CMCDC

2016 POTATO REPORT

Canada

MHPEC Inc.

Manitoba

Contents

2016 Field Season Review

The 2016 growing season was another busy one at CMCDC-Carberry. The Carberry Offsite was fully allocated to potato research in 2016, with projects ranging from water stress testing, a Variable Rate Irrigation (VRI) trial and a seed physiological age management study. The research field at Carberry Main Site was also full, with both Diversification and Potato/Environment projects present.

Carberry was fortunate, and avoided much of the challenging weather encountered in 2016 in other areas of the province. We began planting potato trials on April 29, and had planted the majority of the trials by May 12 (excepting some late planting treatments). The wet fall of 2016 created some challenges in getting all our fall soil testing completed, and highlighted the benefits of soil sampling directly after harvest. Our potato harvest was wrapped up on September 20, but with the range of crops in our research programs, our harvest season stretched into early November.

As with other years, we had numerous Centre visits and tours with outside groups and individuals. The annual CMCDC Field Day was held August 9, with almost 70 participants and attendees from industry and government research and extension programs. We thank everyone who came out for the day, and those that stopped by at other times to visit and see what we have on the go! Other visits and tours included:

Seed Potato Marketers Association – lunch stop

Drs. Helen Tai & Claudia Goyer, with MHPEC & cooperating producers from AIP project

Assiniboine Community College Fall Tour – lunch stop

Assistant Deputy Minister (Dr. Brian Grey), AAFC, Science & Technology Branch

Director General (Dr. Javier Gracia-Garza), AAFC, Science & Technology Branch

A number of MHPEC-led potato projects were in the field this summer. A study looking at Water Use/Stress in Russet Burbank potatoes on the light-textured soil was completed jointly with Gaia Consulting at Carberry (*page 11*). This was the third and final year of the study, which is designed to determine optimal irrigation water requirements for high quality tuber yields. The Winkler Verticillium project (field work by Gaia Consulting) had a fall 2016 application of the Verticillium control treatments: fumigation and compost application (*page 16*). In 2017, the plot of land for this project will be planted to potatoes, and the three management treatments will be compared for soil Verticillium levels, early dying expression and yield: compost, fumigation and a no-treatment control strip. The Seed Physiological Age Trial had its first test plots in 2016 (*page 17*). Early generation seed was grown in 2015, with various agronomic treatments imposed on the seed crop. The seed from 2015 was grown out in test plots in 2016, and observations made on the performance of the various seed crop treatments collected (emergence, stem numbers, yield and quality). Some interesting results from this first season of testing are emerging from this study.

A national AAFC Agri-Innovation Project (AIP) “Securing Export Markets for Potato Processors by Mitigating Limitations to On-Farm Yield” had its first full growing season in 2016. This project has activities in Manitoba related to:

(1) Verticillium and Potato Early Dying Management (*page 23*)
(2) Variable Rate Irrigation (*pages 26; page 33*)
(3) Heat Stress (*page 36*)

The project involves large amounts of coordination with the University of Manitoba, CMCDC and AAFC researchers, with Dr. Mario Tenuta as the lead researcher on some of the activities in Manitoba. The Verticillium sub-project involves fumigation treatments applied in replicated strips to production fields and then tracking the impact of the fumigation on the Verticillium population, as well as the disease incidence in potatoes following application. The fumigated fields are also being sampled for potato plant gene expression and tracking the impact of fumigation on the entire soil microbial community over time. Fumigation treatments were applied in the fall 2015. Work with VRI includes: exploring new field mapping technologies for their applicability for creating a VRI prescription, as well as testing the performance of VRI vs. uniform irrigation across areas of variability. The third sub-project in this group is testing the impact of heat stress on potato yield and quality. Activities started in 2016, with three different heat chamber prototypes tested in potato plots or on bare ground. As we anticipate having to contend with more extreme weather events going into the future, this trial is designed to understand the impact of periods of heat stress on potato growth, yield and quality. The challenge this year was to design a chamber that can induce slightly warmer canopy conditions than ambient, while not compromising disease control within the chamber

CMCDC was happy to support the provincial GF2 Potato Field Variability Project throughout the 2016 field season, providing a base to work from for field operations, as well as equipment and sampling support. It was great to be a part of this large co-operative project, which highlights the close-knit potato production community in Manitoba.

On the staffing front, I am very pleased to announce that Lindsey Andronak was hired as the AAFC research technician at CMCDC-Carberry, supporting the potato and irrigation program. She started in January 2017, and we are happy to welcome her to the CMCDC team!

We are looking forward to another full growing season, with a number of ongoing potato and environment research projects slated for 2017.

Alison Nelson, Ph.D., Agronomist, CMCDC

Overview of the Canada-Manitoba Crop Diversification Centre

Carberry Site

The Manitoba Crop Diversification Centre (MCDC) was established in 1993 under a ten-year agreement among the Government of Canada, Government of Manitoba, and the Manitoba Horticulture Productivity Enhancement Centre Inc. (MHPEC). Subsequent agreements have continued operations of the Centre under the Canada-Manitoba Crop Diversification Centre (CMCDC).

CMCDC's mission is to facilitate the development and adoption of science-based solutions for agricultural crop production, with a focus on water management, crop diversification and environmental stewardship. Its program and outcome areas are broadly classified as:

- Partnerships and communication
- Water supply and irrigation
- Potato industry support (applied research and technology transfer)
- Environment
- Crop diversification

Canada's support is provided through the Science and Technology Branch (STB) of Agriculture and Agri-Food Canada (AAFC). At the Carberry site, presently, this includes four full-time and one seasonal staff position, summer students, support for operating costs, infrastructure support and services.

Manitoba's commitment is through Manitoba Agriculture, which provides one staff position, one staff-equivalent in part-time support from other MAFRI provincial specialists (technology transfer) and an annual contribution toward project costs.

MHPEC Inc. is a consortium formed by the two Manitoba French-fry processors (Simplot Canada [II] Ltd. and McCain Foods [Canada] Ltd.), and Keystone Potato Producers Association (the processing potato growers' association). The MHPEC members support MHPEC through direct cash contributions, which are expended in support of the CMCDC program for supplies, staff (including seasonal, summer students and casual labour) and services.

All partners in CMCDC actively participate in the Centre management and program advisory committees.

The CMCDC site at Carberry is located at the junction of Highways #1 and #5 on a half-section (130 ha) of loam-clay loam soil, approx. 70 ha of which is irrigated. Co-location of Manitoba Agriculture's Carberry Growing Opportunities Center and Manitoba Conservation and Water Stewardship water licensing staff with CMCDC staff benefits all involved in serving our agricultural clients efficiently. Much of the processing potato activities are conducted at this site and at a nearby sandy off-site. In addition, the Centre is affiliated with three provincial diversification sites in Arborg, Roblin and Melita for purposes of planning and coordinating crop diversification activities.

Most Centre programs and projects are conducted in collaboration with other public or private agencies, including universities, AAFC Science and Technology staff, Manitoba government, private crop protection companies and consultants. Given the on-going challenge of limited resources and the need for enhanced communication among agencies, CMCDC has a unique role to play in the coordination of partnerships to ensure knowledge is discovered, interpreted and communicated effectively to producers and the agricultural industry at large.

Communication of activities and results are conducted through the compilation of an Annual Report released in early spring and a series of field tours and workshops held at each site throughout the summer, also coordinated among the various partners and clients.

CMCDC continues to strive for excellence in fulfilling its mission. The need is greater than ever to deliver high quality research and extension programs efficiently that ensure the following outcomes:

- agricultural productivity is enhanced,
- environmental resources are conserved and protected, and
- producers adopt new management practices that encourage sustainable production

CMCDC-Carberry Sites – Aerial Photos and Trial Locations

CMCDC Carberry Site 2016

1. Long-Term Phosphorus Demonstration
2. Potato Seed Age Treatment Plots (year 1)
3. Potato Extra Test Plot
4. Gaia Potato Variety Trial
5. Soybean Moisture Variety Trial
6. Hemp Variety Trial
7. NR Edible Beans and CN WC Soybean
8. Western Canadian RR Soybeans
9. High Yield Spring Wheat Trial
10. Ducks Unlimited Winter Wheat PRG X Variety Trial
11. Nitrogen in Corn Trial
12. MB Corn Growers Asso. Corn Yield Trial
13. SeCan Barley Demo
14. SeCan Wheat Demo
15. SeCan Oats Demo
16. MB Corn Growers Asso. Early Seeded Corn Nursery
17. MB Corn Growers Asso. Late Seeded Corn Nursery
18. MCVET Winter Wheat Variety Trial
19. MCVET Fall Rye Trial
20. FCC Demo A
21. FCC Demo B
22. Quinoa Variety Trial
23. Annual Forage Trial
24. MB Pulse & Soybean Growers (MPSG) Soybean Inoculum Trial
25. MPSG Soybean Seeding Date Trial
26. MPSG Crop Residue Treatments – Soybean Management
27. Cereal Disease Nursery Plots
28. ICMS Trials
29. U of M Gluten Strength in Wheat
30. AAFC Advanced Forage Barley Evaluation
31. ANNP Buckwheat Management
32. MPSG Crop Residue Establishment

CMCDC Carberry Offsite 2016

(spring 2016 bare soil imagery on eastern portion of field)

1. Moisture Monitoring Potato Plot
2. Potato Seed Age Test Plots (year 2)
3. Potato Water Use/Stress Trial
4. Potato Heat Stress Study
5. Potato Horomone Treatments Trial
6. Gaia Consulting Trials
7. Potato Variable Rate Irrigation vs. Uniform Rate Irrigation Trial
8. Sunflower Cutworm Trial
9. Nitrogen Crop Sequence Trial

Weather at CMCDC-Carberry Site

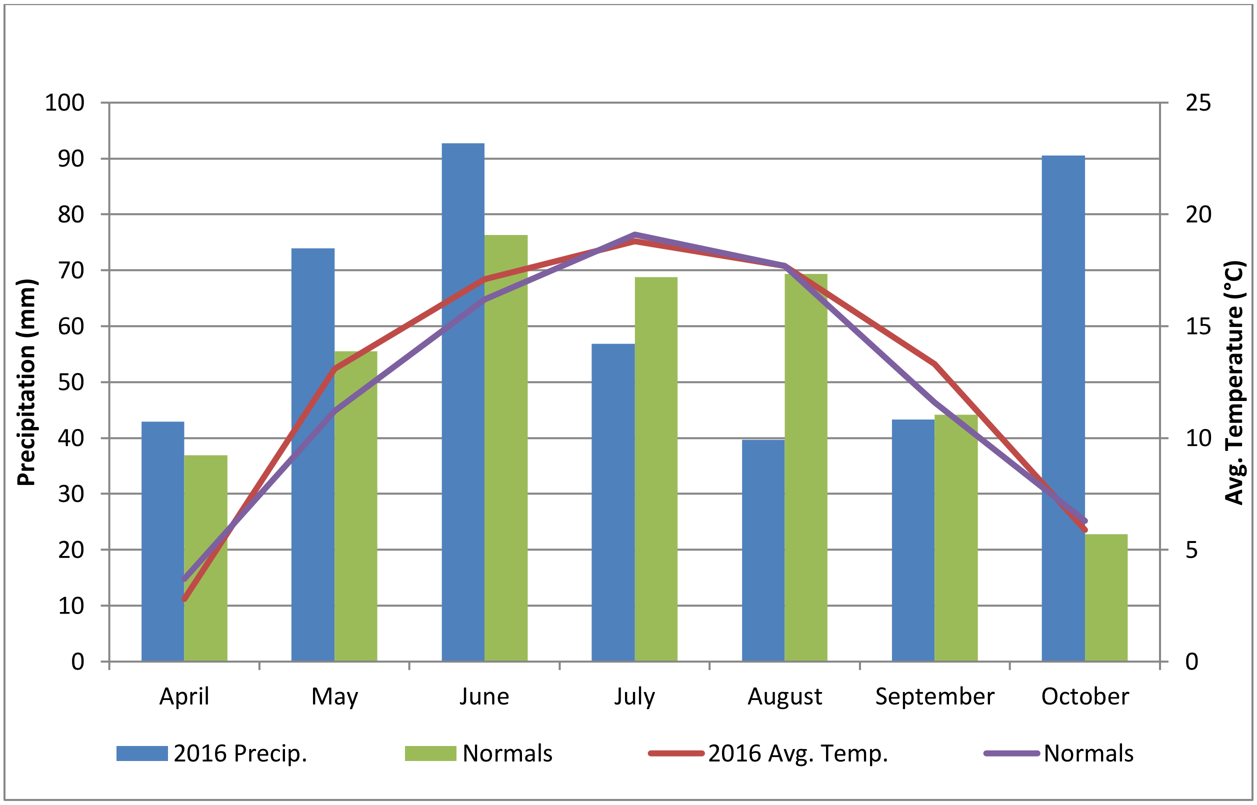

Figure 1. 2016 growing season precipitation and monthly temperatures at CMCDC-Carberry.

Staff at CMCDC Carberry 2016

Full time staff	Supporting CMCDC Partner	Position
Brian Baron	AAFC	Site Supervisor
Craig Linde	Manitoba Agriculture	Diversification Specialist
Alison Nelson	AAFC	Agronomist (Winnipeg)
Sherree Strain	AAFC	Office Administrator

Seasonal/Term staff		
Eric Claeys	AAFC	Field Operations Assistant
Ashley Rosendaal	*AAFC*	*Field Operations Assistant – On Assignment*

Summer students/Casual staff		
Laura Ferguson	AAFC	Summer Research Assistant
Stephanie Hinrichs	AAFC	Summer Research Assistant
Nathan Henderson	AAFC	Summer Research Assistant
Kayla Peters	AAFC	Summer Research Assistant
Mackenzie Shamanski	MHPEC	Summer Research Assistant
Darcy Manns	MHPEC/Manitoba Agriculture	Summer Research Assistant
Beverly Mitchell	MHPEC	Summer Research Assistant
Rylee White	MHPEC	Summer Research Assistant

Water Use Efficiency of Russet Burbank Potatoes on a Light Textured Soil

Principal Investigators: Alison Nelson, AAFC – Carberry
Darin Gibson, Gaia Consulting Ltd. - Winnipeg
Manitoba Potato Research Committee

Support: CMCDC

Progress: Year 3 of 3

Objective: - Identify water requirements for high yield and quality processing potatoes on a light-textured soil

Key 2016 Message: - Irrigation water required to maintain soil plant available water at 60% and 80% was higher than the sum of average crop water demand and growing season precipitation.
- Maintaining soil moisture levels at 80% plant available water demonstrated a consistent trend of improved fry quality, decreasing the incidence of sugar ends.

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Project Report

Introduction

Potatoes are a water-sensitive crop, requiring on average 400-500 mm (approximately 16”-20”) of water throughout the growing season (Tomasiewicz et al. 2003). In Manitoba an average of 250 mm (10”) of precipitation falls during the growing season (Shaykewich et al. 1998). However, total crop demand for water is an aggregation of a large variety of factors and the need for irrigation cannot be summed up by growing season precipitation and average crop water demand. Crop water demand varies over time during the growing season, dependent on conditions such as: crop growth stage, soil texture, crop variety, air and soil temperature. Precipitation does not necessarily fall in a predicable patter each year, nor is all of the growing season precipitation useable by the crop, depending on amounts and timing of various rainfalls. Irrigation to maintain 65-75% plant available soil moisture is recommended (Tomasiewicz et al. 2003).

Water stress during key points of potato crop development can impact yield and quality of processing potatoes. Irrigation is required in Manitoba to ensure stable potato crop yields and quality. Previous studies were conducted in Manitoba to model water use of potatoes (Raddatz et al. 1996; Shaykewich et al. 1998). Field tests of the models were carried out on a clay loam soil, not typical of the majority of the processing potato acres, and have not been revisited in recent years.

The study compares increasing levels of irrigation application on the yield and quality of Russet Burbank potatoes grown on a light-textured soil. Results will demonstrate the water requirements for high yield and quality processing potatoes on light-textured soil typical of the conditions found on the majority of Manitoba's processing potato acres. The study hypotheses are: irrigation water demands are higher than the difference between average crop water demand and growing season precipitation; and that the highest yield and quality processing potatoes will be obtained by maintaining available soil moisture at 80 % plant available water.

Materials and Methods

The study was carried out from 2014-2016 at the CMCDC-Carberry Offsite field. The study was a joint project with Gaia Consulting and CMCDC-Carberry. The location was chosen as a representative site of the light-textured soil types commonly used at present for processing potato acres in Manitoba. Each of the site-years were chosen to have relatively uniform texture in the top 30cm (fine sandy loam texture with 78% sand, 14% silt and 8% clay) across blocks to reduce variability in soil moisture.

The plot design was a randomized complete block design with three replicates.

Treatments included watering potatoes to 80%, 60% and 40% plant available water (PAW). To make irrigation decisions, trigger points for Watermark soil moisture sensors were determined at the start of the project for each of the three water treatments based on generalized soil type. Each plot had Watermark sensors installed at 12" and 24" depths, and average readings (mean and median) across all plots of the same treatment were used to make irrigation decisions. At the start of irrigation, when rooting depth of the potato crop was shallow, the 12" readings only were used in the average soil moisture readings. As potato rooting depths moved into the 24" depths, these readings were used in the averages to help drive irrigation decisions. Decagon Em50 dataloggers with attached soil moisture sensors were installed in all plots at 7.5cm, 22.5cm, 45cm and 75cm depths to continuously measure volumetric water content.

Every two weeks following 50% crop emergence, leaf area index, crop biomass and rooting depth was determined to evaluate in-season crop growth. These crop measures were collected on three adjacent plants in one of two designated sampling rows. Each subsequent sampling date was completed on three new adjacent plants, ensuring that at least one intact plant was present between the previous sampling area to avoid previous sampling impacts.

Two 7m row lengths of each plot were harvested for tuber yield and quality determination according to processing contracts. Tubers were graded into size profiles: <3 oz, 3-6 oz, 6-12 oz (2014 only), 6-10 oz, 10-12 oz, >12 oz. Specific gravity was determined on a 10 lb subsample using the weight in air vs. weight in water method. Grading for internal defects including hollowheart and vascular ring discoloration was conducted on harvest samples. French fry testing was completed using the USDA scale including dark end analysis using the centre strip from ten tubers per plot at harvest, and after 3 and 6 months of storage, respectively.

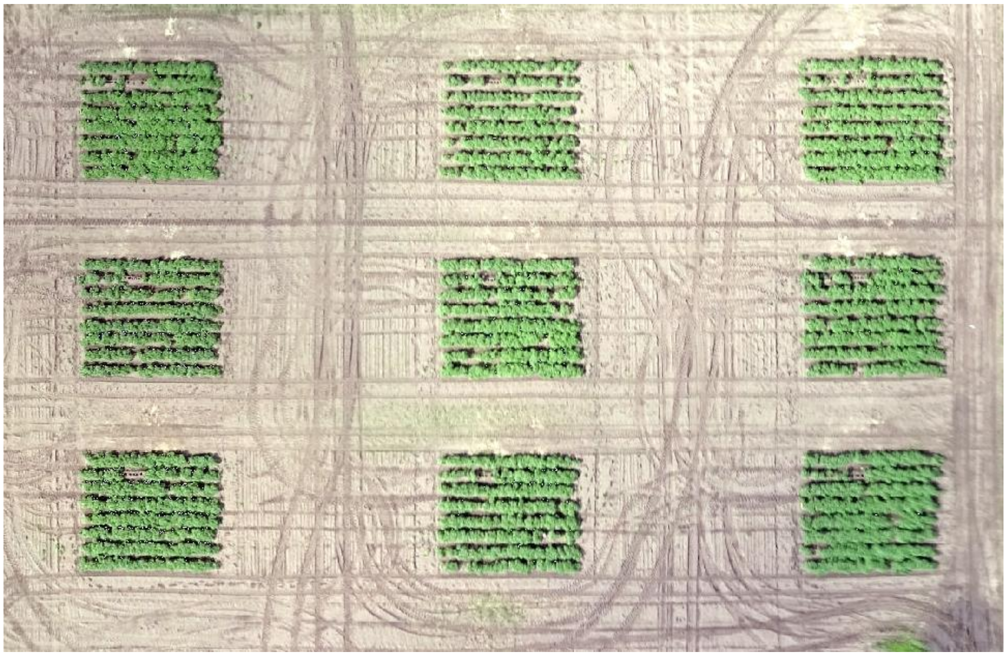

Figure 1. 2016 Water use plots. Large set-backs are required between plots to ensure that water treatments are applied to each treatment accurately. Areas of missing plants are from in-season destructive sampling.

<u>Results and Discussion</u>

In all study years, the irrigation treatments increased in number of applications and total water applied as the treatments increased the maintenance soil moisture from 40% up to 80% PAW (Figure 2). The irrigation treatments closest to the current recommendations (60 and 80% PAW), had higher applied water levels than the estimated sum of modeled crop water demand and growing season precipitation. This supports the hypothesis that total irrigation water requirements are higher than the difference between average crop water demand and growing season precipitation.

In-season crop growth measures are currently being compiled for the three study years, and will be analyzed together.

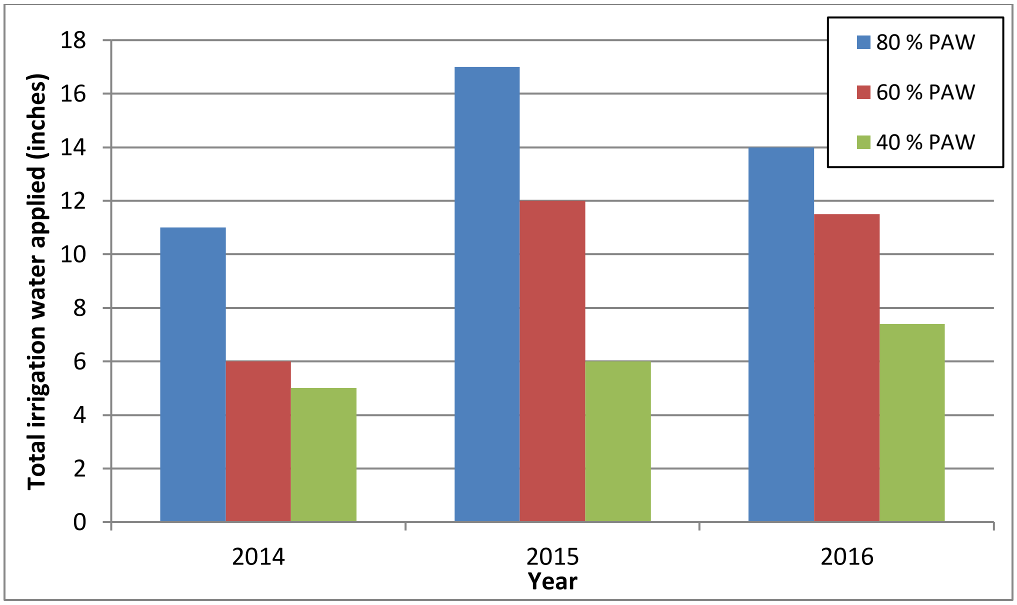

Figure 2. Total irrigation water applied to treatments in each study year.

Yield and tuber quality were assessed in all years of the study. Yields varied significantly between years, but the irrigation treatments did not have a statistically significant impact on yield in any of the three years. The yield data from 2016 are displayed in Table 1.

Table 1. Tuber yield and size profile for water treatments in 2016.

		Yield (cwt/ac)										
Treatment	< 3		3-6 oz		6-10 oz		10-12oz		> 12 oz		Total	
1 80 % PAW	5.5	a	34.5	a	145.6	a	83.4	a	294.4	a	563.5	a
2 60 % PAW	9.1	a	46.7	a	113.2	a	108.1	a	290.5	a	567.6	a
3 40 % PAW	8.9	a	57.0	a	170.3	a	84.1	a	194.0	a	514.3	a
LSD P=.05	ns		ns		ns		ns		ns		ns	
CV	41.9		30.8		25.1		27.5		28.4		7.2	
Treatment Prob(F)	0.4110		0.2661		0.2621		0.4661		0.2787		0.2920	

Fry quality measures, including fry color and sugar ends, varied across years. In 2015 there were high levels of sugar end incidence in all treatments. Despite the high incidence level in 2015, a consistent trend was present in all three years for decreased sugar end incidence with increased irrigation (Figure 3). Statistically significant differences in water treatments were observed in only a select number of years and testing times ($P<0.05$ and $P<0.1$), but the observed trend of more sugar ends with lower irrigation intensity was constant through all years and storage time periods.

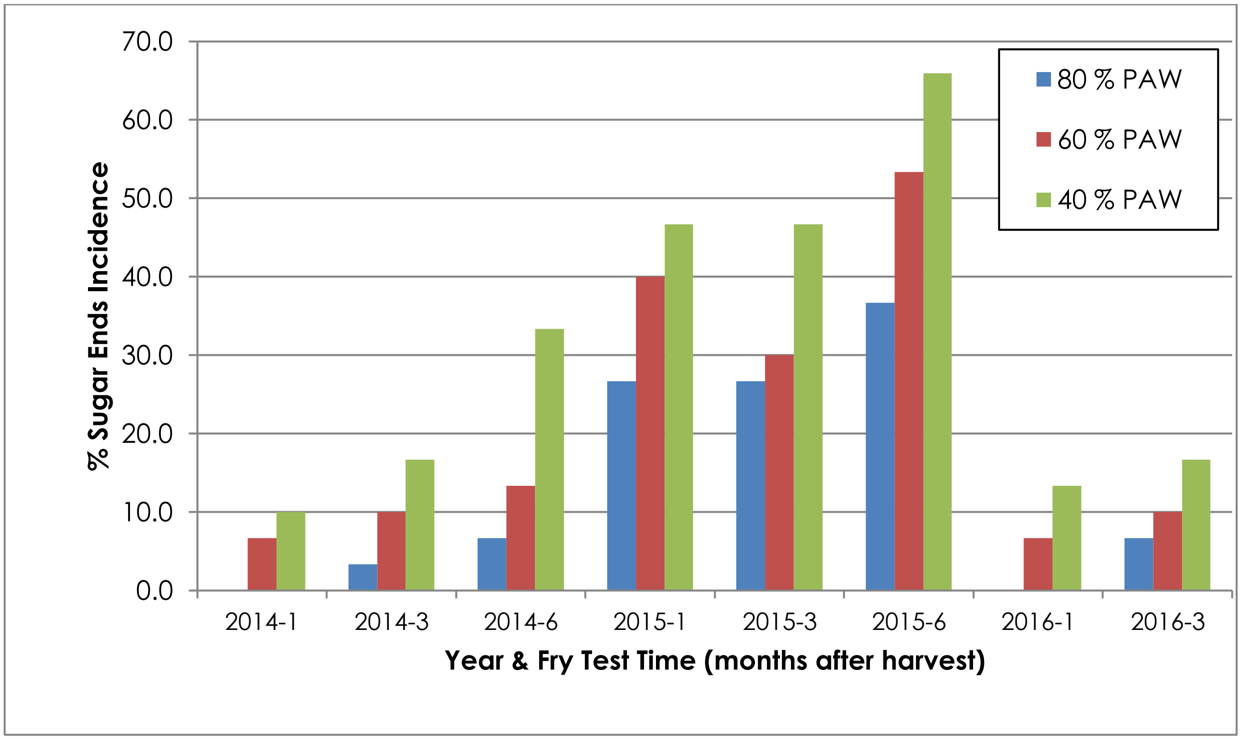

Figure 3. Percent sugar end incidence in tuber samples in the three study years, tested at 1, 3 and 6 months after harvest.

Table 2. Fry color and sugar ends for water treatments in 2016.

		Mean Fry Colour						Sugar End %					
	Treatment	1 Month		3 Month		6 Month		1 Month		3 Month		6 Month	
1	80 % PAW	0.07	a	0.30	a	.	.	0.0	b	6.7	a	.	.
2	60 % PAW	0.13	a	0.17	a	.	.	6.7	ab	10.0	a	.	.
3	40 % PAW	0.07	a	0.17	a	.	.	13.3	a	16.7	a	.	.
LSD P=.05		0.24		0.24				9.3		15.1			
CV		118.59		49.93				61.2		60.0			
Treatment Prob(F)		0.6944		0.3086				0.0400		0.2844			

Potato *Verticillium dahliae* and Potato Early Dying Control Project

Principal Investigators: Darin Gibson, Gaia Consulting - Winnipeg
Alison Nelson, AAFC – Carberry
Manitoba Potato Research Committee
Mario Tenuta, University of Manitoba - Winnipeg

Support: CMCDC

Progress: Year 3 of 4

Objective: - Quantify impact of soil levels and remediation techniques on a native soil population of *Verticillium dahlia*

Key 2016 Message: - The final mitigation treatments were applied in 2016.
- In 2017 the study area will be planted to potatoes, and the impact of mitigation treatments on *V. dahliae* levels, potato early dying incidence and crop yield will be compared with each other and the no-treatment control.

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Project Report

A project at CMCDC-Winkler was designed to help quantify the impact of two separate remediation techniques (compost and fumigation) on a native soil population of *V. dahliae,* the incidence of PED and tuber yield. This demonstration is designed to complement and inform the larger provincial field variability project investigating production-scale site-specific remediation techniques for Potato Early Dying (PED) complex.

In 2014, an approximate 1-acre plot of potatoes was grown to establish the baseline levels of Vert. in the soil, and observe the expression of potato early dying in the plot. The research plot area was selected to encroach into a known zone of soil salinity so observations could be made on the interaction of salinity and *V. dahliae* levels.

In 2015 and 2016, rotational crops of canola and wheat (respectively) were grown, with fall applications of *Verticillium* control applied. The plot was split into three treatment strips:

- one strip receiving two fall applications of compost (one in each of 2015 and 2016),
- one strip receiving a 2016 fumigation application of metam sodium,
- and a third control strip receiving no mitigation treatment.

In 2017, the study area will be planted to potatoes, and the impact of the control treatments on processing potatoes observed.

Seed Physiological Age of Russet Burbank Potatoes

Principal Investigators: Alison Nelson, AAFC – Carberry
Manitoba Potato Research Committee

Support: CMCDC

Progress: Year 2 of 3

Objectives:
- Determine the impact of seeding date, harvest date and soil moisture regime of a potato seed crop, and seed storage regime on physiological seed age and subsequent field performance of a Russet Burbank processing crop.
- Establish base seed performance values and physiological measures for future seed physiological age studies in Manitoba

Key 2016 Message:
- Early seed crop planting date and spring seed warm up sped up processing crop emergence.
- Warming seed for a number of weeks prior to planting did not impact crop yield, but did affect the tuber size profile. The warmed seed produced more tubers sized less than 6 oz. The constant storage temperature had more tubers in the 10-12 and >12 oz categories.

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Project Report

Growing and storage conditions of a potato seed crop are known to affect the seed physiological age, and the performance of the seed in the following production crop. The purpose of this study is to assess the effects and interactions of various potato seed crop management practices on the physiological age and subsequent performance of a processing potato crop.

Treatments are applied to non-replicated seed plots in year 1. The impact of the seed treatments are observed in the randomized, replicated test plots in year 2.

In 2015, non-replicated plots of E3 Russet Burbank seed were planted at CMCDC-Carberry Onsite to obtain all combinations of:

- Early and late planting dates (2 weeks apart)
- Early and late termination and harvest dates (2 weeks apart)
- Irrigated and dryland production
- Constant and ramp-up storage temperature regimes

A total of 16 seed crop treatments were obtained (Table 1) – the treatments are all applied to the seed crop plots (year 1). The seed crop treatment impacts on subsequent (year 2) crop performance were tested in a randomized complete block design trial, at CMCDC-Carberry

Offsite in 2016. The test plots in year 2 are all treated the same to determine the impact of seed crop management on processing crop stand, emergence, yield and quality. A second season of seed crop treatments were also grown in 2016, with the test plots slated for 2017.

Table 1. Treatment listing for the potato seed physiological age trial. All treatments are applied in the seed crop year (year 1), with the test plots (year 2) being treated equally across all plots.

Treatment	Seed Crop Planting	Seed Crop Harvest	Seed Crop Moisture	Seed Storage Temperature
1	Early	Early	Irrigated	Constant
2	Early	Late	Irrigated	Constant
3	Early	Early	Dryland	Constant
4	Early	Late	Dryland	Constant
5	Early	Early	Irrigated	Ramp up
6	Early	Late	Irrigated	Ramp up
7	Early	Early	Dryland	Ramp up
8	Early	Late	Dryland	Ramp up
9	Late	Early	Irrigated	Constant
10	Late	Late	Irrigated	Constant
11	Late	Early	Dryland	Constant
12	Late	Late	Dryland	Constant
13	Late	Early	Irrigated	Ramp up
14	Late	Late	Irrigated	Ramp up
15	Late	Early	Dryland	Ramp up
16	Late	Late	Dryland	Ramp up

2015 Seed Crop Treatments Recap

The year 1 seed plot treatment details are outlined in Table 2. Planting and harvest dates differed by approximately two weeks. The tubers were dug 19 days following vine kill in both cases when field conditions were suitable for harvest. Tubers sized 3-8 oz. were stored for year 2 testing.

Table 2. Details of differences in year 1 seed crop treatment details.

Main Treatment	Treatment Details	
Planting Date	Early - April 30	Late - May 15
Harvest Date	Early - Terminated Aug 13	Late - Terminated Aug 27
Seed Crop Moisture	Irrigated - 6.5" added water	Rainfed
Seed Storage	Ramp up - start Mar 23, held at 10°C from Apr 6-May 5	Warmed starting Apr 28 - May 5

The 2015 seed crop data did show some expected trends in the impact of the agronomic treatments on the seed crop yield and profile. The E3 seed plots that were planted early and harvested late had higher tuber yields and a larger tuber size profile of tubers. Soil temperatures in the dryland versus irrigated plots were not different throughout the growing season, possibly indicating the absence of large differences in in-season seed crop stress between the irrigated and dryland plots. The constant storage treatment had the storage temperatures warmed up in the week before the seed was taken out of storage for cutting, seed treatment and planting. The ramp-up storage treatment was held at 10°C for about four weeks prior to cutting, seed treatment and planting. This was longer than the intended warm holding period. The length of the sprouts on the Ramp Up treatments required all seed pieces to be de-sprouted during handling, cutting and seed treatments. All seed pieces (3-8oz when put into storage) had a single cut made by hand, to make relatively uniform seed pieces with the same cut profile.

<u>2016 Test Plot Results and Discussion</u>

The average percent of emergence for the main factors at various dates after planting are in Table 3. Early seed crop planting and warming the seed before planting in year 2 increased the speed of emergence (Figure 2). Some trends and significant interaction effects were also observed, but these were not consistently strong sources of variation. In some cases, spring seed warming seemed to override the impact of other factors such as a late planting date, with quicker emergence patterns observed. However, one year of data must be interpreted cautiously.

Table 3. The impact of seed crop treatments (year 1) on estimated means of processing (year 2) crop emergence, and stem numbers per plant.

Main Factors	Emergence 23 DAP[t]	Emergence 24 DAP	Emergence 27 DAP	Emergence 29 DAP	Emergence 31 DAP	Stems/Plant
			(%)			(no.)
Planting	**		**	*		
Early	**3.3**	11.8	**72.7**	**87.8**	90.5	3.8
Late	**1.6**	9.3	**62.8**	**82.9**	88.7	3.7
Harvest	*					
Early	**3.1**	11.5	65.8	83.9	89.2	3.8
Late	**1.7**	9.6	69.7	86.8	90.0	3.6
Moisture						
Dryland	2.6	11.5	66.4	84.6	88.5	3.8
Irrigated	2.2	9.6	69.1	86.1	90.6	3.7
Storage		***	*			**
Constant	2.2	**6.3**	**63.4**	84.0	88.4	**3.6**
Ramp up	2.6	**14.8**	**72.1**	86.7	90.8	**3.9**

, **, * indicate a significant effect of the main factor at P<0.1, P<0.05, P<0.01, respectively. Increasing number of stars indicate greater level of statistical significance of the effect. Blank squares indicate that the mean values are not significantly different from one another.*

[t] DAP = Days After Planting

The number of stems per plant was increased with the storage ramp up treatment.

Gross yield out of the field (corrected for dirt), had higher yields from the early planted seed, and a trend of higher yields with late harvested seed (Table 4). Storage regime and seed crop irrigation did not have an effect on gross yields.

When tubers less than three ounces were removed from the yields, there were trends pointing to higher marketable yields from seed that was planted early, and from seed that was irrigated. However, these results were not significant at the P<0.05 level. A second year of study is needed to fully interpret the results.

No significant differences were found in fry quality, defects, or specific gravity. Average fry color was 93% fry color 0, 6% fry color 1, 1% fry color 2, dark ends incidence were 4%. The average percent total defects across the trial were 6.7%. Average specific gravity was 1.098.

Figure 1. Emergence of seed age plots with different spring seed storage temperature regimes. The plot on the left was warmed for approximately a week before planting. The plot on the right was seed that was warmed and held at 10°C for approximately 4 weeks prior to planting. All other treatment factors were the same between these two plots (late seed crop planting date, early seed crop harvest date, and irrigated seed crop).

Table 4. The impact of seed crop treatments (year 1) on estimated means of processing (year 2) crop yields and tuber numbers per acre.

Main Factors	Tuber Number *(#000/ac)*	Gross Yield (no dirt) *(cwt/ac)*	Marketable Yield (no smalls) *(cwt/ac)*
Planting	**	**	*
Early	**155**	**567**	**527**
Late	**145**	**546**	**506**
Harvest	*	*	
Early	**145**	**549**	511
Late	**154**	**565**	522
Moisture			*
Dryland	151	550	**506**
Irrigated	149	564	**527**
Storage	***		
Constant	**139**	551	517
Ramp up	**161**	564	516

, **, * indicate a significant effect of the main factor at P<0.1, P<0.05, P<0.01, respectively. Increasing number of stars indicate greater level of statistical significance of the effect. Blank squares indicate that the mean values are not significantly different from one another.*

While storage regime did not have a significant impact on gross or marketable yield, it did have a significant impact on the tuber size profile (Figure 2). All categories of size profile were impacted by the spring storage regime. The seed held at a constant temperature until a week before planting had more large tubers, in the 10-12 oz and greater than 12 oz categories. The seed that was ramped up and held at 10°C for a number of weeks before planting had more small tubers. The ramp up treatment had 10% more yield in tubers sized less than six oz.

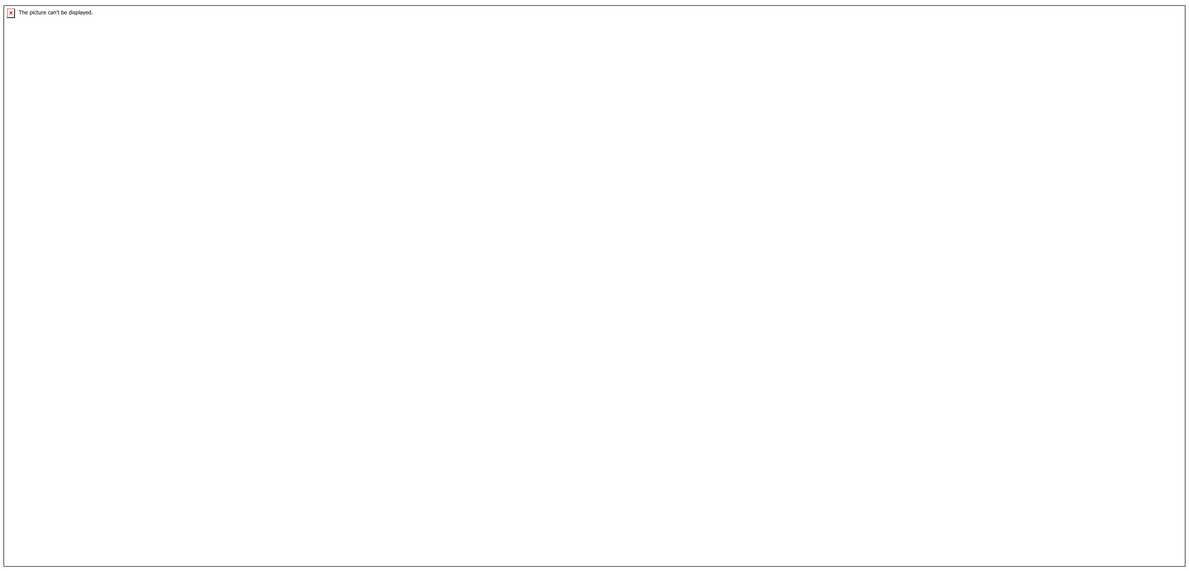

Figure 2. Processing crop (year 2) tuber size profile from the two seed crop storage regimes. The constant treatment had seed warmed a week prior to planting. The ramp up treatment had seed warmed and held at 10°C for approximately 4 weeks prior to planting.

Fumigation as a Mitigation Practice for Potato Early Dying

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Co-Investigators: Alison Nelson, AAFC – Carberry
MHPEC, Inc.

Support: Agri-Innovation Program, AAFC
MHPEC, Inc.

Progress: Year 2 of 3

Objective:
- Assess effects of fumigation on potato productivity and *Verticillium* species on commercial fields
- Develop gene expression indicators for Potato Early Dying disease stress in fumigated and unfumigated treatment strips
- Evaluate changes in diversity of bacterial and fungal microbial communities with fumigation and soil properties over a two-year time period in one commercial field

Key 2016 Message:
- In two of three fields, fall 2015 fumigation significantly decreased the spring 2016 soil levels of *Verticillium* detected by plate counts, and *Verticillium dahliae* detected by PCR assay.
- Fumigation led to a significant yield increase in only one of three production fields.
- The impact of fumigation on soil microbial communities, potato gene expression, and *Verticillium* abundance in stems is also being investigated through laboratory analysis that is ongoing.

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Project Report

Three on-farm fumigation trials were established in the fall of 2015 to assess the effect of soil fumigation with Vapam (Busan), with grower and processor cooperation. All three fields were planted to Russet Burbank potatoes in 2016. Each field trial included replicated treatment strips of a non-fumigated control or fall-applied Vapam at the recommended rate.

In Fields 1 & 3, a commercial applicator was used to apply the fumigation treatments. In Field 2 (the intensively sampled field), a plot-sized applicator was used to apply fumigation strips. Six benchmark positions were established per treatment strip for soil, plant and yield sampling, along with disease assessments. Soil and plant samples were collected to assess *Verticillium dahliae* levels in soil and plants. *Verticillium* soil densities were assessed with plate counting and molecular real time PCR assay on fall 2015 (pre-treatment); and spring and fall 2016 (post-treatment) soil samples. Species identification was done by PCR assay.

Fumigation treatments showed an impact on soil *Verticillium* levels on the spring soil samples in Fields 2 & 3. In Field 2 and 3 the fumigation treatments had significantly less *Verticillium* detected through plate counts than the checks. In Field 2, the fumigated strips also had significantly lower levels of *Verticillium dahliae* and *Verticillium tricorpus* observed using PCR assay. Field 3 also had significantly lower levels of *V. dahlia* under fumigation, but no significant difference in *V. tricorpus* was observed.

Fall 2016 soil samples were collected just prior to harvest in the three fields. No significant differences in plate counts were detected in fall 2016 soil samples. Visual assessments of disease severity were done in late summer in Fields 2 & 3, and both sites showed significant improvement in vascular discoloration ratings and wilt ratings under fumigation.

Spring 2016 soil samples were collected for available extractable N and P, the laboratory analysis will be added to the data analysis later. Potato yield samples were collected to assess tuber yield and quality and crop performance, with 10 foot digs collected before harvest. Only Field 2, with the high *Verticillium* levels, had a significant increase in yield from fumigation (net yields of 458 cwt/ac and 372 cwt/ac for fumigated and non-fumigated, respectively). Fields 1 and 3 did not have significant differences in yield between fumigation and the no-treatment checks.

Field 2 was pre-selected to be used for more detailed study including examination of soil microbial communities, and effects on gene expression analyses. Additionally, plant endophyte populations will be examined at this site. Strong visual treatment effects were present in this field starting in mid-August. Diversity of bacterial and fungal communities will be evaluated using next generation sequencing. The study will evaluate how changes in *Verticillium* induced by soil fumigation (i.e. control vs fumigated strips) influence soil microbial communities, potato gene expression, endophytes and *Verticillium* abundance in stems.

Two commercial fields have been sampled and fumigated as per the project protocol in October 2016, in anticipation of the 2017 growing season.

Figure 1. An image of one of the fumigation treatment fields (August 22, 2016); on the left is a fumigated strip, on the right is a non-fumigated strip.

Remote Sensing Techniques for Field Variability Mapping for Variable Rate Irrigation

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Co-Investigators: Bernie Zebarth, AAFC – Fredericton, NB

Support: Agri-Innovation Program, AAFC
MHPEC, Inc.

Progress: Year 2 of 3

Objectives: - Evaluate the ability and application of soil moisture data collected by an unmanned aerial vehicle (UAV) for variable rate irrigation (VRI)

Key 2016 Message: - Based on data collected from 2016, additional work will be undertaken in 2017 to test field sampling techniques used to validate soil moisture maps generated by the UAV with field data.
- If we can improve the validation of the UAV soil moisture data to field-measured data, then the technology shows potential to be a tool for developing prescription irrigation maps and possibly irrigation scheduling (timing and application rates).

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Project Report

The objective of this study was to evaluate the ability and application of soil moisture data collected by an unmanned aerial vehicle (UAV) for variable rate irrigation (VRI). Year 1 of the study focused on the collection and validation of the UAV collected data. Data was collected at three time periods: early June, mid-July and mid-August. This report discusses the 2016 findings and outlines work for the 2017 season.

<u>UAV Soil Moisture Data</u>
Skaha Remote Sensing was contracted in 2016 to collect soil moisture data on 2 fields in the Carberry, MB area. Skaha uses a radiometer mounted on a UAV (Figure 1) to derive surface soil moisture maps across the entire extent of the study area. The radiometer instrumentation is similar to sensors that are deployed on satellites such as the European Space Agency – Soil Moisture/Ocean Salinity (SMOS) and NASA's Soil Moisture Active/Passive satellites. These satellites are mapping global soil moisture and other variables at a much coarser scale.

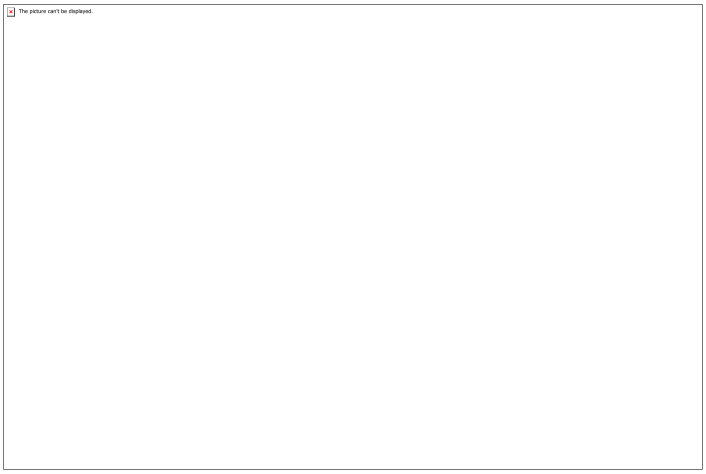

Figure 1. Skaha Remote Sensing's octocopter UAV with radiometer panels.

Radiometers do not measure soil moisture directly; instead, they measure the amount of microwave energy at a prescribed frequency, wavelength, orientation and incidence angle that is emitted from the soil surface. Typically this constitutes the top 5cm of the soil but the sensing depth can be deeper (20cm) if the soil is very dry. A drier soil will have higher microwave emissivity compared to a wetted soil.

Using the Community Microwave Emission Model (CMEM), brightness temperatures (Tb) are calculated from the raw microwave data that is collected by the radiometer and are used as the basis to derive surface soil volumetric water content (VWC) maps (Figure 2). The model allows for different parameters such as vegetation, soil texture, surface roughness and atmospheric contribution to be selected based on the landscape and environmental conditions at the time of acquisition. The CMEM is a forward model that uses soil moisture measurements collected in the field to make adjustments to the model's soil moisture processing algorithm.

An example of soil moisture maps that are produced from the UAV is shown in Figure 2. The field was flown on June 7 and again on June 9. The maps from both dates clearly show a decrease in surface soil moisture values over the field. A precipitation gauge located 4km northeast of the field indicated no precipitation was received between the acquisitions and no irrigation was applied during this time. Overall surface soil moisture levels decreased by 8-10% on the field over 2 days. The only difference was the area on the west side of the field where soil moisture levels were unchanged or slightly above 26-27%.

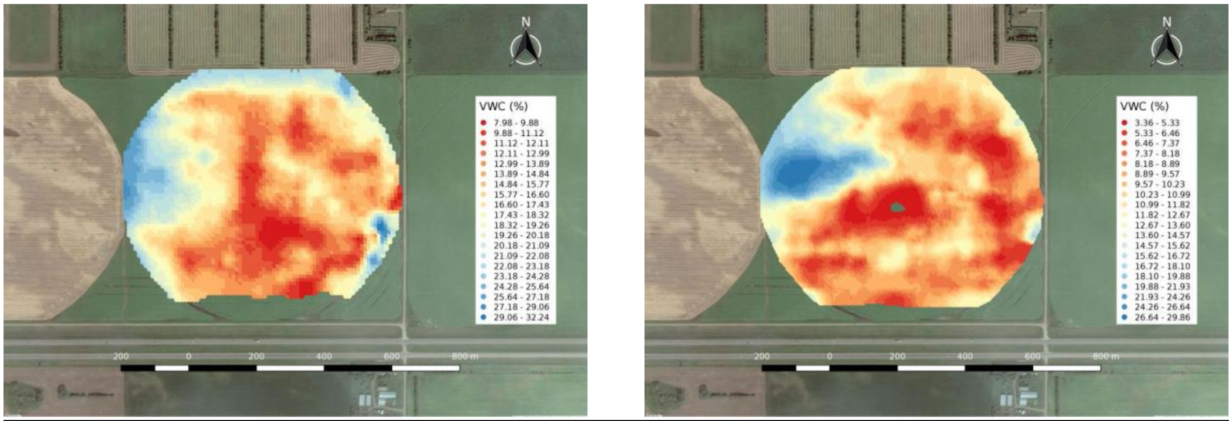

Figure 2. Surface soil moisture maps from the production field on June 7 (left) and June 9 (right).

Sampling Protocol

POGO

Soil moisture measurements were recorded using a Steven's Water Monitoring System Poke and Go (POGO). The POGO measures a number of different properties such as sample time, soil temperature, and raw real dielectric permittivity. Volumetric soil moisture values are calculated from the real dielectric values using a calibration equation that was developed for similar coarse textured soils.

POGO measurements were taken at a set of pre-determined locations. These locations were created in ArcGIS and subsequently loaded into the sampling team`s GPS units. Sample points for the production field ran with the row direction (east-west) as shown in figure 3.
The sampling points for the VRI/URI trial plots were created on-the-fly to ensure that each trial plot was adequately sampled. 2 sampling points within each VRI/URI trial plot were created yielding a total of 16 sample points across the plots. The wheat and canola fields each contained 4 sample points. All sample points are shown in Figure 3.

The sampling team recorded 3 POGO measurements at each sample site. In order to capture the spatial variability of surface soil moisture at a micro-topography level, measurements were recorded at the top of hill; mid-slope; and bottom of the furrow. The team would also record each measurement down on a datasheet. Each POGO measurement was stored using the field and sample site name to provide the ability to link the in-situ measurement to the ground location for validation purposes.

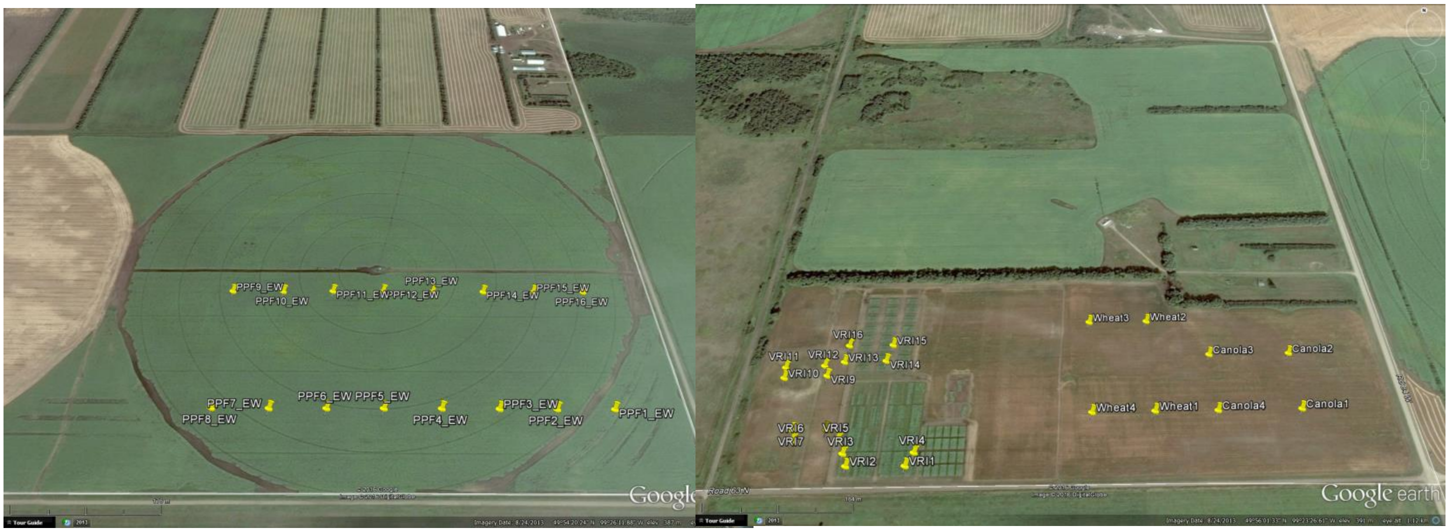

Figure 3. Sample points for the production field (left) and the offsite field (right).

All measurements were quality controlled to remove erroneous data. Datasheets were cross-referenced with the POGO data. In cases where a discrepancy was identified between the data sheet and the electronic measurement, the latter was understood as the correct record. All volumetric water content (VWC) values less than 2% were treated as erroneous data and therefore removed from further analysis.

Temperature

Temperature measurements were recorded so that they may be used as a parameter in the CMEM processing model. Measurements were taken at pre-determined sites using a pocket thermometer and thermal infrared (TIR) gun. Soil temperatures were taken using the pocket thermometer at 5cm and 10cm depths. Sunlit vegetation, shaded vegetation, sunlit soil and shaded soil temperature measurements were taken using the TIR gun. All temperature measurements were recorded on the data sheet.

Temperature measurements were collected from a single site within the canola, wheat and VRI/URI plot field. The sample site rotated each sample day. 2 sets of temperature measurements were recorded within the production field, each spaced 7 sampling points apart from one another. These points rotated each sample day.

Core

Soil cores were extracted at a set of pre-determined sites which rotated throughout the sampling campaign. On a given sample day, 1 core was extracted from the wheat field, 1 core from the canola field, 1 core from the VRI plots and 2 cores from the production field. Cores were weighed, oven dried and then re-weighed to determine the amount of water in the soil sample. All measurements were recorded in the data sheets.

Validation Protocol

Unmanned aerial vehicle (UAV) measurements were taken using a radiometer mounted to an octocopter. Data was processed using the CMEM and the maps were stored as a GeoTIF.

Each GeoTIF image was imported into ArcGIS and projected to UTM 14N. Corresponding sample point locations were overlaid on the VWC data recorded by the UAV. A representative window was created and centred on each sample point for the validation analysis.

Statistics were generated for both point and zone locations corresponding to the sample points. Statistics from the radiometer were compared to the in-situ measurements recorded using the POGO and soil core samples. The r-squared (r2), root mean square error (RMSE), mean absolute error (MAE) and index of agreement (IA) values were calculated for the sample points and validation windows.

Validation Plots

POGO measurements (observed values) were compared to that of the soil moisture values derived from UAV data (expected values). POGO measurements were recorded in triplicates and taken at the top, middle and furrow of the hill. If the field being measured did not contain hilling, the POGO measurements were taken at 3 adjacent sites in close proximity to one another.

Quality control checks were performed on the POGO data prior to further analysis. Data was organized by point location, and cross-examined with the physical data sheets corresponding to each in-situ measurement. Missing data were flagged and adjusted to reflect the data sheet, and data entered incorrectly in the datasheet was removed and the electronic measurement was kept. All remaining POGO data were averaged by sample site location and compared to that of the corresponding UAV measurement.

Discussion

Previous AAFC soil moisture studies (RISMA, SMAPVEX12 & 16, CANEX10) have shown a strong requirement to validate calibrations used for POGO and other soil probes with oven-dried soil moisture values collected from core samples. Analysis of the calibrations used for the POGO measurements indicate they are in good agreement with the soil moisture values derived from the core data with an RMSE of 2% and r2 of 0.95.

Point statistics derived from UAV WFV measurements were compared to the overlaying POGO measurements from the wheat, canola, VRI/URI plots and the production field. An RMSE of 8.3% was generated from this comparison. UAV measurements tend to overestimate dry field conditions and underestimate wet field conditions as shown in figure 4.

The RMSE value of 8.3% would be considered too high of an error for soil moisture studies. RMSE's of 5% VWC or less. This is especially true of field scale soil moisture maps that are required to properly assess the soil moisture state for irrigation planning. NASA's SMAP satellite mission has an accuracy of 4% VWC over non-forested land. SMAP has a much coarser resolution, providing 1 soil moisture value over 9 and 36 km^2 areas.

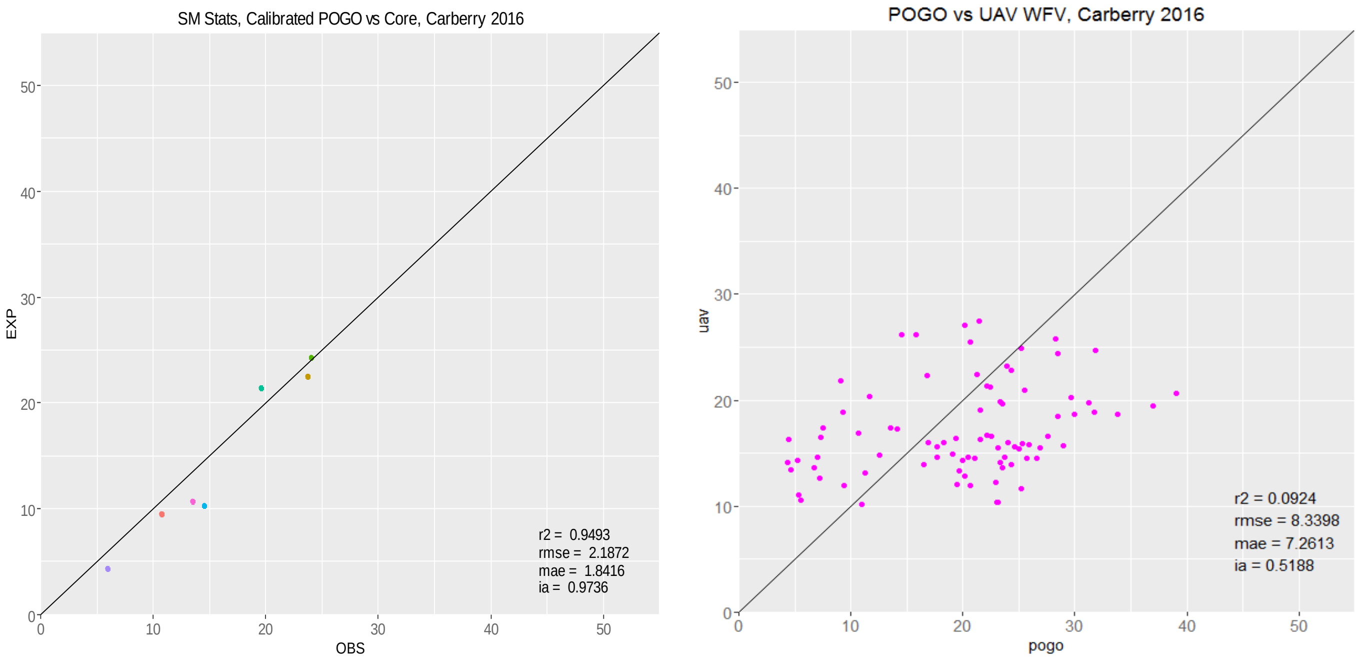

Figure 4. Soil moisture plot generated using the calibrated POGO data and core samples from the plots in Carberry, 2016 with outliers removed (left). OBS values correspond to VWC calculations from core samples while EXP values correspond to the POGO data. POGO vs UAV plot using all overlapping data captured during the 2016 Carberry camapign (right).

The high RMSE values that were noted from year 1 of the study may be the result of field sampling and ensuring that the field samples properly reflect what the radiometer on the UAV 'sees'. A weighted average of the 3 POGO readings that are taken at each site may better represent soil moisture at each location. The weightings would account for the percentage of the profile that is accounted for by the top, mid-slope and bottom of the potato hill. Also, extracting samples from deeper depths down to 10 and 20 cm may be required in drier conditions as the radiometer is able to measure microwave emissions from deeper depths during dry conditions. Although the model 'adjusts' it's processing variables to correct to field-measured soil moisture values, incorporating vegetation and soil temperature information into the CMEM model parameters may also provide some improvement.

<u>Future Work</u>

Based on data collected from 2016, additional work will need to be undertaken in 2017 to validate soil moisture maps generated by the UAV with field data. This includes:

1. testing the zone of influence using POGO measurements from deeper depths (5-10, 10-15 and 15-20cm) and analyse statistics to see which has best correlation with UAV data;

2. installing temporary station(s) and a rain bucket to provide continuous data throughout the UAV campaign. Probes would be installed at multiple depths to monitor moisture within the rooting zone profile;
3. test a different sample protocol, including measurements throughout the soil profile (potato) at 5cm intervals and a weighted function to accurately represent the unique micro-topographical differences associated with hilled potatoes;
4. feed a subset of POGO measurements into the CMEM model to see if error is reduced;
5. create site specific calibration curves using 2017 cores from 2017 UAV campaign.

Once we are able to address the issues identified in Year 1 of the study and improve the validation of the UAV soil moisture data to field-measured data (RMSE of 5% or better), then we can begin to look at the possibility of using the technology to develop prescription irrigation maps and possibly irrigation scheduling (timing and application rates).

Variable Rate Irrigation as a Technology to Improve Potato Yield and Quality

Principal Investigators: Alison Nelson, AAFC – Carberry

Co-Investigators: Bernie Zebarth, AAFC – Fredericton, NB

Support: Agri-Innovation Program, AAFC
MHPEC, Inc.

Progress: Year 2 of 3

Objectives: - Evaluate current VRI management techniques for their effectiveness in improving yield and quality of tubers across areas of soil moisture variability

Key 2016 Message: - Positive impacts of VRI management vs. Uniform Irrigation (URI) were observed in 2016, with improved yields on one study site, and decreased tares on the second study site.
- Additional years and sites of study are required to identify the impact of VRI management in various sites, conditions and growing season weather.

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Project Report

This project is designed to observe VRI field management as it is currently practiced in Manitoba, and compare VRI management to Uniform Rate Irrigation (URI) for potato yield and quality across areas of variability within two test fields.

Based on the topography and grid soil sample data collected at the CMCDC-Carberry Offsite field, a VRI prescription zone map was developed in consultation with a VRI specialist from Alberta. This map informed the placement and management of replicated, paired comparison plots testing VRI management against Uniform Rate Irrigation (URI) across different irrigation management zones (from the VRI prescription map).

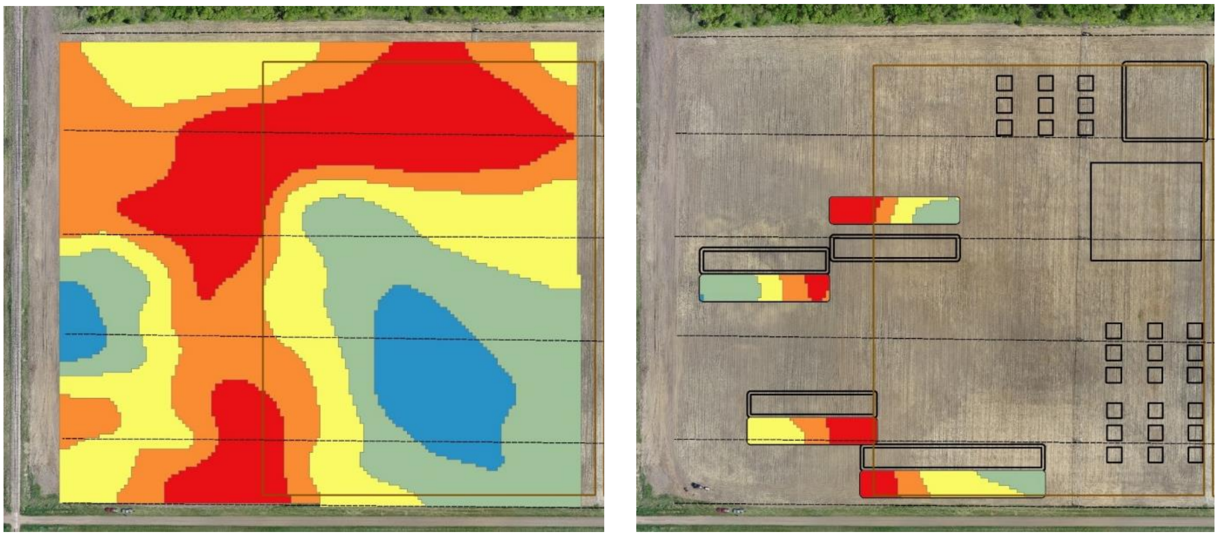

Figure 1. VRI prescription designed for entire western third of the CMCDC Offsite, using topography and soil test results (left image). From this map, four paired comparison plots were identified (right image), showing the VRI (multi-colored rectangles) vs. URI (blank rectangles bordering on the N or S of the colored plots) plots. Multiple benchmark sampling points were established in each of the plots, within the various management zones.

In addition to the work at CMCDC-Carberry, paired plots of variable vs. solid uniform rate irrigation were established on a commercial field operating a VRI system in 2016. Continuous soil moisture monitoring was carried out in selected plots in the field, along with late season biomass, tuber yield and quality and soil sampling. Analysis of the biomass and soil data is pending.

In total, four paired plots of VRI vs. URI were established at each of the two study fields, with multiple benchmark sampling and harvest points within each paired location, across multiple management zones. The commercial VRI field had eight sampling sites, while the CMCDC-Carberry field had 13 sampling sites. In 2016, the commercial VRI field had significantly higher tuber yields under VRI management, but no differences in tares or overall quality.

Alternatively, the CMCDC-Carberry field had no observed difference in yield between VRI vs. URI (Figure 2), but the total tares were significantly higher under URI management. Total tares (hollow heart tare, rot, green tare, etc.) were 16.6% under URI management and 8.3% under VRI management.

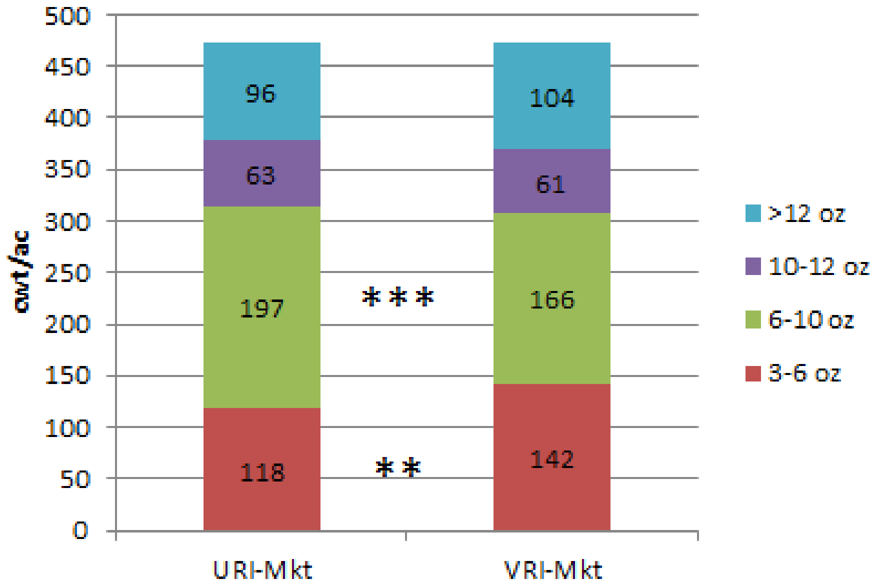

Figure 2. Average marketable tuber yields (<3 oz removed), and size profile of the harvest samples from CMCDC-Carberry. Significant differences (P<0.05) were found between URI and VRI in the 3-6 oz and 6-10 oz size categories.

The results are promising; however, a single year of data is not sufficient to draw conclusions. This study must be replicated over multiple years to identify overall trends and results of VRI under different weather and environmental conditions. The initial results support the hypothesis that different field conditions and ranges of variability in fields will affect the impact of VRI technology on potato yield and quality.

Heat Stress as a Limitation to Potato Yield

Principal Investigators: Mario Tenuta, University of Manitoba – Winnipeg, MB
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Helen Tai, AAFC – Fredericton, NB
Alison Nelson, AAFC – Carberry

Support: Agri-Innovation Program, AAFC
MHPEC, Inc.

Progress: Year 2 of 3

Objective: - Assess effects of heat stress on potato productivity and quality
- Develop gene expression indicators for heat stress in "warmed" and "ambient" plots

Key 2016 Message: - In 2016 different chamber designs were tested in preparation for the trial in 2017.

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Project Report

With climatic variability potentially increasing, this study was designed to understand the impact of higher canopy temperatures on potato crop growth, yield and quality. In 2016, three heat stress chamber designs were constructed and tested to see if we could create a field chamber that would increase canopy temperatures by a few degrees Celsius. Potato plots were planted, and differentially irrigated to fully test the system. Four test chambers were installed in selected plots, and heat readings collected in July and August. Three chamber designs were tested:

1. Three high walled hexagonal chamber prototypes were constructed in three plots, using stakes and Plexiglas. This chamber design would be installed in early season and remain in place throughout the growing season.
2. One low walled hexagonal chamber design was constructed in-plot, using stakes and Plexiglas. This chamber design would be installed in early season and remain in place throughout the growing season.
3. One rectangular chamber design was tested on bare soil to test a design that could be installed and removed at various points in season.

The rectangular chamber design will be used in 2017 plots to be installed and removed at various points in the growing season to test intermittent heat stress on potato yield and quality and gene expression at pre-selected time periods.

Figure 1. Hexagonal Plexiglas heat chamber design installed in a potato plot. Themocouple sensors installed on stakes inside and outside the chambers to monitor canopy temperatures.

Figure 2. Rectangular heat chamber test design – built to span three potato rows and installed and removed multiple times in season.

Testing the Use of a Proximal Sensor for Measuring Soil Moisture Changes In-Season

Principal Investigators: Alison Nelson, AAFC – Carberry
John Fitzmaurice, AAFC - Winnipeg

Support: AAFC

Progress: Year 1 of 3

Objective: - Test the concept and field logistics of using an Em38 sensor for measuring in-season soil moisture changes over time.

Key 2016 Message: - A prototype design to pull an Em38 sensor through potato plots was tested in 2016, and initial sensor data collected on water stress plots.
- A modified sensor field set-up will be tested in the 2017 season, and the data analyzed and compared with physical soil measurements.

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Project Report

In 2016, using the established Water Use/Stress Trial plots, a secondary study was completed to test the concept of using an Em38 sensor to measure in-season temporal changes in soil moisture. The Water Use study is a randomized complete block design, testing three different moisture regime treatments, to maintain soil moisture levels at: 40, 60 and 80 % plant available water, based on Watermark readings.

The Em38 sensor is pulled across the soil surface, or slightly above the soil surface, causing little disturbance. Similar to the Veris sensor, it can be pulled through a field (although it does not have coulters that go into the ground), taking readings at a pre-determined time-interval, so soil mapping density can be adjusted by changing travel speed. We tested the logistics of pulling the sensor through planted potato rows using a test sensor cradle and mount for an ATV. If the sensor is proven to be effective at measuring changes in soil moisture levels over time, it could be a potential tool for scouts or researchers to use to measure soil moisture variability across entire transects in a potato field in season.

Figure 1. The Em38 in a cradle, offset from the ATV, with a GPS receiver mounted above it, to be pulled through the furrow between two potato rows. The cradle rides on the surface of the soil.

Site characterization samples were collected to determine hydraulic and chemical properties of the soil. At two week intervals during the growing season, EM-38 sensor readings were collected in each plot. At the same time, soil samples were collected at 10 cm intervals within each plot for gravimetric soil moisture measurements. The EM-38 readings are currently being processed. The gravimetric soil moisture data and the EM-38 data will be analyzed to test the hypothesis that EM-38 readings in season can be used to measure soil moisture variability following data processing. In addition to physical soil moisture measurements, continuous soil moisture monitoring equipment (Decagon) was installed in all plots. In 2016, the sensor cradle that was built to pull the sensor through the plots was found to require some adjustments to avoid jostling and jumping in the small plot tests. A modified sensor field set-up will be tested in the 2017 season.