ANNUAL REVIEW

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Canada-Saskatchewan
Irrigation
Diversification
Centre

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Saskatchewan SIPA University of Saskatchewan ICDC Irrigation Crop Diversification Corporation Canada

Table of Contents

List of Figures

List of Tables

INTRODUCTION

Canada-Saskatchewan Irrigation Diversification Centre

The Canada-Saskatchewan Irrigation Diversification Centre (CSIDC), located in Outlook, Saskatchewan, is a world class facility established in 1949 by the Prairie Farm Rehabilitation Administration. The Centre was originally designed to demonstrate irrigation technology and to assist farmers transition to irrigated agriculture. In 1986, the facilities were significantly upgraded and modernized to fulfill the Centre's new role of conducting, funding, and facilitating irrigated research and demonstration in response to industry needs.

Since 2008, CSIDC has been a collaborative partnership between Agriculture & Agri-Food Canada (AAFC), the Saskatchewan Ministry of Agriculture, the Irrigation Crop Diversification Corporation (ICDC), the Saskatchewan Irrigation Projects Association (SIPA), and the University of Saskatchewan. Researchers investigate and demonstrate crops, technologies, and best management practices that help producers to sustain land and water resources while maintaining their economic viability.

CSIDC operates under the Canada-Saskatchewan-Industry Framework Agreement for Irrigation Based Economic Development and Environmental Sustainability, which is current until July 31, 2024. The partners form the Executive Management Committee which is responsible for implementation and management of the Framework Agreement, the approval of research, development, and technology transfer activities of the Annual Work Plan, and the overall strategic themes and direction. The partnership is driven by the challenge and the desire to meet the needs of its farmer clients and to serve the western Canadian irrigation industry.

CSIDC's irrigated land base includes a total of 170 (hectares) ha, of which 45 ha is rented by ICDC and 125 ha is owned by AAFC. Water is supplied to CSIDC by a computer controlled variable output pressurized pipe system and 19 ha of subsurface drainage allows environmental monitoring and treatment comparison.

A wide range of equipment and facilities are available for applied irrigation research and demonstration, including: a year-round greenhouse, five cold frame greenhouses, a potato and vegetable storage and handling facility complete with a quality assessment laboratory, an automated weather station, a range of small plot to commercial sized agricultural equipment; drip irrigation equipment, and centre pivot and linear move irrigation systems, five of which are equipped with variable rate technology.

Each year the work at the Centre is highlighted at the annual CSIDC Field Day and Trade Show, as well as numerous commodity tours and extension events. In 2021, CSIDC was closed to the public due to the COVID-19 pandemic and all technology transfer and extension events were conducted virtually.

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2021-22 RESEARCH PROGRAM

CSIDC Work Plan Summary

Table 1. List of research projects led by Agriculture & Agri-Food Canada, including Field Crop Agronomy, Horticultural Crop Agronomy, and Irrigation Water Management trials.

Project	Description	Lead Researcher(s)	Term
AAFC Field Crop Agronomy			
Evaluating the Effect of Seeding Date on the Water Use Efficiency of Canola	To determine and compare irrigation requirements, water use, and water use efficiency for canola seeded in early, mid, and late seeding dates using a replicated trial. Results will be used to better define water/irrigation requirements and water use efficiency for canola as it is actually grown in the field (i.e., over the wide range in seeding dates that occur).	E. Derdall, AAFC-Saskatoon D. Tomasiewicz, AAFC-Outlook E. Karppinen, AAFC-Outlook	1 of 3
Improving the Management of Sclerotinia Stem Rot of Canola Using Fungicides and Better Risk Assessment Tools	To refine the use of qPCR analysis and of spore traps vs. canola petals to determine impact of conditions on inoculum and disease development; to evaluate fungicide application timing and how factors (i.e., seeding rate) influence fungicide response; to determine effects of inoculum and environment on stem rot risk and fungicide efficacy.	D. Tomasiewicz, AAFC-Outlook P. Mooleki, AAFC-Saskatoon	2 of 3
Meeting the Soybean Protein Meal Standard in Western Canada	To increase understanding of soybean protein-yield relationship across Canada, and soybean protein gene expression patterns. Small-plot replicated trials across Canada (both irrigated and rainfed trials at Outlook), and assoc. studies.	E. Cober, AAFC-Ottawa D. Tomasiewicz, AAFC-Outlook P. Mooleki, AAFC-Saskatoon	3 of 4
Putting Soil Residual Nitrate to Work - Variable and Deep Nitrate	Spatial and depth distributions of soil residual nitrate will be determined in one dryland and one irrigated field in each of three years. Management zones will also be established. Crop responses to N fertilization will be determined over the field. Results will be used to develop optimum N fertilization practices to best take advantage of the residual N.	D. Tomasiewicz, AAFC-Outlook P. Mooleki, AAFC-Saskatoon	1 of 4
Addressing Yield Stability Drivers of Canola in a Changing Climate using High Throughput Phenotyping	Given increasing variability in seasonal conditions, efficient selection of crop varieties able to consistently yield will continue to be a top priority for breeders and an increasingly important factor when producers select varieties to grow. There is great potential to improve the efficiency of identifying yield stable breeding lines using two synergistic emerging plant breeding techniques. This project will fund field trials of the B. napus NAM germplasm resource in contrasting climatic environments in order to acquire a sizably sufficient dataset to test and apply emerging phenotyping and selection techniques to improve canola yield stability for Canadian producers.	S. Vail, AAFC-Saskatoon	2 of 2
Evaluating AAC Trueman Alfalfa in Saskatchewan	Determine adaptability of AAC Trueman under three moisture conditions at CSIDC near Outlook, SK. The large-scale plots will compare AAC Trueman performance under excess moisture, normal irrigation and dryland conditions. Evaluate ST1 Timothy as a potential flood tolerant variety that can be mixed with AAC Trueman in higher soil moisture landscapes. Forage production and forage quality will be assessed.	B. Houston, AAFC-Regina C. Kayter, AAFC-Saskatoon	1 of 3

AAFC Horticultural Crop Agronomy			
Climate Change Opens New Opportunities for Vegetable Production on the Prairies	Develop BMP's for sustainable production capitalizing on opportunities presented by climate change (longer, warmer growing season: earlier planting, multiple/successive crops, later harvest). Crop specific agronomic variables including water management, soil mulch (moisture conservation, soil warming – i.e. accelerate growth and maturity, weed control) will be examined using season-extension techniques (high tunnel and mini tunnel) to simulate climate change settings. Yield, storage characteristics, bioactive contents, and economic performance will be evaluated for the three crops under the projected climate change scenario.	J. Wahab, AAFC-Saskatoon	1 of 3
Leafy Green Vegetables in Saskatchewan: Agronomic Refinements for Field and High Tunnel Production	Evaluate adaptability of spinach, kale, and bok choy cultivars and develop BMP's for Saskatchewan (i.e., cool and short) growing conditions. Objectives include: productivity, water use efficiency, sequential cropping, spinach market classes (baby, bunched, freezer, etc.), season extension (high-tunnel), storability, and quality.	J. Wahab, AAFC-Saskatoon	1 of 3
National Potato Variety Trials	There is continued effort by AAFC to develop potato (i.e., seed, processing, and table) cultivars with superior yield, pest resistance/tolerance, culinary, and storage attributes targeted for domestic and export markets. This project is designed to identify 'early-maturing' and 'maincrop' cultivars under standard irrigation management, for prairie growing conditions.	J. Wahab, AAFC-Saskatoon	3 of 5
Horseradish Production at CSIDC	Maintain horseradish germplasm at CSIDC.	D. Tomasiewicz, AAFC-Outlook E. Karppinen, AAFC-Outlook	Ongoing
AAFC Irrigation Water Management			
Validation and Refinement of Thermal Indices for Monitoring Crop Water Stress in the Canadian Prairies	The concept of using thermal based sensors/indices to determine crop water stress was first introduced in the early 1980's. With improvement in infrared thermometer technology (IRTs), the application of using sensors in agriculture has become more economical. The majority of thermal based indices have been developed in the Southern Great Plains or at the USDA research facility in Bushland Texas. The climate of the Southern U.S. is significantly different than that of the Canadian Prairies. The objective of this project is to evaluate and refine current thermal indices for use in irrigation management in Saskatchewan.	E. Derdall, AAFC-Saskatoon	1 of 3
Online Decision Support Tool for Precision Agriculture and Irrigation Scheduling	IrriSat, named for its primary application as an irrigation scheduling tool, was developed in 2009 in a partnership of academia, government agencies and industry in Australia. This free on-line tool utilizes the Google Earth Engine, local meteorological data sets and pre-existing water balance models to help irrigators to spatially schedule irrigation events and benchmark crop productivity. This project will adapt the IrriSAT tool for application in Saskatchewan, complete a reliability assessment and develop the training materials to support producers and agronomists.	E. Derdall, AAFC-Saskatoon	3 of 3

Climate Change Resilience - Understanding of Management and Tools to Address Water Extreme Events and Matching Water Demand with Access	This management requested project aims to develop knowledge and tools to help producers and industry adapt to changing water availability as a result of climate change, three key areas of focus toward this objective: 1) improve the forecasting ability by leveraging existing capacity within AAFC (Droughtwatch), developing reporting tools designed to assist producers plan for short and longer term water availability. Examine enhanced collaboration with the Global Institute for Water Security and ECCC modellers related to Ag water management and climate change, 2) development of agronomic BMP`s – work with partners and industry to improve water use efficiency through agronomic approaches including nutrient management, varietal evaluation, agronomy, etc. 3) evaluation of management tools for improved water and energy use efficiency.	E. Derdall, AAFC-Saskatoon	1 of 3
Crop Coefficients Development for Canola and Dry Bean in Saskatchewan to Improve Yield and Water Use Efficiency	A Bowen Ratio Energy Balance System is installed in a crop field to collect data to measure the crop evapotranspiration of that particular crop. Reference evapotranspiration is estimated using data from meteorological station. The crop evapotranspiration measured in the field and the reference evapotranspiration are then used to develop the crop coefficients.	H. Tanko, AAFC-Regina	3 of 3

Table 2. List of research projects led by Irrigation Crop Diversification Corporation, including Field Crop Variety, Field Crop Agronomy, and Fruit & Vegetable Agronomy trials.

Project	Description	Lead Researcher(s)	Term
ICDC Field Crop Variety			
SVPG Hex 1 Regional Variety Trial	To evaluate the adaptability of current and potential CWRS wheat varieties under irrigated production.	G. Hnatowich, ICDC G. Singh, ICDC	Ongoing
SVPG Hex 2 Regional Variety Trial	To evaluate the adaptability of current and potential CPSR, CWHWS, CWES and CWPG wheat varieties under irrigated production.	G. Hnatowich, ICDC G. Singh, ICDC	Ongoing
Central Bread Wheat Registration Trial	To evaluate the adaptability of 30 potential CWRS wheat varieties from AAFC Brandon under irrigated and dryland production.	G. Hnatowich, ICDC G. Singh, ICDC	Ongoing
SVPG Durum Regional Variety Trial	To evaluate the adaptability of current and potential CWAD wheat varieties under irrigated production.	G. Hnatowich, ICDC G. Singh, ICDC	Ongoing
Soft White Spring Wheat Coop	To evaluate the adaptability of current and potential CWSWS wheat varieties under irrigated production.	G. Hnatowich, ICDC G. Singh, ICDC	Ongoing
SVPG Barley Regional Variety Trial	To evaluate the adaptability of current and potential 2 and 6-row barley varieties under irrigated production.	G. Hnatowich, ICDC G. Singh, ICDC	Ongoing
SVPG Oat Regional Variety Trial	To evaluate the adaptability of current and potential oat varieties under irrigated production.	G. Hnatowich, ICDC G. Singh, ICDC	Ongoing
Regional Flax Variety Trial	To evaluate the adaptability of current and potential flax varieties under irrigated production.	G. Hnatowich, ICDC G. Singh, ICDC	Ongoing
Dry Bean Regional Trial	To evaluate the adaptability of current and newly registered dry bean varieties using both wide and narrow row production systems.	G. Hnatowich, ICDC G. Singh, ICDC	Ongoing
Soybean Regional Variety Trials: Short Season Irrigated	To evaluate new and experimental varieties of soybean under both irrigated and dry land production systems.	G. Hnatowich, ICDC G. Singh, ICDC	Ongoing
Soybean Regional Variety Trials: Long Season Irrigated	To evaluate new and experimental varieties of soybean under both irrigated and dry land production systems.	G. Hnatowich, ICDC G. Singh, ICDC	Ongoing
Conventional Soybean Variety Trial: Irrigated	To evaluate new and experimental conventional varieties of soybean under irrigated production.	G. Hnatowich, ICDC G. Singh, ICDC	Ongoing
Pea Variety Regional Trial	To evaluate the adaptability of current and potential pea varieties under irrigated production.	G. Hnatowich, ICDC G. Singh, ICDC	Ongoing
Canola Performance Trial - Conventional	To evaluate the adaptability of current and newly registered herbicide tolerant canola varieties.	G. Hnatowich, ICDC G. Singh, ICDC	Ongoing
Canola Performance Trial - Straight Cut	To evaluate the adaptability of current and newly registered herbicide tolerant canola varieties.	G. Hnatowich, ICDC G. Singh, ICDC	Ongoing
Demonstration of Fall Rye as an Irrigated Crop	Evaluate fall rye varieties potentially suitable under both irrigated and dry land production systems.	G. Hnatowich, ICDC G. Singh, ICDC	Ongoing

ICDC Field Crop Agronomy			
N Fertilizer Rate Response in Irrigated Dry Bean	Determine nitrogen fertilizer rate yield responses for pinto market class irrigated wide row dry bean production. Determine whether ESN nitrogen fertilizer is beneficial compared to urea as a fertilizer nitrogen source for irrigated dry bean production.	G. Hnatowich, ICDC G. Singh, ICDC	1 of 3
Developing Target Yield Nitrogen Fertilizer Recommendations for Irrigated & Dryland Silage & Grain Corn	Study N uptake and yield response to varying N fertilizer rates in silage and grain corn. Three trials annually on both irrigated and dryland sites.	G. Hnatowich, ICDC G. Singh, ICDC	1 of 3
Crop Rotation Benefits of Annual Forages Preceding Spring Cereals	Evaluate annual forages and study their effect on the following crop and soil health.	G. Hnatowich, ICDC G. Singh, ICDC	2 of 2
Evaluating Cover Crop Options Following Row Crop Harvest on Irrigated Land	Evaluating winter and spring cereals seeded on highly fragile soil following row crops.	G. Hnatowich, ICDC G. Singh, ICDC	1 of 1
Influence of K Fertilizer on Yield and Seed Quality of Malt Barley and Spring Wheat	Evaluate K fertilizer rate and placement on yield, seed quality and lodging of spring wheat and barley.	G. Hnatowich, ICDC G. Singh, ICDC	1 of 1
Faba Bean Agronomy to Enhance Yield, Hasten Maturity, and Reduce Disease	Evaluate the impact of varying seeding dates, seeding rates and fungicide applications on faba bean.	G. Hnatowich, ICDC G. Singh, ICDC	1 of 1
Canola Seed Safety and Yield Response to Novel P Sources in Saskatchewan Soils	Evaluate canola response to varying struvite rates, alone or in blends, relative to other common P fertilizer formulations.	G. Hnatowich, ICDC G. Singh, ICDC	1 of 1
Winter Wheat Variety Evaluation for Irrigation vs Dry Land Production	Evaluate winter wheat varieties best suited to irrigated production.	G. Hnatowich, ICDC G. Singh, ICDC	1 of 1
Demonstrating Spring Wheat Phosphorus Fertilizer Response on a Severely Phosphorus Deficient Irrigated Field	Study annual and residual benefits of P fertilization on a low P soil.	G. Hnatowich, ICDC G. Singh, ICDC	2 of 2
Production Management Strategies to Improve Field Pea Root Health in *Aphanomyces* Contaminated Soils	To evaluate multiple management strategies to reduce the effect of *Aphanomyces* on field pea root health and yield production.	G. Hnatowich, ICDC G. Singh, ICDC	2 of 2
ICDC Fruit and Vegetable Agronomy			
Efficacy of Bumble Bee, Honey Bee, and Leafcutter Bee on Pickling Cucumbers	Evaluation of different pollinators on pickling cucumber production.	C. Achtymichuk, SMA C. Drury, SMA	1 of 1

Demonstration of Short Season Varieties of Sweet Potato	Demonstration of short season varieties of sweet potato.	C. Achtymichuk, SMA C. Drury, SMA	1 of 1
HSSA - Specialty Agriculture Crop Demonstration	Demonstrate specialty crop and herb varieties.	C. Drury, SMA	1 of 1
Determining Size Profiles of SK Grown Cantaloupe for a Retail Market	Growing Cantaloupe in field conditions and determining their size profile.	C. Achtymichuk, SMA C. Drury, SMA	1 of 1
Sequential Plantings to Extend the Harvest Period of Pickling Cucumbers	Sequential plantings of cucumber to extend the harvest period.	C. Achtymichuk, SMA C. Drury, SMA	1 of 1
Pumpkin Processing Demonstration	Purchasing pumpkins from local producers and exploring processing options.	C. Achtymichuk, SMA C. Drury, SMA	1 of 1
Demonstration of a New Product for the Control of Wireworms in Potato	Using Cimegra for the control of Wireworm in potatoes.	C. Achtymichuk, SMA C. Drury, SMA	1 of 1
Apple Scoinwood and Dwarf Apple Rootstock Productivity and Disease Resistance	Evaluate apple scoinwood and dwarf apple rootstock productivity and disease resistance.	F. Scharf, SMA	1 of 2
Methods to Improve Productivity of Sour Cherry Suffering from Blind Wood	Assess productivity of gibberellic acid to relieve blind wood disorder in sour cherry.	F. Scharf, SMA	1 of 2

Table 3. List of research projects led by Saskatchewan Ministry of Agriculture, including Field Crop Agronomy, Horticultural Crop Agronomy, and Irrigation Water Management trials.

Project	Description	Lead Researcher(s)	Term
SMA Field Crop Agronomy			
Effects of Insecticide Application Timing and Seeding Date on Pea Aphid Damage to Lentils and Field Peas	Demonstrate the effects of seeding dates and insecticide applications before and after flowering on pea aphid damage.	J. Tansey, SMA G. Hnatowich, ICDC G. Singh, ICDC	2 of 2
Varietal Assessment of Forage Seed Production	Determine yield potential for irrigated production of grasses for seed.	T. Kowalchuk, SMA G. Hnatowich, ICDC G. Singh, ICDC	2 of 4
Hemp Seeding Date Demonstration for Grain Production	Demonstration of hemp cultivars.	D. Risula, SMA G. Hnatowich, ICDC G. Singh, ICDC	1 of 2
Top Dressing Nitrogen Fertilizer on Frozen or Snow Covered Soils in Saskatchewan	Evaluate loss of production and economic risks associated with broadcast applications of nitrogen fertilizers on frozen and snow covered soils.	K. Stonehouse, SMA G. Hnatowich, ICDC G. Singh, ICDC	1 of 2
Effect of Tillage Management & Seeding Date on Dry Bean Establishment and Yield	Evaluate three levels of tillage management and three seeding dates on dry bean production.	M. O'Connor, SMA G. Hnatowich, ICDC G. Singh, ICDC	1 of 3
SMA Horticultural Crop Agronomy			
Growing Methods to Assist in the Expansion of the SK Garlic Industry	Evaluate different garlic varieties for suitability for Saskatchewan production.	C. Achtymichuk, SMA C. Drury, SMA	2 of 3
Potential to Grow Roma Tomatoes in Saskatchewan for Processing	Demonstration of growing Roma tomatoes as a field crop.	C. Achtymichuk, SMA C. Drury, SMA	1 of 2
Identification of Onion Cultivars Suited to SK Production Conditions	Demonstration of onion cultivars.	C. Achtymichuk, SMA C. Drury, SMA	1 of 2
SMA Irrigation Water Management			
Monitor Production Practices for Irrigated Canola	Monitor production practices for irrigated canola.	M. O'Connor, SMA	1 of 1
Demonstration of Irrigation Scheduling Using Remote Sensor Technology	Demonstration of the Crop X soil probe for irrigation scheduling, conducted with a producer cooperator.	J. Bauer, SMA	1 of 1

Table 4. List of research projects led by University of Saskatchewan, including Field Crop Agronomy and Breeding trials.

Project	Description	Lead Researcher(s)	Term
U of S Field Crop Agronomy			
Fungicide Timing to Mitigate Fusarium Head Blight in Cereal Crops	Study fungicide timing on spring wheat, winter wheat, and durum for reduction in fusarium head blight incidence.	R. Kutcher, U of S G. Hnatowich, ICDC G. Singh, ICDC	1 of 3
Agronomic and Breeding Approaches to Improve the Harvestability of Dry Bean	Evaluate seeding rate of three separate market class dry bean and its influence on pod height.	K. Bett, U of S G. Hnatowich, ICDC G. Singh, ICDC	1 of 2
U of S Breeding			
Dry Bean & Faba Bean Nursery	Maintenance of advanced Crop Development Centre nursery.	K. Bett, U of S B. Vandenberg, U of S T. Warkentin, U of S	Ongoing

Plot Location Maps

CSIDC Main Station

S½ 15-29-08-W3

Figure 1. CSIDC Fields 1 to 11 site plot layout.

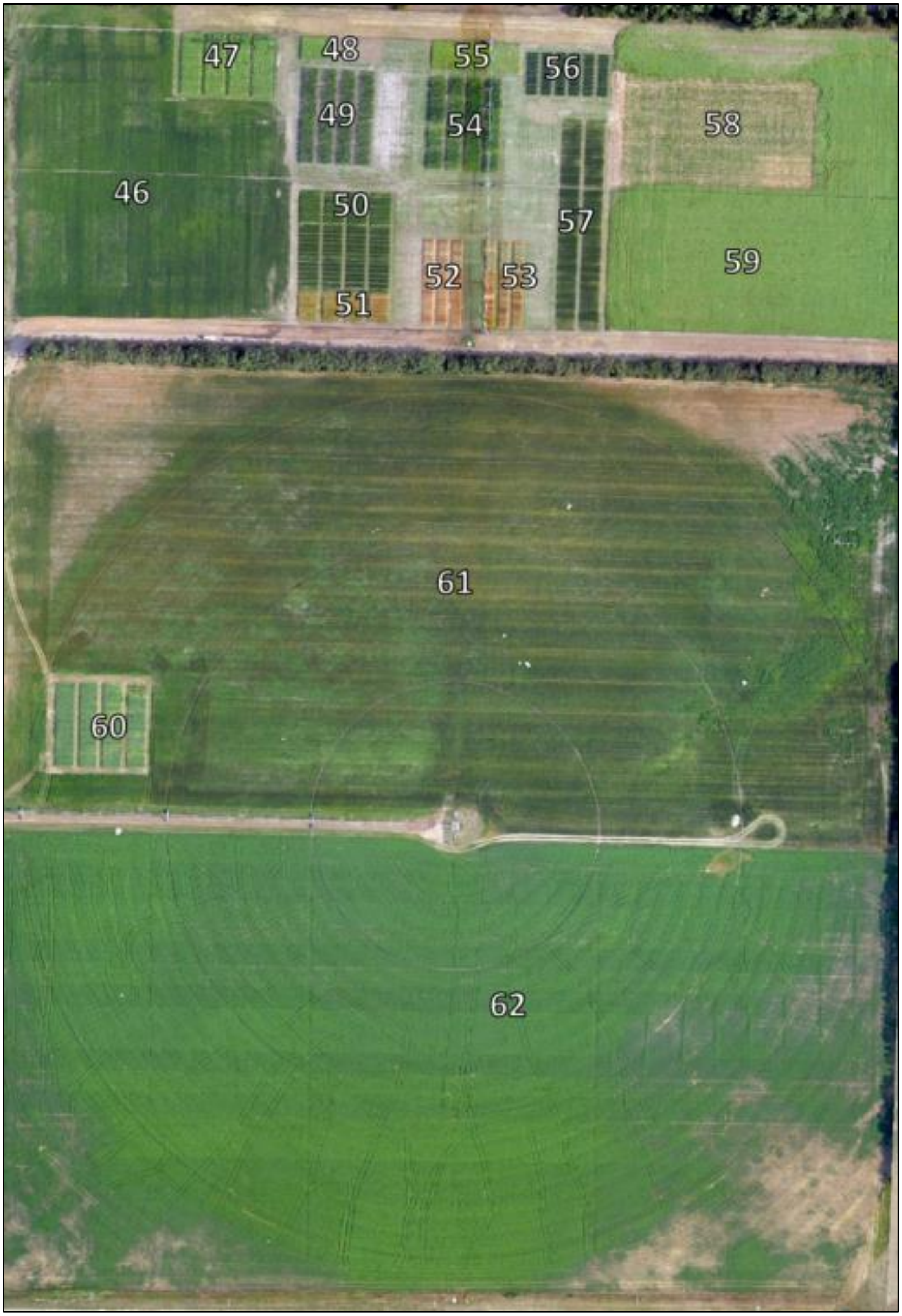

Figure 2. CSIDC Field 12 and ICDC Area 51 site plot layout.

CSIDC Off-Station

NW 12-29-08-W3

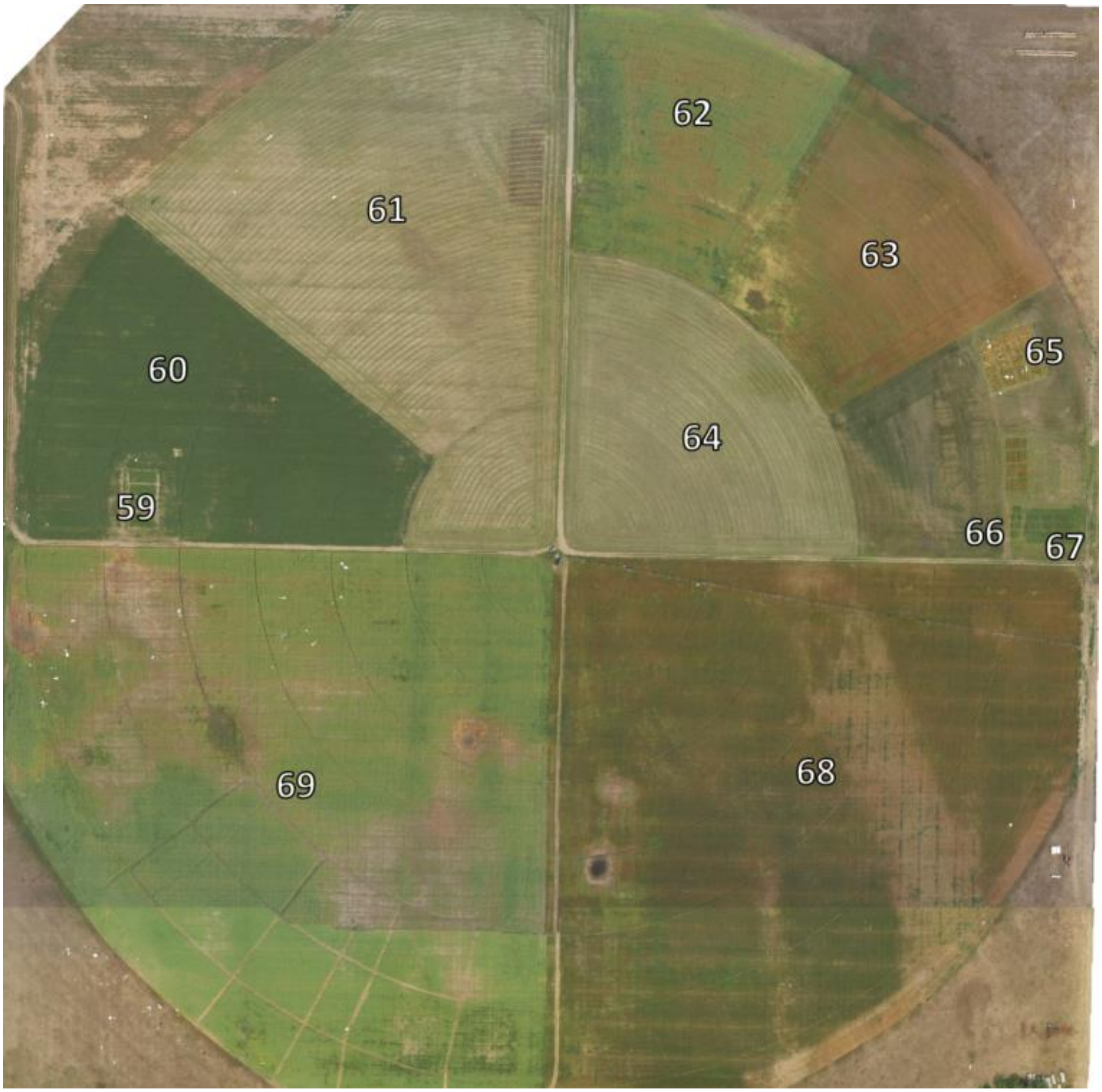

Figure 3. CSIDC Off-Station site plot layout.

Table 5. CSIDC site plot layout legend.

#	Crop	#	Crop
1	Wheat	34	Peas
2	Spinach trial	35	Wheat
3	Rutabaga trial	36	Irrigated/dryland soybean trials
4	Spinach trial	37	Canola seeding date trial
5	Bean trial	38	Canola sclerotinia trial
6	Bean trial	39	Soybeans
7	Spinach trial	40	Canola breeding trial
8	Saskatoon berries	41	Horseradish nursery
9	Raspberries	42	Trueman alfalfa trial
10	High tunnels	43	Pea aphanomyces trial
	A. Spinach	44	Wheat
	B. Bok choy and kale	45	Wheat
	C. Sweet potatoes	46	Canola phosphorous trial
	D. Beans	47	Canola nitrogen trial
11	Cantaloupe size profile trial	48	Corn nitrogen trial – dryland
12	Cucumber pollination trial	49	Wheat, durum, barley fusarium trial
13	Apple blindwood trial	50	Winter wheat fusarium trial
14	Haskaps	51	Winter wheat variety trial - dryland
15	Sour cherries	52	Winter wheat variety trial - irrigated
16	Wheat	53	Corn nitrogen trial – irrigated
17	Soybeans	54	Canola nitrogen trial
18	Wheat	55	Durum variety trial
19	Kale, bok choy, and spinach trials	56	Wheat urea on snow trial
20	National potato variety trials	57	Corn
21	Garlic variety trial	58	Canola
22	Cucumber trial	59	Dry bean breeding trial
23	Soybeans	60	Soybeans
24	Wheat	61	Alfalfa/grass
25	Faba bean fungicide trial	62	Canola
26	Dry bean pod height trial	63	Wheat
27	Crop Diagnostic School demo	64	Alfalfa/grass
28	Flax variety trial	65	Bread wheat variety trial
29	Dry bean tillage trial	66	Trueman alfalfa trial
30	Dry bean nitrogen trial	67	Forage seed trial
31	Pea aphid trial	68	Wheat
32	Lentil aphid trial	69	Canola thermal indices trial
33	Corn nitrogen trial		

Weather Summary

Generally, growing season average maximum and minimum temperatures were above average in 2021 (Figure 4; Table 6). Daily maximum temperatures were above average, with 7 days in June, 14 days in July, 6 days in August, and 2 days in September exceeding 30.0°C.

With the exception of May, precipitation throughout the growing season was below average (Figure 5; Table 7). Precipitation was less than half of the 30-year average in April, June, July, and September.

While minimum temperature dipped to -0.6°C on September 17, there was no killing frost in September and cumulative corn heat units were above average (Figure 6). Corn heat units are accumulated from May 15 to the first *killing* frost (-2.0°C) or to September 30 at the latest.

Growing degree day heat accumulations were above average from June through September 15 (Figure 7; Figure 8; Figure 9).

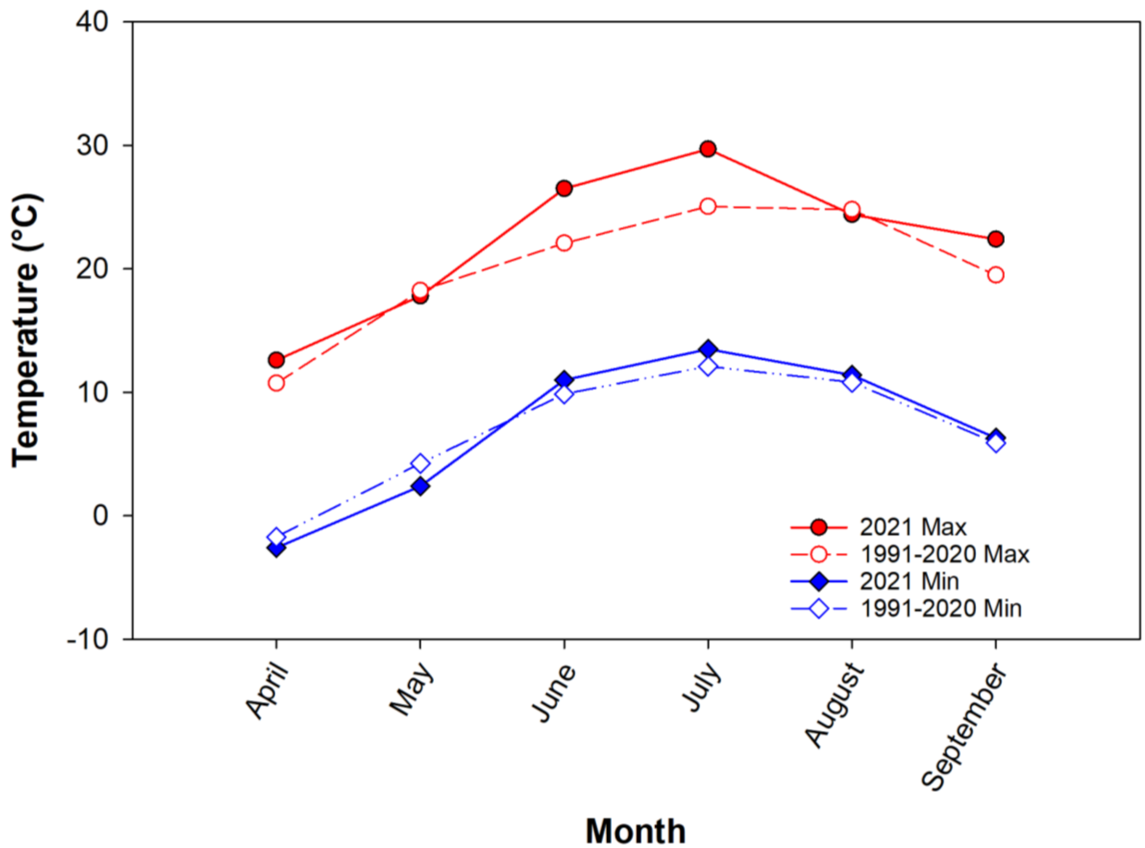

Figure 4. CSIDC growing season temperature (average daily minimum and maximum) by month for 2021 and the 30-year average (1991-2020).

Table 6. CSIDC growing season temperature (average daily minimum and maximum) by month for 2021 and the 30-year average (1991-2020).

Month	Temperature (°C)			
	Maximum		Minimum	
	2021	1991-2020	2021	1991-2020
April	12.6	10.7	-2.6	-1.7
May	17.8	18.3	2.4	4.2
June	26.5	22.1	11.0	9.9
July	29.7	25.1	13.5	12.1
August	24.4	24.8	11.4	10.8
September	22.4	19.5	6.3	5.9

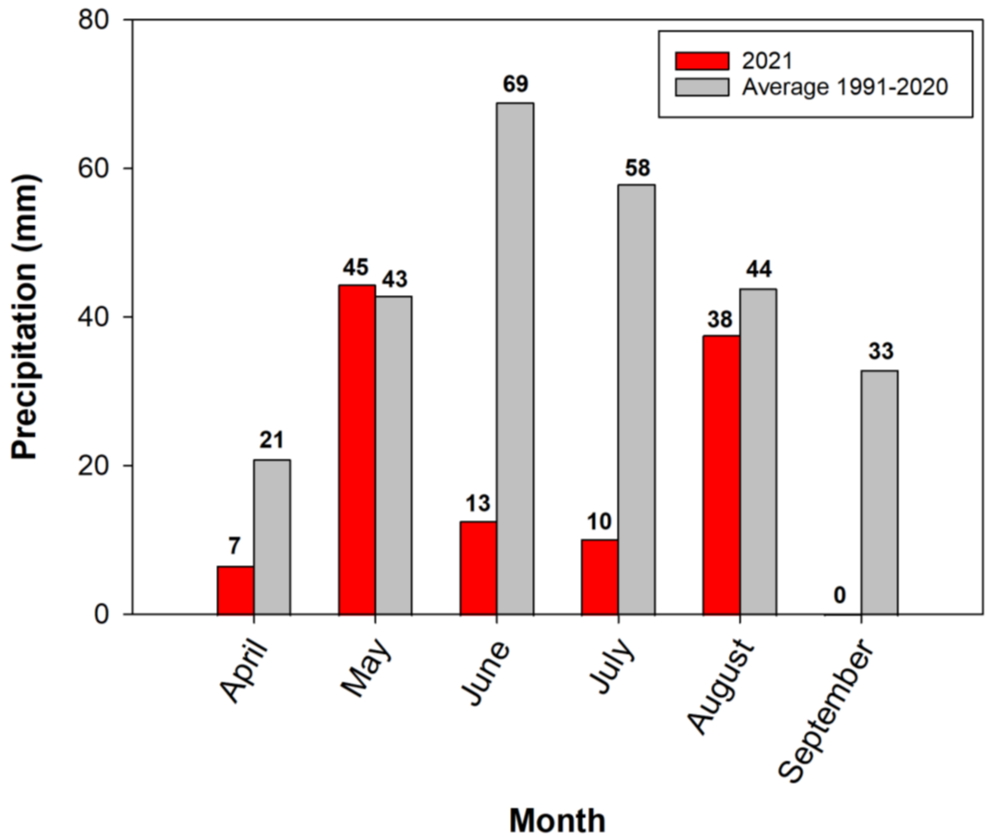

Figure 5. CSIDC growing season precipitation by month for 2021 and the 30-year average (1991-2020).

Table 7. CSIDC growing season precipitation by month for 2021 and the 30-year average (1991-2020).

Month	Precipitation (mm)	
	2021	1991-2020
April	6.7	20.9
May	44.5	43.2
June	12.7	69.3
July	10.3	57.6
August	37.7	44.2
September	0.2	32.7
Total	112.2	267.9

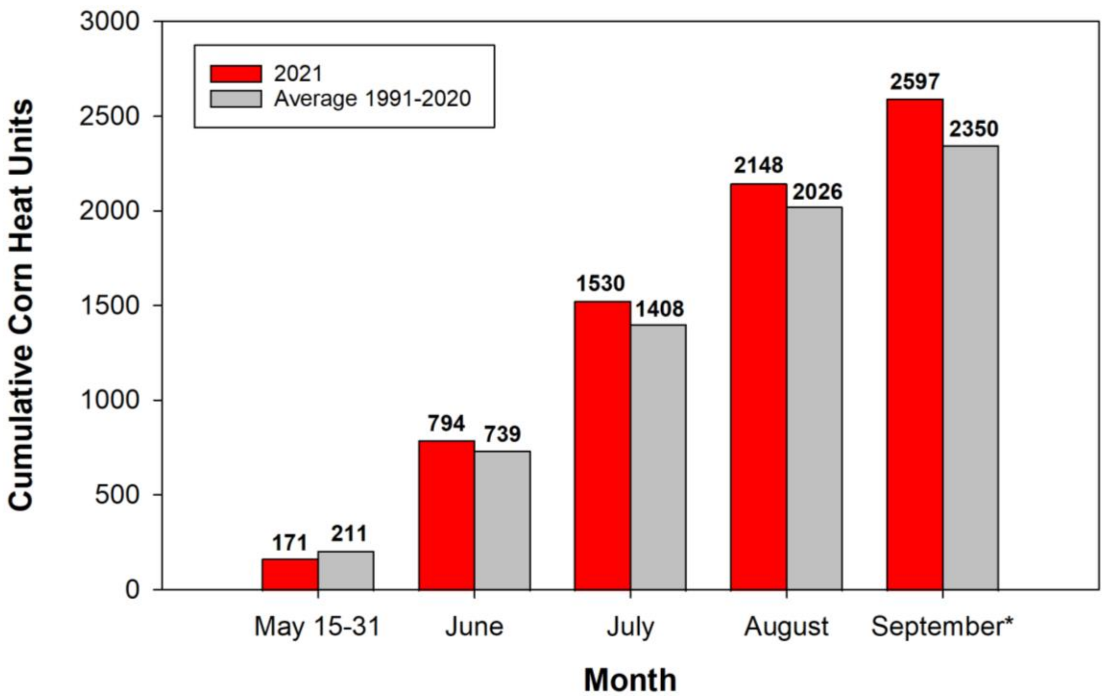

Figure 6. CSIDC cumulative corn heat units (CHUs) by month for 2021 and the 30-year average (1991-2020). An asterisk (*) denotes cumulative CHUs to September 30 or to the first killing frost (-2.0°C), whichever occurs first.

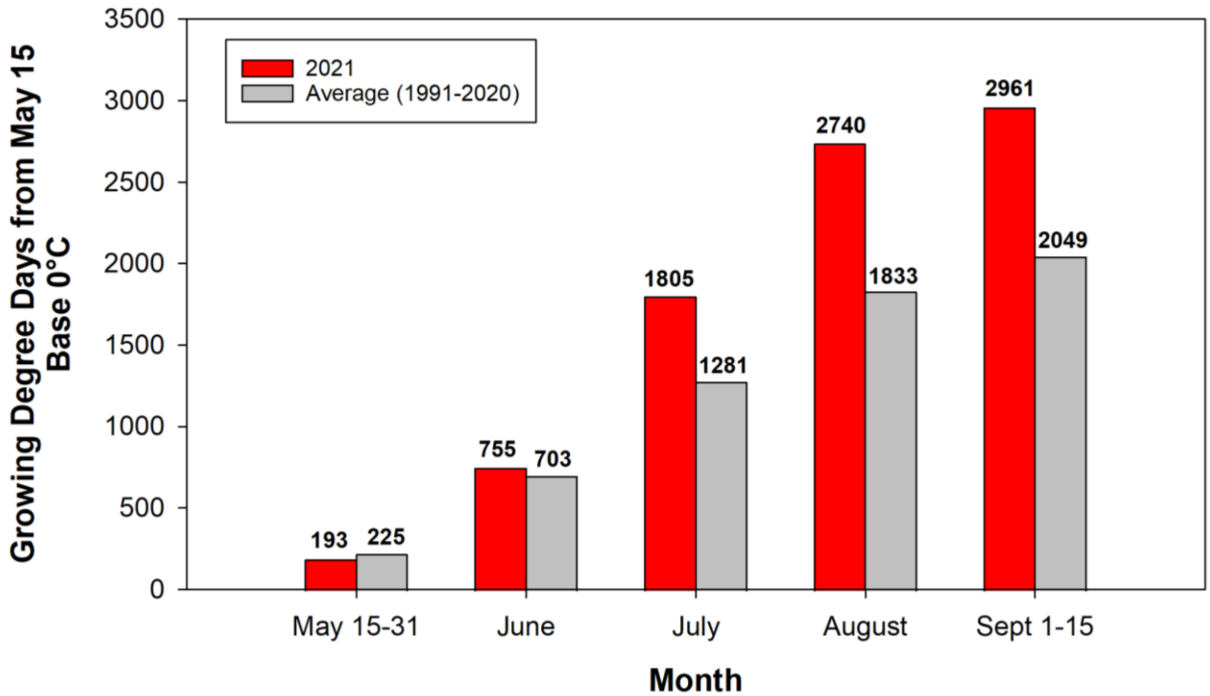

Figure 7. CSIDC cumulative growing degree days (Base 0°C) by month for 2021 and the 30-year average (1991-2020).

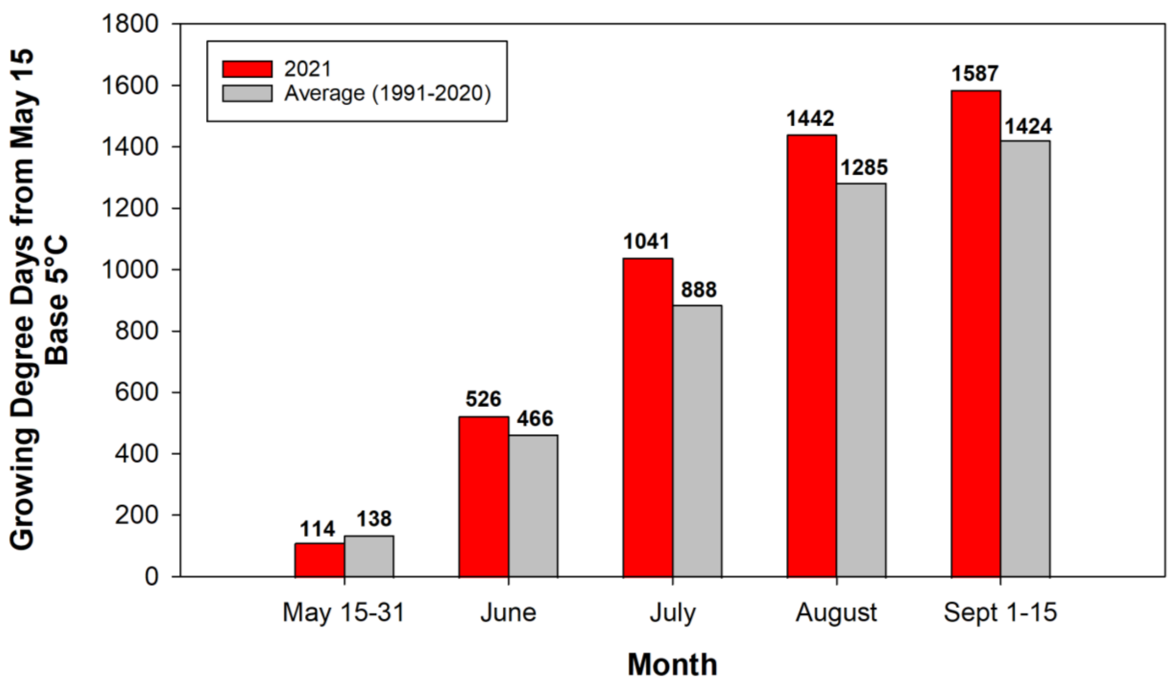

Figure 8. CSIDC cumulative growing degree days (Base 5°C) by month for 2021 and the 30-year average (1991-2020).

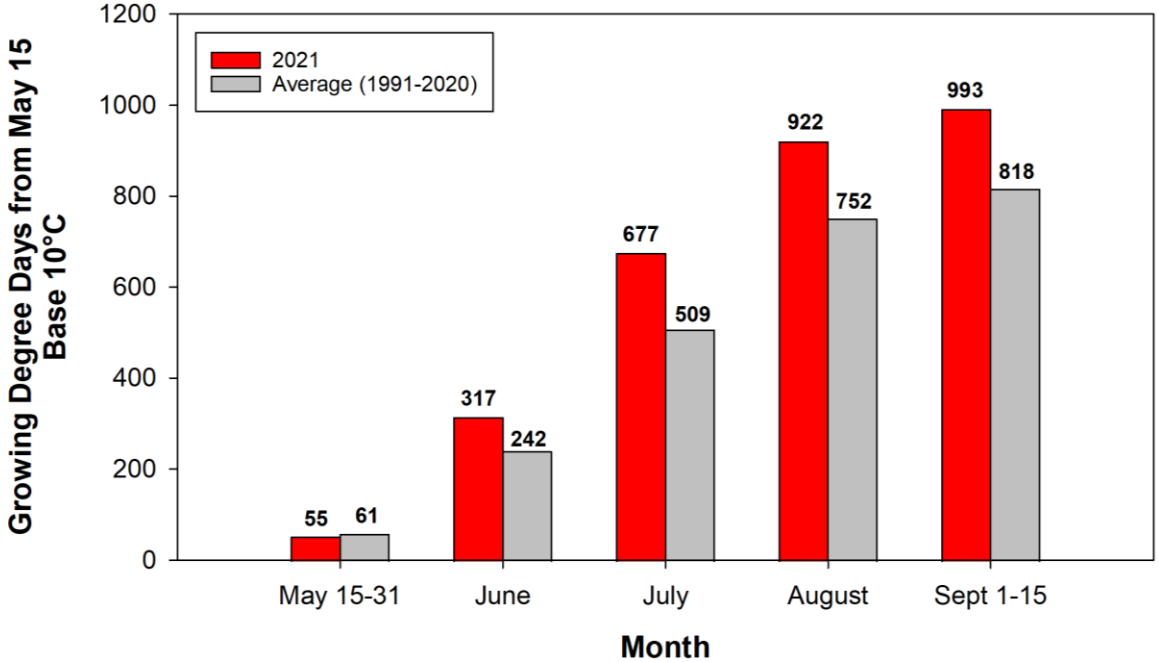

Figure 9. CSIDC cumulative growing degree days (Base 10°C) by month for 2021 and the 30-year average (1991-2020).

Irrigation Summary

Table 8. Irrigation depth applied at the CSIDC Main Station site during the 2021 field season.

Field #	Crop	Irrigation Depth Applied					Total Growing Season Irrigation	Total Water Applied
		May	June	July	August	Sept.		
		---------- mm ----------						
1	Wheat	0	87.5	187.5	12.5	75.0	287.5	362.5
2	Vegetables	0	50.0	37.5	25.0	0	112.5	112.5
3	Wheat	0	85.0	125	0	75.0	210.0	285.0
4 & 5	Soybeans	0	37.5	87.5	90.0	0	215.0	215.0
6	Wheat	25.0	25.0	0	0	0	50.0	50.0
7	Vegetables	32.5	100.0	48.5	37.5	0	218.5	218.5
7	Soybeans	0	37.5	50.1	25.0	0	112.6	112.6
8	Wheat	12.5	123.0	85.0	0	0	220.5	220.5
8	Corn	12.5	123.0	85.0	0	0	220.5	220.5
8	Dry beans	12.5	123.0	85.0	0	0	220.5	220.5
8	Lentils	12.5	123.0	32.5	0	0	168.0	168.0
8	Faba beans	12.5	123.0	85.0	0	0	220.5	220.5
8	Peas	12.5	123.0	65.0	0	0	200.5	200.5
9	Wheat	0	83.0	77.5	0	0	160.5	160.5
10	Irrigated soybeans	0	85.0	122.5	37.5	0	245.0	245.0
10	Wheat	0	105.0	97.5	0	0	202.5	202.5
11	Canola	0	37.5	100.0	25.0	0	162.5	162.5
11	Horseradish	0	50.0	87.5	25.0	0	162.5	162.5
11	Soybeans	0	37.5	112.5	25.0	0	175.0	175.0
12	Wheat	15	57.5	140.0	75.0	125.0	287.5	412.5
12	Peas	15	57.5	90.2	0	75.0	162.7	237.7
12	Trueman alfalfa	0	50.0	125.0	125.0	50.0	350.0	350.0

Table 9. Irrigation depth applied at the CSIDC Off-Station Demo site during the 2021 field season.

Quadrant	Crop	Irrigation Depth Applied					Total Growing Season Irrigation	Total Water Applied
		May	June	July	August	Sept.		
		---------- mm ----------						
NE	Canola/wheat	0	110.0	97.5	0	45.0	207.5	252.5
NE	ICDC cereal trials	15.0	110.0	110.0	0	0	235.0	235.0
NW	Soybeans	0	100.0	62.5	15.0	45.0	222.5	222.5
NW	Alfalfa	0	100.0	62.5	15.0	45.0	222.5	222.5
NW	Dry beans	0	115.0	77.5	0	15.0	192.5	207.5
SE	Wheat	0	135.0	102.5	0	50.0	237.5	287.5
SW	Canola	0	135.0	127.5	0	50.0	262.5	312.5

Technology Transfer Activities

Publications/Posters

- Saskatchewan Irrigation Scheduling Manual

Hosted Tours

- Hosted tours cancelled due to COVID-19 pandemic

Field Days

- In-person field days cancelled due to COVID-19 pandemic
- Crop Diagnostic School, Virtual, July 26-29, 2021
- Irrigation Saskatchewan Field Day, Virtual, November 2-3, 2021

Conferences, Workshops, Meetings

- CSIDC Exploring Future Direction Workshop, Virtual, March 18-19, 2021
- SIPA/ICDC Conference, Whitecap Dakota First Nation, December 7-9, 2021
- AAFC Phenomics Transformative Workshop, Virtual, November 26, 2021

FIELD CROP AGRONOMY

Evaluating the Effect of Seeding Date on Irrigation Requirements and Water Use Efficiency of Canola

Funded by Agriculture and Agri-Food Canada

Principal Investigator: Evan Derdall, AAFC-Saskatoon
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INTRODUCTION

Increasing crop yield per unit of water, defined as water productivity, requires improved cultivars and agronomic practices (Passioura, 2006). Often in research, the focus is on economic or yield improvements of selected cultivar or promoted agronomic practices, where water productivity is usually not investigated due to the perceived lack of value attributed to water conservation. Water, in Canada, does not have defined cost per unit volume. Any associated price is attributed to delivery and not the resource itself. As competition for water increases, the value associated with water should increase in turn; therefore, it is important for the sector to implement practices and select cultivars that utilize the resource efficiently.

Management practices such as irrigation scheduling has also been shown to result in improved water productivity. Low adoption rates of water productivity technologies and practices continue to be an issue despite these demonstrated benefits. For example, only 14% of irrigators in Alberta are using advanced scheduling methods (Wang et al., 2015). Low adoption rates of advanced irrigation scheduling methods are due to a number of barriers, including a lack of understanding of the economic and environmental benefits (Garvin 2014), equipment costs, ability or lack of access to information over the internet, lack of knowledgeable people and continuously evolving technology (Steele, 2017).

Conditions permitting, early May seeding for canola is generally recommended in most production areas of Western Canada. Compared to early-seeded canola, an average of 5.5% and 11.6% yield loss from mid and late-seeded canola, respectively, was reported from 26 station-years of data (Canola Council of Canada 2020). McKenzie et al. (2011) reported the effects of seeding dates for eleven cereals and oilseeds under irrigation in Alberta. The yield loss for canola (1.7% per day of seeding delay through May) was greater than for any other crop, but losses for the others were also substantial (from 0.6% to 1.3% per day for cereals and oilseeds respectively). Despite the generally recognized and sometimes large benefits of early planting, seeding is often delayed into late May and even early June. Between 2007 and 2018, an average of 43% of irrigated canola in Saskatchewan was seeded *after* the third week of May; in one year during the same period, 71% of the crop was seeded late (Saskatchewan Crop Insurance Corporation data).

Early versus late seeding results in very different environments for the crop in terms of weather, soil conditions, and day length at different stages of crop growth. These differences affect crop water requirements, water availability, and water losses – and hence, irrigation requirements and water use efficiency. Few studies to date have examined seeding date as a factor in crop water use and water use efficiency. Thus, the purpose of this study is to determine and compare irrigation requirements, water use, and water use efficiency for canola seeded in early, mid, and late May. Results will be used to better define water/irrigation requirements and water use efficiency for canola, which has the largest irrigated acres in Saskatchewan.

MATERIALS & METHODS

Study Site

The trial was established at the Canada-Saskatchewan Irrigation Diversification Centre (SW 15-29-08-W3) in Outlook, Saskatchewan (Figure 10). Soil samples taken to 120 cm depth were collected in the fall of 2020 and analyzed for a suite of physical and chemical properties (Table 10). The study site is a Bradwell Association soil that has been in irrigated annual crop production for many years. In 2021, total in-season rainfall was well below the long-term average while growing degree day heat accumulations and minimum and maximum temperatures generally exceeded monthly long-term averages.

Figure 10. Canola plots seeded early, mid, and late May at the Canada-Saskatchewan Irrigation Diversification Centre in Outlook, Saskatchewan.

Table 10. Characterization of various soil properties.

Soil Property	Depth (cm)	Value
NO_3^--N (ppm)	0 – 15	3.5
	15 – 30	3.0
	30 – 60	2.5
SO_4^{2-}-S (ppm)	0 – 15	12
	15 – 30	14
	30 – 60	25
P (ppm)	0 – 15	19
K (ppm)	0 – 15	186
pH	0 – 15	7.5
	15 – 30	7.9
	30 – 60	8.3
Soluble Salts (mmho/cm)	0 – 15	0.28
	15 – 30	0.33
	30 – 60	0.36
Organic Matter (%)	0 – 15	1.6
Texture	0 – 15	SiL‡

‡ SiL; silty loam

Experimental Setup

Canola (var. 340PC) was direct seeded into wheat stubble at a target rate of 100 plants/m^2 (adjusted for germination, estimated field emergence, and seed weight). Plots were seeded every two weeks starting with (i) Early on April 30, (ii) Mid on May 17, and (iii) Late on May 31. The trial was established with 11 m x 8 m plots in a randomized complete block design. Large plots were necessary to allow for a 5 m transition zone between seeding date treatments to prevent overspray of adjacent irrigation treatments into th harvest area. Each plot received 155 kg N/ha as side-banded urea (46-0-0) and 15 kg P_2O_5/ha as seed-placed monoammonium phosphate

(11-52-0). Irrigation water was applied with a Valley® linear system equipped with individually controlled low pressure rotator sprinklers. Each plot was irrigated with 4 individual sprinklers to allow for treatment-specific irrigation scheduling. Pest management consisted of post-emergence applications of Liberty® 150 SN herbicide (glufosinate ammonium; 1.35 L/ac), Proline® 480 SC foliar fungicide (prothioconazole; 140 mL/ac), and Decis® 5 EC insecticide (deltamethrin; 60 mL/ac).

Soil Moisture Readings

Gravimetric soil samples were collected from 0 to 90 cm depth at seeding, mid-season, and harvest using a Giddings soil sampling machine. Soil moisture monitoring occurred multiple times per week in each plot using (i) a POGO® Pro sensor inserted to 5 cm depth to monitor volumetric water content and (ii) WATERMARK® Soil Moisture Sensors installed at 30 cm and 60 cm depths to monitor soil water tension. A threshold of 50% soil available water capacity of a silty loam soil was used to determine irrigation requirements and scheduling for each seeding date. Monthly and total rainfall (from the on-site Environment & Climate Change Canada weather station) and irrigation accumulations for each seeding date are presented in Table 11.

Table 11. Monthly and total rainfall and irrigation.

Monthly and Total Moisture Accumulation (mm)	**Seeding Date**		
	Early	Mid	Late
------------------------- May -------------------------			
Irrigation	12.7	0.0	0.0
Rainfall	44.2	38.9	0.0
Total	56.9	38.9	0.0
------------------------- June -------------------------			
Irrigation	95.3	82.6	82.6
Rainfall	12.7	12.7	12.7
Total	108.0	95.3	95.3
------------------------- July -------------------------			
Irrigation	152.4	114.3	114.3
Rainfall	10.3	10.3	10.3
Total	162.7	124.6	124.6
------------------------ August ----------------------			
Irrigation	12.7	12.7	44.5
Rainfall	5.2	5.2	30.8
Total	17.9	17.9	75.3
---------------- Growing Season ----------------			
Irrigation	273.1	209.6	241.4
Rainfall	72.5	67.1	53.9
Total	345.6	276.7	295.3

Data Collection & Analysis

Plant emergence counts were assessed 2 to 3 weeks after seeding by counting four 1 m row sections in each plot to determine plants/m^2. Plant height was measured at flowering stage and calculated by averaging the crop height at two representative locations within the plot. Crop growth stages (i.e., start and end of flowering, maturity, swathing) were monitored and recorded throughout the growing season. Lodging was assessed prior to swathing by recording the percentages of plot area leaning (at 9–45° from vertical), lodged (at 45–85° from vertical), and lodged flat (at 85–90° from vertical) and used to calculate lodging index on a 0-100 scale (Roques and Berry 2015). Water use efficiency was calculated by dividing yield (kg ha^{-1}) by total water use (mm). Total water use was determined by summing rainfall, irrigation, and change in soil moisture over the growing season.

Seed from each plot was collected using a Wintersteiger plot combine to harvest a 8 m x 1.5 m swathed area. Harvested samples were dried and cleaned and yield results were adjusted to 10% moisture content. Seed moisture and oil content was measured using a FOSS Infratec™ 1241 Grain Analyzer. Test weight was determined by weighing the amount of grain in a half-litre cylinder and converting g 0.5 L^{-1} to kg hL^{-1} according to the grain's test weight conversion chart. Thousand kernel weight (TKW) was determined using a seed counter to establish a random sample, weighing the sample, and calculating grams per 1000 seeds.

Statistical Analysis

A one-way analysis of variance (ANOVA) was used to test the effect of seeding date on agronomic data and crop water use efficiency. Data was tested for assumptions of normality and homogeneity of variance and transformed if necessary. Means separation was performed using Tukey's HSD multiple comparisons test. Pearson correlation was used to determine the relationship between yield, total moisture, and water use efficiency. All statistical analyses were executed using the *car* (Fox and Weisberg 2019), *corrplot* (Wei and Simko 2017), *lmerTest* (Kuznetsova et al. 2017), *lme4* (Bates et al. 2015), *PerformanceAnalytics* (Peterson and Carl 2020), and *multcomp* (Hothorn et al. 2008) packages in RStudio v. 4.0.4 (R Core Team 2021) and visualized in SigmaPlot v. 14.5.

RESULTS & DISCUSSION

Yield, Seed Quality, and Plant Growth

Yield was significantly higher in the mid-seeded treatment (4,214 kg ha^{-1}) when compared to the early-seeded treatment (4,023 kg ha^{-1}) (Table 12, ANOVA, $P \leq 0.05$). The mid and early-seeded treatments did not differ from the late-seeded treatment. Based on the literature review, yield was expected to decrease as seeding was delayed so our results were not in agreement. In terms of seed quality, test weight was highest in the mid-seeded treatment, seed weight was highest in the early-seeded treatment, and oil content was not influenced by seeding date. As seeding date was delayed from early to late May, plant height increased but did not result in higher lodging incidence.

Table 12. Effect of seeding date on emergence, yield, seed quality (oil, test weight, seed weight), plant height, and lodging. Different letters indicate significant differences between seeding dates (ANOVA, *P* ≤ 0.05). Significant *P* values are highlighted by bold and underlined text.

Seeding Date	**Emergence** ($plants/m^2$)	**Yield** (kg/ha)	**Oil** (%)	**Test Weight** (kg/hl)	**Seed Weight** (g/1000 seeds)	**Height** (cm)	**Lodging** (1=erect; 100=flat)
Early	77.5 *a*	4,023 *a*	47.6 *a*	65.2 *a*	3.8 *b*	107 *a*	34 *a*
Mid	86.3 *a*	4,214 *b*	46.7 *a*	67.0 *b*	3.6 *a*	118 *b*	46 *a*
Late	93.0 *a*	4,203 a*b*	46.9 *a*	65.8 *a*	3.5 *a*	133 *c*	54 *a*
P-value (0.05)	0.188	**<u>0.036</u>**	0.074	**<u>0.002</u>**	**<u>0.011</u>**	**<u>0.002</u>**	0.071

DAP = days after planting

Crop Growth Stages

Not surprisingly, crop growth stages (i.e., start of flowering, end of flowering, swathing) were influenced by seeding date (Figure 11; *P* ≤ 0.05; Figure 12). For example, days to the start of first flower were 51, 45, and 36 for the early, mid, and late-seeded treatments, respectively. Days to end of flowering and swathing followed a similar trend. By swathing, there was 6 to 7 days difference between the mid and late/early-seeded treatments and 12 days difference between the early and late-seeded treatments.

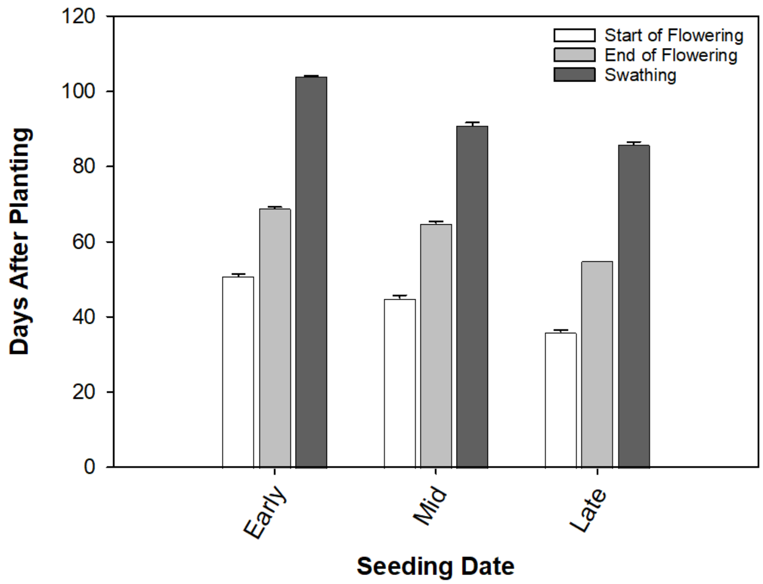

Figure 11. Days to the start of flowering, end of flowering, and maturity for each seeding date treatment. Differences were significant between treatments (ANOVA, P ≤ 0.05).

Figure 12. Crop growth stages on June 24, 2021. Early-seeded treatments at flowering stage, mid-seeded treatments at rosette/early bolting stage, and late-seeded treatments at 4-to 6-leaf stage.

Water Use Efficiency

Compared to the early-seeded treatment, the mid and late-seeded treatments had higher yield and lower water use, resulting in a higher water use efficiency (Figure 13, ANOVA, $P \leq 0.05$). Water use efficiency was positively correlated with yield, height, lodging, and total moisture and negatively correlated with oil content and seed weight (Table 13, $P \leq 0.05$). In a dryland canola trial conducted by Angadi et al. (2004), canola seeded late April had greater WUE when compared to canola seeded late May.

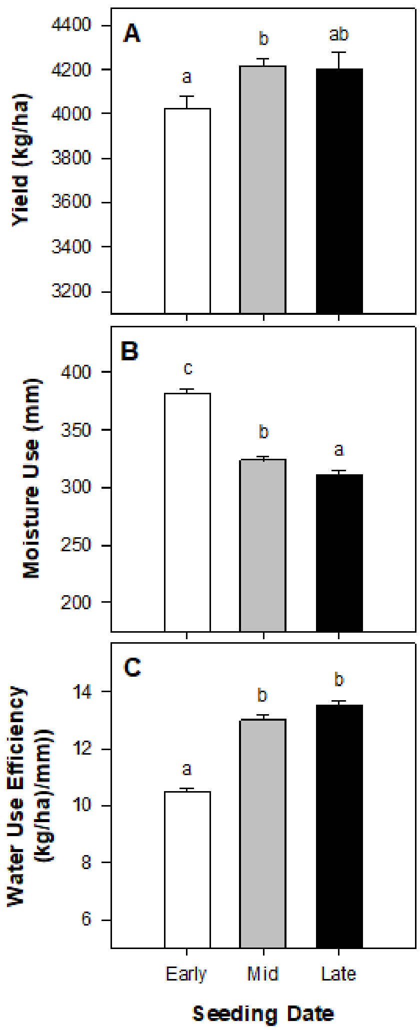

Figure 13. Yield (kg ha^{-1}), total moisture use (mm), and water use efficiency (kg ha^{-1}) mm^{-1})) at early, mid, and late-seeding dates. Different letters indicate significant differences between treatments (ANOVA, P ≤ 0.05).

Table 13. Pearson correlation coefficient (*r*) values between water use efficiency and various agronomic and environmental factors. Bold and underlined text indicates significance at *P* ≤ 0.05.

Factor	Pearson correlation coefficient (*r*)	Pr (> F)
Emergence	0.38	0.227
Yield	**0.72**	0.009
Oil	**-0.61**	0.036
Test Weight	0.54	0.069
Seed Weight	**-0.80**	0.001
Height	**0.80**	0.001
Lodging	**0.61**	0.034
Total Moisture	**0.97**	< 0.001

CONCLUSIONS AND NEXT STEPS

In 2021, yield and WUE was highest in mid and late-seeded canola.

This second year of this trial will be established in 2022.

Improving the Management of Sclerotinia Stem Rot of Canola Using Fungicides and Better Risk Assessment Tools

Funded by the Canola AgriScience Cluster

Principal Investigator: Dr. Kelly Turkington, AAFC-Lacombe
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INTRODUCTION

Sclerotinia stem rot of canola (*Brassica napus* L.) is an economically devastating disease caused by *Sclerotinia sclerotiorum* (Lib) de Bary. Epidemics of this disease can be devastating because of its wide host range, long lived resting structures (sclerotia) and potential for windborne ascospores to be spread from neighbouring fields. These factors coupled with conducive environmental conditions cause disease outbreaks to be unpredictable, with disease levels varying from field to field and year to year. Conditions that favour disease development are cool and wet, with the optimum temperature ranging between 7˚C – 30˚C. Previous methods for control have offered some reprieve from Sclerotinia symptoms, but the most reliable method continues to be routine fungicide applications. Traditionally, growers manage Sclerotinia stem rot by applying fungicides to coincide with early canola flowering, with the goal of covering as many flower petals as possible to prevent the disease from penetrating the host plant once the petals fall into the canopy.

Existing risk assessment systems have attempted to provide producers with more insight as to the risk of disease development, as Sclerotinia only displays symptoms after the disease has penetrated the plant, fungicide application needs to be done prior to symptom development to be effective. Current systems in use include risk checklists, which base their assessments on previous Sclerotinia infections, cropping history and recent weather events, as well as other factors. However, even with these check systems in place, producers make spray decisions with a large degree of uncertainty.

Recent research investigating pathogen levels via qPCR analysis on petals coupled with assessment of factors known to influence disease pressure, like relative humidity and temperature, shows promise in terms of stem rot risk predictions. Development of qPCR for stem rot has allowed for a more timely and accurate DNA based risk assessment versus older approaches such as agar plate petal testing, thus giving producers a more informed spray decision. Some companies are offering petal based DNA tests, while others offer a result based on airborne ascospore levels determined with spore traps positioned above the canola canopy. The research will refine the use of qPCR, and evaluate the utility of existing commercial PCR tools and spore trapping methods, while improving our ability to manage stem rot using fungicides.

Objectives:

1. refining the use of qPCR analysis and investigating the potential of utilizing spore traps instead of canola petals;
2. understanding the role and impact of RH, rainfall, and temperature on inoculum production and disease development;
3. evaluating the efficacy of very early applications alone or in conjunction with later applications of fungicide for management of stem rot;

4. developing a better understanding of factors (i.e., seeding rate) that influence crop development and variability in flowering and how this influences fungicide response at various crop growth stages; and
5. developing a better understanding of how inoculum availability and environmental conditions prior to and during the flowering period influence stem rot risk and the efficacy of fungicide application.

MATERIALS & METHODS

Study Site

The trial was established at CSIDC (SW 15-29-08-W3) in Outlook, Saskatchewan (Figure 14). In 2021, total in-season rainfall was well below the long-term average while growing degree day heat accumulations and minimum and maximum temperatures generally exceeded monthly long-term averages. Of the 286.2 mm of moisture received during the growing season, 98.2 mm was precipitation and 188.0 mm was irrigation.

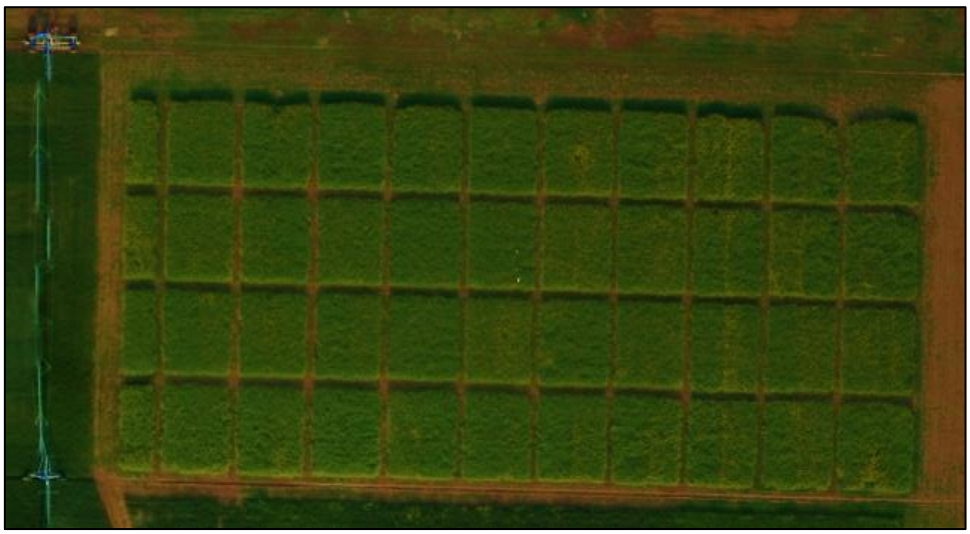

Figure 14. Sclerotinia trial established at CSIDC in 2021.

Experimental Setup

On May 18, canola (L234PC) was direct seeded into lentil stubble at target rates of 60 and 120 plants/m^2 (adjusted for germination, estimated field emergence, and seed weight). The trial was set up as a factorial arrangement of treatments (two seeding rates x nine fungicide treatments) using a randomized complete block trial with four replications (Table 14). Plots were 4 m x 10 m; one half of the plot was used for destructive sampling and the other half was harvested. Each plot received 125 kg N/ha as side-banded urea (46-0-0), 25 kg P_2O_5/ha as seed-placed monoammonium phosphate (11-52-0), and 10 kg S/ha as seed-placed ammonium sulphate (21-0-0-24). Irrigation water was applied with a Valley® linear system. Pest management consisted of a pre-emergence application of Roundup® (glyphosate; 900 g a.e/ac) herbicide on May 4 and post-emergence applications of Liberty® 150 SN (glufosinate ammonium; 1.6 L/ac) and Centurion (clethodim; 60 mL/ac) herbicides on June 16. Proline® 480 SC foliar fungicide (prothioconazole; 140 mL/ac) was applied on various dates according to treatment requirements.

Table 14. Treatments used in factorial arrangement.

Seeding Rate	Fungicide Treatment
60 plants/m^2	Check (no fungicide)
120 plants/m^2	Yellow bud stage (YB)
	YB + 1 week
	YB + 2 weeks
	YB + 3 weeks
	YB + 4 weeks
	YB & YB + 2 weeks
	YB & YB + 3 weeks
	YB & YB + 4 weeks

Data Collection & Analysis

Plant emergence counts were assessed 2 to 3 weeks after seeding by counting four 1 m row sections in each plot to determine plants/m^2. Crop growth stages (i.e., yellow bud, start and end of flowering, maturity, swathing) were monitored and recorded throughout the growing season. Sclerotinia incidence and severity was assessed in-crop, as well as sclerotial contamination of harvested grain samples and associated dockage using Canadian Grain Commission protocols. Lodging was assessed prior to swathing by recording the percentages of plot area leaning (at 9–45° from vertical), lodged (at 45–85° from vertical), and lodged flat (at 85–90° from vertical) and used to calculate lodging index on a 0-100 scale (Roques and Berry, 2015).

Rainfall, temperature and relative humidity (RH) data was collected from the Environment and Climate Change Canada weather station for the entire growing season. In-crop RH and temperature data was monitored in a check plot using a Hobo Weather Station starting prior to the rosette stage and continuing until disease assessments were performed. During the same period, ambient RH and temperature data was also monitored outside of the check plot and adjacent to the in-crop equipment using a Hobo Weather Station.

Samples were collected weekly via spore traps set up in the check plots, starting just prior to the rosette stage of development and continuing until the end of flowering. Samples of fully expanded canola petals in the check plots were also collected weekly, starting as soon as petals were present. Spore trap and petal samples were stored under appropriate conditions until qPCR analysis could be performed.

On August 30, seed from each plot was collected using a Wintersteiger plot combine to harvest a 10 m x 1.5 m swathed area. Harvested samples were dried and cleaned and yield was determined. Seed moisture was measured using a FOSS Infratec™ 1241 Grain Analyzer. Thousand kernel weight was determined using a seed counter to establish a random sample, weighing the sample, and calculating grams per 1000 seeds.

RESULTS & DISCUSSION

General Weather Conditions

In May 2021, temperatures for most of the prairie region were +/-2°C from normal to near normal. In June 2021, most of the prairie region was near normal to +4°C above normal. July temperatures in 2021 were generally close to normal to +3°C from normal, although some larger areas in NE and southern Saskatchewan and areas of southern Alberta were up to +4°C above normal. However, in south and west central Saskatchewan and central to southern Alberta were 2°C from normal to near normal. In August 2021, most of the Prairie region was from -2°C to +2°C from normal.

In May 2021, most of Alberta and Saskatchewan had 60 to 150% of normal precipitation, while areas in the Regina, Edmonton, SE Alberta and SW Saskatchewan regions had 115 to > 200% of normal precipitation. For June 2021, most of Alberta and large areas of central to western Saskatchewan had 85 to < 40% of normal precipitation. Other Prairie regions had from 85 to 150% of normal precipitation. In July 2021, most of the Prairie region was extremely dry with only 85 to < 40% of normal precipitation, although there were small areas in the northern Peace River and Calgary regions with higher precipitation levels. In August 2021, prairie precipitation levels were increased with most of the Prairie region having 85 to > 200% of normal precipitation.

Fungicide Trials

Weather conditions impacted sclerotinia risk at sites in 2021. Dry conditions limited inoculum production and disease development. In the UK, Young et al. (2020) reported the use of relative humidity measurements to indicate a risk of infection whereby ambient relatively humidity (RH) needs to be 80% or above for 23 hours for potential infections to occur. Due to mainly dry conditions at most sites in 2021, hourly RH levels of ≥ 80% generally remained below the 23 hour threshold (Figure 15). However, in-canopy RH more frequently approached or met this threshold, while generally being higher on many dates compared with ambient RH levels (Figure 15).

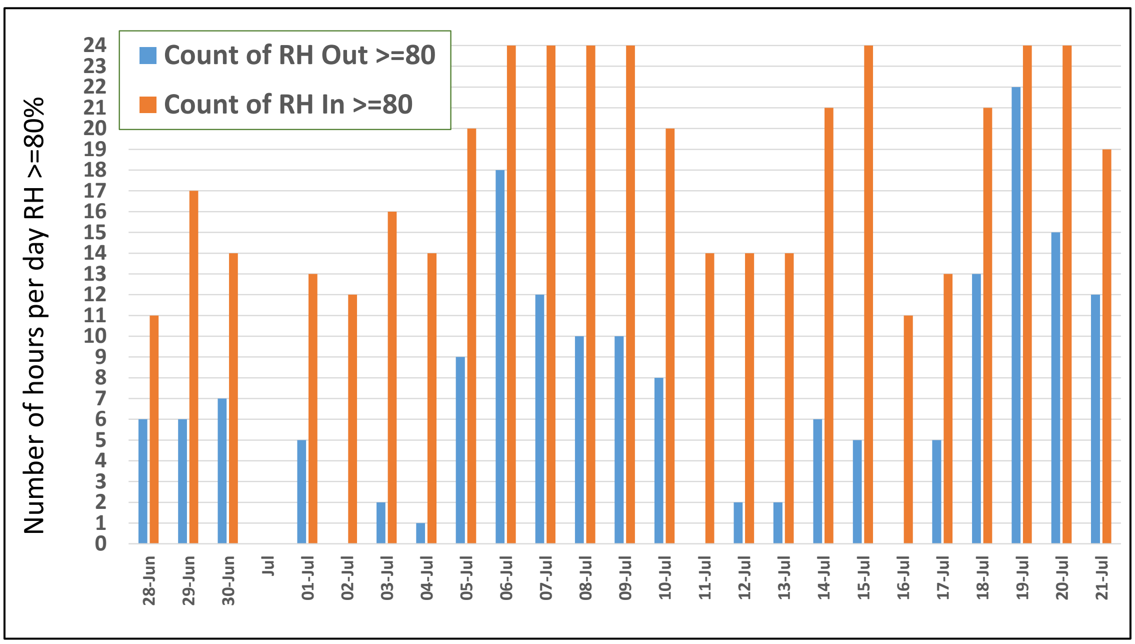

Figure 15. Number of hours per day where the in-canopy (orange) and ambient (blue) relative humidity (RH) was ≥80% during the flowering period, Outlook, SK.

Overall, drier weather conditions and generally no to trace stem rot inoculum resulted in limited treatment effects occurred at most sites. The treatment that most affected response variables was seeding rate. For example, at Outlook, the high seeding rate shortened the period of flowering slightly versus the lower seeding rate and lodging was reduced with the higher seeding rate (Table 15). There were limited treatment effects on grain parameters at Outlook. At other sites, improvements in yield may have reflected improved weed competitiveness, while reductions may have reflected somewhat drier conditions and increased competition for moisture.

Table 15. Analysis of variance for the effect of seeding rate, and fungicide timing on flowering dates, maturity, lodging, yield and grain parameters, and stem rot incidence and severity, Sclerotinia fungicide timing experiment, Outlook, SK.

Effect	First date of flowering (Julian date)		Last date of flowering (Julian date)		Maturity (Julian days)		Lodging index		Yield (bu/ac)		Thous. seed weight (g, TSW)		Oil (%)		Protein content (%)		Stem rot incidence/ severity
Seeding rate, seeds m^{-2} (SR)	*P=1.000*		***<.0001***		*0.4146*		***<.0001***		*0.4172*		*0.5417*		*0.8364*		0.2337		*ND***
60	179	A*	201.9	A	223.7	A	24.7	B	65.6	A	2.9	A	46.2	A	25.0	A	ND
120	179	A	200.0	B	223.5	A	55.3	A	67.4	A	2.9	A	46.2	A	25.1	A	ND
Fungicide timing (FT)	*P=1.000*		*0.4476*		*0.1180*		*0.2012*		*0.8115*		*0.4270*		*0.4651*		0.6733		*ND*
Check (CK)	179	A	201.0	A	223.8	A	44.2	A	64.2	A	2.8	A	46.2	A	25.1	A	ND
Yellow bud (YB)	179	A	201.0	A	222.9	A	41.6	A	63.5	A	2.9	A	45.9	A	25.3	A	ND
YB+1 week	179	A	201.0	A	223.0	A	41.7	A	69.7	A	3.0	A	46.0	A	25.2	A	ND
YB+2 weeks	179	A	201.0	A	224.1	A	44.0	A	68.9	A	3.0	A	46.3	A	25.0	A	ND
YB+3 weeks	179	A	201.0	A	223.5	A	41.9	A	67.7	A	2.9	A	46.0	A	25.0	A	ND
YB+4 weeks	179	A	201.0	A	224.5	A	39.8	A	68.9	A	2.9	A	46.3	A	25.1	A	ND
YB & YB2	179	A	200.8	B	223.4	A	38.5	A	65.1	A	2.9	A	46.3	A	24.8	A	ND
YB & YB3	179	A	201.0	A	223.9	A	30.4	A	67.0	A	3.0	A	46.3	A	25.0	A	ND
YB & YB4	179	A	201.0	A	223.3	A	37.9	A	63.5	A	2.9	A	46.3	A	25.0	A	ND
SR*FT	*P=1.000*		*0.4476*		*0.9641*		*0.7636*		*0.5620*		*0.1893*		*0.6824*		*0.6244*		*ND*

*Means within each two treatment combination that are followed by different letters were significantly different based on the ANOVA (P<0.05), while for treatment combinations with more than two levels the means that are followed by different letters were significantly different according to the lsmeans pdiff procedure. **No data available. *** Low disease and no ratings performed due to this.

In general inoculum levels measured via the petal tests and rotorod assessments were low, although occasional spikes in spore loads did occur. At Outlook, the average amount of *Sclerotinia sclerotiorum* DNA (ng DNA) per petal peaked at 0.000095 at full bloom. Similar low levels of inoculum were also observed using the Spornado where all sample results were either not detected or at the limit of detection prior to and during the flowering period (data not shown), while the Discovery Seed Labs petal test also had generally low levels of petal infestation at most sites for early, full, and late bloom. At Outlook, petal infection levels were 7.1% at early bloom, 28.6% at full bloom, and 0.0% at late bloom. Somewhat higher levels of petal infestation were detected around full bloom for the Quantum Genetix petal tests at some of the Alberta sites, but not at Outlook which had only 6.3% petal infection. The infrequent presence of sufficient *S. sclerotiorum* inoculum coupled with unfavourable RH conditions restricted disease development in 2021.

CONCLUSIONS & NEXT STEPS

Given weather conditions and limited inoculum, there was limited disease development at most sites and no effects of fungicide timing and their interaction on yield. It is interesting to note that trial sites at both Outlook, SK and Brooks, AB were irrigated, yet inoculum loads and weather conditions were not overly favourable for stem rot development. For example, at Outlook there were some dates, from around mid to late flowering, where increased inoculum was detected, but RH conditions were not conducive to infection, with most dates having under 21 hours per day with RH ≥ 80%. Perhaps at Brooks and Outlook, where warmer dry conditions normally prevail, the addition of irrigation wasn't sufficient enough in 2021 to substantially increase the risk of stem rot of canola. Overall, results in 2021 and from some sites in 2019 indicate that when the risk of stem rot is low, based on weather and inoculum conditions, fungicide application is not needed and provides no crop productivity or economic benefit in terms of yield. Moreover, the purported "stay green" effect of fungicide application is not of benefit, as maturities were also not impacted by fungicide application. The "stay green" effect would be primarily associated with controlling disease when the risk is high enough and thus maintaining green healthy plant tissues that can contribute to grain filling and yield.

In general, final stem rot levels generally reflected measurements of inoculum levels using the Rotorod and via petal testing. Preliminary results from the fungicide trial suggest that the frequent occurrence during the flowering period of a minimum of 0.0001 ng *S. sclerotiorum* DNA per petal or per cu m^3/hour, combined with favourable moisture conditions (i.e., ambient RH ≥ 80%) and cooler temperatures, are needed for outbreaks of stem rot that may warrant fungicide application. The Spornado technology is promising based on results from 2021, but in 2019 (fungicide trials and M.Sc. student project) and 2020 (M.Sc. student project) for some sites with limited disease, Spornado risk values were in the moderate range. However, it must be stated that the Spornado technology is quite new and more research is needed to determine how Spornado results relate to stem rot risk and potential need for fungicide application. Given the simplicity of the technology, further refinements in DNA testing have the potential to improve the utility of this technology. The potential use of qPCR to provide more quantitative, rather than qualitative, results may help to clarify spore loads in the detected category where they may correspond to low, moderate and high stem rot risk.

Based on the preliminary results of the current project, producers should monitor inoculum levels prior to and during the flowering period, along with in-field ambient and/or canopy RH levels. As reported by Young et al. (2018), we also found that a RH > 80% was associated with increased stem rot incidence, while a RH < 80% was associated with lower disease incidence that would typically not require a fungicide application. Measurements of RH could be coupled with inoculum assessments based on spore trapping or petal testing, wherein 1.0×10^{-4} ng DNA per canola petal or per cubic meter of air per hour during early flowering would be expected to result in a disease incidence > 15%, at which fungicide is recommended. Spore trapping and monitoring of RH in the two weeks prior to the start of flowering would provide an indication of developing disease risk, where fungicide application might be needed at early flower.

Based on the results, only one spore sampler may be needed per field for a reasonable estimate of airborne ascospore levels, which can limit costs. The location of such a spore trap could either be central, providing better exposure to airborne inoculum from all areas of the field, or in a downwind area of the field, depending on the prevailing wind direction. Petal samples are generally collected throughout the field, so variability in results is less of a concern. The levels of sclerotinia stem rot were similar across each field in 2019 and 2020, with differences in disease only significant in 2019. However, there was variability in stem rot severity between locations within the Grid fields. In both years, disease exceeded the 15% incidence required for a fungicide application; however, fertility levels, variable in-canopy environmental conditions and crop lodging, along with other variables, may also affect final disease in a field. As such, multiple risk assessment tools are warranted, including some form of measuring inoculum levels and RH, to provide the most robust predictions for stem rot in canola.

Advances in DNA-based technologies, refined pathogen identification and a rapid turnover for results can greatly improve our ability to predict *S. sclerotiorium* inoculum loads and stem rot risk in canola (Ziesman 2016; Ziesman et al. 2016). Further refinements in testing procedures to indicate risk and severity of stem rot may improve current forecasting models. Ultimately, measures of ascospore inoculum levels, while important, need to be considered together with environmental conditions and field history. An integrated forecasting system, which takes into account all components of the disease triangle, will be most effective for predicting Sclerotinia stem rot of canola as well as other diseases.

Meeting the Soybean Protein Meal Standard in Western Canada

Funded by Canadian Field Crop Research Alliance

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Co-Investigators: Dr. Patrick Mooleki, AAFC-Saskatoon
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INTRODUCTION

The Canadian Grain Commission Report: Quality of Canadian Oilseed Soybean clearly shows lower protein content in Western Canadian samples versus Eastern samples. In 2016, samples from the eastern provinces of Canada typically showed higher protein content than samples from Western Canada (Prairie protein 36.4% versus Ontario 42.1% and Quebec 42.6%). Lower protein is also an issue in the US Midwest where the lowest protein is seen in the Dakotas and Minnesota but protein content increases as you move south (Rotundo et al., 2016). Typically there is a negative relationship between seed yield and seed protein in soybean (Burton et al., 1987). In some Ottawa high protein germplasm, we have observed less of a protein-yield relationship (Cober et al., 2000). Sulfur containing amino acids limit the feed value of soybean meal (Krishnan et al., 2005) and since the 11S fraction contains more sulfur-containing amino acids compared to the 7S fraction, we will examine environmental effects on protein subunit composition.

We will examine the seed protein differences across Canada and determine the seed protein yield relationship within a protein range high enough to meet meal standards in Western Canada, examine environmental effects on protein subunit composition (since the 11S fraction contains more sulfur-containing amino acids compared to the 7S fraction, a feed quality parameter) and understand the role of environmental parameters, through modelling, on seed protein to inform future breeding objectives.

There is a knowledge gap in the current understanding of protein biosynthesis mechanisms in soybean. We do not know all the key players (genes) and, more importantly, we do not have a clear understanding of environmental factors affecting the quantity and quality of seed protein production. Using a genomics approach, we will investigate the interactions between the environment and the soybean genome. Environmental variation plays an important role in differential gene expression, which can alter biochemical pathways such as seed protein production. We plan to examine the role of environmental variation on seed protein production in Western versus Eastern Canadian soybean. For this work, we propose to use RNA sequencing (a well-established high-throughput technique) to investigate the quality and quantity of RNA (differential gene expression) from selected soybean lines grown (in the trials in Objective 1) in three different locations in Eastern and Western Canada (Severin et al., 2010; Rabelo et al., 2016). We will use the results of the RNA sequencing to select genes that are likely to be influenced by environment.

We will investigate candidates selected through RNA sequencing and quantitative PCR analysis to determine through which pathways (phosphorylation, methylation, or protein-protein interactions) the environment affects the expression of these genes. It has been shown that environmental factors influence the phosphorylation of transcription factors, which can up or down regulate the expression of downstream genes. We will determine whether phosphorylation could be mediating the effects of the environment on gene expression by performing phosphorylation assays. Protein phosphorylation assays show the phosphorylation stage of proteins. DNA methylation is also known to be affected by environmental factors, and to affect differential gene expression. As an alternative or complementary method to phosphorylation assays, we will investigate DNA methylation in different environmental conditions to identify genes affected by environment factors at DNA level. Finally, we will use protein-protein interaction (PPI) analysis to investigate the influence of environmental factors on PPIs.

We will investigate environmental effects on two groups of genes: (1) those that are involved in protein pathways and are directly influenced by environmental variation (differential gene expression); and (2) those that code for proteins that are altered by environmental factors and have regulatory influence on the expression of other genes. Finally, we will look for genetic variation (SNP, coding sequence or regulatory region variations, etc.) in the selected genes, and test the performance (e.g. seed protein content) of different variants in different locations (Eastern and Western Canada) that have different environmental conditions. In this way, we will be able to select best-fitting genotypes (select versions of genes which work better in Western Canada). Identification and characterization of genes involved in protein pathways and influenced by environmental variations between Eastern and Western Canada will lead to allele-specific marker development (for marker-assisted selection) and identification of the alleles that will best enhance soybean breeding programs for seed protein content in specific locations, targeting Western Canada and Northern Regions.

Objectives:

1. Understanding the soybean protein-yield relationship across Canada (agronomy)
   - past and ongoing work has shown some lower protein levels in Manitoba compared to Ontario
   - a series of 20 low to high protein lines (checks and experimentals) will be grown from Saskatchewan to Quebec to 1) measure seed protein and agronomy differences across Canada, 2) determine whether there is a yield penalty with seed protein high enough to meet meal standards in Western Canada, 3) determine environmental effects on protein subunit composition, and 4) model the role of environmental parameters on seed protein to inform future agronomy and breeding objectives
2. Understanding soybean protein gene expression patterns West to East (genomics)
   - use the same low to high protein varieties grown in eastern and western Canada to investigate expression of genes involved in the protein synthesis pathway to 1) find genes with differential geographic expression, and 2) find genes that are affected by environment which in turn control expression of other genes, called modifier genes (type 2 genes are upstream of type 1 genes)
   - look for allelic variation (different versions) of any genes that have different geographic expression, these can be tested east and west to look for genotype x environment interactions
   - there may be versions of genes which work better in Western Canada
   - develop allele specific markers for favourable protein alleles

MATERIALS & METHODS

The trial was grown at ten sites in 2021 with a series of 19 low to high protein lines and a non-nodulating line. At CSIDC, the wheat stubble in the trial area was tilled in the fall of 2020. On May 18, 2021, 20 soybean varieties were seeded under both dryland and irrigated conditions at CSIDC (Figure 16). Plot size was 1.75 m x 5 m with 25 cm (10 inch) row spacing. Each plot received 25 kg P_2O_5/ha as seed-placed monoammonium phosphate (11-52-0) and the recommended rate of TagTeam® inoculant. Seed was treated with Apron Maxx® RTA® fungicide (fludioxonil + metalaxyl-M and S-isomer; 325 mL/100 kg seed), and Sombrero® 600 FS (imidacloprid; 200 mL/100 kg seed). Irrigation water was applied to the irrigated plots with a

Valley® linear system. Pest management consisted of a pre-emergence application of Edge® Microactiv® herbicide (ethalfluralin; 8.5 kg/ha) on May 13 and Viper® ADV herbicide (imazamox; 400 mL/ac) plus UAN (28-0-0; 0.81 mL/ac) on June 18. Dryland plots were harvested on September 29 and irrigated plots were harvested on October 5. The dryland trial received 100 mm total moisture (rainfall) and the irrigated trial received 345 mm total moisture (irrigation + rainfall).

Figure 16. Irrigated soybean protein trial established at CSIDC in 2021.

RESULTS & DISCUSSION

Objective 1

Averaged across all varieties under dryland conditions, emergence was 53% on June 24, days to flowering was 46 days, days to maturity was 122 days, lodging index was 0.4 (on a 1-4 scale), height was 85 cm, and yield was 1,987 kg/ha. Averaged across all varieties under irrigated conditions, emergence was 69% on June 24, days to flowering was 47 days, days to maturity was 128 days, lodging index was 1.8 (on a 1-4 scale), height was 107 cm, and yield was 3,122 kg/ha. The average yield reduction for each 1% increase in protein was 45.3 kg/ha for Eastern Canada, 53.1 kg/ha for Eastern Prairies, and 78.4 kg/ha for Outlook/Saskatoon. Figure 17 shows the seed yield and seed protein for Saskatoon/Outlook. A genotype by location bi-plot for seed protein content showed weak east-west sorting of locations. Data also indicated that the high protein line performs well across all locations without a genotype by environment rank change for seed protein. The winning protein-yield cultivar was earlier maturing in Outlook/Saskatoon compared to the Eastern Canada group. Seed protein quality, as measured by the 11S:7S ratio, was independent of seed protein concentration. For the food soybean industry, higher 11S:7S ratios are preferred as they generally produce firmer tofu. For the feed industry, 11S protein subunits have more of the sulfur-containing amino acids methionine and cysteine. Higher 11S:7S protein quality is seen in Western sites compared to Eastern Canada sites. The favourable seed protein quality seen in Western locations should be encouraging for companies expanding food-type exports from Western Canada and also for livestock feed formulators.

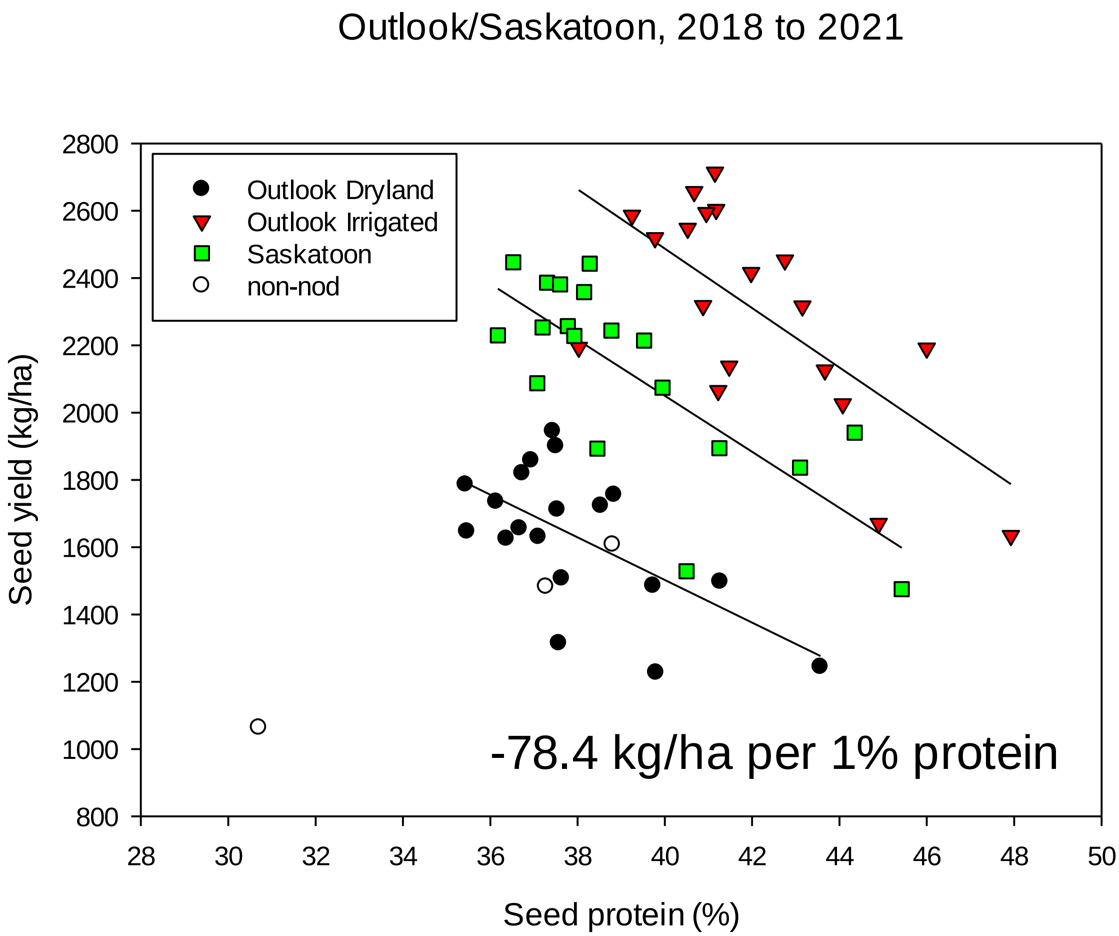

Figure 17. Mean seed yield and protein for the Saskatoon/Outlook site over the four years of the study (2018 - 2021). The 19 low to high soybean lines were used in the yield protein regression. The mean slope of the yield-protein is shown within the panel and is the mean over all locations in that zone. The data for the non-nodulating line is also shown in each panel.

Objective 2

Ten soybean lines from Objective 1 were sampled at four locations across Eastern and Western Canada: Ottawa ON (control), Brandon MB, Morden MB, and Saskatoon SK for the RNA-seq protein project. Preliminary results indicate significantly different expression, in genes involved in lipid pathways, is evident between soybeans from Ottawa and the West, as well as significant differences in expression of genes encoding seed storage proteins.

CONCLUSIONS & NEXT STEPS

In 2022, further analysis of the data is required to determine the role of weather conditions and derived ag met variables on the yield and protein content of soybean at the various locations in eastern and western Canada.

Putting Soil Residual Nitrate to Work – Variable and Deep Nitrate

Funded by Saskatchewan Agricultural Development Fund

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INTRODUCTION

The value of soil residual mineral nitrogen (N; primarily as nitrates [NO_3^-]) as a source of N to the following crop in environments like the Canadian Prairies has long been known. The relatively low rainfall, and cold winters (frozen soil), allows at least much of the nitrate to remain within the root zone until needed by the following crop. Despite this, fewer than one in four fields in Saskatchewan are soil-tested for residual nitrate each year. Most of the testing that is done is to insufficient depth to reflect most of the nitrate that is present in the crop root zone, and producers are reluctant to reduce their fertilizer N rates much even when substantial amounts of nitrate are shown to be present.

This study was initiated with the following objectives:

- To determine the nature and distribution, spatially and with depth, of soil residual nitrate in typical agriculture fields.
- To develop management zones within the test fields, and to relate observed spatial and depth nitrate patterns to the zones.
- To determine fertilizer N response by wheat the following year at many locations in the study fields.
- To improve soil sampling recommendations and interpretive criteria for N, for wheat and other non-legume crops.

MATERIALS & METHODS

This is a three year (2021-22, 2022-23, and 2023-24) study conducted in the Outlook, SK area. Field selection is based on results from initial survey of a number of irrigated and dry fields to determine potential fields that show variation in NO_3^- distribution, spatially and depth-wise. Once the two fields have been identified, intensive grid soil sampling is done in the two selected producer fields (one irrigated and one dryland) to show the distribution of NO_3^- in the soil spatially and with depth (0-15, 15-30, 30-60, 60-90, and 90-120 cm). Results of the soil analysis will be used to create soil characteristic maps and management zones within each field.

In the spring of the following year, wheat as a test crop will be seeded. In order to determine optimum N rate given the NO_3^- distribution, two strips will be established across the field. Each strip will be divided into five sub-strips to which increasing rates of N will be applied. Crop N response (yield and protein) will be determined at a large number of the sampling sites in each field, and will be related to soil nitrate test levels, management zones, and other parameters.

RESULTS & DISCUSSION

This study was initially supposed to begin in the 2020-21 season, but due to COVID-19 restrictions, no work was commenced. With the lifting of the restrictions, the study commenced in the fall of 2021. Two irrigated fields and two dryland fields were soil tested for initial determination of NO_3^- levels. Following those results, one irrigated field and one dryland field were selected and detailed grid soil sampling done in October of 2021. These soil samples were analysed and results were used to create the field maps and management zones (Figure 18; Figure 19). Prior to the 2022 field season, we are preparing to plant wheat and apply the treatments in the two fields. The cooperation of Roger Pederson (irrigated) and John Harrington (dryland) is much appreciated.

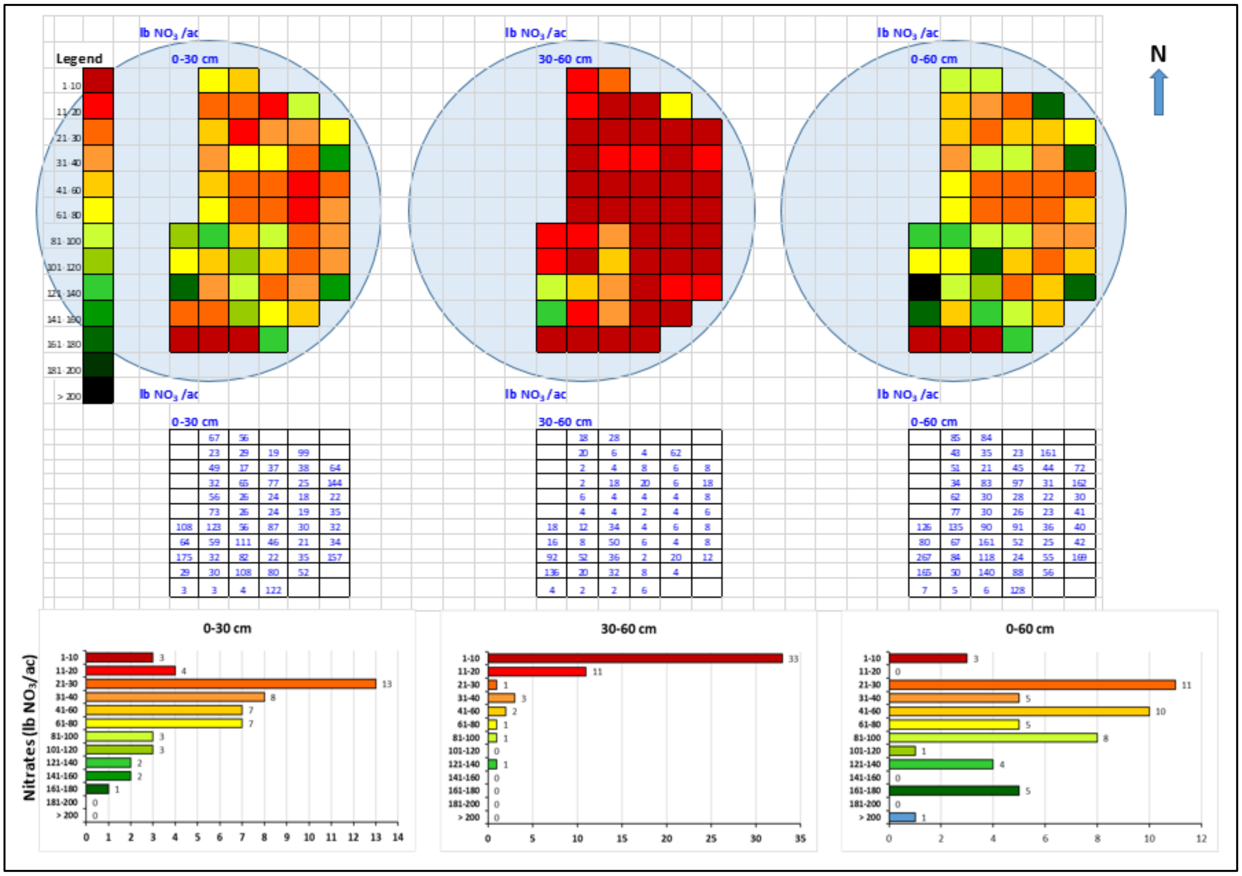

Figure 18. Nitrate levels measured in the irrigated field, October 2021.

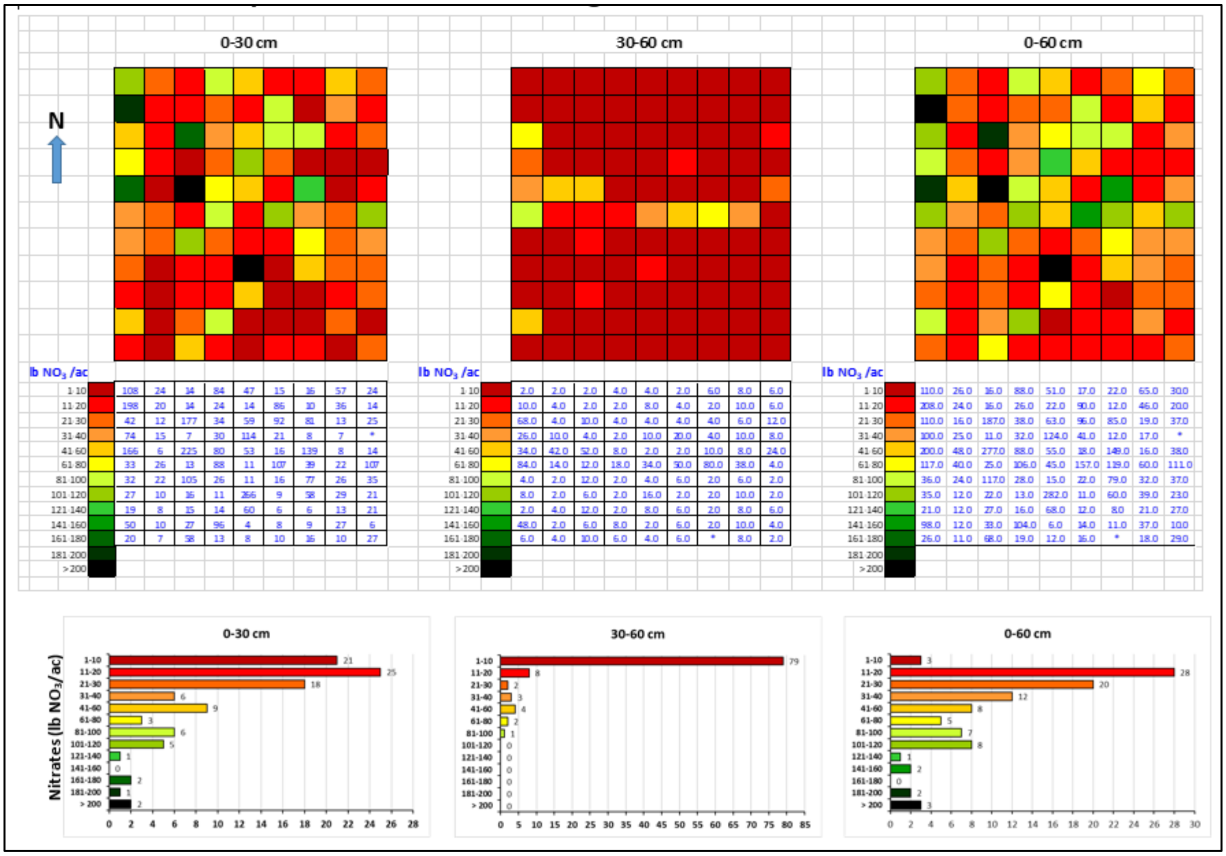

Figure 19. Nitrate levels measured in the dryland field, October 2021.

CONCLUSIONS & NEXT STEPS

Results will be used to formulate recommendations to optimize soil testing protocols for measuring residual nitrate in the soil (depths, number of sampling points, use of management zones, etc.) and to interpret the test results for producers to adjust their fertilizer N rates to confidently take advantage of residual nitrate in their soil. This would result in reduced N fertilizer use without crop yield loss where justified by N test levels. The reduction would not only reduce production costs but also have the environmental benefits associated with avoiding the effects of excess N use (lower energy use, greenhouse gas emissions, and nitrate leaching into groundwater).

Addressing Yield Stability Drivers of Canola in a Changing Climate Using High Throughput Phenotyping

Funded by Canola Agronomic Research Program

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INTRODUCTION

With the increasing incidences of unpredictable weather patterns in recent years its effect on crop production has been realized. Effect of biotic and abiotic factors can be quantified in terms of decline in yield, increase in frequency of novel diseases and insects and reduced performance of crop. Given increasing variability in seasonal conditions, efficient selection of crop varieties able to consistently yield will continue to be a top priority for breeders and an increasingly important factor when producers select varieties to grow. Within crop breeding programs, identification of the optimal combination of yield potential and stability requires extensive field testing under many locations and multiple years. There is great potential to improve the efficiency of identifying yield stable breeding lines using two synergistic emerging plant breeding techniques: Digital Phenotyping and Genomic Selection. Phenotyping is the process of describing or quantifying characteristics of breeding lines within a given environment, which has occurred through manual measurements or observations from the dawn of strategic plant breeding. Digital Phenotyping, however, enhances or replaces this process with sensors and cameras to capture and process data and images collected remotely from ground or aerial-based units over the lifecycle of the crop. Digitalizing the phenotyping process offers unprecedented accuracy, precision, and resolution.

It is unrealistic to believe that substantive changes will be made to current agriculture practices. Thus, maximizing access to available genetic variation from within a species (and possibly close relatives) and breeding for the optimal crop genetic architecture tailored to the local environment could allow increased genetic gain reflected in higher and more stable yields. Yield stability describes the ability of a cultivar to produce high yield, even under stressful growing conditions e.g. high temperatures at flowering, environments that do not receive adequate precipitation during the growing season. Selecting for yield stability and resilience to environmental stresses can be difficult in early generations of breeding programs because genotype x environment (G x E) interaction masks genetic progress. Plant phenotyping using high-throughput methods is an emerging field of study that has the potential to deliver plant breeders novel tools to support prediction of performance under stress conditions. This will be accomplished through the project deliverables which include highly annotated phenomic datasets to support genetic dissection and breeding, association of genotype with phenotype for abiotic-stress tolerance traits, and characterized germplasm for directed crop improvement.

Objectives:

1) Large-scale nursery trials in the 2021 growing season of the spring Brassica napus NAM RIL population under irrigated conditions in Outlook, SK which will yield:
    a) Conventional agronomic and phenological phenotypic as well as grain yield data.
    b) A resource for advanced digital phenotyping data collection through P2IRC.

2) Harvested seed from 2020 field trials for the following purposes:
    a) Conventional seed quality analyses for seed size, contents of oil, protein and fiber, seed colour, fatty acid, and glucosinolate profiles.
    b) A resource to be utilized for experimental testing of seed for physiological and/or new seed quality traits.

MATERIALS & METHODS

In the spring of 2021, a large-scale nursery trial was setup in Type II MAD design with *Brassica napus* NAM RIL population under irrigated conditions in Outlook (Figure 20). NAM RILs was arranged in 5 blocks with 23 ranges each. Each range consisted of 21 test lines and 2 guards at each end of a range. A total of 2415 test plots were evaluated under irrigated conditions.

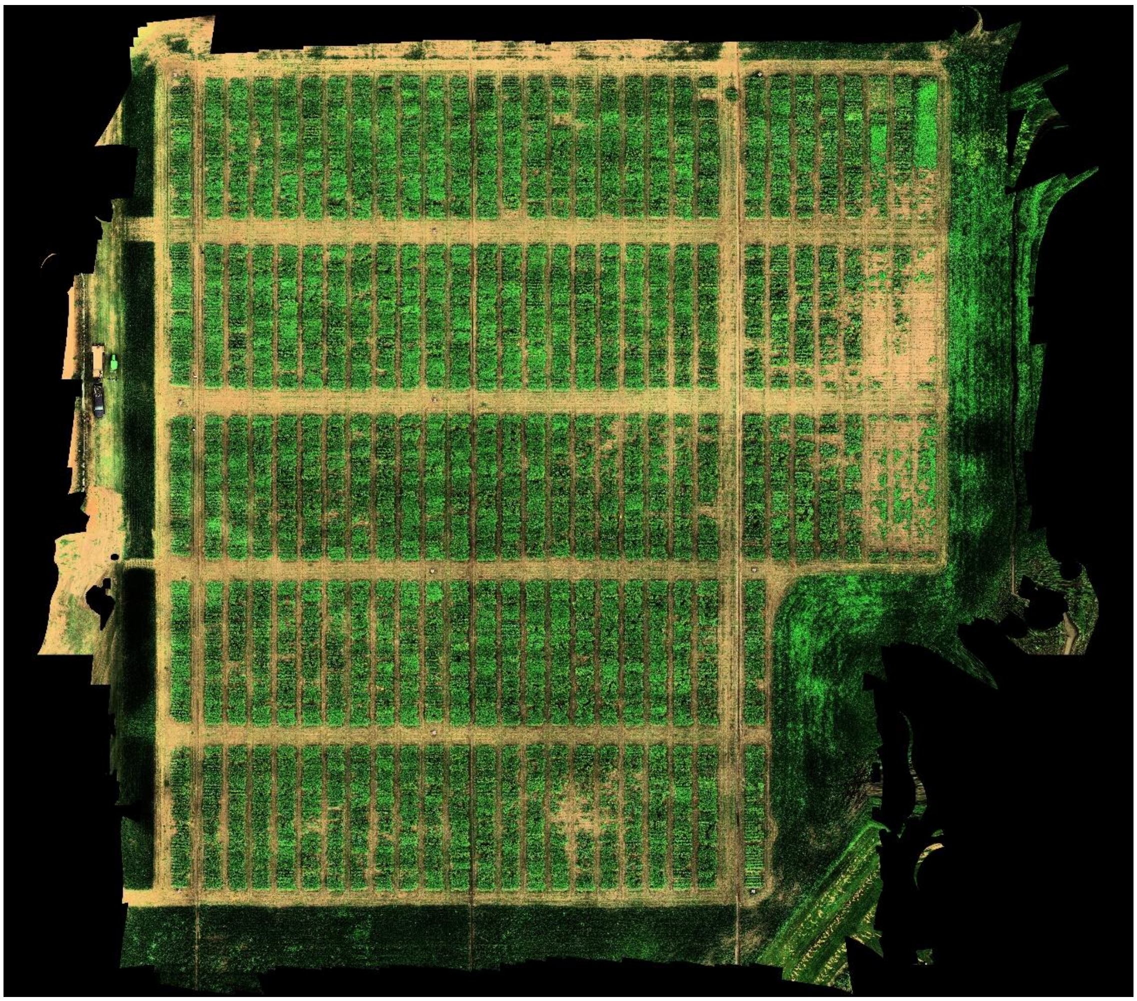

Figure 20. Orthomosaic of the 2021 irrigated NAM RIL trial at the Outlook location from aerial images collected on August 18, 2021.

Ground truth data (conventional agronomic and physiological data) were collected throughout the growing season that include germination count, days to flowering, end of flowering, days to maturity, agronomic rating, shattering, and lodging. From the entire experimental units, a set of lines were sub sampled where data such as stretched height, lodged height, base of canopy height, branch numbers, number of pods, fresh biomass, and dry weight were collected.

Canola quality traits like fibre values (ADF, ADL, NDF), unsaturation of fats and oils (iodine value [IV]), oil content (OilEx, OilHD), protein, total glucosinolates (GSL) and seed colour (white index value [WI]) were obtained from near-infrared (NIR) spectroscopy for the entire experimental units except the guards.

Plot images from throughout the season using P2IRC and AAFC ground and aerial phenotyping platforms was conducted. The sensors used consisted of three RGB sensors (FC350 (8), FC550 (1) and ILCE-7RM3 (4)), Three RedEdge sensors (RedEdge (12), RedEdge-Blue (7) and RedEdge-Red (4)). The values in the parenthesis indicate the numbers of times the imaging performed using the sensors. Ground phenotyping platforms, 'ProTractor' equipped with 4 GoPro was used as a proximal sensing platform to collect high-resolution imagery from individual rows during the growing season. Likewise, pheno-cart (miniPAMM) a custom-built proximal platform equipped with RGB, Thermal, and RedEdge sensors (The sensors could be swapped as per research need) were used during the growing season. The platform also includes novel sensor arrays including LIDAR, upwelling spectrometer, down welling spectrometer, Intel Realsense Depth Camera, an ultraviolet camera and thermal images with the VUE pro.

Following a multivariate analysis (principal component analysis and dendogram) two subsets of founder lines was created for destructive sampling. Group A consisted of 638 lines whereas group B consisted of 330 lines. (Table 16).

Table 16. Sampling protocol for Group A and Group B founder lines.

Groups	Sampling Stage		Sampling Protocol
Group A (638 lines)	S1	Start to mid pod filling	Two plants per plot harvested pod, stem and leaf partitioned followed by dry weight determination.
	S2	Physiological maturity	Two plants per plot harvested seed, and above ground biomass partitioned followed by dry weight determination.
Sub-sample of Group A (100 lines)	-	Physiological maturity	Two plants per plot harvested, pod and branch number counted. Seed, pod and stem partitioned followed by dry weight determination.
Group B (330 lines)	S1	During flowering	Not sampled.
	S2	Physiological maturity	Two plants per plot harvested seed, and above ground biomass partitioned followed by dry weight determination.

Images were collected from entire trial using unmanned aerial vehicles (UAVs) (38 missions) with RGB and Rededge sensors. Protractor, used for proximal sensing, was used (50 mission dates) to capture images of individual row within a in a range at both locations during the growing season. In addition, "phenocart" equipped with thermal, RGB and multispectral sensor, collected data from 8 ranges that included NAM founders and RILs with secondary checks (9 mission dates). Harvested seed has been cleaned, weighed, subjected to NIR analysis for seed oil, protein and fiber content determination and is currently being analyzed by gas chromatography for fatty acid and glucosinolate profiles.

RESULTS & DISCUSSION

1) The image data collected over the growing periods using aerial sensors are being stitched to create orthomosaic using PlotVision, a platform developed through P2IRC. Matrices

related to different vegetation indices, as well as plant height, crop area, flower fraction and crop volume will be extracted following segmentation in PlotVision for all the missions and sensors.

2) Ground truth data (Conventional agronomic and physiological data) collected throughout the growing season will be used to study the correlation and as a validation set with the results obtained from image data.
3) The orthomosaic generated will be used to extract plot images and used in treatment difference studies.
4) Processing of the images collected using 'ProTractor' a proximal sensing platform has begun and we are annotating individual plants form each row to determine the germination count. This will be further extended to other mission dates to acquire plot specific data.
5) The images and data obtained from Flagship 1 will be utilized for deep learning applications. A machine learning pipeline application, latent space phenotyping (LSP) for detecting treatment differences is being applied to study the potential of differentiating response of canola lines using the image data collected using UAVs from field trials.
6) Semantic segmentation and machine learning application in images captured using UAVs form field trials and determine the weeds from canola plants.
7) Additional collection of images and annotations of seeding counts.
8) The images collected using proximal sensors and UAVs after stitching, segmentation and annotation have generated and some yet to be processed to generate matrices related crop indices, plant architecture, treatment differences, temperature signals and many latent phenotypes which would have been impossible for breeders to manually collect.

CONCLUSIONS & NEXT STEPS

The experimental material in this research includes diverse canola lines each coming from different canola founders thus, carrying different genetic makeup. The lines will respond to environmental variables differently suggesting breeders the potential of selection for developing lines with wider adaptability and/or stable yield.

Evaluating AAC Trueman Alfalfa in Saskatchewan

Funded by Saskatchewan Agricultural Development Fund, Agriculture and Agri-Food Canada, and Saskatchewan Alfalfa Seed Producers Development Commission

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INTRODUCTION

Climate change will have a major impact on agricultural production in Canada with average temperature increases anticipated to be twice that of the global average (Bush and Lemmen, 2019). This increase will cause greater uncertainty in weather patterns, resulting in an increase in climate variability and the intensity of extreme events including drought and flooding (Pomeroy and Dumanski, 2017). This increase is forecast to be more frequent and perhaps the 'new normal'. Many experts believe Western Canada could be one of the few areas to see an increase in heat units and a longer growing season for agricultural production (Qian et al., 2010). To capitalize on this opportunity and prepare for periods of water uncertainty, livestock and hay producers will require new climate resilient forage crops and varieties. This will allow for a forage system that can tolerate extreme events in both high and low moisture environments while maintaining good yield, quality and productivity across normal years (Picasso et al., 2019).

Forage legumes like alfalfa are an important feed source for livestock in Western Canada and have the potential to provide a sustainable solution for food and protein security in a changing climate. Alfalfa is often recognized as the 'queen of the forages' because of its combination of high yield per hectare and high nutritional quality. However, cultivation of forage legumes is under threat from changing climatic conditions, indicating the need for breeding cultivars that can sustain and acclimatize to the negative effects of climate change (Kulkarni et al., 2018). For example, flooding is a major limitation to alfalfa production (Barnhart, 2008) and the development of varieties that can tolerate waterlogging will provide producers with additional cropping options in wetter soil conditions.

Development of new perennial forage varieties that are more resilient in extreme weather conditions is ongoing and coincides with agricultural industry needs. For example, at a recent workshop, the Saskatchewan Cattlemen's Association (SCA) identified the following priority: "Develop new annual and perennial grass and legume varieties with improved stand longevity, quality, yield, and adaptability (i.e., flood and drought resistance)" (Possberg, Feb 24, 2020). Although developed in Atlantic Canada, AAFC's new alfalfa variety, AAC Trueman, may help address SCA's priority. It is characterized by its unique rhizomatous growth, late flowering habit, winter hardiness, mid-summer drought tolerance, tolerance to spring and fall waterlogging, and frequent grazing (Belanger et al., 2019). The large root system of this perennial legume can limit soil and nutrients lost to erosion as well as increase soil carbon deposition and improve soil quality traits such as soil aggregate stability, bulk density, and water infiltration.

In order to build a resilient, stable, and productive forage system in a changing climate, new perennial forage varieties must be developed and tested in various geographic locations and climatic conditions. AAC Trueman was evaluated in trials at three locations in Atlantic Canada (Papadopoulos, 2020). Unlike the development of previous alfalfa varieties such as AC Caribou (developed in Quebec but thoroughly tested in Western Canada and released in 1992), AAC Trueman has not been tested extensively in Western Canada. However, during the course of cultivar development AAC Trueman (under pre-variety name CRS-1001) was seeded in a field near Atwater, Saskatchewan by a highly experienced alfalfa seed producer. This occurred at the request of AAFC forage breeder Dr. Yousef Papadopoulos to increase the seed available and to test the alfalfa variety in another area of Canada. Since the release of the variety in late 2018 there has been a lot of interest from Western Canadian producers, especially regarding the higher waterlogging tolerance. These components were highlighted in a recent Canadian Cattlemen magazine article and has created a great deal of interest from producers.

Based on the preliminary interest shown in Western Canada, AAFC partnered with the Saskatchewan Forage Council beginning in 2018 to work with six Saskatchewan producers interested in "testing out" AAC Trueman under typical producer management practices. This was not a formal project with dedicated funding, but rather a cursory activity based out of interest from Saskatchewan producers and AAFC (forage professionals and AAC Trueman breeder Dr. Papadopoulos). Producers worked with AAFC staff who gathered basic qualitative and minimal quantitative information. The intent was not to burden producers with onerous data collection or time-consuming analysis, but simply to get a sense of how well AAC Trueman performed under on-farm conditions. Producers were selected across various locations in Saskatchewan. Due to very dry soil conditions in 2018, some fields were not seeded until the following year or under less than ideal conditions (mid-summer seeding or inadequate pre-seed weed control). This activity is still on-going although no field visits occurred in 2020 due to the COVID-19 pandemic. While this activity is not part of any funded project, it does highlight producer interest and a current information gap, illustrating the need for a formal project to more rigorously assess the potential of AAC Trueman in Saskatchewan.

In addition to assessing the applicability of AAC Trueman under Saskatchewan growing conditions, this project proposal would also look to assess a potential alfalfa-grass mixture including ST1 Timothy as it may provide a good forage mixture in higher moisture environments. The ST1 Timothy line that is being developed in Saskatchewan is close to being released and has been bred for higher biomass yield and higher seed yield (personal communication, Biligetu, 2020).

Project objectives:

1) Evaluate forage production, forage quality, and winter hardiness of AAC Trueman alfalfa in the Brown, Dark Brown, and Black soil zones of Saskatchewan.
2) Determine the adaptability of AAC Trueman in Western Canada under three moisture conditions; excess water, irrigated, and dryland.
3) Evaluate ST1 Timothy as a good candidate to be included in a forage mix with AAC Trueman in higher soil moisture landscapes.
4) Develop knowledge and technology transfer products that will benefit the Saskatchewan agriculture industry with an emphasis on improving long term economic potential.

A large plot trial (seeded in 2020) and a small plot trial (seeded in 2021) were established on CSIDC's irrigated fields in the Dark Brown soil zone to address project objectives.

MATERIALS & METHODS

Large Plot Trials

<u>*Experimental Design*</u>

In 2020, a randomized split plot block design with four forage stands and two replications was established in the Dark Brown Soil Zone at CSIDC (Field 12) in Outlook. The four forage treatments included: 1) AAC Trueman alfalfa; 2) 4010 BR alfalfa; 3) AAC Trueman alfalfa mixed with AC Knowles hybrid brome; and 4) 4010 BR alfalfa mixed with AC Knowles hybrid brome. The site was seeded with field scale equipment, similar to what a farmer would normally use to seed forages. Treatments were seeded into cereal stubble. Soil testing occurred at all sites to determine fertility requirements. Pre-seed weed control followed common agronomic practices for the region. Seeding rate was 12 lbs/ac for alfalfa treatments and for alfalfa-grass mixes, it was 6 lbs/ac alfalfa + 6 lbs/ac hybrid brome.

<u>*Variable Rate Irrigation*</u>

Plots were seeded under a Variable Rate Irrigation (VRI) system. VRI allows for more control of soil moisture conditions within each plot with soil moisture continually monitored to promote desired testing conditions of i) excess moisture (irrigation water applied at 110-120% of evapotranspiration rate [1.1-1.2 x optimum]), ii) normal (irrigation water applied to meet crop evapotranspiration rate), and iii) dryland conditions (no irrigation water applied, water supplied through precipitation only) (Figure 21). Stands were assessed for the same vegetation attributes as Objective 1 (forage production, forage quality, persistence). Soil moisture content was regularly monitored with soil moisture sensors in each water regime in order to adjust irrigation as required to maintain desired soil moisture content throughout the growing season (Figure 22).

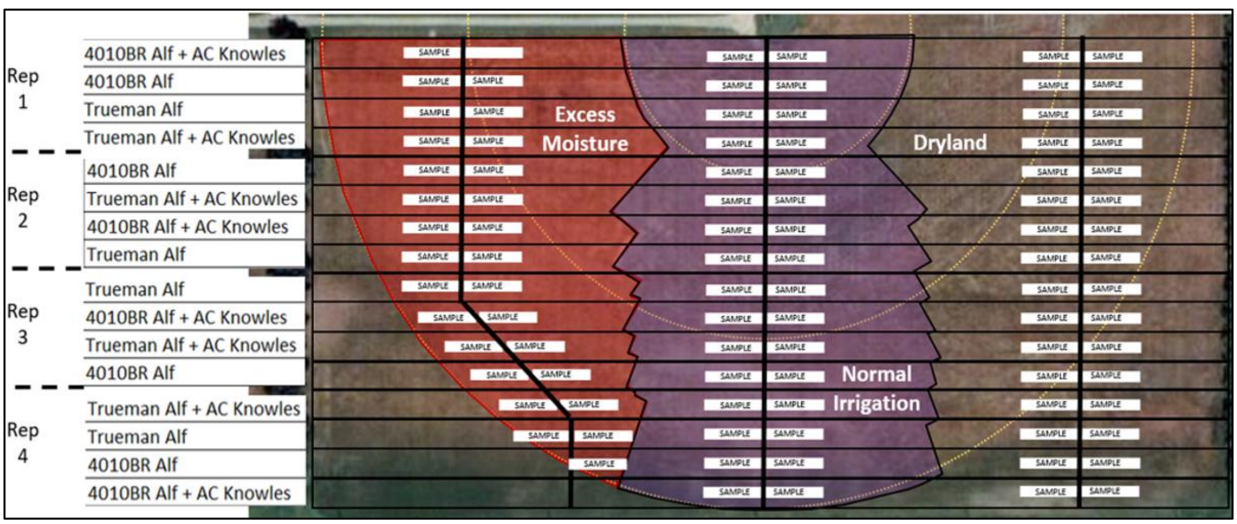

Figure 21. Plot layout and sample locations under three moisture conditions. Plots were seeded in 2020 and 2021 was the first year of data collection.

Data collection in 2021 included: 1) occupancy 1-2 weeks after the first harvest; 2) botanical composition prior to the first harvest; and 3) dry matter yield (taken at the 2 harvest periods and added together for seasonal dry matter yield). Botanical composition will identify seeded legume, grass, and other plants by sampling from every plot using two quadrats of 50 cm × 50 cm (0.25 m^2 in area). Dry matter yield was collected by clipping the quadrats used for botanical composition or through the use of a forage harvester. Plots were managed in a 2-cut system. Forage samples were dried to a constant weight of 55°C for at least 72 hrs and samples were sent to a certified third-party lab for forage quality analysis.

Figure 22. Large plots on September 7, 2021.

Small Plot Trials

Small plots were also seeded on ICDC's land allocation at the CSIDC off-station demonstration site on May 26, 2021 to evaluate ST1 Timothy as a potential forage mix with AAC Trueman in higher soil moisture landscapes (Figure 23). Forage production, forage quality, and winter hardiness of ST1 Timothy will be evaluated beginning in 2022.

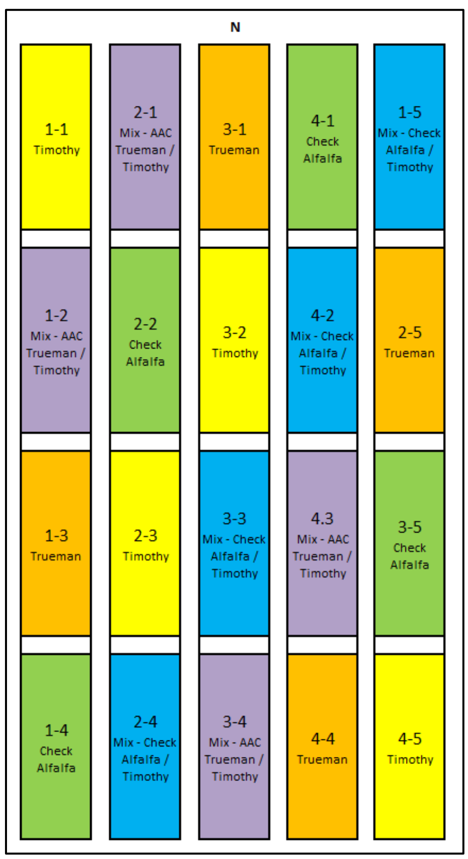

Figure 23. Small plot trial design.

RESULTS & DISCUSSION

Small Plot Trials

Irrigated plots had fair to good emergence in the 2021 establishment year (Figure 24).

Figure 24. Small plots at Outlook on September 7, 2021. Upon closer inspection, Timothy (4-5) shows some establishment.

Large Plot Trials

<u>*Variable Rate Irrigation*</u>

Soil moisture levels were adjusted based on amount of irrigation. In the Outlook region, 2021 was extremely dry and precipitation was only 44% of normal (Table 17). Excess and Optimal added to the growing season water placement. However, due to high evaporation there was less of a distinction between Optional and Excess values. In 2022, we hope to have greater separation in values.

Table 17. Growing season precipitation and Variable Rate Irrigation values (May 1 to September 28, 2021).

Treatment	Rainfall	Irrigation	Total	% of Normal
	---------------------- mm ----------------------			
Excess	108.5	325.0	433.5	176
Optimal	108.5	250.0	358.5	145
Dry	108.5	0.0	108.5	44
Normals (1991-2020)	247	-	247	-

Figure 25 shows a drone image which highlights that the Dryland area has less vegetation. Tile drainage lines are visible in the Dryland zone as they appear to be providing a source of sub surface moisture to the plants. Figure 26 shows a full mosaic Normalized Difference Vegetation Index (NDVI) which measures healthy, green vegetation over a wide range of conditions. The denser health vegetation will transpire more and reduce heat (high NDVI indicated by green colours). Poor vegetation or bare ground will release more heat or cannot cool itself (low NDVI indicated by red-orange colours). Note: only the Normal and Dryland zones were captured. Figure 27 shows a thermal image which demonstrates the sparse vegetation allowing for more topsoil exposure, leading to higher field temperatures (purple = cool, yellow = hot).

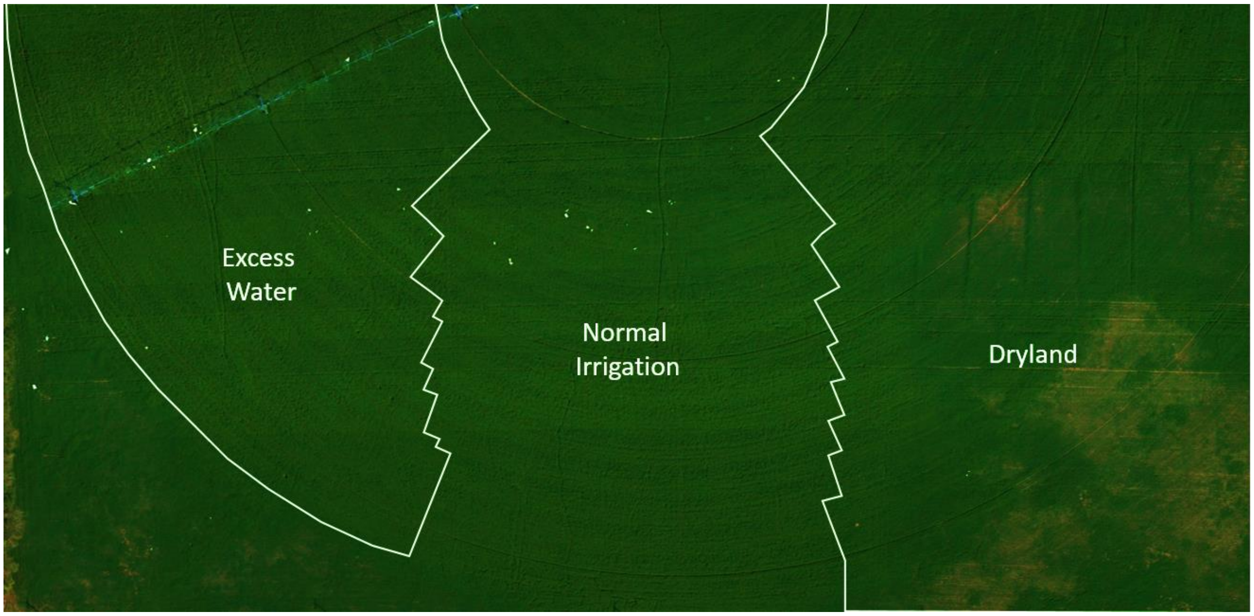

Figure 25. Variable rate irrigation zones on September 8, 2021.

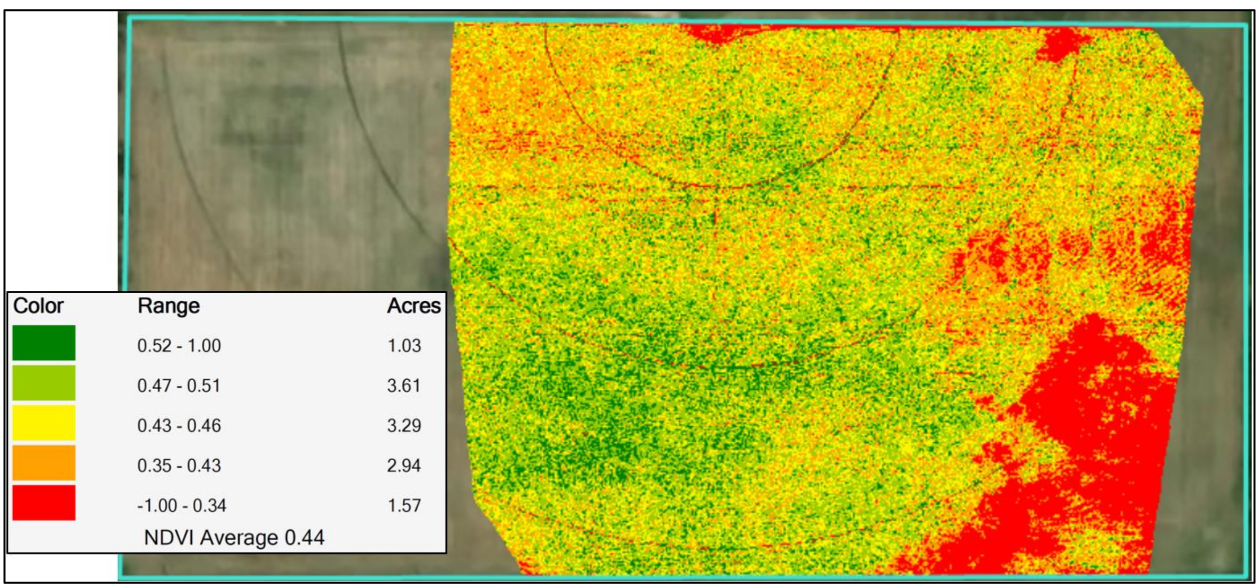

Figure 26. Normalized Difference Vegetation Index (NDVI) on August 25, 2021.

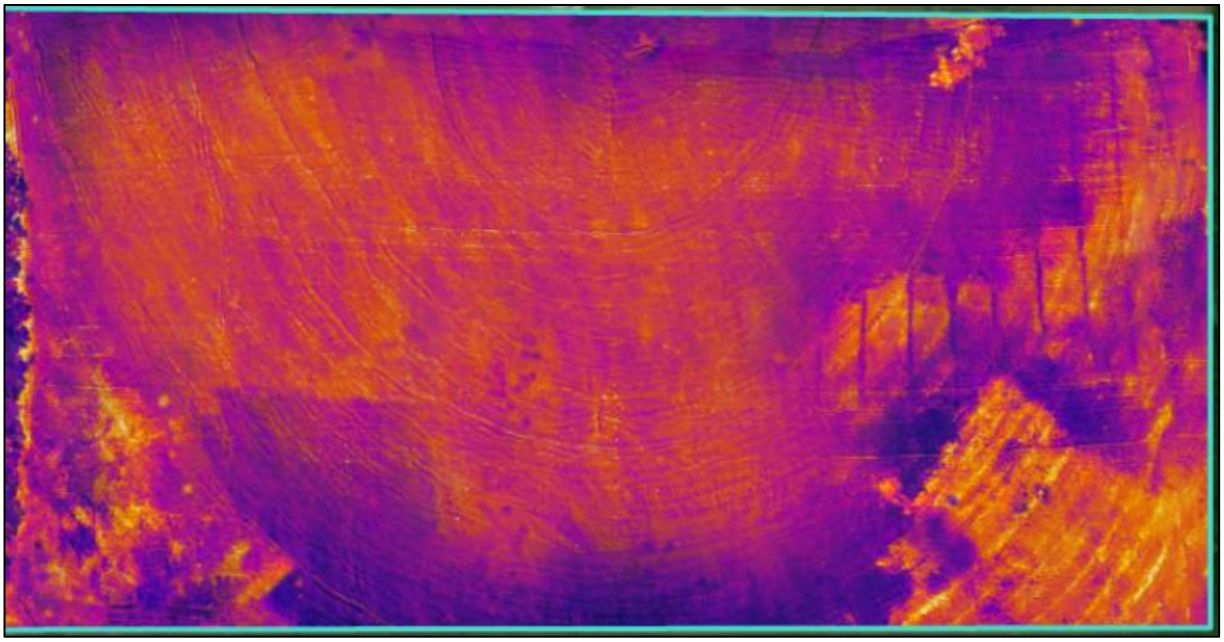

Figure 27. Thermal image captured on August 25, 2021 (Purple - Cool / Yellow - Hot).

Forage Yield

The forage yield from the first cut on June 23, 2021 (Figure 28) ranged from 5,737 kg/ha up to 8,742 kg/ha. The forage yield from the second cut on July 28, 2021 (Figure 29) ranged from 2,169 kg/ha to 5,228 kg/ha. The total yield for the season ranged from 8,416 kg/ha up to 13,785 kg/ha (Figure 30). The dryland treatments produced the lowest forage yields as expected whereas there was not much difference between the excess moisture yield and the irrigated treatment. Further analysis will be conducted as we gather more yield data over the next few years.

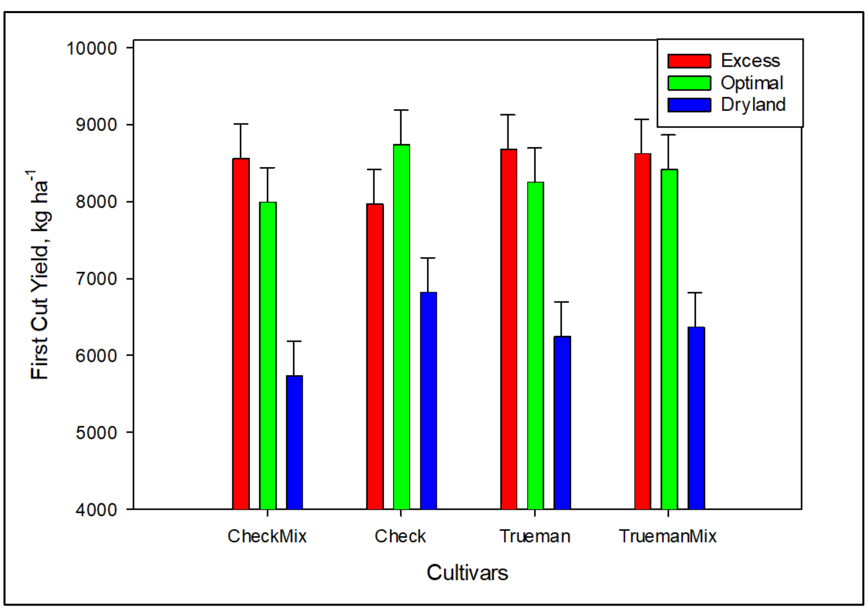

Figure 28. Dry Matter Yield (kg/ha) of first cut on June 23, 2021.

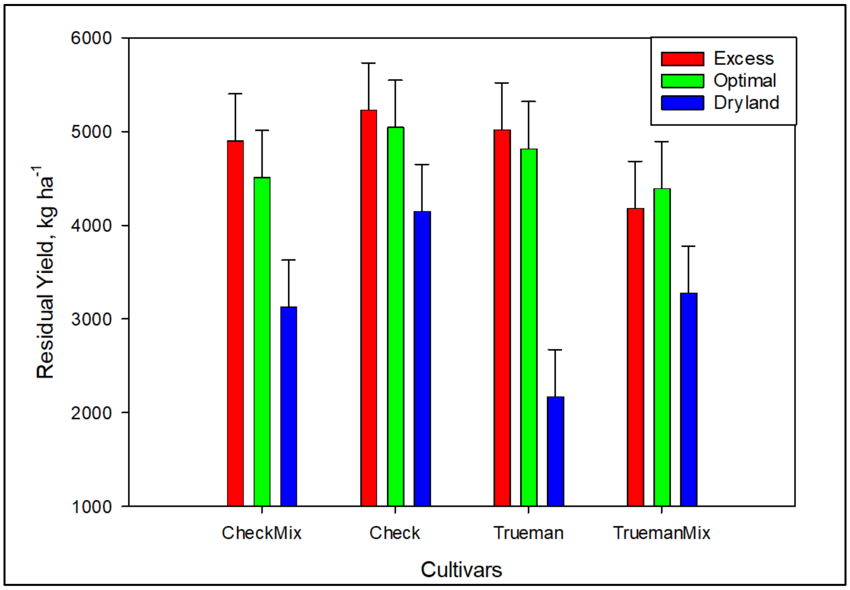

Figure 29. Dry Matter Yield (kg/ha) of second cut on July 28, 2021.

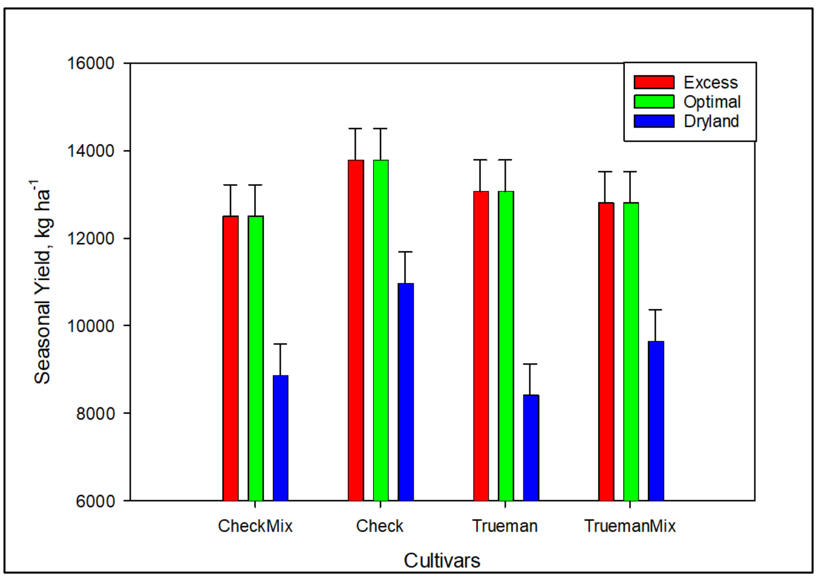

Figure 30. Dry Matter Yield (kg/ha) of entire season.

Forage Quality

AAC Trueman and the check alfalfa had similar protein, acid detergent fibre (ADF) and neutral detergent fibre (NDF) values in the Optimal and Excessive Moisture areas. In the non-irrigated area, all values were lower than in higher moisture regions, with AAC Trueman having higher protein values than the check variety but lower ADF and NDF values. Forage quality values are summarized in Figure 31.

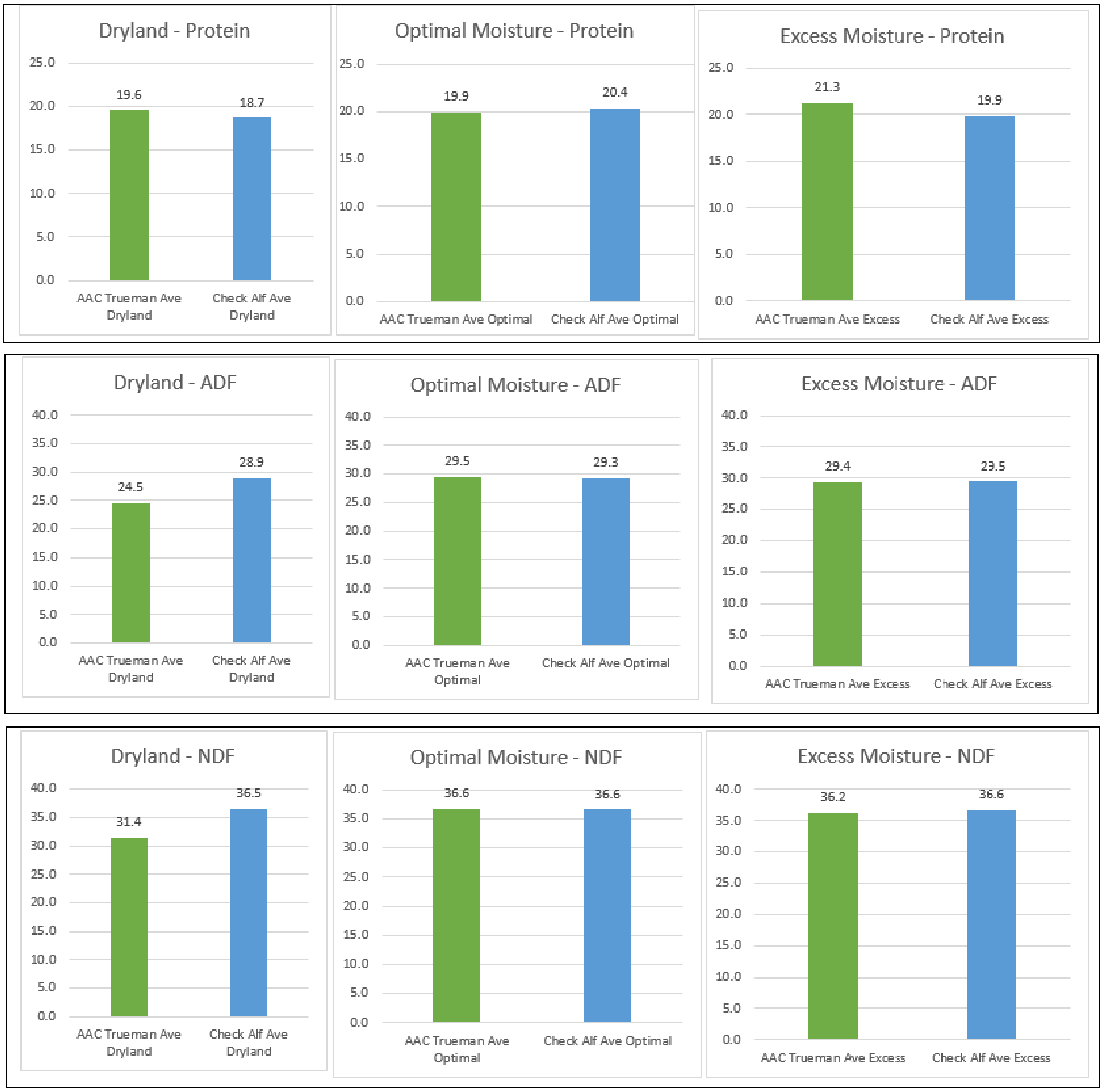

Figure 31. Forage quality of first cut on August 25, 2021. All values in are in percentages.

CONCLUSIONS & NEXT STEPS

A major challenge faced was the unusually dry 2021 growing season. In Outlook, precipitation was 44% of normal. This made it difficult to provide a clear distinction between the optimal and excessive irrigation regimes on the large plot trial. The small plot trial was seeded to explore ST1 Timothy as a potential candidate to be included in a forage mix with AAC Trueman in higher soil moisture landscapes. Due to small seed size there was a concern during seeding that Timothy seed was not making it into the soil due to windy conditions. There was also significant weed pressure and Timothy plots appear to have limited establishment although small plants were observed in the fall. Spring 2022 will provide a better indication of establishment and persistence.

Due to the drought conditions experienced in Swift Current, the bales generated from this project were utilized by the beef research team at AAFC-Swift Current (Figure 32).

Saskatchewan Research Farms Come Together to Overcome Feed and Hay Shortage

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October 7, 2021

Previous Article

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This summer, it was hard to miss the drought affecting the Prairie provinces, as it was one of the worst droughts in the last hundred years. Producers have been under stress as the yield of their grain and oilseed crops has shrunk and cattle producers are concerned about having enough water, forage and grain to keep their livestock alive.

Staff at the Swift Current Research and Development Centre (SCRDC) faced the same fears.

"We keep about 60 beef cows and up to 150 yearlings year round," says Dr. Alan Iwaasa, a research scientist specializing in grazing management and ruminant nutrition. "The Swift Current site is semi-arid to begin with, and this year's drought and elevated heat really affected this area. We were worried about our ability to be self-sufficient in hay, green feed, grain and straw for the winter. We didn't want to be faced with reducing our cattle herd because we couldn't feed them and jeopardizing the ongoing research studies and new studies planned for next grazing season."

Historic decisions pay off

Luckily, Saskatchewan has research farms (sub-sites of the two main research and development centres in Swift Current and Saskatoon) located throughout the province. These sites were set up in different soil zones throughout the Prairies (some over 125 years ago), so that researchers could best adapt their work to the local environment.

Those century-old decisions meant that research farms in Melfort (in the Black soil zone of north east Saskatchewan), Indian Head (in the Dark Brown soil zone near Regina) and Outlook (in the Dark Brown soil zone south of Saskatoon) were located in areas less affected by the drought this year, with some having access to irrigation. They pulled together and, between all of them, had enough hay and green feed to provide Swift Current with the resources to keep their herd supplied through the winter.

Figure 32. Article featuring bales generated from the large plot trials that were donated to the AAFC-Swift Current beef research team.

HORTICULUTRE AND ROOT CROP AGRONOMY

Climate Change Opens New Opportunities for Vegetable Production on the Prairies

Funded by Agriculture and Agri-Food Canada

Principal Investigator: Dr. Jazeem Wahab, AAFC-Saskatoon
Co-Investigators: Evan Derdall, AAFC-Saskatoon
Dr. Dale Tomasiewicz, AAFC-Outlook
Dr. Erin Karppinen, AAFC-Outlook
Greg Larson, AAFC-Outlook

INTRODUCTION

The primary goal of this project is to develop BMPs for profitable and sustainable production of higher-value vegetables, capitalizing on the opportunities presented by climate change on the Prairies. This is a three-year project: Year-1 and Year-2: technology generation; Year-3: technology evaluation and adaptation.

Projected changes to the Prairie climate include warmer temperatures (+2 °C to 3 °C), longer frost-free growing season (+16 to 26 days), and elevated atmospheric CO_2 levels (530 ppm by 2050; 1000 ppm by 2100). Increased moisture deficit due to higher year-round temperatures, extreme hot days in summer, and evapotranspiration will be the major challenges. These stresses can be mitigated through irrigation, growing adapted crops, stress-tolerant cultivars, and appropriate agronomic practices.

Projected future climatic conditions will be simulated using high tunnel and low tunnel systems that vegetable producers are familiar with. Crops to be evaluated are snap bean, spinach and sweet potato. These crops were selected for their market potential and diverse agronomic characteristics. Considerable volumes of green bean, spinach, and sweet potato are imported to meet domestic needs. It is estimated that approximately 6,600, 7,600, and 5,100 ha of green bean, spinach and sweet potato respectively are required to meet import volumes. Out-of-season imports can be displaced either by processing (i.e., freezing, canning etc.) or by medium- to long-term storage (i.e. sweet potato).

Research is planned to screen superior cultivars and develop BMP's for sustainable production capitalizing on opportunities presented by climate change (longer, warmer growing season: earlier planting, multiple/successive crops, later harvest). Crop specific agronomic variables including water management, soil mulch (moisture conservation, soil warming – i.e. accelerate growth and maturity, weed control) will be examined using season-extension techniques (high tunnel and mini tunnel) to simulate climate change settings. Yield, storage characteristics, bioactive contents, and economic performance will be evaluated for the three crops under the projected climate change scenario.

Leafy Green Vegetables in Saskatchewan: Agronomic Refinements for Field and High Tunnel Production

Funded by Saskatchewan Agricultural Development Fund

Principal Investigator: Dr. Jazeem Wahab, AAFC-Saskatoon
Co-Investigators: Evan Derdall, AAFC-Saskatoon
Dr. Dale Tomasiewicz, AAFC-Outlook
Dr. Erin Karppinen, AAFC-Outlook
Greg Larson, AAFC-Outlook

INTRODUCTION

Vegetable production is a large sector of the Canadian horticulture industry with limited production within Saskatchewan. In 2018, Canada grew 103,000 ha of field vegetables valued at $1.2 billion, while Saskatchewan grew only 343 ha of vegetables valued at $ 5 million. During this period, Canada exported 1.0 million tonnes at a value of $2.0 billion and imported 2.0 million tonnes of vegetables at a value of $3.6 billion. It is estimated that Saskatchewan imports $27 million worth of vegetables annually and the domestic production meets just 10% of in-season demand. There is significant potential for expanding the vegetable industry in Saskatchewan. The recent, July 20, 2020, announcement by the Saskatchewan Government of the 202,000 ha irrigation expansion is targeted at crop diversification, higher-value crops production, value-added processing, on-farm profitability, and business attraction and employment among other objectives. Vegetable production is expected to play a key role in this development effort.

Generally, higher-value vegetables are warm-season crops. However, more recently, many cool-season crops have gained prominence as ‘Super Food’ or ‘Super Green’ in the market place. ‘Leafy-Greens’, with edible leaves, is one such category with rapidly increasing consumer demand. They are considered to be the most nutritious of all vegetables, rich in vitamins, minerals, fibre, and phytonutrients, and low in calories and fats. Leafy greens are cool-season crops with short production cycle and less riskier to grow in Saskatchewan than warm-season crops. A wide array of Leafy-Green vegetables, including spinach, kale, and bok choy, are suited for home gardens, small-scale market gardens, and large-scale commercial production in Saskatchewan.

Spinach, kale, and bok choy are examined in this study as they are rapidly growing Leafy-Green options with considerable expansion potential as presently there is limited production in Canada. For example, spinach imports increased by 23% between 2014 and 2018, and kale production increased 400% between 2011 and 2016. Spinach, kale and bok choy are less risky to grow in Saskatchewan as they grow best under cooler temperatures (15oC-22oC) and can tolerate mild frost. Premature bolting, that is favoured by long days and abiotic stress, is a major challenge in spinach, kale, and bok choy production. Spinach is a short season crop with possibilities of multiple production cycles in one season. Spinach has several market classes: ‘Bunch’, ‘Baby’, ‘Teenage’, and ‘Freezer’. ‘Bunch’ spinach, kale, and bok choy are harvested manually, while the other spinach market classes are harvested mechanically. These crops can be grown under small-scale (market garden) and large-scale (commercial) production systems.

There is limited information available on spinach, kale, and bok choy agronomy. This project is designed to identify promising spinach, kale, and bok choy cultivars and develop cost-effective and sustainable management practices to optimize profitability to the producer while providing healthy food option to the consumer. The overall objective of this project is to optimize yield, quality, and profitability by refining agronomic practices, such as sequential planting, multiple harvesting, and the use of high tunnels to extend the growing season. Studies are targeted at selection of cultivars to suit production systems, minimizing bolting, feasibility of manual and machine harvesting, sequential planting and multiple harvests, season extension and off-season crop production using high tunnels, use of soil plastic mulch to increase water use efficiency and improve crop quality, storability and shelf-life, and economic performance of crops and production systems.

Horseradish Germplasm Preservation

Principal Investigator: Dr. Dale Tomasiewicz, AAFC-Outlook
Co-Investigators: Dr. Erin Karppinen, AAFC-Outlook
Don David, AAFC-Outlook
Connie Achtymichuk, SK Ministry of Agriculture

INTRODUCTION

Horseradish (*Armoracia rusticana*) has been widely grown as a farmyard and backyard garden crop in Saskatchewan since European settlement, but it is not commercially produced in the province. Enquiries from foreign buyers about purchasing horseradish root stimulated interest in production of the crop in Saskatchewan. As a result, ADF project (#20140363) was undertaken to assess the yield potential and quality of Saskatchewan grown horseradish. Briefly, ten small-plot irrigated field trials were conducted at the Canada-Saskatchewan Irrigation Diversification Centre in Outlook from 2015 to 2019 (Figure 33). Horseradish root pieces were planted in rows in the spring and the roots were harvested late in the fall of the following year. Root yields were determined, as well as quality. Other agronomic trials involving harvest date and stand establishment variables were also conducted.

Figure 33. Horseradish production trial at CSIDC, 2016.

Key messages from the ADF project were:

1. Horseradish can be successfully produced in Saskatchewan under irrigation (and likely also under rainfed conditions in moister parts of agro-Saskatchewan). In a two-year production system, with root pieces planted in spring and harvest of the roots in the fall of the following year, good root yields were consistently obtained. Almost no winterkill of the plants occurred, even in winters when alfalfa and fall-seeded crops were severely damaged.
2. Several sources of planting stock were assessed. Their performance varied in both yield of acceptable size roots and root quality; some were quite good in both respects. *Quality* for the crop for food purposes is mostly related to its taste and pungency.

3. For the two year production system, early timing of planting in the spring and very late harvesting in the fall are not critical, offering flexibility to the farm operation. Trials also determined the plant populations required, and that that size and orientation of the planted root pieces in the soil were not important for the two-year system. Many production practices and equipment needs are similar to those for other vegetable row crops, but obtaining a suitable harvester for the deep roots could be expensive.
4. Horseradish has potential from the production standpoint to be commercially successful in Saskatchewan, but its future will depend on the wide range of other factors not assessed in the study - markets, profitability, producer interest, and processing development.

Upon completion of the ADF project, the team identified a need to preserve germplasm from the most successful (based on yield and quality) sources.

MATERIALS & METHODS

2020 Nursery Establishment

Germplasm (as root pieces for propagation) from 8 sources selected from the ADF trial were planted on May 21 on the south edge of Field 11. Selected sources included Kotyk, Star City, Makowsky, Broderick, Chinese, Kamsack, Dennis, and Saskatoon. Plot size was 4-36" rows that were 10 m long with 20 plants at 0.5 m spacing. Furrows were made with a two-row potato moldboard hiller. Root pieces were positioned by hand into the furrow face, at an angle of about 30-40° from vertical in one consistent direction, with the tops of the root pieces about 5 cm from the soil surface. The bottom end of the root sections had been cut off at an angle to allow the roots to all be placed right-side-up in the furrow. Shortly after planting the furrows were filled and soil heaped up over the planted roots with a Lilliston rolling row crop cultivator, burying the root pieces so that their tops were approximately 10 cm from the soil surface.

On May 19 a blend consisting of 75 lb P_2O_5/ac, 75 lb K_2O /ac, and 50 lb N/ac was broadcast across the nursery area. Pesticide applications consisted of a Roundup® (glyphosate; 2 L/ac) burnoff on May 14 and Decis® 5 EC insecticide (deltamethrin; 50 mL/ac) on July 10. Roots were not harvested.

2021 Nursery Maintenance

Maintenance of the horseradish nursery continued in 2021. On May 5, 125 kg N/ha was broadcast across the nursery area and incorporated with a rotary hiller. Decis® 5 EC insecticide (deltamethrin; 50 mL/ac) was applied on July 31. Plots were cultivated on July 8 and hand weeded as required. Roots were not harvested.

NEXT STEPS

Maintenance of the horseradish nursery will continue in 2022.

IRRIGATION WATER MANAGEMENT

Validation and Refinement of Thermal Indices for Monitoring Crop Water Stress in the Canadian Prairies

Funded by Saskatchewan Agricultural Development Fund

Principal Investigator: Evan Derdall, AAFC-Saskatoon
Co-Investigators: Dr. Erin Karppinen, AAFC-Outlook
Garry Hnatowich, ICDC
Dr. Gursahib Singh, ICDC

INTRODUCTION

Irrigation scheduling continues to be an opportunity for improved water productivity, resulting in improved yield (8%) and water use efficiency (10%), compared to non-scheduled production (Nair and Amosson, 2016). However, adoption continues to be lacking in Saskatchewan largely due to availability of user friendly methods/technology (Garven and Associates, 2014). Remote sensing has been identified as a potential solution, limiting the need for infield soil moisture sensors and the growing availability and affordability due to technological advancements (i.e., computing, satellite, artificial intelligence). One of the proposed technologies is monitoring canopy temperature using infrared thermometers (IRTs).

IRTs have been available in agricultural production since the 1980's, but due to a lack in computing power, satellite, and unmanned aerial vehicle (UAV)/Drone based instrumentation, the technology has been limited to hand based sensors limiting the applicability. Recent work in Texas (O'Shaughness, 2015) has seen the development of practical methods of using these sensors to schedule irrigation applications.

This project is looking at evaluating thermal based irrigation scheduling methods developed in the southern United States and make the appropriate adjustments for Saskatchewan irrigated production.

Objectives:

i) Evaluate available thermal indices, for quantifying crop water stress, for application in Saskatchewan;
ii) Update the Saskatchewan Irrigation Scheduling Manual with thermal-based scheduling options; and,
iii) Evaluate crop canopy temperature to determine crop water stress in canola.

MATERIALS & METHODS

The 2021 growing season was the initial field season for the project due to an approved deferral associated to the ongoing COVID-19 pandemic. The research field is located at the Canada-Saskatchewan Irrigation Diversification Centre demonstration site near Outlook, Saskatchewan. The field is a variable texture field consisting of sandy loam to loam soils with areas of fine sand overlying the original A-horizon. This variability results in a wide range of soil moisture holding capacities and crop available water. Due to variability and research purposes, the field is serviced with a seven tower center pivot equipped with a variable rate irrigation control system. This system allows the operator to apply various depths of water in user defined zones throughout the field.

For the research trial, a total of three (3) treatments and three (3) replications were laid out on the South West quarter of the center pivot irrigation system (Figure 34). The treatments included a High (H), Medium (M) and Low (L) application regime, with three replications of each treatment.

The treatments were designed to give a range of water availability and water stress to test the extents of the thermal sensors and maximize the amount of data available for analysis.

Figure 34. CSIDC Demonstration Site Field Plot Layout, 2021.

The 2021 field crop tested was canola. Canola is a primary irrigation crop in the region and presents the potential challenge of flowering impacting remotely sensed images/data. The field was initially treated with uniform irrigation during the month of May to encourage uniform canopy development and a consistent starting point between each irrigation treatment. This is a drawback associated with all remotely sensed scheduling methods, as they are only applicable once the crop has emerged and a canopy can be sensed, although there has been some indication that thermal temperature indices can be applied on bare soil.

Beginning June 1st, irrigation treatments were started with the **High** treatment receiving 100% application, **Medium** treatment receiving 66% application, and **Low** treatment receiving 33% application. During the period of June 1st until July 31st, the High, Medium and Low treatments received irrigation applications of **197 mm**, **130 mm**, and **65 mm**, respectively. Due to the above average temperatures the canola crop began maturing early in August and irrigation treatments were discontinued. During the irrigation season, soil moisture was monitored using commercial time domain reflectometry (TDR) sensors (Figure 35). These sensors were accessed remotely throughout the season to monitor crop water status and schedule irrigation events accordingly.

Figure 35. Sensoterra TDR sensor installed at CSIDC Demo Site, Outlook, SK, 2021.

Each treatment and replication was equipped with a sensor cluster (Figure 36). These clusters included TDR sensors installed at depths of 15 cm, 30 cm, 45 cm and 60 cm; each TDR sensor was connected to a data logger and recorded volumetric soil moisture on 1 hr time intervals. The proposed stratified TDR installs monitored the soil moisture in the top 60 cm of the soil profile. Equipment clusters also consisted of Apogee SI-411 Infrared Thermometers and a Decagon SRS-Nr dual band spectrometer for calculating NDVI values. The data was logged on 1 hr time intervals, but for evaluations of indices, solar noon values (approximately 1 pm during growing season) were utilized to be consistent with the literature.

Figure 36. Instrumentation cluster consisting of stratified TDR, NDVI sensor, IRT and data logger.

RESULTS & DISCUSSION

During the first full growing season the focus of the field work looked at the relationship between crop health, as described by NDVI, and the ability to regulate the crops canopy temperature. Two of the thermal indices investigated that rely on canopy temperature is the Water Stress Index (WSI) and the Crop Water Stress Index (CWSI).

Water Stress Index

Water Stress Index (WSI), proposed by Girolimetto and Venturini (2013), requires the development of a NDVI-Ts plot for crop types/classes within the growing region. Using the data collected from the sensor clusters located in the CSIDC-demonstration site, a NDVI-Ts plot was developed for canola in the Outlook area (Figure 37).

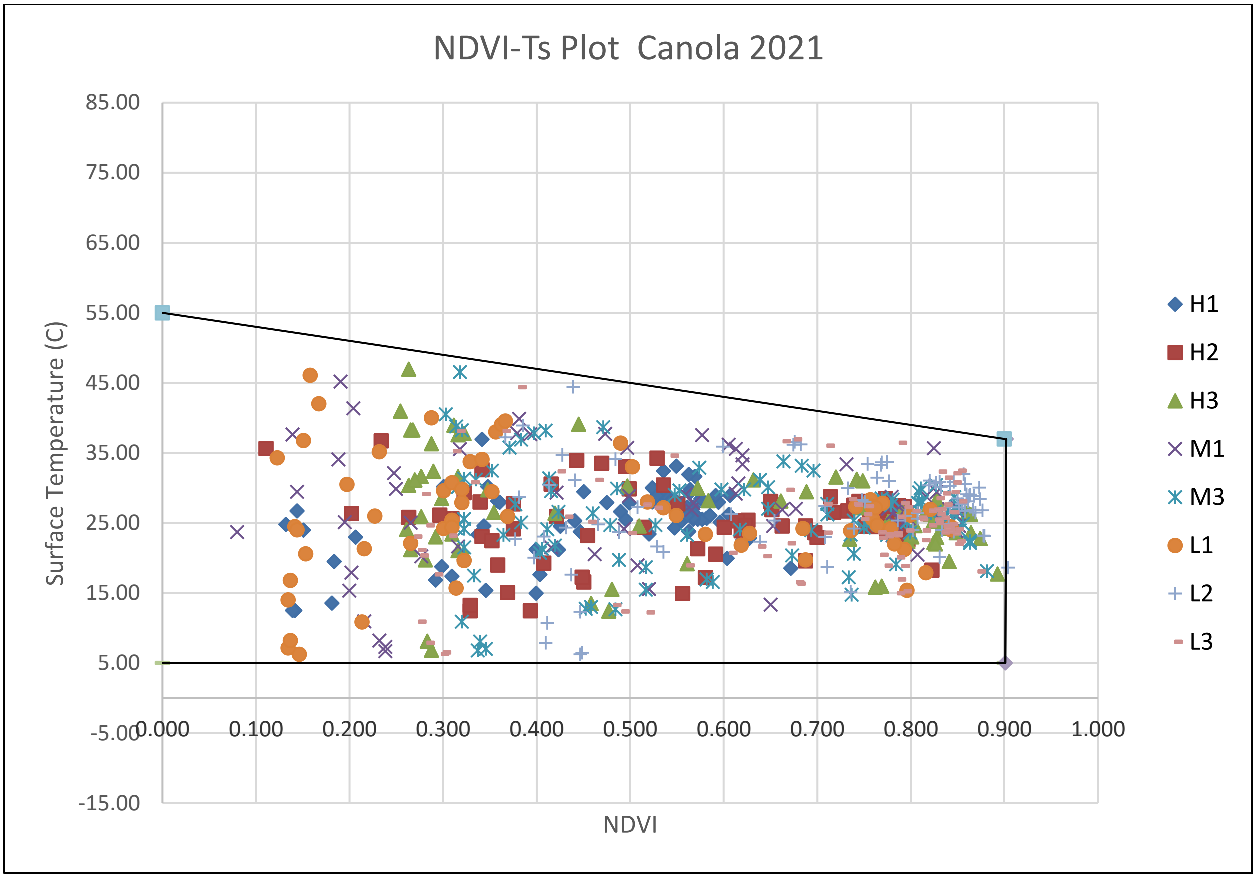

Figure 37. NDVI – Ts plot for irrigated Canola field plots at the CSIDC demonstration site, 2021.

The trapezoid that encompasses the seasonal measurements (Figure 37), is similar in shape to those developed by Jian and Islam (2001) over the southern great plains of the United States. The maximum and minimum surface temperature when NDVI is equal to zero for our test was 55°C and 5°C respectively, compare this to the Jian and Islam values of 53°C and 19°C. The minimum value varies significantly between the two sites, this could be due to insufficient data or variability in regional climate, further years of study should provide some clarification. These constants/values are the basis requirement for calculating WSI for the crop spatially and temporally.

Water Stress Index (WSI) is defined by:

$$\mathbf{WSI = (T_i - T_{min}) / (T_{max} - T_{min})} \qquad \textbf{Eq. 1}$$

Where:

- WSI Water Stress Index (unit less)
- T_i Measured Temperature (°C)
- T_{min} Minimum Temperature from NDVI-T_s plot (°C)
- T_{max} Maximum Temperature from NDVI-T_s plot (°C)

From the NDVI-T_s plot, the minimum and maximum temperature is estimated at 5°C and 55°C, respectively (where the trapezoid lines intersect the value of NDVI = 0). Therefore, Equation 1 becomes:

$$\mathbf{WSI = (T_i – 5)/50} \qquad \textbf{Eq. 2}$$

Applying the WSI to measurements from each instrumentation cluster (example: Replication High 1 – Figure 38), is shown compared to stratified soil moisture measurements. There is some indication of water stress (High WSI) in the early season measurements (dates up to July 4, 2021) when soil moisture levels are low, but for the remainder of the growing season, there does not seem to be significant correlation to the observed soil moisture content.

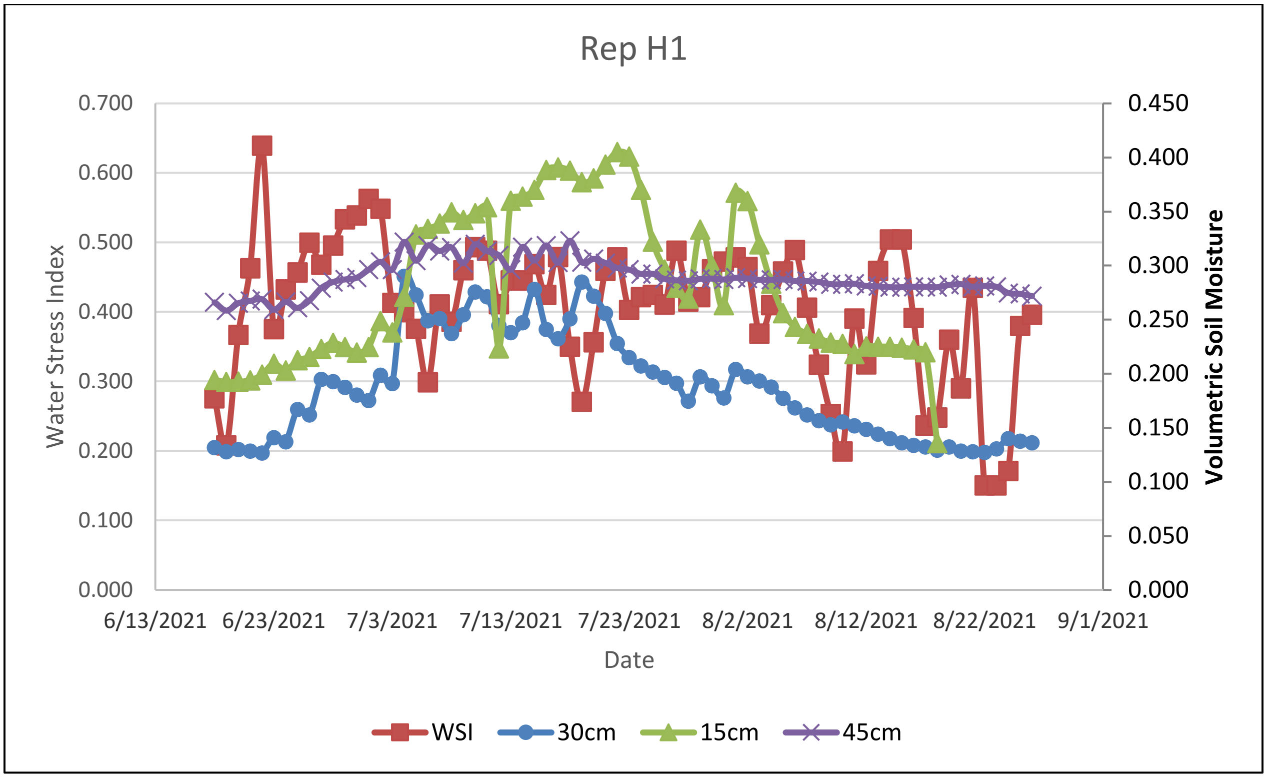

Figure 38. Daily WSI and volumetric soil moisture for Canola field plot H1, CSIDC, Outlook, SK, 2021.

Looking deeper into how WSI is calculated, it does not account for fluctuations in air temperature in comparison to crop temperature. Plotting WSI with the air temperature taken at solar noon shows that the two are strongly linked (Figure 39). When looking at both lines there seems to be potential to tease out useful data, for example when the gap between the two lines is small, it is related to dates with lower soil moisture levels (early and late season), while the largest spacing between lines is more related to midseason where soil moisture levels were higher. Moving forward, the team will look at normalizing the WSI to account for daily temperature fluctuations.

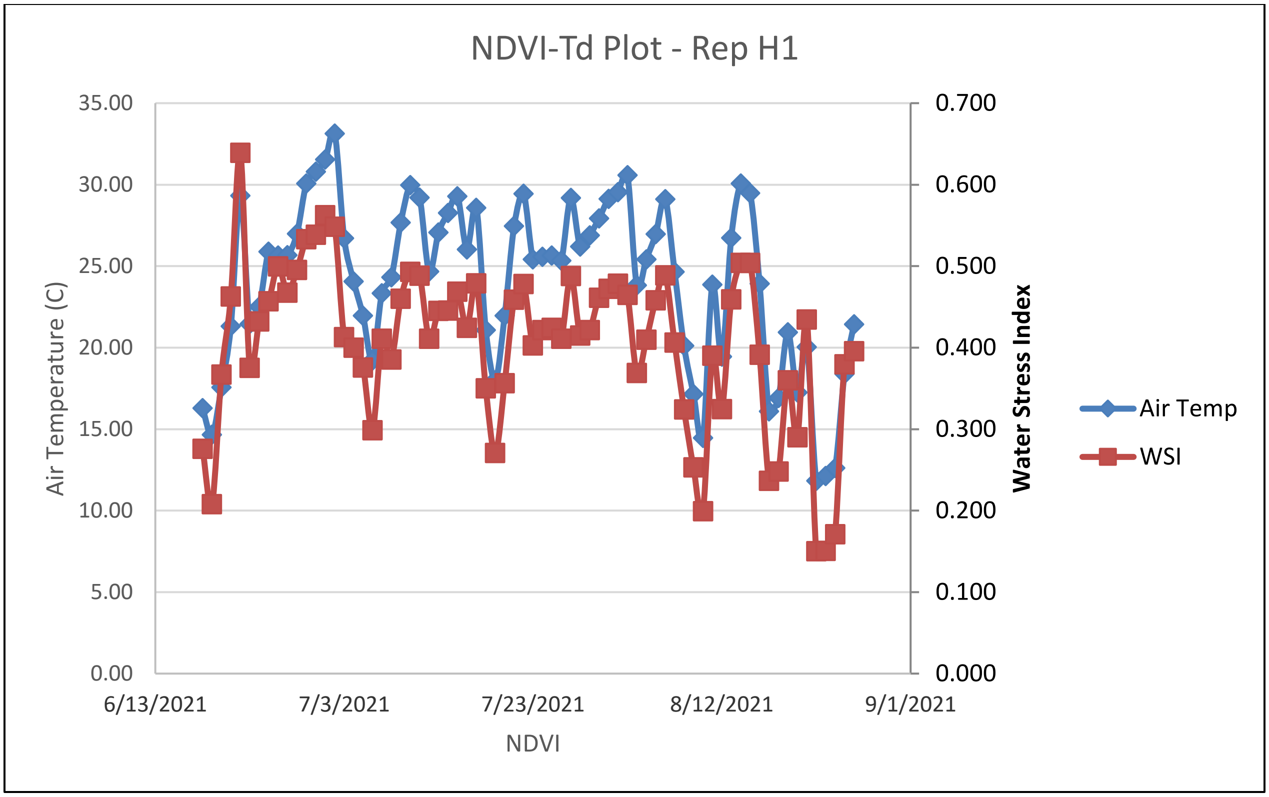

Figure 39. Daily WSI and solar noon air temperature for Canola field plot H1, CSIDC, Outlook, SK, 2021.

Crop Water Stress Index

The second thermal index investigated was the Crop Water Stress Index (CWSI). The CWSI utilizes the relationship between differential temperature (canopy – air) in areas of variable water availability throughout the field (Equation 3).

$$\mathbf{CWSI = [(T_s - T_{air})_i - (T_s - T_{air})_{dry}] / [(T_s - T_{air})_{wet} - (T_s - T_{air})_{dry}] \qquad Eq.\ 3}$$

Where:

T_s Canopy Temperature [area of interest (i), dry area (dry) or well watered area (wet)]
T_{air} Air Temperature

Under the original crop water stress index (CWSI) methodology, a producer is required to maintain a crop under dry water stressed conditions (dry) and optimal water available conditions (wet). This methodology is impractical in everyday irrigation practice. As an alternative, researchers proposed developing NDVI-Td plots that can be used to estimate these extremes by evaluation of differential temperature variability for different degrees of plant health (classified by NDVI). The resulting NDVI-Td plot (Figure 40), follows a similar pattern to those produced in the literature (Moren et al., 1994), just shifted along the temperature axis. This shift is likely due to variability in regional environment and crop type being investigated. One conclusion to the shape of this graph is the relationship between a poor crop canopy (low NDVI) having the highest differential temperature and as the canopy improves (high NDVI) the difference in temperature becomes very small. The graphical results confirm that a well established healthy plant/canopy has the ability to regulate its temperature compared to the surrounding temperatures. Note that there are instances of low NDVI and low differential temperature, but in general a healthy canopy maintains a more controlled temperature (space between the left and right edges of the trapezoid).

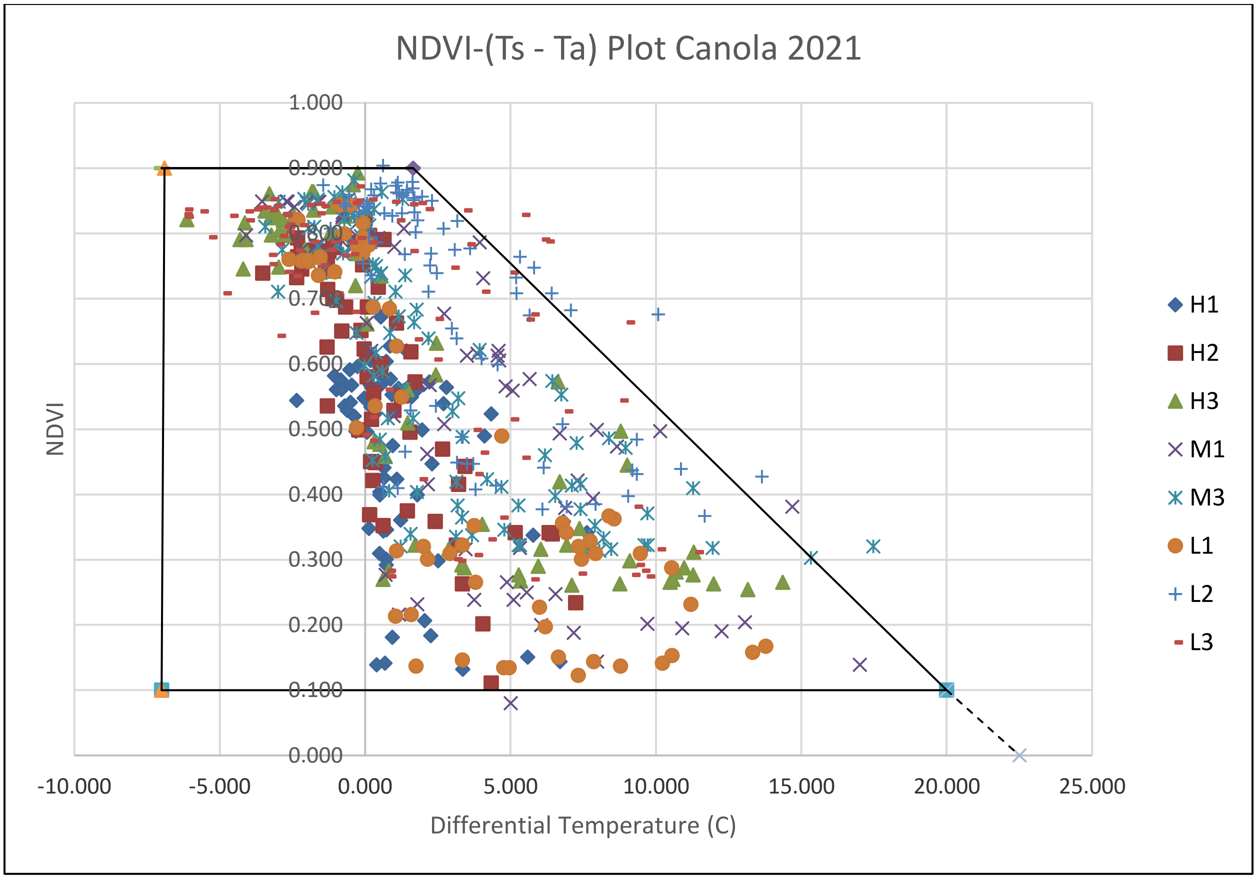

Figure 40. NDVI – Td plot for irrigated canola field plots at the CSIDC demonstration site, 2021.

Utilizing the maximums and minimums from the NDVI-Td plot and applying to the CWSI for wet and dry crop measurements simplifies the application of the index. The results of applying the modified CWSI to the plots are more promising compared to those from the water stress index (WSI).

Looking at Plot H1 as an example (Figure 41), higher CWSI values are associated with the start and end of the irrigation season. There are three possible causes driving this trend, i) insufficient crop canopy to provide a cooler surface compared to air (early season), ii) maturing crop resulting in reduced ET (late season), or iii) insufficient soil moisture.

There is some indication that moisture availability has an affect based on soil moisture levels being inversely related to the CWSI in the resulting graphs. This will need to be investigated closer over multiple seasons to validate the results and more importantly help identify a CWSI level to be maintained for adequate irrigation – as an example a level of CWSI < 0.3 could be an initial recommendation (additional plot results in appendix).

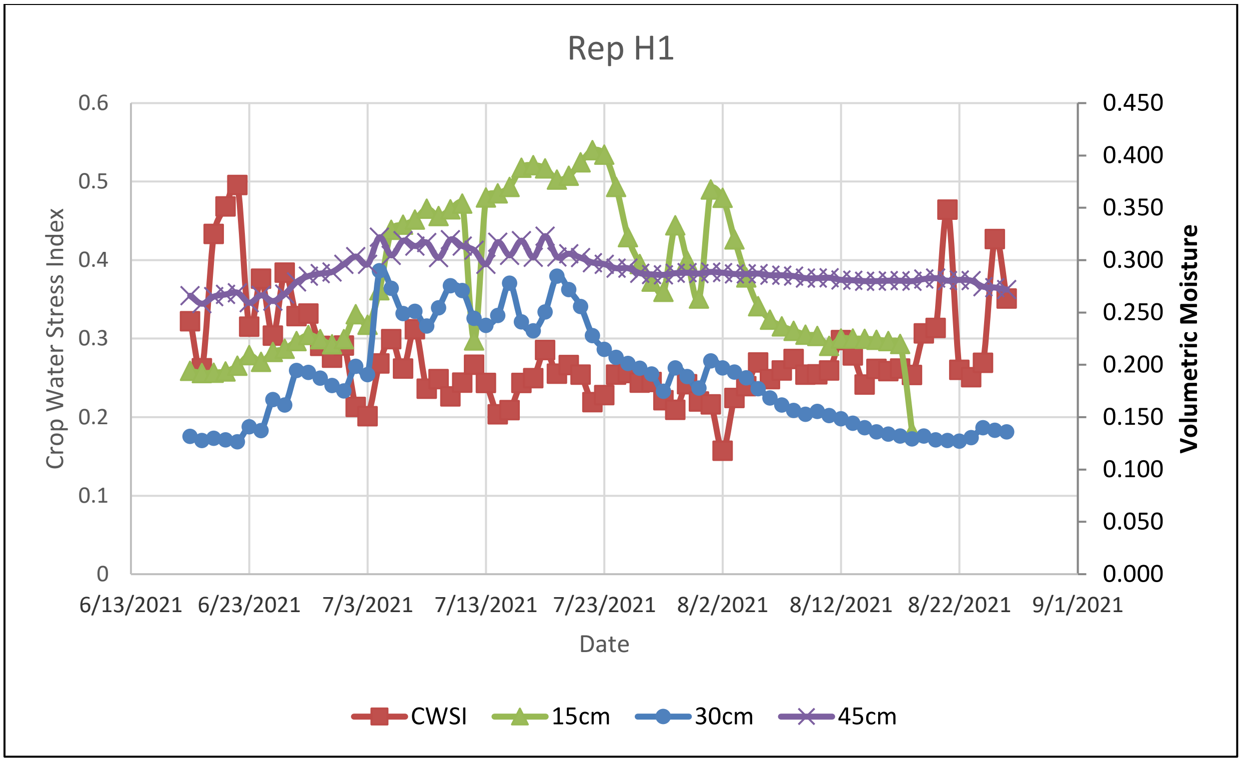

Figure 41. Daily CWSI and volumetric soil moisture for Canola field plot H1, CSIDC, Outlook, SK, 2021.

CONCLUSIONS

- There is a strong correlation between crop canopy health (high NDVI) and a crops ability to regulate its temperature compared to the surroundings.
- Water Stress Index (WSI) cannot be utilized as defined without accounting for variability in air temperatures, further investigation is required.
- Results have been similar to research in great plains of the United States in terms of relationship, but absolute values vary which may be a result of differing climates or crop types.

Online Decision Support Tool for Precision Agriculture and Irrigation Scheduling

Funded by Saskatchewan Agricultural Development Fund

Principal Investigator: Evan Derdall, AAFC-Saskatoon
Co-Investigators: Dr. Ralph Deters, University of Saskatchewan

INTRODUCTION

IrriCAN, is an online decision support mapping tool developed to assist agricultural producers schedule irrigation and monitor crop health using satellite imagery. The objective of this tool was to address the lack of adoption of irrigation scheduling, specifically climate based irrigation scheduling by Saskatchewan irrigation producers (Girven and Associates, 2014). To achieve this, the development team created a freely available online tool, which is user friendly requiring only basic field and irrigation information. IrriCAN also provides the users with weekly Normalized Difference Vegetative Index (NDVI) maps via the Google Earth Engine (GEE); providing users with the added benefit of spatially monitoring crop health.

IrriCAN is a collaboration between Agriculture and Agri-Food Canada, the University of Saskatchewan, the IrriSAT team (Australia) with funding assistance from the Government of Saskatchewan's Agriculture Development Fund (ADF). The team adapted the IrriSAT concept (Satellite based irrigation scheduling), working with local producers to tailor a product that fits the needs of Saskatchewan irrigated producers.

The IrriCAN model is an online system that utilizes online resources (weather data, cloud storage) and spatial imagery to estimate crop water availability. IrriCAN is similar to existing irrigation scheduling models that rely on a simplified water balance to estimate crop available soil moisture (Eq.1).

$$\mathbf{SM_i = SM_{i-1} + P + I - ET_c + SM_{initial} \times RD} \qquad \textbf{(Eq.1)}$$

Where:

SM_i	soil moisture for day i [mm]
SM_{i-1}	soil moisture for day i – 1 [mm]
P	precipitation [mm]
I	irrigation [mm]
ET_c	crop evapotranspiration [mm]
$SM_{initial}$	initial field soil moisture [cm^3/cm^3]
RD	root depth propagation [mm] – depth root zone increases on day i

Soil moisture within the model is adjusted daily based on inputs (precipitation and irrigation) and what is removed from the system (evapotranspiration). IrriCAN incorporated a simplified root growth model and user defined initial soil moisture, this was done to account for moisture that becomes available to the plant as the roots propagate downward in the profile.

Within the model, soil moisture cannot exceed field capacity (upper) and permanent wilting point (lower limit). These limits will vary within the growing season depending on crop type (maximum rooting depth) and soil texture (moisture holding capacity). These limits are displayed graphically within the IrriCAN water balance menu (Figure 42).

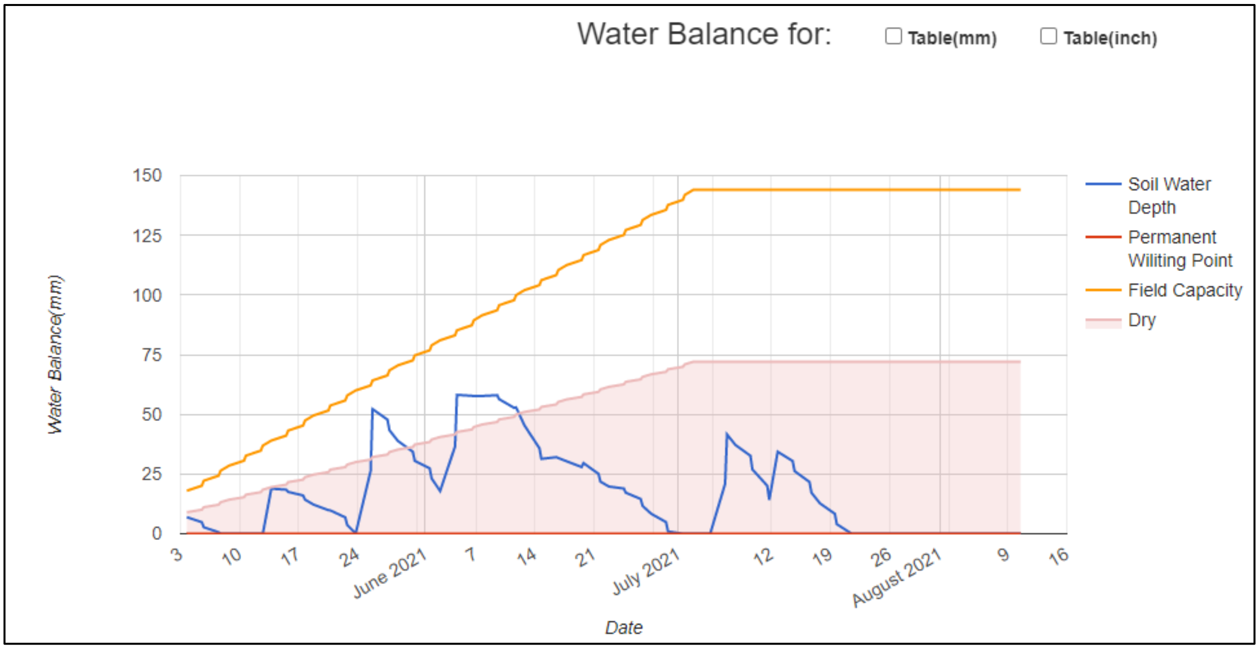

Figure 42. IrriCAN water balance graph.

The model restricts soil moisture between the upper and lower limits; to simplify the system excess (drainage and runoff) and moisture below permanent wilting point are not accounted for within the program.

Precipitation amounts are modelled for each user created field. Based on the geographic location of the users field, IrriCAN utilizes an online weather service provider, which populates historic weather data required for water balance and evapotranspiration calculations. This eliminates the requirement to select a regional weather station that may be located a significant distance from the field. As precipitation can still be spatially variable, the model allows the user to manually overwrite precipitation data with local gauge measurements.

Irrigation application data is the only input that is required to be entered on an ongoing basis throughout the growing season. The calendar interface allows the users to select the date of irrigation and enter current applications or previously applied applications.

The most complex component of the water balance model is estimation of crop evapotranspiration (ET_c). Evapotranspiration is the water lost from the system through evaporation for the soil surface and transpired through the plant during photosynthesis. To estimate crop evapotranspiration (ET_c), IrriCAN models potential evapotranspiration (ET_o) for a reference crop (grass) and then applies a crop water use coefficient (K_c) that adjusts for the crop type and growth stage (Eq.2).

$$ET_c = ET_o \times K_c \qquad \textbf{(Eq.2)}$$

Where:

ET_c crop evapotranspiration [mm day^{-1}]
ET_o reference evapotranspiration [mm day^{-1}]
K_c crop water use coefficient

Potential Evapotranspiration (ET_o), is modelled in IrriCAN using a modified version of the Penman Monteith Equation (Eq.3), online irrigation scheduling calculators will commonly use climate based models such as the Penman Monteith or alternative due to the availability of data and positive results.

$$ET_o = 1.049\left(\frac{1.049\Delta(R_a)+\gamma\frac{900}{T+273}u_2(e_s+e_a)}{\Delta+\gamma(1+0.34u_2)}\right)+0.133 \qquad \textbf{(Eq.3)}$$

Where:

ET_o	reference evapotranspiration [mm day^{-1}]
R_a	extraterrestrial radiation [MJ m^{-2} day^{-1}]
T	mean daily air temperature at 2 m height [°C]
u_2	wind speed at 2 m height [m s^{-1}]
e_s	saturation vapour pressure [kPa]
e_a	actual vapour pressure [kPa]
Δ	slope vapour pressure curve [kPa $°C^{-1}$]
γ	psychrometric constant [kPa $°C^{-1}$]

The majority of environmental values required by the Modified Penman Monteith equation are provided for the users field location through the climatic service provider automatically when the model is run. The exception is extraterrestrial radiation (R_a); IrriCAN utilizes a fields geographic coordinates, specifically latitude, and day of the year to estimate this value.

Crop water use coefficients (K_c), used in most irrigation scheduling programs have been developed over the years utilizing historical research results. The limitation is that these coefficients were developed under ideal conditions (non-stressed), usually at distant (from producers field) research sites with varieties no longer in use. IrriCAN utilizes an established relationship (Trout and Johnson, 2007) between Normalized Difference Vegetation Index (NDVI) and crop water use coefficient (Eq.4).

Kc = 1.37 NDVI – 0.086 (Eq.4)

Where:

Kc, Crop Water use coefficient, converts modelled/measured potential evapotranspiration measurements into crop specific evapotranspiration.

NDVI, Normalized Difference Vegetation Index, a vegetation index that utilizes spectral bands to quantify crop health and canopy density.

The benefit of utilizing the NDVI/Kc relationship is that it is crop and stage independent as it relies on remotely sensed data and not growth assumed under traditional Kc values. With improved availability in NDVI image resolution and acquisition, via Sentinel-2 satellite constellation, and processing imagery into an easily accessible format (Google Earth Engine), has allowed for the development decision support tools such as IrriCAN. As the technology available on these satellite missions continues to improve and become more readily available, it is likely the applicability and accuracy of online decision support tools will improve.

MATERIALS & METHODS

To evaluate the accuracy of the crop water use coefficients generated utilizing the IrriCAN model, two field experiments were conducted.

i) IrriCAN comparison to commercial irrigation sensor

The Arable Mark © is a commercially available infield irrigation sensor (Figure 43). This sensor is a stand alone weather station (temperature, relative humidity, wind speed, radiation, precipitation) with an integrated multispectral sensor for monitoring crop NDVI. Data from the sensor is uploaded via a cellular modem to Arable servers. Utilizing a proprietary algorithm, the software estimates crop evapotranspiration similar to the IrriCAN model by combining ET estimates from environmental conditions and crop stage/health from NDVI data.

Figure 43. Arable Mark (white disk) mounted on tripod (Outlook, SK, 2020).

During the 2020 growing season, four Arable Marks were installed at the CSIDC demonstration site field seeded to wheat. Each location varied slightly in overall texture of the soil profile and elevation (hill, knoll, side slope). Crop water use data was collected throughout the season at each site and compared to the IrriCAN model and the Alberta Irrigation Management Model (AIMM) crop water use coefficients.

ii) IrriCAN comparison to soil moisture measurements

The second trial was designed to measure daily soil moisture flux at the plot level, local environmental conditions and crop NDVI to estimate site specific crop water use coefficient.

To estimate soil flux, time domain reflectometry (TDR) sensors were install at depths of 15 cm, 30 cm, 45 cm and 60 cm (Figure 44a), with the data collected hourly to measure how soil moisture varied during the season.

Potential evapotranspiration (PET) was calculated using the Modified Penman Montieth equation (Eq.3) using weather data from the local (<2.5 km) Environment and Climate Change Canada (ECCC) weather station. With this data a daily water balance was conducted, incorporating irrigation and precipitation data, to estimate daily crop evapotranspiration (ETc) and crop water use coefficient (Eq.5).

$$Kc_i = ETc_i / PET_i \qquad \text{Eq. 5}$$

Field plots were also equipped with a dual band (Red and Near Infrared) NDVI sensor that monitored the local crop canopy (Figure 44b). Comparative analysis of the NDVI and Kc data to quantify the observed relationship and compare to the formula utilized by the online decision support tool. As the water flux in the soil varies significantly from day to day depending on environmental and soil conditions, a seven day rolling average for crop water use was utilized in an attempt to eliminate some of the 'noise' associated with the readings.

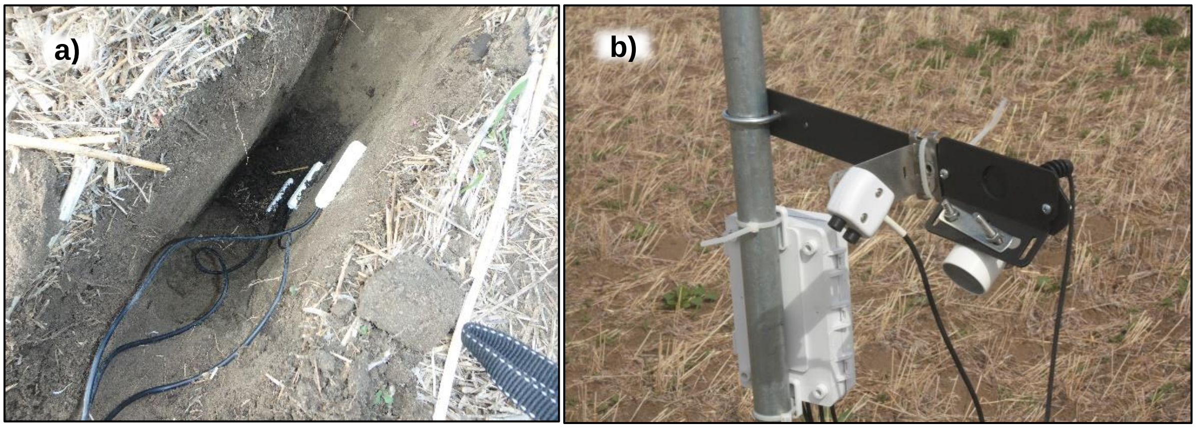

Figure 44. a) TDR sensors installed in the soil profile and b) NDVI and Thermal sensors connected to a data logging system. Outlook, SK, 2021.

RESULTS & DISCUSSION

i) IrriCAN comparison to commercial irrigation sensor

The infield irrigation scheduling sensors (Arable Marks) showed some variability in crop water demand throughout the growing season (Figure 45). Each location followed a similar pattern during crop development but we see a divergence around Day 50.

Locations VRI 1 and VRI 4, develop similarly but reach a peak water demand (peak NDVI value) at Day 50 before leveling off and entering a decline. These locations are positioned on ridges where the overall texture has a higher sand content than the remaining sites, VRI 2 and VRI 3, which are located in a depression with higher silt content in the soil. It can be hypothesized that the reduction in water demand (NDVI) is due to fertility (coarse vs fine texture) or water availability (holding capacity or landscape) or a combination of the two. This analysis does highlight how crop water use coefficients will vary within the same field and stage of crop development.

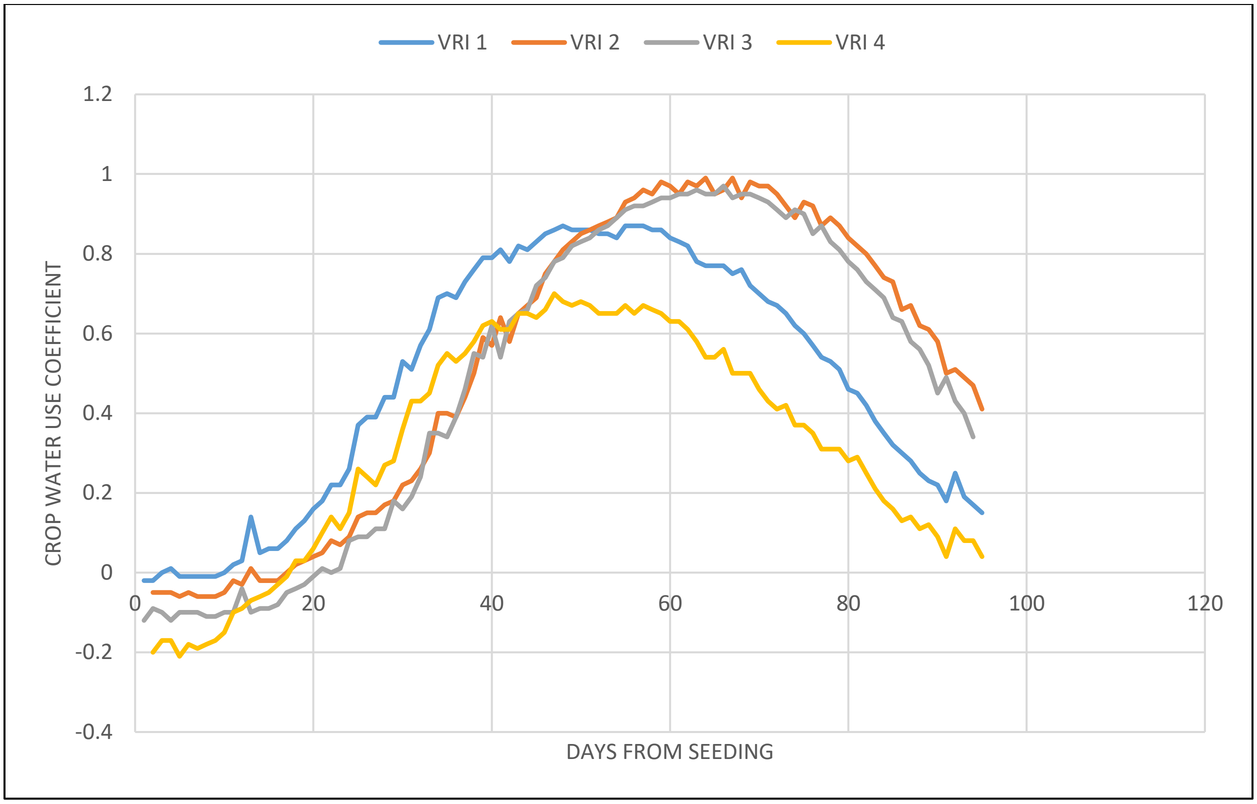

Figure 45. Crop water use coefficient for a wheat crop at four location within a single irrigated field, Outlook, SK, 2020.

The infield irrigation scheduling sensor data was compared to the crop water use coefficients derived from the online decision support tool (IrriCAN) and AIMM (Figure 46).

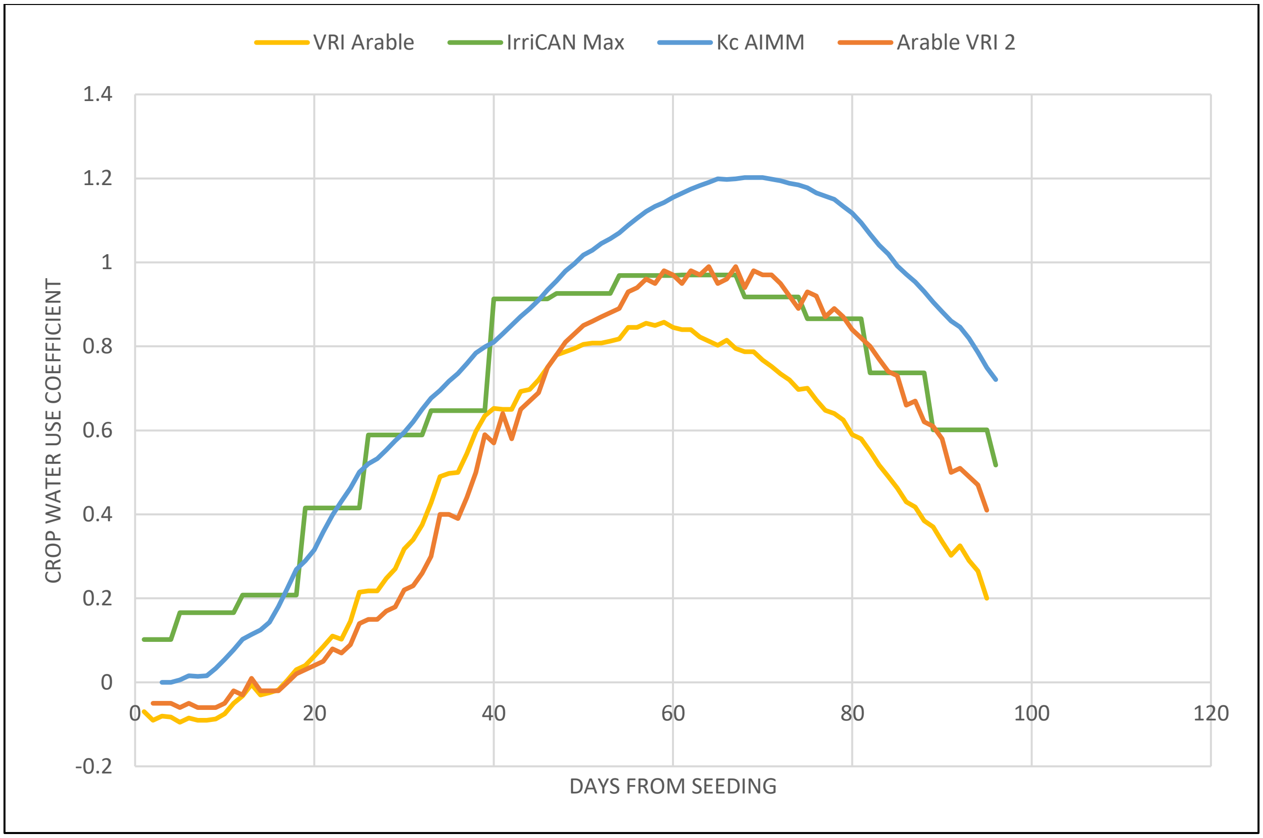

Figure 46. Crop water use coefficient for a wheat crop using three different sources (AIMM, IrriCAN, Arable field sensor), Outlook, SK, 2020.

The IrriCAN model was designed to average the NDVI values (pixel value) within the field boundaries (user defined) of each satellite capture and use the weekly maximum. During a one week period, the field may be subject to multiple satellite captures depending on timing and location; this maximum selection was done in an attempt to account for cloud cover issues. This weekly time step results in a stepwise reporting pattern (Figure 46), as the model assumes a constant Kc over the reporting period (1 week).

In general, the IrriCAN model Kc value was closely representative of the peak infield irrigation sensor (Arable Mark location VRI 2). The model overestimated Kc values early in the season, but the peak water use (timing and values) were similar. The IrriCAN value was an overestimate of the infield sensor average, this could be due to sensor placement (poor areas having greater impact on average) or the sensing footprint.

The AIMM Kc values were higher than both the infield moisture sensor (Arable Mark) and the IrriCAN values. The values follow a similar trend during early season but have a delayed peak water use and higher measured crop water use. This pattern (early season with delay in peak) is similar to the difference between the infield measurement locations (Figure 49). This highlights the issue of the historical reference Kc that is utilized by AIMM. Under ideal conditions we would expect to see a crop water use coefficient follow the pattern shown with AIMM (Figure 46); but this method disregards field conditions that are not ideal for crop growth (fertility, environment, soil and crop) and likely resulting in an overestimation of crop water use.

ii) IrriCAN comparison to soil moisture measurements

The second trial used installations of soil moisture and NDVI sensors to develop a relationship and compare those values to the IrriCAN model. A total of nine field plots were instrumented with soil moisture sensors in the profile (15 cm, 30 cm, 45 cm and 60 cm) and an above ground NDVI sensor measuring crop canopy.

The results (Figure 47) show a relationship between NDVI and crop water use expressed as a linear relationship (Eq.6).

$$Kc = 0.946*NDVI - 0.0863 \quad \text{(Eq. 6)}$$

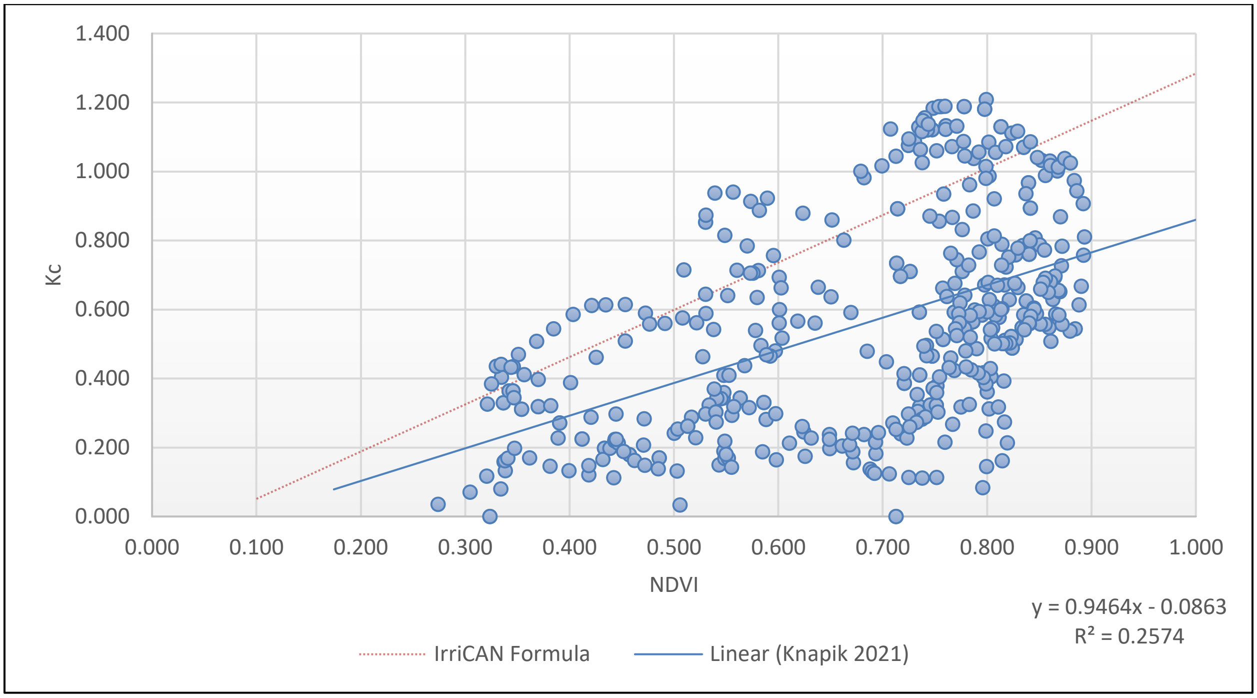

Figure 47. Estimated crop water use coefficients and NDVI based on field measurements, Outlook, SK, 2021.

The relationship had a positive linear agreement but the data varied from the original equation proposed by Trout and Johnson (2007; Eq.4). The variability between the two equation could be the result of a number of issues with the trial setup:

i) Trial lacked data at the upper end of the NDVI range (0.9 – 1.0); values in this range are difficult to achieve under field production as ideal canopy development is required with limited impact from nutrient deficiency or water stress.

ii) Estimation of daily crop water flux utilizing soil moisture sensors is not ideal, as it is prone to variability due to water movement vertically/horizontally within the monitoring area. Common methods, such as weighing lysimeters and flux towers are expensive or not suited for small plot studies.

iii) NDVI values are slow to 'react' to changes in water demand. This was identified as a limitation in previous work completed on variable rate irrigation (Bauer et al., 2019). Example: modelled Kc at Site Low Rep 1 (Figure 48) generally corresponds well with measured Kc during crop development. Values begin to diverge after peak seasonal water demand. As measured Kc begins to reduce later in the season, the modelled Kc remains elevated due to high NDVI values. This delay will result in an overestimation of crop water use later in the growing season.

iv) The delay response, although partially due to NDVI delayed response as reported in previous research (Bauer et al., 2019), may be due to underestimate of measured Kc.

Soil moisture drawdown continues (Figure 49), although soil moisture was only monitored to a depth of 60 cm. Moisture loss below this depth may have been occurring but not incorporated into Kc estimates due to lack of sensor data. This may have to be investigated further.

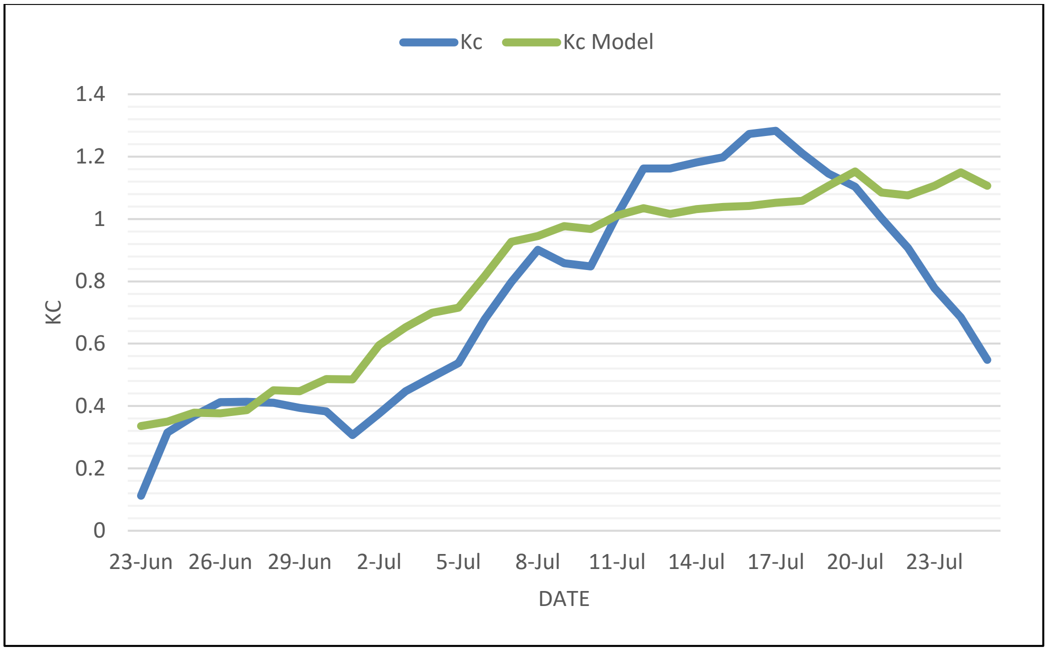

Figure 48. Crop water use coefficient (Kc) estimated and modelled, Site Low Replication 1, Outlook, SK, 2021.

Figure 49. Soil moisture available (0-600 mm), Site Low Replication 1, Outlook, SK, 2021.

The culmination of the proposed issues likely resulted in a general underrepresentation of total soil moisture loss and resulting crop water use coefficient. Therefore, it is reasonable to accept the work.

CONCLUSIONS & NEXT STEPS

The IrriCAN online decision support tool is currently available to producers (www.irrican.com) for use in scheduling irrigation application and scouting field for spatial anomalies. The product has shown to produce similar results to infield soil moisture sensors and currently available irrigation scheduling programs.

NDVI based irrigation scheduling has been shown to work well at adjusting to infield soil moisture availability, both spatially and temporally. Project results show that some caution needs to be taken with late season irrigation scheduling using NDVI, as crop water demand will taper-off prior to impact on NDVI values. Ongoing field testing will continue to validate the NDVI-Kc relationship and improve the overall robustness of the IrriCAN software.

Work is currently underway to find a long term home for the software. This is required to maintain continuity of the product, ensure the continued free for use model and allow for resources to be directed towards improvements to the model and expanded capability of the software.

Climate Change Resilience – Understanding of Management and Tools to Address Water Extreme Events and Matching Water Demand with Access

Funded by Agriculture and Agri-Food Canada

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INTRODUCTION

Climate change will have a major impact on agricultural production in Canada with average temperature increases anticipated to be twice that of the global average (ECCC, 2019). This increase will cause greater uncertainty in weather patterns, resulting in an increase in the intensity of extreme events including drought and flooding (Pomeroy, 2018). These weather events and greater variability are forecast to be more frequent and the new normal. Increased water scarcity is predicted in regions of western Canada while other areas in Canada will see extreme events causing flooding. Increased evapotranspiration resulting from rising average temperatures could eclipse any increase in precipitation, reducing overall soil moisture. There are serious risks of decreased water availability on the prairies, which account for 80% of Canadas farmland (Gracia–Garza et al., 2017).

Drought has a high economic cost for both the Canadian economy and Government budgets. Overall, changes pose management challenges but also opportunities for agricultural production in Canada. Many experts believe western Canada could be one of the few areas to benefit from climate change. Additional heat units and a longer growing season could benefit production if farmers are able to adjust by adopting crops and technologies for this predicted warmer climate. To capitalize on this opportunity, and prepare for periods of water uncertainty, stakeholders will require management practices and tools to address water extreme events in both rain-fed and irrigated production systems. Irrigation is a key resilience mechanism through drought mitigation, crop diversification, and value adding. Irrigation is practiced on 1.0 million hectares in Canada, with a majority in the west, accounting for 90% of the total water consumed in agriculture.

Through research development and knowledge transfer, AAFC is assisting the agricultural industry adapt to a changing environment. This project aims to develop knowledge and tools to help producers and industry adapt to changing water availability as a result of climate change, three key areas of focus toward this objective:

1) Improve the forecasting ability by leveraging existing capacity within AAFC (Droughtwatch), developing reporting tools designed to assist producers plan for short and longer term water availability. Examine enhanced collaboration with the Global Institute for Water Security and ECCC modellers related to agricultural water management and climate change;

2) Development of agronomic Best Management Practices (BMPs) – work with partners and industry to improve water use efficiency through agronomic approaches including nutrient management, varietal evaluation, agronomy, etc., and;

3) Evaluation of management tools for improved water and energy use efficiency. Build on existing work in the areas of precision irrigation, variable rate irrigation, solar irrigation, deficit irrigation, irrigation scheduling and remote sensing that will help match water demand to access. Adoption of these practices and tools will assist producers to make the most efficient use of inputs and improve water use efficiency. They aim to increase productivity and resiliency of agricultural operations.

RESULTS & DISCUSSION

The project consists of a number of activities that are designed to work toward the three outlined objectives.

Activity 1: *Development of multi-variable agro-climate indices and tools to assist in addressing water management challenges under climate change.*

Initial progression on Activity 1 was to calculate the Standardised Precipitation-Evapotranspiration Index (SPEI) for approximately 1700 data nodes located throughout the South Saskatchewan River Basin (SSRB). The SPEI was calculated on a monthly basis over a historical time period (1981-2010). The results allow for visualization of the degree of excess or deficit moisture (Precipitation – Evapotranspiration) throughout the SSRB (Figure 50; Figure 51).

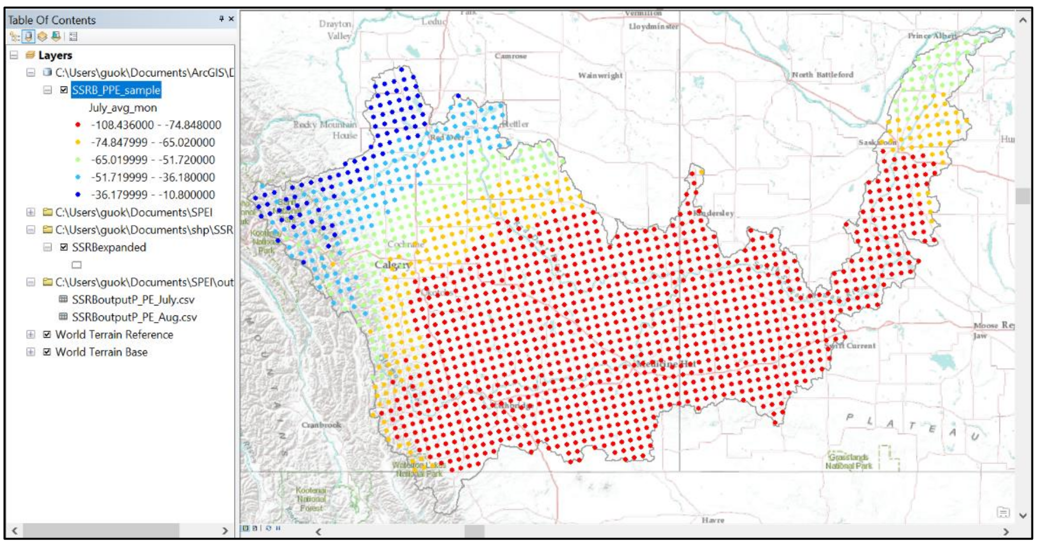

Figure 50. Historical (1981-2010) average standardised precipitation-evapotranspiration index values for July, within the South Saskatchewan River Basin.

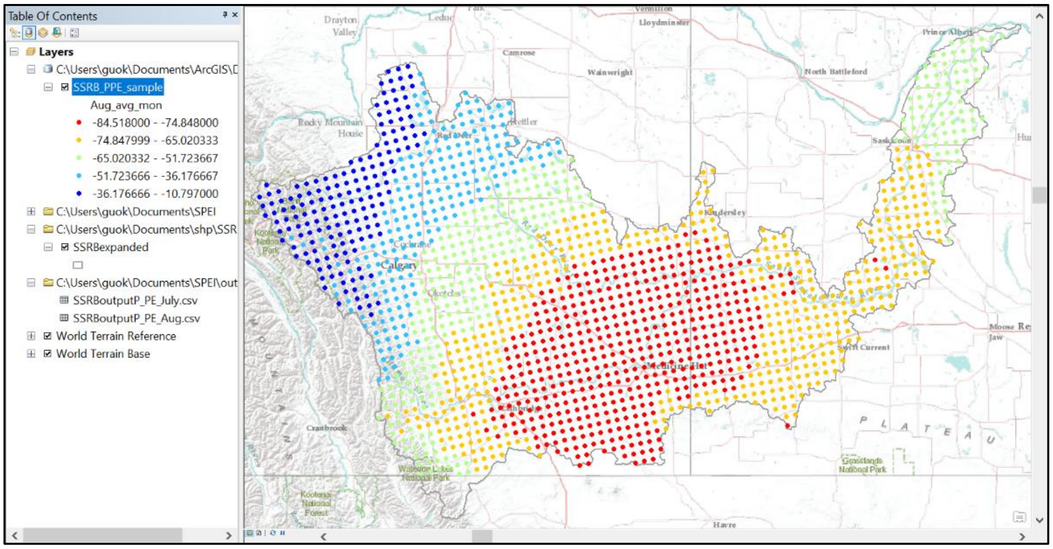

Figure 51. **Historical (1981-2010) average standardised precipitation-evapotranspiration index values for August, within the South Saskatchewan River Basin.**

With this developed system, the team intends on modelling SPEI averages looking forward under proposed climate change scenarios. This data will aide producers and irrigation district operators better understand potential water availability and irrigation demand moving forward. Providing a valuable tool in irrigation water supply management.

Activity 2: *Evaluate water productivity performance of a range of agronomic practices.*

Activity 2 intends to provide value added data to existing irrigation agronomy projects by monitoring water use efficiency. Water use efficiency is currently not actively monitored or calculated on irrigated agronomy projects. As water resources become in higher demand, information on how agronomic practices and varieties impact water use efficiency will become more important.

Current projects included in the water productivity/use efficiency analysis include:

i) Evaluating the Effect of Seeding Date on Irrigation Requirements and Water Use Efficiency of Canola (pg. 26)
ii) Evaluating AAC Trueman in Saskatchewan (pg. 50)

Additional projects will be incorporated in future years, with the intent that water use efficiency or water productivity becomes a standard component of irrigated agronomy work at CSIDC.

Activity 3: *Develop and evaluation of tools to improve water productivity in irrigated production.*

Agriculture and Agri-Food Canada, in collaboration with the Saskatchewan Ministry of Agriculture, have recently produce a *NEW Saskatchewan Irrigation Scheduling Manual*, copies which are available through the Canada-Saskatchewan Irrigation Diversification Centre or the Ministry of Agriculture. The manual updates the existing Irrigation Scheduling Manual, incorporating new technology and providing a section on Variable Rate Irrigation Scheduling. Work is currently underway to expand the manual for use across the Canadian Prairies.

IrriCAN, which is an online irrigation tool has been recently released to producers, available at www.irrican.com. The tool allows producers to schedule their irrigation with ease using the freely available online portal. The tool also provides users with the added benefit of viewing weekly Normalized Difference Vegetative Index (NDVI) images to assist in crop scouting. Work has begun on finding a long-term home for the software which will allow for continued support and improvements moving forward.

NEXT STEPS

The team has completed year one of this three year project. Moving forward, this project looks at increasing its footprint and developing tools and data which can be utilized by irrigation stakeholders to make the best use of the water resources.

Crop Coefficient Development for Canola and Dry Bean in Saskatchewan to Improve Yield and Water Use Efficiency

Funded by Saskatchewan Agricultural Development Fund

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INTRODUCTION

This project looks at developing local crop coefficients (Kc) for canola and dry bean in Saskatchewan through the determination of evapotranspiration (ETc) of each crop in field studies at or near the Canada-Saskatchewan Irrigation Diversification Centre (CSIDC). The studies will take three years to complete and will involve establishment of separate canola and dry bean fields each year, collection of ETc data for each crop from seeding to harvest, and collection of meteorological data such as air temperature, solar radiation, and relative humidity from the meteorological station at CSIDC or instruments on the fields. The three-year data will then be analysed and use to develop crop coefficients for the crops various stages of development.

Canola and dry bean are important irrigated crops in Saskatchewan that respond well to irrigation and are adversely affected by drought or water deficit in terms of yield and seed quality. The crops require appropriate amounts of water throughout their growing cycle for maximum yield and quality product. This project focuses on local crop coefficient development for these crops in Saskatchewan, which currently do not exist, so that ETc for these crops can be better determined and used for more efficient irrigation management to increase yield, improve crop quality, minimize disease and reduce costs associated with excess moisture. Producers, researchers, consultants, and engineers involved in irrigation in Saskatchewan currently estimate crop water use of these crops using Kc values developed elsewhere.

Numerous research studies show ETc determined using Kc values from different regions does not fulfill the need for determining precise irrigation water requirements and either results in excess or deficit water which affects crop production. This is because the crop coefficient for each crop depends on things including local climatic conditions, soil properties, and the particular crop and variety (Allen et al., 1998) and should be determined locally. Unfortunately no such work has been done for these important irrigated crops in Saskatchewan. Canola and dry bean crop coefficients (Kc) will be developed at various phenological stages of development by the end of the project.

The use of Kc will create opportunities to boost production in Saskatchewan through the ability to estimate more precise water requirements. Crop coefficient values are used in irrigation design to calculate the amount of water needed in a reservoir to provide sufficient irrigation water to crops during growing season. They are also used in irrigation planning, irrigation management, and irrigation scheduling to determine the correct amount of water to apply to crops at the right time. With these values, engineers, agronomist, extension officers and producers are well-equipped to achieve more precise crop water application and efficient irrigation management for these crops in Saskatchewan.

The benefits that will be derived from the developed Kc for these crops by producers, Saskatchewan and Canada are enormous in terms of income, economic gains and environmental sustainability. These benefits include enabling producers to more precisely meet the water demand of these crops and avoid excessive or deficit use of water in irrigation which will result in increased crop yield and quality with enhanced water use efficiency; apart from improved profit from yield increases, producers will have extra financial gain through cost reduction on energy and water savings; and canola and dry bean diseases that are worsened by excess moisture would be reduced or eliminated, likewise nutrient leaching or runoff due to excess water application among others.

ICDC RESEARCH AND DEMONSTRATION PROGRAM

This report is published annually. Copies of this report can be found on ICDC's website at: https://irrigationsaskatchewan.com/icdc/publications/annual-program-report/

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