2020 First Stripe Rust Forecast and 2019 Fungicide and Variety Yield Loss Tests

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A. The 2020 first forecast of stripe rust for the eastern Pacific Northwest

Based on the weather conditions in November and December, 2019, stripe rust in the 2020 wheat growing season is forecasted to be in the severe epidemic level range (40-60% yield loss). Using forecast models based on the 2019 November and December weather data, yield loss of highly susceptible winter wheat varieties in the 2020 crop season is forecasted to be in the range of 29 to 56% with an average of **44%**. This number is higher than the forecast (38%) made last January for the 2019 crop season due to the relatively warm weather in November and December, 2019. Currently grown varieties are forecasted to be **0** to **22%** yield losses depending upon the level of resistance or susceptibility. Based on the forecast, fields grown with moderate susceptible or susceptible winter wheat varieties (stripe rust ratings 5 to 9) may need the early fungicide application at the time of herbicide application. The early prediction made in January is often close to the real situation, but is usually not better than the prediction in March based on the entire winter. Therefore, we will make another prediction in early March. However, stripe rust resistant or moderately resistant spring wheat varieties (stripe rust ratings 1 to 4 in the Seed Buyer's Guide) are recommended to plant.

B. Yield losses caused by stripe rust and increases by fungicide application on wheat varieties tested in 2019

The data of stripe rust and yield differences in non-sprayed and fungicide-sprayed plots in our experimental fields near Pullman in 2019 under artificial inoculation are shown in **Table 1** for winter wheat and **Table 2** for spring wheat.

Of the 24 winter wheat varieties tested, including 23 commercially grown varieties and a susceptible check ('PS 279'), 9 varieties (PS 279, Eltan, ORCF-102, Xerpha, PNW Hailey, Whetstone, Puma, WB4303, and Keldin) had significant differences in stripe rust severity, presented as relative area under the disease progress curve (rAUDPC), between their non-sprayed and sprayed treatments (**Table 1**). The percentage of severity reduction by fungicide application in these varieties ranged from 4.1% (WB4303) to 92.0% (PS 279). Only two varieties (PS 279 and Xerpha) had significant differences in grain test weight with increases from 3.9 lb/bu (Xerpha) to 6.6 lb/bu (PS 279) by fungicide spay. Significant yield differences, ranging from 13.7 bu/A (LCS Rocket) to 46.4% (PS 279) were observed for 9 varieties (PS 279, Eltan, ORCL-102, Xerpha, PNW Hailey, SY Ovation, Jasper, Otto, and LCS Rocket). Stripe rust caused 35.8% yield loss on the susceptible check (PS 279) and from 0 to 18.6% yield losses (average 5.5%) on commercially grown varieties. Fungicide application increased grain yield by 0 to 22.9% (average 6.2%) on commercial varieties. Under such a relatively low level of stripe rust, 4 commercial varieties (Eltan, ORCF-102, Xerpha, and PNW Hailey Keldin) received fungicide application ratings 3 or 2 (need fungicide application). Eight varieties (SY Ovation,

Jasper, Otto, LCS Rocket, ARS-Crescent, Whetstone, Puma, and LCS Jet) were rated 1 (may or may not need fungicide application). The remaining 11 varieties (WB4303, SY Touchstone, Skiles, Cara, Bruehl, Keldin, Rosalyn, Bobtail, LCS Hulk, Norwest 553, and Madsen) received fungicide application rating 0 (no need fungicide application).

Of the 24 spring wheat varieties tested including 23 commercial varieties and one susceptible check ('AvS'), 6 varieties (AvS, Solano, Kelse, WB-1035CL+, SY605CL, and Whit) had significant differences and 18 varieties had no significant differences in stripe rust severity (presented as rAUDPC) (**Table 2**). Only two varieties (AvS and Solano) had significant differences in grain test weight. Grain yield losses of sprayed and non-sprayed plots were significantly different for only two commercial varieties (Solano and Alum) in addition to the susceptible check (AvS). Stripe rust caused 32.7% yield loss on the susceptible check and from 0 to 12.1% (average 2.3%) yield losses on commercial varieties. Fungicide application increased grain yields by 0 to 13.8% (average 2.5%) on commercial varieties. Five commercial varieties (Solano, Alum, Kelse, WB-1035CL+, and Ryan) received fungicide application rating 1 (may or may not need fungicide application) while the remaining 18 varieties (SY Selway, Melba, WB9518, Expresso, SY605CL, Diva, Seahawk, WB9662, Louise, SY Steelhead, JD, Glee, Chet, WB6121, SY Basalt, Whit, WB9668, and Buck Pronto) received rating 0 (no need fungicide application) under the low level rust pressure in 2019.

These data can be used to select stripe rust resistant varieties to plant and to determine if fungicide application is needed for a variety based on its relative yield loss and potential epidemic level. Based on the current forecasted epidemic level (44% yield loss on susceptible varieties) for 2020 (see above), fungicide application may be needed for the varieties with a fungicide application rating 2 or higher, or stripe rust ratings 5-9 as mentioned above. Varieties with fungicide application ratings 0 and 1, or stripe rust ratings 1 to 4 in the Seed Buyer's Guide, may not need fungicide application in 2020.

C. Fungicide tests in 2019

In 2019, 31 fungicide treatments, plus a non-treated check, were evaluated for stripe rust control efficacy on winter wheat and 33 fungicide treatments were evaluated on spring wheat in fields near Pullman, Washington under artificial inoculation of the stripe rust pathogen.

In the winter wheat field, stripe rust from natural infection was observed at one spot of the spreader rows on 9 May, but absent in all plots by the time of the first application. Plants in surrounding spreader rows were inoculated with stripe rust spores on 18 May. Stripe rust developed slowly, but reached 100% severity in the non-treated check plots in early July at the soft dough stage (**Table 3**). The relative AUDPC values of all fungicide treatments were significantly less than the non-treated check, except three treatments (2 - 4) applied at Feekes 6. Eleven treatments (10, 13, 19, 24 – 27, 29 – 32) that were either applied at Feekes 10 or at both Feekes 6 and Feekes 10 provided the best control of stripe rust as indicated by the lowest relative AUDPC values. Twenty-three treatments had higher test weight than the non-treated check, including all treatments with applications at Feekes 10. Fifteen treatments produced yields higher than the non-treated check with four treatments (12, 24, 26, and 28) producing the highest

yields. All treatments of either only a Feekes 10 application or both Feekes 6 and Feekes 10 applications had significantly higher yield compared with the non-treated check. Except treatments 3 and 7, all treatments of only application at Feekes 6 did not have higher yields than the non-treated check. The significant yield responses ranged from 9.3 bu/A (11.1%) by treatment 7 to 48.5 bu/A (57.9%) by treatment 26.

The spring wheat field was planted on May 10, later than the normal planting date for the Palouse region due to the wet soil condition in the spring. The field was inoculated with stripe rust spores on June 6 and 20. Stripe rust started appearing in the field on June 19 and finally developed to 99% severity by July 29 (**Table 4**). The early fungicide application was done on June 22 (Feekes 6) when stripe rust just started appearing in some plots. The second application was done on July 3 (Feekes 9) when the non-treated plots had 10% stripe rust severity. All 33 fungicide treatments significantly reduced stripe rust relative AUDPC values while 20 treatments (9, 10, 12, 13, 15 – 20, 24 – 31, 33, and 34) provided similarly best control. Nineteen treatments significantly increased grain test weight compared to the non-treated check. All treatments, except treatment 2, produced significantly higher grain yield than the non-treated check, and the significant increases ranged from 9.4 bu/A (20.7%) by treatment 3 to 34.3 bu/A (75.4%) by treatment 32.

Table 1. Differences in stripe rust severity (as rAUDPC), test weight, and yield in non-sprayed and fungicide sprayed plots of winter wheat varieties tested under artificial inoculation with the stripe rust pathogen near Pullman, WA in 2019

	rAUDPC (%)				Test Weight (LB/BU)				Yield (BU/A)				Yield loss (%)	Yield Inc. (%)	Relative	
Variety	No spray	Spray[a]	Reduction		No spray	Spray[a]	Increase		No spray	Spray[a]	Difference		by stripe rust	by fungicide	yield loss (%)	Rating[b]
PS 279	100.0	8.0	**92.0**	*	54.0	60.6	**6.6**	*	83.2	129.6	**46.4**	*	**35.8**	**55.8**	**100.0**	**4**
Eltan	37.6	2.6	35.0	*	55.0	55.4	0.5		147.8	181.6	33.8	*	18.6	22.9	51.9	3
ORCF-102	21.2	0.6	20.6	*	59.0	60.6	1.6		141.6	167.6	26.0	*	15.5	18.3	43.2	2
Xerpha	33.5	2.6	30.9	*	55.0	58.9	3.9	*	150.1	168.9	18.8	*	11.1	12.5	31.1	2
PNW Hailey	4.5	0.3	4.2	*	61.9	63.2	1.3		153.0	171.5	18.5	*	10.8	12.1	30.1	2
SY Ovation	3.8	0.3	3.5		61.1	61.7	0.6		141.8	159.8	18.0	*	11.3	12.7	31.4	1
Jasper	3.5	0.4	3.1		57.3	58.8	1.5		159.0	175.9	16.9	*	9.6	10.6	26.8	1
Otto	2.3	0.3	2.0		58.5	60.1	1.6		159.4	176.0	16.6	*	9.4	10.4	26.4	1
LCS Rocket	0.4	0.3	0.1		61.4	60.8	-0.6		155.1	168.8	13.7	*	8.1	8.8	22.6	1
ARS-Crescent	4.5	1.1	3.4		56.7	57.4	0.7		162.0	173.6	11.5		6.6	7.1	18.5	1
Whetstone	7.9	0.3	7.6	*	62.0	63.5	1.5		127.5	138.6	11.1		8.0	8.7	22.4	1
Puma	7.9	0.8	7.2	*	60.0	61.3	1.3		155.3	164.1	8.8		5.4	5.7	15.0	1
LCS Jet	3.2	0.3	2.9		61.1	60.2	-0.8		159.2	166.2	7.0		4.2	4.4	11.7	1
WB4303	4.6	0.5	4.1	*	62.8	63.2	0.4		132.2	137.4	5.3		3.8	4.0	10.7	0
SY Touchstone	1.3	0.3	1.0		62.4	62.9	0.5		148.9	153.7	4.8		3.1	3.2	8.8	0
Skiles	0.6	0.3	0.3		60.2	59.2	-1.0		168.4	171.8	3.4		2.0	2.0	5.6	0
Cara	0.3	0.3	0.0		54.5	55.1	0.6		186.2	189.4	3.1		1.7	1.7	4.6	0
Bruehl	0.4	0.3	0.1		57.9	57.2	-0.7		175.8	178.3	2.5		1.4	1.4	3.9	0
Keldin	5.7	0.3	5.4	*	64.0	64.8	0.8		146.9	149.1	2.2		1.5	1.5	4.1	0
Rosalyn	0.5	0.3	0.2		59.0	60.4	1.5		156.5	156.8	0.3		0.2	0.2	0.5	0
Bobtail	0.5	0.3	0.2		57.0	57.2	0.3		182.2	181.3	-0.9		-0.5	-0.5	-1.4	0
LCS Hulk	1.9	0.4	1.5		61.0	61.3	0.3		172.8	171.7	-1.1		-0.6	-0.6	-1.7	0
Norw est 553	4.3	0.8	3.5		59.2	58.8	-0.4		158.8	155.2	-3.6		-2.3	-2.3	-6.5	0
Madsen	0.7	0.4	0.3		60.5	60.9	0.4		170.5	166.6	-3.9		-2.3	-2.3	-6.5	0
Mean	10.5	0.9	9.5	*	59.2	60.1	0.9		153.9	164.7	10.8		6.6	7.0	18.3	
Mean (excl.PS279)	*6.6*	*0.6*	*6.0*	*	*59.4*	*60.1*	*0.7*		*157.0*	*166.2*	*9.3*		*5.5*	*6.2*	*15.4*	
***R*²**	**1.0**				**0.8**				**0.9**							
CV	**49.4**				**2.5**				**5.5**							
***p* -value**	**<0.0001**				**<0.0001**				**<0.0001**							
LSD (*P* = 0.05)	**3.9**				**2.0**				**12.2**							

[a] Quilt Xcel at 14.0 fl oz/A was sprayed twice, at middle jointing stage (Feekes 6) on May 15 when no rust was found in any of the plots, but stripe rust. was found at one spot in the spreader rows; and sprayed second time on May 31 when plants were at the boot stage (Feekes 10) and PS279 had 0-0.1%

[b] Rating = the single digite number of yield difference/LSD. Varieties with rating 0 does not need fungicide application, those with rating 1 may or may not n fungicide application, and those with rating 2 or higher need application.

* The difference between the non-sprayed check and fungicide spray plots is significant at $P \leq 0.05$.

Table 2. Differences in stripe rust severity (as rAUDPC), test weight, and yield in non-sprayed and fungicide sprayed plots of spring wheat varieties tested under natural infection of the stripe rust pathogen near Pullman, WA in 2019

	rAUDPC (%)				Test Weight (LB/BU)				Yield (BU/A)				Yield loss (%)	Yield Inc. (%)	Relative	
Variety	No spray	Spray[a]	Reduction		No spray	Spray[a]	Increase		No spray	Spray[a]	Difference		by stripe rust	by fungicide	yield loss (%)	Rating[b]
AvS	**100.0**	**5.8**	**94.2**	*	**59.0**	**61.5**	**2.5**	*	**54.3**	**80.7**	**26.4**	*	**32.7**	**48.7**	**100.0**	**3**
Solano	21.1	0.7	20.5	*	59.2	60.6	1.4	*	80.4	91.5	11.1	*	12.1	13.8	37.0	1
Alum	2.9	0.4	2.4		62.4	62.3	-0.1		97.9	108.4	10.5	*	9.7	10.8	29.7	1
Kelse	22.6	0.9	21.7	*	61.2	61.9	0.7		91.3	99.4	8.1		8.2	8.9	24.9	1
WB-1035CL+	30.8	2.1	28.7	*	60.4	61.0	0.7		97.6	103.6	6.0		5.8	6.1	17.7	1
Ryan	1.7	0.4	1.2		61.3	61.9	0.6		109.2	114.3	5.0		4.4	4.6	13.4	1
SY Selway	1.3	0.4	0.9		60.4	60.7	0.4		95.3	99.0	3.6		3.7	3.8	11.2	0
Melba	0.4	0.0	0.4		60.5	60.9	0.3		93.5	96.8	3.3		3.4	3.5	10.4	0
WB9518	0.0	0.0	0.0		59.9	59.7	-0.3		70.2	73.1	2.9		3.9	4.1	12.0	0
Expresso	1.7	0.9	0.9		59.8	60.4	0.6		76.1	78.9	2.8		3.5	3.6	10.6	0
SY605CL	7.8	0.0	7.8	*	61.8	61.9	0.1		84.9	87.6	2.6		3.0	3.1	9.2	0
Diva	1.6	0.4	1.1		60.7	60.8	0.1		99.3	101.8	2.5		2.5	2.5	7.5	0
Seahawk	0.0	0.0	0.0		61.4	61.5	0.1		117.1	118.5	1.4		1.2	1.2	3.5	0
WB9662	0.9	0.4	0.4		59.4	59.6	0.2		78.9	80.1	1.2		1.5	1.6	4.7	0
Louise	3.3	0.9	2.4		61.0	60.8	-0.2		92.4	92.5	0.0		0.1	0.1	0.2	0
SY Steelhead	1.8	1.2	0.6		62.6	62.6	0.0		78.2	78.2	0.0		0.0	0.0	-0.1	0
JD	0.4	0.4	0.0		61.3	61.2	-0.2		60.6	60.5	0.0		-0.1	-0.1	-0.3	0
Glee	2.5	0.4	2.1		62.5	62.8	0.3		106.8	106.4	-0.4		-0.3	-0.3	-1.1	0
Chet	3.7	0.4	3.3		62.9	63.2	0.3		102.9	101.9	-1.0		-1.0	-0.9	-2.9	0
WB6121	1.0	0.4	0.6		62.4	62.0	-0.4		110.6	109.4	-1.2		-1.1	-1.1	-3.4	0
SY Basalt	2.6	0.9	1.7		57.8	58.3	0.5		105.2	103.9	-1.3		-1.3	-1.2	11.1	0
Whit	13.4	0.9	12.5	*	61.3	61.3	0.0		107.6	105.5	-2.1		-2.0	-2.0	-6.1	0
WB9668	1.1	0.4	0.7		61.8	61.9	0.1		88.5	86.1	-2.4		-2.7	-2.7	-8.3	0
Buck Pronto	6.7	0.9	5.9		60.5	61.3	0.8		101.3	99.0	-2.4		-2.4	-2.3	-7.3	0
Mean	9.5	0.8	8.7	*	60.9	61.2	0.3		91.7	94.9	3.2		3.5	4.4	11.4	
Mean (excl.AvS)	*5.6*	*0.6*	*5.0*		*61.0*	*61.2*	*0.3*		*93.3*	*95.5*	*2.2*		*2.3*	*2.5*	*7.5*	
R^2	**0.9**				**0.8**				**0.9**							
CV	**82.0**				**1.3**				**6.5**							
***p*-value**	**<0.0001**				**<0.0001**				**<0.0001**							
LSD (*P* = 0.05)	**6.0**				**1.1**				**8.5**							

* The difference between the non-sprayed check and fungicide spray plots is significant at $P \leq 0.05$.

[a] Quilt Xcel at 14.0 fl oz/A was applied at jointing stage (Feekes 6) on June 22 when no rust was found in the plots.

[b] Rating = the single digit number of yield difference/LSD. Varieties with rating 0 do not need fungicide application, those with rating 1 may or may not need fungicide application, and those with rating 2 or higher need application.

Table 3. Stripe rust severities and relative area under the disease progress curve (AUDPC), test weight, and yield in susceptible winter wheat ('PS 279') field plots not sprayed (No fungicide) or sprayed with various fungicide treatments under natural infection of the stripe rust pathogen near Pullman, WA in 2019

		Stripe rust severity (%)[c]												Test		Yield		
Treatment		14 May		29 May		12 Jun		27 Jun		3 Jul		Relative		weight[c]		Mean[c]		Increase
No.	Fungicide, rate, timing[a,b]	E. Jointing		Boot		Flowering		Milk		S. dough		AUDPC		(lb/bu)		(bu/A)		%
1	No fungicide	0.0	A	0.2	A	3.6	A	86.3	AB	100.0	A	100.0	AB	56.7	I	83.8	O	0.0
2	F1179aa 1.0 fl oz/A at Feekes 6	0.0	A	0.0	C	4.5	A	88.8	A	98.8	A	102.6	A	56.7	I	87.2	NO	4.1
3	F2969aa 2.5 fl oz/A at Feekes 6	0.0	A	0.0	C	1.0	B	85.0	AB	96.3	A	94.9	A-C	58.2	F-I	93.3	K-N	11.3
4	F1375ab 2.5 fl oz/A at Feekes 6	0.0	A	0.0	C	0.5	B	85.0	AB	96.3	A	94.3	A-D	59.2	C-G	91.2	L-O	8.8
5	F2970aa 2.5 fl oz/A at Feekes 6	0.0	A	0.0	C	1.0	B	62.5	D	97.5	A	76.4	F	59.3	C-G	92.8	L-O	10.7
6	F2970aa 5.0 fl oz/A at Feekes 6	0.0	A	0.0	C	0.6	B	75.0	C	96.3	A	86.1	C-F	57.5	G-I	91.4	L-O	9.1
7	F1424ab 2.0 fl oz/A at Feekes 6	0.0	A	0.0	C	0.6	B	73.8	C	96.3	A	85.1	D-F	58.3	E-I	93.1	L-N	11.1
8	F2976aa 2.0 fl oz/A at Feekes 6	0.0	A	0.0	C	1.3	B	80.0	A-C	97.5	A	91.3	B-E	57.9	G-I	90.0	O	7.4
9	F2969aa 3.0 fl oz/A at Feekes 10	0.0	A	0.0	BC	0.3	B	12.5	E-J	31.3	E-G	18.2	G	61.2	AB	110.7	F-I	32.1
10	F2969aa 4.0 fl oz/A at Feekes 10	0.0	A	0.0	C	0.1	B	7.5	G-J	25.0	G-I	12.4	J-N	60.8	A-D	110.3	G-I	31.6
11	F2970aa 2.5 fl oz/A at Feekes 10	0.0	A	0.0	BC	0.0	B	16.3	E-G	43.8	CD	24.0	G-I	60.6	A-D	114.6	D-H	36.8
12	F2970aa 5.0 fl oz/A at Feekes 10	0.0	A	0.0	C	0.4	B	12.5	E-J	30.0	F-H	18.0	H-L	60.1	A-E	123.5	A-D	47.4
13	F2975aa 13.7 fl oz/A at Feekes 10	0.0	A	0.0	C	0.0	B	5.3	IJ	15.0	J-L	7.9	MN	61.5	AB	119.8	B-E	43.0
14	Topguard 5.0 fl oz/A at Feekes 6	0.0	A	0.0	C	1.0	B	72.5	C	96.3	A	84.5	EF	59.1	D-H	84.5	NO	0.8
15	Lucento 5.5 fl oz/A at Feekes 10	0.0	A	0.0	C	0.3	B	12.5	E-J	35.0	D-F	19.1	H-K	60.4	A-D	102.1	I-K	21.8
16	Topguard EQ 7.0 fl oz/A at Feekes 10	0.0	A	0.0	C	0.0	B	17.5	EF	42.5	CD	25.0	GH	60.1	A-E	106.3	H-J	26.8
17	F4412-1 5.0 fl oz/A at Feekes 10	0.0	A	0.0	C	0.1	B	15.0	E-H	50.0	C	24.5	GH	60.4	A-D	98.7	J-M	17.8
18	Lucento 5.5 fl oz/A at Feekes 6, followed by Lucento 5.5 fl oz/A at Feekes 10	0.0	A	0.0	C	0.3	B	20.0	E	68.8	B	33.3	G	59.9	A-F	108.1	HI	29.0
19	Topquard EQ 7.0 fl oz/A at Feekes 6, followed by Topquard EQ 7.0 fl oz/A at Feeks 10	0.0	A	0.0	C	0.0	B	8.8	F-J	22.5	G-J	12.6	J-N	60.7	A-D	109.8	G-I	31.0
20	F4412-1 5.0 fl oz/A at Feekes 6, followed by F4412-1 5.0 fl oz/A at Feekes 10	0.0	A	0.0	C	0.0	B	13.8	E-I	40.0	DE	21.0	H-J	59.7	B-F	110.2	G-I	31.5
21	Alto 3.0 fl oz/A + NIS 0.25% v/v at Feekes 6	0.0	A	0.0	C	0.8	B	77.5	BC	97.5	A	88.6	C-E	57.1	I	85.9	NO	2.5
22	Trivapro 9.4 fl oz/A + NIS 0.25% v/v at Feekes 6	0.0	A	0.0	C	1.3	B	77.5	BC	98.8	A	89.5	C-E	57.3	HI	93.5	K-N	11.6
23	Trivapro 13.7 fl oz/A + NIS 0.25% v/v at Feekes 6	0.0	A	0.0	C	0.9	B	81.3	A-C	96.3	A	91.6	B-E	57.0	I	99.1	J-L	18.3
24	Trivapro 9.4 fl oz/A + NIS 0.25% v/v at Feekes 6, followed by Trivapro 13.7 fl oz/A + NIS 0.25% v/v at Feekes 10	0.0	A	0.0	C	0.0	B	4.3	IJ	17.5	I-L	7.7	MN	60.5	A-D	127.4	AB	52.0
25	A21573C 7.0 fl oz/A + NIS 0.25% v/v at Feekes 6, followed by Trivapro 13.7 fl oz/A + NIS 0.25% v/v at Feekes 10	0.0	A	0.0	C	0.0	B	4.8	IJ	13.8	J-L	7.2	MN	61.5	AB	122.8	B-D	46.5
26	A18993B 7.0 fl oz/A + NIS 0.25% v/v at Feekes 6, followed by Trivapro 13.7 fl oz/A + NIS 0.25% v/v at Feekes 10	0.0	A	0.0	C	0.0	B	11.3	E-J	21.3	H-K	14.4	I-N	59.8	B-F	132.3	A	57.9
27	PROSARO 421 SC 6.5 fl oz/A + NIS 0.125% v/v at Feekes 10	0.0	A	0.0	C	0.1	B	6.0	H-J	21.3	H-K	10.2	K-N	60.7	A-D	119.5	B-F	42.6
28	Trivapro 13.7 fl oz/A + NIS 0.25% v/v at Feekes 10	0.0	A	0.1	B	0.0	B	10.0	F-J	31.3	E-G	15.8	K-M	60.3	A-D	124.6	A-C	48.7
29	A12705 [T] 6.02 fl oz/A + A15457 [R] 4.11 fl oz/A + A7402 [T] 6.84 fl oz/A + NIS 0.125% v/v at Feekes 10	0.0	A	0.0	C	0.0	B	3.3	J	12.5	KL	5.7	N	61.7	A	113.0	E-H	34.8
30	A12705 [T] 6.02 fl oz/A + A17414 [A] 2.85 fl oz/A + A15457 [R] 4.11 fl oz/A + NIS 0.125% v/v at Feekes 10	0.0	A	0.1	B	0.0	B	3.3	J	8.8	L	4.9	N	61.3	AB	117.9	C-G	40.7
31	Dexter XCEL 48.00 fl oz/A at Feekes 10	0.0	A	0.0	C	0.3	B	5.5	H-J	15.0	J-L	8.4	L-N	61.0	A-C	122.5	B-D	46.2
32	Dexter Max 2.10 lb/A at Feekes 10	0.0	A	0.0	C	0.5	B	7.5	G-J	18.8	I-K	11.3	K-N	60.5	A-D	115.2	D-H	37.5
	R^2	**0.0**		**0.6**		**0.5**		**1.0**		**1.0**		**1.0**		**0.6**		**0.9**		
	CV	**-**		**277.6**		**182.3**		**19.1**		**12.1**		**16.0**		**2.2**		**6.1**		
	***p*-value**	**-**		**<0.0001**		**<0.0001**		**<0.0001**		**<0.0001**		**<0.0001**		**<0.0001**		**<0.0001**		
	LSD ($P \leq 0.05$)	**0.0**		**0.04**		**1.56**		**9.57**		**9.22**		**9.71**		**1.85**		**9.02**		

[a] The application at Feekes 6 (middle jointing) was done on 15 May, and at Feekes 10 (boot) on 31 May, 2019.

[b] The field was under natural infection of the wheat stripe rust pathogen, and all border rows were inoculated on May 18 with spores collected from the previous year at the same location.

[c] Means sharing one or more letters are not significantly different at $P = 0.05$.

Table 4. Stripe rust severities and relative area under the disease progress curve (AUDPC), test weight, and yield in susceptible spring wheat ('AvS') field plots not sprayed (No fungicide) or sprayed with various fungicide treatments under natural infection of the stripe rust pathogen near Pullman, WA in 2019

Treatment		Stripe rust severity (%)[c]										Test		Yield		
		19 Jun		2 Jul		18 Jul		29 Jul		Relative		weight[c]		Mean[c]		Increase
No.	Fungicide, rate, timing[a,b]	Jointing		Boot		Flower.		S. dough		AUDPC		(lb/bu)		(bu/A)		%
1	No fungicide	0.0	A	2.6	A	61.3	A	98.8	A	100.0	A	59.1	FG	45.5	N	0.0
2	F1179aa 1.0 fl oz/A at Feekes 6	0.0	A	0.8	A-C	46.3	BC	95.0	A	82.3	B	59.1	FG	49.9	NM	9.7
3	F2969aa 2.5 fl oz/A at Feekes 6	0.1	A	0.1	C	42.5	BC	93.8	A	77.5	BC	58.7	G	54.9	ML	20.7
4	F1375ab 2.5 fl oz/A at Feekes 6	0.0	A	0.1	C	30.0	C	96.3	A	66.9	CD	58.9	FG	55.9	ML	22.9
5	F2970aa 2.5 fl oz/A at Feekes 6	0.1	A	0.0	C	12.5	E-H	91.3	AB	47.6	E-G	59.4	D-G	60.4	J-L	32.7
6	F2970aa 5.0 fl oz/A at Feekes 6	0.0	A	0.0	C	12.5	E-H	91.3	AB	47.6	E-G	60.2	A-G	71.5	B-F	57.1
7	F1424ab 2.0 fl oz/A at Feekes 6	0.0	A	0.2	C	13.8	E-G	82.5	BC	45.6	F-H	58.9	FG	66.1	D-J	45.3
8	F2976aa 2.0 fl oz/A at Feekes 6	0.0	A	0.1	C	20.0	DE	92.5	AB	55.4	D-F	58.7	G	58.3	KL	28.1
9	F2969aa 3.0 fl oz/A at Feekes 9	0.0	A	1.9	A-C	4.0	H-J	20.0	EF	13.8	KL	60.9	A-E	69.6	B-H	53.0
10	F2969aa 4.0 fl oz/A at Feekes 9	0.0	A	0.1	C	3.3	H-J	13.3	F-H	8.4	KL	61.0	A-D	74.0	A-C	62.6
11	F2970aa 2.5 fl oz/A at Feekes 9	0.0	A	2.6	AB	5.5	G-J	20.0	EF	15.7	JK	60.9	A-E	63.7	G-K	40.0
12	F2970aa 5.0 fl oz/A at Feekes 9	0.0	A	1.1	A-C	3.3	H-J	10.8	F-I	8.5	KL	61.5	A-C	65.6	E-J	44.2
13	F2975aa 13.7 fl oz/A at Feekes 9	0.0	A	1.1	A-C	2.0	IJ	4.5	HI	4.8	KL	61.7	AB	65.8	E-J	44.6
14	Topguard 5.0 fl oz/A at Feekes 6	0.0	A	0.1	C	24.5	CD	90.0	AB	58.7	DE	59.7	C-G	69.4	B-H	52.5
15	Lucento 5.5 fl oz/A at Feekes 9	0.1	A	0.8	A-C	3.9	H-J	12.5	F-H	9.3	KL	61.2	A-D	65.5	E-J	44.0
16	Topguard EQ 7.0 fl oz/A at Feekes 9	0.1	A	1.4	A-C	2.8	IJ	20.0	EF	11.8	KL	60.7	A-F	66.8	E-J	46.8
17	F4412-1 5.0 fl oz/A at Feekes 9	0.0	A	1.3	A-C	2.8	IJ	12.5	F-H	8.8	KL	61.5	A-C	69.7	B-H	53.2
18	Lucento 5.5 fl oz/A at Feekes 6, followed by Lucento 5.5 fl oz/A at Feekes 9	0.0	A	0.1	C	2.0	IJ	11.3	F-I	6.4	KL	61.2	A-D	67.4	C-J	48.1
19	Topquard EQ 7.0 fl oz/A at Feekes 6, followed by Topquard EQ 7.0 fl oz/A at Feeks 9	0.0	A	0.1	C	1.3	J	11.5	F-I	5.7	KL	61.4	A-C	63.3	H-K	39.1
20	F4412-1 5.0 fl oz/A at Feekes 6, followed by F4412-1 5.0 fl oz/A at Feekes 9	0.0	A	0.1	C	1.5	J	8.3	G-I	4.8	KL	61.7	AB	70.6	B-G	55.2
21	Alto 3.0 fl oz/A + NIS 0.25% v/v at Feekes 6	0.0	A	0.0	C	10.0	F-J	73.8	CD	38.4	G-I	60.2	A-G	66.1	D-J	45.3
22	Trivapro 9.4 fl oz/A + NIS 0.25% v/v at Feekes 6	0.0	A	0.2	C	7.5	F-J	65.0	D	32.8	HI	60.2	A-G	66.3	D-J	45.7
23	Trivapro 13.7 fl oz/A + NIS 0.25% v/v at Feekes 6	0.0	A	0.1	C	11.3	E-I	76.3	C	40.7	GH	59.9	B-G	61.5	I-L	35.2
24	Trivapro 9.4 fl oz/A + NIS 0.25% v/v at Feekes 6, followed by Trivapro 13.7 fl oz/A + NIS 0.25% v/v at Feekes 9	0.0	A	0.0	C	1.0	J	4.8	HI	2.8	L	61.4	A-C	68.5	B-H	50.5
25	A21573C 7.0 fl oz/A + NIS 0.25% v/v at Feekes 6, followed by Trivapro 13.7 fl oz/A + NIS 0.25% v/v at Feekes 9	0.0	A	0.6	C	1.0	J	3.5	HI	2.9	KL	61.1	A-D	70.7	B-G	55.4
26	A18993B 7.0 fl oz/A + NIS 0.25% v/v at Feekes 6, followed by Trivapro 13.7 fl oz/A + NIS 0.25% v/v at Feekes 9	0.0	A	0.8	C	1.0	J	1.5	I	1.6	L	61.6	AB	73.2	A-D	60.9
27	PROSARO 421 SC 6.5 fl oz/A + NIS 0.125% v/v at Feekes 9	0.0	A	1.5	A-C	2.5	IJ	3.3	HI	5.2	KL	61.3	A-C	71.5	B-F	57.1
28	Trivapro 13.7 fl oz/A + NIS 0.25% v/v at Feekes 9	0.0	A	0.6	BC	1.8	IJ	3.5	HI	3.7	KL	61.6	AB	75.0	AB	64.8
29	A12705 [T] 6.02 fl oz/A + A15457 [R] 4.11 fl oz/A + A7402 [T] 6.84 fl oz/A + NIS 0.125% v/v at Feekes 9	0.0	A	0.1	C	4.3	G-J	18.8	E-G	11.5	KL	60.4	A-G	72.6	B-E	59.6
30	A12705 [T] 6.02 fl oz/A + A17414 [A] 2.85 fl oz/A + A15457 [R] 4.11 fl oz/A + NIS 0.125% v/v at Feekes 9	0.0	A	0.5	C	1.3	J	3.0	HI	2.9	KL	61.7	AB	79.8	A	75.4
31	Dexter XCEL 48.00 fl oz/A at Feekes 9	0.0	A	1.4	A-C	2.4	IJ	3.3	HI	5.0	KL	61.4	A-C	74.6	A-C	64.0
32	Dexter Max 2.10 lb/A at Feekes 9	0.1	A	1.1	A-C	16.8	D-F	26.3	E	27.5	IJ	60.4	A-G	64.4	F-K	41.5
33	Aproach Prima 5.50 fl oz/A + NIS 0.25% v/v at Feekes 6, followed by Tilt (432 GAI/L) 4.0 fl oz/A + NIS 0.25% v/v at Feekes 9	0.0	A	0.1	C	1.0	J	2.5	HI	2.0	L	61.9	A	61.2	J-L	34.5
34	Aproach Prima 5.50 fl oz/A + NIS 0.25% v/v at Feekes 6, followed by Aproach 4.0 fl oz/A + NIS 0.25% v/v at Feekes 9	0.0	A	0.1	C	3.5	H-J	17.5	E-G	10.2	KL	60.1	A-G	68.8	B-H	51.2
	R^2	**0.2**		**0.3**		**0.9**		**1.0**		**0.9**		**0.4**		**0.7**		
	CV	**224.4**		**237.2**		**65.4**		**20.6**		**36.1**		**2.2**		**7.8**		
	***p*-value**	**0.85**		**0.38**		**<0.0001**		**<0.0001**		**<0.0001**		**0.0005**		**<0.0001**		
	LSD ($P \leq 0.05$)	**0.06**		**2.00**		**9.72**		**10.85**		**12.90**		**1.84**		**7.20**		

[a] The application at Feekes 6 (middle jointing) was done on 22 June, and at Feekes 9 (early boot) on 3 July, 2019.

[b] The field was inoculated with spores collected from the winter nurseries grown on the same farm on June 6 and 20.

[c] Means sharing one or more letters are not significantly different at $P = 0.05$.