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Research Article

Effect of Early Foliar Disease Control on Wheat Scab Severity (*Fusarium graminearum*) in Argentina

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Wheat scab is common in Argentina mainly durum wheat and some bread varieties. The epidemics occur every 5 to 7 years. During the 2007, 2008, and 2009 growing seasons, three trials were conducted at the INTA Balcarce Experimental Station. Each plot had six rows of 5 m long, spaced 0.15 m apart and was set up in a randomized complete block design with four replications. Trifloxystrobin plus cyproconazole was sprayed at Z3.1 stage. Treatments were sprayed at Z6.1 stage with tebuconazole, prochloraz, and metconazole to improve scab control. Artificial inoculations were made in Z6.1. Severity of *Septoria* leaf bloth and leaf rust was assessed in boot stage (Z3.9). Scab severity was rated at early dough stage (Z8.3). Yields were recorded each year. Fungicide only applied at Z3.1 stage did not reduce field scab severity but reduced the seeds infection and increased the yields. Early fungicide spray produced yield increase at about 22% and a decrease in seed infection of up to 40%. Yields increased in a 55.3% and in a 19.6% when compared with the inoculated and not inoculated check, respectively. The purpose of this study was to evaluate the effect of foliar disease control on scab, crop yield, and seed health.

1. Introduction

Head blight (scab) caused by *Fusarium graminearum* Schwabe (teleomorph *Gibberella zeae* (Schw.) Petch) occurs in humid wheat producing areas of the world [1, 2]. In Argentina, it is common in durum wheat and some bread wheat cultivars depending of susceptibility to the pathogen [3]. Very destructive outbreaks occurred in 1978, 1985, 1993, 2000, 2001, and 2002 growing seasons [4–6]. Damage has been significant in south east of Buenos Aires province. The disease attacks the heads and then seedling of small grains, but it is the most conspicuous and does the most damage when infecting the wheat heads.

In Argentina, the use of foliar fungicides on wheat is common, and it has increased considerably [7]. Near 30% of the crop area in SE of Buenos Aires is sprayed to control of foliar disease like rust and leaf blotch [8]. The control of scab by fungicide applications should be a preventive action because if fungicide applications are done when the symptoms appear, the disease control efficiency would be extremely low. Therefore the use of fungicide to control wheat scab is low compared with the use of fungicide for controlling foliar disease.

Yields can be improved with the use of fungicides, but yield increments vary extremely according to disease severity, fungicide efficiency, timing spray, and number of applications [9, 10]. Fungicide sprays reduce up to 70% head symptoms, and 80% yield increase can be obtained under the climatic conditions of Argentine [11, 12]. Sometimes early applications of fungicides in crop due to severe symptoms of leaf rust and leaf blotch are necessary.

These sprayings produce healthy plants in advance crop stage, reducing the incidence or severity of wheat scab in the field. The objective of this work was to evaluate the effect of early and early plus flowering fungicide spray on the severity of scab in wheat field, as well as the disease's yield and grain infection.

2. Materials and Methods

2.1. Research Sites. During the 2007, 2008, and 2009 growing seasons, three trials were conducted at the INTA Balcarce Experimental Station (Argentina) in a Brunizen soil with 3.9% of organic matter. ProInta Oasis wheat cultivar, bread type, susceptible to the foliar rust (*Puccinia recondita*), leaf blotch (*Septoria tritici*), and scab diseases (*F. graminearum*) were used. The trials were conducted under low mechanical system in a soil precultivated with wheat that was fertilized at sowing time and tillering stage with 100 $kg{\cdot}ha^{-1}$ diamonic fosfate. Weed and insect were controlled according to standard recommended practices for the region.

2.2. Fungicide Treatments and Spray Timing. In tillering stage Zadoks 3.1 [13] trifloxystrobin plus cyproconazole 276.5SC at 140 + 60 $g{\cdot}ha^{-1}$ was sprayed in certain plots to improve foliar rust and leaf blotch disease control and to reach the anthesis stage Zadoks 6.1 [13] with good healthy plants. Plots were sprayed at anthesis stage Zadoks 6.1 with tebuconazole 25EW at 187.5 $g{\cdot}ha^{-1}$, prochloraz 45EC at 450 $g{\cdot}ha^{-1}$, and metconazole 9 SL at 90 $g{\cdot}ha^{-1}$. All fungicide applications were sprayed mixed in water with a carbonic anhydride pressurized backpack sprayer equipped with a constant boom pressure of 40 lb $pulg^{-2}$ and a boom length of 1.2 m with 0.3 m and four ceramic disc-type cone nozzles at a rate of 150 L ha^{-1}.

2.3. Inoculation Method. Inoculations were made 2 days after fungicide sprayings in Z61. A mixture of isolates of *G. zeae* from the culture collection at the Agricultural Regional Experimental Station INTA Balcarce was used. The inoculum was prepared by culturing *F. graminearum* in Petri dishes with APG (2%) + glucose potato agar plus cellulose (2%) at pH 5.5 and incubated at 24°C in darkness for 48 hours. Cultures were then exposed to daylight and ambient temperature to stimulate sporulation. A sterile paintbrush was used to transfer propagules of the fungus including ascospores to a glass bottle of sterile water. The suspension was homogenized and filtered with a cloth of fine mesh. Inoculum was diluted in 1.5 L of sterile water to achieve an inoculum density of 1×10^4 ascospores cc^{-1}. Inoculum was applied on spikes of plants in the two central furrow of each plot with a manual-type sprayer.

2.4. Field Evaluation. Scab severity was rated at early dough stage [13] in relation to the percentage of heads showing symptoms according to Stack and Mcmullen scale [14].

Severity of *Septoria* leaf blotch was assessed on James scale [15] that reflects the vertical progress of symptoms in the canopy and the overall proportion of leaf area affected. Leaf rust was rated on the same scale in relation to the percentage of the least leaf area covered with pustules. Both diseases were rated in boot stage at Zadoks 3.9 scale [13]. Yields were recorded each year, and samples of seeds were obtained for determination of 1000 kernel weight.

2.5. Laboratory Evaluation. The percentage of infected seeds was determined by placing 100 seed per replication in 2% sodium hypochlorite for 15 sec, rinsing in water for 2 min, and placing seed in containers with moist cotton covered with moist filter paper. The containers were incubated in polyethylene bags to maintain high relative humidity during 8 days. Records included the percentage of grains with *Fusarium* mycelium after 7-day incubation.

2.6. Design and Statistical Analysis. Every year each experimental plot had six rows of 5 m long, spaced 0.15 m. Treatments were arranged in a randomized complete block design with four replicates. Data was subjected to analysis of variance, and means were compared by LSD at $P = 0.05$.

3. Results and Discussion

During the evaluation years, significant differences were found between the control check in regards to scab severity, yield, infected kernels, and kernels weight variables. The rates of said variables in the untreated check show the levels of natural infection during test trials, but significant differences were detected between inoculation and no inoculation in the checks and show the efficiency of the artificial inoculation.

Leaf blotch and rust control by trifloxystrobin plus cyproconazolesprayed at Z3.1 stage were very good and show lower infection level than the checks (Tables 1, 2, and 3). In every season the checks that were sprayed with trifloxystrobin plus cyproconazole at Z3.1 stage and that were artificially inoculated did not reduce significantly head blight infection, nor did they increase grain weight. They did, however, heavily reduce the percentage of infected kernels, improving yields compared with inoculated check. In the absence of artificial inoculations on natural infections there was no difference between spray and not spray at Z3.1 stage for all scab parameters analyzed. Similar results were obtained in previous works [10, 11] with fungicide sprays in Z6.1 stage on *aestivum* wheat. Given the results, early sprayings cause healthy plants with a lower level of foliar diseases, which improves the physiological state of the crops, producing a higher amount of kernels with a lower level of infection caused by the pathogen.

During 2007 and 2009 seasons, scab severity was high (Tables 1–3). Early fungicide sprayings at Z3.1 stage plus inoculations improved an increase in yields of an average of 22%, but a decrease infection in seeds of 40% compared with the check plus inoculations.

The combined effects of a high level of foliar diseases infection and scab caused significant yield decrease, high infection in kernels, and noticeable reduction in weight. Nevertheless, spraying in full flowering stage with tebuconazole, prochloraz, or metconazole gives high head protection against *Fusarium* infection, reducing head blight severity and the percentage of infected kernels, thus increasing yields. These results agree with those obtained previously on durum wheat [12].

Fungicide sprayings at Z3.1 and Z6.1 stages reduced foliar disease and scab severity to the minimum and show the best results in yields. Higher yields and lower infection in kernels were found in laboratory tests, although these results did not

TABLE 1: Effect of early fungicides sprays on scab severity, yield, infected kernel, and weight grains in 2007 season.

Treatments	Dose (g·ha^{-1})	Rust severity[1]	Leaf bloth severity[2]	Scab severity[3]	Yield (t/ha^{-1})	Infected kernel (%)	Weight 1000 seeds (g)
Check	—	8/25	6/50	15bc	3.35cde	5cd	32.3a
Check + inoculation	—	8/25	6/50	80a	2.32f	48a	25.6b
Z31 trifloxystrobin + cyproconazole 267.5SC	140 + 60	5/1	4/25	12bcd	3.34cde	6cd	33.2a
Z31 trifloxystrobin + cyproconazole 267.5SC + inoculation	140 + 60	5/1	4/25	76a	3.10de	26b	31.6a
Z61 tebuconazole 25EW	187.5	5/1	6/50	5cd	3.82abc	2cd	34.3a
Z61 prochloraz 45EC	450	8/15	6/50	2d	3.88ab	0d	33.9a
Z61 metconazole 9SL	90	8/15	6/50	6bcd	3.94a	3cd	33.8a
Z61 tebuconazole 25EW + inoculation	187.5	8/15	6/50	18b	3.66abc	5cd	34.5a
Z61 prochloraz 45EC + inoculation	450	8/15	6/50	10bc	3.72abc	5cd	33.7a
Z61 metconazole 9SL + inoculation	90	8/15	6/50	12bcd	3.76abc	4cd	32.9a
Z31 trifloxystrobin + cyproconazole 267.5SC + Z61 tebuconazole 25EW	140 + 60 + 187.5	5/1	4/5	2d	3.95a	4cd	33.9a
Z31 trifloxystrobin + cyproconazole 267.5SC + Z61 prochloraz 45EC	140 + 60 + 450	5/1	4/5	0d	3.92a	3cd	34.6a
Z31 trifloxystrobin + cyproconazole 267.5SC + Z61 metconazole 9SL	140 + 60 + 90	5/1	4/5	1d	4.02a	2cd	34.9a
Z31 trifloxystrobin + cyproconazole 267.5SC + Z61 tebuconazole 25EW + inoculation	140 + 60 + 187.5	5/1	4/5	12bcd	3.68abc	6cd	33.2a
Z31 trifloxystrobin + cyproconazole 267.5SC + Z61 prochloraz 45EC + inoculation	140 + 60 + 450	5/1	4/5	10bcd	3.75abc	6cd	33.2a
Z31 trifloxystrobin + cyproconazole 267.5SC + Z61 metconazole 9SL + inoculation	140 + 60 + 90	5/1	4/5	10bcd	3.79abc	4cd	32.7a
LSD (P = 0.05)				10	0.55	6.5	3.8

[1 and 2] [15]. Where 1st digit = foliar number and 2nd digit = % severity. [3] [14].
Within a column, means followed by the same letter are not significantly different (P = 0.05).

Table 2: Effect of early fungicides sprays on scab severity, yield, infected kernel, and weight grains in 2008 season.

Treatments	Dose ($g{\cdot}ha^{-1}$)	Rust severity[1]	Leaf bloth severity[2]	Scab severity[3]	Yield (t/ha)	Infected kernel (%)	Weight 1000 seeds (g)
Check	—	7/5	4/5	10bc	3.50abc	2cd	34.5a
Check + inoculation	—	7/5	4/5	50a	3.05c	25a	29.6b
Z31 trifloxystrobin + cyproconazole 267.5SC	140 + 60	4/1	3/5	14b	3.50abc	2cd	34.5a
Z31 trifloxystrobin + cyproconazole 267.5SC + inoculation	140 + 60	4/1	3/5	50a	3.15bc	14b	29.8b
Z61 tebuconazole 25EW	187.5	4/1	3/5	2d	3.90a	0d	35.5a
Z61 prochloraz 45EC	450	7/5	4/5	4bcd	3.78a	0d	35.9a
Z61 metconazole 9SL	90	7/5	4/5	5bcd	3.96a	0d	34.7a
Z61 tebuconazole 25EW + inoculation	187.5	7/5	4/5	15b	3.86a	6c	35.5a
Z61 prochloraz 45EC + inoculation	450	7/5	4/5	15b	3.92a	6c	34.9a
Z61 metconazole 9SL + inoculation	90	7/5	4/5	15b	3.86a	4cd	34.1a
Z31 trifloxystrobin + cyproconazole 267.5SC + Z61 tebuconazole 25EW	140 + 60 + 187.5	4/1	3/5	0d	3.99a	1d	36.9a
Z31 trifloxystrobin + cyproconazole 267.5SC + Z61 prochloraz 45EC	140 + 60 + 450	4/1	3/5	0d	3.85a	1d	35.5a
Z31 trifloxystrobin + cyproconazole 267.5SC + Z61 metconazole 9SL	140 + 60 + 90	4/1	3/5	0d	3.97a	0d	36.1a
Z31 trifloxystrobin + cyproconazole 267.5SC + Z61 tebuconazole 25EW + inoculation	140 + 60 + 187.5	4/1	3/5	14b	3.78a	4cd	34.7a
Z31 trifloxystrobin + cyproconazole 267.5SC + Z61 prochloraz 45EC + inoculation	140 + 60 + 450	4/1	3/5	9bc	3.93a	4cd	36.6a
Z31 trifloxystrobin + cyproconazole 267.5SC + Z61 metconazole 9SL + inoculation	140 + 60 + 90	4/1	3/5	9bc	3.84a	3cd	36.7a
LSD ($P = 0.05$)				6	0.55	6	3.9

[1 and 2] [15]. Where 1st digit = foliar number and 2nd digit = % severity. [3] [14].

Within a column, means followed by the same letter are not significantly different ($P = 0.05$).

TABLE 3: Effect of early fungicides sprays on scab severity, yield, infected kernel, and weight grains in 2009 season.

Treatments	Dose (L/ha^{-1})	Rust severity[1]	Leaf bloth severity[2]	Scab severity[3]	Yield (t/ha)	Infected kernel (%)	Weight 1000 seeds (g)
Check	—	8/5	7/20	29b	3.35bc	16c	32.3ab
Check + inoculation	—	8/5	7/20	75a	2.59e	62a	29.6b
Z31 trifloxystrobin + cyproconazole 267.5SC	140 + 60	5/15	4/25	25b	3.33bc	14c	35.5a
Z31 trifloxystrobin + cyproconazole 267.5SC + inoculation	140 + 60	5/15	4/25	69a	3.20c	36b	29.5b
Z61 tebuconazole 25EW	187.5	5/15	7/20	1c	3.98a	0d	35.4a
Z61 prochloraz 45EC	450	8/5	7/20	1c	3.90ab	0d	34.9a
Z61 metconazole 9SL	90	8/5	7/20	2c	4.10a	2d	36.1a
Z61 tebuconazole 25EW + inoculation	187.5	8/5	7/20	8c	3.86ab	4d	35.0a
Z61 prochloraz 45EC + inoculation	450	8/5	7/20	8c	3.79abc	0d	34.9a
Z61 metconazole 9SL + inoculation	90	8/5	7/20	10c	3.91ab	2d	35.2a
Z31 trifloxystrobin + cyproconazole 267.5SC + Z61 tebuconazole 25EW	140 + 60 + 187.5	5/15	4/25	5c	4.12a	2d	35.9a
Z31 trifloxystrobin + cyproconazole 267.5SC + Z61 prochloraz 45EC	140 + 60 + 450	5/15	4/25	5c	4.15a	1d	36.1a
Z31 trifloxystrobin + cyproconazole 267.5SC + Z61 metconazole 9SL	140 + 60 + 90	5/15	4/25	1c	4.20a	0d	35.8a
Z31 trifloxystrobin + cyproconazole 267.5SC + Z61 tebuconazole 25EW + inoculation	140 + 60 + 187.5	5/15	4/25	9c	3.88ab	1d	36.2a
Z31 trifloxystrobin + cyproconazole 267.5SC + Z61 prochloraz 45EC + inoculation	140 + 60 + 450	5/15	4/25	9c	3.93ab	1d	36.7a
Z31 trifloxystrobin + cyproconazole 267.5SC + Z61 metconazole 9SL + inoculation	140 + 60 + 90	5/15	4/25	10c	3.99a	2d	35.9a
LSD (P = 0.05)				12	0.56	8	5.4

[1 and 2] [15]. Where 1st digit = foliar number and 2nd digit = % severity. [3] [14].
Within a column, means followed by the same letter are not significantly different (P = 0.05).

significantly surpassed the sprayed treated checks at Z6.1. The additive effect of foliar diseases (*P. recondita* and *S. tritici*) and scab (*F. graminearum*) can be measured through yield increases on fungicide sprayings at Z3.1 plus Z6.1, reaching average values of 55.3%, in comparison with the inoculated check and a 19.6% with the uninoculated check.

During the 2008 season, scab severity was light due to less favorable environmental conditions. In this season scab infections that observed any inoculated and uninoculated control were lower than the 2007 and 2009 seasons. Treatments with fungicides sprayed in Z3.1 plus Z6.1 stages showed no symptoms of the disease in the field. No significant differences were registered in performance between treatments inoculated or not with fungicides sprayed on any Z3.1 and Z6.1 stages. All these treatments overcome the yields observed with fungicide sprayed at Z3.1 stage and the checks with or without inoculations. A similar relationship was observed when analyzed % infected kernels and weight of the seeds.

4. Conclusions

Based on field trials carried out over three consecutive years, fungicide spray at Z3.1 stage did not reduce significantly head blight infection and grain weight however heavily reduce the percentage of infected kernels.

On natural infections there was no difference between spray and not spray with fungicide at Z3.1 stage for all scab parameters analyzed.

When scab was severity in 2007 and 2009 seasons, early fungicide spray at Z3.1 stage improved an increase in yields of an average of 22%, while a decrease kernel infection of an average of 40% compared with the inoculated check.

Twice fungicide applications at Z3.1 and Z6.1 stages reduced foliar disease and scab severity to the minimum and show that yields increase reaching average values of 55.3%, in comparison with the inoculated check and 19.6% with the uninoculated check.

When scab was light in 2008 season, no significant differences were registered in performance between treatments inoculated or not with fungicides sprayed on any Z3.1 and Z6.1 stages. These treatments overcome the yields registered with fungicide sprayed at Z3.1 stage and the checks with or without inoculations.

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