Sunflower (*Helianthus annuus.* cv 'Jaguar')

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Evaluation of fungicides and fungicide timing on control of sunflower rust (*Puccinia helianthi*) at three locations in North Dakota in 2009.

MATERIALS AND METHODS

This experiment was a continuation from 2008 sunflower rust fungicide trials. The 2008 data was previously presented and the 2009 data will be presented in this report. The 2009 study is similar to the 2008 study with some modifications made in the protocol.

Six to eleven fungicides were evaluated for efficacy of sunflower rust management at three locations in ND; namely, Carrington Research Extension Center (CREC), Cenex Harvest States in Grandin (CHS), and Langdon Research Extension Center (LREC). Fungicides used were applied at R5.2 and at recommended application rates. In adjacent experiments, fungicide timing was evaluated at each location. Two fungicides pyraclostrobin, FRAC 11, (Headline, BASF) and tebuconazole, FRAC 3, (Tebuzol, UPI) were evaluated at three different application timings; R3, R5 and R6. Additionally, at least one treatment in each location was a multiple fungicide application, designed to create a non-diseased plot, used for yield loss assessment. All experimental trials were arranged utilizing a randomized complete block design. Four-row plots were sown at the CREC on 1 June 2009, Grandin on approximately June 1 2009, and at the LREC on 11 May 2009. All plots were seeded with the confection hybrid 'Jaguar' in 30 inch rows. Row length was 15 ft at the LREC and 25 ft at CREC and Grandin. Fertilizers, herbicides, and/or insecticides were used as needed according to recommended sunflower production practices (Berglund, 2007).

Urediniospores of *Puccinia helianthi* isolate ND07-01 (race 336) were produced on susceptible sunflower hybrids grown in greenhouse conditions and harvested in May and June 2009, ensuring fresh viable spores. Urediniospores were quantitated to approximately 275,000 spores/ml in a soltrol 170 suspension and inoculated to all trials using a modified leaf blower. Outer border plots and internal spreader rows were inoculated at LREC on 1 July. No treatment plots were inoculated at the LREC. CREC and Grandin border and spreader rows were inoculated on 16 July and 10 July, respectively. Due to low infection rate, the treatment plots were inoculated in CREC and Grandin on 30 July to facilitate greater infection. Moisture was applied as needed in the form of sprinkler irrigation at LREC and pivot irrigation at CREC. Grandin did not utilize any irrigation system. Disease was evaluated as the average percent leaf area covered by pustules, with the aid of assessment scales (Gulya et al. 1990), on the upper four leaves of ten randomly selected plants in each plot according to Shtienberg (1995). For analysis purposes, 'trace' levels of rust (>0 to 0.1%) were considered zero. Disease was evaluated at approximately R3-R4, R5.5-5.9, R6, R6-7, R7-8 at CREC, R1-2, R3, R5.8-6, R6, R6-7, R7 at LREC, and at R3-4, R5.9-6, R6-7, R7, and R7-8 at Grandin. Yield data was obtained from the center two rows of each plot during harvest.

Fungicide Efficacy. The efficacy of 5.7 fl oz /A Prothioconazole (Proline, Bayer CropScience), 6.5 fl oz /A and 8.2 fl oz prothioconazole + tebuconazole (Prosaro; Bayer CropScience), 4.0 fl oz/A tebuconazole (tebuconazole, UPI), 9.0 fl oz pyraclostrobin (Headline; BASF), and 9.0 fl oz /A axoystrobin (Quadris; Syngenta), and a non-treated control were evaluated at all locations. Additionally, 8.0 fl oz /A metconazole (Quash 2.0 DC; Valent) and 8.0 fl oz /A boscalid (Endura, BASF) were evaluated at LREC and Grandin. The Grandin site also observed the effectiveness of two confidential treatments (confidential-1 and confidential-2) and 4.0 fl oz /A tebuconazole (Folicur; Bayer CropScience). Fungicides were applied with backpack sprayers at 13 gpa at CREC, 20 gpa Grandin, and 9.2 gpa LREC. Fungicide applications were made when sunflower growth stages were approximately R5.2-R5.5. Application dates at CREC, Grandin, and LREC were 14 August, 14 August, and 24 July, respectively.

Fungicide Timing. To assess effectiveness of fungicide applications at different timings, applications were made at three different growth stages, namely R3.5-R4 (hereafter Timing 1 (T1)), R5.2-R5.5 (T2), and R6.0 (T3). In addition to the three timing treatments and a non-treated control, additional treatments consisted either of a rotation of the

two fungicides at different timings or one fungicide being applied at all three timings (T123). T123 was incorporated to keep sunflower plants free of rust in attempt to provide a rust-free comparison to evaluate economic loss in infected plots. At all locations, 9 fl oz of Headline and 4.0 fl oz of Tebuzol was used for T1, T2, T3, and T123. Including the non-treated control, ten, eleven, and twelve treatments were used at CREC, Grandin, and LREC, respectively. Fungicide application dates were 6 August, 14 August, and 26 August at CREC, 4 August, 14 August, and 10 September at Grandin, and 6 July, 24 July, and 18 August at LREC. Fungicides applications were made using the same techniques as described above.

Data analysis.   Area under disease progress curve (AUDPC) and relative area under disease progress curve (rAUDPC) were calculated for each location. PROC ANOVA in SAS v. 9 was used on each rating date, AUDPC, rAUDPC, and yield.

RESULTS AND DISCUSSION

Rust developed slowly at all three locations. This could be attributed to the below average cool temperatures experienced during the growing season. However, infection increased dramatically toward the end of the growing season. Trace levels of rust were first observed on the lower leaves at the LREC on 21 July and on 30 July for CREC and Grandin. Observing the non-treated control plots indicated rust severity was highest at CREC, intermediate at LREC, and lowest at CHS Grandin. Yield data has not been analyzed for LREC or Grandin 2009.

Fungicide Efficacy
All treatments at all three locations had AUDPC values statistically lower than the non-treated control. With rare exceptions, FRAC 3 (DMI or triazole) compounds tended to have statistically lower disease severity and AUDPC values than FRAC 11 (QoI or strobilurins) or FRAC 7 (Boscalid) fungicides. In locations where Boscalid was applied, AUDPC values were among the highest of all treatments. For example at the CREC, Proline @ 5.7 fl oz (triazole) was statistically the same to the strobilurins Headline @ 9.0 fl oz and Quadris 9.0 fl oz when applied at the R5.2-5.5 stage. The LREC indicated the two strobilurins (Headline and Quadris) were among the treatments with the highest AUDPC values. The Grandin location had clear separation between the triazoles and strobilurins as based on the AUDPC values with triazoles being more efficacious.

Fungicide Timing
Most locations had all treatments with statistically lower AUDPC values than the non-treated control with an exception at the Grandin site. At Grandin, the applications of Headline @ 9.0 fl oz and Tebuzol @ 4.0 at timing three (T3) were statistically the same to the non-treated control. The most effective timing for a single application of fungicide was timing two (T2). Regardless of FRAC groups, T2 had lower AUDPC values than the single application at T1 and T3 with several exceptions. The multiple application treatments had the lowest AUDPC values across all locations. At the CREC, a multiple application of Tebuzol/Headline at T1 and T2 was less effective than the multiple application of Headline/Tebuzol at T2 and T3. Also, the Headline/Tebuzol at T2 and T3 was statistically the same when compared to the multiple application treatment of Tebuzol/Headline/Tebuzol applied at T1, T2, and T3. This indicates, based on the conditions at the CREC, that the additional application at T1 was economically not important.

CONCLUSION

The promising results from 2009 will be compared and analyzed with the results from 2008. These comparisons will give us a better understanding on how to formulate the best management strategies for the chemical control of rust. Additional test plot studies will increase the amount of critical information available to strengthen decisions and recommendations on this topic.

LITERATURE CITED

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Table 1. Sunflower rust severity at five evaluation dates, Area Under the Disease Progress Curve (AUDPC), relative Area Under the Disease Progress Curve (rAUDPC), test weight and yield of six fungicide treatments at the Carrington Research Extension Center.

			Disease Severity[a]								
	CARRINGTON 09		7/30/2009	8/13/2009	8/27/2009	9/3/2009	9/17/2009				
	SF RUST EVALUATION		R3-4	R5.5-5.9	R6	R6-7	R7-8				
ID	Treatment	Timing	r0	r1	r2	r3	r4	AUDPC[b]	rAUDPC[c]	Yield (lb/A)	TW (lb/bu)
1	Non-treated Control	2	0 a	0.1975 a	1.6 a	6.925 a	23.75 a	258.53 a	0.052761 a	1555.2 c	148.925 c
2	Proline @ 5.7 fl oz	2	0 a	0.1625 a	0.975 b	1.1625 c	8.775 bc	86.14 bc	0.01758 bc	2120.8 a	160.675 a
3	Prosaro @ 6.5 fl oz	2	0 a	0.175 a	1.0375 b	1.05 c	4.675 c	57.09 c	0.011652 c	2217.8 a	163.425 a
4	Tebuzol @ 4.0 fl oz	2	0 a	0.185 a	1.0125 b	1.05 c	3.825 c	51.02 c	0.010413 c	2118.0 a	160.0 ab
5	Headline @ 9.0 fl oz	2	0 a	0.205 a	0.625c	0.9 c	14.75 b	122.13 b	0.024925 b	2083.1 ab	162.7 a
6	Quadris @ 9.0 fl oz	2	0 a	0.185 a	1.2 b	2.025 b	15.925 ab	147.93 b	0.030189 b	1824.5 bc	155.3 b
LSD			0	0.1107	0.3455	0.8328	8.0691	63.262	0.0129	283.35	5.0054

[a]Disease severity was calculated as the average percent leaf area covered by pustules on the upper four leaves of ten randomly selected plants in each plot.
[b]Area under the disease progress curve (AUDPC) = $\sum[(W_{i+n1}+ W_i) / 2] [t_{i+1}- t_i]$ where W_i = disease severity at the ith observation, t_i = time in days at the ith observation, and n = total number of observations.
[c]Relative area under the disease progress curve (rAUDPC) = AUDPC values divided by the total area of the graph.

Table 2. Sunflower rust severity at five evaluation dates, Area Under the Disease Progress Curve (AUDPC), relative Area Under the Disease Progress Curve (rAUDPC), test weight and yield of ten fungicide and timing treatments at the Carrington Research Extension Center.

			Disease Severity[a]								
	CARRINGTON 09		7/30/2009	8/13/2009	8/27/2009	9/3/2009	9/17/2009				
	SF RUST TIMING		R3-4	R5.5-5.9	R6	R6-7	R7-8				
ID	Treatment	Timing	r0	r1	r2	r3	r4	AUDPC[b]	rAUDPC[c]	Yield (lb/A)	TW (lb/bu)
1	Non-treated Control		0 a	1.1625 a	3.95 a	12.0 a	38.5 a	453.25 a	0.0925 a	1543.7 f	144.925 e
2	Headline @ 9.0 fl oz	1	0 a	0.4075 b	1.4125 c	4.95 bc	25.625 b	251.89 b	0.051405 b	1986.5 cd	161.05 bc
3	Headline @ 9.0 fl oz	2	0 a	0.8525 ab	0.825 c	1.05 d	14.75 d	134.87 cd	0.027525 cd	2295.1 ab	166.075 ab
4	Headline @ 9.0 fl oz	3	0 a	0.8625 ab	2.925 b	5.85 b	16.125 cd	217.09 bc	0.044304 bc	1791.4 de	158.0 c
5	Tebuzol / Headline / Tebuzol	1,2,3	0 a	0.8975 a	0.875 c	1.025 d	4.375 e	63.14 d	0.012886 d	2404.0 a	169.575 a
6	Tebuzol @ 4.0 fl oz	1	0 a	0.71 ab	2.5 b	6.875 b	24.875 bc	282.5 b	0.057654 b	1685.2 ef	151.0 d
7	Tebuzol @ 4.0 fl oz	2	0 a	0.8625 ab	1.4625 c	2.15 cd	8.55 de	109.86 d	0.02242 d	2130.8 bc	162.45 bc
8	Tebuzol @ 4.0 fl oz	3	0 a	0.95 a	2.825 b	7.175 b	14.625 d	220.68 bc	0.045036 bc	1577.2 ef	150.275 de
9	Tebuzol / Headline	1,2	0 a	1.0 a	0.8875 c	1.063 d	14.5 d	135.98 cd	0.02775 cd	2419.4 a	165.125 ab
10	Headline / Tebuzol	2,3	0 a	0.7925 ab	0.875 c	1.088 d	4.6 e	63.9 d	0.013041 d	2296.9 ab	168.475 a
LSD			0	0.4681	0.8312	3.0085	8.9589	92.782	0.0189	224.79	5.7095

[a]Disease severity was calculated as the average percent leaf area covered by pustules on the upper four leaves of ten randomly selected plants in each plot.
[b]Area under the disease progress curve (AUDPC) = $\sum[(W_{i+n1}+ W_i) / 2] [t_{i+1}- t_i]$ where W_i = disease severity at the ith observation, t_i = time in days at the ith observation, and n = total number of observations.
[c]Relative area under the disease progress curve (rAUDPC) = AUDPC values divided by the total area of the graph.

Table 3. Sunflower rust severity at five evaluation dates, Area Under the Disease Progress Curve (AUDPC), relative Area Under the Disease Progress Curve (rAUDPC) of eleven fungicide treatments at the CHS in Grandin.

			Disease Severity[a]						
	GRANDIN 09		7/30/2009	8/11/2009	9/1/2009	9/10/2009	9/24/2009		
	SF RUST EVALUATION		R3-4	R5.9-6	R6-7	R7	R7-8		
ID	Treatment	Timing	r0	r1	r2	r3	r4	AUDPC[b]	rAUDPC[c]
1	Non-treated Control	2	0 a	0.0175 a	0.7175 a	1.525 a	8.625 a	88.964 a	0.015886 a
2	Proline @ 5.7 fl oz	2	0 a	0.0125 a	0.1 de	0.22 c	1.15 c	12.286 c	0.002194 c
3	Prosaro @ 6.5 fl oz	2	0 a	0.0325 a	0.1175 de	0.14 c	0.838 c	9.771 c	0.001745 c
4	Tebuzol @ 4.0 fl oz	2	0 a	0.02 a	0.215 cd	0.3075 bc	1.25 c	15.841 c	0.002829 c
5	Headline @ 9.0 fl oz	2	0 a	0.0225 a	0.165 cde	0.46 bc	4.3 b	38.236 b	0.006828 b
6	Quadris @ 9.0 fl oz	2	0 a	0.0175 a	0.1125 de	0.4325 bc	5.25 b	43.7 b	0.007804 b
7	Quash @ 10 fl oz	2	0 a	0.0325 a	0.065 e	0.1275 c	0.75 c	8.228 c	0.001469 c
8	Endura @ 8 fl oz	2	0 a	0.0325 a	0.415 b	0.875 b	3.85 b	43.774 b	0.007817 b
9	Confidential #1	2	0 a	0.015 a	0.125 de	0.22 c	0.8 c	10.253 c	0.001831 c
10	Confidential #2	2	0 a	0.0075 a	0.14 cde	0.1775 c	1.275 c	13.19 c	0.002355 c
11	Folicur @ 4.0 fl oz	2	0 a	0.025 a	0.255 c	0.3825 bc	1.237 c	17.299 c	0.003089 c
LSD			0	0.0388	0.1213	0.5774	2.1908	18.432	0.0033

[a]Disease severity was calculated as the average percent leaf area covered by pustules on the upper four leaves of ten randomly selected plants in each plot.
[b]Area under the disease progress curve (AUDPC) = $\sum[(W_{i+n1} + W_i) / 2] [t_{i+1} - t_i]$ where W_i = disease severity at the ith observation, t_i = time in days at the ith observation, and n = total number of observations.
[c]Relative area under the disease progress curve (rAUDPC) = AUDPC values divided by the total area of the graph.

Table 4. Sunflower rust severity at five evaluation dates, Area Under the Disease Progress Curve (AUDPC), relative Area Under the Disease Progress Curve (rAUDPC) of eleven fungicide and timing treatments at CHS in Grandin.

			Disease Severity[a]						
	GRANDIN 09		7/30/2009	8/11/2009	9/1/2009	9/10/2009	9/24/2009		
	SF RUST TIMING		R3-4	R5.9-6	R6-7	R7	R7-8		
ID	Treatment	Timing	r0	r1	r2	r3	r4	AUDPC[b]	rAUDPC[c]
1	Non-treated Control		0 a	0 b	0.3125 b	0.5525 a	2.975 a	31.866 a	0.00569 a
2	Headline @ 9 fl oz	1	0 a	0 b	0.05 c	0.1975 bc	2.25 abc	18.771 b	0.003352 b
3	Headline @ 9 fl oz	2	0 a	0.0075 ab	0.0525 c	0.16 bc	1.4875 bcde	13.164 bc	0.002351 bc
4	Headline @ 9 fl oz	3	0 a	0.0075 ab	0.4825 a	0.79 a	2.175 abcd	31.671 a	0.005656 a
5	Tebuzol / Headline / Tebuzol	1,2,3	0 a	0.0025 ab	0 c	0.01 c	0.45 e	3.306 c	0.00059 c
6	Tebuzol @ 4.0 fl oz	1	0 a	0 b	0 c	0.01 c	0.4625 e	3.353 c	0.000599 c
7	Tebuzol @ 4.0 fl oz	2	0 a	0.0025 ab	0.115 c	0.22 bc	1.075 de	11.821 bc	0.002111 bc
8	Tebuzol @ 4.0 fl oz	3	0 a	0.0075 ab	0.4325 ab	0.65 a	2.45 ab	31.236 a	0.005578 a
9	Tebuzol / Headline	1,2	0 a	0 b	0.0075 c	0.0325 bc	0.47 e	3.776 c	0.000674 c
10	Headline / Tebuzol	2,3	0 a	0.01 a	0.09 c	0.25 b	1.15 cde	12.44 bc	0.002221 bc
11	Tebuzol / Headline	1, 3	0 a	0 b	0 c	0.0275 bc	0.36 e	2.836 c	0.000506 c
LSD			0	0.0086	0.1561	0.2387	1.1582	11.871	0.0021

[a]Disease severity was calculated as the average percent leaf area covered by pustules on the upper four leaves of ten randomly selected plants in each plot.
[b]Area under the disease progress curve (AUDPC) = $\sum[(W_{i+n1} + W_i) / 2] [t_{i+1} - t_i]$ where W_i = disease severity at the ith observation, t_i = time in days at the ith observation, and n = total number of observations.
[c]Relative area under the disease progress curve (rAUDPC) = AUDPC values divided by the total area of the graph.

Table 5. Sunflower rust severity at six evaluation dates, Area Under the Disease Progress Curve (AUDPC), relative Area Under the Disease Progress Curve (rAUDPC) of eight fungicide treatments at the Langdon Research Extension Center.

	LANGDON 09		7/21/2009	7/29/2009	8/13/2009	8/27/2009	9/3/2009	9/16/2009			
	SF RUST EVALUATION		R1-2	R3	R5.8-6	R6	R6-7	R7			
ID	Treatment	Timing	r0	r1	r2	r3	r4	r5	AUDPC[b]	rAUDPC[c]	Yield (lb/A)
1	Non-treated Control	2	0 a	0 b	0.0625 a	0.85 a	4.15 a	16.75 a	160.21 a	0.028106 a	1622.4 a
2	Proline @ 5.7 fl oz	2	0 a	0 b	0.0425 a	0.4625 bc	0.7525 c	3.9 c	38.35 c	0.006728 c	1844.8 a
3	Prosaro @ 6.5 fl oz	2	0 a	0 b	0.0325 a	0.4075 c	0.875 c	3.9 c	38.85 c	0.006816 c	1888.4 a
4	Endura @ 8 oz	2	0 a	0.0025 ab	0.0575 a	0.69 ab	1.9 b	9.725 b	90.32 b	0.015846 b	1604.9 a
5	Quash @ 10 oz	2	0 a	0 b	0.04 a	0.495 bc	1.1625 c	3.65 c	41.13 c	0.007215 c	1805.6 a
6	Tebuzol @ 4.0 fl oz	2	0 a	0 b	0.0325 a	0.6675 ab	1.0375 c	5.15 c	51.33 c	0.009005 c	1692.2 a
7	Headline @ 9.0 fl oz	2	0 a	0.005 a	0.06 a	0.4925 bc	1.065 c	5.625 c	53.31 c	0.009353 c	1482.8 a
8	Quadris @ 9.0 fl oz	2	0 a	0 b	0.045 a	0.465 bc	1.175 c	7.35 c	65.06 bc	0.011414 bc	1705.2 a
LSD			0	0.0039	0.0403	0.255	0.7089	4.0071	32.573	0.0057	475.99

[a]Disease severity was calculated as the average percent leaf area covered by pustules on the upper four leaves of ten randomly selected plants in each plot.
[b]Area under the disease progress curve (AUDPC) = $\sum[(W_{i+n1}+ W_i) / 2] [t_{i+1} - t_i]$ where W_i = disease severity at the ith observation, t_i = time in days at the ith observation, and n = total number of observations.
[c]Relative area under the disease progress curve (rAUDPC) = AUDPC values divided by the total area of the graph.

Table 6. Sunflower rust severity at six evaluation dates, Area Under the Disease Progress Curve (AUDPC), relative Area Under the Disease Progress Curve (rAUDPC) of twelve fungicide and timing treatments at the Langdon Research Extension Center.

			Disease Severity[a]								
	LANGDON 09		7/21/2009	7/29/2009	8/13/2009	8/27/2009	9/3/2009	9/16/2009			
	SF RUST TIMING		R1-2	R3	R5.8-6	R6	R6-7	R7			
ID	Treatment	Timing	r0	r1	r2	r3	r4	r5	AUDPC[b]	rAUDPC[c]	Yield (lb/A)
1	Non-treated Control		0 a	0.015 ab	0.35 a	1.1125 a	6.7 a	22.125 a	227.74 a	0.039955 a	1042.3 b
2	Headline @ 9 fl oz	1	0 a	0 b	0.095 b	0.7 b	4.7 ab	12.75 b	138.6 b	0.024316 b	1565.7 a
3	Headline @ 9 fl oz	2	0 a	0.01 ab	0.03 b	0.1925 e	1.163 c	4.125 cde	41.01 cd	0.007195 cd	1543.9 ab
4	Headline @ 9 fl oz	3	0 a	0 b	0.0675 b	0.5375 bc	1.875 c	8.425 bcd	80.14 cd	0.014059 cd	1757.6 a
5	Tebuzol / Headline / Tebuzol	1,2,3	0 a	0.01 ab	0.0275 b	0.2875 de	1.065 c	2.625 e	31.25 d	0.005482 d	1495.9 ab
6	Tebuzol @ 4.0 fl oz	1	0 a	0 b	0.1275 ab	0.4625 cd	1.875 c	6.85 cde	69.98 cd	0.012277 cd	1317.1 ab
7	Tebuzol @ 4.0 fl oz	2	0 a	0.01 ab	0.2625 ab	0.5625 bc	2.513 bc	5.675 cde	71.84 cd	0.012604 cd	1700.9 a
8	Tebuzol @ 4.0 fl oz	3	0 a	0.0225 a	0.075 b	0.665 bc	2.663 bc	9.275 bc	95.24 bc	0.016709 bc	1417.4 ab
9	Tebuzol / Headline	1,2	0 a	0 b	0.025 b	0.2 e	1.085 c	3.925 cde	38.83 cd	0.006811 cd	1526.4 ab
10	Headline / Tebuzol	2,3	0 a	0.0125 ab	0.07 b	0.1225 e	0.868 c	3.425 de	33.38 d	0.005857 d	1657.3 a
11	Tebuzol / Tebuzol / Tebuzol	1,2,3	0 a	0.01 ab	0.0825 b	0.18 e	0.965 c	3.175 de	33.49 d	0.005875 d	1626.7 a
12	Headline / Headline / Headline	1,2,3	0 a	0.0025 b	0.0175 b	0.21 e	0.858 c	3.050 de	30.89 d	0.005419 d	1465.4 ab
LSD			0	0.019	0.2481	0.2091	2.4536	5.6892	58.161	0.0102	518.61

[a]Disease severity was calculated as the average percent leaf area covered by pustules on the upper four leaves of ten randomly selected plants in each plot.
[b]Area under the disease progress curve (AUDPC) = $\sum[(W_{i+n1}+ W_i) / 2] [t_{i+1} - t_i]$ where W_i = disease severity at the ith observation, t_i = time in days at the ith observation, and n = total number of observations.
[c]Relative area under the disease progress curve (rAUDPC) = AUDPC values divided by the total area of the graph.