Evaluation of Fungicides and Fungicide Timing on Control of Sunflower Rust (*Puccinia helianthi*) at Three Locations in North Dakota in 2008

Sam Markell, Blaine G. Schatz, Scott Halley, Joel Schaefer, Tom Gulya, Febina Mathew, James Jordahl, and Scott Meyer

Materials and methods

Eight to ten fungicides were evaluated for control of sunflower rust in experiments at the Carrington Research Extension Center (CREC) in Carrington, ND, at the Langdon Research Extension Center (LREC) in Langdon, ND, and at a Cenex Harvest States research plot near Casselton, ND (CASS) in 2008. Multiple timings of at least one fungicide were evaluated in adjacent experiments at each of the three locations. At each location, the two experiments were planted in adjacent randomized complete block designs. Four-row plots were planted at the CREC and CASS on 22 May 2008 and 19 June 2008, respectively, and two-row plots were planted at the LREC on 20 May 2008. All plots were planted with the confection hybrid 'Jaguar' in 30-inch rows. Row length was 15 ft. at the LREC and 25 ft. at CREC and CASS. 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 2008. Urediniospores were quantitated to 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 both the CREC and LREC on 11 July and 15 July. No treatment plots were inoculated at the CREC or LREC. Due to layout restrictions, all treatment plots at CASS were directly inoculated with urediniospores on 7 August. Pivot and sprinkler irrigation was used at the CREC and LREC, respectively, as needed to create a favorable environment for infection. 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, R7, and R9 at the CREC and the LREC, and at R5, R7, and R9 at CASS. 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), one confidential treatment (confidential 1), and an untreated control were evaluated at all locations. Additionally, 8.0 fl oz / A metconazole (Quash 2.0 DC; Valent) was evaluated at CREC, and 6.0 fl oz/A Headline and another confidential treatment (confidential-2) were evaluated at LREC. Fungicides were applied with backpack sprayers at 20 gpa at CREC and CASS and 10 gpa at LREC. Fungicide applications were made when sunflower growth stages were approximately R5.2-R5.5. Application dates at CREC, LREC, and CASS were 16 August, 13 August, and 25 August, 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 an untreated control, one additional treatment received a fungicide application 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 was used for T1, T2, T3, and T123. At LREC and CASS, additional treatments of 4.0 fl oz of Tebuzol were made for T1, T2, T3, and T123. Including the untreated control, five, nine, and nine treatments were used at CREC, CASS, and LREC, respectively.

Fungicide application dates were 28 July, 16 August, and 28 August at CREC; 30 July, 13 August, and 24 August at LREC;, and 15 August, 25 August, and 28 August at CASS. 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

Disease was first observed (at trace levels) on treatment plots at on 7 August 2008 at CREC and LREC and on 21 August 2008 at CASS. Disease was subsequently evaluated on 21 August, 2 September, and 17 September at CREC; 21 August, 3 September, and 17 September at LREC; and on 10 September and 1 October at CASS. The mean disease severity at the final evaluations in the untreated control plots of the fungicide efficacy and fungicide timing experiments were; 13.625% and 16.5%, respectively at CREC, 19.6 and 24.9%, respectively at CASS, and 0.23 and 0.28%, respectively at LREC. The final disease severity in untreated plots indicates that a severe rust epidemic developed at CREC and CASS, but little rust developed at LREC.

Although disease was observed at LREC early enough for an epidemic to occur, disease progression was limited at successive rating dates (Table 3). Although some statistical separation between treatments was observed, it should be viewed with great caution due to low disease pressure. For this reason, data from the LREC is presented, but not discussed further (Tables 3 and 6).

Fungicide Efficacy

CREC. By the second rating date, significantly more disease was observed on the untreated control plots then every fungicide treatment (Table 1). By the third rating date, fungicide efficacy could be separated into two groups, with Quadris and Confidential-1 having less control than the rest of the treatments, but better control than the untreated. By the last rating date, Proline, Prosaro at 6.5 fl oz, Prosaro at 8.2 fl oz, Tebuzol, and Quash had the lowest disease severity. Disease severity on the Headline treatment was significantly higher than the best treatments, but significantly lower than Quadris and Confidential-1. All fungicide treatments had less disease than the untreated. Statistically, separation of treatments based on AUDPC values was similar to separation based on the final rating severity. No yield differences were observed.

CASS. Significantly more disease was observed on the untreated control than on all treatment plots at rating dates two and three (Table 2). Effectiveness of fungicides was roughly separated into the same groups as in CREC, with Proline, Prosaro at both rates, and Tebuzol having the least disease, Confidential-1 having the highest level of disease, and disease levels of Headline and Quadris being intermediate, although not statistically different than either group. Some yield differences were observed, however, no treatment was statistically different from the untreated.

Summary. Sunflower rust pressure was significant enough to evaluate fungicides and timings at two different locations. All fungicides tested significantly reduced rust at CREC and CASS, and clear differences between fungicides were also observed. In general, Proline, Prosaro at 6.5 and 8.2 fl oz, and Tebuzol (along with Quash at CREC) managed sunflower rust the best, followed by Headline, Quadris, and Confidential-1.

Fungicide Timing

CREC. AUDPC values indicated that the greatest rust control achieved by any single fungicide application was by an application made at T2. AUDPC values indicate that fungicide applications made at T2 and T123 were not significantly different. T1 and T3 applications had statistically the same AUDPC values, indicating that the amount of disease on the plots over time was the same. Although a

T1 application controlled disease early, rust increased dramatically towards the end of the season and disease severity at the last rating date was statistically the same as the untreated. Although the T3 application had statistically the same disease severity at the end of the season as a T2 application, a higher level of disease earlier in the season exposed the plants to similar disease pressure as those plants in T1 plots over time.

Differences in yield mirrored differences in disease severity. The untreated control, T3, and T1 did not significantly differ in yield. However, a T2 application had significantly higher yield than the untreated control, and as high of yield as T123. This data indicates that, in this disease environment, one well-timed fungicide application can limit the yield loss to rust just as well as three fungicide applications.

CASS. All timings of both Headline and Tebuzol had less disease than the untreated control. AUDPC values indicate that the greatest disease control from a Headline application was achieved by an application at T1, although values were not significantly different than those of T3. Conversely, the greatest control from any single application of Tebuzol was achieved by an application at T3, although not statistically different from those at either T2 or T1. Some separation of yield was observed, however, no treatment was different than the control.

Summary. Although all timings significantly reduced AUDPC values, the optimum timing was different for pyraclostrobin and tebuconazole. At CREC, it appeared that a single application of Headline worked best at T2, while the T1 application worked best at CASS. However, disease pressure at the time of those fungicide applications in CREC and CASS was the same (after infection but within seven days of pustule appearance). Thus, at both locations, the most efficacious Headline application was made approximately 4-6 days before the first observation of rust pustules on the untreated controls. Conversely, Tebuzol worked best after disease had already been observed. Although Tebuzol was tested under high disease pressure only at CASS, the most efficacious application was made seven days after pustules were first observed.

Conclusions: Clear differentiation between the effectiveness of fungicides and timing of applications were observed. Data indicate that the most effective timing for a QoI fungicide (Headline and Quadris) is different than that of a triazole fungicide (Proline, Quash, Tebuzol). Furthermore, fungicides in each respective class may not work equally against sunflower rust. In these trials, a single well-timed application of an effective fungicide was as effective at reducing sunflower rust as multiple applications. Additional trials are critical to develop the most appropriate management strategy for this disease.

Table 1. Sunflower rust severity at four sunflower growth stages, Area Under the Disease Progress Curve (AUDPC), relative Area Under the Disease Progress Curve (rAUDPC), test weight and yield of nine fungicide treatments at the Carrington Research Extension Center.

		Disease severity[a]						Test Weight	Seed Yield
ID	Treatment	R3.5	R5	R7	R9	AUDPC[b]	rAUDPC[c]	(lb/bu)	(lb/A)
1	Untreated Control	0 a	2.61 a	9.92 a	13.625 a	270.14 a	0.066 a	18.5 a	2284
2	Proline @ 5.7 fl oz	0 a	0.42 c	0.47 c	0.698 d	17.14 cd	0.004 cd	20.4 d	2469
3	Prosaro @ 6.5 fl oz	0 a	0.39 c	0.46 c	1.120 cd	19.88 cd	0.005 cd	20.2 cd	2268
4	Prosaro @ 8.2 fl oz	0 a	0.39 c	0.39 c	0.545 d	14.55 d	0.004 d	20.5 d	2678
5	Confidential 1	0 a	1.03 bc	5.40 b	8.450 b	149.67 b	0.037 b	19.4 b	2472
6	Tebuzol @ 4.0 fl oz	0 a	0.40 c	0.69 c	0.763 d	20.27 cd	0.005 cd	20.1 bcd	2482
7	Headline @ 9.0 fl oz	0 a	0.70 bc	2.23 c	3.31 c	64.18 c	0.016 c	19.6 bc	2469
8	Quadris @ 9.0 fl oz	0 a	1.23 b	4.55 b	8.52 b	141.39 b	0.034 b	19.9 bcd	2340
9	Quash 2.0 DC @ 8.0 fl oz	0 a	0.78 bc	1.15 c	1.68 cd	38.46 cd	0.009 cd	20.3 cd	2681
LSD		0	0.7712	2.1363	2.4637	47.589	0.0116	0.8	ns

[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. Disease was assessed at four growth stages on the following dates in 2008; 7 August (G.S. R3.5), 21 August (R5), 2 September (R7), and 17 September (R9).
[b]Area under the disease progress curve (AUDPC) = $\sum_{i=1}[(W_{i+n1} + W_i) / 2] [t_{i+1} - t_i]$ 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.

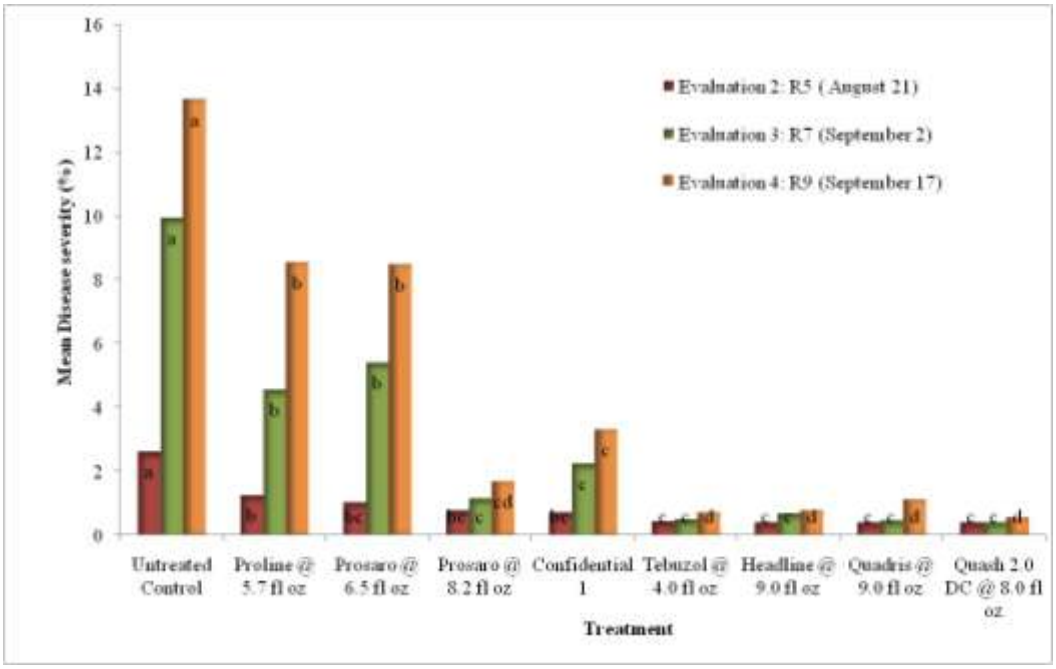


Table 2. Sunflower rust severity at three sunflower growth stages, Area Under the Disease Progress Curve (AUDPC), relative Area Under the Disease Progress Curve (rAUDPC), test weight and yield of eight fungicide treatments at Casselton, ND.

		Disease severity[a]					Seed Yield
ID	Treatment	R5	R7	R9	AUDPC[b]	rAUDPC[c]	(lb/A)
1	Untreated Control	0 a	1.12 a	19.6 a	228.76 a	0.054 a	2004.1 ab
2	Proline @ 5.7 fl oz	0 a	0.22 b	2.32 c	28.87 b	0.0068 b	1789.9 b
3	Prosaro @ 6.5 fl oz	0 a	0.28 b	1.08 c	17.11 b	0.004 b	1848.3 ab
4	Prosaro @ 8.2 fl oz	0 a	0.19 b	1.28 c	17.30 b	0.004 b	1765.0 b
5	Confidential 1	0 a	0.44 b	9.35 b	107.09 b	0.026 b	1977.5 ab
6	Tebuzol @ 4.0 fl oz	0 a	0.26 b	1.76 c	23.89 b	0.006 b	2093.3 a
7	Headline @ 9.0 fl oz	0 a	0.31 b	4.90 bc	57.81 b	0.014 b	1914.1 ab
8	Quadris @ 9.0 fl oz	0 a	0.35 b	7.00 bc	80.73 b	0.019 b	2025.2 ab
LSD		0	0.393	6.9331	91.767	0.0218	281.64

[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. Disease was assessed at four growth stages on the following dates in 2008; 21 August (R5), 10 September (R7), and 1 October (R9).
[b]Area under the disease progress curve (AUDPC) = $\sum_{i=1}[(W_{i+n1} + W_i) / 2] [t_{i+1} - t_i]$ 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.

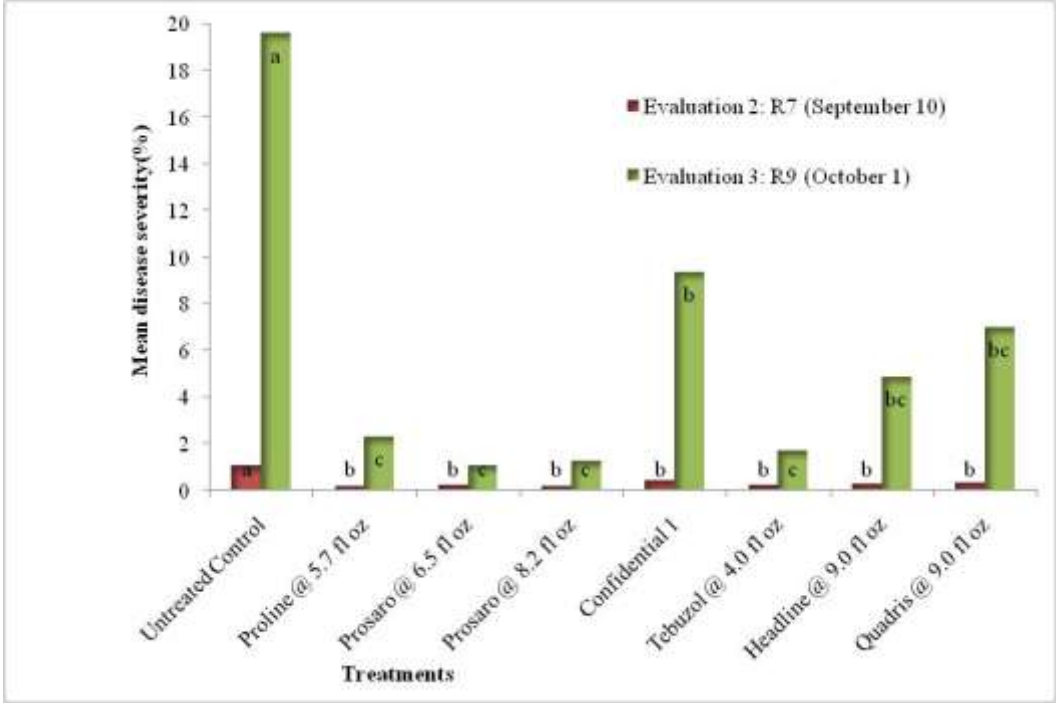


Table 3. Sunflower rust severity at four growth stages, Area Under the Disease Progress Curve (AUDPC), relative Area Under the Disease Progress Curve (rAUDPC), test weight and yield of ten fungicide treatments at Langdon, ND.

		Disease severity[a]						Seed Yield	Test Weight
ID	Treatment	R3.5	R5	R7	R9	AUDPC[b]	rAUDPC[c]	(lb/A)	(lb/bu)
1	Untreated Control	0 a	0.32 a	0.24 b	0.23 a	9.25 b	0.002 b	1530.8 a	22.93 abc
2	Proline @ 5.7 fl oz	0 a	0.29 ab	1.30 a	0.82 a	27.205 a	0.007 a	2028.0 a	23.22 a
3	Prosaro @ 6.5 fl oz	0 a	0.21 bc	0.37 b	0.37 a	10.53 b	0.003 b	1687.8 a	22.16 c
4	Prosaro @ 8.2 fl oz	0 a	0.18 cde	0.36 b	0.40 a	10.089 b	0.002 b	1971.3 a	23.16 ab
5	Confidential 1	0 a	0.19 cd	0.48 ab	0.35 a	11.44 b	0.003 b	1775.0 a	23.23 a
6	Tebuzol @ 4.0 fl oz	0 a	0.13 cde	0.39 b	0.54 a	10.90 b	0.003 b	1823.0 a	22.88 abc
7	Headline @ 9.0 fl oz	0 a	0.095 de	0.31 b	0.36 a	8.073 b	0.002 b	1692.2 a	22.60 abc
8	Quadris @ 9.0 fl oz	0 a	0.107 de	0.52 ab	0.45 a	11.654 b	0.003 b	1714.0 a	22.42 abc
9	Confidential 2	0 a	0.08 e	0.44 b	0.43 a	10.11 b	0.002 b	1692.2 a	22.16 bc
10	Headline @ 6.0 fl oz	0 a	0.15 cde	0.58 ab	0.70 a	14.70 ab	0.004 ab	1570.0 a	22.96 abc
LSD		0	0.7712	2.1363	2.4637	14.913	0.0036	530.16	0.989

[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. Disease was assessed at four growth stages on the following dates in 2008; 7 August (G.S. R3.5), 21 August (R5), 3 September (R7), and 17 September (R9).

[b]Area under the disease progress curve (AUDPC) = $\sum_{i=1}[(W_{i+n1} + W_i) / 2] [t_{i+1} - t_i]$ 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.

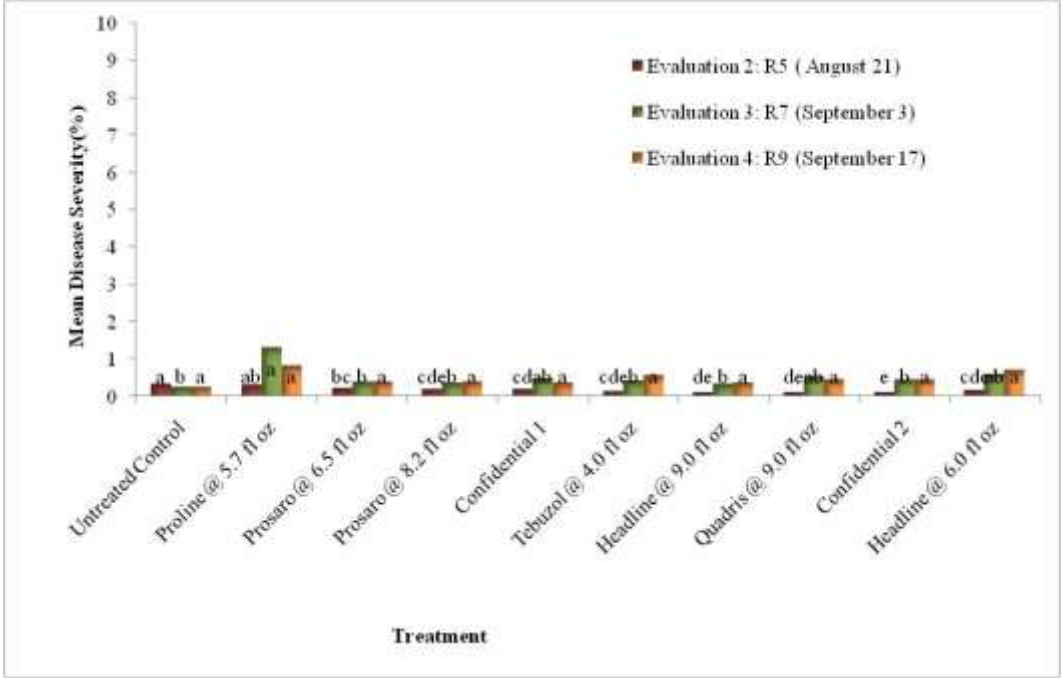


Table 4. Sunflower rust severity at four evaluation dates, Area Under the Disease Progress Curve (AUDPC), relative Area Under the Disease Progress Curve (rAUDPC), test weight and yield of five fungicide treatments at Carrington, ND.

		Disease severity[a]						Seed Yield	Test Weight
ID	Treatment	R3.5	R5	R7	R9	AUDPC[b]	rAUDPC[c]	(lb/A)	(lb/bu)
1	Untreated Control	0 a	1.75 ab	8.73 a	16.5 a	264.29 a	0.064 a	1501 a	19.6 a
2	Headline 1	0 a	0.83 bc	4.05 b	13.87 a	169.59 b	0.041 b	1720 ab	20.4 bc
3	Headline 2	0 a	0.77 bc	1.28 c	3.60 bc	54.44 c	0.013 c	1899 b	20.8 cd
4	Headline 3	0 a	2.65 a	6.00 b	4.57 b	149.76 b	0.037 b	1440 a	20.2 b
5	Headline 1 + 2 + 3	0 a	0.37 c	0.42 c	0.91 c	17.39 c	0.004 c	1941 b	20.9 d
LSD		0	0.9793	2.3515	3.3743	64.1	0.0156	306	0.5

[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. Disease was assessed at four growth stages on the following dates in 2008; 7 August (G.S. R3.5), 21 August (R5), 2 September (R7), and 17 September (R9).

[b]Area under the disease progress curve (AUDPC) = $\sum_{i=1}[(W_{i+n1} + W_i) / 2] [t_{i+1} - t_i]$ 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.

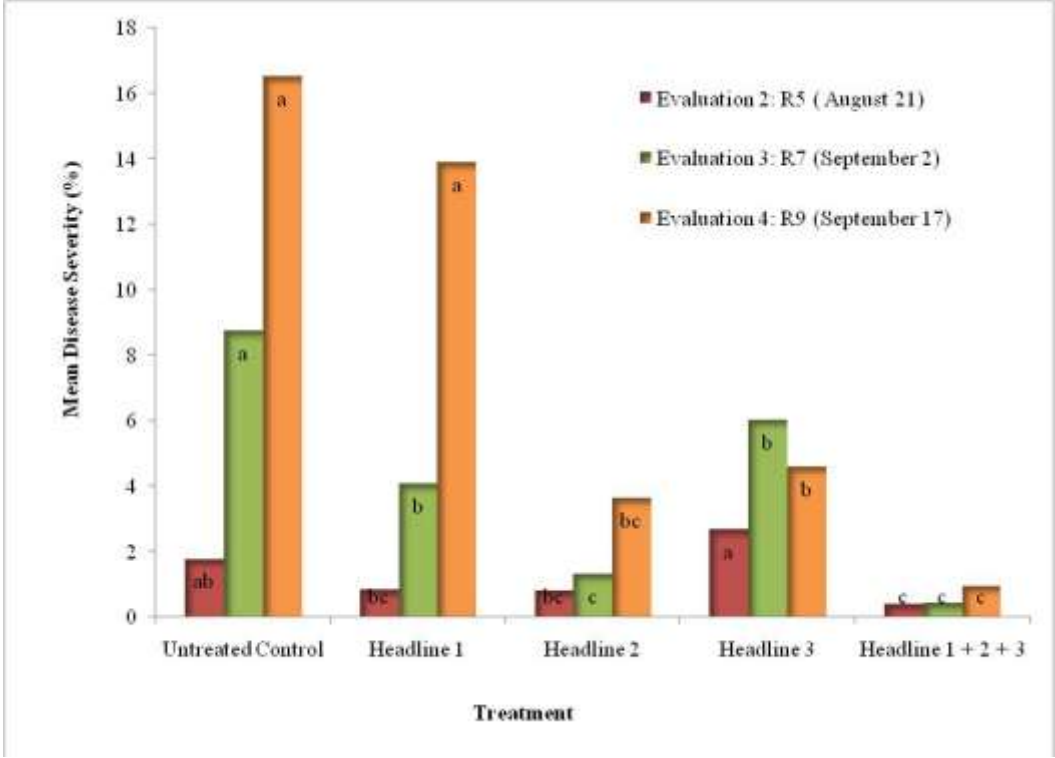


Table 5. Sunflower rust severity at three evaluation dates, Area Under the Disease Progress Curve (AUDPC), relative Area Under the Disease Progress Curve (rAUDPC), test weight and yield of nine fungicide treatment and timing combinations at Casselton, ND.

			Disease severity[a]					Seed Yield
ID	Treatment	Timing	G. S. 5	G. S. 7	G. S. 9	AUDPC[b]	rAUDPC[c]	(lb/A)
1	Untreated Control		0 a	1.46 a	24.88 a	291.17 a	0.069 a	2236.4 ab
2	Headline @ 9 fl oz -1	1	0 a	0.03 c	0.82 d	9.28 c	0.002 c	2295.0 ab
3	Headline @ 9 fl oz - 2	2	0 a	0.75 b	6.49 b	83.44 b	0.019 b	2288.4 ab
4	Headline @ 9 fl oz - 3	3	0 a	0.49 bc	3.26 bcd	44.25 bc	0.011 bc	2165.9 b
5	Headline @ 9 fl oz - 1,2,3	1,2,3	0 a	0.05 c	0.59 d	7.25 c	0.002 c	2582.8 a
6	Tebuzol @ 4.0 fl oz - 1	1	0 a	0.29 bc	5.38 bc	62.38 bc	0.015 bc	2462.6 ab
7	Tebuzol @ 4.0 fl oz - 2	2	0 a	0.48 bc	2.41 bcd	35.09 bc	0.008 bc	2383.6 ab
8	Tebuzol @ 4.0 fl oz - 3	3	0 a	0.61 b	1.012 cd	23.24 bc	0.006 bc	2147.3 b
9	Tebuzol @ 4.0 fl oz - 1,2,3	1,2,3	0 a	0.08 c	0.27 d	4.55 c	0.001 c	2196.7 b
LSD			0	0.4843	4.4145	62.01	0.01	361.22

[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. Disease was assessed at four growth stages on the following dates in 2008; 21 August (R5), 10 September (R7), and 1 October (R9).

[b]Area under the disease progress curve (AUDPC) = $\sum_{i=1}[(W_{i+n1} + W_i) / 2] [t_{i+1} - t_i]$ 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.

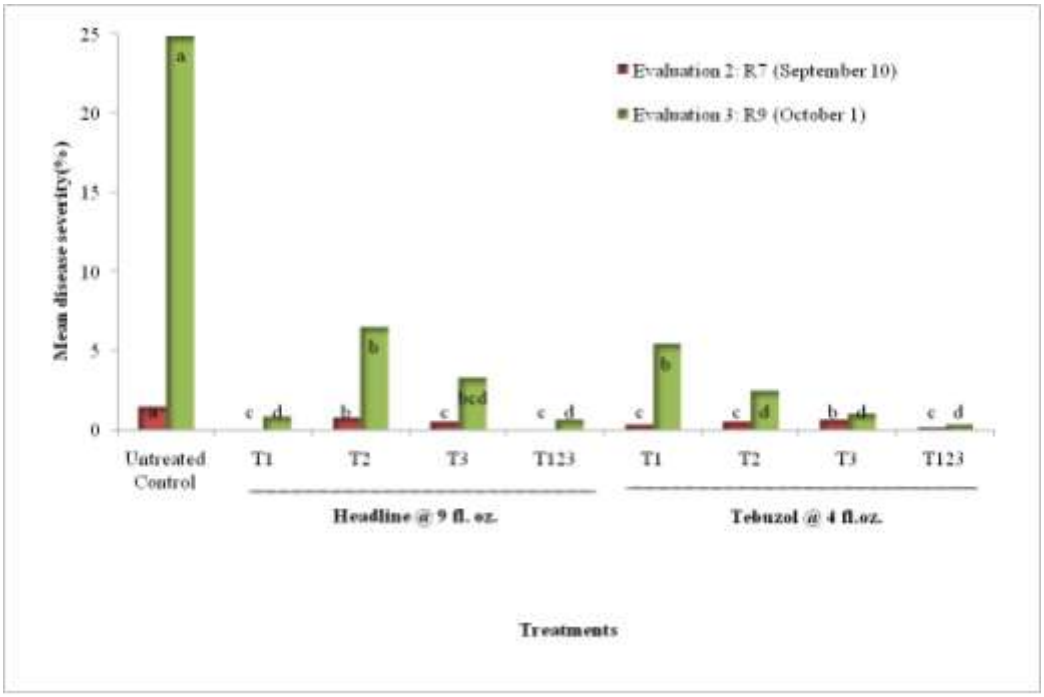


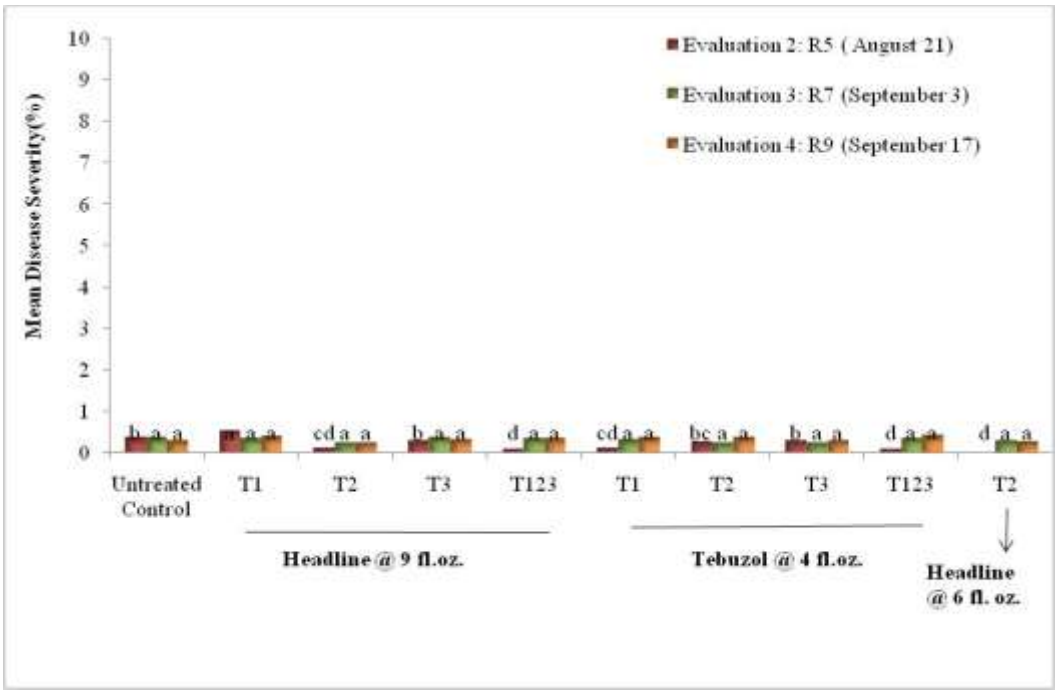
Table 6. Sunflower rust severity at four evaluation dates, Area Under the Disease Progress Curve (AUDPC), relative Area Under the Disease Progress Curve (rAUDPC), test weight and yield of ten fungicide treatments at the Landon Research Extension Center in Langdon, ND.

			Disease severity[a]						Seed Yield	Test Weight
ID	Treatment	Timing	R3.5	R5	R7	R9	AUDPC[b]	rAUDPC[c]	(lb/A)	(lb/bu)
1	Untreated Control		0 a	0.36 b	0.37 a	0.28 a	11.81 ab	0.029 ab	1042.5 ab	22.81 a
2	Headline @ 9 fl oz	1	0 a	0.51 a	0.34 a	0.38 a	14.076 a	0.0034 a	1102.5 a	23.02 a
3	Headline @ 9 fl oz	2	0 a	0.11 cd	0.22 a	0.23 a	5.998 d	0.0015 c	1087.5 a	22.79 a
4	Headline @ 9 fl oz	3	0 a	0.29 b	0.36 a	0.32 a	10.95 abc	0.0027 abc	882.5 abc	22.77 a
5	Headline @ 9 fl oz	1,2,3	0 a	0.075 d	0.34 a	0.34 a	7.97 bcd	0.0019 bc	1030.0 ab	22.15 a
6	Tebuzol @ 4.0 fl oz	1	0 a	0.11 cd	0.31 a	0.38 a	8.30 bcd	0.0020 bc	1125.0 a	22.50 a
7	Tebuzol @ 4.0 fl oz	2	0 a	0.25 bc	0.24 a	0.35 a	9.05 bcd	0.0022 bc	882.5 abc	22.56 a
8	Tebuzol @ 4.0 fl oz	3	0 a	0.30 b	0.24 a	0.28 a	9.18 bcd	0.0022 abc	865.0 abc	23.13 a
9	Tebuzol @ 4.0 fl oz	1,2,3	0 a	0.082 d	0.33 a	0.43 a	8.48 bcd	0.0021 bc	722.5 c	22.32 a
10	Headline @ 6 fl oz	2	0 a	0.055 d	0.30 a	0.27 a	6.62 cd	0.0016 c	800.0 bc	22.26 a
LSD			0	0.1466	0.2286	0.2256	4.96	0.001	275.18	0.98

[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. Disease was assessed at four growth stages on the following dates in 2008; 7 August (G.S. R3.5), 21 August (R5), 3 September (R7), and 17 September (R9).

[b]Area under the disease progress curve (AUDPC) = $\sum_{i=1}[(W_{i+n1} + W_i) / 2] [t_{i+1} - t_i]$ 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.


Mean Disease Severity(%)
10
9
8
7
6
5
4
3
2
1
0
Evaluation 2: R5 (August 21)
Evaluation 3: R7 (September 3)
Evaluation 4: R9 (September 17)
b a a
a a a
cd a a
b a a
d a a
cd a a
bc a a
b a a
d a a
d a a
Untreated Control
T1
T2
T3
T123
T1
T2
T3
T123
T2
Headline @ 9 fl.oz.
Tebuzol @ 4 fl.oz.
Headline @ 6 fl. oz.