

Full Length Research Paper

Effect of fungicide application times in the control management of leaf foliar diseases in maize

Gustavo Moratelli^{1*}, Kaian Albino Corazza Kaefer¹, Fernando Ertel², Regis Tome Vogt², Silvio Douglas Ferreira¹, Vanessa Aline Egewarth¹, Eloisa Mattei¹, Willian Bosquette Rosa¹ and Jonas Francisco Egewarth¹

¹State University of West Paraná - UNIOESTE, Marechal Cândido Rondon – Paraná – Brazil, street Pernambuco, Number 1777, Zip Code: 85960-000, Box: 91, Center, Brazil.

²Pontifical Catholic University of Paraná - PUCPR, Toledo – Paraná – Brazil, Avenue União, Number 500, Zip Code: 85927-600, Center, Brazil.

Received 8 June, 2015; Accepted 21 August, 2015

This study aimed to evaluate the effect of fungicide trifloxystrobin (200 g/L 20% m/v) + tebuconazole (100 g/L 10% m/v) at different phenological stages in controlling southern rust and *Cercospora* leaf spot in the maize crop and on its productivity. This work was carried out in 2013, Ertel farm, located in the city of Toledo – PR of Brasil. The experimental design was a randomized complete block in a factorial (2x4+1) with four replications. The treatments consisted of evaluating two diseases, Southern Rust and *Cercospora* leaf spot, and four phenological stages of fungicide application (V8, V10, VT and R1 of maize) with the presence of a control. The authors evaluated the disease incidence and severity, the Area Under Disease Progress Curve (AUDPC) and the fungicide control efficiency for foliar diseases were observed. In addition to this, some agronomic variables were also evaluated: plant height, ear insertion height, stem diameter, average diameter of ear, ear length, number of rows per ear, number of grains per row, number of grains per ear, thousand grain weight and productivity. The results showed no significant statistical difference for the variables evaluated, except for plant height. Based on these results, it can be concluded that the mixture of triazole with estrobirulina is feasible to control the severity of these diseases in maize, though it was not observed any statistical difference in the different treatments in relation to the average productivity. It is worth mentioning that the use of fungicide tends to provide greater sanity to plants and consequently it improves production rates. In general, the application of the fungicide in the pre-anthesis stage (VT) tends to exhibit better responses.

Key words: *Zea mays* L., *Puccinia polysora*, *Cercospora zeae-maydis*.

INTRODUCTION

The maize crop has wide geographic reach, developing in various soil and climatic conditions; therefore, being exposed to various biotic and abiotic stresses, making it

difficult to exploit the maximum genetic potential for grain yield, regardless of the adopted production system (Brito et al., 2013). Thus, considering the productive potential of

*Corresponding author. E-mail: Gustavo.Moratelli@gmail.com Tel: +55(45) 32847878. Fax: +55(45) 32847879.

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the crop, the losses of income are linked to the lack of employment of better farming techniques and agricultural technology, also added to the unfavorable weather conditions in some regions and the emergence of diseases that limit the increase in productivity (Trentin, 2007).

Especially from the 90s in Brazil, the increase in the incidence and severity of some foliar fungal diseases was observed, causing sensitive qualitative and quantitative reduction in the production of maize (Pinto, 2004). This increase has been attributed to several factors, such as successive maize crops, monoculture, irrigation without technical criteria and direct seeding system in the absence of crop rotation (Fernandes, 2000). Among the diseases with major potential reduction in the production of maize are the common rust (*Puccinia sorghi*), southern rust (*Puccinia polysora*) and Cercospora leaf spot (*Cercospora zea-maydis*) (Juliatti et al., 2007).

The southern rust is currently one of the most important diseases of maize in Brazil, and it is considered the most destructive of rust occurring in this crop (Oliveira et al., 2004). The symptoms are characterized by the presence of circular and oval shape pustules, light brown color, mainly distributed in the upper face of the sheet (Kimati et al., 2005). The incidence and severity of the disease are favored by conditions of high humidity and relative temperatures between 23 and 28°C (Oliveira et al., 2004). Economic damage of up to 65% has been observed in experimental areas with incidence of disease history (Pereira et al., 2005). In off-season conditions with well distributed rainfall and susceptible hybrid cultivation, losses can be really significant (Machado and Cassetari Neto, 2007).

Another foliar disease of great importance in Brazil is Cercospora leaf spot, both for damages, for its wide distribution, being found in all producing regions (Brito et al., 2008). Symptoms of the disease are characterized by elongated and irregular lesions that usually accompany the direction of the ribs. These spots are gray in color, bronze or brown and may have reddish or purple edges (Brito et al., 2007). The incidence and severity increase in conditions of high relative humidity (90%) and diurnal temperature ranging from moderate to high (22 to 32°C) as well as cold nights, with dew formation (Casella, 2006). This disease was responsible for the discontinuation of the use of various commercial hybrids susceptible, high yield potential, which came to achieve grain yield reduction levels of up to 40% (Souza, 2005).

The use of the triazole group fungicides and their mixtures with strobilurin may be an effective method to control foliar diseases and maintaining crop health, when combined with the right time application, thus enabling increased crop productivity (Casa et al., 2004). The timing of fungicide application will depend on these diseases during the crop cycle and the level of response of hybrids (Silva and Schipanski, 2006).

Bussolaro et al. (2009) evaluating the effectiveness of

fungicides to control diseases at different stages of maize, found that the use of fungicides led to an increase in production compared to the control. Lago and Nunes (2008), report that fungicide in maize did not differ significantly, but had productivity gains around 195 kg ha⁻¹.

The application of these products is often performed in the pre-bolting stage of maize. However, applications in stages just before the pre-anthesis, as in V10, can contribute to inhibit the germination of the initial inoculum of pathogens and ensure that the crop is protected and successful on its production.

Taking into consideration the aforementioned information, this study aimed to evaluate the effect of fungicide trifloxystrobin + tebuconazole in different growth stages on the control of southern rust and Cercospora leaf spot in maize and on its productivity.

MATERIALS AND METHODS

An experiment was carried out in 2013, Ertel farm, located in the city of Toledo - PR, situated in the geographical coordinates 24° 42' 49" S, 53° 44' 35" W and altitude of 574 m. Based on the climatic classification of Köppen, the climate is humid subtropical mesothermal, with hot summers without dry seasons and with few frosts. The average temperatures of the warmest month is above 22°C and the coldest month is less than 18°C (Iapar, 2011). The soil of the farm was classified as Dystroferic Red Latosol, gently rolling and clayey texture terrain (Embrapa, 2012).

The experimental design was a randomized complete block in a factorial (2x4+1) with four replications. Treatments consisted of evaluating two diseases, Southern Rust and Cercospora leaf spot and four phenological stages of application of fungicide (V8, V10, VT and R1 of maize), in the presence of a control.

The size of each plot was 3.5 m wide and 6 meters long, totaling 18.9 m². The plots were composed of seven lines of maize, which is sampled with the five lines in the middle, having a useful area of 9 m².

The treatments were: T1 - control (without any chemical control); T2 - fungicide application at the V8 stage (8 fully developed leaves); T3 - application in the V10 stage (10 fully developed leaves); T4 - VT application (pre-anthesis); T5 - application in the reproductive stage (flowering).

The hybrid AG 9010 YG is considered super-young, having modern plant architecture, with erect leaves and resistance to breakage. Therefore allows the dense planting, in other words, the reduced spacing between lines, exploring the environmental and agronomic interactions, which also enables increased plant population. In the off-season crop, the AG 9010 YG flourish before possible droughts or frosts, ensuring the best results (Agrocere, 2013).

During the work it was necessary to perform some cultural practices such as drying of the previous crop, soil analysis, maize sowing, base fertilization and coverage, weed control and application of fungicide. To facilitate the sowing and early development of maize, desiccation was performed with glyphosate (potassium salt of N- (phosphonomethyl)) glycine at the recommended dosage, immediately after soybean harvest. Before the deployment, chemical analyses of soil were carried out, to subsequently fix it with 250 kg ha⁻¹ NPK 08-20-20 formulation. The seeds were treated with Imidacloprid + Thiodicarb in the recommended dosage by the manufacturer Cropstar and sown on 05 February 013. For the topdressing was applied ammonium

Table 1. Grade scale used for the evaluation of the severity of Polissora rust and Cercosporiose of maize (Toledo – PR, 2015).

Scale	Infection level
1	No symptoms
2	0,5% the injured leaf area
3	10% the injured leaf area
4	30% the injured leaf area
5	50% the injured leaf area
6	70% the injured leaf area
7	80% the injured leaf area
8	90% the injured leaf area
9	100% the injured leaf area

Source: Agrocere (1996).

sulfate at a dose of 75 kg ha⁻¹ in the V4 stage. The pest control was not necessary due to the hybrid resistance and also for not achieving levels of economic damage. The weeds were chemically controlled with post-emergent herbicides, such as Atrazine (5.0 L ha⁻¹) and Nicosulfuron (50 g ha⁻¹) in the V4 stage of the crop. For the experiment, the application of the fungicide trifloxystrobin + tebuconazole (60 + 120 g ai ha⁻¹) + vegetable oil was conducted, (250 mL 100 L water⁻¹) using a backpack sprayer of twenty liters with approximately 124 L ha⁻¹ of flow and nozzle array for better coverage of the area applied.

The evaluation of the disease was performed at 15 days after each application in different phenological stages and follow fortnightly until the last application. For this, 15 plants were chosen at random from the useful area, which were demarcated, and evaluated for incidence and severity of Southern Rust and Cercospora leaf spot in the crop as its appearance. Thus, there were four evaluations in the experiment.

For the disease incidence, we counted the number of plants or parts of plants with symptoms of the disease in the randomly selected plants per plot. On the other hand, the severity evaluation was carried out using a score scale adapted from Azevedo (1997) described in Table 1.

The severity values obtained for each treatment were processed in proportion of disease to be plotted versus time and expressed in disease progress curve, in order to represent the outbreak in each study. With the severity data in each assessment, the author calculated for each plot, the values of Area Under Disease Progress Curve (AUDPC), using the equation quoted by Shaner and Finney (1977):

$$\text{AUDPC} = \sum_{i=1}^n (Y_{i+1} + Y_i)/2 * [(T_{i+1} - T_i)]$$

Where: n- is the number of observations; Y_i - is the disease severity in the "i"-th observation and T_i - is the time in days in the "i"-th observation.

For the average severity, notes of each treatment (each assessment) were used and the averages between these values were carried out. The efficiency of control was obtained based on the average grade of severity of each treatment, stipulated by percentage calculations (%) of efficiency obtained.

To determine the effect of fungicide in the maize, it was necessary to evaluate the agronomic variables such as plant height, height of ear insertion, stem diameter, average ear diameter, ear length, number of grain rows, number of grains per row, number of grains per ear, thousand grain weight and productivity.

The data were submitted to analysis of variance and the treatment means when significant were compared by Tukey test at 5% significance, using the SASM-AGRI software (Canteri, et al., 2001).

RESULTS AND DISCUSSION

Incidence, severity, AUDPC and control efficiency of Southern Rust

Regarding the incidence of southern rust, it is observed that there was no significant difference between the different treatments evaluated ($p > 0.05$); however, it should be noted that the highest percentages of infected plants of the disease are observed in VT treatment (Table 2). As for the severity score, significance is noted between treatments ($p < 0.05$) and the control treatment having the largest average, demonstrating that the southern rust is one of the diseases that most attack the off-season maize crop (Table 2). Therefore, it is interesting to carry out a chemical control to minimize losses in productivity due to high infestations.

Such data can be explained by the fact that, at the time of trial deployment, the weather conditions were adequate for the disease occurrence (Figure 1). The disease was favored by high humidity conditions and relative temperatures in the range of 23 to 28°C, and in areas of altitude between 600 and 800 m, having no limitation for its development.

However, when considering the AUDPC, treatments with chemical control showed lower values when compared to the control, demonstrating the difference in control efficiency (Table 2). This response can be explained by the fact that the product applied at recommended doses has healing and anti-sporulation properties in trifloxystrobin (Estróbirulina) and tebuconazole (Triazole). Although the disease has emerged in the area of the experiment, the control efficiency was even higher in the treated plots compared

Table 2. Average values of percentage of plants of the experimental area to attack the disease (incidence), medium severity, area under the disease progress curve (AUDPC) for Polissora rust of maize and percentage of control efficiency (Toledo – PR, 2015).

Treatment	Incidence	Severity	AUDPC	Control efficiency (%)
Control	80.8 ^a	1.98 ^b	36.4	66.5
V8	49.6 ^a	0.51 ^a	18.3	93.4
V10	72.5 ^a	0.75 ^a	20.4	87.7
VT	90.4 ^a	0.96 ^{ab}	24.88	84.5
R1	79.5 ^a	1.01 ^{ab}	28.1	82.2
Average	74.6 ^{ns}	1.04	21.61	84.5
CV (%)	37.54	52.72		
F	1.20	4.05 ^{**}		

Averages followed by the same letter in the column, do not differ significantly at 5% in the Tukey test. ^{ns}: non-significant; *: significant at 5%.

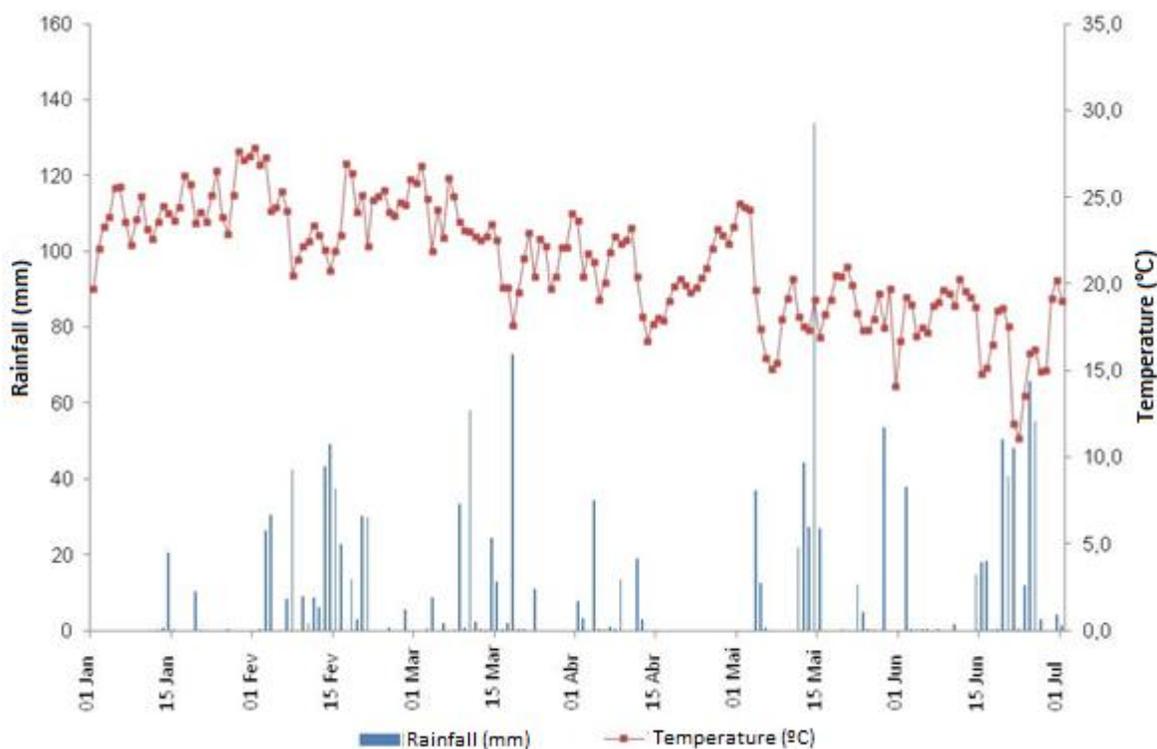


Figure 1. Weather conditions (Rainfall and Temperature) of the experimental period in 2013. Toledo – PR, 2015. Source: Weather Station from PUCPR – Campus Toledo.

to the control.

The data are in agreement with those obtained by Duarte et al. (2009), who studied the efficacy of different fungicides on maize crop in two application times (49 and 79 days after sowing). The authors found that the fungicide epoxiconazole + pyraclostrobin was effective in controlling diseases in maize, with 60% of efficiency compared to the control.

The association of estrobirulina and triazoles reduced the number of pustules or the level of severity of this in relation to the control. The same result was observed by Galli et al. (1993), wherein the application of tebuconazole (triazole), unassociated with strobilurin in doses of 0.75 kg ha⁻¹ of active principle and 1.0 kg ha⁻¹ of active principle, reduced significantly the number of pustules of *Puccinia polysora* in the leaves.

The efficiency of fungicides when compared with the control may be assigned the fungicidal action against the pathogen, along with the residual effect of it (Duarte et al., 2009), which may have contributed to the observed results.

Among the treatments with fungicides, the one with the highest highlight was the treatment at the V8 stage with values of 49.6; 0.51; 18.3 and 93.4 for the incidence, severity, AUDPC and control efficiency, respectively (Table 2). Picinini and Fernandes (2003) when performing treatments with fungicides had satisfactory results, having efficient control of powdery mildew and rust in relation to the control, in the wheat crop.

Duarte et al. (2009) point out that, currently, the use of fungicides in a mixture as triazoles and strobilurins or benzimidazole in agricultural production systems, is of great importance in the production of maize.

The treatments V8 and V10 obtained the greatest efficiencies in the control of *P. polissora*, reaching 93.4 and 87.7% of control, respectively (Table 2). Such highlighting cannot be observed in the other treatments, considering that clarity as the product was applied, the disease was already installed in the area.

This fact can be explained by Fancelli (1999), which states that for maize manifest its high biomass production capacity, it is necessary that the plant have adequate interception structure of available radiation, which can only be obtained when evidenced by at least 85 to 90% of its maximum leaf area.

Brandao (2002) and Appelt (2003) works showed that the effective period of the fungicide for triazoles and strobilurine is 30 days, not having the product effect on the disease after this period. The ideal to have more control in the critical period of the crop would be an application in the VT stage, as well as in the present experiment that showed better productivity results.

Incidence, severity, AUDPC and Cercospora leaf spot control efficiency

In the incidence of *Cercospora* leaf spot assessment, it is observed that there were significant differences between the different treatments evaluated ($p < 0.05$). It is worth noting that the highest percentages of infected plants, in other words, those with highest grades of the disease are observed in the control treatments and R1, with averages of 48.5 and 39.75, respectively (Table 3).

Cercospora leaf spot severity also showed significant differences between the different treatments evaluated ($p < 0.05$) (Table 3). For this parameter, the control treatment showed the highest rate of the disease (0.99); however, it was similar to R1 (0.88) treatment. This demonstrates that, *Cercospora* leaf spot is a major disease of maize crop in several countries, highlighting the importance of chemical control to minimize losses in productivity due to high infestations.

These results obtained in this study can be explained in the same way as for the southern rust disease, bearing in mind that at the time of the work deployment, the weather conditions were favorable for the development of the disease (Figure 1). These weather conditions had temperatures between 23 to 28°C, long periods of high relative humidity and altitude regions between 600 and 800 m, having no limitation for its development.

By observing AUDPC in the different treatments, it can be verified that the treatments in which it was carried out the application of fungicides, the values were lower compared to the control; thus demonstrating the efficiency of chemical control (Table 3). These results can be explained by the healing and anti-sporulative properties of the product when applied at recommended doses of the active ingredients trifloxystrobin (Estrobirulina) and tebuconazole (Triazole).

Thereby, the association of estrobirulina and triazoles was effective in controlling the disease or reducing the level of severity of this in relation to the control. The same result was observed by Horst and contributors (2003), who report that the fungicides azoxystrobin, propiconazole, flutriafol, trifloxystrobin + propiconazole, tebuconazole and pyraclostrobin + epoxiconazole reduced significantly the severity of cercospora leaf spot.

Table 3 presents treatments with V8, V10 and VT achieved the greatest efficiencies for *Cercospora* leaf spot control, all of them reaching 98% of control. These responses were not observed in the other treatments (control and R1), bearing in mind that as far as the product was applied, the disease was already installed in the area.

Ammermann et al. (2000) report that infections caused by fungi impair crops efficiency, by reducing the tissue area to inhibit photosynthetic activity and translocation of assimilates, presenting a strong impact on the physiological processes of the plant and this fact was observed in this study.

Supporting this study, Koguishi (2011) when evaluating *Cercospora* leaf spot control at different growth stages, noted that, as in the present work, the application for R2 could not handle *Cercospora* leaf spot, getting similar severity to the control. This response was due to the late application, period in which the disease was already with high severity, with no significant effect of fungicide on the disease.

The results agree with those obtained by Barros and Lourenção (2009), which studied different fungicides and application times in the off-season maize in Mato Grosso do Sul and found that *Cercospora* leaf spot control with spraying in pre-bolting (stage VT) was more effective, independently of the fungicide used.

Maize production components

According to the obtained results, it is observed that there

Table 3. Average values of percentage of plants of the experimental area to attack the disease (incidence), medium severity, area under the disease progress curve (AUDPC) for Cercosporiose of maize and percentage of control efficiency (Toledo – PR, 2015).

Treatment	Incidence	Severity	AUDPC	Control efficiency (%)
Control	48.5 ^c	0.99 ^b	33.86	83
V8	5.28 ^a	0.08 ^a	3.60	98
V10	7.5b ^a	0.14 ^a	4.25	98
VT	10 ^{ba}	0.18 ^a	2.12	98
R1	39.75 ^b	0.88 ^{ab}	30.82	84
Average	22.2	0.454	14.93	92
CV (%)	69.6	85.9	-	-
F	6.92	5.11 ^{**}	-	-

Averages followed by the same letter in the column, do not differ significantly at 5% in the Tukey test. ^{ns}: non-significant; *: significant at 5%.

Table 4. Summary of the variance analysis for the production components: ear insertion height (IEA), stem diameter (DC), ear length (EL), number of rows per ear (NRE), number of grains per row (NGR) in the hybrid AG 9010 plants due to the chemical control application at different growth stages in maize (Toledo – PR, 2015).

Treatment	IEA (cm)	DC (mm)	EL (cm)	NRE	NGR
Control	80.30 ^a	23.39 ^a	17.95 ^a	14.5 ^a	36.2 ^a
V8	81.22 ^a	23.93 ^a	18.58 ^a	15.1 ^a	35.9 ^a
V10	82.14 ^a	22.00 ^a	18.66 ^a	14.7 ^a	37.0 ^a
VT	83.27 ^a	24.36 ^a	19.29 ^a	14.4 ^a	37.5 ^a
R1	78.08 ^a	23.41 ^a	18.48 ^a	14.6 ^a	35.6 ^a
Average	81	23.58	18.59	14.68	36.50
CV (%)	4.12	3.82	3.63	2.5	3.6
F	1.39 ^{ns}	1.74 ^{ns}	1.99 ^{ns}	2.04 ^{ns}	1.32 ^{ns}

Averages followed by the same letter in the column, do not differ significantly at 5% in the Tukey test. ^{ns}: non-significant; *: significant at 5%.

was no significance ($p < 0.05$) for the production components: ear insertion height (EIH), stem diameter (SD), ear length (EL) number of rows per ear (NRE), and number of grains per row (NGR) (Table 4).

For EIH, it can be noted that when the application was given in the early stages of the crop, better answers were obtained; however, having no significant difference between the different treatments ($p > 0.05$) (Table 4). This result can be explained by Ritchie et al. (2003), which reported that the application does not influence this variable, since the morphological characters tested are initially set in the crop cycle.

The values obtained in this experiment are considered low when compared to the ones in the literature. An example is the work of Vilela et al. (2012), which present values around 1.30 m, when various hybrids were studied together.

The factors that may explain the low ears insertion are the population distribution, the characteristic of the hybrid (it has lower size and is super-young) and even the

planting season, because in off-season conditions, maize cannot find its ideal conditions for development as temperature, solar radiation and relative humidity.

Sangoi et al. (2001) report that the shortest distance between the ground and the ear insertion point is desirable, because it contributes to better balance of the plant while minimizing disruption of thatch, especially at higher populations.

When it comes to stem diameter SD (Table 4), there is positive behavior for the treatment means in V8 and VT (23.93 and 24.36 mm), but not differing from the other treatments ($p > 0.05$). The results can already be explained by the fact that the definition of the stem diameter occurs in the early stages of crop, as reported by Fancelli and Dourado Neto (2000). The authors state that this variable is also related with the support of the plant, acting as a soluble solids storage structure that will later be used in the formation of the grains.

Brachtvogel (2008) also states that the stem diameter is defined in the early stages of crop, having as one of

Table 5. Summary of the variance analysis for the production components: height of plant (HP) number of grains per ear (NGE) middle ear diameter (MED), thousand grain weight (TGW) and productivity (P) in the hybrid AG 9010 plants due to the chemical control application at different growth stages in maize (Toledo – PR, 2015).

Treatment	HP (cm)	NGE	MED (mm)	TGW (g)	P (kg ha ⁻¹)
Control	2.13 ^{ab}	527.2 ^a	45.93 ^a	350.91 ^a	7.399.01 ^a
V8	2.17 ^a	543.4 ^a	47.38 ^a	390.87 ^a	7.446.43 ^a
V10	2.13 ^{ab}	544.7 ^a	46.75 ^a	352.51 ^a	7.936.37 ^a
VT	2.10 ^{ab}	540.0 ^a	47.06 ^a	383.83 ^a	8.208.81 ^a
R1	2.06 ^b	522.3 ^a	46.64 ^a	355.64 ^a	8.030.08 ^a
Average	2.12	535.53	46.75	366.75	7.804.14
CV (%)	1.94	4.53	2.37	7.24	6.23
F	3.60 ^{**}	0.70 ^{ns}	0.96 ^{ns}	2.06 ^{ns}	2.22 ^{ns}

Averages followed by the same letter in the column, do not differ significantly at 5% in the Tukey test. ^{ns}: non-significant; *: significant at 5%.

the preponderant factors the population increase. Thereby, if the goal is to increase the stem diameter, then it would be necessary an application at the early stages of crop, favoring this variable.

For the EL's behavior, it is observed that there was no significant difference between treatments ($p > 0.05$), but it can be seen that the application of chemical control promotes a greater length compared to the control, which presented the lowest value for this observation (Table 4). Corroborating the results of the work, Ramos et al. (2012) found in their experiment with fungicide application in maize, that there was no difference between treatments for this variable.

Magalhães et al. (1994) report that the ear size is defined in the V12 stage, this can be one of the explanations for which the treatments were not significantly different, since the applications after this stage would have more influence on this variable. As for the NRE, it is observed that the application is not influenced in great number in this variable (Table 4), since the higher average was obtained for V8 treatment, but did not differ from other groups ($p > 0.05$).

Similar results were found by Vilela et al. (2012) when studying the agronomic performance of maize hybrids according to foliar application of fungicides, they have reported no statistical difference for this variable. Fancelli and Dourado Neto (2004) report that the number of grain rows on the ear is defined in the vegetative phase, which in some cases may warrant early application of fungicides. This fact can be justified with productivity increase by the increase in number of rows have been higher in V8 and V10 stages.

In Table 4, the NGR tends to be higher in V10 and VT stages; however there was no significant difference between treatments ($p > 0.05$). Nevertheless, you can notice that the fungicide application favored the best average when compared to the control. Similar results were observed by Vilela et al. (2012) when studying the application of fungicide (pyraclostrobin + epoxiconazole and azoxystrobin + cyproconazole) belonging to the

chemical group of triazoles and strobilurins in maize crop in the pre-bolting stage.

Balbinot et al. (2005) observed different results from the ones presented in this paper. These authors report that one of the most important yield components for maize is the number of grains per row. The authors point out that, besides the fungicide prevent and control diseases, it would also be related to the increase of grains per row, and consequently would influence on productivity. Magalhães et al. (1994) report that the number of grains per row on the maize crop is established around the V17 stage (predecessor R1 stage). Thus, the authors report that the treatments later applied to that stage, do not influence this variable, explaining the results presented. One of the fungicide application forms to influence positively this variable would be an earlier application, but it cannot be positioned after bolting.

According to the results, it is observed that there was significance ($p < 0.05$) only for plant height (PH) according to the fungicide application at different growth stages on off-season maize. For other production components, number of grains per ear (NGE), the average diameter of the ear (ADE), the thousand grains weight (TGW) and productivity no significant differences were observed ($p > 0.05$) (Table 5).

In the PH variable, it can be observed an average downward trend in relation to the advancement of application times, reaching its highest value in V8 and its lowest in R1, 2.17 and 2.06 cm, respectively (Table 5). Different results were found by Ceccon et al. (2007), in which plant height had no significant effect with the application of fungicides in the off-season maize crop. This may have occurred due to the different times of applications. In the treatments that the application proceeded in the early stages, there was a further growth due to maintenance for longer periods of active leaf area; thus allowing further growth of plants. Moreover, when applied later, this behavior was not observed due to pathogen attack in plants, resulting in reduction in size, or

population increased. Furthermore, because of difficulties encountered during the period of the off-season, the maize did not have the ideal conditions for its best development.

Campos et al. (2010) state that the best results in relation to plant height depend on the environmental conditions of the experiment site and may be influenced by temperature, humidity and solar radiation, favoring greater plant growth. This factor can be observed in this experiment. Currently, the smallest height of the plant is one of the changes involved in the architecture of maize plants (Almeida et al., 2000). This is a desirable feature of maize producers because it allows the crop in higher density and higher mechanical harvesting efficiency, while it reduces problems relating to breakage and bedding plants before the harvest point, usually evidenced high-growing plants (Mundstock, 1977).

According to Sangoi et al. (2000) and Sangoi (2001), in general, the plant height is greater, the larger is the population of plants, due to the effect of intra-specific competition for light, with consequent stimulation of apical dominance of the plants. In addition to this, Kappes (2010) reports that the smallest plant height has allowed greater light penetration in the canopy (even with high leaf area index) and decreased intraspecific competition for natural resources in high plant populations.

The data obtained for NGE (Table 5) indicate that there was no significant difference for this variable ($p > 0.05$). Agreeing with the results presented, Ramos (2012) reported that in the fungicide application in hybrid 30F53 there was no difference between treatments for the variable number of grains per ear. Magalhães et al. (1994) reported that the number of grains per ear is defined in the V12 stage as part of the treatments used in the experiment were quoted after the aforementioned stage, a fact that eventually contributed to that there was no difference between the treatments.

For the variable Ear Diameter, data were not statistically different ($p > 0.05$), but it is possible to see that the applications of chemical control in different stages favored a rapid increase of this variable in relation to the control (Table 5). Different results were reported by Kappes et al. (2009), which studied the off-season maize crop, verified that there was a difference between the fungicide application timing in this culture, along with the application of nitrogen sources and doses. The authors report that this is one of the characters that are defined in the early stages of the crop, a fact that contributed to no difference between treatments in this experiment.

On Table 5, for TGW variable has no statistical difference between the different treatments that ($p > 0.05$) was found. The values of this variable were superior when there was application of chemical control in V8 and VT stages in relation to the control, in other words, the fungicide application timing in this work did not interfere positively in this variable. Vilela et al. (2012) when studying the fungicide application in maize crop, also

found no significant positive responses for this variable compared with the control.

Disagreeing with Swartz and Marchioro (2009), which in an experiment conducted in the city of Cascavel-PR in disease control with fungicide used in off-season maize, concluded that the application of fungicides increased significantly the yield and thousand grain weight. The application of fungicide in VT stadium considering the PROD (Table 5) differed about 869 kg ha^{-1} (higher productivity between treatments) compared to the control, but not significantly between treatments ($p > 0.05$).

Corroborating the results, Lago and Nunes (2008) report that fungicide application in the maize crop did not differ significantly, but had productivity gains around 195 kg ha^{-1} . As Bussolaro et al. (2009), evaluating the effectiveness of fungicides to control diseases at different stages of maize, found that the use of fungicides led to an increase in production compared to control. Jardine and Laca-Buendía (2009), as in this study, report that when testing various active ingredients of fungicides, including Tebuconazole and Epoxiconazole + Pyraclostrobin did not find statistically significant differences in grain yield compared to the control.

Lourenção and Barros (2008) also observed greater response tendency to fungicide application in the pre-bolting stage with a gain of 4.0 bags ha^{-1} , although there was no significant difference compared to the control. According to BASF (2011), this increased productivity provided by the fungicide use in the stages of maize development, can be attributed to the physiological effect of the product, which provides increased net photosynthesis and the activity of the enzyme nitrate-reductase, combined with the decrease in ethylene production.

Duarte et al. (2009) point out that nowadays the use of fungicides in a mixture as triazoles and strobilurins and or benzimidazole in agricultural production systems is of great importance in the maize production. Thus, the foliar diseases present in this work had significant negative correlation with productivity, in other words, with increasing severity that they occur the grain yield is reduced, which was verified by Pires et al. (2011) with a work with off-season maize in Montividiu, Goiás.

Conclusion

It can be concluded that the mixture of triazole with estrobirulina is feasible for the management of the severity of these diseases in maize, though not statistical difference was observed in the treatments compared to the average productivity.

It is worth mentioning that the use of fungicide tends to provide greater sanity to plants and consequently it improves production rates. In general, the application of the fungicide in the pre-anthesis stage (VT) tends to show better responses.

Conflict of Interest

The authors have not declared any conflict of interest.

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