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Response of lentil cultivars to Sclerotinia white mold and Botrytis grey mold infection under irrigated and dryland conditions

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Abstract

Diseases such as Sclerotinia white mold (SWM) caused by the fungus *Sclerotinia sclerotiorum* (Lib.) de Bary and Botrytis grey mold (BGM) caused by the fungus *Botrytis cinerea* Pers. may be limiting factors for lentil production in wetter areas of Alberta, Canada. Field trials were conducted at the Lethbridge Research and Development Centre from 2013-2015 to evaluate the response of lentil cultivars to SWM and BGM and yield impacts. Ten lentil cultivars from five market classes were evaluated under irrigated and dryland plots with two planting densities (120 plants m⁻² and 160 plants m⁻²). Year and irrigation had the largest effect on disease incidence, with highest SWM incidence occurring under irrigation in 2013, followed by 2014 and 2015. Conversely, BGM incidence under irrigation was highest in 2015 and lowest in 2013, but levels were lower than SWM. Significantly ($P < 0.05$) lower disease incidences were observed in dryland plots, which also produced higher yield than irrigated plots. Cultivars varied significantly in SWM incidence and yield under irrigated and dryland conditions, perhaps due to variable disease pressure, but there was no consistent trend in cultivar performance. BGM incidence was similar in cultivars, but differed among years. These findings indicate that SWM may be a limiting factor to lentil production in wetter areas, as the ten cultivars from five market classes tested were all highly susceptible to SWM.

Keywords: lentil, white mold, grey mold, *Sclerotinia sclerotiorum*, *Botrytis cinerea*

Introduction

Lentil (*Lens culinaris* Medik.) is an important pulse crop grown worldwide, including western Canada and the northern Great Plains of the United States. Lentil was grown on approximately 1.7 million hectares in Saskatchewan and Alberta provinces in 2020, making Canada the leading producer and the largest lentil exporter in the world (Statistics Canada 2020). In Alberta, lentil is grown primarily in the semi-arid, southern part of the province. In 2019, lentil production in Alberta was 370,600 metric tonnes from 171,100 seeded hectares, and lentil was exported for a value of 90 million dollars (Statistics Canada 2020). Lentil is not only a major source of protein but also improves soil health by adding atmospheric nitrogen into soil (Lupwayi and Kennedy 2007). There is interest in expanding lentil production area to central Alberta to increase crop diversity and sustainability (Bowness et al. 2019), but this area has a much wetter and cooler climate than southern Alberta that could be more conducive to foliar diseases.

Lentil production under wetter climates may be challenged by Sclerotinia white mold (SWM) caused by *Sclerotinia sclerotiorum* (Lib.) de Bary and Botrytis grey mold (BGM) caused by *Botrytis cinerea* Pers., which are of minor importance in semi-arid areas (Chen et al. 2016; Morrall 1997). SWM symptoms are characterized by the presence of bleached tissue and girdled stems. Initially upper leaves appear chlorotic and wilted, later plants may die due to stem infections, resulting in a visible patchwork of sclerotinia-infected areas throughout a field. The signs include presence of fungal apothecia in the soil underneath the canopy, white cottony mycelial growth and the formation of black sclerotia on diseased stems (Bailey et al. 2003). BGM often first develops on flowers and pods, in the lower to mid plant canopy. In lentil fields,

patches of dead plants are seen surrounded by a thin border of chlorotic plants, and symptoms appear as small, cream coloured lesion on leaves. Lesions can enlarge and coalesce to infect whole leaflets which senesce and fall to the ground (Bailey et al. 2003). Stem lesions are light brown or bleached which may girdle the stem. Signs are presence of grey mold on infected stem and pods, and small black sclerotia in diseased tissue. Patches of dead plants will become noticeable in the field as the infected portion of the stem rots, leading to plant death (Davidson and Krysinska-Kaczmarek 2007). Infected seeds are discoloured and shriveled and can be an inoculum source for this pathogen (Lindbeck et al. 2009). Survival structures are sclerotia and mycelia in plant debris (Lindbeck et al. 2009). Yield loss may exceed 50%, however, total crop loss is reported in highly susceptible cultivars (Davidson and Krysinska-Kaczmarek 2007).

Management of SWM and BGM is difficult. Management practices for both diseases rely on crop rotation, use of host resistance and fungicides. However, crop rotation is not always effective to control SWM or BGM as the sclerotia can survive in soil for many years, and both pathogens have a wide host range (Adams and Ayers 1979; Schwartz and Steadman 1978). Measures to manage BGM in lentil also include delayed sowing time, reduced seed rate, use of fungicides and cultivar selection (Lindbeck et al. 2008). However, in field trials neither crop rotation or tillage practices had a significant effect on reducing lentil diseases, including BGM (Bailey et al. 2000). Fungicides such as thiophanate-methyl and propiconazole were reported effective in controlling SWM (Vagelas 2014), and boscalid for BGM management in lentil (Kuchuran et al. 2021). In Alberta, there are a number of seed treatments registered for control of seed-borne *Botrytis* on lentil, and foliar fungicides registered for control or suppression of both BGM and SWM (Alberta Agriculture and Forestry 2020). However, genetic resistance of lentil to these pathogens would be the preferred option not only to manage these diseases but also

ensure maximum yield. Field resistance of Australian lentil germplasm lines to BGM was described in Australian field conditions (Lindbeck et al., 2008), however there have been no studies published on response of lentil lines or cultivars to SWM in Canada.

There is no information available on lentil susceptibility to SWM and BGM infection or disease impact on yield of lentil in Alberta. Therefore, the objectives of this study were to determine cultivar responses to SWM and BGM in irrigated and dryland conditions and variable disease pressure, and the influence of plant density on disease pressure.

Materials and methods

Field trials

Field trials were conducted from 2013 to 2015 at the Lethbridge Research and Development Centre in Alberta (49.7° N and 112.833° W) in clay loam soil. The trial site was prepared by mold board plough followed by harrow disc. For weed control, ethalfluralin herbicide was applied and incorporated at the recommended rate to fields 10-14 days before planting. Each plot was 4 rows and 5 m long for a plot size of 4.6m² with a row spacing of 23 cm (Balasubramanian et al. 2014), and seeded to achieve a target plant density of 120 or 160 plants m⁻² based on seed weight of each cultivar and an 85% germination rate based on seed testing. Plots within each block were separated by 30 cm to reduce air flow, whereas each block was separated by a 1-m pathway that was seeded to winter wheat. Rhizobium inoculant specific for lentil (*Rhizobium leguminosarum* biovar *viceae*) was applied at seeding at the manufacturer's recommended rate. Nitrogen fertilizer was not applied, but phosphorous fertilizer was seed-

placed at recommended rates according to soil test results. Every year lentil was planted during the second week of May, desiccated using diquat in the first week of September, and harvested 7-10 days later using a small plot combine, and yields of whole lentil seed were adjusted to 14% moisture (Bowness et al. 2019). Prior to planting, sclerotia of *S. sclerotiorum* were collected from dry bean debris, and spread by hand over the soil surface at an approximate rate of 30 sclerotia m⁻² (Kader et al. 2018). For BGM development we relied on natural infection. Fungicidal seed treatments were not applied. All lentil cultivars were imidazolinone resistant which enabled the herbicides imazamox + imazethapyr to be applied when plants were at the 4-5 node stage.

A split-split plot experimental design was used with six replications. The main plots were irrigation vs. dryland, the sub-plots were plant densities of 120 and 160 plants m⁻², and the sub-sub plots were cultivars. Irrigation and the higher plant densities were chosen to increase disease pressure. Cultivars were arranged randomly in sub-sub plots within each block/ replication. Ten lentil cultivars, provided by the Crop Development Centre (CDC), University of Saskatchewan; CDC Dazil, CDC Imax, CDC Imigreen, CDC Impact, CDC Impala, CDC Imperial, CDC Impower, CDC Improve, CDC Invincible and CDC Maxim from five market classes (Table 3) were used in this study. Cultivars were chosen based on being imidazolinone resistant, and their popularity as cultivars commonly grown by lentil growers in Alberta and Saskatchewan. There were no previous reports of the reaction of these cultivars to SWM or BGM. For irrigated treatments, irrigation was applied starting in early July, with 1.5 cm applied three times per week, unless there was a rain event. Irrigated and non-irrigated main plots were separated north to south by a 4-m break, and were each surrounded by a border of CDC Dazil to account for any border effects. Irrigation was applied using hand-move pipes that were placed in the pathway

between each block with overhead sprinklers (1-m high) at every third plot (including border plots). The trial was also located directly east of a tree shelterbelt to minimize the effect of west-prevailing winds on irrigation drift.

Disease assessment and yield

Disease incidence was determined by counting the number of plants, out of 100, with symptoms of *Sclerotinia* or *Botrytis* stem infection, in the inner two rows of each plot. Plants were rated on the following dates: September 3, 2013; August 25, 2014 and August 24, 2015, when plants were at the R7 or physiological maturity stage (Saskatchewan Pulse Growers 2019). These two diseases were distinguishable from each other on the stems of plants by presence of fluffy grey mold mycelia indicating *Botrytis* infection, or white mold indicating *Sclerotinia* infection. The presence of pathogens were confirmed periodically by collecting diseased stems. Stems were cut into pieces, surface sterilized in 0.5% NaOCl for 1 min, rinsed in sterile distilled water three times, and placed onto potato dextrose agar media amended with streptomycin. Plates were incubated at room temperature for 1 week. Sclerotia identical to SWM fungus (*S. sclerotiorum*) were identified, while conidia and microsclerotia were identified for BGM fungus (*B. cinerea*). Severity ratings were not assigned, because when infection was present almost all plants with infection showed entire stem decay, and when incidence was low, disease severity was also low.

Yield data was recorded from each plot and climatic data were also recorded during the growing season in each year using the Government of Alberta Agro-Climatic Information Service (<http://agriculture.alberta.ca/acis/weather-data-viewer.jsp>) for Lethbridge, Alberta.

Statistical analysis

Irrigation, plant density, cultivar and respective interactions were designated as the fixed effects. Analysis of variance was performed by the GLIMMIX procedure in SAS (Statistical Analysis Systems, Cary, NC) to determine the influence of year and the interaction of year with the fixed effects on response variables, namely, SWM, BGM incidence and yield. Year, block (year), block-irrigation (year) and block-irrigation-plant density (year) were random effects. To determine the approximation of denominator degree of freedom, the 'ddfm= satterth' option was chosen in the model statement. Residuals were generated using PROC UNIVARIATE in SAS to test data for normal distribution. Prior to analysis, arcsine transformation of SWM incidence and root square transformation of BGM incidence were performed to normalize variance in the data set. When the interaction term between year and fixed effects was significant, the lsmeans, standard error and significant differences between means was determined between and across all effects included in the highest level interaction term (e.g. when a 3-way interaction term was significant). Treatment means were separated by Fisher's protected least square difference (LSD) test at 5% level of significance using the LSMEANS statement.

Results

Environmental conditions

Climatic data during the growing seasons for 2013 to 2015 is presented in Table 1. Precipitation and temperature varied (May – August) each year. In comparison to the 30-yr average, total precipitation was above average in 2013 and 2014 (281 and 290 mm, respectively)

and below average in 2015 (106 mm). In 2013 and 2015, average temperature was 1°C warmer than the long-term average, while in 2014 it was similar (Table 1).

Tests of fixed effects

Analysis of variance testing of fixed effects on the response variables (SWM, BGM and yield) are presented in Table 2. Irrigation conditions significantly affected both SWM and BGM incidence and yield. SWM incidence and yield were significantly affected by plant density but not BGM incidence. The interaction of cultivars by years significantly affected SWM incidence in which disease level was high in some years but not in others but did not affect BGM incidence. Irrigation x cultivar was significant for SWM and yield but not for BGM incidence. There was a significant interaction of year with plant density and cultivar, and with irrigation and cultivar for SWM incidence. For BGM incidence, there was a significant interaction between year, irrigation and plant density. For yield, the interaction between year, irrigation and plant density was significant ($P < 0.05$) (Table 2). Similarly, the interaction between year, irrigation and cultivar was also significant (Table 2).

Sclerotinia white mold

The relative susceptibility of cultivars to SWM varied and changed over the years. Cultivars CDC Imperial, CDC Imax, CDC Impower and CDC Improve consistently showed greater susceptibility to SWM in 2013 and 2014 (Table 3). However, cultivar susceptibility to disease was not discernible in 2015. Under dryland conditions, disease level was much lower and cultivars CDC Impala, CDC Imperial, CDC Impact, CDC Maxim and CDC Imigreen had greater

disease than other cultivars in 2013. Disease level was almost non-detectable in 2014-2015 (Table 3).

To explore the interaction between year, plant density and cultivar, the SWM incidence of cultivar was analyzed separately by year for each plant density, and then for each cultivar across year x plant density (Table 4). There were no significant differences in SWM incidence between cultivars in any of the years at either density (Table 4). There were significant differences in disease levels (SWM) between years with 2013 levels higher than those in 2014 or 2015 at both planting densities.

Botrytis grey mold

BGM incidence was significantly influenced by year and irrigation conditions, but not by cultivar or plant density (Table 2). Only the interactions of year x irrigation, and year x plant density, and year x irrigation x plant density had a significant effect on BGM incidence. Therefore, BGM varied between planting densities (Table 5). There was no difference in disease level between years at either plant density in dryland plots.

Yield

All of the main effects, i.e. irrigation condition, plant density and cultivar, significantly affected lentil yield (Table 2). The interaction of year x irrigation, year x irrigation x plant density, year x cultivar, irrigation x cultivar, year x irrigation x cultivar and plant density x cultivar were significant. For the year x irrigation x plant density interaction, the highest yield was observed in 2014 in dryland plots with a density of 160 plants m⁻² and was significantly higher than those at 120 plants m⁻² (Table 6). In irrigated plots, lentil yield was greatest in 2014, however, there was

no significant difference between plant densities. A significant year x irrigation x cultivar interaction also occurred. The yield of lentil was influenced by cultivars that responded differently to irrigation conditions between the years (Table 7). The greatest yield was recorded in 2014 across all cultivars, regardless of irrigation conditions (Table 7).

Discussion

Although *Sclerotinia* white mold and *Botrytis* grey mold are generally considered minor diseases of lentil in Saskatchewan, it was previously observed that expansion of lentil acreage in Alberta was impeded by these diseases, especially in wetter growing regions (M. Olson, personal observation). Therefore, the objectives of this research were to determine lentil cultivar response to SWM and BGM and yield impact. Although the Lethbridge Research and Development Centre is located in the semi-arid region of southern Alberta, this site was chosen for the study due to the ability to alter moisture level and resulting disease pressure with irrigation and compare to dryland conditions. Similarly, plant density was also included to determine whether it influenced disease pressure. These conditions provided the opportunity to effectively evaluate cultivar response under varying disease pressure. In particular, inoculation by sclerotia and irrigation provided higher disease pressure which can be used to determine resistance in lentil germplasm to white mold, as is routinely performed for evaluation of dry bean lines for white mold response (Balasubramanian et al. 2014).

There was considerable variation in precipitation throughout the study years and the SWM and BGM incidence, as well as yield. Both 2013 and 2014 were wetter than average, while 2015 was much drier than average. SWM disease level varied among cultivars and across years, and it was lowest in 2015. This may be attributed to variation in inoculum and subsequent

disease levels among years. There is very little published information on environmental conditions conducive to white mold development on lentil specifically, but *S. sclerotiorum* is generally favoured by temperatures between 15 – 25°C, crop standability, and cool, wet conditions after canopy closure (McLaren et al. 2004; Schwartz et al. 2005). Although canopy closure dates were not collected in this study, closure generally occurs in early to mid-July in lentil in southern Alberta. Ambient temperatures from meteorological stations in July were the coolest and wettest in 2013 compared to 2014 and 2015, but no canopy temperatures and relative humidity data were recorded directly from field plots in the experiments in all years. Heavy vegetative growth and lodging of plants in the plots was also observed to be highest in 2013. It appears that cool, wet weather during bloom and pod formation may be favorable for SWM development. In Greece, heavy white mold infections of lentil were reported under cool (12 – 15°C) and moist conditions during flowering (Vagelas 2014).

In contrast, *Botrytis* grey mold incidence showed the opposite pattern of white mold, and was highest in 2015 among irrigated plots and lowest in 2013. It is possible that infection by *S. sclerotiorum* precluded later infections by *B. cinerea*, as the two diseases often occupy the same tissue, and older, necrotic tissue is required to start the infection process (van Kan et al. 2014). In these experiments infection by *B. cinerea* relied on natural infection. *Botrytis cinerea* survives on infected crop residue and infected seed (Lindbeck et al. 2009). The BGM infestation levels of the seed lots used in the field trials each year were not tested, so it is possible that variation in inoculum source in these trials could contribute to differences in disease levels.

As expected, lower disease incidence and higher yields were observed in dryland plots when compared to irrigated plots. Yields obtained in 2014 dryland plots were on par with long-

term average lentil yields of 1500 kg/ha for Alberta, but were lower than the provincial average in 2013 and 2014 (Statistics Canada 2020). Maximum yields of lentil were observed between growing season precipitation levels of 150 – 250 mm (Bowness et al. 2019), and these conditions were present in the 2013 and 2014 trials. The lower yields obtained in 2013 were likely due to the high SWM incidence in both dryland and irrigated plots.

Large differences in resistance of lentil lines to BGM were found in field studies in Australia, with the Canadian cultivars Indianhead and Matador showing highest resistance (Lindbeck et al. 2008). However, these cultivars are not currently grown in Canada, due to late flowering, poor yield and the lack of tolerance to herbicide imazamox. In our study, there was no variability in response to BGM infection among the ten cultivars belonging to a number of different market classes because there were very low disease levels to accurately discern any cultivar differences at all. The variation in response of lentil cultivars to *S. sclerotiorum* disease in Alberta, Canada has not been previously reported. Differences in SWM incidence between cultivars in this study, was not consistent over the years, likely also due to the variable environment conditions observed. Similar variability in genotypic responses to SWM across environmental conditions have been described on sunflower and soybean (Godoy et al. 2005; Kim et al. 1999). Differences in the response of cultivars to SWM incidence were observed in 2013 and 2014 may be attributed to higher disease pressure under irrigation in those years.

Overall, lentil yield was significantly higher at a density of 160 plants m⁻² compared to 120 plants m⁻² except in 2013 and 2014 under irrigated conditions. This was also influenced by irrigation, with dryland plots generally showing a bigger difference in yield between planting densities than irrigated ones. Kasper (2018) reported that a lower plant density (130 plants m⁻²)

was insufficient to achieve maximum yield potential in lentil. However, our results in this study differ from the above in that lower planting density had no significant differences in lentil yield under irrigated conditions in 2013 and 2014, and in dryland treatment in 2014, perhaps the differences may be a result of cultivar variation. Bowness et al. (2019) reported higher yields in Alberta when plant density exceeded 90 plants m⁻².

Conclusion

SWM and BGM incidence in lentil was low in dryland plots over the three years of this study. Significantly higher yield was also obtained from dryland plots. The lentil cultivars evaluated performed well under rain-fed conditions in southern Alberta. Lentil cultivars response to SWM disease varied and was not consistent between years, perhaps due to the interaction of cultivar by year and climatic conditions. Because many cultivars exhibited moderate to high susceptibility to SWM disease, it appears that lentil cultivars studied in this experiment may not be well adapted in cool, wet climates where SWM is predominant or occurs frequently. Although variety selection for SWM or BGM may be a viable tool for disease management, the cultivars used in this study did not show remarkable differences in disease reactions, due to variable disease levels among years and irrigation or dryland conditions. To our knowledge, this is the first report of response of lentil cultivars to SWM infection under field conditions in Canada. SWM may be a limiting factor to lentil production in wetter and cooler areas, as the ten cultivars from the five market classes tested were susceptible to SWM.

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Table 1. Monthly precipitation amounts and temperatures during the growing season at Lethbridge, Alberta from 2013 to 2015.

Month	Precipitation (mm)				Temperature (°C)			
	2013	2014	2015	30-yr mean ^a	2013	2014	2015	30-yr mean ^a
May	50	45	32	50	13.3	11.3	10.5	11.5
June	150	182	22	84	15.5	14.2	17.7	15.4
July	51	19	37	41	18.5	20.1	19.5	18.4
August	30	44	15	40	19.4	18.0	19.4	17.9
Total	281	290	106	215	-	-	-	-
Mean	-	-	-	-	16.7	15.9	16.8	15.8

^a30-yr mean is from 1981 to 2010.

Table 2. Analysis of variance results for fixed effects and interactions on Sclerotinia white mold (SWM) and Botrytis grey mold (BGM) incidence and yield of lentil at Lethbridge, Alberta from 2013 to 2015.

Effects	df	SWM ^{a, c}	BGM ^{b, c}	Yield
Year	2	<0.0001	<0.0001	<0.0001
Irrigation	1	<0.0001	<0.0001	<0.0001
Year x Irrigation	2	0.0001	<0.0001	0.0006
Plant density	1	0.0403	0.2831	0.0007
Year x Plant density	2	0.5124	<0.0001	0.1631
Irrigation x Plant density	1	0.1252	0.7066	0.6751
Year x Irrigation x Plant density	2	0.2684	0.0011	<0.0001
Cultivar	9	<0.0001	0.6440	<0.0001
Year x Cultivar	18	<0.0001	0.4392	<0.0001
Irrigation x Cultivar	9	<0.0001	0.2501	0.0010
Year x Irrigation x Cultivar	18	<0.0001^d	0.3630	0.0401
Plant density x Cultivar	9	0.1792	0.2359	0.0237
Year x Plant density x Cultivar	18	0.0248	0.3011	0.9652
Irrigation x Plant density x Cultivar	9	0.7762	0.7838	0.1265
Year x Irrigation x Plant density x Cultivar	18	0.3550	0.7359	0.1617

^a Sclerotinia white mold.

^b Botrytis grey mold.

^c Analysis of variance was performed after Arcsine transformation of SWM incidence and square root transformation of BGM incidence.

^d Bold p-values indicate significant interaction effects explored using ANOVA for means separation of respective variables.

df: degrees of freedom.

Table 3. Influence of year and irrigation on SWM incidence of lentil with data combined across the two plant densities at Lethbridge, Alberta from 2013 to 2015.

Cultivars	SWM incidence (%) ^a					
	Irrigated			Dryland		
	2013	2014	2015	2013	2014	2015
CDC Impala	68.1bc A ^b	23.4ae B	4.9 C	16.7 BC	0.0C	0.0C
CDC Imperial	80.1abc A	38.7acde B	5.8 D	22.7 BC	0.0D	0.0D
CDC Dazil	82.5abc A	18.3a B	6.8 C	10.3 BC	0.0C	0.0C
CDC Imax	75.8abc A	54.6bcd B	6.1 CD	18.4 C	0.0D	0.0D
CDC Impact	66.5c A	63.6bc A	6.1 BC	22.3 B	0.3C	0.0C
CDC Maxim	70.5abc A	22.5ae B	6.9 C	17.9 BC	0.0D	0.0D
CDC Imigreen	85.2ab A	28.6ade B	5.3 CD	15.1 BC	0.1D	0.0D
CDC Impower	87.2a A	44.7bcde B	7.7 C	11.5C	0.3C	0.0C
CDC Improve	81.4abc A	68.8b A	7.7 B	10.8B	0.0B	0.0B
CDC Imvincible	68.7bc A	40.1acde B	6.3 C	10.8C	0.0C	0.0C
SE	4.94	8.83	1.29	3.49	0.13	n/a
C.V.%	9.5	40.6	42.1	37.4	32.7	n/a

^a SWM incidence was determined by (Infected plants/ Total plants) x 100.

^b Means in columns followed by the same lowercase letter, and in rows followed by the same uppercase letter, are not significantly different according to Fisher's protected least significance difference test ($P \leq 0.05$). Mean separation for SWM was based on arcsine transformed data.

Untransformed mean data are presented.

There was a significant interaction effect between year x irrigation x cultivar ($P < 0.0001$), but not with plant density x irrigation terms.

Table 4. Influence of year and plant density on SWM incidence of lentil cultivars with data combined across the two irrigation conditions at Lethbridge, Alberta from 2013 to 2015.

Cultivars	SWM incidence (%) ^a					
	120 plants m ⁻²			160 plants m ⁻²		
	2013	2014	2015	2013	2014	2015
CDC Impala	41.3 A ^b	7.7 B	1.0 B	43.4 A	15.8 AB	3.9 B
CDC Imperial	46.5 A	19.1 AB	1.1 B	56.3 A	19.6 AB	4.7 B
CDC Dazil	43.5 AB	6.1 C	2.2 C	49.3 A	12.2 BC	4.7 C
CDC Imax	55.3 A	25.0 AB	2.0 B	38.9 AB	29.6 AB	4.1 B
CDC Impact	45.6 A	30.1 ABC	1.8 C	43.2 AB	33.8 ABC	4.3 BC
CDC Maxim	45.3 A	10.6 B	2.3 B	43.2 A	11.9 B	4.6 B
CDC Imigreen	53.4 A	14.5 BC	1.8 C	47.5 AB	14.1 C	3.5 C
CDC Impower	49.9 A	19.1 AB	1.8 B	48.8 A	26.0 AB	5.8 B
CDC Improve	41.6 AB	39.1 AB	2.3 B	50.7 A	29.7 AB	5.4 AB
CDC Imvincible	37.1 A	16.8 AB	2.3 B	42.4 A	23.3 AB	4.0 B
SE	11.97	7.74	0.74	12.03	9.40	1.61
C.V.%	45.5	41.0	43.2	43.6	43.9	29.1

^a SWM incidence was determined by (Infected plants/ Total plants) x 100.

^bMeans in rows followed by the same uppercase letter are not significantly different according to Fisher's protected least significance difference test ($P \leq 0.05$). Mean separation for SWM was based on arcsine transformed data. Untransformed mean data are presented.

There was a significant interaction effect between year x plant density x cultivar ($P = 0.0248$), but there were no significant effects of plant density x irrigation.

Table 5. Influence of year and irrigation on *Botrytis* grey mold incidence at two plant densities on lentil cultivars at Lethbridge, Alberta from 2013 to 2015.

Plant density	BGM incidence (%) ^a					
	Irrigated			Dryland		
	2013	2014	2015	2013	2014	2015
120 plants m ⁻²	1.6 aA ^b	10.6 aB	15.1 aC	0.1 aA	1.8 aA	0.0 A
160 plants m ⁻²	0.3 bA	8.4 bB	22.1 bC	0.4 aA	0.9 bA	0.0 A
SE	0.34	2.05	1.56	0.10	0.34	-
C.V.%	52.7	61.5	73.4	38.1	75.1	n/a

^a BGM incidence was determined by (Infected plants/ Total plants) x 100.

^b Means in columns followed by the same lowercase letter, and in rows followed by the same uppercase letter, are not significantly different according to Fisher's protected least significance difference test ($P \leq 0.05$). Mean separation for BGM was based on square root transformed data. Untransformed mean data are presented.

Table 6. Influence of year and irrigation on yield of lentil cultivars at two plant densities at Lethbridge, Alberta from 2013 to 2015.

Plant density	Yield (kg ha ⁻¹)					
	Irrigated			Dryland		
	2013	2014	2015	2013	2014	2015
120 plants m ⁻²	473.8 A ^a	1111.8 B	392.1 aA	787.0 aC	1746.3 aD	892.0 C
160 plants m ⁻²	568.7 A	1017.7 B	827.5 bCE	1057.6 bBC	1920.3 bD	797.2 E
SE	52.16	86.68	48.18	121.33	53.10	34.51
C.V.%	53.5	37.6	54.8	51.4	41.5	40.4

^a Means in columns followed by the same lowercase letter, and in rows followed by the same uppercase letter, are not significantly different according to Fisher’s protected least significance difference test ($P \leq 0.05$). There was a significant year x irrigation x plant density interaction on yield ($P < 0.0001$).

Table 7. Influence of year and irrigation on yield of lentil cultivars at two plant densities at Lethbridge, Alberta from 2013 to 2015.

Cultivars	Yield (kg ha ⁻¹)					
	Irrigated			Dryland		
	2013	2014	2015	2013	2014	2015
CDC Impala	656.9 ac A ^a	1109.7 bd B	670.0 A	1098.7ab B	1630.8 d C	805.1 bc AB
CDC Imperial	555.5 ab A	985.5 b B	780.4 AB	696.5 bc AB	1607.2 d C	821.1 bc AB
CDC Dazil	529.5 ab A	1585.2 a B	658.8 AC	1150.4 ab BD	2161.9 a E	1016.9 ab CD
CDC Imax	443.8 ab A	901.3 bc AB	798.6 BC	992.7 abc AB	1709.9 bcd C	1230.0 a B
CDC Impact	594.6 ac AB	504.4 c B	499.0 B	936.4 abc A	1496.2 d C	671.9 c AB
CDC Maxim	903.4 c AC	1508.3 ad B	708.6 C	1248.0 a AB	2097.2 abc D	850.1 bc AD
CDC Imigreen	254.3 b A	1016.9 b B	375.4 A	572.9 c A	1693.0 cd C	549.6 c A
CDC Impower	415.8 ab A	966.1 b B	684.7 AB	819.7 abc AB	1763.4 abcd C	1033.6 ab AB
CDC Improve	345.3 ab A	939.9 b B	448.5 A	738.2 bc AB	2115.6 ab C	640.9 c AB
CDC Invincible	513.3 ab AC	1130.0 bd B	473.6 C	969.4 abc AB	2057.5 abc D	826.7 bc ABC
SE	81.67	121.39	98.81	151.01	95.43	71.24
C.V.%	51.2	43.2	57.6	42.4	21.2	36.5

^a Means in columns followed by the same lowercase letter, and in rows followed by the same uppercase letter, are not significantly different according to Fisher's protected least significance difference test ($P \leq 0.05$).

There was a significant year x irrigation x cultivar interaction on yield ($P = 0.0401$)