	75	MAP	Broadcast	21.3	21.3	10.7	20.5	1.0819
18	100	Crystal Green	Broadcast	21.3	21.3	18.7	19.4	1.0820
Significance[2]				*	*	NS	NS	NS
MSD (0.1)				10.9	10.9	--	--	--

[1]**Crystal Green** (CG: Ostara Nutrient Recover Technologies, Inc.): 5-28-0-10Mg. **Compacted Crystal Green** (cpCG): NPK-Mg varies

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

Fresh Market Potato Variety Testing

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Executive Summary
New variety adoption is important to the vitality of the potato industry in the Red River Valley and for the irrigated central sands of Minnesota. This purpose of this trial was to compare the graded yield of 22 red-skinned cultivars and 10 yellow-skinned cultivars. Of the cultivars tested at Becker, MN the most promising new red-skinned varieties were ND7982-1R and W6002-1R. At the dryland study the most promising red-skinned varieties were W6002-1R, W8405-1R, and ND6002-1R. Of the yellow-skinned varieties Soraya, Yukon Gem, Satina, and Milva all performed well under irrigation and dryland conditions. There were many other cultivars that yielded well and were not statistically different than the aforementioned cultivars. Future trials will help validate the data from this trial.

Introduction
Potato growers are continually looking for the next potato variety that provides a high yield and profitable size profile. Potato breeders continue to develop new potato varieties with many desirable genetic traits. Some of these traits may include increased yield potential, resistance to diseases, better size profile, improved skin color, drought tolerance, or enhanced nutrient efficiency. Additionally, many of these varieties can take 10 to 15 years to develop. With such a long time commitment, it is essential to develop the best agronomic practices for successful commercial production of these potatoes. Additionally, many potato varieties are bred outside of North Dakota and Minnesota, and for this reason it is important to test new varieties in the Red River Valley and Minnesota sands to determine how they respond when grown in the Red River Valley and in Minnesota sands. Research for 2013 found the MN0216, CO098102-5R, and ND8555-8R were promising cultivars with similar yield to Viking, Pontiac, and Red Norland. Continuous studies for cultivars will help determine the best cultivars over multiple years and environments.

Not only is marketable yield important to growers, but potatoes that store well is essential. Many wash plants like to hold potatoes for eight months or longer, but pressure bruising, shrink loss, and color loss of potatoes in the lower pile often increases the number of culls and reduces profits. Previous research in the Red River Valley reported that there was a varietal effect on pressure bruising. Additionally, Fusarium dry rot and black spot can compromise quality of fresh market tubers and make them less profitable.

Materials and Methods
This study was conducted in two locations, Becker, MN and Crystal, ND. Potato cultivars at Becker, MN were grown under irrigation on a commercial potato field. The dryland site near Crystal, ND was also grown on a commercial potato field. A randomized complete block design was utilized at each location with four replications. Seed was hand cut to 2.0 oz seed pieces and suberized for approximately 10 days in 55 °F and 95% humidity prior to planting. Tubers were planted within rows at 9 in with-row spacing and rows were spaced at 36 in. Plots were single rows measuring 25 ft because many varieties being tested do not have large quantities of seed available. Agronomic practices followed typical agronomic practices for North Dakota and Minnesota. Plots were killed on 11 August and harvested in 9 September in Becker, MN. In Crystal plots were harvested on 22 of September and shortly thereafter graded for size. Size profile distribution was determined by sorting potatoes into C size (<1.875 inches), B size (1.875 to 2.25 inches), A size (2.25 to 3.5 inches), and Jumbo size (>3.5 inches).

Data were then subject to SAS Proc GLM to test for significant effects of each graded yield parameter. LSD was used to determine if cultivar had a significant effect ($P \leq 0.05$) on graded yield.

Tubers from Becker were tested for the development of fusarium dry rot by Dr. Secor's laboratory. The results for the potato variety trial inoculated with *Fusarium sambicinum*. Ten of the 34 varieties there is no data to report due to soft rot. The tubers were evaluated for dry rot symptoms after 4 weeks of incubation. The size of the lesion (area in mm) was used to compared varieties for the tolerance to *Fusarium sambucinum*. Data was analyzed at $P = 0.05$.

Results and Discussion

There was a statistical difference between the Becker (irrigated) and Crystal (dryland) sites, thus data were analyzed by location. Total yield of red-skinned potatoes in Becker ranged from 203 to 417 cwt/a (Table 1). Red Norland was the highest yielding variety. Numbered varieties that performed well were ND7982-1R, W6002-1R, and CO98012-5R. ND7982-1R had the highest number of B sized tuber and lacked A sized tubers when compared to other top yielding varieties. These data indicate that Red Norland is still a top variety to grow in the central sands of Minnesota for total yield and tuber size. The yellow-skinned potatoes had a total yield from 279 to 495 cwt/a (Table 2). The standard comparison was Yukon Gold. Milva, Satina, Yukon Gem, and Soraya had higher total yield compared to Yukon Gold. The size of the top yielding yellow-skinned potatoes was similar.

At Crystal, ND the trial had different results than Becker, MN. The top three yielding red varieties were W6002-1R, W8405-1R, and ND6002-1R which all had a numerically higher yield than Red Norland (Table 3). The size profile on these top cultivars were similar in general, only W8405-1R numerically had more B sized potatoes than A sized when compared to top yielders. The yellow-skinned trial had a similar result to the irrigated location with the top yielding varieties being Soraya, Milva, Yukon Gem, and

Satina (Table 4). Soraya had a large percentage of tubers in the A size. Yukon Gold, the commercial standard, fell short of the top yielding varieties in this trial.

Pressure bruise testing is currently in progress for the Crystal trial. We are also testing the varieties from Becker for blemishes and the Crystal varieties for fusarium dry rot. Future research will focus on continuing to test the top yielding cultivars and brining in new varieties to test in ND and MN growing conditions.

The fusarium dry rot testing was completed in Dr. Gary Secor's laboratory. Differences were found among the cultivars tested. The best performing cultivars were CO98012-5R, Dark Red Norland, and MN04844-07 which all had less then 300 mm of lesions. The highest amount of lesions >800 mm were W8405-1R and Colorado Rose. It is not unusual to loose some tuber due to soft rot, we think that varieties that are more susceptible to soft rot are prone develop soft rot symptoms due to the injury we made to inoculate with Fusarium and the condition of high humidity that the tubers are incubated to favor the development of dry rot.

Table 1. Graded yield of red-skinned potato varieties grown in Becker, MN in 2014 in a commercial potato field.

Location	Cultivar	C[1]	B	A	Chef	Yield	Stand
		-----------------		cwt/a		-----------------	no.
Becker, MN	Red Norland	7	57	327	26	417	29
Becker, MN	ND7982-1R	28	166	212	8	414	29
Becker, MN	Dark Red Norland	7	56	294	52	409	27
Becker, MN	Dakota Rose	4	42	278	73	397	26
Becker, MN	W6002-1R	25	115	243	10	392	25
Becker, MN	Dakota Ruby	20	107	259	1	387	28
Becker, MN	Viking	7	51	266	44	367	26
Becker, MN	Modoc	11	81	269	1	362	25
Becker, MN	CO98012-5R	28	135	195	3	361	27
Becker, MN	Runestone Gold	9	87	254	10	361	28
Becker, MN	MN10020PLWR-08R	5	51	263	31	350	25
Becker, MN	ND6002-1R	6	69	256	6	336	27
Becker, MN	W8405-1R	20	134	179	2	335	28
Becker, MN	Colorado Rose	7	64	241	22	335	24
Becker, MN	Red Maria	7	57	245	3	312	21
Becker, MN	MN10003PLWR-03R	19	107	171	8	305	29
Becker, MN	Sangre	11	75	214	5	304	23
Becker, MN	ND7132-1R	7	61	213	18	299	23
Becker, MN	MN10001PLWR-14R	7	44	227	20	298	28
Becker, MN	CO05228-4R	46	128	115	0	289	25
Becker, MN	MN10020PLWR-05R	6	40	174	25	245	21
Becker, MN	MN10025PLWR-07R	3	21	161	18	203	15
LSD at P=0.05		*7*	*27*	*79*	*28*	*91*	*4*

[1]Size of potatoes were sorted on a Kerian Speed sizer as C = <1.875 in, B = 1.875 – 2.25 in, A = 2.25 – 3.5 in, Chef = > 3.5 in.

Table 2. Graded yield of yellow-skinned potatoes grown in a commercial field in Becker, MN 2014.

Location	Cultivar	C[1]	B	A	Chef	Yield	Stand
		---------------------- cwt/a ----------------------					no.
Becker, MN	Soraya	15	118	344	17	495	28
Becker, MN	Yukon Gem	10	121	331	20	482	27
Becker, MN	Satina	12	92	330	15	448	25
Becker, MN	Milva	14	126	290	9	440	25
Becker, MN	MN02586	27	139	237	1	405	27
Becker, MN	Sierra Gold	12	77	260	21	370	22
Becker, MN	Yukon Gold	9	72	250	20	352	26
Becker, MN	W6703-1Y	15	99	211	3	329	28
Becker, MN	Yukon Nugget	31	118	136	3	287	27
Becker, MN	MN04844-07	19	106	148	7	279	27
LSD at P=0.05		*8*	*28*	*87*	*ns*	*88*	*ns*

[1]Size of potatoes were sorted on a Kerian Speed sizer as C = <1.875 in, B = 1.875 – 2.25 in, A = 2.25 – 3.5 in, Chef = > 3.5 in.

Table 3. Graded yield of red-skinned potatoes grown dryland in a commercial field in Crystal, ND in 2014.

Location	Cultivar	C[1]	B	A	Chef	Yield
		---------------------- cwt/a ----------------------				
Crystal, ND	W6002-1R	49	95	291	3	438
Crystal, ND	W8405-1R	27	137	210	6	379
Crystal, ND	ND6002-1R	14	78	261	8	362
Crystal, ND	Red Norland	14	71	254	11	350
Crystal, ND	Colorado Rose	8	70	250	15	343
Crystal, ND	Sangre	15	90	225	7	337
Crystal, ND	CO98012-5R	16	80	236	3	335
Crystal, ND	Viking	2	26	254	47	329
Crystal, ND	ND7132-1R	10	87	215	3	316
Crystal, ND	Dakota Ruby	20	73	199	3	295
Crystal, ND	Modoc	12	89	193	1	295
Crystal, ND	Dark Red Norland	7	47	232	8	294
Crystal, ND	Runestone Gold	15	85	166	6	271
Crystal, ND	ND7982-1R	17	107	134	5	263
Crystal, ND	Dakota Rose	10	50	185	6	252
Crystal, ND	CO05228-4R	22	77	144	2	245
Crystal, ND	Red Maria	3	45	190	3	242
Crystal, ND	MN10003PLWR-03R	30	83	122	1	236
Crystal, ND	MN10025PLWR-07R	9	42	161	7	219
Crystal, ND	MN10020PLWR-08R	14	67	128	5	214
Crystal, ND	MN10020PLWR-05R	6	35	158	5	204
Crystal, ND	MN10001PLWR-14R	7	29	67	3	106
LSD at P=0.05		*ns*	*52*	*121*	*11*	*133*

[1]Size of potatoes were sorted on a Kerian Speed sizer as C = <1.875 in, B = 1.875 – 2.25 in, A = 2.25 – 3.5 in, Chef = > 3.5 in.

Table 4. Graded yield of yellow-skinned potatoes grown dryland in a commercial field in Crystal, ND 2014.

Location	Cultivar	C[1]	B	A	Chef	Yield
		----------------------- cwt/a ------------------------				
Crystal, ND	Soraya	19	95	256	20	389
Crystal, ND	Milva	17	125	213	4	359
Crystal, ND	Yukon Gem	14	138	183	0	336
Crystal, ND	Satina	9	75	238	7	329
Crystal, ND	Sierra Gold	16	72	231	8	328
Crystal, ND	MN02586	20	134	137	0	290
Crystal, ND	Yukon Gold	10	66	207	2	285
Crystal, ND	Yukon Nugget	39	103	77	0	219
Crystal, ND	MN04844-07	25	71	105	0	202
Crystal, ND	W6703-1Y	15	79	101	0	195
LSD at P=0.05		*16*	*29*	*59*	*ns*	*68*

[1]Size of potatoes were sorted on a Kerian Speed sizer as C = <1.875 in, B = 1.875 – 2.25 in, A = 2.25 – 3.5 in, Chef = > 3.5 in.

Table 5. Fusarium evaluation of varieties. Lesion (area) was used to compare varieties for the tolerance to *Fusarium sambucinum*.

Selection	Lesion size (mm)
Dark Red Norland	254.9
Dakota Rose	568.0
Colorado Rose	988.3
Red Norland	743.1
Modoc	430.6
Sangre	-
Viking	558.5
ND7982-1R	-
MN10003PLWR-03R	623.8
CO05228-4R	-
Red Maria	479.6
W6002-1R	-
W8405-1R	899.1
MN02616	-
MN1001PLWR-14R	-
MN10020PLWR-05R	-
MN10020PLWR-08R	-
MN10025PLWR-07R	359.5
CO98012-5R	217.2
ND6002-1R	557.6
ND7132-1R	363.7
ND8555-8R	675.3
W6703-1Y	734.9
MN02586	-
Yukon Nugget	-
Satina	582.3
Soraya	499.4
Yukon Gem	391.9
Sierra Gold (Tx1523)	-
Yukon Gold	211.1
Milva	-
MN04844-07	262.7
Russet Burbank	157.7
Russet Norkotah	382.0
LSD P = 0.05	163.5

From Hybridizing to Release – Cultivar Development for the Northern Plains
North Dakota State University
2014 Summary

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Potato is the most important horticultural crop produced in North Dakota and is an important vegetable crop in Minnesota. The NDSU potato breeding program is involved in germplasm enhancement efforts, breeding, selection of superior genotypes, evaluation, and development of improved cultivars for potato producers and the potato industry in North Dakota, Minnesota and beyond. The breeding program focuses on improvements including durable pest and stress resistances, improved nutrient-use efficiency, enhanced nutritional and quality attributes, and high yield potential, to address stakeholder (including consumers) needs, via conventional breeding efforts.

We have established the following research objectives in order to address stakeholder needs:
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 are used in hybridization efforts to develop resistance to biotic and abiotic stresses, and in improving quality attributes. In 2014, hybridizing efforts, using 145 diverse parental genotypes from around the globe, resulted in 529 new families. Parental genotypes were evaluated using a set of molecular markers for PVY (adg and sto), Golden Nematode, *Verticillium* (Mfe1), and cold sweetening resistance. This information is providing valuable details regarding the progeny families, including families from previous years, and has been useful in parental selection for our 2015 crossing block. Seedlings representing 112 families were produced in the summer greenhouse, totaling 24,710 individual genotypes. Another crop is currently in the greenhouse, representing 30 families and about 20,000 additional individuals. Fifty-six families, totaling approximately 5,600 genotypes were evaluated for late blight resistance using a detached leaf assay in collaboration with Dr. Gary Secor and Viviana Rivera. Resistant selections were retained separately for multi-hill agronomic evaluations in 2015.

In the Langdon, ND, seedling nursery, 34,916 seedlings, representing 240 families, were evaluated; 442 selections were retained. In 2014, 677 second, 249 third year, and 273 fourth year and older selections, were produced in maintenance and increase lots at Baker, MN and Absaraka, ND. Unselected seedling tubers were shared with the breeding programs in Idaho, Maine, Colorado and Texas. Unselected seedling tubers received from these cooperating programs were grown at Larimore, ND; 136 genotypes were selected for evaluation in 2015.

Yield and evaluation trials were grown at eight locations in North Dakota and Minnesota, five irrigated (Larimore, Oakes, Inkster, Williston, Park Rapids) and three non-irrigated locations (Hoople, Crystal and Grand Forks). Twenty-two selections and commercially acceptable cultivars were grown in the Oakes processing trial, 24 in the Larimore processing trial, and 22 in the Williston processing trial. The preliminary processing trial at Larimore had 101 entries. The NFPT is an industry driven trial with evaluations in WA, ID, ND, WI and ME; 68 genotypes were evaluated for agronomic traits and will assessed for sugar, asparagine and acrylamide levels. Three hundred thirty-three clones selected from out-of-state seedlings in 2013, and 14 third year and older selections were grown in maintenance plots. A processing trial with 20 entries, including six clones from the NDSU breeding program was grown at Park Rapids, in collaboration with RDO/Lamb-Weston. A scab screening trial was also initiated; 80 russet and long-white selections and named cultivars were evaluated.

Trials at Inkster included the irrigated chip processing yield trial with 20 entries, the North Central (NC) Regional Potato Variety Trial (irrigated) which was reconfigured by the NC breeders in 2014 to focus on fresh market genotypes and assessments (38 entries, six from NDSU), evaluation of genotypes for resistance to Verticillium wilt in collaboration with Drs. Neil Gudmestad and Ray Taylor (21 clones across all market types), and a metribuzin screening trial with 16 recently released and advancing selections as entries conducted in collaboration with Dr. Harlene Hatterman-Valenti and Collin Auwarter.

Twenty-four entries were grown in the chip trial at Hoople, including 16 advancing selections from the NDSU program, and eight standard chipping cultivars. In the preliminary chip trial 65 entries were grown. The National Chip Breeders Trial (NCBT), with goals to rapidly identify and develop clones to replace Atlantic for southern production areas, and Snowden from storage, initiated by the USPB and regional chip processors, had 130 entries in the unreplicated trial, and 60 in the replicated trial. At Crystal, the state fresh market trial had 22 entries and the preliminary fresh market trial had 105 entries were evaluated, including 92 advanced selections and 13 industry standards. The NCRPVT (non-irrigated) trial had 30 entries as some programs didn’t submit enough seed for two trials and preferred to have their materials assessed under irrigated conditions.

Two trials were grown at the NPPGA Research Farm south of Grand Forks. They included seedling family evaluation for Colorado Potato Beetle (CPB) resistance (information used during selection at Langdon in September), and individual clone assessment for defoliation twice weekly throughout the summer. The trials were not successful due to losses from drown-out/seed piece decay and the lack of weed control early in June/early July.

Our focus continues to be identification of processing (both chip and frozen) germplasm that will reliably and consistently process from long term cold storage. As we grade, chip processing selections are sampled, ‘field chipped’, stored at 42F and 38F (5.5C and 3.3C) for eight weeks, while a fourth set is evaluated the following June from 42F storage. Frozen processing selections are evaluated after grading (field fry) and from 45F (7.2C) storage after eight weeks and again in June. All trial entries are evaluated for blackspot and shatter bruise potential.

Collaborative field trials for late blight foliar and tuber evaluations with Dr. Secor were very successful in 2014. Sixteen selections were evaluated by Drs. Neil Gudmestad and Ray Taylor for resistance to pink rot (caused by *Phytophthora erythroseptica* Pethyb), *Phytophthora nicotianae,* and *Pythium* leak (*Pythium ultimum* Trow.). Most selections were rated as resistant or moderately resistant to pink rot and *Phytophthora nicotianae*. Identifying resistant lines to *Pythium* leak has been more difficult. A breeding line from Cornell for glandular trichomes possessed resistance to all pathogens. This will be very useful in our breeding efforts.

Sucrose rating, invertase/ugpase analysis, and serial chipping of chip and frozen processing selections is conducted by Marty Glynn (USDA-ARS) and Dr. Joe Sowokinos (UMN Professor Emeritus) at the USDA-ARS Potato Worksite in East Grand Forks, MN. Many entries were submitted for cooperative trials with various producers, industry, and research groups across North America.

The NDSU potato breeding program is supported by Dr. Jose Rodriguez and Mr. Dick (Richard) Nilles (research specialists). Dr. Rob Sabba, post doctoral research fellow, accepted a research specialist position with the weed genetics group at the beginning of December. Whitney Harchenko completed and successfully defended her MS thesis on the use of marker assisted selection for PVY resistance in a breeding program. Adriana Rodriguez, successfully defended her MS thesis on glandular trichome mediated resistance to Colorado potato beetle resistance; she is currently finishing her editting. Leah Krabbenhoft and James Bjerke joined the breeding program in May as MS students. Leah is working on the starch evaluation project. This originated with the Potato Innovation group a few years ago, and she is conducting her work under the guidance of Drs. Senay Simsek, Susan Raatz, and myself. She has already found differences between genotypes in her assessment, indicating the potential for an array of end uses. James is working on late blight with the guidance of Dr. Gary Secor and myself, and will be characterizing the resistance in the genotypes of our dedicated crossing block, and assessing heritability.

A highlight for the year was the release of Dakota Ruby, evaluated as ND8555-8R, by the Agricultural Experiment Station on April 11. We are receiving wonderful feedback and interest from across North America. Characteristics are reviewed in a figure following this summary. The most promising advancing red fresh market selections continue to include ND4659-5R, ND6002-1R, ND7132-1R and AND00272-1R. Dual-purpose russet selections, ND8068-5Russ and several hybrids between Dakota Trialblazer and Dakota Russet possess excellent appearance, yield, and processing qualities. ND7519-1, ND7799c-1, and ND8304-2, advancing chip processing selections, possess excellent appearance and cold sweetening resistance. Several specialty selections with unique colored flesh and skin are advancing through the program, including AND99331-2PintoY. Clones are summarized in figures following this review.

Goals for 2015 include development of improved potato cultivars for ND, MN, the Northern Plains and beyond, using traditional hybridization, and utilizing early generation selection techniques including the use of marker assisted selection and greenhouse screening procedures for rapid identification of genetically superior germplasm. Focus will be on resistance to major insect, disease and nematode pests, and to environmental stresses, with an emphasis on improved quality characteristics, important to Northern Plain's potato producers. We work closely with Drs. Gudmestad and Secor breeding and screening for resistance to new and emerging pests, and with Drs. Robinson, Rosen, MacRae, and Hatterman-Valenti on agronomic and quality characteristics. Seed maintenance and increase efforts are conducted in cooperation with the North Dakota State Seed Departement (NDSSD) and MN Department of Agriculture (MDA).

We are extremely grateful for the continued support and cooperation in providing resources of land, certified seed, research funds, and equipment from our grower and industry collaborators. Thank you for this support and for your guidance as we strive to develop improved and superior cultivars for adoption in North Dakota, Minnesota and beyond.

Dakota Ruby

- Evaluated as ND8555-8R
- ND7188-4R x ND5256-7R
- Suited for the fresh market
- Medium maturity
- Medium-large vine size
- High yield potential
- Bright red, round, smooth tubers with white flesh and shallow eyes
- Very uniform tuber size profile
- Medium specific gravity
- Stores well

ND7519-1

- ND3828-15 x W1353
- Medium sized vine
- Medium-late maturity
- High yield potential
- High specific gravity (+1.090 average in ND)
- Chips from 42F storage

NDSU

ND7799c-1

- Dakota Pearl x Dakota Diamond
- 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

ND8304-2

- ND860-2 x ND7083-1
- Medium early maturity
- Small to medium sized vine
- Medium yield potential
  - Nice tuber type, smaller size profile
- High specific gravity
- Chips from 42F storage
  - Excellent cold chipping selection

NDSU

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

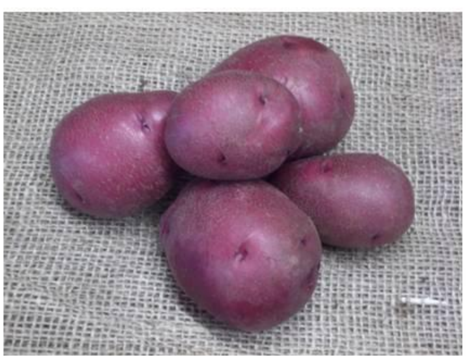
NDSU

Dakota Russet x Dakota Trailblazer Hybrids

- Hybrids include ND049546B-10Russ, ND049546B-15Russ, ND049546b-27Russ, ND050032-4Russ, ND060735-3Russ, and ND060735-4Russ
- Yield potential for all is medium to high
- Maturity is medium for all
- Specific gravity is midpoint between parents
- All are dual-purpose
- All have excellent French fry quality and low sugar accumulation in storage
- Early in evaluation process for cultivar specific management information

NDSU

ND4659-5R



- NorDonna x ND2842-3R
- Suited for the fresh market
- Medium vine with red-purple flowers
- Medium maturity
- Medium yield potential
- Bright red, round, smooth tubers with white flesh and shallow eyes
- Medium specific gravity
- No outstanding disease or pest susceptibilities
- Stores well

NDSU

ND6002-1R

- NorDonna x Bison
- Medium sized vine
- Medium maturity
- Medium yield potential
- Round, smooth, bright red tubers with smooth eyes and bright white flesh
- Medium specific gravity
- Early in evaluation process. Some silver scurf noted.

NDSU

ND7132-1R

- ND5002-3R x ND5438-1R
- Medium maturity
- Medium yield potential
- Bright red skinned, oval to oblong tubers with white flesh
- Early in evaluation process

NDSU

Improving Postemergence Herbicides in Potato Production

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Executive Summary
There are limited herbicides to control postemergence broadleaf weeds in potato production. The two available herbicides for broadleaf weed control are metribuzin and rimsulfuron. However, once weeds grow above two inches tall they become difficult to control. Adjuvants can improve the efficacy of herbicides, but will vary by adjuvant type, environment, herbicide used, and weeds. In potato weed control there is little information on the efficacy of adjuvants for improving weed control with metribuzin and rimsulfuron. The focus of this experiment was to quantify the effect of various adjuvants on weed control, crop tolerance, and potato yield. There was some injury seen on potato plants after herbicide application, but nothing more than 20% injury. Wild proso millet was the only weed with sufficient density in the trial to record data and control of prosos millet was > 80% with all treatments. Graded yield was not different between treatments.

Background
Controlling weed postemergence in potato can be challenging because of limited herbicide options. This is especially problematic when weather conditions are unfavorable for preemergence herbicide applications. Other factors that affect the use of postemergence herbicides are potato tolerance, limited row cultivation, and weed size. Postemergence herbicides are further limited because of tolerance to herbicides. This is especially true for metribuzin treatments in all red skinned and white skinned cultivars and in some russet cultivars. Many growers have stopped row cultivation due to suspicion of root pruning and reduced water uptake by affected plants. Likewise, postemergence herbicide applications are avoided in order to reduce the potential plant stress during herbicide metabolism. Such production changes generally shift natural selection pressures favoring those species that have multiple flushes throughout the year or species that germinate later in the growing season. These species shifts generally result in the emergence of species tolerant to existing weed management practices especially when control measures are limited and often lead to the development of weed infestations that are difficult to control, and ultimately reduce crop yield.

Weeds not only reduced yield, but they also can be hosts for aphids and PVY, Colorado Potato Beetles, and diseases. Weeds lefts uncontrolled in potato can reduce yield by up to 68% and reduce US No. 1 tuber yield by 92% (Love et al., 1995). Nightshade species are difficult to control in potato fields with limited herbicide options. There are three main reasons why nightshade weeds have become so problematic. First, the most commonly used broadleaf herbicide in potatoes is metribuzin, which does not control nightshade species. Secondly, ALS herbicides like imazamox, which provide excellent nightshade control in a rotation crop, are not being used due to ALS weed resistance problems including eastern black nightshade. Lastly, multiple flushes and short juvenility stages for some nightshade species enable seed germination later in the season, after early season herbicides have dissipated, yet plants still produce a large number of seeds by potato harvest (Zhou, 1999). However, it's the ability of several nightshade species to potentially act as an alternative host for numerous diseases (PVY, PVM, PLRV, late blight, and powdery scab) as well as nematode and insect pests (Columbia root-knot nematode, PCN, stubby root nematode, green peach aphid, and Colorado potato beetle) that warrants their control in a potato crop (Boydston et al., 2008, Nitzan et al., 2009, Tscheulin et al., 2009).

Adjuvants are an effective and relatively inexpensive option to improve herbicide efficacy. Previous work studied the effect of three types of adjuvants: nonionic surfactant (NIS), crop oil concentrate (COC), and methylated seed oil (MSO) tank mixed with metribuzin and rimsulfuron. Tank mixing rimsulfuron and metribuzin had better weed control and rimsulfuron applied alone with an adjuvant. Adding MSO or COC to the tank caused more injury than NIS, but had better control of common lambsquarters and had no effect on graded yield (Hutchinson et al., 2004). This study only examined three adjuvants, therefore current recommendations on adjuvants come from studies done on non-potato crops. NDSU research reports a wide range of effects from different adjuvants from antagonizing herbicides to improve weed control by 25% (Zollinger et al., 2014). More knowledge is needed to understand which adjuvants are most beneficial in potato production systems.

Identifying the best adjuvants can help improve herbicide efficacy and can improve the use of reduced herbicide rate system. Small acreage crops, such as sugar beets and onions are like potatoes, where there are limited herbicide options. Potato growers need season-long control of weeds, especially nightshade species, in order to protect the quality of their potato crop and not just early season control.

Materials and Methods

A field trial was conducted in Ottertail, MN on a commercial farm. A randomized complete block design was used with four replications. Treatments consisted of a non-treated check, a hand-weeded check, metribuzin + rimsulfuron, and metribuzin + rimsulfuron + different adjuvants (Table 1). A hand-held CO_2 pressurized sprayer was used to treat the plots. The boom measured 9 feet and was equipped with XR11002 nozzles spaced 18 in apart and calibrated to deliver 15 gallons/acre at 17 psi. Treatments were applied on June 21 at 10:40 am. The wind was 4 mph from the south, air temperature was 81 °F and soil temperature was 75 °F, the relative humidity was 68%, and potato plants were 12 in tall. The soil had 90% sand, 8% silt, and 2% clay with a CEC of 6.3, pH of 6.8, and organic matter of 1.4%. Measurements were taken at 14 days after treatment (DAT) for estimated crop injury (ranging from 0 to 100% with 0 being complete plant destruction and 100 be in injury) and at 14 and 28 DAT for efficacy of weed control from 0 to 100% (with 0 being no control and 100 being complete weed control). Plots were harvested on September 23, 2014 with a single row plot harvester and graded at East Grand Forks, MN thereafter.

Results

Some crop injury was observed at 14 DAT. Injury was not greater than 20%, but R-11, NIS-EA and Class Act NG had the highest injury when combined with metribuzin + rimsulfuron. Weed density throughout the plot was not consistent for any weed but wild proso millet. Control of wild proso millet was greater than 80% in all treatments. Climb and Class Act NG when combined with metribuzin + rimsulfuron had the worst control of wild proso millet when compared to the other treatments, but was still sufficient for grower acceptable standards. Graded yield was not different for any treatment, indicating that all the adjuvants did not have a significant effect on yield. Further work will be conducted to determine if adjuvants can improve weed control and still maintain quality yield.

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Table 1. Response of Russet Burbank potato and wild proso millet to rimsulfuron + metribuzin + various adjuvants at Ottertail, MN 2014.

Treatment		Rate	Rate unit	Crop injury 14 DAT	Proso millet control 14 DAT	Proso millet control 28 DAT
				%		
1	Non-treated check			0	0	0
2	Handweeded check			0	0	0
3	Metribuzin	0.67	lb/a	8	93	95
	Rimsulfuron	1.5	oz/a			
4	Metribuzin	0.67	lb/a	18	91	96
	Rimsulfuron	1.5	oz/a			
	R-11	0.5	% v/v			
5	Metribuzin	0.67	lb/a	16	93	90
	Rimsulfuron	1.5	oz/a			
	R-11	1	% v/v			
6	Metribuzin	0.67	lb/a	6	80	91
	Rimsulfuron	1.5	oz/a			
	Climb	3.125	% v/v			
7	Metribuzin	0.67	lb/a	13	91	95
	Rimsulfuron	1.5	oz/a			
	Dyne-Amic	6	fl oz/a			
8	Metribuzin	0.67	lb/a	9	86	90
	Rimsulfuron	1.5	oz/a			
	Prefer90	0.5	% v/v			
9	Metribuzin	0.67	lb/a	14	83	84
	Rimsulfuron	1.5	oz/a			
	Class Act NG	2.5	% v/v			
10	Metribuzin	0.67	lb/a	14	96	96
	Rimsulfuron	1.5	oz/a			
	NIS-EA	0.25	% v/v			
11	Metribuzin	0.67	lb/a	11	95	95
	Rimsulfuron	1.5	oz/a			
	Destiny HC	1.5	pt/a			
LSD P=.05				*9*	*10*	*8*

MN Area II Potato Research and Promo Council and the Northern Plains Potato Growers Association (NPPGA)
FY 2014 Progress Report.

TITLE: Inheritance of Biochemical Markers for Resistance to Cold-Induced Sweetening and Improved Nutritional Quality to Compliment Potato Breeding and New Variety Development.

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Executive Summary:

Biochemical markers to predict cold sweetening resistance in stored potatoes are reliable selection tools for potato breeding programs because they have the capacity to predict a clone's ability to process after coming out of long term cold storage. These biochemical markers Acid Invertase (AcInv) and UGPase have been used in various potato breeding programs to characterize a diverse set of breeding clones from US potato breeding programs, as well as the segregating progeny population from the cross of Premier Russet (PR) x Rio Grande Russet (RGR). In addition to genotyping, the 124 clones from PR X RGR population were characterized for AcInv and UGPase (biochemical markers), sucrose and glucose (sugars), and sugar end defects. Results showed wide variation in acid invertase activity in the population. Most of the clones had enzyme activity values ranging between the two parents. However, some progeny performed better than the parents, thus transgressive segregation was observed in these progeny. Similar patterns were observed in terms of reducing sugar accumulation and other parameters. In the segregating population only a small portion of clones had desirable range for processing. Higher storage temperature increased the portion of desirable clones. These results set the stage for the current study. In order to better understand the inheritance of these biochemical markers and use them in selecting parents a robust genetic analysis need to be done with parents representing various combinations of cold sweetening resistance classes.

NB: In a complimentary study submitted to the USPB's NCPT and NFPT research boards, we are determining the inheritance of the three enzymes in relation to sugars, and processing quality. Combined, these research projects will identify superior processing advanced clones, identify parents to cross for superior processing quality progeny, and finally, identify which progeny to select from these crosses because they would have a high probability of being superior processing clones.

Rationale:

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 goal of this proposal is to study the keys enzymes (UGPase, AcInv and acid invertase inhibitor protein) directly related to high levels of reducing sugar accumulation and their interaction during long term cold storage using biochemical and genetic approaches. The information generated through this study will directly contribute to state, regional and national potato processing industry; and state and federal 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 University of 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. Some examples of crosses made are shown in Figure 2. In the year 2014 these 39 families were planted in third week of May 2014 at Gully, MN as four hills to increase tuber number. All potatoes were harvest early November 2014, suberized for three weeks at room temperature. Six families out of 39, representing promising class combinations, were evaluated for specific gravity, chip color, sugars.

Ten gram fresh tuber sample from each progeny was ground under liquid nitrogen and stored at -80°C for biochemical analysis. All the 39 families have been stored at 42°F storage for evaluations after cold storage to study the inheritance of biochemical markers for cold induced sweetening trait. Due to limited number of tubers in several families a full biochemical analysis will be done after 9 month storage.

Results:
Six families evaluated at 0 time were divided in two groups. Group 1 has the families with both parents from Class A whereas Group 2 has families with only one parent from Class A. Group 1 families showed no significant variation in terms of specific gravity and chip color. Families in Group 1 like MN02696 X NY138 had slightly higher percentage clones with desirable chip color compared to the families in group 2. (e.g. Atlantic X NY139).

Families in group 1 demonstrated wide variation in terms of total sucrose accumulated. The average sucrose accumulation in group 1 ranged from 0.4601 mg/g FW to 0.5236 mg/g FW. In group 2 the average sucrose accumulation ranged from 0.4866 mg/g FW to 0.8475 mg/g FW (Table 1).

The average reducing sugar glucose demonstrated wide variation within the families and between the groups. Families in group 1 demonstrated lower levels of glucose and higher percentage of clones with desirable level of glucose (0.1 mg/g FW). The glucose level in group 1 ranged from 0.0139 mg/g FW (100 % desirable clones) to 0.0982 mg/g FW (73% desirable clones). Whereas, families in group 2 accumulated higher levels of glucose ranged from 0.0968 mg/g FW (75% desirable clones) to 0.2332 mg/g FW (52% desirable clones) (Table 1). Similar patterns were observed in terms of basal (with) and total acid invertase (without inhibitor) activities (data not shown). This is the middle of the storage season. Full storage evaluation will be done after 9 months storage. A predictive model will be developed that will determine processing quality of progeny based on parent clone performance.

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 high levels 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 inhibitor protein makes the enzyme catalytically inactive. 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.

Summary:

For successful breeding of new potato cultivars 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.

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APPENDIX 1:

Figure1: Potato clones were divided into three different main classes based on the expression of marker enzymes.

A. Clones with best CIS resistance – acceptable for processing
   a. Clones with A-II isozyme of UGPase (A+)
   b. Clones without A-II isozyme of UGPase (A-)

B. Clones with intermediate CIS resistace – acceptable for processing
   a. Clones with A-II isozyme of UGPase (B+)
   b. Clones without A-II isozyme of UGPase (B-)

C. Clones with very low or no CIS resistance – not acceptable for processing
   a. Clones with A-II isozyme of UGPase (C+)
   b. Clones without A-II isozyme of UGPase (C-)

Figure 2: Parents in 39 diverse families were categorized according to the biochemical markers. Here are some examples

Family Selection

FRY (3 Families, 150 Clones)

- Premier Rus X AF4526-2 (Class A- x __)
- Premier Rus X AOND95249-1 (Class A- x C)
- Premier Rus X MN 18747 (Class A- x C)

CHIP (39 Families, 1124 Clones)

- Dakota Pearl X Atlantic (Class B- x B+)
- Dakota Pearl X MN02696 (Class B- x A-)
- Atlantic X Dakota Pearl (Class B+ x B-)
- Atlantic X ND860-2 (ClassB+ x A-)
- Atlantic X NY138 (Class B+ x A+)
- Atlantic X NY139 (Class B+ x A+)
- OTHERS

Table 1: Average sugars, chip color and specific gravity in selected potato families at harvest.

Family	Female	Male	Class	n	Desirable chip color (%)[3]	Specific Gravity From	Specific Gravity to	Ave Suc[1]	Ave Glc[2]	Desirable Glc (%)[3]
142	MN99380-1Y	MN02696	A - * A-	35	97	1.062	1.084	0.4601	0.0344	97%
148	ND860-2	MN99380-1Y	A- * A-	16	73	1.05	1.083	0.5236	0.0982	73%
138	MN02696	NY138	A- * A+	19	100	1.069	1.092	0.5078	0.0139	69%
161	W6609-3	Snowden	A- * B+	16	75	1.057	1.086	0.4866	0.0968	65%
126	Atlantic	NY138	B+ * A+	26	60	1.055	1.088	0.8475	0.1218	60%
127	Atlantic	NY139	B+ * A+	23	52	1.06	1.088	0.6488	0.1272	52%

1 Suc (sucrose) = mg/g FW
2 Glc (glucose) = mg/g FW
3 Number of desirable clones

Irrigated Potato Response to Timing and Rate of Application of Two Polymer-Coated Urea Fertilizers and a Microbial Enhancer Relative to Uncoated Urea

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Summary: A field experiment was conducted at the Sand Plain Research Farm in Becker, MN, to evaluate nitrogen fertilization strategies with the overall objective of improving nitrogen use efficiency in irrigated potato production. Specifically, the purposes of the study were (1) to evaluate two polymer-coated urea products, ESN and Agrocote Max, relative to uncoated urea, as nitrogen sources for potatoes, (2) to test different application strategies for ESN, urea, and urea/ammonium nitrate (UAN) to find a cost-effective way to maximize yield, (3) to determine the optimum N application rate for maximizing yield and minimizing nitrate leaching, and (4) to test the efficacy of Generate, a product intended to increase soil microbial activity and, as a result, soil nutrient availability to plants. A total of 18 treatments were used to determine the effects of nitrogen source, application timing, and application rate on tuber yield, size, and quality, petiole total nitrogen concentration, nitrogen uptake, and residual soil nitrate and ammonia concentrations at the end of the season. High soil moisture early in the season resulted in the loss of some plots, resulting in a highly unbalanced experimental design. Nitrogen application rate had substantial effects on total and marketable yield and tuber size distribution, with yield peaking at rates of 180 to 240 total lbs N/ac and the percentage of yield represented by tubers over six or ten ounces rising to a plateau at 240 to 300 total lbs N/ac. End-of-season residual soil NO_3-N concentration increased with N application rate, with the effect more pronounced at higher rates. These results suggest that the optimum N application rate in this field and this season was approximately 240 lbs N/ac. The effects of nitrogen source and application timing on crop performance were less clear-cut. The treatments receiving Agrocote Max generally had high total and marketable yields for their application rates, but not statistically higher than other treatments at the same rates, and even the observed effect may be an artifact of uneven replication. Treatments with low replication had higher mean yields, and three of the four Agrocote Max treatments had only one or two replicates. There were also no clear effects of N source or application timing on the percentage of yield represented by large tubers, tuber grade or quality, or residual soil NO_3-N. The treatment receiving urea, UAN, and Generate was not found to perform significantly differently from the one receiving only urea and UAN at the same rate and on the same schedule. Overall, these results do not provide a basis for recommending one N source or application timing over another, but they do indicate that the optimum total application rate of N was 180 to 240 lbs/ac. However, the influence of damage from high soil moisture early in the season on these results cannot be determined, and they may not be representative of the outcomes that would be obtained in other years.

Background

Urea is an excellent nitrogen source for crops, primarily because its high nitrogen density (46% by weight) reduces its transportation cost and application rate. However, the nitrogen in urea is rapidly converted to plant-available forms (ammonium and nitrate) by soil bacteria, and those forms of nitrogen are rapidly lost (through volatilization and leaching, respectively) if not taken up by plants. In addition, ammonium is phytotoxic in high concentrations, especially to seedlings. It has therefore become common practice to use multiple, light applications of urea, sometimes as urea-ammonium nitrate (UAN), throughout the growing season in order to reduce nitrogen loss and water pollution through nitrate leaching.

Another approach to spreading the release of urea into the soil over several weeks or months is to use polymer-coated ureas (PCUs). The use of PCUs reduces the concentration of free urea in the soil at any given time, and thus the concentrations of ammonium and nitrate, relative to an application of uncoated urea at the same rate, reducing N losses and the risk of phytotoxicity. It also extends the period over which supplemental N is available in the soil, as the polymer coating of the fertilizer prills slows both the penetration of water into the prill and the diffusion of urea out of it.

Studies on PCUs as nitrogen fertilizers for potato agriculture have been ongoing for eleven years at the Sand Plain Research Farm in Becker, Minnesota. One product that has received particular attention is Environmentally Smart Nitrogen (ESN; 44-0-0; Agrium, Inc.). In the course of this research, it has been established that ESN is a viable alternative to multiple applications of urea and UAN. ESN has been found to be most effective when applied at shoot emergence. However, it is not certain that a regimen of emergence-applied ESN alone optimizes the timing of urea release for use by potato plants. Furthermore, because PCUs are more expensive than uncoated urea, the strategies that combine PCUs and uncoated urea may be more cost-effective than those that use PCUs exclusively.

This year, we also evaluated a PCU that has not previously been evaluated in these studies: Agrocote Max 44-0-0, an Everris product with a polymer coating designed to release urea over one to two months.

The overall goal of this research was to evaluate alternative methods of improving nitrogen use efficiency (measured here as both the tuber yield and the total nitrogen uptake per acre as functions of nitrogen application rate) and the economic efficiency of nitrogen fertilization (return of yield on investment in fertilizer) in irrigated potato production.

We compared multiple nitrogen fertilization regimes on potato yield, size, grade, and quality. These regimes included (1) a control treatment receiving no N beyond the 30 lbs N/ac applied to all treatments at planting; (2) pelletized urea at emergence with five subsequent fertigations with UAN at four total N rates (120, 180, 240, 300 lbs N/ac); (3) ESN applied at emergence at the same four total N rates; (4) split applications of ESN, before planting and at emergence, at 240 and 300 lbs total N/ac; (5) ESN applied at emergence with two subsequent fertigations with UAN at 240 and 300 lbs total N/ac; and (5) Agrocote Max applied with pelletized urea at emergence with a subsequent fertigation with UAN at four total N rates (160, 180, 200, and 240 lbs N/ac).

An additional objective was to test the effectiveness of Generate (GPotato-01-14-IF; Agnition), a product designed to increase soil microbial activity and, as a result, soil nutrient availability to plants when applied in-furrow at planting.

Materials and Methods

This study was conducted in 2014 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, collected on April 14, 2014, are shown in Table 1.

The study was replicated four times in a randomized complete block design. Potatoes were planted by hand with three-foot spacing between rows and one-foot spacing within. Each block was surrounded by a buffer strip of Russet Burbank one row wide along either side and five feet wide at either end. 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 the 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. In the harvest rows, the buffer strip had red potatoes. Whole "B single drop" seed was used for Russet Burbank, while the red seed potatoes were cut "A" seed.

There were 18 nitrogen fertilizer treatments (Table 2). Seventeen treatments were designed to evaluate the effects of application rate and timing of nitrogen as urea, urea/ammonium nitrate (UAN), ESN, and Agrocote Max. The other treatment (treatment 18) involved an application of Generate in-furrow prior to row closure at planting at a rate of 1.75 qts/ac, with 210 lbs N/ac applied as a combination of urea (150 lbs N/ac at planting) and UAN (10 or 15 lbs N/ac in each of five applications after emergence – see below for application timing).

Belay 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. The nitrate and ammonium concentrations of irrigation water were monitored throughout the year. In total, approximately 23 lbs NO_3-N/ac and 8 lbs NH_4-N/ac were deposited in irrigation water, and 6 lbs NO_3-N and 34 lbs NH_4-N were deposited in rainfall.

Two-hundred lbs/ac 0-0-60 and 200 lbs/ac 0-0-22 were broadcast and incorporated with a chisel plow on April 15 and 21, respectively. Potatoes were planted on May 14, 2014. Prior to row opening, pre-planting ESN fertilizer for treatments 8 and 9 was hand-broadcast and incorporated with a field cultivator. At row closure, planting fertilizer was applied to all plots, 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 lbs N/ac, 77 lbs P_2O_5/ac, 181 lbs K_2O/ac, 20 lbs Mg/ac, 41 lbs S/ac, 1 lbs B/ac, and 2 lbs Zn/ac, as a blend of diammonium phosphate (DAP), potassium chloride, potassium magnesium sulfate, Granubor 2, and EZ 20 Granular Zinc.

Nitrogen applications at emergence (June 4) were hand-broadcast and mechanically incorporated during hilling. Post-hilling UAN was applied over the row with a tractor-mounted sprayer as a 28% UAN solution in 25 gal of water/ac. 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 UAN was applied on June 26, July 2, July 14, July 23, and July 30.

A WatchDog weather station from Spectrum Technologies was used to monitor soil moisture and soil temperature. Although this station also collects rainfall and air temperature data, National Weather Service data were used for these variables. Two pairs of soil moisture and temperature sensors were installed at different times in two locations. One pair was installed in a plot receiving a pre-planting application of 90 lb N/ac and an emergence application of 180 lbs N/ac, both as ESN (treatment 8). These probes were placed in the planting hill two inches below the soil surface, at about the depth of the seed pieces, soon after planting. The second pair of probes was placed in a plot receiving 210 lbs N/ac as ESN at emergence (treatment 12). This pair of probes was installed at emergence and initially placed at the same depth as the first pair, two inches below the soil surface. Both pairs of probes were then buried deeper by the hilling process, placing them four inches below the surface of the hill for the remainder of the growing season.

Measured amounts of ESN or Agrocote Max fertilizer were placed in plastic mesh bags and buried at the depth of fertilizer placement during the pre-planting (ESN only) and emergence (ESN and Agrocote Max) applications were made (May 14 and June 4, respectively). Bags from the pre-planting group were removed on May 20, May 29, June 4, June 10, June 20, July 8, July

22, August 13, August 26, and September 12. Bags from the emergence group were removed on June 10, June 20, June 27, July 8, July 22, July 28, August 13, August 26, and September 12. The dry weight of the remaining fertilizer (minus the mean prill coat weight) was determined for each collection date to track urea release over time.

A shorter method for assessing the speed of nitrogen release from prills was also employed. Pre-weighed (three- to five-gram) masses of prills of ESN or Agrocote Max were submerged in 400 mLs distilled water in 500-mL beakers, gently stirred for 15 seconds, and allowed to incubate for 24 hours at room temperature (about 70). They were then removed from the water by sieving through a 1.2-mm^2 mesh polypropylene screen and dried at 104°F to a constant weight and weighed again. Percent weight loss was calculated and assumed to be roughly equal to the percentage of N released. The weight of the prill casings was not accounted for, but is assumed to represent a small fraction of the total prill weight; in previous research, three grams of ESN have been found to contain 0.13 g of prill casings (4.3% of total weight).

Plant stands were measured and stems counted for the harvest rows in each plot on June 26. Due to high early-season soil moisture, many plots had poor stand or weak plants at this time. Each harvest row was therefore rated as acceptable or unacceptable. Only data from rows rated as acceptable were analyzed. Some plots had no acceptable rows and are therefore omitted from analysis entirely. In plots with one acceptable row, that row was treated as representative for that treatment in that replicate, and yield per acre was calculated from that row alone.

The petiole of the terminal leaflet of the 4th leaf from the shoot tip was collected on four dates: July 1, July 16, July 28, and August 5. Petioles were analyzed for total N concentration on a dry weight basis with an Elementar Vario EL III element analyzer. NO_3-N analysis with a Wescan nitrogen analyzer is in progress.

Vines were harvested on September 12 from one 10-ft section of each row rated as acceptable during the stand count (see above). Vines were sprayed with Reglone desiccant on September 12 and 17 and chopped on September 22. Plots were machine harvested on September 24, and tubers were sorted and graded on September 25 - 26. Sub-samples of vines and tubers were collected to determine moisture percentage and nitrogen concentration, which were used to calculate nitrogen uptake and distribution within the plant. Tuber sub-samples were also used to determine tuber specific gravity and dry matter content, as well as the prevalences of hollow heart, brown center, and scab.

Samples from the top two feet of soil were collected on October 16 and their concentrations of NH_4-N and NO_3-N were determined with a Wescan nitrogen analyzer.

Urea release from mesh bags over time was fitted to negative exponential curves in SigmaPlot (to produce graphs) and using the NLIN procedure in SAS 9.4 (to produce confidence intervals around each parameter in each curve). These curves take the general form:

$$Release = a\,(1 - e^{-bt})$$

where **a** is the maximum percentage of urea that can be released, **b** determines how quickly the amount of urea released approaches this maximum, and **t** is time since teabag installation (and emergence fertilizer application). Significant differences in the values of **a** and **b** between different curves were identified based on the 95% confidence intervals around those values. Significant differences between emergence-installed ESN and Agrocote Max urea release on each mesh bag collection date were determined with independent-samples t-tests using the TTEST procedure in SAS 9.4.

The tuber harvest and quality and plant stand data were analyzed using the GLM procedure in SAS 9.4, which is robust to missing data. 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.

Results

Weather and soil conditions

Daily rainfall and irrigation amounts for the 2014 growing season are provided in Figure 2, and mean daily soil water potential is in Figure 2. Between planting (May 14) and harvest (September 24), 20.40 inches of rainfall were supplemented with 10.65 inches of irrigation for a total of 30.05 inches of water. There were six rain events with at least one inch of rainfall, on May 19, May 31, June 14, June 18, July 7, and August 21. The soil water potential as indicated by the probe installed before planting dropped after each of the first five events, dropping to 2 kPa or less after each of the first four. The probe installed at emergence detected similar changes in direction in water potential over time, but often found substantially higher or lower potentials than the probe installed before planting. It appears that the soil was frequently quite moist, possibly saturated, before mid-July, but not thereafter. Neither weather station was placed in a plot severely damaged by high soil moisture. Soil moisture was presumably near saturation for longer periods of time in the heavily-damaged plots.

Minimum and maximum daily air temperatures are shown in Figure 3, and mean daily soil temperatures are shown in Figure 4. Minimum daily air temperatures remained above freezing throughout the entire period except on September 13, when the temperature dropped to 30˚F, and generally remained above 50˚F between May 24 and September 8. Maximum daily temperatures generally remained above 70F between May 22 and September 9, but exceeded 90˚F on only two occasions: July 21 and July 31. Mean daily soil temperature was between 51 ˚F and 77 ˚F between planting and vine harvest, on September 12 (the soil and temperature probes were disconnected at that time). Between May 22 and September 8, mean daily soil temperature never fell below 63 ˚F.

Nitrogen release from ESN and Agrocote Max

The urea release curves for mesh bags of PCU prills installed during the pre-planting and emergence fertilizer applications (May 14 and June 4) are shown in Figure 5. ESN released urea at a similar rate whether installed before planting or at emergence. Agrocote Max released urea substantially faster than ESN. Total N release from Agrocote Max was significantly greater than release from ESN by six days after the bags were installed in the soil, and it remained greater throughout the 100 days the bags installed at emergence remained in the field.

Based on negative-exponential curve fits, ESN had a similar urea release rate over time whether it was installed at planting or emergence, but the urea release rate for Agrocote Max (installed at emergence) was significantly faster than that of ESN installed at either time (parameter **b** was significantly higher for Agrocote Max – data not presented). All three curves approached similar limits of urea release (parameter – data not presented) around 95% to 100% of their approximate initial urea content.

Qualitatively similar results were obtained from the 24-hour immersion test. ESN prills immersed in distilled water for 24 hours at room temperature released 7.9% ± 0.1% (mean ± S.E., N = 3) of their nitrogen, as compared to 24.1% ± 0.2% for Agrocote Max.

Plant stand

Results for plant stand are presented in Table 3. Although plant stand varied greatly among treatments, ranging from 62% (for treatment 16, which received 200 lbs N/ac as Agrocote Max, urea, and UAN) to 99% (for treatment 4, which received 240 lbs N/ac as urea and UAN), there was no significant effect of treatment on stand (P = 0.2666). The block effect was highly significant (.0006).

The major factor limiting plant stand was early-season soil wetness, which varied greatly among blocks, but did not vary systematically with treatment. Treatments with low average stand had extremely poor stand in the wetter blocks, but high stand in the drier blocks. When plots with zero or near-zero stand were excluded from analysis (as they were for all variables discussed hereafter), stand varied from 84.7% (for treatment 15, which received 180 lbs N/ac as Agrocote Max, urea, and UAN) to 100% (for treatments 2 and 3, which received 120 and 180 lbs N/ac, respectively, as urea and UAN).

Total petiole N concentration

Total petiole N concentrations are presented in Table 3. Concentrations of NO_3-N are still being determined and are therefore not presented.

Petioles from all four sampling dates displayed a strong response of total N concentration to fertilization treatment. Petiole total N concentration consistently increased with the total amount of N applied. The treatments receiving split preplanting and emergence applications of ESN (treatments 9 and 8) had noticeably low petiole total N for their application rates on July 28 and August 5, the last two sampling dates. There were no other obvious effects of N source on petiole total N concentration.

Tuber yield

Tuber yield results are presented in Table 4. The control treatment (treatment 1) had significantly lower total yield and marketable yield than any of the other treatments.

In terms of total yield, the eight highest-yielding treatments received 180 to 240 lbs total N/ac, and the ninth-highest-yielding treatment (treatment 14) received 160 lbs total N/ac. For most of the fertilization strategies tested, all treatments receiving between 180 and 240 lbs total N/ac had higher yield (though usually not significantly so) than those receiving larger or smaller amounts. The only exception was the strategy of applying ESN at emergence with two later fertigations with UAN, in which the treatment receiving 300 lbs total N/ac (treatment 7) had a slightly higher total yield than the one receiving 240 lbs N/ac (treatment 6).

The treatments receiving Agrocote Max (treatments 14-17) or Generate (treatment 18) generally had relatively high yields, while those receiving ESN at both planting and emergence (treatments 8 and 9) had relatively low yields. However, there was a potentially confounding tendency for treatments with more missing data to have higher average yields. The three highest-yielding treatments receiving Agrocote Max (treatments 15-17, which ranked first, sixth, and second overall for total yield) had 2, 1, and 2 replicates, respectively.

The overall trends for marketable yield were very similar to those for total yield.

Tuber size

In contrast to yield, the percentage of tuber yield in large size categories (over six ounces or over ten ounces; Table 4) generally increased with increasing N application rate, with the effect being much more pronounced for yield over ten ounces than for yield over six ounces.

However, no difference in either percentage was observed between application rates of 240 and 300 lbs N/ac.

Nitrogen source and application timing appeared to have some effect on the percentage of yield in tubers over six ounces, but not over ten ounces. Treatments receiving Agrocote Max tended to have relatively high percentages of their yield in tubers over six ounces.

Tuber grade and quality

Yields for U.S. No. 1 and U.S. No. 2 tubers are presented in Table 4. Except that the control treatment (treatment 1) had low yields of both grades of tubers, there was no clear relationship between yield of either grade and fertilization strategy or application rate. The percentage of marketable yield represented by U.S. No. 2 tubers was somewhat greater in the blocks that had wetter soil early in the season, and this may have masked any effect of application rate, application timing, or nitrogen source.

Tuber quality results are presented in Table 5. Nitrogen treatment had no effect on the prevalences of hollow heart, brown center, or scab, nor on tuber dry matter content or specific gravity. Hollow heart and brown center occurred together or were both absent in every tuber tested.

N uptake

Results for N uptake are presented in Table 6. Tuber N concentration and uptake tended to increase with N application rate. This effect was more evident for N concentration, possibly because uptake is partially a product of fresh-weight yield, which peaked at 180 – 240 lbs N/ac.

Vine N concentration did not respond significantly to treatment, but vine N uptake did. There was a pronounced tendency for uptake to increase with application rate.

Total N uptake, which is the sum of tuber and vine uptake, showed the same clear tendency to increase with N application rate.

Nitrogen source had no evident effect on N concentration or uptake into vines, tubers, or whole plants.

End-of-season residual soil N

The end-of-season (October 16) soil NH_4-N and NO_3-N concentrations are presented in Table 7. Nitrogen treatment affected NO_3-N, but not NH_4-N. Treatments receiving higher total N rates generally had higher residual NO_3-N, and the effect appeared to accelerate at higher N rates. Treatments receiving ESN had high residual soil NO_3-N for their application rates. Results for total combined NH_4-N and NO_3-N paralleled those for NO_3-N, which was present in much higher concentrations than NH_4-N.

Conclusions

Total and marketable tuber yield were maximized at total N application rates of 180 to 240 lbs N/ac, generally declining slightly at rates above or below this range. The percentage of yield represented by tubers over six or ten ounces increased with application rate, but not between 240 and 300 lbs N/ac. Residual soil NO_3-N concentration approximately one month after harvest also increased with application rate, with the difference being greater at higher application rates. Taken together, these results suggest that the optimum nitrogen application rate in this study was 240 lbs N/ac. This rate maximized marketable yield and the percentage of tubers over six ounces but resulted in lower residual soil NO_3-N concentrations than the 300 lbs N/ac rate.

No treatment receiving 240 lbs N/ac had significantly greater or lower total or marketable yield or percentage of yield in tubers over ten ounces than the one receiving the conventional urea/UAN treatment at that rate (treatment 4). Only the treatment receiving Agrocote, urea, and UAN at 240 lbs N/ac (treatment 17) had significantly higher yield in tubers over six ounces. The same was true at 300 lbs N/ac, except that no treatment at that rate had significantly more of its yield in tubers over six ounces than the urea/UAN treatment (treatment 5). Similarly, no treatment had significantly greater or lower residual soil NO_3-N at 240 or 300 lbs applied N/ac than the urea/UAN treatments at those rates (treatments 4 and 5, respectively). Based yield, tuber size, or residual NO_3-N results for this year, there is no justification to recommend one nitrogen source over another. This is surprising given the excessive rainfall received in May and June.

Treatments receiving Agrocote Max had relatively high yields. The difference was neither dramatic nor statistically significant, however, and it may be attributable to the negative correlation between yield and number of replicates mentioned above. By chance, three of four treatments with Agrocote Max had only one or two replicates, while only two of the remaining 14 treatments had so few. The results cannot, therefore, be used to conclude that Agrocote Max performed significantly better than any other N source, but it is very unlikely that this source would perform worse than other sources under ideal testing conditions.

The treatment receiving Generate in addition to urea and UAN (treatment 18) had high total and marketable yield for its application rate (240 lbs N/ac total). However, the total yield for this treatment was only 22 CWT/ac higher than that for the treatment receiving urea and UAN at the same rate without Generate (treatment 4), and its marketable yield was only 30 CWT/ac higher. These differences were not significant. Generate produced no apparent advantage in the percentage of yield represented by tubers over six or ten ounces.

Due to high soil moisture early in the season, plant stand was severely depressed in some study plots, and surviving plants were often stunted. To minimize the impact of this uneven crop damage on our results, the most heavily impacted harvest rows were excluded from statistical analyses. This depressed replication in some treatments (treatments 2-3 and 15-17) to one or two replicates. Treatment yield generally decreased as replication increased, possibly because treatments with more replicates were more likely to include plots with mild to moderate water damage. Aside from this trend, the effects of the water damage on the results of this study cannot be known. The results of this study may therefore not be representative of what would be obtained in other years.

Figure 1. Rainfall and irrigation amounts between planting (May 14) and harvest (September 24) in the 2014 growing season. On days when rainfall and irrigation both occurred, the amount of water deposited by irrigation is shown stacked on top of the amount deposited by rainfall.

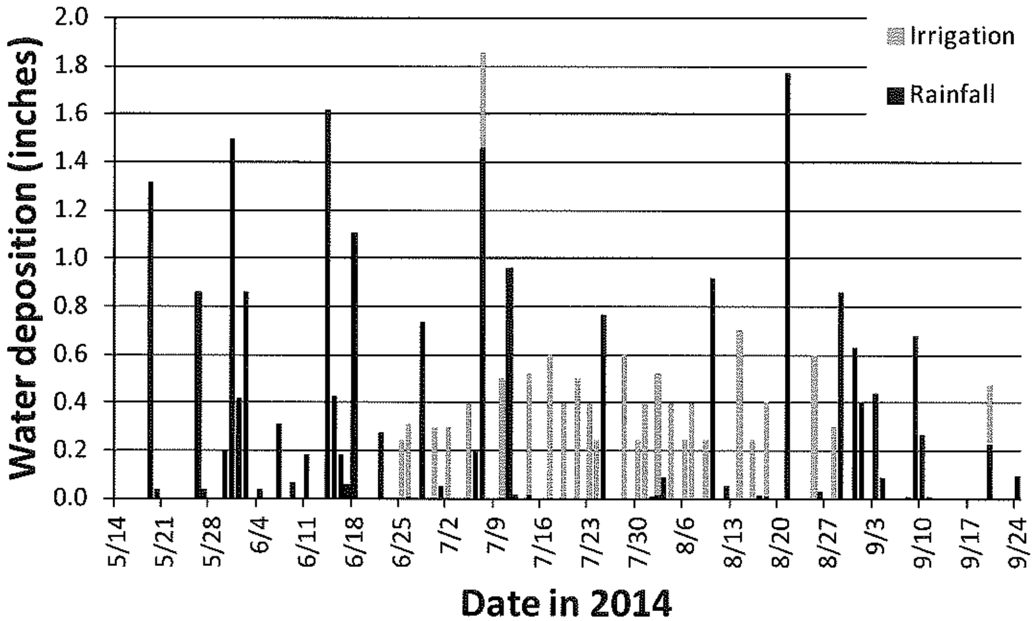

Figure 2. Soil moisture during the 2014 growing season, recorded by a probe placed before planting (black line) and one placed at shoot emergence and hilling (gray line). The probes were placed at the depth of the potato seed pieces.

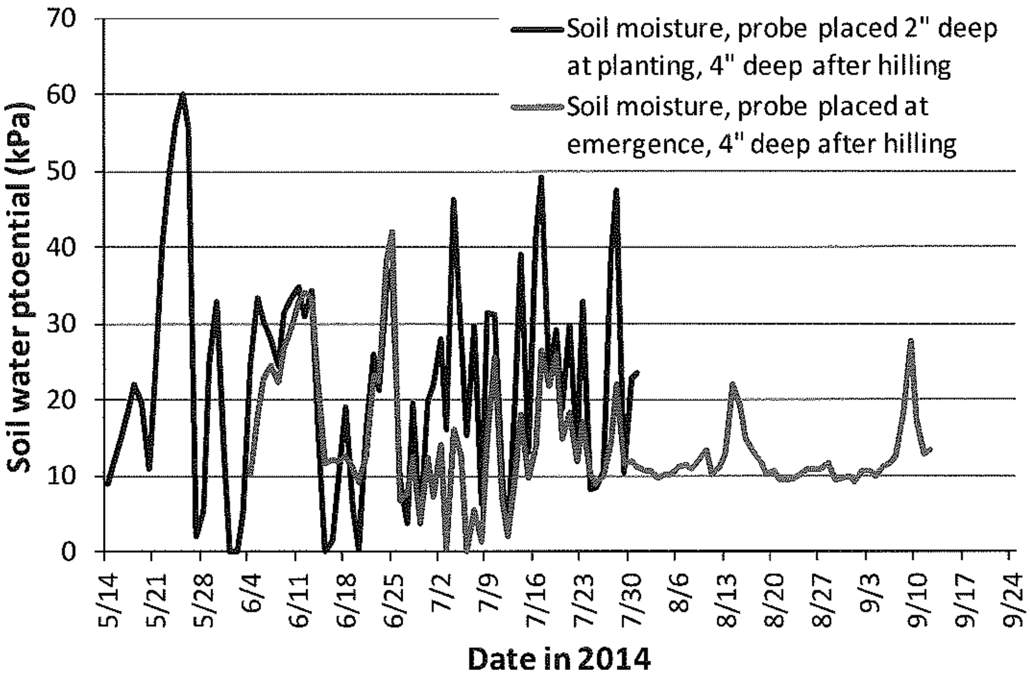

Figure 3. Maximum and minimum daily temperatures between planting (May 14) and harvest (September 24) in the 2014 growing season.

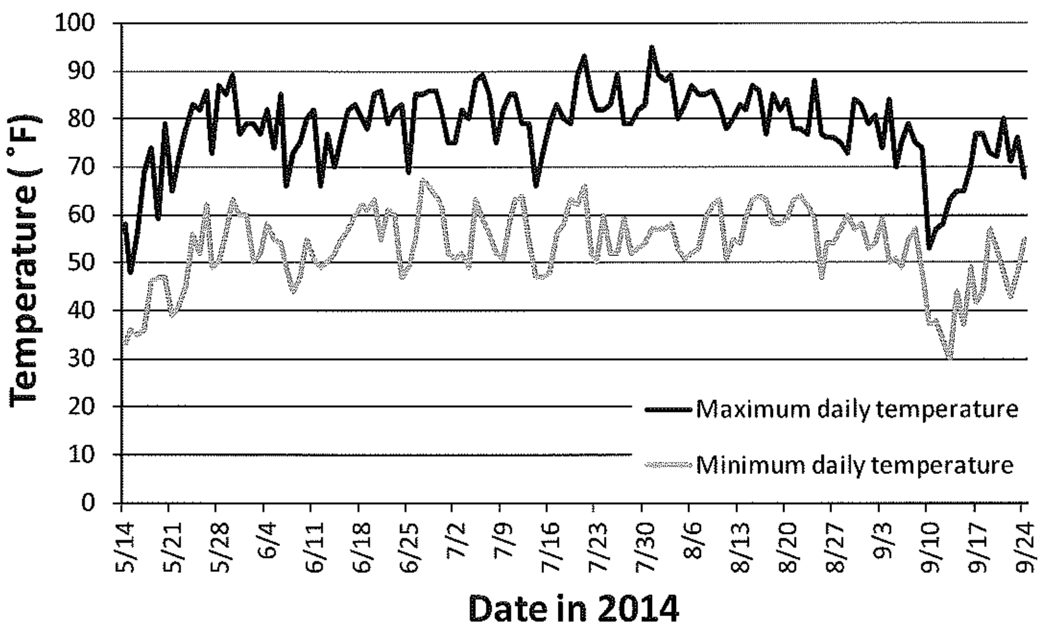

Figure 4. Mean daily soil temperature between planting (May 14) and vine harvest (September 12). The probes were placed at the depth of the potato seed pieces.

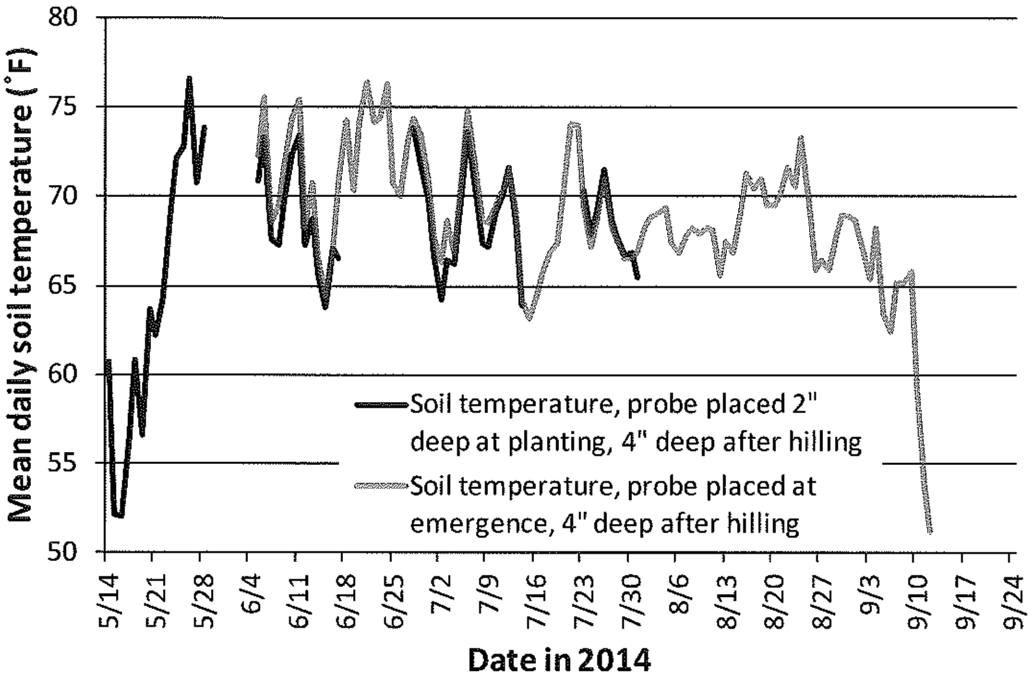

Figure 5. Nitrogen release over time from mesh bags of ESN or Agrocote Max, buried at tuber depth before planting (2" deep) or at potato shoot emergence (4" deep; the bags buried at planting were also approximately 4" deep after hilling at emergence). Preplant treatments were installed on May 14, on the day of planting. The final date of bag removal was September 12, 121 days after planting. Points represent means; error bars represent standard errors.

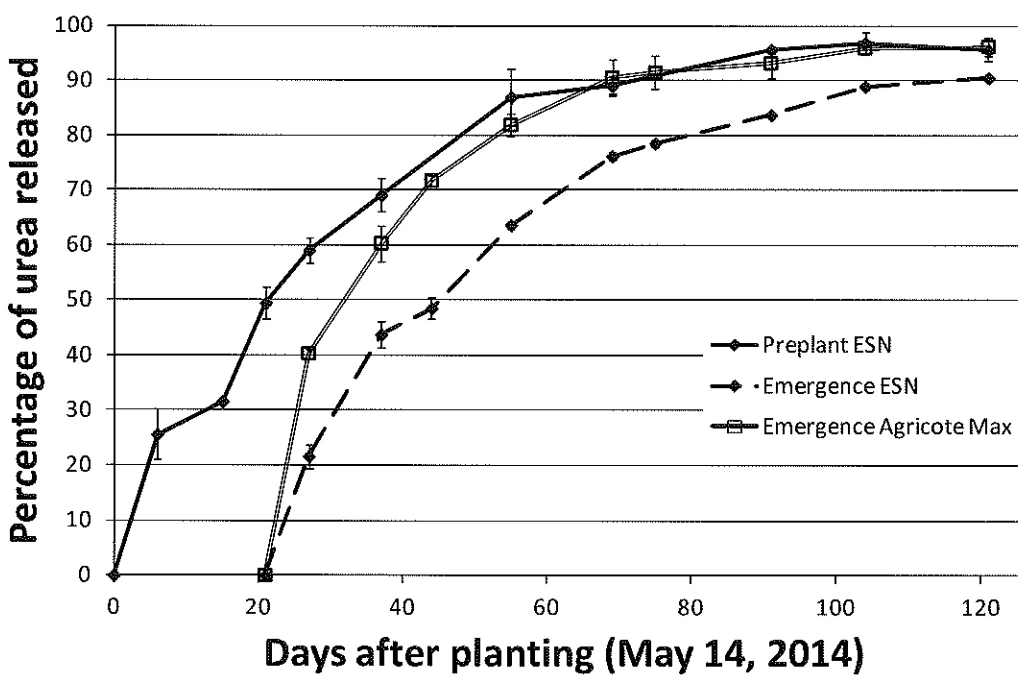

Table 1. Soil characteristics of the study site at the beginning of the season.

Bray P (ppm)	NH_4OAc-K (ppm)	NH_4OAc-Ca (ppm)	NH_4OAc-Mg (ppm)	DTPA-Zn (ppm)	DTPA-Cu (ppm)	DTPA-Fe (ppm)	DTPA-Mn (ppm)	SO4-S (ppm)	Hot Water B (ppm)	Water pH	O.M. LOI (%)
54	135	899	161	2.28	0.771	29.2	7.82	2	0.263	6.5	2.1

Table 2. Nitrogen treatments applied to irrigated Russet Burbank potato plants grown in Becker, MN, in 2014. Preplant and planting applications were made on May 14, and emergence applications were made on June 5.

Treatment	Timing of nitrogen applications				Total nitrogen (lbs N/ac)
	Preplant	Planting	Emergence	Post-hilling UAN[1]	
	Nitrogen sources[2] and rates (lbs N/ac)				
1	0	30 DAP	0	0, 0, 0, 0, 0	30
2	0	30 DAP	30 Urea	10, 15, 10, 15, 10	120
3	0	30 DAP	90 Urea	10, 15, 10, 15, 10	180
4	0	30 DAP	150 Urea	10, 15, 10, 15, 10	240
5	0	30 DAP	150 Urea	24, 24, 24, 24, 24	300
6	0	30 DAP	180 ESN	0, 15, 0, 15, 0	240
7	0	30 DAP	240 ESN	0, 15, 0, 15, 0	300
8	90 ESN	30 DAP	120 ESN	0, 0, 0, 0, 0	240
9	90 ESN	30 DAP	180 ESN	0, 0, 0, 0, 0	300
10	0	30 DAP	90 ESN	0, 0, 0, 0, 0	120
11	0	30 DAP	150 ESN	0, 0, 0, 0, 0	180
12	0	30 DAP	210 ESN	0, 0, 0, 0, 0	240
13	0	30 DAP	270 ESN	0, 0, 0, 0, 0	300
14	0	30 DAP	75 AM+ 35 Urea	0, 0, 20, 0, 0	160
15	0	30 DAP	87.5 AM + 42.5 Urea	0, 0, 20, 0, 0	180
16	0	30 DAP	100 AM + 50 Urea	0, 0, 20, 0, 0	200
17	0	30 DAP	125 AM + 65 Urea	0, 0, 20, 0, 0	240
18	0	30 DAP + GPotato-01-14-IF @ 1.75 qt/ac	150 Urea	10, 15, 10, 15, 10	240

[1]Post-hilling application rates are gal/ac of 28% UAN on each of five application dates: 6/26, 7/2, 7/14, 7/23, 7/30

[2]DAP (diammonium phosphate): 18-46-0. ESN (Environmentally Smart Nitrogen, Agrium, Inc.): 44-0-0. AM (Agrocote Max, Everris): 44-0-0. UAN (urea + ammonium nitrate): 28-0-0. Urea: 46-0-0. GPotato-01-14-IF: Generate (Agnition).

Table 3. Effect of nitrogen treatment on plant stand and petiole total nitrogen concentration in Russet Burbank potato plants grown in Becker, MN, in 2014. NO_3-N analyses are in progress.

Treatment	Timing of nitrogen applications				Total nitrogen (lbs N/ac)	Number of usable reps	Stand		Petiole % N			
	Preplant	Planting	Emergence	Post-hilling[1]			% stand for all plots	% stand of harvested plots	1-Jul	16-Jul	28-Jul	5-Aug
	Nitrogen sources[2] and rates (lbs N/ac)											
1	0	30 DAP	0	0	30	3	80	95	2.0	1.5	1.4	1.2
2	0	30 DAP	30 Urea	2x15, 3x10 UAN	120	2	93	100	3.7	1.9	1.9	1.3
3	0	30 DAP	90 Urea	2x15, 3x10 UAN	180	2	83	100	4.5	3.0	2.1	1.4
4	0	30 DAP	150 Urea	2x15, 3x10 UAN	240	4	99	99	5.5	3.5	2.4	1.6
5	0	30 DAP	150 Urea	5 x 24 UAN	300	4	97	97	5.5	3.6	3.2	2.5
6	0	30 DAP	180 ESN	2 x 15 UAN	240	3	90	93	5.4	4.2	2.8	1.7
7	0	30 DAP	240 ESN	2 x 15 UAN	300	4	97	97	5.4	4.0	3.4	2.1
8	90 ESN	30 DAP	120 ESN	0	240	4	94	94	5.1	3.1	2.0	1.4
9	90 ESN	30 DAP	180 ESN	0	300	3	85	93	5.4	4.0	2.3	1.6
10	0	30 DAP	90 ESN	0	120	4	96	96	4.8	2.2	1.5	1.2
11	0	30 DAP	150 ESN	0	180	3	73	96	5.1	3.4	2.0	1.3
12	0	30 DAP	210 ESN	0	240	2	70	94	5.4	3.9	2.4	1.7
13	0	30 DAP	270 ESN	0	300	4	95	95	5.1	4.8	3.2	2.1
14	0	30 DAP	75 AM+ 35 Urea	1 x 20 UAN	160	4	98	98	5.1	2.7	1.8	1.3
15	0	30 DAP	87.5 AM + 42.5 Urea	1 x 20 UAN	180	2	63	85	4.8	2.9	1.9	1.3
16	0	30 DAP	100 AM + 50 Urea	1 x 20 UAN	200	1	62	94	4.9	3.6	2.2	1.7
17	0	30 DAP	125 AM + 65 Urea	1 x 20 UAN	240	2	64	97	5.3	3.8	2.2	1.5
18	0	30 DAP + GPotato-01-14-IF @ 1.75 qt/ac	150 Urea	2x15, 3x10 UAN	240	4	90	90	5.1	3.1	2.4	1.4
Treatment significance[3]							NS	NS	**	**	**	**
Minimum significant difference (0.1)							—	—	0.3	0.7	0.4	0.3

[1]Post-hilling application dates: 6/26, 7/2, 7/14, 7/23, 7/30

[2]DAP (diammonium phosphate): 18-46-0. ESN (Environmentally Smart Nitrogen, Agrium, Inc.): 44-0-0. AM (Agrocote Max, Everris): 44-0-0. UAN (urea + ammonium nitrate): 28-0-0. Urea: 46-0-0. GPotato-01-14-IF: Generate (Agrition).

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

Table 4. Effect of nitrogen treatment on Russet Burbank potato tuber yield, size, and grade for plants grown in Becker, MN, in 2014.

Treatment	Timing of nitrogen applications				Total nitrogen (lbs N/ac)	Number of usable reps	Tuber Yield										
	Preplant	Planting	Emergence	Post-hilling[1]			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 rates (lbs N/ac)						cwt / ac									%	
1	0	30 DAP	0	0	30	3	19	76	91	40	14	240	114	107	222	61	22
2	0	30 DAP	30 Urea	2x15, 3x10 UAN	120	2	18	97	180	98	30	422	277	128	405	73	30
3	0	30 DAP	90 Urea	2x15, 3x10 UAN	180	2	23	95	171	112	82	482	364	94	458	75	40
4	0	30 DAP	150 Urea	2x15, 3x10 UAN	240	4	40	75	127	113	102	456	257	159	416	75	47
5	0	30 DAP	150 Urea	5 x 24 UAN	300	4	21	62	129	123	114	450	302	127	429	81	52
6	0	30 DAP	180 ESN	2 x 15 UAN	240	3	29	78	110	122	94	433	208	196	404	75	49
7	0	30 DAP	240 ESN	2 x 15 UAN	300	4	29	75	129	100	106	439	253	157	410	76	47
8	90 ESN	30 DAP	120 ESN	0	240	4	35	84	137	118	72	446	248	163	411	73	42
9	90 ESN	30 DAP	180 ESN	0	300	3	28	83	125	101	91	427	245	155	400	74	45
10	0	30 DAP	90 ESN	0	120	4	41	86	147	74	50	398	231	126	357	68	31
11	0	30 DAP	150 ESN	0	180	3	35	99	131	106	68	438	230	174	403	69	39
12	0	30 DAP	210 ESN	0	240	3	30	90	124	123	110	477	262	185	447	75	49
13	0	30 DAP	270 ESN	0	300	4	20	66	123	118	109	437	266	151	416	80	52
14	0	30 DAP	75 AM+ 35 Urea	1 x 20 UAN	160	4	21	73	150	116	80	441	265	154	420	79	45
15	0	30 DAP	87.5 AM + 42.5 Urea	1 x 20 UAN	180	2	35	100	202	118	68	522	334	153	488	74	36
16	0	30 DAP	100 AM + 50 Urea	1 x 20 UAN	200	1	15	67	143	130	104	461	260	185	445	82	51
17	0	30 DAP	125 AM + 65 Urea	1 x 20 UAN	240	2	18	59	173	118	118	485	310	157	467	84	48
18	0	30 DAP + GPotato-01-14-IF @ 1.75 qt/ac	150 Urea	2x15, 3x10 UAN	240	4	32	86	153	121	87	479	279	168	446	75	43
Treatment significance[3]							NS	NS	**	**	++	**	**	*	**	NS	*
Minimum significant difference (0.1)							--	--	30	37	71	45	58	52	53	--	18

[1]Post-hilling application dates: 6/26, 7/2, 7/14, 7/23, 7/30

[2]DAP (diammonium phosphate): 18-46-0. ESN (Environmentally Smart Nitrogen, Agrium, Inc.): 44-0-0. AM (Agrocote Max, Everris): 44-0-0. UAN (urea + ammonium nitrate): 28-0-0. Urea: 46-0-0. GPotato-01-14-IF: Generate (Agnition).

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

Table 5. Effect of nitrogen treatment on Russet Burbank tuber hollow heart/brown center, specific gravity, and dry matter percentage for plants grown in Becker, MN, in 2014.

Treatment	Timing of nitrogen applications: Preplant	Planting	Emergence	Post-hilling[1]	Total nitrogen (lbs N/ac)	Number of usable reps	Tuber Quality: Hollow Heart	Brown Center	Scab	Dry matter	Specific Gravity
	Nitrogen sources[2] and rates (lbs N/ac)						%				
1	0	30 DAP	0	0	30	3	8	8	7	20	1.0731
2	0	30 DAP	30 Urea	2x15, 3x10 UAN	120	2	6	6	0	20	1.0827
3	0	30 DAP	90 Urea	2x15, 3x10 UAN	180	2	14	14	8	20	1.0835
4	0	30 DAP	150 Urea	2x15, 3x10 UAN	240	4	21	21	2	19	1.0725
5	0	30 DAP	150 Urea	5 x 24 UAN	300	4	16	16	3	20	1.0784
6	0	30 DAP	180 ESN	2 x 15 UAN	240	3	26	26	3	19	1.0749
7	0	30 DAP	240 ESN	2 x 15 UAN	300	4	27	27	4	19	1.0748
8	90 ESN	30 DAP	120 ESN	0	240	4	18	18	5	20	1.0805
9	90 ESN	30 DAP	180 ESN	0	300	3	26	26	0	20	1.0803
10	0	30 DAP	90 ESN	0	120	4	15	15	0	21	1.0801
11	0	30 DAP	150 ESN	0	180	3	12	12	7	21	1.0733
12	0	30 DAP	210 ESN	0	240	3	17	17	1	19	1.0771
13	0	30 DAP	270 ESN	0	300	4	17	17	3	20	1.0771
14	0	30 DAP	75 AM+ 35 Urea	1 x 20 UAN	160	4	18	18	2	20	1.0807
15	0	30 DAP	87.5 AM + 42.5 Urea	1 x 20 UAN	180	2	12	12	0	22	1.0825
16	0	30 DAP	100 AM + 50 Urea	1 x 20 UAN	200	1	16	16	0	20	1.0829
17	0	30 DAP	125 AM + 65 Urea	1 x 20 UAN	240	2	22	22	0	20	1.0820
18	0	30 DAP + GPotato-01-14-IF @ 1.75 qt/ac	150 Urea	2x15, 3x10 UAN	240	4	23	23	2	21	1.0798
						Treatment significance[3]	NS	NS	NS	NS	NS
						Minimum significant difference (0.1)	--	--	--	--	--

[1]Post-hilling application dates: 6/26, 7/2, 7/14, 7/23, 7/30

[2]DAP (diammonium phosphate): 18-46-0. ESN (Environmentally Smart Nitrogen, Agrium, Inc.): 44-0-0. AM (Agrocote Max, Everris): 44-0-0. UAN (urea + ammonium nitrate): 28-0-0. Urea: 46-0-0. GPotato-01-14-IF: Generate (Agnition).

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

Table 6. Effect of nitrogen treatment on tissue N concentration and N uptake into tubers and vines of Russet Burbank potato plants grown in Becker, MN, in 2014.

Treatment	Timing of nitrogen applications: Preplant	Planting	Emergence	Post-hilling[1]	Total nitrogen (lbs N/ac)	Number of usable reps	Tuber % N	Tuber N uptake (lbs N/ac)	Vine % N	Vine N uptake (lbs N/ac)	Total N uptake (lbs N/ac)
	Nitrogen sources[2] and rates (lbs N/ac)										
1	0	30 DAP	0	0	30	3	0.68	33	1.05	4	37
2	0	30 DAP	30 Urea	2x15, 3x10 UAN	120	2	0.88	73	0.75	11	83
3	0	30 DAP	90 Urea	2x15, 3x10 UAN	180	2	1.09	102	0.81	12	114
4	0	30 DAP	150 Urea	2x15, 3x10 UAN	240	4	1.09	94	0.99	16	110
5	0	30 DAP	150 Urea	5 x 24 UAN	300	4	1.22	108	1.18	27	136
6	0	30 DAP	180 ESN	2 x 15 UAN	240	3	1.14	97	1.03	22	119
7	0	30 DAP	240 ESN	2 x 15 UAN	300	4	1.18	97	1.11	33	130
8	90 ESN	30 DAP	120 ESN	0	240	4	0.93	84	0.99	14	98
9	90 ESN	30 DAP	180 ESN	0	300	3	1.18	99	1.15	21	120
10	0	30 DAP	90 ESN	0	120	4	0.74	60	0.98	9	69
11	0	30 DAP	150 ESN	0	180	3	0.97	91	1.02	19	109
12	0	30 DAP	210 ESN	0	240	2	1.26	115	1.09	18	133
13	0	30 DAP	270 ESN	0	300	4	1.17	102	1.24	28	130
14	0	30 DAP	75 AM+ 35 Urea	1 x 20 UAN	160	4	0.83	73	1.03	13	86
15	0	30 DAP	87.5 AM + 42.5 Urea	1 x 20 UAN	180	2	0.82	92	1.01	16	108
16	0	30 DAP	100 AM + 50 Urea	1 x 20 UAN	200	1	0.86	78	1.00	16	94
17	0	30 DAP	125 AM + 65 Urea	1 x 20 UAN	240	2	1.10	108	1.11	21	129
18	0	30 DAP + GPotato-01-14-IF @ 1.75 qt/ac	150 Urea	2x15, 3x10 UAN	240	4	1.05	104	1.10	24	128
						Treatment significance[3]	**	**	NS	*	**
						Minimum significant difference (0.1)	0.28	24	--	17	31

[1]Post-hilling application dates: 6/26, 7/2, 7/14, 7/23, 7/30

[2]DAP (diammonium phosphate): 18-46-0. ESN (Environmentally Smart Nitrogen, Agrium, Inc.): 44-0-0. AM (Agrocote Max, Everris): 44-0-0. UAN (urea + ammonium nitrate): 28-0-0. Urea: 46-0-0. GPotato-01-14-IF: Generate (Agnition).

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

Table 7. Effect of nitrogen treatment on residual soil NH_4-N, NO_3-N (0-2 ft), and their sum, on October 16, 2014, in plots in Becker, MN, from which Russet Burbank potatoes were harvested.

Treatment	Timing of nitrogen applications				Total nitrogen (lbs N/ac)	Number of usable reps	NH_4-N, ppm	NO_3-N, ppm	Total, ppm
	Preplant	Planting	Emergence	Post-hilling[1]					
	Nitrogen sources[2] and rates (lbs N/ac)								
1	0	30 DAP	0	0	30	3	0.4	1.8	2.2
2	0	30 DAP	30 Urea	2x15, 3x10 UAN	120	2	0.2	1.6	1.8
3	0	30 DAP	90 Urea	2x15, 3x10 UAN	180	2	0.2	1.8	2.0
4	0	30 DAP	150 Urea	2x15, 3x10 UAN	240	4	0.4	2.0	2.4
5	0	30 DAP	150 Urea	5 x 24 UAN	300	4	0.2	2.7	2.9
6	0	30 DAP	180 ESN	2 x 15 UAN	240	3	0.2	2.9	3.1
7	0	30 DAP	240 ESN	2 x 15 UAN	300	4	0.1	4.2	4.3
8	90 ESN	30 DAP	120 ESN	0	240	4	0.2	2.6	2.8
9	90 ESN	30 DAP	180 ESN	0	300	3	0.3	2.6	2.8
10	0	30 DAP	90 ESN	0	120	4	0.4	1.9	2.3
11	0	30 DAP	150 ESN	0	180	3	0.4	2.6	3.0
12	0	30 DAP	210 ESN	0	240	3	0.3	3.6	3.8
13	0	30 DAP	270 ESN	0	300	4	0.1	3.5	3.7
14	0	30 DAP	75 AM+ 35 Urea	1 x 20 UAN	160	4	0.2	2.1	2.4
15	0	30 DAP	87.5 AM + 42.5 Urea	1 x 20 UAN	180	2	0.3	1.8	2.0
16	0	30 DAP	100 AM + 50 Urea	1 x 20 UAN	200	1	0.4	1.7	2.1
17	0	30 DAP	125 AM + 65 Urea	1 x 20 UAN	240	2	0.1	2.5	2.6
18	0	30 DAP + GPotato-01-14-IF @ 1.75 qt/ac	150 Urea	2x15, 3x10 UAN	240	4	0.3	2.2	2.5
Treatment significance[3]							NS	*	++
Minimum significant difference (0.1)							--	1.7	1.7

[1]Post-hilling application dates: 6/26, 7/2, 7/14, 7/23, 7/30

[2]DAP (diammonium phosphate): 18-46-0. ESN (Environmentally Smart Nitrogen, Agrium, inc.): 44-0-0. AM (Agrocote Max, Everris): 44-0-0. UAN (urea + ammonium nitrate): 28-0-0. Urea: 46-0-0. GPotato-01-14-IF: Generate (Agnition).

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

Managing PVY Vectors, 2014

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Executive Summary – This is a multiple component proposal consisting of continuing and new research. A) The continuing portion expands and maintains an aphid trapping and monitoring network for aphid vectors of virus disease in potatoes (focusing on PVY) and provides near real-time maps of aphid population distribution in MN and ND. New research focuses on the evaluating the relative contribution of various tactics to limit the spread of PVY; these are B) the use and improvement of border crops to manage colonizing aphid vectors, C) ameliorating the attraction of skips and rogueing holes as potential attractants for colonizing aphids, and D) integrating the use of oils and anti-feedant insecticides into a PVY vector management system.

Rationale – The Minnesota and North Dakota seed potato industry is at a critical juncture. Seed production acreage has suffered a significant decrease since 1995 in part because of aphid vectored viral diseases of seed potato, notably Potato Leaf Roll Virus (PLRV) and Potato Virus Y (PVY). While PLRV is a non-persistent (circulative) virus which takes a comparatively lengthy time to be transferred to a plant and can be controlled by well-timed insecticide applications against the vector, PVY is a non-persistent and is transferred to the plant within moments of the aphid probing the plant. Consequently, controlling PVY through vector control using insecticides is more problematic.

Certification programs in Minnesota and North Dakota are operationally excellent, but it is difficult to turn the corner on potato virus epidemics because large amounts of virus-inoculum must be flushed from the seed production system. This is an increasingly difficult proposition with Potato Virus Y (PVY). New virus strains with variable levels of expression and a new vector species have resulted in what appears to be a change in the epidemiology of this viral disease.

The ordinary (common) strain of PVY is PVY^{o}, which is present in all potato growing areas, causes mild to severe mosaic, leaf drop and leaf and stem necrosis. Of greater concern are PVY^{N} (tobacco veinal necrosis) and the relatively new strain PVY^{NTN}. While PVY^{N} produces mild to severe mosaic symptoms, PVY^{NTN} causes potato tuber necrotic ringspot disease (PTNRD). Visible symptoms of infection of either strain vary according to potato cultivar with some cultivars being nearly or completely asymptomatic making within season diagnosis difficult.

In past years, the most important vector of PVY has been green peach aphid, *Myzus persicae* (Sulzer). It is by far the most efficient vector of PVY in the northern Great Plains. Green peach aphid doesn't overwinter in the Red River Valley and populations are reestablished each year by spring immigrants so there is great annual variation in abundance. Distributions of *M. persicae* are concentrated within a few meters of field margins in the days immediately following inflights but this edge distribution is temporally limited with aphid colonies eventually dispersing across fields (Suranyi et al. 2004, Carroll et al. 2004). This alighting preference is likely a response to the contrast provided by the interface of fallow and crop border. This facilitates the use of targeted border applications to control aphid vectors. Treating just the 18 m adjacent to the fallow headlands resulted in spraying only 38.5 of 730 hectares saving an estimated 93% (mean savings of $58.29 per hectare, application costs included) compared to treating the entire field (Carroll et al. 2004, Olson et al. 2004). For this technique to be successful, application timing is critical and treatments must be applied prior to aphid populations dispersing across the field. Consequently, an accurate method of monitoring the arrival of aphids within the fields is essential. From 1992 to 1994 and from 1998 to 2003, this monitoring was delivered by a regional aphid trapping network, *Aphid Alert*, which provided Minnesota and North Dakota seed potato growers with real-time information on virus vector flight activity.

In recent years, however, there have been high rates of certification failure, despite low populations of aphids typically associated as virus vectors. In 2011, for example, MN and ND had extremely high rates of PVY infection in seed potato fields, resulting in one of the lowest annual acreages of certified seed. However, a 9m suction trap, established as part of a multi-state aphid monitoring effort, indicated low populations of *M. persicae* but extremely high numbers of the invasive soybean aphid, *Aphis glycines* Matsumura (Fig. 2).

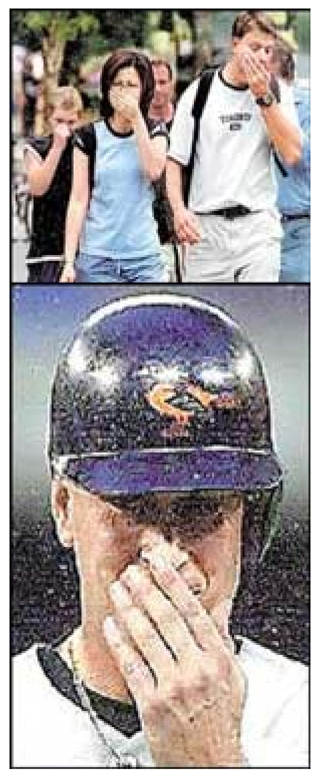


Figure 1. High soybean populations in Toronto as a result of a dispersal event from SE Minnesota and SW Wisconsin in 2001. These populations disrupted pedestrian traffic and caused a delay in a Toronto Blue Jays professional baseball game. Photo Credit: Toronto Star

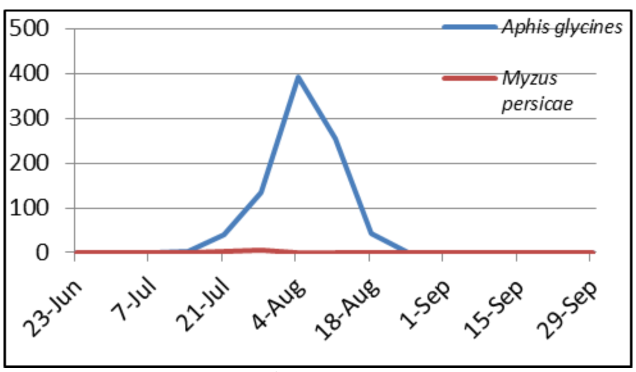


Figure 2. Seasonal dynamics of immigrating soybean aphid, *Aphis glycines* Matsumara, and green peach aphid, *Myzus persicae* Sulzer. Note that while very high numbers of soybean aphid were recovered approximately at the same time as aphids would be colonizing seed potato fields, there were only negligible numbers of green peach recorded.

Soybean aphid was first recorded in the U.S. in 2000 and in Minnesota in 2001 (Ragsdale 2004). Since then, this invasive species has spread to all of the soybean producing states in the North Central region becoming the most important insect pest of soybeans in those states. Minnesota has the most consistent populations of NC states, with some area of the state requiring insecticide treatment every year since 2001. Soybean aphid is prone to large scale dispersal events triggered by decreasing host plant quality or overcrowding. There is also a late summer dispersal (Ragsdale 2004) triggered by environmental cues (late July to early August). In years with high soybean aphid populations, dispersal events can be almost locust like in scale (Fig. 1). Soybean aphid show only a limited tendency to colonize the field edge (Hodgson et al. 2005) and individual soybean aphids will continue into the field, colonizing the interior. Late in August, soybean aphids develop a winged generation and return to buckthorn to lay eggs and overwinter. Soybean aphid vectors a number of virus diseases to soybean and has been shown to vector PVY to potatoes although not as effectively as green peach aphid (Davis et al. 2005).

Aphid dynamics in potato fields indicate that aphid populations develop in other host plant systems through the early summer, moving into potatoes usually after mid-July. When first colonizing fields, most aphid species first settle at the edge for 7-10 days before dispersing throughout the rest of the field. This is believed to be a response of the aphids to the difference in reflected light of bare soil and plant canopy. This colonization behavior facilitates management tactics such as the use of border plantings of non-PVY hosts (e.g. soybeans), to clean virus from the mouthparts of infected aphids and the targeted application of insecticide at the field edge.

The application of these tactics has been questioned. Border crops have been used with success in a number of growing areas but there is some question as to the best crop. Early border crops included small grains, which, while not hosting PVY could function as a source for grain aphid populations. These growing populations may enter the field and move existing inoculum. The apparent answer was to use soybean as a border crop, the introduction of soybean aphid and its confirmation as a PVY vector, however, meant this crop to could serve as a potential source of vector population which would move existing inoculum within fields. The attraction of aphids to the edge of plant canopy and bare soil occurs not only on the field edge but within fields as well. Davis etal (2009) found that a hole as large as $0.6m^2$, comparable to the hole left by rogueing, is attractive to colonizing aphids. They attempted to ameliorate this attraction by seeding gaps with oats, this technique was only moderately successful and they held more research was necessary to refine the technique.

The technique of targeted application of insecticide works well with green peach aphid and a number of other aphids that are traditionally important in vectoring PVY into potatoes. This control tactic, however, will not control the colonization of a field by soybean aphid. Soybean aphid will attempt to colonize a number of host plants during summer dispersal events, but will only colonize soybeans. When testing the suitability of a host aphids probe to sample plant fluids, in the process they will transfer any non-persistent virus on their mouthparts. Even if a low number of soybean aphids are viruliferous, and even if only a subset of these can efficiently vector the virus, the sheer numbers of soybean aphids entering fields during a large dispersal event means indicates these insects may be a significant driver in PVY epidemiology.

Integrating multiple management tactics should provide a more effective way of limiting the spread of PVY. Using border crops and directing targeted applications when aphids are present, using crop oils (a demonstrated effective method of preventing aphids from probing plants), and filling skips and rogueing holes in combination may provide a much more complete solution to the problem. These methods rely heavily on timing and all require accurate method of predicting when aphids are present (DiFonzo et al. 1997). Consequently, monitoring populations and determining where and when aphids are occurring in the region and what species are involved is essential in applying appropriate management tactics.

Procedures – A – Aphid Alert II Trapping Network. A network of 20 - 2m tall suction traps was 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 was changed weekly. Sample jars were sorted, aphids identified to species and aphid population dynamics at sample locations were determined. Maps were prepared weekly showing these dynamics. This 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. Recommendations for beginning oil treatments or targeted edge applications could be made based on the information obtained from the regional monitoring system. For 2014, we expanded the 2013 Aphid Alert II network and provided better coverage of the RRV seed producing area. Partial funding for this expansion 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. 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.

B) Using soybean borders to manage colonizing aphid vectors – Soybean has been used successfully in the past but the recent advent of soybean aphids now call the suitability of this crop into question. It may, however, be possible to manage soybean aphid growth in this border crop. Twelve large replicated, large scale plots will be established at the UMN-NWROC in Crookston. Eight will be planted with soybeans as a crop border, the remaining four will not have crop borders. Aphids will be scouted in all plots twice weekly (intensive sampling will occur at the edge of each plot. If aphid populations remain low and soybean aphids are present in the area, then soybean aphids will be released at the plot edges to simulate immigrating aphids (as stipulated, this will ***only*** occur if soybean aphids are already present in local soybean fields!). Border crops will be either left untreated or will receive targeted applications of insecticide when aphids start to colonize the field edge (i.e. border). Aphid populations within fields post-application will be assessed and tubers sampled from each plot, grown out in the greenhouse and tested for PVY infection using ELISA. In addition, simulated overspray of herbicides will applied to representative plots to assess the efficacy of border crops to ameliorate herbicide drift.

C) Ameliorating the attraction of skips and rogueing holes as potential attractants for colonizing aphids – holes and skips will be created in the experimental plots (see Procedure A) by pulling plants 1 week prior to canopy closure. Replicated holes ($1m^2$) will be seeded with rye grass, oats, a spray-on paint over the soil, or left bare. Aphid populations on neighboring plants will be monitored for the rest of the season and compared to see if the treatments prevented colonization. Tubers from surrounding plants and the rest of the field will be sampled, grown out in the greenhouse and tested for PVY infection using ELISA.

D) Integrating the use of oils and anti-feedant insecticides into a PVY vector management system. Subplots within the large experimental plots (see Procedure A) will be established and treated with crop oil (1X/week), crop oil (2X/wk), an anti-feedant insecticide (either Fulfill or

Beleaf), Crop oil (1X) plus insecticide, and crop oil (2X) plus insecticide. Half the plots will be placed over simulated rogueing holes and half over unbroken canopy.

The large plots used in B, C, and D form a multi-factorial design which will provide data on the contribution of each of the treatments and assess which combinations are most effective in limiting the spread of PVY. The additional benefit of border crops in ameliorating herbicide drift will be similarly assessed. I expect the integration project will require two field seasons.

Results

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. This 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 made based on the information obtained from the regional monitoring system. For 2014, we expanded the 2013 Aphid Alert II network and provided better coverage of the RRV seed producing area. Partial funding for this expansion 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.

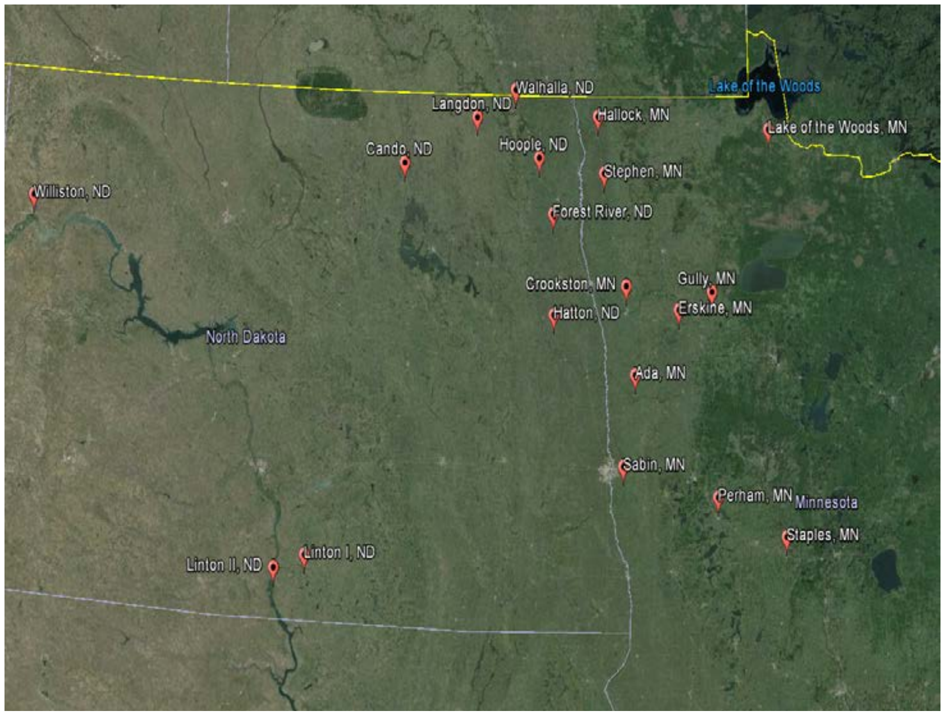
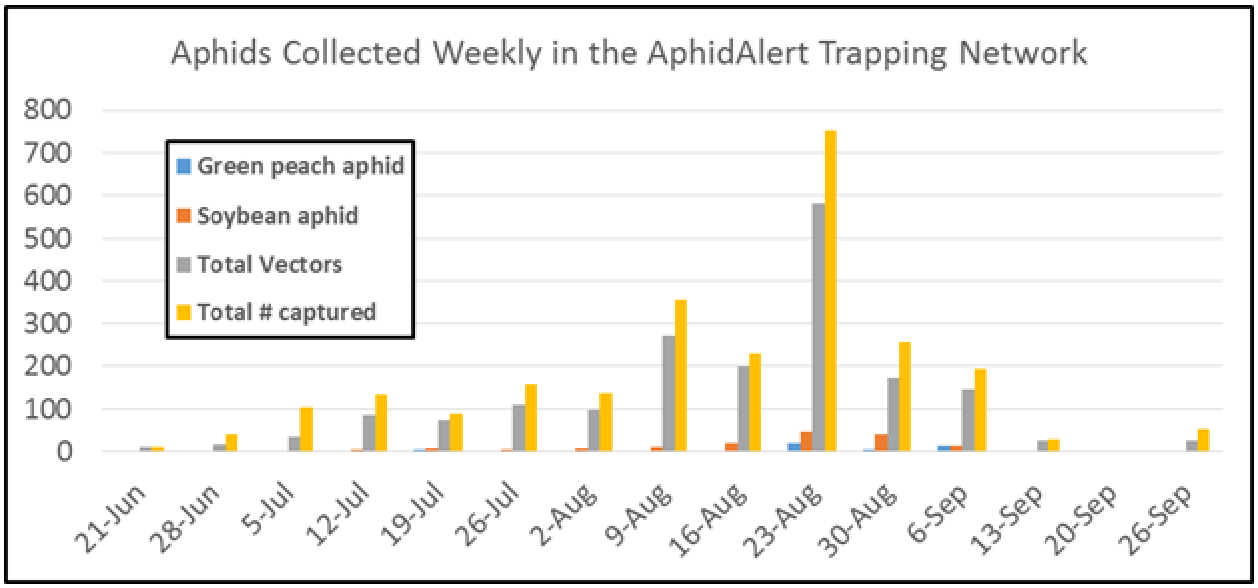


Figure 2. Aphid Alert suction trap locations, 2014.

A total of 2509 aphids, representing 15 potential PVY vector species, were recovered from traps in 2014. While difficult to directly compare the two years due to the increased number of traps in 2014, total captures in 2014 were higher than those in 2013 (which saw a total capture of 1855 vector aphids). Much of the additional trap catch in 2014 (~600 vector species aphids) were collected from the new trap locations at Ada and Hallock. The number of green peach aphids remained essentially the same compared to last year (52 in 2013 and 53 in 2014), whereas the number of soybean aphids recovered in 2014 was almost 4 times as great as the number in 2013 (154 soybean aphids in 2013 compared to 531 in 2014). A total of 418 Greenbug aphids, a species virtually absent in the past two years, were captured and were present at all but the Linton II trap location. This species is also a serious vector of virus diseases in small grains. The peak flight timing of aphids occurred later in 2014 than in 2013 (Fig 3), not surprising given the delayed start of the growing season in 2014. Alternate hosts upon which aphid populations develop would have matured later, triggering a later movement of aphids from these plants to



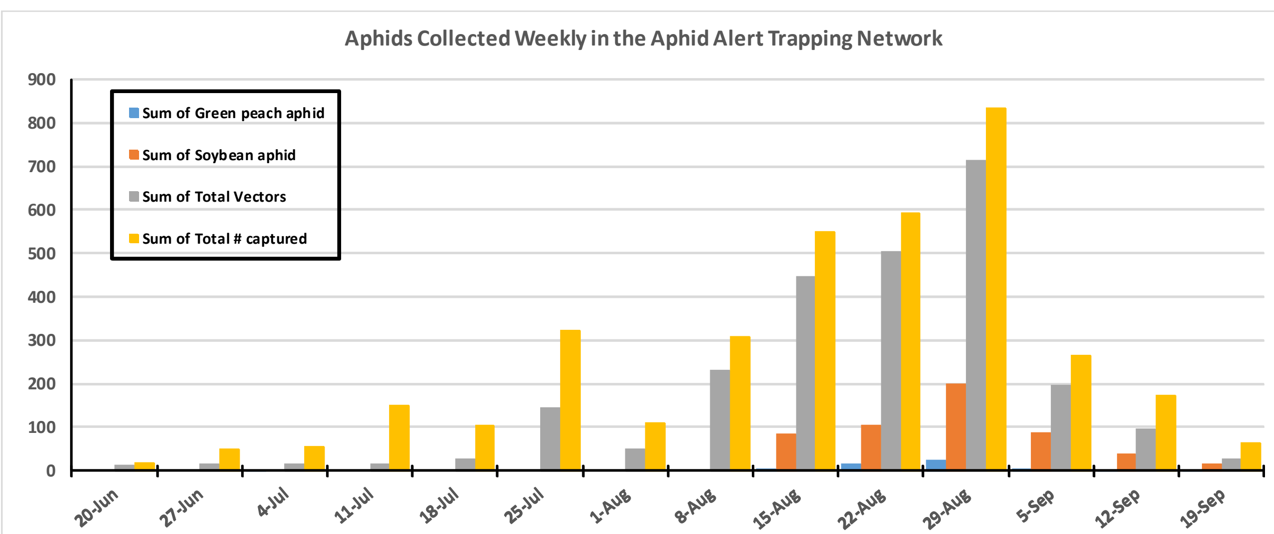


Figure 3. Seasonal trap catch of the Aphid Alert trapping network in 2013 (upper graph) and 2014 (lower graph). Note Y-axes are not equal.

potato fields. Consequently, aphid pressure across the region was not considerably higher than in 2013 but did occur later in the season. Given the importance of late season transmission of PVY, this may have influenced virus movement in 2014. Seasonal pressure, as measured by trap capture, seems greatest along the central Red River Valley (Fig 4).

What is of greater importance is the site to site comparison of trap captures between the two years (Fig 5 – note the Y-axis has been adjusted to be the same for both years). Several sites had lower catch numbers, such as Cando, Gully, Hoople, Lake of the Woods both Linton sites, Stephen and Walhalla (some of which were significantly lower such as Lake of the Woods, the Linton sites and Walhalla). Some were relatively the same as 2013, such as Erskine and Hatton, while some sites had higher trap catches, such as Crookston, Forest River, Perham, and Sabin; Crookston, Forest River and Perham had significantly higher numbers than in 2013. Consequently, many areas that had little to no aphid pressure last year suffered moderate to high pressure this year and vice versa.

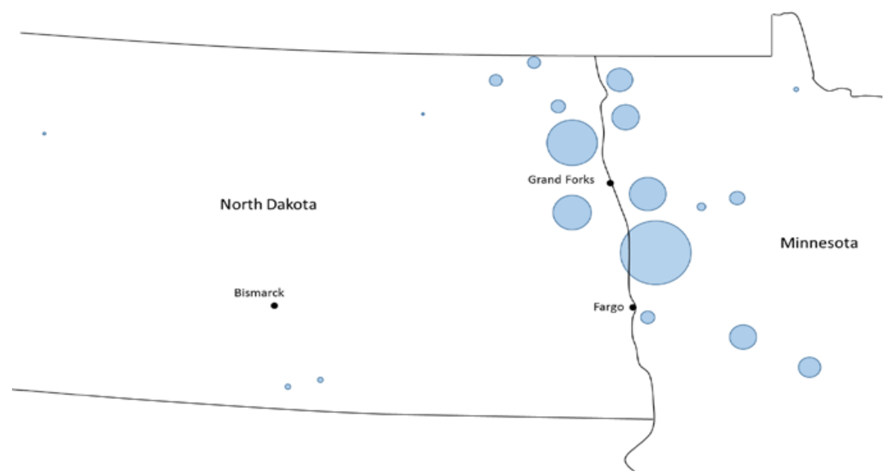


Figure 4. The 2014 seasonal aphid pressure by site location. The larger the dot, the greater the trap capture at that location.

In 2014, 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 add 3 additional trapping locations targeted at sugarbeet root aphid. 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.

Another ancillary benefit to the Aphid Alert Network in 2014 was the establishment of 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).

B) Using soybean borders to manage colonizing aphid vectors – A large ~1 ac block of potatoes was established at the UMN-NWROC in Crookston. Ten different plots of crop borders were established around the margin of this block. Soybeans were planted in 3 of these, ryegrass in 3 more and the remainder were left open (no border). Aphids were scouted intensively twice weekly 18m into the rows neighboring the borders and sampled weekly throughout the rest of the field.

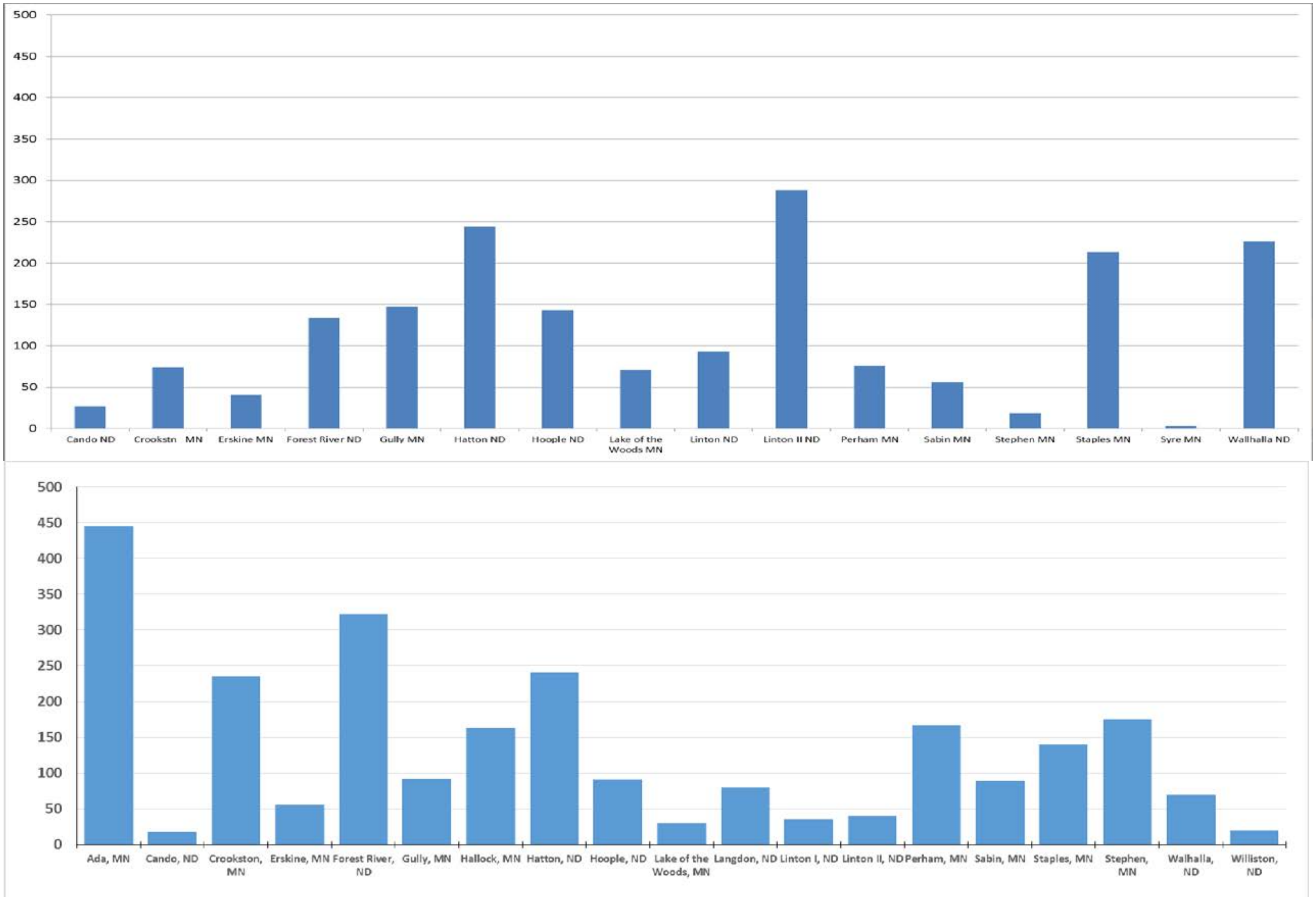


Figure 5. Total vector species capture by location in 2013 (upper graph) compared to 2014 (lower graph).

There were sufficient soybean aphids in Crookston to preclude the necessity of releasing soybean aphids from colony. Numbers of aphids inside the large potato field were very low and consequently numbers were not sufficient to discern differences between the various border treatments. No symptoms of PVY were found within season or in later testing.

Herbicide applications were not applied in 2014. It was planned to apply herbicides after aphids had established in the large plot, prior to this occurring, we wanted to maintain plants on the border as attractive to aphid colonization. Herbicide treatments will be pursued next year as part of a separate project.

C) Ameliorating the attraction of skips and rogueing holes as potential attractants for colonizing aphids – Artificial rogueing holes were created at 12 random locations in the 1 ac large block by removing two neighboring plants within a row. These holes were then treated with one of 3 different ground covering treatments: untreated, rapidly sprouting ryegrass seed, or green colored outdoor paint (Rust-Oleum Marking Spray, RustOleum, Ont. Can). Plants neighboring the holes (out to 3-4 plants away from the hole in any direction) were sampled for aphids weekly until the end of the growing season.

There were no significant differences through the summer in the number of aphids in plants neighboring plants. Unfortunately, aphid populations in the field were very low, providing insufficient numbers to differentiate between any of the treatments. There were no symptoms of PVY in any plants neighboring the holes nor was any found at later testing.

D) Integrating the use of oils and anti-feedant insecticides into a PVY vector management system – Plots were established at the NWROC in Crookston, MN. Replicated plots were treated with Aphoil (once and twice weekly), WetCit (Oro Agri, Fresno, CA) of left untreated. Plots were monitored for aphids weekly and foliage collected and tested for PVY at the end of the season. Yields were collected and compared at the end of the season.

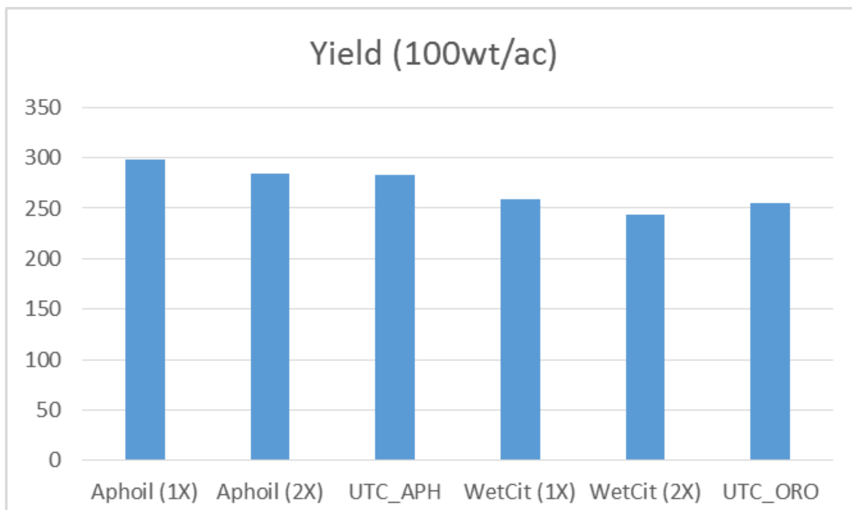


Figure 6. Mean yields (100wt/ac) for AphOil and WetCit trials.

The relative absence of aphids within plots negated the necessity of responding with anti-feedant insecticides. These insecticides have been linked to decreasing the within field spread of planted inoculum and operate by stopping feeding behaviors, including probing, of aphids exposed to the insecticide. Prophylactic application of these insecticides are not effective in the absence of the vector. An appropriate threshold, however, is the presence of colonizing aphids at the field's edge.

Yield data (Figs. 6 & 7) had significant variability in the results; several plots received excessive rain during June but unfortunately the pattern of plot flooding was not compensated for by blocking. In addition, all plots had very low aphid numbers (in some weeks, no aphids at all were found in any plot). Collected yield data indicated there was no difference in the yields of any oil treatment. The very low number of aphids precluded a difference.

No evidence of PVY infection was found in any treatment plot, including the untreated controls. It is assumed that that seed planted in border rows around the oil trial plots were not infected with PVY. It also supports the supposition that aphids are, for the most part, entering fields uninfected and that PVY spread is more dependent in the movement of inoculum from the seed source rather than post planting colonization by aphids.

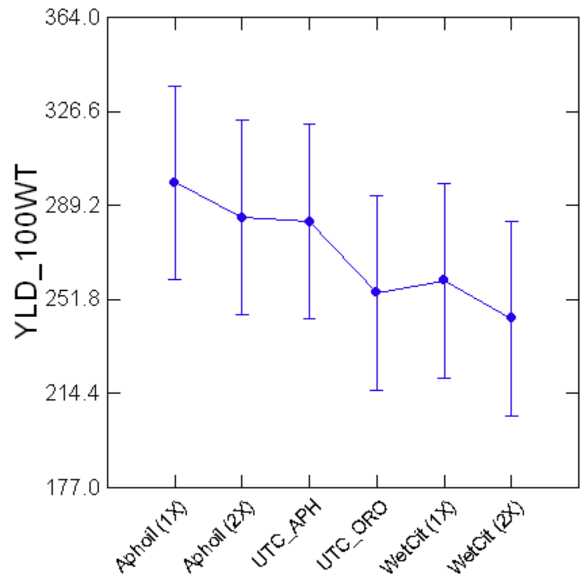


Figure 7. Mean yields (100wt/ac) of Aphoil and WetCit. Vertical bars are 95% Confidence Intervals, overlapping bars indicate no significant difference in yields.

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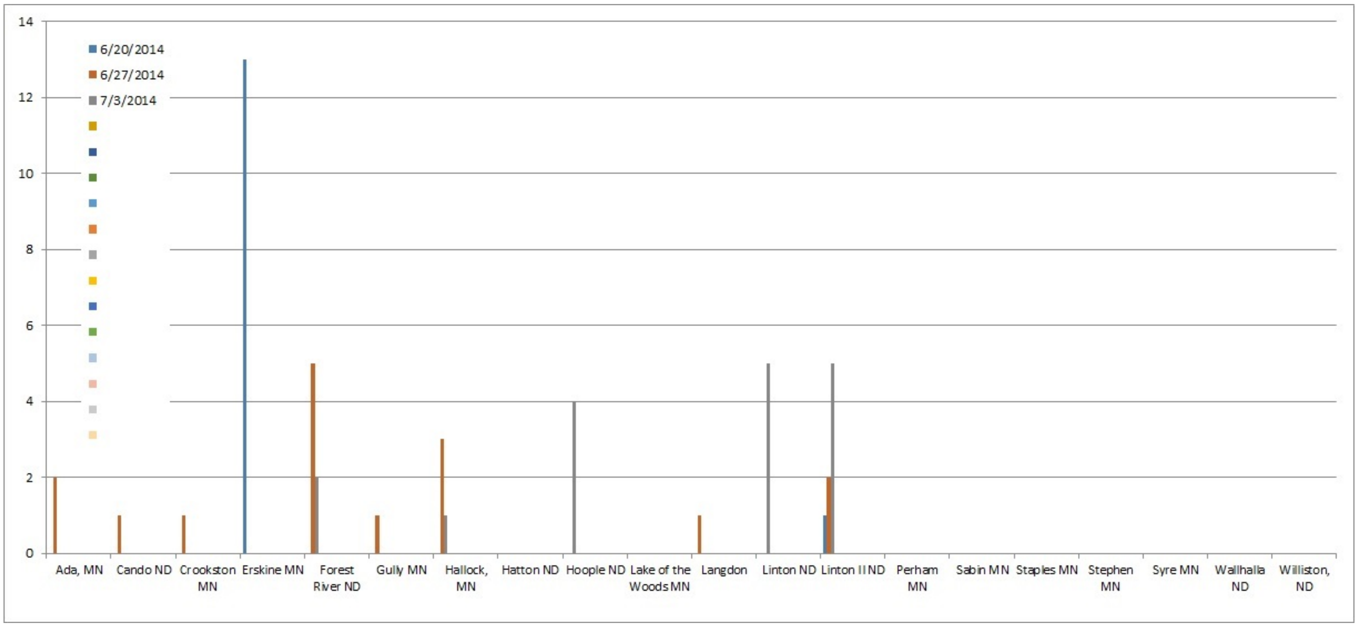
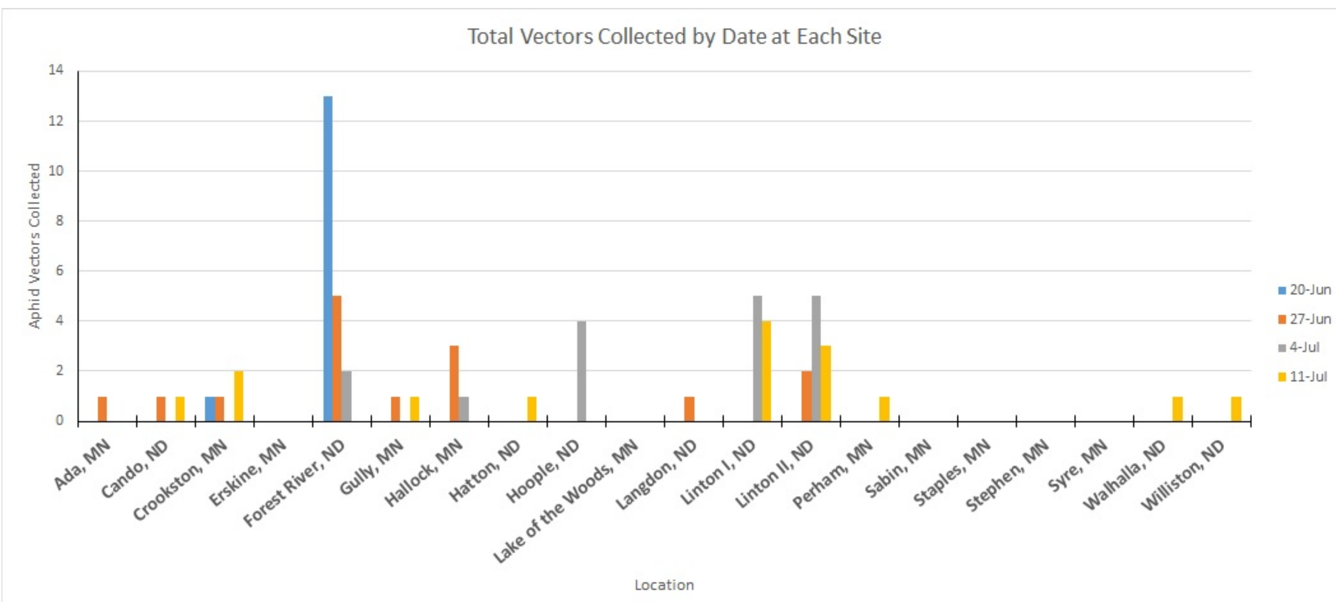
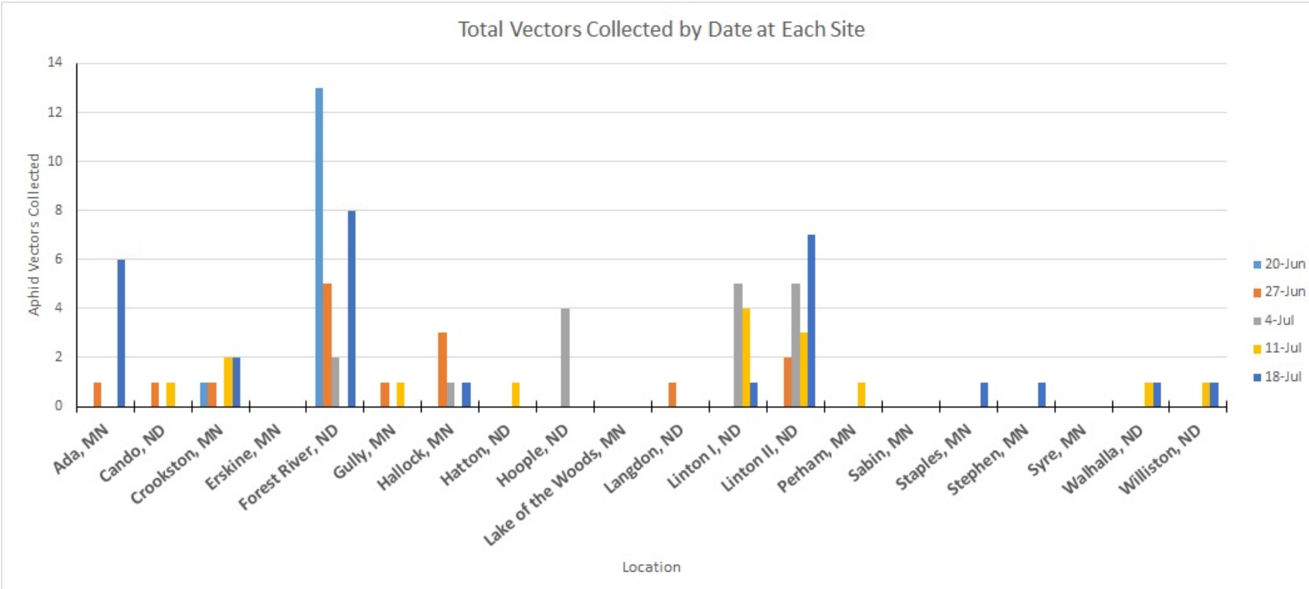
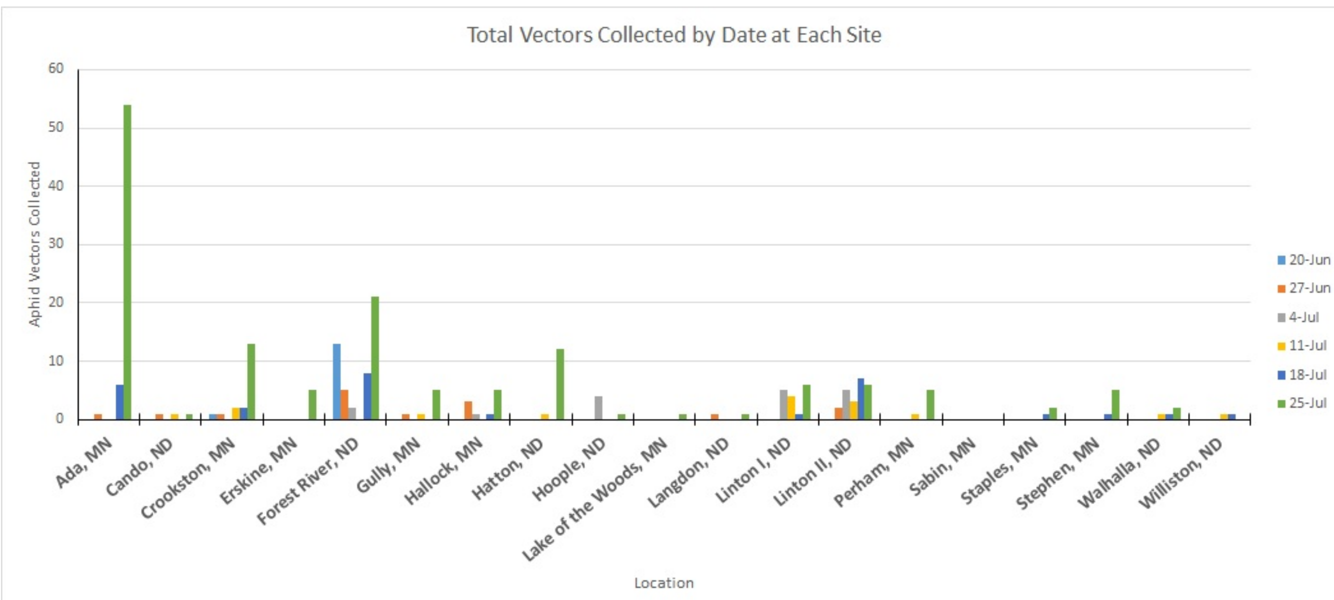
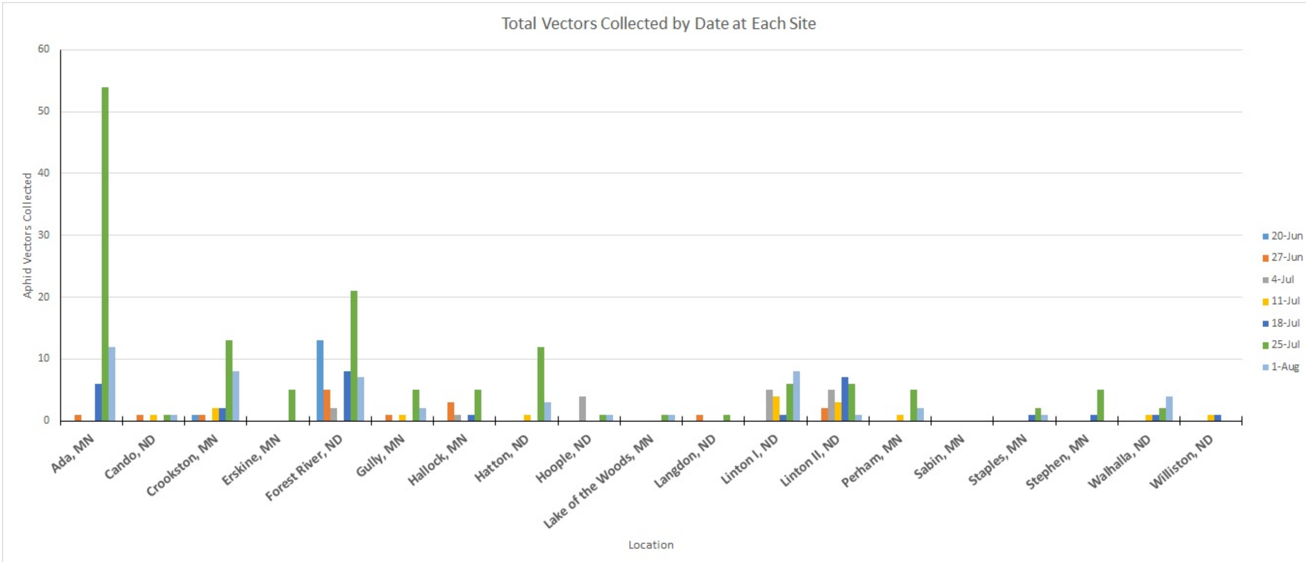
Appendix 1. Weekly Aphid Alert Network trap catches.



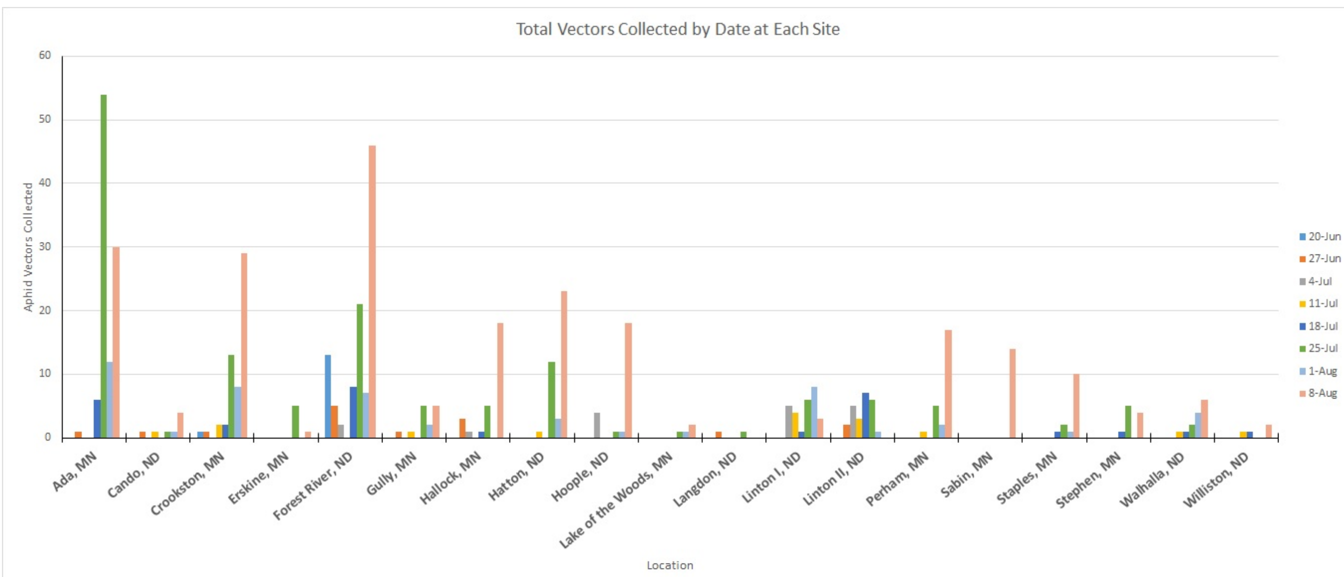



Total Vectors Collected by Date at Each Site
Aphid Vectors Collected
Location
20-Jun
27-Jun
4-Jul
11-Jul
18-Jul
Ada, MN
Cando, ND
Crookston, MN
Erskine, MN
Forest River, ND
Gully, MN
Hallock, MN
Hatton, ND
Hoople, ND
Lake of the Woods, MN
Langdon, ND
Linton I, ND
Linton II, ND
Perham, MN
Sabin, MN
Staples, MN
Stephen, MN
Syre, MN
Walhalla, ND
Williston, ND

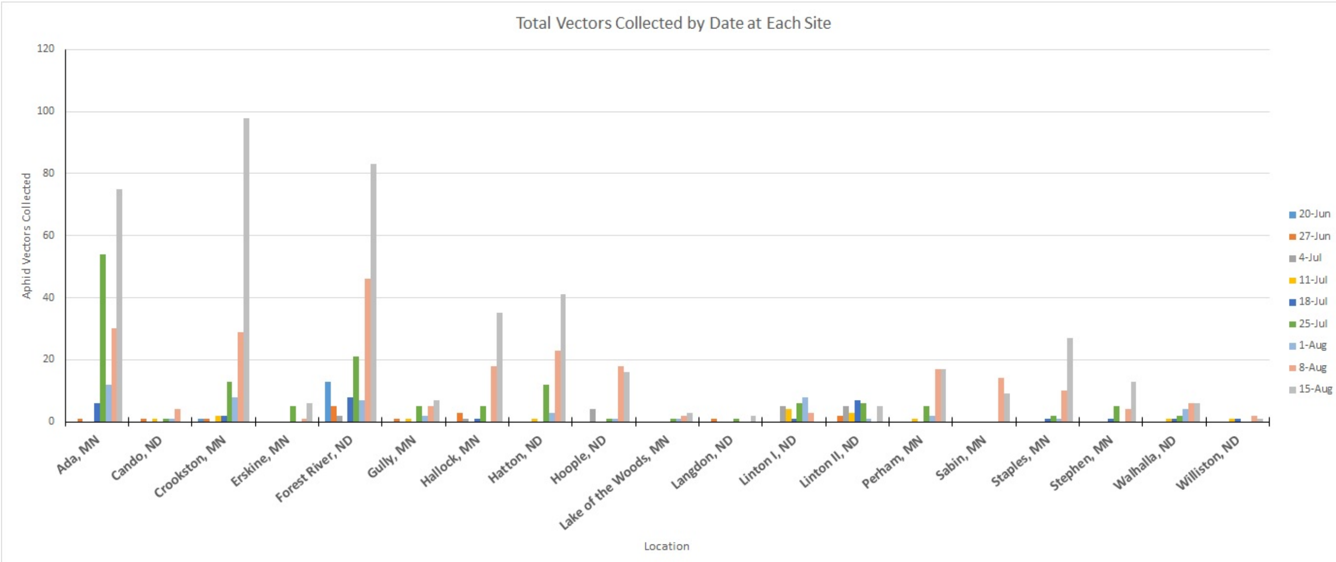

Total Vectors Collected by Date at Each Site
Aphid Vectors Collected
Location
20-Jun
27-Jun
4-Jul
11-Jul
18-Jul
25-Jul
Ada, MN
Cando, ND
Crookston, MN
Erskine, MN
Forest River, ND
Gully, MN
Hallock, MN
Hatton, ND
Hoople, ND
Lake of the Woods, MN
Langdon, ND
Linton I, ND
Linton II, ND
Perham, MN
Sabin, MN
Staples, MN
Stephen, MN
Walhalla, ND
Williston, ND



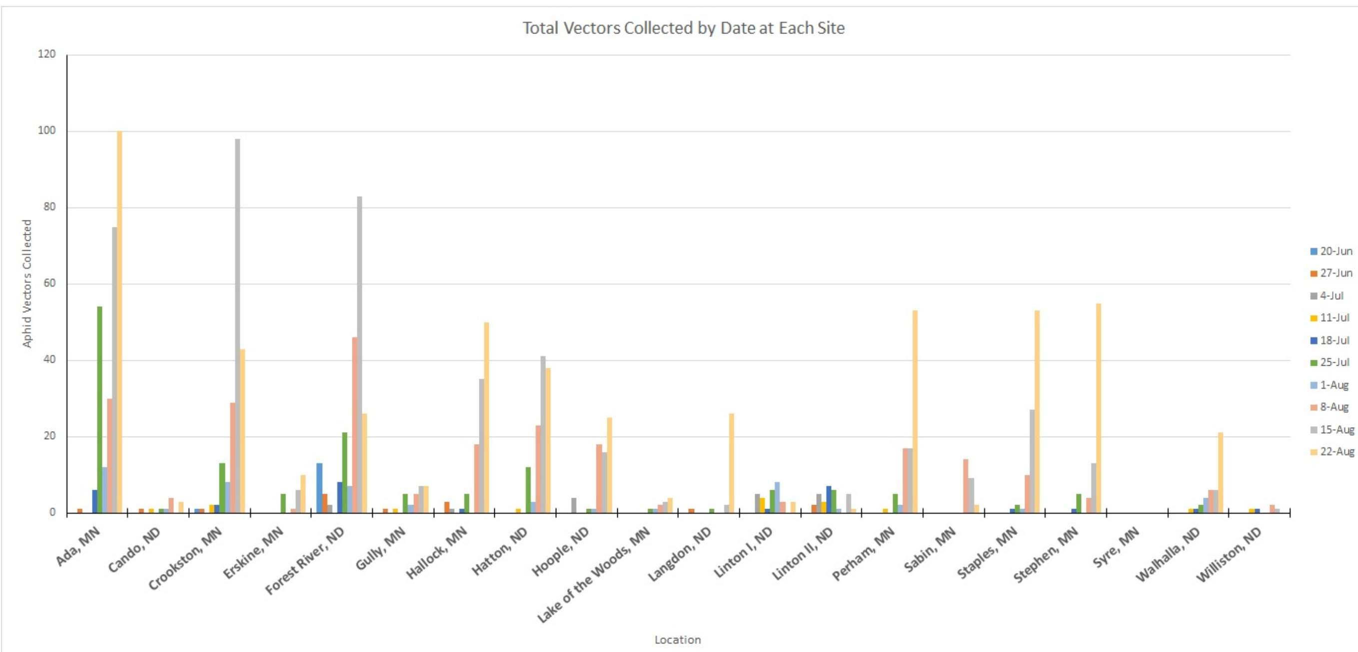
Total Vectors Collected by Date at Each Site
Aphid Vectors Collected
0
10
20
30
40
50
60
Ada, MN
Cando, ND
Crookston, MN
Erskine, MN
Forest River, ND
Gully, MN
Hallock, MN
Hatton, ND
Hoople, ND
Lake of the Woods, MN
Langdon, ND
Linton I, ND
Linton II, ND
Perham, MN
Sabin, MN
Staples, MN
Stephen, MN
Walhalla, ND
Williston, ND
Location
20-Jun
27-Jun
4-Jul
11-Jul
18-Jul
25-Jul
1-Aug



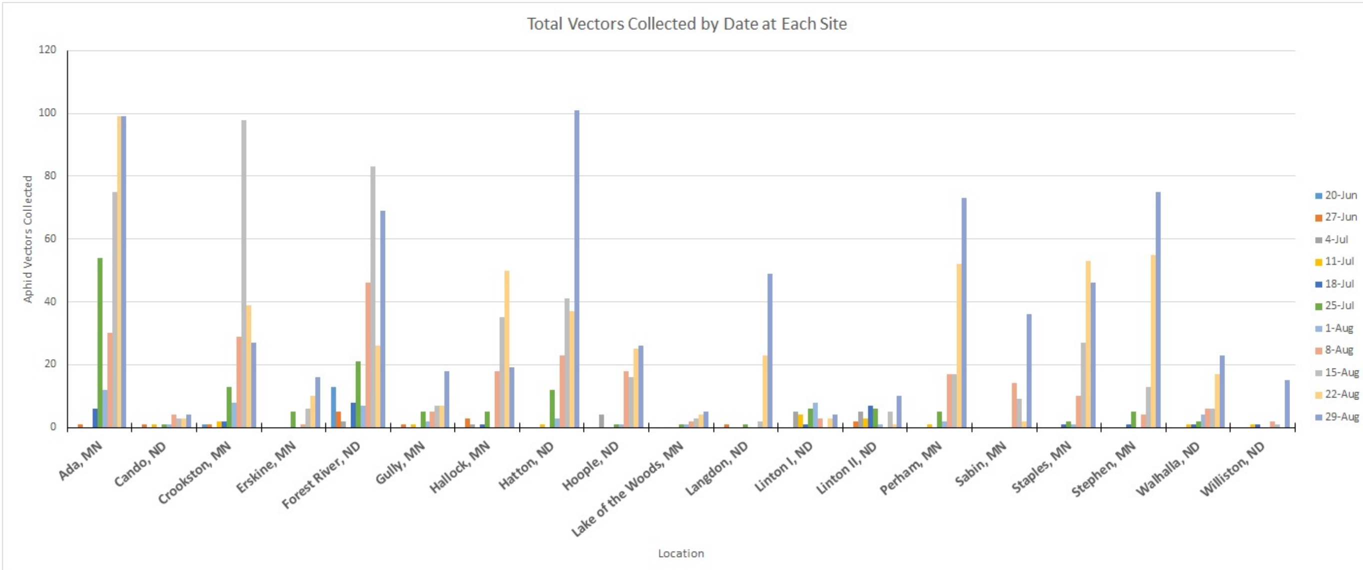
Total Vectors Collected by Date at Each Site
Aphid Vectors Collected
0
10
20
30
40
50
60
Ada, MN
Cando, ND
Crookston, MN
Erskine, MN
Forest River, ND
Gully, MN
Hallock, MN
Hatton, ND
Hoople, ND
Lake of the Woods, MN
Langdon, ND
Linton I, ND
Linton II, ND
Perham, MN
Sabin, MN
Staples, MN
Stephen, MN
Walhalla, ND
Williston, ND
Location
20-Jun
27-Jun
4-Jul
11-Jul
18-Jul
25-Jul
1-Aug
8-Aug



Total Vectors Collected by Date at Each Site
Aphid Vectors Collected
Location
20-Jun
27-Jun
4-Jul
11-Jul
18-Jul
25-Jul
1-Aug
8-Aug
15-Aug
Ada, MN
Cando, ND
Crookston, MN
Erskine, MN
Forest River, ND
Gully, MN
Hallock, MN
Hatton, ND
Hoople, ND
Lake of the Woods, MN
Langdon, ND
Linton I, ND
Linton II, ND
Perham, MN
Sabin, MN
Staples, MN
Stephen, MN
Walhalla, ND
Williston, ND



Total Vectors Collected by Date at Each Site
Aphid Vectors Collected
Location
20-Jun
27-Jun
4-Jul
11-Jul
18-Jul
25-Jul
1-Aug
8-Aug
15-Aug
22-Aug
Ada, MN
Cando, ND
Crookston, MN
Erskine, MN
Forest River, ND
Gully, MN
Hallock, MN
Hatton, ND
Hoople, ND
Lake of the Woods, MN
Langdon, ND
Linton I, ND
Linton II, ND
Perham, MN
Sabin, MN
Staples, MN
Stephen, MN
Syre, MN
Walhalla, ND
Williston, ND


Total Vectors Collected by Date at Each Site
Aphid Vectors Collected
Location
20-Jun
27-Jun
4-Jul
11-Jul
18-Jul
25-Jul
1-Aug
8-Aug
15-Aug
22-Aug
29-Aug
Ada, MN
Cando, ND
Crookston, MN
Erskine, MN
Forest River, ND
Gully, MN
Hallock, MN
Hatton, ND
Hoople, ND
Lake of the Woods, MN
Langdon, ND
Linton I, ND
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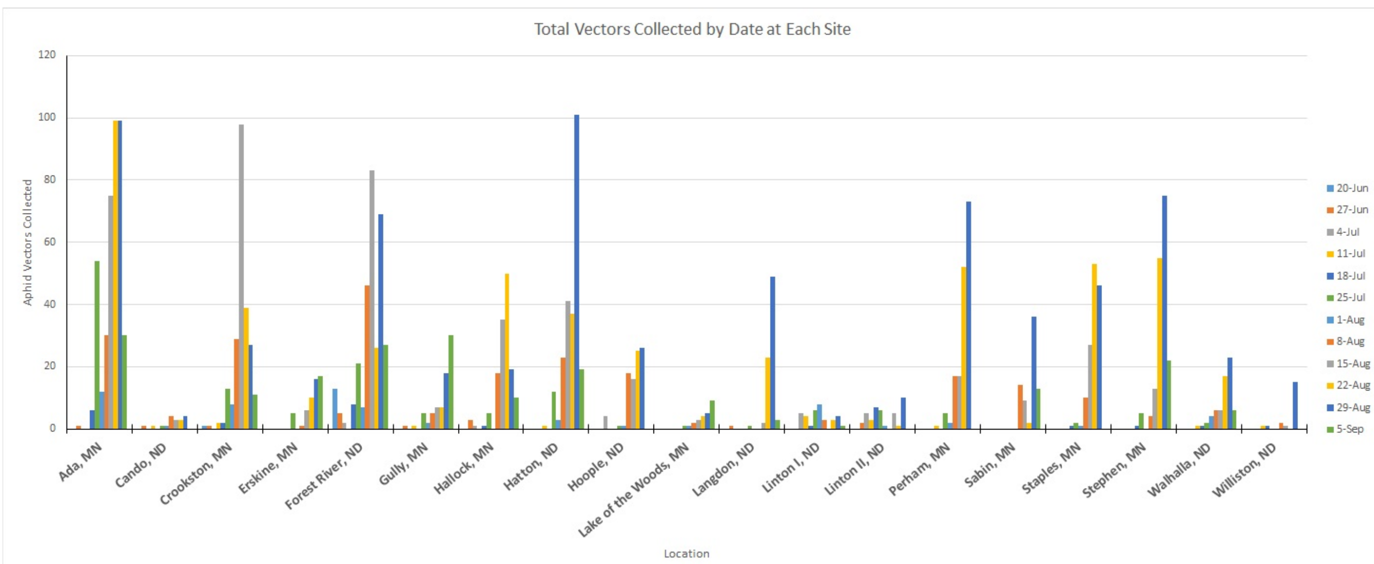
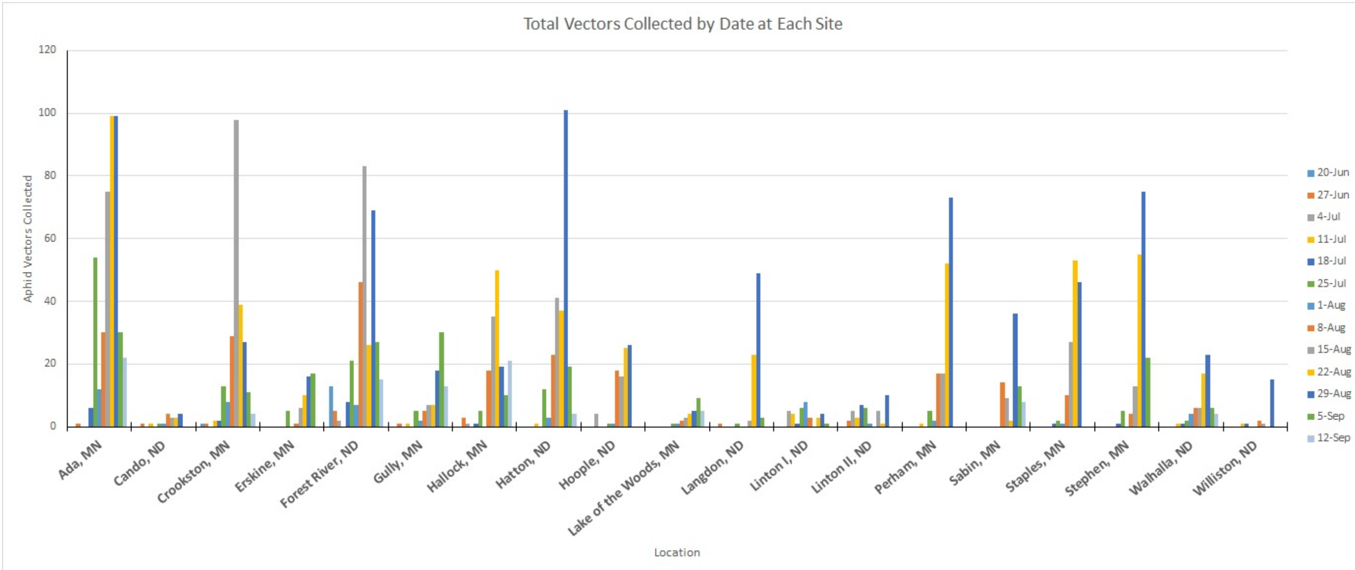
Perham, MN
Sabin, MN
Staples, MN
Stephen, MN
Walhalla, ND
Williston, ND


Total Vectors Collected by Date at Each Site
Aphid Vectors Collected
Location
20-Jun
27-Jun
4-Jul
11-Jul
18-Jul
25-Jul
1-Aug
8-Aug
15-Aug
22-Aug
29-Aug
5-Sep
Ada, MN
Cando, ND
Crookston, MN
Erskine, MN
Forest River, ND
Gully, MN
Hallock, MN
Hatton, ND
Hoople, ND
Lake of the Woods, MN
Langdon, ND
Linton I, ND
Linton II, ND
Perham, MN
Sabin, MN
Staples, MN
Stephen, MN
Walhalla, ND
Williston, ND


Total Vectors Collected by Date at Each Site
Aphid Vectors Collected
120
100
80
60
40
20
0
Ada, MN
Cando, ND
Crookston, MN
Erskine, MN
Forest River, ND
Gully, MN
Hallock, MN
Hatton, ND
Hoople, ND
Lake of the Woods, MN
Langdon, ND
Linton I, ND
Linton II, ND
Perham, MN
Sabin, MN
Staples, MN
Stephen, MN
Walhalla, ND
Williston, ND
Location
20-Jun
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18-Jul
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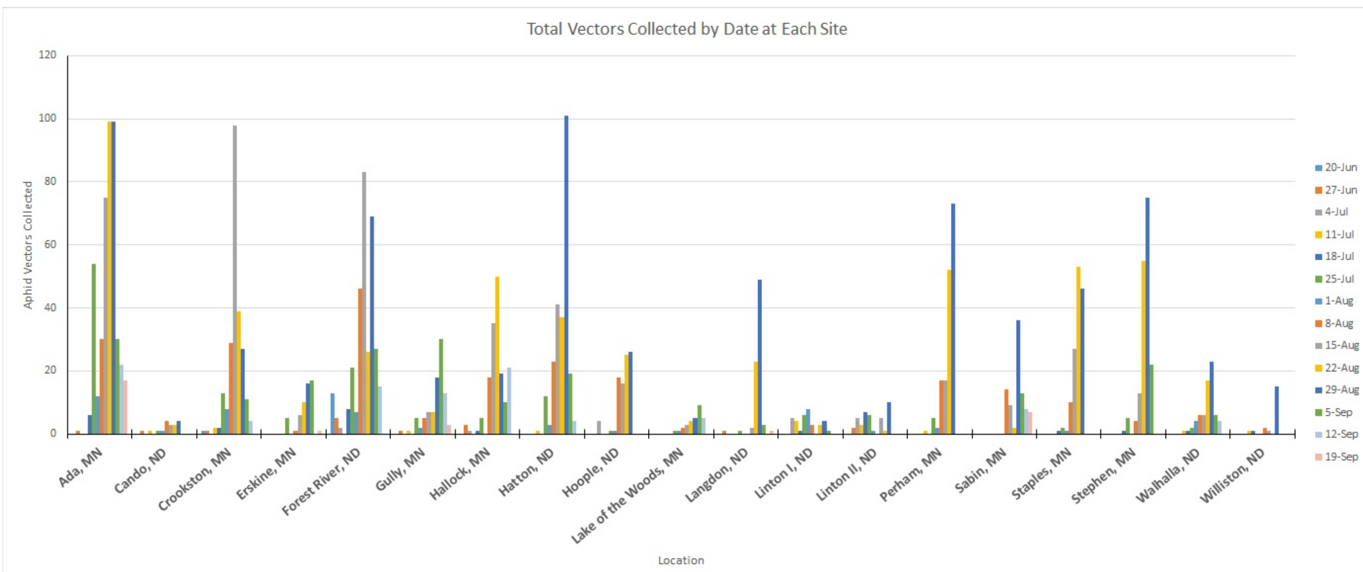
15-Aug
22-Aug
29-Aug
5-Sep
12-Sep


Total Vectors Collected by Date at Each Site
Aphid Vectors Collected
120
100
80
60
40
20
0
Ada, MN
Cando, ND
Crookston, MN
Erskine, MN
Forest River, ND
Gully, MN
Hallock, MN
Hatton, ND
Hoople, ND
Lake of the Woods, MN
Langdon, ND
Linton I, ND
Linton II, ND
Perham, MN
Sabin, MN
Staples, MN
Stephen, MN
Walhalla, ND
Williston, ND
Location
20-Jun
27-Jun
4-Jul
11-Jul
18-Jul
25-Jul
1-Aug
8-Aug
15-Aug
22-Aug
29-Aug
5-Sep
12-Sep
19-Sep

Marketability and Seed Production Effects from Sub-lethal Glyphosate Doses to Red Norland Potato - Amanda Crook, Harlene Hatterman-Valenti and Collin P Auwarter.

Field research was conducted at the NPPGA Research site near Grand Forks, ND in 2014 to evaluate the effects when sub-lethal rates of glyphosate were applied to 'Red Norland' potatoes. Glyphosate was applied at one-quarter, one-eighth, one-sixteenth and one-thirty-second the standard use rate (840g ae ha-1) during three crucial growth stages: tuber initiation (A), early tuber bulking (B) and late tuber bulking (C). Previous crop was Soybeans. Plots were 4 rows by 6 meters arranged in a randomized complete block design with three replicates. Seed pieces (65-75g) were planted June 9 in 0.9m rows and 0.3 m spacing. Treatments were applied on July 21 (tuber initiation), August 11 (early tuber bulking), and August 19 (late tuber bulking) to the middle 2 rows with a C02 backpack sprayer. Potatoes were manually harvested from two plants/plot on September 9.

Table 1. Glyphosate Treatments

Trt No	Trt Name	Rate	Unit	A.I.	Rate	Unit	Code
*1	Untreated	0			0	g ae/ha	A
*2	Roundup WeatherMax	0.048	L/ha	glyphosate	26	g ae/ha	A
*3	Roundup WeatherMax	0.096	L/ha	glyphosate	53	g ae/ha	A
*4	Roundup WeatherMax	0.195	L/ha	glyphosate	105	g ae/ha	A
5	Roundup WeatherMax	0.385	L/ha	glyphosate	210	g ae/ha	A
*6	Untreated	0			0	g ae/ha	B
*7	Roundup WeatherMax	0.048	L/ha	glyphosate	26	g ae/ha	B
*8	Roundup WeatherMax	0.096	L/ha	glyphosate	53	g ae/ha	B
*9	Roundup WeatherMax	0.195	L/ha	glyphosate	105	g ae/ha	B
10	Roundup WeatherMax	0.385	L/ha	glyphosate	210	g ae/ha	B
*11	Untreated	0			0	g ae/ha	C
*12	Roundup WeatherMax	0.048	L/ha	glyphosate	26	g ae/ha	C
*13	Roundup WeatherMax	0.096	L/ha	glyphosate	53	g ae/ha	C
*14	Roundup WeatherMax	0.195	L/ha	glyphosate	105	g ae/ha	C
15	Roundup WeatherMax	0.385	L/ha	glyphosate	210	g ae/ha	C
	*AMS added	4.8	g/L				

Table 2. Herbicide Drift application information

Date:		21-Jul	11-Aug	19-Aug
Time:		A	B	C
Sprayer:	**L/Ha:**	187	187	187
	KPA:	275	275	275
	Nozzle:	FF 8002	FF 8002	FF 8002
Air Temperature (C):		29.5	21.5	26.5
Relative Humidity (%):		67	66	67
Wind (Km/H):		20	10	8.5
Could Cover (%):		0	0	30

Table 3. Collected Data

Trt No.	Glyphosate Rate	Rate Unit	App Code	Yield	Total Tuber		Damaged Tuber		Tubers <56.7g	
				g/Plant	---------------------Number/Plant----------------------					
1	0	g ae/ha	A	1595.7	9.3	c	0.0	c	0.8	c
2	26	g ae/ha	A	781.5	7.2	c	4.2	b	2.3	b
3	53	g ae/ha	A	1004.9	13.8	b	11.0	a	4.3	b
4	105	g ae/ha	A	940.6	17.3	a	10.5	a	7.8	a
5	210	g ae/ha	A	781.3	18.7	a	11.2	a	6.5	ab
6	0	g ae/ha	B	1009.3	7.3	c	0.0	c	0.3	c
7	26	g ae/ha	B	1317.5	7.8	c	0.0	c	0.2	c
8	53	g ae/ha	B	1138.2	7.2	c	0.3	c	0.7	c
9	105	g ae/ha	B	1075.1	9.2	c	0.3	c	1.5	c
10	210	g ae/ha	B	1037.3	8.3	c	1.0	c	0.8	c
11	0	g ae/ha	C	1272.4	9.0	c	0.2	c	0.3	c
12	26	g ae/ha	C	1235.4	8.7	c	0.0	c	0.7	c
13	53	g ae/ha	C	1044.1	7.7	c	0.7	c	1.0	c
14	105	g ae/ha	C	1015.0	8.7	c	0.2	c	0.7	c
15	210	g ae/ha	C	1269.3	8.5	c	0.2	c	0.8	c
			LSD (P=0.05)	NS	1.1		0.6		0.9	

Data was collected on yield, total tuber numbers, number of damaged-cracked tubers and tubers less than 56.7g (undesirable size for seed). Visible foliar damage symptoms (chlorosis at the growing points) were most noticeable at the TI stage due to the determinant growth nature of this cultivar. Although no significant yield differences occurred, other symptoms developed creating unmarketable tubers for fresh market or creating severely undersized tubers for seed production. Glyphosate applied to plants at the EB and LB growth stages did not affect total tuber number, total cracked tuber number or less than 56.7 g seed pieces. In contrast, glyphosate applied at 53, 105, and 210 g/ha to plants at the TI stage resulted in greater total tuber numbers. Additionally, glyphosate applied at all sub-lethal rates to plants at the TI stage resulted in more damaged-cracked tubers. More daughter tubers were less than 56.7 g when plants at the TI stage were treated with 105 and 210 g/ha glyphosate. Further research is focusing on sprout inhibition on daughter tubers used for seed pieces as well as quantifying glyphosate residue within the seed pieces.

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 have no idea if these application parameters are ideal for fine textured soils with higher OM levels (>2%). Many growers in the ND and MN area have asked that 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 will 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, will be collected as the season progresses.

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

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Summary: A field experiment was conducted with Russet Burbank potatoes in adjacent center pivot fields near park Rapids, MN, to evaluate strategies for nitrogen fertilization, specifically addressing three questions: (1) Based on tuber yield and quality and end-of-season residual soil NO_3-N and NH_4-N, what is the optimum application rate for Environmentally Smart Nitrogen (ESN, Agrium, Inc.: a controlled release polymer-coated urea product, or PCU) at shoot emergence? (2) By the same measures, which of several nitrogen sources performs the best when applied at a rate of 120 lbs N/ac at emergence? (3) Does the answer to these questions depend on the field's planting history? To address these questions, ten treatments were applied in a randomized complete block design in two fields with four replicates. Six of these treatments differed in the amount of nitrogen they received as ESN at shoot emergence: 0, 80, 120, 160, 200, or 240 lbs N/ac. The remaining treatments received emergence applications of uncoated urea, ammonium sulfate, a blend of ESN and Duration (a slower-release PCU than ESN), or Agrocote Max (a faster-release PCU than ESN) at a rate of 120 lbs N/ac, and their performance was compared to that of the treatment receiving ESN at that rate and time. Of the two fields, one (the "old field") had a long history of potato cultivation, while the other (the "new field") had been covered in perennial grasses previous years. In addition to the treatment-specific N application at emergence, all plots received 93 lbs N/ac (new field) or 105 lbs N/ac (old field) from other sources at other times. In the old field, total and marketable yield increased with ESN application rate up to a rate of 120 lbs N/ac (225 lbs N/ac total), but not at higher rates. The new field had a similar yield response except that yields were higher at the lower N rates than similar rate in the old field, suggesting larger amounts of available N from soil organic matter. The percentage of yield represented by tubers over six or ten ounces was highest when the application rate was 160 lbs N/ac as ESN, though there was little difference in the percentage of yield in tubers over six ounces among treatments receiving at least 120 lbs ESN-N/ac. Tuber specific gravity decreased with increasing nitrogen application rate, especially in the new field. Application rate had no effect on residual soil NO_3-N and NH_4-N concentrations. The treatment receiving 120 lbs N/ac as ESN at emergence had significantly greater total and marketable yield than those receiving Agrocote Max or uncoated urea, and significantly greater marketable yield than the treatment receiving a blend of ESN and Duration. It also had more of its yield in tubers over six ounces than the treatment receiving uncoated urea, higher tuber specific gravity than the treatments receiving ammonium sulfate, the ESN/Duration blend, or Agrocote Max, and a lower prevalence of hollow heart than the treatments receiving the ESN/Duration blend or Agrocote Max. The new field had larger percentages of yield in tubers over six or ten ounces than the old field. It also had a lower prevalence of scab on tubers, a lower concentration of *Verticillium* propagules in its soil prior to planting, and a higher residual soil NH_4-N concentration than the old field. Overall, based on tuber yield and quality and residual soil NO_3-N and NH_4-N, the optimum application rate for ESN at emergence in the old field was in the range of 120 to 160 lbs N/ac (225-265 lb N/ac total), and ESN was a highly effective nitrogen source in this system. The new field had more large tubers and lower pathogen loads than the old field, and its yield at low N application rates was higher.

Background

Polymer coated ureas (PCUs) are controlled-release nitrogen fertilizers with a polymer coating that slows the diffusion of water into and the diffusion of 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 nitrogen to nitrate leaching (nitrate is produced from ammonia by nitrification) and ammonia volatilization before plants are able to take it up. Over the course of 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 nitrogen source for potatoes. However, it is possible that the value and optimum rate and timing of application for ESN are site-dependent. Studies in other locations would help determine whether the results obtained at Becker apply more broadly.

In this study, we evaluated ESN in a field near Park Rapids, MN, approximately 120 miles NNW of Becker. Using ten treatments, ESN was tested at six different rates (0, 80, 120, 160, 200, and 240 lbs N/ac) and compared with four other nitrogen sources. The other sources were uncoated urea, ammonium sulfate, Agrocote Max, and a 1:1 blend of ESN and Duration. Agrocote Max (Everris: 44-0-0) is a PCU with an elemental sulfur and polymer coating similar in thickness to the polymer coating of ESN. It is designed to release its contents in one to two months. Duration (Koch Agronomic Services, LLC: 43-0-0) is a thicker-coated PCU than ESN, with a longer release time. The different products were used at 120 lbs N/ac. The products were applied at emergence; the potatoes also received approximately 100 lbs N/ac at planting and fertigation (see methods for details).

A field's agricultural history may also have substantial effects on crop performance and the optimum rates and sources of nitrogen. To examine these effects, this study was conducted on two locations in adjacent center pivot fields. The "old field" was planted in an area with a long history of potato cultivation, while the "new field" was planted in an area that was covered in grassy vegetation the previous year.

The overall objectives of this study were (1) to evaluate the polymer-coated urea product ESN as a nitrogen source for potatoes, relative to other sources (2) to determine the optimum application rate for ESN in a field near Park Rapids, (3) to evaluate Agrocote Max as a nitrogen source for potatoes, and (4) to determine the effect of field planting history on the response of potato yield and tuber quality to nitrogen application rate.

Materials and Methods

The study was conducted in 2014 under two center pivots in a field (the Summers Field) near Park Rapids, MN, on soil in a Verndale-Nymore soil complex, using the potato cultivar Russet Burbank. The study was established on two fields in close proximity. The "new field" was planted on soil with a sandy texture previously covered with grassy vegetation. The "old field" was planted on soil with a sandy texture and a long history of potato cultivation. 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). Each plot was 18 feet wide and 50 feet long. Tubers were planted on May 16, 2014, with 3-foot spacing between rows (six rows per plot) and 15-inch spacing within rows. Plots 50 feet long and 18 feet (6 rows) wide were marked on May 27. Tubers harvested for analysis were collected from the central 40 feet of the middle two rows.

The new field and the old fields received, respectively, 562 and 399 lbs/ac KCl (0-0-60) on April 10, 2014 (337 and 239 lbs P_2O_5/ac, respectively). At planting (May 16), the new field received 49 lbs N/ac, 76 lbs P_2O_5/ac, 143 lbs K/ac, 70.5 lbs S/ac, 1.9 lbs Zn/ac, and 1.1 lbs B/ac as a mixture of urea (57 lbs/ac), MESZ (190 lbs/ac), sulfate of potash (286 lbs/ac), and 15% boron (7 lbs/ac). The old field received 71 lbs N/ac, 63 lbs P_2O_5/ac, 33.4 lbs S/ac, and 1.1 lbs B/ac as a mixture of urea (37 lbs/ac), diammonium phosphate (137 lbs/ac), ammonium sulfate (139 lbs/ac), and 15% boron (7 lbs/ac). In addition, the new and old fields received 205 and 151 lbs/ac Pellime, respectively. Each field received nitrogen as fertigations with UAN (32-0-0) on July 1 and 8. The new field received 7.1 gal/ac (25 lbs N/ac) on July 1 and 5.1 gal/ac (18 lbs N/ac) on July 8. The old field received 5.3 gal/ac (19 lbs N/ac) on July 1 and 4.4 gal/ac (15.5 lbs

N/ac) on July 8. In total, the new field received 93 lbs N/ac and the old field received 105 lbs N/ac, in addition to any N applied at emergence.

Shoot emergence occurred on June 5, and emergence fertilizer was applied on June 9. Study treatments differed in the amount and form of nitrogen applied at shoot emergence. Five treatments received 80, 120, 160, 200, or 240 lbs N/ac as ESN, and four treatments received 120 lbs N/ac as urea, ammonium sulfate, a blend of ESN and Duration, or Agrocote Max. A control treatment received no fertilizer at emergence.

From June 12 through September 18, rainfall, soil moisture and temperature, and air temperature were monitored on-site, and overhead irrigation was applied, a half-inch at a time, as needed. Rainfall and air temperature data were also obtained from the National Weather Service weather station in Park Rapids from May 16 (planting) to September 19 (second and last day of harvest).

Mesh bags containing 3 grams of polymer coated fertilizer were placed 4 inches below the soil surface in each field after the emergence fertilizer application. Sixty bags with ESN or Agrocote Max were installed on June 9, and 40 bags with a 1:1 ESN:Duration blend were installed on June 12. The bags were planted in groups of 10 in an equal number of plots rain each field (2 plots per field for the ESN:Duration blend; 3 plots per field for ESN and Agrocote Max). The bags were placed in plots receiving 120 lbs N/ac of the fertilizer contained in the bags. One bag from each group of 10 was collected 13, 20, 27, 34, 41, 55, 69, 83, and 104 days after emergence (i.e., on June 18 and 25, July 2, 9, 16, and 30, and August 13 and 27, and two bags from each group were collected on September 17. Collected bags were dried and their contents weighed to measure the percentage of their fertilizer content that had been released (accounting for the weight of the prill coats, which were assumed not to have changed).

Soil was sampled in each field to test it for *Verticillium dahliae* propagules per gram of soil. The samples were sent to Pest Pros Inc. (Plainfield, WI) for testing using a dilution planting method on Sorenson's NPX, a selective growth medium. Intensity of infestation was measured as *Verticillium* propagules per gram (VPPG) of soil. Treatment thresholds for potato are placed at 8 VPPG.

Terminal petioles were collected on June 24, July 9, and July 29. The petiole of the terminal leaflet of the 4^{th} leaf from the end of a shoot was sampled and analyzed for NO_3-N concentration on a dry-weight basis with a Wescan nitrogen analyzer.

Tubers were harvested on September 18 and 19, and cleaned, sorted, and graded as soon as possible afterward. About 2.3% of harvested tubers were classified as "unusable" and 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 28 (old field) and November 6 (new field). These were analyzed for NO_3 and NH_4 concentrations using a Wescan nitrogen analyzer.

ANOVA tests were performed (GLM procedure in SAS 9.3) using field, treatment, replicate, and the field*treatment interaction as independent variables. To test for an effect of the emergence ESN application rate, analyses were performed that included only treatments 1 – 6, using field, ESN rate, replicate, and field*rate as independent variables. To test for an effect of nitrogen source, analyses were performed that included only treatments 3 and 7-10, with field, nitrogen source, replicate, and field*source as independent variables. In all analyses, Waller-Duncan k-ratio t-tests were performed on all significant results for treatment, rate, or source, to determine the minimum significant difference between treatments.

Results:

Weather and soil conditions

Total precipitation for the 2014 growing season, including both rainfall and precipitation, is shown in Figure 1. There were three large rainfall events (over an inch) between planting (May 16) and harvest (September 18-19), on May 31, June 11, and June15. Five inches of rain were measured at the Park Rapids NWS weather station before the in-field weather stations were activated and irrigation began. After irrigation started, the new field received 14.1 inches of total precipitation, while the old field received 12.9 inches, indicating that the new field received somewhat heavier irrigation.

Probes measuring volumetric soil water content at seed-piece depth consistently measured higher soil water content in the new field, with the old field becoming especially dry between July 24 and August 16 (Figure 2). The higher moisture in the new field may be attributable to its higher organic matter or to its location at the bottom of a slope; the old field was at the top of the same slope. The increased difference in moisture in late July through mid August may be due to the difference in received irrigation between the two fields. Moisture was highest in mid to late June, soon after probe installation, and declined after August 24, soon after irrigation ceased. Soil moisture did not track same-day precipitation (linear regressions, new field, R^2 = 0.0529; old field, R^2 = 0.0312), but was weakly related to precipitation on the previous day (new field, R^2 = 0.2259; old field, R^2 = 0.1512).

Daily minimum and maximum air temperatures are presented in Figure 3. The minimum daily air temperature was above 40°F from May 18 through September 9. It was generally between 50°F and 60°F throughout this period. The maximum daily temperature was at or above 60°F from May 17 through September 10. It was generally between 70°F and 80°F over this period, with a seasonal maximum of 91°F on July 21.

Daily mean soil temperature is presented in Figure 4. Daily mean soil temperatures were mostly between 60 °F and 70 °F from June 12, when probes were installed, through September 9. Soil temperature closely tracked mean daily air temperature as measured by the in-field weather stations (linear regressions: new field, R^2 = 0.7341; old field, R^2 = 0.8544).

Verticillium propagules were detected in the old field at 22 propagules/gram of soil, while no propagules were detected in the new field.

Fertilizer release rate in the soil

Fertilizer release over time for ESN, Agrocote Max, and a 1:1 blend of ESN and Duration placed in mesh bags in the soil at potato seed depth is illustrated in Figure 3. Bags were installed at the time of the shoot emergence fertilizer treatments, on June 9. Because the release dynamics were very similar between the two fields (data not shown), combined data are presented.

The release curve for ESN is typical for polymer-coated fertilizers, with the release rate rapid soon after application and reaching a plateau when most of the fertilizer is depleted. Half of the fertilizer in the prills had been released by 16 days after installation (June 25). The release rate slowed distinctly after the bag collection by 23 days (July 2), by which time 62% of the fertilizer had been released. By the final collection date, 100 days after installation (September 17, the day before harvest began), the prills had released 86% of their contents.

The release curve for the blend did not apparently plateau. The release rate was slower than that of pure ESN in the first week and remained fairly steady until the 23 days after installation, by which time 40% of the fertilizer had been released. After that, the release rate slowed. The prills had released 50% of their contents by 51 days after installation (July 30). By 100 days after installation (September 17), they had released 76% of their contents. Assuming the ESN in the blend (like that in the bags of pure ESN) had released 86% of its contents by that time, the Duration in the blend had released approximately 66% of its fertilizer by harvest time.

Agrocote Max had the fastest release rate of the three PCUs tested. It had released 52% of its urea by 9 days after installation (June 18), and its release rate did not clearly begin to plateau until 16 days (June 25), when it had released 72% of its content. By 100 days (September 17), Agrocote Max had released 94% of its urea content.

Plant stand

Plant stand results are presented in Table 3. There were no significant effects of application rate, nitrogen source, field, or interactions between field and rate or source on stand.

Petiole NO_3-N concentration

Results for petiole NO_3-N are presented in Table 3. Comparing the treatments receiving ESN at different rates (treatments 1 – 6), petiole NO_3-N increased with ESN application rate in both fields at the last two sampling times (July 9 and July 29). The new field had a significantly greater mean NO_3-N concentration at all three times. On the first collection date (June 24), petiole NO_3-N concentration increased much more rapidly with ESN application rate in the old field than in the new field for rates between 0 and 120 lbs ESN-N/ac, resulting in a significant rate-by-field interaction (Figure 6a).

Comparing the different N sources at 120 lbs N/ac at emergence, on the first date (June 24), the treatments receiving uncoated urea (treatment 7) and ammonium sulfate (treatment 8) had significantly higher concentrations than the other treatments. On the second date (July 9), the treatments receiving uncoated urea (treatment 7), ammonium sulfate (treatment 8), and ESN (treatment 3) at emergence had greater petiole NO_3-N concentrations than the ones receiving the ESN/Duration blend (treatment 9) or Agrocote Max (treatment 10). N source had no effect on petiole NO_3-N concentration on the third date (July 29). The new field had higher mean petiole NO_3-N concentrations than the old field on the second and third collection dates. These results suggest a greater nitrogen release from soil organic matter in the new field, which was slightly higher than in the old field (1.5% - new vs. 1.3% - old), or possibly better N acquisition by roots of plants in the new field due to a healthier root system (less *Verticillium*).

When the data from each field was considered separately, there was no effect of N source on petiole NO_3-N concentration in the new field on the first collection date. In contrast, in the old field on that date, the treatments receiving ammonium sulfate and urea (treatments 8 and 7, respectively) had greater petiole NO_3-N concentrations than those receiving ESN or Agrocote Max (treatments 3 and 10), which had greater concentrations than the one receiving the ESN/Duration blend (treatment 9). As a result of this difference between the fields in the effect of N source on petiole NO_3-N concentration, there was a significant field-by-source interaction for the June 24 petiole samples (Figure 6b).

Tuber yield

Results for tuber yield are presented in Table 4. The new field had significantly greater total and marketable yield than the old field. There were a significant rate-by-field interaction effects for both total and marketable yield, reflecting a much stronger response to application rate (at rates between 0 and 120 lbs ESN-N/ac) in the old field (Figure 7). In the old field, total and marketable yield increased with ESN application rate for rates from 0 to 120 lbs ESN-N/ac (approximately 100 – 220 lbs total N/ac), remaining nearly constant at higher application rates. There was essentially no response to N application above 120 lb N/ac in the new field.

Nitrogen source also had significant effects on total and marketable yield. The treatments receiving ESN (treatment 3), ammonium sulfate (treatment 8), or a 1:1 mixture of ESN and Duration (treatment 9) at emergence had significantly greater total yield than the one receiving urea (treatment 7), and the first two treatments also had greater total yield than the treatment receiving Agrocote Max (treatment 10). The results were similar for marketable yield, except that the treatment receiving the ESN/Duration blend did not have significantly greater yield than the one receiving urea, and the treatment receiving ammonium sulfate did not have significantly greater yield than the one receiving Agrocote Max.

Tuber size

The tuber size distribution results are presented in Table 4. The percentage of total yield represented by tubers over six or ten ounces peaked at an application rate of 160 lbs ESN-N/ac. The treatment receiving this rate (treatment 4) had a higher percentage of its yield in tubers over six ounce than the one receiving 80 lbs ESN-N-ac, and a higher percentage of yield in tubers over ten ounces than any treatment but the one receiving 240 lbs ESN-N/ac. All treatments receiving ESN at emergence had higher percentages of yield in tubers over six or ten ounces than the control treatment (treatment 1) did.

The treatment receiving urea at emergence (treatment 7) had a significantly lower percentage of its total yield in tubers over six ounces than did those receiving ESN (treatment 3), ESN/Duration blend (treatment 9), or Agrocote Max (treatment 10). There was no effect of N source on the percentage of yield in tubers over 10 ounces.

Tuber quality

The tuber quality results are shown in Table 5. Tuber specific gravity decreased with increasing ESN application rate in both fields, but the effect was more pronounced in the new field, resulting in a significant field-by-rate interaction (Figure 8). The new field had higher tuber specific gravity than the old field at lower application rates (0 to 120 lbs ESN-N/ac).

All treatments receiving ESN at emergence (treatment 2 – 6) had significantly lower prevalences of hollow heart than the control (treatment 1).

There was no effect of ESN application rate on the prevalence of scab, but the old field had a much higher prevalence than the new field. There was also a rate-by-field interaction effect, but this was due entirely to the comparatively high prevalence of scab in the control treatment plots of the old field.

The treatment receiving 120 lbs ESN-N/ac (treatment 3) had a significantly higher mean tuber specific gravity than those receiving ammonium sulfate (treatment 8), the ESN:Duration blend (treatment 9), or Agrocote Max (treatment 10). The effect was more pronounced in the new field, resulting in a significant effect of field, with the new field having a higher mean specific gravity, as well as a marginal source-by-field interaction effect.

The treatment receiving the ESN:Duration blend (treatment 9) had a significantly higher prevalence of hollow heart than did those receiving other N sources at the same rate (120 lbs N/ac at emergence), and the treatment receiving Agrocote Max (treatment 10) had a higher prevalence of hollow hear than the one receiving 120 lbs ESN-N/ac at emergence (treatment 3). There were no other significant effects of ESN rate, nitrogen source, or field on tuber quality.

Residual soil nitrogen

Residual soil NO_3-N and NH_4-N concentrations are presented in Table 6. Fertilization treatment had no significant effect on the residual soil concentrations of NO_3-N, NH_4-N, or their sum. The new field had a significantly higher residual NH_4-N concentration than the old field. Among treatments 1 – 6 (the control plus those receiving ESN at emergence), the old field had a significantly greater mean soil NO_3-N concentration than the new field, but this was not observed when all treatments were statistically evaluated together.

Conclusions

In the old field, as the application rate of ESN increased, total and marketable yield reached a plateau at 120 lbs ESN-N/ac (approximately 220 lbs total N/ac), and the percentage of yield represented by tubers over six or ten ounces peaked at a rate of 160 lbs ESN-N/ac (about 260 lbs total N/ac). Based on these results, the optimum application rate for ESN in this study was in the range of 120 to 160 lbs ESN-N/ac (220 – 260 lbs total N/ac).

Tuber specific gravity did not vary significantly at application rates above 160 lbs ESN-N/ac, and the prevalence of hollow heart did not vary significantly among treatments receiving any ESN at emergence. Petiole NO_3-N concentration continued to increase with rate above the rate of 120 lbs N/ac, especially later in the season, while residual soil NO_3-N and NH_4-N were not related to N application rate. Taken together, these results suggest that increasing the total application rate above approximately 260 lbs N/ac has no effect on tuber quality or soil NO_3-N or NH_4-N concentrations, but increases the nitrogen concentrations of at least some plant tissues. These results do not contradict the conclusion that a total N application rate of 220 to 260 lbs N/ac maximizes crop performance while minimizing N fertilizer application rate.

Applied at a rate of 120 lbs N/ac, ESN produced the highest total and marketable yield of any N source, as well as the highest percentage of yield in tubers over six ounces, indicating that ESN was a highly effective N source in this system. ESN also produced a low prevalence of hollow heart. These positive results did not come at a cost in high residual soil NO_3-N or NH_4-N concentrations, which were unrelated to N source.

The new field had higher total and marketable yield and more of its yield in large tubers than the old field. Tubers from the new field had a significantly lower prevalence of scab than the old field, and new-field soil showed no evidence of *Verticillium* propagules, in contrast to 22 propagules/gram of soil in the old field (8 propagules/gram is the treatment threshold for potatoes). These results may also be indicative of the relative exposures to other diseases, and a higher overall pathogen load in the old field could explain the lower yield in that field. Alternative explanations include the drier soil conditions in the old field and nitrogen released from decomposing grassland vegetation in the new field.

There were several indications of higher baseline N availability in the new field. This field had higher mean petiole NO_3-N concentrations at all three collection times, a higher residual soil NH_4-N concentration, and showed weaker responses of petiole NO_3-N concentration on June 24. In addition, while total and marketable yield response was optimized at a similar nitrogen rate as the old field, yields at the lower nitrogen rates in the new field were higher than at similar rates in the old field. However, the tuber specific gravity was more sensitive to N application rate in the new field than the old field.

Table 1. Initial soil characteristics in each of the two study fields.

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)	Soil Type
New	1.5	6.0	8.3	24	86	184	1057	5	0.6	2	32	0.4	0.3	Sand
Old	1.2	6.2	6.4	65	153	147	791	9	2.8	5	47	0.3	0.3	Sand

Table 2. Nitrogen treatments tested on irrigated Russet Burbank potatoes.

Treatment	Nitrogen source[1] at emergence	Nitrogen application rate at emergence (lbs N/ac)	Total nitrogen application rate, new field (lbs N/ac)	Total nitrogen application rate, old field (lbs N/ac)
1	Control	0	93	105
2	ESN	80	173	185
3	ESN	120	213	225
4	ESN	160	253	265
5	ESN	200	293	305
6	ESN	240	333	345
7	Urea	120	213	225
8	AS	120	213	225
9	ESN + Duration	120	213	225
10	Agrocote Max	120	213	225

[1]Ammonium sulfate: 21-0-0. Urea: 46-0-0. ESN (Environmentally Smart Nitrogen, Agrium, Inc.): 44-0-0. Agrocote Max (Everris): 44-0-0. Duration (Agrium, Inc.): 43-0-0.

Figure 1. Daily precipitation received as rainfall and irrigation. Data from May 16 – June 11 come from a NWS weather station in Park Rapids. Data from June 12 – September 18 come from weather stations established in both experimental fields. Seed tubers were planted May 16; irrigation was applied June 12 – September 18; tubers were harvested September 18 – 19. Arrows indicate when fertilizer treatments were applied.

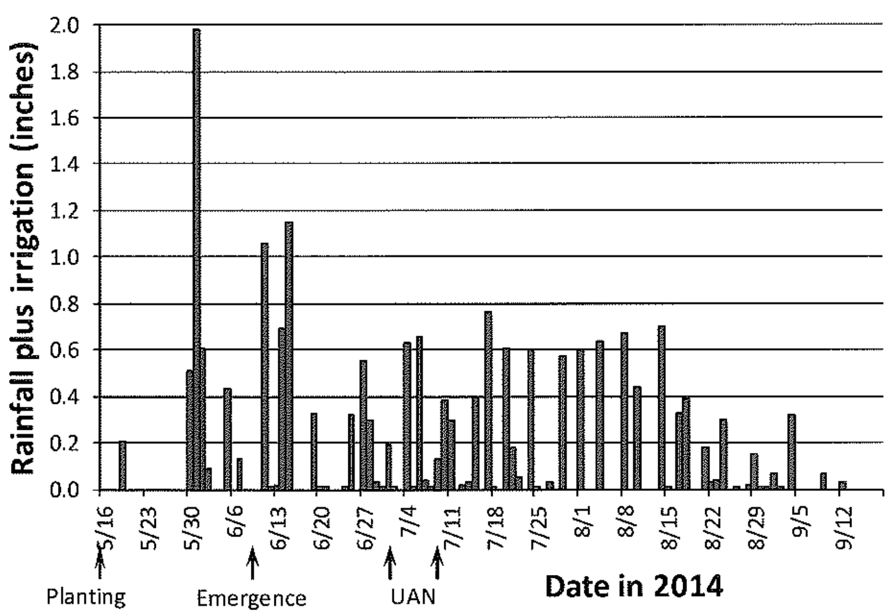

Figure 2. Daily mean soil water content (m^3 water / m^3 soil) in each field between June 12 (three days after emergence fertilizer treatments were applied) and September 16 (the day before tuber harvest commenced). Probes were placed at seed-piece depth.

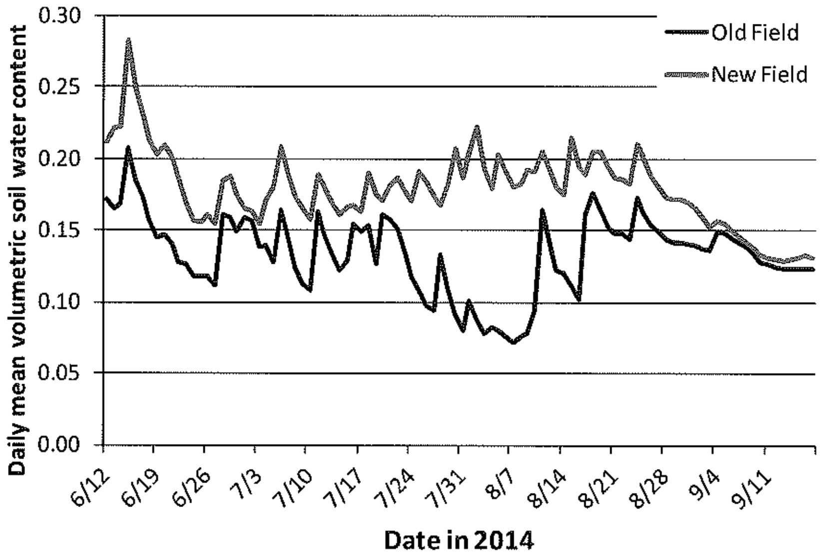

Figure 3. Daily maximum and minimum temperatures recorded by a NWS weather station in Park Rapids during the 2014 growing season. Seed tubers were planted on May 16, and tubers were harvested on September 18 – 19. Emergence fertilizer treatments were applied on June 9.

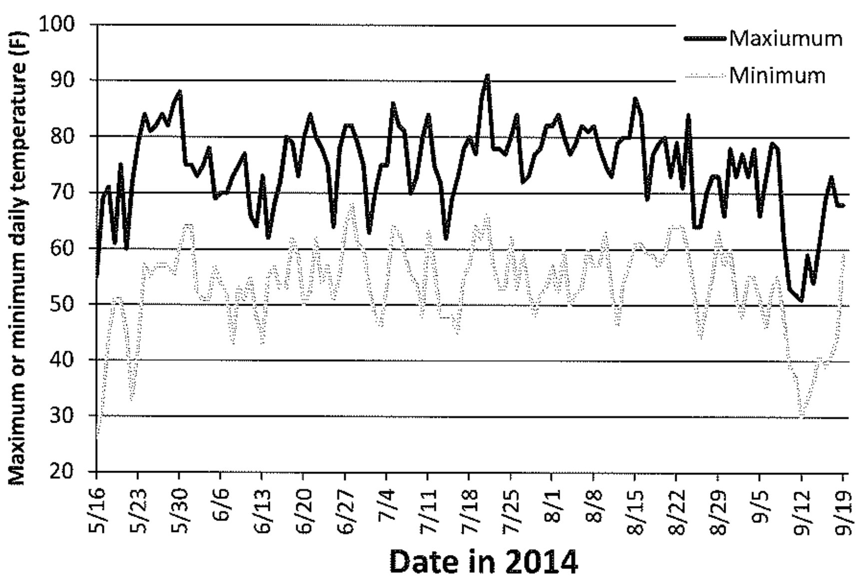

Figure 4. Daily mean soil temperature in each field between June 12 (three days after emergence fertilizer treatments were applied) and September 16 (the day before harvest commenced). Probes were placed at seed-piece depth.

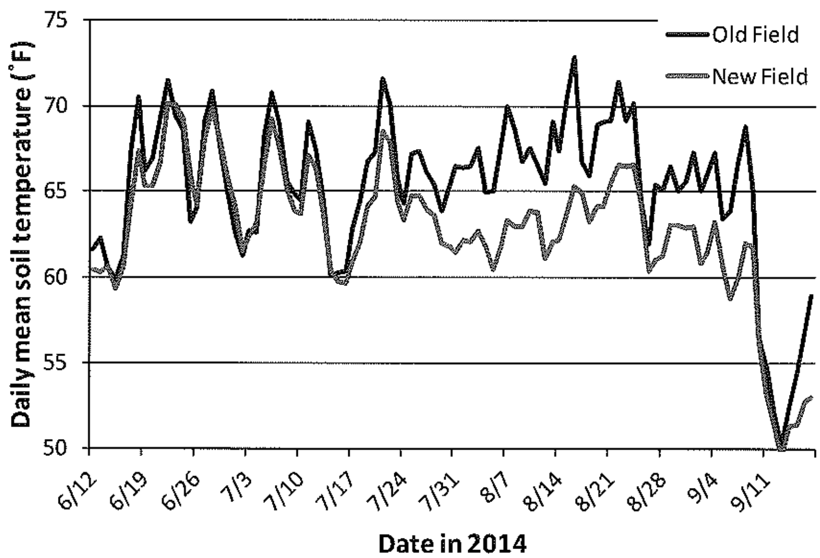

Figure 5. Percentage of fertilizer released from prills of ESN, a 1:1 blend of ESN and Duration, and Agrocote Max buried in mesh bags 4 inches beneath the soil surface in study plots. The bags were installed when the emergence fertilizer applications were made, on June 9.

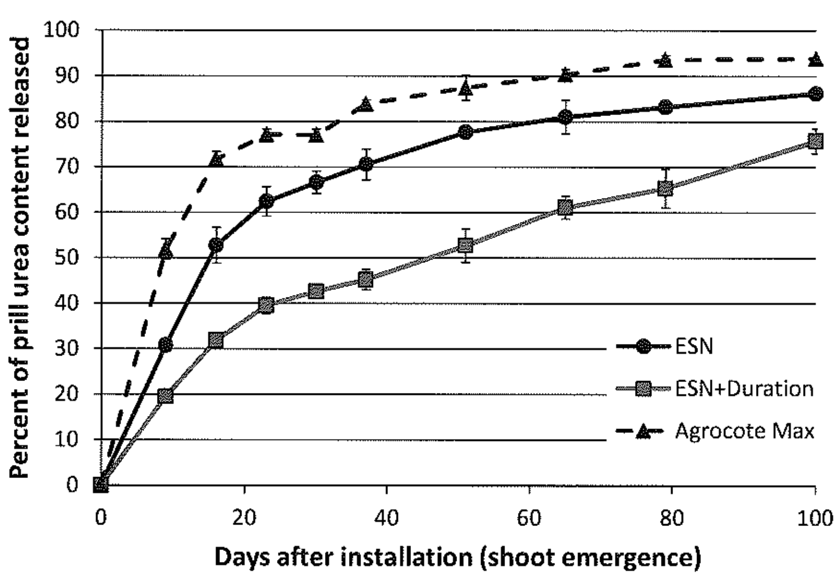

Table 3. Effects of nitrogen application rate and source on Russet Burbank plant stand and petiole NO_3-N concentrations in Park Rapids, MN, in 2014. Total N application rates are rough averages for the two fields; see Table 2 for actual non-emergence N application rates.

	Nitrogen Treatments				Plant stand and petiole NO_3-N			
	Treatment	Nitrogen source[1]	Application rate at emergence (lbs N / ac)	Total nitrogen (lbs N / ac)	Plant stand, June 24	Petiole NO_3-N, June 24	Petiole NO_3-N, July 9	Petiole NO_3-N, July 29
						ppm		
Effect of ESN application rate (comparing treatments 1-6).	1	Control	0	100	89	10445	4415	1230
	2	ESN	80	180	89	14616	11178	3658
	3	ESN	120	220	87	18396	15254	5312
	4	ESN	160	260	84	20440	15903	8705
	5	ESN	200	300	87	18834	18859	10075
	6	ESN	240	340	89	20789	18220	13609
	Treatment significance, both fields combined				NS	**	**	**
	Treatment MSD (P < 0.1)				--	2454	1737	2185
	Contrasts[2]			Linear	NS	**	**	**
				Quadratic	NS	*	**	++
	Field			New	88	18842	14979	8322
				Old	88	15664	12964	5875
	Field significance				NS	**	**	**
	Field * Treatment significance				NS	**	NS	NS
Effect of nitrogen source (comparing treatments 3, 7 - 10).	3	ESN	120	220	87	18396	15254	5312
	7	Urea	120	220	91	22598	16136	6019
	8	AS	120	220	89	22203	16170	4787
	9	ESN + Duration	120	220	88	16285	13149	6576
	10	Agrocote Max	120	220	86	18551	13144	4928
	Treatment significance, both fields combined				NS	**	**	NS
	Treatment MSD (P < 0.1)				--	2313	1895	2183
	Field			New	86	19321	16080	7231
				Old	90	19931	13461	3818
	Field significance				++	NS	**	**
	Field * Treatment significance				NS	**	NS	NS

[1]Ammonium sulfate: 21-0-0. Urea: 46-0-0. ESN (Environmentally Smart Nitrogen, Agrium, Inc.): 44-0-0. Agrocote Max (Everris): 44-0-0. Duration (Agrium, Inc.): 43-0-0.

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

Figure 6. Petiole NO_3-N concentration (mean ± S.E.) as a function of (a) application rate of N as ESN at emergence and (b) nitrogen source applied at 120 lbs N/ac at emergence in the new field versus the old field.

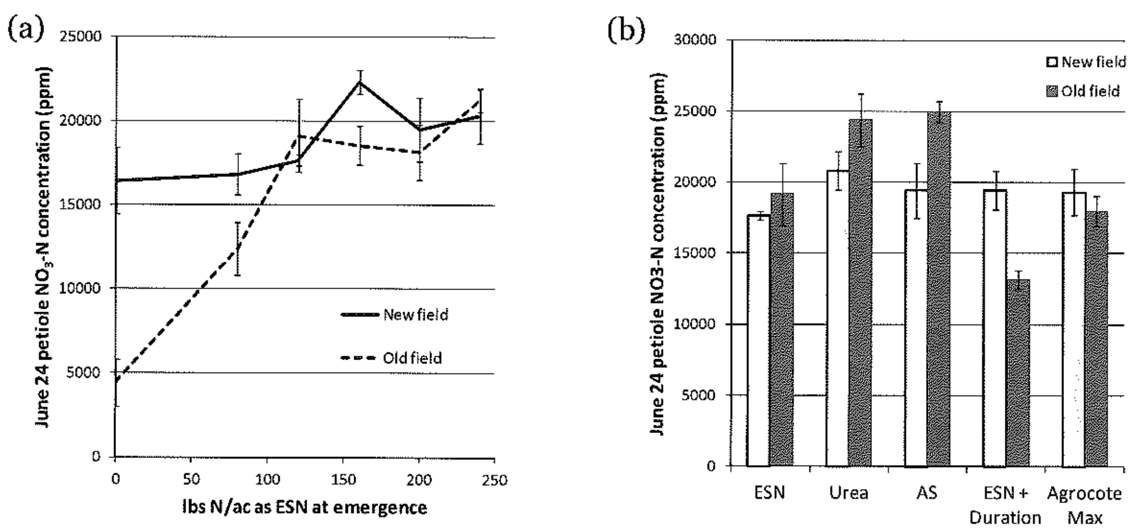

Table 4. Effects of nitrogen application rate and source on Russet Burbank tuber yield, grade, and size distribution in Park Rapids, MN, in 2014. Total nitrogen application rates are rough averages for the two fields; see Table 2 for actual non-emergence N application rates.

	Nitrogen Treatments				Tuber yield										
	Treatment	Nitrogen source[1]	Application rate at emergence (lbs N / ac)	Total nitrogen (lbs N / ac)	Unusable	0-3 oz	3-6 oz	6-10 oz	> 10 oz	Total yield	#1s > 3 oz.	#2s > 3 oz	Marketable yield	> 6 oz	> 10 oz
					cwt / ac									%	
Effect of ESN application rate (comparing treatments 1-6).	1	Control	0	100	22	25	149	166	49	411	305	59	364	51	11
	2	ESN	80	180	11	24	152	207	87	480	385	60	445	61	18
	3	ESN	120	220	3	25	159	223	101	510	430	52	482	63	20
	4	ESN	160	260	13	24	135	205	123	500	401	63	464	66	25
	5	ESN	200	300	7	23	150	214	100	494	418	46	463	63	20
	6	ESN	240	340	10	25	146	213	110	505	426	44	470	64	22
				Treatment significance[2]	*	NS	NS	**	**	**	**	++	**	**	**
				Treatment MSD (P < 0.1)	9	--	--	15	15	16	24	16	19	4	3
	Contrasts[3]			Linear	*	NS	NS	**	**	**	**	*	**	**	**
				Quadratic	*	NS	NS	**	**	**	**	NS	**	**	**
	Field			New	14	23	146	221	109	515	416	62	477	64	21
				Old	8	25	151	188	80	452	372	46	419	58	17
				Field significance[2]	*	NS	NS	**	**	**	**	**	**	**	**
				Field * Treatment significance[2]	NS	NS	NS	**	NS	**	++	*	**	NS	NS

Effect of nitrogen source (comparing treatments 3, 7 - 10).	3	ESN	120	220	3	25	159	223	101	510	430	52	482	63	20
	7	Urea	120	220	6	31	172	188	89	485	409	40	448	57	18
	8	AS	120	220	8	30	165	209	93	505	419	48	467	60	18
	9	ESN + Duration	120	220	18	22	150	208	106	504	409	55	464	62	21
	10	Agrocote Max	120	220	11	27	153	200	98	489	397	53	451	61	20
				Treatment significance[2]	**	*	++	**	NS	*	NS	NS	*	*	NS
				Treatment MSD (P < 0.1)	7	5	17	11	--	15	--	--	18	4	--
	Field			New	10	26	154	211	116	517	431	50	481	63	22
				Old	8	28	166	200	79	481	395	49	444	58	16
				Field significance[2]	NS	NS	*	*	**	**	**	NS	**	**	**
				Field * Treatment significance[2]	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1]Ammonium sulfate: 21-0-0. Urea: 46-0-0. ESN (Environmentally Smart Nitrogen, Agrium, Inc.): 44-0-0. Agrocote Max (Everris): 44-0-0. Duration (Koch Agronomic Services, LLC): 43-0-0.

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

Figure 7. Total tuber yield (a) and marketable tuber yield (b) as functions of application rate of N as ESN at emergence (means ± S.E.) in the new field versus the old field.

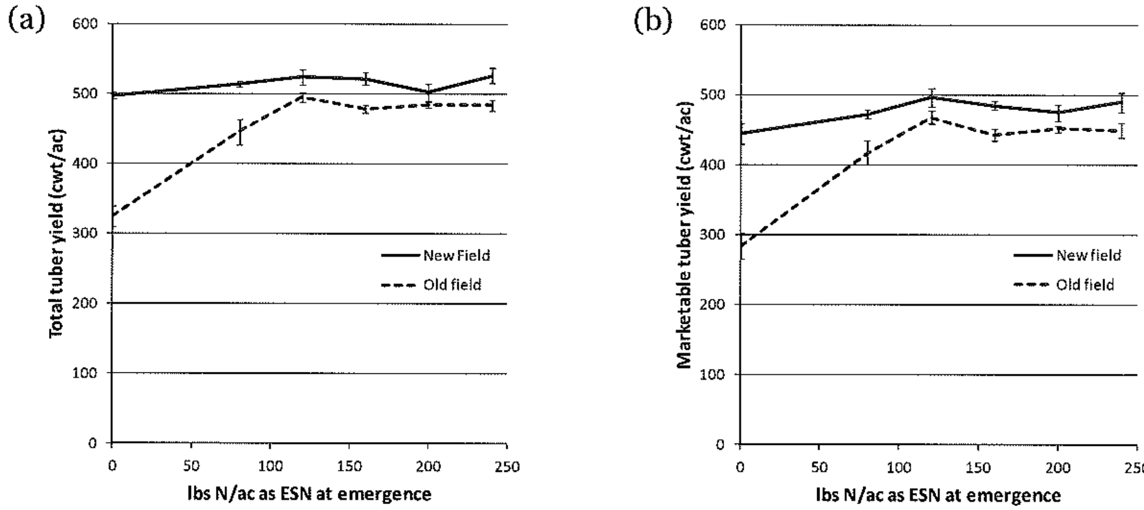

Table 5. Effects of nitrogen application rate and source on Russet Burbank tuber quality in Park Rapids, MN, in 2014. Total nitrogen application rates are rough averages for the two fields; see Table 2 for actual non-emergence N application rates.

	Nitrogen Treatments				Tuber Quality			
	Treatment	Nitrogen source[1]	Application rate at emergence (lbs N / ac)	Total nitrogen (lbs N / ac)	Specific Gravity	HH	Scab	Other unusable
						%		
Effect of ESN application rate (comparing treatments 1-6).	1	Control	0	100	1.097	3.62	0.40	1.42
	2	ESN	80	180	1.094	1.51	0.13	0.59
	3	ESN	120	220	1.096	0.24	0.06	0.35
	4	ESN	160	260	1.091	1.56	0.29	0.63
	5	ESN	200	300	1.091	0.85	0.29	0.39
	6	ESN	240	340	1.089	1.50	0.05	0.45
	Treatment significance, both fields combined				**	**	NS	NS
	Treatment MSD (P < 0.1)				0.003	1.33	--	--
	Contrasts[2]			Linear	**	**	NS	++
				Quadratic	NS	**	NS	NS
	Field			New	1.095	1.83	0.02	0.93
				Old	1.091	1.27	0.38	0.34
	Field significance				**	NS	*	++
	Field * Treatment significance				**	NS	NS	NS
Effect of nitrogen source (comparing treatments 3, 7 - 10).	3	ESN	120	220	1.096	0.24	0.06	0.35
	7	Urea	120	220	1.093	0.83	0.07	0.31
	8	AS	120	220	1.093	1.05	0.05	0.44
	9	ESN + Duration	120	220	1.093	3.23	0.03	0.34
	10	Agrocote Max	120	220	1.092	1.61	0.18	0.44
	Treatment significance, both fields combined				++	**	NS	NS
	Treatment MSD (P < 0.1)				0.002	1.34	--	--
	Field			New	1.095	1.55	0.04	0.36
				Old	1.091	1.24	0.11	0.39
	Field significance				**	NS	NS	NS
	Field * Treatment significance				++	NS	++	NS

[1]Ammonium sulfate: 21-0-0. Urea: 46-0-0. ESN (Environmentally Smart Nitrogen, Agrium, Inc.): 44-0-0. Agrocote Max (Everris): 44-0-0. Duration (Agrium, Inc.): 43-0-0.

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

Figure 8. Tuber specific gravity as a function of application rate of N as ESN at emergence (means ± S.E.) in the new field versus the old field.

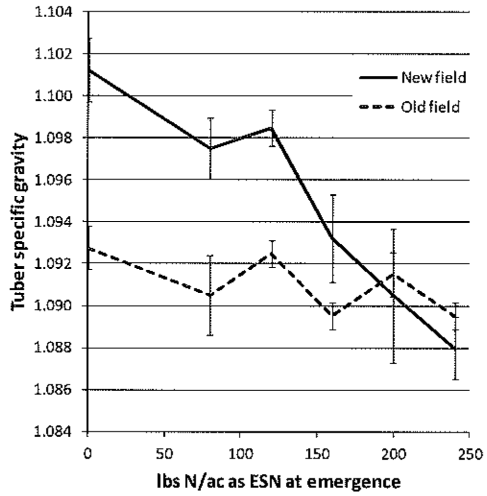

Table 6. Effects of nitrogen application rate and source on residual soil nitrogen in the study field on October 28 (Old Field) and November 6 (New Field). Total nitrogen application rates are rough averages for the two fields; see Table 2 for actual non-emergence N application rates.

	Nitrogen Treatments				Residual soil N (ppm)		
	Treatment	Nitrogen source[1]	Application rate at emergence (lbs N / ac)	Total nitrogen (lbs N / ac)	NH4-N	NO3-N	Total
Effect of ESN application rate (comparing treatments 1-6).	1	Control	0	100	0.17	8.34	8.51
	2	ESN	80	180	0.33	6.95	7.28
	3	ESN	120	220	0.14	8.47	8.60
	4	ESN	160	260	0.33	7.93	8.26
	5	ESN	200	300	0.16	8.13	8.29
	6	ESN	240	340	0.26	7.95	8.21
	Treatment significance, both fields combined				NS	NS	NS
	Treatment MSD (P < 0.1)				--	--	--
	Contrasts[2]			Linear	NS	NS	NS
				Quadratic	NS	NS	NS
	Field			New	0.38	7.23	7.61
				Old	0.07	8.70	8.77
	Field significance				**	*	++
	Field * Treatment significance				NS	NS	NS

Effect of nitrogen source (comparing treatments 3, 7 - 10).	3	ESN	120	220	0.14	8.47	8.60
	7	Urea	120	220	0.34	7.97	8.31
	8	AS	120	220	0.32	7.81	8.13
	9	ESN + Duration	120	220	0.27	9.16	9.44
	10	Agrocote Max	120	220	0.45	7.81	8.26
	Treatment significance, both fields combined				NS	NS	NS
	Treatment MSD (P < 0.1)				--	--	--
	Field			New	0.54	8.35	8.88
				Old	0.07	8.14	8.21
	Field significance				**	NS	NS
	Field * Treatment significance				NS	NS	NS

[1]Ammonium sulfate: 21-0-0. Urea: 46-0-0. ESN (Environmentally Smart Nitrogen, Agrium, Inc.): 44-0-0. Agrocote Max (Everris): 44-0-0. Duration (Koch Agronomic Services, LLC): 43-0-0.

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

Optimizing Potassium Management for Irrigated Potato Production: Red Norland

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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 Red Norland yield and quality, petiole K concentrations, and differences in soil test K at three soil depths after harvest. Six K treatments were tested: a zero K control; 160 and 320 lb K_2O/A applied preplant; 160 lb K_2O/A applied at planting; a split application of 160 lb K_2O/A preplant + 160 lb K_2O/A at planting; and a split application of 160 lb K_2O/A at planting + 160 lb K_2O/A at emergence. The 160 lb K_2O/A rate significantly increased total yield above the zero K control. Total yield was similar at 320 lb K_2O/A, but tuber size was significantly smaller compared with the 160 lb K_2O/A rate. Tuber size was also affected by application timing, but the effect varied depending on the total K rate. At the 160 lb K_2O/A rate tuber size was greater when the K was applied preplant rather than at planting, but at the 320 lb K_2O/A rate, tuber size was significantly greater with split application than when the total amount was applied preplant. None of the treatments affected skin color or the amount of skinning, but the 160 lb K_2O/A rate had significantly greater specific gravity and tuber dry matter than both the zero K and 320 lb K_2O/A rates. Petiole K concentrations were similar for all treatments on the first two sampling dates, but were significantly affected by both K application rate and timing on the final two dates. Petiole K increased linearly as the K rate increased and the highest concentrations, which were still slightly below sufficiency levels, occurred with 320 lb K_2O/A in a single preplant application rather than split-applied. Low petiole K indicates conditions were favorable for a yield response to K, so lack of response could have been due to another factor that was limiting yield more than K. Soil K decreased throughout the upper two ft. of soil between the fall of 2013 and the spring of 2014 before fertilizer application, suggesting there was leaching of K during this time interval. Between the spring and fall of 2014, significant linear increases in residual soil K occurred in both the 0-6 in. and 6-12 in. soil depths as the K application rate increased. Increases were greater in the 0-6 in. depth when all of the K was applied preplant. Soil K decreased 26 ppm between spring and fall in the 0-6 in. soil layer of the zero K control, showing the drawdown in soil K from a 282 cwt/A crop. The change in soil K for the 160 lb K_2O/A rate was a decrease of 6 ppm. This indicates that a somewhat higher rate was required to maintain soil test K, which is consistent with the currently recommended K rate of 200 lb K_2O/A for the initial soil test level in this field and the yields achieved.

Background: In response to numerous questions over several growing seasons about soil test potassium (K) levels, potential leaching losses of K, and lower petiole K levels than normal, a K study was initiated on Russet Burbank potatoes in 2012. This study was designed 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. Following the first year of this research, similar questions were asked about K management for Red Norland, so the study was expanded to include this earlier maturing potato cultivar.

The objectives of the Red Norland part of the study were to: 1) evaluate Red Norland response to K fertilizer rate and timing, 2) determine changes in soil test K resulting from K fertilization, and 3) determine the extent of K movement in the soil during the growing season. This is the second year of K management research on Red Norland.

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, 6.3; organic matter, 1.4%; Bray P1, 22 ppm; ammonium acetate extractable K, Ca, and Mg, 72, 714, and 131 ppm, respectively; Ca-phosphate extractable SO_4-S, 1 ppm; hot water extractable B, 0.1 ppm; and DTPA extractable Fe, Mn, Cu, and Zn, 20, 6, 0.4, and 0.8 ppm, respectively. Extractable nitrate-N in the top 2 ft of soil was 12.7 lb/A and ammonium-N was 42.1 lb/A.

Four, 20-ft rows were planted for each plot with the middle two rows used for sampling and harvest. Whole "B" seed of Red Norland potatoes were hand planted in furrows on April 22, 2014. Row spacing was 10 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 K treatments were tested as described in Table 1 below: a zero K control; 160 and 320 lb K_2O/A applied preplant; 160 lb K_2O/A applied at planting; a split application of 160 lb K_2O/A preplant + 160 lb K_2O/A at planting; and a split application of 160 lb K_2O/A at planting + 160 lb K_2O/A at emergence. Preplant K was broadcast and incorporated to a depth of 3 to 4 inches with a field cultivator on April 15. Potassium applied at planting was banded 3 inches to each side and 2 inches below the seed piece using a metered, drop fed applicator. Emergence K was sidedressed on May 29 and mechanically incorporated during hilling. Potassium chloride (0-0-60) was the K source for all treatments.

All treatments received a total of 230 lb N/A applied at planting (40 lb N/A), emergence/hilling (140 lb N/A), and post-hilling (one application of 30 lb N/A and a second application of 20 lb/A). Nitrogen at planting was supplied as diammonium phosphate (DAP) and was banded as described above for the treatments with K applied at planting. Emergence N applications were supplied as urea and mechanically incorporated during hilling on May 29 (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 June 30 and July 10. In addition to N, banded fertilizer at planting (for all treatments) included 102 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 DAP, zinc sulfate and zinc oxide (EZ 20), and sodium tetraborate (Granubor 2).

Plant stands and stem number per plant were measured on June 16. Petiole samples were collected from the 4th leaf from the terminal on four dates: June 16, July 1, July 8, and July 22. Petioles were analyzed for K on a dry weight basis. Vines were chemically killed using two applications of the dessicant Reglone on Aug 1 and Aug 8 and were chopped on Aug 19. Tubers were machine harvested on Aug 25 from two, 18-ft sections of row in 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 were collected in the fall of 2013 and in the spring and fall of 2014 from three soil depths (0-6 in., 6-12 in., and 12-24 in.) in each plot and analyzed for ammonium acetate extractable K. Fall 2013 samples were collected after soybean harvest on Oct 9. Spring 2014 samples were collected on April 10 before preplant fertilizer application and planting. Fall 2014 samples were collected after harvest on Oct 20.

Table 1. Potassium treatments[1] tested on irrigated Red Norland potatoes.

Treatment #	Timing and rate of potassium application			Total potassium
	Preplant	Planting	Emergence	
	lbs K_2O/A			
1	0	0	0	0
2	160	0	0	160
3	320	0	0	320
4	0	160	0	160
5	160	160	0	320
6	0	160	160	320

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

Results

Tuber Yield and Size Distribution: Table 2 shows the effects of K rate and application timing on tuber yield and size distribution. The only significant effect on total tuber yield was a quadratic increase in total yield with increasing K rate. The zero K treatment had the lowest yield, but there was no significant difference in total yield when the 160 lb K_2O/A treatments were compared with the 320 lb K_2O/A treatments. Potassium application rate did have significant effects on tuber size. Significantly lower yields of tubers in the two smallest size classes (< 2.25 in.) occurred at the 160 lb K_2O/A rate than at 320 lb K_2O/A. The situation was reversed for the two largest size classes (> 2.50 in.), where yields were significantly greater at the 160 lb K_2O/A rate than at 320 lb K_2O/A. There was also a steady linear increase in yield of tubers in the 2.25 to 2.50 in. size class as K rate increased from zero to 160 to 320 lb K_2O/A.

Application timing also had significant effects on tuber size. Preplant rather than split application of 320 lb K_2O/A resulted in significantly greater yields of 1.75 to 2.25 in. tubers and significantly lower yields of tubers > 2.50 in. Preplant rather than planting application of 160 lb K_2O/A resulted in significantly greater yields of tubers in both the < 1.75 in. and 2.50 to 3.00 in. size classes.

Tuber Quality: Table 3 shows the effects of K rate and timing on tuber quality, plant stand, and the number of stems per plant. For the Munsell color components related to the intensity and quality of Norland's red color, none of the K treatments had any effect. The same was true for the subjective Visual Red rating scale. And neither K rate nor application timing affected the amount of tuber skinning.

Tuber specific gravity was affected by K rate, but not by application timing. The two treatments receiving 160 lb K_2O/A had the highest specific gravities and the zero and 320 lb K_2O/A treatments had the lowest. The same pattern occurred for tuber dry matter. The 160 lb K_2O/A treatments had significantly greater dry matter percentages than either the zero or 320 lb K_2O/A rates, which were similar.

Hollow heart and brown center were also affected by K rate, but not by application timing. Although the overall incidence of these disorders was relatively low, they both were significantly greater when the K rate was 320 lb K_2O/A. The two lower K rates had similar incidences of both disorders. Scab, plant stand, and the number of stems per plant were not affected by either K application rate or timing.

Petiole K Concentrations: Petiole K concentrations on four dates as affected by K fertilizer rate and application timing are presented in Table 4. On the first two sampling dates there were no significant differences in petiole K among any of the treatments. Concentrations ranged from 5.9 to 7.6 % K on the first date and 6.3 to 7.2% K on the second. The sufficiency range for petiole K in potatoes is 8.0-10.0%, so all treatments on the first two dates were at least slightly below this range. However, this sufficiency range was established for petioles sampled 40-50 days after emergence and the first sampling dates were 18 and 33 days after emergence. Potassium application rate had significant effects on petiole K on the last two sampling dates, which occurred 40 and 54 days after emergence. There were significant linear increases in petiole K as the K application rate increased on both dates, although the range in concentration was much greater on the final sampling date. On the 3rd date, the range was from 6.0% K for the zero K control to 6.1% for 160 lb K_2O/A and 6.9% for the 320 lb K_2O/A rate. On the 4th date, petiole K increased from 2.7% to 3.1% to 7.1% as the K rate increased. Only the 320 lb K_2O/A rate was within 1% K of the sufficiency level. These petiole concentrations suggest that conditions were right for a yield response to K in this study, but since yields were comparable for the 160 lb K_2O/A and 320 lb K_2O/A rates, the lack of response could have been due to some other factor that was limiting yield more than K.

As with application rate effects, application timing had no effect on petiole K on the first two sampling dates, but significant differences did occur at the 320 lb K_2O/A rate on the final two samplings. Petiole K on both dates was greater when all 320 lb K_2O/A was applied preplant compared with split applications of 160 lb K_2O/A preplant + 160 lb K_2O/A at planting or 160 lb K_2O/A at planting + 160 lb K_2O/A at emergence. Petiole K on the 3rd date was 7.5% for the single preplant application and averaged 6.6% for the split applications. On the 4th sampling date preplant was 7.9% and split application was 6.7%. So petiole K on these dates was very close to the critical level of 8.0% K for the 320 lb K_2O/A preplant treatment.

Soil Test K: Table 5 shows K concentrations at the 0-6 in., 6-12 in., and 12-24 in. soil depths in the fall of 2013 after soybean harvest, in the spring of 2014 before K fertilizer application and potato planting, and in the fall of 2014 after potato harvest. It also shows the change in soil K between spring and fall in 2014 at all three depths.

Soil K levels in the fall of 2013 were variable across the study area and some of the variability coincided with significant differences among the future plots that had been randomly assigned to certain treatments. Most of this variability had disappeared by the following spring, leaving a relatively uniform area suitable for the initiation of the study. The only remaining pattern in the spring of 2014 was a relatively small decrease in soil K as the assigned K rate increased: 70 ppm average for the zero K control, 66 ppm for the 160 lb K_2O/A plots, and 62 ppm average for the plots assigned to the 320 lb K_2O/A treatment. The change toward greater uniformity in soil K in the study area was associated with a decrease in soil K over the winter at all soil depths. Soil K decreased by an average of 15 ppm in the 0-6 in. depth, 7 ppm at 6-12 in., and 18 ppm at 12-24 in. These changes in soil K between the fall of 2013 and the spring of 2014 suggest there was leaching of K throughout the upper two ft. of this loamy sand soil.

Changes in soil test K levels between the spring and fall of 2014 appeared to be driven by the effects of spring fertilizer application rather than leaching. There were significant linear increases in residual soil K in both the 0-6 in. and 6-12 in soil depths as the K application rate increased. In the 12-24 in. depth, soil K generally decreased slightly between spring and fall, but there were no significant differences among treatments in the amount of change over the growing season. In the 0-6 in. soil depth, application timing also affected residual soil K in the fall and changes in soil K between spring and fall. Preplant application of 320 lb K_2O/A significantly increased soil K in the fall, as well as the change from spring to fall, compared with the two treatments that received the same total K rate in split applications. Similarly, preplant application of 160 lb K_2O/A significantly increased soil K in the fall compared with the same rate applied at planting. Preplant application resulted in a small positive change in K between spring and fall in the 0-6 in soil depth, whereas application at planting resulted in a decrease.

For the zero K control, there was a 26 ppm decrease in soil K between spring and fall in the 0-6 in. soil layer. This decrease represents the drawdown in soil K from a Red Norland potato crop with a total yield of 282 cwt/A (Table 2). The average change in soil K for the 160 lb K_2O/A treatments was a decrease of 6 ppm and the average change for the 320 lb K_2O/A rate was an increase of 19 ppm. This suggests that an intermediate K rate, closer to 160 than 320 lb K_2O/A, is required to maintain soil test K at the average yield levels of 322 cwt/A achieved at those rates in this study. At the initial soil test K level in this field and for the highest total yields achieved, the recommended K rate would have been 200 lb K_2O/A, which is consistent with these results.

Conclusions

This study found that in a field with an initial soil test K level of 70 ppm, applying 160 lb K_2O/A increased total yield of Red Norland and there was no further increase at 320 lb K_2O/A. The 160 lb K_2O/A rate produced significantly larger tuber size than the 320 lb K_2O/A rate and the size increase was greater when the K was applied preplant rather than at planting. At the 320 lb K_2O/A rate, tuber size was significantly greater with split application than when the total amount was applied preplant.

Potassium application rate and timing did not affect skin color or the amount of skinning, but the 160 lb K_2O/A rate had significantly greater specific gravity and tuber dry matter than both the zero K and 320 lb K_2O/A rates.

Petiole K concentrations were similar for all treatments on the first two sampling dates, but were significantly affected by both application rate and timing on the final two sampling dates. There were significant linear increases in petiole K as the K application rate increased on the 3rd and 4th sampling dates, although all of the treatments were below the K sufficiency range of 8.0 to 10.0%. The 320 lb K_2O/A rate was the only one with petiole K in the 7% range. Highest petiole K (7.5 and 7.9% on the last two sampling dates) occurred when the highest K rate was in a single preplant application rather than split into two applications. These petiole concentrations suggest that conditions were right for a yield response to K in this study, but since yields were comparable for the 160 lb K_2O/A and 320 lb K_2O/A rates, the lack of response could have been due to some other factor that was limiting yield more than K.

Soil K decreased by 7 to 18 ppm at all three measured soil depths between the fall of 2013 and the spring of 2014 before any fertilizer application, suggesting there was leaching of K throughout the upper two ft. of soil. Changes in soil test K levels between the spring and fall of 2014 were affected by both K application rate and timing. Significant linear increases in residual soil K occurred in both the 0-6 in. and 6-12 in. soil depths as the K application rate increased. Preplant K application significantly increased soil K in the 0-6 in. depth compared with application at planting or split applications, although the reason for these differences is unclear.

Soil K decreased 26 ppm between spring and fall in the 0-6 in. soil layer of the zero K control, representing the drawdown in soil K from a 282 cwt/A crop yield. The average change in soil K for the 160 lb K_2O/A rate was a decrease of 6 ppm, indicating that a somewhat higher rate is required to maintain soil test K under the conditions of this study. This is consistent with the currently recommended K rate of 200 lb K_2O/A for the initial soil test level in this field and the yields achieved.

Table 2. Effect of potassium application rate and timing on Red Norland tuber yield and size distribution.

Potassium treatments			Tuber yield					
Treatment #	Potassium timing[1] (PP, P, E)	Total potassium	< 1.75"	1.75" - 2.25"	2.25" - 2.50"	2.50" - 3.00"	> 3.00"	Total
	lbs K_2O/A		cwt/A					
1	0, 0, 0	0	13	61	93	75	41	282
2	160, 0, 0	160	13	44	122	105	62	346
3	320, 0, 0	320	15	78	143	51	21	309
4	0, 160, 0	160	9	46	111	84	65	315
5	160, 160, 0	320	14	71	133	66	33	318
6	0, 160, 160	320	15	55	112	88	49	320
		Significance[2]	NS	**	++	**	**	NS
		BLSD (0.1)	--	9	32	18	18	--
Contrasts[2]	K rate: 160 vs. 320 (trt 2,4 vs. 3,5,6)		*	**	NS	**	**	NS
	Preplant vs. Split (trt 3 vs. 5,6)		NS	**	NS	**	*	NS
	Preplant vs. Planting (trt 2 vs. 4)		++	NS	NS	*	NS	NS
	Linear K rate (trt 1, 2/4, 3/5/6)		NS	**	*	++	*	NS
	Quadratic K rate (trt 1, 2/4, 3/5/6)		NS	**	NS	**	**	*

[1]PP: preplant. P: planting. E: emergence / hilling.

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

Table 3. Effect of potassium application rate and timing on Red Norland tuber quality, plant stand, and number of stems per plant.

Potassium treatments			Tuber quality										Plant stand	Stems per plant
Treatment #	Potassium timing[1] (PP, P, E)	Total potassium	Munsell color (Red)			Visual red[2]	Visual skinning[3]	Specific gravity	Hollow heart	Brown center	Scab	Dry matter		
			Hue	Value	Chroma									
	lbs K_2O/A								%					
1	0, 0, 0	0	3.9	4.3	3.4	3.0	1.0	1.0608	0.8	0.8	70.9	16.1	99.4	3.3
2	160, 0, 0	160	4.3	4.3	3.3	3.0	1.0	1.0633	0.8	0.8	72.5	17.0	99.4	3.5
3	320, 0, 0	320	4.0	4.3	3.3	3.0	1.0	1.0597	2.5	2.5	74.2	15.6	98.3	3.5
4	0, 160, 0	160	4.2	4.2	3.2	3.0	1.0	1.0650	0	0	73.3	16.6	97.7	4.1
5	160, 160, 0	320	4.1	4.2	3.2	3.0	1.0	1.0613	1.7	1.7	75.8	16.4	98.9	3.6
6	0, 160, 160	320	4.2	4.3	3.3	3.0	1.0	1.0610	2.5	3.3	65.8	16.2	97.2	3.8
		Significance[4]	NS	NS	NS	NA	NA	*	NS	NS	NS	**	NS	NS
		BLSD (0.1)	--	--	--	--	--	0.0031	--	--	--	0.5	--	--
Contrasts[4]	K rate: 160 vs. 320 (trt 2,4 vs. 3,5,6)		NS	NS	NS	NA	NA	**	*	++	NS	**	NS	NS
	Preplant vs. Split (trt 3 vs. 5,6)		NS	NS	NS	NA	NA	NS	NS	NS	NS	*	NS	NS
	Preplant vs. Planting (trt 2 vs. 4)		NS	NS	NS	NA	NA	NS	NS	NS	NS	NS	NS	NS
	Linear K rate (trt 1, 2/4, 3/5/6)		NS	NS	NS	NA	NA	NS	++	++	NS	NS	NS	NS
	Quadratic K rate (trt 1, 2/4, 3/5/6)		NS	NS	NS	NA	NA	**	NS	NS	NS	**	NS	NS

[1]PP: preplant. P: planting. E: emergence / hilling.

[2]On a scale of 1: pale red to 5: dark red.

[3]On a scale of 1: < 10% to 5: > 80%.

[4]NS: Non significant. NA: no variability. ++, *, **: Significant at 10%, 5%, and 1%, respectively.

Table 4. Effect of potassium application rate and timing on petiole potassium concentrations on four dates.

Potassium treatments			Petiole K			
Treatment #	Potassium timing[1] (PP, P, E)	Total potassium	16-Jun	1-Jul	8-Jul	22-Jul
	lbs K_2O/A		%			
1	0, 0, 0	0	7.09	6.74	5.99	2.70
2	160, 0, 0	160	7.57	6.27	6.22	5.61
3	320, 0, 0	320	6.92	6.85	7.48	7.95
4	0, 160, 0	160	6.62	7.08	5.92	4.59
5	160, 160, 0	320	5.92	7.20	6.04	6.94
6	0, 160, 160	320	7.05	7.00	7.20	6.42
		Significance[2]	NS	NS	**	**
		BLSD (0.1)	--	--	0.86	1.26
Contrasts[2]	K rate: 160 vs. 320 (trt 2,4 vs. 3,5,6)		NS	NS	*	**
	Preplant vs. Split (trt 3 vs. 5,6)		NS	NS	*	*
	Preplant vs. Planting (trt 2 vs. 4)		NS	NS	NS	NS
	Linear K rate (trt 1, 2/4, 3/5/6)		NS	NS	**	**
	Quadratic K rate (trt 1, 2/4, 3/5/6)		NS	NS	NS	NS

[1]PP: preplant. P: planting. E: emergence / hilling.

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

Table 5. Potassium concentrations at three soil depths: 1) in the fall of 2013 after soybean harvest, 2) in the spring of 2014 before K fertilizer application and potato planting, 3) in the fall of 2014 after potato harvest, and 4) the change in soil K between spring 2014 and fall 2014 (fall minus spring).

Potassium treatments			Soil potassium[2] (ppm)											
Treatment #	Potassium timing[1] (PP, P, E)	Total potassium	Fall 2013			Spring 2014			Fall 2014			Change from Spring '14 to Fall '14		
			Soil depth (inches)											
	lbs K_2O/A		0-6	6-12	12-24	0-6	6-12	12-24	0-6	6-12	12-24	0-6	6-12	12-24
1	0, 0, 0	0	76	77	78	70	52	59	45	37	49	-26	-15	-10
2	160, 0, 0	160	77	66	76	66	51	62	68	44	54	3	-7	9
3	320, 0, 0	320	86	76	80	63	49	60	92	57	57	29	9	-3
4	0, 160, 0	160	76	67	64	65	49	54	51	39	51	-15	-10	-4
5	160, 160, 0	320	78	72	81	62	54	59	73	64	57	11	11	-2
6	0, 160, 160	320	84	71	71	60	49	48	78	51	46	18	2	-2
		Significance[3]	NS	NS	NS	NS	NS	NS	**	**	++	**	*	NS
		BLSD (0.1)	--	--	--	--	--	--	17	12	8	16	15	--
Contrasts[3]	K rate: 160 vs. 320 (trt 2,4 vs. 3,5,6)		*	++	++	NS	NS	NS	**	**	NS	**	**	NS
	Preplant vs. Split (trt 3 vs. 5,6)		NS	NS	NS	NS	NS	NS	++	NS	NS	++	NS	NS
	Preplant vs. Planting (trt 2 vs. 4)		NS	NS	++	NS	NS	NS	++	NS	NS	++	NS	NS
	Linear K rate (trt 1, 2/4, 3/5/6)		*	NS	NS	*	NS	NS	**	**	NS	**	**	NS
	Quadratic K rate (trt 1, 2/4, 3/5/6)		NS	*	++	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1]PP: preplant. E: emergence / hilling.

[2]Ammonium acetate extractable K.

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

Optimizing Potassium Management for Irrigated Potato Production: Russet Burbank

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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. Application season (fall vs. spring) had no effect on tuber yield. Both total and marketable yields increased significantly as K rate increased to 180 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, single-application treatments also tended to increase tuber size compared to split-application treatments. Tuber specific gravity, dry matter, and incidence of hollow heart and brown center all decreased significantly as K rate increased. Single application resulted in significantly more hollow heart, brown center, and dry matter than split K application, but significantly lower incidence of scab. Increasing K rate significantly reduced early plant stands and stem numbers per plant, although final stands were not affected by treatment. Delayed emergence and reduced stem numbers could have contributed to the lack of a yield response at the highest K rates. 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. Only the 270 and 360 lb K_2O/A rates ever reached the minimum sufficiency level of 8% K. Because yields peaked at 180 lb K_2O/A, and additional K did increase petiole K above or closer to the sufficiency range, the absence of a yield response to K at the highest K rates may have been due to other limiting growth factors. For the group of treatments that had fall-applied K, soil K increased significantly in the 0-6 in. depth as the K rate increased in both the spring and fall of 2014 in. The zero K treatment decreased 12 ppm K over the winter between fall 2013 and spring 2014, indicating some K leaching occurred from the 0-6 in. soil layer. The annual change in soil test K in the 0-6 in. soil depth from fall 2013 to fall 2014 decreased significantly as the K application rate increased. For the zero K control, there was a 44 ppm decrease in soil K from fall to fall that corresponds to the drawdown in soil K from a Russet Burbank potato crop with a total yield of 411 cwt/A. The 360 lb K_2O/A rate in a single application was the only fall-applied K treatment that increased soil test K (by 20 ppm). This suggests that something less than 360 lb K_2O/A is adequate to maintain soil test K at 0-6 in. for a yield of 458 cwt/A. The current recommendation to obtain this yield at the fall 2013 soil test K level of 79 ppm is right on the cusp between the 200 or 300 lb K_2O/A rate recommendations. For the group of treatments that did not have any fall-applied K, post-harvest soil sampling showed a significant linear increase in K concentrations in the in the 0-6 in. soil depth as the K application rate increased. For the zero K control, there was a 27 ppm decrease in soil K between spring and fall, indicating the drawdown in soil K from a Russet Burbank crop yielding 397 cwt/A. The average change in soil K for the 180 lb K_2O/A treatments was a decrease of 7 ppm and the average change for the 270 lb K_2O/A rate was an increase of 16 ppm. This suggests that an intermediate K rate, closer to 180 than 270 lb K_2O/A, is required to maintain soil test K levels at the average 458 cwt/A yields achieved at those rates in this study. This conclusion is consistent with current K fertilizer recommendations.

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 third year of the study and the first 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 soybeans. Selected soil chemical properties before planting were as follows (0-6"): pH, 6.4; organic matter, 1.5%; Bray P1, 27 ppm; ammonium acetate extractable K, Ca, and Mg, 93, 783, and 138 ppm, respectively; Ca-phosphate extractable SO_4-S, 3 ppm; hot water extractable B, 0.2 ppm); and DTPA extractable Fe, Mn, Cu, and Zn, 24, 7.3, 0.7, and 1.6 ppm, respectively. Extractable nitrate-N in the top 2 ft of soil was 16.0 lb/A and ammonium-N was 29.9 lb/A.

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 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.

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 2013 and a split application of 180 lb K_2O/A in the fall + 180 lb K_2O/A at crop emergence in 2014; and 0, 90, 180, 270, and 360 lb K_2O/A applied preplant in the spring of 2014 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 13, 2013. Preplant K was broadcast and incorporated to a depth of 3 to 4 inches with a field cultivator on Apr 15, 2014. Emergence K was sidedressed on June 4 and mechanically incorporated during hilling. Potassium chloride (0-0-60) was the K source for all treatments.

All treatments received a total of 260 lb N/A applied preplant (90 lb N/A), at planting (30 lb N/A), at emergence/hilling (80 lb N/A), and post-hilling (three applications of 20 lb N/A). Preplant N was supplied as ESN and broadcast incorporated to a depth of 3 to 4 inches with a field cultivator on May 5. Nitrogen at planting (May 7) 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 ESN and mechanically incorporated during hilling on June 4 (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 June 30, July 10, and July 23. 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 and stem number per plant were measured on June 26. Petiole samples were collected from the 4th leaf from the terminal on four dates: June 27, July 8, July 22, and July 31. Petioles were analyzed for K on a dry weight basis. Vines were killed by mechanical beating on Sept 12 and tubers were machine harvested on Sept 22. 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 were collected in the fall of 2013 and in the spring and fall of 2014 from three soil depths (0-6 in., 6-12 in., and 12-24 in.) in each plot and analyzed for ammonium acetate extractable K. Fall 2013 samples were collected after soybean harvest on Oct 9. Spring 2014 samples were collected on April 11 and 15 before preplant fertilizer application and planting. Fall 2014 samples were collected after harvest on Oct 20 and 21.

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

Tuber Yield and Size Distribution: Table 2 shows the effects of K rate and timing on tuber yield and size distribution. Significant differences occurred due to K rate and single vs. split application timing, but application season (fall vs. spring) had no effect and there were no significant rate x season interactions.

Both total and marketable yields increased significantly as K rate increased to 180 lb K_2O/A, before leveling off at the higher K rates. Yield increases were due to increases in tuber size. As K rate increased, there were significant linear decreases in tuber yield for the two smallest size classes and significant linear yield increases for the two largest size classes. These rate effects on tuber size generally occurred up to 270 lb K_2O/A and leveled off at 360 lb K_2O/A. All K rates produced similar yields of intermediate-sized 6-10 oz tubers.

When applied at the same total K rate, single-application treatments tended to increase tuber size compared to split-application treatments. Single application resulted in significantly greater yield of 10-14 oz tubers and a significantly greater percentage of tubers >10 oz. Split application resulted in significantly greater yields of tubers in the 6-10 oz size class.

Tuber Quality, Plant Stand, and Stems per Plant: Application season had no effects on tuber quality, but K application rate significantly affected all measured quality components except the incidence of scab (Table 3). Overall, specific gravity decreased significantly as K rate increased, although the zero K treatment was inconsistent with the otherwise uniform decrease with rate. Hollow heart, brown center, and tuber dry matter also decreased as K rate increased. Single application resulted in significantly more hollow heart, brown center, and dry matter than split application, but significantly lower incidence of scab.

Plant stand was measured twice because of lower than expected emergence on June 11 (Table 3). At this time there was a significant decrease in stand as K rate increased and reduced stand for single rather than split K application. Two weeks later stands had improved and there were no significant stand differences among treatments. Delayed emergence as K rate increased may not have affected yield up to the180 lb K_2O/A rate, but it could have played a role in the lack of further increases in yield at the two highest K rates (Table 2). The number of stems per plant also decreased significantly as K rate increased (Table 3). This could have been due to delayed emergence and may have contributed to yield effects.

Petiole K Concentrations: Petiole K concentrations on four dates during the growing season are presented in Table 4. 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. On the 1st sampling date, the split application treatments averaged significantly greater petiole K than the treatments receiving the same total rate in a single application. On the other three dates there were no differences between single vs. split application of K.

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 applicable at other growth stages. The sampling times in Table 4 are 24, 34, 48, and 57 days after emergence. The only times petiole K was above 8% was on the 3rd sampling date for both of the 270 lb K_2O/A treatments and three of the four 360 lb K_2O/A treatments, and on the 4th sampling date for one of the 360 lb K_2O/A treatments. Petiole K was above 7% on all four sampling dates for the 360 lb

K_2O/A rate and above 6% K on all four dates for 270 lb K_2O/A. Since yields peaked at 180 lb K_2O/A, and applying additional K did increase petiole K above or closer to the sufficiency range, the absence of a yield response to K at the highest K rates may have been due to other limiting growth factors.

Soil Test K: Table 5 provides soil K concentrations at three soil depths for the treatments that received fall-applied K. Samples were collected in the fall of 2013 after soybean harvest and before fall fertilizer applications, in the spring of 2014 before potato planting, and in the fall of 2014 after potato harvest. The over winter change in soil K between fall 2013 and spring 2014, the growing season change in soil K between spring 2014 and fall 2014, and the annual change in soil K between fall 2013 and fall 2014 are also shown.

In the 0-6 in. soil depth, most plots had similar K concentrations in fall 2013 before fertilizer was applied, except for a pre-existing significant difference between the plots that were going to receive single or split applications of 360 lb K_2O/A. In the spring and fall of 2014, there were significant linear increases in soil K as the K rate increased. These contrasts did not include the split application of 360 lb K_2O/A, where only ½ of the total K rate was applied in the fall and the remaining ½ had not yet been applied at the time of spring soil sampling. This difference in application timing led to a significant difference between the split-applied and single application treatments in the overwinter change in soil K from fall 2013 to spring 2014.

The zero K treatment decreased 12 ppm K over the winter between fall 2013 and spring 2014, indicating some K leaching occurred from the 0-6 in. soil layer during this time interval. For the other treatments, there was a significant linear increase between fall and spring as K application rate increased. The growing season change from spring 2014 to fall 2014 was negative for all treatments and there was a significant linear decrease in soil K as the K rate increased. This linear decrease was due to the high soil test K levels in the spring following fall 2013 K application. Increasing yield increases removal of K in harvested tubers, but yield did not increase continuously with K rate (Table 2). Yield only increased as K rate rose to 180 lb K_2O/A and leveled off at higher rates. These decreases in soil K between spring and fall suggest that the K requirement to maintain soil K at the yield levels achieved in this experiment is greater than 360 lb K_2O/A. This is much more than current recommendations at these yields and soil test K levels.

The annual change in soil test K in the 0-6 in. soil depth from fall 2013 to fall 2014 decreased significantly as the K application rate increased (Table 5). For the zero K control, there was a 44 ppm decrease in soil K from fall to fall that corresponds to the drawdown in soil K from a Russet Burbank potato crop with a total yield of 411 cwt/A (Table 2). The 360 lb K_2O/A rate in a single application was the only fall-applied K treatment that increased soil test K (Table 5). This suggests that something less than 360 lb K_2O/A is adequate to maintain soil test K at 0-6 in. for a yield of 458 cwt/A. The current recommendation to obtain this yield at the fall 2013 soil test K level of 79 ppm is right on the cusp between the 200 or 300 lb K_2O/A rate recommendations.

In the 6-12 in. soil depth in fall 2013, before fertilizer application, pre-existing conditions resulted in a linear decrease in soil K in the plots corresponding to those that would receive increasing K rates when they were applied. This condition would work against observing a response to increasing K application rates in these plots. This may have occurred in spring 2014 when soil K increased as K application rate increased, but leveled of by the 180 or 270 lb K_2O/A rates. The linear increase in soil K with increasing application rate was more pronounced in fall 2014, but still leveled off at 270 lb K_2O/A. The over winter change in soil K from fall 2013 to spring 2014 and the change in soil K between fall 2013 and fall 2014 both increased (became less negative) as the K application rate increased. There were no significant differences among treatments in changes in soil K between spring 2014 and fall 2014.

In the 12-24 in. soil depth, there were few treatment effects on soil K concentrations. Similar to the 0-6 in. depth, most plots had similar K concentrations in fall 2013 before fertilizer was applied, except for a pre-existing significant difference between the plots that were going to receive single or split applications of 360 lb K_2O/A. A significant difference in these treatments also occurred for the change in soil K between the fall of 2013 and the fall of 2014. In this case, the single application decreased significantly more than the split application. This could have occurred if there were leaching conditions and K movement between the fall K applications and the second of the split applications at emergence the following spring. In this case the split application treatment would have been exposed to less leaching pressure.

Table 6 provides soil K concentrations at three soil depths for the treatments that did not have any fall-applied K. Samples were collected in the spring before fertilizer application and planting and in the fall after harvest. The change in soil K between spring and fall is also shown. In the spring, there were similar K concentrations in the 0-6 in. soil depth of all plots, so this was an area with uniform K fertility for the study. In the fall, there was a significant linear increase in residual K concentrations as the K application rate increased. For the zero K control, there was a 27 ppm decrease in soil K between spring and fall in the 0-6 in. soil layer. This decrease represents the drawdown in soil K from a Russet Burbank potato crop with a total yield of 397 cwt/A (Table 2).

The average change in soil K between spring and fall for the 180 lb K_2O/A treatment was a decrease of 7 ppm and the average change for the 270 lb K_2O/A treatment was an increase of 16 ppm (Table 6). This suggests that an intermediate K rate, closer to 180 than 270 lb K_2O/A, is required to maintain soil test K levels at the average yields of 458 cwt/A achieved at those rates in this study. At the average initial soil test K level of 73 ppm in the 0-6 in. depth of the plots receiving those treatments, the recommended K rate would have been 300 lb K_2O/A to achieve a 458 cwt/A yield. This is greater than the maintenance level just described of between 180 and 270 lb K_2O/A. However, the average initial soil test K level in the plots being discussed was only 7 ppm below the transition point between a 300 lb K_2O/A recommendation and a 200 lb K_2O/A recommendation, so the results are actually reasonably consistent with current K fertilizer recommendations.

In the 6-10 in. and 12-24 in. soil depths, there were no significant differences due to K rate in either spring or fall. There were significant differences between single vs. split application of 360 lb K_2O/A in the change between spring and fall in the 6-12 in. depth, and in both spring and fall samples in the 12-24 in. depth. The change at 6-12 in. was due to the single-application treatment having an increase in soil K between spring and fall, compared with decreases for all of the other treatments, so this may have been an aberration. The differences at 12-24 in. were not meaningful, since a significant difference between the single- and split-application plots was present in the spring before any treatments were applied, and this initial difference then carried over to similarly affect the fall comparison.

Conclusions

This study found that in a field with an initial soil test K level of 93 ppm, both total and marketable yields increased significantly as K rate increased to 180 lb K_2O/A before leveling off at higher K rates. Application season (fall vs. spring) had no effects on tuber yield. Yield increases were due to increases in tuber size as K rate increased. The percentage of tubers >6 oz and >10 oz both increased significantly as the K rate increased up to 270 lb K_2O/A, before leveling off at 360 lb K_2O/A. When applied at the same total K rate, single-application treatments also tended to increase tuber size compared to split-application treatments. However, the increase in tubers >10 oz with single application was accompanied by significantly greater yields of tubers in the 6-10 oz size class with split application.

Tuber specific gravity and dry matter, and incidence of hollow heart and brown center, all decreased significantly as K rate increased. Single application resulted in significantly more hollow heart, brown center, and dry matter than split K application, but significantly lower incidence of scab. Increasing K rate significantly reduced early plant stands, although final stands were not affected by treatment. Delayed emergence could have affected yield at the highest K rates. The number of stems per plant also decreased significantly as K rate increased, which could have been due to delayed emergence and may have had yield effects.

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. However, only the 270 and 360 lb K_2O/A rates ever reached the minimum sufficiency level of 8% K. Since yields peaked at 180 lb K_2O/A, and additional K did increase petiole K above or closer to the sufficiency range, the absence of a yield response to K at the highest K rates may have been due to other limiting growth factors. The annual change in soil test K in the 0-6 in. soil depth from fall 2013 to fall 2014 decreased significantly as the K application rate increased. For the zero K control, there was a 44 ppm decrease in soil K from fall to fall that corresponds to the drawdown in soil K from a Russet Burbank potato crop with a total yield of 411 cwt/A. The 360 lb K_2O/A rate in a single application was the only fall-applied K treatment that increased soil test K (by 20 ppm). This suggests that something less than 360 lb K_2O/A is adequate to maintain soil test K at 0-6 in. for a yield of 458 cwt/A. The current recommendation to obtain this yield at the fall 2013 soil test K level of 79 ppm is right on the cusp between the 200 or 300 lb K_2O/A rate recommendations.

For the group of treatments that had fall-applied K, there were significant linear increases in the spring and fall of 2014 in soil K at the 0-6 in. soil depth as the K rate increased. The zero K treatment decreased 12 ppm K over the winter between fall 2013 and spring 2014, indicating some K leaching occurred from the 0-6 in. soil layer during this time interval. For the other treatments, there was a significant linear increase between fall and spring as K application rate increased.

The annual change in soil test K in the 0-6 in. soil depth from fall 2013 to fall 2014 decreased significantly as the K application rate increased. For the zero K control, there was a 44 ppm decrease in soil K from fall to fall that corresponds to the drawdown in soil K from a Russet Burbank potato crop with a total yield of 411 cwt/A. The 360 lb K_2O/A rate in a single application was the only fall-applied K treatment that increased soil test K (by 20 ppm). This suggests that something less than 360 lb K_2O/A is adequate to maintain soil test K at 0-6 in. for a yield of 458 cwt/A. The current recommendation to obtain this yield at the fall 2013 soil test K level of 79 ppm is right on the cusp between the 200 or 300 lb K_2O/A rate recommendations.

In the 6-12 in. soil depth, soil K increased as K application rate increased in the spring and fall of 2014, but leveled of by the 180 or 270 lb K_2O/A rates. This indicates there was some movement of K below the zone of fertilizer incorporation. In the 12-24 in. soil depth, K application rate had no significant effects on soil K concentrations.

For the group of treatments that did not have any fall-applied K, the fall samples showed a significant linear increase in K concentrations in the in the 0-6 in. soil depth as the K application rate increased. For the zero K control, there was a 27 ppm decrease in soil K between spring and fall, which represents the drawdown in soil K from a Russet Burbank potato crop with a total yield of 397 cwt/A. The average change in soil K for the 180 lb K_2O/A treatments was a decrease of 7 ppm and the average change for the 270 lb K_2O/A rate was an increase of 16 ppm. This suggests that an intermediate K rate, closer to 180 than 270 lb K_2O/A, is required to maintain soil test K levels at the average yields of 458 cwt/A achieved at those rates in this study. This conclusion is relatively consistent with current K fertilizer recommendations.

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

Potassium treatments			Tuber yield										
Treatment #	Application timing[1] (Fall, Sp PP, Sp Em)	Total potassium	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
	lbs K_2O/A		cwt/A									%	
1	0, 0, 0	0	49	112	160	66	24	411	313	49	362	61	22
2	90, 0, 0	90	43	90	158	85	44	420	318	59	377	69	31
3	180, 0, 0	180	45	99	177	101	66	487	345	97	443	70	34
4	270, 0, 0	270	27	67	157	122	67	441	342	71	414	78	43
5	360, 0, 0	360	33	72	149	122	82	458	328	97	425	77	45
6	180, 0, 180	360	36	84	178	107	67	472	366	70	436	74	37
7	0, 0, 0	0	48	83	167	66	20	383	248	87	336	66	23
8	0, 90, 0	90	45	98	189	88	35	454	341	68	409	69	27
9	0, 180, 0	180	34	105	170	86	55	450	350	66	416	70	32
10	0, 270, 0	270	28	78	142	128	89	465	342	95	437	77	46
11	0, 360, 0	360	26	54	149	143	82	455	319	110	428	82	50
12	0, 180, 180	360	39	88	176	111	54	468	333	96	429	73	36
Overall treatment effect	Significance[2]		NS	NS	NS	**	*	NS	*	NS	*	++	**
	BLSD (0.1)		–	–	–	39	42	–	62	–	70	13	15
Main effects: Rate and application season	Application rate		++	++	NS	**	**	*	*	NS	**	**	**
	Application season (Fall vs. Spring)		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Rate * Season		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Contrasts	Single vs. split application (trt 5,11 vs. 6, 12)		NS	NS	++	++	NS	NS	NS	NS	NS	NS ,	*
	Linear K rate		*	*	NS	**	**	**	*	*	**	**	**
	Quadratic K rate		NS	NS	NS	NS	NS	++	*	NS	*	NS	NS

[1]Sp PP: spring, preplant. Sp Em: spring, at crop emergence and hilling.

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

Table 3. Effect of potassium application rate and timing on Russet Burbank tuber quality, plant stand, and number of stems per plant.

Potassium treatments			Tuber quality					Plant stand		Stems per plant
Treatment #	Application timing[1] (Fall, Sp PP, Sp Em)	Total potassium	Specific Gravity	Hollow heart	Brown center	Scab	Dry matter	June 11	June 26	June 26
	lbs K_2O/A			%						#
1	0, 0, 0	0	1.0870	25.0	25.0	8.0	20.6	93.1	97.9	4.1
2	90, 0, 0	90	1.0799	30.0	30.0	6.0	22.0	95.1	97.2	3.5
3	180, 0, 0	180	1.0808	14.7	14.7	8.0	21.3	93.8	96.5	3.4
4	270, 0, 0	270	1.0771	23.3	23.3	11.3	20.7	94.5	95.8	3.4
5	360, 0, 0	360	1.0779	17.3	17.3	8.0	21.4	85.5	96.5	3.5
6	180, 0, 180	360	1.0772	7.8	7.8	8.0	19.5	91.7	92.4	3.9
7	0, 0, 0	0	1.0782	24.0	24.0	12.0	21.3	97.2	97.2	4.4
8	0, 90, 0	90	1.0831	19.9	19.9	1.9	21.7	93.1	95.8	4.2
9	0, 180, 0	180	1.0778	17.2	17.2	7.1	21.1	95.8	95.1	3.7
10	0, 270, 0	270	1.0799	14.0	14.0	7.0	20.3	93.7	97.2	3.3
11	0, 360, 0	360	1.0767	23.1	23.1	0.0	20.5	87.5	97.2	3.4
12	0, 180, 180	360	1.0744	16.0	16.0	18.0	18.9	95.8	96.5	3.5
Overall treatment effect	Significance[2]		++	NS	NS	NS	**	NS	NS	NS
	BLSD (0.1)		0.0054	--	--	--	1.2	--	--	--
Main effects: Rate and application season	Application rate		*	++	++	NS	**	NS	NS	*
	Application season (Fall vs. Spring)		NS	NS	NS	NS	NS	NS	NS	NS
	Rate * Season		NS	NS	NS	NS	NS	NS	NS	NS
Contrasts	Single vs. split application (trt 5,11 vs. 6, 12)		NS	++	++	++	**	*	NS	NS
	Linear K rate		*	*	*	NS	**	++	NS	*
	Quadratic K rate		*	NS	NS	NS	*	NS	NS	++

[1]Sp PP: spring, preplant. Sp Em: spring, at crop emergence and hilling.

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

Table 4. Effect of potassium application rate and timing on petiole K concentrations on four dates.

Potassium treatments			Petiole K			
Treatment #	Application timing[1] (Fall, Sp PP, Sp Em)	Total potassium	June 27	July 8	July 22	July 31
	lbs K_2O/A		% K			
1	0, 0, 0	0	6.16	5.73	5.62	3.70
2	90, 0, 0	90	6.29	6.39	7.04	4.58
3	180, 0, 0	180	6.64	6.77	7.05	4.75
4	270, 0, 0	270	6.33	7.12	8.68	6.84
5	360, 0, 0	360	6.65	7.19	9.14	7.90
6	180, 0, 180	360	7.54	6.92	7.41	7.89
7	0, 0, 0	0	5.89	5.93	5.24	3.36
8	0, 90, 0	90	7.05	6.47	6.79	4.82
9	0, 180, 0	180	5.88	7.51	7.87	5.91
10	0, 270, 0	270	5.70	7.26	8.56	6.68
11	0, 360, 0	360	6.42	6.95	8.88	7.40
12	0, 180, 180	360	7.64	7.77	9.42	8.11
Overall treatment effect	Significance[2]		**	*	**	**
	BLSD (0.1)		0.80	1.18	1.65	0.72
Main effects: Rate and application season	Application rate		**	**	**	**
	Application season (Fall vs. Spring)		NS	NS	NS	NS
	Rate * Season		NS	NS	NS	NS
Contrasts	Single vs. split application (trt 5,11 vs. 6, 12)		**	NS	NS	NS
	Linear K rate		**	**	**	**
	Quadratic K rate		NS	++	NS	NS

[1]Sp PP: spring, preplant. Sp Em: spring, at crop emergence and hilling.

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

Table 5. Potassium concentrations at three soil depths for the treatments with fall-applied K: 1) in fall 2013 after soybean harvest, but before K fertilizer application, 2) in spring 2014 before preplant K fertilizer application and potato planting, 3) in fall 2014 after potato harvest, 4 over winter change in soil K between fall 2013 and spring 2014 (spring minus fall), 5) change in soil K between spring 2014 and fall 2013 (fall minus spring), and 6) change in soil K between fall 2013 and fall 2014 (fall 2014 minus fall 2013).

Fall potassium treatments			Soil potassium[1] (ppm)											
Treatment #	Application timing[2] (Fall, Sp PP, Sp Em)	Total potassium	Fall 2013[3]	Spring 2014[4]	Fall 2014[5]	Change[6] over winter	Change[7] Sp. to Fall	Change[8] Fall to Fall	Fall 2013[3]	Spring 2014[4]	Fall 2014[5]	Change over winter[6]	Change[7] Sp. to Fall	Change[8] Fall to Fall
	lbs K_2O/A		0 - 6" depth						6 - 12" depth					
1	0, 0, 0	0	84.8	72.8	41.3	-12.0	-31.5	-43.5	79.3	50.8	43.8	-28.5	-7.0	-35.5
2	90, 0, 0	90	93.5	97.5	58.0	4.0	-39.5	-35.5	74.0	55.3	47.3	-18.8	-8.0	-26.8
3	180, 0, 0	180	81.3	132.8	64.5	51.5	-68.3	-16.8	84.5	58.0	46.8	-26.5	-11.3	-37.8
4	270, 0, 0	270	90.3	148.0	82.0	57.8	-66.0	-8.3	72.8	59.3	65.5	-13.5	6.3	-7.3
5	360, 0, 0	360	78.5	180.0	98.8	101.5	-81.3	20.3	67.0	60.3	61.8	-6.8	1.5	-5.3
6	180, 0, 180	360	94.5	156.8	90.3	62.3	-66.5	-4.3	69.8	59.5	50.0	-10.3	-9.5	-19.8
		Significance[9]	*	**	**	**	NS	**	NS	NS	*	NS	NS	**
		BLSD (0.1)	11.3	39.2	17.1	38.2	--	16.5	--	--	14.2	--	--	10.2
Contrasts	Single vs. split application (trt 5 vs. 6)		*	NS	NS	++	NS	*	NS	NS	NS	NS	NS	*
		Linear K rate	NS	**	**	**	*	**	++	++	*	*	NS	**
		Quadratic K rate	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Fall potassium treatments			Soil potassium[1] (ppm)					
Treatment #	Application timing[2] (Fall, Sp PP, Sp Em)	Total potassium	Fall 2013[3]	Spring 2014[4]	Fall 2014[5]	Change[6] over winter	Change[7] Sp. to Fall	Change[8] Fall to Fall
	lbs K_2O/A		12 - 24" depth					
1	0, 0, 0	0	75.0	56.8	49.5	-18.3	-7.3	-25.5
2	90, 0, 0	90	78.0	53.3	55.3	-24.8	2.0	-22.8
3	180, 0, 0	180	85.8	59.8	58.5	-26.0	-1.3	-27.3
4	270, 0, 0	270	78.5	55.8	51.5	-22.8	-4.3	-27.0
5	360, 0, 0	360	89.3	64.5	51.5	-24.8	-13.0	-37.8
6	180, 0, 180	360	76.0	58.8	55.3	-17.3	-3.5	-20.8
		Significance[9]	NS	NS	NS	NS	NS	NS
		BLSD (0.1)	--	--	--	--	--	--
Contrasts	Single vs. split application (trt 5 vs. 6)		*	NS	NS	NS	NS	**
		Linear K rate	NS	NS	NS	NS	NS	NS
		Quadratic K rate	NS	NS	NS	NS	NS	NS

[1]Ammonium acetate extractable K.

[2]Sp PP: spring, preplant. Sp Em: spring, at crop emergence and hilling.

[3]Soil K concentration before fall treatments applied.

[4]Soil K concentration before spring planting.

[5]Soil K concentration in the fall after harvest.

[6]Over winter change, spring 2014 soil K minus fall 2013 soil K .

[7]Fall 2014 soil K minus spring 2014 soil K.

[8]Fall 2014 soil K minus fall 2013 soil K .

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

Table 6. Potassium concentrations at three soil depths for the treatments without fall-applied K: 1) spring 2014 before K fertilizer application and planting, 2) fall 2014 after harvest, and 3) change in soil K between spring 2014 and fall 2014 (fall minus spring).

Spring potassium treatments			Soil potassium[1] (ppm)								
Treatment #	Application timing[2] (Fall, Sp PP, Sp Em)	Total potassium	Spring 2014[3]	Fall 2014[4]	Change[5] Sp. to Fall	Spring 2014[3]	Fall 2014[4]	Change[5] Sp. to Fall	Spring 2014[3]	Fall 2014[4]	Change[5] Sp. to Fall
	lbs K_2O/A		0 - 6" depth			6 - 12" depth			12 - 24" depth		
7	0, 0, 0	0	71.8	44.5	-27.3	54.5	48.5	-6.0	53.8	47.0	-6.8
8	0, 90, 0	90	68.3	58.3	-10.0	52.3	46.3	-6.0	55.8	58.5	2.8
9	0, 180, 0	180	70.5	63.3	-7.3	52.8	48.3	-4.5	58.0	58.5	0.5
10	0, 270, 0	270	79.8	95.8	16.0	51.3	50.5	-0.8	58.5	49.8	-8.8
11	0, 360, 0	360	71.0	89.8	18.8	51.5	65.8	14.3	62.0	60.3	-1.8
12	0, 180, 180	360	70.5	94.0	23.5	59.8	48.8	-11.0	48.5	49.0	0.5
		Significance[6]	NS	**	**	NS	NS	NS	NS	NS	NS
		BLSD (0.1)	--	16.4	18.6	--	--	--	--	--	--
Contrasts	Single vs. split application (trt 11 vs. 12)		NS	NS	NS	NS	NS	++	*	++	NS
	Linear K rate		NS	**	**	NS	NS	NS	NS	NS	NS
	Quadratic K rate		NS	NS	NS	NS	NS	NS	NS	NS	NS

[1]Ammonium acetate extractable K.

[2]Sp PP: spring, preplant. Sp Em: spring, at crop emergence and hilling.

[3]Soil K concentration before treatments applied in the spring before planting.

[4]Soil K concentration in the fall after harvest.

[5]Fall soil K minus spring soil K.

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

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

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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.

2014 RESEARCH OBJECTIVES

OBJECTIVE 1	BREEDING, EVALUATION, AND SELECTION FOCUSED ON FRY AND CHIP PROCESSING AND FRESH MARKET RUSSET, RED AND YELLOW VARIETIES, GROWER FIELD TRIALS (Fry & Chip processing, Fresh russet, Fresh Red, and Fresh Yellow)
OBJECTIVE 2	TISSUE CULTURE BANK MANAGEMENT, VIRUS CLEAN-UP RESEARCH
OBJECTIVE 3	NATIONAL TRIALS (NFPT & NCPT); REGIONAL TRIAL (NCRPVT)
OBJECTIVE 4	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 G6. 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*. In 2014 we had 101 families (crosses). Single hills were grown in Gully, MN, Williston, ND, and Sikeston, MO.

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. 39 families consisting of 1200 clones were evaluated and screened for cold induced sweetening.

Early Generations Planted in 2014

Market	Gully SH	Gully G1	Williston SH	Williston G1	Sikeston SH
Reds	131	10	10	3	-
Yellows	53	3	1	0	-
Russets	178	15	14	13	-
Chip	1163	25	0	4	66
Total	1525	53	25	20	66

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 2014 the *G3's and beyond* were planted at Becker Early harvest, Becker Late harvest, Williston, Crystal, and Grand Forks.

Locations	Total	G2	G3	G4	G5	G6	G7	G12	G16
	2014 Number of Clones Tested by Generation*								
Fresh Market									
Becker Early	36	5	5	18	-	1	2	3	2
Becker Late	38	7	5	18	-	1	2	3	2
Williston	36	7	5	18	-	1	2	-	3
Crystal	9	-	-	9	-	-	-	-	-
Grand Forks	37	5	5	18	-	1	2	3	3
Processing									
Becker Late	57	20	13	12	5	-	4	1	2
Williston	57	20	13	12	5	-	4	1	2
Grand Forks	51	15	12	12	5	-	4	1	2
Chippers									
Becker Late	29	6	7	2	2	3	8	1	-
Williston	29	6	6	2	2	3	8	1	1
Grand Forks	42	19	6	2	2	3	8	1	1

***Totals include dual purpose clones**

G3 clones and above were also evaluated in *Grower Field Trials at Peterson Farms* (24), *Dechene Farms* (24), *Hammer Farms* (12), *Five Star Produce* (3), *and Goener Farms* (12).

Generation 7 and beyond - Advanced, Seed Spacing, and Advanced Processing Trials:

After *G6*, several of our clones are evaluated in *seed spacing*, and *Processing Trials.*

At Williston, ND 11 advanced clones were evaluated in strip trials. Trials are planted in 100 to 400 hill strips. Tubers were harvested and evaluated by Ag World, Grand Forks, ND for processing quality.

Objective 2

TISSUE CULTURE AND VIRUS ELIMINATION IN UM BREEDING LINES

In 2014 all clones from *G3 and beyond were put* into tissue culture for clonal preservation and virus elimination. Genotypes were tissue cultured by taking sprouts from tubers, . After introduction into a sterile environment, each genotype underwent sub-culturing 3 times to produce healthy plantlets from which virus testing can be done. We are scheduled to virus test the germplasm bank from February to March 2015. Currently 120 clones are in tissue culture and will tested and cleaned for virus.

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 on all selections from the *G2 and beyond*.

Objective 3

NCPT and NFPT Trial

As has occurred in the past 4 years, UM participates in the NCPT and NFPT program. UM Breeding lines have been entered into both programs. Clonal performance data can be found at the NCPT and NFPT database websites. An additional role for UM is the evaluation of ALL entered lines for disease characterization.

- In NCPT for 2014, 4 UM lines advanced from Tier 1 to Tier 2 in NCPT; 10 new lines were entered into Tier Additionally, UM is studying the inheritance of biochemical markers UGPase, acid invertase, and invertase inhibitor in relation to the cold sweetening process.

- In NFPT, UM is evaluating the processing potential of NFPT clones. In this research, Dr. Gupta is exploring biochemical markers UGPase, acid invertase, and invertase inhibitor in relation to the cold sweetening process and tuber quality related to sugar ends. (See Gupta progress report for inheritance study.)

Objective 4

EXTENSION / OUTREACH / COMMUNICATION:

1. MN Area II: Reporting Conference & Field-day @ Becker
2. NPPGA: Reporting Conference / Expo & Twilight Field Tour
3. MONDAK: MonDak Ag Tour @ Nesson Valley
4. NPC EXPO: Orlando, Florida

FUNDING: NPPGA, MN Area II Research and Promotion Council, Williston Ag Diversification, USPB, NIFA, Minnesota Ag Experiment Station. We appreciate the funding that these organizations provide to this program. This has been a difficult year for all of us, and the continued financial assistance from the NPPGA and MN Area II is greatly appreciated.

THANK YOU.

ID #	Clone	Mkt	Loc	% Mkt Yld	CWT Total	CWT Mkt Yld	(+/-) % Mkt Yld *Stnd 1	**Stnd 2	***Stnd 3	Size Distribution <2oz cnt	<2oz Cwt	2-4oz cnt	2-4oz Cwt	4-6oz cnt	4-6oz Cwt	6-8oz cnt	6-8oz Cwt	8-10oz cnt	8-10oz Cwt	10-12oz cnt	10-12oz Cwt	12-14oz cnt	12-14oz Cwt	>14 cnt	>14 Cwt
	Clone																								
1	MN02467Rus/Y	FF/FM	BL	74.8	157.6	117.8	-71.3	-	-	14	9.4	23	30.4	19	41.6	11	34.4	3	10.2	4	19.5	1	6.1	1	6.1
2	MN02586	FM	BL	71.1	518.4	368.4	-24.2	0.7	-9.3	42	27.1	89	121.5	71	158.5	37	114.1	14	55.1	6	28.7	2	12.1	0	0.0
3	MN02616R/Y	FM	BL	66.2	282.1	186.6	-61.6	-49.0	-54.1	16	10.8	62	84.7	44	97.3	22	66.3	5	18.2	1	4.9	0	0.0	0	0.0
4	MN04844-07	C/FM	BL	48.2	223.9	107.9	-59.1	-	-	26	18.1	70	96.9	35	75.6	5	15.9	3	11.8	1	4.7	0	0.0	0	0.0
5	MN07112WB-01W/P	C/FM	BL	13.7	288.5	39.5	-85.0	-	-	194	123.5	103	125.6	14	29.0	2	6.0	1	4.4	9	0.0	0	0.0	0	0.0
6	MN09152BW-01Rus	FF	BL	89.0	651.0	579.6	31.1	65.0	-	15	10.7	33	44.2	41	92.2	29	90.8	29	116.9	23	111.2	11	63.0	15	105.6
7	MN10001PLWR-03LW	FF	BL	69.8	355.8	248.4	-43.8	-29.3	-	3	1.8	9	11.6	20	44.4	15	47.8	5	20.4	9	42.7	5	29.8	8	63.2
8	MN10001PLWR-14R	FM	BL	88.4	265.5	234.8	-51.7	-35.8	-42.2	6	3.4	19	27.3	20	44.9	19	60.0	12	47.7	5	24.3	5	29.0	4	29.0
9	MN10003PLWR-02R	FM	BL	44.8	292.3	130.9	-73.1	-64.2	-67.8	58	39.3	91	122.2	38	81.4	12	35.5	4	14.0	0	0.0	0	0.0	0	0.0
10	MN10003PLWR-03R	FM	BL	62.9	277.5	174.6	-64.1	-52.3	-57.0	23	15.4	58	78.2	41	92.9	13	39.4	6	23.5	2	7.4	2	11.5	0	0.0
11	MN10003PLWR-06R	FM	BL	87.4	300.1	262.2	-46.1	-28.4	-35.5	11	7.3	22	30.7	31	70.2	31	97.1	14	53.8	4	19.5	3	14.9	1	6.8
12	MN10003PLWR-07R	FM	BL	69.9	261.4	182.6	-62.4	-50.1	-55.1	22	15.4	47	63.4	37	83.5	19	58.3	6	23.6	4	17.2	0	0.0	0	0.0
13	MN10003PLWR-13R	FM	BL	70.4	244.9	172.3	-64.6	-52.9	-57.6	12	7.7	46	63.4	34	76.5	20	62.0	4	16.0	1	5.0	1	6.2	1	6.6
14	MN10008PLWR-06R	FM	BL	48.0	294.4	141.4	-70.9	-61.4	-65.2	32	22.7	98	130.3	44	96.3	8	23.7	6	21.4	0	0.0	0	0.0	0	0.0
15	MN10010WW-06Rus	FF	BL	82.8	293.8	243.3	-45.0	-30.7	-	10	6.5	26	35.4	35	79.2	21	66.5	9	36.3	8	37.1	2	11.9	2	12.3
16	MN10013PLWR-03LR	FF	BL	93.8	308.1	289.0	-34.6	-17.7	-	2	1.5	13	17.5	18	40.4	20	61.3	16	64.6	10	49.6	7	38.8	5	34.3
17	MN10013PLWR-04	C/FM	BL	45.5	312.3	142.1	-46.1	-	-	29	20.1	104	141.4	47	100.0	8	23.7	4	13.7	1	4.7	0	0.0	0	0.0
18	MN10020PLWR-04R	FM	BL	69.5	279.5	194.1	-60.1	-47.0	-52.2	12	8.0	34	48.1	43	95.5	18	55.2	7	27.5	2	10.2	1	5.7	0	0.0
19	MN10020PLWR-05R	FM	BL	79.6	325.1	258.7	-46.8	-29.3	-36.3	17	10.8	36	49.8	26	57.8	21	64.5	13	52.4	6	30.3	5	29.1	3	24.6
20	MN10020PLWR-08R	FM	BL	77.1	370.2	285.3	-41.3	-22.1	-29.8	8	5.7	21	28.6	25	57.2	17	53.6	14	56.4	14	69.5	4	20.3	4	28.3
21	MN10023BB-01Rus	FF	BL	67.8	170.3	115.5	-73.9	-67.1	-	8	5.3	28	39.6	20	44.1	9	27.9	6	24.3	3	12.2	0	0.0	1	7.0
22	MN10023BW-01Rus	FF	BL	86.0	307.0	263.9	-40.3	-24.9	-	8	5.5	16	20.5	22	50.4	22	68.2	13	51.7	9	42.3	3	14.6	5	36.8
23	MN10024PLWR-09R	FM	BL	59.0	209.9	123.9	-74.5	-66.1	-69.5	22	14.1	50	66.9	32	70.4	9	26.1	4	13.9	2	7.3	1	6.3	0	0.0
24	MN10024PLWR-11R	FM	BL	60.3	267.9	161.5	-66.8	-55.9	-60.3	25	17.1	63	86.7	47	102.3	12	35.6	1	3.9	4	19.6	0	0.0	0	0.0
25	MN10025PLWR-07R	FM	BL	89.4	290.2	259.3	-46.7	-29.2	-36.2	6	3.9	20	27.0	14	31.8	18	56.1	14	56.7	7	35.5	8	44.1	5	35.1
26	MN10025PLWR-20R	FM	BL	46.3	259.1	119.9	-75.3	-67.2	-70.5	51	33.6	83	105.6	33	71.2	9	26.2	2	7.9	3	14.5	0	0.0	0	0.0
27	MN10030WB-04Rus	FF	BL	71.9	268.4	192.9	-56.4	-45.1	-	14	9.8	37	47.3	27	59.2	12	38.6	10	37.8	7	32.5	3	18.0	1	6.8
28	MN10053BW-01Rus	FF	BL	62.2	241.0	149.8	-66.1	-57.4	-	23	16.5	56	74.7	27	59.3	14	43.1	6	24.2	4	17.2	1	5.9	0	0.0
29	MN10054BW-01Rus	FF	BL	84.1	360.0	302.7	-31.5	-13.8	-	7	4.6	20	28.8	30	68.3	21	64.7	12	47.0	10	46.4	7	37.3	5	39.1
30	MN10056WB-10Rus	FF	BL	53.5	172.4	92.3	-79.1	-73.7	-	22	14.8	45	60.8	23	51.2	10	29.3	3	11.9	0	0.0	0	0.0	0	0.0
31	MN10056WW-05Rus	FF	BL	51.6	163.3	84.3	-80.9	-76.0	-	24	15.4	50	63.6	12	26.8	3	9.2	1	3.6	0	0.0	3	14.4	4	30.3
32	MN10056WW-10Rus	FF	BL	73.9	199.9	147.8	-66.6	-57.9	-	6	4.4	30	42.1	23	52.3	20	60.7	6	22.3	3	12.5	0	0.0	0	0.0
33	MN10064BW-01Rus	FF	BL	72.2	382.6	276.4	-37.5	-21.3	-	22	14.7	63	84.3	49	109.7	33	103.9	10	38.0	2	7.6	3	17.2	0	0.0
34	MN11026WB-07Rus	FF	BL	62.6	259.2	162.2	-63.3	-53.8	-	24	16.0	57	75.7	27	58.6	10	32.3	5	20.1	3	11.9	2	11.4	3	28.0
35	MN11027WW-06Rus	FF	BL	69.5	290.4	201.7	-54.4	-42.6	-	11	7.5	25	34.8	27	60.5	17	49.8	11	45.4	6	27.5	2	11.6	1	6.9
36	MN11031WW-01Rus	FF	BL	81.9	333.3	272.9	-38.3	-22.3	-	13	8.8	38	51.6	39	88.3	27	85.7	13	52.7	6	26.2	2	11.7	1	8.4
37	MN11035PLWRGR-01R	FM	BL	70.0	285.8	200.2	-58.8	-45.3	-50.7	32	20.5	50	65.1	30	66.1	15	45.2	5	17.6	9	42.8	1	5.6	3	22.8
38	MN11035WB-06LW	FF	BL	86.2	354.3	305.5	-30.9	-13.0	-	5	3.0	13	17.4	16	37.5	17	51.6	23	90.0	8	37.4	7	40.2	7	48.8
39	MN11037PLWRGR-04R	FM	BL	46.5	234.8	109.2	-77.5	-70.2	-73.1	30	21.4	80	104.1	33	72.3	7	21.8	3	10.1	1	5.0	0	0.0	0	0.0
40	MN11040WB-04Rus	FF	BL	47.6	353.9	168.5	-61.9	-52.0	-	71	48.3	105	133.9	40	86.1	10	31.1	3	9.7	4	17.3	2	11.3	2	13.0
41	MN11040WB-07RusCT	FF	BL	86.1	353.7	304.4	-31.1	-13.4	-	7	4.6	25	33.7	27	60.4	19	60.2	14	56.6	9	42.7	6	32.4	7	52.1
42	MN11040WB-12Rus	FF	BL	89.6	471.7	422.8	-4.4	20.3	-	6	3.8	16	22.3	30	66.5	23	71.9	23	90.3	16	77.2	9	53.6	9	63.3
43	MN11040WW-07RusCT	FF	BL	93.1	227.2	211.5	-52.2	-39.8	-	6	3.8	9	11.9	9	20.7	13	41.6	8	30.9	5	22.3	7	41.0	7	55.0
44	MN11042PLWRGR-03R	FM	BL	55.8	208.2	116.1	-76.1	-68.3	-71.4	21	13.9	58	78.2	38	81.2	9	27.2	2	7.7	0	0.0	0	0.0	0	0.0
45	MN11048WW-04Rus	FF	BL	75.3	399.2	300.7	-32.0	-14.4	-	14	9.7	54	75.6	46	100.6	24	73.9	9	36.5	7	31.6	4	23.4	5	34.7
46	MN11057WB-03Rus	FF	BL	76.5	309.3	236.5	-46.5	-32.7	-	15	9.7	43	57.0	36	81.2	23	70.0	5	18.3	7	31.9	4	20.4	2	14.7
47	MN11057WB-04Rus	FF	BL	75.2	371.9	279.7	-36.7	-20.4	-	13	8.9	52	72.0	39	85.2	32	100.1	15	61.4	4	16.9	1	5.9	2	10.3
48	MN11057WW-04Rus	FF	BL	71.3	324.4	231.5	-47.6	-34.1	-	20	13.1	47	66.1	37	82.6	20	60.4	8	29.7	6	27.4	0	0.0	4	31.3
49	MN11059PLWRGR-07R	FM	BL	43.8	273.6	119.9	-75.3	-67.2	-70.5	37	25.2	93	128.5	36	79.7	9	26.6	2	6.3	2	7.3	0	0.0	0	0.0
50	MN11124PLWRGR-01Rus	FF	BL	69.0	191.3	131.9	-70.2	-62.5	-	7	5.2	40	54.1	33	72.6	12	34.6	5	19.9	1	4.8	0	0.0	0	0.0
51	MN11130PLWRGR-02	C	BL	50.5	95.5	48.2	-84.5	-81.9	-85.2	20	12.2	26	35.0	9	18.7	4	13.0	3	11.3	1	5.3	0	0.0	0	0.0
52	MN11136PLWRGR-10	C	BL	86.7	341.6	296.2	-4.8	11.3	-9.4	11	6.3	30	39.1	25	57.2	21	65.3	13	50.7	9	42.7	5	30.1	6	50.3
53	MN11136PLWRGR-11	C	BL	47.9	241.9	115.9	-62.8	-56.5	-64.5	35	23.7	77	102.3	32	67.8	10	31.1	4	17.0	0	0.0	0	0.0	0	0.0
54	MN11142PLWRGR-01	C	BL	89.4	403.1	360.4	15.8	35.4	10.3	8	5.4	23	31.9	43	96.8	26	79.9	20	78.3	11	54.9	3	18.1	4	32.3
55	MN11153PLWRGR-03	C	BL	41.4	228.6	94.7	-69.6	-64.4	-71.0	53	34.5	75	96.2	29	64.4	7	19.8	2	5.7	1	4.8	0	0.0	0	0.0
56	MN11158PLWRGR-01	C	BL	59.3	200.0	118.6	-61.9	-55.4	-63.7	16	9.4	33	43.7	18	40.5	11	33.3	1	4.0	4	17.5	2	11.6	2	11.6
57	MN11189PLWRGR-02	C	BL	48.5	187.4	90.9	-70.8	-65.9	-72.2	31	19.9	56	74.0	25	53.7	7	20.4	3	12.1	1	4.8	0	0.0	0	0.0
58	MN12004WB-01R	FM	BL	67.9	246.4	167.2	-65.6	-54.3	-58.8	21	15.0	47	64.2	46	103.5	18	56.0	2	7.7	0	0.0	0	0.0	0	0.0
59	MN12004WW-01R	FM	BL	62.4	174.4	108.9	-77.6	-70.2	-73.2	19	12.0	39	53.5	32	72.1	12	36.8	0	0.0	0	0.0	0	0.0	0	0.0
60	MN12006WW-01R	FM	BL	66.8	427.2	285.3	-41.3	-22.1	-29.8	40	26.6	82	108.5	42	94.9	32	100.6	12	48.1	6	29.0	1	6.0	1	6.7
61	MN12028WB-01Rus	FF	BL	93.5	482.2	451.0	2.0	28.3	-	2	1.3	7	10.3	14	32.6	29	91.4	35	142.5	11	54.0	9	51.9	10	78.6
62	MN12028WW-01R/Y	FM	BL	60.8	303.1	184.3	-62.1	-49.6	-54.6	19	13.0	75	105.8	41	92.7	19	60.8	5	20.6	2	10.2	0	0.0	0	0.0
63	MN12073WW-01	C	BL	15.2	104.3	15.8	-94.9	-94.0	-95.2	39	24.7	53	63.7	6	12.5	1	3.3	0	0.0	0	0.0	0	0.0	0	0.0
64	MN12077WB-01	C	BL	32.4	225.9	73.1	-76.5	-72.5	-77.6	61	39.6	87	113.1	28	61.0	2	6.3	0	0.0	0	0.0	1	5.9	0	0.0
65	MN12077WB-02	C	BL	47.4	251.0	118.9	-61.8	-55.4	-63.6	49	31.8	72	92.3	27	57.0	15	46.1	3	11.2	1	4.5	0	0.0	0	0.0
66	MN12077WW-02	C	BL	50.4	334.4	168.6	-45.8	-36.7	-48.4	63	41.0	95	124.8	51	107.3	14	44.1	3	12.2	1	5.1	0	0.0	0	0.0
67	MN12088WW-01Rus	FF	BL	80.6	501.4	404.0	-8.6	15.0	-	23	16.0	45	66.6	45	103.3	37	116.6	19	75.9	10	49.3	5	28.9	4	29.8
68	MN12113WW-01Rus	FF	BL	93.1	319.0	296.9	-32.8	-15.5	-	12	7.3	12	14.7	17	39.5	27	85.2	17	69.9	8	42.1	5	29.2	3	31.1
69	MN12114WB-02LW	FF	BL	70.3	230.2	161.8	-63.4	-54.0	-	20	13.2	41	55.3	36	81.7	16	49.8	5	19.8	1	5.2	1	5.2	0	0.0
70	MN12114WW-02LW	FF	BL	79.9	300.2	240.0	-45.7	-31.7	-	12	8.8	39	51.4	40	88.5	18	57.3	16	64.8	6	29.3	0	0.0	0	0.0
71	MN12124WB-01Rus	FF	BL	77.0	250.6	193.0	-56.3	-45.1	-	4	3.3	39	54.3	34	74.8	14	43.7	11	45.5	3	14.8	0	0.0	2	14.2
72	MN12124WW-01Rus	FF	BL	89.8	381.7	343.0	-22.4	-2.4	-	3	1.6	17	25.4	31	70.4	31	96.0	18	72.4	6	30.3	7	40.6	5	33.3
73	MN12138WB-01	C	BL	85.4	258.4	220.6	-29.1	-17.1	-32.5	5	3.4	27	34.4	34	76.6	20	62.2	10	38.8	5	24.3	3	18.7	0	0.0
74	MN12138WW-01	C	BL	80.2	367.8	295.0	-5.2	10.8	-9.7	16	10.5	28	37.1	33	73.4	16	49.3	15	61.3	15	75.0	5	29.0	1	7.1
75	MN18747	FF/FM	BL	88.7	253.9	225.3	-45.1	-	-	7	4.6	15	20.3	12	27.0	16	51.0	12	48.5	11	53.1	4	23.3	3	22.3
76	MonDak Gold	FF/FM	BL	72.0	458.2	329.8	-19.6	-	-	21	14.6	66	89.2	44	98.5	26	81.7	14	56.9	6	27.2	9	52.0	2	13.5
77	NDMN120013WB-01Rus	FF	BL	89.5	580.9	520.0	17.6	48.0	-	7	4.9	28	41.7	68	156.9	49	152.9	31	122.0	14	69.4	2	11.9	1	6.9
78	NDMN120013WW-01Rus	FF	BL	67.4	169.8	114.4	-74.1	-67.4	-	11	7.7	34	47.8	15	34.2	11	34.8	7	28.4	1	4.6	2	12.4	0	0.0
79	NDMN120015WB-01Rus	FF	BL	34.1	65.7	22.4	-94.9	-93.6	-	14	8.4	29	35.0	4	8.4	3	9.3	0	0.0	1	4.7	0	0.0	0	0.0
80	NDMN120015WW-02Rus	FF	BL	83.7	342.0	286.2	-35.3	-18.5	-	9	6.8	29	40.9	30	70.2	32	97.7	18	71.9	7	34.1	1	5.9	1	6.5
81	NDMN120020WW-01Rus	FF	BL	32.0	173.5	55.5	-87.4	-84.2	-	16	10.4	77	100.5	21	45.7	3	9.9	0	0.0	0	0.0	0	0.0	0	0.0
82	NDMN120022WB-01Rus	FF	BL	89.9	604.4	543.3	22.9	54.6	-	6	4.3	22	30.8	43	98.7	58	184.0	40	160.0	12	58.3	5	28.7	2	13.5
83	NDMN120022WW-01Rus	FF	BL	40.4	131.7	53.2	-88.0	-84.9	-	24	17.6	48	61.0	19	39.9	4	13.3	0	0.0	0	0.0	0	0.0	0	0.0
84	NDMN120024WW-02Rus	FF	BL	60.2	337.0	202.9	-54.1	-42.3	-	23	16.6	87	117.5	58	128.5	16	48.9	4	16.1	2	9.4	0	0.0	0	0.0
85	NDMN120029WW-01Rus	FF	BL	84.5	318.5	269.0	-39.2	-23.5	-	4	2.9	17	22.5	25	58.4	13	40.8	13	52.6	7	33.0	10	58.8	3	25.4
86	NDMN120048WW-01Rus	FF	BL	81.0	379.7	307.6	-30.4	-12.4	-	5	3.6	23	32.1	50	114.8	24	76.8	17	70.8	7	33.7	2	11.6	0	0.0
87	NDMN120053WB-02Rus	FF	BL	35.6	190.5	67.8	-84.7	-80.7	-	22	15.2	68	93.5	32	67.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
88	NDMN120053WW-01Rus	FF	BL	46.0	255.7	117.7	-73.4	-66.5	-	38	25.5	86	112.5	24	53.3	14	42.8	3	11.2	1	4.8	1	5.6	0	0.0
89	NDMN120058WW-01Rus	FF	BL	72.8	372.2	271.1	-38.7	-22.8	-	10	7.2	48	65.3	45	102.0	22	70.1	5	19.7	4	20.2	4	23.7	5	35.5
90	NDMN120063WW-01Rus	FF	BL	70.3	411.7	289.3	-34.6	-17.7	-	20	13.9	47	61.3	52	115.8	25	80.7	9	36.1	9	43.9	1	6.0	1	6.9
A	Atlantic	C	BL	85.3	365.1	311.3	0.0	16.9	-4.8	9	6.0	17	25.6	26	59.6	24	74.2	19	77.2	11	51.9	5	27.3	3	21.1
B	Cascade	FM	BL	84.4	429.1	362.2	-25.5	-1.0	-10.9	13	8.1	32	43.1	33	75.2	23	73.2	19	77.2	10	48.7	9	50.4	5	37.4
C	NorValley	C	BL	68.2	390.6	266.3	-14.5	0.0	-18.5	25	16.4	69	93.4	36	79.0	27	84.5	13	50.7	6	30.1	3	14.7	1	7.2
D	Red Lasoda	FM	BL	93.2	521.4	486.2	0.0	32.8	19.7	9	6.3	17	22.3	24	54.1	18	54.1	22	90.3	19	92.7	13	76.9	16	118.1
E	Red Norland	FM	BL	90.1	406.1	366.0	-24.7	0.0	-9.9	11	7.1	25	32.9	25	57.0	31	97.0	19	76.6	9	44.4	7	40.5	7	50.5
F	Red Pontiac	FM	BL	82.4	493.0	406.3	-16.4	11.0	0.0	16	11.4	52	72.5	50	113.3	37	114.9	24	96.9	7	31.4	7	38.3	2	11.5
G	Russet Burbank	FF	BL	80.9	546.3	442.1	0.0	25.8	-	5	3.7	20	26.6	24	54.7	26	79.4	19	76.2	12	59.3	10	56.6	15	116.0
H	Russet Norkotah	FF/FM	BL	89.5	458.3	410.4	0.0	-	-	12	8.4	27	36.2	28	64.0	32	99.0	24	95.2	12	58.6	9	50.0	6	43.5
I	Shepody	FF	BL	83.6	420.1	351.4	-20.5	0.0	-	8	5.5	10	14.3	20	44.4	12	37.7	14	55.8	11	52.6	10	55.8	14	105.0
J	Snowden	C	BL	81.3	401.9	326.8	5.0	22.7	0.0	17	10.7	47	64.3	60	137.2	33	101.0	17	66.5	2	9.5	1	6.0	1	6.7
K	Yukon Gold	C/FM	BL	90.8	290.3	263.7	0.0	-	-	4	2.7	17	23.9	22	49.6	13	40.0	19	77.8	7	34.6	6	31.8	4	29.9

Mkt	*Standard 1	**Standard 2	***Standard 3
FM	Red Lasoda	Red Norland	Red Pontiac
FF	Russet Burbank	Shepody	
C	Atlantic	Norvalley	Snowden
C/FM	Yukon Gold		
FF/FM	Russet Norkotah		

			% Defects									Chip/Fry**		Specific Gravity			Scab	
			External				Internal					OTF*		OTF		Range		
ID #	Clone	Mkt	GC	GR	Kn	Br	HH	IN	VD	BC	Br	Rep 1	Rep 2	Rep 1	Rep 2		T[1]	C[2]
	Clone																	
1	MN02467Rus/Y	FF/FM	0	0	0	0	13	0	0	0	0	-	-	1.079	-	1.079 - 1.079	1	3
2	MN02586	FM	0	0	0	0	0	0	0	0	0	2.5	-	1.092	-	1.092 - 1.092	2	3
3	MN02616R/Y	FM	0	0	0	0	0	0	0	0	0	-	-	1.084	1.085	1.084 - 1.085	3	2
4	MN04844-07	C/FM	0	0	0	0	0	0	0	0	31	2.0	2.5	1.075	1.076	1.075 - 1.076	2	4
5	MN07112WB-01W/P	C/FM	0	0	0	0	0	0	0	0	0	-	1.0	1.076	1.084	1.076 - 1.084	1	3
6	MN09152BW-01Rus	FF	0	0	0	0	6	0	0	0	0	0	1	1.085	1.090	1.085 - 1.090	3	2
7	MN10001PLWR-03LW	FF	0	0	0	0	0	0	0	0	13	2	-	1.075	-	1.075 - 1.075	6	5
8	MN10001PLWR-14R	FM	0	0	0	0	0	0	0	6	0	-	-	1.072	1.074	1.072 - 1.074	3	2
9	MN10003PLWR-02R	FM	0	0	0	0	0	0	0	0	0	-	-	1.078	1.075	1.075 - 1.078	2	3
10	MN10003PLWR-03R	FM	0	0	0	0	0	0	0	6	0	-	-	1.064	1.063	1.063 - 1.064	6	6
11	MN10003PLWR-06R	FM	6	0	0	0	0	0	12.5	13	19	-	-	1.064	1.066	1.064 - 1.066	3	2
12	MN10003PLWR-07R	FM	0	0	0	0	0	0	0	0	6	-	-	1.060	1.059	1.059 - 1.060	-	-
13	MN10003PLWR-13R	FM	0	0	0	0	6	18.8	0	0	0	-	-	1.059	1.061	1.059 - 1.061	5	1
14	MN10008PLWR-06R	FM	0	0	0	0	0	0	0	0	0	-	-	1.066	1.071	1.066 - 1.071	6	4
15	MN10010WW-06Rus	FF	0	0	0	0	0	0	0	0	0	1	0	1.076	1.079	1.076 - 1.079	5	1
16	MN10013PLWR-03LR	FF	0	0	0	0	0	0	0	0	0	-	-	1.071	-	1.071 - 1.071	5	1
17	MN10013PLWR-04	C/FM	6	0	0	0	13	0	0	0	0	-	-	1.091	1.078	1.078 - 1.091	5	2
18	MN10020PLWR-04R	FM	0	0	0	0	19	0	12.5	13	0	-	-	1.058	1.062	1.058 - 1.062	6	4
19	MN10020PLWR-05R	FM	0	0	0	0	6	0	0	13	0	-	-	1.071	1.072	1.071 - 1.072	5	2
20	MN10020PLWR-08R	FM	25	0	0	0	0	0	0	0	0	-	-	1.072	1.069	1.069 - 1.072	6	3
21	MN10023BB-01Rus	FF	0	0	0	0	0	0	0	0	0	0	1	1.082	1.083	1.082 - 1.083	4	4
22	MN10023BW-01Rus	FF	0	0	0	0	0	0	0	0	0	0	0	1.085	1.088	1.085 - 1.088	4	3
23	MN10024PLWR-09R	FM	0	0	0	0	0	0	0	0	0	-	-	1.065	1.070	1.065 - 1.070	2	3
24	MN10024PLWR-11R	FM	0	0	0	0	0	0	0	0	0	-	-	1.060	1.059	1.059 - 1.060	1	2
25	MN10025PLWR-07R	FM	0	0	0	0	0	0	0	6	0	-	-	1.066	1.067	1.066 - 1.067	6	4
26	MN10025PLWR-20R	FM	0	0	0	0	0	0	0	0	0	-	-	1.067	1.065	1.065 - 1.067	6	3
27	MN10030WB-04Rus	FF	0	0	0	0	0	0	0	0	0	1	00	1.087	1.083	1.083 - 1.087	4	5
28	MN10053BW-01Rus	FF	0	0	0	0	13	0	0	0	0	0	00	1.079	1.075	1.075 - 1.079	6	6
29	MN10054BW-01Rus	FF	0	0	0	0	0	0	0	0	0	00	0	1.072	1.065	1.065 - 1.072	4	6
30	MN10056WB-10Rus	FF	0	0	0	0	0	0	0	0	0	1	0	1.072	1.071	1.071 - 1.072	4	4
31	MN10056WW-05Rus	FF	0	0	0	0	0	0	0	0	6	2	0	1.078	1.085	1.078 - 1.085	6	1
32	MN10056WW-10Rus	FF	0	0	0	0	6	0	0	0	0	1	0	1.076	1.072	1.072 - 1.076	3	1
33	MN10064BW-01Rus	FF	0	0	0	0	0	0	6.25	0	0	0	0	1.083	1.083	1.083 - 1.083	5	2
34	MN11026WB-07Rus	FF	0	0	0	0	0	0	0	0	0	2	1	1.078	1.078	1.078 - 1.078	5	1
35	MN11027WW-06Rus	FF	0	0	0	0	0	0	0	0	0	1	00	1.081	1.095	1.081 - 1.095	2	3
36	MN11031WW-01Rus	FF	0	0	0	0	0	0	0	0	0	00	-	1.073	-	1.073 - 1.073	6	6
37	MN11035PLWRGR-01R	FM	0	0	0	0	0	0	0	0	0	-	-	1.058	1.067	1.058 - 1.067	6	6
38	MN11035WB-06LW	FF	0	0	0	0	13	0	0	0	0	2	1	1.082	1.077	1.077 - 1.082	6	3
39	MN11037PLWRGR-04R	FM	0	0	0	0	0	0	0	6	0	-	-	1.064	1.064	1.064 - 1.064	2	3
40	MN11040WB-04Rus	FF	0	0	0	0	13	0	0	0	0	0	0	1.081	1.078	1.078 - 1.081	6	6
41	MN11040WB-07RusCT	FF	0	0	0	0	0	0	0	0	0	-	-	-	-	- - -	6	1
42	MN11040WB-12Rus	FF	0	0	0	0	0	0	0	0	0	2	1	1.091	1.081	1.081 - 1.091	6	4
43	MN11040WW-07RusCT	FF	0	0	0	0	0	0	0	0	0	-	-	1.087	-	1.087 - 1.087	6	4
44	MN11042PLWRGR-03R	FM	0	0	0	0	0	0	0	0	0	-	-	1.074	1.068	1.068 - 1.074	2	2
45	MN11048WW-04Rus	FF	0	0	0	0	6	0	0	0	0	1	1	1.080	1.080	1.080 - 1.080	3	3
46	MN11057WB-03Rus	FF	0	0	0	0	0	0	0	0	0	2	2	1.080	1.078	1.078 - 1.080	4	6
47	MN11057WB-04Rus	FF	0	0	0	0	0	0	0	0	0	1	0	1.069	1.068	1.068 - 1.069	4	6
48	MN11057WW-04Rus	FF	0	0	0	0	0	0	0	0	0	1	00	1.062	1.072	1.062 - 1.072	2	3
49	MN11059PLWRGR-07R	FM	0	0	0	0	0	0	0	0	0	-	-	1.082	1.081	1.081 - 1.082	6	3
50	MN11124PLWRGR-01Rus	FF	0	0	0	0	0	0	0	0	0	1	0	1.073	1.073	1.073 - 1.073	4	3
51	MN11130PLWRGR-02	C	0	0	0	0	0	0	0	0	0	1.5	-	1.091	-	1.091 - 1.091	1	1
52	MN11136PLWRGR-10	C	0	0	0	0	0	0	0	0	6	2.0	1.5	1.088	1.088	1.088 - 1.088	5	2
53	MN11136PLWRGR-11	C	0	0	0	0	0	0	0	0	0	1.5	1.5	1.078	1.080	1.078 - 1.080	4	2
54	MN11142PLWRGR-01	C	6	0	0	0	25	0	0	0	0	2.5	2.0	1.088	1.075	1.075 - 1.088	2	3
55	MN11153PLWRGR-03	C	0	0	0	0	0	0	0	0	0	1.5	2.0	1.068	1.068	1.068 - 1.068	4	5
56	MN11158PLWRGR-01	C	0	0	0	0	6	0	0	0	0	1.0	1.0	1.083	1.071	1.071 - 1.083	-	-
57	MN11189PLWRGR-02	C	0	0	0	0	19	0	0	0	0	-	1.5	1.069	1.063	1.063 - 1.069	0	0
58	MN12004WB-01R	FM	0	0	0	0	0	0	0	0	0	-	-	1.073	-	1.073 - 1.073	4	2
59	MN12004WW-01R	FM	0	0	0	0	0	0	0	0	0	-	-	1.074	-	1.074 - 1.074	4	3
60	MN12006WW-01R	FM	0	0	0	0	0	0	0	0	0	-	-	1.074	-	1.074 - 1.074	4	4
61	MN12028WB-01Rus	FF	0	0	0	0	0	0	0	0	0	1.5	-	1.091	-	1.091 - 1.091	6	6
62	MN12028WW-01R/Y	FM	0	0	0	0	0	0	0	0	0	-	-	1.080	-	1.080 - 1.080	1	1
63	MN12073WW-01	C	0	0	0	0	0	0	0	0	0	1.5	-	1.076	-	1.076 - 1.076	-	-
64	MN12077WB-01	C	0	0	0	0	0	0	0	0	0	1.5	-	1.075	-	1.075 - 1.075	4	3
65	MN12077WB-02	C	0	0	0	0	0	0	0	0	0	-	-	1.079	-	1.079 - 1.079	6	2
66	MN12077WW-02	C	0	0	0	0	0	0	0	0	0	1.5	-	1.085	-	1.085 - 1.085	3	4
67	MN12088WW-01Rus	FF	0	0	0	0	0	0	0	0	0	00	-	1.074	-	1.074 - 1.074	4	3
68	MN12113WW-01Rus	FF	0	0	0	0	0	0	0	0	0	-	-	-	-	- - -	5	2
69	MN12114WB-02LW	FF	0	0	0	0	0	0	0	0	0	2	-	1.071	-	1.071 - 1.071	6	4
70	MN12114WW-02LW	FF	0	0	0	0	0	0	0	0	0	1	-	1.073	-	1.073 - 1.073	5	1
71	MN12124WB-01Rus	FF	0	0	0	0	0	0	0	0	0	0	-	1.088	-	1.088 - 1.088	5	2
72	MN12124WW-01Rus	FF	0	0	0	0	0	0	0	0	0	0	-	1.095	-	1.095 - 1.095	5	1
73	MN12138WB-01	C	0	0	0	0	13	0	0	0	0	2.5	-	1.080	-	1.080 - 1.080	4	2
74	MN12138WW-01	C	0	0	0	0	25	0	0	0	0	1.5	-	1.070	-	1.070 - 1.070	4	3
75	MN18747	FF/FM	0	0	0	0	0	0	0	0	0	0	1	1.072	1.048	1.048 - 1.072	3	2
76	MonDak Gold	FF/FM	0	0	13	0	0	0	12.5	0	0	-	-	-	1.090	1.090 - 1.090	4	2
77	NDMN120013WB-01Rus	FF	0	0	0	0	13	0	0	0	0	1	-	1.074	-	1.074 - 1.074	3	2
78	NDMN120013WW-01Rus	FF	0	0	0	0	0	0	0	0	0	0	-	1.082	-	1.082 - 1.082	5	1
79	NDMN120015WB-01Rus	FF	0	0	0	0	0	0	0	0	0	0	-	1.069	-	1.069 - 1.069	4	4
80	NDMN120015WW-02Rus	FF	0	0	0	0	0	0	0	0	0	2	-	1.090	-	1.090 - 1.090	3	2
81	NDMN120020WW-01Rus	FF	0	0	0	0	0	0	0	0	0	0	-	1.074	-	1.074 - 1.074	2	4
82	NDMN120022WB-01Rus	FF	0	0	0	0	0	0	0	0	0	1	-	1.080	-	1.080 - 1.080	3	4
83	NDMN120022WW-01Rus	FF	0	0	0	0	0	0	0	0	0	1	-	1.074	-	1.074 - 1.074	2	4
84	NDMN120024WW-02Rus	FF	0	0	0	0	0	0	0	0	0	0	-	1.076	-	1.076 - 1.076	6	6
85	NDMN120029WW-01Rus	FF	0	0	0	0	0	0	0	0	0	00	-	1.094	-	1.094 - 1.094	1	2
86	NDMN120048WW-01Rus	FF	0	0	0	0	0	0	0	0	0	1	-	1.084	-	1.084 - 1.084	1	5
87	NDMN120053WB-02Rus	FF	0	0	0	0	0	0	0	0	0	0	-	1.074	-	1.074 - 1.074	4	4
88	NDMN120053WW-01Rus	FF	0	0	0	0	0	0	0	0	0	00	-	1.073	-	1.073 - 1.073	6	5
89	NDMN120058WW-01Rus	FF	0	0	0	0	0	0	0	0	0	0	-	1.078	-	1.078 - 1.078	4	1
90	NDMN120063WW-01Rus	FF	0	0	0	0	0	0	0	0	0	2	-	1.076	-	1.076 - 1.076	6	4
A	Atlantic	C	0	0	0	0	63	0	0	0	0	3.5	3.5	1.068	1.085	1.068 - 1.085	6	6
B	Cascade	FM	0	0	0	0	0	0	0	0	6	-	-	1.082	1.088	1.082 - 1.088	6	4
C	NorValley	C	0	0	0	0	0	0	0	0	0	1.0	2.0	1.086	1.085	1.085 - 1.086	5	1
D	Red Lasoda	FM	0	0	0	0	6.3	0	6.25	6.25	0	-	-	1.067	1.070	1.067 - 1.070	5	2
E	Red Norland	FM	0	0	0	0	13	0	0	0	0	-	-	1.072	1.071	1.071 - 1.072	4	3
F	Red Pontiac	FM	0	0	0	0	0	0	6.25	6.25	0	-	-	1.065	1.076	1.065 - 1.076	6	5
G	Russet Burbank	FF	0	0	0	0	19	0	0	0	0	2	2	1.084	1.079	1.079 - 1.084	5	1
H	Russet Norkotah	FF/FM	0	0	0	0	6.3	0	0	0	0	-	-	1.079	1.081	1.079 - 1.081	6	5
I	Shepody	FF	0	0	0	0	19	0	0	0	0	0	00	1.090	1.094	1.090 - 1.094	6	5
J	Snowden	C	0	0	0	0	13	0	0	0	0	-	2.5	-	1.092	1.092 - 1.092	6	5
K	Yukon Gold	C/FM	0	0	0	0	31	0	0	0	0	-	-	1.086	1.089	1.086 - 1.089	4	4

Scab	
[1]Type = 0 - 6	[2]Coverage = 0 - 6
0= no lesions	1=1 lesion to 2% surface area
1= superfical discrete	2= 2.1-5%
2=coalescing superficial	3=5.1-10%
3= raised discrete	3 = 5 - 10%
4= raised coalescing	4= 10.1-25%
5= pitted discrete	5=25.1%-50%
6=pitted coalescing	6= > 50%

*Off the Field
Chips 90 seconds @ 375F
Fries 3 min. @ 375

**Chip SFA Score 1.0-5.0 (>2.5 unacceptable)
**Fry Score USDA 00 = best; 5 = worst

2014 University of Minnesota
Potato Breeding and Genetics

Williston, ND
Preliminary Yield Trials

					Size Distribution															
					<2oz		2-4oz		4-6oz		6-8oz		8-10oz		10-12oz		12-14oz		>14	
Loc	Clone	Trial	Mkt	Skin	*cnt	Cwt	cnt	Cwt	cnt	Cwt	cnt	Cwt	cnt	Cwt	cnt	Cwt	cnt	Cwt	cnt	Cwt
W	Atlantic	Chk	C	W	3	2.054	18	23.107	20	39.653	23	63.773	12	42.278	10	43.932	4	20.911	9	61.762
W	MN02467Rus/Y	G12	FF/FM	Rus	9	5.727	29	36.501	23	46.157	25	70.356	15.5	56.441	14	61.455	4	20.618	5.5	33.962
W	MN04844-07	G10	FM/C	W	51	31.865	97.5	113.097	17	31.758	3	8.059	3	11.254	1	4.236	0	0	0	0
W	MN07014GFB-01LW	G6	FF	LW	22	14.249	58.5	69.878	35	68.487	16	44.096	10	35.574	3.5	15.94	4	21.096	5	35.174
W	MN07023BB-01Rus	G6	FF	Rus	10	6.49	29	35.745	46	90.86	23	63.702	18	66.183	12	52.205	7	36.886	6	41.079
W	MN07051BB-01Rus	G6	FF	Rus	16	9.913	46	57.982	42	83.899	15	42.178	8	27.971	2	8.958	2	10.412	0	0
W	MN07106GFB-01	G6	C	W	33	19.983	68	83.685	40	79.506	12	33.662	2	7.217	0	0	0	0	1	6.447
W	MN07112WB-01W/P	G6	FM	W/Purple	146	83.1	161	183.859	79	153.035	37	101.372	20	71.561	13	58.424	8	42.377	3	21.681
W	MN07257BB-01Rus	G6	FF	Rus	12	7.332	47	57.896	44	88.278	33	92.101	21	74.542	9	39.895	6	31.851	1	6.618
W	MN07286GFB-01R/Y	G6	FM	Red	47	29.797	70	82.572	40	79.135	16	45.629	11	39.082	4	17.673	1	5.434	0	0
W	MN07289BB-01	G6	C	W	68	41.172	118.5	136.632	21.5	39.325	4	11.126	0	0	0	0	0	0	0	0
W	MN07312BB-01	G6	C	W	27	17.915	81	97.706	52	100.416	12	33.135	3	10.94	1	4.122	0	0	0	0
W	MN07330BB-01	G6	C	W/Red splash	28	17.715	59	70.848	54	110.258	24	67.567	8	28.556	4	17.416	2	10.084	0	0
W	MN08001BB-01R	G6	FM	Red	14	8.216	42	53.432	44	85.183	27	77.495	14	50.308	11	49.837	3	15.234	3	18.457
W	MN08025BW-01	G6	C	W	66	39.368	88	106.678	16	30.767	7	18.4	1	3.537	1	4.136	0	0	0	0
W	MN08102BW-01	G6	C	W	31	18.643	63	79.52	43	86.481	21	58.167	14	49.638	1	4.208	0	0	2	15.419
W	MN09059BB-01	G5	C	W	33	20.04	118	141.025	52	98.048	7	18.457	2	6.732	0	0	1	5.434	0	0
W	MN09075BW-01Rus	G5	FF	Rus	5.5	3.295	26	32.757	26.5	55.122	17.5	48.646	17.5	63.095	11	48.076	3.5	18.429	5.5	37.093
W	MN09107BB-01Rus	G5	FF	Rus	24	14.57	62.5	76.254	38.5	75.376	32	89.176	11	39.696	6.5	28.656	3	15.319	2.5	14.977
W	MN09135BW-01Rus	G5	FF	Rus	14.5	9.435	38.5	47.969	37.5	75.961	16.5	46.1	7	24.655	4	17.238	3	16.075	1	6.504
W	MN09151BW-01Rus	G5	FF	Rus	10	6.69	24	31.608	16	31.979	26	69.692	5	16.96	12	52.833	2	10.969	2	12.381
W	MN09152BW-01Rus	G5	FF	Rus	5.5	3.516	16.5	21.039	26.5	53.161	20	56.099	16	57.839	21.5	94.162	7	36.508	17	120.892
W	MN10001PLWR-03LW	G4	FF/FM	LW	3	1.954	8.5	10.191	15	29.854	12.5	34.646	18	64.757	11	48.554	10.5	53.888	10.5	67.738
W	MN10001PLWR-14R	G4	FM	Red	4.5	2.746	12.5	15.169	19	39.311	16.5	47.576	18	65.52	12	53.032	7	36.843	2.5	15.726
W	MN10003PLWR-02R	G4/NCR	FM	Red	25	15.112	79	96.758	58.5	116.891	25.5	70.37	7.5	26.923	6	25.546	2	10.099	0	0
W	MN10003PLWR-03R	G4/NCR	FM	Red	20	11.354	57	69.45	47	93.655	30	86.381	5	17.473	1	4.179	2	10.127	0	0
W	MN10003PLWR-07R	G4/NCR	FM	Red	13	7.118	27	30.268	17	33.876	7	19.698	10	36.215	3	13.451	0	0	1	6.889
W	MN10008PLWR-06R	G4	FM	Red	30	17.744	101	123.908	45	86.481	8	22.223	4	13.836	1	4.736	0	0	0	0
W	MN10010WW-06Rus	G4	FF	Rus	4	2.667	26	32.735	34	68.109	32	89.348	22	78.179	15	66.854	8	41.051	4	25.532
W	MN10013PLWR-04	G4/NCR	C/FM	W	19	11.197	91	113.425	74	146.474	26	69.307	9	31.651	2	8.943	1	4.964	0	0
W	MN10020PLWR-04R	G4/NCR	FM	Red	7	4.336	38	46.257	26	51.092	19	52.747	8	29.326	3	13.165	3	15.947	0	0
W	MN10023BB-01Rus	G4	FF	Rus	4.5	3.031	13	16.753	26	51.827	17	48.154	8	28.263	4.5	20.04	3	15.84	1	6.347
W	MN10023BW-01Rus	G4	FF	Rus	2.5	1.555	16.5	20.447	26.5	54.081	21	59.843	11	39.938	7	30.938	4	21.303	4	28.77
W	MN10024PLWR-09R	G4	FM	Red	15	8.33	29	33.02	13	24.534	3	7.503	1	3.908	3	13.864	1	5.563	1	5.834
W	MN10024PLWR-11R	G4	FM	Red	14	8.658	23	27.657	23	47.855	19	53.86	9	31.266	4	17.658	1	5.135	2	11.639
W	MN10025PLWR-07R	G4/NCR	FM	Red	5	2.724	13	17.587	11	22.965	8	22.308	15	53.76	3	13.579	9	47.441	1	7.246
W	MN10025PLWR-20R	G4	FM	Red	26	15.276	75	89.661	35	69.778	10	26.901	1	3.338	0	0	0	0	0	0
W	MN10030WB-04Rus	G4	FF	Rus	8	5.007	43.5	52.505	50.5	101.094	21.5	59.508	10	35.602	4	18.093	1	5.263	1.5	10.37
W	MN10053BW-01Rus	G4	FF	Rus	7	4.586	37.5	46.179	40	79.548	21.5	61.348	15	54.017	8	35.438	5	25.931	5	34.818
W	MN10054BW-01Rus	G4	FF	Rus	0	0	8	10.177	15.5	31.223	15.5	43.354	8	29.162	9.5	42.598	6.5	34.154	14.5	97.87
W	MN10056WB-10Rus	G4	FF	Rus	19	11.518	43.5	53.781	24	46.842	8.5	23.72	4.5	15.961	1.5	6.854	0	0	2	13.172
W	MN10056WW-05Rus	G4	FF	Rus	12.5	8.301	40.5	49.124	26	49.395	6	16.624	2	6.932	0	0	0	0	0	0
W	MN10056WW-10Rus	G4	FF	Rus	5	2.96	21.5	26.174	35	70.134	22	60.478	14.5	52.64	2.5	10.655	2	10.163	0	0
W	MN10064BW-01Rus	G4	FF	LW	33.5	21.823	58.5	72.602	49.5	97.592	29	81.702	12	43.461	7.5	33.363	4	20.896	3	18.429
W	MN11026WB-07Rus	G3	FF	Rus	17	10.47	44	55.015	34	68.252	21	59.323	27	96.052	8	35.417	5	27.144	5	35.902
W	MN11027WW-06Rus	G3	FF	Rus	2	1.134	8.5	10.84	14.5	29.048	18.5	51.848	14	51.363	7	30.688	7.5	39.724	13.5	95.631
W	MN11031WW-01Rus	G3	FF	Rus	6.5	3.737	22	25.418	23	45.473	20	57.704	14	49.944	12	53.567	3.5	18.044	9	59.287
W	MN11035WB-06LW	G3	FF	LW	4.5	3.003	14	17.601	19.5	40.316	14.5	39.881	14	51.585	11.5	51.15	9.5	50.436	10	71.026
W	MN11037PLWRGR-04R	G3	FM	Red	30	17.787	66	78.521	39	75.084	6	17.473	0	0	0	0	0	0	0	0
W	MN11040WB-04Rus	G3	FF	Rus	27	16.453	48.5	57.14	25.5	50.023	6.5	17.737	4	13.608	2	8.523	2	9.985	0	0
W	MN11040WB-07RusCT	G3	FF	Rus	6	3.366	18	21.966	21	44.389	18	50.565	9	31.993	4	17.088	3	15.576	2	12.524
W	MN11040WB-12Rus	G3	FF	Rus	9	5.078	32	40.58	43	85.639	20	55.058	5	17.245	2	8.444	1	5.406	0	0
W	MN11042PLWRGR-03R	G3	FM	Red	21.5	13.272	58.5	72.495	39	79.156	13	34.718	5.5	19.869	2	8.701	1	4.992	1	5.976
W	MN11048WW-04Rus	G3	FF	Rus	9	5.42	43.5	54.737	52	105.138	23.5	65.313	10.5	37.221	2.5	10.869	2	10.598	0	0
W	MN11057WB-03Rus	G3	FF	Rus	12	8.066	44.5	55.543	40.5	79.456	16.5	45.587	9.5	33.192	1.5	6.469	0	0	0	0
W	MN11057WB-04Rus	G3	FF	Rus	7.5	5.342	32	40.166	26.5	56.177	28	78.265	14	50.451	2	8.843	1	5.092	1.5	9.749
W	MN11057WW-04Rus	G3	FF	Rus	18	11.311	47	59.622	50	100.816	24	66.141	6	21.695	3	13.18	0	0	2	15.547
W	MN11059PLWRGR-07R	G3	FM	Red	52	31.209	97	112.526	43	82.843	10	26.188	4	14.649	1	4.493	2	10.355	1	7.802
W	MN11124PLWRGR-01Rus	G3	FF	Rus	1	0.442	9	11.397	8	15.776	10	28.442	10	36.273	11	49.281	6	31.694	21	152.678
W	MN11136PLWRGR-10	G3	C	W	4	2.354	19	23.521	20	38.811	16	46.143	16	57.197	15	65.813	9	47.726	8	57.597
W	MN11136PLWRGR-11	G3	C	W	26	16.332	104	123.566	54	106.521	16	42.563	3	10.427	1	4.678	2	10.512	0	0
W	MN11142PLWRGR-01	G3	C	W	18	10.455	32	40.152	37	75.74	22	60.421	8	27.629	0	0	0	0	0	0
W	MN11153PLWRGR-03	G3	C	W	24	14.92	63	77.138	40	79.663	15	42.306	6	20.739	7	31.623	0	0	0	0
W	MN11189PLWRGR-02	G3	C	W	50	29.996	81	95.082	60	121.455	19	53.047	7	25.133	6	27.015	1	5.092	0	0
W	MN12004WB-01R	G2	FM	Red	13	8.159	19	22.993	20	38.94	10	28.527	8	29.012	3	13.978	2	10.598	2	15.405
W	MN12004WW-01R	G2	FM	Red	15	9.072	28	35.745	23	48.268	15	42.163	4	13.864	1	4.607	1	5.035	3	20.739
W	MN12028WB-01Rus	G2	FF	Rus	6	3.837	25	31.594	22	42.934	32	88.606	14	51.62	10	44.859	5	26.559	8	58.253
W	MN12088WW-01Rus	G2	FF	Rus	7	4.165	18	22.365	19	39.339	21	59.565	17	62.09	8	36.358	8	42.477	22	164.104
W	MN12113WW-01Rus	G2	FF	Rus	10	5.663	20	24.448	29	58.666	23	63.973	22	79.934	9	40.594	8	41.222	1	5.962
W	MN12114WB-02Rus	G2	FF	LW	16	9.913	35	42.306	26	49.709	19	53.646	6	20.996	1	4.094	0	0	1	5.877
W	MN12114WW-02LW	G2	FF	LW	6	3.766	41	53.746	26	50.693	18	49.252	17	60.278	7	30.068	2	10.227	0	0
W	MN12124WB-01Rus	G2	FF	Rus	1	0.799	8	10.07	23	47.384	14	39.439	17	62.175	11	48.154	6	31.266	14	98.12
W	MN12124WW-01Rus	G2	FF	Rus	2	1.255	15	19.769	27	54.53	23	64.572	19	69.05	14	61.933	9	46.057	16	109.274
W	MN12138WW-01	G2	C	W	10	6.076	25	30.481	21	42.663	21	59.422	13	46.771	5	22.565	4	20.896	1	5.82
W	MN18747	G16	FF/FM	LW	2	1.155	3	3.152	6	13.123	10	29.868	10	36.13	16	70.12	5	26.787	18	131.825
W	MonDak Gold	G16	FF/FM	Red	9	5.834	26	33.377	29	61.205	41	115.664	28	102.442	22	97.35	6	31.323	10	65
W	NDMN120013WB-01Rus	G2	FF	Rus	8	4.564	36	44.56	53	112.555	25	69.307	20	71.404	9	39.04	5	26.459	2	14.663
W	NDMN120013WW-01Rus	G2	FF	Rus	0	0	14	17.644	24	47.027	31	88.135	21	75.868	15	66.298	11	58.139	2	12.338
W	NDMN120015WB-01Rus	G2	FF	Rus	18	10.897	64	80.946	31	59.323	9	24.819	3	10.698	1	4.436	0	0	0	0
W	NDMN120015WW-02Rus	G2	FF	Rus	7	4.194	35	43.319	29	56.256	24	68.851	6	21.567	5	22.037	1	5.206	1	5.877
W	NDMN120020WW-01Rus	G2	FF	Rus	32	19.655	80	93.37	11	20.04	1	3.052	1	3.951	0	0	0	0	0	0
W	NDMN120022WB-01Rus	G2	FF	Rus	27	17.302	61	72.73	37	72.688	7	18.5	3	10.07	2	9.243	0	0	0	0
W	NDMN120022WW-01Rus	G2	FF	Rus	17	10.912	58	68.822	55	111.442	27	76.838	15	54.402	0	0	2	9.956	2	11.768
W	NDMN120024WW-02Rus	G2	FF	Rus	5	3.124	43	53.917	35	69.179	27	74.342	13	45.843	7	31.708	3	15.562	1	5.934
W	NDMN120029WW-01Rus	G2	FF	Rus	6	3.281	15	19.498	18	37.314	17	49.267	6	22.209	8	35.93	6	32.165	19	139.028
W	NDMN120048WW-01Rus	G2	FF	Rus	12	7.118	22	28.427	24	47.256	21	58.852	11	38.726	6	25.846	0	0	1	5.763
W	NDMN120053WB-02Rus	G2	FF	Rus	20	11.696	37	42.035	18	35.231	4	10.641	3	10.598	0	0	0	0	0	0
W	NDMN120053WW-01Rus	G2	FF	Rus	73	43.747	101	116.976	19	37.528	2	5.905	0	0	0	0	0	0	0	0
W	NDMN120058WW-01Rus	G2	FF	Rus	7	4.436	24	31.166	32	65	28	77.01	13	47.37	5	22.066	1	5.278	6	38.055
W	NDMN120063WW-01Rus	G2	FF	Rus	8	5.192	51	62.09	42	86.609	23	62.204	1	3.38	4	17.288	0	0	0	0
W	NorValley	Chk	C	W	14	7.988	29	35.017	46	92.671	36	100.388	27	97.193	12	52.333	8	41.45	7	44.36
W	Red Lasoda	Chk	FM	Red	9.5	5.677	18.5	23.014	18	36.094	27	76.482	19	68.894	11.5	50.294	10	52.982	15	106.999
W	Red Norland	Chk	FM	Red	9	5.206	8	10.798	7	13.978	16	45.316	15	56.641	10	44.66	4	21.167	14	97.82
W	Russet Burbank	Chk	FF	Rus	11	6.668	31.5	38.405	48.5	97.549	37.5	105.302	27.5	99.211	24.5	107.149	17	89.305	14.5	100.994
W	Shepody	Chk	FF	LW	2.5	1.533	4	4.671	8.5	16.96	6.5	18.621	10	36.593	8	34.525	6.5	34.825	23.5	174.316
W	Yukon Gold	Chk	FM	W	4	1.897	7	7.959	10	20.44	5	13.75	7	25.261	8	35.716	6	30.752	8	49.267

*cnt = count (# tubers)

Resistance in Colorado Potato Beetle in Minnesota and North Dakota – Mapping and Management

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Executive Summary – This is a continuing project designed to initiate a resistance monitoring program for neonicotinoid insensitive Colorado Potato Beetles in Minnesota and North Dakota and investigates the efficacy and relative economic benefit of alternate insecticides. The monitoring program, once established as a result of this project, will continue in the future as a listed extension activity of the PI.

Rationale – Colorado Potato Beetle (CPB), *Leptinotarsa decimlineata* Say is one of the most damaging insect pests of potatoes in Minnesota and North Dakota. Typically, this defoliating insect has required intensive chemical management with broad spectrum insecticides. This, combined with the detoxification systems which permit the insect to feed on the foliage of potato plants, high in toxic alkyloids, has led to CPB developing resistance to essentially every insecticide ever used against it (Weisz et al. 1994, Alyokhin et al. 2007). Reduced sensitivity to an insecticide (i.e. resistance) results from the presence in certain individuals of a gene that allows that individual to be less or completely unaffected by the insecticide. As the presence of the insecticide increases, the individuals in the population who lack this gene die and the only survivors are individuals that possess the 'resistant' gene. Consequently, resistance is both an inherited and a population trait. To ascertain if resistance is developing, multiple individuals from a population must be tested. Further, resistance has a spatial aspect, the area within which resistance may develop is somewhat bounded by the area within which there is exchange of genes (the area within the group of insects are breeding).

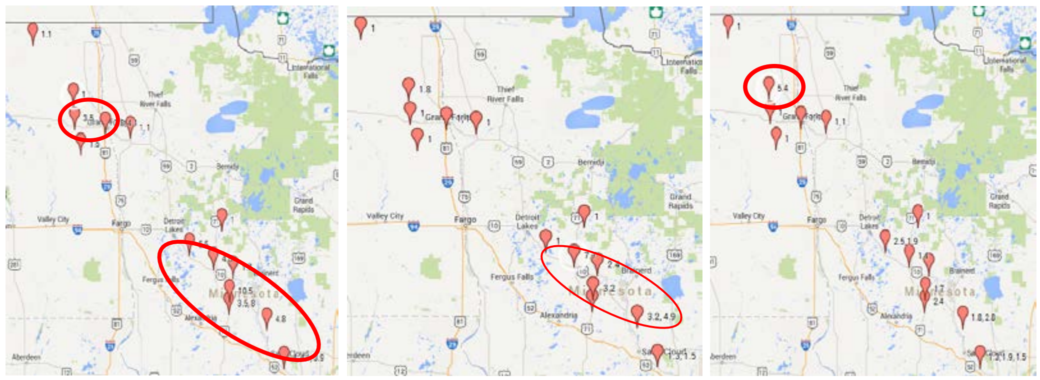
The development of resistance continues to be a significant problem in managing CPB (Jorg et al. 2007). The rapidity with which CPB can develop resistance is remarkable; some insecticides (e.g. oxymyl) have lost effectiveness within their first season of use (Forgash 1985). In some cases, the development of resistance to insecticides by a local population of CPB results in its 'appearance' as a pest in areas where it has not previously been a problem. This may result from these beetle populations losing their susceptibility to insecticides used in the production system that had previously been suppressing their populations. The introduction of the neonicitinoid insecticides initially provided some alternatives to existing classes of insecticides. The systemic abilities of these insecticides made them especially efficacious for whole field treatment and provided excellent protection. It was, however, recognized that resistance would develop and their effectiveness would eventually fade.

In 2000, the first reports of resistance to the neonicotinoid insecticide imidacloprid (Admire, Bayer Crop Science) was reported in New York (Olson et al. 2000, Zhang et al. 2000) and later from Maine (Alyokhin & Dwyer 2005). This resistance was later linked to cross-resistance to the neonicotinoid insecticide thiamethoxam (Platinum, Cruiser, Syngenta Crop Protection) (Alyokhin et al 2007). These insecticides are used on ~70% of all potatoes grown from Maine to North Dakota, belong to the same class of insecticides, and have the same mode of action. The development of cross-resistance refers to a population of insects that develop resistance to an insecticide with a specific mode of action that are then resistant, or partially resistant, to all other insecticides with the same mode of action (which may include all insecticides in that class).

This situation was reported from a number of field locations in Minnesota in 2007. In certain locations, populations of CPB were apparently tolerant of field rate applications of imidacloprid. It was subsequently learned that an associated cross resistance to thiamethoxam was also present in these populations. Although not a linear relationship (a 15 fold resistance to thiamethoxam was associated with a 100 fold resistance to imidacloprid), the presence of this cross-resistance does suggest that the future use of these and other neonicotinoids to control CPB in Minnesota and North Dakota may be problematic. In addition, research indicates CPB resistant to imidacloprid will be partially resistant to new neonicotinoid insecticides such as acetamiprid, introduced in 2005 (Assail, Cerexagri), and dinotefuran (Venom, Valent Corp.), even prior to their use in the field (Grafius & Byrne, 2005).

In 2013, a population of CPB from Inkster, ND demonstrated what may be a tolerance to Abamectin (a.i. = avermectin, moa group 6). This insecticide is an important alternate chemistry in managing CPB and its loss to tolerance would be a significant impact in managing resistant populations in MN and ND.

Recently, populations of CPB that are insensitive to neonicotinoid insecticides have been reported from Central Minnesota and this insensitivity may be spreading geographically. This has resulted in a significant increase in control costs for this insect pest. The initial response to this situation is to identify alternative chemistries and application methods that remain effective or may either alleviate insensitivities in CPB. In 2010-2013, CPB populations were sampled from multiple locations in Minnesota and North Dakota and assessed for tolerance to neonicotinoid insecticides at the entomology lab at UMN-NWROC (2010 samples were analyzed at U. Mich). Results indicate a number of locations have either well-established or developing resistance to Imidacloprid and/or *Clothianidin* while resistance to Thiamethoxam does not seem be as well developed in Minnesota & North Dakota (Table 1). The efficacy of Imidacloprid is decreasing in CPB populations in central MN and in some of those in the central Red River Valley, and the efficacy of Clothianidin seems to be decreasing in some CPB populations in Central MN (Fig 1). The only reported CPB population demonstrated to tolerate Thiomethoxam is in the west central Red River Valley (Fig 1).



Imidacloprid **Clothianidin** **Thiomethoxam**

Figure 1. Geographical distribution of the tolerance of three neonitcotinoid insecticides in Colorado Potato Beetle populations sampled in MN and ND. Numbers on the maps represent the comparative Resistance Ratio of insects sampled at that location. Circles represent areas within which decreased efficacy of neonicotinoids have been demonstrated through laboratory testing.

Considering neonicotinoid insecticides were effective in these locations only 10 years ago, it can be assumed we are seeing an increase in resistance to neonicotinoids in CPB in Minnesota. Monitoring the current and future geographic distribution of resistant CPB in Minnesota and North Dakota is necessary to estimate rates of spread of neonicotinoid resistance to other potato producing areas in the states and facilitate the development of resistance management programs. Unfortunately, the number of sites that can be evaluated by outstate labs in any one year is limited. Therefore, an instate program to test and map developing neonicotinoid resistance in MN and ND would enhance our ability to respond to this developing problem.

We propose to establish a program to annually assess and map the susceptibility of CPB in potato growing areas of MN and ND. By conducting this program within state we will be able to assess significantly more areas in a given year. In addition, to provide economically sustainable, working alternative controls, both registered and unregistered chemical controls will be evaluated for efficacy and economic cost.

Table 1. Comparison of relative resistance rates of sampled sites and those of a known susceptible population, 2011-2013. Numbers indicate the comparative resistance factor (i.e. a value of 3.92 indicates the population at that sampled site is 3.92 times as resistance as a susceptible population – i.e. it would take 3.92 times as much insecticide to kill these less susceptible insects). Values of 0x-3x indicate susceptibility to that chemical, values 3x-5x indicate minor resistance, 5x-8x indicate low levels of resistance, values 8x-10x are moderate resistance, values over 10x indicate well-established, high resistance. Rations presented in red or italics are results of concern. NT = Not Tested.

2011	**Imidacloprid (Admire)**	**Thiomethoxam (Cruiser)**	**Clothianidin (Belay)**
Becker	**4**	**1.3**	NT
Long Prairie	**3.5**	2.4	NT
Perham	**8**	2.5	NT
Crookston	1	1	
2012			
Becker	**4.1**	1.9	1
Browerville2	**10.5**	1.7	**3.2**
Browerville1	1.4	1	1
Hubbard	1	1	1
Hatton	1.6	1	1
Rice	1.5	NT	**3.2**
Perham	**5.5**	1.9	1
Wadena	**4.5**	1.4	**7.7**
Grand Forks	**3.8**	1	1
Forest River	2.5	1.1	1.1
2013			
Becker	**3.9**	1.5	1.3
Rice2	**4.8**	2.8	**4.9**
Rice1	NT	1.8	1.9
Staples	1.7	NT	2.4
Crookston	1	1	1
Forest River	2	NT	NT
Langdon	1.1	1	1
Larimore	**3.5**	1	1
Inkster	1	**5.4**	1.8
Grand Forks	**4.1**	1	1

Procedures

Geographic Distribution of Resistance in MN and ND - Colorado potato beetle adults will be sampled from potato production areas within Minnesota and North Dakota. Both overwintering adults and summer generation adults will be sampled. Larvae will be sampled whenever possible but are more difficult to transport, maintain, and test than are adults.

Sampled beetles will be assessed for susceptibility to neonicotinoid insecticides using a direct exposure bioassay. Residual bioassays were found to be time consuming and not to provide much additional information. Consequently, direct exposure bioassays will be used in 2014. Various concentrations of active ingredient (ai), the actual toxin in the insecticide, are used in trials to determine how much insecticide is required to kill 50% of the population (i.e. the Lethal Concentration 50% or 'LC_{50}'). In direct exposure trials, drops of insecticide are directly applied to the insect using a microsyringe. Beetles are assessed for mortality at 24, 48, 96, and 120 hours after removal. They are placed onto their backs and evaluated for movement. Any insect not righting itself is assessed as dead or impacted by the insecticide.

The only way to determine if a population of insects is developing resistance is to calculate the LC_{50} of a suspected resistant population and compare it to that of population known to be susceptible to the insecticide. Populations of CPB at the University of Minnesota's Northwest Research & Outreach Center (NWROC) in Crookston, MN have not yet shown decreased sensitivity to neonicotinoid insecticides. Preliminary bioassays of this population have indicated LC_{50}'s consistent with those of susceptible populations reported in the literature. A colony of these individuals will be established and maintained at the NWROC and used as a susceptible population. In addition, a colony of susceptible individuals used at other locations as susceptible, is being obtained and will also be maintained as a susceptible population. The LC_{50} of populations sampled from across Minnesota and North Dakota will be calculated for three neonicotinoid insecticides (imidacloprid [Admire Pro], thiamethoxam [Platinum], and clothianidin [Belay]) and for the avermectin based insecticide, Abamectin. These LC_{50} values from sampled populations will be compared to those of the susceptible population. LC_{50} values will be calculated using PROBIT analyses. These analyses will provide a measurement of how much more insecticide it takes to kill the sampled population than it does to kill the susceptible population. The LC_{50}'s of sampled populations divided by that of the susceptible populations provide a resistance ratio, or measurement of how more resistant the sampled population is than the susceptible population. Resistance ratios greater than 3 indicate developing or established resistance.

The rate of spread of neonicotinoid resistance is of importance to area wide management. Regional levels of neonicotinoid insensitivity will be calculated and mapped annually for Minnesota and North Dakota. To facilitate management decisions in the next growing season, annual maps will be distributed at the annual research reporting sessions for both production areas and a publication prepared for the Valley Potato Grower magazine and available on the potato extension entomology website.

The high levels of variability in the genotypes of individuals in a population and, consequently, the levels of resistance being expressed, means a very high sample number is required for these trials; >400 beetles per location will be sampled and at least 75% of these will be used in testing. It is apparent that not all potato production areas within the two states can be sampled in one year; CPB populations that appear to becoming less susceptible to neonicotinoid insecticides will have priority in being assessed first. However, baseline levels of susceptibility should eventually be obtained for all CPB populations across the 2 states and monitored in future years. The establishment of a testing facility in Minnesota will facilitate future monitoring of resistance in MN and ND.

Changes for 2014 – In 2013, we were not able to test as many populations as we had hoped. Emergence of CPB in many locations in central MN were delayed or low. In addition, delayed emergence meant extended presence of overwintered adults, thereby confounding trial results (see Appendix 1 for a summarized report of 2013 findings). In 2014 we will expand our testing to include Abamectin. We found a suspected tolerance for this insecticide in the population at the Forest River test plot site. This is of concern as Abamectin is one of the most effective alternate insecticides available for neonicotinoid tolerant adult CPB in central Minnesota.

Field collection will again be conducted with UMN field crews from multiple locations both early in the season and later, collecting summer generation adults, requiring increased travel but providing better coverage and hopefully a comparison between overwintering and summer adults in the same populations. Samples will also still be sought from cooperators experiencing product failures or apparent decreased efficacy from neonicotinoid applications.

Alternative Chemical Controls – To determine the efficacy and economic sustainability of alternative chemical controls a series of insecticide trials will be established at the Sand Plains Research Farm in Becker, MN. Populations of CPB at this location have been repeatedly shown low levels of resistance to imidacloprid (Table 1). Registered and unregistered chemistries will be tested for efficacy and their cost per acre / season (some alternate chemistries may require multiple applications) will be calculated and compared to current management costs. Trials will include both at-plant and foliar applications. In addition, specific rotations of registered chemicals will be evaluated for season-long beetle suppression. Beetle populations will be monitored weekly and foliar applications will be started when action thresholds are reached and continue until CPB is no longer defoliating plants. Seasonal CPB population dynamics, yield, and quality data from plots will be analyzed and compared. Economic analyses will be analyzed and related to beetle suppression.

Results and Discussion

Geographic Distribution of Resistance in MN and ND – The late spring and wet June (wettest recorded in MN weather records) suppressed emergence of Colorado Potato Beetle populations in 2014. We had suppressed and delayed emergence of adult CPB and overwintered individuals were found in fields into August (overwintered adults are identifiable by their red flight wings (Fig 2).

As a result, there were few locations that had high levels of CPB populations and those that were found were mixed between overwintered and summer adults. In laboratory assessments of resistance levels, it is best to avoid mixing the two generations as summer adults have significantly higher levels of resistance and can skew the results to indicate at-plant insecticides are less effective than they may be.

Figure 2. Overwintered adult Colorado Potato Beetle. Note the red flight wings, found under the hard, striped outer wings.

As a result, we were able to sample only three additional locations: a second Wadena site, Forest River and Grand Forks (Table 2). These data add to our knowledge of the distribution of neonicotinoid resistance in MN and ND. We had our first record of thiomethoxam resistance in central MN (the Wadena site recorded a minor resistance to the active ingredient in Platinum/Cruiser). Resistance levels in Grand Forks did not change significantly, although there was a higher level of resistance in thiomethoxam than in previous years. Although our lab assays found minor levels of resistance to both imidacloprid and thiomethoxam at the Forest River research site, these may well have been influenced by low sample numbers and should be interpreted with caution. Our sample numbers were limited at Forest River and we reserved enough to test against Abamectin.

The Abamectin assays on Forest River CPB were limited by sample numbers, as were the neonicotinoid assays of that population, and were compared to a laboratory population that had not been exposed to avermectin based insecticides. Data from 2014 was inconclusive for Abamectin resistance, variability in the data due to low sample size precluded determining if the Forest River population is resistant to Abamectin. However, given the failure in 2013, the use of Abamectin at the Forest River research site should be moderated. This trial will be repeated in 2015 if populations permit.

Alternative Chemical Controls – In 2014, three small plot insecticide trials were conducted at the UMN Sand Plains Research Farm in Becker, MN. The first was an at-plant trials followed by foliar applications of different insecticides applied in response to foliar CPB thresholds (20% pre-bloom and ~10%-15% post-bloom). At-plant insecticides used were either neonicotinoids or diamides (e.g. Verimark, Corragen) followed by a number of different modes of action (Table 3).

Table 2. Comparison of relative resistance rates of sampled sites and those of a known susceptible population, 2011-2013. Numbers indicate the comparative resistance factor (i.e. a value of 3.92 indicates the population at that sampled site is 3.92 times as resistance as a susceptible population – i.e. it would take 3.92 times as much insecticide to kill these less susceptible insects). Values of 0x-3x indicate susceptibility to that chemical, values 3x-5x indicate minor resistance, 5x-8x indicate low levels of resistance, values 8x-10x are moderate resistance, values over 10x indicate well-established, high resistance. Rations presented in red or italics are results of concern. NT = Not Tested.

2011	Imidacloprid (Admire)	Thiomethoxam (Cruiser)	Clothianidin (Belay)
Becker	4	1.3	NT
Long Prairie	3.5	2.4	NT
Perham	8	2.5	NT
Crookston	1	1	
2012			
Becker	4.1	1.9	1
Browerville2	10.5	1.7	3.2
Browerville1	1.4	1	1
Hubbard	1	1	1
Hatton	1.6	1	1
Rice	1.5	NT	3.2
Perham	5.5	1.9	1
Wadena	4.5	1.4	7.7
Grand Forks	3.8	1	1
Forest River	2.5	1.1	1.1
2013			
Becker	3.9	1.5	1.3
Rice2	4.8	2.8	4.9
Rice1	NT	1.8	1.9
Staples	1.7	NT	2.4
Crookston	1	1	1
Forest River	2	NT	NT
Langdon	1.1	1	1
Larimore	3.5	1	1
Inkster	1	5.4	1.8
Grand Forks	4.1	1	1
2014			
Forest River	*7.5**	*4.9**	0.9
Wadena	8.8	4.8	6.2
Grand Forks	3.8	2.9	1.7

*very low sample numbers

In addition, two foliar-only trials were conducted; one a foliar trial incorporating foliar applications of a new diamide at several rates and the second a trial of organic alternative insecticides. The mean number of Colorado potato beetle, aphids and potato leafhoppers in each treatment were assessed weekly along with percent defoliation in each plot. Yields and tuber size were calculated for each treatment.

Table 3. At-plant treatment combinations. Letters indicate the insecticide used as a following foliar treatment.

At-Plant Treatment		**Following Foliar Treatment**	
At-Plant	**Foliar**		**Insecticide**
No Insecticide (UTC)	(A, B, C, D)	A	No Insecticide (UTC)
Platinum	(A, B, C)	B	Blackhawk (Sponosyn)
Belay & Platinum (both full rate)	(A, B, C)	C	Cyclaniliprole
Cyzapyr (Verimark)	(A, B, D)	D	Belay
Belay	(A, B, C)		
Unregistered Diamide	(A, B, D)		

i) At-plant / foliar trials showed distinct differences in mean yields (P<0.001, Table 4, fig. 3 and 4). Treatments with Platinum at plant, followed by foliar applications of Blackhawk or Cyclaniliprole, Belay & Platinum at plant followed by no foliar or a foliar

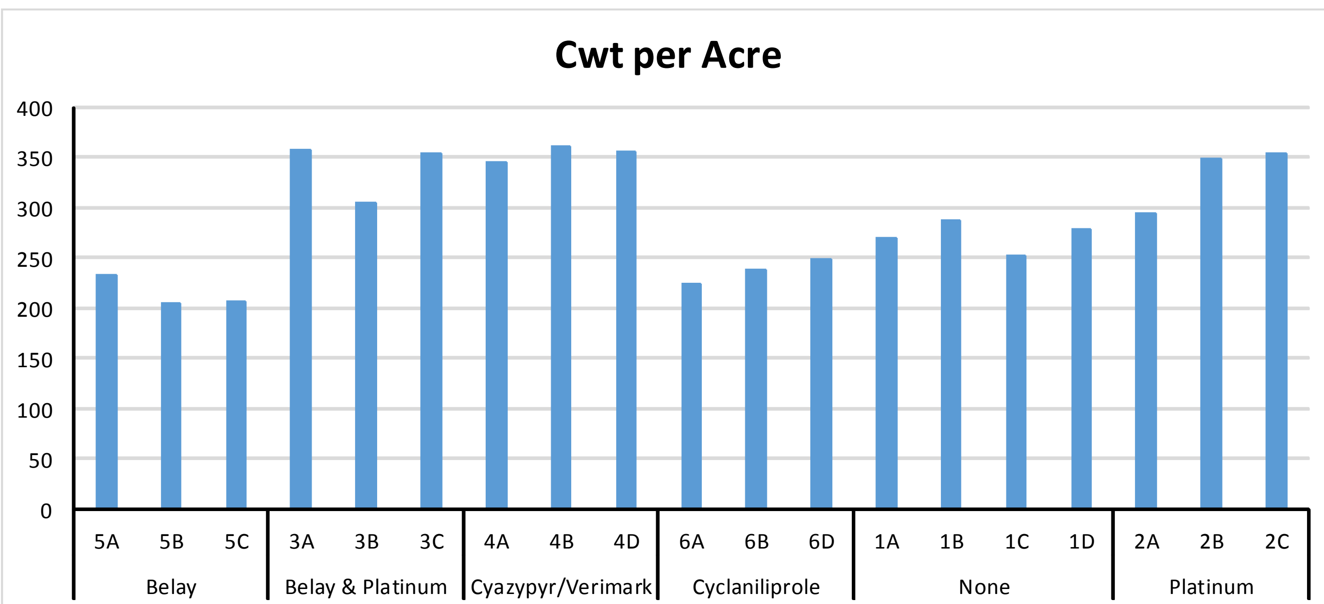


Figure 3. Yields (in 100wt/ac) of at-plant followed by foliar insecticide trials. Insecticide names at bottom of graph represent the at-plant insecticide used. Letters above the at-plant insecticide represent the foliar insecticide used. A = no foliar insecticide, B = Blackhawk (Spinosad), C = Cyclaniliprole, D = Belay.

treatment of Cyclaniliprole, and treatments with Cyazypyr (Verimark) at plant followed by no foliar insecticide, or foliar applications of Blackhawk or Cyclaniliprole had significantly higher yields than did plots treated with Belay at plant followed by foliar applications of Blackhawk or Cyclaniliprople or than did plots with Cyclaniliprole at plant followed by no foliar insecticide (fig. 4). There were no significant differences in any other at plant and following foliar treatment.

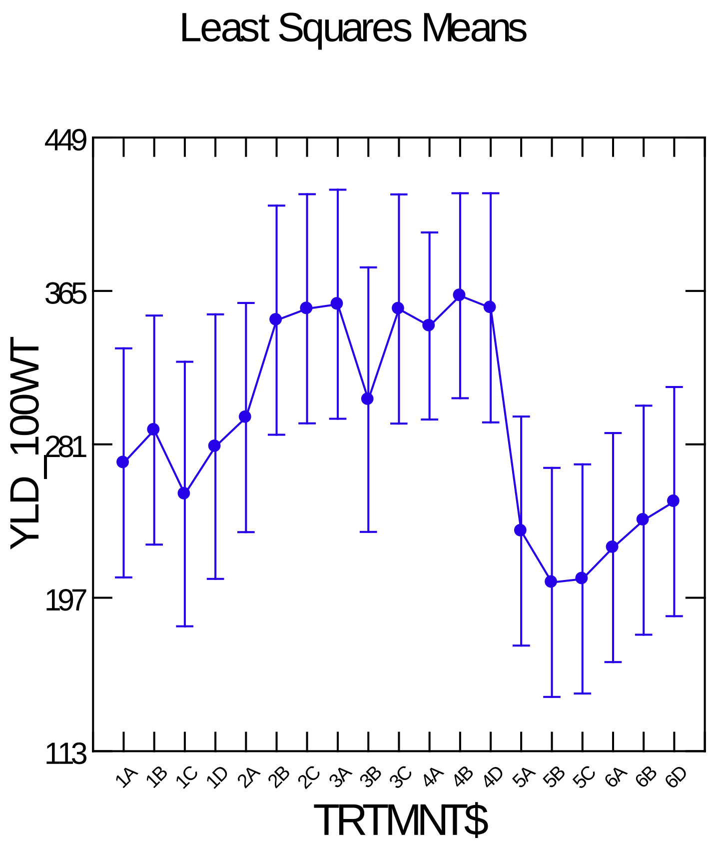


Figure 4. Mean yields (in 100wt/ac) per treatment, vertical bars represent 95% CIs. Vertical lines are 95% Confidence Intervals, overlap bars are not statistically different.

Statistical differences between weekly population levels of CPB within plots were not calculated but the weekly CPB population dynamics are presented in Appendix 1. It is clear that all products were somewhat effective in reducing CPB populations but the yield data is of the most appropriate to present in this context.

ii) Foliar Trial (new diamide insecticide) – Cyclaniliprole is a new diamide insecticide considered for registration as a foliar treatment for potato insects. Trials were established at the UMN Sand Plains Research Farm in Becker, MN. Three concentrations of Cyclaniliprole (10, fl oz, 11 fl. oz, and 16.4 fl oz) were tested against untreated control plots. Insect numbers, including Colorado potato beetles, were sampled weekly and other stressors, such as disease were monitored. Mean yields from plots treated with any of the 3 concentrations of Cyclaniliprole were significantly higher than untreated control plots (fig. 5 and 6). There was no difference in the yields between the three different concentrations of Cyclaniliprole.

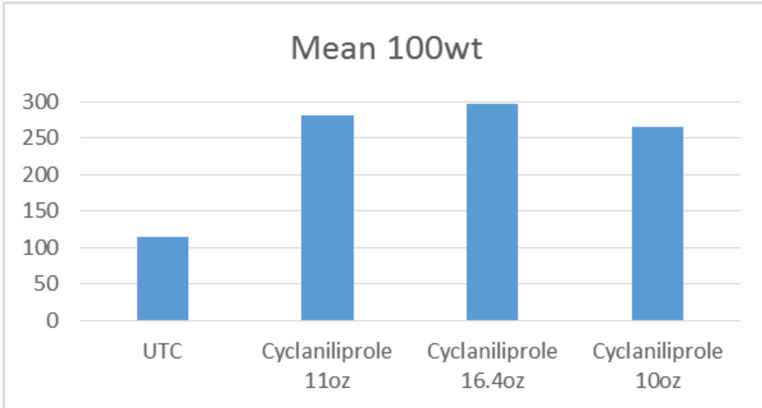


Figure 5. Mean yields (in 100wt/ac) for the 3 Cyclaniliprole treatments and UTC.

Statistical differences between weekly population levels of CPB within plots were not calculated but the weekly CPB population dynamics presented in Appendix 2. There were some trends in CPB management in the 3 different concentrations, however, the lack o9f difference in the yields indicates these may not translate to a basis for the preference of any of the three rates in management decisions.

From the yield data, it is clear that all 3 concentrations were effective in reducing CPB populations over untreated control plots.

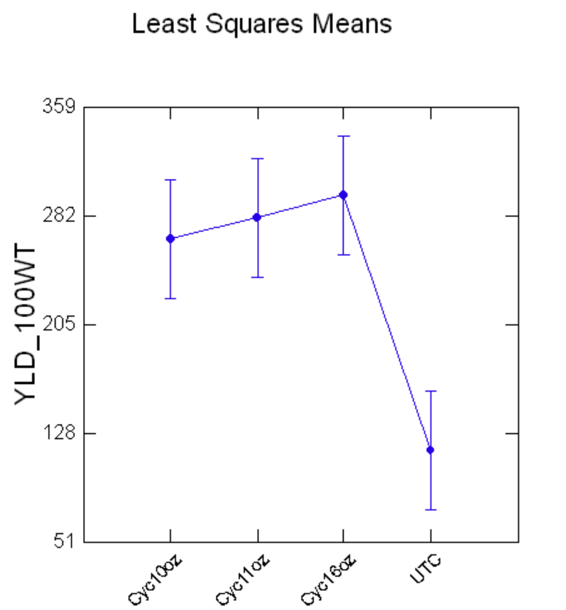


Figure 6. Mean yields (100 wt/ac) of diamide treatments and UTC. Vertical lines are 95% Confidence Intervals, overlap of bars indicates no statistical difference in values.

iii) Organic foliar treatments. In an effort to examine non-traditional control strategies, a number of organic products were examined as possible management for Colorado potato beetle. All insecticide products (Table 4) were manufactured by MGK (Minneapolis, MN). Veratran D is a plant extract of alkaloids, toxic to insects; the active ingredient in Azera is Azifarachtin, an extract of the African Neem plant, widely used as an insecticide; the active ingredient in both Tersus and PyGanic is a mixture of Pyrethrin s, insecticidal extracts of the chrysanthemum plant. The actives were tested with a number of adjuvants and surfactants. Once triggered by defoliation thresholds, insecticides were applied weekly.

Table 4. Treatments in organic foliar trials. All insecticide products available from MGK Inc (Minneapolis, MN).

MGK1	Veratran D	15 lbs/acre
MGK2	Veratran D + Indicate 5	15 lbs/acre + amount to buffer to pH 4.5-5.5 (pink color change)
MGK3	Veratran D + Azera	15 lbs/ acre + 56 fl.oz/acre
MGK4	Azera	56 fl.oz /acre
MGK5	Azera (w/o Py) X numbered	56 fl.oz /acre
MGK6	Tersus	9 fl.oz /acre
MGK7	Tersus + Indicate 5	9 fl.oz /acre + amount to buffer to pH 4.5-5.5 (pink color change)
MGK8	Tersus + Umbrella	9 fl.oz /acre + 16 fluid oz / acre
MGK9	PyGanic 5.0	9 fl.oz /acre
MGK10	PyGanic 5.0 + Surfact 50	9 fl.oz /acre + 16 fluid oz / 100 gallon
MGK11	PyGanic 5.0 + S-K-H	9 fl.oz /acre + 0.75 lbs / 100 gallon
MGK12	PyGanic 5.0 + Ecotec	9 fl.oz /acre + 64 fl. oz / 100 gallon / acre
MGK13	UTC	

Statistical differences between weekly population levels of CPB within plots were not calculated but the weekly CPB population dynamics presented in Appendix 3. There were some trends in CPB management in the 3 different concentrations, however, the lack o9f difference in the yields indicates these may not translate to a basis for the preference of any of the three rates in management decisions.

Yield data showed no differences between any treatment and any treatments and the UTC plots (Fig 7 and 8). This

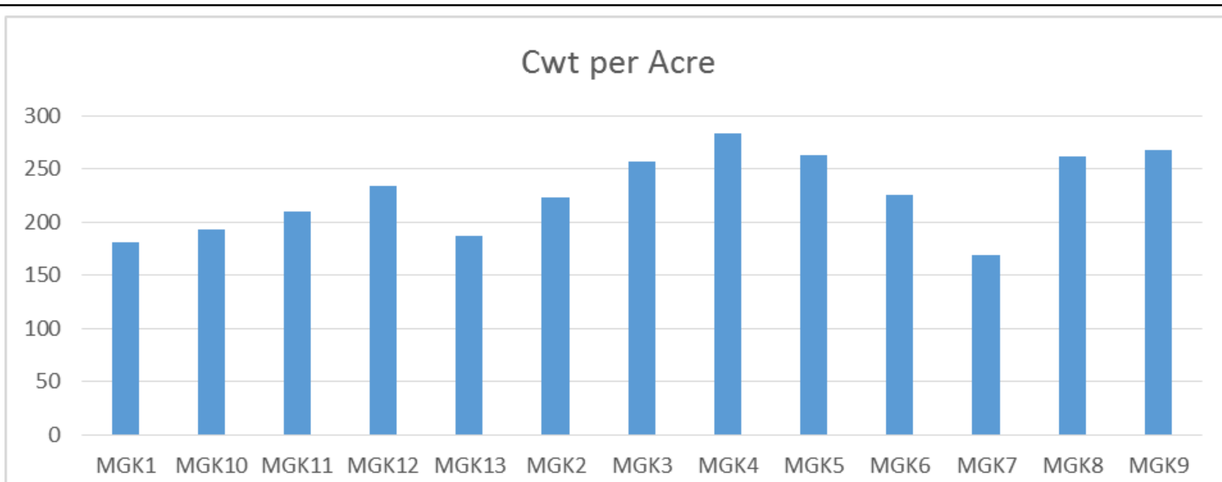


Figure 7. Mean yields (100wt/ac) from organic trials (see Table 4, above, for treatments)

may have been due in part to adult summer CPB moving into treatment plots from untreated plots, where defoliation was excessive.

Generally, organic treatments did suppress CPB numbers (Appendix 3) but were less satisfactory in controlling higher populations of CPB than were standard insecticides.

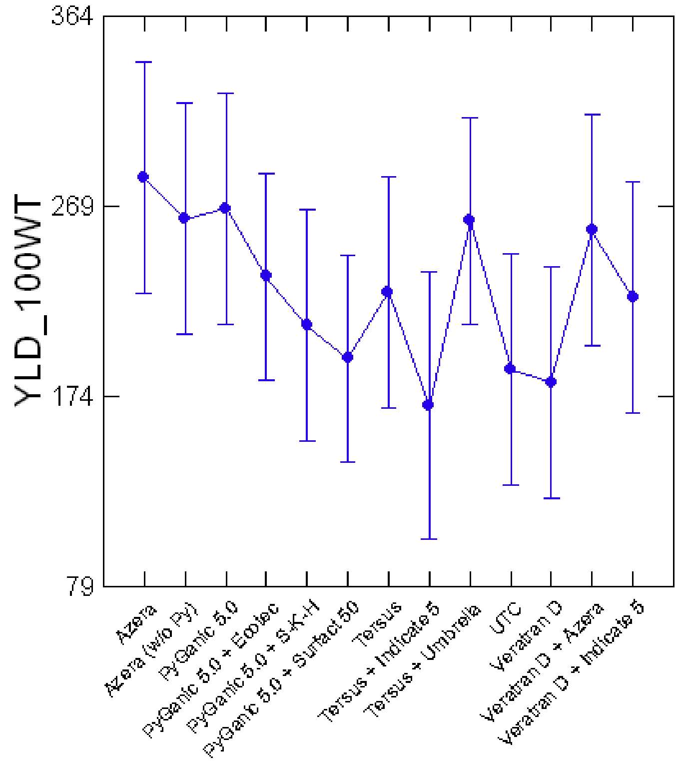


Figure 8. Mean yields (100wt/ac) of organic treatment and UTC plots. Vertical lines are 95% Confidence Intervals, overlap of bars indicates no statistical difference in values.

Remote Sensing of Colorado Potato Beetle Defoliation – the insecticide plots provided the opportunity to investigate the potential to use both visible and Near Infra-red (NIR) cameras to estimate defoliation caused by Colorado potato beetle. Cameras were flown over plots using an unmanned aircraft system (UAS, commonly called a drone). The UAS was a DJI TurboAce, this is an eight bladed rotorcraft approximately 2 ft across, incorporating autopilot and auto-stabilization systems. These systems enable the vehicle to follow a pre-determined flight path and maintain attitudinal position in the air (i.e. minimize the drift and banking resulting from wind, etc). The UAS carried a stabilized camera gimbal that compensated for the vehicles turning and banking, keeping the camera's lens pointing straight at the ground.

Two cameras were used, a TetraCam ADC (and purpose-built agricultural NIR camera) and a Sony NEX-5T, modified to be sensitive to NIR light, were used to obtain imagery. Both of these cameras are sensitive only to green, blue, red and Near Infra-red light spectra. These wavelengths of light are all parts of the sunlight striking plants (called 'incident' light) but their reflectance by plants can be changed if the plants are under stress. Consequently, these specific wavelengths are often used to estimate plant health in remote sensing. For example, chlorophyll absorbs red light and the cells that make up the center of the leaf (parenchyma cells) reflect NIR. Stress (insect feeding, disease, drought, etc) can decrease chlorophyll content or damage parenchyma cells. Consequently, healthy plants tend to reflect less red light and more NIR light than do stressed plants. In the case of defoliation, these wavelengths also accurately reflect the remaining canopy and quite clearly differentiate plant material from the ground.

Flights were conducted 40m above ground, between the hours of 10 a.m. and 2 p.mn., ensuring the amount of reflected light would be comparable across dates. Attempts were made to make flights weekly but this type of data collection requires skies be 70% clear of clouds. Fortunately we were able to get several successful flights over the growing season.

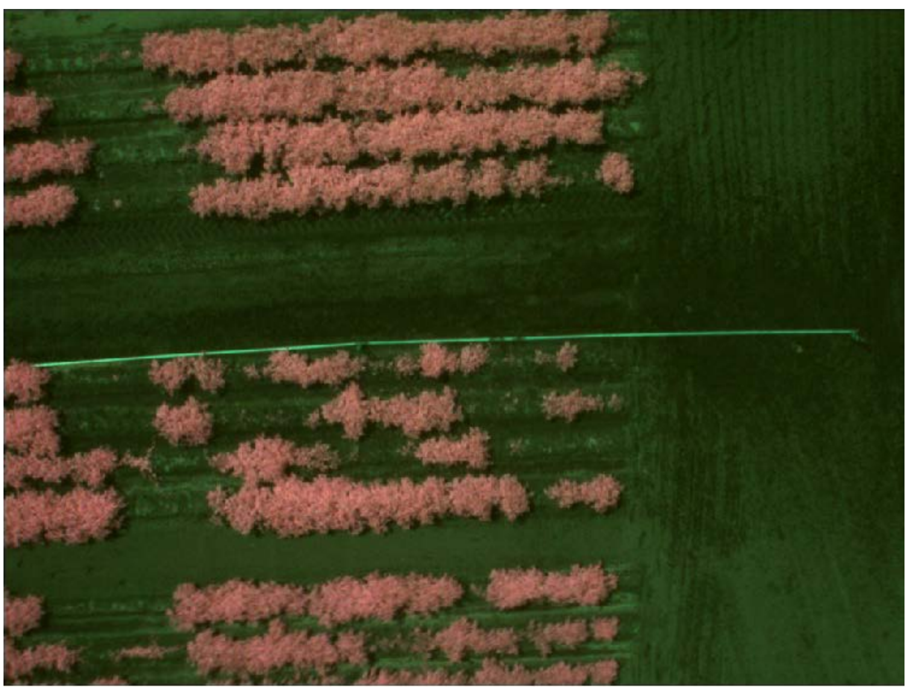


Figure . Near Infra-red (NIR) image of Colorado potato beetle insecticide trial plots at Becker, MN. Note differing levels of defoliation in each plot. Bright green line is an irrigation pipe.

Individual images from the cameras were then ‘stitched’ together, and orthorectified (optically corrected for any skewness and geographic coordinates assigned to image pixels). Image analysis software was used to analyze the images and construct Normalized Difference Vegetative Index (NDVI) values for each plot. The NDVI is an index calculated the amounts of red and NIR light being reflected by plants and can be used to assess stress levels and biomass. NDVI values range from -1 to +1, higher values indicate less stress (healthier plants).

Percent defoliation data was available for each plot in the study field. Regression analysis indicated that NDVI value was significantly dependent on the percent defoliation in a plot (R^2 = 0.67, ANOVA results in Table 4). We are currently analyzing the datasets using a Leaf Area Index the amount of vegetation in a canopy and comparing index values over time to determine if this method can be used to quickly and effectively estimate defoliation in a field and determine if defoliation threshold levels are occurring.

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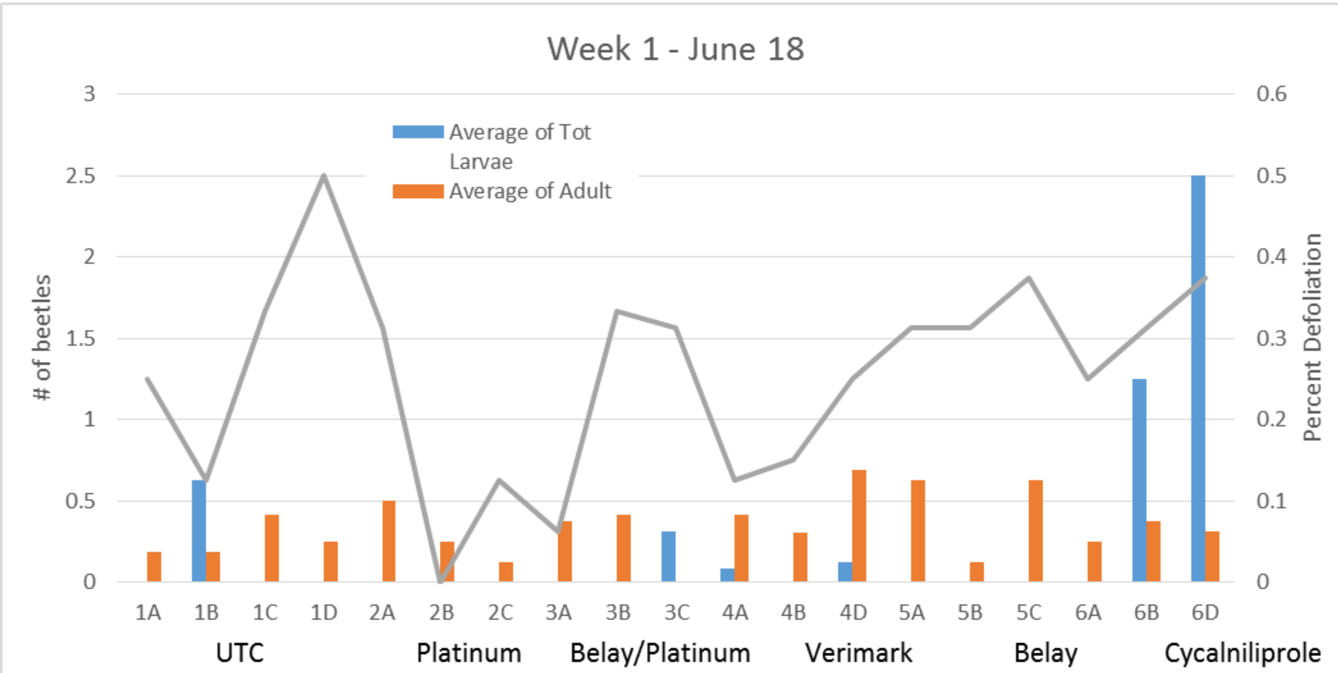
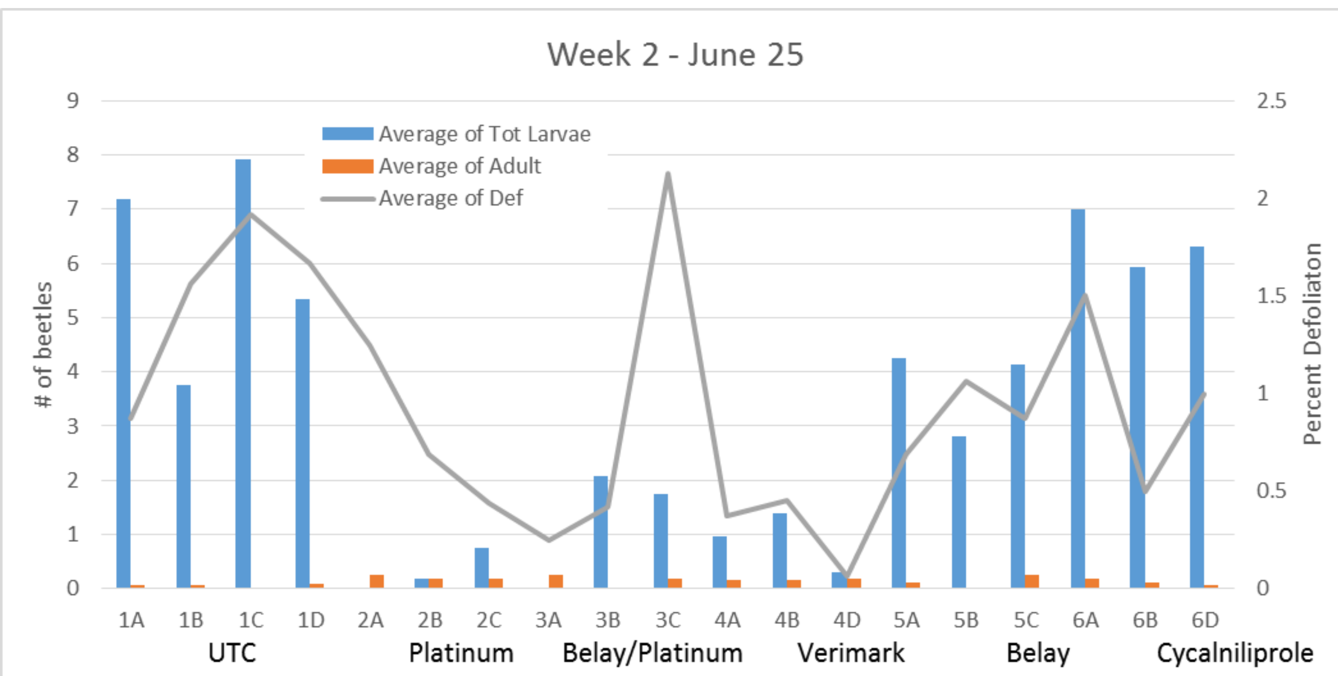
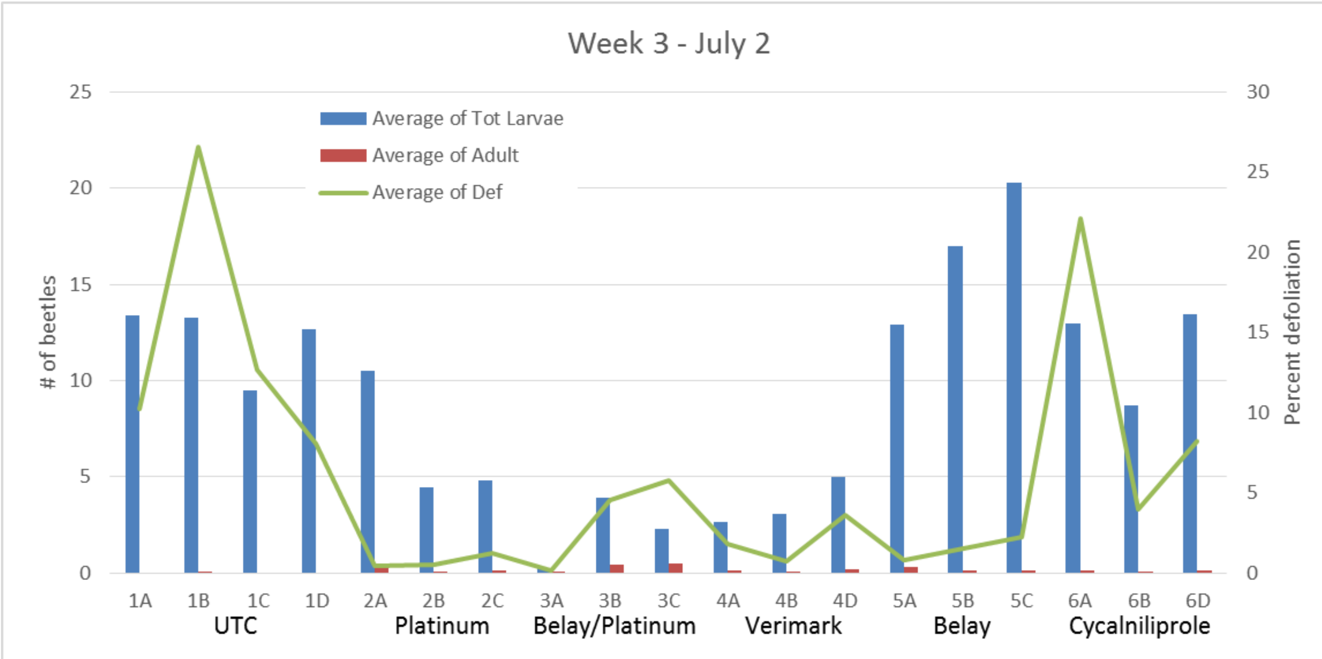
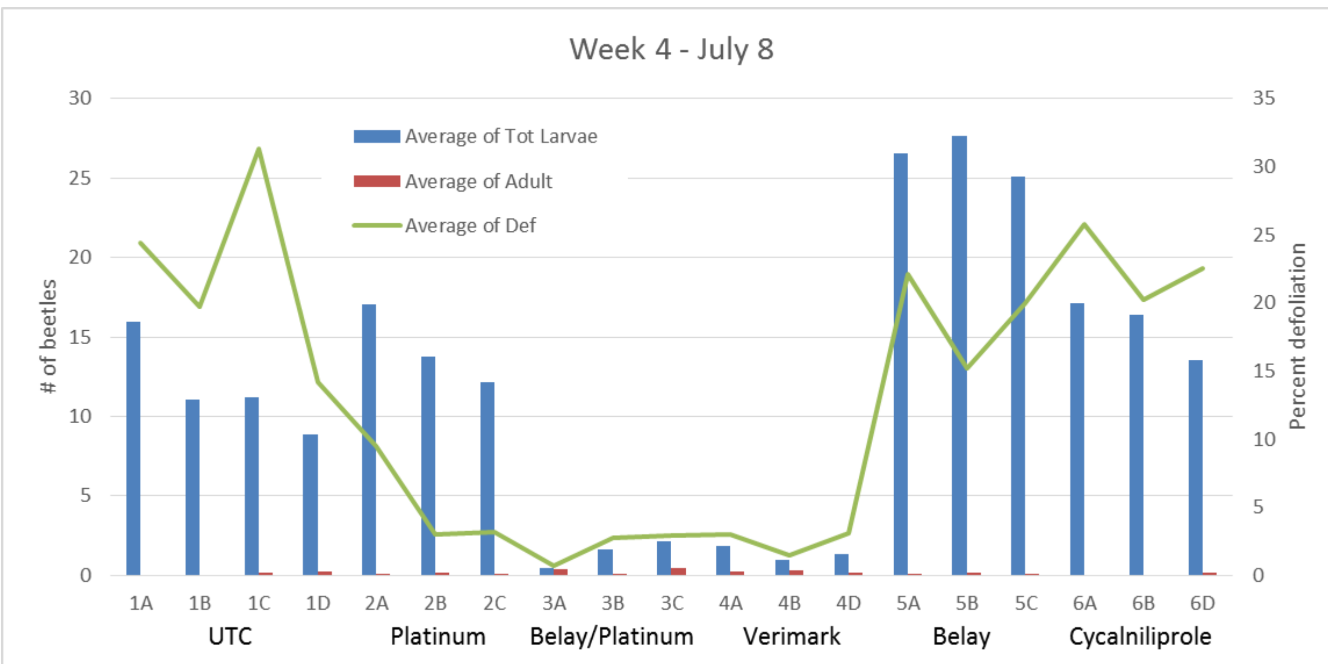
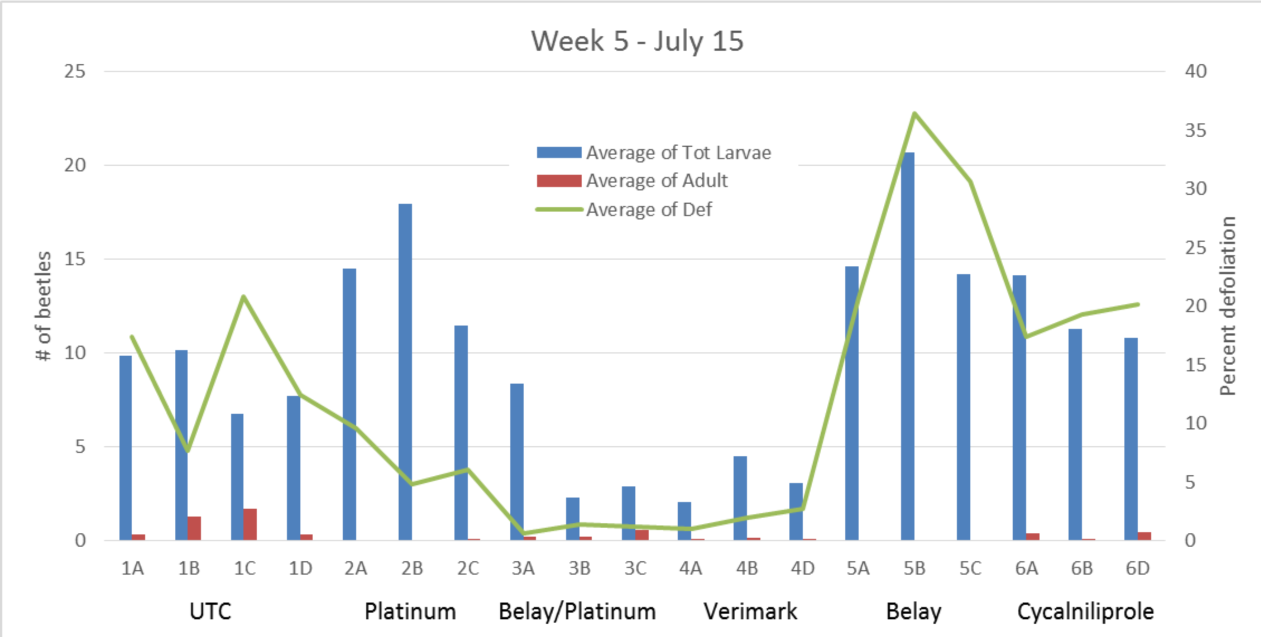
Appendix 1. Weekly Colorado potato beetle populations in at-plant trials. Vertical bars are mean beetle numbers per plant (value on left hand Y-axis), solid line is % defoliation (value on right hand Y-axis).

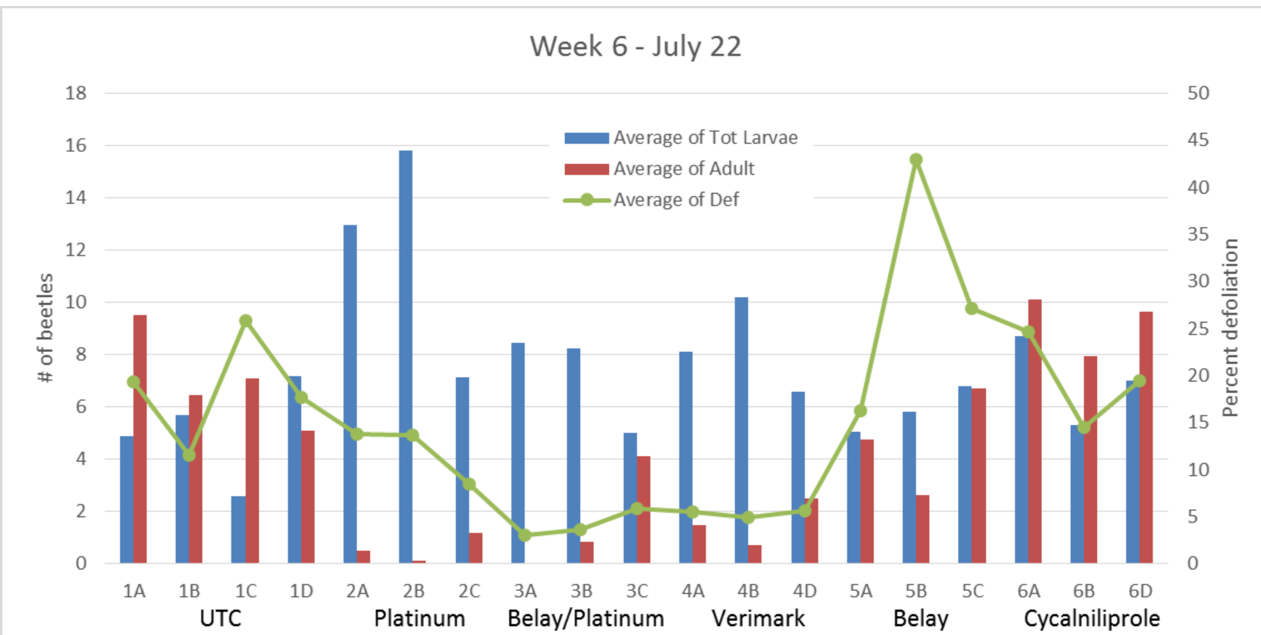


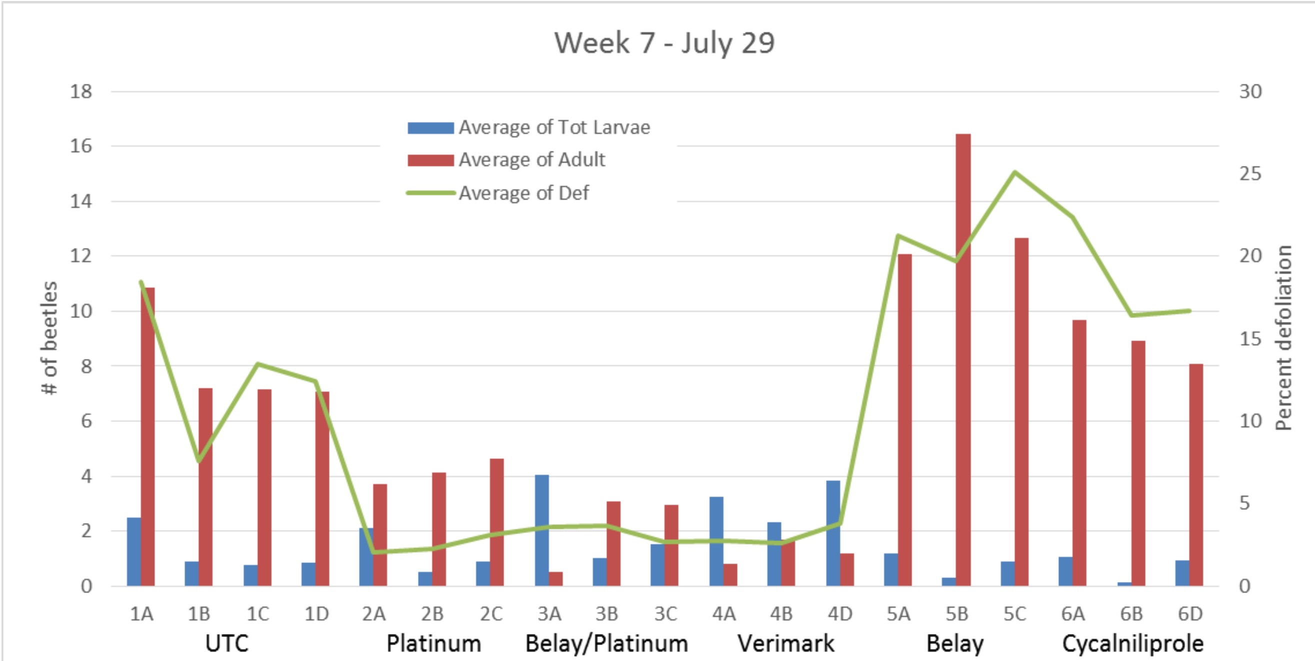


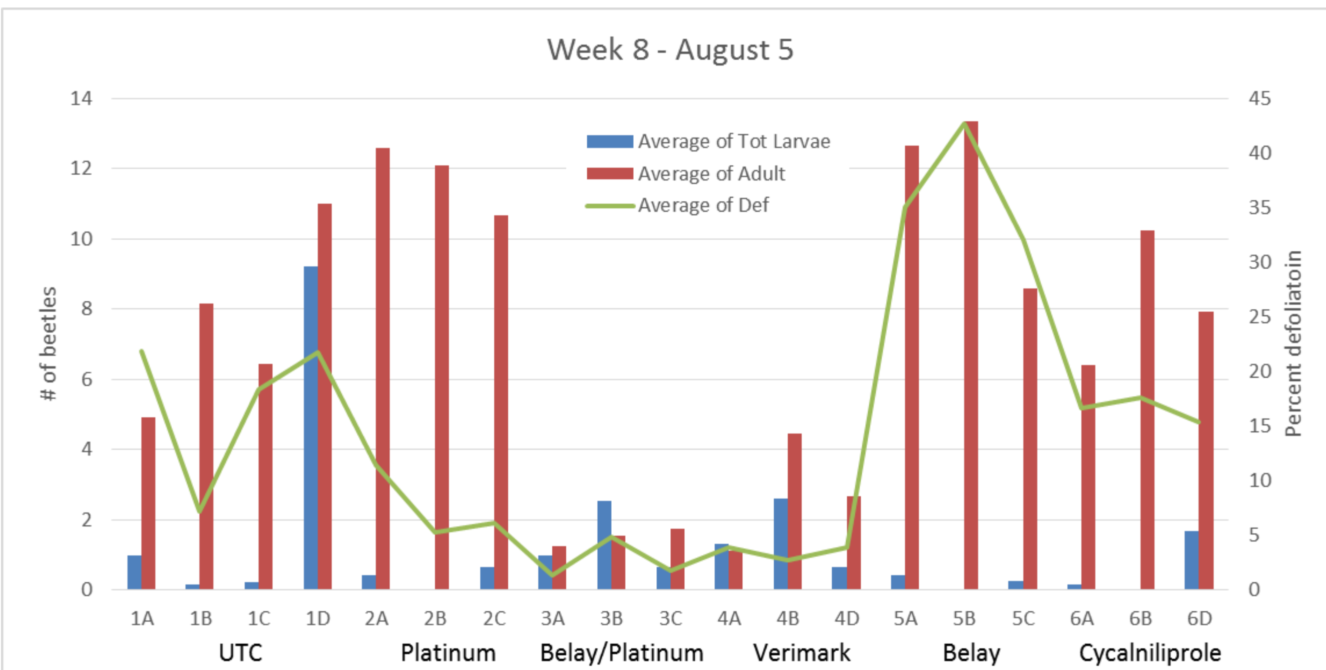

Week 3 - July 2
Average of Tot Larvae
Average of Adult
Average of Def
# of beetles
Percent defoliation
25
20
15
10
5
0
30
25
20
15
10
5
0
1A 1B 1C 1D 2A 2B 2C 3A 3B 3C 4A 4B 4D 5A 5B 5C 6A 6B 6D
UTC
Platinum
Belay/Platinum
Verimark
Belay
Cycalniliprole

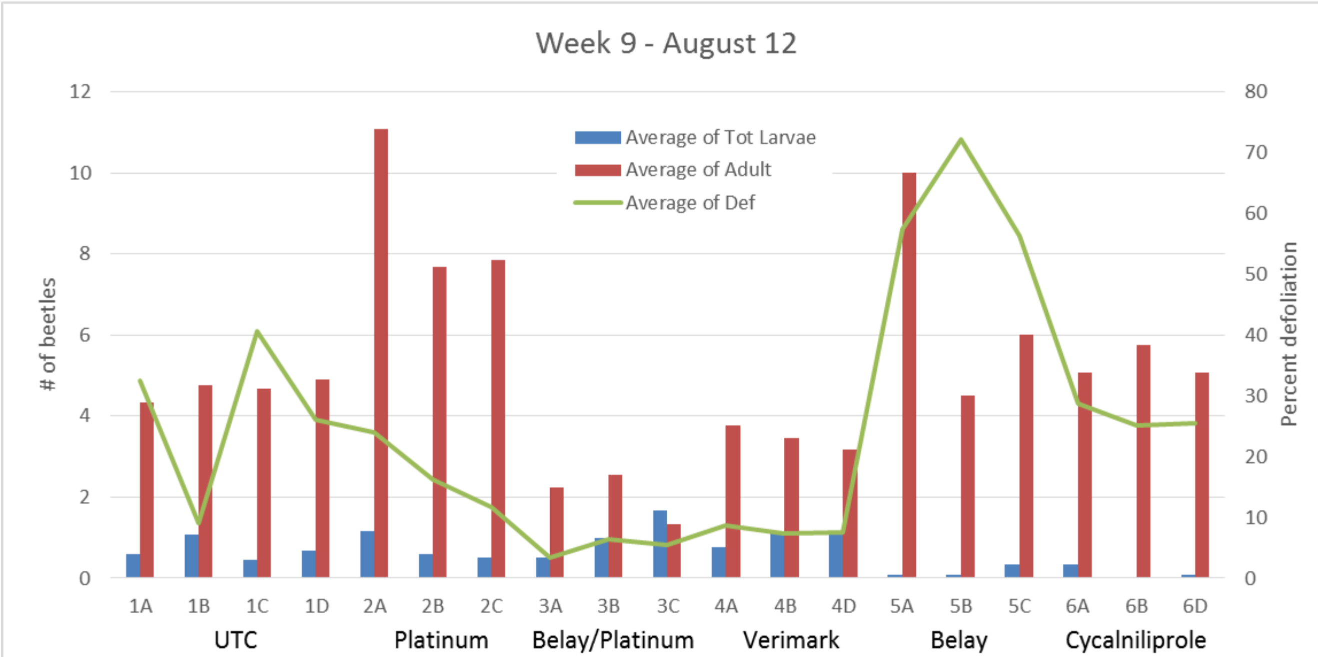

Week 4 - July 8
Average of Tot Larvae
Average of Adult
Average of Def
# of beetles
Percent defoliation
30
25
20
15
10
5
0
35
30
25
20
15
10
5
0
1A 1B 1C 1D 2A 2B 2C 3A 3B 3C 4A 4B 4D 5A 5B 5C 6A 6B 6D
UTC
Platinum
Belay/Platinum
Verimark
Belay
Cycalniliprole

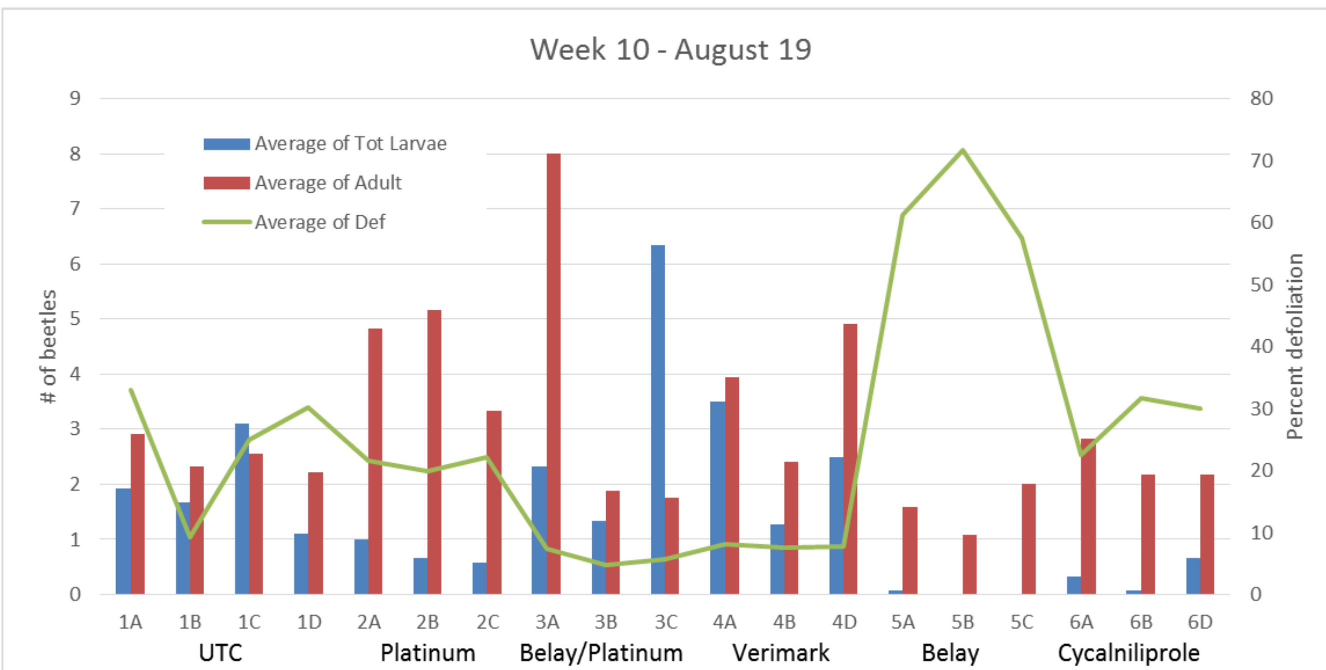

Week 5 - July 15
Average of Tot Larvae
Average of Adult
Average of Def
# of beetles
Percent defoliation
0
5
10
15
20
25
30
35
40
1A 1B 1C 1D 2A 2B 2C 3A 3B 3C 4A 4B 4D 5A 5B 5C 6A 6B 6D
UTC
Platinum
Belay/Platinum
Verimark
Belay
Cycalniliprole


Week 6 - July 22
Average of Tot Larvae
Average of Adult
Average of Def
# of beetles
Percent defoliation
0
2
4
6
8
10
12
14
16
18
0
5
10
15
20
25
30
35
40
45
50
1A 1B 1C 1D 2A 2B 2C 3A 3B 3C 4A 4B 4D 5A 5B 5C 6A 6B 6D
UTC
Platinum
Belay/Platinum
Verimark
Belay
Cycalniliprole

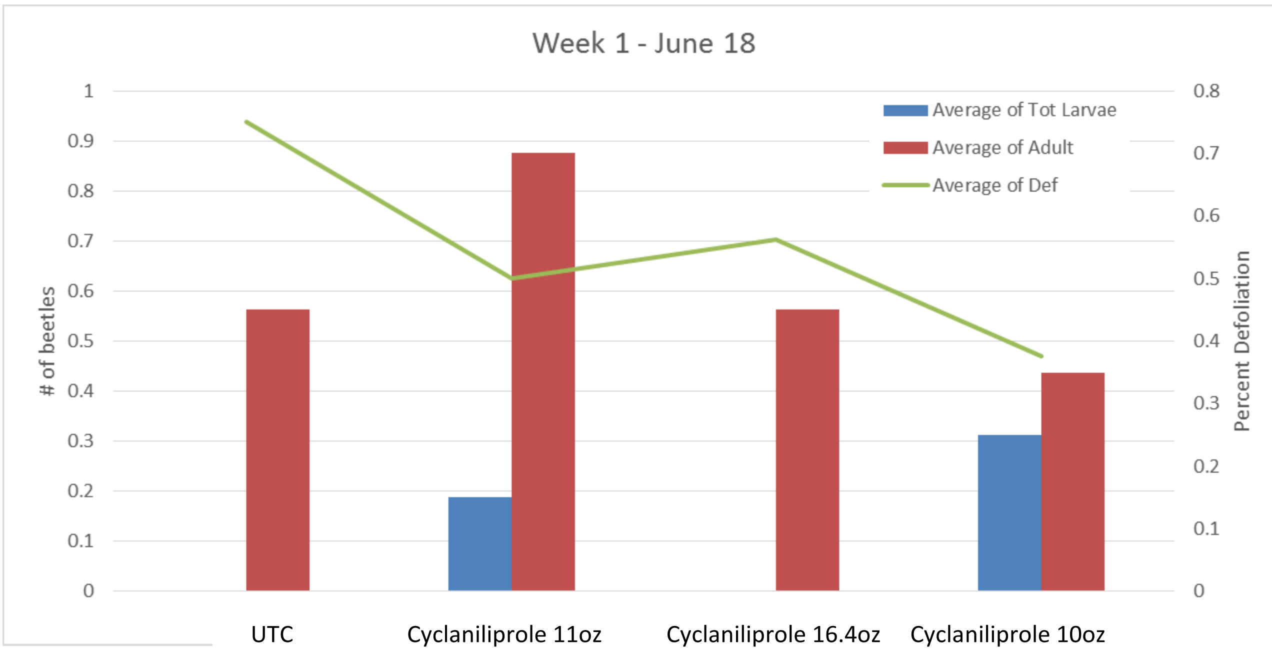

Week 7 - July 29
Average of Tot Larvae
Average of Adult
Average of Def
# of beetles
Percent defoliation
1A 1B 1C 1D 2A 2B 2C 3A 3B 3C 4A 4B 4D 5A 5B 5C 6A 6B 6D
UTC
Platinum
Belay/Platinum
Verimark
Belay
Cycalniliprole

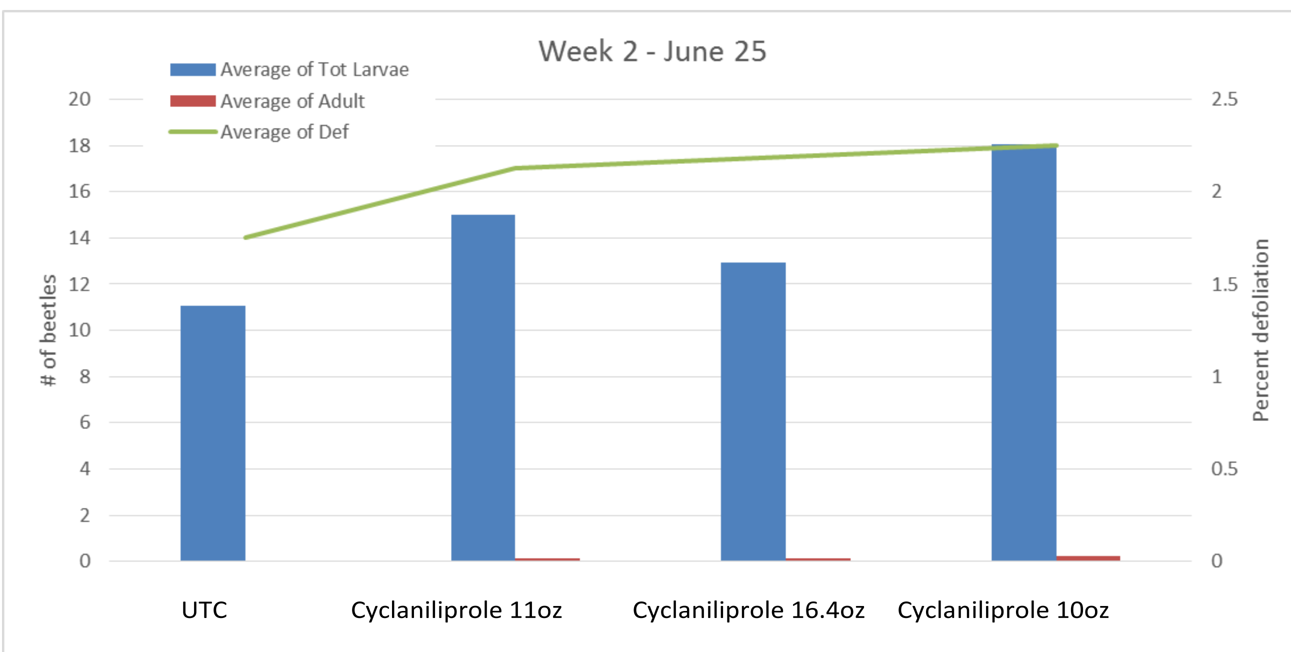

Week 8 - August 5
Average of Tot Larvae
Average of Adult
Average of Def
# of beetles
Percent defoliatoin
1A 1B 1C 1D 2A 2B 2C 3A 3B 3C 4A 4B 4D 5A 5B 5C 6A 6B 6D
UTC
Platinum
Belay/Platinum
Verimark
Belay
Cycalniliprole

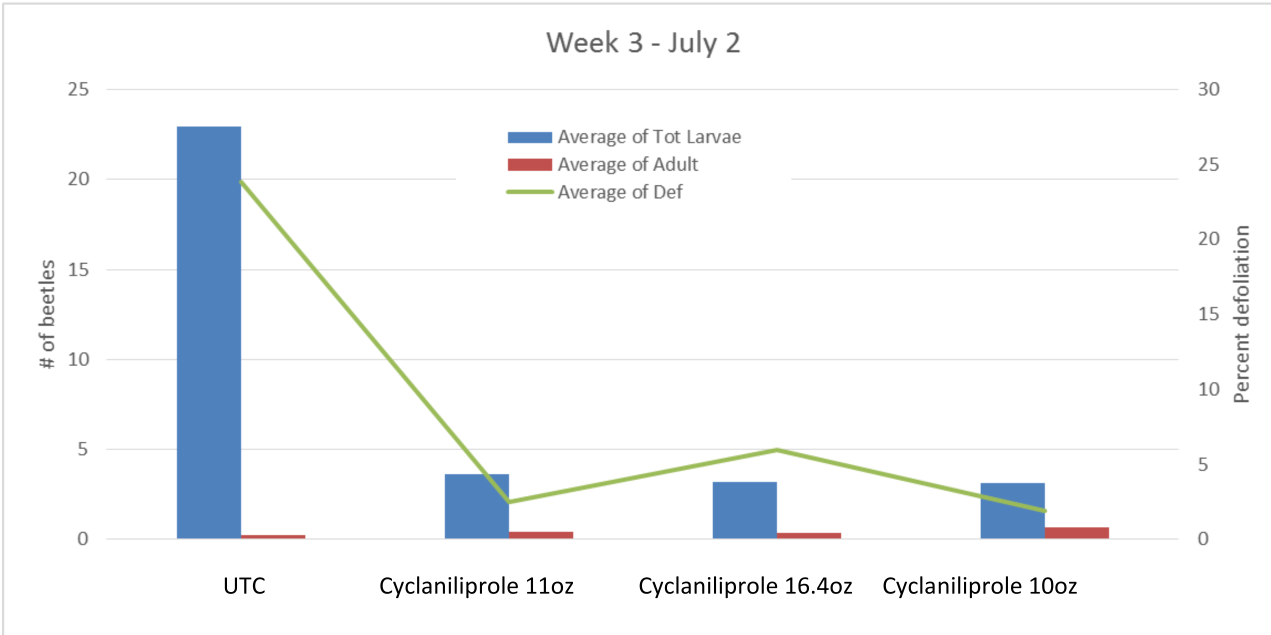

Week 9 - August 12
Average of Tot Larvae
Average of Adult
Average of Def
# of beetles
Percent defoliation
0
2
4
6
8
10
12
0
10
20
30
40
50
60
70
80
1A 1B 1C 1D 2A 2B 2C 3A 3B 3C 4A 4B 4D 5A 5B 5C 6A 6B 6D
UTC
Platinum
Belay/Platinum
Verimark
Belay
Cycalniliprole

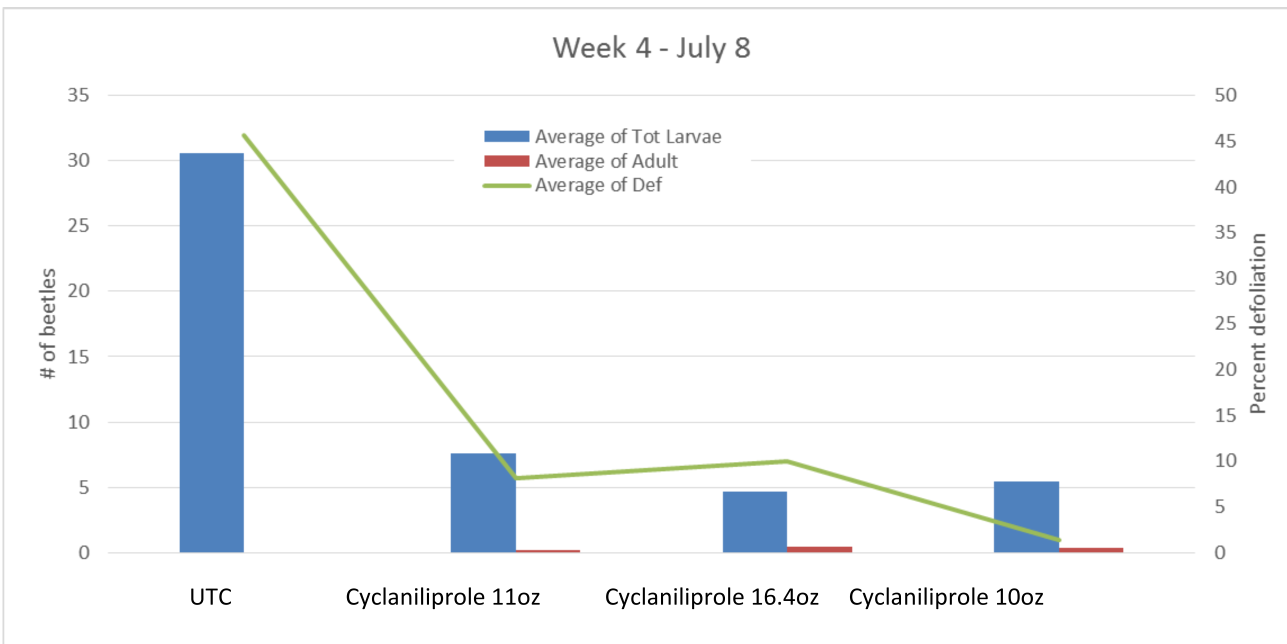

Week 10 - August 19
Average of Tot Larvae
Average of Adult
Average of Def
# of beetles
Percent defoliation
0
1
2
3
4
5
6
7
8
9
0
10
20
30
40
50
60
70
80
1A 1B 1C 1D 2A 2B 2C 3A 3B 3C 4A 4B 4D 5A 5B 5C 6A 6B 6D
UTC
Platinum
Belay/Platinum
Verimark
Belay
Cycalniliprole

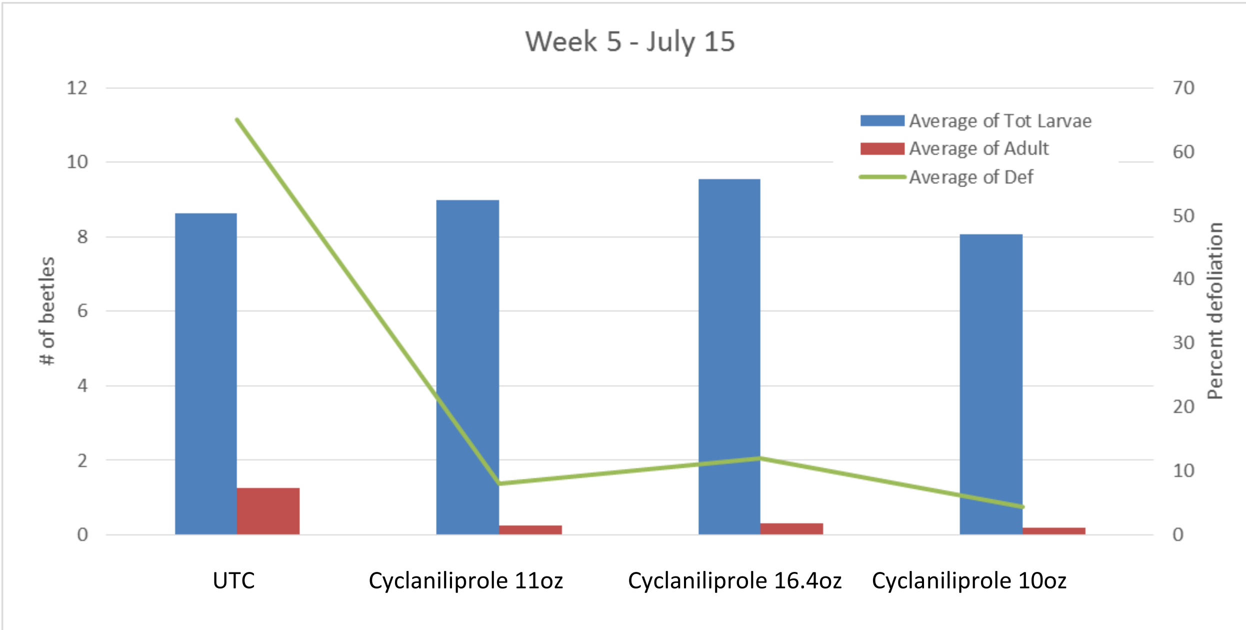
Appendix 2. Weekly Colorado potato beetle populations in new diamide trials. Vertical bars are mean beetle numbers per plant (value on left hand Y-axis), solid line is % defoliation (value on right hand Y-axis).



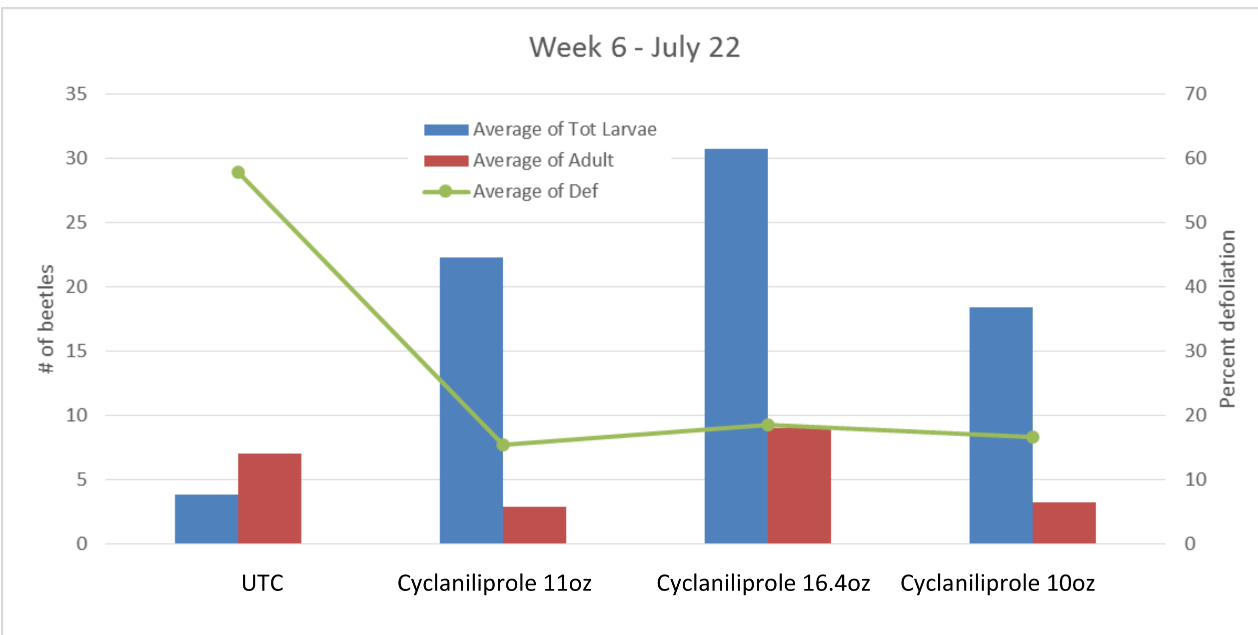



Week 3 - July 2
Average of Tot Larvae
Average of Adult
Average of Def
# of beetles
Percent defoliation
0
5
10
15
20
25
30
UTC
Cyclaniliprole 11oz
Cyclaniliprole 16.4oz
Cyclaniliprole 10oz

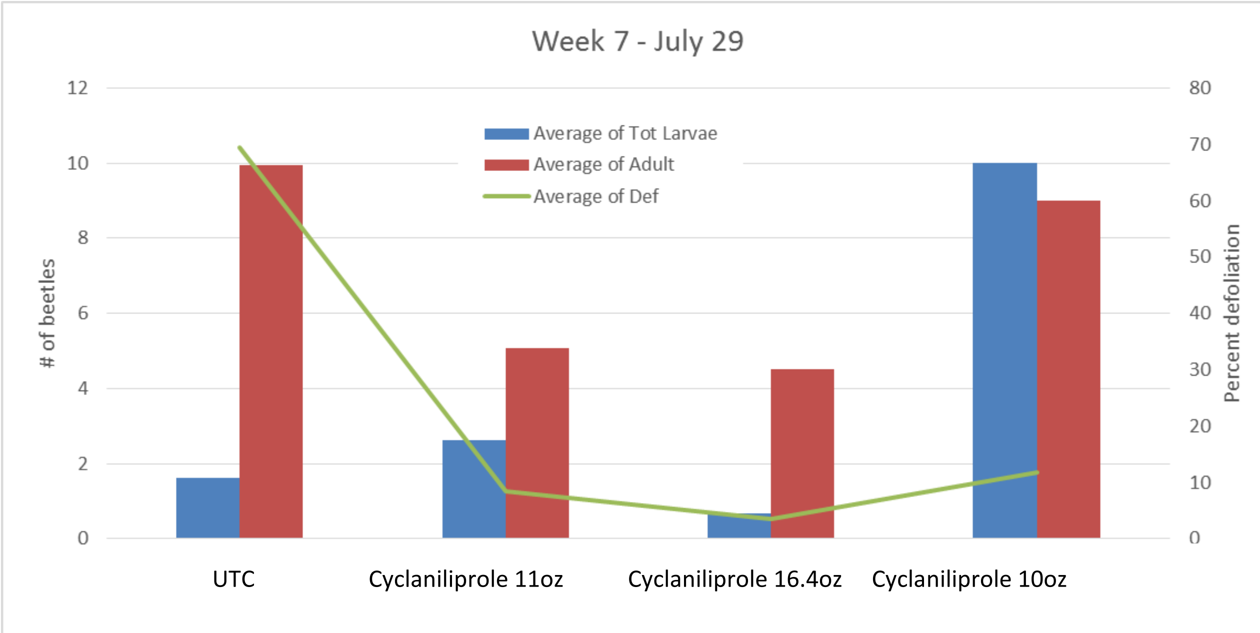

Week 4 - July 8
Average of Tot Larvae
Average of Adult
Average of Def
# of beetles
Percent defoliation
0
5
10
15
20
25
30
35
40
45
50
UTC
Cyclaniliprole 11oz
Cyclaniliprole 16.4oz
Cyclaniliprole 10oz

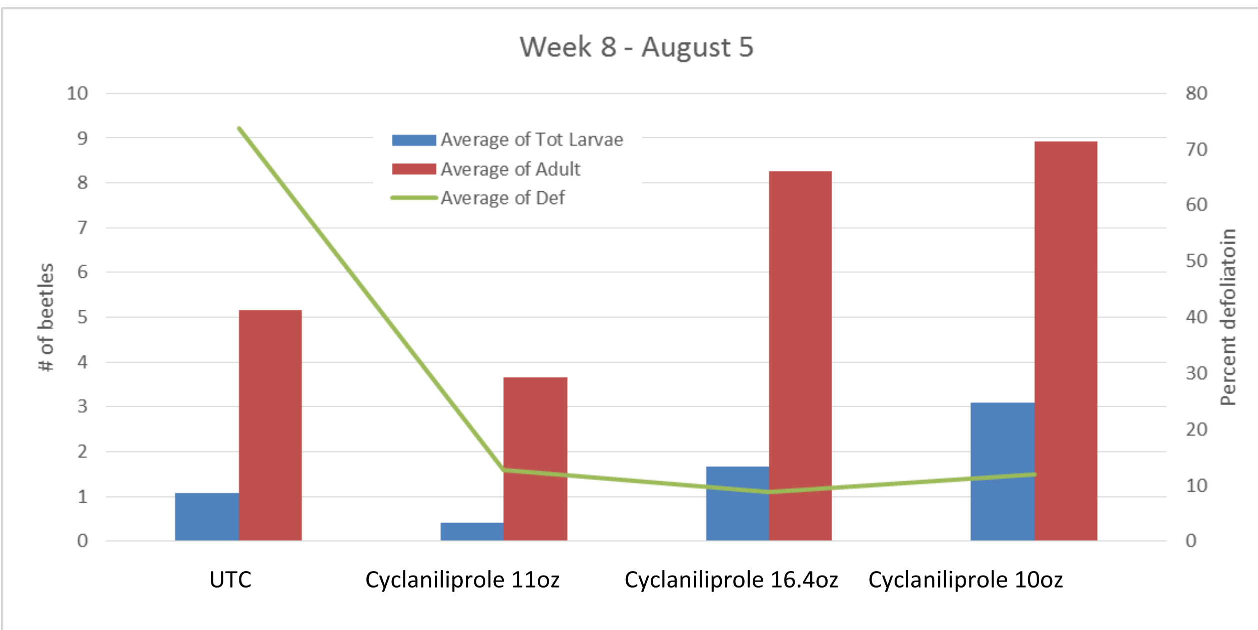


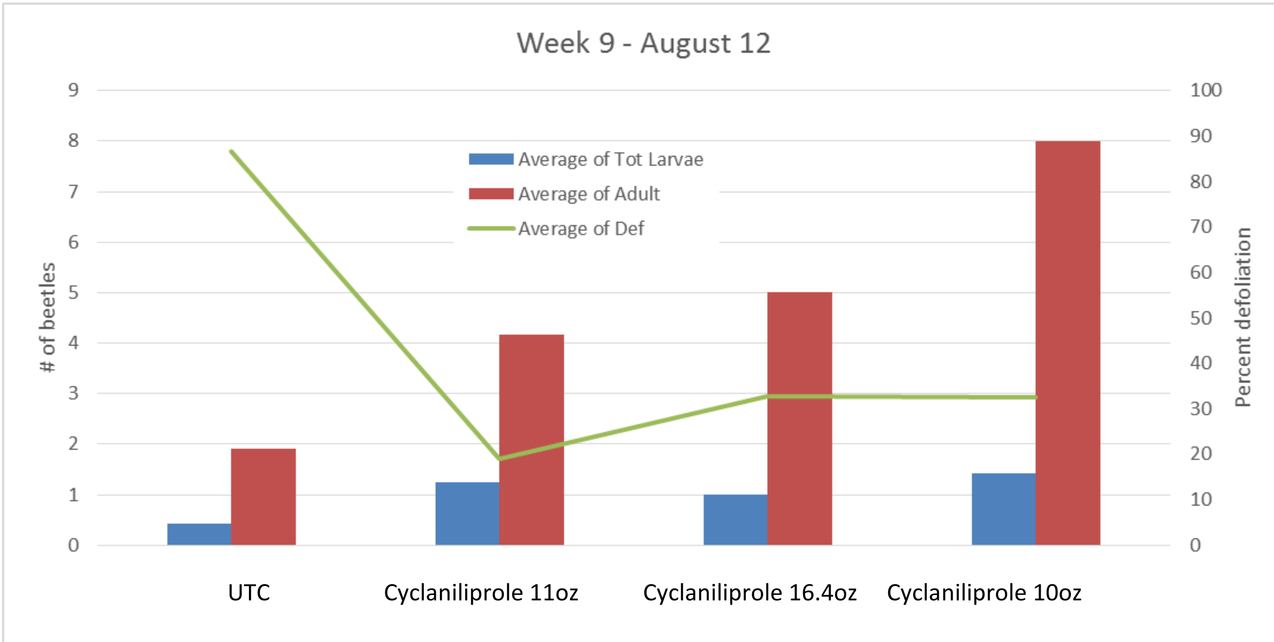
Week 5 - July 15
12
10
8
6
4
2
0
70
60
50
40
30
20
10
0
# of beetles
Percent defoliation
Average of Tot Larvae
Average of Adult
Average of Def
UTC
Cyclaniliprole 11oz
Cyclaniliprole 16.4oz
Cyclaniliprole 10oz

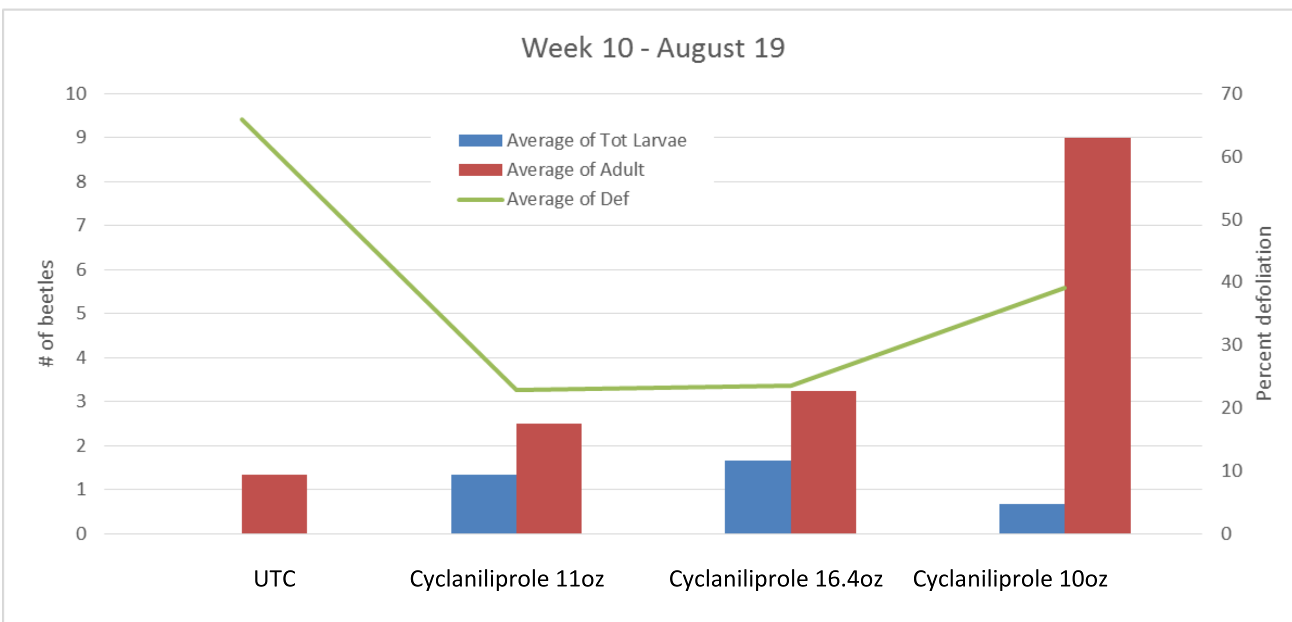


Week 6 - July 22
35
30
25
20
15
10
5
0
70
60
50
40
30
20
10
0
# of beetles
Percent defoliation
Average of Tot Larvae
Average of Adult
Average of Def
UTC
Cyclaniliprole 11oz
Cyclaniliprole 16.4oz
Cyclaniliprole 10oz

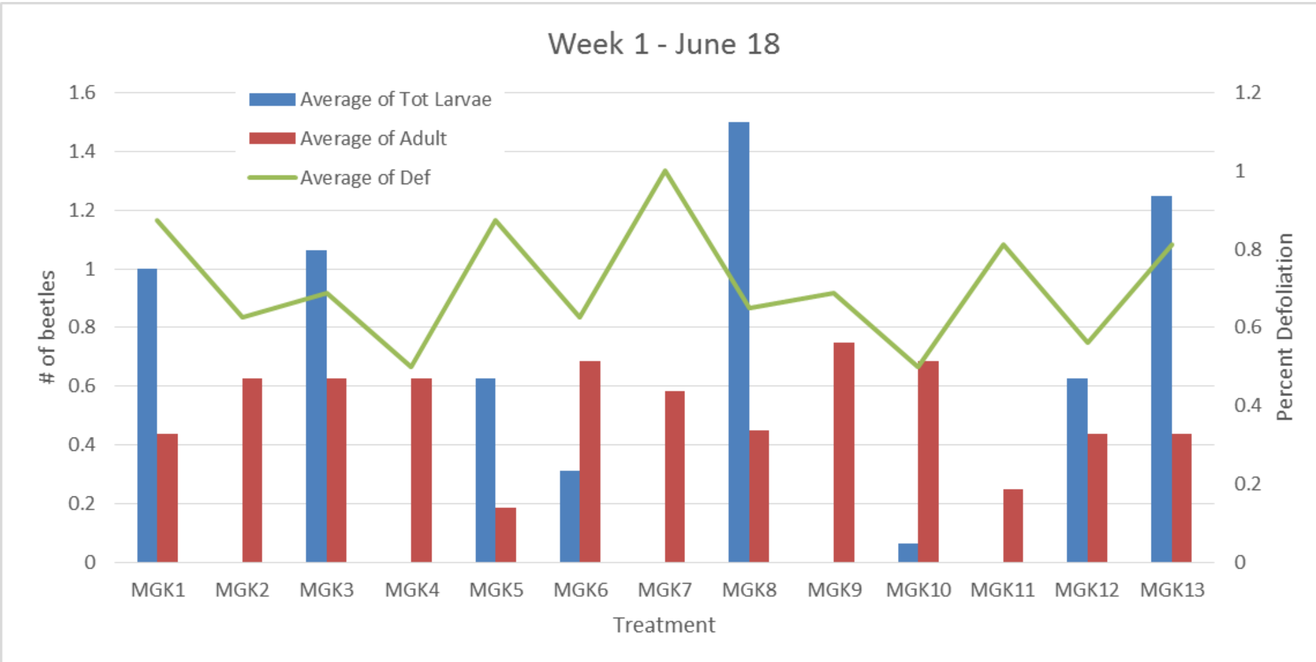

Week 7 - July 29
Average of Tot Larvae
Average of Adult
Average of Def
# of beetles
Percent defoliation
12
10
8
6
4
2
0
80
70
60
50
40
30
20
10
0
UTC
Cyclaniliprole 11oz
Cyclaniliprole 16.4oz
Cyclaniliprole 10oz

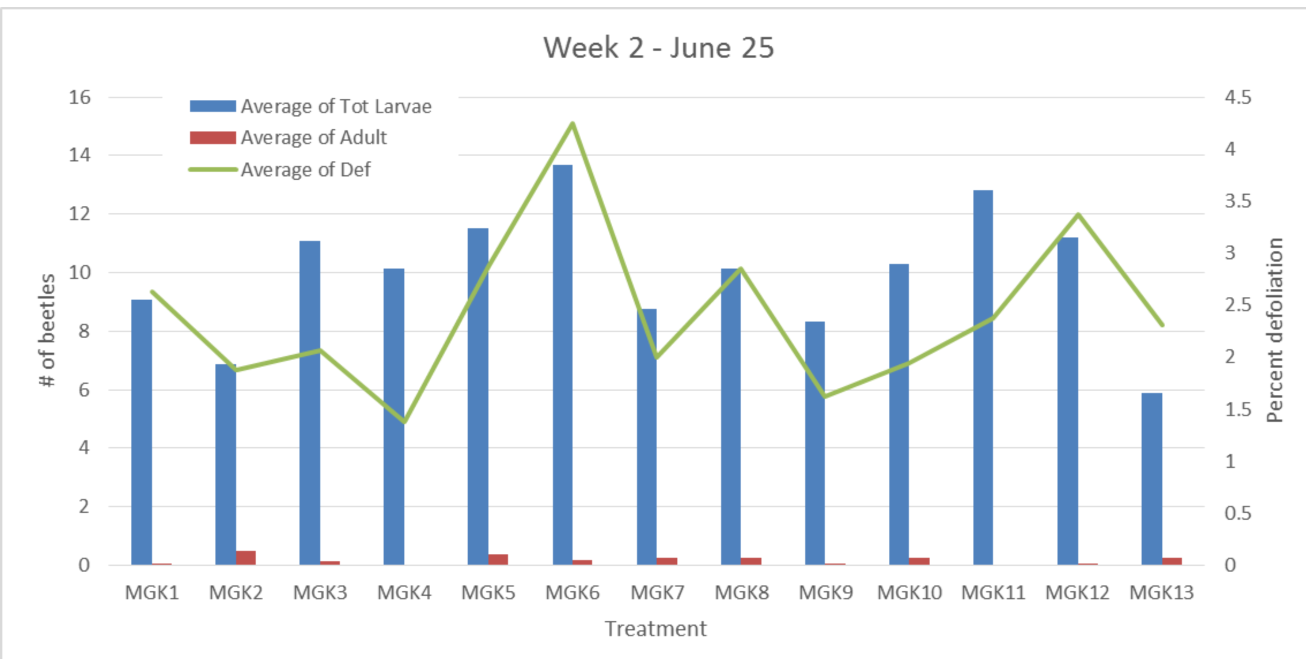

Week 8 - August 5
Average of Tot Larvae
Average of Adult
Average of Def
# of beetles
Percent defoliatoin
10
9
8
7
6
5
4
3
2
1
0
80
70
60
50
40
30
20
10
0
UTC
Cyclaniliprole 11oz
Cyclaniliprole 16.4oz
Cyclaniliprole 10oz

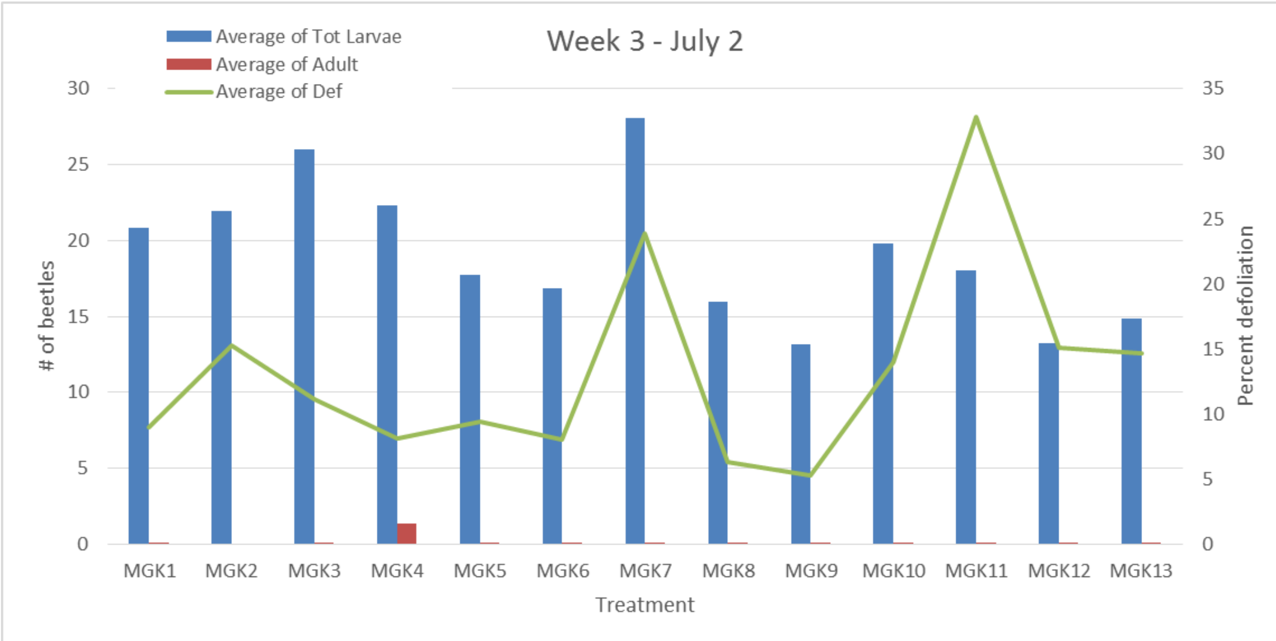

Week 9 - August 12
Average of Tot Larvae
Average of Adult
Average of Def
# of beetles
Percent defoliation
0
1
2
3
4
5
6
7
8
9
0
10
20
30
40
50
60
70
80
90
100
UTC
Cyclaniliprole 11oz
Cyclaniliprole 16.4oz
Cyclaniliprole 10oz


Week 10 - August 19
Average of Tot Larvae
Average of Adult
Average of Def
# of beetles
Percent defoliation
0
1
2
3
4
5
6
7
8
9
10
0
10
20
30
40
50
60
70
UTC
Cyclaniliprole 11oz
Cyclaniliprole 16.4oz
Cyclaniliprole 10oz

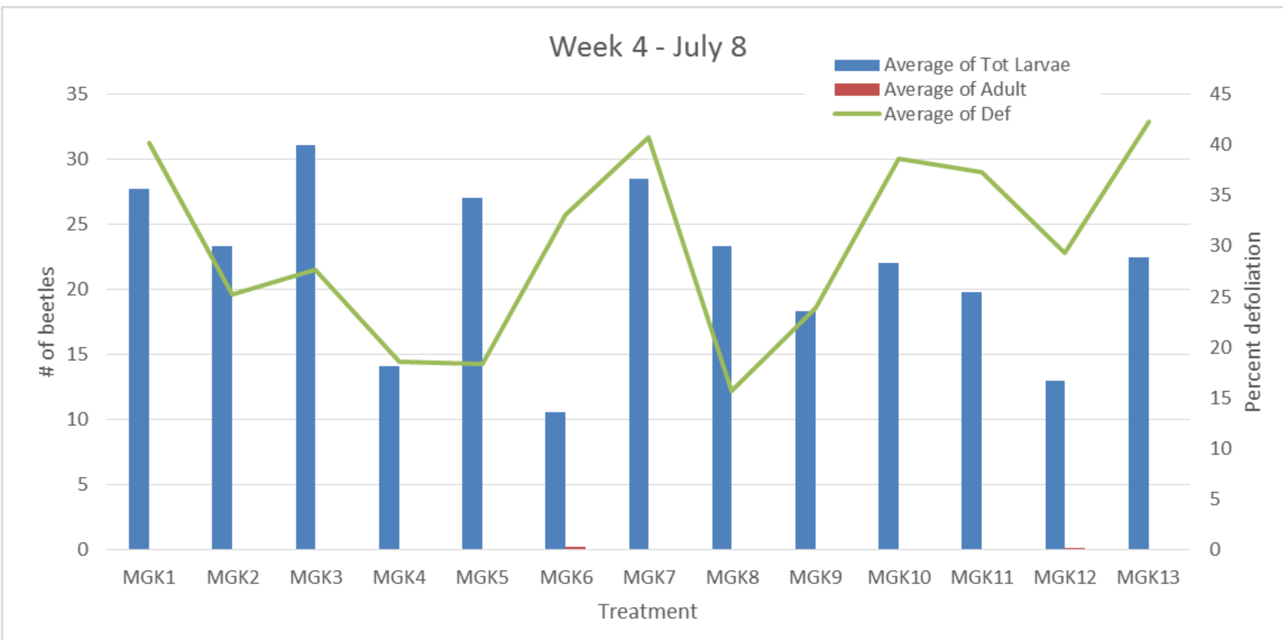
Appendix 3. Weekly Colorado potato beetle populations in organic insecticide trials. Vertical bars are mean beetle numbers per plant (value on left hand Y-axis), solid line is % defoliation (value on right hand Y-axis).



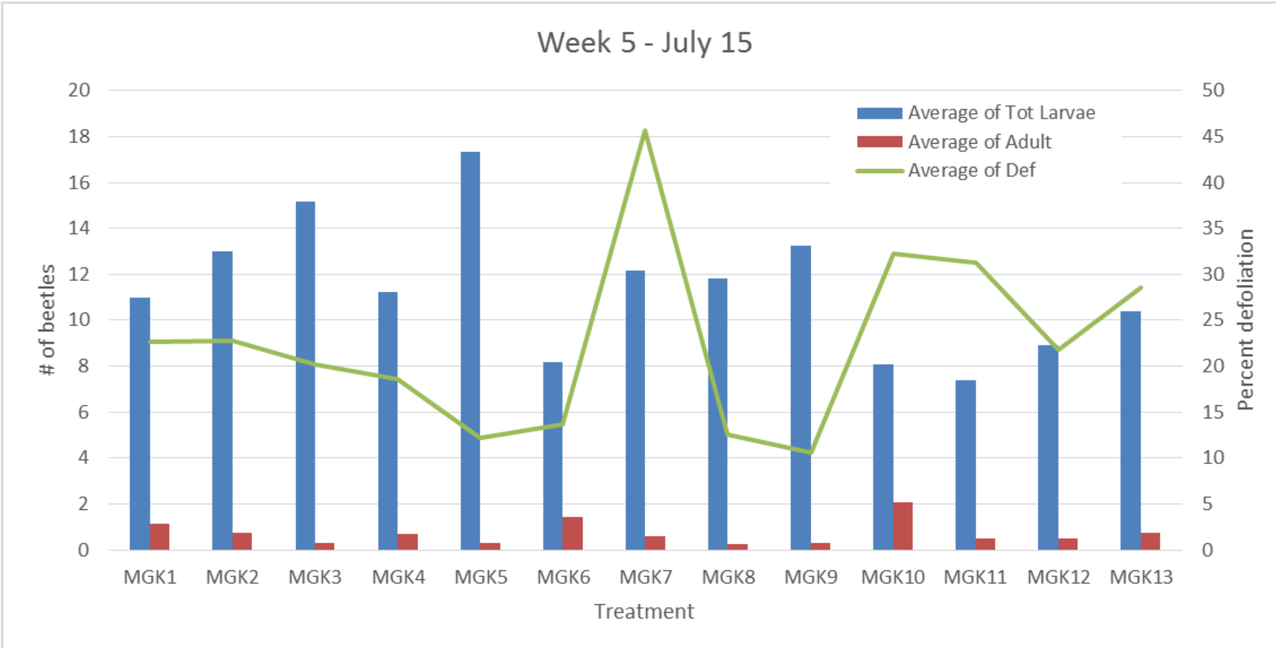


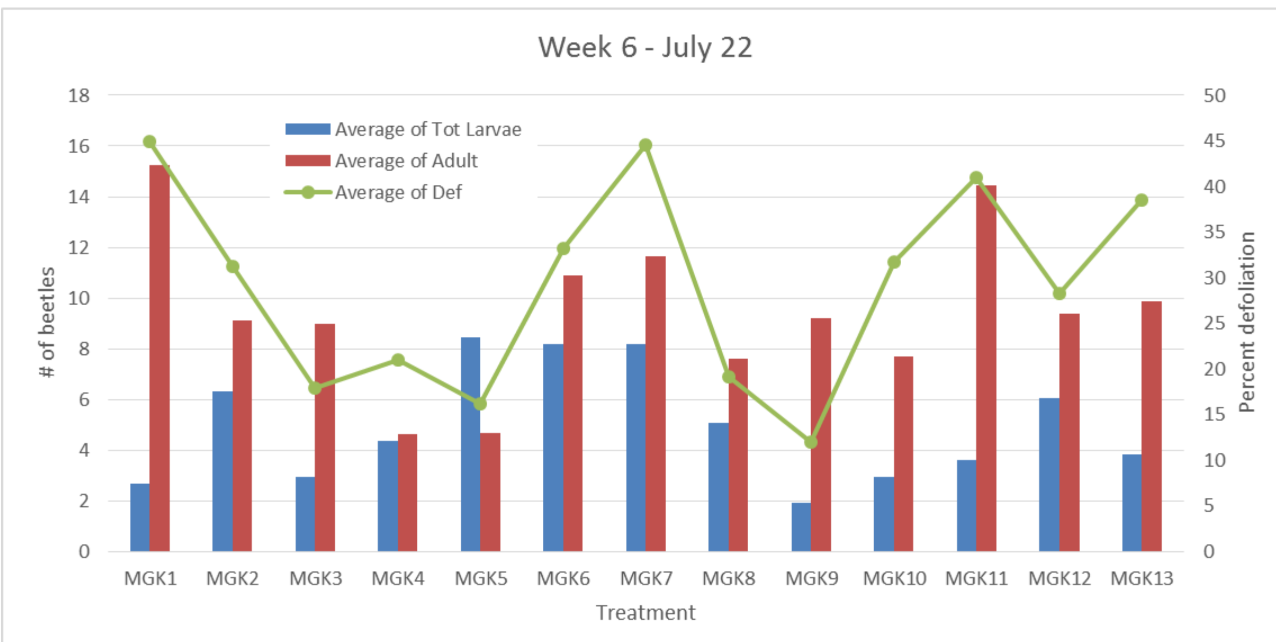


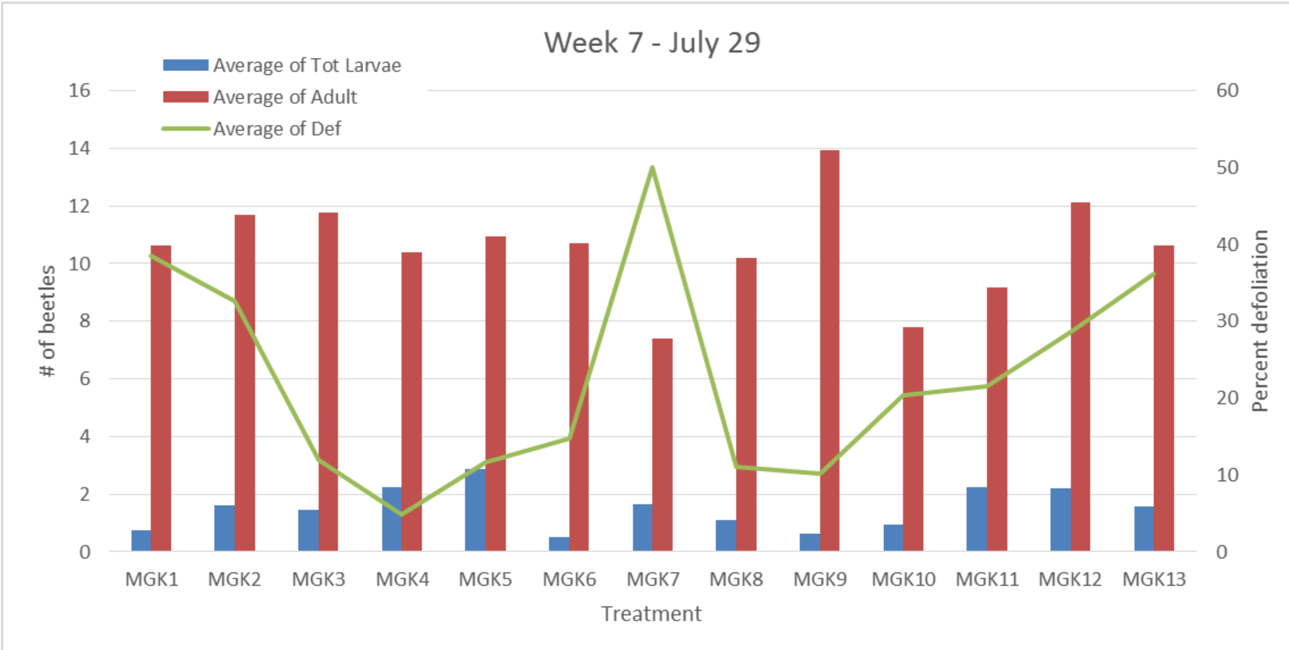
Week 3 - July 2
Average of Tot Larvae
Average of Adult
Average of Def
# of beetles
Percent defoliation
0
5
10
15
20
25
30
35
MGK1
MGK2
MGK3
MGK4
MGK5
MGK6
MGK7
MGK8
MGK9
MGK10
MGK11
MGK12
MGK13
Treatment



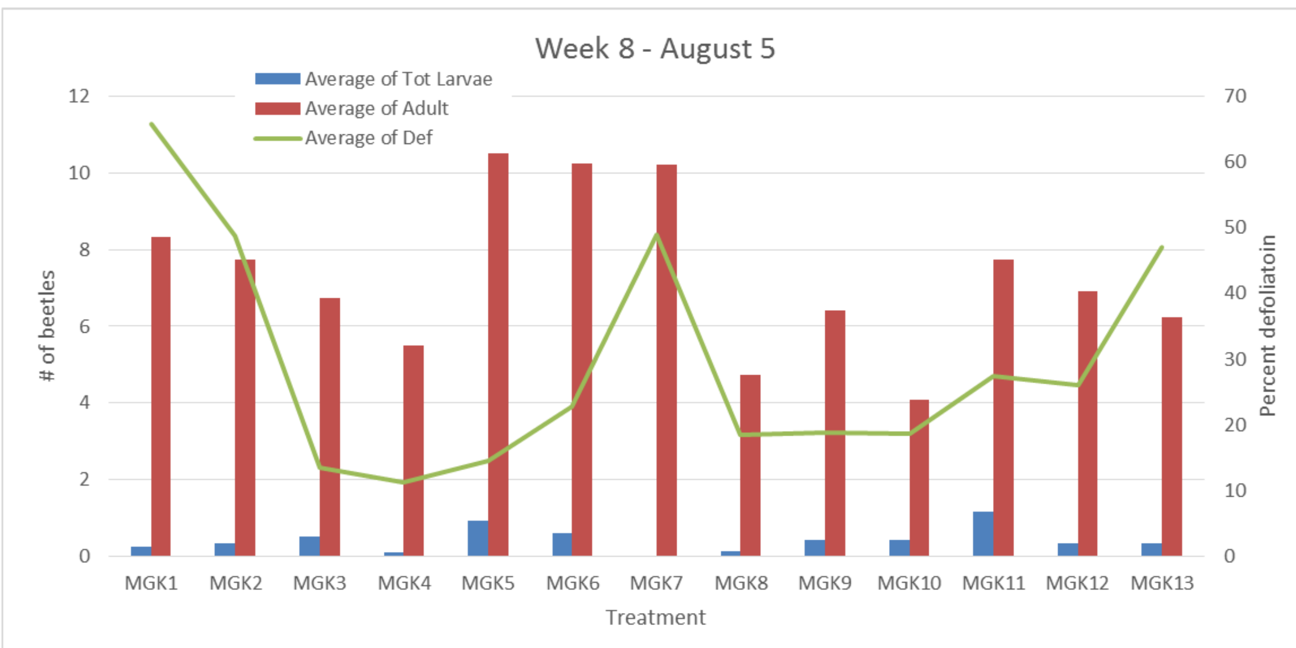
Week 4 - July 8
Average of Tot Larvae
Average of Adult
Average of Def
# of beetles
Percent defoliation
0
5
10
15
20
25
30
35
40
45
MGK1
MGK2
MGK3
MGK4
MGK5
MGK6
MGK7
MGK8
MGK9
MGK10
MGK11
MGK12
MGK13
Treatment


Week 5 - July 15
Average of Tot Larvae
Average of Adult
Average of Def
# of beetles
Percent defoliation
20
18
16
14
12
10
8
6
4
2
0
50
45
40
35
30
25
20
15
10
5
0
MGK1
MGK2
MGK3
MGK4
MGK5
MGK6
MGK7
MGK8
MGK9
MGK10
MGK11
MGK12
MGK13
Treatment

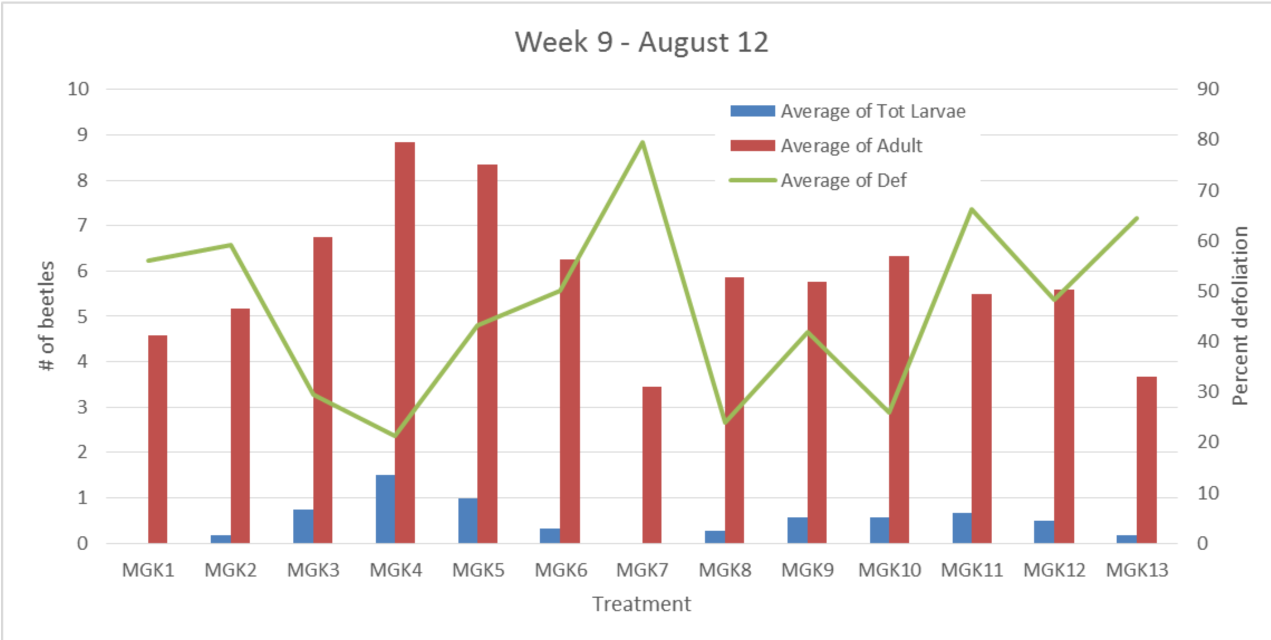

Week 6 - July 22
Average of Tot Larvae
Average of Adult
Average of Def
# of beetles
Percent defoliation
18
16
14
12
10
8
6
4
2
0
50
45
40
35
30
25
20
15
10
5
0
MGK1
MGK2
MGK3
MGK4
MGK5
MGK6
MGK7
MGK8
MGK9
MGK10
MGK11
MGK12
MGK13
Treatment



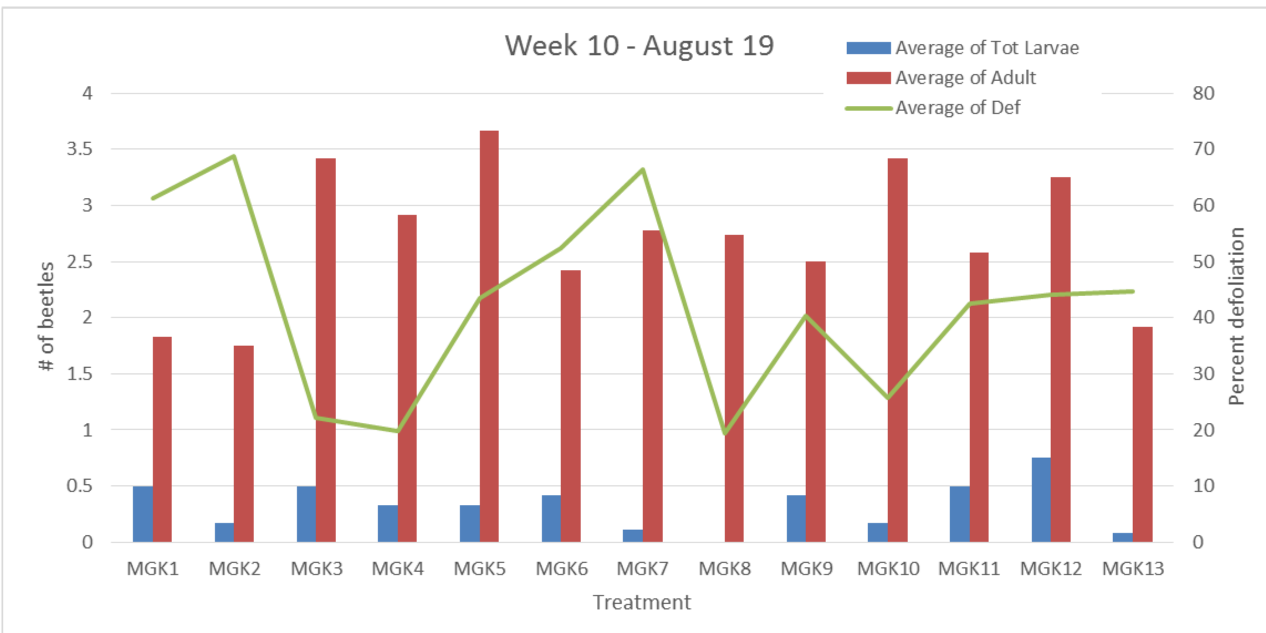
Week 7 - July 29
Average of Tot Larvae
Average of Adult
Average of Def
# of beetles
Percent defoliation
Treatment
MGK1 MGK2 MGK3 MGK4 MGK5 MGK6 MGK7 MGK8 MGK9 MGK10 MGK11 MGK12 MGK13
0 2 4 6 8 10 12 14 16
0 10 20 30 40 50 60



Week 8 - August 5
Average of Tot Larvae
Average of Adult
Average of Def
# of beetles
Percent defoliatoin
Treatment
MGK1 MGK2 MGK3 MGK4 MGK5 MGK6 MGK7 MGK8 MGK9 MGK10 MGK11 MGK12 MGK13
0 2 4 6 8 10 12
0 10 20 30 40 50 60 70



Week 9 - August 12
Average of Tot Larvae
Average of Adult
Average of Def
# of beetles
Percent defoliation
10
9
8
7
6
5
4
3
2
1
0
90
80
70
60
50
40
30
20
10
0
MGK1
MGK2
MGK3
MGK4
MGK5
MGK6
MGK7
MGK8
MGK9
MGK10
MGK11
MGK12
MGK13
Treatment



Week 10 - August 19
Average of Tot Larvae
Average of Adult
Average of Def
# of beetles
Percent defoliation
4
3.5
3
2.5
2
1.5
1
0.5
0
80
70
60
50
40
30
20
10
0
MGK1
MGK2
MGK3
MGK4
MGK5
MGK6
MGK7
MGK8
MGK9
MGK10
MGK11
MGK12
MGK13
Treatment

Sensitivity of the potato dry rot fungus *Fusarium sambucinum* to fungicides. Gary Secor, Viviana Rivera and Neil Gudmestad. Department of Plant Pathology, North Dakota State University, Fargo, ND 58108

INTRODUCTION. Fusarium dry rot of potato continues to be a major disease of all market classes of stored potatoes, and has become a frequent cause of storage losses in recent years. The primary cause of potato dry rot is *Fusarium sambucinum*, although other Fusarium species, notably *solani* and *graminearum*, are often recovered from tubers with dry rot symptoms. The disease occurs when soil inoculum enters through harvest wounds such as cuts, bruises and sticky stolons. Disease develops slowly in storage, and planting infected seed infests the soil where it can persist for many years. Dry rot management in storage is difficult because of the lack of resistant cultivars, the inability to reduce soil inoculum and the paucity of post-harvest fungicides. The difficulty in management of seed-borne inoculum has been exacerbated by the development of resistance of *F. sambucinum* to the commonly used seed treatment fungicide fludioxonil (Maxim), illustrating the need to identify additional fungicides for disease control.

OBJECTIVE. The objective of this work is to evaluate sensitivity of *F. sambucinum* isolates from seed potatoes with dry rot collected from midwestern states to six fungicides used as potato seed treatments.

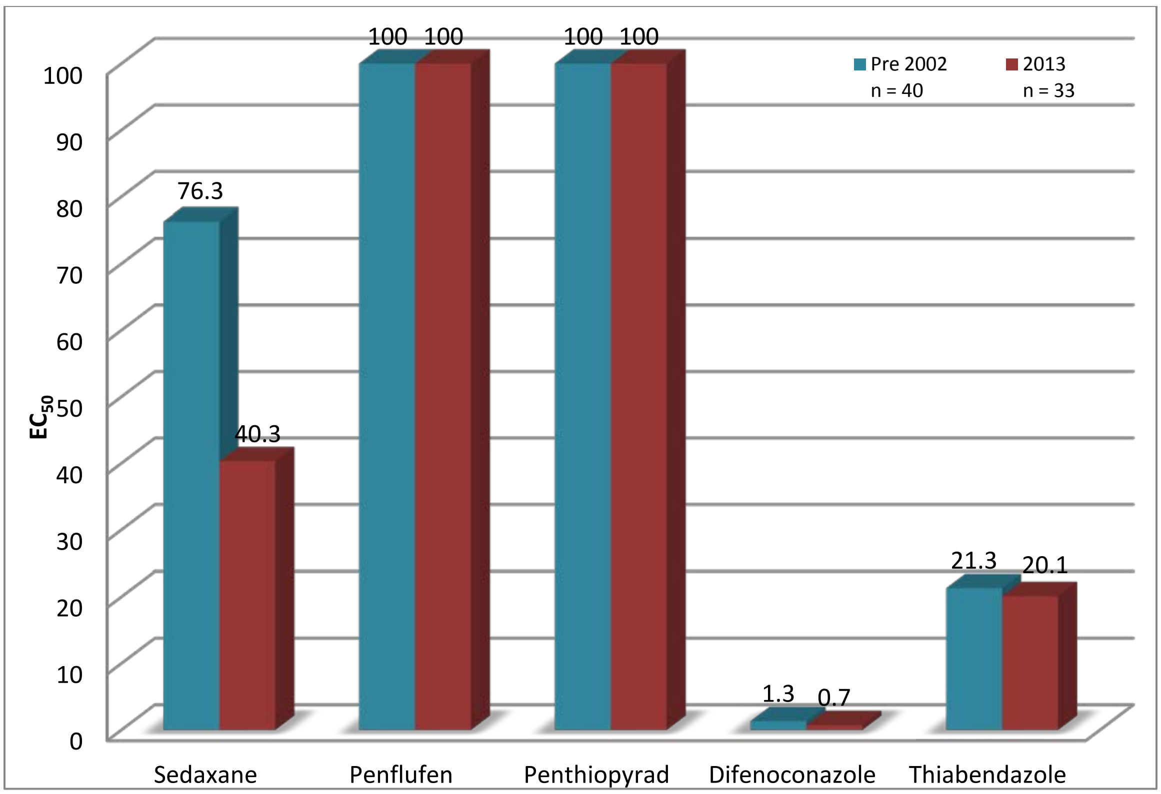
METHODS AND MATERIALS. **SDHI Fungicides**. *F. sambucinum* isolates collected from potato tubers with dry rot prior to 2002 and in 2013 were compared for sensitivity to three SDHI fungicides, penthiopyrad (Vertisan), penflufen (Emesto) and sedaxane (Vibrance), and to thiabendazole (Mertect)and difenoconazole (in Cruiser Maxx Extreme partnered with Maxim). Sensitivity was assessed by reduction of radial growth as measured by EC_{50} values. Pre-2002 isolates (n=40) were from ID, MN, ND, NE, and NY, and isolates from 2013 (n=33) were collected in ND and MN. Isolates were grown on half-strength PDA amended with dilutions of technical grade fungicide from 0-100 µg/ml and evaluated after incubating at 20C° for seven days.

Fludioxonil. *F. sambucinum* isolates collected from potato tubers with dry rot in 2013 -2014 were tested for sensitivity to fludioxonil using a similar procedure of radial growth reduction. Isolates (n=139) were collected by cooperators from ND, MN,NE, and CO. EC_{50} values were calculated on both half-strength PDA and water agar after incubation for seven days at 20C°.

RESULTS. The EC_{50} values of *F. sambucinum* isolates collected pre-2002 and in 2013 were at least 100 µg/ml for both penflufen and penthiopyrad, and for sedaxane were 76 µg/ml for pre-2002 isolates and 40 µg/ml for isolates from 2013 (Figure 1). From this data it appears that penflufen and penthiopyrad do not have good activity against *F. sambucinum*, and activity of sedaxane was better against isolates from 2013 than pre-2002. This data serves as baseline data of *F. sambucinum* for these three SDHI fungicides that can be used to monitor changes in sensitivity in future years. Isolates from both collections dates were highly sensitive to difenoconazole and remained equally resistant to TBZ (Figure 1).

Approximately 87% of the isolates collected had EC_{50} values >50 ppm that are considered resistant to fludioxonil; some had values were >100 ppm. Isolates resistant to fludioxonil were found in isolates from all locations sampled, including the states of ND, MN, NE and CO for the first time. Isolates from one location (Cando) were generally sensitive to fludioxonil; interestingly, this farm does not use fludioxonil as part of its fungicide program. Differences in resistance, as measured by EC_{50} values, were not consistent on half-strength PDA and water agar; 63% of the isolates has the same EC_{50} value on both PDA and water agar; 21% of isolates had a higher EC_{50} on PDA than on water agar, and 16% of the isolates had a higher EC_{50} value on water agar than on PDA. It appears that SDHI fungicides may not be effective as seed treatments or post-harvest fungicides for Fusarium dry rot management, and high levels of resistance to fludioxonil are present in the Midwestern USA.

Figure 1. Comparative sensitivity of *Fusarium sambucinum* isolates collected before 2002 and in 2013 to five fungicides as measured by inhibition of radial growth (EC_{50})



Starter Fertilizer in Potato. Harlene Hatterman-Valenti and Collin Auwarter. Field research was conducted at the Northern Plains Potato Growers Association irrigation research site near Inkster, ND to evaluate different rates of Inrow and FPF fertilizer in comparison to standard grower recommended fertilizer applications. Prior to planting the field received 61#N, 200#K, 30#S and 2#B. On May 30, before planting, we opened the seed furrow and applied Inrow and 10-34-0 (30 gpa) on both sides of where seed pieces were to be placed. We planned on planting, but rain (1.08") delayed planting until June 3. On June 3 we planted the seed pieces (2 oz) on 12" intervals with 36" row spacing with a Harriston Double Row planter. On June 16, we applied 70#N, hilled, applied herbicide, and immediately applied the 1st FPF treatment with a CO2 backpack sprayer at 40 psi using 8002 flat fan nozzles and 20 gpa. The second application of FPF was applied on June 30 and the 3rd application was applied on July 21 just prior to bloom with same sprayer. Potatoes were harvested October 9 and graded December 9.

Treatments:

		5/30	5/30		6/16	6/30	7/21
Treatment	PPI	10-34-0	Inrow	@Hilling	FPF	FPF	FPF
1	61#N,200#K,30#S, 2#B	35#N,119#P	48 fl oz/a	70#N	16 fl oz/a	16 fl oz/a	16 fl oz/a
2	61#N,200#K,30#S, 2#B	35#N,119#P	64 fl oz/a	70#N	16 fl oz/a	16 fl oz/a	16 fl oz/a
3	61#N,200#K,30#S, 2#B	35#N,119#P	64 fl oz/a	70#N	24 fl oz/a	24 fl oz/a	24 fl oz/a
4	61#N,200#K,30#S, 2#B	35#N,119#P		70#N			
5	61#N,200#K,30#S, 2#B			70#N			

Yield:

Trt	Stand Count 20'		CWT/A	----------B Row Tuber Counts in 20'----------					
No.	A Row	B Row	A Row	<4oz	4-6oz	6-12oz	>12oz	Total	>4oz
1	18a	18a	514a	87a	62a	65a	6a	221a	134a
2	18a	18a	538a	85a	54a	59a	13a	212a	127a
3	18a	18a	525a	77a	60a	66a	8a	211a	134a
4	18a	19a	516a	91a	68a	62a	6a	227a	136a
5	18a	18a	525a	92a	61a	61a	7a	221a	129a
LSD (P=.05)	1.08	1.40	36.45	30.71	8.53	7.16	0.25	28.74	20.09

Trt	------------------------B Row CWT/A------------------------					
No.	<4oz	4-6oz	6-12oz	>12oz	Total	>4oz
1	94a	141a	234a	37a	516a	422a
2	95a	122a	218a	88a	538a	443a
3	85a	136a	239a	56a	520a	434a
4	100a	152a	221a	37a	515a	414a
5	104a	137a	224a	45a	514	410a
LSD (P=.05)	34.49	28.15	41.53	0.28	43.66	61.13

Treatment 4 only received 10-34-0 at planting and treatment 5 did not receive anything at planting.
We collected data at grading of tuber counts and yield of: 0-4 oz, 4-6 oz, 6-12 oz, and >12 oz. With the limited number of treatments (less than 21 df error), it is very difficult to have significance, especially with a crop like potato. As somewhat expected, there were no significant differences among treatments. Treatment 2 in both the B row (weighed in the field) and the A row (graded) had the highest total yield of 538 cwt/a. This was attributed to a shift to larger tubers, especially tubers greater than 12 oz. All three treatments with Inrow and FPF had fewer unmarketable (<4 oz) tubers. Treatments 4 and 5 had the greatest numbers of total tubers, but because more were small sized tubers, total yields were on the low end of 515 and 514cwt/a, respectively. Treatments 1 and 3 had the highest yields in the 6-12 oz grade, which is ideal for processing into French fries.

Storage and Processing Evaluation of Advanced Potato Breeding Clones

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USDA/ARS
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Dr. Joe Sowokinos
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University of Minnesota
St. Paul, MN

Potato breeding is an expensive and labor-intensive process. Tens of thousands of potato clones are grown annually by breeders in an effort to find a "single clone" that may meet all of the horticultural requirements necessary to make a successful processing cultivar (i.e., high yield and solids, low levels of sugars, disease resistance, etc.). Too often, a new promising clone fails because of its inability to store successfully. The bottom line for color quality is related to the quantity of reducing sugars (i.e., glucose and fructose) that are present at the time of processing. The undesirable effect that these sugars contribute to the browning of chips or fries is well known. These annual evaluations have consistently shown that sugar accumulation varies 150- to 200-fold among clones, even when they are subjected to the same growing and storage environments (Sowokinos and Glynn, 2000). Clones which demonstrate resistance to sweetening in cold storage, also genetically maintain an ability to resist sweetening when subjected to environmental stresses in the field e.g., temperature, moisture, fertility and early dying (Sowokinos, 2001).

This study is designed to aid state and federal potato breeders in selecting which of their clones might have the potential for insertion into the USPB-SFA Chip Trials and/or into the National Chip or National Fry Processing Trials. Potato clones are segregated according to their ability to accumulate glucose during 42° F storage. This study is funded, in part, by the Northern Plains Potato Growers Association.

Materials and Methods:

Sixty-one advanced clones from Maine, Michigan, Minnesota, North Dakota, Colorado, Oregon, Texas, Wisconsin, Idaho and Canada were grown under irrigation south of Larimore, ND. All potatoes were harvested mid-September, suberized two weeks at room temperature and then placed into 45° F, 42° F and 38° F storage. Eight tubers of each clone were evaluated for glucose, Agtron color values (AGT) and chip color (CC) at three intervals (i.e., harvest, 3 and 7 month's storage). Potatoes were also reconditioned at 55° F for two weeks following storage at 42° F and 38° F for five months. All storage and processing evaluations were conducted at the USDA/ARS Potato Research Worksite, East Grand Forks, MN.

Results and Discussion:

The individual clones demonstrated a wide range of glucose accumulation when subjected to cold stress. At 42° F storage, the concentration of glucose ranged from 0.03 mg/g in ND 7519-1 (Table 1) to 4.79 mg/g in COTX 01403-4RY (Table 3). This represented a 160-fold difference in their sweetening potential. Based on sugar content and chip appearance, the clones were categorized into three classes based on their storage performance.

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

Table 1 shows twenty-six 'Class A' clones that chipped successfully from 42° F without the need for reconditioning. Reconditioning, however, did improve most of the Agtron scores (data not shown). Of the top 10 clones, 4 were from ND, 2 each from MI and WI, 1 from MN, and 1 from CO/OR. This is the eighth straight year that ND 7519-1 was near the top or close to the top of the Class A clones. This consistency in quality should stimulate interest for it being inserted in up-coming regional and national trials.

Table 2 shows the 'Class B' clones that chip from 45° F but not 42° F. There were only six clones represented in this class. Three new clones were represented i.e., COO 2024-9W (CO/OR), W 6609-3 (WI), and NDO 59694B-20RUS (ND/OR). Tundra (W 2310-3) was close to being a Class A clone, as it was in 2012. Shepody (CAN/NB) performed better this year, as it was a Class C clone in 2012.

Table 3 lists 'Class C' clones that chip neither from 42° F or 45° F storage following storage for 7 months. Cultivars such as Russet Norkotah, Dark Red Norland, and Red Pontiac fall into this class. Clones e.g., Umatilla and Russet Burbank that inherently have higher sugar content that Class A or B clones, they are generally directed towards french fry and/or fresh markets utilization.

All sixty-one of the potato clones evaluated in this study failed to produce acceptably colored chips following storage at 38° F for seven months. It is noted that several of the previously highly rated clones, identified through these annual storage evaluations, have gone on to become leading U.S. chipping cultivars as well as serving as valuable parents for future crossings.

Summary

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

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

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

References:

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

Sowokinos, J.R. 2001. Invited Review: Biochemical and molecular control of cold-induced sweetening in potatoes. Am. J. Potato Res. 78:221-236.

State	Breeder	Phone	E-Mail
MN	Dr. Christian Thill	612-624-9737	thill005@umn.edu
ND	Dr. Susie Thompson	701-231-8160	asunta.thompson@ndsu.edu
USDA/ID	Dr. Richard Novy	208-397-4181	novy@uidaho.edu
WI	Mr. Jeff Endelman	608-250-0754	endelman@wisc.edu
Alberta	Dr. Benoit Bizimungu	403-317-2276	bbzimungu@agr.gc.ca
MI	Dr. Dave Douches	517-355-6887	douches@pilot.msu.edu
ME	Mr. Greg Porter	207-581-2943	porter@maine.edu
OR	Mr. Vidyasagar Sathuvalli	541-567-6337	vidyasagar@oregonstate.edu
TX	Dr. Creighton Miller	979-845-3828	cmiller@taexgw.tamu.edu
NY	Dr. Walter DeJong	607-254-2467	wsd2@cornell.edu
CO	Dr. David Holms	719-754-2619	spudmkr@lamar.colostate.edu
For other experimental details contact:			
MN	Dr. Joe Sowokinos	701-739-2467	sowok001@umn.edu
USDA	Mr. Martin Glynn	218-773-2473	marty.glynn@ars.usda.gov

Table 1. 2012-2013 Class A Clones: Potato clones that chip following 7 months storage at 45° F and 42° F. Clones are aligned in order of increasing glucose values rom 42° F.

				45° F			42° F
VARIETY	Source	CC[1]	AGT[2]	GLUCOSE	CC[1]	AGT[2]	GLUCOSE
				(mg/g)			(mg/g)
ND 7519-1	ND	1	69	0.01	1	68	0.03
MSR-061-1	MI	1	72	0.02	1	68	0.03
MSK 061-4	MI	---	---	---	1	68	0.03
W 2133-1 (NICOLET)	WI	1	67	0.02	1	65	0.04
W 2717-5 (LELAH)	WI	1	70	0.00	1	66	0.04
ND 7192-1	ND	1	68	0.03	1	65	0.04
COO 2033-1W	CO/OR	1	67	0.05	1	67	0.05
NORVALLEY	ND	1	71	0.01	1	68	0.06
MN 99380	MN	1	65	0.19	1	68	0.08
DAKOTA PEARL	ND	1	71	0.01	1	69	0.09
IVORY CRISP	ND/OR/ID/USDA	1	67	0.04	1	68	0.11
ND 7799c-1	ND	1	70	0.03	1	65	0.12
COO 2321-4W	CO/OR	1	67	0.04	1	65	0.12
QNDSU 05-4	ND	1	68	0.06	1	64	0.12
MSJ 126-9Y	MI	1	66	0.22	1	65	0.13
WV 4993-1	CAN	1	68	0.09	1	66	0.14
ACO 1151-5W	ID/OR	1	67	0.04	1	64	0.14
MSS-165-2Y	MI	1	69	0.03	1	62	0.15
MN 02467-RUS/Y	MN	1	62	0.16	1	64	0.15
MSL 292-A	MI	1	68	0.09	1	65	0.17
MSR 169-8Y	MI	1	58	0.07	2	60	0.18
MSR -127-1	MI	---	---	---	1	64	0.21
ND 8305-1	ND	1	62	0.13	2	60	0.29
SNOWDEN	WI	1	62	0.10	2	59	0.30
W 5955-1	WI	1	60	0.25	2	62	0.31
W 5015-12	WI	1	62	0.33	2	60	0.31

CC[1] = Represents chip color relating to the Potato Chip/Snack Food Association five-code color chart: 1 and 2 are acceptable, 3 is marginal, 4 and 5 are unacceptable.

AGT[2] = Agtron values of 60 or greater yield acceptably colored chips.

Table 2. 2012-2013 Class B Clones: Potato clones that chip following 7 months storage at 45° F, but not from 42° F. Clones are aligned in order of increasing glucose values rom 42° F.

				45° F			42° F
VARIETY	Source	CC[1]	AGT[2]	GLUCOSE	CC[1]	AGT[2]	GLUCOSE
				(mg/g)			(mg/g)
COO 2024-9W	CO/OR	1	65	0.13	3	54	0.42
W 2310-3 (TUNDRA)	WI	2	62	0.26	3	54	0.44
SHEPODY	CAN/NB	2	64	0.13	3	51	0.57
W 6609-3	WI	2	62	0.20	3	52	0.57
NDO 59694B-20RUS	ND/OR	2	64	0.19	3	54	0.69
YUKON GOLD	CAN	2	59	0.36	3	45	0.94

CC[1] = Represents chip color relating to the Potato Chip/Snack Food Association five-code color chart: 1 and 2 are acceptable, 3 is marginal, 4 and 5 are unacceptable.

AGT[2] = Agtron values of 60 or greater yield acceptably colored chips.

Table 3. 2012-2013 Class C Clones: Potato clones that do not chip acceptably following 7 months storage from either 45° F and 42° F. Clones are aligned in order of increasing glucose values rom 42° F.

				45° F			42° F
VARIETY	Source	CC[1]	AGT[2]	GLUCOSE (mg/g)	CC[1]	AGT[2]	GLUCOSE (mg/g)
W 8946-1 RUS	WI	3	54	0.77	3	55	0.47
W 9161-3 RUS	WI	3	53	0.62	3	54	0.43
MN 02574	MN	3	52	0.50	3	53	0.56
COTX 04015-3WY	CO/OR/TX	3	53	0.71	3	52	0.64
MN 02586	MN	3	53	0.56	3	53	0.68
UMATILLA	ID/OR	3	55	1.05	3	49	0.69
MSL 007B	MI	3	52	0.64	3	49	0.77
W 2324-1 (ACCUM)	WI	3	56	1.10	3	52	0.87
WND 8625-2RUS	WI/ND	3	55	1.30	3	54	0.91
ND 5255-59	ND	3	61	0.52	3	50	1.09
AND 97279-5RUS	ID/ND	3	52	1.12	3	49	1.23
RUSSET NORKOTAH	ND	4	42	0.96	4	44	1.28
ATTX 98453-3R	ID/TX	3	49	1.04	3	45	1.47
MN 04844-07Y	MN	2	59	0.76	3	50	1.47
NDO 49546b-10RU	ND/OR	3	54	1.92	3	53	1.52
DR NORLAND	ND	4	44	2.20	4	42	1.84
ATTX 98453-6R	ID/TX	3	51	0.65	4	44	1.87
RUSSET BURBANK	CO	3	48	0.90	3	45	2.02
ACOO 395-2RU	ID/CO/OR	4	44	2.47	4	45	2.18
BTX 2332-1R	USDA/TX	3	50	1.46	4	44	2.20
ADTX 96216-2RU	ID/OR/TX	3	51	1.00	4	43	2.97
WND 8624-2RUS	WI/ND	3	48	2.03	4	42	3.06
MN 18747-LW	MN	3	53	1.34	4	41	3.14
RED PONTIAC	ND	3	48	2.03	4	39	3.24
ATXO 3564-1Y/Y	ID/TX/OR	3	49	1.03	4	40	3.24
ND 8068-5 RUS	ND	3	49	1.44	4	47	3.36
CV 00088-3	CAN	4	46	3.20	4	39	3.94
CV 98173-4	CAN	3	54	2.62	4	42	3.96
COTX 01403-4RY	CO/TX	5	31	2.49	5	30	4.79

CC[1] = Represents chip color relating to the Potato Chip/Snack Food Association five-code color chart: 1 and 2 are acceptable, 3 is marginal, 4 and 5 are unacceptable.

AGT[2] = Agtron values of 60 or greater yield acceptably colored chips.

Sustainable Production of Dakota Trailblazer

Andrew P. Robinson, Ryan Larsen, Asunta Thompson, Neil Gudmestad

Executive Summary
A trial was established in Becker, MN to determine the effect of different nitrogen rates and water on three potato cultivars (Russet Burbank, Dakota Trailblazer, and ND8068-5Russ). Three irrigation blocks were established to represent 50, 75, and 100% irrigation and within each block three cultivars and five nitrogen rates were implemented. The 75% irrigation regime totaled 31.34 inches, or 93% of the 100% irrigation regime. The 50% irrigation regime had total moisture of 28.60 inches, or 85% of the 100% irrigation regime. Russet Burbank had the highest yield, while Dakota Trailblazer and ND 8068-8Russ had similar yields. Response to nitrogen was observed across cultivars with the optimal amount being between 180 and 270 lb N/a. Dakota Trailblazer had reduced marketable yield and tuber size at the 100% irrigation rate. The reduced irrigation rates improved Dakota Trailblazer graded yield.

Introduction
The newly developed variety, Dakota Trailblazer has shown promise as a tablestock and frozen processing variety. Dakota Trailblazer is a long tuber type with medium russet skin with white flesh and a high yield potential. Additionally, Dakota Trailblazer has resistance to *Verticillium wilt*, sugar ends, and foliar late blight, which may allow a reduction in the number of fungicide treatments and eliminate the need for fumigation. It also requires less nitrogen than Russet Burbank. Today's culture is concerned with how food is grown and minimizing inputs. Because of the traits Dakota Trailblazer possesses, further research needs to explore what is the relationship of Dakota Trailblazer when pesticides treatments are reduced, less nitrogen is applied, and smaller amounts of water are used for irrigation. The objectives of this study were to determine the effect of reduced nitrogen and irrigation rates and to quantify the cost of production for Dakota Trailblazer, Russet Burbank, and ND8068-5Russ.

Materials and Methods
Potatoes were planted May 6, 2014 at the Sand Plains Research Farm in Becker, MN. At the beginning of the experiment there was 3 lb/acre of available nitrogen in the soil. Three irrigation rate blocks were established with the intent to irrigate at 50, 75, and 100% normal field irrigation. Because rainfall also accounts for moisture, about 70% of the water needed for production was supplied through irrigation (Table 1). Within each irrigation regime a split-plot design was used. The main plot factor was cultivar (Russet Burbank, Dakota Trailblazer, and ND8068-5Russ) and the sub-plot was nitrogen rate (50, 90, 180, 270, and 360 lb N/acre).

Potassium was applied as 0-0-60 and 0-0-22 at 200 lb/a on April 15 and 21st, respectively. Following potassium application it was tilled in. Starter nitrogen was banded on May 17th at 50 lb N/acre (urea 46-0-0) and lightly hilled in on the same day. Before re-hilling on May 24th, ESN was applied at 0, 40, 130, 220, and 310 lb N/acre. Seed from each cultivar was cut to an average size of 2 oz. All pesticides and other agronomic practices were completed according to recommended practices for potato production in Minnesota. Vines were chopped on September 12th and plots were harvested on September 18, 2014. Following harvest tubers were weighted and graded.

Data were analyzed in SAS Proc Mixed to test for significant effects of cultivar, nitrogen rate, and cultivar × nitrogen rate. Each irrigation regime was analyzed separately because they were not replicated. Tukey pairwise comparison was used to determine if cultivar, irrigation rate, nitrogen rate, cultivar × nitrogen, irrigation × nitrogen, irrigation × nitrogen rate, and irrigation rate × cultivar × nitrogen rate had a significant effect ($P \leq 0.05$) on graded yield and specific gravity.

Results and Discussion

Precipitation and irrigation

Total rainfall from May 6th to September 12th was 23.35 inches. When added to the total amount of irrigation the 100% irrigation regime had 33.75 inches of moisture for 2014 (Table 1). The 75% irrigation regime totaled 31.34 inches, or 93% of the 100% irrigation regime. And the 50% irrigation regime had total moisture of 28.60 inches, or 85% of the 100% irrigation regime.

Table 1. Total amount of moisture, through precipitation and irrigation on potatoes in 2014 in Becker, MN.

Irrigation regime	Precipitation	Irrigation	Total moisture	Percent of total moisture
	———	inches	———	%
100	23.35	10.40	33.75	100
75	23.35	7.99	31.34	93
50	23.35	5.25	28.60	85

Graded yield

Graded yield of the various treatments had a significant effect for cultivar, nitrogen rate, and irrigation rate × cultivar. The other factors such as irrigation rate alone, irrigation rate × nitrogen rate, cultivar × nitrogen rate, and irrigation rate × cultivar × nitrogen rate did not have a significant effect. Of the cultivars tested, Russet Burbank had the highest marketable yield (344 cwt/a) while ND8068-8Russ and Dakota Trailblazer had lower total marketable yield (193 and 233 cwt/a, respectively) across all irrigation and nitrogen rates (Table 2). The percent of tubers > 6 oz was similar between Russet Burbank and Dakota Trailblazer (58-60% > 6 oz), which ND8068-8Russ had a smaller tuber profile (38% > 6 oz). Specific gravity was lowest for Russet Burbank at 1.076, ND8068-8Russ averaged 1.082, and Dakota Trailblazer had a specific gravity average of 1.090 across all irrigation and nitrogen rates. Although yields may seem low, the average yield appears lowers because this is an average across all irrigation and nitrogen rates.

Nitrogen rate did effect graded yield in most categories measured (Table 3). Total marketable yield was lowest with only 50 lb N/a, as expected. A trend could be observed as the nitrogen rate increased from 50 lb N/a to 180 lb N/a total marketable yield increased. From 180 to 360 lb N/a were no differences in total marketable yield. The percent of tubers > 6 oz had the same separation of data as total marketable yield, indicating the importance of nitrogen in yield and tuber size.

The response of irrigation rate × cultivar showed no differences in total marketable yield (Table 4). The percent of tubers > 6 oz was not different by irritation rate for ND8068-8Russ or Russet

Burbank, but Dakota Trailblazer had a lower percentage of tubers > 6 oz when grown with 100% irrigation. Irrigation rates of 50 to 75% were sufficient for tuber size for Dakota Trailblazer as was observed from the 10-14 oz tuber size as well.

The goal of this experiment was to have reduced irrigation rates as a means of testing the ability of newer cultivars to be more sustainable. However, because the rainfall amounts were so high (23.35 inches) there was not a lot of different in total irrigation ranging from 85 to 100%. Potato production in the Upper Midwest is challenging because of varied precipitation. Cultivars that can withstand lower soil moisture and produce an economically profitable crop are important to develop and identify. This will ensure the sustainability of potato production in the future.

Table 2. Response of graded yield of cultivars grown at Becker, MN in 2014.

Cultivar	< 3 oz	3-6 oz	6-10 oz	10-14 oz	> 14 oz	Total	US#1 > 3 oz	US#2 > 3 oz	Total marketable	> 6 oz	> 10 oz	Specific gravity
	cwt/a									%		
ND8068-8Russ	33 a[a]	95 b	71 b	21 b	6 c	225 b	187 b	6 b	193 b	38 b	10 c	1.082 b
Russet Burbank	25 b	116 a	146 a	54 a	27 b	369 a	321 a	23 a	344 a	58 a	20 b	1.076 c
Dakota Trailblazer	16 c	61 c	77 b	52 a	42 a	249 b	223 b	10 b	233 b	60 a	30 a	1.090 a

[a] Within columns, at each irrigation rate, means followed by the same letter are not significantly different according to Tukey pairwise comparison ($P \leq 0.05$). No letter following a value indicates no difference.

Table 3. Response of graded yield of cultivars to nitrogen rate in 2014 at Becker, MN.

Nitrogen	< 3 oz	3-6 oz	6-10 oz	10-14 oz	> 14 oz	Total	US#1 > 3 oz	US#2 > 3 oz	Total marketable	> 6 oz	> 10 oz	Specific gravity
	cwt/a									%		
50	30	94	48 b[a]	8 c	4 b	183 c	149 c	4 b	153 c	29 c	6 b	1.081 bc
90	26	103	97 a	28 bc	5 b	260 b	228 b	7 b	234 b	47 b	12 b	1.086 a
180	23	87	116 a	50 ab	22 b	297 ab	264 ab	10 ab	275 ab	59 ab	22 a	1.086 ab
270	23	81	113 a	65 a	47 a	329 a	286 a	20 a	306 a	64 a	31 a	1.083 ab
360	21	83	111 a	62 a	48 a	324 a	282 ab	21 a	303 a	63 a	30 a	1.079 c

[a] Within columns, at each irrigation rate, means followed by the same letter are not significantly different according to Tukey pairwise comparison ($P \leq 0.05$). No letter following a value indicates no difference.

Table 4. Response of irrigation rate × cultivar on graded yield in 2014 at Becker, MN.

Irrigation	Cultivar	< 3 oz	3-6 oz	6-10 oz	10-14 oz	> 14 oz	Total	US#1 > 3 oz	US#2 > 3 oz	Total marketable	> 6 oz	> 10 oz	Specific gravity
		------ cwt/a ------									------ % ------		
50	ND8068-8Russ	46 a	109	71	12 c	2 c	241	186	9	195	31 c	5 d	1.081 b
50	Russet Burbank	24 bcd	121	160	63 ab	32 bc	399	351	25	376	60 a	22 bc	1.077 bc
50	Dakota Trailblazer	11 d	56	93	63 ab	54 ab	277	257	9	266	70 a	37 ab	1.094 a
75	ND8068-8Russ	29 b	97	77	18 c	3 c	224	190	5	195	42 bc	9 cd	1.083 b
75	Russet Burbank	29 b	115	126	44 abc	17 bc	331	290	12	302	55 ab	18 cd	1.079 bc
75	Dakota Trailblazer	12 cd	48	82	70 a	67 a	280	252	16	268	71 a	40 a	1.096 a
100	ND8068-8Russ	23 bcd	80	64	32 bc	13 c	212	185	4	188	41 bc	15 cd	1.082 b
100	Russet Burbank	24 bcd	111	150	54 abc	32 bc	370	315	32	347	61 ab	21 cd	1.072 c
100	Dakota Trailblazer	25 bc	80	56	25 c	7 c	192	163	4	167	41 bc	14 cd	1.081 b

[a] Within columns, at each irrigation rate, means followed by the same letter are not significantly different according to Tukey pairwise comparison ($P \leq 0.05$). No letter following a value indicates no difference.

A Two-Year Agronomic Evaluation of New Potato Genotypes for Tuber Yield, Quality, and Low Reducing Sugars

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Abstract: 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. Low concentration of its precursors (reducing sugar and asparagine) can potentially reduce acrylamide content. A field study was conducted at the Sand Plain Research Farm in Becker, Minnesota to evaluate tuber yield, quality, and sugar content of new potato genotypes from university breeding programs in 2013 and 2014. 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 in five locations in the U.S. This effort is part of a USDA Specialty Crop Research Initiative to reduce acrylamide content in fried potato products. All the results reported here are for the Minnesota location at the Sand Plain Research Farm in Becker. The effects of potato genotype were significant for tuber yield, size distribution and tuber quality. Among all new genotypes and Russet Burbank (RB - as control) tested, AF3001-6 and AF4296-3 were found to be the best choices, with high yield, tuber quality, and percentages of large tubers. The glucose concentrations of these two genotypes were lower than RB in both years. Of the genotypes that were only tested in 2014, A02424-83LB, A03158-2TE and A06084-1TE had yields and tuber size that were similar to those of RB, but with higher tuber quality and lower sugar concentrations. 09152BW-01 had similar yield and tuber quality to RB, but the highest levels of sucrose and glucose among all genotypes. Dakota Russet was among the lowest for reducing sugars, but did not yield as well as many of the other genotypes.

Background:

It is widely known that the neurotoxin and possible carcinogen acrylamide is formed during the high temperature frying process in Maillard reaction in potato chips and fries. French fries and other processed potato products make up more than 50% of all potatoes consumed in the US. 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.

In the potato industry, new varieties for processing need to meet the following requirements: lower acrylamide concentration in the final fried products with other criteria equaling or exceeding the quality and yield of the standard varieties. In this USDA/NIFA funded SCRI-Acrylamide project, 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 in five locations in the U.S. The results reported here are for the Minnesota location.

The objectives of this study were to (1) characterize plant growth (stand count, stems per plant and vine maturity) and tuber set; (2) determine tuber yield and size distribution; and (3) evaluate tuber quality and sugar content of new genotypes in relation to the industry standard, Russet Burbank (RB).

Materials and methods:

This study was conducted in 2013 and 2014 at the Sand Plain Research Farm in Becker, Minnesota, on a Hubbard loamy sand soil. The previous crop for both years was winter rye. Soil chemical properties before planting in 2013 were as follows: (0-6"): pH, 6.2-6.7; organic matter, 1.2-2.0 %; Bray P1, 28-54 ppm; ammonium acetate extractable K, Ca and Mg, 83-151, 697-1106, and 132-207 ppm respectively; Ca-phosphate extractable SO_4-S, 3-5 ppm; hot water extractable B, 0.25-0.3 ppm; DTPA-Fe, DTPA-Mn, DTPA-Zn and DTPA-Cu, 19-30, 16-22, 1.2-1.9 and 0.5-0.8 ppm respectively. Soil chemical properties before planting in 2014 were as follows: (0-6"): pH, 6.3-6.5; organic matter, 1.8-2.1 %; Bray P, 28-47 ppm; ammonium acetate extractable K, Ca and Mg, 79-126, 886-924, and 171-179 ppm respectively; Ca-phosphate extractable SO_4-S, 2-3 ppm; hot water extractable B, 0.18-0.20 ppm; DTPA-Fe, DTPA-Mn, DTPA-Zn and DTPA-Cu, 26-34, 7-10, 0.9-1.4 and 0.6-1.0 ppm respectively.

In both years, pre-plant fertilizers were 200 lbs/ac 0-0-60 and 200 lbs/ac 0-0-22 broadcasted and incorporated with a chisel plow in 2013 and a field cultivator in 2014. Each plot had four 20-ft rows planted, with the middle two rows (18 feet) used for sampling and harvest. Cut "A" seed of the red potato Chieftain was used as marker potatoes at both ends of the harvest rows. Cut "A" seeds of all cultivars were hand planted in furrows on April 30, 2013 and May 5, 2014. Row spacing was 12 inches within each row and 36 inches between rows. 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.

In 2013, 490 lbs/ac of a blended fertilizer containing 63 lb/ac N, 101 lb/ac P_2O_5, 93 lb/ac K_2O, 27 lb/ac S, 1.5 lb/ac Zn, and 0.81 lb/ac B was banded 3 inches to each side and 2 inches below the seed piece in all plots at planting. At emergence (May 29, 2013), 405 lbs/ac of Environmentally Smart Nitrogen (ESN) providing 178 lb/ac N) were applied in all plots and hilled in. In 2014, 708 lbs/ac of a blended fertilizer containing 30 lb/ac N, 130 lb/ac P_2O_5, 181 lb/ac K_2O, 46 lb/ac S, and 20 lb/ac Mg was banded 3 inches to each side and 2 inches below the seed piece in all plots at planting. At emergence (May 29, 2014), 386 lbs/ac of ESN providing 170 lb/ac N) were applied in all plots and hilled in. In 2014, additional N as UAN was applied at the rate of 20 lb/ac N on June 30 and 20 lb/ac N July 23. A randomized complete block design was used with four replicates.

In 2013, 14 genotypes (AF3001-6, AF4296-3, AF4342-3, AC00395-2RU, AC99375-1RU, A0012-5, A0073-2, A02138-2, A02507-2LB, A03921-2, W6234-4rus, W8152-1rus, AO00057-2 and AO01114-4) and Russet Burbank (as control) were evaluated. In 2014, five of these genotypes (AF3001-6, AF4296-3, AF4342-3, A02507-2LB and W8152-1rus) with high yield and tuber quality were selected and evaluated again. In addition, six new genotypes/varieties (A02424-83LB, A03158-2TE, A06084-1TE, Dakota Russet, 09107BB-01 and 09152BW-01) were added in with RB still used as the control.

Plant stands, stem number per plant and tuber set count were measured in both years. See date information in Table 1. When plants were removed from the soil, some of the tubers or hooks were broken. Since we could not distinguish if the plant part was a tuber or a hook, it was only counted in the total number.

Table 1. Dates of plant growth and tuber set measurements.

Year	Stand (%)	Stems Per Plant	Tuber Set Count
2013	14-Jun	3-Jul	20-Jun
2014	27-Jun	27-Jun	23-Jun

Petiole samples were collected from the fourth leaf from the terminal on four dates: June 24, July 3, July 15 and July 29 in 2013; June 23, July 8, July 22 and July 31 in 2014. Petioles were analyzed for nitrate-nitrogen on a dry-weight basis. Analysis is still in progress and therefore petiole nitrate data are not presented in this report. Vine maturity (visual assessment of the percentage of green vines left on the ground) was rated on September 12, 2013 and 2014. Vines were then sprayed and killed on that same day. Plots were machine harvested on September 24 in both years. Total yield and graded yield were measured over the next two days.

Tuber sub-samples were collected to determine the internal defects (hollow heart, brown center, vascular discoloration and heat necrosis), tuber dry matter content, specific gravity, and length to width ratio. Tuber internal disorders were determined from different tuber sizes. Internal defects and tuber dry matter was determined from 10, 10 - 13 oz tubers per replication; Specific gravity was from 20, 6-10 oz tubers per replication. Length to width ratio was from 10, 8-10 oz tubers per replication.

Tuber sugar content was measured both years three weeks after harvest. In 2013, whole tuber glucose and sucrose concentrations were determined while in 2014, bud- and stem-end sucrose and glucose were measured.

Results

Plant stand:

In both years, the effect of variety/genotype on plant stand was significant (Table 2 and Table 3).

In 2013, Plant stand ranged from a low of 63.9-% to 100% of tubers planted for each genotype. A0012-5 had a plant stand of 63.9%, significantly lower than all other genotypes, which had high percentages of standing vines (more than 92%).

In 2014, plant stand ranged from 88.9% to 100% of tubers planted for all genotypes. The five genotypes (AF3001-6, AF4296-3, AF4342-3, A02507-2LB and W8152-1RUS) selected from 2013 still had a high plant stand (>96%), especially AF4296-3 and W8152-1RUS reaching 100%. Dakota Russet and 09152BW-01 had a lower plant stand (88.9%) than all other genotypes. Plant stands of the new genotypes in 2014 A03158-2TE, A06084-1TE, and

09107BB-01 had had similar stands as RB (98.6-100%). A02424-83LB had a plant stand of 96.5%, which was statistically lower than RB.

Stems per plant:

The effect of genotype on the number of stems per plant was significant in both years (Table 2 and Table 3).

In 2013, RB had the most stems per plant (3.4). AF4296-3, AC00395-2RU, A0073-2, A02138-2, A03921-2, W6234-4RUS and AO01114-4 had stems per plant ranging from 2.7 to 3.1, which was statistically the same level as RB. Genotypes AF4342-3 and A0012-5 had significant fewer stems per plant (1.8 and 1.7) than RB. Other genotypes had significantly fewer stems per plant than RB, but the average number was still greater than 2.

In 2014, RB had 2.7 stems per plant. The number of stems per plant of the five genotypes (AF3001-6, AF4296-3, AF4342-3, A02507-2LB and W8152-1rus) from 2013 were not significantly different from RB. New genotypes 09107BB-01 had 5.7 stems per plant, which was the highest among all the genotypes. A02424-83LB and A06084-1TE had fewer stems per plant (4.8 and 3.9) than 09107BB-01, but still significantly higher than RB and others. All other genotypes had similar numbers of stems per plant as RB. Dakota Russet had 2 stems per plant, which was the lowest number of stems among all genotypes.

Tuber set:

The effect of genotype on tuber set measured at approximately 50 days after planting was significant (Table 2 and Table 3).

In 2013, RB had highest total number (20.3) of tubers and hooks. AF4342-3 and A0012-5 had significantly fewer total numbers of tubers and hooks (11 and 11.8) than RB. All other genotypes had total numbers of tubers and hooks that were not significantly different from RB. For the category of tubers only, AF4296-3 was the only genotype that had significantly more tubers than RB (17.0 vs. 9.8). AF4342-3, A0073-2, A03921-2, AO01114-4 and A0012-5 had significantly fewer tubers (< 4.1) than RB.

In 2014, due to the late emergence, tuber set data of genotype A02507 was not determined. Among all other 11 genotypes, the other four genotypes from 2013 (AF3001-6, AF4296-3, AF4342-3, and W8152-1rus), the new 2014 genotype A03158-2TE and Dakota Russet had the total tubers and hooks that were not significantly different from RB (13.5). New genotypes A02424-83LB, A06084-1TE, 09107BB-01 and 09152BW-01 had total numbers of tubers and hooks (27.5, 24.3, 24.8 and 27.8) that were significantly higher than RB. For the category of tubers only, 09107BB-01 was the only genotype that had significantly more tubers (16.8) than RB (8.8). AF4342-3 and A03158-2TE had significantly fewer tubers (1.8 and 1.3) than RB. All other genotypes had tuber numbers that were not different from RB.

Vine maturity:

Vine maturity was rated as the percentage of green vines covering the ground on September 12 in both years, 12 days before tuber harvest. The genotype effect on vine maturity was also significant in both years (Table 2 and Table 3).

In 2013, most vines of RB, A0073-2, A02138-2, A03921-2, W6234-4RUS and AO01114-4 were dead (8% or less). In contrast, most vines of AC00395-2RU, AC99375-1RU and A0012-5 were still alive (62.5%, 77.5% and 83.8%). Other genotypes still had part of their vines living, but less than 50%. They had either more living vines or the same level as RB.

In 2014, almost all vines of RB were dead when rated (only 1.3% left). A06084-1TE, W8152-1RUS and 09107BB-01 had the same level of green vines left (no more than 20%) as RB. All other genotypes had significantly more vines left than RB, especially A02507, AF3001-6 and AF4342-3 (no less than 80%). Among the five genotypes from the 2013, four of them (AF3001-6, AF4342-3, A02507-2LB and W8152-1rus) had consistent results on vine maturity compared to RB. AF4296-3 had about the same percentage of green vines left over the two years, but in 2014, the percentage was statistically higher than RB.

Tuber yield:

In both years, the genotype effect on yield was significant for all tuber size categories (Table 4 and Table 5).

In 2013, RB had a total yield of 532 cwt/A with 459 cwt/A as marketable yield. AF3001-6 (584 cwt/A) and AF4296-3 (578 cwt/A) genotypes had total yields that were not statistically different than RB yields. A0012-5, A0073-2, W8152-1RUS, AO00057-2 and AO01114-4 had significantly lower yields than RB, especially A0012-5 (252 cwt/A), which also had the lowest stand count and stems per plant. All other genotypes had total yields that were similar to RB. For marketable yield, AF3001-6 (560 cwt/A) and AF4296-3 (538 cwt/A) were the only two genotypes that were significantly higher than RB. All others had marketable yields that were the same or lower level than RB.

In 2014, RB had a lower yield than in 2013, with 490 cwt/A as total yield and 444 cwt/A as marketable yield. The genotype AF3001-6 was the only genotype that had significantly higher total and marketable yields than RB. Total and marketable yields of AF4296-3, new genotypes A03158-2TE, A06084-1TE, 09107BB-01 and 09152BW-01 were not significantly different from RB. Dakota Russet had lower total yield than RB, but marketable yields were similar. All other genotypes had significantly lower total and marketable yields than RB.

In the category of No.1 tubers, yields of AF3001-6, AF4296-3 AC00395-2RU, A03921-2 and W6234-4RUS were significantly higher than RB in 2013. Other genotypes were either not significantly different or had significantly lower yield than RB. In the same year,, AF3001-6, AF4342-3, AF4296-3, A02507-2LB, W6234-4RUS and A03921-2 had significantly higher percentages of tubers greater than 6 or 10 oz than RB. Other genotypes either had lower percentages of tubers in both categories than RB (AC99375-1RU, A0073-2 and A02138-2) or were not different than RB (AC00395-2RU, W8152-1RUS, AO00057-2 and AO01114-4). An exception was A0012-5, which had a higher percentage of tubers in these two categories than RB, but had extremely low total and marketable yield.

In 2014, AF3001-6, AF4296-3 and 09152BW-01 had significantly higher yields of No. 1 tubers than RB. Dakota Russet had lower total yield than Russet Burbank. Other genotypes either had lower yields or no significant difference from RB. AF3001-6 had significantly higher percentages of tubers greater than 6 oz and 10 oz than RB. Dakota Russet and

09152BW-01 had significantly higher percentages of tubers greater than 10 oz, but not 6 oz, than RB. A02507-2LB and 09107BB-01 were the only two genotypes that had significantly lower percentages of tuber greater than 6 oz and 10 oz than RB. No other genotypes had significantly different percentages of yield in tubers greater than 6 oz or 10 oz than RB.

AF3001-6 and AF4296-3 generally had larger tubers than RB. In 2013, AF4342-3, AC00395-2RU, A02507-2LB, A03921-2 and W6234-4RUS had similar total and marketable yield to RB, but with higher percentages of tubers greater than 6 oz and 10 oz. In 2014, genotypes AF3001-6 and AF4296-3 again had high yield and large tubers, AF3001-6 having the highest total and marketable yields and highest percentages of tubers greater than 6 and 10 oz. Among all the new genotypes, 09152BW-01 had similar total and marketable yields to RB, but with more No.1 tubers and a higher percentage of tubers greater than 10 oz.

Tuber quality:

In both years, the effects of genotype on the percentages of hollow heart, brown center, specific gravity, tuber dry matter and the length/width ratio were significant (Table 6 and Table 7). There was also a significant effect of genotype on the percentage of disqualified tubers in 2013 (Table 6).

In 2013, the genotypes AF3001-6, AF4296-3, A0073-2, A02138-2, A02507-2LB, W6234-4RUS and AO00057-2 had a significantly lower percentages of hollow heart, brown center and disqualified tubers (<12.5%) than RB. AF4342-3, AC99375-1RU, W8152-1RUS and AO01114-4 had similar or significantly higher percentages in all three categories. A03921-2 had significantly lower percentages of hollow heart and brown center, but the percentage disqualified was not significantly different from RB.

In 2014, 30% of RB tubers had hollow heart, and 25% had brown center. W8152-1RUS and AF4342-3 from 2013 were the only two genotypes with significantly higher or similar prevalences of hollow heart (56.5% and 20.0%) and brown center (56.4% and 12.5%) to RB. 17.5% of 09152BW-01 tubers had hollow heart, similar to RB, but it had a lower percentage of tubers with hollow heart than RB. All other genotypes had significantly lower percentages of tubers with hollow heart and brown center (no more than 10%) than RB. 2.5% of Dakota Russet tubers had hollow heart and brown center.

In 2013, A0012-5 and W8152-1RUS were the only two genotypes that showed significantly lower specific gravity than RB. The specific gravity of A03921-2 was significantly higher than RB. No other cultivars had significantly different tuber specific gravity than RB. AF4342-3, AC00395-2RU, A03921-2 and AO01114-4 had significantly higher tuber dry matter content than RB. AF3001-6, AC99375-1RU and W6234-4RUS had significantly low tuber dry matter content than RB. No other cultivars had significantly different tuber dry matter content than RB. The ratio of length to width of AF4296-3 was significantly higher than RB. AF4342-3, AC00395-2RU, AC99375-1RU, A0012-5, W8152-1RUS and AO01114-4 had lower length to width ratios than RB. Other genotypes had shape that was not significantly different than RB.

In 2014, A02424-83LB, A02507-2LB, A06084-1TE and AF4342-3 had significantly higher specific gravity (>1.0889) than RB (1.0796). W8152-1RUS and 09107BB-01 had lower specific gravity than RB (1.0684 and 1.0714). All other genotypes had similar specific gravity to RB, ranging from 1.0800 to 1.0843. Genotype 09107BB-01 had lower tuber dry matter content (19.04%) than RB (20.39%). A02424-83LB, A02507-2LB, A06084-1TE and AF4342-3 had higher tuber dry matter contents than RB, ranging from 21.87% to 23.2%. All other genotypes had similar dry matter content to RB. RB had the highest ratio of length to width (2.13) in 2014. A02424-83LB, A03158-2TE, A06084-1TE, AF3001-6 and AF4296-3 all had similar length/width ratios to RB. The remaining genotypes had lower ratios than RB.

The effect of genotype on heat necrosis was significant at alpha = 0.10 in 2013, but not 2014. In 2013, A0073-2, W6234-4RUS and AO00057-2 had the highest percentage of heat necrosis (5%), which was significantly higher than all other genotypes except for A02138-2 and AO01114-4 (2.5%). No other genotypes exhibited heat necrosis.

The genotype effect on vascular discoloration was not significant in either year.

Sugar content:

The genotype effect on tuber sugar was significant in both years. In 2013, AO01114-4 had significantly higher glucose than RB. AC00395-2RU and A0073-2 had similar glucose concentrations to RB. All other genotypes had significantly lower glucose concentrations than RB.

AF3001-6 and AC99375-1RU had significantly lower sucrose concentrations than RB. AF4342-3, AC00395-2RU, A0012-5, A02507-2LB and W6234-4RUS had significantly higher sucrose concentrations than RB. The glucose concentrations of the remaining genotypes were not significantly different than that of RB.

In 2014, glucose content ranged from 0.22 to 2.41 mg/g at stem end and 0.06 to 1.04 mg/g at bud end among all genotypes. Stem-end glucose concentrations were 1.7- to 11.8-fold higher than the bud end glucose concentrations among all genotypes. RB and 09152BW-01 had the highest glucose concentrations at both the stem (2.33 and 2.41mg/g, respectively) and the bud ends (0.77 and 1.04 mg/g, respectively). AF4342-3 also had a high stem-end glucose concentration. All other genotypes had lower of glucose concentration at both ends than RB.

The sucrose concentration ranged from 0.55 to 1.64 mg/g at the stem end and 0.83 to 1.37 mg/g at the bud end for all genotypes. Sucrose concentrations did not vary as much as glucose concentrations did, either among genotypes or between the stem and bud ends of the tuber. AF4342-3 and 09152BW-01 had among the highest sucrose concentrations at both the stem (1.36 and 1.52 mg/g) and bud (1.26 and 1.32 mg/g) end. AF3001-6 had the highest sucrose concentration at the stem end. RB had 0.55 mg/g sucrose at stem end, which was the lowest concentration of any genotype, though A03158-2TE and 09107BB-01 did not have significantly greater concentrations. The genotype effect on the sucrose concentration of bud end was significant at alpha = 0.10. A02424-83LB had the highest bud-end sucrose concentration (1.37 mg/g). Dakota Russet, W8152-1RUS and AF4296-3 had the lowest sucrose concentrations at the bud end (0.87, 0.83 and 0.89 mg/g, respectively).

Conclusions:

AF3001-6, AF4296-3, A0073-2, A02138-2, A02507-2LB, W6234-4RUS and AO00057-2 genotypes all had low percentages of hollow heart and brown center (<8%) in 2013. Among these genotypes, AF3001-6 and W6234-4RUS had significantly lower percentages of tuber dry matter (19.78% and 19.81%) than RB (21.40%). Others had either higher or similar percentages of dry matter to RB. All these genotypes had higher or similar specific gravity and length to width ratio to RB. A03921-2 had a similar percentage of disqualified tubers to RB, but higher specific gravity and tuber dry matter. In 2014, AF4342-2 had high percentages of hollow heart and brown center (20% and 12.5%, respectively), as did W8152-1RUS (56.5% and 56.4%, respectively); both were selected from 2013. The other genotypes from 2013, AF3001-6, AF4296-3 and A02507-2LB, all had low percentages of hollow heart and brown center, and their specific gravity and tuber dry matter were either higher than or similar to those of RB. Among the new genotypes in 2014, all but 09107BB-01, had low percentages of hollow heart and brown center, with similar or higher specific gravity and tuber dry matter than RB.

Among the genotypes with low percentages of disqualified tubers in 2013, A0073-2 and AO00057-2 had significantly lower total and marketable yield than RB in 2013. AF3001-6 and AF4296-3 had similar total yield to RB, but significantly higher marketable. A02138-2 had a similar total yield to RB, but significantly lower marketable yield. The total and marketable yields of the other genotypes were not significantly different from those of RB. A02138-2 was the only genotype that had lower percentage of large tubers than RB. In 2014, only AF3001-6 had significantly higher total and marketable yield with more of its yield in large tubers than RB. Among the other genotypes selected from 2013, AF4296-3 had similar total and marketable yield and percentage of yield in large tubers to RB. AF4342-3 and W8152-1RUS had significantly lower yield, but similar percentages of yield in large tubers to RB. A02507-2LB had a significantly lower yield and percentage of yield in large tubers than RB. Among the new genotypes from 2014, A02424-83LB, A03158-2TE, A06084-1TE and 09152BW-01 all had similar yield and percentage of yield in large tubers as RB. Dakota Russet had significantly lower total and marketable yield, while 09107BB-01 had a significantly lower percentage of yield in large tubers, than RB.

For sugar content, among the genotypes with low percentages of internal defects (disqualified tubers≤15%) in 2013, all genotypes had significantly lower glucose concentrations than RB. AF3001-6 had a significantly lower sucrose concentration (0.68 mg/g) than RB (1.25 mg/g). A02507-2LB and W6234-4RUS had significantly higher sucrose concentrations (1.70 and 2.10 mg/g) than RB, but the total sugar concentrations (glucose + sucrose) of these two genotypes (1.84 and 2.27 mg/g) were still lower than RB (3.11mg/g). Others were not significantly different. In 2014, A02507-2LB, A06084-1TE, Dakota Russet and W8152-1RUS had the lowest concentrations of glucose at both the stem and bud ends of the tuber. AF3001-6 and 09107BB-01 also had low glucose concentrations at the bud end.

To generalize the results in all categories, AF3001-6 and AF4296-3 were found to be the best choices, with high yield and tuber quality and high percentages of large tubers. The glucose concentrations of these two genotypes were lower than RB in both years. Among the genotypes that were only grown in 2014, A02424-83LB, A03158-2TE and A06084-1TE all had similar yields and percentages of large tubers to RB, with high tuber quality and lower sugar concentrations. 09152BW-01 had similar yield and tuber quality to RB, but the highest sucrose and glucose concentrations of all the genotypes. The concentrations of reducing sugars in Dakota Russet tubers were among for all genotypes, but this variety did not yield as well as many of the other genotypes.

Table 2. Genotype effect on plant growth and tuber set forming in 2013.

Genotype	State of Origin	Stand (%)	Stems per plant	Tuber Set Count			Vine Maturity (%)
				Tuber	Hook	Total	
AF3001-6	ME	98.6 ab	2.2 cd	12.0 abcd	6.8 cde	19.8 abcd	37.5 cd
AF4296-3	ME	99.3 ab	2.8 abc	17.0 a	5.0 de	22.0 ab	23.0 def
AF4342-3	ME	99.3 ab	1.8 d	1.0 gh	8.5 bcd	11.0 f	45.0 c
AC00395-2RU	CO	99.3 ab	2.7 abc	10.0 bcde	13.0 abcd	23.8 a	62.5 b
AC99375-1RU	CO	98.6 ab	2.6 bc	6.3 efg	10.5 bcd	16.8 bcde	77.5 ab
A0012-5	ID	63.9 d	1.7 d	1.5 fgh	10.3 abc	11.8 ef	83.8 a
A0073-2	ID	92.4 c	2.9 ab	0.0 h	14.3 ab	14.8 cdef	4.8 g
A02138-2	ID	95.1 abc	3.1 ab	14.3 abc	7.3 cde	22.5 ab	2.5 g
A02507-2LB	ID	93.8 bc	2.6 bc	5.8 efg	17.3 a	23.0 ab	30.0 cd
A03921-2	ID	99.3ab	3.1 ab	3.8 fgh	10.5 bcd	15.8 cdef	8.0 gf
W6234-4RUS	WI	98.6 ab	2.8 abc	10.0 bcde	9.8 bcd	20.0 abc	8.0 gf
W8152-1RUS	WI	98.6 ab	2.5 bc	15.3 ab	1.3 e	16.8 bcde	11.3 efg
AO00057-2	OR	98.6 ab	2.6 bc	7.0 def	11.5 abcd	18.5 abcd	27.5 de
AO01114-4	OR	100.0 a	2.9 ab	4.0 fgh	11.0 abcd	16.5 bcde	3.8 g
Russet Burbank	--	100.0 a	3.4 a	9.8 bcde	9.8 bcd	20.3 abc	8.0 gf
Significance		**	**	**	++	*	**
LSD (0.1)		5.6	0.6	5.7	6.7	5.5	17.1

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

Table 3. Genotype effect on plant growth and tuber set in 2014.

Genotype	State of Origin	Stand (%)	Stems Per Plant	Tuber Set Count			Vine Maturity
				Tuber	Hook	Total	
Russet Burbank	--	100.0 a	2.7 def	8.8 bc	4.8 d	13.5 cd	1.3 f
A02424-83LB	ID	96.5 b	4.8 b	14.3 ab	13.3 ab	27.5 a	52.5 bc
A02507-2LB	ID	99.3 ab	2.8 def	NA	NA	NA	80.0 a
A03158-2TE	ID	100.0 a	3.1 cd	1.3 d	10.5 bc	11.8 cd	42.5 cd
A06084-1TE	ID	100.0 a	3.9 c	8.5 bc	15.8 a	24.3 ab	11.3 ef
AF3001-6	ME	99.3 ab	2.3 ef	11.0 abc	6.8 cd	18.0 bc	86.3 a
AF4296-3	ME	100.0 a	2.9 de	9.5 bc	6.5 cd	16.0 cd	23.8 de
AF4342-3	ME	96.3 b	2.1 ef	1.8 d	9.3 bc	11.0 d	82.5 a
Dakota Russet	ND	88.9 c	2.0 f	6.3 cd	8.0 cd	14.3 cd	68.8 ab
W8152-1RUS	WI	100.0 a	3.3 cd	13.8 ab	4.5 d	18.3 bc	20.0 ef
09107BB-01	MN	98.6 ab	5.7 a	16.8 a	8.0 cd	24.8 ab	16.3 ef
09152BW-01	MN	88.9 c	3.3 cd	12.3 ab	15.5 a	27.8 a	47.5 bc
Significance		**	**	**	**	**	**
LSD (0.1)		3.1	0.8	5.9	4.4	6.9	21.4

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

Table 4. Genotype effect on tuber yield and size distribution in 2013.

Genotype	State of Origin	Tuber Yield (cwt/A)					
		Total	1's > 4 oz.	2's > 4 oz.	Tot. Mkt.	% > 6 oz.	% > 10 oz.
AF3001-6	ME	584.0 a	504.6 a	55.1 b	559.7 a	88.0 a	62.2 a
AF4296-3	ME	577.8 a	501.9 a	35.8 cd	537.7 ab	81.0 bc	46.5 c
AF4342-3	ME	470.0 cdef	396.8 cdef	44.7 bc	441.5 cd	83.8 ab	50.0 bc
AC00395-2RU	CO	533.6 abc	469.9 ab	12.1 e	482.0 bc	72.0 d	27.9 e
AC99375-1RU	CO	535.1 ab	418.8 bcd	19.7 de	438.4 cd	54.2 g	15.1 fg
A0012-5	ID	252.4 h	188.5 h	36.2 cd	224.7 f	78.3 c	55.4 ab
A0073-2	ID	452.6 defg	337.3 g	48.8 bc	386.1 de	60.4 f	18.5 f
A02138-2	ID	489.1 bcde	340.8 fg	21.3 de	362.1 e	46.2 h	11.3 g
A02507-2LB	ID	478.5 bcdef	367.6 defg	77.9 a	445.5 cd	80.6 bc	48.4 c
A03921-2	ID	525.6 abc	447.6 abc	45.7 bc	493.3 bc	84.0 ab	57.1 a
W6234-4RUS	WI	499.4 bcd	439.4 abc	32.0 cd	471.3 c	81.4 bc	48.1 c
W8152-1RUS	WI	416.9 fg	312.0 g	10.0 e	322.0 e	51.4 gh	14.9 fg
AO00057-2	OR	400.3 g	352.1 efg	9.3 e	361.4 e	70.9 d	33.5 de
AO01114-4	OR	428.0 efg	363.3 defg	10.1 e	373.3 e	68.2 de	35.7 d
Russet Burbank	--	531.5 abc	400.7 cde	58.1 b	458.8 c	63.7 ef	31.3 de
Significance		**	**	**	**	**	**
LSD (0.1)		64.7	57.3	18.5	64.4	5.3	6.8

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

Table 5 Genotype effect on tuber yield and size distribution in 2014.

Genotype	State of Origin	Tuber Yield (cwt/A)				% > 6 oz.	% > 10 oz.
		Total	1's > 4 oz.	2's > 4 oz.	Tot. Mkt.		
Russet Burbank	--	490.0 bc	345.4 cd	98.4 a	443.8 bcd	76.4 bcd	41.3 cde
A02424-83LB	ID	476.9 bc	348.5 cd	73.6 b	422.1 cd	74.5 cd	39.2 de
A02507-2LB	ID	298.9 f	221.9 f	23.1 e	245.0 g	52.5 f	16.3 f
A03158-2TE	ID	450.8 cd	345.9 cd	66.9 bc	412.8 cd	77.4 bcd	54.1 bc
A06084-1TE	ID	449.1 cd	338.3 cd	72.5 b	410.8 cd	75.4 cd	43.4 cde
AF3001-6	ME	599.8 a	468.1 a	119.0 a	587.1 a	93.0 a	72.7 a
AF4296-3	ME	523.8 b	427.4 ab	73.3 b	500.7 b	86.5 abc	51.8 bcd
AF4342-3	ME	367.7 e	295.9 de	35.7 de	331.6 ef	70.4 de	34.0 e
Dakota Russet	ND	398.4 de	344.6 cd	39.5 de	384.1 def	88.4 ab	59.9 ab
W8152-1RUS	WI	354.6 ef	257.8 ef	58.6 bcd	316.4 f	73.1 d	35.5 e
09107BB-01	MN	478.9 bc	373.4 bc	21.8 e	395.2 de	59.7 ef	19.6 f
09152BW-01	MN	518.3 b	434.5 ab	43.2 cde	477.7 bc	83.2 abcd	60.7 ab
Significance		**	**	**	**	**	**
LSD (0.1)		58.1	72.4	24.1	70.6	12.9	13.8

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

Table 6. Genotype effect on potato tuber quality in 2013.

Genotype	State of Origin	Hollow Heart (%)	Brown Center (%)	Disqualified (%)	Vascular Discoloration (%)	Heat Necrosis (%)	Specific Gravity	Tuber Dry Matter (%)	Length/Width
AF3001-6	ME	10.0 fg	5.0 f	2.5 hi	0.0	0.0 b	1.0778 bc	19.78 f	1.88 b
AF4296-3	ME	12.5 fg	7.5 f	5.0 hi	0.0	0.0 b	1.0788 bc	21.02 de	2.04 a
AF4342-3	ME	60.0 d	40.0 cd	42.5 de	0.0	0.0 b	1.0780 bc	22.57 b	1.58 h
AC00395-2RU	CO	87.5 ab	87.5 a	77.5 b	7.5	0.0 b	1.0815 b	22.79 ab	1.41 i
AC99375-1RU	CO	62.5 cd	55.0 bc	52.5 cd	2.5	0.0 b	1.0756 bcd	20.11 ef	1.68 efg
A0012-5	ID	95.0 a	92.5 a	92.5 a	0.0	0.0 b	1.0308 e	21.11 d	1.67 fgh
A0073-2	ID	0.0 g	2.5 f	0.0 i	5.0	5.0 a	1.0827 ab	21.30 d	1.76 cdef
A02138-2	ID	2.5 g	5.0 f	0.0 i	10.0	2.5 ab	1.0847 ab	21.30 d	1.79 bcd
A02507-2LB	ID	7.5 fg	2.5 f	2.5 hi	17.5	0.0 b	1.0821 b	22.28 bc	1.80 bc
A03921-2	ID	17.5 f	17.5 ef	15.0 gh	17.5	0.0 b	1.0921a	23.66 a	1.78 bcde
W6234-4RUS	WI	10.0 fg	10.0 f	7.5 hi	0.0	5.0 a	1.0695 cd	19.81 f	1.74 cdefg
W8152-1RUS	WI	75.0 bc	62.5 b	65.0 bc	0.0	0.0 b	1.0678 d	21.09 d	1.64 gh
AO00057-2	OR	5.0 fg	0.0 f	0.0 i	2.5	5.0 a	1.0692 cd	20.94 de	1.81 bc
AO01114-4	OR	42.5 e	30.0 ef	30.0 ef	0.0	2.5 ab	1.0830 ab	22.71 ab	1.69 defg
Russet Burbank	--	50 de	45.0 bcd	25.0 fg	7.5	0.0 b	1.0779 bc	21.40 cd	1.81 bc
Significance		**	**	**	NS	++	**	**	**
LSD (0.1)		12.6	18.4	14.5	--	3.7	0.0098	0.97	0.1

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

Table 7. Genotype effect on potato tuber quality in 2014.

Genotype	State of Origin	Hollow Heart (%)	Brown Center (%)	Vascular Discoloration	Heat Necrosis (%)	Specific Gravity	Tuber Dry Matter (%)	Length/Width
Russet Burbank	--	30. 0 b	25.0 b	0	0	1.0796 d	20.39 d	2.13 a
A02424-83LB	ID	10.0 cd	10.0 bc	0	0	1.0919 ab	21.87 bc	2.01 abc
A02507-2LB	ID	0 d	0 c	0	0	1.0931 ab	23.20 a	1.84 de
A03158-2TE	ID	0 d	0 c	0	0	1.0800 d	21.05 cd	2.06 ab
A06084-1TE	ID	5.0 cd	5.0 c	0	0	1.0890 bc	22.69 ab	2.13 a
AF3001-6	ME	2.5 cd	0 c	0	5.3	1.0843 cd	20.95 cd	2.00 abc
AF4296-3	ME	2.5 cd	2.5 c	0	0	1.0802 d	20.46 d	2.08 ab
AF4342-3	ME	20.0 bc	12.5 bc	0	2.5	1.0967 a	23.20 a	1.68 f
Dakota Russet	ND	2.5 cd	2.5 c	0	0	1.0843 cd	20.39 d	1.91 cde
W8152-1RUS	WI	56.5 a	56.4 a	0	0	1.0684 e	20.70 d	1.79 ef
09107BB-01	MN	0 d	0 c	0	2.5	1.0714 e	19.04 e	1.97 bcd
09152BW-01	MN	17.5 bcd	7.5 c	0	2.5	1.0801 d	20.01 de	1.69 f
Significance		**	**	NS	NS	**	**	**
LSD (0.1)		17.7	15.5			0.0063	1.17	0.14

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

Table 8 Genotype effect on tuber sugar content in 2013

Genotype	State of Origin	Whole tuber Sugar (mg/g)	
		Glucose	Sucrose
Russet Burbank	--	0.86 bc	1.25 def
AF3001-6	ME	0.07 g	0.68 h
AF4296-3	ME	0.11 fg	1.07 efg
AF4342-3	ME	0.57 d	1.73 c
AC00395-2RU	CO	0.98 b	2.46 a
AC99375-1RU	CO	0.25 ef	0.82 gh
A0012-5	ID	0.55 d	2.45 a
A0073-2	ID	0.81 c	1.16 ef
A02138-2	ID	0.12 fg	1.10 efg
A02507-2LB	ID	0.14 fg	1.70 c
A03921-2	ID	0.15 fg	1.12 efg
W6234-4RUS	WI	0.17 efg	2.10 b
W8152-1RUS	WI	0.06 g	0.98 fgh
AO00057-2	OR	0.32 e	1.54 cd
AO01114-4	OR	1.18 a	1.30 de
Significance		**	**
LSD (0.1)		0.15	0.31

Table 9 Genotype effect on tuber sugar content in 2014

Genotype	State of Origin	Stem (mg/g)		Bud (mg/g)	
		Sucrose	Glucose	Sucrose	Glucose
Russet Burbank	--	0.55 e	2.33 a	1.20 abc	0.77 ab
A02424-83LB	ID	1.10 bc	1.10 cde	1.37 a	0.43 cd
A02507-2LB	ID	1.00 cd	0.55 efg	1.06 bcd	0.08 e
A03158-2TE	ID	0.68 de	1.59 bc	1.12 abcd	0.84 ab
A06084-1TE	ID	1.12 bc	0.69 defg	1.09 abcd	0.24 de
AF3001-6	ME	1.64 a	0.91 def	1.02 bcd	0.10 de
AF4296-3	ME	0.98 cd	1.20 cd	0.89 cd	0.69 bc
AF4342-3	ME	1.36 ab	2.10 ab	1.26 ab	0.65 bc
Dakota Russet	ND	0.98 cd	0.42 fg	0.87 d	0.13 de
W8152-1RUS	WI	0.91 cd	0.22 g	0.83 d	0.06 e
09107BB-01	MN	0.87 cde	0.95 cdef	1.04 bcd	0.08 e
09152BW-01	MN	1.52 a	2.41 a	1.32 ab	1.04 a
Significance		**	**	++	**
LSD (0.1)		0.35	0.64	**0.3**	**0.34**

<u>Weed Control and Russet Burbank Potato Response from New and Standard Herbicides</u>. Harlene Hatterman-Valenti and Collin Auwarter.

Field research was conducted in 2014 at the Oakes irrigation research site south of the town of Oakes, ND to evaluate different rates of F9312-3 alone and tank mixed with Sencor and Matrix. We also looked at F9314-3 at two rates and F9350-1 compared to standard grower recommended herbicide applications. Russet Burbank potato seed pieces (2 oz) were planted on May 16 with 36" rows and 12" spacing using a Harriston Double Row planter. On June 2, we hilled and sprayed treatments with a CO2 backpack sprayer at 40 psi using 8002 flat fan nozzles and 20 gpa. Potatoes were harvested on September 19 and graded December 10.

Trt		Rate	---Tuber Counts in 20'---											
Name	Rate	Unit	---<4 oz---		---4-6 oz---		---6-12 oz---		--->12 oz---		---Total---		--->4 oz---	
F9312-3	0.122	lb ai/a	82.0	a	47.5	a	51.8	a	8.8	a	190.0	a	108.0	a
F9312-3	0.144	lb ai/a	69.5	a	49.0	a	55.5	a	9.3	a	183.3	a	113.8	a
F9312-3	0.191	lb ai/a	72.0	a	44.5	a	60.5	a	12.0	a	189.0	a	117.0	a
F9312-3	0.29	lb ai/a	83.0	a	52.8	a	48.8	a	7.5	a	192.0	a	109.0	a
F9312-3	0.122	lb ai/a	72.3	a	43.8	a	63.8	a	11.5	a	191.3	a	119.0	a
Sencor 75DF	0.375	lb ai/a												
F9312-3	0.144	lb ai/a	77.5	a	44.5	a	55.5	a	10.3	a	187.8	a	110.3	a
Sencor 75DF	0.375	lb ai/a												
F9312-3	0.122	lb ai/a	98.8	a	56.3	a	58.3	a	6.0	a	219.3	a	120.5	a
Matrix	0.016	lb ai/a												
F9314-3	0.2	lb ai/a	75.5	a	41.0	a	58.8	a	11.5	a	186.8	a	111.3	a
F9314-3	0.258	lb ai/a	89.0	a	42.3	a	54.5	a	10.5	a	196.3	a	107.3	a
F9350-1	2.7	oz/a	86.0	a	42.8	a	55.5	a	10.0	a	194.3	a	108.3	a
Sencor 75DF	0.375	lb ai/a	83.3	a	49.8	a	64.8	a	7.5	a	205.3	a	122.0	a
Boundary	2.68	lb ai/a	101.3	a	55.8	a	51.3	a	6.5	a	214.8	a	113.5	a
Matrix	0.016	lb ai/a	82.5	a	50.0	a	63.0	a	5.5	a	201.0	a	118.5	a
Fierce	0.166	lb ai/a	79.3	a	37.8	a	44.5	a	12.5	a	174.0	a	94.8	a
		LSD (P=.05)	32.41		14.25		13.18		5.64		32.68		17.04	

Trt Name	Rate	Rate Unit	Row A CWT/a		---Row B CWT/a---											
					---<4 oz---		---4-6 oz---		---6-12 oz---		--->12 oz---		---Total---		--->4 oz---	
F9312-3	0.122	lb ai/a	534.0	a	84.9	a	107.8	a	189.5	a	59.3	a	441.4	a	356.6	a
F9312-3	0.144	lb ai/a	560.5	a	71.9	a	112.4	a	204.6	a	61.2	a	450.1	a	378.1	a
F9312-3	0.191	lb ai/a	519.5	a	67.0	a	101.2	a	229.3	a	83.2	a	480.8	a	413.7	a
F9312-3	0.29	lb ai/a	547.9	a	90.1	a	118.3	a	183.6	a	51.7	a	443.8	a	353.7	a
F9312-3 +	0.122	lb ai/a	561.8	a	72.5	a	101.4	a	241.9	a	82.2	a	498.0	a	425.5	a
Sencor 75DF	0.375	lb ai/a														
F9312-3 +	0.144	lb ai/a	538.8	a	74.4	a	101.4	a	205.8	a	65.9	a	447.4	a	373.0	a
Sencor 75DF	0.375	lb ai/a														
F9312-3 +	0.122	lb ai/a	574.8	a	101.0	a	127.2	a	214.8	a	38.5	a	481.6	a	380.5	a
Matrix	0.016	lb ai/a														
F9314-3	0.2	lb ai/a	596.4	a	76.5	a	91.6	a	222.4	a	72.0	a	462.5	a	386.0	a
F9314-3	0.258	lb ai/a	589.9	a	89.2	a	96.6	a	202.0	a	73.4	a	461.2	a	372.0	a
F9350-1	2.7	oz/a	530.6	a	88.7	a	97.9	a	211.1	a	66.8	a	464.5	a	375.8	a
Sencor 75DF	0.375	lb ai/a	554.3	a	83.4	a	112.1	a	238.5	a	54.2	a	488.2	a	404.8	a
Boundary	2.68	lb ai/a	551.8	a	106.2	a	123.4	a	190.2	a	43.4	a	463.2	a	357.0	a
Matrix	0.016	lb ai/a	560.9	a	82.9	a	115.1	a	232.2	a	37.8	a	467.9	a	385.0	a
Fierce	0.166	lb ai/a	482.8	a	84.4	a	84.4	a	163.8	a	80.2	a	412.8	a	328.4	a
		LSD (P=.05)	82.49		32.63		32.64		51.89		38.12		55.62		67.40	

All treatments had sufficient weed control. Increasing the rate of F9312-3 or tank mixed with metribuzin or rimsulfuron did not show any benefits for controlling redroot pigweed, common lambsquarter, nightshade (hairy and eastern black) and foxtail (green and yellow) 17 and 36 DAA. Weed average counts in border rows that were not sprayed in one square foot were 8 redroot pigweed, 10 common lambsquarter, 2 foxtail, and 1 nightshade. No potato injury was observed.

Potato yields were not affected by any of the treatments. Yields varied from 413 to 575 cwt/A with the lowest in both the A and B rows when Fierce was applied at 0.17 lb/A with 483 and 413 cwt/A, respectively. F9312-3 tank mixed with Matrix had the highest yield in row A with 575 cwt/a. Stand counts 9 DAE showed row A had a slightly higher stand than row B. Row B’s highest yielding treatment was F-9312-3 (0.122 lb ai/A) tank mixed with Sencor with a yield of 498 cwt/A.

West Central Starter Fertilizer on Irrigated Russet Burbank Potato. Harlene Hatterman-Valenti and Collin Auwarter. Field research was conducted at the Northern Plains Potato Growers Association irrigation research site near Inkster, ND to evaluate WC 041 and different rates of WC 139 fertilizer in comparison to standard grower recommended fertilizer applications. Soil tests at 0-6” showed 5#N, 12 ppm P (medium) and 75 ppm K (high). On May 30, furrows were made with a Harriston Double Row planter and treatments were applied to both furrow sides and adjacent to where the seed pieces were to be placed. Rain (1.08”) delayed planting until June 3 when the seed pieces (2 oz) were spaced at 12” intervals in 36” rows. Prior to planting, the field received 61#N, 200#K, 30#S and 2#B. On June 16, 70#N was applied just before hilling. Potatoes were harvested October 7 and graded December 9.

Treatments:

		5/30	5/30	5/30	5/30	6/16
Treatment	**PPI**	**10-34-0**	**28% UAN**	**WC 139**	**WC 041**	**46-0-0**
1	61#N,200#K,30#S,2#B		35#N			70#N
2	61#N,200#K,30#S,2#B	31#N,107#P		2#N,4#P,0.6#K		70#N
3	61#N,200#K,30#S,2#B	29#N,99#P		3#N,6#P,1#K		70#N
4	61#N,200#K,30#S,2#B	23#N,79#P		6#N,12#P,2#K		70#N
5	61#N,200#K,30#S,2#B	35#N,119#P				70#N
6	61#N,200#K,30#S,2#B		35#N		1#/A	70#N

Yield Data:

Trt	Stand Count 20’		CWT/A	----------B Row Tuber Counts in 20’----------					
No.	A Row	B Row	A Row	<4oz	4-6oz	6-12oz	>12oz	Total	>4oz
1	15a	17a	344a	69a	43a	60a	10a	181a	112a
2	17a	18a	351a	83a	47a	56a	10a	195a	112a
3	16a	18a	411a	99a	51a	59a	8a	216a	117a
4	16a	17a	414a	73a	46a	52a	11a	180a	108a
5	17a	17a	404a	94a	51a	57a	12a	214a	120a
6	17a	16a	356a	79a	44a	58a	12a	193a	114a
LSD (P=.05)	3.50	1.78	79.80	30.10	19.75	13.82	6.10	57.14	32.99

Trt	-------------------------B Row CWT/A-------------------------				
No.	<4oz	4-6oz	6-12oz	>12oz	Total	>4oz
1	72a	97a	225a	65a	460a	388a
2	89a	106a	208a	63a	467a	378a
3	104a	115a	212a	53a	484a	380a
4	80a	104a	192a	73a	449a	369a
5	99a	118a	207a	85a	508a	410a
6	81a	99a	216a	83a	480	398a
LSD (P=.05)	31.18	45.47	49.87	39.93	117	99.17

With only six treatments and four replications, significance between treatments at the 95% confidence level was not expected. Even though two rows were harvested, one row (Row A) was weighed in the field and the other row (Row B) bagged for grade and yield. The highest yielding treatment in Row A was treatment 4, which had the highest amount of WC 139 with 414 cwt/a. However, in Row B, treatment 4 had the lowest total yield with 449 cwt/a. The lowest yield in Row A was treatment 1 with

344 cwt/a, which had the second lowest yield in Row B with 460 cwt/a. Although treatments 1 and 6 did not receive any phosphorus at planting, they did not have the lowest marketable yields.

Grading showed that treatments 3 and 5 had the greatest amounts of unmarketable tubers (< 4 oz) and small tubers (4-6 oz), which are undesirable for processing into French fries. Processors want 6-12 oz tubers and often pay a premium for this category. Treatments 1 and 6 had the greatest tuber yield in the 6-12 oz category.

West Central Starter Fertilizer on Red Norland Potatoes. Harlene Hatterman-Valenti and Collin Auwarter. Field research was conducted at the Northern Plains Potato Growers Association non-irrigation site near Grand Forks, ND to evaluate WC 041 and different rates of WC 139 fertilizer in comparison to standard grower recommended fertilizer applications. Soil tests at 0-12" showed 40#N, 8 ppm P, which is low/medium in the NDSU Extension Service 'Growing Irrigated Potatoes' publication and 75 ppm K (low). On June 9, seed furrows were made with a Harriston Double Row planter and treatments applied to both furrow sides at a depth parallel to where the seed piece would drop. Red Norland seed pieces (2 oz) were planted on 12" intervals with 36" row spacing. On July 5, 75#N and 100#K was applied to all treatments followed by hilling and herbicide application. Potatoes were 100% emerged by July 17 and no differences among treatments were observed for stand counts. On August 11, during the early tuber bulking stage, plants in treatments 1 and 7 were 100% flowering while plants in all other treatments were 50% flowering; no other differences were observed.

Treatments:

	6/9	6/9	6/9	6/9	7/5	7/5
Trt	**28% UAN**	**10-34-0**	**WC139**	**WC041**	**46-0-0**	**0-0-62**
1	35#N				75#N	100#K
2		31#N,107#P	2#N,4#P,0.6#K		75#N	100#K
3		29#N,99#P	3#N,6#P,1#K		75#N	100#K
4		23#N,79#P	6#N,12#P,2#K		75#N	100#K
5		35#N,119#P			75#N	100#K
6	35#N			1#/A	75#N	100#K
7	Ss1	`			75#N	100#K

Row A Data:

Trt	Count	----------Tuber Counts in 20'----------						-------------------------CWT/A-------------------------					
No.	20'	<4oz	4-6oz	6-10oz	>10oz	Total	>4oz	<4oz	4-6oz	6-10oz	>10oz	Total	>4oz
1	19a	45a	38a	15a	18a	116a	71a	44a	106a	52a	109a	312a	268a
2	19a	46a	42a	16a	23a	128a	82a	43a	117a	59a	139a	358a	315a
3	19a	54a	40a	17a	24a	135a	81a	51a	110a	60a	147a	368a	317a
4	19a	47a	42a	19a	26a	134a	87a	44a	124a	66a	149a	383a	338a
5	19a	47a	38a	19a	28a	131a	84a	49a	111a	67a	171a	398a	349a
6	19a	52a	44a	17a	22a	135a	83a	51a	123a	62a	130a	366a	315a
7	19a	52a	41a	14a	23a	130a	79a	53a	109a	52a	139a	353a	301a
LSD (P=.05)	1.42	11.33	9.30	4.84	11.66	17.97	15.76	11.81	23.35	16.48	70.45	78.55	81.75

Row B Data:

Trt	Count	----------Tuber Counts in 20'----------						-------------------------CWT/A-------------------------					
No.	20'	<4oz	4-6oz	6-10oz	>10oz	Total	>4oz	<4oz	4-6oz	6-10oz	>10oz	Total	>4oz
1	20a	54a	42a	17a	21b	134a	80a	54a	117a	61a	125a	358a	304a
2	20a	55a	44a	18a	27ab	143a	88a	54a	124a	62a	160a	401a	345a
3	18a	49a	46a	20a	22b	136a	86a	48a	130a	70a	126a	373a	326a
4	19a	43a	41a	17a	36a	137a	93a	44a	114a	58a	216a	433a	389a
5	19a	56a	40a	15a	29ab	139a	83a	54a	111a	54a	171a	391a	337a
6	19a	49a	43a	18a	25ab	135a	86a	49a	123a	63a	142a	377a	328a
7	20a	46a	40a	17a	28ab	130a	85a	41a	116a	61a	167a	385a	344a
LSD (P=.05)	1.19	13.71	10.89	4.34	9.54	19.41	15.62	13.56	27.00	15.49	60.24	55.60	57.71

Yields varied but were not significantly different. Row A showed that increasing the rate of WC139 and decreasing the rate of 10-34-0 (treatments 2-4) resulted in greater yields; 358, 368, 383 cwt/a, respectively. However, treatment 5 had the highest yield with 398 cwt/a. The lowest yielding treatment was treatment 1 with 312 cwt/a. The WC041 (treatment 6) had a yield of 366 cwt/a.

The B row had treatment 4 as the highest yielding treatment with 433 cwt/a. The second highest yielding treatment was treatment 2 followed by treatment 5 with 401 and 390 cwt/a, respectively. The WC041 treatment had a yield of 377 cwt/a.

Grading showed that treatment 5 had the greatest amount of large tubers (>10 oz), which accounted for almost half of its marketable yield. For the fresh market, these large tubers are generally not desirable. Treatments 4 and 5 had the greatest amount of 6-10 oz tubers, while treatments 4 and 6 had the greatest amount of 4-6 oz tubers.