

Update on winter wheat projects from the agronomy project *Enhanced Economic Returns and Ecosystem Services with the Expansion of Winter Wheat*

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Executive Summary

The overall objective of this DIAP project was to overcome obstacles in the adoption of winter wheat in western Canada. A two-fold approach was undertaken towards this objective. Firstly, studies were established to broaden the stubble acreage available late summer for seeding winter wheat. This included using alternate stubble types, managing alternate stubble types, and through the use of seed treatments to expand the amount of stubble available to seed winter wheat into in late summer. Secondly, studies were established to evaluate a number of pest and nutrient management strategies to promote winter wheat plant health, growth and yield stability. Improving these components of winter wheat allow producers to widen the length of the seeding window or seed into less optimum conditions and still realize reasonable success. The overarching theme of the research was the development of improved management practices.

The results of a number of the studies have provided some invaluable information for the industry. Furthermore, since this study was largely a collaboration of AAFC investigators, Ducks Unlimited Canada, and the producer-directed winter cereal commissions of the three Prairie Provinces, there has been several opportunities and venues to conduct extension events to transfer the information learned directly to the farm gate. For example, we have already observed a significant increase in the adoption of seed treatments, stubble alternative to canola such as pea stubble were proven to provide similar results, a better understanding of controlled-release N products has been derived from this project, and new chemistries have been identified

to improve weed management systems for winter wheat. Additional research is still required to reap all of the benefits of these studies and a number of these studies require more data collection but the activities conducted in this DIAP initiative have certainly provided an excellent starting point to supporting increased successful winter wheat production.

The first field season (2011) of the winter wheat project was challenging, but it was interesting to see that the winter wheat plots generally looked best on field day tours compared to the spring annual plots. In many cases, there were no spring annual plots due to flooding. In 2012, most experiments were conducted and executed without incident. In some experiments, we now have up to 19 site-years collected and will be continuing with other experiments to generate the necessary data required to adequately test to address the experimental objectives.

Human Resources

We have a few notable changes to our science team over the course of the study. Dr. Gary Peng assumed Dr. Randy Kutcher's role on the team. Dr. Ramona Mohr agreed to assume Dr. Byron Irvine's science duties related to these winter wheat studies.

We used this project as an opportunity to recruit and train Graham Collier, a graduate student under the supervision of Dr. Dean Spaner at the University of Alberta and Dr. Shuhao Qin, a visiting scientist from Gansu Agricultural University in the Gansu province of China working with Dr. Brian Beres.

On a much sadder note, we have lost Dr. Guy Lafond to cancer. The impact of Guy's passing will extend across the various projects that he lead or co-investigated. We are currently assessing how to deal with the optical sensor activities and data that Guy was leading.

Sub-Activity Updates

Sub-activity 1.1 (Test 211)

Determine the influence of seed-applied fungicides and insecticides on fall stand establishment and overwinter survival of winter wheat.

Seed Treatment Results

A total of 20 sites were established over the course of two growing seasons (2010-2011 and 2011-2012). Plant stand was not affected by the treatments, despite the fact the treatment visibly seemed to have affected winter wheat stand and growth early in the growing season (Fig. 1 and Table 1). Grain yield was improved relative to the untreated check when seed was treated with Imidacloprid insecticide or with Tebuconazole + Metalxyl fungicides + Imidacloprid insecticide (Raxil WW). The application of foliar fungicide (Prothioconazole – 'Proline') increased yield slightly to 4.56 Mg ha⁻¹ from 4.50

Mg ha⁻¹ (check). These results are intriguing as it would appear that the fungicide application elicited a favorable plant physiological response even in the absence of symptoms from foliar pathogens (e.g., strip rust at 200-11 sites). Furthermore, contrasts indicated that foliar fungicide positively affected stand survival and kernel wt., and nearly yield only with metalaxyl seed treatment. For test wt., the effect of foliar fungicide was significant only with Imidacloprid.

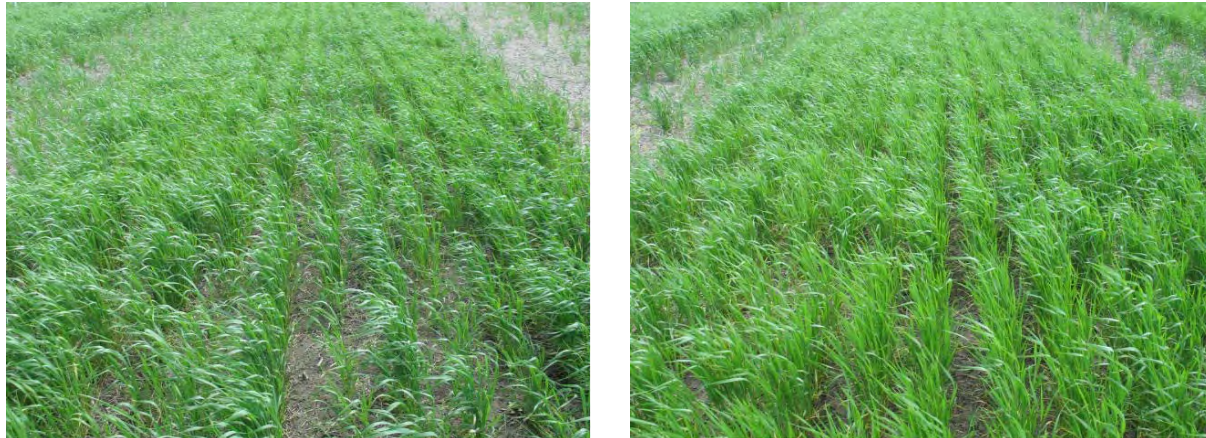


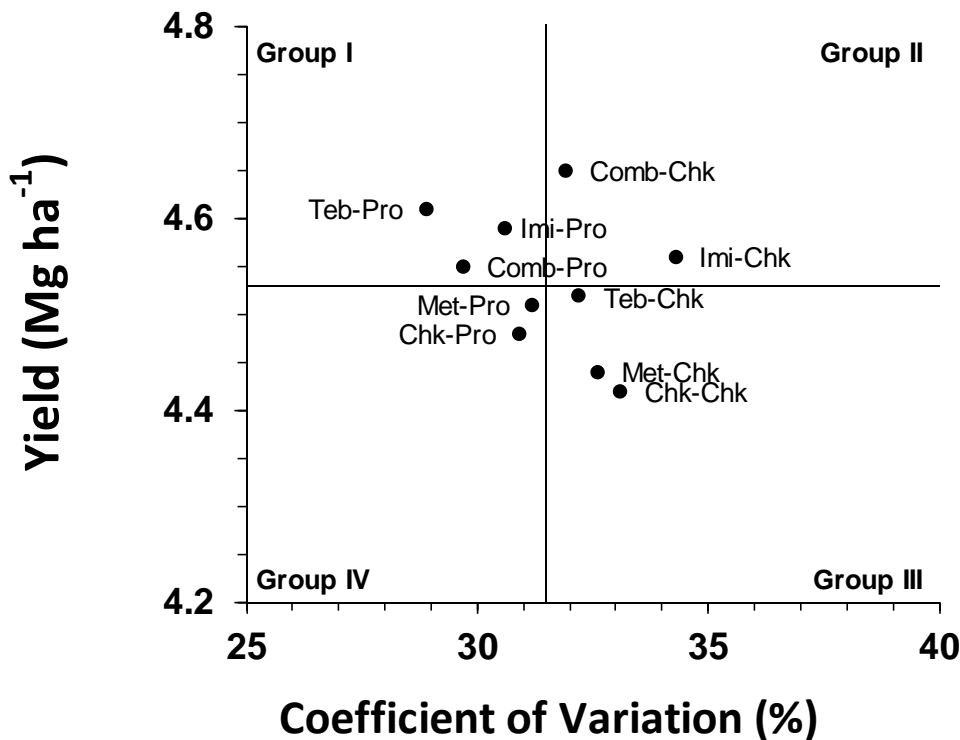
Fig. 1. Photo on left shows control treatment (no seed treatments applied) of CDC Buteo planted south of Lethbridge. Photo of right shows Raxil WW treatment of CDC Buteo planted south of Lethbridge.

Table 1. Winter wheat responses to seed treatment and fall applied foliar fungicide Prothioconazole.

	Survival		Yield		Kernel wt.		Test wt.	
	Check	Fung	Check	Fung	Check	Fung	Check	Fung
	(%)		(Mg ha ⁻¹)		(mg)		(kg hL ⁻¹)	
Check	109	113	4.42	4.52	34.1	34.0	80.0	79.9
Tebuconazole	113	112	4.52	4.56	34.1	34.1	79.9	79.9
Metalxyl	106	116	4.41	4.53	33.8	34.3	79.8	79.9
Imidacloprid	110	112	4.51	4.60	34.0	33.8	80.1	79.9
Combination	114	112	4.62	4.61	34.0	34.2	79.9	79.9
LSD0.05	6		0.12		0.5		0.2	

Abbreviations: Fung = fall foliar applied fungicides (Prothioconazole) and Combination = seed treatment combination of Tebuconazole + Metalxyl + Imidacloprid.

A plot of mean grain yield and the coefficient of variation for all treatment combinations showed that the check and metalaxyl seed treatment combinations were in the lesser yielding quadrats than other seed treatment combinations including Tebuconazole and Imidacloprid (Fig. 2). Also, treatments including foliar fungicide, Prothioconazole resulted in more stable (lesser CV) yields. The treatment providing the most stable, greater yields was the 'combination' seed treatment with fall-applied foliar fungicide, thus representing one way to stabilize winter wheat production on the Canadian Prairies.



Group I: High mean, low variability (optimal)
Group II: High mean, high variability
Group III: Low mean, high variability (poor)
Group IV: Low mean, low variability

Fig. 2. Biplot of grain yield vs. coefficient of variation for each treatment combination. Abbreviations: Chk = Check, Teb = Tebuconazole, Met = Metalxyl, Imi = Imidacloprid, Tebuconazole + Metalxyl + Imidacloprid, and Pro = fall foliar applied fungicides (Prothioconazole).

Sub-activity 1.2 (Test 212)

Improving the success of planting winter wheat into barley grain stubble.

One of the goals of this project is to successfully grow winter wheat in stubble other than canola. Barley would be a reasonable alternative, particularly in shorter season areas. We were interested to see what management strategies would be needed to control volunteer barley. Volunteer barley was suppressed by the winter wheat (cv. CDC Buteo) at all locations in 2010. Therefore, we concluded that we should instead change the objective to the following: Determine the efficacy of novel herbicides in controlling weeds in sub-optimal and optimal stands of winter wheat. If a producer does experience reduced stand establishment (i.e., not excessively damaged by winterkill), this study will help develop herbicide recommendations to optimize weed management.

Weeds such as wild oat and cleavers can be problematic if winter wheat stands are thin. Pyroxasulfone is an experimental herbicide that has activity on wild oat, *Bromus* spp., cleavers and other broadleaf weeds; however, its efficacy is inconsistent as it is a soil applied herbicide that relies on soil moisture for activation. The objective of this study is to determine the weed control efficacy of pyroxasulfone in managing weeds in optimal and sub-optimal stands of winter wheat. The study was conducted at five locations in Manitoba, Saskatchewan, and Alberta in 2012. Pyroxasulfone was applied pre-seed at rates of 100, 150, 200, and 250 g ai ha⁻¹ to winter wheat seeded at 450 (optimal stand) seeds m⁻² and 150 (sub-optimal stand) seeds m⁻². Pyroxasulfone weed control efficacy was compared to two post-emergence commercial standards.

Herbicide application did not affect plant density indicating that pyroxasulfone did not affect emergence. Visual tolerance of winter wheat to pyroxasulfone was generally low and considered acceptable. Pyroxsulam application resulted in the highest number of heads m⁻² (Table 2). It is speculated that spring pyroxsulam application may have resulted in some crop injury; thus, reducing apical dominance; an effect periodically observed with ALS inhibitor herbicides.

Table 2. Winter wheat responses to seeding rate and herbicide treatment.

Effect / Level	Winter wheat heads	Wild oat density (no. m ⁻²)	Cleaver density
Seeding rate (seeds m ⁻²)			
150	482	ns ^a	18
450	602	ns	6
Herbicide			
Pyroxasulfone 100	542	10	14
Pyroxasulfone 150	536	7	13
Pyroxasulfone 200	540	4	8
Pyroxasulfone 250	520	4	8
Pinoxaden / fluroxypyr / MCPA	557	4	5
Pyroxsulam	595	5	4
Weedy check	506	15	33

^a Not significant.

Weed densities often were low (mean location densities < 20 m⁻²). Seeding rate had no effect on wild oat density and pyroxasulfone often reduced wild oat density at rates ≥ 150 g ai ha⁻¹ across all locations (Table 2). An optimal winter wheat stand had lesser wild oat biomass than the sub-optimal stand and all herbicides resulted in lower wild oat biomass than the untreated check only at the location (Lacombe) with greatest wild oat density (results not shown). A pyroxasulfone rate ≥ 150 g ai ha⁻¹ reduced cleavers density at the location (Lacombe) where it was notably present (results not shown). An optimal stand (seed rate of 450 seeds m⁻²) resulted in a reduction in the pyroxasulfone rate required to reduce broadleaf weed biomass to levels similar to the commercial herbicide standards (Fig. 3).

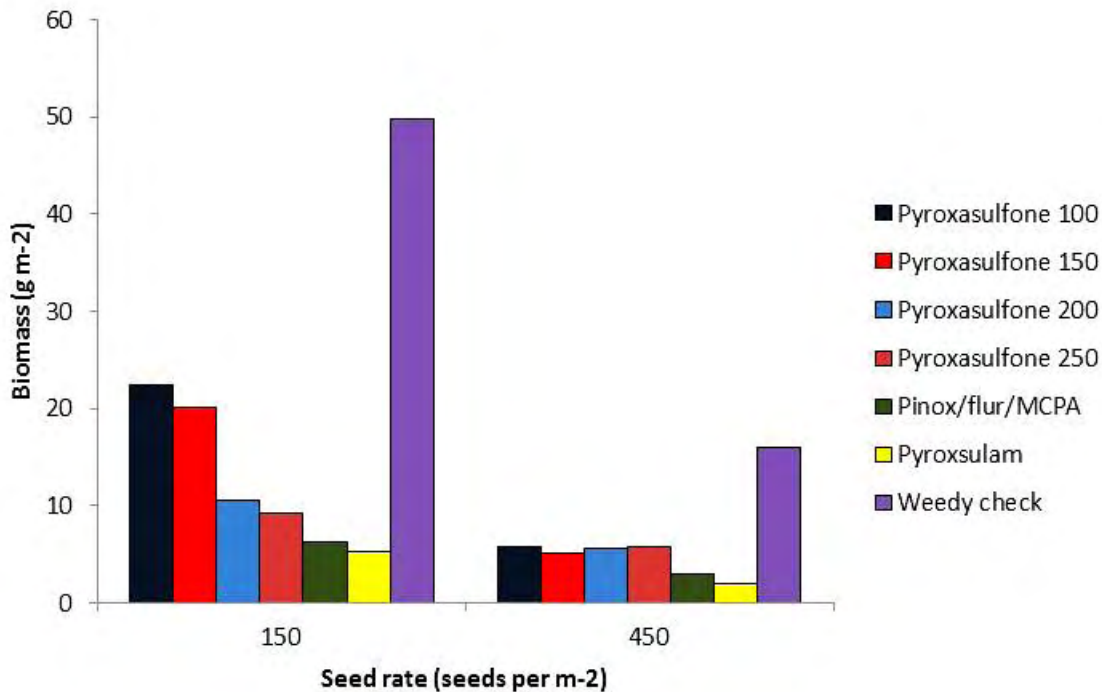


Fig. 3. Interaction of seed rate (plant density) and herbicide application on broadleaf weed biomass (mean of 5 locations) in winter wheat.

Winter wheat yield increased by 5% (4.85 to 5.10 Mg ha⁻¹) when seeding rate was increased from 150 to 450 seeds m⁻². Herbicide treatment did not affect yield due to low weed densities and the competitiveness of winter wheat.

Results from one year of data indicated integrated benefits of spring winter plant populations exceeding 250 plants m⁻² along with soil-applied pyroxasulfone to optimizing broadleaf weed control. The experiments will be conducted at the same locations for 2 more years if funding is secured from Growing Forward 2.

Sub-activity 1.3 (Test 213)

Managing nitrogen when planting winter wheat on barley grain stubble.

The major focus of this sub-activity is to determine if nitrogen management recommendations need to be altered when planting winter wheat into barley stubble. There is some concern that heavy trash left after barley is harvested could lead to N immobilization and cause deficiencies in winter wheat. This study was established at Brandon, and at locations in northern (Fahler) and southern (Lethbridge) Alberta in the fall of 2011. Treatments consisted of a factorial combination of four N rates (0, 40, 80, 120 kg N ha⁻¹) and six N application/straw treatments (urea banded at seeding, straw on surface; urea banded at seeding, straw removed; ESN banded at seeding, straw on

surface; SuperU banded at seeding, straw on surface; UAN dribble band in spring, straw on surface; SuperU broadcast in spring, straw on surface).

Also, N fertilizer rate increased most winter wheat responses, the exceptions being plant density, and kernel/test wt. (results not shown). Of more interest was N/straw management and interactions between the two N management responses. No significant interactions were evident between N fertilizer rate and N/straw treatment for any of the winter wheat responses. Nitrogen/straw management alone did impact some winter wheat responses.

Nitrogen/straw management did not affect plant density, grain quality, and N uptake responses. Midseason biomass yield at Lethbridge was greater when UAN was dribble-banded in spring (with barley residue on soil surface) relative to when urea was banded at seeding (barley residue removed); biomass yield was intermediate for the remaining treatments (Table 3). Greenseeker assessments of winter wheat growth in May and June showed that NDVI was affected by N/straw treatment only for the initial three assessments at Brandon. The consistent difference that emerged was that urea banded at seeding (residue removed) consistently resulted in an NDVI equivalent to or greater than other N/straw treatments (Table 3). At Brandon, grain yield was greater where urea was banded at seeding (residue removed) than where SuperU was spring broadcast (with residue applied in the spring) (Table 3). This followed the same general trend as NDVI values observed earlier in the season, suggesting that under the relatively dry conditions experienced in fall 2011 in Manitoba, urea banded at seeding (with residue removed) was more effective than spring broadcast SuperU (with residue applied in the spring) and as effective as the other N/straw treatments employed in this study. The extent to which spring-application of straw may have impacted the plant-available N supply in this treatment is unclear. No differences were evident between the spring broadcast SuperU treatment, and the remaining N/straw management treatments at Brandon, and for all treatments at Lethbridge.

Table 3. Winter wheat responses to N/straw management at Lethbridge and Brandon, 2012.

Location / N/straw management	Biomass yield (Mg ha ⁻¹)	NDVI ^a				Yield (Mg ha ⁻¹)
		1	2	3	4	
Lethbridge						
ESN banded at seeding	8.45ab	0.574	0.768	0.843		8.29
SuperU / banded at seeding	8.43ab	0.571	0.773	0.846		8.46
SuperU / spring broadcast	8.70ab	0.579	0.791	0.849		8.62
Urea / banded at seeding	8.41ab	0.559	0.775	0.834		7.82
Urea / banded at seeding	8.01b	0.0553	0.744	0.846		8.30
UAN / dribble banded in spring	8.87a	0.571	0.753	0.833		8.73
Brandon						
ESN banded at seeding		0.496ab	0.572ab	0.654b	0.664	4.43ab
SuperU / banded at seeding		0.525ab	0.583ab	0.654b	0.654	4.32ab
SuperU / spring broadcast		0.461b	0.549b	0.625b	0.658	4.16b
Urea / banded at seeding		0.469b	0.589ab	0.665ab	0.669	4.56ab
Urea / banded at seeding		0.595a	0.646a	0.719a	0.694	4.60a
UAN / dribble banded in spring		0.450b	0.554b	0.661ab	0.645	4.42ab

^a Greenseeker measurements 1, 2, 3 were conducted on May 14, 22, 29, respectively at Lethbridge. Greenseeker measurements 1, 2, 3, 4 were conducted on May 30th, and June 6, 13, and 22nd, respectively at Brandon.

Additional site-years of data are required to reach reliable conclusions regarding the impact of nitrogen fertilizer management on winter wheat established on barley stubble. A better understanding of the relative efficacy of conventional and enhanced efficiency N fertilizers, and their interaction with surface crop residues in winter wheat production systems, will be a necessary part of a more effective and efficient management package for winter wheat producers in western Canada.

Sub-activity 1.4 (Test 214)

Crop growth enhancement through improved residue management strategies.

This sub-activity builds upon sub-activities 1.2 and 1.3, but involves a wider array of potential alternative stubbles from barley to camelina.

Crop residue management is critical to successful winter wheat production on the Canadian prairies because it controls snow cover, which ultimately protects winter wheat from winterkill. The suitability of different stubble types for winter wheat is determined by the efficacy of stubble in trapping snow and the availability of stubble relative to the narrow window in which winter wheat can be seeded. Field studies were conducted to assess the direct and indirect impacts of surface crop residues from a wide range of crops on the growth, development, yield and quality of winter wheat.

The experiment was established at locations in Manitoba and Alberta in 2010 (2011 for one location near Brandon, MB). The stubble-establishment (1st) year treatments included: barley (swath removed); barley (swath removed, barley seeds broadcast at a rate of 400 seeds m⁻²); barley (combined to retain straw and chaff); canola (swathed and combined to retain straw and chaff); dry pea (desiccated and combined, with winter wheat seeded between stubble rows of the cereal preceding the pea crop); dry pea (desiccated and peas pulled rather than cut, with winter wheat seeded between stubble rows of the cereal crop preceding the pea crop); spring-seeded camelina (combined to retain straw and chaff); spring-seeded camelina (swath removed); fall-seeded camelina (combined with straw and chaff retained); and fall-seeded camelina (swathed with residue removed). Camelina treatments were not included at all locations. Winter wheat was seeded into the various stubble treatments in the fall of the establishment year.

The snow trapping potential (STP; stubble height in cm x stubble stems per square meter) / 100) of barley was considerably > 20 (considered adequate) whereas STP for canola or pea was consistently < 20 regardless of the residue management practices employed (Table 4). Spring camelina inconsistently resulted in STP that was adequate, but levels of STP were not as high as barley.

Table 4. Snow trapping potential responses to stubble treatment.

Stubble treatment	BrandonA	BrandonB	Beaverlodge	Lacombe	Lethbridge					
STP - Snow trapping potential										
Barley- swath removed	98	a ^a	70	a	76	a	103	a	31	a
Barley- swath removed, then barley seeds broadcast	111	a	61	a	69	ab	119	a	32	a
Barley- combined to retain straw and chaff	93	a	66	a	62	b	113	a	29	a
Canola- swathed and combined to retain straw and chaff.	12	b	9	bc	13	c	17	b	8	b
Dry pea- desiccated and combined; winter wheat seeded onto pea rows	12	b	5	c	11	cd	13	b		
Dry pea- desiccated and peas pulled rather than cut	13	b	6	bc	6	cd	28	b		
Camelina (spring) - combined to retain straw and chaff	38	b	19	bc	4	cd			22	a
Camelina (spring) - swath removed	41	b	24	b	8	cd			24	a
Camelina (fall) - combined to retain residue	--		--		2	d				
Camelina (fall) - swathed with residue removed	--		--		6	cd				

^a Values within a column followed by the same letter are not significantly different based on Tukey's multiple comparison procedure.

Seeding winter wheat after canola reduced winter wheat stands compared to seeding winter wheat after barley, pea or spring-seeded camelina at 2 of 3 locations (Table 5). It is likely that stand reductions for canola stubble contributed to the lesser winter wheat yields for canola stubble at Beaverlodge (Table 5). Seeding winter wheat after pea, but between the stubble rows from the cereal crop preceding the pea crop, resulted in similar winter wheat stands and greater grain yields than seeding winter wheat after barley at all locations. Estimated grain N uptake was greater for winter wheat after pea than after barley suggesting that differences in available N supply may have contributed in part to observed yield differences (Table 5).

Table 5. Winter wheat responses to stubble treatment.

Stubble treatment	Beaverlodge		Lacombe		Lethbridge	
Plant density (no. m ⁻²)						
Barley- swath removed	58	bc ^a	185	ab	102	a
Barley- swath removed, then barley seeds broadcast	65	abc	209	ab	113	a
Barley- combined to retain straw and chaff	71	ab	212	ab	103	a
Canola- swathed and combined to retain straw and chaff.	20	c	148	b	95	a
Dry pea- desiccated and combined; winter wheat seeded onto pea rows	93	ab	230	a	126	a
Dry pea- desiccated and peas pulled rather than cut	69	ab	211	ab	90	a
Camelina (spring) - combined to retain straw and chaff	82	ab			114	a
Camelina (spring) - swath removed	72	ab			114	a
Camelina (fall) - combined to retain residue	105	a				
Camelina (fall) - swathed with residue removed	109	a				
Yield (Mg ha ⁻¹)						
Barley- swath removed	2.64	abc	2.66	b	3.31	cd
Barley- swath removed, then barley seeds broadcast	2.99	ab	2.47	b	3.94	abc
Barley- combined to retain straw and chaff	2.82	abc	2.96	b	3.59	bc
Canola- swathed and combined to retain straw and chaff.	2.05	c	3.81	a	3.82	abc
Dry pea- desiccated and combined; winter wheat seeded onto pea rows	3.39	ab	3.78	a	4.18	ab
Dry pea- desiccated and peas pulled rather than cut	3.35	ab	3.71	a	4.26	a
Camelina (spring) - combined to retain straw and chaff	2.85	abc			2.79	d
Camelina (spring) - swath removed	3.42	a			2.82	d
Camelina (fall) - combined to retain residue	3.32	ab				
Camelina (fall) - swathed with residue removed	2.55	bc				
Grain N uptake (kg N ha ⁻¹)						
Barley- swath removed	53	cd	63	b	83	bc
Barley- swath removed, then barley seeds broadcast	59	bcd	59	b	98	ab
Barley- combined to retain straw and chaff	54	cd	70	b	90	abc
Canola- swathed and combined to retain straw and chaff.	50	d	90	a	102	a
Dry pea- desiccated and combined; winter wheat seeded onto pea rows	71	abc	85	a	106	a
Dry pea- desiccated and peas pulled rather than cut	71	abc	94	a	107	a
Camelina (spring) - combined to retain straw and chaff	67	abcd			76	c
Camelina (spring) - swath removed	79	a			73	c
Camelina (fall) - combined to retain residue	77	ab				
Camelina (fall) - swathed with residue removed	59	bcd				

^a Values within a column followed by the same letter are not significantly different based on Tukey's multiple comparison procedure.

Funding has been applied for to continue this study in order to collect additional site-years of data to reach reliable conclusions regarding the suitability of crop residue management practices for winter wheat production in western Canada.

Sub-activity 2.1 (Test 221)

The interaction of seed treatments and fall-applied foliar fungicides on winter hardiness and plant health of winter wheat.

This sub-activity parallels 1.1; explore seed treatment effects in winter wheat. We also introduced seed size, a proxy for seed vigour, and 2 levels of seeding rate (200 or 400 seeds m⁻²) as factors in this study. Consequently, we ended up with a range of agronomic systems from weak (low seed rate, small/thin seed, no seed protection) to superior (high seed rate, heavy/plump seed, dual seed treatment).

As with test 211, treatment visibly affected winter wheat stand and growth early in the growing season (Fig. 4). Results showed that winter wheat seed that included a dual (fungicide + insecticide) treatment improved plant stand, winter survival and yield (Table 6). Furthermore, the positive effect of seed treatment for yield was significant only for the least seeding rate.

Weak agronomic system without seed treatment (200 seeds m^{-2} + light/thin seed weight)



Superior agronomic system (400 seeds m^{-2} + heavy seed weight) without seed treatment



Weak agronomic system (200 seeds m^{-2} + light/thin seed weight) with seed treatment Raxil WW



Superior agronomic system (400 seeds m^{-2} + heavy seed weight) with seed treatment Raxil WW



Fig. 4. Photos show contrasting visual differences of the different winter wheat systems.

Table 6. Winter wheat responses to seed treatment and seeding rate.

Variable / Seeding rate	Check	Dual treated ^a	LSD0.05
Fall density (plants m^{-2})	183	193	7
Spring density (plants m^{-2})	171	188	6
Survival (%)	104	110	3
Yield (Mg ha^{-1})			
200 seeds m^{-2}	4.65	4.83	0.09
400 seeds m^{-2}	4.71	4.74	

^a Dual seed treatment (fungicides + insecticide).

A plot of mean grain yield vs. the coefficient of variation indicated three distinct clusters of treatment combinations (Fig. 4). The first group was a dense group of 400 seeds m^{-2} treatments that produced average, stable yields and the second group was the seed-

treated 200 seeds m^{-2} treatments resulting in greater, but less stable yields. The most inferior group (lesser average yield and greater variability) was the 200 seeds m^{-2} treatments without seed treatment, particularly the treatments with inferior seed quality (moderate and thin seeds).

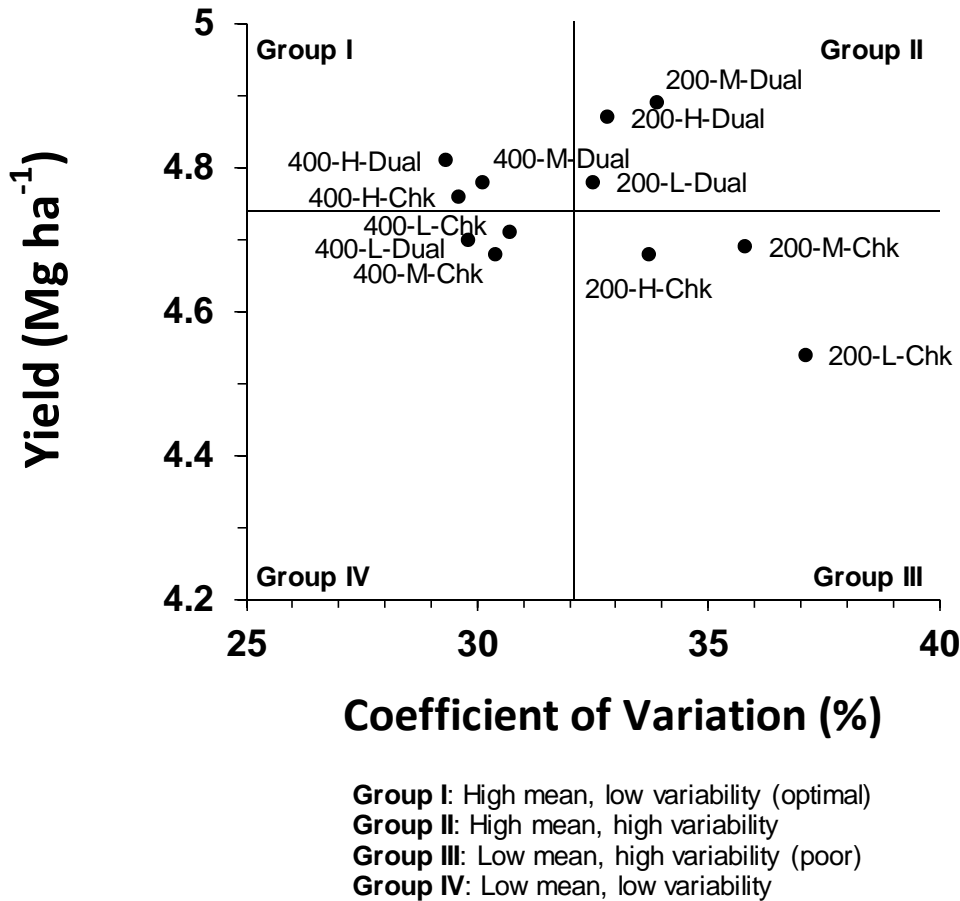


Fig. 4. Biplot of grain yield vs. coefficient of variation for each treatment combination of seed size (Heavy = H (plump), medium = M, and L = light (thin)), seed treatment (Chk = Check and Dual fungicide + insecticide = Tebuconazole + Metalxyl + Imidacloprid), and seeding rate (200 seeds m^{-2} or 400 seeds m^{-2}).

The results of tests 211 and 221 indicated that seed treatments enhanced winter wheat productivity, particularly if the agronomic system is compromised with less than desirable seed lots, thinner plant stands, or perhaps other components not assessed in this study. An economic analysis will be used to fully understand how the added input of seed treatments will affect net returns.

Sub-activity 2.2 (Test 222)

Integration of microbial control strategies to manage the cereal leaf beetle in winter wheat.

The cereal leaf beetle is considered an emerging pest of cereals, including winter wheat. It was reported east of Lethbridge in 2005, in the Swan River region of northwest Manitoba in 2009 and south of Edmonton in 2011. It is the goal of this study to integrate a microbial a microbial (*Beauveria bassiana*) biopesticide (Botanigard) strategy with an effective parasitoid insect biocontrol agent (a natural enemy wasp *Tetrastichus julis*). Two experiments were used to address the overall objective of this study.

Experiment 1: Determination of bioefficacy of *Beauveria bassiana* (BotaniGard 20WP) to manage CLB: Laboratory evaluation

The effects of Botanigard on the cereal leaf beetle populations under field and laboratory conditions were examined through a series of stepwise experiments. Four Botanigard treatments namely, 0 g/L, 2.5 g/L (recommended dose), 5 g/L (2X recommended) and 10 g/L (4X recommended) were tested. The results of this experiment indicated that the optimum rate for the laboratory experiments was 2.5 g/L while for the field application was 5 g/L of Botanigard (Table 7). The application rates calculated for the laboratory experiments were further used to plan a series of experiments to study its non-target effects on the principal natural enemy of CLB, *Tetrastichus julis*.

Table 7. Mortality of cereal leaf beetle larvae after spraying plants with Botanigard at various concentrations in the lab and greenhouse.

Greenhouse <i>B. bassiana</i> Trial					
Treat	N	Total Dead from infection	Total Alive	% Mortality	LT50 (days)
T1	32	0	32	0	0
T2	32	19	13	59.4	7.56
T3	32	25	7	78.1	6.81
T4	32	28	4	87.5	6.75
Laboratory <i>B. bassiana</i> Trial					
Treat	N	Total Dead from infection	Total Alive	% Mortality	LT50 (days)
T1	30	0	30	0	0
T2	30	25	5	83.3	2.77
T3	30	26	4	86.7	2.66
T4	30	29	1	96.7	2.55

Experiment 2: Studies on non-target effects of Botanigard on the principal natural enemy, *T. julis*

The treatments included spraying of parasitized larvae with three doses: 0 g/L (control), 0.25 g/L and 2.5 g/L of Botanigard. The 2012 results indicated that up to 36% of parasitoids could emerge successfully from the parasitized CLB larvae treated with 0.25 g/L of Botanigard (Fig. 5). An emergence rate of 32% was noticed even at a high dose of 2.5 g/L. The results were in line with the results obtained in 2011. The parasitoids emerging from Botanigard treated larvae did not show any abnormalities in development and fitness, or deaths, which indicates that the Botanigard treatment does not adversely affect the development of parasitoids. Hence, it may be possible in future to use both the bioagents in synchrony for the effective management of CLB populations.

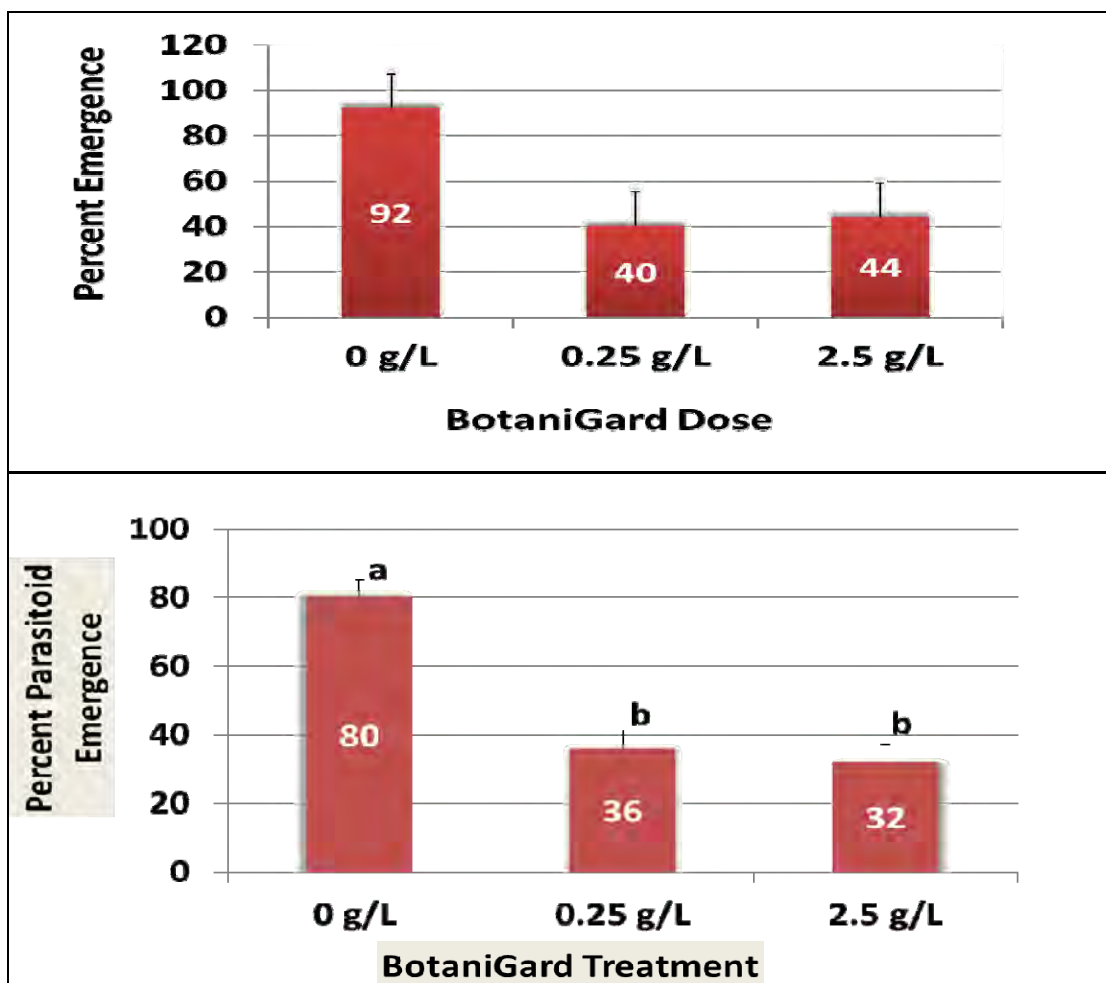


Fig. 5. Percentage emergence of parasitoids from the parasitized larvae of *Oulema melanopus* treated with Botanigard 20WP in 2011 (top chart) and 2012 (bottom chart). The histograms with different letters indicate significant treatment differences.

Experiment 3: Determination of bioefficacy of Botanigard 20WP under field conditions to manage CLB populations

A field experiment was conducted in a 200m long and 8m wide strip of a winter wheat field. Eight 1 m by 1 m served as the experimental unit in each block, and the plant stand in each such plot was thinned to retain about 50 plants of wheat. The CLB larvae reared in the laboratory were then set on the wheat plants in each plot such that there were 30 CLB larvae set per plot. Within each block, two plots (one open and one caged) were not infested artificially with CLB larvae to control for the background infestation. Treatments included 5 g/L of Botanigard as the basal dose, a ten times lower dose of 0.50 g/L as a sub-lethal dose, and an untreated check. Cereal leaf beetle larvae death and post-death conditions were monitored in each plot.

The results indicated that CLB larvae mortality was greater at the 5 g/L dose (Fig. 6) and ranged from 32 to 42%. Furthermore, it was noticed that greater CLB damage per flag leaf was noticed in plots treated with water alone while the least damage was found in the plots treated with 5 g/L of Botanigard (Fig. 7).

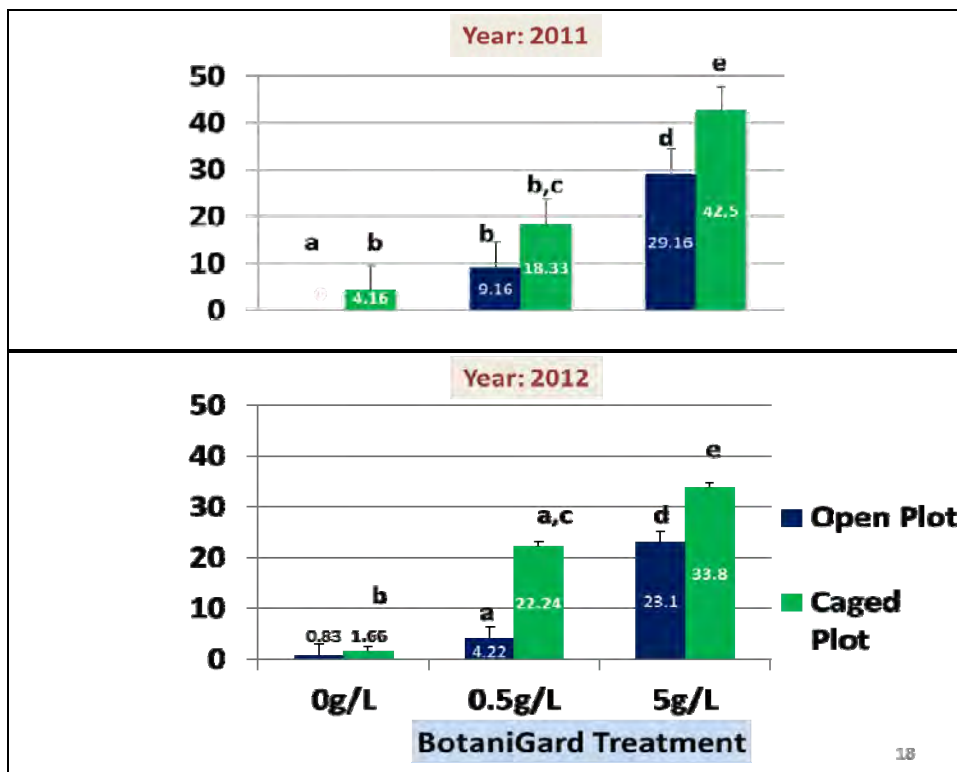


Fig. 6. Percent mortality (y-axis) in CLB populations upon field treatment with Botanigard.

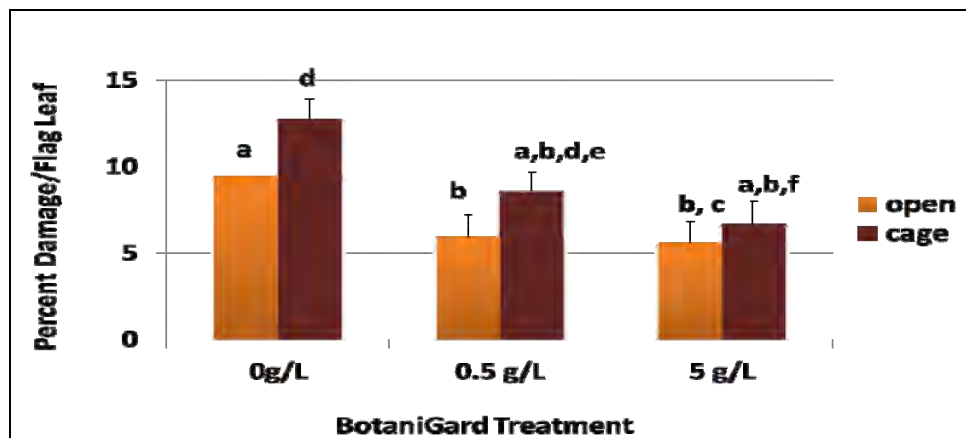


Fig. 7. Damage caused by CLB larvae to wheat plants for different BotaniGard treatments. The histograms with different letters indicate significant treatment differences.

Botanigard has good potential to manage cereal leaf beetle in combination with the biological control agent. The parasitoid *T. julis* is becoming more prevalent, which will complement CLB control. In the future, studies should attempt to validate our controlled experiment by finding a field with high pest levels that also have *T. julis* and spraying some areas with Botanigard to assess levels of parasitism in situ.

Sub-activity 2.3 (Tests 223a and 223b)

Development of algorithms using optical sensors to create yield potential models for integrated nutrient management.

The goal of this sub-activity is to develop an algorithm specific to the winter wheat grown in western Canada, which would be integrated into a Greenseeker optical sensor and used for precision in-crop fertility management. In 2010, experiments were initiated to develop a range of responses from western Canadian winter wheat cultivars. This fall, a second experiment has been initiated to validate the model created from the data collected this past season.

Sub-activity 2.4 (Tests 291 and 292)

Optimizing seed quality and net returns through enhanced N management strategies for milling and general purpose winter wheat production in the Canadian prairies.

This project was designed to provide information about the efficiency of nitrogen (N) management practices for western Canadian winter wheat producers. Three factors were included: 1) urea type (urea, urea+urease inhibitor - 'Agrotain'; urea+urease and denitrification inhibitor - 'SuperU', polymer-coated urea - 'ESN', and urea ammonium nitrate - UAN), 2) application method (fall side-band vs. spring broadcast vs. 50% side-band: 50% spring broadcast), and 3) cultivar (AC Radiant hard red winter wheat vs. CDC Ptarmigan soft white winter wheat). A second experiment (292) with the same

urea types and AC Radiant was established to test additional application methods: 1) fall side-band, 2) 50% side-band:50% late fall broadcast, 3) 50% side-band:50% early-spring broadcast, 4) 50% side-band:50% mid-spring broadcast, 5) 50% side-band:50% late-spring broadcast. We have now completed this study and are in the process of preparing manuscripts for this sub-activity.

Cultivar and N management (both tests 291 and 292) main effects significantly influenced grain yield, test weight and protein concentration. Radiant produced less grain but had greater total N uptake than CDC Ptarmigan, which was more efficient at scavenging to recover soil nitrogen (Fig. 8).

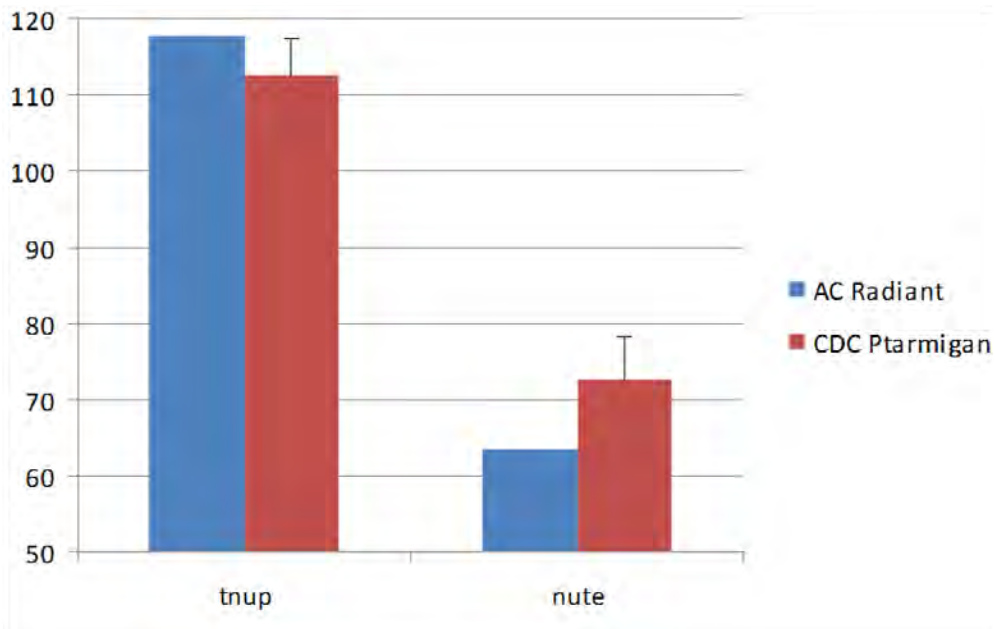


Fig. 8. Comparison of total N uptake (tnup) vs. total N utilization (nute) for AC Radiant and CDC Ptarmigan for test 291.

Urea type UAN performed poorly in test 291 (Fig. 9). It is thought that an N stabilizer may help mitigate the apparent losses that caused low protein and yield. Aside from UAN in all scenarios, and ESN and urea when all N was applied in spring, all other forms produced similar yields across the timing/placement scenarios. Aside from UAN in all scenarios, all other forms produced similar levels of grain protein across the timing/placement scenarios. For test 292, grain yield and protein concentration were significantly influenced by N management. A split application involving a fall application had lesser yield in most forms except SuperU and produced unstable protein levels below the 11% minimum standard for Select CWRW (results not shown). Nitrogen uptake was least with UAN compared with other urea types, and tended (not statistically confirmed) to be greatest in spring broadcast and/or split-application situations of Agrotain or Super U (Fig. 10). Test 292 results also indicated that split application of N had greater total N uptake (results not shown).

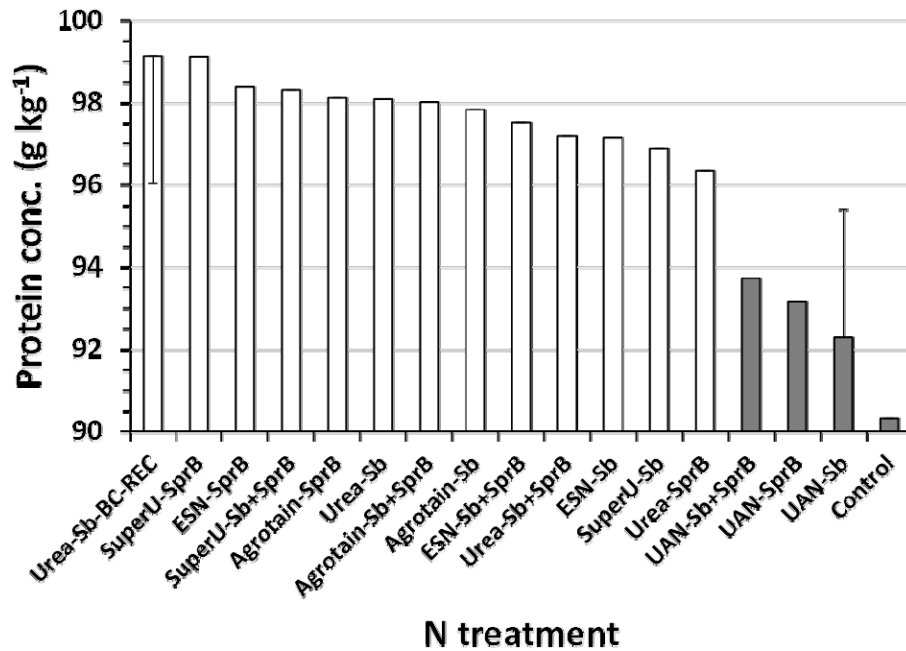
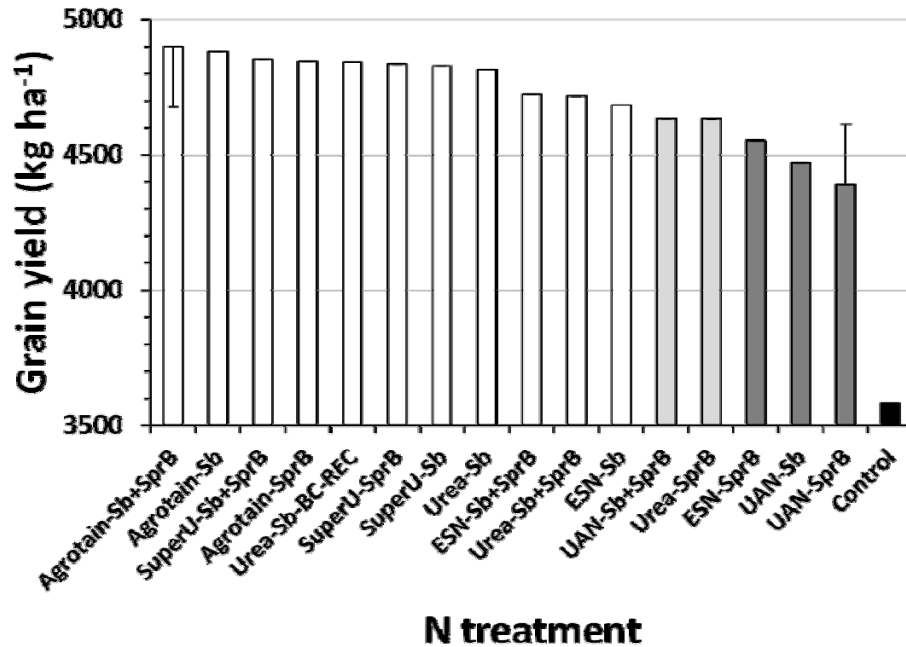


Fig. 9. Grain yield and protein response of winter wheat to N fertilizer form, timing, and placement scenarios for test 291. Abbreviations: Sb+SprB, 50% of N sidebanded + 50% broadcast in early spring (SprB); Sb, 100% of N sidebanded at seeding; SprB, 100% of N broadcast with air boom in early spring. Shade of bars represent significantly different values (LSD 0.05).

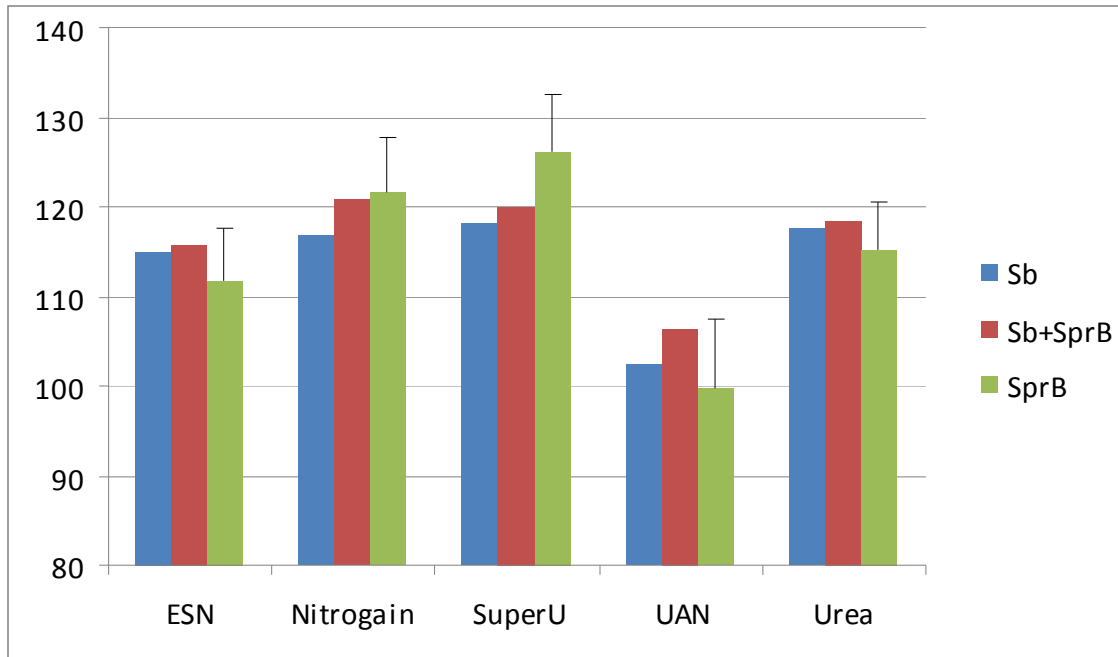


Fig. 10. Comparison of total N uptake (tnup) vs. total N utilization (nute) for form different urea type (Nitrogain = Agrotain) by timing/placement methods for test 291. Abbreviations: Sb+SprB, 50% of N sidebanded + 50% broadcast in early spring (SprB); Sb, 100% of N sidebanded at seeding; SprB, 100% of N broadcast with air boom in early spring.

There are 4 points arising from this research:

- 1) Winter wheat production can be optimized with split applications of N thereby avoiding losses in fall by placing all requirements at seeding.
- 2) Some controlled-release urea products may not release soon enough; i.e. ESN not seed-placed.
- 3) Greater attention needs to be the environmental benefits of controlled release urea relative to conventional urea. At some points, these benefits should be factored into a cost/returns scenario with these products.
- 4) One product, a dual urease and nitrification inhibitor (SuperU), appeared to prevent losses of N when applied in late fall, which is a first as all N forms to date have not prevented losses from this high risk timing of application.

Sub-activity 2.5 (Test 225)

The interaction of herbicide selection and timing of application on suppression of Japanese and downy brome in winter wheat.

Downy brome has resurged and a new species, Japanese brome, has become established in southern Alberta, and spread to other southern regions of the Canadian Prairies. Consequently, these weed species have infested a great portion of the Prairie winter wheat acres. We were interested to see if winter wheat would respond to timing

(fall vs. spring applications) and herbicide chemistry (4 registered and 2 unregistered) at all three locations in 2011 and 2012.

Winter wheat expressed good visual tolerance to the pre-seed and post-emergent applications for both experiments; average crop injury did not exceed 15%. Biplots indicated that spring-applied Flucarbazone, Pyroxulam, and Thien carbazole-methyl, and fall-applied Thien carbazole-methyl provided consistently lesser winter wheat injury.

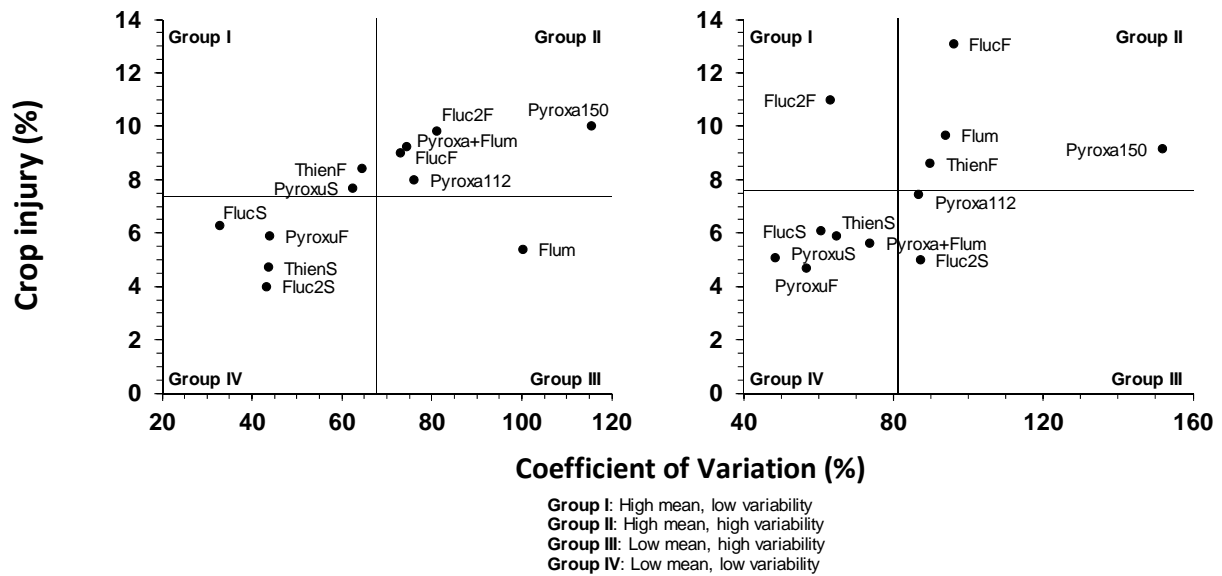


Fig. 11. Biplot of mean winter wheat injury responses vs. coefficient of variation for each brome species and treatment combination. Abbreviations are as follows: Pyroxulam = Pyroxu; Flucarbazone 70 or SC– Fall = Fluc or Fluc2; Thien carbazole-methyl = Thien; Flumioxazin = Flum; and Pyroxaulfone (2 rates 112 and 150) = Pyroxu. Treatments followed by F or S indicated fall and spring application, and those without F or S were applied in spring.

Final visual control ratings and biomass data demonstrates that all herbicide treatments resulted in good to excellent control of Japanese brome (Tables 8 and 9). Final visual control rating was greater (near to 100%) and corresponding growth (dry wt.) was lesser for Downy and Japanese brome controlled with the unregistered, pre-plant chemistries, flumioxazin and pyroxasulfone. However, addition of flumioxazin to pyroxasulfone did not improve Japanese or downy brome control compared to pyroxasulfone alone.

Table 8. Brome weed species control responses to herbicide treatments for two Brome experiments.

Treatment	Downy brome		Japanese brome	
	2011	2012	2011 ^a	2012
			(%)	
Flucarbazone 70 Fall	34	53	83	91
Flucarbazone 70 Spring	53	68	86	71
Flucarbazone SC Fall		55		89
Flucarbazone SC Spring		56		79
Pyroxaulfone 112g		91		96
Pyroxaulfone 150g		93		96
Flumioxazin		62		82
Pyroxasulfone + Flumioxazin		94		96
Pyroxulam Fall	45	71	89	92
Pyroxulam Spring	53	65	83	77
Thiencarbazone-methyl – Fall	39	55	62	65
Thiencarbazone-methyl – Spring	30	26	86	62
LSD0.05	21	14		10

^a Means were not available from ANOVA; therefore, means were estimated directly from data and LSD0.05 is not available for these means.

Table 9. Brome weed species dry wt. responses to herbicide treatments for two Brome experiments.

Treatment	Downy brome		Japanese brome	
	2011	2012	2011 ^a	2012
	(g m ⁻²)			
Flucarbazone 70 Fall	6.2	22.6	0.3	0.5
Flucarbazone 70 Spring	7.0	38.8	1.2	1.3
Flucarbazone SC Fall		35.5		0.9
Flucarbazone SC Spring		25.6		1.6
Pyroxaulfone 112g		2.8		1.1
Pyroxaulfone 150g		3.5		0.2
Flumioxazin		37.2		11.1
Pyroxasulfone + Flumioxazin		2.2		0.3
Pyroxulam Fall	3.9	10.1	1.9	0.4
Pyroxulam Spring	4.5	16.8	0.1	1.1
Thiencarbazone-methyl - Fall	7.5	37.7	1.9	5.2
Thiencarbazone-methyl - Spring	9.0	47.9	0.1	12.9
LSD0.05	21.1	21.1	5.8	5.8

^a Means were not available from ANOVA; therefore, means were estimated directly from data and LSD0.05 is not available for these means.

Pre-plant chemistries, and to a lesser extent select spring-applied Flucarbazone and Thiencarbazone-methyl treatments, resulted in consistently greater yields, with one clear exception (Fig. 12). There may be an antagonistic grain yield response when winter wheat is treated with the pre-plant tank mix of Pyroxasulfone + Flumioxazin as this treatment provided consistently lower yield. With a few exceptions, the fall-applied post-emergent treatments had lesser and more variable yields.

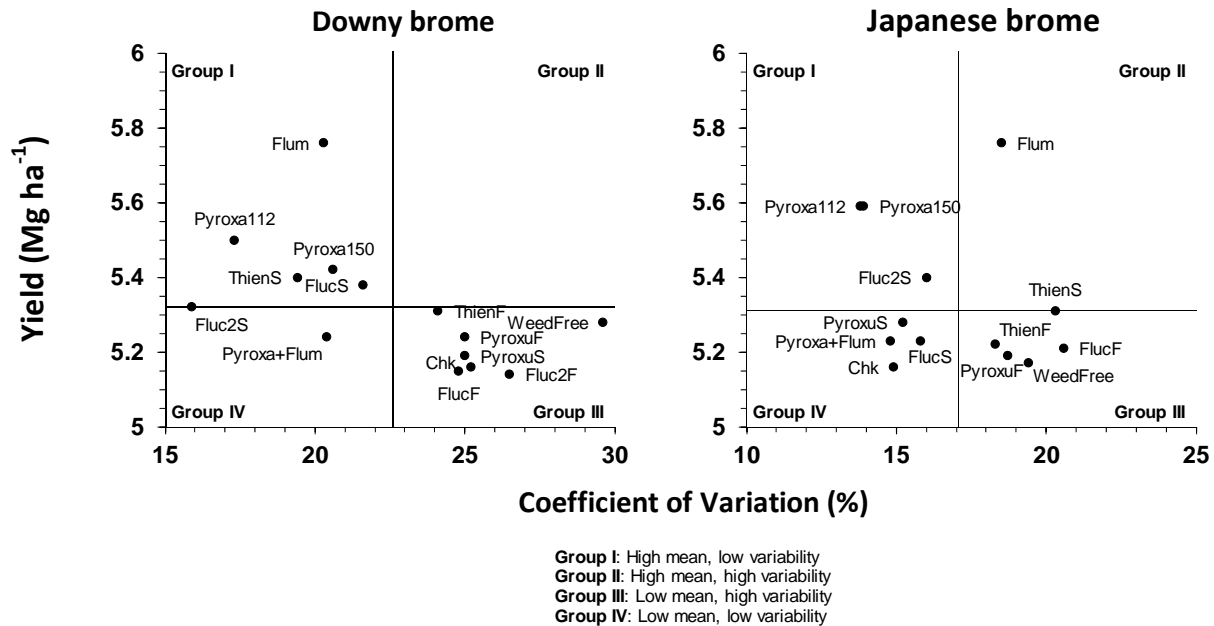


Fig. 12. Biplot of mean winter wheat yield responses vs. coefficient of variation for each brome species and treatment combination. Abbreviations are as follows: Pyroxulam = Pyroxu; Flucarbazono 70 or SC– Fall = Fluc or Fluc2; Thien carbazono-methyl = Thien; Flumioxazin = Flum; and Pyroxaulfone (2 rates 112 and 150) = Pyroxa. Treatments followed by F or S indicated fall and spring application, and those without F or S were applied in spring.

Reasonably good crop tolerance combined with nearly complete and consistent control of both brome weed species would suggest that the new pre-plant chemistries, Flumioxazin and Pyroxasulfone are promising alternatives to control brome weed species for winter wheat.

Final Thoughts

It has been a very rewarding experience thus far working with Duck's Unlimited, Winter Cereals Canada, Winter Cereals Manitoba Inc, Saskatchewan Winter Cereals Development Committee, and the Alberta Winter Wheat Producer's Commission. I think we have created some momentum for interest in winter wheat production and have established a great synergy between the agronomy research community and the industry partners. I hope this momentum can carry forward for several more years!