Journal of Plant Studies; Vol. 4, No. 2; 2015
ISSN 1927-0461 E-ISSN 1927-047X
Published by Canadian Center of Science and Education

Effect of Plant Height on Fusarium Head Blight in Spring Wheat

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Received: April 21, 2014 Accepted: June 4, 2015 Online Published: August 13, 2015
doi:10.5539/jps.v4n2p105 URL: http://dx.doi.org/10.5539/jps.v4n2p105

Abstract

Fusarium Head Blight (FHB), caused by the fungal species *Fusarium graminearum,* is a disease affecting wheat cultivars across Canada. Recent and severe outbreaks have spurred research in developing FHB-resistant cultivars and evaluating the underlying causes of FHB susceptibility. In this study, the effect of plant height on Fusarium Head Blight in Canadian spring wheat was evaluated over a two-year period. Cultivars of spring wheat varying in origin, height, and disease susceptibility were artificially inoculated with FHB, and the subsequent disease symptoms and height data was collected. It was found that plant height is negatively correlated with FHB incidence and severity. However, varieties originating from Eastern Canada had a much stronger negative correlation between plant height and FHB, whereas the trials with Western Canada origins had a weaker correlation.

Keywords: Fusarium Head Blight, spring wheat, plant height, Canada, correlation

1. Introduction

Fusarium Head Blight (FHB), caused by the fungal species *Fusarium graminearum*, is the principal head blight pathogen in Canada and around the world (Sutton, 1982). This fungus is prevalent in areas of high precipitation, high humidity, or heavy dews (Windels, 2000) and commonly attacks wheat spikes and stems at the heading stage (Sutton, 1982). Plants infected with FHB are characterized by: dark purple, brown, or black lesions on the glume and florets, deformed awns (Yuen & Schoneweis, 2007), premature blighting, bleaching of spikes, sterile florets and poorly filled grains (Sutton, 1982). In recent years, severe FHB outbreaks have occurred in Canada, specifically in the provinces of Ontario, Quebec, the Maritimes, Manitoba and Alberta (Sutton, 1982).

The susceptibility of wheat lines to FHB is of great concern to the agri-food industry (Miller et al., 2010), because plants infected with this disease have lower yields, shriveled and discolored kernels, and lighter-weight and poorer-quality seeds (Windels, 2000). Furthermore, *F. graminearum* produces the mycotoxin deoxynivalenol, commonly referred to as DON, on the infected grain, which then becomes unsuitable for flour, cereals, or malt and too toxic for use as non-ruminant animal feed (Windels, 2000). These symptoms are the cause of wheat losses of nearly $300 million over a five year period in certain provinces (Windels, 2000). Because of the prevalence, severity, and detrimental commercial implications of FHB, the USDA ranks it as the worst plant disease since the 1950s. The damaging effect of *F. graminearum* on wheat plants has led to a demand for resistant varieties and spurred much research on the subject. Plant resistance mechanisms for FHB can be active or passive; examples include physiological processes for active mechanisms and morphological features for passive mechanisms (Mesterházy, 2006). Scientists have evaluated many factors that influence passive resistance, such as awn presence and floret density on spikes (Yuen & Schoneweis, 2007), however plant height in Canadian trials has not yet been evaluated in any depth. The purpose of this study was to examine the relationship between plant height and FHB incidence and its severity for Eastern and Western Canadian spring wheat varieties.

2. Materials and Methods

2.1 Field Preparation and Plant Materials

This study was conducted over a two-year period, in 2013 and 2014, at the Eastern Cereal and Oilseed Research Centre located in Ottawa, Ontario, Canada. The Fusarium nursery was planted in a different field each year, however both fields had been planted with corn in the previous year, and both fields had a sand–sandy loam soil type. Field preparation was consistent in both years: individual plots of spring wheat varieties varying in FHB susceptibility, plant height, and origin were planted in two parallel rows, each 1.0 m long and 0.1 m wide. Herbicides were applied two weeks after emergence: in 2013, Buctril M at 1.0 L ha^{-1} and Puma at 770 mL ha^{-1} were applied, and in 2014, Buctril M at 1.0 L ha^{-1} and Puma at 1.02 L ha^{-1} were applied. In each year, the field was sprinkler-irrigated twice daily and hand-weeded periodically.

2.2 Inoculum Preparation and Application and Fusarium Head Blight Assessment

The Fusarium inoculum was prepared using a 1:1 barley and corn mixture, which was soaked for 24 hours and autoclaved at 120 °C twice for 90 minutes each time. The autoclaved grain was seeded with 80 mL of three separate FHB strains (DAOM 178148, DAOM 212678, and DAOM 232369) and stored in covered trays for four to six weeks. After the wheat was planted and 15 days before heading occurred, fresh inoculum was hand-applied twice between the planted rows at a rate of 50 g m^{-2}, immediately after which the field was irrigated.

Percent severity and percent incidence of FHB disease were determined 24 days after 50% of the plant heads in the plot showed extended anthesis. Fusarium Head Blight occurrence on the plant head is measured by obtaining the product of the percent severity and percent incidence values and is called the FHB index. Height measurements were taken in centimeters by placing a standard measuring stick in a single row and recording the average plant height for the plot. Lodging, awn presence, and plot abnormalities were also collected.

2.3 Statistical Analysis

Analysis of variance was performed on the data sets using Stata 13 software. Pearson's correlation coefficients, probability values, means, and range values were determined.

3. Results

The results from the 2013 and 2014 replications of this study are consistent. In 2013 (Table 1), the trials originating from Western Canada did not support the hypothesis that plant height is correlated with FHB index. Given the critical value $P = 0.01$, only 5 of the 18 Western trials showed statistical significance between plant height and FHB index. Conversely, 9 of the 15 Eastern trials showed statistical significance between plant height and FHB index. The Western trials also had, on average, a much lower Pearson's correlation coefficient than the Eastern trials did (−0.21 vs. −0.51).

The results from the 2014 replication parallel those from 2013 (Table 2). Of the 14 Western trials, only 8 showed statistical significance between plant height and FHB index, whereas of the 28 Eastern trials, 26 showed statistical significance between plant height and FHB index. The Western trials also had, on average, a much lower Pearson's correlation coefficient than the Eastern trials did (−0.011 vs. −0.220).

In both the 2013 and 2014 replications of this study, the Eastern plant height mean is approximately 10 cm greater than the Western plant height mean. This difference in plant height is matched by a 2% to 3% difference in FHB index between the Eastern and Western trials. However, after a t test for FHB, means between the Eastern and Western trials was performed, P values of 0.6913 for the 2013 data and 0.3842 for the 2014 data were obtained. From this we can conclude that the 2% to 3% difference in FHB index between the Eastern and Western trials is not statistically significant.

To summarize, the Eastern trials showed strong statistical significance between plant height and FHB index in both 2013 and 2014, whereas the Western trials did not. Although the Western trials had both consistently shorter plants and a higher FHB index than the Eastern trials did, this difference in FHB index was not significant and can therefore not be explained by the difference in plant height. The average Pearson's correlation coefficients for the Eastern and Western trials were consistent with the general trend: there is a strong correlation with the Eastern trials whereas the Western trials show a weaker correlation.

Table 1. Pearson's correlation coefficient (r) between wheat plant height and Fusarium head blight (FHB) resistance scores in 33 trials at the Eastern Cereal and Oilseed Research Centre in 2013 using genetic materials received from several breeding programs in Eastern and Western Canada

					FHB (%)		Height (cm)	
Trial	Origin	r	Probability	n	Mean	Range	Mean	Range
1	Eastern	−0.49	0.034	36	37.1	33.1	100	76
2	Eastern	−0.69	0.000	36	31.5	94.9	91	25
3	Eastern	−0.48	0.002	42	26	91.9	91	28
4	Eastern	−0.5	0.000	60	38	91.7	93	37
5	Eastern	−0.48	0.014	27	55.7	82.4	80	27
6	Eastern	−0.42	0.081	20	21.6	91.7	87	23
7	Eastern	−0.7	0.000	32	36.5	90.1	100	44
8	Eastern	−0.49	0.005	33	41.8	88.5	83	37
9	Eastern	−0.68	0.000	56	45.7	76.8	82	35
10	Eastern	−0.64	0.000	32	36.5	85	98	36
11	Eastern	−0.13	0.500	32	30.5	91.3	100	37
12	Eastern	−0.5	0.005	32	36.1	89.1	101	37
13	Eastern	−0.77	0.000	32	43.3	63	101	38
14	Eastern	−0.38	0.102	22	36.4	81.9	86	26
15	Eastern	−0.34	0.663	6	42.5	14.9	96	27
16	Western	−0.55	0.000	60	25.1	90.4	95	35
17	Western	−0.37	0.004	90	27.8	85.9	84	23
18	Western	−0.43	0.000	90	23	82.2	85	28
19	Western	−0.71	0.000	35	25.4	94.6	85	28
20	Western	−0.06	0.654	56	29.4	73.5	80	30
21	Western	−0.08	0.563	56	39.3	63.9	85	27
22	Western	0.03	0.878	36	43	60	83	23
23	Western	−0.28	0.150	30	27.5	25.5	88	19
24	Western	−0.22	0.268	30	70.7	45	78	16
25	Western	−0.52	0.004	32	46	85.4	82	23
26	Western	−0.3	0.126	30	31.2	59.4	81	23
27	Western	0.27	0.159	30	29.6	55.9	91	20
28	Western	0.11	0.446	56	59.4	54.3	81	26
29	Western	−08	0.564	56	54.2	60.2	77	29
30	Western	−0.11	0.438	56	37.2	52.5	77	21
31	Western	0.13	0.352	56	37	67.5	81	23
32	Western	−09	0.641	32	41.1	80	81	27
33	Western	−0.5	0.011	27	52.8	92.6	86	31
	Eastern	−0.51	0.094	33.2	37.3	77.8	92	35
	Western	−0.21	0.292	47.7	38.9	68.3	83	25

Origin was defined by the origin of the varieties tested. Probability was defined by the probability, under the assumption of hypothesis H, of obtaining a result equal to or more extreme than what was actually observed. n was defined by the number of varieties tested. FHB (%) was defined by Fusarium Head Blight index in percent, obtained from the product of FHB severity in percent and FHB incidence in percent. Height (cm) was defined by the average height of a variety.

Table 2. Pearson's correlation coefficient (r) between wheat plant height and Fusarium head blight (FHB) resistance scores in 42 trials at the Eastern Cereal and Oilseed Research Centre in 2014 using genetic materials received from several breeding programs in Eastern and Western Canada

					FHB (%)		Height (cm)	
Trial	Origin	r	Probability	n	Mean	Range	Mean	Range
1	Eastern	−0.27	0.000	270	23.0	82.5	84	62
2	Eastern	−0.62	0.000	60	24.0	57.5	89	47
3	Eastern	−0.38	0.000	216	22.7	97.0	89	42
4	Eastern	−0.26	0.000	216	25.2	97.0	90	61
5	Eastern	−0.22	0.001	216	23.9	42.0	96	48
6	Eastern	−0.55	0.000	108	33.4	92.0	95	72
7	Eastern	−0.11	0.253	108	29.3	96.5	95	47
8	Eastern	−0.41	0.000	216	20.7	42.0	84	58
9	Eastern	−0.31	0.000	216	24.8	42.0	91	47
10	Eastern	−0.57	0.000	75	24.1	37.0	95	42
11	Eastern	−0.20	0.008	180	23.6	42.0	90	34
12	Eastern	−0.29	0.000	180	33.6	82.0	97	53
13	Eastern	−0.57	0.000	75	50.7	77.0	84	71
14	Eastern	−0.56	0.000	60	54.9	71.0	78	51
15	Eastern	−0.39	0.001	75	18.7	32.0	97	37
16	Eastern	−0.50	0.000	81	39.3	91.0	108	58
17	Eastern	−0.73	0.000	93	39.4	91.0	104	56
18	Eastern	−0.15	0.006	360	31.7	97.5	96	76
19	Eastern	−0.29	0.000	168	38.6	92.0	96	42
20	Eastern	−0.59	0.000	96	40.1	96.5	106	60
21	Eastern	−0.42	0.000	96	39.5	96.5	103	48
22	Eastern	−0.60	0.000	96	45.8	96.5	101	55
23	Eastern	−0.65	0.000	66	38.0	96.5	103	62
24	Eastern	−0.59	0.000	42	46.7	97.5	86	44
25	Eastern	−0.25	0.032	75	47.6	77.0	112	55
26	Eastern	−0.58	0.000	48	49.8	71.0	85	50
27	Eastern	−0.54	0.007	24	36.5	62.0	111	30
28	Eastern	−0.44	0.000	90	36.5	97.0	97	42
29	Western	−0.21	0.001	243	25.4	50.0	86	38
30	Western	−0.62	0.000	81	32.5	97.0	90	50
31	Western	−0.26	0.000	270	24.2	62.0	83	40
32	Western	−0.31	0.000	270	27.3	67.0	85	53
33	Western	−0.42	0.000	108	33.6	72.0	87	42
34	Western	−0.11	0.311	90	52.4	75.0	96	38
35	Western	−0.19	0.104	75	32.7	51.5	89	28
36	Western	−0.38	0.000	90	48.4	65.0	84	43
37	Western	0.00	0.993	75	40.4	60.0	90	44
38	Western	−0.27	0.004	112	56.4	55	83	42
39	Western	0.13	0.091	180	30.7	51	78	38
40	Western	0.03	0.683	180	32.4	45	78	44
41	Western	−0.22	0.006	163	47.5	75	84	40
42	Western	−0.01	0.892	90	38.6	77	87	47
	Eastern	−0.43	0.011	129	34.4	76.1	95	52
	Western	−0.20	0.220	145	37.3	64.5	86	42

Origin was defined by the origin of the varieties tested. Probability was defined by the probability, under the assumption of hypothesis H, of obtaining a result equal to or more extreme than what was actually observed. n was defined by the number of varieties tested. FHB (%) was defined by Fusarium Head Blight index in percent, obtained from the product of FHB severity in percent and FHB incidence in percent. Height (cm) was defined by the average height of a variety.

4. Discussion

The results of this study confirm the hypothesis of an overall negative linear correlation between plant height and FHB severity and incidence. However, there is a distinct difference between the trials with the Eastern spring wheat varieties and those with the Western spring wheat varieties.

The Eastern trials showed a strong negative relationship between plant height and FHB index, meaning that taller plants were less susceptible to FHB than shorter plants were. One possible explanation for this difference is that in taller plants, the spikes and flowering heads are farther away from the soil surface, which is where *F. graminearum* spores are found. Fusarium Head Blight is more likely to infect plants that are closer to the ground, and thus, taller plants are at an advantage. Another possible explanation is that the microclimate of taller plants is less favorable to the disease: relative humidity is lower at higher spike heights, and because FHB thrives in humid climates, taller plants are less vulnerable to infection.

Conversely, the Western trials did not show dependence between plant height and FHB index. Not only did many of the individual trials not show statistical significance, the correlation was markedly weaker than it was in the Eastern trials. The low Pearson's correlation coefficient for the Western trials signifies that factors other than plant height are causing the incidence and severity of FHB. These auxiliary factors can include morphological traits such as awn presence, floret density on spikes, or anther extrusion. Alternatively, whereas structural features such as plant height largely governed the Eastern trials, genetic differences could have governed the Western trials. Researchers have proposed pleiotropic explanations (Lu et al., 2010) for FHB in wheat. If there is a similarity in genetics in the Western varieties, pleiotropy may be the underlying reason for the inconsistency between plant height and FHB correlation in the Western trials.

Regardless of the Western and Eastern origin distinction, plant height was still a dominant factor influencing the incidence and severity of FHB, with a total of 64% of trials supporting the hypothesis. Although taller plants are significantly less susceptible to FHB, they are also known to be linked to lower yields, reduced fertilizer efficacy, and lodging problems. Further research is required to develop wheat varieties that optimize yield and disease resistance.

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