2020

Irrigation Crop Diversification Corporation

Research and Demonstration Report

ICDC

Irrigation Crop Diversification Corporation

Through innovation, the Irrigation Crop Diversification Corporation stimulates and services the development and expansion of sustainable irrigation in Saskatchewan.

Research and Demonstration Program Report 2020

ICDC Staff

Garry Hnatowich, PAg
Research Director
306-867-5405
garry.icdc@sasktel.net

Erin Karppinen
Research Director
306-867-5407
erin.icdc@sasktel.net

Damian Lee
Field Research Technician
306-867-2101
damian.icdc@sasktel.net

Theodore Nodge, AAg
Research Associate
306-867-9104
ted.icdc@sasktel.net

Brenda Joyes
Executive Administrator
306-867-5669
admin.icdc@sasktel.net

Saskatchewan Ministry of Agriculture Crops and Irrigation Branch Staff

Kelly Farden, PAg
Manager, Agronomy Services
Crops and Irrigation, Ministry of Agriculture
306-867-5507
kelly.farden@gov.sk.ca

Joel Peru, PAg, CCA
Provincial Irrigation Agrologist
Crops and Irrigation, Ministry of Agriculture
306-860-7201
joel.peru@gov.sk.ca

Gary Kruger, Pag, CCA
Provincial Irrigation Agrologist
Crops and Irrigation, Ministry of Agriculture
306-867-5524
gary.kruger@gov.sk.ca

Cara Drury, PAg
Provincial Irrigation Agrologist
Crops and Irrigation, Ministry of Agriculture
306-867-5517
cara.drury@gov.sk.ca

Travis Peardon, PAg
Livestock and Feed Extention Specialist
Crops and Irrigation, Ministry of Agriculture
306-867-5504
travis.peardon@gov.sk.ca

ICDC Research and Demonstration Report 2020

This report is published annually. Copies of this report can be found on our website. If you would like to be added to our mailing list, please contact us:

Irrigation Crop Diversification Corporation
Box 1460
Outlook, SK S0L 2L0
Phone: 306-867-5669
Email: admin.icdc@sasktel.net
http://irrigationsaskatchewan.com/icdc

VISION

To be the leading research and development organization for maximizing the value of irrigation.

OBJECTIVES AND PURPOSES OF ICDC

a) to research and demonstrate to producers and irrigation districts profitable agronomic practices for irrigated crops;

b) to develop or assist in developing varieties of crops suitable for irrigated conditions;

c) to provide land, facilities and technical support to researchers to conduct research into irrigation technology, cropping systems and soil and water conservation measures under irrigation and to provide information respecting that research to district consumers, irrigation districts and the public;

d) to co-operate with the Ministry in promoting and developing sustainable irrigation in Saskatchewan.

CONTACT

Irrigation Crop Diversification Corporation

901 McKenzie Street South
Box 1460
OUTLOOK, SK S0L 2N0
Bus: 306-867-5669 Fax: 306-867-2102
email: admin.icdc@sasktel.net
Web: http://irrigationsaskatchewan.com/icdc

BOARD OF DIRECTORS

Director	Position	Irrigation District	Development Area Represented	Term Expiry (current term)
Anthony Eliason	Chairman	Individual Irrigator	Non-District	2021 (2nd)
Jeff Ewen	Vice Chairman	Riverhurst	SEDA	2022 (1st)
Murray Purcell	Director	Moonlake	NDA	2020 (1st)
Nick Eliason	Director	Riverhurst	LDDA	2022 (1st)
Paul Heglund	Director	Consul-Nashlyn	SWDA	2020 (2nd)
Kaitlyn Gifford	Director	LDDA	SSRID	2020 (1st)
Greg Oldhaver	Director	Miry Creek	SWDA	2020[1]
Larry Lee	Director	SSRID	SIPA representative	Appointed
Aaron Gray	Director	Miry Creek	SIPA representative	Appointed
Kelly Farden	Director	N/A	SA representative	Appointed
Dianna Emperingham	Director	N/A	SA representative	Appointed

[1] Pursuant to Bylaw 7, Greg Oldhaver was appointed to a one year term

The four Development Areas (DA), as defined in ICDC's bylaws, are:

Northern (NDA),
South Western (SWDA),
South Eastern (SEDA), and
Lake Diefenbaker (LDDA).

ICDC Directors are elected by District Delegates who attend the annual meeting. Each Irrigation District is entitled to send one Delegate per 5,000 irrigated acres or part thereof to the annual meeting. Two Directors are elected from LDDA, two from SWDA and one each from NDA and SEDA. Non-district irrigators elect one representative.

The Saskatchewan Irrigation Projects Association (SIPA) and the Saskatchewan Ministry of Agriculture (SA) appoint two directors each to the ICDC board.

In accordance with the *Irrigation Act, 2019*, the majority of the ICDC board must be comprised of irrigators.

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FIELD CROP VARIETY TRIALS

Irrigated Flax Variety Trial

Funding

Funded by the Irrigation Crop Diversification Corporation and the Saskatchewan Variety Performance Group

Principal Investigators

- Garry Hnatowich, PAg, Research Director, ICDC
- Erin Karppinen, PhD, PAg, Co-Research Director, ICDC

Organizations

- Irrigation Crop Diversification Corporation (ICDC)
- Saskatchewan Variety Performance Group (SVPG)
- Saskatchewan Advisory Council on Grain Crops (SACGC)

Objectives

The objectives of this study were to:

1. Evaluate registered and experimental flax varieties;
2. Assess entries for suitability to irrigated production; and
3. Update ICDC's annual *Crop Varieties for Irrigation* guide.

Research Plan

The irrigated flax trials were conducted at two locations - at the CSIDC on-station location (Field 8) and at the ICDC Pederson off-station location. Twenty flax varieties (7 registered and 13 experimental entries) were tested for their agronomic performance under irrigation. The ICDC site was seeded on May 25, 2020 and the Pederson site was seeded on May 22, 2020. Plot size was 1.5 m x 4.0 m, treatments were replicated three times, and the trials were established in an experimental lattice design.

At seeding, the ICDC site received 80 kg N/ha as side-banded urea (46-0-0) and 20 kg P_2O_5/ha as seed-placed monoammonium phosphate (MAP; 11-52-0). The ICDC trial was established on wheat stubble that had a soil N reserve of 66 k N/ha and a soil P reserve of 36 kg P_2O_5/ha (Table A4). On May 11, 2020, the Pederson site received a pre-seeding application of 60 kg N/ha as anhydrous ammonia (82-0-0). At seeding, the Pederson site received 30 kg N/ha as side-banded urea (46-0-0) and 20 kg P_2O_5/ha as seed-placed MAP (11-52-0). The Pederson trial was established on potato stubble that had a soil N reserve of 82 kg N/ha and soil P reserve of 13.5 kg P_2O_5/ha (Table A1).

Chemical applications occurred on the same day at both sites. Weed control consisted of post-emergent tank mix application of Centurion® (clethodim; 0.15 L/ac), Buctril® M (bromoxynil + MCPA ester; 0.4 L/ac), and Amigo® (30-phosphate ester; 0.5 L/ac). A fungicide application of Priaxor® (fluxapyroxad + pyraclostrobin; 0.18 L/ac) was applied on July 24, 2020. Trials were desiccated with Reglone® Ion (diquat, 0.83 L/ac) on September 25, 2020.

Yields were estimated by direct cutting the entire plot with a small plot combine when the plants were dry enough to thresh and seed moisture content was < 20%. Harvested samples were cleaned and yields were adjusted to a moisture content of 10%. In-season precipitation from mid-May through to

September 25, 2020 was 145 mm (5.7") at the ICDC site and 157.5 mm (6.2") at the Pederson site. Total in-season irrigation was 162.5 mm (6.4") at the ICDC site and 101.6 mm (4.0") at the Pederson site.

Results

Results from the ICDC and Pederson sites are shown in Tables 1 and 2, respectively.

Results of these trials are used for registration purposes. Further, results from these trials are used to update the irrigation variety database at ICDC and provide recommendations to irrigators on the best flax varieties suited to irrigated conditions and will be used in the development of the annual publications *"Crop Varieties for Irrigation"* and the Saskatchewan Ministry of Agriculture's *"Varieties of Grain Crops 2021."*

Table 1. Yield and agronomic data for the Saskatchewan Variety Performance Group Irrigated Flax Regional Trial, ICDC On-Station Location (Field 8), 2020.

Variety	**Yield** (kg/ha)	**Yield** (% of CDC Bethune)	**Test Weight** (kg/hl)	**Seed Weight** (g/1000)	**Flower** (days)	**Maturity** (days)	**Height** (cm)	**Lodging** (1=erect; 9=flat)
AAC Bright	2,513	105	68.9	6.5	56	114	68	1.0
AAC Marvelous	3,297	137	70.8	6.4	53	113	64	1.0
AAC Prairie Sunshine	3,539	147	71.4	6.1	55	115	63	1.0
CDC Bethune	***2,404***	***100***	***71.2***	***6.0***	***54***	***109***	***67***	***1.0***
CDC Dorado	2,780	116	70.6	6.7	48	118	61	1.0
CDC Glas	3,258	136	70.0	5.0	55	109	63	1.0
CDC Rowland	3,157	131	70.7	7.1	53	110	64	1.0
Experimental Lines								
FP2573	2,769	115	71.2	6.3	54	110	69	1.0
FP2591	3,510	146	71.0	7.0	52	112	62	1.0
FP2592	3,129	130	70.9	7.2	53	109	68	1.0
FP2596	2,727	113	70.1	6.6	51	108	63	1.0
FP2597	2,833	118	70.9	6.5	51	109	65	1.0
FP2598	2,889	120	70.6	6.4	52	110	69	1.0
FP2599	2,962	123	71.1	6.9	53	110	67	1.0
FP2600	2,870	119	70.4	6.2	56	109	67	1.0
FP2601	2,734	114	70.9	6.0	52	116	66	1.0
FP2602	3,135	130	70.8	6.4	56	116	70	1.0
FP2603	2,965	123	70.7	6.4	51	121	67	1.0
FP2604	2,961	123	70.4	5.8	57	117	62	1.0
FP2605	2,897	120	70.8	6.8	54	119	66	2.5
LSD (0.05)	NS	-	0.7	0.7	2.1	4.5	4.0	0.6
CV (%)	14.99	-	0.59	6.42	2.38	2.13	3.73	32.1

NS = not significant

Table 2. Yield and agronomic data for the Saskatchewan Variety Performance Group Irrigated Flax Variety Trial, ICDC Off-Station Pederson Location, 2020.

Variety	Yield (kg/ha)	Yield (% of CDC Bethune)	Test Weight (kg/hl)	Seed Weight (g/1000)	Flower (days)	Maturity (days)	Height (cm)	Lodging (1=erect; 9=flat)
AAC Bright	4,381	100	68.3	5.9	58	112	76	1.0
AAC Marvelous	4,841	111	70.4	6.3	55	111	72	1.0
AAC Prairie Sunshine	4,325	99	70.6	5.9	57	113	71	1.3
CDC Bethune	***4,374***	***100***	***70.3***	***6.0***	***55***	***109***	***73***	***1.3***
CDC Dorado	3,739	85	69.4	5.9	48	117	60	2.7
CDC Glas	4,663	107	69.5	5.4	57	109	73	1.0
CDC Rowland	4,899	112	70.1	6.9	53	111	71	1.7
Experimental Lines								
FP2573	4,296	98	70.1	6.1	53	112	72	3.3
FP2591	4,656	106	70.1	6.7	53	111	69	3.0
FP2592	4,425	101	70.5	6.9	53	111	74	2.0
FP2596	4,244	97	70.0	6.5	52	109	69	1.0
FP2597	4,155	95	70.3	6.7	52	110	69	3.7
FP2598	3,912	89	69.7	6.1	55	110	74	4.0
FP2599	3,993	91	70.5	6.8	56	112	75	5.0
FP2600	3,877	89	70.3	6.0	59	115	72	3.0
FP2601	3,498	80	70.0	5.6	58	119	72	3.0
FP2602	4,137	95	69.4	5.6	60	121	77	2.7
FP2603	3,884	89	69.7	5.5	57	118	70	2.0
FP2604	4,363	100	69.9	5.8	59	112	71	2.7
FP2605	3,525	81	70.2	5.8	58	120	70	3.7
LSD (0.05)	408	-	0.5	0.4	1.4	5.4	3.1	2.0
CV (%)	5.86	-	0.43	3.66	1.51	2.91	2.66	50.1

Irrigated Wheat, Durum, Barley and Oat Regional Variety Trials

Funding

Funded by the Irrigation Crop Diversification Corporation and the Saskatchewan Variety Performance Group

Principal Investigators

- Garry Hnatowich, PAg, Research Director, ICDC
- Erin Karppinen, PhD, PAg, Co-Research Director, ICDC

Organizations

- Irrigation Crop Diversification Corporation (ICDC)
- Saskatchewan Variety Performance Group (SVPG)
- Saskatchewan Advisory Council on Grain Crops (SACGC)

Objectives

The objectives of this study were to:

(1) Evaluate experimental cereal lines pursuant for registration requirements;

(2) Assess entries for suitability to irrigated production; and

(3) Update ICDC's annual *Crop Varieties for Irrigation* guide.

Research Plan

The Saskatchewan Variety Performance Group (SVPG) wheat, durum, barley, and oat regional trials were seeded on May 22, 2020 at the ICDC Pederson off-station location. The spring wheat were divided into two separate trials: Hex 1 and Hex 2. The Hex 1 trial was comprised of Canadian Western Red Spring (CWRS) wheat class varieties or experimental lines with a total of 42 entries. The Hex 2 trial was comprised of high yielding classes of spring wheat with 15 entries. The durum trial had 14 entries. The barley trial was exclusively 2-row barleys with 27 entries. The oat trial comprised a total of 8 entries. Trials were arranged in a randomized complete block design with three replicates. Harvested plot size was 1.5 m x 4.0 m.

All trials received a pre-seeding application of 60 kg N/ha as anhydrous ammonia (82-0-0) on May 11, 2020. At seeding, each trial received 30 kg N/ha as side-banded urea (46-0-0) and 25 kg P_2O_5/ha as seed-placed monoammonium phosphate (MAP; 11-52-0). These trials were established on potato stubble that had a soil N reserve of 82 kg N/ha (Table A1). Weed control consisted of post-emergence tank mix application of Simplicity™ (pyroxsulam; 28 g/ac) and Buctril® M (bromoxynil +MCPA ester; 0.4 L/ac) to the wheat trials (Hex 1, Hex 2, Durum), while only Buctril® M (bromoxynil +MCPA ester; 0.4 L/ac) was applied to the barley and oat trials. Yields were estimated by direct cutting the entire plot with a small plot combine when the plants were dry enough to thresh and seed moisture content was < 20%. Harvested samples were cleaned and yields were adjusted to a moisture content of 14.5%. In-season precipitation from mid-May through August was 157.5 mm (6.2") and in-season irrigation was 101.6 mm (4.0").

Results

Hex 1, Hex 2, Durum, Barley, and Oat data are shown in Tables 1, 2, 3, 4, and 5, respectively.

Results of these trials are used for registration purposes. Further, results from these trials are used to update the irrigation variety database at ICDC and provide recommendations to irrigators on the best wheat, barley, and oat varieties suited to irrigated conditions and will be used in the development of the annual publications *"Crop Varieties for Irrigation"* and the Saskatchewan Ministry of Agriculture's *"Varieties of Grain Crops 2021"*.

Table 1. Saskatchewan Variety Performance Group Irrigated Hex 1 Wheat Regional Variety Trial, ICDC Off-Station Pederson Site, 2020.

Variety	Yield (kg/ha)	Yield (% of Carberry)	Protein (%)	Test Weight (kg/hl)	Seed Weight (g/1000)	Heading (days)	Maturity (days)	Height (cm)	Lodging (1=erect; 9=flat)
Canada Western Red Spring (CWRS)									
AAC Alida VB	5,416	109	13.7	79.7	38.6	51	91	97	1
AAC Brandon	5,821	117	12.7	80.0	37.5	51	92	84	1
AAC Leroy VB	5,382	108	12.5	80.3	39.6	49	89	92	1
AAC Magnet	5,661	114	13.0	78.5	39.9	48	88	91	1
AAC Redstar	4,788	96	13.0	78.8	37.7	50	88	93	1
AAC Russell VB	5,166	104	12.7	79.3	40.3	49	89	93	1
AAC Starbuck VB	6,115	123	12.9	80.2	40.9	50	90	91	1
AAC Tisdale	5,755	116	13.2	79.3	39.2	51	88	92	1
AAC Warman VB	5,373	108	12.6	80.2	36.7	49	88	101	1
AAC Wheatland VB	6,396	129	12.1	80.2	38.5	51	90	91	1
Bolles	5,390	109	13.0	79.2	39.4	55	92	87	1
Carberry	***4,964***	***100***	***13.2***	***79.4***	***38.0***	***49***	***90***	***89***	***1***
CDC Adamant VB	6,072	122	12.9	79.8	37.0	50	89	91	1
CDC Ortona	6,410	129	13.3	79.0	35.0	51	89	96	1
Daybreak	5,765	116	12.8	80.8	42.0	50	90	92	1
Ellerslie	6,016	121	13.0	78.7	34.8	51	90	93	1
Jake	6,293	127	14.0	79.9	35.3	51	89	93	1
Parata	5,419	109	14.2	80.0	36.7	48	88	92	1
Rednet	4,806	97	12.8	80.4	36.5	54	91	104	1
SY Gabbro	5,916	119	13.2	79.3	43.3	51	90	92	1
SY Obsidian	4,764	96	12.7	79.3	37.8	51	90	90	1
SY Torach	6,497	131	12.9	80.8	32.5	51	98	85	1
Tracker	5,689	115	12.8	79.2	34.2	52	89	91	1
Canada Prairie Spring – Red (CPSR)									
AAC Goodwin	5,965	120	12.2	80.1	39.7	52	91	91	1
Canada Western Hard White Spring (CWHWS)									
AAC Cirrus	5,765	116	12.6	80.6	33.7	53	92	89	1
Experimental Lines									
BW1064	5,639	114	13.1	79.7	36.4	52	88	99	1
BW1069	5,933	120	12.3	80.2	38.5	50	89	94	1
BW1093	5,150	104	12.0	79.6	34.0	53	91	85	1

BW5031	6,523	131	13.2	78.8	42.2	52	91	93	1
BW5044	6,576	132	12.8	81.5	35.6	51	92	88	1
BW5045	6,510	131	12.0	78.7	38.0	57	94	92	1
BW5047	5,976	120	12.9	79.2	41.0	51	92	98	1
BW5055	6,074	122	12.4	80.9	36.1	49	89	93	1
CS11200104-11	5,821	117	13.0	79.1	38.9	52	90	87	1
CS11200214-17	5,904	119	12.6	78.6	39.0	51	93	95	1
HW402	5,972	120	13.4	78.6	38.7	49	89	88	1
HW506	4,355	88	12.1	77.4	40.7	51	91	88	1
LNR15-1405	2,822	57	12.5	77.9	44.5	54	94	95	1
LNR15-1741	5,995	121	12.0	80.0	36.8	52	94	87	1
PT598	6,985	141	12.7	79.6	38.3	50	91	85	1
PT599	5,962	120	12.7	79.8	36.0	53	90	93	1
PT652	4,669	94	12.9	79.1	38.1	49	88	94	1
LSD (0.05)	591	-	0.7	0.7	1.8	1.3	2.3	3.3	NS
CV (%)	6.41	-	3.53	0.53	2.84	1.55	1.56	2.23	-

NS = not significant

Table 2. Saskatchewan Variety Performance Group Irrigated Hex 2 Wheat Regional Variety Trial, ICDC Off-Station Pederson Site, 2020.

Variety	**Yield** (kg/ha)	**Yield** (% of Carberry)	**Protein** (%)	**Test Weight** (kg/hl)	**Seed Weight** (g/1000)	**Heading** (days)	**Maturity** (days)	**Height** (cm)	**Lodging** (1=erect; 9=flat)
Canada Western Red Spring (CWRS)									
AAC Brandon	6,466	142	14.6	79.5	38.1	52	99	87	2.0
Carberry	***4,546***	***100***	***14.8***	***78.7***	***40.6***	***49***	***96***	***91***	***1.0***
Sheba	5,849	129	14.5	80.7	36.1	55	97	94	1.7
Canada Northern Hard Red (CNHR)									
Faller	6,498	143	12.7	78.4	41.7	53	93	93	1.0
Prosper	6,977	153	13.1	79.3	42.2	54	95	95	1.3
Canada Prairie Spring – Red (CPSR)									
AAC Castle VB	7,045	155	14.0	80.3	45.7	53	100	87	5.3
AAC Crossfield	5,831	128	13.7	77.8	40.4	51	94	92	1.3
AAC Entice	6,573	145	13.8	78.1	38.0	52	95	90	1.7
Accelerate	6,100	134	13.4	79.7	34.9	49	93	82	1.0
CDC Reign	7,369	162	13.5	79.9	37.9	58	101	93	1.7
KWS Alderon	7,471	164	11.4	68.8	36.8	64	107	81	1.0
SY Rowyn	6,226	137	13.3	79.4	34.5	51	98	86	1.7
Canada Western Special Purpose (CWSP)									
AAC Awesome VB	7,968	175	11.4	80.0	41.7	62	100	96	3.3
WPB Whistler	7,203	158	11.6	75.5	41.9	60	102	86	1.0
Canada Western General Purpose (CWGP)									
KWS Sparrow VB	8,014	176	11.6	74.7	39.3	63	106	89	1.0
LSD (0.05)	911	-	0.7	1.6	2.2	2.0	3.7	2.5	1.4
CV (%)	8.16	-	3.15	1.23	3.35	2.17	2.23	1.70	47.8

Table 3. Saskatchewan Variety Performance Group Irrigated Canadian Western Amber Durum (CWAD) Wheat Regional Variety Trial, Off-Station Pederson Site, 2020.

Variety	Yield (kg/ha)	Yield (% of Carberry)	Protein (%)	Test Weight (kg/hl)	Seed Weight (g/1000)	Heading (days)	Maturity (days)	Height (cm)	Lodging (1=erect; 9=flat)
AAC Donlow	7,875	165	14.0	79.0	44.3	57	100	96	1.3
AAC Goldnet	7,729	162	14.6	78.4	43.7	53	102	99	1.0
AAC Grainland	7,876	165	14.2	77.6	44.2	55	99	98	3.3
AAC Stronghold	7,905	166	14.4	78.9	45.1	59	106	95	1.0
AAC Succeed VB	8,089	170	14.8	78.6	43.4	58	101	101	2.3
Carberry	***4,770***	***100***	***15.2***	***79.2***	***38.1***	***50***	***98***	***87***	***1.0***
CDC Covert	8,477	178	13.7	78.9	42.1	55	102	96	1.7
CDC Credence	7,913	166	14.3	79.3	44.0	58	102	104	3.0
CDC Defy	8,472	178	13.3	80.4	44.3	55	103	101	1.0
Strongfield	7,226	151	14.9	79.3	44.3	57	100	96	1.7
Experimental Lines									
DT591	7,906	166	14.1	77.3	43.9	51	97	96	1.0
DT897	8,013	168	13.9	79.1	43.3	60	104	99	2.7
DT1010	8,171	171	13.9	79.5	41.3	55	100	97	3.7
DT1011	8,575	180	13.2	78.7	43.8	56	103	101	1.0
LSD (0.05)	656	-	0.7	1.3	3.6	1.9	3.3	3.6	1.8
CV (%)	5.02	-	3.07	0.94	4.93	2.01	1.91	2.22	58.2

Table 4. Saskatchewan Variety Performance Group Irrigated Barley Regional Variety Trial, ICDC Off-Station Pederson Site, 2020.

Variety	Yield (kg/ha)	Yield (% of AC Metcalfe)	Protein (%)	Test Weight (kg/hl)	Seed Weight (g/1000)	Heading (days)	Maturity (days)	Height (cm)	Lodging (1=erect; 9=flat)
Malting Acceptance: Recommended									
AAC Connect	9,341	113	11.7	67.9	47.1	60	83	86	1.3
AAC Synergy	9,811	119	11.4	66.4	44.5	60	83	88	1.0
AC Metcalfe	***8,272***	***100***	***12.1***	***67.1***	***44.6***	***59***	***84***	***89***	***1.3***
CDC Bow	9,164	111	11.2	65.8	45.5	65	88	89	1.0
CDC Copeland	9,272	112	11.0	66.6	45.8	62	86	94	1.7
CDC Fraser	9,709	117	11.1	65.1	46.4	65	88	87	1.0
Malting Acceptance: In Development or Limited Demand									
AB BrewNet	8,966	108	11.5	64.5	46.6	65	88	95	1.0
CDC Churchill	9,509	115	11.1	66.6	45.2	65	87	82	1.0
CDC Copper	9,739	118	11.2	66.9	45.3	60	87	79	1.0
Lowe	9,688	117	10.8	66.1	44.9	67	88	90	1.0
Other: Malting Market May Exist									
CDC Goldstar	9,556	116	11.3	66.2	42.6	61	85	90	1.0
Esma	9,579	116	11.1	66.5	45.8	61	88	75	1.0
KWS Coralie	9,326	113	10.6	60.6	44.3	67	90	68	1.3
KWS Kellie	9,226	112	10.9	62.9	45.0	68	89	70	1.0

Feed: Hulled									
AB Advantage	9,852	119	11.6	64.6	49.9	54	87	102	1.0
AB Cattlelac	9,618	116	11.9	66.4	40.5	54	85	97	1.0
AB Tofield	9,990	121	10.4	64.6	39.9	58	88	89	1.0
AB Wrangler	9,265	112	11.0	67.6	46.7	59	84	86	1.0
Sirish	8,688	105	11.4	67.2	43.3	65	88	72	1.0
TR16742	8,967	108	10.8	61.2	40.9	63	85	78	1.0
Feed: Hulless									
CDC Ascent	8,351	101	12.7	74.8	42.0	66	87	84	1.0
Experimental Lines									
FB209	9,103	110	11.9	62.7	47.9	64	89	91	3.0
TR16929	8,967	108	11.3	63.8	44.1	67	86	69	1.0
TR18647	9,942	120	10.5	66.8	43.3	65	87	89	1.0
TR18747	9,971	121	11.1	65.3	46.8	61	87	85	1.0
TR18748	9,848	119	11.1	66.6	46.8	59	84	90	1.0
TR18749	10,421	126	11.1	66.3	46.3	63	87	92	1.0
LSD (0.05)	771	-	0.3	2.2	4.1	2.2	2.2	4.3	0.5
CV (%)	5.00	-	1.85	2.02	5.58	2.20	1.54	3.07	26.1

Table 5. Saskatchewan Variety Performance Group Irrigated Oats Regional Variety Trial, ICDC Off-Station Pederson Site, 2020.

Variety	**Yield** (kg/ha)	**Yield** (% of CS Camden)	**Protein** (%)	**Test Weight** (kg/hl)	**Seed Weight** (g/1000)	**Heading** (days)	**Maturity** (days)	**Height** (cm)	**Lodging** (1=erect; 9=flat)
AAC Douglas	7,124	94	12.6	53.1	36.7	51	91	112	1
CDC Arborg	7,855	104	12.2	54.4	38.9	52	96	123	1
CDC Skye	7,100	94	11.9	52.8	37.3	52	92	120	1
CDC Endure	7,512	99	12.4	54.3	35.2	52	93	118	1
CS Camden	***7,583***	***100***	***13.1***	***53.5***	***36.9***	***52***	***90***	***110***	***1***
Experimental Lines									
CFA1502	8,694	115	12.4	55.3	36.3	52	95	110	1
ORe3541M	6,215	82	12.7	54.8	34.7	51	97	111	1
ORe3542M	7,221	95	12.0	53.0	37.3	51	98	114	1
LSD (0.05)	639	-	0.4	0.9	NS	NS	2.9	3.8	NS
CV (%)	4.92	-	2.02	0.99	4.23	1.23	1.78	1.91	-

NS = not significant

Central Bread Wheat Irrigated Coop Trials

Funding

Funded by SeCan

Principal Investigators

- Garry Hnatowich, PAg, Research Director, ICDC
- Erin Karppinen, PhD, PAg, Co-Research Director, ICDC

Organizations

- Irrigation Crop Diversification Corporation (ICDC)
- AAFC Brandon – Dr. Santosh Kumar
- SeCan – Jim Downey

Objectives

The objectives of this study were to:

(1) Evaluate experimental CWRS wheat pursuant for registration requirements;
(2) Assess entries for suitability to irrigated production; and
(3) Update ICDC's annual *Crop Varieties for Irrigation* guide.

Research Plan

The Central Bread Wheat Irrigated Coop trial was seeded on May 28, 2020 at the ICDC Knapik off-station location. The trial was comprised of primarily experimental classes of bread wheat with 25 entries. The trial was arranged in a 5 x 5 lattice design with three replicates and plot size was 1.5 m x 4.0 m.

Nitrogen fertilizer (urea, 46-0-0) was side-banded at a rate of 140 kg N/ha and phosphorous (monoammonium phosphate (MAP), 12-51-0) was seed-placed at a rate of 30 kg P_2O_5/ha. Weed control consisted of a post-emergence tank mix application of Simplicity™ (pyroxsulam; 28 g/ac) and Buctril® M (bromoxynil + MCPA ester; 0.4 L/ac). The trial was harvested on September 9, 2020. Yields were estimated by direct cutting the entire plot with a small plot combine when the plants were dry enough to thresh and seed moisture content was < 20%. Harvested samples were cleaned and yields were adjusted to a moisture content of 14.5%. In-season precipitation from June to September was 134.4 mm (5.3") and in-season irrigation was 213 mm (8.4").

Results

The CBWC results are shown in Table 1.

Results of these trials are used for registration purposes. Further, results from these trials are used to update the irrigation variety database at ICDC and provide recommendations to irrigators on the best wheat varieties suited to irrigated conditions and will be used in the development of the annual publications *"Crop Varieties for Irrigation"* and the Saskatchewan Ministry of Agriculture's *"Varieties of Grain Crops 2021"*.

Table 1. Central Bread Wheat Irrigated Coop Trial, ICDC Off-Station Knapik Location, 2020.

Variety	Yield (kg/ha)	Yield (% of Carberry)	Protein (%)	Test Weight (kg/hl)	Seed Weight (g/1000)	Heading (days)	Maturity (days)	Height (cm)	Lodging (1=erect; 9=flat)
Unity VB	4,693	108	11.7	80.7	34.9	51	90	87	1
Glenn	4,204	97	11.7	83.0	34.6	49	90	84	1

Carberry	***4,355***	***100***	***12.4***	***81.2***	***38.4***	***50***	***93***	***76***	***1***
AAC Viewfield	4,468	103	11.8	81.5	35.6	50	90	77	1
AAC Brandon	4,613	106	11.4	82.2	33.4	51	91	74	1
Experimental Lines									
BW1085	4,633	106	12.2	79.6	36.4	54	92	76	1
BW1094	4,835	111	11.3	80.3	34.1	51	91	79	1
BW1095	4,779	110	11.1	81.6	37.4	50	89	81	1
BW1097	4,946	114	10.9	79.6	36.3	49	90	82	1
BW1103	4,416	101	11.8	79.8	37.5	50	92	80	1
BW1106	4,265	98	11.5	81.5	33.0	49	90	80	1
BW1111	5,252	121	11.2	82.1	34.6	53	93	72	1
BW1112	4,936	113	11.7	82.1	34.1	50	91	72	1
BW1113	4,831	111	11.2	82.0	33.4	51	92	76	1
BW1114	4,714	108	11.7	81.2	37.4	50	91	79	1
BW1115	5,246	120	10.9	81.0	34.1	52	93	76	1
BW1116	4,859	112	11.1	81.7	35.8	53	92	76	1
BW1117	5,066	116	11.1	82.4	33.8	50	91	75	1
BW1118	4,578	105	11.3	82.4	34.8	53	93	73	1
BW1119	4,421	101	11.4	79.7	35.4	53	93	81	1
BW1120	4,145	95	11.7	79.7	37.2	52	89	77	1
BW1121	4,661	107	12.1	78.9	38.4	52	94	80	1
BW1122	4,546	104	12.0	79.2	38.5	54	90	79	1
BW1123	4,976	114	11.4	79.3	36.8	54	93	81	1
BW1124	4,424	102	12.4	79.3	36.5	54	95	75	1
LSD (0.05)	481	-	0.8	1.8	2.5	1.7	2.9	3.1	NS
CV (%)	6.27	-	4.21	1.37	4.28	1.98	1.95	2.39	-

NS = not significant

Soft White Spring Wheat Irrigated Coop Trials

Funding

Funded by SeCan

Principal Investigators

- Garry Hnatowich, PAg, Research Director, ICDC
- Erin Karppinen, PhD, PAg, Co-Research Director, ICDC

Organizations

- Irrigation Crop Diversification Corporation (ICDC), Outlook
- AAFC Lethbridge – Dr. Harpinder Randhawa
- SeCan – Jim Downey

Objectives

The objectives of this study were to:

(1) Evaluate experimental SWS wheat pursuant for registration requirements;
(2) Assess entries for suitability to irrigated production; and
(3) Update ICDC's annual *Crop Varieties for Irrigation* guide.

Research Plan

The Soft White Spring Wheat Irrigated Coop trial was seeded on May 28, 2020 at the ICDC Knapik off-station location. The trial was comprised of 16 soft white spring wheat varieties. The trial was arranged in a 4 x 4 lattice design with four replicates and plot size was 1.5 m x 4.0 m.

Nitrogen fertilizer (urea, 46-0-0) was side-banded at a rate of 140 kg N/ha and phosphorous (monoammonium phosphate (MAP), 12-51-0) was seed-placed at a rate of 30 kg P_2O_5/ha. Weed control consisted of a post-emergence tank mix application of Simplicity™ (pyroxsulam; 28 g/ac) and Buctril® M (bromoxynil + MCPA ester; 0.4 L/ac). The trial was harvested on September 16, 2020. Yields were estimated by direct cutting the entire plot with a small plot combine when the plants were dry enough to thresh and seed moisture content was < 20%. Harvested samples were cleaned and yields were adjusted to a moisture content of 14.5%. In-season precipitation from mid-May through September was 137.4 mm (5.4") and in-season irrigation was 213 mm (8.4").

Results

Results are shown in Table 1.

Results of these trials are used for registration purposes. Further, results from these trials are used to update the irrigation variety database at ICDC and provide recommendations to irrigators on the best wheat varieties suited to irrigated conditions and will be used in the development of the annual publications *"Crop Varieties for Irrigation"* and the Saskatchewan Ministry of Agriculture's *"Varieties of Grain Crops 2021"*.

Table 1. Soft White Spring Wheat Irrigated Coop Variety Trial, ICDC Off-Station Knapik Site, 2020.

Variety	**Yield** (kg/ha)	**Yield** (% of Carberry)	**Protein** (%)	**Test Weight** (kg/hl)	**Seed Weight** (g/1000)	**Heading** (days)	**Maturity** (days)	**Height** (cm)	**Lodging** (1=erect; 9=flat)
AC Andrew	7,010	156	9.0	77.5	37.8	58	100	80	1.3
Carberry	***4,505***	***100***	***12.3***	***79.6***	***36.4***	***51***	***97***	***75***	***1.0***
Sadash	6,125	136	9.4	78.9	36.4	57	99	77	1.5
Experimental Lines									
SWS427	7,175	159	8.9	74.7	38.9	61	104	84	1.0
SWS471	6,377	142	9.5	79.2	37.7	57	101	79	1.5
SWS484	6,885	153	8.6	79.6	39.0	58	98	82	1.0
SWS485	6,221	138	9.5	79.8	37.8	57	100	75	1.5
SWS487	6,508	144	8.6	76.5	41.8	55	100	83	1.0
SWS488	6,588	146	8.7	76.5	41.0	55	101	84	1.0
SWS489	6,144	136	9.7	77.6	36.9	59	100	79	1.5
SWS490	7,162	159	9.0	77.5	39.3	59	101	85	1.3
SWS491	5,888	131	9.7	79.6	39.4	55	99	75	1.0
SWS492	6,845	152	9.2	80.5	39.8	61	98	79	1.0
SWS493	6,611	147	9.5	79.7	37.5	60	98	80	1.0
SWS494	6,317	140	9.8	78.8	32.9	58	98	71	1.0
SWS495	6,172	137	9.0	77.2	37.8	58	101	81	1.0
SWS496	6,607	147	9.2	78.3	39.7	58	99	80	1.0
LSD (0.05)	737	-	0.7	1.4	3.2	1.4	2.1	4.2	NS
CV (%)	8.08	-	5.13	1.23	5.91	1.70	1.49	3.76	35.9

NS = not significant

Winter Wheat Variety Evaluation for Irrigation vs. Dryland Production

Funding

Funded by Agricultural Demonstration of Practices and Technologies (ADOPT) Program and ICDC

Organizations

- Irrigation Crop Diversification Corporation (ICDC), Outlook
- Agriculture & Agri-food Canada (AAFC), Lethbridge

Project Lead

- Project Leads: Erin Karppinen & Garry Hnatowich (ICDC)
- AAFC-Lethbridge Lead: Dr. Robert Graf

Objectives

This project's objective is to identify the top producing or best adapted varieties of winter wheat for irrigated production. Until recently, winter wheat varieties had not been evaluated for their irrigation production potential for approximately 25 years. At that time, no variety suited intensive irrigation management. Genetic improvements to the latest winter wheat varieties warrant a renewed assessment for their potential under irrigation management. Results from these trials will also be used to develop a data base on winter wheat varieties for entry into the *"Crop Varieties for Irrigation"* publication.

Research Plan

Seed of 12 winter wheat varieties were acquired from winter wheat breeder Dr. Robert Graf (AAFC-Lethbridge). On September 17, 2019, varieties were direct seeded into canola stubble on ICDC land rented from the Town of Outlook and adjacent to the federal CSIDC Research Station (Field 51). Winter wheat varieties were established in a complete randomized block design with 3 replicates. All varieties were evaluated under both irrigated and dryland production systems.

At seeding, each trial received 100 kg N/ha as side-banded urea (46-0-0), 25 kg P_2O_5/ha as side-banded monoammonium phosphate (MAP; 11-52-0), and an additional 25 kg P_2O_5/ha as seed-placed MAP. Soil test results are presented in Table A3. Weed control consisted of a post-emergence tank mix application of Simplicity™ (pyroxsulam; 28 g/ac) and Buctril® M (bromoxynil + MCPA ester; 0.4 L/ac). Foliar fungicides were not applied for leaf disease or fusarium head blight.

Yields were estimated by direct cutting the entire plot with a small plot combine when the plants were dry enough to thresh and seed moisture content was < 20%. Both trials were harvested August 11, 2020. Harvested samples were cleaned and yields were adjusted to a moisture content of 14.5%. Total in-season precipitation was 139.7 mm (5.5") and an additional 203.2 mm (8.0") of in-season irrigation was applied to the irrigated production system.

Mean monthly temperatures and precipitation amounts are listed in Tables 1 and 2. The 2020 season was comparable to the long-term average with respect to temperature, but rainfall was below average.

Table 1. Mean monthly temperature from May to September, 2020 at the ICDC trial location.

Location	Year	May	June	July	August	September	Average
		------------------------------*Mean Temperature (°C)* -------------------					
Outlook	2020	11.3	15.9	19.1	18.8	NA	16.3
	Long-term	***11.5***	***16.1***	***18.9***	***18.0***	**NA**	**16.1**

Table 2. Precipitation amounts vs. long-term (30 year) means for the 2020 growing season.

Location	Year	May	June	July	August	September	Average
		----------------------------*Precipitation (mm)* -------------------					
Outlook	2020	27.8	79.2	29.6	19.0	NA	155.6
	Long-term	***42.6***	***63.9***	***56.1***	***42.8***	**NA**	**205.4**

Results

Irrigated Trial

Under irrigated production, any varietal differences in average yield, protein content, seed weight, and heading were not statistically significant (Table 3, ANOVA, $P \leq 0.05$). Although these parameters did not differ between varieties, a summary of trends in the data is provided. Experimental line W520 yielded the highest and Radiant yielded the lowest. Yields of the 12 varieties ranged from 5,060 kg/ha to 6,561 kg/ha (75.2 bu/ac to 97.5 bu/ac), with a mean yield of 5,858 kg/ha (87.1 bu/ac). Grain protein content was highest in Emerson (11.3%) and the lowest in AAC Icefield (9.6%). For all evaluated varieties, mean seed weight was 34.2 g/1,000 seeds. Heading occurred over a 6-day period, with AAC Gateway being the earliest and AAC Wildfire being the latest.

Between varieties, differences in test weight, maturity, and height were statistically significant (Table 3, ANOVA, $P \leq 0.05$). Mean test weight was 76.7 kg/hl, with experimental line W520 the heaviest at 80.0 kg/hl and AAC Wildfire the lightest at 70.7 kg/hl. Similar to heading, maturity was spread over a 7-day period, with AAC Goldrush being the earliest and AAC Wildfire being the latest. CDC Buteo was the tallest variety (102.5 cm) and experimental line W569 was the shortest variety (83.3 cm), while the mean height of all varieties was 92.7 cm. There was no incidence of lodging in any plots.

Table 3. Winter Wheat Variety Evaluation, Irrigated Site, 2020.

Variety	Yield (kg/ha)	Yield (% of CDC Buteo)	Protein (%)	Test Weight (kg/hl)	Seed Weight (g/1000)	Heading (days)	Maturity (days)	Height (cm)	Lodging (1=erect; 9=flat)
AAC Elevate	5,849	96	11.0	74.7	34.9	178.3	215.7	93.0	1
AAC Gateway	5,877	96	10.7	78.6	37.3	177.3	214.7	86.2	1
AAC Goldrush	5,871	96	10.7	79.3	35.5	179.0	212.7	95.5	1
AAC Icefield	6,122	100	9.6	77.3	32.1	177.7	216.7	89.7	1
AAC Wildfire	5,738	94	10.3	70.7	38.0	182.7	219.0	94.3	1
CDC Buteo	***6,102***	***100***	***10.1***	***79.2***	***34.3***	***177.7***	***215.3***	***102.5***	***1***
Emerson	5,130	84	11.3	78.2	30.8	178.0	218.0	95.2	1
Radiant	5,060	83	10.1	71.4	35.0	180.0	217.7	101.8	1
Experimental Lines									
W520	6,561	108	10.3	80.0	33.7	179.3	216.0	92.2	1
W522	6,260	103	10.2	79.3	35.7	178.3	213.7	86.2	1
W563	6,482	106	9.8	75.9	31.7	178.3	217.0	92.8	1
W569	5,246	86	10.8	76.1	31.7	179.3	217.3	83.3	1
LSD (0.05)	NS	-	NS	3.8	NS	NS	2.6	3.8	NS
CV (%)	11.8	-	6.31	2.91	7.80	1.16	0.71	2.44	-

NS = not significant

Dryland Trial

Under dryland production, any varietal differences in average yield were not statistically significant (Table 4, ANOVA, $P \leq 0.05$). Although yield did not differ between varieties, a summary of trends in the data is provided. Experimental line W563 yielded the highest and Radiant yielded the lowest. Yields of the 12 varieties ranged from 4,496 kg/ha to 5,557 kg/ha (66.8 bu/ac to 82.6 bu/ac), with a mean yield of 5,092 kg/ha (75.7 bu/ac).

Between varieties, differences in protein, test weight, seed weight, heading, maturity, and height were statistically significant (Table 4, ANOVA, $P \leq 0.05$). Grain protein content was highest in Emerson (11.4%) and the lowest in AAC Icefield (9.1%), while the average protein content of all varieties was 10.0%. For all evaluated varieties, mean test weight was 79.6 kg/hl and mean seed weight was 34.9 g/1,000 seeds. Heading occurred over a 7-day period, with experimental line W522 being the earliest and AAC Wildfire being the latest. Similar to heading, maturity was spread over an 8-day period, with experimental line W522 being the earliest and Emerson being the latest. CDC Buteo was the tallest variety (98.2 cm) and experimental line W522 was the shortest variety (77.7 cm), while the mean height of all varieties was 88.3 cm. There was no incidence of lodging in any plots.

Table 4. Winter Wheat Variety Evaluation, Dryland Site, 2020.

Variety	Yield (kg/ha)	Yield (% of CDC Buteo)	Protein (%)	Test Weight (kg/hl)	Seed Weight (g/1000)	Heading (days)	Maturity (days)	Height (cm)	Lodging (1=erect; 9=flat)
AAC Elevate	4,720	93	10.3	79.9	39.7	177.7	216.0	89.3	1
AAC Gateway	4,890	97	10.5	79.8	36.7	176.7	214.0	82.8	1
AAC Goldrush	4,832	96	10.6	80.3	34.0	180.3	216.0	89.3	1
AAC Icefield	5,379	106	9.1	78.1	31.5	178.7	216.7	84.8	1
AAC Wildfire	5,236	104	9.4	78.7	38.9	181.7	218.3	90.3	1
CDC Buteo	***5,058***	***100***	***10.0***	***81.7***	***35.5***	***178.3***	***217.3***	***98.2***	***1***
Emerson	5,101	101	11.4	79.5	31.9	176.0	218.7	92.8	1
Radiant	4,496	89	9.4	76.8	35.1	179.7	218.0	92.5	1
Experimental Lines									
W520	5,229	103	9.8	81.9	33.0	178.7	216.0	88.7	1
W522	5,360	106	9.7	80.2	36.5	175.0	214.0	77.7	1
W563	5,557	110	9.7	78.4	34.1	177.3	217.0	90.3	1
W569	5,242	104	10.1	80.6	31.9	178.3	216.3	83.2	1
LSD (0.05)	NS	-	1.2	2.2	2.7	2.0	2.9	4.0	NS
CV (%)	9.33	-	7.02	1.62	4.53	0.65	0.79	2.66	-

NS = not significant

Irrigated vs. Dryland

The mean yield of all varieties grown under irrigated production were statistically higher yielding than the mean yield of those grown under dryland production (Table 5, ANOVA, $P \leq 0.05$). On average, the irrigated site produced 766 kg/ha (11.4 bu/ac) more winter wheat grain yield, or 15% greater production, than the dryland site. Protein content and height were statistically higher at the irrigated site, but test weight was higher at the dryland site (ANOVA, $P \leq 0.05$).

When data from both the irrigated and dryland sites were combined, there were no varietal differences in yield (ANOVA, $P \leq 0.05$). However, all other agronomic observations differed with variety (ANOVA, $P \leq 0.05$). A production system by variety interaction was not detected for most agronomic observations (except test weight), which suggests that the different varieties responded to irrigation in a similar manner. It also indicates that either the production system or the variety drove differences, but not both.

Table 5. Winter Wheat Variety Evaluation, Irrigated vs Dryland, 2020.

System / Variety	Yield (kg/ha)	Yield (bu/ac)	Protein (%)	Test Weight (kg/hl)	Seed Weight (g/1000)	Heading (days)	Maturity (days)	Height (cm)	Lodging (1=erect; 9=flat)
Production System									
Irrigated	5,858	87.1	10.4	76.7	34.2	178.8	216.1	92.7	1
Dryland	5,092	75.7	10.0	79.6	34.9	178.2	216.5	88.3	1
LSD (0.05)	430	6.4	0.3	0.9	NS	NS	NS	1.4	NS
CV (%)	16.6	16.6	6.92	2.37	6.45	0.93	0.78	3.20	-
Variety									
AAC Elevate	5,284	78.5	10.7	77.3	37.3	178.0	215.8	91.2	1
AAC Gateway	5,384	80.0	10.6	79.2	37.0	177.0	214.3	84.5	1
AAC Goldrush	5,351	79.6	10.7	79.8	34.7	179.7	214.3	92.4	1
AAC Icefield	5,751	85.5	9.3	77.7	31.8	178.2	216.7	87.3	1
AAC Wildfire	5,487	81.6	9.8	74.6	38.5	182.2	218.7	92.3	1
CDC Buteo	***5,580***	***83.0***	***10.0***	***80.4***	***34.9***	***178.0***	***216.3***	***100.3***	***1***
Emerson	5,115	76.0	11.3	78.9	31.4	177.0	218.3	94.0	1
Radiant	4,778	71.0	9.7	74.1	35.0	179.8	217.8	97.2	1
Experimental Lines									
W520	5,895	87.6	10.1	80.9	33.4	179.0	216.0	90.4	1
W522	5,810	86.4	10.0	79.8	36.1	176.7	213.8	81.9	1
W563	6,019	89.5	9.7	77.2	32.9	177.8	217.0	91.6	1
W569	5,244	78.0	10.5	78.4	31.8	178.8	216.8	83.3	1
LSD (0.05)	NS	NS	0.8	2.2	2.6	1.9	2.0	3.4	NS
Production System x Variety Interaction									
LSD (0.05)	NS	NS	NS	S	NS	NS	NS	NS	NS

NS = not significant; S = significant

Discussion

This project shows irrigators in Saskatchewan that winter wheat benefits from irrigation, particularly by increasing yield and protein content. In 2020, there was no yield advantage to growing one variety over another. Further demonstration of the performance of winter wheat varieties under irrigation and extension of this year's results will help provide awareness to Saskatchewan irrigators of both its risk and potential as an irrigated crop. This trial was continued with 12 winter wheat entries seeded on September 11, 2020.

Acknowledgements

Financial support was provided by the ADOPT initiative under the Canada-Saskatchewan Canadian Agricultural Partnership (CAP) bi-lateral agreement. Funding is gratefully acknowledged.

Fall Rye Variety Evaluation for Irrigation vs. Dryland

Funding

Funded by ICDC

Organizations

- Saskatchewan Ministry of Agriculture (SMOA), Outlook
- Irrigation Crop Diversification Corporation (ICDC), Outlook
- Agriculture & Agri-Food Canada (AAFC), Lethbridge

Project Lead

- SMOA Lead: Joel Peru
- ICDC Leads: Erin Karppinen & Garry Hnatowich
- AAFC-Lethbridge Lead: Dr. Jamie Larsen

Objectives

This demonstration provided local producers a yield comparison of fall rye production under irrigated and dryland conditions in central Saskatchewan. Producers had the opportunity to compare how new hybrid varieties perform compared to conventional varieties.

Research Plan

Seed of five fall rye (3 conventional and 2 hybrid) varieties were acquired from fall rye breeder Dr. Jamie Larsen (AAFC-Lethbridge). On September 17, 2019, varieties were direct seeded into canola stubble on ICDC land rented from the Town of Outlook and adjacent to the federal CSIDC Research Station (Field 51). Fall rye varieties were established in a complete randomized block design with 3 replicates. All varieties are evaluated under both irrigated and dryland production systems. At seeding, each trial received 110 kg N/ha as side-banded urea (46-0-0), 25 kg P_2O_5/ha as side-banded monoammonium phosphate (MAP; 11-52-0), and an additional 25 kg P_2O_5/ha as seed-placed MAP. Soil test resutls are provided in Table A3.

Weed control consisted of a post-emergence tank mix application of Buctril® M (bromoxynil + MCPA ester, 0.4 L/ac) and Bison® (tralkoxydim, 0.2 L/ac). No foliar fungicides were applied for either leaf disease or fusarium head blight. Yields were estimated by direct cutting the entire plot with a small plot combine when the plants were dry enough to thresh and seed moisture content was < 20%. Harvest plot size was 4 m x 1.5 m. Both trials were harvested August 11, 2020. Harvested samples were cleaned and yields were adjusted to a moisture content of 14.5%. Total in-season precipitation was 139.7 mm (5.5") and an additional 203.2 mm (8.0") of in-season irrigation was applied to the irrigated production system.

Mean monthly temperatures and precipitation amounts are listed in Tables 1 and 2. The 2020 season was comparable to the long-term average with respect to temperature, but rainfall was below average.

Table 1. Mean monthly temperature from May to September, 2020 at the ICDC trial location.

Location	Year	May	June	July	August	September	Average
		------------------------------*Mean Temperature (°C)* -------------------					
Outlook	2020	11.3	15.9	19.1	18.8	NA	16.3
	Long-term	***11.5***	***16.1***	***18.9***	***18.0***	**NA**	**16.1**

Table 2. Precipitation amounts vs. long-term (30 year) means for the 2020 growing season.

Location	Year	May	June	July	August	September	Average
		------------------------------*Precipitation (mm)* -------------------					
Outlook	2020	27.8	79.2	29.6	19.0	NA	155.6
	Long-term	***42.6***	***63.9***	***56.1***	***42.8***	**NA**	**205.4**

Results

Irrigated Trial

Under irrigated production, varietal differences in yield, protein content, test weight, seed weight, and maturity were statistically significant (Table 3, ANOVA, $P \leq 0.05$). KWS Trebiano yielded the highest and Hazlet yielded the lowest. Yields of the 7 varieties ranged from 6,216 kg/ha to 9,191 kg/ha (99.0 bu/ac to 146.4 bu/ac), with a mean yield of 8,089 kg/ha (128.8 bu/ac). On average, the hybrid varieties were approximately 40% higher yielding than the conventional varieties. Grain protein content was highest in Hazlet (9.4%), the lowest in KWS Serafino (8.2%), and averaged 8.7% across all varieties. Mean test weight was 74.1 kg/hl, with KWS Serafino the heaviest at 73.0 kg/hl and KWS Bono the lightest at 74.7 kg/hl. For all evaluated varieties, mean seed weight was 34.5 g/1,000 seeds. Maturity was spread over a 5-day period, with Prima being the earliest and Gatano being the latest.

Any varietal differences in heading and lodging were not statistically significant (Table 3, ANOVA, $P \leq 0.05$). Although these parameters did not differ between varieties, a summary of trends in the data is provided. Heading occurred over a 4-day period, with Prima being the earliest and Hazlet being the latest. The mean lodging rating in all varieties was 1.4; KWS Bono and KWS Trebiano were the only varieties that did not have any incidence of lodging. There was no incidence of ergot.

Table 3. Fall Rye Variety Evaluation, Irrigated Site, 2020.

Variety	Yield (kg/ha)	Yield (bu/ac)	Protein (%)	Test Weight (kg/hl)	Seed Weight (g/1000)	Maturity (days)	Heading (days)	Lodging (1=erect; 9=flat)	Ergot (%)
Open-Pollinated Conventional Varieties									
Hazlet	6,216	99.0	9.4	74.8	39.5	214.0	164.3	1.7	0
Prima	6,335	100.9	8.8	74.3	33.2	210.7	162.3	2.0	0
Hybrid Varieties									
KWS Bono	8,886	141.5	9.2	74.7	32.8	213.0	163.7	1.0	0
KWS Daniello	8,722	138.9	8.3	74.0	33.3	213.3	164.0	1.3	0
KWS Gatano	8,614	137.2	8.4	73.4	31.5	214.3	163.3	1.7	0
KWS Serafino	8,659	137.9	8.2	73.0	35.1	214.0	164.0	1.3	0
KWS Trebiano	9,191	146.4	8.7	74.4	36.4	214.0	163.7	1.0	0
LSD (0.05)	984	15.7	0.4	0.8	2.0	1.3	NS	NS	NS
CV (%)	6.84	6.84	2.81	0.63	3.22	0.34	0.79	36.4	-

NS= not significant

Dryland Trial

Under dryland production, varietal differences in yield, protein content, test weight, seed weight, and maturity were statistically significant (Table 4, ANOVA, $P \leq 0.05$). KWS Serafino yielded the highest and Prima yielded the lowest. Yields of the 7 varieties ranged from 5,241 kg/ha to 7,244 kg/ha (83.5 bu/ac to 115.4 bu/ac), with a mean yield of 6,416 kg/ha (102.2 bu/ac). On average, the hybrid varieties were approximately 30% higher yielding than the conventional varieties. Grain protein content was highest in Hazlet (10.0%), the lowest in Gatano (8.4%), and averaged 8.9% across all varieties. Mean test weight was 73.5 kg/hl, with Prima the heaviest at 75.0 kg/hl and Hazlet the lightest at 70.9 kg/hl. For all evaluated varieties, mean seed weight was 35.1 g/1,000 seeds. Maturity was spread over a 5-day period, with Prima being the earliest and Gatano being the latest.

Any varietal differences in heading and lodging were not statistically significant (Table 4, ANOVA, $P \leq 0.05$). Although these parameters did not differ between varieties, a summary of trends in the data is provided. Heading occurred over a 4-day period, with Prima being the earliest and Gatano being the latest. There was no incidence of lodging or ergot.

Table 4. Fall Rye Variety Evaluation, Dryland Site, 2020.

Variety	Yield (kg/ha)	Yield (bu/ac)	Protein (%)	Test Weight (kg/hl)	Seed Weight (g/1000)	Maturity (days)	Heading (days)	Lodging (1=erect; 9=flat)	Ergot (%)
Open-Pollinated Conventional Varieties									
Hazlet	5,335	85.0	10.0	70.9	42.8	214.3	164.0	1.0	0
Prima	5,241	83.5	9.2	75.0	32.8	210.0	164.0	1.0	0
Hybrid Varieties									
KWS Bono	7,120	113.4	8.8	74.4	34.5	213.0	164.0	1.0	0
KWS Daniello	7,004	111.6	8.7	74.4	32.8	213.3	164.0	1.0	0
KWS Gatano	6,047	96.3	8.4	73.0	30.8	214.7	166.7	1.0	0
KWS Serafino	7,244	115.4	8.7	73.1	34.3	214.0	164.3	1.0	0
KWS Trebiano	6,918	110.2	8.7	74.0	37.5	214.3	164.7	1.0	0
LSD (0.05)	934	14.9	0.4	1.7	2.5	1.1	NS	NS	NS
CV (%)	8.2	8.2	2.69	1.27	4.06	0.30	0.77	-	-

NS= not significant

Irrigated vs. Dryland

The mean yield of all varieties grown under irrigated production were statistically higher yielding than the mean yield of those grown under dryland production (Table 5, ANOVA, $P \leq 0.05$). On average, the irrigated site produced 1,674 kg/ha (26.7 bu/ac) more fall rye grain yield, or 26% greater production, than the dryland site. At the irrigated site, heading was earlier and lodging incidence was higher (ANOVA, $P \leq 0.05$) but there were no differences between sites for protein content, test weight, seed weight, and maturity (ANOVA, $P \leq 0.05$).

When data from both the irrigated and dryland sites were combined, the hybrid varieties had a clear yield advantage - averaging a yield increase of 32.8 bu/ac - over the conventional varieties. Protein content, test weight, seed weight, and maturity differed between varieties but there was no distinct grouping based on variety type (hybrid and conventional) as seen with yield (ANOVA, $P \leq 0.05$). A production system by variety interaction was not detected for most agronomic observations (except test weight), which suggests that the different varieties responded to irrigation in a similar manner. It also indicates that either the production system or the variety drove differences, but not both.

Table 5. Fall Rye Variety Evaluation, Irrigated vs Dryland, 2020.

System / Variety	Yield (kg/ha)	Yield (bu/ac)	Protein (%)	Test Weight (kg/hl)	Seed Weight (g/1000)	Heading (days)	Maturity (days)	Lodging (1=erect; 9=flat)
Production System								
Irrigated	8,089	128.8	8.9	74.1	35.1	163.6	213.3	1.4
Dryland	6,416	102.2	8.7	73.5	34.5	164.5	213.4	1.0
LSD (0.05)	621	9.9	NS	NS	NS	0.8	NS	0.3
CV (%)	13.5	13.5	4.78	1.22	0.8	0.78	0.36	35.9
Variety								
Open-Pollinated Conventional Varieties								
Hazlet	***5,775***	***92.0***	***9.7***	***72.8***	***41.1***	***164.2***	***214.2***	***1.3***
Prima	5,788	92.2	9.0	74.7	33.0	163	210.3	1.5
Hybrid Varieties								
KWS Bono	8,003	127.5	9.0	74.6	33.7	163.8	213.0	1.0
KWS Daniello	7,863	125.3	8.5	74.2	33.0	164.0	213.3	1.2
KWS Gatano	7,330	116.8	8.4	73.2	31.2	165.0	214.5	1.3
KWS Serafino	7,952	126.7	8.4	73.1	34.7	164.2	214.0	1.2
KWS Trebiano	8,055	128.3	8.7	74.2	37.0	164.2	214.2	1.0
LSD (0.05)	1,161	18.5	0.5	1.1	1.6	NS	0.9	NS
Production System x Variety Interaction								
LSD (0.05)	NS	NS	NS	S	NS	NS	NS	NS

NS = not significant; S = significant

Discussion

This project showed irrigators in Saskatchewan that fall rye benefits greatly from irrigation and the newer hybrid varieties have a yield advantage. Despite the high cost of hybrid fall rye seed at approximately $69.60/acre (Government of Saskatchewan, 2020a), its yield advantage has the potential to generate higher net profit compared to conventional fall rye. Further demonstration of this crop under irrigation and extension of this year's results will help provide awareness to Saskatchewan irrigators of both its risk and potential as an irrigated crop.

This trial was continued with 7 fall rye entries seeded September 11, 2020.

Agronomic Trials

Demonstrating 4R Nitrogen Management Principals for Winter Wheat

Funding

Funded by the Agricultural Demonstration of Practices and Technologies Fund (ADOPT) & Fertilizer Canada

Organizations

- Irrigation Crop Diversification Corporation (ICDC), Outlook

Project Lead

- ICDC Leads: Erin Karppinen & Garry Hnatowich

Objectives

Developing Best Management Practices (BMPs) for nutrient applications has long been focused on the 4R principles which refer to using the: 1) right source, 2) right rate, 3) right time, and 4) right placement. This can create unique challenges for winter cereals, however, since the growing season is much longer and crop requirements for N are relatively small for the 8- to 9-month period after seeding. Consequently, and especially when considering that establishment of winter cereals can be variable from year-to-year, it is often recommended that N applications be split between fall side- or mid-row band applications and an early spring surface broadcast. This results in extra cost/labour for producers; however, N applied in the fall can be more prone to losses prior to crop uptake (especially in wet falls) while spring applied N can also be subject to loss and is not always available early enough to prevent early season deficiencies and subsequent yield loss. Consequently, split applications tend to be the least risky option when averaged over time and across a broad range of conditions.

A key objective of this project is to demonstrate the relative winter wheat responses to varying N fertilizer rates when all the fertilizer is applied either as side-banded urea, early spring broadcast urea, or a split application where 50% of the supplemental urea is side-banded and the remainder is applied in an early season broadcast application. While the source is not being specifically varied in this demonstration, urea is the most commonly used N formulation in western Canada and an appropriate choice to illustrate differences amongst the rates and placement/timing options being evaluated.

Research Plan

A field demonstration with winter wheat was established on September 18, 2019 on ICDC land rented from the Town of Outlook and adjacent to the federal CSIDC Research Station (Field 51). A composite soil sample was collected and sent to AgVise Laboratories for analysis (Table A3). The trial was established in a randomized complete block design and each treatment was replicated four times. Seeded plot size was 8 m long and 1.5 m wide. Fertilizer treatments are shown in Table 1. Fall side-banded fertilizer applications occurred at the time of seeding and spring broadcast applications occurred on May 4, 2020. Fertilizer N (urea, 46-0-0) was side-banded 25 cm to the side and 25 cm below the seed furrow. Soil testing procedures revealed a total of 8 kg N/ha available in the 0 – 60 cm soil profile depth (Table A3). All fertilizer applications were calculated to account for this value of soil available N. At seeding, all plots also received 30 kg P_2O_5/ha as seed placed monoammonium phosphate (MAP; 11-52-0).

Weed control consisted of a post-emergence tank mix application of Simplicity™ (pyroxsulam; 28 g/ac) and Buctril® M (bromoxynil + MCPA ester; 0.4 L/ac). No foliar fungicides were applied for either leaf disease or fusarium head blight. Yields were estimated by direct cutting the entire plot with a small plot combine when the plants were dry enough to thresh and seed moisture content was < 20%. The trial was harvested August 17, 2020. Harvested samples were cleaned and yields were adjusted to a moisture content of 14.5%. Total in-season rainfall was 139.7 mm (5.5") and total in-season irrigation was 203.2 mm (8.0").

Table 1. Fertilizer rate, time of application, and fertilizer placement for winter wheat (2019/2020).

Trt #	Total N Rate (soil + fertilizer)	Timing/Placement
1	0X (no added N fertilizer)	N/A
2	60 kg soil + fertilizer N/ha	Fall Side Band
3	90 kg soil + fertilizer N/ha	Fall Side Band
4	120 kg soil + fertilizer N/ha	Fall Side Band
5	150 kg soil + fertilizer N/ha	Fall Side Band
6	180 kg soil + fertilizer N/ha	Fall Side Band
7	60 kg soil + fertilizer N/ha	Spring Broadcast
8	90 kg soil + fertilizer N/ha	Spring Broadcast
9	120 kg soil + fertilizer N/ha	Spring Broadcast
10	150 kg soil + fertilizer N/ha	Spring Broadcast
11	180 kg soil + fertilizer N/ha	Spring Broadcast
12	60 kg soil + fertilizer N/ha	Split Application (50% fall side band + 50% spring broadcast)
13	90 kg soil + fertilizer N/ha	Split Application (50% fall side band + 50% spring broadcast)
14	120 kg soil + fertilizer N/ha	Split Application (50% fall side band + 50% spring broadcast)
15	150 kg soil + fertilizer N/ha	Split Application (50% fall side band + 50% spring broadcast)
16	180 kg soil + fertilizer N/ha	Split Application (50% fall side band + 50% spring broadcast)

Results

Fertilizer N Rate

Winter wheat seed yield responded positively to each increase in fertilizer N applied, regardless of the timing or placement (Figure 1, Table 2, ANOVA, $P \leq 0.05$). However, there was no additional yield benefit from fertilizer applications that exceeded 150 kg N/ha. The greatest increases in yield were 29% from 0 kg N/ha to 60 kg N/ha, 15% from 60 kg N/ha to 90 kg N/ha, and 12% from 120 kg N/ha to 150 kg N/ha. From 0 kg N/ha to 120 kg N/ha, average grain protein content was 9.4% and there was no difference in protein content between these treatments. At 150 kg N/ha and 180 kg N/ha, grain protein content significantly increased to 10.1% and 10.8%, respectively (Table 2, ANOVA, $P \leq 0.05$). In general, the mean effect of increased N rates resulted in decreased test weight, delayed heading and maturity, and increased plant height (Table 2, ANOVA, $P \leq 0.05$). In this study, only thousand kernel weight (TKW) was not influenced by N fertilizer rates. Lodging was not observed at any N fertilizer rate.

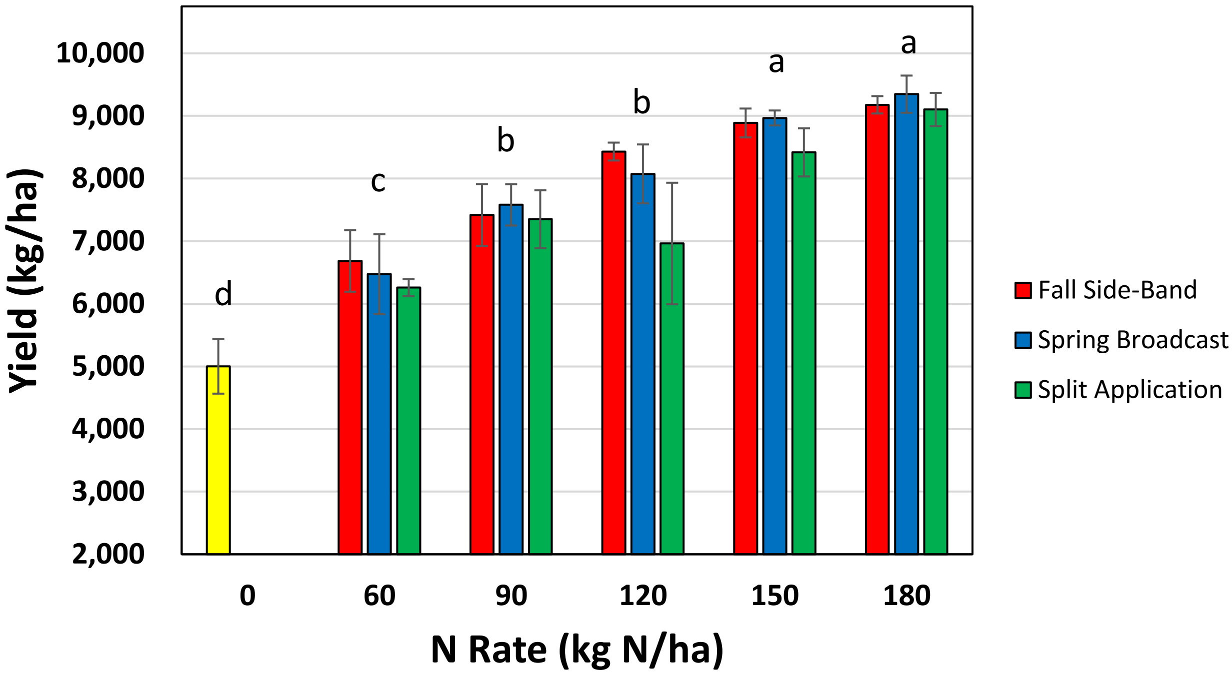

Figure 1. Winter wheat grain yield response to increasing rates of N fertilizer. Different letters indicate significant differences between N fertilizer rate (ANOVA, *P* ≤ 0.05).

Table 2. Influence of N fertilizer rate and time/placement on winter wheat. Different letters indicate significant differences between N fertilizer rate and time/placement (ANOVA, *P* ≤ 0.05).

N Fertilizer Rate & Time/Placement	**Yield** (kg/ha)	**Protein** (%)	**Test Weight** (kg/hl)	**Seed Weight** (g/1000)	**Height** (cm)	**Heading** (days)	**Maturity** (days)	**Lodging** (1=erect; 9=flat)
Rate								
0 kg N/ha	5,001 *d*	9.3 *c*	81.6 *a*	37.7 *a*	69.9 *d*	177.8 *d*	212.3 *d*	1 *a*
60 kg N/ha	6,472 *c*	9.3 *c*	80.9 *ab*	38.6 *a*	81.3 *c*	179.4 *c*	216.0 *bc*	1 *a*
90 kg N/ha	7,450 *b*	9.5 *c*	81.2 *ab*	37.3 *a*	85.0 *b*	179.3 *c*	215.8 *c*	1 *a*
120 kg N/ha	7,823 *b*	9.5 *c*	80.6 *b*	37.0 *a*	85.6 *b*	180.6 *b*	217.2 *b*	1 *a*
150 kg N/ha	8,758 *a*	10.1 *b*	80.7 *b*	37.8 *a*	90.6 *a*	181.3 *ab*	218.4 *a*	1 *a*
180 kg N/ha	9,210 *a*	10.8 *a*	80.5 *b*	37.9 *a*	90.0 *a*	182.2 *a*	219.4 *a*	1 *a*
LSD (0.05)	605	0.43	3.7	NS	2.5	1.1	1.2	NS
CV (%)	9.9	5.41	1.12	7.03	3.65	0.76	0.66	-
Time/Placement								
Fall Side Band	7,600 *a*	9.9 *a*	81.0 *a*	37.1 *a*	84.8 *a*	180.6 *a*	217.0 *a*	1 *a*
Spring Broadcast	7,574 *a*	9.8 *a*	80.8 *a*	37.8 *a*	83.4 *a*	179.6 *b*	216.2 *a*	1 *a*
Split Application	7,182 *a*	9.6 *a*	80.9 *a*	38.3 *a*	82.9 *a*	180.0 *ab*	216.3 *a*	1 *a*
LSD (0.05)	NS	NS	NS	NS	NS	0.8	NS	NS
Rate x Time/Placement								
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS = not significant

Fertilizer N Application Time & Placement

For most agronomic factors evaluated (i.e., yield, protein content, maturity), there were no differences between applying fertilizer as a fall side band application, spring broadcast application, or a split application (Table 2, ANOVA, $P \geq 0.05$). On average, yield was 7,452 kg/ha (111 bu/ac), protein content was 9.8%, and maturity was 216.5 days. The only factor influenced by the time and placement of N fertilizer was date of heading, with plants receiving fall side-banded N fertilizer heading 1.0 days later than those receiving a spring broadcast application (Table 2, ANOVA, $P \leq 0.05$).

Conclusions

In this study, N fertilizer rate was the most important factor driving differences in most agronomic observations. Yield increased with increasing fertilizer rate up to 150 kg N/ha, which suggests this was the optimal N fertilizer application rate. Time and placement were less important factors, only resulting in marginal differences in days to heading. Based on their specific soil test recommendations, producers should be able to gain benefits in yield and quality from applying N fertilizer whether it is side-banded in the fall, broadcast in the spring, or as a fall side-band/spring broadcast split application. The greatest yield increase occurred with application of the first 60 kg N/ha (29%), with less substantial increases from 60 kg N/ha to 90 kg N/ha (15%) and from 120 kg N/ha to 150 kg N/ha (12%).

Acknowledgements

Financial support was provided by the Agricultural Demonstration of Practices and Technologies Fund (ADOPT) initiative under the Canada-Saskatchewan Canadian Agricultural Partnership (CAP) bi-lateral agreement. Funding is gratefully acknowledged.

A Continuation of Double Cropping Irrigated Winter Cereals for Silage

Funding

Funded by the Agricultural Demonstration of Practices and Technologies Fund (ADOPT) & Saskatchewan Cattlemen's Association

Organizations

- Irrigation Crop Diversification Corporation (ICDC), Outlook
- Saskatchewan Ministry of Agriculture (SMOA), Outlook

Project Lead

- ICDC Leads: Erin Karppinen & Garry Hnatowich
- SMOA Lead: Travis Peardon

Objectives

This project builds from ADOPT Project # 20180387 (Double Cropping Irrigated Winter Cereals for Silage). This project is not complete, but it is evident that fall rye is a standout for double cropping due to its advanced maturity compared to other winter cereals. Its early maturity provides a long enough growing season for a successful follow crop enabling the harvest of two forage crops in one year. This study will evaluate two hybrid fall rye varieties and one conventional fall rye in a double cropping system (seeded fall of 2019) that will be harvested in June 2020. We will then immediately reseed these plots to barley, oats, and millet (harvested fall of 2020). This novel cropping system will be compared to spring seeded barley, oats, and millet (harvested late summer of 2020). This study will display the forage capabilities of new hybrid fall rye varieties in comparison to a conventional fall rye and it will also determine the best option for a follow crop. KWS Propower; a newly released hybrid rye variety will be used in this trial. The seed distributor claims it has a 10 to 15% yield advantage for silage over other hybrid rye varieties.

This production system is practiced in Ontario and there has been interest in double cropping in the irrigated portions of southern Alberta with anecdotal reports of producers attempting the practice. Dr. Jamie Larsen (AAFC-Lethbridge) believes the practice is feasible in higher degree day areas of the prairies. The ability to grow two crops in a single growing season is a great attraction to cattle producers. In the Outlook irrigation area, the largest factor limiting expansion of cattle enterprises is the cost of land. Growing two crops in one year could potentially provide substantially more forage than current single crop production practices which could facilitate expansion of the cattle industry in the irrigated areas of Saskatchewan. Stamp Seeds (Enchant, Alberta) reports that hybrid fall rye has been producing 15-18 tons/ac of silage production under irrigation. This amount of silage production rivals corn with potentially better net returns due to cheaper production costs. If this yield could be augmented with an additional forage harvest of spring barley, oats, or millet the economic returns could possibly greatly exceed the returns of a single cut of an annual forage production system. In the irrigated area of the South Saskatchewan Irrigation Development District, the ability of planting fall cereals onto either potato or dry bean harvested ground could have large environmental benefits in the prevention of soil erosion from wind drift. Some potato and bean producers seed fall rye to prevent wind erosion but typically the crop is terminated in the spring as the forage potential of winter cereals has not been demonstrated in the area. A double crop production system would also facilitate custom harvesting in that custom operators are typically available in early July having completed the first cut of alfalfa and waiting for the annual cereal harvest.

Research Plan

A field demonstration with fall rye was established in the fall of 2019 on ICDC land rented from the Town of Outlook and adjacent to the federal CSIDC Research Station (Field 51). The trial was established in a randomized complete block design and each treatment was replicated three times. Two hybrid fall rye varieties (KWS Gatano and KWS Propower) and a conventional fall rye variety (Hazlet) were seeded on September 17, 2019. For comparison silage production varieties of spring barley (CDC Maverick), oat (Haymaker) and millet (Red Proso) where seeded on May 13, 2020. All cereals were planted to achieve a plant population of 300 plants/m^2. The winter cereals were harvested for silage yield on July 3, 2020 while in the soft dough development stage. These plots were immediately sprayed with 0.67 L/ac of glyphosate. Plots were reseeded to either barley, oat or millet on July 6, 2020. May planted spring cereals were harvested July 27, 2020. Re-cropped spring millet was harvested on September 16 and oat on October 6, 2020, both at the soft dough stage. Re-cropped spring barley was not harvested. All plots were harvested with a Hege small plot forage harvester. Harvest plot size was 6 m x 1.5 m. Forage subsamples were collected for moisture determination and for feed quality analyses. Feed quality analyses were conducted by Central Testing Laboratories (Winnipeg, MB). Treatments are shown in Table 1.

For the fall rye and May seeded spring cereals, nitrogen fertilizer (urea, 46-0-0) was applied at 100 kg N/ha and phosphorus fertilizer (monoammonium phosphate, 11-52-0) at 25 kg P_2O_5/ha in a side banded application at seeding along, an additional 25 kg P_2O_5/ha was seed placed. Re-cropped spring cereals received a topdressed application of 50 kg N/ha post emergent. A composite soil sample was collected prior to fertilization and sent to AgVise Laboratories for analysis (Table 2).

Seasonal and 30 year historic precipitation and temperature at CSIDC are outlined in Tables 3 & 4. Seasonal precipitation was significantly lower in May, higher in June, and lower throughout the growing period compared to 30 year averages, seasonal precipitation on the trials by seasons end was significantly less than long term averages. Seasonal monthly temperatures were, on average, close to historical. In-season precipitation was 156 mm (6.1"), total irrigation applied was 230.2 mm (8.0").

Table. 1. Treatments in the double crop and annual production systems.

Trt	Initial Crop	Double Crop
Double Crop Production System		
1	Hybrid Fall Rye (KWS Gatano)	Barley (terminated)
2	Hybrid Fall Rye (KWS Gatano)	Oats
3	Hybrid Fall Rye (KWS Gatano)	Millet
4	Hybrid Fall Rye (KWS Propower)	Barley (terminated)
5	Hybrid Fall Rye (KWS Propower)	Oats
6	Hybrid Fall Rye (KWS Propower)	Millet
7	Conventional Fall Rye (Hazlet)	Barley (terminated)
8	Conventional Fall Rye (Hazlet)	Oats
9	Conventional Fall Rye (Hazlet)	Millet
Annual Production System		
10	Spring Barley	n/a
11	Spring Millet (terminated)	n/a
12	Spring Oats	n/a

n/a = not applicable

Table 2. Soil Testing Report, Agvise Labs, Sampled fall 2019

Depth (cm)	NO_3-N (lb/ac)	P (ppm)	K (ppm)	SO_4-S (lb/ac)
0 - 15	2	2	308	76
15 - 30	3			120+
30 - 60	2			
Organic Matter	2.5%			
pH (0 - 15 cm)	8.1			
pH (15 - 60 cm)	8.2			
Soluble Salts (0 - 15 cm)	0.44 mmho/cm			
Soluble Salts (15 - 60 cm)	1.43 mmho/cm			

Table 3. 2020 Growing Season Precipitation vs Long-Term Average, CSIDC.

	Year		
Month	**2020 mm (inches)**	**30 Year Average mm (inches)**	**% of Long-Term**
May	27.8 (1.1)	42.6 (1.7)	65
June	79.2 (3.1)	63.9 (2.5)	124
July	29.6 (1.2)	56.1 (2.2)	53
August	19.0 (0.7)	42.8 (1.7)	44
Total	155.6 (6.1)	205.4 (8.1)	**76**

Table 4. Mean monthly temperature from May to August 2020 at the ICDC trial location.

	Year	
Month	**2020**	**30 Year Average**
May	11.3	11.5
June	15.9	16.1
July	19.1	18.9
August	18.8	18.0
Average May-August	16.3	16.1

Results

General Comments on Results Obtained and Discussed

Fall rye established well and spring growth visually revealed little, if any, significant over winter losses (winter kill). Fall rye forage yield was high. However, May seeded millet establishment was very poor and eliminated from the trial. Poor emergence was attributed to cold soil/environmental conditions existing at seeding which were detrimental to the warm season cereal. Spring seeded millet has not harvested and data was not collected.

Further re-cropped spring barley on fall rye establishment was very poor and considered unacceptable with respect to normal, or typical, cereal establishment. This phenomena is shown in the cover title picture. Spring barley, shown in the center of the photograph, is clearly showing poor establishment and growth. Oat (left of center) and millet (right of center) demonstrated target plant populations establishment and growth.

The picture reflects a major issue in potential double cropping and requires further investigation. In an associated study conducted in 2019 we witnessed a similar event but speculated that spring barley seeding depth may have been an issue – however seeding depth itself was unlikely the sole barley establishment issue. With the reoccurrence of poor barley establishment and growth in this study (and in a further fall rye/spring barley N fertilizer study conducted in 2020) it is hypothesized that a strong "alleopathic effect" is occurring from fall rye residue on barley germination and seedling growth. Fall rye has sometime been noticed to suppress germination of weeds and other crops. Therefore, caution is advised when considering suitable cropping options following fall rye in double crop scenarios. Further evaluation of suitable double crop spring cereals following fall rye is warranted. Re-cropped barley plots were not harvested and data not collected.

Forage yield results for annual, double crop and cumulative growing season from the study are shown in Table 5. Statistical analyses was unbalanced due to higher number of fall rye plots compared to spring cereal plots (to allow for re-cropping of barley, oat and millet to each fall rye variety) and, consequently, failed to show a statistically significant yield differences between fall and spring seeded cereals. However, results do demonstrate that all fall rye varieties were numerically higher yielding compared to spring seeded oat or barley. On average fall rye production was approximately 24% higher yielding than spring cereal forage yields. Within fall rye varieties the hybrid varieties outperformed the conventional variety (Hazlet) with the KWS Propower 11% higher yielding than KWS Gatano. This is in agreement with seed distributor claims for this newer hybrid.

For the two spring cereals which established when planted onto fall rye residue, oats produced approximately twice the forage yield compared to millet. Millet may have been adversely influenced by a frost event on September 7 which is believed to have hastened the maturity of the cereal. Oat appeared to "weather" the frost event without negative effects. Data suggests that no particular fall rye variety was preferred in a double crop production system.

Cumulative growing season yield favored a double crop system compared to annual single crop production systems. Double cropping did, in fact, nearly double the total forage produced on the same ground. Though an economic analyses was not conducted, results suggest that this system could be profitable. No definitive conclusions can be made from a single trialing year but the results do suggest further evaluation would be justified.

Table 5. Initial crop, double crop, and cumulative forage dry yield in the double crop and annual production systems. Different letters indicate significant differences between treatments (ANOVA, $P \leq 0.05$).

Initial Crop	**Initial Crop Dry Yield** (kg/ha)	**Initial Crop Dry Yield** (t/ac)	**Double Crop**	**Double Crop Dry Yield** (kg/ha)	**Double DRY Crop Yield** (t/ac)	**Cumulative Growing Season Dry Yield** (kg/ha)	**Cumulative Growing Season Dry Yield** (t/ac)
Double Crop Production System							
Hybrid Fall Rye (KWS Gatano)	15,067 *a*	6.7 *a*	Barley	***---Plots Terminated---***		14,868 *cd*	6.6 *cd*
			Oats	8,304 *b*	3.7 *b*	21,173 *ab*	9.4 *ab*
			Millet	3,181 *c*	1.4 *c*	20,643 *abc*	9.2 *abc*
Hybrid Fall Rye (KWS Propower)	16,513 *a*	7.3 *a*	Barley	***---Plots Terminated---***		15,139 *bcd*	6.7 *bcd*
			Oats	7,705 *b*	3.4 *b*	23,682 *a*	10.5 *a*
			Millet	3,699 *c*	1.7 *c*	22,121 *a*	9.9 *a*
Conventional Fall Rye (Hazlet)	14,136 *a*	6.3 *a*	Barley	***---Plots Terminated---***		13,681 *d*	6.1 *d*
			Oats	8,410 *b*	3.8 *b*	23,488 *a*	10.5 *a*
			Millet	4,025 *c*	1.8 *c*	17,673 *abcd*	7.9 *abcd*
Annual Production System							
Spring Barley	12,257 *a*	5.5 *a*	-	12,257 *a*	5.5 *a*	12,257 *d*	5.5 *d*
Spring Oats	12,151 *a*	5.4 *a*	-	12,151 *a*	5.4 *a*	12,151 *d*	5.4 *d*
Spring Millet	***-- Plots Terminated --***						
LSD (0.05)	NS	NS	-	1,867	0.9	6,913	3.1
CV (%)	2.96	2.96	-	14.3	14.3	10.8	10.8

NS = not significant

Days to heading, plant height and lodging ratings are shown in Table 6. Differences are generally minor however, spring cereals did exhibit a higher degree of lodging compared to fall planted rye.

Table 6. Forage heading, height, and lodging in the double crop and annual production systems. Different letters indicate significant differences between treatments (ANOVA, $P \leq 0.05$).

Treatment	**Heading** (days)	**Plant Height** (cm)	**Lodging** (1=erect; 9=flat)
Double Crop Production System			
HFR (KWS Gatano)	164.9 *a*	125.6 *c*	1.0 *c*
HFR (KWS Propower)	163.4 *b*	133.2 *b*	1.0 *c*
CFR (Hazlet)	163.3 *b*	150.4 *a*	1.0 *c*
Spring Barley	***--------- Plots Terminated ---------***		
Spring Oats	n/a	n/a	n/a
Spring Millet	n/a	n/a	n/a

Annual Production System			
Spring Barley	n/a	115.3 *d*	6.7 *a*
Spring Oats	n/a	119.7 *cd*	4.3 *b*
Spring Millet	--------- ***Plots Terminated*** ---------		
LSD (0.05)	0.7	6.6	1.0
CV (%)	0.43	3.84	10.48

HFR = hybrid fall rye; CFR = conventional fall rye; n/a = not available

Forage quality results for the double crop and annual productions systems is shown in Table 7. All three varieties of fall rye had a relatively poor nutrient profile. Crude protein of the fall rye varieties ranged from 6.89% to 7.88%. In comparison, the spring oat and spring barley annual productions system crops had proteins of 8.0% and 8.7%. The double crop oats also had poor protein content at 6.66%, while the spring millet had the best protein of all treatments at 9.38%. Neutral Detergent Fibre (NDF) was also high in the fall rye varieties and would likely cause a reduction in feed intake in beef cattle. The NDF ranged from 62.3% to 68.9% amongst the fall rye varieties. The spring oat also had a high NDF at 65.6%. In comparison, the spring barley annual crop had an NDF of 49.8%. The double crop oats had a much lower NDF at 53.1%, with the millet having an NDF of 62.7%. Total Digestible Nutrients (TDN) varied across treatments. The fall rye varieties ranged from 49.7% to 56% TDN. In comparison, the annual crop barley had a TDN of 65.7% and the annual crop oats had a TDN of 54.5%. The double crop oats had a TDN of 65.4%, while the double crop millet had a TDN of 60.6%. Overall, the annual production system crop of spring barley resulted in the best nutrient profile of all crops.

Table 7. Fall rye forage quality analysis. Different letters indicate significant differences between treatments (ANOVA, $P \leq 0.05$).

Treatment	**Crude Protein** (%)	**ADF** (%)	**NDF** (%)	**TDN** (%)	**Ca** (%)	**P** (%)	**K** (%)	**Na** (%)
Double Crop Production System								
HFR (KWS Gatano)	7.88 *a*	39.9 *b*	62.3 *d*	56.0 *c*	0.20 *b*	0.14 *cd*	1.52 *c*	0.01 *c*
HFR (KWS Propower)	7.36 *a*	44.2 *a*	67.2 *ab*	51.4 *d*	0.18 *b*	0.15 *bcd*	1.52 *c*	0.01 *c*
CFR (Hazlet)	6.89 *a*	45.8 *a*	68.9 *a*	49.7 *d*	0.18 *b*	0.13 *d*	1.64 *c*	0.01 *c*
Spring Barley	--------------------------------------- ***Plots Terminated*** ---------------------------------------							
Spring Oats	6.66 *a*	31.9 *d*	53.1 *e*	64.5 *a*	0.17 *b*	0.18 *ab*	1.69 *c*	0.03 *c*
Spring Millet	9.38 *a*	35.6 *c*	62.7 *cd*	60.6 *b*	0.19 *b*	0.19 *a*	1.90 *b*	0.01 *c*
Annual Production System								
Spring Barley	8.0 *a*	30.8 *d*	49.8 *f*	65.7 *a*	0.29 *a*	0.14 *cd*	0.18 *c*	0.16 *b*
Spring Oats	8.7 *a*	41.4 *b*	65.6 *bc*	54.5 *c*	0.19 *b*	0.17 *abc*	0.13 *a*	0.25 *a*
Spring Millet	--------------------------------------- ***Plots Terminated*** ---------------------------------------							
LSD (0.05)	NS	2.5	3.1	2.7	0.06	0.03	0.20	0.08
CV (%)	13.8	3.64	2.87	2.60	15.6	11.7	6.47	3.37

Conclusions

This study demonstrates that double cropping may be a viable system within the west central irrigated region of Saskatchewan. With respect to forage yield, fall rye had higher yields than spring cereals, and by re-cropping oat after fall rye total forage production per land area almost doubled. Results indicate additional investigation of double cropping is warranted. Although no concrete recommendations can be made from a single test year the results generated in this study are positive. The study did identify a couple of tangible observations.

- Warm season millet planted in early to mid-May does not establish to satisfactory plant stands and delaying planting until soils sufficiently warm may not be practical, nor desirable, in a double crop production scenario, and
- Extreme caution is needed in deciding the feasibility of growing fall rye followed by spring barley in an irrigated double crop production system. Apparent allelopathic effects associated with the fall rye severely influenced spring barley emergence and growth of surviving plants. This phenomenon also warrants further investigation.

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Effect of Nitrogen Fertilizer Applications on Double Cropped Fall Rye and Spring Barley

Funding

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Organizations

- Irrigation Crop Diversification Corporation (ICDC), Outlook
- Saskatchewan Ministry of Agriculture (SMOA), Outlook

Project Lead

- ICDC Leads: Erin Karppinen & Garry Hnatowich
- SMOA Lead: Travis Peardon

Objectives

Double cropping is practiced or under development in many regions of the continental USA and in central Canada. In these geographies, the crop selection can be two summer crops (i.e., pulse followed by corn or grain sorghum) or winter wheat followed by corn or soybean. Due to the short Saskatchewan growing season, a winter cereal harvested for forage followed by a second crop also harvested for its forage potential, likely has the highest potential for success. Presently, ICDC is evaluating spring barley forage yield following winter wheat, fall rye, and winter triticale. Land following high value irrigable crops such as dry bean and potato is at a high risk of soil erosion prior to the succeeding growing season. A double cropping scenario within irrigated production would be an environmentally sound method of protecting soil from erosion and increase land use efficiency. The trial is also designed to assess nitrogen (N) fertilizer response to N rates, placement, and time of application. The N fertilizer applications will also assess the two crops individually as well as fertilizing as single two forage harvest production system.

Due to the drought conditions widely experienced in 2018 and the widespread dry conditions leading into the 2019 crop season, availability of forage for livestock production is being challenged and quality feed will be in demand. This study has the potential to produce greater returns than an annual cereal forage harvest and increase livestock feed production in years where dry land pasture and forage production is severely limited by drought. Irrigated double cropping could prove to be an agronomically and socially viable means of increasing forage production.

Research Plan

A field demonstration with fall rye was established in the fall of 2019 on ICDC land rented from the Town of Outlook and adjacent to the federal CSIDC Research Station (Field 51). A composite soil sample was collected and sent to AgVise Laboratories for analysis (Table A3). The trial was established in a randomized complete block design and each treatment was replicated four times. A hybrid fall rye variety (Gatano) was seeded on September 17, 2019. Following a forage harvest (soft dough stage) on July 3, 2020, the plots were immediately sprayed with 0.67 L/ac of glyphosate. Plots were reseeded to barley on July 6, 2020.

For the fall rye, N fertilizer (urea, 46-0-0) was applied at varying rates either as fall side-banded applications at seeding or as broadcast applications in the spring. For the spring barley, N fertilizer rates were inverse to those applied to the fall rye and all N fertilizer applications were side banded at seeding. Table 1 presents the rate, time, and placement of N fertilizer for the fall rye and subsequent spring barley crop. At seeding, all fall rye plots received monoammonium phosphate (MAP; 11-52-0) that was side-banded at a rate of 25 kg P_2O_5/ha and seed-placed at a rate of 25 kg P_2O_5/ha. At seeding, all spring barley plots also received 25 kg P_2O_5/ha of seed-placed MAP.

Table 1. Nitrogen rate, time, and placement of urea fertilizer for the fall rye and subsequent spring barley crop.

Trt	Fall Rye		Spring Barley	
	Timing/Placement	kg N/ha	Timing/Placement	kg N/ha
1	Absolute Control	0	Absolute Control	0
2	Fall/Side-Band	30	Spring/Side-Band	90
3	Fall/Side-Band	60	Spring/Side-Band	60
4	Fall/Side-Band	90	Spring/Side-Band	30
5	Fall/Side-Band	120	Unfertilized	0
6	Unfertilized	0	Spring/Side-Band	120
7	Spring/Broadcast	30	Spring/Side-Band	90
8	Spring/Broadcast	60	Spring/Side-Band	60
9	Spring/Broadcast	90	Spring/Side-Band	30
10	Spring/Broadcast	120	Unfertilized	0

Weed control consisted of a post-emergence application of Buctril® M (bromoxynil +MCPA ester; 0.4 L/ac) on August 12, 2020, supplemented by hand weeding. No foliar fungicides were applied for either leaf disease or fusarium head blight. Wet field yields were recorded, and subsamples of cut material was dried and sub-sampled for processing. Harvest plot size was 6 m x 1.5 m. Forage harvests were taken at soft dough stage using a Hege small plot forage combine on July 3, 2020 (fall rye) and October 6, 2020 (spring barley). Total plot weight was recorded, and subsamples were obtained for forage material moisture content. Initial crop and double crop forage subsamples from each replicate were sent for quality analysis at Central Testing Laboratories (Winnipeg, MB). Total in-season rainfall was 139.7 mm (5.5”) and total in-season irrigation was 203.2 mm (8.0”).

Results

Moisture Content & Yield

Moisture content at harvest did not differ significantly for the fall rye or spring barley forage crops (data not shown, ANOVA, $P \leq 0.05$). Average moisture content was 61.4% for fall rye forage and 63.3% for spring barley forage.

Overall, the initial fall rye crop (7.68 T/ha) was higher yielding than the subsequent spring barley crop (3.38 T/ha). For the fall rye, differences in dry matter yield were not influenced by the timing of N fertilizer application (fall/spring side-band vs. spring broadcast/side-band), but by the rate of N application (Figure 1, ANOVA, $P \leq 0.05$). Fall rye dry matter yield was lowest at 0 kg N/ha and significantly increased at 60 kg N/ha, but there was no dry matter yield advantage with increasing fertilizer rates. The spring barley responded similarly to the fall rye, but significant increases in dry matter yield did not occur until the 90 kg N/ha application rate (Figure 2, ANOVA, $P \leq 0.05$). Although the 0 kg N/ha application rate was seeded into a plot that had previously received 120 kg N/ha, dry matter yield was only marginally higher than the absolute control plot which received no N fertilizer. This suggests that there was an insufficient amount of residual soil N left over from the previous fall rye crop. Establishment of the spring barley crop was poor, which might indicate there was an allelopathic effect from the fall rye harvest residue. This observation has also been noted in other past projects where spring barley was seeded immediately following a fall rye forage harvest.

Fall rye and spring barley forage dry matter yield was highly variable between treatments, but when considering the cumulative dry matter yield of both crops, all fertilized treatments were higher yielding than the unfertilized control (Figure 3, ANOVA, $P \leq 0.05$). The average dry matter yield of the unfertilized control was 7.30 T/ha while the average dry matter yield of fertilized plots receiving a total of 120 kg N/ha was 11.48 T/ha.

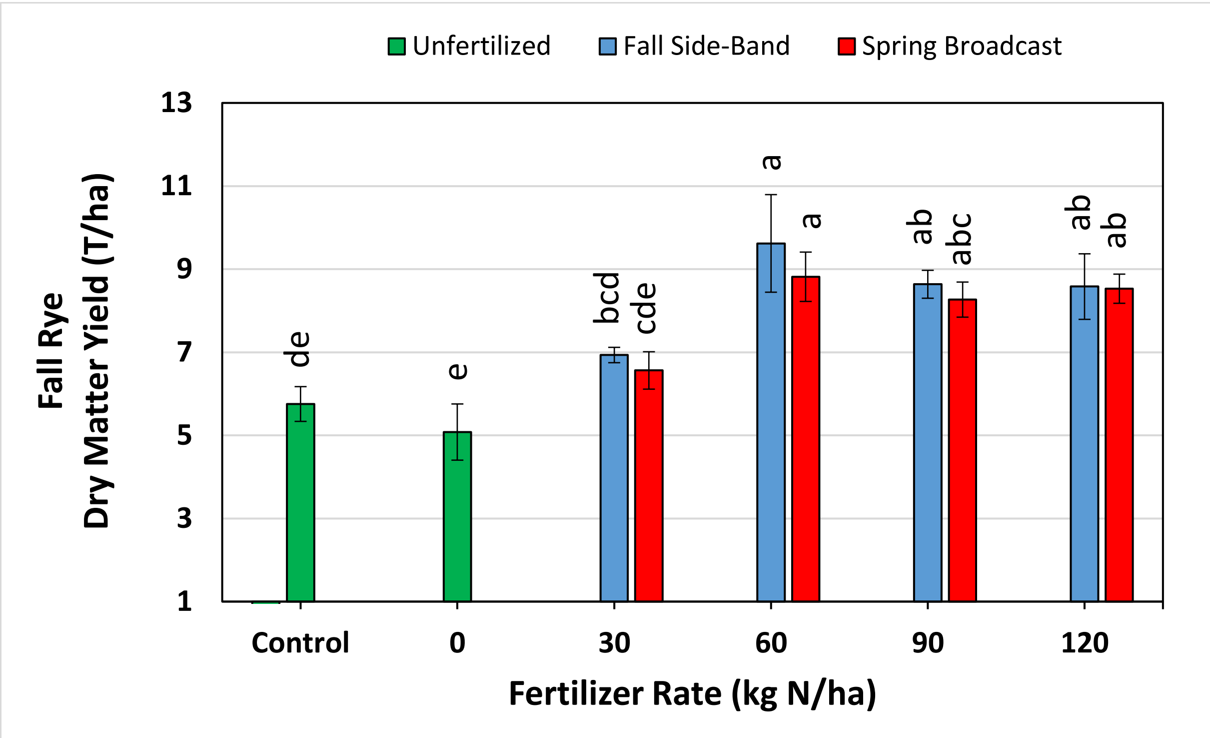

Figure 1. Fall rye dry matter yield (T/ha). Different letters indicate significant differences between treatments (ANOVA, $P \leq 0.05$).

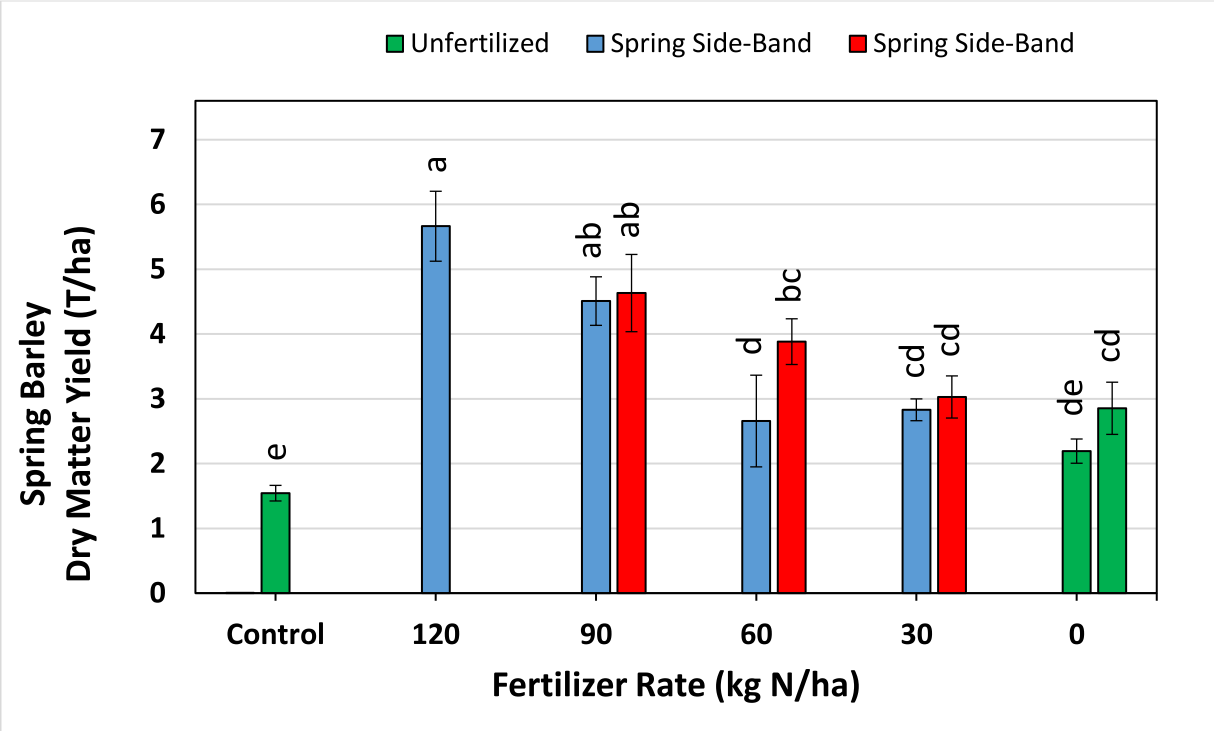

Figure 2. Spring barley dry matter yield (T/ha). Different letters indicate significant differences between treatments (ANOVA, $P \leq 0.05$).

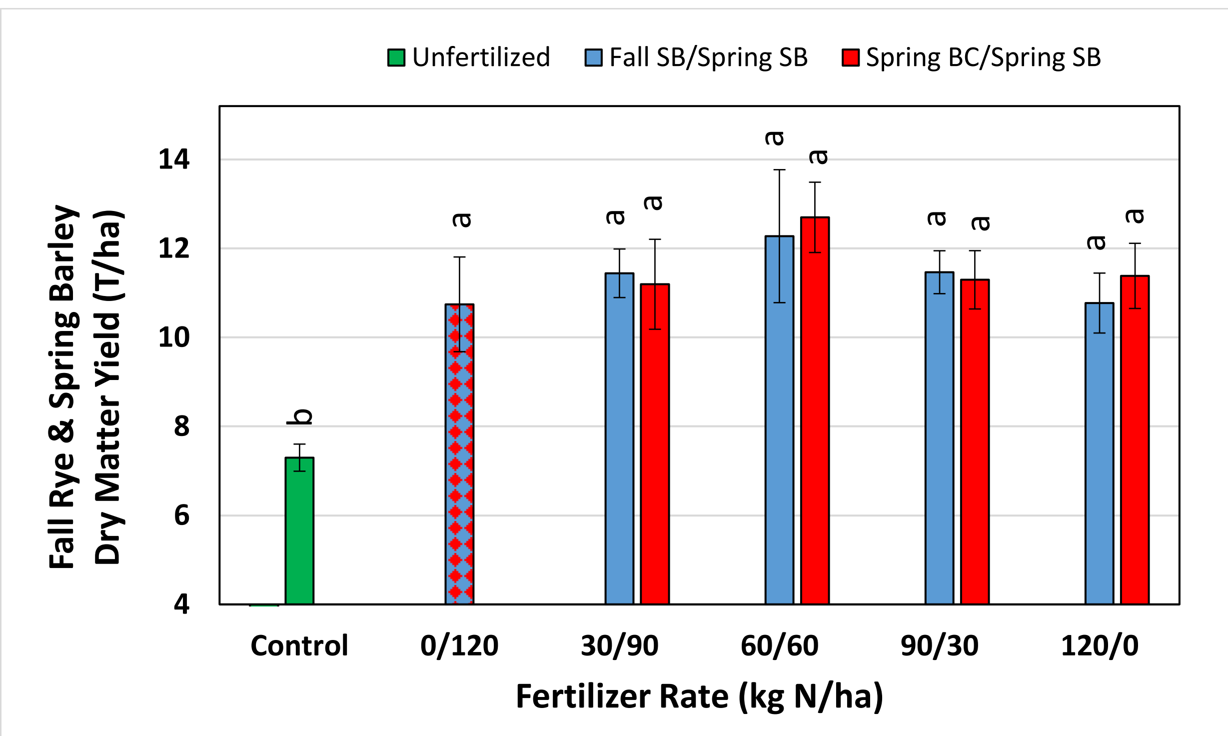

Figure 3. Cumulative fall rye and spring barley dry matter yield (T/ha). Different letters indicate significant differences between treatments (ANOVA, $P \leq 0.05$). SB = side-band; BC = broadcast

Forage Quality

A higher crude protein (CP) is indicative of higher forage quality, and young cattle and gestating/lactating cows have increased protein requirements (Beef Council Research Council, 2020a). Overall, the mean CP was 8.37% for fall rye and 9.81% for spring barley - this is lower than expected as the CP of cereal silage is usually 11% to 13%. For fall rye with fall side-banded N fertilizer, only treatments receiving 120 kg N/ha had higher CP than the control (7.98%), while all spring broadcasted N rates (30, 60, 90, and 120 kg N/ha) had higher CP than the control (Table 2). For spring barley, most treatments receiving ≥ 60 kg N/ha had higher CP when compared to the control (10.05%) (Table 3).

Neutral detergent fibre (NDF) is a measure of the bulkiness of the diet so when NDF increases, cattle consume less, but high levels of NDF (≥ 70%) can restrict animal intake (Beef Council Research Council, 2020b). Feeds high in acid detergent fibre (ADF) are less digestible, so a high ADF indicates poor digestibility of forage (Beef Council Research Council, 2020b). Both NDF and ADF were higher in the fall rye forage (Table 2) compared to the spring barley forage (Table 3). Average fall rye forage NDF was 63.1%, so it is possible that levels this high may restrict intake.

Energy content, often reported as total digestible nutrients (TDN), includes carbohydrates, fats, and proteins supplied by cattle feed. TDN ranged between 58.6% and 58.4% for fall rye (Table 2) and between 68.1% and 73.5% for the spring barley (Table 3). TDN in cereal silage usually ranges from 60 to 65%.

Forage macrominerals such as calcium (Ca), phosphorus (P), potassium (K), and sodium (Na) are important components of cattle feed (Beef Council Research Council, 2020b). Generally, macrominerals were higher in the spring barley forage (Table 3) when compared to the fall rye forage (Table 2). In both fall rye and spring barley forage, K increased with increasing N rate, regardless of application method.

Table 2. Fall rye forage quality analysis.

Treatment	Crude Protein (%)	ADF (%)	NDF (%)	TDN (%)	Ca (%)	P (%)	K (%)	Na (%)
Control (0 kg N/ha)	7.98	37.6	62.2	54.5	0.15	0.21	1.33	0.01
Fall Side-Band								
0 kg N/ha	7.70	40.8	63.5	55.1	0.15	0.22	1.34	0.01
30 kg N/ha	7.27	38.4	58.6	57.6	0.13	0.17	1.46	0.01
60 kg N/ha	6.77	39.6	62.1	56.3	0.15	0.15	1.51	0.02
90 kg N/ha	7.61	40.2	62.7	55.7	0.13	0.14	1.56	0.01
120 kg N/ha	9.33	41.6	62.9	54.2	0.18	0.16	1.67	0.01
Spring Broadcast								
30 kg N/ha	8.47	40.9	64.2	54.9	0.13	0.18	1.31	0.01
60 kg N/ha	9.31	37.7	62.7	58.4	0.15	0.19	1.49	0.01
90 kg N/ha	9.41	41.3	64.7	54.5	0.17	0.21	1.47	0.01
120 kg N/ha	9.83	43.6	66.9	52.0	0.18	0.19	1.63	0.01

TDN = total digestible nutrients; ADF = acid detergent fibre; NDF = neutral detergent fibre;
Ca = calcium; P = phosphorus; K = potassium; Na = sodium

Table 3. Spring barley forage quality analysis.

Treatment	Crude Protein (%)	ADF (%)	NDF (%)	TDN (%)	Ca (%)	P (%)	K (%)	Na (%)
Control (0 kg N/ha)	10.05	27.7	56.3	69.1	0.25	0.29	1.77	0.09
Spring Side-Band following Fall Side-Band								
120 kg N/ha	10.42	27.3	47.8	69.5	0.25	0.19	1.76	0.18
90 kg N/ha	10.63	25.7	47.3	71.2	0.22	0.21	1.78	0.10
60 kg N/ha	10.18	24.9	48.4	72.1	0.22	0.27	1.73	0.12
30 kg N/ha	8.96	24.7	44.5	72.2	0.19	0.23	1.40	0.13
0 kg N/ha	9.68	26.6	49.5	70.2	0.19	0.24	1.43	0.10
Spring Side-Band following Spring Broadcast								
90 kg N/ha	9.28	28.6	49.4	68.1	0.21	0.19	1.60	0.10
60 kg N/ha	11.04	25.3	46.1	71.6	0.23	0.24	1.69	0.08
30 kg N/ha	8.44	26.0	44.9	70.9	0.23	0.25	1.61	0.13
0 kg N/ha	9.43	23.6	45.4	73.5	0.20	0.28	1.51	0.13

TDN = total digestible nutrients; ADF = acid detergent fibre; NDF = neutral detergent fibre;
Ca = calcium; P = phosphorus; K = potassium; Na = sodium

Conclusions

This study demonstrates the feasibility of growing fall rye followed by spring barley in an irrigated double crop production system, but that there may be allelopathic effects associated with that cropping sequence that could have reduced the yield, and potentially forage quality, of the spring barley crop. However, we demonstrated that the overall cumulative dry matter yield of double cropped fall rye and spring barley was driven by total N fertilizer rate over the growing season. All treatments received a total of 120 kg N/ha but how that application was split and when it was applied only affected the specific crop, not the overall yield. Fall rye yielded much higher than spring barley but the spring barley had superior forage quality in terms of protein, fibre, energy, and nutrients. Fertilizer management decisions in a fall rye and spring barley double crop production system should consider how to invest N fertilizer inputs into based on both yield and forage quality goals.

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Increasing Wheat Protein with a Post Emergent Applications of Urea Ammonium Nitrate (UAN) vs Dissolved Urea

Funding

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Organizations

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- Western Applied Research Corporation (WARC), Scott
- Northern Applied Research Foundation (NARF), Melfort
- Wheatland Conservation Association (WCA), Swift Current

Project Lead

- Project Lead: Mike Hall (ECRF)
- ICDC Leads: Erin Karppinen & Garry Hnatowich

Objectives

Recently, producers have been disappointed by low levels of grain protein. When area wide protein levels are low, the premiums offered for high protein wheat tend to increase. This has left producers wondering what they could do to increase protein levels in the future. Post emergent application of nitrogen (N) fertilizer is one of the only options to increase grain protein during the growing season. The results from this practice vary but it is more likely to be economical when yield potential is high and soil N is inadequate to maintain high protein levels. Applying N as a broadcast foliar spray is convenient for producers and some may feel that this is an efficient way to get N into the plant quickly late in the season; however, applying N in this manner comes with a higher risk of leaf burn and subsequent yield loss. To reduce this risk, producers can dilute the urea ammonium nitrate (UAN) 50:50 with water and try to avoid spraying during the heat of the day, but this may not always be realistic. Dribble banding reduces the risk of crop damage due to less fertilizer coming into direct contact with the leaves and may be a better alternative. However, UAN (28-0-0) produces large drops that do not disperse on the leaf surface because they have a high surface tension and tend to roll off. Dilution may reduce surface tension and potentially increase leaf burn.

Foliar sprays with dissolved urea, instead of UAN may prove to be more beneficial. Recently, Amy Mangin with the University of Manitoba found that foliar sprays of dissolved urea sprayed post-anthesis not only resulted in less leaf burn but also produced greater yields and higher grain protein when compared to UAN (Mangin and Flaten, 2019). Dissolved urea is a standard product used for foliar applications in the UK and is considered safer on the crop than UAN. While both UAN and dissolved urea were applied at 30 lb N/ac in Mangin's study, the % N concentration of the solutions differed between the products. The UAN solution was 14%, whereas the urea solution was only 9%. This may have also contributed to the greater crop safety observed with dissolved urea. In this demonstration, dissolved urea and UAN will be compared at a 14% solution of N. Producers can create their own solution of urea on farm; however, care must be taken as dissolving urea is extremely endothermic and can freeze lines. Urea should be dissolved slowly into warm water and not into cold water pulled from a well for example. In addition, producers should only dissolve urea with less than 1% biuret. Biuret is a by-product that can cause severe leaf burning but it is normally removed from North American production.

The overall objective of this project is to demonstrate the potential of an additional 30 lb N/ac applied late season to increase either wheat yield or grain protein compared to applying all N at seeding. The impact of nitrogen source, crop staging and application method will be compared.

Specifically, the following concepts will be demonstrated:

a. Dribble banded applications of UAN cause less leaf burn than broadcast foliar sprays post-anthesis.
b. Dribble banding UAN at the earlier boot stage causes less leaf burn than when applied post-anthesis.
c. Diluting dribble band applications of UAN is not necessary and may increase leaf burn.
d. When broadcast foliar sprays are applied post-anthesis, dissolved urea will result in less leaf burn than UAN applied as a solution of 14% nitrogen.
e. Strategies resulting in less leaf burn will produce a better yield/protein response (i.e., more protein/ac).

Research Plan

The trial was established on canola stubble at the ICDC Knapik off-station location. On May 28, 2020, AAC Brandon Canadian Western Red Spring wheat was seeded into canola stubble at a seeding rate of 300 seeds/m^2 (adjusted for % germination and seed weight). A total of 9 treatments were arranged in a four-replicate randomized complete block design trial. Treatments are shown in Table 1 and all fertilizer applications are in Imperial measurements (i.e., pounds, acres, US gallons). The 28% N UAN (28-0-0) treatments (Treatments 4 & 6) were diluted with water to create the 14% N UAN (14-0-0) treatments (Treatments 3, 5, & 8). Likewise, the 14% N urea (14-0-0) treatments (Treatments 7 & 9) were created by adding 1.66 kg of urea (46-0-0) to every gallon of water. Urea with less than 1% biuret was used to ensure optimum crop safety. All post-emergent applications of nitrogen were sprayed to deliver an extra 30 lb N/ac to a base rate of 70 lb N/ac side-banded at seeding. These treatments were compared to base rates of 70 lb N/ac (Treatment 1) and 100 lb N/ac (Treatment 2) to determine if there are any benefits from split applications of N. Comparisons between Treatments 3 to 9 will determine if N source, application method, or timing influences crop safety and in turn the resulting yield and protein.

In the trial area, CleanStart® (glyphosate; 360 g/ac + carfentrazone-ethyl; 30 mL/ac) was applied as a pre-seeding herbicide on May 19, 2020. Each treatment received an application of 30 lb P_2O_5/ac as seed-placed monoammonium phosphate (MAP; 11-52-0). Individual plot size was 8 m x 2 m and row spacing was 25 cm (10”). Each plot consisted of six rows of AAC Brandon and two outside guard rows of winter wheat. A composite soil sample was collected within the trial area and submitted to AgVise Laboratories for analysis (Table A2). Weed control consisted of post-emergent applications of Simplicity™ (pyroxsulam; 28 g/ac) and Infinity® (bromoxynil + pyrasulfotole + fluroxypyr; 0.33 L/ac). Boot stage applications occurred on July 13, 2020 when ambient air temperature was 17 °C and post-anthesis N applications occurred on July 29, 2020 when ambient air temperature was 19 °C. Leaf burn, a subjective evaluation of the percentage of leaf exhibiting chlorosis from 10 random plants within each plot, was assessed on July 31, 2020. No determination was made to distinguish between foliar N leaf burn and foliar leaf disease. Actual foliar burn would be assumed by differences and comparisons between untreated vs. treated in-season post emergent N application treatments. Yields were estimated by direct cutting the entire plot with a small plot combine when the plants were dry enough to thresh and seed moisture content was < 20%. The trial was harvested on September 16, 2020. Total in-season rainfall from May through September 15 was 165.2 mm (6.5") and total in-season irrigation was 155.0 mm (6.1").

Table 1. Experimental treatments for post-emergent applications of UAN and dissolved urea.

Treatment	Side-Band at Seeding N (lb/ac)	Post Emergent Applications				
		N (lb/ac)	Product	%N	Method	Stage
1	70	n/a	-	-	-	-
2	100	n/a	-	-	-	-
3	70	30	UAN	14	dribble[1]	boot
4	70	30	UAN	28	dribble[2]	boot
5	70	30	UAN	14	dribble[1]	post-anthesis
6	70	30	UAN	28	dribble[2]	post-anthesis
7	70	30	Dissolved Urea	14	dribble[3]	post-anthesis
8	70	30	UAN	14	foliar[4]	post-anthesis
9	70	30	Dissolved Urea	14	foliar[5]	post-anthesis

[1] Sprayed with dribble band nozzle at 20 ga/ac (10 ga/ac UAN + 10 ga/ac water = 14% N solution)
[2] Sprayed with dribble band nozzle at 10 ga/ac (undiluted UAN =28% N solution)
[3] Sprayed with dribble band nozzle at 20 ga/ac (1.66 kg of urea dissolved in 1 US gallon of water = 14% N solution)
[4] Sprayed with 02 flat fan nozzles at 20 ga/ac (10 ga/ac UAN + 10 ga/ac water = 14% N solution)
[5] Sprayed with 02 flat fan nozzles at 20 ga/ac (1.66 kg of urea dissolved in 1 US gallon of water = 14% N solution)

Results

Seed yield and seed quality parameters measured are shown in Table 2 and agronomic observations are shown in Table 3.

Statistically, yields did not differ between treatments at a 5% confidence level. However, statistically significant differences did occur with grain yield at a 10% confidence interval. At $P < 0.10$, results indicate that a side band application of 100 lb N/ac (Treatment 2) and the addition of 30 lb N/ac at the boot wheat stage (Treatments 3 & 4) resulted in grain yield responses above the control (Treatment 1). The additional application of 30 lb N/ac during post-anthesis were ineffective in elevating yield. This conforms to most trials conducted across western Canada which suggest that N applications for maximum yield potential are required early in the growing season. Yield response to this early season 30 lb N/ac addition was approximately 470 kg/ac (7.0 bu/ac). Wheat yield response to treatments applied is shown in Figure 1. Generally, post-emergent applications resulted in higher seed protein content than the base fertilizer level of 70 lb N/ac. The exceptions being the side band application of 100 lb N/ac and the addition of 30 lb N/ac at the boot wheat stage as UAN at 10 gal/ac (Treatments 2 & 4, respectively). These two treatments did not statistically differ in protein content from the control. These treatments were among the highest yielding, so a yield-protein dilution effect was occurring. All other treatments did statistically increase % seed protein from the base control treatment. The 30 lb N/ac dribble band UAN post-anthesis at 20 gal/ac produced seed protein contents significantly higher than all other treatments. Similarly, protein on a per acre bases was highest for this treatment. Wheat seed protein response to treatments applied is shown in Figure 2.

Post-emergent applications had no influences on test weight, maturity, plant height, or lodging. Seed weight tended to increase with post seeding applications of 30 lb N/ac. Flag leaf burn increased significantly for the two treatments applied post-anthesis as a foliar application with flat fan nozzles. This evidence of foliar burn would be expected to be detrimental to grain yield.

This was the second year of trialing and will be repeated for a final year of evaluation in 2021. At the completion of three years these results will be combined with trials conducted at other Agri-ARM locations and a final report prepared for the Saskatchewan Wheat Development Commission. The final report should be made available on either the Saskatchewan Wheat Development Commission or Agri-ARM websites.

Acknowledgements

Financial support was provided by the Saskatchewan Wheat Development Commission. All funding is gratefully acknowledged.

Table 2. Influence of initial N application and in-season N applications on yield and seed quality.

Side-Band at Seeding N (lb/ac)	**Post-Emergent Applications**			**Yield** (kg/ha)	**Yield** (bu/ac)	**Protein** (%)	**Protein** (lb/ac)	**Test Weight** (kg/hl)	**Seed Weight** (g/1000)
	N Source/ Rate (lb/ac)	**% N**	**Method/ Stage**						
70	n/a			3,517	52.3	10.8	338	80.6	36.4
100	n/a			3,948	58.7	11.1	393	80.3	37.0
70	30 UAN	14	dbl-boot[1]	3,971	59.0	11.8	417	79.7	37.2
70	30 UAN	28	dbl-boot[2]	3,899	58.0	11.7	406	79.7	36.5
70	30 UAN	14	dbl-post anthesis[1]	3,678	54.7	13.9	455	80.4	39.1
70	30 UAN	28	dbl-post anthesis[2]	3,524	52.4	12.0	376	80.3	37.4
70	30 Dissol. Urea	14	dbl-post anthesis[3]	3,594	53.4	12.9	413	80.6	37.9
70	30 UAN	14	foliar-post anthesis[4]	3,573	53.1	12.9	410	80.8	38.2
70	30 Dissol. Urea	14	foliar-post anthesis[5]	3,631	54.0	12.4	401	81.1	37.7
			LSD (0.05)	360*	5.3*	0.9	48	NS	1.6
			CV (%)	6.7	6.7	5.4	8.2	0.8	2.9

[1] Sprayed with dribble band nozzle at 20 ga/ac (10 ga/ac UAN + 10 ga/ac water = 14% N solution)
[2] Sprayed with dribble band nozzle at 10 ga/ac (undiluted UAN =28% N solution)
[3] Sprayed with dribble band nozzle at 20 ga/ac (1.66 kg of urea dissolved in 1 US gallon of water = 14% N solution)
[4] Sprayed with 02 flat fan nozzles at 20 ga/ac (10 ga/ac UAN + 10 ga/ac water = 14% N solution)
[5] Sprayed with 02 flat fan nozzles at 20 ga/ac (1.66 kg of urea dissolved in 1 US gallon of water = 14% N solution)
*not significant at $P < 0.05$ but significant at $P < 0.07$
NS = not significant

Table 3. Influence of initial N application and in-season N applications on days to maturity, plant height, lodging, and flag leaf burn.

Side-Band at Seeding N (lb/ac)	**Post-Emergent Applications**			**Maturity** (days)	**Plant Height** (cm)	**Lodging** (1=erect; 9=flat)	**Flag Leaf Burn** (%)
	N Source/ Rate (lb/ac)	**% N**	**Method/ Stage**				
70	n/a			89	69	1	7.4
100	n/a			91	72	1	3.8
70	30 UAN	14	dbl-boot[1]	92	71	1	4.5
70	30 UAN	28	dbl-boot[2]	90	70	1	4.0
70	30 UAN	14	dbl-post anthesis[1]	92	67	1	6.4
70	30 UAN	28	dbl-post anthesis[2]	89	68	1	7.4
70	30 Dissol. Urea	14	dbl-post anthesis[3]	91	70	1	5.4
70	30 UAN	14	foliar-post anthesis[4]	91	68	1	56
70	30 Dissol. Urea	14	foliar-post anthesis[5]	90	69	1	42
			LSD (0.05)	NS	NS	NS	-
			CV (%)	2.2	3.8	0	29.2

[1] Sprayed with dribble band nozzle at 20 ga/ac (10 ga/ac UAN + 10 ga/ac water = 14% N solution)
[2] Sprayed with dribble band nozzle at 10 ga/ac (undiluted UAN =28% N solution)
[3] Sprayed with dribble band nozzle at 20 ga/ac (1.66 kg of urea dissolved in 1 US gallon of water = 14% N solution)
[4] Sprayed with 02 flat fan nozzles at 20 ga/ac (10 ga/ac UAN + 10 ga/ac water = 14% N solution)
[5] Sprayed with 02 flat fan nozzles at 20 ga/ac (1.66 kg of urea dissolved in 1 US gallon of water = 14% N solution)
*not significant at $P < 0.05$ but significant at $P < 0.07$
NS = not significant

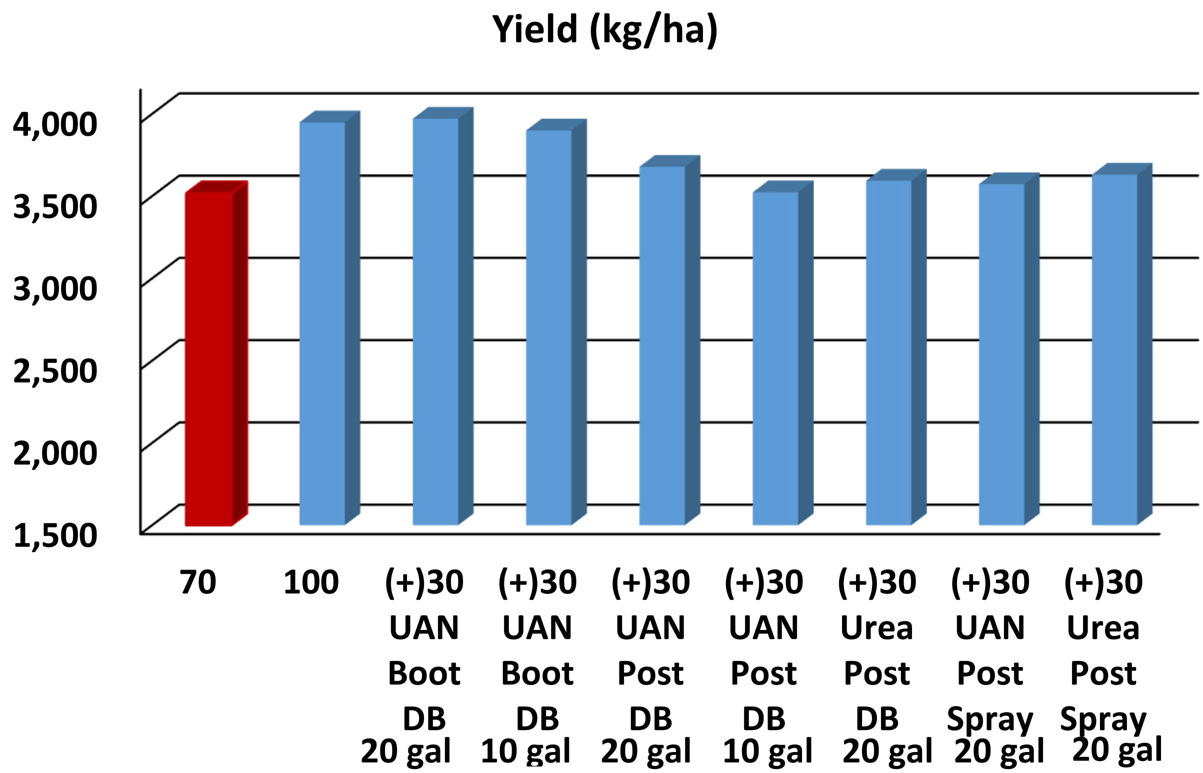

Figure 1. Influence of fertilizer rate, timing, and method of application on wheat grain yield in 2020.

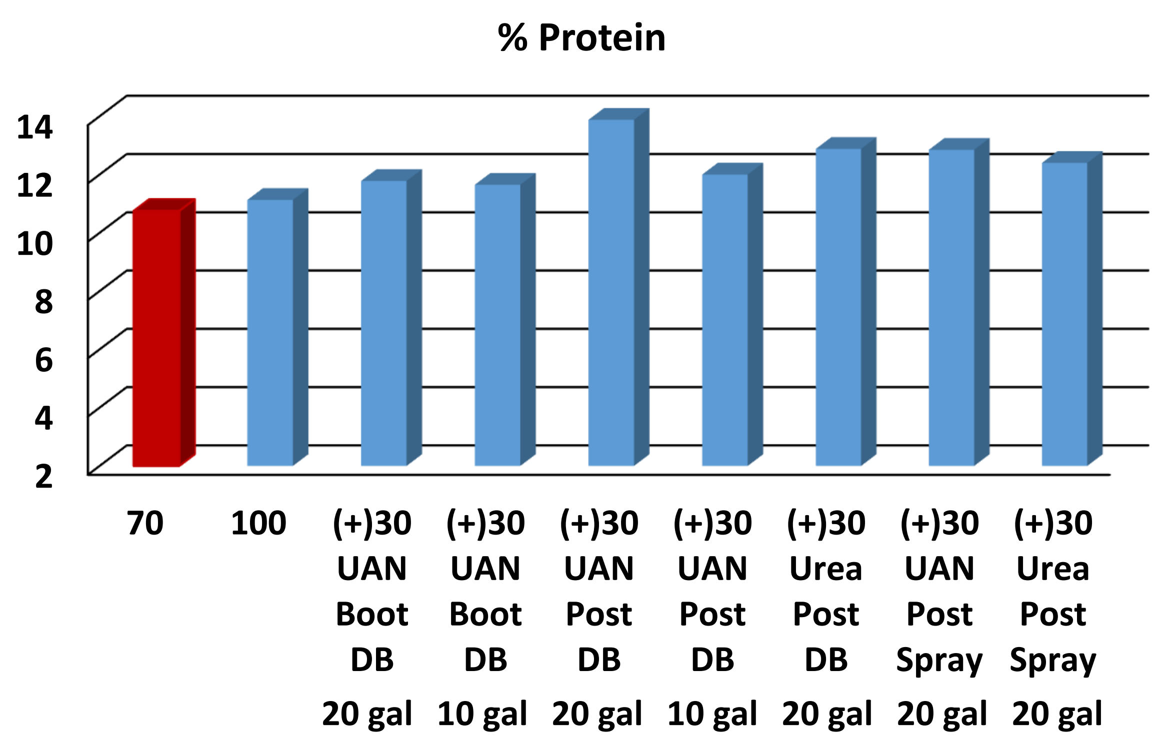

Figure 2. Influence of fertilizer rate, timing, and method of application on wheat grain protein.

Can Farm Saved Seed Wheat (*Triticum aestivum L.)* Perform as well as Certified Seed in Saskatchewan?

Funding

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Organizations

- Irrigation Crop Diversification Corporation (ICDC), Outlook
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- Conservation Learning Center (CLC), Prince Albert

Project Lead

- Project Lead: Mike Hall (ECRF)
- ICDC Leads: Erin Karppinen & Garry Hnatowich

Objectives

While the yield loss from growing saved seed from hybrid crops such as canola has been well documented (Clayton et al., 2009), little research has compared yields between certified and farmer-saved seed for wheat, and particularly for oats, in western Canada.

Certified seed is "true to type" which means it has retained all the genetic benefits developed by the breeder. To be "certified", seed must meet high standards of varietal purity, germination, and freedom from impurities, which are determined by an officially recognized third-party agency. Producers of cereal grains are not required to use certified seed and may retain seed from their own farm for planting. This retained seed is commonly referred to as "farmer-saved seed" (FSS). Despite the guaranteed quality of certified seed, a phone survey of 800 producers in 2004 determined approximately 70 to 80% of cereal acres in western Canada were seeded with FSS. The survey was conducted by Blacksheep Strategy Inc. The lowest use of certified seed occurred in Alberta and Saskatchewan with only 10 to 20% of wheat, barley, oat, and pea acres being seeded with certified seed. Manitoba was closer to 40% due to greater disease concerns. The survey found that high income producers were more likely to use certified seed. Two thirds of producers who did not frequently use certified seed cited "reduced costs" and "knowing what is in the seed" as reasons for preferring FSS. Another 25% felt the quality of FSS was close enough to certified. Many believe the quality of FSS can be as good as certified seed (Pratt, 2004). Producers will typically grow FSS for 2 to 3 years and then purchase certified seed to introduce better varieties to the farm.

Farmer-saved seed is typically a cheaper seed source than certified seed. A 13-year study in Alberta (2003 to 2016) found the average price premium for certified wheat seed over FSS was $3.75/bu (Furtas, 2018). There was only 1 year out of 13 in the study where the cost of producing FSS was more expensive than purchasing certified seed. Economically, the bottom line must take into consideration the relative yield performance of FSS and certified seed in the field. Assuming a modest 1.5 bu/ac yield benefit from using a new variety of certified seed, the report determined "purchasing certified seed was only economically beneficial two out of the thirteen years". The report made no justification for the magnitude of the proposed yield benefit.

Studies with winter wheat in central Oklahoma found FSS could often perform as well as certified seed (Edwards and Krenzer, 2006). In 2003, they observed only 9 out of 19 lots of FSS were inferior for grain production compared to the best certified seed source. In 2004, only 2 out of 27 FSS samples were inferior and only 4 out of 17 were inferior in 2005. The authors concluded, "that if farmers use quality control measures similar to those required for certified seed, FSS (wheat) can produce forage and grain yield comparable to that of certified seed". In contrast, an unpublished study conducted in western Canada by Syngenta suggests the yield benefit from growing certified wheat seed could be substantial. Syngenta observed yield losses ranging from 5 to 14% from using FSS that was 2 years removed from certified (personal communication). However, increasing disease load and poorer quality seed may have been a confounding factor in that study.

There are many seed labs which offer vigor testing and disease screenings to help producers determine the suitability of a seed lot for seeding. Vigor tests are superior to the standard germination test as they will give a better indication of crop emergence and vigor under adverse conditions. A fungal screen can determine the presence of several seed-borne pathogens that can also affect the vigor of a seed lot. Low vigor seed lots with high fungal screens can be retested with seed treatment to determine if vigor can be improved. Seed treatment will often improve the vigor of a seed lot by 10%. However, the level of seed borne disease may be such that locating a better seed lot would be advisable.

The quality of FSS lots are likely to be more variable in quality than certified seed which must meet exacting standards. The intent of this proposal is to randomly compare the vigor and yield potential of FFS relative to certified seed in Saskatchewan over the next 3 years. We want to sample seed lots as broad as possible. For that reason, the same varieties will not likely be grown at each location and year. Vigor tests and fungal screens for all seed lots will be conducted to help explain any differences observed in the field.

The objectives of this study are to:

(1) Compare the yield and vigor performance of various lots of farm-saved wheat seed relative to the same varieties of certified seed and
(2) To determine if a seed treatment can improve the yield and vigor of the farm-saved and certified seed.

Research Plan

This was the second establishment year of three for the study. The trial was established in a 2 x 3 x 2 level factorial in a randomized complete block design with 4 replicates. The first factor contrasted treated and untreated seed. The seed treatment selected to treat all seed lots was Cruiser® Vibrance® Quatro (thiamethoxam + difenoconazole + sedaxane + metalaxyl-M + fludioxonil; 325 mL/100 kg seed). The second factor contrasted 3 different variety pairings. The same variety was used within a variety pairing and varieties differed between pairings. The third factor contrasted certified versus farmer-saved seed. The following 12 treatments were established (Table 1).

Table 1. Detailed treatment list.

Treatment	Seed Treatment	Variety Pairing	Seed Type	Seed Source
1	Untreated	AAC Brandon (A)	Certified	Ardell Seeds
2	Untreated	AAC Brandon (A)	Farm-Saved Seed	Harrington Farms
3	Untreated	AAC Brandon (B)	Certified	P3 Seeds
4	Untreated	AAC Brandon (B)	Farm-Saved Seed	Redden Farms
5	Untreated	AAC Viewfield (C)	Certified	P3 Seeds
6	Untreated	AAC Viewfield (C)	Farm-Saved Seed	Lee Farms
7	Treated	AC Brandon (A)	Certified	Ardell Seeds
8	Treated	AC Brandon (A)	Farm-Saved Seed	Harrington Farms
9	Treated	AC Brandon (B)	Certified	P3 Seeds
10	Treated	AC Brandon (B)	Farm-Saved Seed	Redden Farms
11	Treated	AAC Viewfield (C)	Certified	P3 Seeds
12	Treated	AAC Viewfield (C)	Farm-Saved Seed	Lee Farms

Farm-saved seed samples were provided by local producers John Harrington, Damian Lee, and Redden Farms. Certified seed was obtained from Ardell Seeds and P3 Seeds. Samples of all seed obtained were submitted to Discovery Seed Labs for seed assessment (Table 2).

Table 2. Seed analysis results from Discovery Seeds.

Variety	Seed Type	Seed Source	Germ. (%)	Vigor (%)	Dead Seed (%)	Abnormal Seed (%)	Fusarium graminearum (%)	Seed Weight (g/1000)
AAC Brandon (A)	Certified	Ardell Seeds	97	98	1	2	0	36.5
AAC Brandon (A)	Farm-Saved	Harrington Farms	93	91	4	3	2.5	39.0
AAC Brandon (B)	Certified	P3 Seeds	99	97	0	1	0	40.3
AAC Brandon (B)	Farm-Saved	Redden Farms	94	91	3	3	0.5	39.7
AAC Viewfield (C)	Certified	P3 Seeds	99	92	0	1	0	37.4
AAC Viewfield (C)	Farm-Saved	Lee Farms	94	90	4	2	0.5	38.7

This trial was established at the ICDC Pederson off-station location. On May 22, 2020, all treatments were seeded into canola stubble at a seeding rate of 300 viable seeds/m^2 (adjusted for % vigor and seed weight). Individual plot size was 8 m x 2 m with 25 cm (10") row spacing. Each plot consisted of six rows of the treatment variety and two outside guard rows of winter wheat. All treatments received a pre-seeding application of 60 kg N/ha as banded anhydrous ammonia (82-0-0), and 30 kg N/ha as side-banded urea (46-0-0) and 20 kg P_2O_5/ha as seed-placed MAP (11-52-0) at seeding. The trial was established on potato stubble that had a soil N reserve of 82 kg N/ha (Table A1).

Emergence counts were attempted but unrelenting and continuous winds prevented accurate emergence assessment. Plant vigor was rated on a subjective visual scale of 1 – 10, with 10 exhibiting the most vigor. Weed control consisted of a post-emergence tank mix application of Simplicity™ (pyroxsulam; 28 g/ac) and Buctril® M (bromoxynil +MCPA ester; 0.4 L/ac) on June 16, 2020. No foliar fungicide applications were deemed necessary during 2020. The trial was harvested on August 31, 2020 and yields were estimated by direct cutting the entire plot with a small plot combine when the plants were dry enough to thresh and seed moisture content was < 20%. Harvested plot size was 8.0 m x 1.5 m. All yield samples were cleaned to remove foreign material on stationary seed cleaners and cleaned seed yield and seed quality characteristics determined. Total in-season rainfall from May through August was 157.5 mm (6.2”) and total in-season irrigation applied was 101.6 mm (4.0”).

Results

Seed yield and seed quality parameters measured are shown in Table 3 and agronomic observations are shown in Table 4.

Seed treatment had no influence on seed yield in 2020 (Table 3). This result is not surprising given the early season environmental conditions of 2020. Over-winter snow accumulation was sparse and seed bed moisture conditions at planting was very dry. Fortunately, irrigation was available and applied shortly after seeding so plant stand establishment was not impacted. However, the dry conditions were not conducive for seedling diseases, particularly root diseases, and there was no benefit obtained for seed treatment. Varietal yield differences did occur, with AAC Viewfield having higher grain yield than either of the AAC Brandon comparisons. There was also no statistical difference between certified versus farm-saved seed. No statistical interactions for grain yield were obtained between any of the three factors evaluated: seed treatment, variety pairing, or seed type. Results indicate that for the 2020 growing season, farm-saved seed did not experience a yield drag in comparison to certified seed. Seed treatment and seed type did not influence grain protein content. AAC Viewfield was significantly lower in grain protein than the AAC Brandon variety pairings. This is not unexpected given the statistically higher yield obtained with AAC Viewfield and reflects a classic yield-protein dilution effect. In general, neither seed treatment, variety, nor seed type had any significant impact on any remaining seed quality parameters outlined in Table 3. The exception was within varieties where AAC Viewfield had significantly lower seed weight compared to AAC Brandon paired varieties.

Plant growth and development observations are shown in Table 4. Seed treatment did not influence any observed or evaluated measurements for plant growth. In general, varietal differences were not observed and, when occurring, differences were not of agronomic concern. Certified seed produced taller plants, but these exhibited less lodging compared to farm saved seed. Lodging differences within the entire trial were minimal and any observed measurements were not of a nature to impede nor impose harvest management difficulties.

This is the second year of a multi-site, multi-year trial. Results from ICDC will be combined with those of other participating sites for an interim report of results for 2020. This trial will be repeated in 2021.

Acknowledgements

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- Mr. Lance Redden, Macrorie SK
- Mr. Damian Lee, Outlook SK
- Mr. John Harrington, Glenside SK

Table 3. Influence of treatments on yield and seed quality parameters.

Factor	**Yield** (kg/ha)	**Yield** (bu/ac)	**Protein** (%)	**Test Weight** (kg/hl)	**Seed Weight** (g/1000)
Seed Treatment					
Untreated	6,052	90.0	12.7	79.2	37.8
Treated	6,108	90.8	12.7	79.3	36.8
LSD (0.05)	NS	NS	NS	NS	0.6
CV (%)	4.3	4.3	3.5	2.0	2.9
Variety Pairing					
AAC Brandon (A)	5,933	88.2	12.8	79.1	37.9
AAC Brandon (B)	5,934	88.2	12.9	79.0	37.6
AAC Viewfield (C)	6,373	94.8	12.3	79.6	36.3
LSD (0.05)	188	2.8	0.3	NS	0.8
Seed Type					
Certified	6,094	90.6	12.6	79.0	37.4
Farm-Saved Seed	6,067	90.2	12.7	79.5	37.1
LSD (0.05)	NS	NS	NS	NS	NS
Seed Treatment x Variety Pairing Interaction					
LSD (0.05)	NS	NS	NS	NS	NS
Seed Treatment x Seed Type Interaction					
LSD (0.05)	NS	NS	NS	NS	NS
Variety Pairing x Seed Type Interaction					
LSD (0.05)	NS	NS	NS	NS	NS
Seed Treatment x Variety Pairing x Seed Type Interaction					
LSD (0.05)	NS	NS	NS	NS	NS

NS = not significant

Table 4. Influence of treatments on agronomic observations.

Treatment	Plant Vigor Scale (1-10)	Heading (days)	Maturity (days)	Plant Height (cm)	Lodging (Belgian Scale)
Seed Treatment					
Untreated	9.6	51	91	86	0.3
Treated	9.8	51	91	87	0.3
LSD (0.05)	NS	NS	NS	NS	NS
CV (%)	5.1	1.1	1.6	2.3	72
Variety Pairing					
AAC Brandon (A)	9.6	51	91	86	0.3
AAC Brandon (B)	9.9	51	91	89	0.4
AAC Viewfield (C)	9.8	51	90	85	0.2
LSD (0.05)	NS	NS	1.0	1.4	NS
Seed Type					
Certified	9.8	51	91	88	0.2
Farm-Saved Seed	9.7	51	91	85	0.4
LSD (0.05)	NS	NS	NS	1.1	0.1
Seed Treatment x Variety Pairing Interaction					
LSD (0.05)	NS	NS	NS	NS	NS
Seed Treatment x Seed Type Interaction					
LSD (0.05)	NS	NS	NS	NS	NS
Variety Pairing x Seed Type Interaction					
LSD (0.05)	NS	NS	NS	NS	NS
Seed Treatment x Variety Pairing x Seed Type Interaction					
LSD (0.05)	NS	NS	NS	NS	NS

NS = not significant

Demonstrating 4R Nitrogen Management Principals for Spring Wheat

Funding

Funded by the Agricultural Demonstration of Practices and Technologies Fund (ADOPT) & Fertilizer Canada

Organizations

- Irrigation Crop Diversification Corporation (ICDC), Outlook

Project Lead

- ICDC Leads: Erin Karppinen & Garry Hnatowich

Objectives

Developing Best Management Practices (BMPs) for fertilizer applications has long been focused on the 4R principles which refer to using the: 1) right source, 2) right rate, 3) right time, and 4) right placement. These factors are not necessarily independent of each other. For example, depending on the source, application times or placement options that would normally be considered high risk can become viable. The objective of this trial is to demonstrate the feasibility of various nitrogen (N) management strategies and overall N rate response using spring wheat as a test crop. Nitrogen rates included in the demonstration range from 0X to 1.75X of a conservative soil test recommendation. The management strategies vary regarding source (untreated urea and enhanced efficiency fertilizer (EEF) products: ESN®, Agrotain®, SuperU®), timing (fall vs. spring), and placement (surface broadcast vs. side-band). The demonstration encompasses all four considerations (source, rate, time, and placement) for 4R nutrient management.

Nitrogen is commonly the most limiting nutrient in annual crop production and is often one of the most expensive crop nutrients, particularly for crops with large N requirements like high protein spring wheat. Most inorganic N fertilizers contain ammonia-N (i.e., anhydrous ammonia, urea), but some (i.e., urea ammonium-nitrate) also contain NO_3^--N – both forms are readily available for crop uptake but are also subject to unique and important environmental losses. Urea-based fertilizers initially convert to NH_3 which, in addition to potentially being harmful to seedlings, can be readily lost via volatilization before converting to NH_4 if on or near the soil surface. In contrast, under saturated conditions, NO_3^--N can be leached beneath the rooting zone or lost through denitrification as soil microbes seek alternate forms of oxygen and convert it back to N_2 or N_2O. Such losses can not only result in substantial economic losses to producers but also lead to potential environmental harm such as ground/surface water contamination and climate change (i.e., N fertilizers are energy intensive to manufacture and N_2O is a powerful greenhouse gas).

Since the advent of no-till and innovations in direct seeding equipment, side or mid-row band applications and single pass seeding/fertilization quickly became the standard and most recommended BMP for nitrogen application. Side- or mid-row banding is effective with the major forms of N including anhydrous ammonia (82-0-0), urea (46-0-0), and urea ammonium-nitrate (28-0-0) and the combination of concentrating fertilizer safely away from the seed row and placing it beneath the soil surface dramatically reduced the potential for environmental losses while maintaining seed safety. Fall applications have always been popular, at least on a regional basis, in that fertilizer prices are usually lower and applying N in a separate pass can reduce logistic pressure during seeding when labour and time are limited. While fall applied anhydrous ammonia is always banded beneath the soil surface, granular products are more commonly surface broadcast as this tends to be much faster and less expensive than in-soil applications. With narrow seeding windows, large farm sizes, and higher fertilizer rates to consider, many growers are reverting to or considering two pass seeding/fertilization strategies. Despite certain inefficiencies, two-pass seeding/fertilization systems are a means of spreading out the workload and managing logistic challenges associated with handling large product volumes at seeding time. While the timing and/or placement associated with two-pass systems are usually not ideal, EEFs such as polymer coats (ESN®), volatilization inhibitors (Agrotain®), and volatilization/nitrification inhibitors (SuperU®) can reduce the potential risks associated with applying N well ahead of peak crop uptake (i.e., fall applications) or sub-optimal placement methods (i.e., surface broadcast). Enhanced efficiency N products are more expensive than their traditional counterparts; however, this higher cost may be justified by the potential improvements in efficacy and logistics advantages of alternative fertilization practices. Even with banding there can be merits to EEF products as crops may benefit from the delayed N availability under certain conditions and, when placed shallow into dry soils, volatilization losses can still occur.

This project is relevant to producers because, for many, there has been a movement back to two-pass seeding fertilization systems to increase efficiency at seeding. While we do not necessarily want to specifically encourage growers to revert to a two-pass seeding/fertilization system, it is vital for growers to have a certain amount of flexibility with respect to how they manage N on their farms. By demonstrating different N fertilization strategies according to the 4R principles and providing data on their efficacy relative to benchmark practices, we can help farmers make better informed decisions while taking into consideration both the advantages and disadvantages of some of their options. Spring wheat is an ideal candidate for this project since it is a rotationally and economically important field crop throughout all of Saskatchewan and sensitive to N management with regard to both grain yield and protein.

Research Plan

A field demonstration with spring wheat was established in the fall of 2019 on ICDC land rented from the town of Outlook and adjacent to the federal CSIDC Research Station (Field 51). A composite soil sample was collected from the study area and submitted to AgVise Laboratories for analysis (Table A3). Total residual soil NO_3^-- N in the 0 to 60 cm profile was 8 kg N/ha and residual soil P was relatively low at 2 ppm (4.5 kg P/ha). Plots were direct seeded with AAC Brandon (CWRS spring wheat) into canola stubble on May 13, 2020. Seed was planted at 300 viable seeds/m^2, after adjusting for % germination and seed size.

The trial was established in a randomized complete block design and each treatment was replicated 4 times. The demonstration consisted of two separate trials but was managed as a single entity for both efficiency and to aid in the interpretation of results in the N source/timing/ placement component (Figure 1).

401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418
301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318
119	120	121	122	123	124	125	126	127	128	129	212	213	214	215	216	217	218
101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118

Random Trial #1 Treatments (side-banded untreated urea rates)	Trial #1 & 2 Shared Treatment (1x side-banded untreated urea)	Random Trial # 2 Treatments (N timing/placement/form options)

Figure 1. Generalized plot layout for ADOPT-Fertilizer Canada 4R Nitrogen Management Demonstration.

In the first trial that evaluated N rates, urea was side-banded at seeding at 7 rates: 0X, 0.5X, 0.75X, 1X, 1.25X, 1.5X, and 1.75X of the soil test adjusted rate of 150 kg N/ha (residual NO_3^--N + fertilizer N). The second trial focused on N management options and consisted of a factorial combination of three timing/placement options (fall broadcast, spring side-band, and spring surface broadcast) and four N sources (untreated urea, ESN®, Agrotain® treated urea, and SuperU®). One treatment (1X side-banded untreated urea) was shared between the two trials. The treatment lists for both trials are provided in Table 1. Fall broadcast applications occurred in October of 2019, spring broadcast applications occurred on May 4, 2020, and spring side-band applications occurred on May 13, 2020. The total N rate used was equivalent to the 1X rate (150 kg N/ha) in the first component (adjusted for residual NO_3-N and N provided by monoammonium phosphate (MAP; 11-52-0)). MAP was side-banded (15 kg P_2O_5/ha seed) and seed-placed (30 kg P_2O_5/ha), for a total of 45 kg P_2O_5/ha applied to each plot.

Table 1. 4R nitrogen management principles in spring wheat treatment list, 2020.

Trial #1: Right Rate*	Trial #2: Right Time, Right Place, Right Form
1) 0X Urea (no added N fertilizer) **	1) Fall Broadcast – untreated Urea
2) 0.5X Urea (75 kg total N/ha)	2) Fall Broadcast – ESN
3) 0.75X Urea (112.5 kg total N/ha)	3) Fall Broadcast – Agrotain
4) 1.0X Urea (150 kg total N/ha)	4) Fall Broadcast – SuperU
5) 1.25X Urea (187.5 kg total N/ha)	5) Side Banded – untreated Urea
6) 1.5X Urea (225 kg total N/ha)	6) Side Banded – ESN
7) 1.75X Urea (262.5 kg total N/ha)	7) Side Banded – Agrotain
*1.0X rate (soil + fertilizer = 150 kg N/ha) in all trts	8) Side Banded – SuperU
**All treatments received 6 kg N/ha from 11-52-0	9) Spring Broadcast – untreated Urea
	10) Spring Broadcast – ESN
	11) Spring Broadcast – Agrotain
	12) Spring Broadcast – SuperU

Weed control consisted of a post-emergence tank mix application of Simplicity™ (pyroxsulam; 28 g/ac) and Buctril® M (bromoxynil +MCPA ester; 0.4 L/ac). Yields were estimated by direct cutting the entire plot with a small plot combine when the plants were dry enough to thresh and seed moisture content was < 20%. The trial was harvested on September 4, 2020. Plot samples were cleaned, and yields were adjusted to 14.5% moisture. Total in-season rainfall was 139.7 mm (5.5”) and total in-season irrigation was 190.5 mm (7.5”).

Results

Fertilizer N Rates

Yields statistically increased with increasing N fertilizer rate up to the 0.75X rate of 113 kg N/ha (Figure 2, Table 2, ANOVA, $P \leq 0.05$). Fertilizer additions greater than the 0.75X rate did not increase yield and yield began to decline at the 1.75X rate, likely due to ammonia and salt toxicity near the seed. Soil testing procedures revealed very low levels of available soil N at this site and the recommended rate of N fertilizer was 159 kg N/ha (142 lb N/ac). We moved this target recommendation downwards to 150 kg N/ha to ensure the 1.75X rate was within equipment metering capability. In this case, the 1X rate provided slight over fertilization in terms of yield.

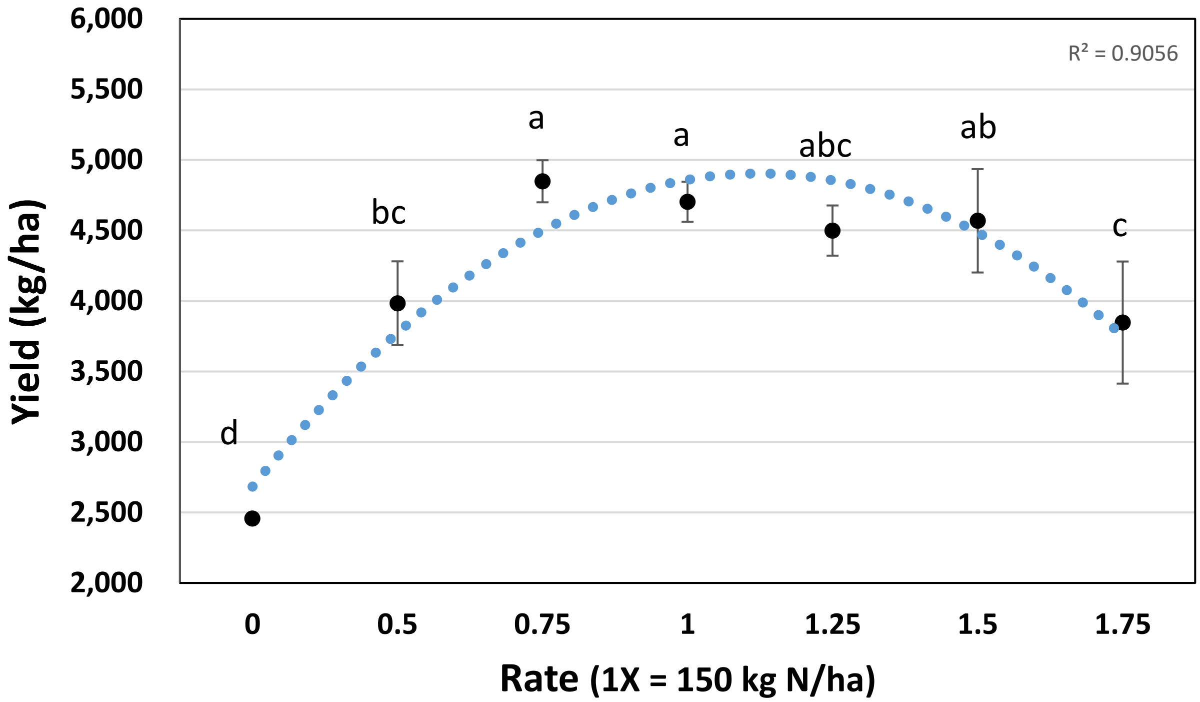

Figure 2. Wheat grain yield response to increasing rates of N fertilizer. Different letters indicate significantly different yield (kg/ha) at each N fertilizer rate (ANOVA, $P \leq 0.05$).

There was no difference in protein content between rates of 0X and 0.5X, then protein content increased with increasing N fertilizer rate up to the 1X rate (Figure 3, Table 2, ANOVA, $P \leq 0.05$). There were no statistical differences between protein content at the 1X rate and any higher rates. Protein contents achieved a desired marketable level of 13.5% or higher at the 0.75X rate. Nitrogen use efficiency decreases with increasing fertilizer rate (Gauer et al., 1992), which is highlighted by increases in protein content from 0.5X to 1X and the lack of statistical differences in protein contents from 1X to 1.75X.

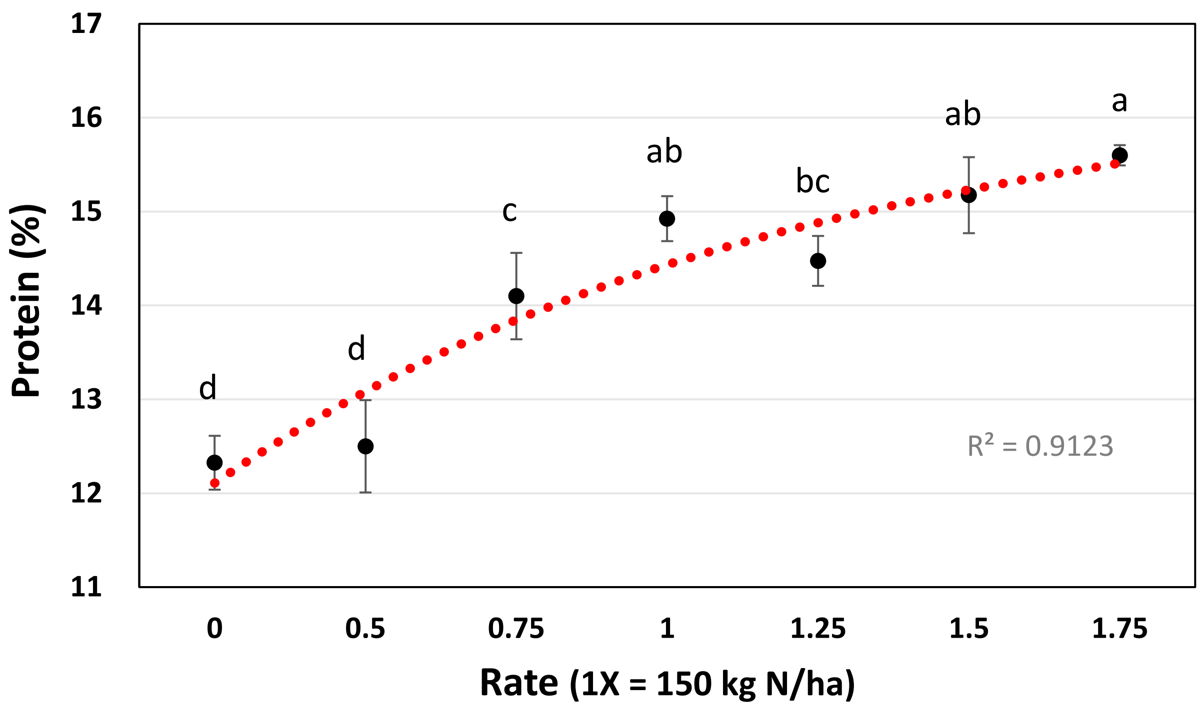

Figure 3. Protein response to increasing rates of N fertilizer. Different letters indicate significantly different protein content (%) at each N fertilizer rate (ANOVA, $P \leq 0.05$).

Seed weight was not influenced by N rate additions and test weights decreased at 1.25X and remained unchanged with higher rates of N applied (Table 2, ANOVA, $P \leq 0.05$). Generally, days to heading and maturity were delayed as N fertilizer rates increased. However, when compared to the unfertilized control, the optimal rate of 0.75X did not delay heading or maturity compared to the unfertilized control (Table 2, ANOVA, $P \leq 0.05$). Significant difference in maturity occurred as N fertilizer increased at the 1X rate and 1.75X rate. Plant height was increased with the first increment of N fertilizer applied, with no further height gains with additional N rates (Table 2, ANOVA, $P \leq 0.05$). Lodging was not observed at any N fertilizer rate (data not shown).

Table 2. Influence of N fertilizer rate on yield, protein content, test weight, seed weight, heading, maturity, and height of spring wheat. Different letters indicate significant differences between N fertilizer rate (ANOVA, $P \leq 0.05$).

N Rate	**Yield** (kg/ha)	**Yield** (bu/ac)	**Protein** (%)	**Test Weight** (kg/hl)	**Seed Weight** (g/1000)	**Heading** (days)	**Maturity** (days)	**Height** (cm)
0X	2,458 *d*	36.5 *d*	12.3 *d*	80.8 *a*	38.3 *a*	56.5 *c*	95.5 *c*	69.6 *b*
0.5X	3,983 *bc*	59.2 *bc*	12.5 *d*	80.8 *a*	37.6 *a*	56.5 *c*	95.5 *c*	83.1 *a*
0.75X	4,848 *a*	72.1 *a*	14.1 *c*	80.3 *ab*	39.0 *a*	57.5 *bc*	97.8 *c*	85.8 *a*
1.0X*	4,703 *a*	69.9 *a*	14.5 *ab*	78.6 *abc*	37.5 *a*	58.0 *ab*	101.8 *b*	86.8 *a*
1.25X	4,499 *abc*	66.9 *abc*	14.9 *bc*	76.5 *cd*	37.9 *a*	58.0 *ab*	103.5 *b*	87.1 *a*
1.5X	4,568 *ab*	67.9 *ab*	15.2 *ab*	77.6 *bc*	38.7 *a*	58.0 *ab*	104.5 *b*	87.1 *a*
1.75X	3,847 *c*	57.2 *c*	15.6 *a*	74.0 *d*	37.6 *a*	59.0 *a*	108.8 *a*	85.4 *a*
LSD (0.05)	703	10.5	0.8	3.1	NS	1.1	4.0	4.2
CV (%)	11.46	11.47	3.79	2.65	4.0	1.24	2.65	3.35

* = 150 kg N/ha total all sources (fertilizer N from 46-0-0 + fertilizer N from 11-52-0 + soil N)
NS = not significant

Fertilizer N Application Timing, Placement, and Source

Fertilizer N application timing, placement, and source were all significant factors in driving yield differences between treatments (Table 3, ANOVA, $P \leq 0.05$), but the interaction between these factors was not significant. Regardless of application time and placement, ESN® was higher yielding than conventional urea and SuperU®, but there were no yield differences between ESN® and Agrotain® (Figure 4, ANOVA, $P \leq 0.05$). Within this study, the EEF products Agrotain® and SuperU® offered no yield benefit over conventional urea fertilizer. We suspect the hard polymer coating associated with ESN® allowed a slow release of N that reduced N losses or delayed N release to better matched crop demand and ultimately, benefited yield. Agrotain® and SuperU® contain inhibitors that claim to reduce volatilization and/or nitrification but these products did not provide a benefit over conventional urea in fall or spring applications.

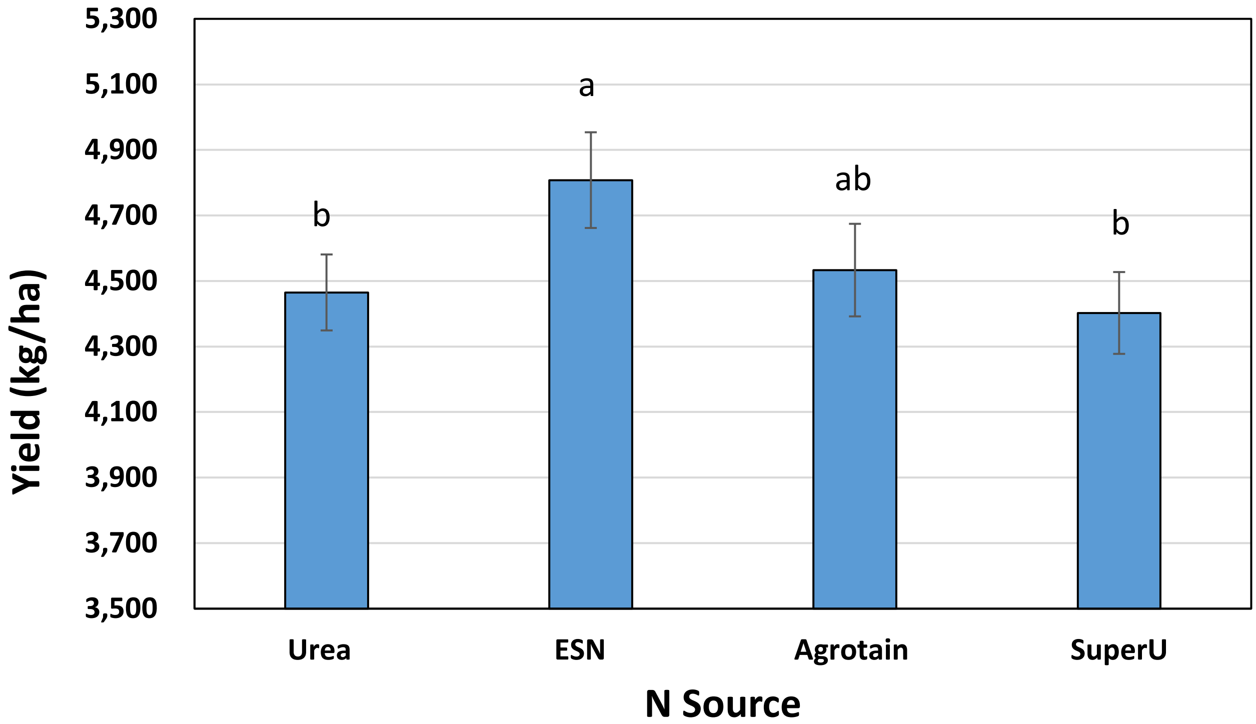

Figure 4. Wheat grain yield response to N fertilizer source. Different letters indicate significant differences between N fertilizer source (ANOVA, $P \leq 0.05$).

On average, the spring fertilizer applications statistically elevated yield by an additional 536 kg/ha (8 bu/ac) when compared to the fall broadcast fertilizer application (Figure 5, ANOVA, $P \leq 0.05$). However, spring broadcast and spring side-band applications were not statistically different. Mean yields were 4,195 kg/ha (62.4 bu/ac) for fall broadcast applications, 4,687 kg/ha (69.7 bu/ac) for spring broadcast applications, and 4,774 kg/ha (71.0 bu/ac) for spring side band applications. It is apparent that over-winter losses may have occurred with the fall broadcast applications and this observation was expected. However, the relatively small yield differences between spring broadcast and side-band applications were surprising. It is possible that environmental conditions in the spring were favorable enough that the ammonia volatilization typically associated with unincorporated broadcast applications was not a factor.

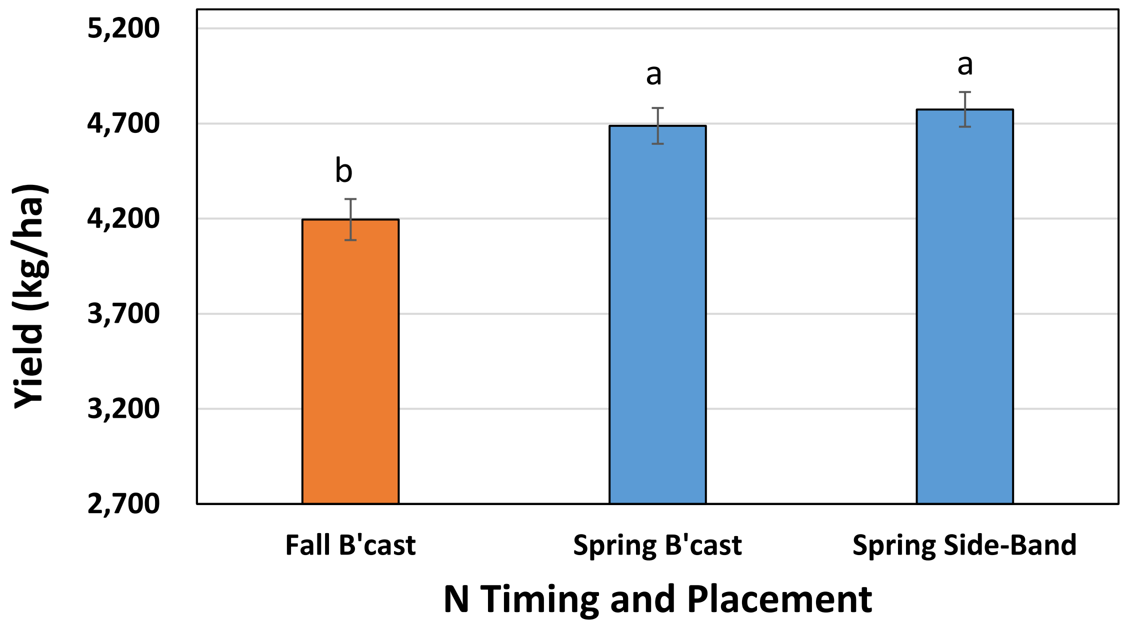

Figure 5. Wheat grain yield response to N fertilizer application timing and placement. Different letters indicate significant differences between N fertilizer timing and placement (ANOVA, $P \leq 0.05$).

Differences in protein content were driven by both N source and N timing and placement (Table 3, ANOVA, $P \leq 0.05$), but the interaction between the two factors was not significant. Protein content achieved a desired marketable level of ≥ 13.5% with ESN® but protein content was less than ideal for conventional urea (13.2%) even though they were not statistically different. Protein contents were lower with Agrotain® (12.9%) and SuperU® (12.8%). Protein content was highest with spring side-banded applications, followed by spring broadcast applications, and fall broadcast applications (Table 3, ANOVA, $P \leq 0.05$). Generally, yield and protein content demonstrated a positive relationship.

Table 3. Influence of N fertilizer source, time of application, and placement on spring wheat yield, protein, test weight, seed weight, heading, maturity, and height. Different letters indicate significant differences between N fertilizer source, time, and/or placement (ANOVA, *P* ≤ 0.05).

N Source*, Time, & Placement	**Yield** (kg/ha)	**Yield** (bu/ac)	**Protein** (%)	**Test Weight** (kg/hl)	**Seed Weight** (g/1000)	**Heading** (days)	**Maturity** (days)	**Height** (cm)
N Source								
Urea	4,465 *b*	66.4 *b*	13.2 *ab*	79.8 *a*	37.6 *a*	57.2 *a*	98.3 *a*	85.0 *a*
ESN	4,799 *a*	71.3 *a*	13.5 *a*	79.8 *a*	38.6 *a*	57.3 *a*	98.3 *a*	86.0 *a*
Agrotain	4,517 *ab*	67.2 *ab*	12.9 *b*	80.8 *a*	38.4 *a*	57.0 *a*	97.1 *a*	85.2 *a*
SuperU	4,407 *b*	65.5 *b*	12.8 *b*	80.2 *a*	38.1 *a*	56.9 *a*	97.3 *a*	85.2 *a*
LSD (0.05)	302	4.5	0.5	NS	NS	NS	NS	NS
CV (%)	7.87	7.87	4.04	2.65	4.00	0.51	1.69	2.72
N Time of Application & Placement								
Fall Broadcast	4,195 *b*	62.4 *b*	12.2 *c*	80.7 *a*	38.1 *a*	56.6 *b*	96.4 *b*	84.2 *b*
Spring Broadcast	4,647 *a*	69.1 *a*	13.1 *b*	80.2 *ab*	38.1 *a*	57.0 *b*	97.0 *b*	84.7 *b*
Spring Side-Band	4,833 *a*	71.8 *a*	14.2 *a*	79.3 *b*	38.3 *a*	57.7 *a*	99.8 *a*	87.5 *a*
LSD (0.05)	264	3.9	0.39	0.9	NS	0.7	0.7	1.7
N Source x N Time of Application & Placement								
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

N Rate* = 150 kg N/ha total all sources (fertilizer N from 46-0-0 + fertilizer N from 11-52-0 + soil N)
NS = not significant

The timing and placement of N fertilizer drove differences in test weight, heading, maturity, and height (Table 3, ANOVA, P ≤ 0.05). Test weight was highest in fall broadcast applications, and lowest in sspring side-band applications. Heading and maturity were both earlier in fall/spring broadcast applications and later in spring-side band applications. Differences in maturity likely would not cause concerns at harvest as there was only 4 days separation between the earliest and latest maturing applications. The wheat crop was significantly taller in the spring side-banded applications when compared to the fall or spring broadcast applications, but there was no lodging observed.

Conclusions

In the N rate study, the 0.75X rate of 113 kg N/ha was optimal with regard to yield and protein content. Any additional fertilizer did not significantly increase either paramter. In the N ource, time, and placement study, yield and protein content demonstrated a positive relationship. At the 1X rate, ESN® provided a yield advantage of ~8% over conventional urea which is likely due to its mechanism of providing slow-release N. Finally, spring fertilizer applications yielded higher than fall fertilizer applications, which was expected.

Acknowledgements

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Revisiting Nitrogen Fertilizer Recommendations for SK: Are We Measuring the Right Soil Nitrogen Pool?

Funding

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Organizations

- University of Saskatchewan (U of S) Department of Soil Science, Saskatoon
- Irrigation Crop Diversification Corporation (ICDC), Outlook
- Indian Head Applied Research Foundation (IHARF), Indian Head
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- Western Applied Research Corporation (WARC), Scott
- North East Research Foundation (NARF), Melfort
- Wheatland Conservation Association (WCA), Swift Current
- Conservation Learning Center (CLC), Prince Albert

Project Lead

- U of S Leads: Dr.'s Richard Farrell & Fran Walley
- ICDC Leads: Erin Karppinen & Garry Hnatowich

Objectives

Nitrogen (N) fertilizer represents one of the highest single input costs for wheat and canola growers, yet there is a growing concern that the current soil N tests and fertilizer N recommendations do not provide, or are no longer accurate, in assisting in making fertilizer rate decisions. This project is a large, multi-objective study where the University will evaluate soil testing procedures and soil N fractions. Participating Agri-ARM locations will evaluate rate response to N fertilizer in both wheat and canola.

Research Plan

In 2020, ICDC only evaluated wheat due to poor emergence in the canola trial.

On May 25, 2020, the wheat trial was established on canola stubble on ICDC land rented from the town of Outlook and adjacent to the federal CSIDC Research Station (Field 51). The trial was established in a randomized complete block design and each treatment was replicated 4 times. Plot size was 8 m in length and 1.5 m wide. A composite soil sample was collected from the trial are; a subsample was provided to the University of Saskatchewan and the remainder was submitted to Farmers Edge for available soil nutrient analyses (Table 1).

Table 1. Soil Testing Report, Farmers Edge Labs, Sampled Spring 2020.

Soil Parameter	Depth (cm)	Value
NO_3^--N (lb/ac)	0 – 15	11
	15 – 30	7
	30 – 60	12
SO_4^{2-}-S (lb/ac)	0 – 15	66
	15 – 30	280
P (lb/ac)	0 – 15	8
K (lb/ac)	0 – 15	640
pH	0 – 15	7.8
	15 – 30	8.1
EC (ds/m)	0 – 15	0.61
	15 – 30	1.18
Organic Matter (%)		2.5
CEC (meq)		19.8

Nitrogen fertilizer was applied at rates of 0X, 0.5X, 1.0X, 1.5X and 2.0X to determine N rate response. Fertilizer rates were established by the ability to accurately meter the 2.0X rate of N fertilizer through fertilizer boxes. Once determined, the 1.0X rate was established as 130 kg N/ha. All N fertilizer was side-banded as urea (46-0-0) and all treatments received 30 kg P_2O_5/ha seed placed as monoammonium phosphate (MAP; 11-52-0). Plots were direct seeded into canola stubble with AAC Brandon CWRS spring wheat. The seeding rate was 300 viable seeds/m^2, after adjusting for % germination and seed size.

Weed control consisted of a post-emergent tank mix application of Simplicity™ (pyroxsulam; 0.28 g/ac) and Infinity® (bromoxynil + pyrasulfotole + fluroxypyr; 0.33 L/ac). Biomass samples were collected by cutting a 1 m x 0.25 m area from each plot and weighing the material before and after drying. Biomass samples were collected on July 31, 2020 (mid-season) and August 24, 2020 (late-season). Yields were estimated by direct cutting the entire plot with a small plot combine when the plants were dry enough to thresh and seed moisture content was < 20%. The trial was harvested on September 17, 2020. Plot samples were cleaned, and yields were adjusted to 14.5% moisture. Total in-season rainfall was 139.7 mm (5.5”) and total in-season irrigation was 190.5 mm (7.5”).

Results

Biomass

Mid- and late-season biomass significantly increased with increasing N rates up to 1.0X N (Figure 1, ANOVA, $P \leq 0.05$). Beyond the 1.0X N application rate, yield either increased or decreased but differences were not significant. For example, mid-season biomass was 855 g/m^2 at 1.0X N, 693 g/m^2 at 1.5X N, and 907 g/m^2 at 2.0X N.

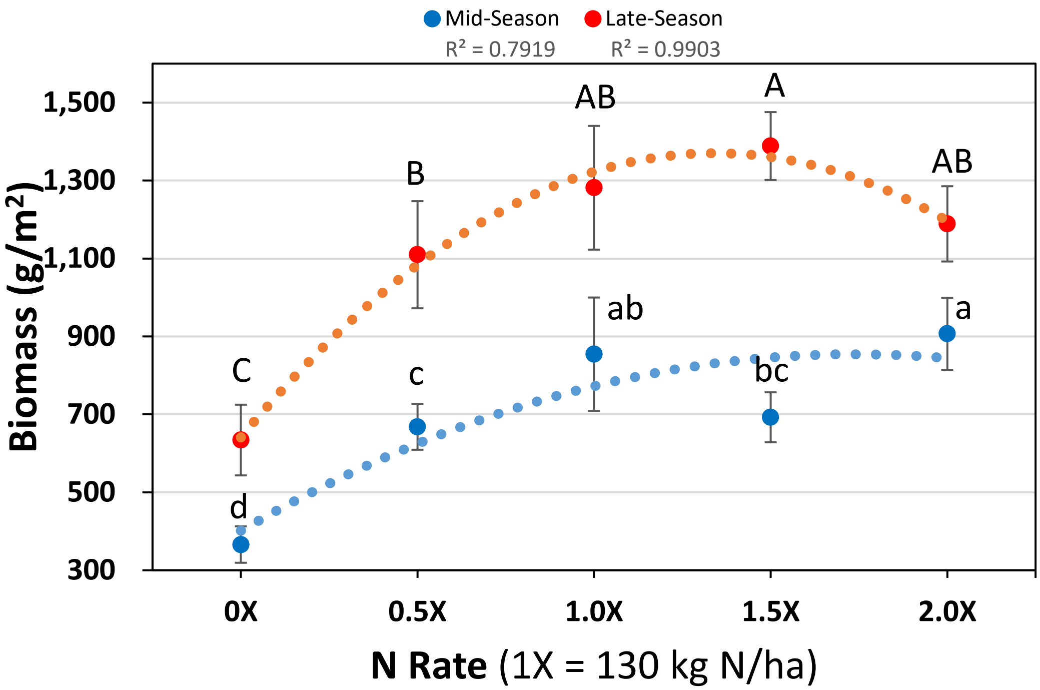

Figure 1. Influence of N rate on mid- and late-season biomass. Different lowercase letters indicated significant differences in mid-season biomass and different uppercase letter indicate significant differences in late-season biomass (ANOVA, $P \leq 0.05$).

Yield

The effect of N fertilizer rates on the yield, seed quality, and plant growth characteristics of wheat are shown in Table 2. Wheat grain yield increased with each increase of applied N fertilizer, and yield increases were statistically significant up to the 1.0X N application rate (Figure 2, ANOVA, $P \leq 0.05$). Beyond the 1.0X N rate, yield increased at 1.5X N but decreased at 2.0X N, although neither rate was statistically different from the 1.0X N rate. As illustrated in Figure 1, yield was strongly correlated to N fertilizer rate.

Quality

Grain protein increased as N rates increased beyond the 0.5X N rate. Test weight was highest at the 1.0X N rate, but fertilizer rate did not influence seed weight. Both days to heading and maturity increased with higher rates of N fertilizer, as did plant height. Lodging occurred at rates of 1.0X N and higher.

Table 2. Influence of N rate on yield, seed quality, and other agronomic parameters. Different letters indicated significant differences between N fertilizer rate (ANOVA, $P \leq 0.05$).

N Rate	**Yield** (kg/ha)	**Yield** (bu/ac)	**Protein** (%)	**Test Weight** (kg/hl)	**Seed Weight** (g/1000)	**Heading** (days)	**Maturity** (days)	**Height** (cm)	**Lodging** (1=erect; 9=flat)
0X N	2,054 *c*	30.5 *c*	12.4 *c*	81.5 *ab*	35.8 *a*	51.0 *c*	85.5 *d*	82.1 *b*	1.0 *b*
0.5X N	3,957 *b*	58.8 *b*	12.4 *c*	81.7 *ab*	37.9 *a*	53.3 *b*	87.3 *c*	100.8 *a*	1.0 *b*
1.0X N	4,833 *a*	71.8 *a*	14.1 *b*	82.2 *a*	37.8 *a*	54.3 *a*	95.3 *b*	106.4 *a*	3.5 *a*
1.5X N	4,988 *a*	74.1 *a*	14.5 *b*	81.4 *b*	36.9 *a*	54.0 *a*	95.3 *b*	104.3 *a*	3.3 *a*
2.0X N	4,788 *a*	71.2 *a*	15.5 *a*	81.1 *b*	37.1 *a*	54.5 *a*	98.8 *a*	103.3 *a*	2.8 *a*
LSD (0.05)	285	4.3	0.7	0.6	NS	0.6	1.0	6.9	0.4
CV (%)	4.49	4.5	3.12	0.51	3.32	0.78	0.68	4.49	16

1.0X N = 130 kg N/ha; NS = not significant

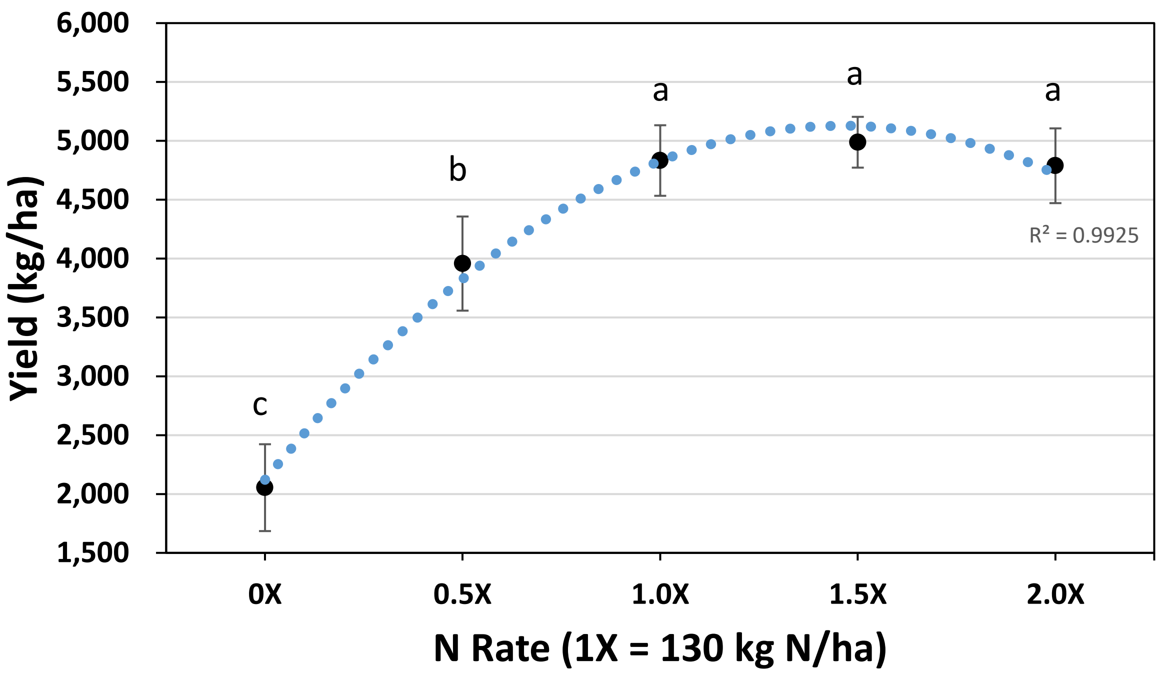

Figure 2. Wheat grain yield response to increasing rates of N fertilizer. Different letters indicate significant differences between treatments (ANOVA, $P \leq 0.05$).

Conclusions

Beyond the 1.0X N rate of 130 kg N/ha, there were no additional benefits to yield or biomass with increasing fertilizer additions. Protein content increased by 1.5% from 1.0X N to 2.0X N, but that increase likely wouldn't justify the additional fertilizer costs.

Acknowledgements

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Demonstrating Spring Wheat Phosphorous Fertilizer Response on a Severely Phosphorous Deficient Irrigated Field

Funding

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Organizations

- Irrigation Crop Diversification Corporation (ICDC), Outlook

Project Lead

- ICDC Leads: Erin Karppinen & Garry Hnatowich

Objectives

The objective of this project was to evaluate the yield response of spring wheat to varying rates, time, and placement of phosphorus (P) fertilizer on a deficient P soil under irrigated production. The importance of appropriate P fertilization in Saskatchewan has been demonstrated amply since the 1950s. Yet, many Saskatchewan soils continue to decline in soil test available P, with P exported in grain exceeding annual P inputs from fertilizer additions. This trial demonstrates the influence of P fertilization and its importance on spring wheat yield on land where years of under-fertilization has resulted in very low soil test available P.

Saskatchewan soils are among the lowest in North America with respect to available P levels (Fixen et al., 2010). Reasoning for this include uncontrollable factors such as soil parent material. However, present agricultural practices have contributed to low soil P values. These factors include cultural factors such as unwillingness to invest fertilizer dollars on rented land and risk aversion (short or long term) in terms of input investment, markets, or to yield limiting growing season precipitation. In 2017, ICDC acquired a rental agreement with the Town of Outlook for a 14-acre parcel of land immediately adjacent to the AAFC-Outlook Research Station. Prior to 2017, this land was annually cropped under dryland conditions on a rental agreement with local producers. Upon acquiring the land base, soil testing indicated levels of soil test available P of 2 ppm. ICDC bought and installed a linear irrigation system on this field and converted it to irrigation production.

This field offers a unique opportunity to demonstrate the importance of P fertilization to Saskatchewan producers. In accordance with defining Best Management Practices (BMPs), we will evaluate the influence of P application timing, rate, and placement. This trial will also strengthen the Ministry of Agriculture's memorandum of understanding with Fertilizer Canada to demonstrate and develop 4R fertilizer strategies in Saskatchewan.

Research Plan

A field demonstration with spring wheat was established on ICDC land rented from the Town of Outlook and adjacent to the federal CSIDC Research Station (Field 51). The trial was established in a randomized complete block design and each treatment was replicated 4 times. The trial was direct seeded into canola stubble on May 14, 2020. A composite soil sample was collected from the study area and submitted to AgVise Laboratories for analysis. Total soil NO_3^-- N in the 0 to 60 cm profile was 7.8 kg N/ha and residual soil P was relatively low at 2 ppm (4.5 kg P/ha).

Nitrogen fertilizer (urea, 46-0-0) was side-banded in either the spring or fall at a rate of 120 kg N/ha. Phosphorous fertilizer (monoammonium phosphate, 12-51-0) was either side-banded in the fall, side-banded in the spring, or seed-placed in the spring at rates of 20 kg P_2O_5/ha (20P), 40 kg P_2O_5/ha (40P), and 60 kg P_2O_5/ha (60P). Treatments 1 and 5 (spring and fall control treatments) did not receive any P fertilizer additions (0P). Fertilizer treatments are shown in Table 1.

Table 1. Nitrogen and phosphorous fertilizer treatments established in 2019/2020.

Trt	N Rate (kg N/ha)	N Placement	P Rate (kg P_2O_5/ha)	P Placement
1	120	Fall Side-Band	0	-
2	120	Fall Side-Band	20	Fall Side-Band
3	120	Fall Side-Band	40	Fall Side-Band
4	120	Fall Side-Band	60	Fall Side-Band
5	120	Spring Side-Band	0	-
6	120	Spring Side-Band	20	Spring Side-Band
7	120	Spring Side-Band	40	Spring Side-Band
8	120	Spring Side-Band	60	Spring Side-Band
9	120	Spring Side-Band	20	Spring Seed-Placed
10	120	Spring Side-Band	40	Spring Seed-Placed
11	120	Spring Side-Band	60	Spring Seed-Placed

Weed control consisted of a post-emergence tank mix application of Simplicity (pyroxsulam; 28 g/ac) and Buctril M (bromoxynil + MCPA ester; 0.4 L/ac). No foliar fungicides were applied for either leaf disease or fusarium head blight. Yields were estimated by direct cutting the entire plot with a small plot combine when the plants were dry enough to thresh and seed moisture content was < 20%. Harvest plot size was 8 m x 1.5 m. The trial was harvested August 25, 2020. Harvested samples were cleaned, and yields were adjusted to a moisture content of 14.5%. Total in-season rainfall was 139.7 mm (5.5") and total in-season irrigation was 190.5 mm (7.5").

In 2021, the plots will be reseeded to canola without any additional P fertilizer inputs. This will allow ICDC to evaluate the effects of different P rate, time, and placement on the subsequent years crop.

Results & Discussion

<u>Rate Response</u>

Differences in yield, protein content, height, and 1,000 kernel weight were driven by the rate of P fertilizer applied and were not influenced by timing (spring vs. fall) or placement (side-band vs. seed placed) (ANOVA, $P \leq 0.05$). Yield significantly increased with increasing P fertilizer rate (Figure 1). The incremental additions of 20 kg P_2O_5 increased yield by 78%, 16%, and 11%. On a typical fertilizer response curve, (A) yield increases with increasing fertilizer rate (nutrient supply is limiting) until maximum efficiency is reached, (B) yields are unaffected by increasing fertilizer rate (nutrient supply is non-limiting) and finally, (C) yields decrease with increasing fertilizer rate (nutrient supply is in excess) due to nutrient and salt toxicities (Figure 2) (McKenzie et al., 2003). In this experiment, it is possible that the highest application rate of 60P was still in the deficient range and maximum potential yield was not realized (Figure 2). The 60P application rate marginally exceeds the recommended safe rate of 56 kg P_2O_5/ha, or 50 lb P_2O_5/ac, of seed-placed P for cereals (Government of Saskatchewan, 2020b), but under irrigation, the additional moisture can buffer the toxic effects usually associated with high fertilizer rates. This could explain why there was no evidence of fertilizer damage at what is considered an unsafe P rate.

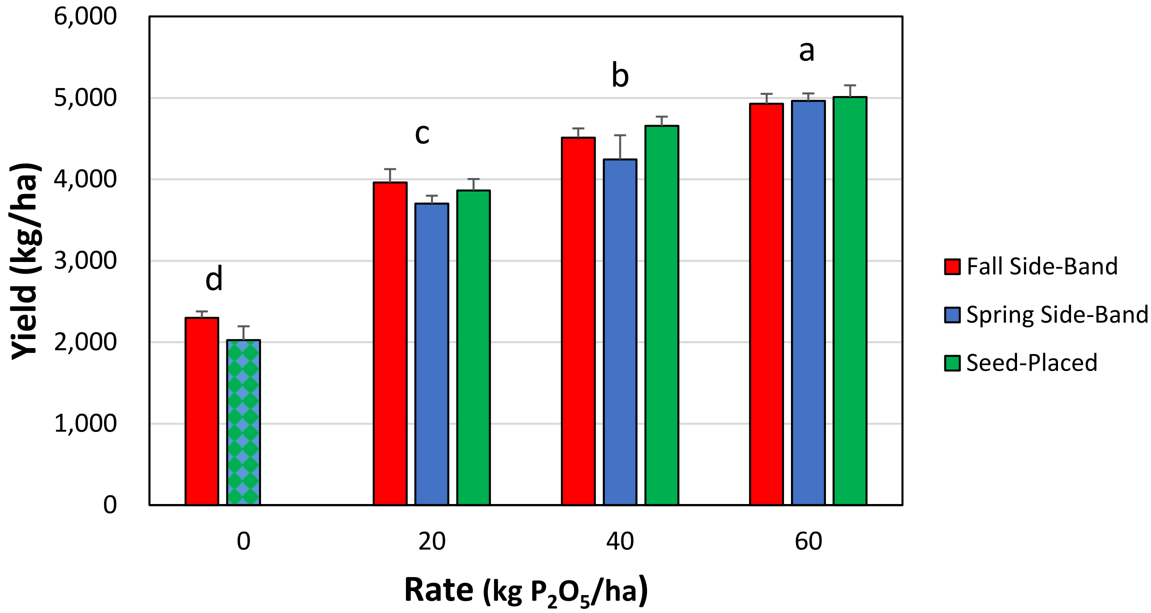

Figure 1. Yield response to increasing P fertilizer rate. Different letters indicate significantly different yield at each P fertilizer rate (ANOVA, $P \leq 0.05$).

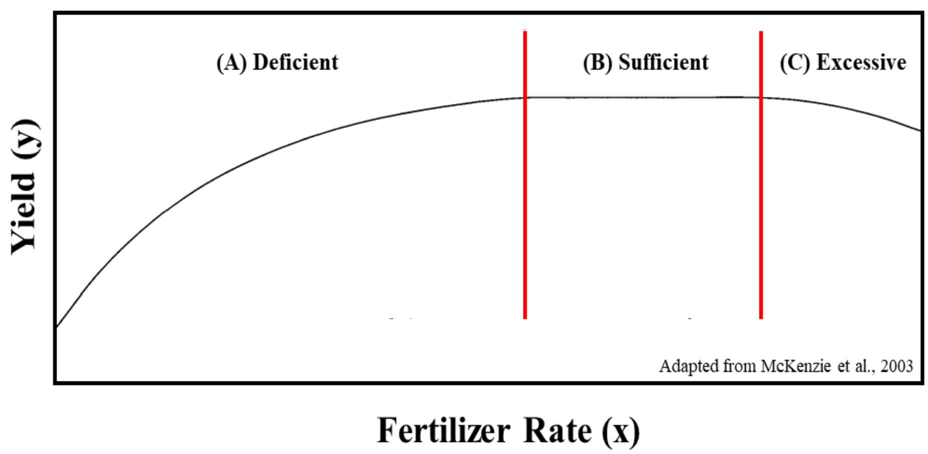

Figure 2. Typical fertilizer response curve (McKenzie et al., 2003).

Grain protein was highest at 0P and 20P and lowest at 60P (Table 2, ANOVA, $P \leq 0.05$). However, in plots receiving 60P, the yield increase was substantial enough that total protein was higher. For example, the protein content of plots receiving 60P was 13.0% but yield was 4,967 kg/ha so total protein was 647 kg/ha, whereas plots receiving 0P had a higher protein content of 13.8% but yield was only 2,293 kg/ha so total protein content was significantly lower at 299 kg/ha. Protein contents achieved a desired marketable level of 13.5% or higher at the 0P, 20, and 40P rates but protein content was < 13.5% at 60P. Generally, grain yield and protein content demonstrated an inverse relationship.

As expected, 1,000 kernel weight was lowest at 0P, but there was no difference between the higher application rates (Table 2, ANOVA, $P \leq 0.05$). Plant height increased significantly at 20P and 60P application rates (Table 2, ANOVA $P \leq 0.05$). Both heading and maturity were delayed at the 0P application rate when compared to the 20, 40, and 60P application rates (Table 3). However, this likely would not cause concerns at harvest as the 0P rate matured only 2 days later than the higher application rates.

Time/Placement Response

Time of application was the most important factor in explaining differences between test weight (Table 2, ANOVA, $P \leq 0.05$). Regardless of application rate or placement, test weights were significantly higher in plots with fall applied fertilizer than in plots with spring applied fertilizer. Grain test weight is often used as an indicator of grain quality and does not necessarily correlate with grain yield. The fall side-banded plots headed earlier than the spring-side banded plots, which headed earlier than the spring seed-placed plots (Table 2, ANOVA, $P \leq 0.05$). Maturity followed a similar trend as the fall applied fertilizer matured earlier than the spring applied fertilized, but there was no difference between the spring side-band and seed-placed fertilizer (Table 2, ANOVA, $P \leq 0.05$). Yield, protein content, 1,000 kernel weight, and height did not significantly differ between different P fertilizer timings and placements.

Table 2. Yield, protein content, total protein, test weight, 1,000 kernel weight (TKW), plant height, heading, and maturity at each application rate and timing/placement. Different letters indicated significant differences between treatments (ANOVA, $P \leq 0.05$).

P Rate/Timing/ Placement	**Yield** (kg/ha)	**Protein** (%)	**Total Protein** (kg/ha)	**Test Weight** (kg/hl)	**TKW** (g/1000)	**Height** (cm)	**Heading** (days)	**Maturity** (days)
Rate (kg/ha)								
0	2,293 *d*	13.8 *a*	299 *c*	77.7 *a*	33.9 *b*	72.2 *c*	56.7 *a*	96.4 *a*
20	3,842 *c*	14.0 *a*	539 *b*	80.3 *a*	37.3 *a*	83.5 *b*	55.5 *b*	94.7 *b*
40	4,471 *b*	13.5 *ab*	600 *a*	80.5 *a*	37.0 *a*	85.3 *ab*	55.3 *b*	94.4 *b*
60	4,967 *a*	13.0 *b*	646 *a*	80.2 *a*	37.8 *a*	87.5 *a*	55.3 *b*	95.1 *b*
LSD (0.05)	435	0.7	48	NS	1.4	3.7	0.8	1.3
CV (%)	13.44	5.91	11.05	3.53	4.46	5.49	1.81	1.62
Timing/Placement								
Fall Side-Band	3,926 *a*	13.4 *a*	530 *a*	81.5 *a*	36.4 *a*	82.3 *a*	54.6 *c*	93.6 *b*
Spring Side-Band	3,734 *a*	13.7 *a*	522 *a*	78.1 *b*	36.1 *a*	81.5 *a*	55.8 *b*	96.4 *a*
Spring Seed-Placed	4,020 *a*	13.6 *a*	511 *a*	79.4 *b*	37.0 *a*	82.6 *a*	56.7 *a*	95.4 *a*
LSD (0.05)	NS	NS	NS	2.0	NS	NS	0.7	1.1
Rate x Timing/Placement								
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS = not significant

Conclusions

In this study, the rate of P fertilizer applied was the most signifcant factor driving differences in most agronomic observations. Time and placement were less important, only resulting in marginal differences in test weight, heading, and maturity. In this study, the 60P application rate generated the highest yield, with no evidence of fertilizer toxicity or detrimental effects to protein or other quality parameters. Based on their specific soil test recommendations, producers should be able to gain crop benefits from applying P fertilizer whether it is side-banded in the fall, side-banded in the spring, or placed with the seed. The greatest benefit occurred from application of the first 20 kg P_2O_5/ha increment, so the benefits of P fertilizer application to soils with medium to high levels of soil P would not be as substantial.

Acknowledgements

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Irrigated and Dryland Faba Bean & Corn Intercrop for Silage

Funding

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Organizations

- Irrigation Crop Diversification Corporation (ICDC), Outlook
- Wheatland Conservation Area (WCA), Swift Current
- Saskatchewan Ministry of Agriculture (SMOA), Outlook

Project Leads

- ICDC Leads: Erin Karppinen & Garry Hnatowich
- WCA Lead: Bryan Nybo
- SMOA Leads: Gary Kruger & Travis Peardon

Objectives

The objective of the project is to show the benefit for corn silage quality by growing an intercrop of corn and faba bean under both irrigated and dryland production. Currently, many producers in the Lake Diefenbaker Irrigation area are growing corn silage as a winter feed source for their beef cattle. While corn produces a large volume of feed, it has some nutritional imbalances that create challenges. Corn is typically high in energy yet low in protein. In order to feed a correct amount of energy, corn silage needs to be diluted with poor quality feeds such as straw. This creates a new challenge of bringing up protein to meet nutritional needs. This project intends to show producers the value of intercropping and developing a crop mixture that will provide the ultimate feed for beef cattle: high in energy and high in protein. It is hoped that yields of the intercrop will be similar to those of corn as a monocrop, but the result will be a more balanced forage with appropriate levels of energy and protein. Faba bean is a long season crop and is expected to mature at a similar date as corn facilitating harvest when both crops are at an ideal stage for silaging.

Research Plan

A corn-faba bean intercrop demonstration was established on June 2, 2020 at the ICDC on-station location (Field 8) in Outlook (irrigated site) and on May 22, 2020 at Wheatland Conservation Area in Swift Current (dryland site). The trial was established in a randomized complete block design that was replicated four times at the Outlook site and three times at the Swift Current site. Plot size was 8 m x 1.5 m. Composite soil samples were collected in the respective trial areas and submitted to AgVise Laboratories for analysis (Table 1).

Table 1. Soil test analysis results at Outlook and Swift Current.

Soil Parameter	Depth (cm)	Outlook	Swift Current
NO_3^--N (lb/ac)	0 – 15	4	10
	15 – 30	4	11
	30 – 60	8	-
SO_4^{2-}-S (lb/ac)	0 – 15	52	20
	15 – 30	32	24
P (ppm)	0 – 15	7	14
K (ppm)	0 – 15	153	338
pH	0 – 15	8.0	6.2
	15 – 30	8.1	6.6

Soluble Salts (mmho/cm)	0 – 15	0.24	0.19
	15 – 30	0.20	0.19
Organic Matter (%)		1.3	2.8

At both locations, the trial was direct seeded into wheat stubble as either a corn monocrop, a faba bean monocrop, or at varying corn/faba bean intercrop rates (Table 2). At Outlook, the corn monocrop was seeded with 76.2 cm (30") row spacing while the faba bean monocrop and corn/faba bean intercrop was seeded with 25.4 cm (10") row spacing. At Swift Current, the corn monocrop was seeded with 63.5 cm (25") row spacing while the faba bean monocropcrop and corn/faba bean intercrop was seeded with 21.0 cm (8.25") row spacing. Nitrogen (N) fertilizer rates were calculated to account for soil available N from 0 to 60 cm in Outlook (16 lb/ac) and from 0 to 30 cm in Swift Current (42 lb/ac in Swift Current). All N fertilizer applications were applied as side-banded urea (46-0-0) in corn rows only. At seeding, all plots also received 50 kg P_2O_5/ha as seed placed monoammonium phosphate (MAP; 11-52-0). At Outlook, Nodulator® FB Peat faba bean inoculant (*Rhizobium leguminosarum*) was seed-placed into faba bean rows. At Swift Current, TagTeam® granular nitrogen-fixing and phosphate-solubilizing inoculant (*Rhizobium leguminosarum*, *Penicillium bilaiae*) for faba bean was used in faba bean rows.

Table 2. Detailed treatment list.

Treatment	Crop	Corn N Rate (kg N/ha)
Monocrop	Corn	160
	Faba bean	0
Intercrop	Corn/Faba bean	0
		40
		80
		120
		160

At Outlook, weed control consisted of a post-emergent application of Basagran® Forte (thiadiazine, 0.91 L/ac), supplemented by hand weeding. Matador® (lambda-cyhalothrin; 0.03 L/ac) was applied on July 21, 2020 to control blister beetles on the faba bean plants. The trial was harvested September 11, 2020. The silage was harvested with a Hegi forage harvest combine equipped with a corn silage chopper header. Wet field yield was recorded, and subsamples of chopped material was dried and sub-sampled for processing. There were 2,156 cumulative Corn Heat Units (CHUs) from May to August. Notably, hail and extremely high winds caused damage to corn plants on August 27, 2020 and a killing frost terminated the trial on September 8, 2020. Total in-season precipitation was 134.4 mm (5.3") and an additional 144.8 mm (5.7") was applied by a linear irrigation system.

At Swift Current, weed control consisted of exclusively hand weeding. Biomass samples were collected from each plot on September 4, 2020. There were 2,081 cumulative CHUs from May to August. Total in-season precipitation was 154.9 mm (6.1").

Results

The results of this project include two sites: an irrigated site at Outlook and a dryland site at Swift Current. The sites are analyzed separately, with no combined analysis, as the dryland site had a great degree of variability within treatments so there would be no additional value.

Moisture Content & Weed Control

At both sites, moisture content was lowest in the faba bean monocrop and highest in the corn monocrop (Table 4, ANOVA, $P \leq 0.05$). Moisture contents ranged from 53.4% to 78.1% at Outlook and from 8.3% to 67.3% at Swift Current. Silage corn is usually harvested around 65% moisture content but due to late seeding and an early frost event at Outlook, the corn had not reached maturity at harvest.

Weed control was issue as there are no registered herbicides that are compatible with both corn and faba bean. At both sites, extensive hand weeding was required in all treatments. At field-scale, hand weeding is not practical so an important consideration for intercropping is how to address weed control. Likely, yields would have been lower at either site without supplemental hand weeding.

Irrigated Emergence, Flowering/Tassel/Silk, & Height

For both faba bean and corn, there were no differences in plant emergence between treatments (Table 3, ANOVA, $P \leq 0.05$). Faba bean flowering and height differed between treatments (Table 3, ANOVA, $P \leq 0.05$). Faba bean flowering was delayed by 0.5 days in the 160N Intercrop when compared to all other applicable treatments. Except for the 80N Intercrop, faba bean height was higher in the Intercrops than in the Monocrop. Corn silk, tassel, and height also differed between treatments (Table 3, ANOVA, $P \leq 0.05$). Days to silk and tassel increased in the 0N Intercrop when compared to the Monocrop and all other Intercrops. Corn height was highest in the 160N Intercrop and Corn Monocrop, both of which received 160 kg N/ha. Generally, corn height increased with increasing fertilizer rate.

Table 3. Plant emergence, flowering/tassel/silk, and canopy height for each treatment at the irrigated Outlook site. Different letters indicate significant differences between treatments (ANOVA, $P \leq 0.05$).

Treatment	Faba Bean			Corn			
	Emergence (plants/m^2)	**Flowering** (days)	**Height** (cm)	**Emergence** (plants/m^2)	**Tassel** (days)	**Silk** (days)	**Height** (cm)
Corn Monocrop	n/a	n/a	n/a	7.3 *a*	80.3 *b*	80.3 *b*	238.0 *a*
Faba Bean Monocrop	25.6 *a*	43.0 *b*	101.0 *b*	n/a	n/a	n/a	n/a
0N Intercrop	22.8 *a*	43.0 *b*	112.5 *a*	7.0 *a*	82.0 *a*	82.0 *a*	193.8 *c*
40N Intercrop	25.6 *a*	43.0 *b*	113.8 *a*	7.6 *a*	79.5 *b*	79.5 *b*	217.3 *b*
80N Intercrop	24.2 *a*	43.0 *b*	105.0 *b*	7.5 *a*	79.5 *b*	79.5 *b*	206.0 *bc*
120N Intercrop	24.9 *a*	43.0 *b*	112.5 *a*	7.5 *a*	79.8 *b*	79.8 *b*	220.3 *b*
160N Intercrop	24.7 *a*	43.5 *a*	119.4 *a*	7.3 *a*	80.3 *b*	80.3 *b*	239.0 *a*
LSD (0.05)	NS	0.4	7.4	NS	1.0	1.0	17.0
CV (%)	7.01	0.55	4.46	7.7	0.82	0.82	5.14

NS = not significant; n/a = not applicable

Irrigated Yield

At the irrigated site in Outlook, dry matter yields were highest in the 160N Intercrop and lowest in the Faba Bean Monocrop (Table 4, ANOVA, $P \leq 0.05$). Compared to the Faba Bean Monocrop that had a dry matter yield of 8.01 T/ha, all other treatments were significantly higher yielding. Compared to the Corn Monocrop that had a dry matter yield of 16.95 T/ha, the 160N Intercrop was higher yielding at 19.74 T/ha. There were no significant yield differences between the Corn Monocrop and the 0N, 40N, 80N, or 120N Intercrop treatments.

Dryland Yield

At the dryland site in Swift Current, dry matter yield ranged from 2.83 T/ha in the Faba Bean Monocrop to 8.07 T/ha in the Corn Monocrop, but there were no statistically significant differences between treatments (Table 4, ANOVA, $P \geq 0.05$). This lack of measurable differences can be attributed to extensive variability within treatments (i.e., relative standard deviations of 31% in the 40N Intercrop and 56% in in the Corn Monocrop).

Table 4. Yield and moisture content for each treatment at the irrigated Outlook site and at the dryland Swift Current site. Different letters indicate significant differences between treatments (ANOVA, *P* ≤ 0.05).

Treatment	**Dry Matter Yield** (T/ha)	**Wet* Yield** (T/ha)	**Yield** as % of Corn Monocrop	**Moisture** (%)
Outlook (Irrigated)				
Corn Monocrop	16.95 *bc*	48.4 *bc*	100	78.1 *a*
Faba Bean Monocrop	8.01 *d*	22.9 *d*	47	53.4 *c*
0N Intercrop	14.83 *c*	42.4 *c*	87	63.5 *b*
40N Intercrop	15.96 *c*	45.6 *c*	94	74.3 *a*
80N Intercrop	16.98 *bc*	48.5 *bc*	100	73.0 *a*
120N Intercrop	18.99 *ab*	54.3 *ab*	112	72.6 *a*
160N Intercrop	19.74 *a*	56.4 *a*	116	74.2 *a*
LSD (0.05)	2.64	7.6	-	8.5
CV (%)	11.18	11.18	-	8.2
Swift Current (Dryland)				
Corn Monocrop	8.07 *a*	-	100	67.3 *a*
Faba Bean Monocrop	2.83 *a*	-	35	8.3 *d*
0N Intercrop	3.97 *a*	-	49	63.3 *b*
40N Intercrop	6.43 *a*	-	80	63.3 *b*
80N Intercrop	6.33 *a*	-	79	61.0 *bc*
120N Intercrop	4.63 *a*	-	57	59.7 *c*
160N Intercrop	5.03 *a*	-	62	62.0 *bc*
LSD (0.05)	NS	-	-	3.3
CV (%)	40.15	-	-	3.34

* = adjusted to 65% moisture content; NS = not significant

<u>Irrigated Forage Quality</u>

Forage quality parameters for the irrigated Outlook site are presented in Table 5. Crude protein was 18.6% in the Faba Bean Monocrop and < 10% in the 0N and 160N Intercrops. Crude protein was < 10% in the remaining treatments and ranged from 8.53% in the 80N Intercrop to 9.95% in the 120N Intercrop. Total digestible nutrients (TDN) were < 60% in the Faba Bean Monocrop and 0N Intercrop and ≥ 60% in the Control and all other treatments (Table 4). Although the 120N and 160N Intercrop treatments had a higher protein content than the Corn Monocrop, they had less TDN so overall forage quality was not superior. Forage macrominerals, calcium (Ca), phosphorus (P), potassium (K), and sodium (Na), were highest in the Faba Bean Monocrop.

<u>Dryland Forage Quality</u>

Forage quality parameters for the dryland Swift Current site are presented in Table 5. Crude protein was 11.4% in the Faba Bean Monocrop and < 10% in the remaining treatments, ranging from 6.16% in the 0N Intercrop to 8.08% in the 80N Intercrop. TDN was < 60% in the Faba Bean Monocrop and 160N Intercrop and ≥ 60% in the Control and all other treatments. Ca, K, and Na were highest in the Faba Bean Monocrop, and P was highest in the 0N Intercrop.

Table 5. Corn and faba bean forage quality analysis for each treatment at the irrigated Outlook site and at the dryland Swift Current site.

Treatment	Crude Protein (%)	TDN (%)	Ca (%)	P (%)	K (%)	Na (%)
Outlook (Irrigated)						
Corn Monocrop	9.18	62.4	0.24	0.20	1.24	0.02
Faba Bean Monocrop	18.6	56.0	0.74	0.30	1.54	0.70
0N Intercrop	11.0	57.7	0.49	0.23	1.44	0.29
40N Intercrop	8.80	60.6	0.34	0.18	1.29	0.17
80N Intercrop	8.53	63.6	0.33	0.18	1.15	0.12
120N Intercrop	9.95	61.6	0.33	0.20	1.16	0.14
160N Intercrop	10.7	60.1	0.36	0.18	1.14	0.16
Swift Current (Dryland)						
Corn Monocrop	7.63	65.8	0.33	0.13	1.74	0.00
Faba Bean Monocrop	11.4	51.0	0.57	0.14	2.08	0.07
0N Intercrop	6.16	62.3	0.25	0.18	2.06	0.01
40N Intercrop	6.58	64.6	0.29	0.20	1.58	0.01
80N Intercrop	8.08	65.1	0.29	0.17	2.06	0.01
120N Intercrop	6.73	61.2	0.33	0.17	1.80	0.02
160N Intercrop	7.14	59.5	0.36	0.14	2.04	0.03

TDN = total digestible nutrients; Ca = calcium; P = phosphorus; K = potassium; Na = sodium

Irrigated Economic Analysis

A basic economic analysis was conducted to provide a relative overview of economic performance for each treatment at the irrigated Outlook site. Prices were estimated from ICDC's Irrigation Economics and Agronomics guide (ICDC, 2020). Seed, inoculant, and chemical input costs are shown in Table 6 and N and P fertilizer costs for various application rates are shown in Table 7. Based on row spacing required by each crop, there were two tows of corn in the Corn Monocrop plots and there were eight rows of faba bean in the Faba Bean Monocrop plots. In the Intercrop treatments, there were two rows of corn and six rows of faba bean. Granular inoculant and the insecticide, Matador, were only required in treatments containing faba bean. The herbicide Basagran was applied to all treatments. In terms of input costs relating to seed, inoculant, and chemical inputs, the Faba Bean Monocrop was the cheapest at $65.02/ac and the Intercrop treatments were the most expensive at $152.74/ac. P fertilizer was applied at 50 kg P_2O_5/ha in all treatments while N fertilizer was applied at rates of 0, 40, 80, and 120 kg N/ha. P fertilizer costs were $22.32/ac and N fertilizer costs ranged from $0/ac in the Faba Bean Monocrop and 0N Intercrop to $71.43/ac in the Corn Monocrop and 160N Intercrop.

Table 6. Seed, inoculant, and chemical input costs.

Crop	**Variety**	**Target Plant Population** (plants/m^2)	**Seed** ($/ac)	**Inoculant** ($/ac)	**Insecticide Matador** ($/ac)	**Herbicide Basagran** ($/ac)	**Total Cost** ($/ac)
Monocrop							
Faba Bean	Snowdrop	45.0	$ 40.50	$ 13.00	$ 5.45	$ 6.07	**$ 65.02**
Corn	NorthStar 9325	7.9	$ 99.84	$ -	$ -	$ 6.07	**$ 105.91**
Intercrop (100% Corn + 66% Faba Bean)							
Faba Bean	Snowdrop	29.7	$ 26.73	$ 8.58	$ 5.45	$ 6.07	**$ 152.74**
Corn	NorthStar 9325	7.9	$ 99.84	$ -	$ -	$ 6.07	

Table 7. N and P fertilizer costs at each application rate.

Source	**Cost** ($/lb of Nutrient)	**Rate** (kg/ha)	**Rate** (lb/ac)	**Cost** ($/ac)
N	$ 0.50	0	0.0	$ -
		40	35.7	$ 17.86
		80	71.4	$ 35.71
		120	107.1	$ 53.57
		160	142.9	$ 71.43
P	$ 0.50	50	44.6	$ 22.32

Wet yield, estimated silage price, gross revenue, and net revenue are shown in Table 8. Wet yields, adjusted to 65% moisture content, were used to calculate gross revenue using a corn silage price of $40.00/t (personal communication with Travis Peardon, SK Ministry of Agriculture). The corn silage price was used for all treatments as there is no price available for faba bean silage. Likely, the increase in protein associated with the Faba Bean Monocrop and 120N and 160N Intercrops could generate a higher silage price but will not be considered for the purpose of this economic analysis. Net revenue was calculated by subtracting expenses (seed, inoculant, chemical inputs, fertilizer) from gross revenue. With a net revenue of $571.49/ac, the Corn Monocrop was more profitable than the Faba Bean Monocrop and the 0N, 40N, and 80N Intercrops. Compared to the Corn Monocrop, the 120N Intercrop and 160N Intercrop were more profitable at $636.52/ac and $652.12/ac, respectively.

Table 8. Wet yield, estimated silage price, gross revenue, and net revenue for each treatment.

Treatment	**Wet* Yield** (T/ha)	**Wet* Yield** (t/ac)	**Silage Price** ($/t)	**Gross Revenue** ($/ac)	**Total Expenses** ($/ac)	**Net Revenue** ($/ac)
Monocrop						
Faba Bean	22.9	9.1	$ 40.00	$ 364.84	$ 87.34	$ 277.52
Corn	48.4	19.3	$ 40.00	$ 771.15	$ 199.66	$ 571.49
Intercrop (100% Corn + 66% Faba Bean)						
0N Intercrop	42.4	16.9	$ 40.00	$ 675.55	$ 175.06	$ 500.49
40N Intercrop	45.6	18.2	$ 40.00	$ 726.54	$ 192.92	$ 533.62
80N Intercrop	48.5	19.3	$ 40.00	$ 772.74	$ 210.78	$ 561.97
120N Intercrop	54.3	21.6	$ 40.00	$ 865.15	$ 228.63	$ 636.52
160N Intercrop	56.4	22.5	$ 40.00	$ 898.61	$ 246.49	$ 652.12

* = adjusted to 65% moisture content

Conclusions

Under irrigated production, the 160N Intercrop receiving 160 kg N/ha yielded 2.79 T/ha, or 16%, higher than the Corn Monocrop also receiving 160 kg N/ha. Corn plants were shorter when < 160 kg N/ha was applied which suggests that corn yield was reduced in most intercropped treatments but the faba bean contributed enough yield that there were no significant yield differences between the Corn Monocrop and the 0N, 40N, 80N, or 120N Intercrop treatments. Except for protein and macromineral content in the Faba Bean Monocrop, there were no major differences in forage quality between treatments. In 2020, the 120N and 160N Intercrops were more profitable than the Corn Monocrop which demonstrates that intercropping corn with faba bean may be a viable strategy for irrigated producers in Saskatchewan.

Under dryland production, yields differences between treatments were not statistically significant due to high variability between individual plots. Some components of forage quality (crude protein, macrominerals) were higher in the Faba Bean Monocrop, but generally, treatment differences were small and variable.

Acknowledgements

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Seed Production Viability of Crimson Clover and Berseem Clover Grown Under Irrigation in Saskatchewan

Funding

Funded by the Agricultural Demonstration of Practices and Technologies Fund (ADOPT)

Organizations

- Irrigation Crop Diversification Corporation (ICDC), Outlook
- Saskatchewan Forage Seed Development Commission (SFSDC), Saskatoon

Project Lead

- ICDC Leads: Erin Karppinen & Garry Hnatowich
- SFSDC Lead: J. Relf-Eckstein

Objectives

The objectives of this study were to:

1. Demonstrate the use of irrigation technology to expand the geographic range and diversity of clover species grown for seed in Saskatchewan.
2. Determine grain yield potential and evaluate the economic returns to producers in the Outlook area of Saskatchewan.

Crimson clover (*Trifolium incarnatrum L.*) and berseem clover (*Trifolium alexandrinum)* are cool season nitrogen-fixing annual legume forages. They are primarily used as crop management tools (green manure or living mulch) to improve soil fertility and aggregation while creating a healthy soil ecosystem for soil microbes, fungi, and other organisms such as earth worms. Both species are used as nitrogen-fixing cover crops, particularly in nutrient deficient soils. Crimson clover will tolerate poor-quality soils and thrives with high levels of soil-phosphorous. The seedings grow quickly from the crown and establish a rosette. Bright crimson coloured conical flower heads are comprised of many florets (75 to 125), opening from bottom to top and with abundant nectar, they are known to attract many pollinators. Berseem clover is quick to germinate and with its fast-growing habit, it is often used as a living mulch and may be used for early season grazing. It is recognized for its weed-suppressing ability and will tolerate saline conditions and lower soil phosphorous than crimson clover.

Both species have been introduced to North America and are increasingly utilized in grazing hay and sileage mixtures as they are recognized as low to moderate bloat legumes. Producers are interested in planting multispecies annual crop mixtures for forage production and in cover crop grazing mixtures. When grown in western Canada, both clovers have high dry matter yield and protein content and are used in combination with other crops (polycropping) to extend the grazing season for livestock. These forage legumes are also of interest for use in intercropping and/or organic production systems. Both are areas showing increased growth for the agriculture industry in Saskatchewan and are emerging areas of research. Seed sources of these species are imported and increase the cost of the crop cocktails. Oregon is indicated the main area of production, though berseem clover seed may actually be imported from Egypt where is has been grown for several centuries.

Saskatchewan forage seed producers and processors have a demonstrated capacity in production of high quality (northern vigour) clover. The potential for seed production of crimson and berseem clover, nor the economic feasibility for use as a seed crop diversification alternative, have not been demonstrated in Saskatchewan. However, the Outlook area of Saskatchewan has environmental conditions not unlike the irrigated areas in Alberta (Brooks, Bow Island, Lethbridge) where seed of both species has been successfully grown in field research trials (Nadja et al., 2007). Using the best management practices currently known for planting crimson and berseem clovers for seed production, this project will demonstrate the use of irrigation technology and determine seed yield potential of these two crops, the economic returns to forage seed producers and evaluate the potential for local producers to leverage the existing infrastructure and expertise of the Saskatchewan forage seed industry and supply the local and export market.

Research Plan

On May 29, 2020, crimson and berseem clover were direct seeded into canola stubble at the ICDC off-station Knapik location. Clover seed was pre-inoculated with Nitragin® Gold (*Rhizobium leguminosarum*). The trial was established as a split-plot design with clover variety (crimson clover, berseem clover) as the whole plots and seeding rate (75 seeds/m^2, 150 seeds/m^2) as the subplots. Treatments are shown in Table 1. At seeding, each treatment received 35 kg P_2O_5/ha as mid row-banded monoammonium phosphate (MAP; 11-52-0). Spring soil test results are shown in Table A2.

Table 1. Clover and seeding rate treatments.

Clover	**Seeding Rate** (seeds/m^2)
Crimson	75
	150
Berseem	75
	150

Weed control consisted of exclusively hand weeding throughout the growing season. The berseem clover trial was terminated after failing to establish early in the growing season and was not harvested. A 1 m^2 biomass sample was collected from the crimson clover trial on September 30, 2020. Crimson clover was harvested by direct cutting the entire plot with a small plot combine. The combine was set to high rotor speed and tight concave, with minimum airflow at the sieves. The crimson clover trial was harvested on October 14, 2020 and harvest plot size was 6 m x 3.6 m. Harvested samples were cleaned by hand using 10 and 16 µm round-hole sieves. Total in-season rainfall was 144.0 mm (5.7”) and total in-season irrigation was 213.4 mm (8.4”).

Mean monthly temperatures and precipitation amounts are listed in Tables 2 and 3. The 2020 season was comparable to the long-term average with respect to temperature, but rainfall was below average.

Table 2. Mean monthly temperature from May to August 2020 at the ICDC trial location.

Location	**Year**	**May**	**June**	**July**	**August**	**Average**
		------------ *Mean Temperature (°C)* -----------				
Outlook	2020	11.3	15.9	19.1	18.8	16.3
	Long-term	***11.5***	***16.1***	***18.9***	***18.0***	**16.1**

Table 3. Precipitation amounts vs. long-term (30 year) means for the 2020 growing season.

Location	**Year**	**May**	**June**	**July**	**August**	**Average**
		------------- *Precipitation (mm)* -------------				
Outlook	2020	27.8	79.2	29.6	19.0	155.6
	Long-term	***42.6***	***63.9***	***56.1***	***42.8***	**205.4**

Results

Yield, Plant Emergence, Canopy Height, & Blossom Counts

Due to poor stand establishment, the berseem clover trial was terminated, and only the results from the crimson clover trial are reported. There were no significant differences between seed yield, plant emergence, canopy height, or blossom counts between the two seeding rates of 75 seeds/m^2 and 150 seeds/m^2 (Table 4, ANOVA, $P \geq 0.05$). Yield and plant emergence was higher at a seeding rate of 150 seeds/m^2 when compared to a seeding rate of 75 seeds/m^2, but the difference was not significant due to high variability within treatments. Similarly, there was no significant difference between blossom counts between the two seeding rates although the average blossom count at the 150 seeds/m^2 rate was higher than the 75 seeds/m^2 rate.

Table 4. Yield, plant emergence, canopy height, and blossom counts for crimson clover. Different letters indicate significant differences between treatments (ANOVA, $P \leq 0.05$).

Seeding Rate	**Yield** (kg/ha)	**Emergence** (plants/m^2)	**Canopy Height** (cm)	**Blossom Counts** (blossoms/m^2)
75 seeds/m^2	79.9 *a*	54.7 *a*	53.4 *a*	511 *a*
150 seeds/m^2	129.3 *a*	93.2 *a*	54.5 *a*	618 *a*
LSD (0.05)	NS	NS	NS	NS
CV (%)	41.4	41.6	7.29	32.6

NS = not significant

Establishment, Maturity, & Harvest

Initially, we had issues with metering the small, light clover seed through our drill which created patches of clover plants rather than even rows. It appeared that the third row in every plot was missing. We suspect that germination was poor and also contributed to the uneven establishment in both clover trials. Although the crimson clover was able to fill out, the berseem clover never properly established. As a result, the berseem clover trial was abandoned and would not be recommended as a suitable clover species in Saskatchewan.

At harvest, there was extreme variability in the maturity of blooms. There were new blossoms in the weeks prior to harvest even though we received significant frost events that did not terminate flowering. A large portion of the harvested seed appeared immature, ranging from green to yellow to light brown coloured, rather than the dark brown colour characteristic of mature clover seed. The combine was set to high rotor speed, tight concave, with the airflow turned to the minimum at the sieves but most of the seed remained trapped in the tough hull. As we seeded May 29, 2020, much of the seed was not mature at harvest so it is likely that clover needs to be seeded quite early in the spring (early May) to produce vigorous plants and mature seed in our climate.

Acknowledgements

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Crop Rotation Benefits of Annual Forages Preceding Spring Cereals

Funding

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Organizations

- Wheatland Conservation Area (WCA), Swift Current
- Irrigation Crop Diversification Corporation (ICDC), Outlook

Project Lead

- WCA Lead: Bryan Nybo
- ICDC Leads: Erin Karppinen & Garry Hnatowich

Objectives

This project is based on ongoing work demonstrated by Dr. Jillian Bainard at AAFC-Swift Current. Most recently, her research has addressed environmental stability by exploring ways to reduce herbicide and fertilizer inputs (Bainard, 2018), improve forage and feed grains by assessing the nutritive value of these mixtures (Bainard et al., 2018), and determining the economic and agronomic impact of incorporating annual forage mixtures into a cropping system (Bainard et al., 2014). Results from past and ongoing projects have found that creating polyculture mixtures (more than one species) with annual crops can result in high quality forage, increased biomass production, enhanced weed suppression, greater microbial activity and diversity, and increased soil nutrients.

Many producers are looking to improve soil rotational health and effects in order to create environmental stability that allows for a reduction in herbicides and fertilizers, higher quality forages, and provides multiple benefits for monoculture in the following year. Benefits to improving soil health includes the integration of larger, and more stable aggregates occurring in soils after annual forage polycultures are grown, indicating increased microbial activity and overall soil quality compared to single seeded monoculture (**Control**), such as barley or oats.

Although mixtures are not likely to maintain fertility over multiple years without additional inputs, legume species (**Nitrogen-Fixing Mix**) may allow for less fertilizer to be applied in both crop years due to the N fixation occurring in the soil.

Weed suppression in a cereal crop after incorporating forages into a rotation is significantly higher. Mixtures with higher amounts of root crops, or brassica species (**Weed Control Mix**) may account for some weed control, with the possibility of reducing herbicide applications in the following cereal year. Care must be taken to create a mix in which the proportion of Brassica species are not too high, as they have shown to contain high amounts of nitrates and sulfate, which is toxic to animals at high levels.

Polyculture mixes are shown to create higher quality forages compared to a single monocrop. It is important to pick mixes with that provide high crude protein and low non-digestible fibre with high digestibility. As many producers are creating their own mix, they may prefer to make something simple, which will still accomplish a range of tasks, therefore includes a balance of legumes, cereals, and brassicas (**Balanced Mix**), or a balanced mix, with more species to increase biomass (**Simple Balanced Mix**). Others may be willing to produce a more complicated polyculture that includes more species. The more species included, the higher the productivity to improving biomass yield and increasing the nutritional value of the forage (**Complex Balanced Mix**).

As for the cereal monoculture in the following year, grain yield increases are shown when forages precede cereal crops in a rotation, especially when mixtures that include N-fixing legumes are included allowing a lower input fertility system. Having a cover crop that can accomplish a range of tasks, including weed control, improved forage nutrition, and nitrogen fixation for the following crop provides a number of benefits to improving overall soil rotational health and effects (**Complex Soil Amendment Mix**).

Research Plan

On May 28, 2020, the trial was established on canola stubble at the ICDC Knapik off-station location. A total of 7 treatments were arranged in a four-replicate randomized complete block design trial (Table 1). A composite soil sample was collected and sent to AgVise Laboratories for analysis (Table A2). At seeding, each trial received 45 kg N/ha as side-banded urea (46-0-0) and 35 kg P_2O_5/ha as side-banded monoammonium phosphate (MAP; 11-52-0). Weed control was not required during the growing season. Wet field yield was recorded, and subsamples of cut material was dried and sub-sampled for processing. The trial was harvested August 13, 2020 and a post-harvest tank mix application of Roundup® (glyphosate; 2 L/ac) and Heat® (saflufenacil; 2 L/ac) was applied to prevent regrowth in the spring. Total in-season rainfall was 114.0 mm (4.5”) and total in-season irrigation was 200.0 mm (7.9”).

Table 1. Detailed treatment list.

Treatment	# of Species	Proportion	Purpose of Treatment	Species
1	Monoculture	1C	Control	C: Advantage Barley
2	3 species	1L:1C:1B	Balanced Mix	L: Persian Clover C: Advantage Barley B: Groundhog Radish
3	3 species	3L	N-Fixing Mix	L: Persian Clover, Forage Pea (Leroy), Hairy Vetch
4	4 species	1L:2C:1B	Simple Balanced Mix	L: Persian Clover C: Advantage Barley, Haymaker Oats B: Groundhog Radish
5	6 species	1L:2C:3B	Weed Control Mix	L: Persian Clover C: Advantage Barley, Haymaker Oats B: Groundhog Radish, Tillage Radish, Winfred Radish
6	6 species	2L:2C:2B	Complex Balanced Mix	L: Persian Clover, Hairy Vetch C: Advantage Barley, Haymaker Oats B: Groundhog Radish, Winfred Radish
7	8 species	2L:4C:2B	Complex Soil Amendment Mix	L: Persian Clover, Hairy Vetch C: Advantage Barley, Haymaker Oats Corn, Millet B: Groundhog Radish, Winfred Radish

L = Legume species; C = Cereal species; B = Brassica species

In 2021, a spring wheat variety will be seeded into the forage stubble of each treatment. The cereal crop will receive low amounts of fertility, but, depending which forage stubble it is seeded into, may be able to use the residual N fixed in the previous year.

Results

<u>Moisture Content, Yield, & Weed Control</u>

Moisture content was variable between treatments and ranged from 60.5% in the Control to 79.6% in the N-Fixing Mix (Table 2, ANOVA, $P \leq 0.05$).

Compared to the Control (7.7 T/ha), the Balanced Mix was 26% lower yielding, and the Complex Balanced Mix was 29% higher yielding (Table 2, ANOVA, $P \leq 0.05$). The highest yielding Complex Balanced Mix, at 9.9 T/ha, contained six species (2L:2C:2B) while the lowest yielding Balanced Mix, at 5.6 T/ha, contained 3 species (1L:1C:1B). There were no significant yield differences between the Control and the N-Fixing, Simple Balanced, Weed Control, and Complex Soil Amendment Mixes. Multiple studies have found that as the proportion of legumes in a mixture increases, so does the forage yield and quality (Lithourgidis et al., 2011). In this study, the N-Fixing Mix contained three species (3L) but the dry matter yield (7.1 T/ha) was not statistically higher than the Control.

Brassica species are being tested as forage crops as they provide a source of high-quality feed (Westwood and Mulcock, 2012), as well as show considerable weed control through competition. However, we found that the Weed Control Mix, which included 3 brassica species, was not statistically different than the Control in its weed control rating (Table 2, ANOVA, $P \geq 0.05$). However, it is possible that fewer herbicide applications will be required in the following cereal year. While most treatments were not significantly different than the Control, we found that the N-Fixing Mix had significantly more weeds than the Control and all other treatment mixes.

Table 2. Yield, moisture content, and weed control for each treatment. Different letters indicate significant differences between treatments (ANOVA, $P \leq 0.05$).

Forage Mix	**Dry Matter Yield** (T/ha)	**Yield** as % of Control	**Moisture** (%)	**Weed Control** (1=weedless; 5=weedy)
Control	7.7 *b*	100	60.5 *e*	1.5 *b*
Balanced	5.6 *c*	74	77.9 *a*	1.0 *b*
N-Fixing	7.1 *b*	93	79.6 *a*	3.5 *a*
Simple Balanced	8.2 *b*	107	69.5 *cd*	1.3 *b*
Weed Control	7.2 *b*	94	72.7 *bc*	1.0 *b*
Complex Balanced	9.9 *a*	129	69.1 *d*	1.0 *b*
Complex Soil Amendment	7.8 *b*	102	74.1 *b*	1.3 *b*
LSD (0.05)	1.1	-	3.4	0.5
CV (%)	9.87	-	3.14	23.4

<u>Forage Quality</u>

A higher crude protein (CP) is indicative of higher forage quality, and young cattle and gestating/lactating cows have increased protein requirements (Beef Council Research Council, 2020a). The addition of legumes in forage mixtures can improve forage quality in terms of protein content and digestibility (Lithourgidis et al., 2011; Bainard et al., 2018). Protein content was significantly higher in the N-Fixing Mix than in the control and all other treatment mixes (Table 3, ANOVA, $P \leq 0.05$). Average crude protein in the N-Fixing Mix was 14.3% while the average crude protein in all other treatments was 4.44%.

Energy content, often reported as total digestible nutrients (TDN), includes carbohydrates, fats, and proteins supplied by cattle feed. TDN in cereal silage usually ranges from 60 to 65%. TDN was significantly higher in the Control than in all other treatment mixes (Table 3, ANOVA, $P \leq 0.05$). Average TDN in the Control was 69.2% while the average TDN in all other treatments was 60.8%.

Neutral detergent fibre (NDF) is a measure of the bulkiness of the diet so when NDF increases, cattle consume less, but high levels of NDF (≥ 70%) can restrict animal intake (Beef Council Research Council, 2020b). NDF was significantly higher in treatment mixes containing 4 or more species (Simple Balanced, Weed Control, Complex Balanced, and Complex Soil Amendment Mixes) than in treatment mixes containing less than 4 species (Control, Balanced and N-Fixing Mixes) (Table 3, ANOVA, $P \leq 0.05$). At 55.5%, NDF was highest in the Simple Balanced Mix and the lowest at 45.9% in both the Control and the N-Fixing Mix.

Feeds high in acid detergent fibre (ADF) are less digestible, so a high ADF indicates poor digestibility of forage (Beef Council Research Council, 2020b). ADF was significantly lower in the Control than in all other treatment mixes (Table 3, ANOVA, $P \leq 0.05$). Average ADF in the Control was 27.6% while the average ADF in all other treatments was 35.5%.

Forage macrominerals such as calcium (Ca), phosphorus (P), potassium (K), and sodium (Na) are important components of cattle feed (Beef Council Research Council, 2020b). Ca, P, and K were higher in the N-Fixing Mix (Table 3, ANOVA, $P \leq 0.05$) when compared to the Control and most other treatments. Na was highest in the Balanced Mix when compared to the Control and most other treatments.

Table 3. Forage quality analysis for each forage mix treatment. Different letters indicate significant differences between treatments (ANOVA, $P \leq 0.05$).

Forage Mix	**Crude Protein** (%)	**TDN** (%)	**ADF** (%)	**NDF** (%)	**Ca** (%)	**P** (%)	**K** (%)	**Na** (%)
Control	4.12 *b*	69.2 *a*	27.6 *b*	45.9 *b*	0.24 *d*	0.22 *ab*	1.39 *c*	0.09 *b*
Balanced	4.48 *b*	59.1 *b*	37.0 *a*	50.6 *ab*	0.63 *b*	0.20 *b*	1.74 *b*	0.18 *a*
N-Fixing	14.3 *a*	59.9 *b*	36.3 *a*	45.9 *b*	1.02 *a*	0.23 *a*	2.42 *a*	0.12 *b*
Simple Balanced	4.08 *b*	61.6 *b*	34.7 *a*	55.5 *a*	0.23 *d*	0.20 *b*	1.72 *b*	0.10 *b*
Weed Control	4.39 *b*	60.3 *b*	35.9 *a*	54.4 *a*	0.40 *cd*	0.21 *b*	1.76 *b*	0.13 *ab*
Complex Balanced	4.76 *b*	62.3 *b*	34.0 *a*	53.0 *a*	0.33 *cd*	0.20 *b*	1.74 *b*	0.10 *b*
Complex Soil Amendment	4.81 *b*	61.5 *b*	34.8 *a*	52.0 *a*	0.50 *bc*	0.20 *b*	1.99 *b*	0.12 *b*
LSD (0.05)	1.48	4.6	4.3	5.3	0.20	0.02	0.30	0.05
CV (%)	17.0	5.01	8.46	6.99	28.08	7.36	10.92	29.92

TDN = total digestible nutrients; ADF = acid detergent fibre; NDF = neutral detergent fibre; Ca = calcium; P = phosphorus; K = potassium; Na = sodium

Conclusions

Compared to the Control (1C), the Complex Balanced Mix (2L:2C:2B) was higher yielding and had higher NDF. This demonstrates that a balanced polyculture mix with more species has potential to increase biomass yield and forage quality over a monoculture. Although the N-Fixing Mix (3L) was not higher yielding than the Control (1C), there were benefits to forage quality (i.e., increased protein and macromineral contents) and there is potential to require less fertilizer in both crop years due to the biological N fixation associated with legumes. Energy (TDN) and digestibility (ADF) were higher in the Control (1C) than any of the polyculture mixes, but there were likely less benefits to soil health and quality. There may be further benefits to using polycultures over a cereal monoculture such as higher grain yield or quality in the subsequent years crop.

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Varietal Assessment of Forage Seed Production

Funding
Funded by the Strategic Field Program (SFP)

Organizations
- Irrigation Crop Diversification Corporation (ICDC), Outlook
- Saskatchewan Ministry of Agriculture (SMOA), Outlook
- University of Saskatchewan (U of S), Saskatoon
- Livestock and Forage Centre of Excellence (LFCE), Saskatoon
- Saskatchewan Forage Seed Development Commission (SFSDC), Saskatoon

Project Lead
- SMOA Lead: Terry Kowalchuk
- U of S Lead: Dr. Bill Biligetu
- SFSDC Lead: JoAnne Relf-Eckstein
- ICDC Leads: Erin Karppinen & Garry Hnatowich

Objectives
The objectives of this project were:
1. To assess seed yield for the forage seed crops commonly grown in Saskatchewan;
2. To evaluate forage seed as a possible irrigated cash crop as a means of expanding the sector;
3. To explore potential turf grass varieties as a possible diversification opportunity for the forage seed sector; and
4. To enable the SRP chair for forage breeding to evaluate seed production of new lines and compare to current commercial varieties.

At one time Saskatchewan was the second largest producer of forage seed in Canada. Over the past decade overall forage seed production has declined. As a result, the Saskatchewan Forage Seed Development Commission is interested in exploring opportunities for growing their sector. This project seeks to provide seed yield data for current forage seed species and turf varieties within the South Saskatchewan Irrigation Development Areas and the University of Saskatchewan. Evaluating seed production trials on irrigated land may provide growers with a new cash crop that would fit well into current horticultural and small grain rotations. An irrigated site at Outlook would provide additional seed yield data as part of this assessment. Information from both trials will be used to help promote the forage seed sector and encourage new growers to enter the market in both traditional and non-traditional seeding areas. There is a lack of data about seed yield for specific forage varieties. This project will help producers make more informed decisions by providing information for estimating net returns. These estimates will also help new or potential growers assess opportunities for growing various forage seed crops under irrigation. Existing growers will be able to use the information as a benchmark for yield comparisons to their own operations. If they have not tried growing a particular species or variety, it will also give them an idea of the average yield potential.

Research Plan
Note that this trial was also established under dryland conditions at the Livestock and Forage Centre of Excellence near Clavet, SK.

Forage plots were established on May 29, 2020 at the ICDC Knapik off-station location. A total of 28 treatments were arranged in a three-replicate split plot design, with species as the whole plots and variety as the subplot (Table 1). A composite soil sample was collected prior to seeding and fertilizer applications were based off soil nutrient determinations (Table A2). At seeding, each plot received 35 kg P_2O_5/ha as mid row-banded monoammonium phosphate (MAP; 11-52-0). On October 9, 2020 100 kg N/ha of urea was broadcast across the entire trial. Weed control was not required during the growing season. In-season precipitation was 144.0 mm (5.7") and total in-season irrigation applied was 213.4 mm (8.4").

Table 1. Treatment list and seed information.

Entry	Species	Variety	Seeding Rate (plants/m^2)	Germination (%)	Seed Weight (g/100)
1	Hybrid Bromegrass	AC Knowles (check)	300	82	0.40
2	Hybrid Bromegrass	AC Success (check)	300	84	0.45
3	Hybrid Bromegrass	S9073Q	300	92	0.40
4	Hybrid Bromegrass	S9570	300	82	0.44
5	Hybrid Bromegrass	S9593	300	94	0.41
6	Meadow Bromegrass	Fleet (check)	300	90	0.49
7	Meadow Bromegrass	S9549	300	96	0.53
8	Smooth Bromegrass	Carleton (check)	300	32	0.32
9	Crested wheatgrass	Kirk (check)	300	74	0.32
10	Crested wheatgrass	S9598	300	80	0.29
11	Hybrid wheatgrass	AC Saltlander (Check)	300	82	0.43
12	Hybrid wheatgrass	S9615	300	86	0.38
13	Hybrid wheatgrass	S9600	300	72	0.36
14	Western wheatgrass	Walsh (check)	300	60	0.52
15	Northern wheatgrass	Elbee (check)	300	78	0.26
16	Intermediate wheatgrass	Chief (check)	300	82	0.70
17	Intermediate wheatgrass	S9578	300	90	0.62
18	Tall Fescue	Courtenay (check)	300	86	0.23
19	Tall fescue	S9582	300	98	0.23
20	Timothy	Climax (check)	460	96	0.07
21	Timothy	ST1	460	96	0.06
22	Creeping red fescue	Boreal	300	90	0.14
23	Perennial ryegrass	Replicator	300	92	0.27
24	Festolulium	Lofa	300	88	0.37
25	Galega	Common	400	78	0.59
26	Cicer milkvetch	Oxley II (check)	400	62	0.37
27	Sainfoin	Common	200	88	1.91
28	Sainfoin	SF900	200	90	1.93

Mean monthly temperatures and precipitation amounts are listed in Tables 2 and 3. The 2020 season was comparable to the long-term average with respect to temperature, but rainfall was below average.

Table 2. Mean monthly temperature from May to August 2020 at the ICDC trial location.

Location	Year	May	June	July	August	Average
		------------ Mean Temperature (°C) -----------				
Outlook	2020	11.3	15.9	19.1	18.8	16.3
	Long-term	***11.5***	***16.1***	***18.9***	***18.0***	**16.1**

Table 3. Precipitation amounts vs. long-term (30 year) means for the 2020 growing season.

Location	Year	May	June	July	August	Average
		------------- Precipitation (mm) -------------				
Outlook	2020	27.8	79.2	29.6	19.0	155.6
	Long-term	***42.6***	***63.9***	***56.1***	***42.8***	**205.4**

Results

This trial was in its first year of establishment so there are no results to report for 2020. For the next 3 years (2021-2024), seed will be harvested, and yield data will be collected.

Acknowledgements

Financial support was provided by the Strategic Field Program. All funding is gratefully acknowledged.

Demonstrating Effects of Insecticide Application Timing and Seeding Date on Pea Aphid Damage to Lentils and Field Peas

Funding

Funded by the Strategic Field Program (SFP)

Organizations

- Irrigation Crop Diversification Corporation (ICDC), Outlook
- Saskatchewan Ministry of Agriculture (SMOA), Outlook
- Agriculture & Agri-Food Canada (AAFC), Saskatoon
- South East Research Farm (SERF), Redvers
- Wheatland Conservation Area (WCA), Swift Current

Project Lead

- SMOA Lead: James Tansey
- ICDC Leads: Erin Karppinen & Garry Hnatowich

Objectives

The objectives of this study were to:

1. To demonstrate and compare the effects of applying insecticidal control of pea aphid prior to and after flowering in lentils and field peas; and
2. To demonstrate the effects of seeding date on the effects of pea aphid damage to lentils and field peas.

Pea aphid pressure on lentils has been high in recent years and was at outbreak densities in 2019. Current recommendations for control of these insects in both peas and lentil are based on thresholds developed for Century peas (an old variety, no longer grown) and work from the US. These thresholds and recommendations for pea aphid control are associated with evaluations of aphid populations at the beginning of flowering. Recent evidence developed by Drs. Tyler Wist (AAFC) and Sean Prager (U of S) indicates that insecticide applications to pulse crops prior to flowering can have dramatic effects on aphid damage. That is, there is recent evidence that the timing of insecticide applications is as important as aphid density (assuming that the insects are at damaging levels). Planting date also has the potential to influence the effects of aphids. Early seeded crops have the potential to develop past the vulnerable flowering stage before aphids reach damaging levels. Validating information collected by AAFC and demonstrating effects in demonstration plots for growers will do much to improve aphid control in lentils and peas and contribute to our understanding of control strategies.

Research Plan

Note that this trial was also conducted at each of the additional Agri-ARM sites listed above.

A field demonstration with pea and lentil was established in the spring of 2020 at the CSIDC on-station location (Field 8). The trials were established in a split plot design with seeding date as the whole plots and insecticde application as the subplots. Each treatment was replicated 3 times. Seeded plot size was 8 m in length and 1.5 m wide. A composite soil sample was collected from the study area and submitted to AgVise Laboratories for analysis (Table A4). At seeding, pea and lentil plots received 15 kg P_2O_5/ha as seed placed monoammonium phosphate (11-52-0) and 3.7 kg/ha Nodulator® Duo SCG inoculant.

Seeding, harvest, and chemical application dates are provided in Table 1. Pea and lentil were planted at three seeding dates: i) mid May (early), ii) early June (mid), and iii) mid June (late). Insecticide application ocurred at three timings: i) not applied (control), ii) prior to flowering, and iii) post-flowering. Using sweep nets, aphid densities were evaluated: i) 48 hours prior to insecticide application, ii) 48 hours post insecticide application, and iii) 7 days post insecticde application.

Table 1. Seeding, harvest, and chemical application dates.

Trt	Seeding Date		Insecticide Application		Herbicide Date	Harvest Date
1	Early	May 15/20	control	n/a	Jun 16/20	Aug 27/20
2			pre-flower	Jul 6/20		
3			post-flower	Jul 20/20		
4	Mid	Jun 1/20	control	n/a	Jun 16/20	Sep 4/20
5			pre-flower	Jul 20/20		
6			post-flower	Jul 31/20		
7	Late	Jun 15/20	control	n/a	Jul 7/20	Sep 11/20
8			pre-flower	Jul 29/20		
9			post-flower	Aug 10/20		

n/a = not applicable

Weed control consisted of post-emergent tank mix applications of Viper® ADV (imazamox + bentazon; 0.4 L/ac) and 28% UAN (urea-ammonium nitrate; 0.8 L/ac) for peas and Ares™ (imazamox + imazapyr; 0.24 L/ac) and Merge® Adjuvant (surfactant blend + solvent; 0.5 L/ac) for lentils (Table 1). Matador® (lambda-cyhalothrin; 0.032 L/ac) was applied to both peas and lentils in treatments that required an insecticide application (Table 1). Mid-seeded pea and lentil plots were desiccated with Reglone® Ion (diquat, 0.83 L/ac) on August 31, 2020.

Yields were estimated by direct cutting the entire plot with a small plot combine when the plants were dry enough to thresh and seed moisture content was <20%. Harvest plot size was 6 m x 1.5 m. Plot samples were cleaned, and yields were adjusted to 14.5% moisture. In-season precipitation was 155.6 mm (6.1”) and total in-season irrigation applied was 40.6 mm (1.6”).

Mean monthly temperatures and precipitation amounts are listed in Tables 2 and 3. The 2020 season was comparable to the long-term average with respect to temperature, but rainfall was below average.

Table 2. Mean monthly temperature from May to August 2020 at the ICDC trial location.

Location	Year	May	June	July	August	Average
		------------ *Mean Temperature (°C)* -----------				
Outlook	2020	11.3	15.9	19.1	18.8	16.3
	Long-term	***11.5***	***16.1***	***18.9***	***18.0***	**16.1**

Table 3. Precipitation amounts vs. long-term (30 year) means for the 2020 growing season.

Location	Year	May	June	July	August	Average
		-------------- *Precipitation (mm)* --------------				
Outlook	2020	27.8	79.2	29.6	19.0	155.6
	Long-term	***42.6***	***63.9***	***56.1***	***42.8***	**205.4**

Results

Seeding date was the only factor driving differences in yield and maturity (Table 4). Early seeded pea and lentil yielded 19% and 30% higher than their mid-seeded counterparts, respectively. For both crops, yields were further reduced at the late seeding date. These differences in yield are expected as there was not enough time for plants in the mid or late seeded plots to reach maximum yield during their reduced growing season. Ambient aphid populations appeared to be below economic threshold levels and had no effect on yield in unsprayed plots at any seeding date.

Table 4. Influence of seeding date and insecticide application on yield and maturity of pea and lentil. Different letters indicate significant differences between seeding dates (ANOVA, $P \leq 0.05$).

Factor	Pea		Lentil	
	Yield (kg/ha)	**Maturity** (days)	**Yield** (kg/ha)	**Maturity** (days)
Seeding Date				
Ealy Seeded	2,657 *a*	229.8 *c*	1,442 *a*	232.5 *c*
Mid Seeded	2,142 *b*	242.2 *b*	1,005 *b*	242.8 *b*
Late Seeded	868 *c*	250.2 *a*	439 *c*	250.4 *a*
LSD (0.05)	163	0.9	141	1.3
CV (%)	10.26	0.46	17.4	0.62
Insecticide Application				
No Application	1,934 *a*	240.3 *a*	946 *a*	241.8 *a*
Pre-Flower	1,907 *a*	240.7 *a*	936 *a*	241.8 *a*
Post-Flower	1,827 *a*	241.1 *a*	1,004 *a*	242.1 *a*
LSD (0.05)	NS	NS	NS	NS
Seeding Date x Insecticide Application				
LSD (0.05)	NS	NS	NS	NS

NS = not significant

Acknowledgements

Financial support was provided by the Strategic Field Program. All funding is gratefully acknowledged.

Enhanced Fertilizer Management for Optimizing Yield and Protein in Field Pea

Funding

Funded by the Saskatchewan Pulse Growers Applied Research and Demonstration Program (ARD)

Organizations

- Irrigation Crop Diversification Corporation (ICDC), Outlook
- Indian Head Applied Research Foundation (IHARF), Indian Head
- East Central Research Foundation (ECRF), Yorkton
- Western Applied Research Corporation (WARC), Scott
- North East Research Foundation (NARF), Melfort
- Wheatland Conservation Association (WCA), Swift Current

Project Lead

- Project P.I: Chris Holzapfel (IHARF)
- ICDC Leads: Erin Karppinen & Garry Hnatowich

Objectives

The objective of the study is to evaluate field pea yield and protein response to various rates and combinations of nitrogen (N), phosphorus (P) and sulphur (S) fertilizer additions.

Research Plan

Note that this trial was also conducted at each of the additional Agri-ARM sites listed above.

The ICDC trial was established at CSIDC in the spring of 2020 on Field #8. The trial was established in a factorial randomized complete block design with four replicates. Treatments are listed in Table 1. The treatments were designed to evaluate phosphorus (P) and sulphur (S) responses as well as several nitrogen (N) fertilization strategies on yield and protein. To capture the possible full response range, an absolute control (unfertilized) and "high" fertility treatment were included. P and S sources used were monoammonium phosphate (11-52-0) and ammonium sulphate (21-0-0-24). The N source was urea (46-0-0) except for treatments 12 & 13 where polymer coated urea (ESN; 44-0-0) was used.

Table 1. Fertilizer Treatments of Field Pea, 2020.

<table>
<tr><th>Treatment</th><th>Fertilizer Applied
(kg N-P_2O_5-K_2O-S/ha)</th><th colspan="2">Treatment Description/Objectives</th></tr>
<tr><td>1</td><td>0-0-0-0</td><td colspan="2">Absolute control – no fertilizer</td></tr>
<tr><td>2</td><td>17.2-0-0-10</td><td>0 P control</td><td rowspan="5">Phosphorus Response</td></tr>
<tr><td>3</td><td>17.2-20-0-10</td><td>20 P</td></tr>
<tr><td>4</td><td>17.2-40-0-10</td><td>40 P</td></tr>
<tr><td>5</td><td>21.4-60-0-10</td><td>60 P</td></tr>
<tr><td>6</td><td>25.7-80-0-10</td><td>80 P</td></tr>
<tr><td>7</td><td>17.2-40-0-0</td><td>0 S</td><td rowspan="3">Sulphur Response</td></tr>
<tr><td>8</td><td>17.2-40-0-5</td><td>5 S</td></tr>
<tr><td>9</td><td>21.6-40-0-15</td><td>15 S</td></tr>
<tr><td>10</td><td>40-40-0-10</td><td colspan="2" rowspan="3">N Rates, Forms, and Timing/Placement for Yield and Protein</td></tr>
<tr><td>11</td><td>17.2-40-0-10 + 40 N in-crop broadcast Urea</td></tr>
<tr><td>12</td><td>40-40-0-10* (40 N as MAP/AS/ESN)</td></tr>
<tr><td>13</td><td>40-80-0-15* (ultra high fertility/ESN)</td><td colspan="2">High Fertility</td></tr>
</table>

Soil test results from soils within the trial area and collected on May 15, 2020 are shown in Table 2.

Table 2. Soil Test Analysis Results, ICDC Field 8 on-station location.

Soil Parameter	Depth (cm)	Value
NO_3^--N (lb/ac)	0 – 15	22
	15 – 30	11
	30 – 60	26
SO_4^{2-}-S (lb/ac)	0 – 15	42
	15 – 30	120+
P (ppm)	0 – 15	24
K (ppm)	0 – 15	200
pH	0 – 15	7.6
	15 – 30	7.8
Soluble Salts (mmho/cm)	0 – 15	0.34
	15 – 30	0.65
Organic Matter (%)		2.4
CEC (meq)		25.2

On May 16, 2020, CDC Spectrum field pea was seeded at a rate of 100 viable seeds/m^2 (adjusted for % germination, seed size, and 90% seedling survival). The trial area received a pre-seed herbicide application of granular Edge (ethalfluralin) on May 11, 2020. Weed control consisted of post-emergent tank mix applications of Viper® ADV (imazamox + bentazon; 0.4 L/ac) and 28% UAN (urea-ammonium nitrate; 0.8 L/ac). The entire trial was desiccated with Reglone® Ion (diquat, 0.83 L/ac) on August 24, 2020. The trial was direct harvested with a small plot combine August 26, 2020. Plot yield samples were cleaned, and yields adjusted to 16% moisture.

Mean monthly temperatures and precipitation amounts are listed in Tables 3 and 4. The 2020 season was comparable to the long-term average with respect to temperature. Rainfall was below average. The irrigation applied to the site was 27.5 mm in May, 12.5 mm in June, and 12.5 mm in July.

Table 3. Mean monthly temperature from May to August 2020 at the ICDC trial location.

Location	Year	May	June	July	August	Average
		------------ Mean Temperature (°C) -----------				
Outlook	2020	11.3	15.9	19.1	18.8	16.3
	Long-term	***11.5***	***16.1***	***18.9***	***18.0***	**16.1**

Table 4. Precipitation amounts vs. long-term (30 year) means for the 2020 growing season.

Location	Year	May	June	July	August	Average
		-------------- Precipitation (mm) --------------				
Outlook	2020	27.8	79.2	29.6	19.0	155.6
	Long-term	***42.6***	***63.9***	***56.1***	***42.8***	**205.4**

Results

Results obtained are outlined in Tables 5 and 6.

Table 5. Pea yield and % protein as influenced by fertilizer applications.

Trt	**Fertilizer Applied** (kg N-P_2O_5-K_2O-S/ha)	**Yield** (kg/ha)	**Yield** (bu/ac)	**Protein** (%)	**Test Weight** (kg/hl)	**Seed Weight** (g/1000)
1	0-0-0-0 (no fertilizer)	5,328	79.2	24.4	81.9	232
2	17.2-0-0-10 (0 P)	5,312	79.0	24.0	81.8	231
3	17.2-20-0-10 (20 P)	5,268	78.3	24.1	81.8	231
4	17.2-40-0-10 (40 P)	5,306	78.9	24.7	81.4	234
5	21.4-60-0-10 (60 P)	5,362	79.7	24.5	81.8	222
6	25.7-80-0-10 (80 P)	5,065	75.3	24.8	81.8	210
7	17.2-40-0-0 (0 S)	5,383	80.0	24.5	81.9	221
8	17.2-40-0-5 (5 S)	5,271	78.4	24.6	81.8	235
9	21.6-40-0-15 (15 S)	5,157	76.7	24.6	81.7	217
10	40-40-0-10 (40 N as MAP/AS/Urea)	5,135	76.4	25.0	81.4	220
11	17.2-40-0-10 + 40 N in-crop broadcast Urea	5,055	75.2	25.0	81.5	223
12	40-10-0-10* (40 N as MAP/AS/ESN)	5,149	76.2	24.8	81.4	212
13	40-80-0-15* (ultra high fertility/ESN)	5,388	80.1	24.9	81.8	226
	LSD (0.05)	NS	NS	NS	NS	12.4
	CV (%)	4.0	4.0	2.7	0.5	3.9

*Supplemental N provided as ESN in Treatments 12 & 13
NS = not significant

Table 6. Plant growth characteristics as influenced by fertilizer applications.

Trt	**Fertilizer Applied** (kg N-P_2O_5-K_2O-S/ha)	**10% Flower** (days)	**Maturity** (days)	**Height** (cm)	**Lodging** (1=erect; 9=flat)
1	0-0-0-0 (no fertilizer)	54	94	86	1.50
2	17.2-0-0-10 (0 P)	55	94	89	1.75
3	17.2-20-0-10 (20 P)	54	94	91	1.50
4	17.2-40-0-10 (40 P)	55	95	89	1.75
5	21.4-60-0-10 (60 P)	55	94	88	1.50
6	25.7-80-0-10 (80 P)	55	94	88	2.00
7	17.2-40-0-0 (0 S)	55	94	89	1.25
8	17.2-40-0-5 (5 S)	54	94	77	1.75
9	21.6-40-0-15 (15 S)	54	94	86	1.75
10	40-40-0-10 (40 N as MAP/AS/Urea)	55	94	87	1.75
11	17.2-40-0-10 + 40 N in-crop broadcast Urea	55	94	84	2.25
12	40-10-0-10* (40 N as MAP/AS/ESN)	55	93	88	1.75
13	40-80-0-15* (ultrahigh fertility/ESN)	55	93	89	1.75
	LSD (0.05)	NS	NS	NS	NS
	CV (%)	0.9	0.6	7.8	23.5

*Supplemental N provided as ESN in Treatments 12 & 13
NS = not significant

In general, pea yields where good, median seed yield of all treatments was 5,241 kg/ha (77.9 bu/ac). However, no response to any fertilizer treatments with respect to seed yield, seed protein content, or any other agronomic parameter measured was found to occur (except for seed weight which was variable). This is undoubtable attributed to the high residual soil fertility of the selected site. The trial location had soil available levels of N, P and S sufficient to provide optimal yields without supplemental fertilizer applications.

Ideally, this site would not have been chosen on which to conduct the trial. Unfortunately, this project was influenced by the Covid-19 pandemic of 2020. Access to the CSIDC research station was not allowed until mid-May. As a consequence of the shortened planting season, planting occurred prior to receiving the soil test results. It was hoped and expected based on typical soil test levels at CSIDC, that soil fertility would be lower. Unfortunately, high residual nutrient levels persisted from high fertilizer applications to potato trials grown several years prior. Due to Covid-19 restrictions, we were not afforded the ability to soil test earlier, nor seek alternative land allocation. The results do, however, provide an indication of soil test nutrient levels that are sufficient for high field pea yields.

The study results will be combined in a multi-year, multi-site analyses by IHARF and made available to ICDC upon completion.

Acknowledgements

Financial support was provided by the Saskatchewan Pulse Growers. All funding is gratefully acknowledged.

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Appendix A

Table A1. Soil Testing Report Pederson Off-Station Location, Agvise Laboratories, Sampled Spring 2020.

Soil Parameter	Depth (cm)	Value
NO_3^--N (lb/ac)	0 – 15	31
	15 – 30	16
	30 – 60	26
SO_4^{2-}-S (lb/ac)	0 – 15	30
	15 – 30	60
P (ppm)	0 – 15	9
K (ppm)	0 – 15	204
pH	0 – 15	7.8
	15 – 30	8.0
Soluble Salts (mmho/cm)	0 – 15	0.42
	15 – 30	0.48
Organic Matter (%)		3.3
CEC (meq)		20.5

Table A2. Soil Testing Report Knapik Off-Station Location, Agvise Laboratories, Sampled Spring 2020.

Soil Parameter	Depth (cm)	Value
NO_3^--N (lb/ac)	0 – 15	4
	15 – 30	4
	30 – 60	8
SO_4^{2-}-S (lb/ac)	0 – 15	52
	15 – 30	32
P (ppm)	0 – 15	7
K (ppm)	0 – 15	153
pH	0 – 15	8.0
	15 – 30	8.1
Soluble Salts (mmho/cm)	0 – 15	0.24
	15 – 30	0.20
Organic Matter (%)		1.3
CEC (meq)		12.3

Table A3. Soil Testing Report ICDC On-Station Location (Field 51), Agvise Laboratories, Sampled Spring 2020.

Soil Parameter	Depth (cm)	Value
NO_3^--N (lb/ac)	0 – 15	2
	15 – 30	3
	30 – 60	2
SO_4^{2-}-S (lb/ac)	0 – 15	76
	15 – 30	120+
P (ppm)	0 – 15	2
K (ppm)	0 – 15	308
pH	0 – 15	8.1
	15 – 30	8.2
Soluble Salts (mmho/cm)	0 – 15	0.44
	15 – 30	1.43
Organic Matter (%)		2.5
CEC (meq)		18.3

Table A4. Soil Testing Report CSIDC On-Station Location (Field 8), Agvise Laboratories, Sampled Spring 2020.

Soil Parameter	Depth (cm)	Value
NO_3^--N (lb/ac)	0 – 15	22
	15 – 30	11
	30 – 60	26
SO_4^{2-}-S (lb/ac)	0 – 15	42
	15 – 30	120+
P (ppm)	0 – 15	24
K (ppm)	0 – 15	200
pH	0 – 15	7.6
	15 – 30	7.8
Soluble Salts (mmho/cm)	0 – 15	0.34
	15 – 30	0.65
Organic Matter (%)		2.4
CEC (meq)		25.2

FRUIT AND VEGETABLE CROPS

Specialty Agriculture Demonstration

Funding

This project was funded by the Ag Demonstration of Practices and Technology (ADOPT) program, through the Canadian Agricultural Partnership (CAP).

Principal Investigator

- Cara Drury, PAg, Irrigation Agrologist, Ministry of Agriculture

Organizations

- Irrigation Crop Diversification Corporation (ICDC)
- Canada-Saskatchewan Irrigation Diversification Centre (CSIDC)
- Saskatchewan Vegetable Growers' Association (SVGA)

Objectives

The objective of this trial is to provide an opportunity for new growers and buyers to see these specialty crops produced in Saskatchewan's growing conditions. The specialty crops include:

(1) Monkshood, *Aconitum carmichaelli*
(2) Foxglove, *Digitalis sp.*
(3) Valerian, *Valeriana officinalis*
(4) Chicory*, Cicoria siciliana*
(5) Oregano, *Origanum vulgare*
(6) Caraway, *Carum carvi*
(7) Borage, *Borago officinalis*
(8) Coriander, *Coriandrum sativum*
(9) Hops, *Humulus lupulus*
(10)Hemp (for CBD oil), *Cannabis sp.*

Research Plan

Significant delays in accessing facilities and land at CSIDC occurred in the spring due to Covid-19. It was originally planned to start plants in CSIDC's greenhouse, then transplanting to the herb garden. It was not possible to start seeds in the greenhouse; therefore, many plants were direct seeded and slow to develop.

The borage, hemp, coriander, caraway and chicory seed were planted on May 27. An EarthWay planter, was used to seed at ¼" depth and seeding disks appropriate to each seed size.

The oregano, valerian and hops were mailed out from Richters' on May 25, due to shipping delays from Covid-19 they did not arrive in Outlook until June 3 (oregano) and 4 (valerian and hops). All plants were alive when they arrived, but not in the best condition. Transplanting took place on June 4 and 5.

Results

Due to delays and access restrictions from Covid-19 restrictions, this project has been extended for an extra year. Results will be available in 2022.

Growing Methods to Assist in the Expansion of the Garlic Industry in SK

Funding

This trial is funded by the Strategic Field Program (SFP), through the Canadian Agricultural Partnership (CAP).

Principal Investigator

- Connie Achtymichuk, PAg, Provincial Vegetable Specialist, Ministry of Agriculture
- Dr. Doug Waterer, PAg, Judd Street Associates

Organizations

- Irrigation Crop Diversification Corporation (ICDC)
- Canada-Saskatchewan Irrigation Diversification Centre (CSIDC)
- Saskatchewan Vegetable Growers' Association (SVGA)
- Conservation Learning Centre (CLC)

Objectives

The objectives of this trial include:

(1) To compare appropriate varieties of garlic for fresh market and for processing.
(2) To try to control bulb size through different management techniques.
(3) To evaluate agronomic protocols for establishment of garlic from bulbils.
(4) To compare processing quality of garlic rounds compared to standard bulbs.

Research Plan

Garlic Variety Evaluation
3 repetitions x 2 sites x 2 years).
Up to 10 varieties will be planted in spring of year 1. Some planting material was retained from the ADOPT 2018 garlic trial – while other cultivars may be accessed from commercial suppliers if required. Varieties that do not perform well will be eliminated as the trial proceeds. Information collected will include: emergence, marketable yield, bulb weight, number of cloves per head, bulbil type – (lots of bulbils vs few bulbils). Samples of promising varieties will be submitted to the Food Centre for processing trials. Processing parameters investigated will include color, flavour, oil content and texture. A portion of the crop will be held back and its quality following cold storage (0C and 50% RH) will assessed over the course of the winter, to ensure that the crop will be marketable throughout the winter.

In the fall of 2019 another crop will be established using the plant material generated by the spring planted corp. Overwinter survival will be assessed in the next year, along with the previously outlined yield and quality parameters.

Evaluation of techniques to manage Bulb Size
3 repetitions x 2 sites x 2 years
Different markets require different sizes of garlic bulbs. At present, the garlic bulbs grown in SK is larger

than what is preferred in some markets. Literature suggests that planting garlic in spring reduces bulb size. Not removing the scapes may also reduce bulb size in stiff neck types of garlic. Closer in-row spacing might also reduce bulb size. In this trial, the impact on bulb size and overall yield potential will be compared for: spring versus fall planted garlic, in-row spacing of 3" vs 5" inches, scapes removed or left to develop.

Multiplication of garlic by bulbils
3 repetitions x 2 years
The fact that Bulbils are an efficient method of increasing production has already been proven (Waterer –ADOPT Project 2014). However, when bulbils are planted, the resulting crop is usually comprised of "rounds" – that is garlic heads which have not yet separated into multiple cloves. This project will assess the processing attributes of garlic rounds. Bulbils of the cultivars from the cultivar evaluation trial will be planted in the spring of 2019. Three quarters of the resulting crop will be harvested in the fall. Yields will be determined and then samples will be sent to the Food Centre for processing analysis. The remaining one quarter of the crop will be left to overwinter and regrow the next year Yields of this crop will be assessed the following summer. The weights and the number of cloves per head will be assessed to confirm that this is not changed by the type of seed used.

Results

This trial is currently ongoing, final results will be published in 2022. An update on progress to date follows:

Garlic Variety Evaluation
Garlic variety trials were established under dryland conditions at the Conservation Learning Center (CLC) near Prince Albert and under irrigation at the Canada-Saskatchewan Irrigation Diversification Center (CSIDC) in Outlook in the spring and fall of 2019. In the spring planted trial, some of the varieties tested performed well - but others failed - likely because of disease problems in the seeded material. Yields obtained from the spring planted variety trial were generally low, and many plants failed to produce a cloved bulb. At both test sites, the performance of the new variety Krestova (hardneck) was clearly superior to all of the other varieties tested in the spring planted trial. Krestova also had the best overall quality in assessments conducted by the Food Center. As expected, yields and crop quality from the fall planted trial were superior to a spring planted crop. At the CSIDC site, California Artichoke (softneck) and Persian Star (hardneck) had the best overall yield performance in the fall planted trial. Yugoslavian (hardneck) also performed well at the CSIDC site, but this variety produces very few cloves per bulb and will therefore be very expensive to plant. At the CLC site, Persian Star and Spanish Roja (hardneck) were outstanding. Krestova, which had performed well in spring planted trials, did not over-winter well at either site, even though the plantings were protected through the winter with straw mulch. Music, which is presently the most widely grown variety of hardneck garlic, performed poorly in spring and fall planted trials at both test sites.

Multiplication of garlic by bulbils
Using bulbils instead of cloves to establish a garlic crop has several potential advantages;
a) when using cloves to establish a garlic crop, growers must hold back 10-20% of their crop for replanting, as each bulb typically consists of only 5-10 cloves. By contrast, each garlic flower produces

30-300 bulbils, depending on the variety. Using bulbils to establish the crop makes efficient use of a crop component that otherwise would be discarded.

b) garlic cloves may be contaminated with a range of persistent soil-borne pathogens such as Fusarium, Penicillium and stem and bulb nematodes. As the bulbils do not come in contact with the soil, they should harbor fewer of these potential pathogens.

c) bulbils store better than bulbs - with less dehydration and disease. This should mean that the bulbils are in better condition at planting than standard cloves.

d) the roundish shaped bulbils are easy to singulate and seed using speciality crop seeders or even standard corn planters.

Spring and fall planted trials conducted under dryland conditions at the Conservation Learning Center (CLC) near Prince Albert and under irrigation at the Canada-Saskatchewan Irrigation Diversification Center (CSIDC) in Outlook over the 2019 and 2020 growing seasons showed that it was possible to use bulbils to establish a garlic crop. The crop had to be seeded heavily, as only 20-50% of the bulbils went on to produce a viable plant. Weed control was important as the seedlings produced from bulbils were small and slow growing. When bulbils were used as planting material, most varieties produced uncloved "rounds" by the end of the first growing season. However, the Italian Purple variety formed small but fully cloved bulbs in a single growing season when planted as bulbils. Typically, the rounds are harvested and then replanted - yielding a fully cloved bulb by the end of the next growing season. Alternatively, the rounds may be consumed as they have all the flavor attributes of standard cloves - and are easier to store and peal. This project also showed that it was also possible to harvest standard sized, fully-cloved bulbs of garlic using bulbils as the starting material if the crop was allowed to grow for 2 full growing seasons without harvesting and then replanting at the end of year 1. This eliminated the time and labor costs associated with harvesting and then re-planting the rounds - and it also reduced weed problems in the 2nd growing season.

TECHNOLOGY TRANSFER

CSIDC Irrigation Field Day and Tradeshow, July 11

- Joel Peru – Irrigated Canola Production Survey
- Cara Drury - Horticulture Trials, Crops with Opportunities and Irrigated Beet Cultivar Demonstration
- Dry Bean Field Tour, Riverhurst, July 27 – 45 people in attendance
- Gary Kruger- ICDC Dry Bean Project Overview
- Conservation Learning Centre Field Day, July 18 - 35 in attendance
- Garry Hnatowich – 4R N Fertilizer of Winter & Spring Wheat, Farm Saved Seed vs Certified Seed, Fall Rye N Fertilization, Wheat Seeding Rate & Row Spacing Effect on Weed Density, Spring Wheat Soil & Fertilizer N Response

Workshops

- Growing Corn: From Seeding to Feeding, Outlook, March 21st
- Joel Peru- Irrigation Scheduling and Crop Water Use of Corn
- Gary Kruger – Enhanced Efficiency Nitrogen Fertilizers for Irrigation
- Garry Hnatowich – Agri-ARM Agronomy Update, Dry Bean Production, Jan. 17
- Garry Hnatowich – SeCan Soybean Expo, Soybean Production in SK, Jan. 30
- Garry Hnatowich – Guest Lecture, U of S, Feb. 14
- Garry Hnatowich – WARC Crop Opportunities, March 13

Irrigation Management workshop, Outlook, March 27th

- Joel Peru-AIMM Alberta Irrigation Management Model Demonstration
- Gary Kruger – Irrigation Scheduling – Methods and Tools
- Kelly Farden- Reclamation and Water Management of Saline Soils

Crop Diagnostic School – Scott – July 23-24 – 175 in attendance

- Joel Peru- Apps for Farmers and Agrologists station
- Gary Kruger – Dry bean inoculant and N Fertilization Demonstration Posters
- ICID Conference - Gary Kruger – Specialized Nitrogen for Irrigated Canola (Brassica napus) in Saskatchewan

Publications

- Crop Varieties for Irrigation, January
- Irrigator, March - Horticulture trial ventures into value added processing - Cara Drury
- Nitrogen Efficiency Enhancer Fertilizer for Irrigation - Gary Kruger
- Irrigated Corn for Silage or Grazing – Travis Peardon
- Irrigated Wheat Survey Results and Going Forward – Joel Peru
- Saskatchewan Agricultural Hall of Fame – Roger Pederson
- Irrigator, November - ICDC Research and Development – Garry Hnatowich
- Disease Management of Dry Beans – Gary Kruger
- Fababean: Diversification Crop for Lake Diefenbaker Irrigation Area in 2020? - Gary Kruger
- Learn about ICDC's Research on their new YouTube Channel – Joel Peru
- ICDC's Horticulture Program – Cara Drury
- 2019 ICDC Research and Demonstration Report – March

Presentations

Joel Peru

- 2019 SIPA/ICDC Conference– 2018 Irrigated Canola Survey, December 3

Gary Kruger

- 2019 SIPA/ICDC Conference– 2019 Irrigated Canola Survey, December 3

Cara Drury

- 2019 SIPA/ICDC Conference– Expansion of the Pickling Cucumber Industry in Saskatchewan, December 3
- 2020 SVGA Annual Conference and AGM- Demonstration on Beet Varieties and Demonstration of Crops with Opportunities, January 2020
- Garry Hnatowich – ICDC Research Program Overview

Crop Production Newsletter

Joel Peru

- Crop Production News #1 Crop Walks Return for 2019
- Crop Production News #2 Importance of Irrigation Scheduling 2019
- Crop Production News #6 ICDC's Youtube Channel

Gary Kruger

- Crop Production News #4 – Alternative control products for white mold and bacterial blight in irrigated dry bean
- Lake Diefenbaker Development Area Cropping Survey (Joel Peru, Gary Kruger)
- 2018 Irrigated Canola Survey (Joel Peru, Gary Kruger, Cara Drury)

Social Media

- Weekly Crop Water Use updates
- Twitter
- YouTube Videos

ABBREVIATIONS

AAFC	Agriculture and Agri-Food Canada
ac	acre or acres
ACC	Alberta Corn Committee
ADF	Agriculture Development Fund
ADOPT	Agriculture Demonstration of Practices and Technologies (Canadian Agricultural Partnership Program)
AIMM	Alberta Irrigation Management Model
bu	bushel or bushels
CCC	Canola Council of Canada
CDC	Crop Development Centre, University of Saskatchewan
cm	centimetre
CSIDC	Canada-Saskatchewan Irrigation Diversification Centre
DM	dry matter
FHB	Fusarium head blight
GPS	Global Positioning System
ICDC	Irrigation Crop Diversification Corporation
ICID	International Commission on Irrigation & Drainage
L	litre
lb	pound or pounds
m	metre
MAFRI	Manitoba Agriculture, Food and Rural Initiatives
mm	millimetre
SPARC	Semiarid Prairie Agricultural Research Centre
SVPG	Saskatchewan Variety Performance Group
t	tonne
TKW	thousand kernel weight
WGRF	Western Grains Research Foundation

The Irrigation Saskatchewan website at http://irrigationsaskatchewan.com is designed so that site visitors have access to irrigation topics related to ICDC, SIPA and the Ministry of Agriculture. The site directs visitors to an ICDC subsection, a SIPA subsection, and a link to the irrigation section of the Saskatchewan Ministry of Agriculture's website.

The ICDC section includes ICDC reports, publications, and events, as well as links to information relevant to irrigation crops.

ICDC Publications

ICDC Research and Demonstration Program Report Detailed descriptions of the projects undertaken each year.

Irrigation Economics and Agronomics An annual ICDC budget workbook designed to assist irrigators with their crop selection process. Irrigators can compare their on-farm costs and productivity relative to current industry prices, costs and yields. A copy of the workbook is available in an excel format on the ICDC website

Crop Varieties for Irrigation A compilation of yield comparison data from irrigated yield trials managed by ICDC. It is useful as a guide for selecting crop varieties suitable for irrigation.

Irrigation Scheduling Manual Provides technical information required by an irrigator to effectively schedule irrigation operations for crops grown under irrigation in Saskatchewan.

Irrigated Alfalfa Production in Saskatchewan Provides technical information regarding the production practices and recommendations for irrigated alfalfa forage production.

Irrigator A semi-annual newsletter providing irrigators with updates from ICDC

***Management of Irrigated Dry Bean*s** This factsheet provides a comprehensive overview of agronomic management requirements for producing dry beans under irrigation.

Corn Production This factsheet provides information on corn heat units, variety selection and an overview of agronomic management requirements for producing grain, silage and grazing corn under irrigation in Saskatchewan.

Copies of these and other ICDC publications are available from the Ministry of Agriculture's Irrigation Branch office in Outlook, SK, ICDC office or on the ICDC website at http://irrigationsaskatchewan/icdc.