Suitable weather condition frequency for fungicide soybean application in Tangará da Serra, Mato Grosso, Brazil[1]

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ABSTRACT

The aim of this study was to model the decendial and hourly variability of meteorological variables, namely air temperature, relative air humidity and wind speed, in the Tangará da Serra region, Mato Grosso, Brazil, to determine the best schedules for fungicide applications to soybean crops. Hourly weather data between 2004 and 2017 from the Tangará da Serra municipality's automatic station were made available by Brazil's National Meterological Institute (*Instituto Nacional de Meteorologia*, INMET). Decendial variability (ten days 01 to 36) and hourly variability were analyzed for ten days that concentrated fungicide soybean crop applications, namely ten days 34, 35, 36 and 01. The following parameters were adopted as suitable fungicide application climate: wind speed $\geq 0.83 \leq 2.77$ m s^{-1}, relative air humidity $\geq$ 50% and air temperature $\leq$ 30 °C. Relative humidity was not a limiting factor for application on ten days 34, 35, 36 and 01. Due to hourly maximum temperatures, suitable application conditions are less than 10% at 1:00 PM. The most frequent suitable weather conditions schedules are concentrated between 5:00 AM and 7:00 AM, and at night, from 7:00 PM.

Keywords: variability; pulverization; climate.

INTRODUCTION

The Brazilian state of Mato Grosso exhibits pronounced geoenvironmental diversity (climate, soil, relief), due to its geographical position. This environmental heterogeneity has influenced land occupation processes and different land use arrangements which have, in turn altered environmental responses to climate variations (Souza *et al*., 2013).

Agricultural activities are the main economic sources in this state, and are highly dependent on climatic factors. Thus, understanding climatic factor variability through time series assessments enables the implementation of research concerning agroclimatic crop adaptability, yield and zoning (Moreira *et al*., 2015).

Crop application technology continues to be the bottleneck for better efficiency and economic revenue, overcoming specific problems such as effective phytosanitary product deposition on desired crop targets (Azevedo, 2007). Certain environmental variables play an important role in phytosanitary product application success and may either aid or hinder product deposition on their targets, subsequently affecting plant absorption and translocation (Azevedo, 2007).

In this sense, air temperature, relative humidity and wind speed comprise climate elements that may impair fungicide application and should be considered in phytosanitary product application (Azevedo, 2007). Their interactions influence both phytosanitary product deposition and drift potential during spraying (Fritz & Hoffmann, 2008).

In this context, the aim of the present study was to analyze the monthly behavior of meteorological variables

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obtained from 2004 to 2017 and determine suitable fungicide application times for soybean crops from hourly air temperature, relative air humidity and wind speed analyses, using climatic data time series from the Tangará da Serra region, Mato Grosso, Brazil. These analyses will provide subsidies for agricultural planning and decision-making, aiding in the determination of the most appropriate times for crop fungicide application.

MATERIAL AND METHODS

This study evaluated data from an automatic surface observation weather station at Tangará da Serra, Mato Grosso, Brazil (latitude 14º 39' 0" S, longitude 57º 25' 53" O). The área exhibits an type “Aw”climate (tropical savanna climate) by the Köppen classification, with a rainy season in summer (from November to April) and a dry season in winter (from May to October), with average temperature in the coldest month above 18° C and precipitation of the driest month of less than 60 mm (Alvares *et al*., 2013).

The weather station is equipped with sensors connected to a measuring datalogger central memory unit, recording hourly measurements of the following variables: global solar radiation at 2 m in height, wind speed and wind direction at 10 meters in height, psychrometer with a thermometer shelter set 2 m high and rainfall determined at 1.50 m n height. The time partition database was made available by the INMET automatic stations network.

Table 1: Reference values of suitable fungicide spraying weather conditions

Wind speed	**Relative air humidity**	**Air temperature**
$\geq 0.83 \leq 2.77$ m s^{-1}	$\geq 50\%$	≤ 30 ºC

Search: ANDEF, 2004. Elaborated by the author

The criteria used for the climate variables analysis was established based on the parameters described by Brazil’s National Plant Defense Association (*Associação Nacional de Defesa Vegetal*) (ANDEF, 2004) (Table 1) which have been used in several prior assessments (Cunha *et al*., 2008; Cunha *et al*., 2011; Reis *et al*., 2010; Aguiar Junior *et al*., 2011).

For the decendial variability analysis, the hourly data for average air temperature, average relative air humidity and average wind speed for all months of the year obtained from January 2004 to December 2017 were used. The organization of the hourly variables was performed using the R statistical software, through the tidyverse (Wickham, 2017), readxl, and lubridate (R Core Team, 2018) packages. The consistency of the hourly database was analyzed using spreadsheets, and periods in which sensors did not record information were excluded. Subsequently, the data were distributed into ten days of each year, hours in each of the ten days and the daily average values of each times (Santos *et al*., 2013). The meteorological variables were submitted to descriptive statistical analysis. The data percentages used in the decendial and hourly analyses are presented in Table 2.

Soybean cycles in the state of Mato Grosso range from October to April (CONAB, 2018), and fungicide applications are concentrated in the sequential ten

Table 2: Meteorological data percentages used in the decendial and hourly wind speed, air temperature and relative air humidity analyses, obtained from the applied INMET time partition from 2004 to 2017

Variable	**Period**	**Tem days**	**Percentage (%)**	
			Minimum	**Maximum**
Average wind speed	Decendial	01 to 36	58.39	86.04
Average wind speed	Hourly	1	59.29	71.43
		34	70.71	82.86
		35	66.43	76.43
		36	61.69	68.83
Average air temperature	Decendial	01 to 36	68.63	97.89
Average air temperature, maximum and minimum	Hourly	1	70.71	80.00
		34	83.57	91.43
		35	75.00	86.43
		36	70.13	79.22
Average air humidity	Decendial	01 to 36	68.63	97.89
Average air humidity and minimum	Hourly	1	70.71	80.00
		34	83.57	91.43
		35	75.00	86.43
		36	70.13	79.22

days 34, 35, 36 (December) and 1 (January). Therefore, air temperature (maximum and average), humidity relative air (minimum and average) and wind speed (average) hourly variability analyses were performed for this period.

The percentage frequency distribution was obtained by dividing the absolute frequency by the total number of observations of each climatic condition for the determination of frequency occurrence percentages for suitable and unsuitable weather conditions, (Equation 1).

$$F = \frac{Fa}{N} \times 100 \qquad \text{Equation 1}$$

where: F = relative frequency (%); Fa = absolute frequency, corresponding to the number of observations for a given variable and the variation class; N = total number of observations. To identify favorable weather conditions times for fungicide application, a 10-hourly calendar was prepared from the frequency data for each of the analyzed ten days.

RESULTS AND DISCUSSION

Meteorological analysis from 2004 to 2017 for Tangará da Serra, Mato Grosso, Brazil

The municipality of Tangará da Serra exhibits rainfall variability, with high rainfall from October to April, comprising 92.06% of total rainfall volume, and a dry period from June to August, with precipitation volume of around 2.90% (Table 3). Monthly rainfall ranged from 280.18 to 113.92 mm during the rainy season, and below 22.05 mm during the dry period, corroborating previous assessments by Martins *et al*. (2010) and Dallacort *et al*. (2011).

Temperatures displayed an annual variation due to the alternation of a wet and dry season, with higher temperatures in late winter and early spring, particularly in September, before water behavior changes in the state (Marcuzzo *et al*., 2012). The Intertropical Convergence Zone (*Zona de Convergência Intertropical*, ZCIT), characterized by intense convective activity, determines the rainy season in the region (Reboita *et al*., 2010).

Table 3: Monthly descriptive statistics for the assessed climate variables air temperature, relative air humidity, wind speed (WS) and precipitation (Prec.), from 2004 to 2017, at Tangará da Serra, Mato Grosso, Brazil

Month	Prec. (mm)	Air temperature (ºC)			Relative air humidity (%)			WS ms^{-1}
	Total	Max	Med	Min	Max	Med	Min	Med
January	278.59	25.27	24.66	24.09	85.73	82.91	79.87	2.34
February	280.18	24.93	24.35	23.8	86.98	84.32	81.43	2.25
March	222.76	25.34	24.72	24.15	86.19	83.43	80.43	2.02
April	113.92	25.17	24.54	23.95	83.53	80.77	77.81	2.15
May	44.44	23.75	23.11	22.5	79.62	76.99	74.25	2.36
June	13.65	24.00	23.26	22.54	71.94	69.00	66.04	2.31
July	11.24	24.15	23.3	22.47	60.87	57.81	54.83	2.48
August	22.05	26.54	25.61	24.71	49.94	47.03	44.17	2.72
September	36.86	27.34	26.5	25.69	57.64	54.51	51.4	2.63
October	136.76	26.69	25.95	25.25	73.65	70.37	66.97	2.51
November	183.69	26.04	25.38	24.77	80.43	77.35	74.11	2.47
December	273.03	25.31	24.68	24.1	85.06	82.22	79.14	2.36

Max: Maximum average. Med: Average. Min: Minimum average.

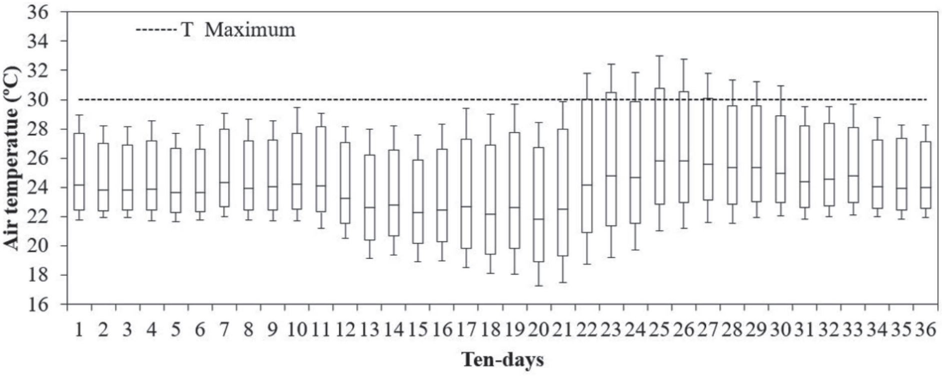

Figure 1: Variability of the mean decendial air temperature at Tangará da Serra, MT, Brazil, from 2004 to 2017. The dotted line represents the maximum limit recommended by the ANDEF (2004).

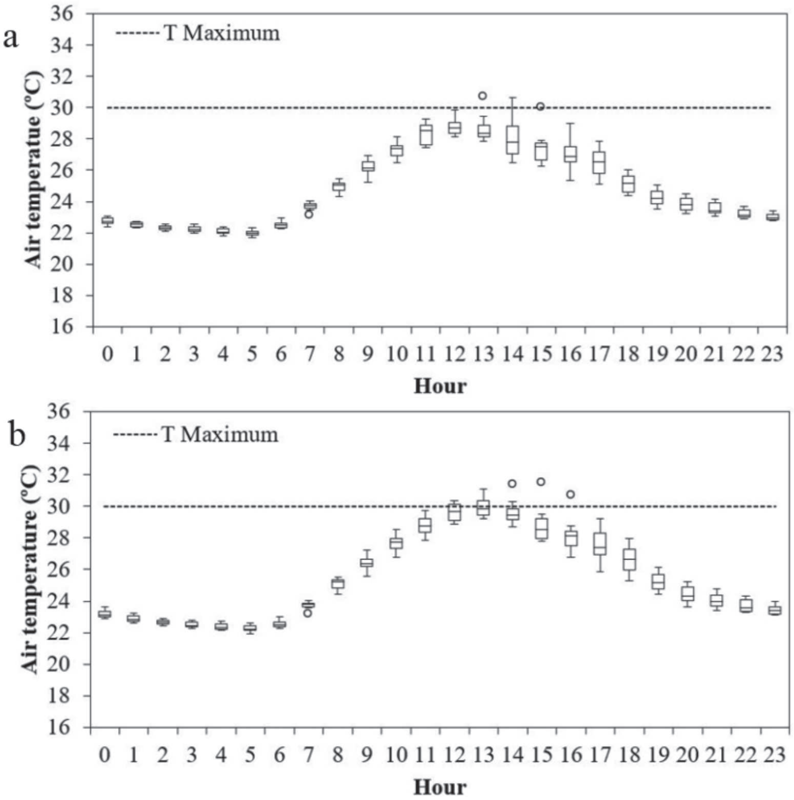

Figure 2: Average (a) and maximum (b) hourly air temperatures on December ten day 34 at Tangará da Serra, Mato Grosso, Brazil, from 2004 to 2017. The dotted line represents the upper limit recommended by the ANDEF (2004).

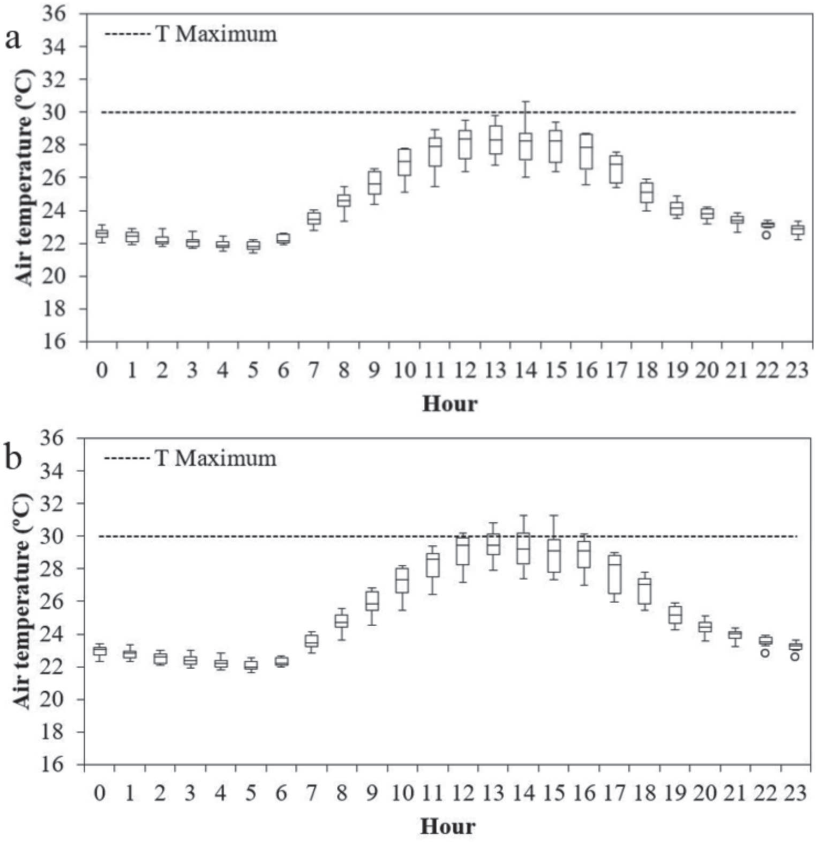

Figure 3: Average (a) and maximum (b) hourly air temperatures on ten day 35 at Tangará da Serra, Mato Grosso, Brazil, from 2004 to 2017. The dotted line represents the upper limit recommended by the ANDEF (2004).

The relative humidity average (ratio between the absolute humidity and the saturation point) (Queiroz & Costa, 2012) at Tangará da Serra during the year ranges from 47.0 to 84.0%. As it is proportionally inverse to temperature, it is a factor that delimits the occurrence of greater intensity rainfall (Menezes *et al*., 2015).

Air temperature

The highest thermal amplitudes recorded at Tangará da Serra (Figure 1) were observed in July and August, in ten days 23, 22, 21 and 24, respectively, when the average temperatures ranged from 14.9 ºC, with a maximum of 32.4 ºC on December 23, and a minimum of 17.4 ºC, on December 21.

The dry months between June and August are characterized by concentrating, on average, less than 3.0% of the annual rainfall volume (Martins *et al*., 2010). Due to low precipitation volumes and lower water vapor concentrations in atmosphere, heat exchanges with the atmosphere decrease, resulting in higher thermal amplitudes, a phenomenon often observed in regions where climate is influenced by continentality (Rocha *et al*., 2018).

The lowest thermal amplitude was observed in the ten days 5, at a minimum of 21.6 ºC and a maximum of 27.6 ºC. The ten days 01 to 09 and 34 to 36 exhibited similar behavior, indicating that the decendial thermal amplitude is lower during months that concentrate the highest precipitation volumes.

Temperatures above 30.0 ºC, unsuitable for fungicide application, occurred in the late winter and early spring, on ten days 22 to 30. An average increase of 3.3 ºC in the minimum temperature was noted, with a maximum temperature of 32.9 ºC observed in September (ten days 25), considered a transition month (Martins *et al*., 2010; Marcuzzo *et al*., 2012). The average hourly temperature analysis on ten day 34 indicated unsuitable conditions for application at 2 PM, with variations ranging from 26.5° C to 30.6° C, and atypical temperatures at 1 PM and 3 PM (Figure 2a). Maximum temperatures exceeded the ideal limit between 12 and 2 PM hours, with typical records exceeding 30.0° C between 2 and 4 PM (Figure 2b).

For average temperatures on ten day 35 (Figure 3a), the highest amplitude was recorded at 2 PM, the only time of day when the temperature exceeded 30.0° C. Concerning the maximum temperature data series, records of temperatures over 30.0° C are noted between 12 and 4 PM, especially at 1 and 2 PM hours, when higher frequencies of unsuitale improper fungicide application temperatures are observed (Figure 3b).

The average air temperature series on ten day 36 was always lower than 30.0° C throughout the day (Figure 4a).

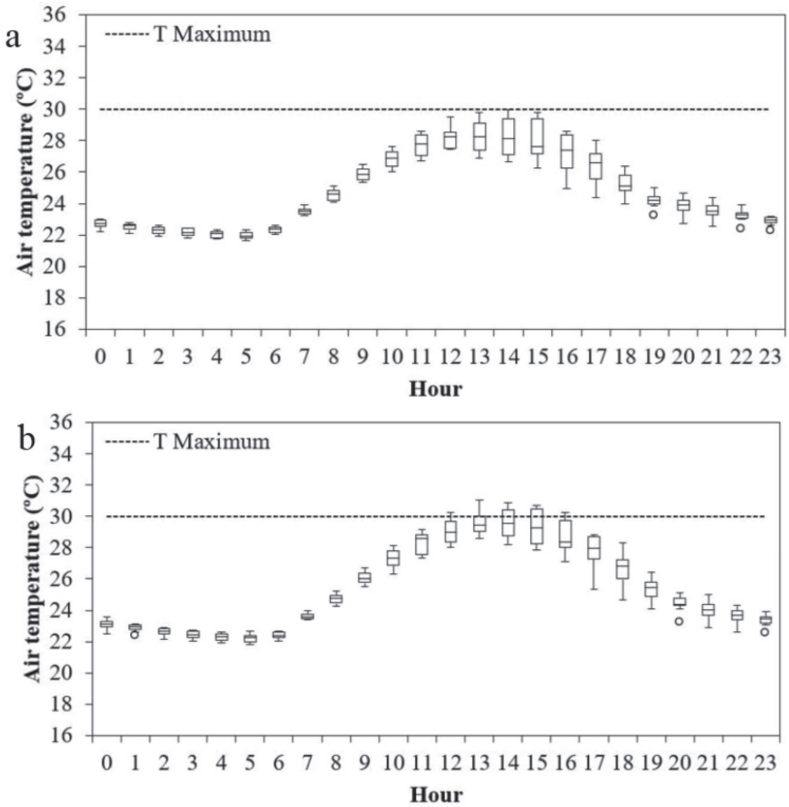

Figure 4: Average (a) and maximum (b) hourly air temperatures on ten days 36 at Tangará da Serra, Mato Grosso, Brazil, from 2004 to 2017. The dotted line represents the upper limit recommended by the ANDEF (2004).

Average hourly data variability peaked at 2 PM, the time exhibiting the largest data amplitude. Comparing average hourly temperature (Figure 4a) and maximum hourly values (Figure 4b) behaviors, the period between 12 and 4 PM hours becomes critical, due to the occurrence of high maximum temperatures, with the highest temperature recorded at 1 PM (31.0 ºC).

During period 1, the average temperature at 2 PM was above 30.0 ºC (2.8 ºC amplitude) (Figure 5a). The maximum hourly temperature series (Figure 5b) indicates critical high temperature occurrences from 1 to 3 PM, with atypical records at 4 PM.

The hourly maximum temperature averages indicate variations in unsuitable fungicide application hours, with

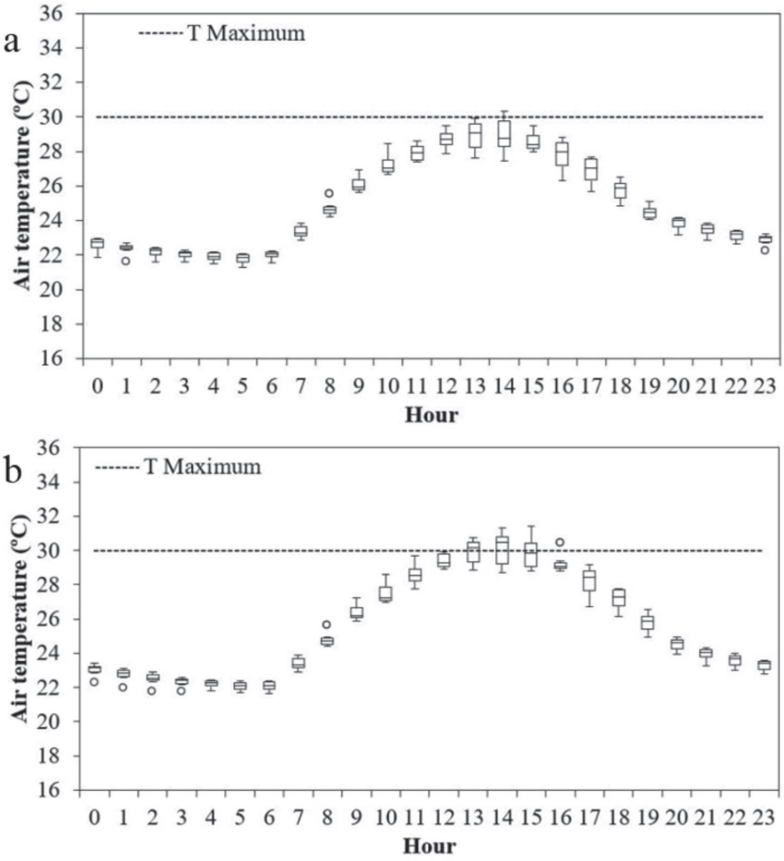

Figure 5: Average (a) and maximum (b) hourly air temperatures on ten days 1 at Tangará da Serra, Mato Grosso, Brazil, from 2004 to 2017. The dotted line represents the upper limit recommended by the ANDEF (2004).

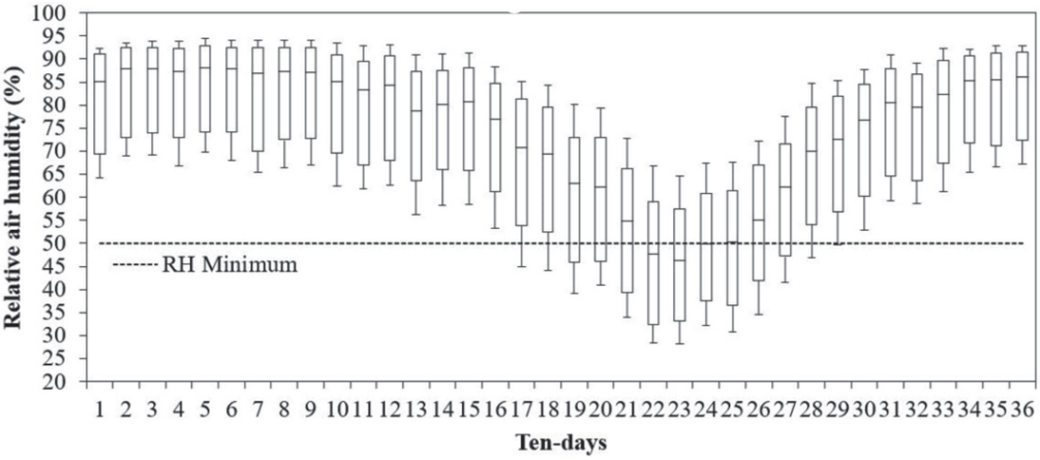

Figure 6: Average decendial relative air humidity variability at Tangará da Serra, Mato Grosso, Brazil, from 2004 to 2017. The dotted line represents the minimum limit recommended by the ANDEF (2004).

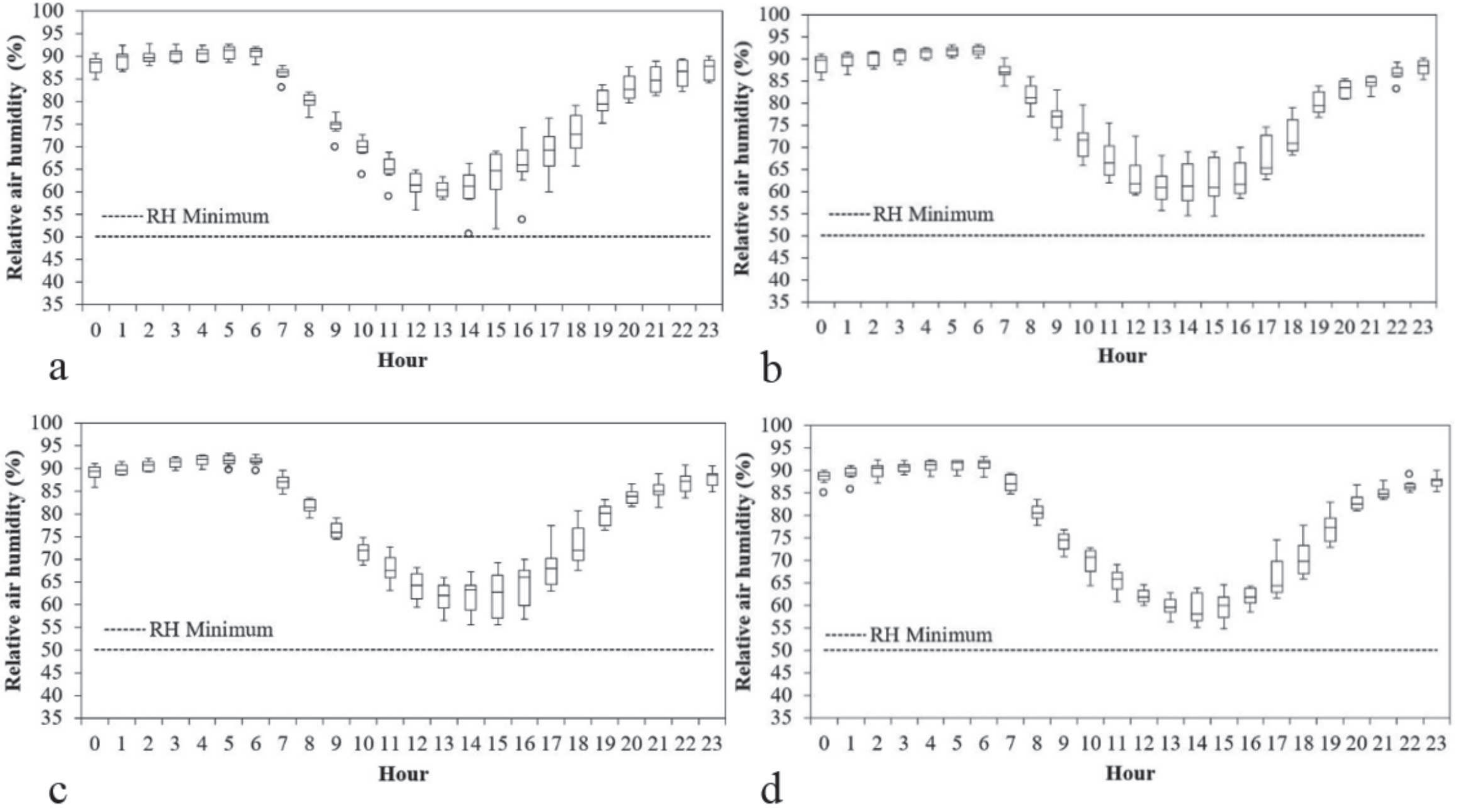

Figure 7: Hourly relative air humidity on ten days 34 (a), 35 (b), 36 (c) and 1 (d) at Tangará da Serra, Mato Grosso, Brazil, from 2004 to 2017. The dotted line represents the minimum limit recommended by the ANDEF (2004).

higher frequencies between the ten-days, generally between 12 and 3 PM. After 4 PM, with the solar decline and decreased solar radiation available for air heating, gradual air cooling begins.

The ten days 34, 35 and 36 (December) are characterized by regular precipitation, and, according to Martins *et al*. (2010), the variation between maximum and minimum probable precipitation values are less pronounced in December compared to the other months of the year. The findings reported by Dallacort *et al*. (2011) reinforce that the average monthly occurrence of rainy days with precipitation equal to or greater than 5.1 mm is higher from December to March.

During the rainy season, the greater presence of clouds influences direct solar radiation dissipation, resulting in lower solar irradiation values (Maciel *et al*., 2014), since clouds tend to scatter and reflect shortwave radiation into the atmosphere (Querino *et al*., 2011). The intensity of absorbed and reflected solar radiation acts on surface temperature fluctuation. Increasing surface temperatures immediately raise surrounding air temperatures and, by convection, increase upper layer air temperatures layers (Maciel *et al*., 2014).

It is estimated that most products sprayed on crops are lost during application (Reis *et al*., 2010). Applications under high temperature conditions and winds over 2.77 m s^{-1} may result in pesticide volatilization and product drift to non-target locations. Pesticide application drift raises concerns, as off target pesticides represent decreased doses over the intended target and exhibit the potential to cause damage to other crops, as well as leading implications for human health and environmental damage implications (Hoffmann *et al*., 2011).

Relative air humidity

The ten day relative air humidity as lowest during the driest months of the year (Figure 6). The transition months of May and September presented minimum values of 53.12% and 28.70%, respectively, while the wetter months of October to April displayed values above 53.12%. This climatic variability is typical of Cerrado areas, with only two annual seasons, similar behavior to that observed in Diamantino, also in the state of Mato Grosso (Rocha *et al*., 2018) and in Ituiutaba, in the state of Minas Gerais (Queiroz & Costa, 2012).

The most severe relative air humidity conditions throughout the year were observed between ten days 22 and 25, when maximum values did not exceed 70.0% and minimum values reached 28.11%. The critical low relative air humidity period occurs during the dry season of the year, especially in August. On ten days 34, 35, 36 and 01, when fungicide soybean crop applications are most frequent, the median and minimum values were higher than 85.0% and 64.0%, respectively.

The hourly minimum relative air humidity variability on ten days 34, 35, 36 and 01 (Figure 7) was similar among the analyzed ten days. The highest relative air humidity values wer eobserved between 2 and 6 AM, and the lowest values, at 3 PM on all ten days.

Wind speed

Wind directly interferes with spray drop deposition, as droplets are more likely to move away from the application zone, also providing better coverage due to the higher number of drops cm^{-2} and the ability to penetrate the crop canopy. Figure 8 exhibts the variability of the decendial wind speed at Tangará da Serra.

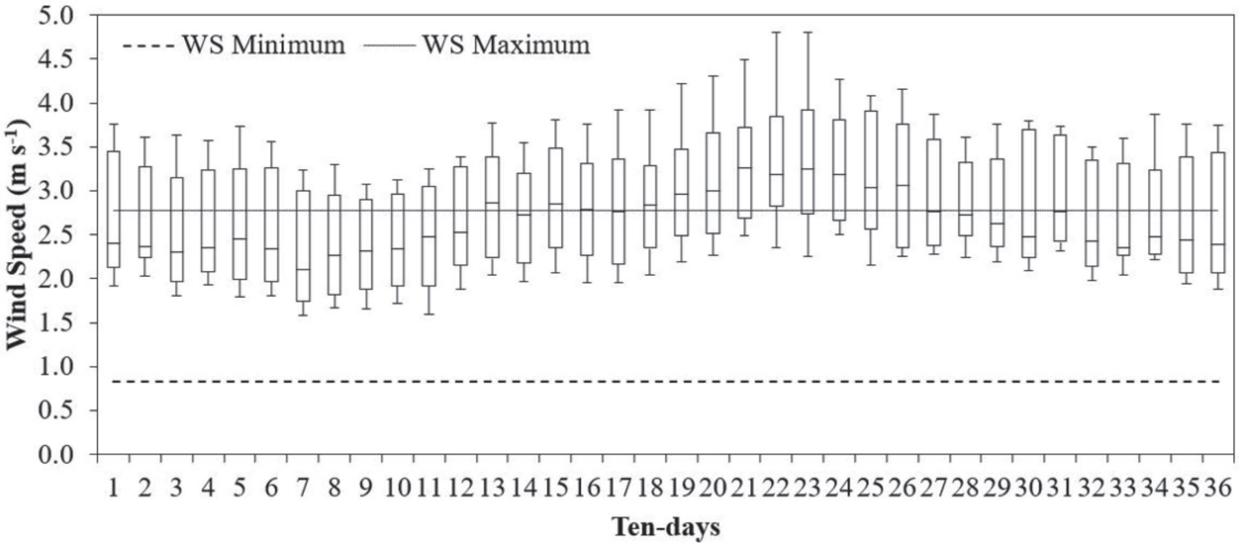

Figure 8: Wind speed (WS) variability at Tangará da Serra, Mato Grosso, Brazil, from 2004 to 2017. The dotted lines represent the maximum and minimum limits recommended by the ANDEF (2004).

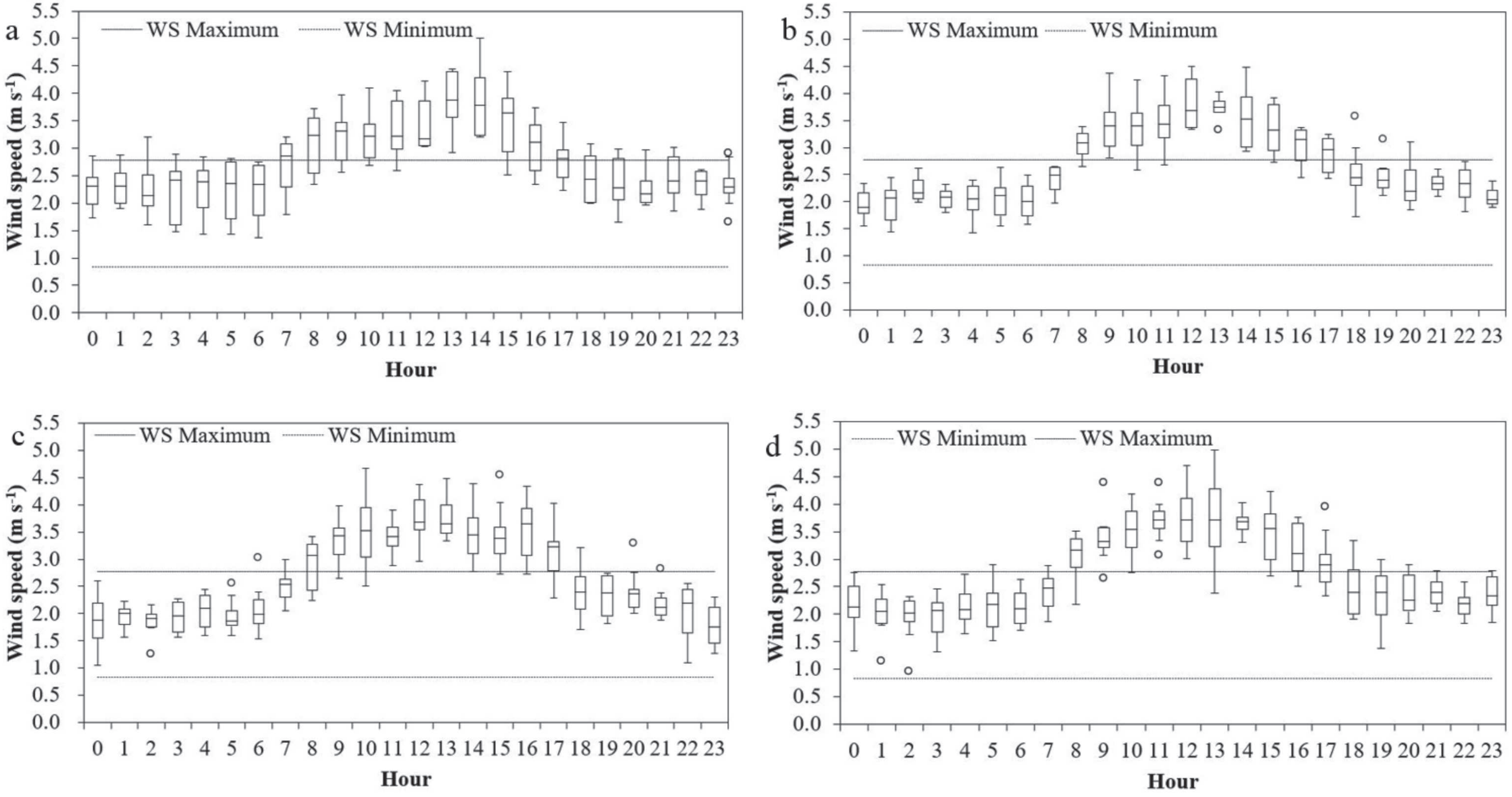

Figure 9: Hourly average wind speed on ten days 34 (a), 35 (b), 36 (c) and 1 (d) at Tangará da Serra, Mato Grosso, Brazil, from 2004 to 2017. The dotted lines represent the maximum and minimum limits recommended by the ANDEF (2004).

The ten day 28 displayed the smallest data dispersion, while ten days 22 and 23 exhibited the highest amplitudes (~ 2.45 m s^{-1}). No period in the analyzed set presented an ideal wind speed (minimum of 0.88 m s^{-1} and maximum of 2.77 m s^{-1}).

The highest decendial averages were recorded between ten days 20 and 26, with winds above 3.0 m s^{-1}. Ten days 07 and 08 exhibited the lowest averages, of 2.10 and 2.26 m s^{-1}, respectively. Concerning hourly wind behavior on ten days 34 (Figure 9), a higher occurrence of winds above 2.77 m s^{-1} throughout the day was observed compared to the other ten days, except at 6 and 10 AM, when records fall within the recommended minimum and maximum wind limits. The highest amplitudes were observed at 2 and 3 PM.

For ten days 35, unsuitable times were observed between 8 AM and 6 PM, as well as at 8 PM, with the smallest data dispersion observed at 1 PM. In the morning, data dispersion was greater between 9 and 11 AM compared to the other hours, ranging between 2.58 m s^{-1} (10 AM) and 4.33 m s^{-1} (9 AM).

On ten day 36, values above the recommended limit were observed between 7 AM and 6 PM, with the greatest amplitude noted at 10 AM. At all other times, wind conditions were favorable for fungicide application, although it should be noted that atypical winds were observed in the early morning (6 AM), and early evening (8 and 9 PM). On ten day 01, the occurrence of winds beyond those considered adequate were observed between 7 AM and 9 PM hours, as well as at 5 AM and 11 PM.

For ten days 34 and 35 from 12 to 2 PM, all wind speed values were above 2.77 m s^{-1}, with maximum wind speed recorded at 2 PM on ten-day 34, of 5.00 m s^{-1}, and at 12 PM on ten day 35, of 4.50 m s^{-1}. On tenday 3,6, values above the ideal, of up to 4.98 m s^{-1}, were observed between 11 AM and 2 PM, and between 9 AM and 2 PM on ten day 01.

When wind speed was higher than the ideal limit, the median exceeded 2.77 m s^{-1} between 8 AM and 5 pM on ten days 36, 35 and 01, and between 7 AM and 5 PM on ten day 34.

All records in the series meet the ideal limits for fungicide applications between 7 PM and 6 AM on ten days 35 and 36, and at 6 AM and 10 PM on ten days 34 and 01, including the gap between 12 AM and 4 AM.Chemical control efficiency depends, among other factors, on target coverage, especially in lower plant third portions, a critical site for soybean rust control and thus, under unfavorable weather conditions, i.e. strong winds, smaller drops are more susceptible to drift and less plant deposition (Cunha *et al*., 2008).

Costa *et al*. (2007) demonstrated a linear relationship between drift and wind speed in field essays with herbicides, where winds above 3.89 m s^{-1} prevented a higher number of drops from reaching their target. Different weather conditions lead to spray drops reaching up to 150 m beyond their targets in herbicide applications (Carlsen *et al*., 2006), with 5- to 7-fold increased drift with increasing wind speeds from 2.0 m s^{-1} to 4.8 m s^{-1}. Figure 10 displays the hourly frequency occurrence of suitable weather conditions for fungicide soybean crop applications.

Both ten days exhibited similar behavior regarding hourly variable variability. Between 41.55 and 54.55% of the hourly records showed optimal air temperature and wind speed conditions between 5 and 7 AM. Below-optimal wind speed is the main event that makes this period unsuitable for fungicide applications, especially on ten-days 01 and 36, where, 38.49 and 35.65% of the observations, respectively, indicated wind speeds below 0.83 m s^{-1}. On the other ten days, the frequencies of unfavorable application wind conditions were 21.31% (TD 35) and 27.72% (TD 34) of records above 2.77 m s^{-1}.

Btween 8 and 10 AM, ideal conditions frequencies were on average 32.21% (TD 34), 27.60% (TD 35), 23.04% (TD 36) and 24.76% (TD 1). On average, 73.10% of events were classified as unsuitable during this period. On ten days 01 and 36, approximately 30% of occurrences were

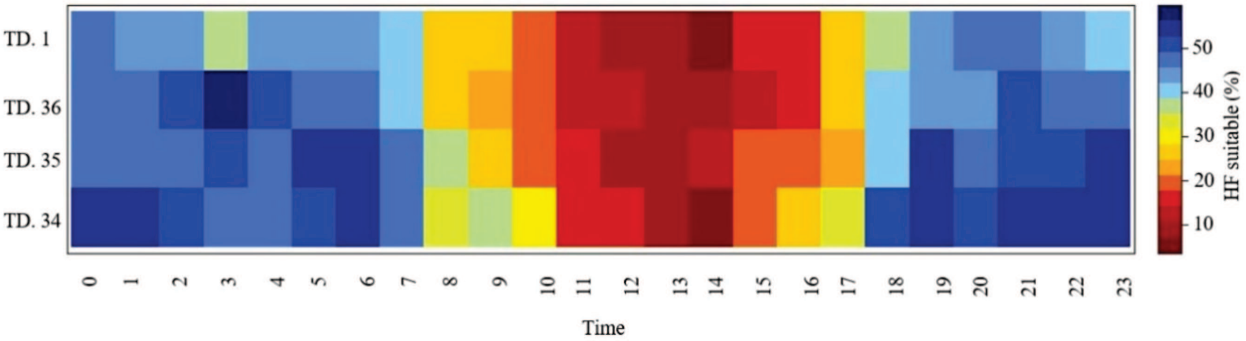

Figure 10: Hourly frequency (HF%) occurrence of suitable fungicide soybean crop application weather conditions on ten days 1 (TD 1); 34 (TD 34); 35 (TD 35) and 36 (TD 36), at Tangará da Serra, Mato Grosso, Brazil, from 2004 to 2017.

of winds below 0.83 m s^{-1}, while on ten days 34 and 35, percentages were 12.99 and 25.76%, respectively. The greatest interference during these times, in general, is represented by winds above 2.77 m s^{-1} (between 37.32% and 53.54%). From then on, the occurrence of suitable weather decreased and temperature also becomes a limiting factor, due to higher solar radiation surface incidence, with suitable frequencies of less than 10% at 1 PM.

Between 11 AM and 5 PM, high temperatures combined with low winds ranged from 9.09 to 37.21%, while low temperatures and high winds corresponded, on average, to 10.0%. From 7 PM, with surface cooling, temperature is no longer a limiting factor and suitable weather conditions were close to 50.0%, which allows for fungicide applications at night on certain occasions. However, wind speed is still a limiting factor for the quality of this operation.

According to Santos *et al*. (2013), it is difficult to control all of the variables that influence fungicide application quality under field conditions and performing applications only when all climatic parameters are under control is complicated.

In this sense, application technology aims at higher efficiency by using air-induced tips, along with the use of appropriate drop sizes for the weather conditions at the time of application. The use of adjuvants applied for the modification of physical pesticide properties by altering surface tension coefficient and viscosity parameters leads to spray drops size modifications and, consequently, drift (Heidary *et al*., 2014). Correct product deposition reflects fungicide application success, while uneven targeting coverage provides poor disease control efficacy, especially in the case of contact fungicides, which require uniform plant-wide coverage (Reis *et al*., 2010).

One alternative is to use air-induced tips that produce aerated droplets which, compared to solid droplets, are less prone to drift due to less wind and high temperature influences (Cunha *et al*., 2011). The recommendation is to avoid the production of “very thin” drops (<100 ì m) under unfavorable weather conditions, also observing the specific orientations of each spray tip in relation to the applied treatment, as well as the drift risk degree (ANDEF, 2004).

CONCLUSIONS

Relative air humidity at Tangará da Serra, in Mato Grosso, Brazil, is not a limiting factor for the fungicide soybean crop applications. However, high air temperatures and average wind speeds above recommended limits lead to unsuitable weather conditions between 11 AM and 4 PM.

Suitable weather conditions are concentrated in the early hours of the day, between 5 Am and 7 AM, and from 7 PM onwards. However, wind speed is still a limiting factor for adequate fungicide soybean crop applications at night.

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REFERENCES

Aguiar Junior HO, Raetano CG, Prado EP, Dal Pogetto MHFA, Chistovam RS & Gimenes MJ (2011). Adjuvantes e assistência de ar em pulverizador de barras sobre a deposição da calda e controle de *Phakopsora pachyrhizi* (Sydow & Sydow). Summa Phytopathologica, 37:103-109.

Alvares CA, Stape JL, Sentelhas PC, Gonçalves LM & Sparovek G (2013) Köppen’s climate classification map for Brazil. Meteorologische Zeitschrift, 22:711-728.

ANDEF - Associação Nacional De Defesa Vegetal (2004) Manual de tecnologia de aplicação. Campinas, ANDEF. 78p.

Azevedo LAS (2007) Fungicidas sistêmicos - Teoria e prática. Campinas, EMOPI. 284p.

Carlsen SCK, Spliid NH & Svensmark B (2006) Drift of 10 herbicides after tractor spray application. 2. Primary drift (droplet drift). Chemosphere, 64:778-786.

CONAB – Companhia Nacional de Abastecimento (2018) Levantamentos de safra. Available at: https://www.conab.gov.br/info-agro/safras/graos/boletim-da-safra-de-graos/item/download/21088_8ca248b277426bb3974f74efa00abab6. Accessed on: December 13th, 2018.

Costa AGF, Velini ED, Negrisoli E, Carbonari CA, Rossi CVS, Corrêa MR & Silva FML (2007) Efeito da intensidade do vento, da pressão e de pontas de pulverização na deriva de aplicações de herbicidas em pré-emergência. Planta Daninha, 25:203-210.

Cunha JPAR, Eudes AC, Moura JLSJ, Zago FA & Juliatti FC (2008) Efeito de pontas de pulverização no controle químico da ferrugem da soja. Engenharia Agrícola Jaboticabal, 28:283-291.

Cunha JPAR, Farnese AC, Olivet JJ & Villalba J (2011) Deposição de calda pulverizada na cultura da soja promovida pela aplicação aérea e terrestre. Engenharia Agrícola Jaboticabal, 31:343-351.

Dallacort R, Martins JA, Inoue MH, Freitas PSL & Coletti AJ (2011) Distribuição das chuvas no município de Tangará da Serra, médio norte do Estado de Mato Grosso, Brasil. Acta Scientiarum Agronomy, 33:193-200.

Fritz BK & Hoffmann WC (2008) Atmospheric Effects on Fate of Aerially Applied Agricultural Sprays. Agricultural Engineering International: the CIGR Ejournal, 10:1-15.

Heidary MA, Douzals JP, Sinfort C & Vallet A (2014) Influence of spray characteristics on potential spray drift of field crop sprayers: A literature review. Crop Protection, 63:120-130.

Hoffmann WC, Fritz BK & Martin DE (2011) Air and Spray Mixture Temperature Effects on Atomization. Agricultural Engineering International: the CIGR Journal. Manuscript, 13:1-8.

Maciel CR, Luz VS, Santos FM, Nogueira MCJA & Nogueira JS (2014) Interação das variáveis microclimáticas e cobertura do solo em região urbana e limítrofe-urbana na cidade de Cuiabá/MT. Caminhos de Geografia, 15:199-215.

Marcuzzo FFN, Melo DCR & Rocha HM (2012) Distribuição Espaço-Temporal e Sazonalidade das Chuvas no Estado do Mato Grosso. Revista Brasileira de Recursos Hídricos, 16:157-167.

Martins JA, Dallacort R, Inoue MH, Santi A, Kolling EM & Coletti AJ (2010) Probabilidade de precipitação para a microrregião de Tangará da Serra, Estado Do Mato Grosso. Pesquisa Agropecuária Tropical, 40:291-296.

Menezes HEA, Medeiros RM, Santos JLG & Lima TS (2015) Variabilidade climática para o município de Patos, Paraíba, Brasil. **Revista Verde**, 10:37-41.

Moreira PSP, Dallacort R, Galvanin EAP, Neves RJ, Carvalho MAC & Barbieri JD (2015) Ciclo diário de variáveis meteorológicas nos biomas do Estado de Mato Grosso. Revista Brasileira de Climatologia, 17:173-188.

Queiroz AT & Costa RA (2012) Caracterização e variabilidade climática em séries de temperatura, umidade relativa do ar e precipitação em Ituiutaba – MG. Caminhos de Geografia, 13:346-357.

Querino, CAS, Moura MAL, Querino JKAS, Von Radow C & Marques Filho (2011) Estudo da radiação solar global e do índice de transmissividade (kt), externo e interno, em uma floresta de mangue em Alagoas – Brasil. Revista Brasileira de Meteorologia, 26:204-294.

R Development Core Team (2018) A language and environment for statistical computing. Vienna, R Foundation for Statistical Computing. Available at: https://www.R-project.org. Accessed on: December 10th, 2018.

Reboita MS, Gan MA, Rocha RP & Ambrizzi T (2010) Regimes De Precipitação na América do Sul: Uma Revisão Bibliográfica. Revista Brasileira de Meteorologia, 25:185-204.

Reis EF, Queiroz DM, Cunha JPAR & Alves SMF (2010) Qualidade da aplicação aérea líquida com uma aeronave agrícola experimental na cultura da soja (*Glycine max l.*) Engenharia Agrícola Jaboticabal, 30:958-966.

Rocha AA, Novais JWZ, Souza RD, Santos ARC & Aleixes VF (2018) Caracterização da variabilidade climática em Diamantino/MT - Brasil no período de 1987 a 2017. Enciclopédia Biosfera, 15:69-80.

Santos RB, Souza AP, Silva AC, Almeida FT, Arantes KR & Siqueira JL (2013) Planejamento da pulverização de fungicidas em função das variáveis meteorológicas na região de Sinop – MT. Global Science and Techonology, 06:72-87.

Souza AP, Mota LL, Zamadei T, Martim CC, Almeira FT & Paulino J (2013) Classificação climática e balanço hídrico climatológico no Estado de Mato Grosso. Nativa, 1:34–43.

Wickham H, Averick M, Bryan J, Chang W, McGowan LD, François R, Grolemund G, Hayes A, Henry L, Hester J, Kuhn M, Pedersen TL, Miller E, Bache SM, Müller K, Ooms J, Robinson D, Seidel DP, Spinu V, Takahashi K, Vaughan D, Wilke C, Woo K & Yutani H (2019) Welcome to the tidyverse. Available at: https://CRAN.R-project.org/package=tidyverse. Accessed on: December 10th, 2018.