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Research Article

Effect of Application Timing of Artea and Amistar Xtra on the Yield of Wheat (*Triticum aestivum* L.) under Foliar Disease in the East-Algerian

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Abstract

Background and Objective: In the field of agriculture, the use of fungicides are necessary to control fungal disease caused by the phytopathogenic. The aim of the present study was to examine the effect of application timing of the fungicide for investigate how choice of partner, either eradicate (Artea+Amistar Xtra) or protecting the crop and to evaluate the benefit of a third (T3) spray application in wheat. **Methodology:** Three applications of fungicide are recommended: at the stem extension, booting and heading stage of crop growth. Azoxystrobin, cyproconazole and propiconazole belong to two different chemical classes and are commonly used as chemical groups for control the diseases on wheat in Algeria. **Result:** The study show that, application of fungicides at the stem elongation (T1), booting (T2) and at the heading stage (T3) resulted in a significant reduces the disease severity with 63.33, 91.66 and 87.5% reduction for powdery mildew, yellow rust and brown rust, respectively and increase in yield, compared to one or two applications by this treatment. **Conclusion:** Application of fungicides at timing of the T3 had a significant impact at protecting green leaf or yield compared to one or two applications.

Key words: Wheat (*Triticum aestivum* L.), chemical control, cyproconazole, propiconazole, azoxystrobine, incidence disease, growth stages, yield

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important food crops in the world. Wheat (*Triticum aestivum* L.) is also a very important cereal crop and an contributing prominently to the nutrient furnish of the global population and a very adaptable crop[1,2]. Regarding production, the common wheat (*T. aestivum*) and durum wheat (*Triticum durum* Desf.) contribute a total of 90% of the world's wheat production and they are grown on approximately 17% of the world's cultivatable land, covering over 200 million hectares[3]. It forms more than 40% of the world's staple food and 95% of people in the developing countries eat wheat or maize in form of flour as a main staple food source[4,5].

During the long wheat growing season in Algeria, starting with sowing in October and ending with harvesting in July or August and with progressive global climatic change, plants are exposed to a wide variety of diseases, fungal, bacterial and viral. In nature, spikes, leaves and roots of wheat plants can be infected and that leads to substantial yield loss, wheat production is influenced greatly.

Wheat is attacked throughout its life by a number of fungal diseases of the stem, leaves and ear. The five major foliar diseases are *Septoria tritici*, yellow rust (*Puccinia striiformis*), brown rust (*Puccinia recondita*), Fusarium head blight (*F. graminearum* Schwabe) and powdery mildew (*Erysiphe gramminis*).

All of these diseases reduce supply of photosynthesis, negatively affects development of root system, weight and leaf assimilation on area, affects all three yield components and finally the weight of 1000 grains[6,7].

The obligatory pathogens, for example powdery mildew and leaf rust very often occur on wheat together. Powdery mildew, caused by fungus *Blumeria graminis* f. sp., *tritici* (syn. *Erysiphe graminis* (DC) f. sp., *tritici* is one of the most worldwide devastating diseases of durum and common wheat[8]. The disease can completely cover plant surfaces under favorable climatic conditions, occurring mostly on the upper leaf surface[9]. The disease damage range from 13-34% when low infestation but 50-100% under severe infestation could be recorded in a field[10,11]. Environmental conditions are very crucial for successful colonization of the fungus[12]. With availability of favorable developing conditions, the fungus can complete a repeating cycle in 7-10 days thereby providing a high possibility of rapid conidia production, which results in development of new virulent powdery mildew races through increased mutation frequency of the fungus[12].

Similarly, fungal rust diseases caused by members of the genus *Puccinia* consistently cause yield losses and occasional devastating epidemics in the majority of wheat-growing regions worldwide[13,14]. Yield losses of up to 50 and 70% have been reported in wheat for leaf rust[15] and stripe rust[16], respectively.

As with other major disease, *Septoria tritici* blotch, caused by *Zymoseptoria tritici* (formerly *Septoria tritici*, teleomorph: *Mycosphaerella graminicola*) is currently among the most frequent foliar diseases on both bread wheat (*Triticum aestivum*) and durum wheat (*T. durum*). During wet years, *Septoria tritici* is leading the parasitic complex of durum wheat in Algeria, losses can reach 50%[17].

The disease management to reduce crop losses includes cultural practices, biological and immunological methods of controlling infections, the application of fungicides and host resistance in combination with monitoring of the virulence range in the pathogen.

Several chemical control methods are available for control of disease on wheat, specifically the use of fungicides, may be employed of great importance in stabilizing wheat production. A fungicide kills or inhibits the growth of a fungus or a number of fungi[18]. Wegulo *et al.*[19] showed that up to 42% yield loss was prevented by applying foliar fungicides to winter wheat. The amount of applied fungicide, the period between application, timing and dose both affect the effectiveness of disease control[20].

Hence, appropriate fungicide application is an important part of cereal husbandry. However, there are three aspects to improving the application of fungicides to wheat crops: Predicting the effect on the diseases, predicting the impact of reduced disease on increased yield and determining the optimum application of fungicides. In the current study we are defining disease progress up the plant and analyzing the effect of the applied amount and application frequency of two fungicides treatments to yield at different growth stages of the crop, as evaluated on wheat trials performed in the East-Algerian.

MATERIALS AND METHODS

Based on earlier investigations one wheat cultivars "HD 1220" were selected and tested during years 2016 at Guelma (36°28'33.1" N-7°30'54.4" E), Algeria with mean minimum and maximum temperatures of 14.43 and 26°C, respectively and mean average rainfall of 531 mm between October and May. The two factorial randomized block design were used including untreated-T0 and with fungicide treated-T1 variants.

The commercial fungicides tested were: (1) Cyproconazole 80 g L^{-1}+propiconazole 250 g L^{-1} (Artéa 330 EC) and (2) Cyproconazole 80 g L^{-1}+azoxystrobin 200 g L^{-1} (Amistar Xtra), labeled for the control of leaf rust, septoriose, powdery mildew and other leaf diseases of wheat were evaluated in field experiment. The experimental units were 7 row field plots of 6 m^2 with an inter-row spacing of 20 cm design with four replications.

The fungicides were applied using a knapsack sprayer at recommended water volume of 200 L ha^{-1} for Artea 330 EC and 300 L ha^{-1} for Amistar Xtra.

This study reports four experiments conducted under natural infection to determine the effect of foliar fungicides on wheat:

- **Experiment T0:** Untreated
- **Experiment T1:** Consisted of applying the fungicide (Artea and Amistar Xtra) at the stem extension stage of crop growth
- **Experiment T2:** The fungicide applied from stem extension and booting
- **Experiment T3:** The fungicide applied at the stem extension, booting and heading stage of crop growth

Herbicide was applied in winter during the tillering stage of wheat growth. The readings for each experiment and different treatments are presented in Fig. 1.

Parameters and disease assessments: Disease incidence was measured by using the Saari-Prescott scale (0-9). Test the weight of 1,000 grains, the height of plant (cm), number of ear (m^2), number of ear per plant number of grain per ear parameters and experimental baking were determined on both untreated, infected (T0) and treated, protected (T1) variants:

Note	0	1	2	3	4	5	6	7	8	9
Leaf area affected (%)	0	0.05	0.5	1.5	3.5	7.5	17.5	37.5	62.5	87.5

The infection ratio is calculated by multiplying the incidence by severity[21].

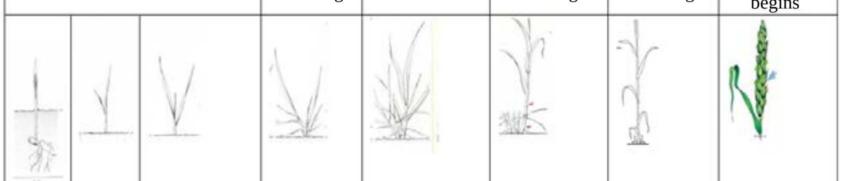
Statistical analysis: All results were analyzed with analysis of variance (ANOVA) using STATBOX 6.0.4 grimmer soft. The data were analyzed by one way analysis of variance test. Means were compared using a t-test at p = 0.05 or p = 0.01.

RESULTS

In the year 2016, due to more humid climatic conditions, the powdery mildew attack was a little stronger. The disease severity was estimated on several sampling dates (Fig. 1). Severity of powdery mildew was 20% from tillering stage in the untreated plots progress of powdery mildew in 2016 was moderate and disease severity was strong. Maximal values of disease severity in the date of experiments are shown in heading stage (60%).

One fungicide application at the stem extension stage of crop growth had the lowly and provided the protection against the powdery mildew. On the control plot, the severity was 50% than yield achieved in the treatment with fungicide 20% (Fig. 2).

It was determined that two fungicide applications were required from stem extension and booting stage to protect the crop of wheat, the inhibition percentages of the severity of powdery mildew was 63.33% compared to the untreated control.



Pre-stem 3rd leaf			Tillering	Stem-extension	Booting	Heading	Gran filling begins
		1st application nitrogen 46%	Treatment herbicide	2nd application nitrogen		Treatment insecticide	
T0		18/02/2016	28/02/2016	03/03/2016 + application of fungicides (T1) 01/03/2016		15/04/2016	
T1							
T2					Application of fungicides (T2) 24/03/2016		
T3						Application of fungicides (T3) 24/03/2016	

Fig. 1: Application of different treatment at different stages on wheat "HD 1220"

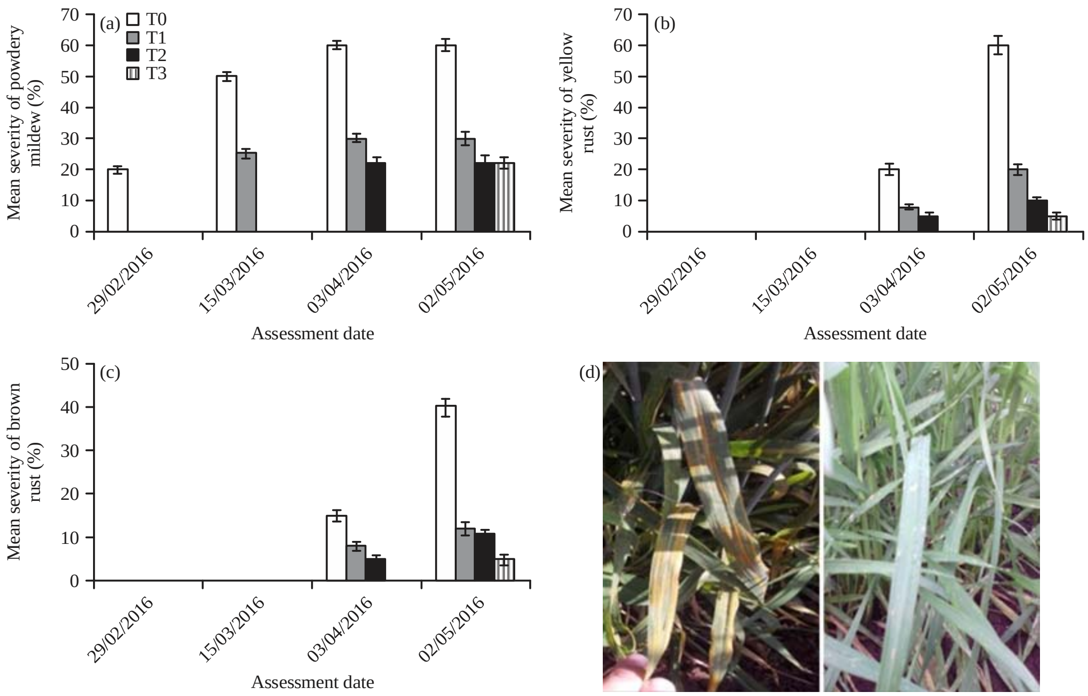


Fig. 2(a-d): Mean of the severity progress for different leaves of wheat for fungicide treatments applied at three different stages of crop growth (stem extension, booting and heading)

The similar inhibition percentage of the disease severity (63.33%) was also obtained by three fungicides applications from stem extension, booting and heading stage of a mixture of Artea and Amestar Xtra.

The trend of reduction on powdery mildew severity was maintained after 1st, 2nd and 3rd fungicide application, respectively at stem extension, booting and heading stage. Effects of fungicide treatments had significance in all stages.

In the same years, the wheat leaf was not affected by yellow rust (*Puccinia striiformis*) and brown rust (*Puccinia recondita*) at the pre-stem extension to booting stage. Leaf rust on the cultivars HD1220 appeared out after this phenological stage. On the other hand, the development of leaf rust began later than of powdery mildew (*Erysiphe gramminis*).

Disease severity from yellow rust in untreated plots was 20% at heading and 60% at filling stage. In the same time severity, brown rust showed at heading and filling stage was moderate 15 and 40%, respectively (Fig. 2).

The two foliar fungicide treatments reduced rust severity on wheat cultivar HD1220. Fungicide applications significantly ($p \leq 0.05$) reduced mean rust severity compared to the untreated control plots, with Amistar Xtra (Cyproconazole+azoxystrobin) and Artea 330 EC (Cyproconazole+propiconazole).

The reduction on yellow rust severity was observed in plots after first and second fungicide application 20 and 8% at heading and 20 and 10% at filling stage, respectively. The highest disease severity reduction were obtained after the 3rd treatment (5%).

Similar reduction on brown rust severity occurred up to 15, 8 and 5% at heading and 12, 11 and 5% at filling stage were recorded on the first, second and third fungicide application, respectively.

In the present experiment, HD 1220 wheat was analyzed for quality parameters character. The average height of wheat stem, weight of 1,000 grains, number of ear (m^2), number of ear per plant and number of grain per ear, were decreased under disease but treatment by fungicide (Artea and Amestar Xtra) increased these morphometric parameters. Highest mean values for yield is found in third fungicide application (Fig. 2). Compared to the untreated control, this treatment type increased 1,000 grains weight, number of ear (m^2), yield plots g m^{-2} and number of grain per ear by 16, 16.61, 29.92 and 24.86%, respectively. In both variety, the fungicide treatment significantly increased grain yield ($p \leq 0.01$), (Fig. 3).

DISCUSSION

Many fungal species attack and cause decrease of yield and grain quality of wheat, during three leaves to grain filling stage. Powdery mildew and rusts symptoms were relatively frequent in these experiments. In 2016, air temperature and

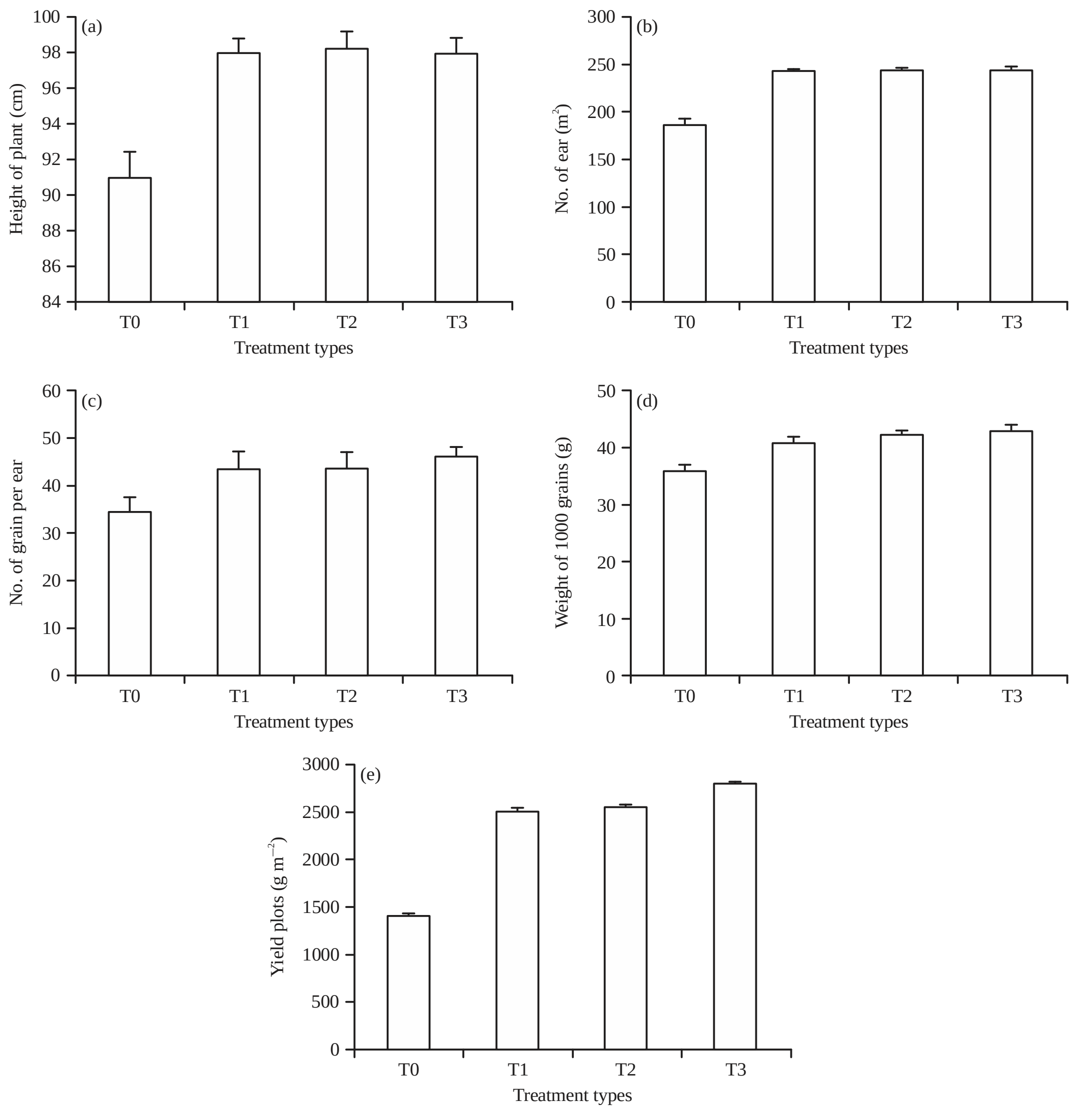


Fig. 3(a-e): Effect of fungicides treatments on various other characters for HD1220 wheat variety in field trials carried out during 2016 in East-Algerian

precipitation factors in the preceding growing season influenced growth stage, powdery mildew and brown rust.

Powdery mildew symptoms were already apparent in winter and became much more common at the stem elongation and at milk ripe stages. Our experiments showed that the start of powdery mildew was earlier. More symptoms were noted in the 2016 growing season at both locations. This increase was probably because autumn and winter were warm and wet. Disease symptoms may be evident at tillering stage. Maximal values of disease severity are shown in heading stage (60%). Other authors have indicated the increasing importance of this disease by highest temperatures[22,23]. Te-Beest *et al*.[24] found that temperature, humidity and rain in April-June to best explain disease severity and wind to predict a damaging epidemic (>5% severity).

On the contrary, rust started progress quickly (booting stage) later than powdery mildew. It indicates the influence of higher temperatures on the development of rusts just in the month of May (60%) in comparison with April (20%) when temperatures were lower. In comprehensive reviews by Line[25] and Chen[26] yellow rust is described as very dependent on weather conditions, specifically moisture, temperature and wind.

Gladders *et al*.[27] and Papastamati and van den Bosch[28] emphasized temperature as the most important weather variable and its effects on reproduction and winter survival.

Marsalis and Goldberg[29] found that rust to be developed optimally at temperatures between 15 and 22°C and the disease will progress until temperatures are above 27°C. The high temperature in March probably facilitated sporulation and infection processes on young leaves.

Chemical control is one of the most effective, sound and economical means of control of diseases on wheat. Several reserachers used different fungicides successfully in order to control plant disease accompanied with cultural practices and host resistance with monitoring of the virulence range in the pathogen. In more recent years, the disease management to reduce crop losses includes the application of fungicides. It is recommended that fungicides can be an effective means to protect green leaf area of the top leaves depending on the time, rate and number of applications[30,31].

In the present study, fungicides used are from different chemical groups but they have both protectant and eradicate activity. The efficiency of azoxystrobin in controlling rust and powdery mildew is mostly attributed to its systemic action and inhibition of spore germination but it also has some eradicate activity[32].

Cyproconazole, which has some growth regulating properties can also inhibit hence infection[33]. Propiconazole shows more efficacy in June where inoculum development beginning in may could be a factor of severity because of humidity and night temperature elevation.

All fungicide applications in the study resulted in lower disease severity and higher yields than untreated check plots.

Result indicated that one application of azoxystrobin, propiconazole and cyproconazole at stem extension stages which is already in practice for management of powdery mildew disease, gave the maximum reduction in severity 20%.

Twice applications of fungicides at stem extension and booting stage resulted in least incidence 30% with 63.33% reduction in the incidence.

In case of third application of fungicides (Artea and Amestra Xtra), that is at stem extension, booting and heading stage it resulted in least incidence 22% with 63.33, 91.66 and 87.5% reduction in incidence for powdery mildew, yellow rust and brown rust, respectively. Yadav *et al.*[34] reported that minimum spot blotch disease incidence was recorded in crop which was twice sprayed with propiconazole at tillering and boot leaf stages of crop, resulted in least severity, that is 27.58% with 44.42% reduction. Results achieved in this study are in accordance to previous studies, that azoxystrobin showed antisporulant activity against *C. beticola* and modestly effective against *Erysiphe betae*[35] and this is low curative activity against *Guignardia bidwelli*[36]. The dominant effect of strobilurin fungicides on the inhibition of spore germination has also been reported in several other pathogens[37,38], consisting of inhibition of mitochondrial respiration[39,40]. However, this fungicide is expensive and can be ineffective if applied at the wrong time or not economical if applied under conditions of low disease pressure[41,42]. It is important to note that, strobilurins are highly effective when applied preventively and/or retarding foliar senescence[43,44].

Triazoles, a class of fungicides are highly effective and reliable[45], that inhibits sterol biosynthesis of fungal[46,47]. Habitual protective triazoles such as propiconazole was the most effective fungicides for management of leaf rust of wheat[48]. According to Mesta *et al.*[49] reported propiconazole (0.1%) was effective fungicide against *Alternaria* blight of sunflower. On the other hand, the largest and most important group of systemic compounds developed for control of crop fungal diseases[50].

Three applications of azoxystrobin+propiconazole+cyproconazole at the stem elongation (T1), booting (T2) and at the heading stage (T3) resulted in a significant increase in height, number of ear (m^2), number of grain per ear, weight 1000 grains (g) and yield plots (g m^{-2}), compared to one or two applications of fungicide. Results achieved in this study are in accordance to previous studies, which showed that yield is increased by fungicides treatment quantitatively such as qualitatively[51].

When the fungicide is applied to wheat before the flag leaf emergences, it generally results in less disease control on the upper leaves during grain development and smaller yield benefits[52]. To be effective, most fungicides need to be applied before the disease occurs or at the appearance of the first symptoms at three times[53]. However, Hershman[54] and McGrath[53] explained that when the disease severity is low and there is minimal yield loss, applying a fungicide will not result in either a yield or an economic advantage. Several studies of Wiik and Rosenqvist[55] and frequent technical reports by Swart[56], reported yield increases greater than 30% of the treated plots over untreated plots. Wegulo *et al.*[19] showed that up to 42% yield loss was prevented by applying foliar fungicides to winter wheat. Mellbye and Gingrich[57] and Zhang *et al.*[58] found that strobilurin (azoxystrobin) fungicides significantly increased seed yield in perennial ryegrass in a low rust pressure year. On the other hand, Zhang *et al.*[58] and Hunger and Edwards[59] explain that fungicides protect the yield potential by increasing the activity of the plant antioxidants and by slowing chlorophyll and leaf protein degradation, which allows plants to keep their leaves longer and use more nutrients during late developmental stages[60,61].

Pfender[62] found that, propiconazole and azoxystrobin were applied to ryegrass plants infected with *Puccinia graminis*, they reduced urediniospore production by 73 and 95%, respectively.

CONCLUSION

In conclusion, this study allowed us to make an initial finding on the influence of a fungicide (Artea and Amestar Xtra) at different stages of wheat and their impact on the morphology and disease inhibition. Results show that the fungicide applied between the stem elongation and the heading stage significantly increases the yield of wheat grain and reduces the disease severity compared with control plants. It is important to recall that, application of fungicides at the stem elongation (T1), booting (T2) and at the heading stage (T3) resulted in a significant increase in yield, compared to one or two applications by this treatment.

SIGNIFICANCE STATEMENT

Yield losses due to disease of wheat may reach 70% in Algeria. Where susceptible varieties are grown, the control depends primarily on multiple fungicide applications. The fungicide program recommended to growers in Algeria, which consisted of one applications of azoxystrobin and propiconazole at the stem elongation (T1) and booting stage (T2). Various studies have shown that the efficacy of a preventative application of azoxystrobin, cyproconazole and propiconazole at different stage of wheat. However, in Algeria producers rely on a curative approach, waiting until symptoms are visible to initiate fungicide applications. The present study provides evaluation of fungicide application timing for management of wheat in the East-Algeria. The effective control of disease in particular is often very dependent on timing. Where spray days, the use of fungicide programmes that allow considerable flexibility in their application timings is likely to be of benefit.

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