GSC Advanced Research and Reviews

eISSN: 2582-4597 CODEN (USA): GARRC2

Cross Ref DOI: 10.30574/gscarr

Journal homepage: https://gsconlinepress.com/journals/gscarr/

(Research Article)

Reaction of bread wheat cultivars and advanced lines to black point under natural conditions in crop seasons 2016-2017 and 2017-2018

Guillermo Fuentes-Dávila [1, *], Ivón Alejandra Rosas-Jáuregui [2], Pedro Félix-Valencia [3], María Monserrat Torres-Cruz [4] and Alberto Borbón-Gracia [5]

[1] *INIFAP, Wheat Pathology.*
[2] *INIFAP, Wheat Biotechnology.*
[3] *INIFAP, Agroclimatology.*
[4] *Autonomous University of Sinaloa, Faculty of Agriculture of the Fuerte Valley, Juan José Ríos, Sinaloa, Mexico.*
[5] *INIFAP, Wheat Breeding.*

GSC Advanced Research and Reviews, 2025, 25(01), 184-194

Publication history: Received on 03 September 2025; revised on 08 October 2025; accepted on 11 October 2025

Article DOI: https://doi.org/10.30574/gscarr.2025.25.1.0304

Abstract

Twenty one advanced bread wheat lines (ABWL) and cultivars Borlaug 100 F2014, Onavas F2009, Roelfs F2007, and Villa Juárez F2009 were evaluated for their reaction to black point, under natural conditions at the Norman E. Borlaug Experimental Station in the Yaqui Valley, Mexico, during crop season 2016-2017, and sixteen ABWL and cultivars Borlaug 100 F2014, Onavas F2009, RSM-Norman F2008, and Roelfs F2007 during 2017-2018. Sowing dates were November 17 and 24, 2016, and 14 and 24, 2017, respectively. Healthy and infected grains in ten spikes per line/cultivar were counted. In 2016-2017, infection in the first date ranged from 0 to 24.3 %, with an average of 4.8, and for the second date 0 to 25.9 %, with an average of 6.9 %. Average infection for Villa Juárez F2009 was 2.9 %, 2.5 % for Borlaug 100 F2024, 3.6 % for Roelfs F2007, and 3.8 % for Onavas F2009. The line with the highest percentage of infection was SITE/MO//PASTOR/3/TILHI/4/WAXWING/KIRITATI/5/KACHU#1/KIRITATI//KACHU in the second date with 25.9 %. In 2017-2018, infection in the first date ranged from 0 to 19.8 %, with an average of 4.8, and for the second date 0 to 29.5 %, with an average of 7.1. The average infection for Onavas F2009 was 0.7 %, 3.9 % for RSM Norman F2008, 5.8 % for Borlaug 100 F2014, and 9.6 % for Roelfs F2007. The line with the highest percentage of infection was: SOKOLL*2/3/BABAX/LR42//BABAX with 29.5 % in the second sowing date. Despite the higher average relative humidity present in March of 2017 than in 2018, greater incidence of black point was detected in 2018.

Keywords: Bread wheat; *Triticum aestivum*; *Alternaria* spp; Natural infection

1. Introduction

Black point (BP) is a worldwide wheat disease, especially in Australia, Canada, China, India, Guatemala, Mexico, Peru, Russia, the United Kindom, and the United States [1]. Many of the fungi that cause BP are saprophytic [2], *Alternaria alternata* (Fr.:Fr.) Keissl. and *Bipolaris sorokiniana* (Sacc.) Shoemaker are generally considered the primary causal agents of the disease [3]. Many fungal species can be isolated from harvested wheat grain, as for example, Kai-Ge *et al.* [4] isolated 21 strains from 11 genera of these fungi. These fungal species are important in humid field environments, where they infect seed when relative humidity exceeds 90 % and seed moisture content exceeds 20 %. Rainfall during seed maturation, along with several days of humid weather leading up to harvest, promotes the development of BP; the condition primarily affects expanding green kernels, which are the most vulnerable [5,6]. Infected ears which could look normal, may have 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 (Figure 1).

* Corresponding author: Guillermo Fuentes-Dávila

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 shrivelling of the whole seed [3], and significantly reduces grain quality, and leads to toxic secondary metabolites that may cause esophageal cancer [1]. Vertical sections may show brown to black spots in the endosperm of infected seed [7].

Figure 1 Symptoms of black point on grain of bread wheat

The disease known as red spot caused by *Pyrenophora tritici-repentis* (Died.) Drechs., can also occur in seed affected by BP [8]. 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 [4]. It 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 [9]. BP also affects triticale (X *Triticosecale* Wittmack) [2]. Artificial inoculation of wheat germplasm may help breeding programs in identifying resistant genotypes to BP. It has been demonstrated that inoculation by injection and vacuum infiltration of *Alternaria alternata* [10] and by spraying with *Bipolaris sorokiniana* [11] and with several species that cause BP [4], is useful to identify resistant and susceptible germplasm. In order to contribute to the monitoring of this disease in southern Sonora, the objective of this work was to evaluate the reaction of bread wheat commercial cultivars and advanced lines candidates for commercial release, during the 2016-2017 and 2017-2018 fall-winter crop seasons under natural infection.

2. Materials and methods

Twenty one advanced bread wheat lines (ABWL) and cultivars Borlaug 100 F2014 [12], Onavas F2009 [13], Roelfs F2007 [14], and Villa Juárez F2009 [15] (Table 1) 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, 37 masl) in a clay soil with pH of 7.8, during crop season 2016-2017, and sixteen ABWL and cultivars Borlaug 100 F2014, Onavas F2009, RSM Norman F2008 [16], and Roelfs F2007 during 2017-2018 (Table 2). Sowing dates were November 17 and 24, 2016, and 14 and 24, 2017, respectively, 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 season. Before the first complementary irrigation, 100 kg/ha of urea were applied. Thirty days after sowing, the herbicide Situi® XL (metsulfuron methyl) [17] 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 [18].

Table 1 Bread wheat nursery evaluated for resistance to black point under natural conditions, during the crop season 2016-2017 at the Norman E. Borlaug Experimental Station in the Yaqui Valley, Sonora, Mexico

No	Pedigree and selection history
1	SITE/MO//PASTOR/3/TILHI/4/WAXWING/KIRITATI/5/KACHU#1/KIRITATI// KACHU CMSS11B00147S-099M-099NJ-099NJ-5WGY-0B
2	ROELFS F2007 CGSS00B00169T-099TOPY-099M-099Y-099M-9CEL-0B-0Y-0Y
3	SAUAL/MUTUS/4/KACHU #1//WBLL1*2/KUKUNA/3/BRBT1*2/KIRITATI CMSS11B00042S-099M-099NJ-099NJ-4RGY-0B
4	VILLA JUAREZ F2009 CGSS01B00062T- 099Y-099M-099M-099Y-099M-12Y-0B-0CEVY-0CEVY
5	GRACK*2/6/FRET2*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ*2/5/BOW/URES//2*WEAVER/3/CROC_1/AE.SQUARROSA (213)//PGO CMSS10Y01107T-099TOPM-099Y-099M-9WGY-0B
6	ONAVAS F2009 CGSS01B00069T-099Y-099M-099M-099Y-099M-20Y-0B-0CEVY-0CEVY
7	ND643/2*WBLL1/5/PRL/2*PASTOR/4/CHOIX/STAR/3/HE1/3*CNO79//2*SERI/6/PRL/2*PASTOR/4/CHOIX/STAR/3/HE1/3*CNO79//2*SERI CMSS08B00773T-099TOPY-099M-099Y-5M-0WGY
8	PBW343//CAR422/ANA/3/ELVIRA CMSS02M00409S-030M-1Y-0M-040Y-10ZTB-0Y-02B-0Y
9	ATTILA/3*BCN//BAV92/3/PASTOR/4/TACUPETOF2001*2/BRAMBLING/5/PAURAQ CMSS07B00525T-099TOPY-099M-099NJ-099NJ-1WGY-0B
10	BABAX/LR42//BABAX/3/ER2000/4/2*MUNAL CMSA09Y00390T-099B-050Y-050ZTM-0NJ-099NJ-6WGY-0B
11	BORLAUG100 F2014 CMSS06Y00605T-099TOPM-099Y-099ZTM-099Y-099M-11WGY-0B
12	SOKOLL*2/3/BABAX/LR42//BABAX CMSA05Y01225T-040M-040ZTP0Y-040ZTM-040SY-12ZTM-01Y-0B
13	HUIRIVIS #1*2/MURGA/3/TACUPETO F2001/BRAMBLING*2//KACHU CMSS11Y00343S-099Y-099M-099NJ-099NJ-11WGY-0B
14	WBLL1*2/KKTS//PASTOR/KUKUNA/3/KINGBIRD#1//INQALAB91*2/TUKURU/5/KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/SAUAL CMSS11Y00824T-099TOPM-099Y-099M-099NJ-099NJ-23WGY-0B
15	SHORTENEDSR26TRANSLOCATION/4/ATTILA/3*BCN//BAV92/3/PASTOR/5/MUNAL/6/MUTUS*2/TECUE #1 CMSS11B00492S-099M-099NJ-099NJ-4WGY-0B
16	KACHU/KIRITATI//BORL14 CMSS11B00551S-099M-0SY-16M-0WGY
17	ATTILA*2/PBW65//MUU#1/3/FRANCOLIN#1/4/ATTILA*2/PBW65*2//KACHU/5/ATTILA*2/PBW65//MUU #1/3/FRANCOLIN #1 CMSS11B00899T-099TOPY-099M-099NJ-099NJ-13WGY-0B
18	NADI/3/PBW343*2/KUKUNA*2//FRTL/PIFED/4/NADI

	CMSS11B00908T-099TOPY-099M-099NJ-099NJ-32WGY-0B
19	NADI/4/KZA//WH 542/2*PASTOR/3/BACEU #1/5/NADI CMSS11B00911T-099TOPY-099M-099NJ-099NJ-15WGY-0B
20	SAUAL/MUTUS/4/KACHU #1//WBLL1*2/KUKUNA/3/BRBT1*2/KIRITATI CMSS11B00042S-099M-099NJ-099NJ-4RGY-0B
21	SAUAL/MUTUS/4/KACHU #1//WBLL1*2/KUKUNA/3/BRBT1*2/KIRITATI CMSS11B00042S-099M-099NJ-099NJ-12RGY-0B
22	TACUPETOF2001/6/CNDO/R143//ENTE/MEXI_2/3/AEGILOPSSQUARROSA(TAUS)/4/ WEAVER/5/PASTOR/7/ROLF07/8/PBW343*2/KUKUNA*2//FRTL/PIFED CMSS11B00311S-099M-099NJ-099NJ-3RGY-0B
23	TACUPETOF2001/6/CNDO/R143//ENTE/MEXI_2/3/AEGILOPSSQUARROSA(TAUS)/4/ WEAVER/5/PASTOR/7/ROLF07/8/PBW343*2/KUKUNA*2//FRTL/PIFED CMSS11B00311S-099M-099NJ-099NJ-7RGY-0B
24	OASIS/SKAUZ//4*BCN/3/PASTOR/4/KAUZ*2/YACO//KAUZ/5/2*QUAIU#3/6/BECARD/ QUAIU #1 CMSS11B00391S-099M-099NJ-099NJ-8RGY-0B
25	WBLL1*2/KUKUNA//KIRITATI/3/WBLL1*2/KUKUNA/4/KINGBIRD#1//INQALAB91*2/ TUKURU/5/WBLL1*2/BRAMBLING//KACHU CMSS11B00973T-099TOPY-099M-099NJ-099NJ-7RGY-0B

Table 2 Bread wheat nursery evaluated for resistance to black point under natural conditions, during the crop season 2017-2018 at the Norman E. Borlaug Experimental Station in the Yaqui Valley, Sonora, Mexico

No	Pedigree and selection history
1	ROELFS F2007 CGSS00B00169T-099TOPY-099M-099Y-099M-9CEL-0B-0Y-0Y
2	RSM Norman F2008 CGSS96BO2235-099 B-019Y-22B-OY-58B-OM-03CJ-03T-OMX
3	ONAVAS F2009 CGSS01B00069T-099Y-099M-099M-099Y-099M-20Y-0B-0CEVY-0CEVY
4	PBW343//CAR422/ANA/3/ELVIRA CMSS02M00409S-030M-1Y-0M-040Y-10ZTB-0Y-02B-0Y
5	SOKOLL*2/3/BABAX/LR42//BABAX CMSA05Y01225T-040M-040ZTP0Y-040ZTM-040SY-12ZTM-01Y-0B
6	BORLAUG100 F2014 CMSS06Y00605T-099TOPM-099Y-099ZTM-099Y-099M-11WGY-0B
7	ATTILA/3*BCN//BAV92/3/PASTOR/4/TACUPETOF2001*2/BRAMBLING/5/PAURAQ CMSS07B00525T-099TOPY-099M-099NJ-099NJ-1WGY-0B
8	ND643/2*WBLL1/5/PRL/2*PASTOR/4/CHOIX/STAR/3/HE1/3*CNO79//2*SERI/6/PRL/ 2*PASTOR/4/CHOIX/STAR/3/HE1/3*CNO79//2*SERI CMSS08B00773T-099TOPY-099M-099Y-5M-0WGY
9	SAUAL/MUTUS/4/KACHU #1//WBLL1*2/KUKUNA/3/BRBT1*2/KIRITATI CMSS11B00042S-099M-099NJ-099NJ-4RGY-0B
10	SITE/MO//PASTOR/3/TILHI/4/WAXWING/KIRITATI/5/KACHU#1/KIRITATI// KACHU

	CMSS11B00147S-099M-099NJ-099NJ-5WGY-0B
11	ND643/2*TRCH//BECARD/3/BECARD/4/SUP152*2/TECUE #1 CMSS11B00490S-099M-099NJ-099NJ-12WGY-0M
12	WBLL1*2/BRAMBLING//WBLL1*2/BRAMBLING/3/2*BORL14 CMSS12Y00929T-099TOPM-099Y-099M-0SY-14M-0WGY
13	KACHU/BECARD//WBLL1*2/BRAMBLING/3/ONIX/KBIRD CMSS12B00313S-099M-0SY-14M-0RGY
14	KACHU/BECARD//WBLL1*2/BRAMBLING/3/FRNCLN*2/TECUE #1 CMSS12B00317S-099M-0SY-33M-0WGY
15	BORL14*2/MUNAL #1 CMSS12B00626T-099TOPY-099M-0SY-25M-0WGY
16	BORL14*2//MUNAL #1/FRANCOLIN #1 CMSS12B00629T-099TOPY-099M-0SY-15M-0WGY
17	BORL14*2/3/KBIRD//WBLL1*2/KURUKU CMSS12B00630T-099TOPY-099M-0SY-11M-0WGY
18	BORL14*2/3/WBLL1*2/TUKURU//CROSBILL #1 CMSS12B00631T-099TOPY-099M-0SY-4M-0WGY
19	BORL14*2//KFA/2*KACHU CMSS12B00633T-099TOPY-099M-0SY-43M-0WGY
20	STLN/MUNAL #1//2*BORL14 CMSS12B00828T-099TOPY-099M-0SY-42M-0WGY

3. Results and discussion

During the crop season 2016-2017, the range of infection for the first sowing date was 0 to 24.3 % with an average of 4.8 (Figure 2); cultivar Borlaug 100 F2014 did not have infected grains, 9 lines and cultivars Villa Juárez F2009 and Roelfs F2007 fell within the 0.1-2.5 % infection category, 3 lines within 2.6-5.0 %, 6 lines and cultivar Onavas F2009 within 5.1-10 %, and 3 lines within 10.1-30 % infected grains. The range of infection for the second date was 0 to 25.9 % with an average of 6.9; 3 lines did not have infected grains, 5 lines and cultivar Onavas F2009 fell within the 0.1-2.5 % infection category, 4 lines and Borlaug 100 F2014 within 2.6-5.0 %, 2 lines and cultivars Villa Juárez F2009 and Roelfs F2007 within 5.1-10 %, and 7 lines within 10.1-30 %. Ten lines and cultivar Onavas F2009 showed greater percentage of infection in the first date than in the second one, and 11 lines and cultivars Borlaug 100 F2014, Roelfs F2007, and Villa Juárez F2009 showed the opposite. A difference in percentage of infection between 0.0.1 and 0.88 % was shown by lines ND643/2*WBLL1/5/PRL/2*PASTOR/4/CHOIX/STAR/3/HE1/3*CNO79//2*SERI/6/PRL/2*PASTOR/4/CHOIX/STAR/3/HE1/3*CNO79//2*SERI (No. 7), KACHU/KIRITATI//BORL14 (No. 16), SAUAL/MUTUS/4/KACHU#1//WBLL1*2/KUKUNA/3/BRBT1*2/KIRITATI (No. 21), and WBLL1*2/KUKUNA//KIRITATI/3/WBLL1*2/KUKUNA/4/KINGBIRD#1//INQALAB91*2/TUKURU/5/WBLL1*2/BRAMBLING//KACHU (No. 25).

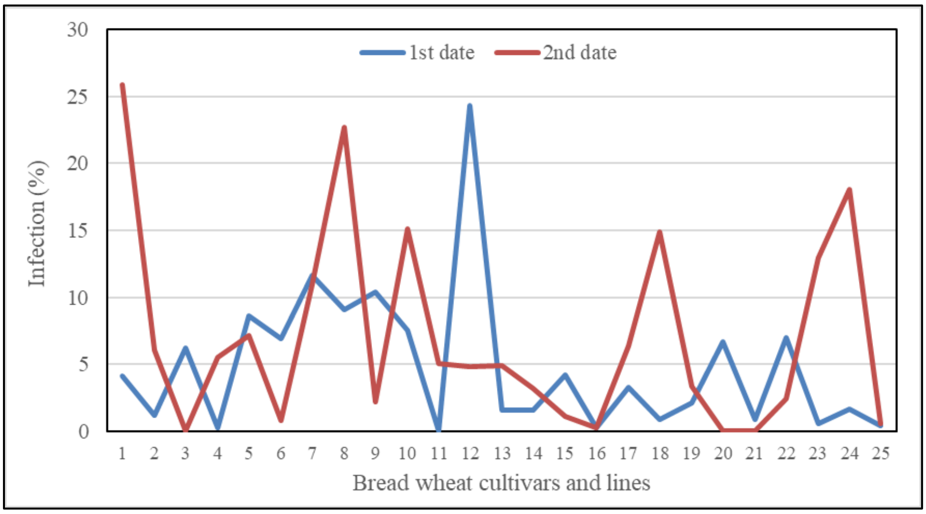

Figure 2 Percentage of infection with black point (*Alternaria* spp.) in two sowing dates, of 21 bread wheat advanced lines and 4 commercial cultivars, evaluated under natural infection in the field, during the fall-winter crop season 2016-2017, at the Norman E. Borlaug Experimental Station in the Yaqui Valley, Sonora, Mexico. 2= Roelfs F2007, 4= Villa Juárez F2009, 6= Onavas F2009, 11= Borlaug 100 F2014

Three lines showed a difference between 1.29 and 1.65 % (No. 5, 14, and 19), eight lines (No. 3, 9, 10, 13, 15, 17, 20 and 22) and the four cultivars showed a difference between 3.02 and 8.24 %, four lines between 12.35 and 16. 46 % (No. 8, 18, 23, and 24), and the lines SITE/MO//PASTOR/3/TILHI/4/WAXWING/KIRITATI/5/KACHU#1/KIRITATI//KACHU (No. 1) and SOKOLL*2/3/BABAX/LR42//BABAX (No. 12) showed a difference between 19.5 and 21.73 % infection. Lines with the lowest average percentage of infection were KACHU/KIRITATI//BORL14 (No. 16) with 0.27, followed by SAUAL/MUTUS/4/KACHU#1//WBLL1*2/KUKUNA/3/BRBT1*2/KIRITATI (No. 21) with 0.44 %, and those with the highest average percentage of infection were PBW343//CAR422/ANA/3/ELVIRA (No. 8) with 15.9 and SITE/MO//PASTOR/3/TILHI/4/WAXWING/KIRITATI/5/KACHU#1/KIRITATI//KACHU (No. 1) with 15.0 %. Lines that showed the highest percentage of infection were: line No. 1 in the second date with 25.9 %, followed by line No. 12 in the first date with 24.4 %.

During the crop season 2017-2018, the range of infection for the first sowing date was 0 to 19.8 % with an average of 4.8 (Figure 3); 1 line did not have infected grains, 3 lines and cultivars Borlaug 100 F2014 and Onavas F2009 fell within the 0.1-2.5 % infection category, 6 lines and cultivar Roelfs F2007 within 2.6-5.0 %, 5 lines and cultivar RSM Norman F2008 within 5.1-10 %, and 1 line within 10.1-30 %.

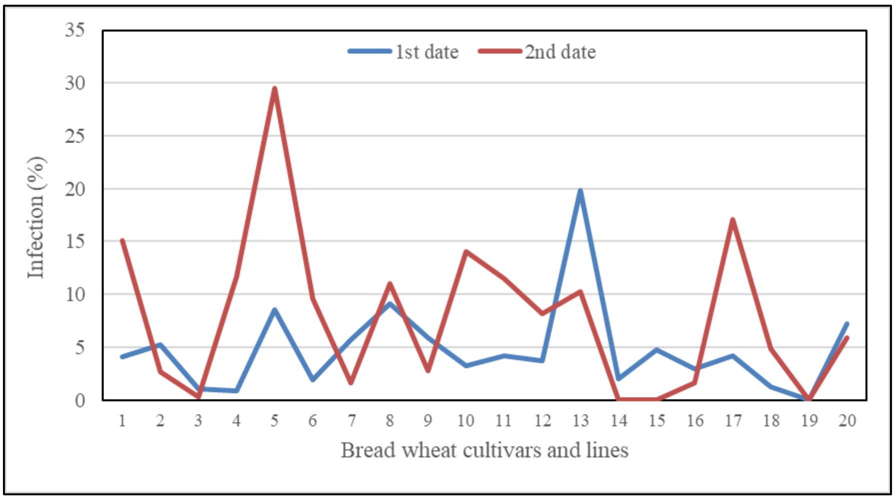

Figure 3 Percentage of infection with black point (*Alternaria* spp.) in two sowing dates, of 16 bread wheat advanced lines and 4 commercial cultivars, evaluated under natural infection in the field, during the fall-winter crop season 2017-2018, at the Norman E. Borlaug Experimental Station in the Yaqui Valley, Sonora, Mexico. 1= Roelfs F2007, 2= RSM Norman F2008, 3= Onavas F2009, 6= Borlaug 100 F2014

For the second date, the range of infection was 0 to 29.5 % with an average of 7.1; 3 lines did not have infected grains, 2 lines and cultivar Onavas F2009 fell within the 0.1-2.5 % infection category, 2 lines and cultivar RSM Norman F2008 within 2.6-5.0 %, 2 lines and cultivar Borlaug 100 F2014 within 5.1-10.0 %, and 7 lines and cultivar Roelfs F2007 within 10.1-30 %. The line BORL14*2//KFA/2*KACHU (No. 19) did not show any infected grain in both dates, 7 lines and cultivars Onavas F2009 and RSM Norman F2008 showed greater percentage of infection in the first date than in the second one, and 8 lines and cultivars Borlaug 100 F2014 and Roelfs F2007 showed greater infection in the second date. A difference in percentage of infection between 0.79 and 1.98 % was shown by cultivar Onavas F2009 and lines No. 8, 14, 16, and 20; six lines (No. 7, 9, 11, 12, 15, and 18) and cultivars RSM Norman F2008 and Borlaug 100 F2014 showed a difference between 2.58 and 7.69 %; four lines (No. 4, 10, 13, and 17) and cultivar Roelfs F2007 showed a difference of 9.60 – 12.96 %; and the line SOKOLL*2/3/BABAX/LR42//BABAX (No. 5) showed a difference of 21.0 %. Lines with the lowest average percentage of infection were KACHU/BECARD//WBLL1*2/BRAMBLING/3/FRNCLN*2/TECUE#1 (No. 14) with 0.99 % followed by BORL14*2//MUNAL#1/FRANCOLIN #1 (No. 16) with 2.25 %. Lines with the highest average percentage of infection were SOKOLL*2/3/BABAX/LR42//BABAX (No, 5) with 19.04 % followed by KACHU/BECARD//WBLL1*2/BRAMBLING/3/ONIX/KBIRD (No. 13) with 15.02 %. Lines that showed the highest percentage of infection were No. 5 with 29.5 % in the second sowing date and No. 13 with 19.8 % in the first date. The average percentage of infection was higher in crop season 2017-2018 with 6.33 % while crop season 2016-2017 showed an average of 5.93 % (Figure 4).

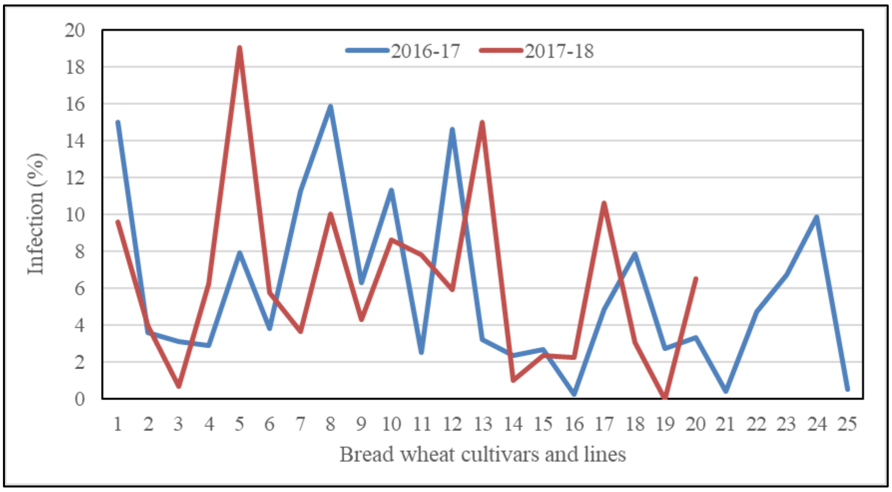

Figure 4 Average percentage of infection with black point (*Alternaria* spp.) in two sowing dates and in two crop seasons (2016-2017 and 2017-2018), of 21 bread wheat advanced lines and 4 commercial cultivars (2= Roelfs F2007, 4= Villa Juárez F2009, 6= Onavas F2009, 11= Borlaug 100 F2014) in the first season, and 16 and four cultivars (1= Roelfs F2007, 2= RSM Norman F2008, 3= Onavas F2009, 6= Borlaug 100 F2014) in the second one, evaluated under natural infection in the field, at the Norman E. Borlaug Experimental Station in the Yaqui Valley, Sonora, Mexico

Cultivars Roelfs F2007, and Borlaug 100 F2014 had higher average infection in the second crop season with a difference of 62.4 and 55.9 %, respectively, while cultivar Onavas F2009 showed greater average infection in the first season with a difference of 81.8 %. The average relative humidity during March 2017 had a range between 58.6 and 84.8 % with an average of 70.8 %, while in 2018 the range was 48.4 to 79.8 % with an average of 65.9 % (Figure 5). Average relative humidity was higher in 2017 than in 2018 on 25 days, with a range of 0.20 to 21.15 %, while higher in 2018 on 6 days with a range of 1.26 to 9.99 %.

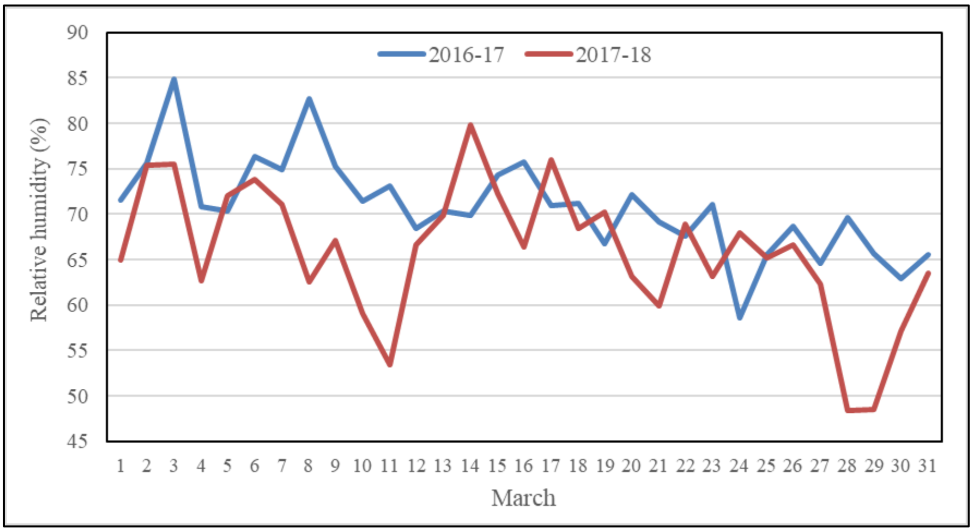

Figure 5 Average relative humidity during March 2017 and 2018, recorded by the weather station CIANO-910, located in block 910 at the Norman E. Borlaug Experimental Station in the Yaqui Valley, Sonora, Mexico

A similar case was found on durum wheat during the crop seasons 2017-2018 and 2018-2019 in which the average relative humidity during March 2018, already indicated, while in 2019 the range was 61.1 to 83.8 % with an average of 68.9 %. Average relative humidity was higher in 2018 than in 2019 on 10 days, with a range of 0.68 to 14.41 %, while higher in 2019 on 21 days with a range of 0.06 to 25.3 %. Despite this, greater infection by BP in cultivars and lines was found in 2018 than in 2019 [19]. Although the percentage of infection by BP might be expressed due to influence of weather during kernels in full expansion close to physiological maturity (stages 83-91, Zadoks scale [20]), as reported by Fuentes-Dávila *et al*. [21] in crop seasons 2015-2016 and 2016-2017, BP can be also prevalent if weather is hot and dry and when wheat maturity is delayed [22], as well as when there are stress factors like premature seed senescence or other environmental stressors [23]. As reported previously [5,6], rainfall during seed maturation favors BP, as well as humid weather prevailing for a few days prior to harvest. Within the infection categories of the groups based on the average of the two dates in each crop season, in 2016-2017, 5 lines fell within the 0.1-2.5 % infection category, 6 lines and the four cultivars within 2.6-5.0 %, 5 lines within 5.1-10.0 %, and 5 lines within 10.1-30.0 % (Figure 6). The overall average of the group was 5.93 % with a range of 0.27 to 15.9 %.

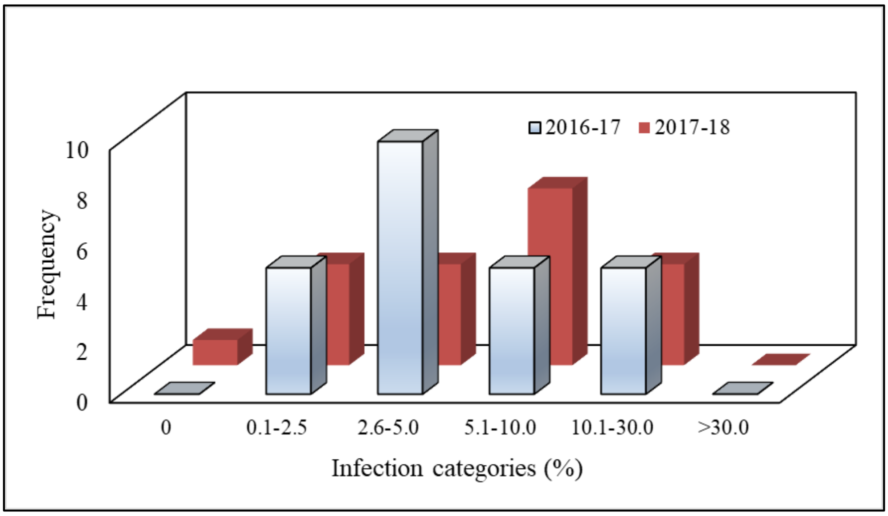

Figure 6 Infection categories (%) with black point (*Alternaria* spp.) in two sowing dates and in two crop seasons (2016-2017 and 2017-2018), of 21 bread wheat advanced lines and 4 commercial cultivars (Roelfs F2007, Villa Juárez F2009, Onavas F2009, Borlaug 100 F2014) in the first season, and 16 and four cultivars (Roelfs F2007, RSM Norman F2008, Onavas F2009, Borlaug 100 F2014) in the second one, evaluated under natural infection in the field, at the Norman E. Borlaug Experimental Station in the Yaqui Valley, Sonora, Mexico

In 2017-2018, one line did not show any infected grains, 3 lines and cultivar Onavas F2009 fell within the 0.1-2.5 % category, 3 lines and cultivar RSM Norman F2008 within 2.6-5.0 %, 5 lines and cultivars Borlaug 100 F2014 and Roelfs F2007 within 5.1-10.0 %, and 4 lines within 10.1-30.0 %. The overall average of the group was 6.33 % with a range of 0 to 19.0 %. The incidence of BP in southern Sonora during the fall-winter season where wheat is cultivated varies among bread [24], durum wheat, and triticale [9]. This variation is likely influenced not only by the seasonal weather patterns but also by the region´s climatic zones [25,26]. Another key factor is the presence of primary inoculum, which depends on environmental conditions and the ability of certain fungal species such as *Alternaria triticina* Pras. & Prab., *Helminthosporium sativum* Pamm., King & Bakke, and *Fusarium* spp. to survive as saprophytes in crop residues [2]. As observed in this study, BP infection rates can reach high levels during certain crop seasons, like in 2009-2010 where the durum wheat line SOMAT_4/INTER_8/4/GODRIN/GUTROS//DUKEM/3/THKNEE_11/5/CNDO/PRIMADUR//HAI-OU_17/3/SNITAN exhibited 50.6 % infection, and 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 showed infection rates of 30.8 %, 27.3 %, and 20.5 %, respectively [24]. In 2013-2014, the bread wheat lines SOKOLL*2/3/BABAX/LR42//BABAX and KISKADEE#1/CHYAK both showed 31.4 % infected grains [27], in 2015-2016 durum wheat lines 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 showed 50.4 % infected grains, 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 showed 32.7 %, and CIRNOC2008*2/3/KNIPA/TAGUA//PLANETA/TRILE 32.1 % [21], and in 2017-2018 durum wheat lines SWAHEN_2/KIRKI_8//PROZANA_1/4/ADAMAR_15//ALBIA_1/ALTAR84/3/SNITAN/9/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/SILK_3/DIPPER_6/3/ACO89/DUKEM_4//5*ACO89/4/PLAT showed 51.3 % infected grains and CNDO/VEE//PLATA_8/3/6*PLATA_11/6/PLATA_8/4/GARZA/AFN//CRA/3/GTA/5/RASCON/9/USDA595/3/D67.3/RABI//CRA/4/ALO/5/HUI/YAV_1/6/ARDENTE/7/HUI/YAV79/8/POD_9/10/ALTAR84/BINTEPE85/3/STOT//ALTAR84/ALD/4/POD_11/YAZI_1/5/VANRRIKSE_12/SNITAN/6/SOOTY_9/RASCON_37 34.0 % [19]. Liu *et al*. [28] reported even higher scores of BP infection in a recombinant inbred line population derived from the cross Linmai 2/Zhong 892 in China. High percentage of wheat grains infected with BP negatively impacts grain quality, and consequently, the market value of wheat products. In addition to the use of resistant cultivars [23], BP can be partially managed by reducing irrigation frequency after heading and lowering nitrogen application rates, practices that do not compromise grain yield or quality. Continuous evaluation of experimental bread wheat germplasm for BP reaction is essential to identify tolerant or highly resistant genotypes that may be suitable for future commercial release. The use of landraces can be valuable in breeding programs to enhance resistance in wheat germplasm, as Tang *et al*. [1] have reported the identification of 11 QTLs, which explained 8.22 to 10.99% phenotypic BP variation mapped to eight wheat chromosomes.

4. Conclusion

Within the infection categories of the groups based on the average of the two dates in each crop season, in 2016-2017, 5 lines fell within the 0.1-2.5 % infection category, 6 lines and cultivars Borlaug 100 F2014, Onavas F2009, Roelfs F2007, and Villa Juárez F2009 within 2.6-5.0 %, 5 lines within 5.1-10.0 %, and 5 lines within 10.1-30.0 %.

In 2017-2018, one line did not show any infected grains, 3 lines and cultivar Onavas F2009 fell within the 0.1-2.5 % category, 3 lines and cultivar RSM Norman F2008 within 2.6-5.0 %, 5 lines and cultivars Borlaug 100 F2014 and Roelfs F2007 within 5.1-10.0 %, and 4 lines within 10.1-30.0 %.

Lines with the highest percentage of infection in crop season 2016-2017 were SITE/MO//PASTOR/3/TILHI/4/WAXWING/KIRITATI/5/KACHU#1/KIRITATI//KACHU in the second sowing date with 25.9 %, followed by SOKOLL*2/3/BABAX/LR42//BABAX in the first date with 24.4 %, while in season 2017-2018 SOKOLL*2/3/BABAX/LR42//BABAX with 29.5 % in the second sowing date and KACHU/BECARD//WBLL1*2/BRAMBLING/3/ONIX/KBIRD with 19.8 % in the first date.

Despite the higher average relative humidity present in March of 2017 than in 2018, greater incidence of black point was detected in 2018.

Compliance with ethical standards

Acknowledgments

This research was financially supported by the Mexican National Institute for Forestry, Agriculture, and Livestock Research (INIFAP).

Disclosure of conflict of interest

The authors declare that No conflict of interest.

References

[1] Tang H, Tan Z, Wang X, Yang L, Chen G, Yu H, Pu Z, Jiang Q, Li M, Cheng M, Qi P, Li W, Liu Y, Wang J. 2022. Genome-wide association study of kernel black point resistance in Chinese wheat landraces. Plant Disease 106(5):1428-1433. doi: 10.1094/PDIS-09-21-1898-RE.

[2] Wiese MV. 1987. Compendium of Wheat Diseases. APS Press. The American Phytopathological Society. St. Paul, MN, USA. 112 p.

[3] Mathur SB, and Cunfer BM. 1993. Seed-borne Diseases and Seed Health Testing of Wheat. Danish Government Institute of Seed Pathology for Developing Countries. Hellerup, Denmark. 168 p.

[4] Kai-Ge X, Yu-Mei J, Yang-Kun L, Qiao-Qiao X, Ji-Shan N, Xin-Xin Z, and Qiao-Yun L. 2018. Identification and pathogenicity of fungal pathogens causing black point in wheat on the north China plain. Indian Journal of Microbiology 58(2):159-164. Doi:10.1007/s12088-018-0709-1.

[5] Duveiller E, Singh PK, Mezzalama M, Singh RP, Dababat A, 2012. Wheat Diseases and Pests: A Guide for Field Identification (2nd. Edition). CIMMYT. Mexico, D.F., Mexico. 138 p. available at: https://www.researchgate.net/profile/Abdelfattah-Dababat/publication/259592502_Wheat_Diseases_and_Pests_A_Guide_for_Field_Identification_2nd_Edition/links/02e7e52cd62a0b2d83000000/Wheat-Diseases-and-Pests-A-Guide-for-Field-Identification-2nd-Edition.pdf.

[6] Watkins JE. 2013. Black point disease of wheat. University of Nebraska-Lincoln. http://baylor.agrilife.org/files/2011/06/blackpointnebguide_2.pdf. Accessed on March 23, 2024.

[7] Patel DJ, and Minipara DB. 2015. Symptomatology of black point infected wheat (Triticum aestivum L.) seeds. International Journal of Agriculture Sciences 7(6):533-535. Available at: https://www.researchgate.net/profile/Dipal-Minipara/publication/324675073_SYMPTOMATOLOGY_OF_BLACK_POINT_INFECTED_WHEAT_Triticum_aestivum_L_SEEDS/links/5adacdb40f7e9b28593e67f4/SYMPTOMATOLOGY-OF-BLACK-POINT-INFECTED-WHEAT-Triticum-aestivum-L-SEEDS.pdf.

[8] Fernandez MR, and Conner RL. 2011. Black point and smudge in wheat. Prairie Soils and Crops Journal 4:158-164. https://prairiecca.ca/articles/volume-4-18-screen.pdf.

[9] Fuentes Dávila G, Ammar K, Figueroa López P, Camacho Casas MA, Félix Valencia P, Cortés Jiménez JM, Félix Fuentes JL, Chávez Villalba G, and Ortiz Ávalos AA. 2014. Reaction to black point by triticale advanced lines during the agricultural crop season 2011-2012. pp. 345-350. Proceedings of the XVII International Congress of Agricultural Sciences. October 9 and 10, 2014. Mexicali, Baja California, México. 622 p. ISBN: 978-0-9908236-1-290000>9780990823612.

[10] Conner RL, and Thomas JB. 1985. Genetic variation and screening techniques for resistance to black point in soft white spring wheat. Canadian Journal of Plant Pathology 7:402-407. https://doi.org/10.1080/07060668509501669.

[11] Gao C, Song G, Qu K, Li M, Jiang Y, Yin G, Niu J, Tang J, Gao Y, Li Q. 2023. Quantitative trait loci for resistance to black point caused by Bipolaris sorokiniana in bread wheat. Molecular Breeding 43(2):10. doi: 10.1007/s11032-023-01356-6.

[12] Chavez-Villalba G, Camacho-Casas MA, Alvarado-Padilla JI, Huerta-Espino J, Villaseñor-Mir HE, Ortiz-Monasterio JI, and Figueroa-López P. 2021. Borlaug 100, variety of bread wheat for irrigated conditions in northwestern Mexico. Revista Fitotecnia Mexicana 44(1):123-125. DOI: https://doi.org/10.35196/rfm.2021.1.123.

[13] Figueroa-López P, Fuentes-Dávila G, Valenzuela-Herrera V, Chávez-Villalba G, Félix-Fuentes JL, and Mendoza-Lugo JA. 2013. Onavas F2009, bread wheat cultivar for northwest Mexico. Revista Mexicana de Ciencias Agrícolas 4(1):175-179. https://doi.org/10.29312/remexca.v4i1.1270.

[14] Figueroa-López P, Fuentes-Dávila G, Valenzuela-Herrera V, Chávez-Villalba G, Félix-Fuentes JL, and Mendoza-Lugo JA. 2011. Roelfs F2007, new bread wheat variety for northwest Mexico. Revista Fitotecnia Mexicana 34(3):221-223. Available at: https://revistafitotecniamexicana.org/documentos/34-3/10a.pdf.

[15] Valenzuela-Herrera V, Fuentes-Dávila G, Figueroa-López P, Chávez-Villalba G, Félix-Fuentes JL, and Mendoza-Lugo JA. 2012. Villa Juárez F2009, bread wheat variety for northwest Mexico. Revista Mexicana de Ciencias Agrícolas 3(7):1447-1451. https://doi.org/10.29312/remexca.v3i7.1351.

[16] RSI (Resource Seeds International). 2023. RSM Norman F2008. Bread wheat variety (Triticum aestivum), of high yield potential. Available at: http://resourceseedsinternational.com.mx/products.html.

[17] FMC. 2022. Situi XP, agricultural herbicide. Data sheet. https://fmcagroquimica.com.mx/wp-content/uploads/2021/08/FT-Situi-181220.pdf.

[18] REMAS (Network of Automatic Meteorological Stations of Sonora). 2022. Download data. http://www.siafeson.com/remas/. Accessed on July 24, 2022.

[19] Fuentes-Dávila G, Rosas-Jáuregui IA, Félix-Valencia P, Torres-Cruz MM, and Borbón-Gracia A. 2025. Reaction of durum wheat cultivars and advanced lines to black point under natural conditions in crop seasons 2017-2018 and 2018-2019. World Journal of Advanced Research and Reviews 27(02):1057-1065. DOI:https://doi.org/10.30574/wjarr.2025.27.2.2960.

[20] Zadoks JC, Chang TT, and Konzak CF. 1974. A decimal code for the growth stages of cereals. Weed Research 14:415-421. https://doi.org/10.1111/j.1365-3180. 1974.tb01084.x

[21] Fuentes-Dávila G, Rosas-Jáuregui IA, Ayón-Ibarra CA, Félix-Valencia P, and Torres-Cruz MM. 2024. Performance of durum wheat cultivars and advanced lines to black point under natural conditions in two crop seasons. Open Access Research Journal of Science and Technology 12(01):052-059. https://doi.org/10.53022/oarjst.2024.12.1.0113.

[22] CPN (Crop Protection Network). 2019. Black Point of wheat. Available at: https://cropprotectionnetwork.org/encyclopedia/black-point-of-wheat.

[23] UC-IPM (University of California, Agriculture and Natural Resources – Statewide Integrated Pest Management Program). 2019. Agriculture: small grains pest management guidelines. Black Point of wheat. Available at: https://ipm.ucanr.edu/agriculture/small-grains/black-point-of-wheat/?utm#gsc.tab=0.

[24] Fuentes-Dávila G, Figueroa-López P, Cortés-Jiménez JM, Félix-Valencia P, Camacho-Casas MA, Félix-Fuentes JL, Chávez-Villalba G, and Ortiz-Ávalos AA. 2013. Reaction of selected cultivars and lines of durum and bread wheat to black point. Annual Wheat Newsletter 59:48-52. Available at: https://wheat.pw.usda.gov/ggpages/awn/59/TEXTFILES/MEXICO.pdf.

[25] Torres-Cruz MM, Castro-Quiroa LA, Fuentes-Dávila G, and Félix-Valencia P. 2021a. Determination of climatic zones of influence in the Yaqui and Mayo Valleys, Mexico. International Journal of Agriculture, Environment and Bioresearch 6:44-56. https://doi.org/10.35410/IJAEB.2021.5650.

[26] Torres-Cruz MM, Fuentes-Dávila G, and Félix-Valencia P. 2021b. Prevailing temperatures, cold and heat units in the Yaqui and Mayo Valleys, Mexico, during the 2019-2020 wheat season. International Journal of Agriculture, Environment and Bioresearch 6:1-6. https://doi.org/10.35410/IJAEB.2021.5647.

[27] Fuentes-Dávila G, Ayón-Ibarra CA, Félix-Valencia P, Figueroa-López P, Camacho-Casas MA, Félix-Fuentes JL, Chávez-Villalba G, and Rosas-Jáuregui IA. 2016. Reaction of advanced bread wheat lines to black point (Alternaria spp.) during the crop season 2013-2014. pp. 817-823. Proceedings of the XIX International Congress of Agricultural Sciences. Mexicali, Baja California, México. October 27 and 28, 2016. 980 p.

[28] Liu JD, He ZH, Wu L, Wen WE, Xie CJ, and Xia XC. 2016. Genome-wide linkage mapping of QTL for black point reaction in bread wheat (*Triticum aestivum* L.). Theoretical and Applied Genetics 129:2179-2190. https://doi.org/10.1007/s00122-016-2766-3.