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Summary

Hail events often decrease wheat yields in Kansas; however, estimates of yield loss due to hail event timing and position relative to the flag leaf are only available for old varieties. Our objectives were to quantify wheat yield losses as affected by timing of hail event relative to the crop development and positioning of the damage relative to the flag leaf. A total of 12 hail damage treatments including six different timings during the growing season (boot, anthesis, milk, soft dough, hard dough, and ripe) and two different positionings relative to the flag leaf (above or below) were evaluated in a trial conducted in Manhattan, KS, during the 2015-16 growing season. Hail damage was simulated by bending 100% of the stems within each plot. Wheat yield loss due to stem bending treatment ranged from 5.8 bushels per acre (9.0%) for treatment imposed below the flag leaf during hard dough to as much as 23.7 bushels per acre (36.7%) for treatment imposed during the milk stage, above the flag leaf. The greatest loss in wheat grain test weight was 4.5 pounds per bushel (8.1%) for treatments established during the milk stage. More years of research are needed to achieve robust estimates of wheat yield loss due to hail damage, but these preliminary data indicate that the milk stage of development is more sensitive to hail damage than other studied stages.

Introduction

Winter wheat is often subjected to several environmental yield-reducing events throughout the growing season in Kansas. Drought conditions are common during the majority of the growing seasons, winterkill might occur in particular years mostly due to lack of snow cover or abrupt shifts in air temperature. Spring freeze often causes some level of yield loss in different portions of the state, and heat stress during late season often reduces the duration of the grain filling phase. Still, one of the most devastating weather events to wheat grain yield is hail. Hail damage might fully compromise a particular field's productivity, and a solid estimation of hail damage can help producers and crop insurance agencies make better decisions regarding maintaining a hail-damaged crop for grain yield. The objectives of this project were to understand the wheat yield losses associated with stem positioning and timing of stem bending to simulate hail damage, and to ultimately improve the yield loss estimates performed when assessing hail-damaged wheat fields.

Procedures

One experiment was conducted at the Kansas State University Agronomy North Farm in Manhattan, KS. The experiment was conducted in an incomplete factorial treatment structure established in a randomized complete block design with six replications. One variety (WB Cedar) was exposed to six different timings of stem bending at two different positions in regards to the flag leaf (Table 1). Stem bending timing treatments were at the following stages of wheat development: boot, anthesis, milk, soft dough, hard dough, and ripe. Position of stem bending was above or below the flag leaf. One hundred percent of the stems in the plot were bent at treatment application. Treatment structure was an incomplete factorial because it is not possible to bend the stems above the flag leaf at boot stage.

The trial was sown October 20, 2015, in a continuous wheat field under conventional tillage in a Smolan silty clay loam soil. Plots were seven 7.5-inch row spacing wide by approximately 8 ft long. Nitrogen (N) fertilization was performed with a yield goal of 75 bushels per acre, considering approximately 2.4 lb of N was needed for each bushel of yield goal. The trial had about 49 lb N/a at sowing in the 0- to 6-inch soil depth and another 93 lb N/a in the 6- to 24-inch profile and approximately 2.7% organic matter. Therefore, topdress N fertilization was performed with an additional 42 lb N/a on February 28, 2016. Weeds and foliar diseases were controlled so these were not confounding factors in the study. Weeds were controlled on March 10, 2016 with 0.3 oz/a Finesse, 16 oz/a MCPA Ester, and 32 oz/100 gal spray mix NIS, and foliar diseases were controlled April 22, 2016, with 14 oz/a Quilt Xcel. Measurements included grain yield, grain moisture content, and grain test weight. Plots were harvested using a small plot combine. Moisture and test weight were measured in the lab immediately following wheat harvest, and grain yield was corrected for 13.5% moisture content. Statistical analysis was performed to compare: hail vs. non-hail, above vs. below flag leaf, and between each timing of treatment application pooled across the bending position. Regression analysis between percent heads affected by hail and percent grain yield relative to the control were also performed.

Results

Growing Season Weather

The weather in Manhattan was characterized by a warm and moist fall, followed by a dry and mild winter and a cool and moist spring. Growing season precipitation total was 24.4 inches, mostly concentrated during the fall (approximately 1/3 of the total precipitation) and spring (approximately 2/3 of the total precipitation, Figure 1).

Grain Yield

There was a significant treatment effect on wheat grain yield and grain test weight (Table 2). The control, where no stem bending treatment was imposed, yielded 64.6 bushels per acre, which was highest grain yield among all treatments and was only statistically similar to treatment imposed at soft or hard dough below the flag leaf (56.9 and 58.8 bushels per acre, respectively). The lowest grain yield (or highest grain yield loss) due to simulated hail occurred when treatments were imposed during milk stage or anthesis (above and below flag leaf) and during soft dough stage above flag leaf (Table 3). During these stages, bending the stem more likely decreased nitrogen and carbohydrate translocation from vegetative organs to the developing grain, which would ultimately contribute to the measured yield losses. Stem bending before anthesis (i.e. boot stage) yielded slightly higher than the aforementioned treatments, most likely because of new heads that emerged from secondary tillers to compensate for tiller loss due to stem bending. Delaying treatment to hard dough, when most of the photosynthates have already been translocated to the grain, also decreased grain yields when compared to the control, especially when stem bending occurred above the flag leaf. Similarly, treatments imposed at harvest maturity (i.e. "Ripe") decreased grain yield when compared to the control, possibly due to increased pre-harvest shattering due to an upside-down head position, which may have increased the likelihood of wheat grains to fall off the head. Wheat yield loss due to stem bending treatment ranged from 5.8 bushels per acre (9.0%) for treatment imposed below the flag leaf during hard dough to as much as 23.7 bushels per acre (36.7%) for treatment imposed during the milk stage, above the flag leaf (Table 3).

Yield Loss as Affected by Positioning of Stem Bending

Yield losses were greater when the breakpoint was above the flag (average yield 47.8 bushels per acre) as compared to below the flag leaf (51.8 bushels per acre), most likely due to the importance of photosynthates produced in the flag leaf to fill grain. When the breakpoint occurred below the flag leaf, the stem between the flag leaf and the developing grain was still intact, and there was no physical constraint for photosynthate translocation between flag leaf and grain, resulting in less yield loss than when the breakpoint was above the flag leaf (Table 2).

Yield Loss as Affected by Wheat Growth Stage

Stem bending resulted in similar yield loss when it occurred during anthesis or soft dough (48 vs. 49.6 bushels per acre), during soft dough or ripe (49.6 vs. 54.7 bushels per acre), and during hard dough or ripe (56.1 vs. 54.7 bushels per acre, Table 2). Otherwise, stem bending during anthesis resulted in more severe yield loss than when it occurred at hard dough or ripe (48 vs. 56.1 or 54.7 bushels per acre), and less severe yield loss when compared to milk stage (41.6 bushels per acre). Stem bending during the milk stage resulted in significantly lower yields than at any other stage (Table 2), and stem bending at soft dough resulted in greater yield loss than at hard dough (49.6 vs. 56.1 bushels per acre).

Figure 1 shows an interesting analysis of the yield loss as affected by days after boot and stem bending positioning in regards to the flag leaf. The greatest decrease in grain yield when the breakpoint was below the flag leaf occurred when treatments were imposed at milk stage, whereas the lowest yield for the treatment imposed above the flag leaf occurred during soft dough. The biggest difference in grain yields between above and below the flag leaf occurred when treatments were imposed at soft dough, when the breakpoint above the flag leaf had a much greater decrease in grain yield as compared to the breakpoint above the flag leaf (Figure 1). This difference was still present, but at a lower magnitude, when treatments were imposed at hard dough.

Grain Test Weight

Wheat test weight was also significantly affected by treatment application, but at a smaller magnitude than grain yield was (Tables 2 and 3). Similarly to grain yield, test weight was most affected by stem bending during the milk stage of growth, which was significantly lower than any other treatment. Test weight measured from the treatments imposed later on the growing season (hard dough, ripe, and soft dough below the flag leaf) did not differ statistically from the control. Stem bending during boot stage decreased test weight significantly from the control, most likely as a consequence of newly emerged heads that had a slightly later grain filling period than the primary heads. This delayed grain fill exposed the later developing grains to hotter temperatures, reducing test weights. Simulated hail decreased test weight (59.3 vs. 58.4 pounds per bushel) but there was no difference between treatments imposed above or below the flag leaf. Performing the stem bending during milk stage of growth significantly reduced test weights when compared to any other treatment, and treatments imposed when the crop was ripe resulted in higher test weight than during anthesis or soft-dough. Test weight was positively affected by later treatments (hard dough below the flag leaf and ripe, non-significant) and the greatest loss in test weight was 4.5 pounds per bushel (8.1%) for treatments established during the milk stage (Table 3).

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Table 1. Treatment description, stage of treatment establishment, breakpoint regarding the flag leaf, tentative date for treatment application, and actual date treatment was applied for simulated hail damage trial near Manhattan, KS, during the 2015-16 growing season

Treatment	Stage	Breakpoint regarding flag leaf	Tentative date for treatment application	Date treatment applied
1	Control	-	-	
2	Boot	Below	4/20/2016	4/17/2016
3	Anthesis	Below	5/1/2016	4/26/2016
4	Anthesis	Above	5/1/2016	4/26/2016
5	Milk	Below	5/10/2016	5/15/2016
6	Milk	Above	5/10/2016	5/15/2016
7	Soft dough	Below	5/15/2016	5/27/2016
8	Soft dough	Above	5/15/2016	5/27/2016
9	Hard dough	Below	5/20/2016	6/3/2016
10	Hard dough	Above	5/20/2016	6/3/2016
11	Ripe	Below	6/1/2016	6/13/2016
12	Ripe	Above	6/1/2016	6/13/2016

Table 2. Wheat grain yield and test weight as affected by stem bending treatment in Manhattan, KS, during the 2015-16 growing season

Stage	Breakpoint (flag leaf)	Yield		Test weight	
		------------ bu/a -------------		------------ lb/bu -------------	
Control	-	64.6	a	59.3	ab
Boot	Below	49.6	cde	57.7	c
Anthesis	Above	47.4	def	58.5	bc
Anthesis	Below	48.6	def	59.3	ab
Milk	Above	40.9	f	55.5	d
Milk	Below	42.2	ef	54.8	d
Soft dough	Above	42.2	ef	58.2	bc
Soft dough	Below	56.9	abc	59.2	ab
Hard dough	Above	53.4	bcd	58.9	abc
Hard dough	Below	58.8	ab	59.9	a
Ripe	Above	54.9	bcd	60.0	a
Ripe	Below	54.4	bcd	59.9	a

Same letters within column indicate no statistical difference between treatments.

Table 3. Wheat grain yield and test weight loss (in measured unit and in percent of control) when compared to the control treatment near Manhattan, KS, during the 2015-16 growing season

Stage	Breakpoint (flag leaf)	Yield loss		Test weight loss	
		bu/a	%	lb/bu	%
Control					
Boot	Below	15.0	23.2	1.6	2.7
Anthesis	Above	17.2	26.6	0.8	1.3
Anthesis	Below	16.0	24.8	0.0	0.0
Milk	Above	23.7	36.7	3.8	6.4
Milk	Below	22.4	34.7	4.5	7.6
Soft dough	Above	22.4	34.7	1.1	1.9
Soft dough	Below	7.7	11.9	0.1	0.2
Hard dough	Above	11.2	17.3	0.4	0.7
Hard dough	Below	5.8	9.0	-0.6	-1.0
Ripe	Above	9.7	15.0	-0.7	-1.2
Ripe	Below	10.2	15.8	-0.6	-1.0

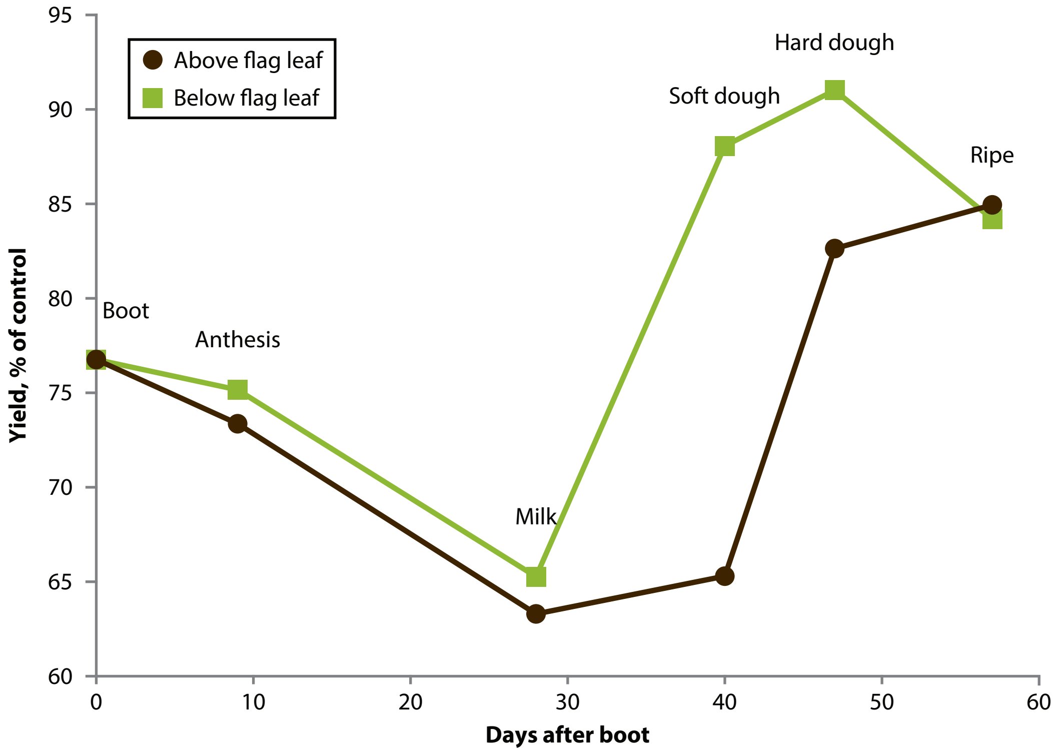

Figure 1. Wheat grain yield shown as percent of the yield attained by the control treatment and affected by days after boot and positioning of stem bending treatment in regards to the flag leaf near Manhattan, KS, during the 2015-16 growing season.