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Potash and Phosphate Institute of Canada

Management for maximum yield of open pollinated and hybrid canola

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Abstract

With the advent of high yielding hybrid canola varieties questions related to the crop management strategies required to increase the likely hood of attaining these higher maximum yield potentials have been asked. To create a better understanding of the impact seeding rate, nitrogen level, and fungicides have on canola growth and to identify the management steps required to maximize yields for both a conventional open pollinated variety and hybrid canola a three year study was initiated in 1999 at three locations; Scott in the Dark Brown soil zone, Melfort in the Black, and Indian Head in the Thin Black soil zone. Although the trial at Melfort (Star City) was lost as a result of herbicide leaching into the root zone the growing season at Scott and Indian Head was characterized by above normal rainfall with below normal temperatures in May, June and July creating lush canopies with high yield potential. Many of the response differences between locations can be attributed to a rain caused delay of seeding at Indian Head resulting in anthesis and seed filling at Indian Head occurring during a period of higher temperatures while very high biomass yields likely contributed to a lack of soil water and/or nutrient reserves at the time of seed filling. As a result high yield potentials at Indian Head were not reached as evidenced by a mean harvest index of only 0.16. At Scott harvest index was more then double at 0.38 indicative of a long period of anthesis during a period of near ideal temperatures with sufficient soil moisture and nutrient reserves later in the season to complete seed filling. As well very wet conditions at Indian Head made seeding difficult and inhibited plant emergence causing a substantial reduction in plant densities. At Scott the hybrid canola yielded 109 kg/ha more then the open pollinated variety with no differences observed between cultivars at Indian Head. At Indian Head an increase in yield with increased plant densities despite ranging between only 42 and 78 plants/m^2 was attributed to an earlier flowering date and avoidance of high temperatures during anthesis later in July. At Scott an increase in seed rate from 2.3 kg/ha to 9 kg/ha increased plant densities from 47 plants/m^2 to 192 plants/m^2 and hastened seed maturity by 8 days but did not result in yield differences. Increased nitrogen levels as expected increased yields at both locations. At Indian Head a seed rate x nitrogen level interaction revealed the grain yield response to nitrogen was improved as seeding rate increased. Disease surveys revealed the presence of blackleg and sclerotinia but at levels to low to have any significant impact on yield. As a result disease reductions from Ronilan applications were also small and failed to significantly affect yield. Protein yield differences between treatments reflected harvest grain yield differences. While these results are preliminary they do indicate that increased nitrogen levels were the most important factor contributing to higher yields, while increased seeding rates showed the potential to interact with nitrogen and increase yields in a year characterized by above normal precipitation. Unfortunately the range of nitrogen levels was insufficient to produce yield response curves that allow us to determine if the fertility management strategy required to optimize yields is different for a hybrid canola then it is for an open pollinated variety.

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Introduction:

Recent fluctuations in canola prices have underlined the need for a greater understanding of the input investment required to optimize returns. Research to identify inputs required to maximize yield would provide producers with an increased understanding of how canola responds to various levels of inputs and enhance their ability to optimize return on their investment. To address this need a 3 year study was initiated in 1999 with field experiments at Melfort, Indian Head, and Scott with the following objective.

Objective: To evaluate the effect of seeding rate, fertilizer addition and fungicides on the maximum yield potential of hybrid and open pollinated canola in the Thick Black, Thin Black and Dark Brown soil zones.

Materials and Methods:

The 3 year study was initiated in 1999 with field experiments at Melfort (Thick Black), Indian Head (Thin Black), and Scott (Dark Brown) to evaluate the effect of seeding rate, fertilizer, and fungicides on the yield of both a open pollinated variety (Quantum) and Hybrid variety (Invigor 2273 at Scott and Melfort and 2273 at Indian Head). The trial at Melfort (Star City) was lost when the herbicide Muster damaged the growing point on the seedlings and as a result no data was collected. It is speculated that heavy rain after herbicide application leached the herbicide into the root zone, leading to crop damage. Similar effects were observed on canola variety trials at Melfort and Lashburn. Each test was established as a 3 level factorial with a fungicide strip. Factors included 2 canola cultivars (hybrid and open pollinated variety), three seeding rates (Scott:2.25 (low),4.5 (middle),9 kg/ha (high), Indian Head: 2.8,5.6,8.4 kg/ha), and three nitrogen levels (67% (low), 100% (target), and 133% (high) of 80 kg/ha at Scott and 112 kg/ha at Indian Head). At Indian Head phosphorous levels were adjusted with N levels based on 67%, 100% and 133% of 34 kg/ha. Plots at Scott were seeded on May 7th using a Versatile hoe drill on a 20 cm row spacing. At Scott metering constraints of the drill required bulking up seed with non viable seed (heat treated) to achieve lower seed rates. Plots at Indian Head were seeded on May 25th with a Conserva-Pak and 30 cm row spacing. Plots were swathed between August 20th and 25th at Scott and on August 31st at Indian Head after all agronomic and pathology data was collected.

Background levels of nitrogen to 60 cm depth, phosphate to 15 cm, potassium to 15 cm and sulfur to 60 cm depth were measured in April of 1999. Nitrogen as urea (46-0-0) at Scott was mid row banded at rates of 35 kg/ha , 91 kg/ha, and 148 kg/ha while phosphorous as monamonium phosphate (11-51-0) was applied below the seed row to all treatments at Scott at a rate of 34 kg/ha. Summing soil nitrogen and applied nitrogen revealed N levels of 58 kg/ha, 84 kg/ha and 110 kg/ha. Other nutrient levels were 60 kg/ha of phosphate, 622 kg/ha of potassium and 112 kg/ha of sulfur. At Indian Head urea was side banded at rates of 128 kg/ha, 191 kg/ha, and 255 kg/ha with a fertilizer blend of 14-20-10-10 also side banded at rates of 115 kg/ha 170 kg/ha, and 226 kg/ha to adjust P levels. This created nitrogen levels of 110 kg/ha, 147 kg/ha and 188 kg/ha. Associated with increased levels of N were increased levels of phosphate (34 kg/ha, 45 kg/ha, 62 kg/ha), increased levels of potassium (583 kg/ha, 588 kg/ha, 594 kg/ha) and increased levels of sulphur (107 kg/ha, 112 kg/ha, 118 kg/ha). Seed-fertilizer separation was approximately 2.5 cm to the side and 6.4 cm below the seed.

The fungicide strip received an application of Ronalin EG on June 29th at Scott (500 g ai/ha vinclozolin) and July 22nd at Indian Head (750-1000 g ai/ha at Indian Head) at early flowering for control of sclerotinia. Weed control consisted of a spring application of Edge granular (ethafluralin at

1130 g ai/ha) at Indian Head, pre-emergent application of Roundup (445 g ai/ha of glyphosate at Scott and 890 g ai/ha at Indian Head). At Scott an in crop application of Liberty (glufosinate ammonium at 500 g ai/ha) on Invigor 2273 was used while Quantum received Poast Ultra (sethoxydim at 211 g ai/ha) and Muster (ethametsulfuron-methyl at 22 g ai/ha). At Indian Head both cultivars received an in crop application of ethametsulfuron-methyl at14.8 g ai/ha and Assure (quizalofop ethyl at 102 g ai/ha).

Data collection included plant counts (Scott: June 2nd , Indian Head: June 29th), identifying anthesis initiation and seed maturity dates, a disease survey prior to swathing (Scott:August 19th, Indian Head: August 24th) pre- harvest above ground biomass yields (Scott: August 19th-20th, Indian Head: August 25th), and grain yield (Scott: August 27th-Sept. 4th, Indian Head: Sept. 16th) with a small plot combine. Percent protein with NIR analyzer and percent green seed of harvest grain samples was determined with samples submitted for % oil content.

Results

1.0 Climatic Conditions

At Scott precipitation between May 1st and August 31st was 23 mm above the 36 year average of 215 mm with only June having below normal rainfall (Table 1). Initially dry soil conditions at Scott were alleviated by above normal precipitation in April (52 mm) providing a moist seed bed at the time of seeding. At Indian Head precipitation between May 1st and August 31st was 39% above the long term average of 255 mm with above normal rainfall in each of the 4 months. Above normal rainfall in May at Indian Head delayed seeding to the end of May and created very wet soil conditions at the time of seeding. Both Scott and Indian Head experienced slightly below normal temperatures during the months of May, June, and July.

2.0 Cultivar Response

The larger seed size of Invigor 2273 (4.5 gm/1000) then Quantum (3.25 gm/1000) at Scott resulted in Invigor 2273 plant densities being 38-45% less then Quantum when seeded at the same rate (Table 2). At Scott plant densities averaged across seeding rates revealed a plant density for Invigor 2273 of only 81 plants/m^2 compared to 139 plants/m^2 for Quantum. Plots at Indian Head despite having generally lower plant densities showed a similar trend with an average plant density for Invigor 2273 of 56 plants/m^2 compared to 64 plants/m^2 for Quantum.

Growth stage measurements at Indian Head revealed no differences in the flower initiation or seed maturity date between cultivars (Table 2). In contrast Quantum at Scott began flowering approximately 2 days earlier than Invigor 2273 and reached seed maturity 2.7 days earlier then Invigor 2273 when averaged across treatments. The difference between locations is likely linked to the fact that seeding at Indian Head occurred approximately three weeks later than at Scott resulting anthesis and seed development during a period of higher temperatures shortening the time of anthesis and hastening crop maturity. Green seed of Invigor 2273 at Indian head was 3.4% compared to 3.0% for Quantum. At Scott both cultivars averaged 1.3% green seed.

A combined location analyses of cultivar biomass revealed a similar response at both locations with Invigor producing on average 1050 kg/ha more biomass then Quantum. Invigor 2273 at Indian Head produced 1184 kg/ha more above ground biomass on average than Quantum(9839 kg/ha) however both cultivars produced an average seed yield of 1766 kg/ha. At Scott Invigor also produced more biomass

then Quantum (6693 kg/ha vs 5773 kg/ha) but out yielded Quantum by an average of 109 kg/ha (2467 vs 2358 kg/ha). Higher biomass yields and lower seed yields resulted in a harvest index of 0.16 at Indian Head compared to 0.38 at Scott. A contributing factor to the low harvest index at Indian Head may have been the very high biomass yields and increased likely hood that soil water and/or nutrient reserves at the time of seed filling were diminished. Protein yield differences mirrored seed yield differences (Table 2). Protein content was slightly higher at Indian Head with 24.9% and 24.0% for Invigor 2273 and Quantum respectively compared to a mean of 23.3 % for Invigor 2273 and Quantum at Scott. Analyses showed the protein response by cultivar was the same at both locations with Invigor producing an average protein yield of 504 kg/ha compared to 491 kg/ha for Quantum.

The high blackleg resistance characteristic of Quantum resulted in lower levels of blackleg severity then Invigor 2273 at Scott (0.13 vs 0.34) and lower levels then Invigor 2273 at Indian head (0.02 vs 0.11) (Table 2). Blackleg incidence in Quantum at Scott was reduced to 5.1% from 14.5% in Invigor 2273 and to 1% from 4.1% for Invigor 2273 at Indian Head.

3.0 Response to Seed Rate

As expected a doubling of seed rate from 2.3 kg/ha to 4.5 kg/ha and 4.5 kg/ha to 9 kg/ha at Scott increased plant densities by a factor of 2 with 47, 92 and 192 plants/m^2 achieved (Table 3). Seeding at Indian Head occurred in late May when the soil was very wet resulting in seed bed conditions that inhibited emergence and reduced plant densities. At Indian Head plant densities increased by only 30% (42-60 plants/m^2) when seed rates were increased from a low seed rate of 2.8 kg/ha to a seed rate of 5.6 kg/ha and by 40% (60-78 plants/m^2) when seed rates were increased from 5.6 kg/ha to the high rate of 8.4 kg/ha.

A combined analyses of Scott and Indian Head data revealed no disease response differences between locations and no impact of seeding rate on blackleg severity or sclerotinia incidence and severity. Both locations did show an average decline in blackleg incidence from 6.9% to 5.3% when seed rates were increased from low to high rates.

Seed maturity notes from Indian Head revealed all plots matured at the same time regardless of seeding rate in contrast to Scott where high seeding rate plots on average matured 4.7 days earlier then middle seeding rate plots and 7.9 days earlier then low seeding rate plots (Table 3).

No yield response difference between cultivars to increased seeding rates at Indian Head or Scott was observed. Although a trend of reduced biomass production with increased seeding rates was observed at Scott and Indian Head the differences were not significant. Grain yields at Indian Head were highest when the high seeding rate was used with 1889 kg/ha followed by 1784 kg/ha for the middle seed rate and 1625 kg/ha for the low seed rate (Table 3). This is surprising given the range of plant densities between low and high seeding rates was only 36 plants/m^2. At Scott where the plant density difference between low and high seeding rates was much larger (145 plants/m^2) no yield response to different seeding rates was observed. A later seeding date at Indian head resulted in anthesis initiation occurring approximately 2 weeks later than at Scott (July 14th vs June 27th). A three week flowering period at Scott was characterized by mean daily temperatures of 14.0 Celsius compared to 16.3 Celsius at Indian Head during the last 2 weeks in July putting canola at Indian head more at risk of pod abortion which potentially contributed to a low harvest index. Higher seeding rate plots began flowering one day earlier than low seeding rate plots at Indian Head reducing the potential for pod abortion and yield loss from high mean daily temperatures of 19.7 and 20.6 on July 28th and 30th.

Protein yields mirrored seed yields with no observed differences between seed rates at Scott but higher protein yields with increased seed rates at Indian Head with high seeding rate plots producing 459 kg/ha of protein followed by 430 kg/ha at the middle seeding rate and 407 kg/ha at the low seed rate (Table 3). Low seeding rate plots however produced seed with higher protein content (25.1%) than either the middle or high seed rate (24.1%). There were no observed differences in protein content between treatments at Scott.

4.0 Response to Nitrogen Level

Despite a trend towards reduced plant densities with increased N levels at Scott and Indian Head banding additional nitrogen mid row at Scott and beside the seed furrow at Indian Head produced no statistically significant decline. An investigation into growth stage responses to changing N levels at Indian Head revealed that both cultivars began flowering 1 day earlier at the low N rate than at target or high N levels (Table 4). At Scott there were no observed differences in flower initiation between N levels for either cultivar. Seed maturity notes from Scott however revealed that low N level plots matured 1.5 days earlier than target N level plots and 3.1 days earlier then high N level plots. No seed maturity differences between N levels were observed at Indian Head. Different seeding dates is likely the main contributing factor to the different responses between locations. Increasing nitrogen above low levels increased green seed count that was consistent across locations. Low levels of N produced an average of 1.9% compared to 2.3% and 2.6% for medium and high levels of N.

Although increasing N rates at Scott resulted in an increase in disease incidence of blackleg a combined analyses revealed no significant location interaction and no incidence response to N level (Table 4). No significant change in blackleg severity was observed at either location. Despite low sclerotinia pressures at both locations lack of a location interaction and subsequent combined analyses across locations revealed incidence at low levels of N were lower than at target N levels (2.9% vs 3.8%). High levels of N produced a mean sclerotinia incidence of 3.2% when averaged across locations.

As we might expect, canola yields were more responsive to changing nitrogen levels than seed rates however the yield response was different between locations. At Indian Head a large increase in biomass production between the high rates of N and target or low levels of N occurred with an average biomass yield increase of 2530 kg/ha (Table 4). Biomass increases at Scott with increased levels of N were smaller and more consistent increasing by 527 kg/h from low to target levels of N and 319 kg/ha from target to high levels of N. Seed yields at Scott increased by an average of 210 kg/ha for every increase in N to a maximum of 2618 kg/ha compared to an increase of 180 kg/ha from low N to target N at Indian Head and only an 86 kg/ha increase from target to high N for a maximum yield of 1883 kg/ha. An analyses revealed the increase in protein yield with increased nitrogen was the same across locations increasing from 442 kg/ha at low N to 502 kg/ha at target levels of N and 549 kg/ha at high levels of N. A common seed maturity date for all N levels at Indian Head suggests that higher seed yield potential for higher levels of N as evidenced by higher biomass yields was removed because of a shortened period of anthesis and possibly heat or moisture stress at seed filling. Higher yield potentials at Scott however were attained as flowering occurred over an extended period with relatively cool temperatures and had sufficient levels of soil moisture to complete seed filling.

5.0 Response to Fungicides

There were no observable differences in plant maturity, yield or disease as a result of Ronilan

applications at Scott or Indian Head (Table 5). Green seed content was higher at Scott when fungicides were not applied (1.7% vs 1.0%). At Indian Head 3.3% green seed was observed for both sprayed and unsprayed plots.

6.0 Treatment Interactions

Seed Rate x Cultivar

An analyses of plant densities revealed a significant seed rate*cultivar interaction at Scott but no interaction at Indian Head where the range of plant densities were much smaller (Table 6). A smaller seed size for Quantum then Invigor 2273 at Scott resulted in an increase in plant density for Quantum of 183 plants/m^2 from a low seed rate to a high seed rate and only 107 plants/m^2 for Invigor. The same general trends were observed for low and target seeding rates at Indian Head. Seed size measurements for larger seeds such as peas and chickpeas has long been recommended to ensure target plant densities are achieved as seed size can vary greatly and can greatly impact the cost of seeding with the larger volumes of seed required. The small seed size of canola in addition to its plasticity (ability to increase growth when plant densities decline) has resulted in less emphasis being placed on canola seed size measurements to ensure a target plant density is achieved. However with the advent of larger hybrid seeds and a recent trend in the industry that suggests seed costs may be reduced with lower seeding rates means measuring canola seed size to achieve a specific plant density may become standard practice to minimize costs while still ensuring maximum yields is achievable.

A seed rate x cultivar interaction was also observed for blackleg with analyses revealing both locations showed a decline in blackleg incidence for Invigor from low and middle seed rates (10.3 %) to high seed rates (7.3%) but no observed difference between seed rates of Quantum (Table 8). The blackleg incidence decline with increased seed rates can be linked to a biomass yield decline of 423 kg/ha and a canopy environment less conducive to the spread of blackleg. Quantum despite showing larger biomass yield differences between seed rates when averaged across locations (684 kg/ha) was able to contain blackleg incidence to levels near 3.1% regardless of seed rate because of its high blackleg resistance.

Seed Rate x Nitrogen Level

A seed rate* nitrogen level interaction for grain yield observed at Indian head is surprising considering the smaller yield differences between N levels and restricted range of plant densities between different seed rates (Table 7). Results indicate that the response to nitrogen was improved as the rate of seeding increased. At a plant density of 42 plants/m^2 yields increased by 139 kg/ha from low to high rates of N compared to an average yield increase of 329 kg/ha for plant densities of 60 plants/m^2 or 78 plants/m^2.

A yield seed rate x nitrogen level interaction at Indian Head also resulted in a similar interaction for protein yield with greater yield increases with additional nitrogen as seed rate increased (Table 7). Protein yield between low and high N levels at Indian Head increased by 74 kg/ha at the low seed rate and 122 kg/ha at the high seed rate.

Sclerotinia incidence response to changing seed and nitrogen rates was similar between locations with a combined analyses revealing a significant interaction between seed rate and N level (Table 9). Differences however were small and trends inconsistent with the highest disease incidence (4.3%) occurring with the target level of N and a low seed rate and lowest(mean of 2.8%) with low levels of N in combination with middle & high seed rates and high levels of N in combination with low and high

seed rates.

Nitrogen Level x Cultivar

A combined analyses of plant densities showed no significant nitrogen level x cultivar response difference between locations but did reveal Invigor canola germinated and emerged differently in response to changing N rates then Quantum. Plant density declines with increasing N levels however were small averaging only 10 plants/m^2 for both Invigor and Quantum and was insufficient to result in any yield differences.

Nitrogen* Fungicide

Nitrogen levels in addition to interacting with seed rates at Indian Head to cause differences in sclerotinia incidence also interacted with Ronilan applications (Table 9). The response was the same at both locations with Ronilan and low levels of N and high levels of N with no Ronilan producing the lowest levels of sclerotinia incidence. The differences however were small and had no impact on yield.

Fungicide x Cultivar

Although no fungicide x cultivar interaction for blackleg incidence was observed at Scott a significant interaction at Indian Head revealed Ronilan reduced blackleg incidence of Invigor 2273 by 2% from 5.1% to 3.0 % (Table 8). Not surprisingly no decline in incidence with Ronilan on Quantum was observed as it's disease resistance ensured very low levels of incidence (1%).

Table 1. Monthly precipitation and mean monthly temperatures at Scott and Indian Head..

Month	Precipitation (mm)		Temperature (Celsius)	
	1999	Long Term	1999	Long Term
	Scott			
May	66	36	9.4	10.5
June	43	66	13.6	14.6
July	81	67	15.1	17.1
August	48	46	16.8	16.4
	Indian Head			
May	67	44	10.4	11.9
June	116	88	14.5	16.2
July	84	48	16	18.7
August	88	45	16.6	16.4

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Table 2. Influence of cultivar on days to flowering and maturity, plant density, biomass and grain yield, and disease severity and incidence at Scott and Indian Head in 1999.

	Scott		Indian Head	
	Invigor 2273	Quantum	Invigor 2273	Quantum
seeding to beginning of flowering (days)	52 a	50 b	48	48
seeding to maturity (days)	105 a	103 b	96	96
plant density (#/m^2)	81.4 b	139 a	56.0 b	63.9 a
*Biomass yield (kg/ha)	6693 a	5773 b	11020 a	9839 b
Grain yield (kg/ha)	2467 a	2358 b	1746	1785
*Protein yield (kg/ha)	573	553	435	429
Green seed (%)	1.3	1.4	3.4 a	3.0 b
blackleg severity(0-5)	0.34 a	0.13 b	0.11 a	0.02 b
blackleg incidence(%)	14.5 a	5.1 b	4.1 a	1.0 b
*sclerotinia severity (0-1)	0.03	0.02	0.02	0.01
*sclerotinia incidence (%)	7	6.1	0.06	0.01

* indicates the cultivar response was the same at both locations. Values at a location followed by the same letter are not different (P=0.05)

Table 3. Influence of seed rate on days to flowering and maturity, plant density, biomass and grain yield, and disease severity and incidence at Scott and Indian Head in 1999.

	Scott			Indian Head		
	low	middle	high	low	middle	high
seeding to beginning of flowering (days)	51	51	51	49	48	48
seeding to maturity (days)	108 a	104 b	100 c	96	96	96
plant density (#/m^2)	47.1 c	91.6 b	191.9 a	42.1 c	60.1 b	77.6 a
*Biomass yield (kg/ha)	6384	6178	6136	10702	10318	10268
Grain yield (kg/ha)	2398	2424	2417	1625 c	1784 b	1889 a
Protein yield (kg/ha)	565	564	560	407 c	430 b	459 a
Green seed (%)	1.5	1.1	1.4	3.3	3.2	3.1
*blackleg severity(0-5)	0.22	0.24	0.25	0.09	0.06	0.05
*blackleg incidence(%)	10.2	10.7	8.5	3.2	2.3	2
*sclerotinia severity (0-1)	0.02	0.02	0.03	0.01	0.04	0
*sclerotinia incidence (%)	6.7	6.6	6.3	0.06	0.04	0

* indicates the seed rate response was the same at both locations. Values at a location followed by the same letter are not different (P=0.05)

Table 4. Influence of nitrogen level on days to flowering and maturity, plant density, biomass and grain yield, and disease severity and incidence at Scott and Indian Head in 1999.

	Scott			Indian Head		
	low	target	high	low	target	high
seeding to beginning of flowering (days)	51	51	51	48	49	48
seeding to maturity (days)	103 b	104 ab	105a	96	96	96
*plant density (#/m^2)	113	111	106	64	57	59
Biomass yield (kg/ha)	5775 b	6302 a	6621 a	9396 b	9777 b	12116 a
Grain yield (kg/ha)	2199 c	2422 b	2618 a	1617 c	1797 b	1883 a
*Protein yield (kg/ha)	506 c	563 b	620 a	378 c	440 b	478 a
*Green seed (%)	1.0 b	1.5 a	1.5 a	2.7 c	3.2 b	3.6 a
*blackleg severity(0-5)	0.21	0.22	0.27	0.07	0.06	0.07
*blackleg incidence(%)	8.8 b	9.6 b	11.1 a	2.6	2.4	2.5
*sclerotinia severity (0-1)	0.021	0.027	0.03	0	0.05	0
*sclerotinia incidence (%)	5.8 b	7.4 a	6.4 ab	0	0.1	0

* indicates the N level response was the same at both locations. Values at a location followed by the same letter are not different (P=0.05)

Table 5. Influence of Ronilan fungicide on days to flowering and maturity, plant density, biomass and grain yield, and disease severity and incidence at Scott and Indian Head in 1999.

Fungicide	Scott		Indian Head	
	Ronilan	No Ronilan	Ronilan	No Ronilan
seeding to beginning of flowering (days)	51	51	48	48
seeding to maturity (days)	104	104	96	96
*plant density (#/m^2)	110.3	110.1	61.9	58
*Biomass yield (kg/ha)	6173	6292	10172	10687
*Grain yield (kg/ha)	2439	2387	1823	1708
*Protein yield (kg/ha)	573	551	443	421
Green seed (%)	1.0 b	1.7 a	3.2	3.2
*blackleg severity(0-5)	0.23	0.24	0.05	0.08
*blackleg incidence(%)	9.9	9.8	1.9	3.1
*sclerotinia severity (0-1)	0.02	0.03	0	0.03
*sclerotinia incidence (%)	6.6	6.5	0	0.07

* indicates the fungicide response was the same at both locations. Values at a location followed by the same letter are not different (P=0.05)

Table 6. Seed Rate x cultivar interaction affects on plant density at Scott in 1999.

		Seed Rate		
		Low	Middle	High
	Invigor 2273	36.3 E	64.9 D	142.9 B
	Quantum	57.9 D	118.2 C	240.9 A

Seed rate X cultivar values following by the same letter are not different (P=0.05)

Table 7. Combined grain and protein() yield response (kg/ha) to increase nitrogen of Invigor 2273 and Quantum at Indian Head in 1999.

		N Level		
		Low	Target	High
Seed Rate	Low	1579 D (377 E)	1576 D (394 E)	1719 C (451 CD)
	Middle	1610 CD (377 E)	1823 B (438 D)	1917 AB (477 BC)
	High	1661 CD (384 E)	1992 A (489 AB)	2012 A (506 A)

Seed rate X nitrogen interactions followed by the same letter are not different.

Table 8. Cultivar x seed rate interaction affects on blackleg incidence (%) in a combined analyses across locations (Indian Head and Scott) and cultivar x fungicide interaction affects on blackleg incidence at Indian Head in 1999.

			Invigor	Quantum
Scott & Indian Head	Seed Rate	Low	10.8 A	3.1 C
		Middle	9.8 A	2.8 C
		High	7.3 B	3.3 C
Indian Head	Fungicide	no	5.1 A	1.0 C
		yes	3.0 B	0.9 C

Interactions followed by the same letter are not different (P=0.05).

Table 9. Seed rate x nitrogen level and fungicide x nitrogen level interaction affects on sclerotinia incidence (%) in a combined analyses across locations (Scott and Indian Head) in 1999.

			N level		
			Low	Target	High
Scott and Indian Head	Seed Rate	Low	3.2 ABC	4.3 A	2.6 C
		Middle	2.4 C	3.8 AB	3.8 AB
		High	3.1 BC	3.2 ABC	3.1 BC
Scott and Indian Head	Fungicide	no	3.0 BC	3.9 A	2.9 C
		yes	2.8 C	3.6 AB	3.5 AB

Interactions followed by the same letter are not different (P=0.05).