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(RESEARCH ARTICLE)

Performance of durum wheat cultivars and advanced lines to black point under natural conditions in two crop seasons

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Abstract

Twenty seven advanced durum wheat lines and cultivars CIRNO C2008, Baroyeca Oro C2013, and Quetchehueca Oro C2013 were evaluated for their reaction to black point, under natural conditions at the Norman E. Borlaug Experimental Station, in the Yaqui Valley, Sonora, Mexico, during crop seasons 2015-2016 and 2016-2017. Sowing dates were November 12 and 19, 2015, for the first season, and November 17 and 24, 2016 for the second one, using 8 g of seed for a 0.7 m bed with two rows without replications. Harvest was done manually and the evaluation by visual inspection counting the number of healthy and infected grains in ten spikes per line/cultivar, in order to determine the percentage of infection. Based on the average of the two dates, in the first season one line did not show any infected grain, ten fell within the 0.1-2.5 % infection category, six within 2.6-5.0 %, three within 5.1-10.0 %, and seven within 10.1-30 %. Quetchehueca Oro C2013 did not show any infected grain, while CIRNO C2008 and Baroyeca Oro C2013 showed 1.7 and 12.3 % infection, respectively. In the second season, two lines did not show infected grains, seventeen lines and the three cultivars with 2.4, 1.5, and 1.0 %, respectively, fell within the 0.1-2.5 % infection category, six within 2.6-5.0 %, and two within 5.1-10.0 %. Lines with the highest percentage of infection were: 1A.1D5+1-06/3*MOJO//RCOL/4/ ARMENT//SRN_3/NIGRIS_4/3/CANELO_9.1/5/CF4-JS40//SOOTY_9/RASCON_37/4/CNDO/PRIMADUR//HAI-OU_17 /3/SNITAN/9/CBC509CHILE/6/ECO/CMH76A.722//BIT/3/ALTAR84/4/AJAIA_2/5/KJOVE_1/7/AJAIA_12/ F3LOCAL(SEL.ETHIO.135.85)//PLATA_13/8/S with 50.4 % in the first date of the first season, and WBDTBO/10/ PLATA_10/6/MQUE/4/USDA573//QFN/AA_7/3/ALBA-D/5/AVO/HUI/7/PLATA_13/8/THKNEE_11/9/CHEN/ ALTAR84/3/HUI/POC//BUB/RUFO/4/FNFOOT/11/MÂALI/10/ALTAR84/CMH82A.1062//ALTAR 84/3/YAZI_10/4/ SNITAN/9/USDA595/3/D67.3/RABI//CRA/4/ ALO/5/HUI/YAV_1/6/ARDENTE with 16.3 % in the second date of the second season. Higher infection was detected in crop season 2015-2016 possibly to the occurrence of higher relative humidity during grain expansion.

Keywords: Durum wheat; *Triticum durum*; *Alternaria* spp; Natural infection

1. Introduction

More than 100 species of fungi, including *Alternaria*, *Fusarium*, and *Helminthosporium* spp., can be isolated from newly harvested wheat grain. Kai-Ge et al. [1] were able to isolate 21 strains representing 11 genera of these fungi. These fungi are most important in humid field environments, where they infect seed when relative humidity exceeds 90% and seed

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moisture content exceeds 20%. Rainfall during seed maturation favors black point (BP), as well as humid weather prevailing for a few days prior to harvest [2,3]. Expanding green kernels are most susceptible. Premature seed senescence also promotes BP because many of the fungi are saprophytic [4]. *Alternaria alternata* (Fries: Fries) von Keissler and *Bipolaris sorokiniana* (Sacc.) Shoemaker are generally considered the primary causal agents of the disease [5]. Infected ears may look normal, but there may be elliptical, brown to dark brown lesions on the inner side of the glumes. The disease is more pronounced as brown to dark brown or blackish, localized discolored areas, usually around the embryo end of seeds (Figure 1). The discoloration may also occur near the brush, in the crease or any part of the seed. It may be light or dark or with a distinct margin. Severe infection causes discoloration and shriveled seed [5]. In the endosperm of infected grain, vertical sections may show brown to black spots [6]. The disease known as red spot caused by *Pyrenophora tritici-repentis* (Died.) Drechs., can also occur in grains affected by BP [7]. Black point not only causes economic losses due to the degradation in the quality of flour and semolina, but also affects seed germination and inhibits seedling growth [1].

Figure 1 Symptoms of black point on grain of durum wheat

Black point is an endemic disease of durum wheat (*Triticum durum* Desf.) and bread wheat (*Triticum aestivum* L.) in the southern region of the state of Sonora in Mexico, although its incidence varies from one agricultural crop season to another. The disease also affects triticale (X *Triticosecale* Wittmack) [4,8]. In wheat breeding programs, during the evaluation of seed from segregating populations, those that present BP or some other disease are discarded; however, there is no program designed and financed specifically to evaluate black tip in Sonora, either in introductions, segregating populations and/or advanced lines. Conner and Thomas [9] demonstrated that inoculation by injection and vacuum infiltration of *Alternaria alternata* (Fr.:Fr.) von Keissler is useful to identify resistant and susceptible germplasm. On the other hand, Kai-Ge *et al*. [1] completed Koch's postulates with several species that cause BP, by spraying plants in the greenhouse. In order to contribute to the monitoring of this disease in southern Sonora, the objective of this work was to evaluate the reaction of durum wheat commercial cultivars and advanced lines candidates for commercial release, during the fall-winter crop seasons 2015-2016 and 2016-2017.

2. Materials and methods

Twenty seven advanced durum wheat lines and cultivars CIRNO C2008 [10], Baroyeca Oro C2013 [11], and Quetchehueca Oro C2013 [12] were evaluated for their reaction to black point, under natural conditions at the Norman E. Borlaug Experimental Station which belongs to the National Institute for Forestry, Agriculture, and Livestock Research, located in block 910 in the Yaqui Valley, Sonora, Mexico (27º22´3.01" N and 109º55´40.22" W) in a clay soil with pH of 7.8, in the Yaqui Valley, Sonora, Mexico, during crop seasons 2015-2016 and 2016-2017. Sowing dates were November 12 and 19, 2015, for the first season, and November 17 and 24, 2016 for the second one, using 8 g of seed for a 0.7 m bed with two rows without replications. Fertilization consisted of 150 kg/ha of urea before sowing. One irrigation for seed germination and three complementary irrigations were applied during the cycle. Before the first complementary irrigation, 100 kg/ha of urea were applied. Thirty days after sowing, the herbicide Situi® XL (metsulfuron methyl) [13] was applied at a dose of 25 g/ha of commercial product. Harvest was done manually and the evaluation by visual inspection counting the number of healthy and infected grains in ten spikes per line/cultivar, in order to determine the percentage of infection. The daily average temperature (°C), the maximum and minimum, relative humidity, and precipitation were recorded from March 1 to 31, during 2016 and 2017, by the weather station CIANO-910, located in block 910 in the Yaqui Valley, which belongs to the automated weather station network of Sonora [14].

3. Results and discussion

During the crop season 2015-2016, the range of infection for the first sowing date was 0 to 50.4 % with an average of 9.1 (Figure 2); 6 lines and cultivars CIRNO C2008 and Quetchehueca Oro C2013 did not have infected grains, 8 lines fell within the 0.1-2.5 % infection category, 2 lines within 2.6-5.0 %, 2 lines within 5.1-10 %, 7 lines within 10.1-30 %, and 3 lines showed more than 30.1 % infected grains. The range of infection for the second date was 0 to 24.1 % with an average of 3.1; 4 lines and Quetchehueca Oro C2013 did not have infected grains, 12 lines fell within the 0.1-2.5 % infection category, 7 lines and CIRNO C2008 within 2.6-5.0 %, 3 lines within 5.1-10 %, and 1 line and Baroyeca Oro C2013 within 10.1-30 %.

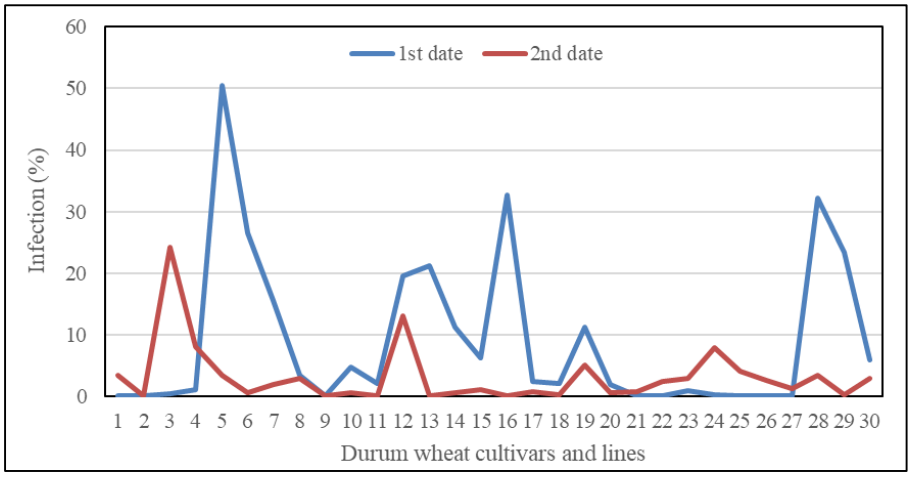

Figure 2 Percentage of infection with black point (*Alternaria* spp.) in two sowing dates, of 27 durum wheat advanced lines and 3 commercial cultivars, evaluated under natural infection in the field, during the fall-winter crop season 2015-2016, at the Norman E. Borlaug Experimental Station in the Yaqui Valley, Sonora, Mexico. 1= CIRNO C2008, 2= Quetchehueca Oro C2013, 3= Baroyeca Oro C2013

Some lines showed consistency in their reaction to BP: line RANCO//CIT71/CII/3/COMDK/4/TCHO//SHWA/MALD/3/CREX/5/SNITAN/6/YAZI_1/AKAKI_4//SOMAT_3/3/AUK/GUIL//GREEN/7/CIRNOC2008 and cultivar Quetchehueca Oro C2013 did not show any infected grains in the two dates, and eight showed a range of infection between 0 and 2.5 %; however, seven lines showed a difference greater than 20 % infection. More lines showed greater infection in the first than in the second date. Lines with the highest percentage of infection were: 1A.1D5+1-06/3*MOJO//RCOL/4/ARMENT//SRN_3/NIGRIS_4/3/CANELO_9.1/5/CF4-JS40//SOOTY_9/RASCON37/4/CNDO/PRIMADUR//HAI-OU_17/3/SNITAN/9/CBC509CHILE/6/ECO/CMH76A.722//BIT/3/ALTAR84/4/AJAIA_2/5/KJOVE_1/7/AJAIA_12/F3LOCAL(SEL.ETHIO.135.85)//PLATA_13/8/S with 50.4 %, GUAYACANINIA/GUANAY/8/GEDIZ/FGO//GTA/3/SRN_1/4/TOTUS/5/ENTE/MEXI_2//HUI/4/YAV_1/3/LD357E/2*TC60//JO69/6/SOMBRA_20/7/JUPAREC2001/10/TADIZ/9/USDA595/3/D67.3/RABI//CRA/4/ALO/5/HUI/YAV_1/6/ARDENTE/7/HUI/YAV79/8/POD_9 with 32.7 %, and CIRNOC2008*2/3/KNIPA/TAGUA// PLANETA/TRILE with 32.1 %, all in the first date.

During the crop season 2016-2017, the range of infection for the first sowing date was 0 to 9.4 % with an average of 1.4 (Figure 3); 11 lines and cultivar CIRNO C2008 did not have infected grains, 10 lines and Baroyeca Oro C2013 fell within the 0.1-2.5 % infection category, 5 lines and Quetchehueca Oro C2013 within 2.6-5.0 %, and 1 line within 5.1-10 %. The range of infection for the second date was 0 to 16.3 % with an average of 2.6; 6 lines did not have infected grains, 10 lines and cultivars Quetchehueca Oro C2013 and Baroyeca Oro C2013 fell within the 0.1-2.5 % infection category, 8 lines and CIRNO C2008 within 2.6-5.0 %, 1 line within 5.1-10 %, and 2 lines within 10.1-30 %. This group of lines showed more consistency in their reaction to BP in both dates than the group in crop season 2015-2016: lines MOHAWK/6/LOTUS_5/F3LOCAL(SEL.ETHIO.135.85)/5/CHEN/ALTAR84/3/HUI/POC//BUB/RUFO/4/FNFOOT/7/SORA/2*PLATA_12/3/SORA/2*PLATA_12//SOMAT_3/4/AJAIA_13/YAZI//DIPPER_2/BUSHEN_3 and DWL5023/7/MOHAWK/6/LOTUS_5/F3LOCAL(SEL.ETHIO.135.85)/5/CHEN/ALTAR84/3/HUI/POC//BUB/RUFO/4/FNFOOT did not show any infected grains in the two dates, and 12 showed a range of infection between 0 and 2.5%. Only one line showed a difference of 15.6 % and two lines a difference of 8 %. More lines showed greater infection in the second date than in the first one. Lines with the highest percentage of infection in each date were: WBDTBO/10/PLATA_10/6/MQUE/4/USDA573//QFN/AA_7/3/ALBAD/5/AVO/HUI/7/PLATA_13/8/THKNEE_11/9/CHEN/ALTAR84/3/HUI/POC//BUB/RUFO/4/FNFOOT/11/MÂALI/10/ALTAR84/CMH82A.1062//ALTAR84/3/YAZI_10/4/SNITAN/9/USDA595/3/D67.3/RABI//CRA/4/ALO/5/HUI/YAV_1/6/ARDENTE with 16.3 % in the second date, and GUAYACANINIA/

POMA_2//SNITAN/4/D86135/ACO89//PORRON_4/3/SNITAN/7/CAMAYO//HYDRANASSA30/SILVER_5/3/SOOTY_9/RASCON_37/5/DUKEM_15/3/BISU_1/PLATA_16//RISSA/4/SOOTY_9/RASCON_37/6/SOOTY_9/RASCON_37//TILO_1/LOTUS_4 with 9.4 % in the first date.

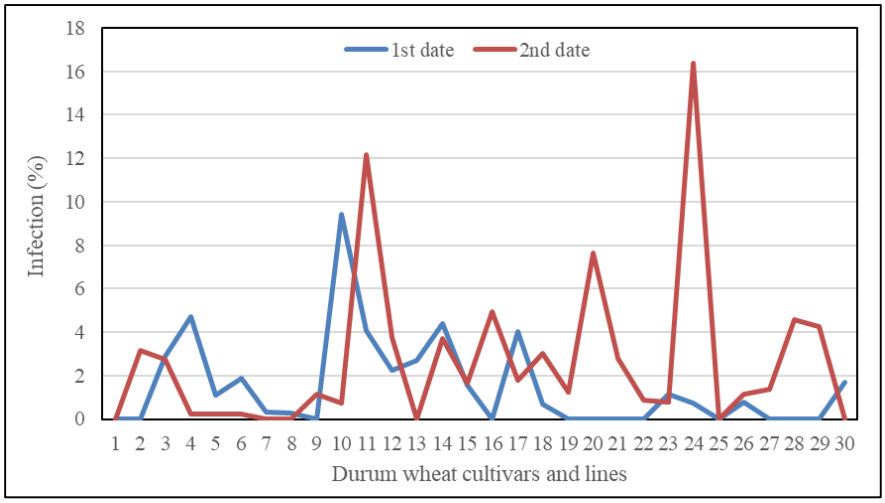

Figure 3 Percentage of infection with black point (*Alternaria* spp.) in two sowing dates, of 27 durum wheat advanced lines and 3 commercial cultivars, evaluated under natural infection in the field, during the fall-winter crop season 2016-2017, at the Norman E. Borlaug Experimental Station in the Yaqui Valley, Sonora, Mexico. 2= CIRNO C2008, 4= Quetchehueca Oro C2013, 6= Baroyeca Oro C2013

The average percentage of infection was quite different in both seasons (Figure 4), and in general higher in the crop season 2015-2016. Cultivars CIRNO C2008 and Baroyeca Oro C2013 had more infection in the first season (2015-2016) with a difference of 0.11 and 11.2 %, respectively, while Quetchehueca Oro C2013 had more infection in the second season (2016-2017) with 2.4 %, being the difference the same percentage. Aside from the three cultivars, 18 lines showed greater infection in 2015-2016, a difference ranging from 0.3 to 26.2 %, while 9 lines had more infection in 2016-2017 with a difference ranging from 0.08 to 7.1 %. Out of the 27 lines evaluated, 8 were present in both crop seasons, and with exception of one which had a difference of 0.1 %, the rest showed greater infection in 2015-2016. The difference in percentage of infection ranged from 0.6 to 15.6.

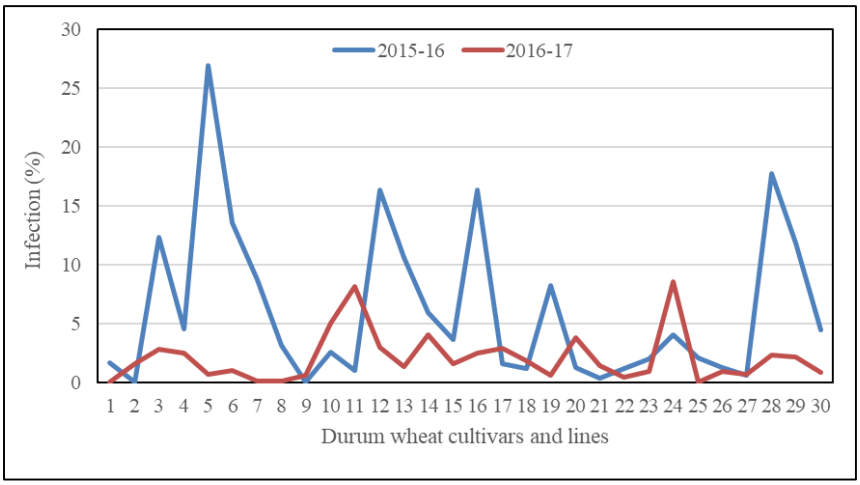

Figure 4 Average percentage of infection with black point (*Alternaria* spp.) in two sowing dates and in two crop seasons (2015-2016 and 2016-2017), of 27 durum wheat advanced lines and 3 commercial cultivars, evaluated under natural infection in the field, at the Norman E. Borlaug Experimental Station in the Yaqui Valley, Sonora, Mexico. 1= CIRNO C2008, 2= Quetchehueca Oro C2013, 3= Baroyeca Oro C2013 in 2015-2016. 2= CIRNO C2008, 4= Quetchehueca Oro C2013, 6= Baroyeca Oro C2013 in 2016-2017

Relative humidity during March 2016 had a range of 31.2 to 100 % with an average of 75.3 %, while in 2017 the range was 24.4 to 99.6 % with an average of 70.8 % (Figure 5). From March 7 onwards and with the exception of March 15

and 16, the rest of the days had greater relative humidity in 2016 than in 2017, which may have led to greater infection by BP in cultivars and lines (Figure 4). The cultivars used in this work have an average of 122 days to physiological maturity [10,11,12], so by March 7, cultivars and lines had reached 116 days after the first sowing date and 108 for the second one, and therefore, kernels were in full expansion close to physiological maturity (stages 83-91, Zadoks scale [15]). As Duveiller *et al*. [2] and Watkins [3] reported, rainfall during seed maturation favors BP, as well as humid weather prevailing for a few days prior to harvest, and also expanding green kernels are most susceptible.

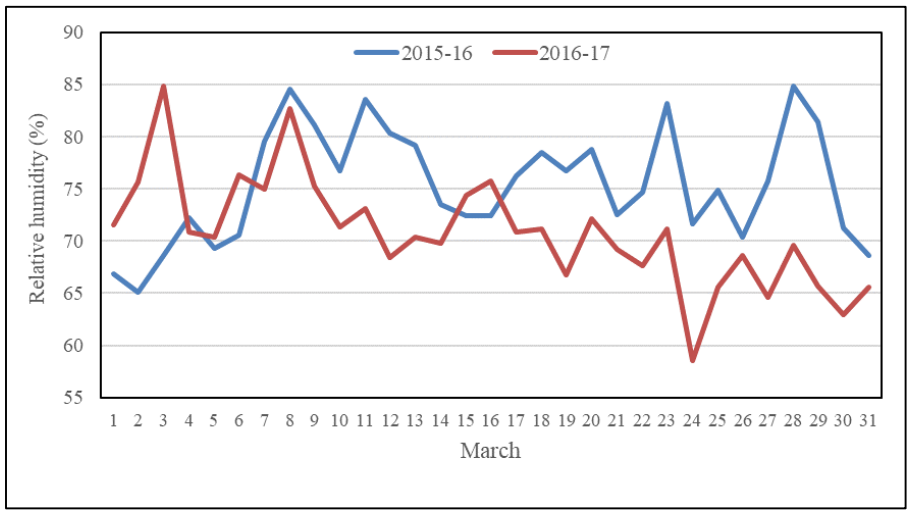

Figure 5 Average relative humidity during March 2016 and 2017, recorded by the weather station CIANO-910, located in block 910 at the Norman E. Borlaug Experimental Station in the Yaqui Valley, Sonora, Mexico

Within the infection categories of the groups based on the average of the two dates in each crop season, in 2015-2016, one line and cultivar Quetchehueca Oro C2013 did not show any infected grains, 10 lines and CIRNO C2008 fell within the 0.1-2.5 % infection category, 6 lines within 2.6-5.0 %, 3 lines within 5.1-10.0 %, and 7 lines and Baroyeca Oro C2013 within 10.1-30.0 % (Figure 6). The overall average of the group was 6.1 % with a range of 0 to 26.9 %. In 2016-2017, two lines did not show any infected grains, 17 lines and the three cultivars fell within the 0.1-2.5 % category, 6 lines within 2.6-5.0 %, and 2 lines within 5.1-10.0 %. The overall average of the group was 2.09 % with a range of 0 to 8.5 %.

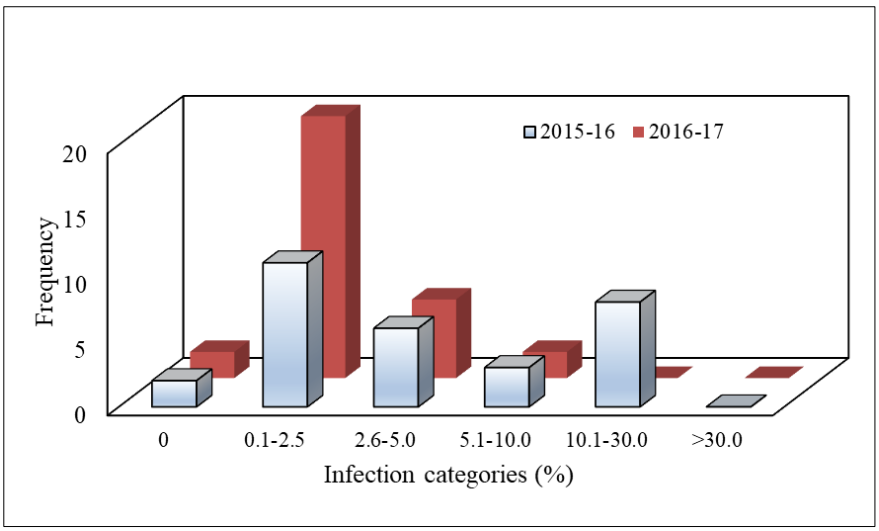

Figure 6 Infection categories (%) with black point (*Alternaria* spp.) in two sowing dates, of 27 durum wheat advanced lines and 3 commercial cultivars, evaluated under natural infection in the field, during the fall-winter crop seasons 2015-2016 and 2016-2017, at the Norman E. Borlaug Experimental Station in the Yaqui Valley, Sonora, Mexico

Incidence of BP in regions where wheat is cultivated in southern Sonora during the fall-winter is variable, in both bread [16], durum wheat, and triticale [8]; it might be inferred that this is partly due not only to the weather conditions that prevail during the season, but also, due to the different climatic zones that have been described [17,18]. Another

important aspect is the primary inoculum which is influenced by weather, as well as by the capacity of some fungal species like *Alternaria triticina* Pras. and Prab., *Helminthosporium sativum* Pamm., King and Bakke, and *Fusarium* spp. to act as saprophytes, as they may survive in plant debris [4]. As in the present study, the percentage of infection of BP may be high in some crop seasons, like in 2009-2010, Fuentes-Dávila *et al*. [16] reported that the durum wheat line SOMAT_4/INTER_8/4/GODRIN/GUTROS//DUKEM/3/THKNEE_11/5/CNDO/PRIMADUR//HAI-OU_17/3/SNITAN showed 50.6 % infection under natural conditions, while the bread wheat lines BABAX/LR42//BABAX /3/ER2000, BABAX/LR42//BABAX*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ, and TC870344/GUI//TEMPORALERAM87/AGR /3/2*WBLL1 had 30.8, 27.3, and 20.5 % infected grains, respectively; and in 2013-2014, bread wheat lines SOKOLL*2/3/BABAX/ LR42//BABAX and KISKADEE#1/CHYAK both had 31.4% infected grains [19]. A high percentage of wheat grains infected with BP affects the quality and consequently the value of the products. Therefore, besides aiming to the use of resistant cultivars [20], BP can be partially controlled by reducing the frequency of irrigation after heading and by reducing nitrogen rates, without affecting the grain yield or its quality. Testing experimental durum wheat germplasm for their reaction to BP should be a continuous effort in order to secure tolerant, and even more resistant genotypes that could be candidates for commercial release. In the Yaqui Valley, 98.8 % of the area grown with wheat, corresponded to durum wheat during the fall-winter crop seasons 2015-2016 and 2016-2017 [21,22). This will not only contribute to improve the economic return for the wheat producers, but it will also be positively reflected in the region and the country.

4. Conclusion

Based on the average of two sowing dates, in crop season 2015-2016 one line did not show any infected grain with black point, ten fell within the 0.1-2.5 % infection category, six within 2.6-5.0 %, three within 5.1-10.0 %, and seven within 10.1-30 %. Cultivar Quetchehueca Oro C2013 did not show any infected grain, while CIRNO C2008 and Baroyeca Oro C2013 showed 1.7 and 12.3 % infection, respectively.

In crop season 2016-2017, two lines did not show infected grains, seventeen lines and the three cultivars with 2.4, 1.5, and 1.0 % infection, respectively, fell within the 0.1-2.5 % infection category, six within 2.6-5.0 %, and two within 5.1-10.0 %.

Lines with the highest percentage of infection were: 1A.1D5+1-06/3*MOJO//RCOL/4/ARMENT//SRN_3/NIGRIS_4/3/ CANELO_9.1/5/CF4-JS40//SOOTY_9/RASCON_37/4/CNDO/PRIMADUR//HAI-OU_17/3/SNITAN/9/CBC509CHILE /6/ECO/CMH76A.722//BIT/3/ALTAR84/4/AJAIA_2/5/KJOVE_1/7/AJAIA_12/F3LOCAL(SEL.ETHIO.135.85)// PLATA_13/8/S with 50.4 % in the first date of the first season, and WBDTBO/10/PLATA_10/6/MQUE/4/USDA573 //QFN/AA_7/3/ALBA-D/5/AVO/HUI/7/PLATA_13/8/THKNEE_11/9/CHEN/ALTAR84/3/HUI/POC//BUB/RUFO/4/ FNFOOT/11/MÂALI/10/ALTAR84/CMH82A.1062//ALTAR84/3/YAZI_10/4/SNITAN/9/USDA595/3/D67.3/RABI// CRA/4/ALO/5/HUI/YAV_1/6/ARDENTE with 16.3 % in the second date of the second season.

Higher percentage of infection with black point was detected in crop season 2015-2016, possibly due to the occurrence of higher relative humidity during grain expansion and physiological maturity. This season had a range of 31.2 to 100 % with an average of 75.3 % during the month of March, while in season 2016-2017, the range was 24.4 to 99.6 % with an average of 70.8 %.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declare that No conflict of interest.

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