Seasonal and Vertical Distribution of Dalbulus maidis (Hemiptera: Cicadellidae) in Brazilian Corn Fields

Authors: Meneses, Aurélio R., Querino, Ranyse B., Oliveira, Charles M., Maia, Aline H. N., and Silva, Paulo R. R.

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Seasonal and vertical distribution of *Dalbulus maidis* (Hemiptera: Cicadellidae) in Brazilian corn fields

Aurélio R. Meneses[1], Ranyse B. Querino[2,], Charles M. Oliveira[3], Aline H. N. Maia[4], and Paulo R. R. Silva[1]*

Abstract

The corn leafhopper, *Dalbulus maidis* (DeLong & Wolcott) (Hemiptera: Cicadellidae), is one of the most important pests of corn, *Zea mays* L. (Poaceae), in Latin America. We assessed the seasonal and vertical distribution of *D. maidis* in corn fields in Brazil, in addition to describing the effect of 2 types of yellow traps positioned at 2 heights on the capture of this leafhopper. Sampling was conducted using yellow pan traps and yellow sticky cards throughout the cropping period, in both the rainy and dry seasons. The population of *D. maidis* in the dry season was much larger than in the rainy season. During both the rainy season and dry seasons, the greatest abundance of *D. maidis* was observed at 77 d post emergence of the corn, which corresponded to physiological maturity. Greater numbers of insects were captured with yellow cards than with pan traps, at both heights and in both cropping seasons. Also, more insects were captured at the 1.5 m than at the 0.5 m sampling height. The corn leafhopper was able to maintain significant populations throughout the phenological cycle of corn, but was especially numerous in the dry season. Knowledge of the seasonality of *D. maidis* aids in understanding how population dynamics may change with cropping seasons.

Key Words: *Zea mays*; maize; corn leafhopper; mollicutes; vector

Resumen

La chicharrita del maíz, *Dalbulus maidis* (DeLong y Wolcott) (Hemiptera: Cicadellidae), es una de las plagas más importantes del maíz, *Zea mays* L. (Poaceae), en América Latina. Se evaluó la distribución estacional y vertical de *D. maidis* en campos de maíz en Brasil, además de describir el efecto de las 2 clases de trampas amarillas colocadas en 2 alturas sobre la captura de este saltahoja. Se realizó el muestreo utilizando trampas de paila amarillas y tarjetas amarillas pegajosas durante todo el período de cultivo, tanto en la estación lluviosa y seca. La población de *D. maidis* en la estación seca fue mucho más grande que en la época de lluvias. Tanto durante la época de lluvias y la estación seca, se observó la mayor abundancia de *D. maidis* a los 77 días pos-emergencia del maíz, lo que correspondía a la madurez fisiológica. Un mayor número de insectos fueron capturados con las tarjetas amarillas que con las trampas de paila, tanto por alturas y en ambos ciclos de cultivo. También, más insectos fueron capturados en el 1,5 m de altura que en el muestreo de 0,5 m. La chicharrita del maíz fue capaz de mantener poblaciones importantes en todo el ciclo fenológico del maíz, pero fueron especialmente numerosos en la época seca. El conocimiento de la estacionalidad de *D. maidis* ayuda en la comprensión de cómo la dinámica de población pueden cambiar con estaciones de cultivo.

Palabras Clave: *Zea mays*; maíz; chicharrita del maíz; mollicutes; vector

The corn leafhopper, *Dalbulus maidis* (DeLong & Wolcott) (Hemiptera: Cicadellidae), is one of the most important pests of corn, *Zea mays* L. (Poaceae), in Latin America. *Dalbulus maidis* is responsible for persistent and propagative transmission of *Spiroplasma kunkelii* Whitcomb et al., which causes corn stunt spiroplasma, and the phytoplasma responsible for maize bushy stunt, in addition to the Maize rayado fino virus (Nault & Delong 1980; Nault 1990). The combined effects of *D. maidis* feeding and the transmission of these phytopathogens cause substantial losses of productivity and quality in corn crops (Summers et al. 2004). In central Brazil, a high prevalence (10–60%) of plants presenting symptoms of these diseases, predominantly maize bushy stunt phytoplasma, was observed in non-irrigated corn fields. In irrigated corn fields, 65.3 to 100% of all corn plants were infected, leading to a complete loss of production in some areas (Oliveira E et al. 1998).

The corn leafhopper transmits phytopathogens very efficiently (Oliveira E et al. 2011) and has a high capability of migration, abandoning senescent corn fields and colonizing newly planted ones (Oliveira CM et al. 2013a; Oliveira E et al. 2015). Investigating the ecological and epidemiological characteristics of this insect vector are essential steps towards successfully managing it. In light of this need, studies on fluctuations in *D. maidis* populations and determination of the seasons and environmental conditions that most favor the occurrence of population peaks are fundamental elements for implementing adequate control measures and mitigating the spread of diseases transmitted by the corn leafhopper.

No information is available on the population dynamics of *D. maidis* in semiarid regions with drastic climatic differences throughout the year, such as some areas of northeastern Brazil. However, *D. maidis*

[1]Universidade Federal do Piauí, Núcleo de Pós-Graduação em Ciências Agrária, Rua Dirce Oliveira 3597, 64049-550, Teresina, PI, Brazil; E-mail: aurelioribeiromeneses@gmail.com (A. R. M.), pramalhoufpi@yahoo.com.br (P. R. R. S.)
[2]Embrapa Meio-Norte, Av. Duque de Caxias 5650, 64006-220, Teresina, PI, Brazil; E-mail: ranyse.silva@embrapa.br (R. B. Q.)
[3]Embrapa Cerrados, Rodovia BR 020 km 18, 73310-970, Sobradinho, DF, Brazil; E-mail: charles.oliveira@embrapa.br (C. M. O.)
[4]Embrapa Meio Ambiente, Rodovia SP 340 KM 127, 13820-000, Jaguariúna, SP, Brazil; E-mail: aline.maia@embrapa.br (A. H. N. M.)
*Corresponding author; E-mail: ranyse.silva@embrapa.br (R. B. Q.)

was recorded in the states of Bahia, Pernambuco, Rio Grande do Norte, and Maranhão in northeastern Brazil (Oliveira CM et al. 2004, 2007, 2013b). This region has seen a significant expansion of corn cultivation in recent years and currently has the third largest area planted with corn in Brazil, albeit with the lowest productivity among corn-growing regions in the country (CONAB 2015).

Cropping season could influence the distribution pattern of corn leafhoppers. Furthermore, knowledge of the vertical distribution of a pest can expedite sampling and increase reliability. Such knowledge is also supportive of important practices such as defining the most adequate locations to apply insecticides or natural enemies (Fernandes et al. 2006). Collection methods based on insect attraction to yellow visual stimuli can be important because they permit a simultaneous investigation of population fluctuations and vertical distribution of an insect (Nault 1990; Ávila & Arce 2008; Oliveira CM et al. 2013a). Thus, we conducted a study to assess the seasonal and vertical distribution of *D. maidis* in corn fields in northeastern Brazil, in addition to describing the effect of yellow trap placement at 2 heights on the capture of this corn leafhopper, thus increasing knowledge about the population dynamics of this pest.

Material and Methods

STUDY SITE

The corn field used in this study was located at an experiment station of Embrapa, in Teresina, Piauí, in northeastern Brazil (5.03503°S, 42.78592°W; 62 m asl). Under the Köppen classification system, this region has a tropical wet climate with rains concentrated in the summer and fall (Aw'). Climatic data were recorded from a meteorological station located at Embrapa in the same area where the experiment was conducted.

The corn field was planted with the BRS 'Catingueiro' variety in a field of 30 × 80 m, with 0.70 m of spacing between rows. The 1st corn crop was grown in the rainy season. The corn plants emerged on 15 Feb 2012. The 2nd corn crop was grown in the dry season (when irrigation was needed); plant emergence occurred on 4 Jul 2012. Chemical insecticides were not applied during the experiments, and infestation by the fall armyworm, *Spodoptera frugiperda* Smith (Lepidoptera: Noctuidae), was controlled using a selective biological insecticide based on *Bacillus thuringiensis.* Weeds were managed manually.

SAMPLING METHOD

Sampling was conducted in both the rainy season and dry season. *Dalbulus maidis* was sampled using yellow pan traps and yellow sticky cards during the entire phenological cycle of each corn planting. We used sticky cards measuring 10.0 × 24.5 cm (Biocontrole®) and circular plastic yellow pan traps with 300 mL capacity and an internal diameter of 15 cm that contained a solution of water, detergent, and salt (NaCl) (1,000:1:1).

The population of *D. maidis* was assessed at heights of 0.5 and 1.5 m above the soil. For population assessment, we drove wood stakes into the soil and attached the yellow pan traps and sticky cards at the 2 heights studied. The yellow pan traps were suspended from the stakes with flexible aluminum wire (4 mm). The traps were distributed uniformly across the field in 2 rows of 5 stakes each, with 13 m of spacing between rows and between stakes. One row was equipped with sticky cards, making up 10 cards (5 stakes × 2 heights). In the other row, 10 pan traps were installed (5 stakes × 2 heights).

The sticky cards were replaced at 7 d intervals, and the yellow pan traps at 2 d intervals. The *D. maidis* specimens collected from the sticky cards were identified and quantified using a stereoscopic microscope. The samples collected in the yellow pan traps were sieved to retrieve the insects from the solution, after which they were transferred into an 80% ethanol solution and subsequently sorted and quantified using the microscope. Voucher specimens of adults were deposited at the collections of Embrapa Meio-Norte, Teresina, State of Piauí, Brazil.

DATA ANALYSES

The seasonal populations of *D. maidis* in the 2 cropping seasons, as determined by the number of adults captured by the traps during the sampling period, are presented graphically. Also, we present corresponding temperature, relative humidity, and rainfall during these periods.

To assess the effect of the type of trap on capture of *D. maidis* at 2 heights, as represented by the number of insects captured per trap per day, the following generalized linear model was fitted for each sampling height: $\log(Yijk) = \mu_i + T_{ij} + e_{ijk}$, where *Yijk* is the mean number of insects captured per day at repetition *k* of trap type *j* (*j*=1,2), installed at height *i* (*i*=1,2); T_{ij} is the differential effect of trap type *j* at height *i*, and e_{ijk} is the random error associated with each observation. *Yijk* is considered to have a Poisson distribution. The effect of trap type at each height was assessed using *t*-tests for contrasts associated with the hypotheses $T_{ij}=0$ versus $T_{ij}\neq 0$. To fit the generalized linear model and perform the derivative hypothesis tests, we used the GLIMMIX procedure feature of the SAS/STAT statistics suite (SAS Institute 2008).

Vertical distribution was determined by counting the number of individuals of *D. maidis* captured in the yellow sticky cards and pan traps. At the 2 sampling heights, the abundance of *D. maidis* was recorded for 2 cropping season (rainy, dry). We present a descriptive analysis of the time pattern of differences between densities observed in the height of the 2 traps.

Results

SEASONAL DISTRIBUTION OF *DALBULUS MAIDIS*

We collected 2,263 specimens of *D. maidis* in the corn fields. Out of this total, 7% of the corn leafhoppers were collected in the rainy season and 93% were collected in the dry season.

In the rainy season, the greatest abundance of *D. maidis* was observed in the month of May (*n* = 34 specimens), whereas the greatest abundance in the dry season was observed in Sep (*n* = 432 specimens) (Fig. 1). During both the rainy season and dry season, an early colo-

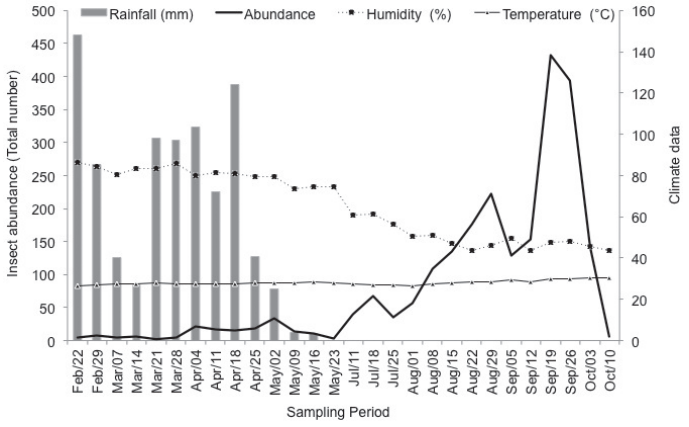

Fig. 1. Trends in capture of *Dalbulus maidis*, and weather variables, during the study at Teresina, Piauí, Brazil, in 2013.

nization process was observed during the vegetative stage, followed by an increase in abundance, with some degree of fluctuation during the reproductive stage, culminating in a population peak at the early maturity stage. The greatest abundance of corn leafhoppers during the rainy season was observed during the reproductive stage, whereas the greatest abundance during the dry season was observed at the maturity stage. After the greatest abundance had been recorded in both areas, the populations of *D. maidis* declined abruptly.

Dalbulus maidis populations were much larger during the dry season than during the rainy season in Teresina, Brazil, even with the drastic climatic conditions found during this period in this semi-arid region. We also observed an abrupt decline in the population of *D. maidis* in the last 2 wk of sampling during the dry season. This decline was also a result of physiological maturity and consequent senescence of the corn plants, an effect accelerated by environmental conditions. It is likely that the corn leafhoppers present in the field abandoned the area using their well-known migration capabilities to find new corn fields to be colonized (Oliveira CM et al. 2013a).

CAPTURE OF *DALBULUS MAIDIS* WITH YELLOW TRAPS POSITIONED AT TWO HEIGHTS

Greater numbers of insects were captured with yellow cards than with pan traps, at both heights and in both cropping seasons ($P < 0.001$) (Table 1; Fig. 2a and b). During the rainy season, the card traps captured 4.6 and 7.9 additional insects per trap per day, relative to the pan traps, at 0.5 and 1.5 m, respectively (Table 1). During the dry season, the card traps captured 41.1 and 152.2 additional insects per trap, relative to the pan traps, at 0.5 and 1.5 m, respectively (Table 1).

VERTICAL DISTRIBUTION OF *DALBULUS MAIDIS*

During the 1st cropping season (rainy season), no corn leafhoppers were collected at 1.5 m on either trap type until 14 d after emergence (Fig. 3a and c). The yellow sticky cards installed at 0.5 m captured a larger number of leafhoppers by 28 d post emergence (Fig. 3a). From 42 d post emergence onward, a larger number of *D. maidis* specimens were collected at 1.5 m, and this pattern persisted throughout the reproductive stage of the corn, until the end of the growing cycle. Using the yellow pan traps, few individuals were captured in the rainy season, and most of them at 1.5 m (Fig. 3c).

During the first 2 wk of sampling in the 2nd cropping season (dry season), leafhoppers were only captured by traps at 0.5 m (Fig. 3b and d). The yellow sticky cards and yellow pan traps placed at 1.5 m began capturing a larger number of leafhoppers starting at 28 d post emergence, and this pattern persisted until the end of the cycle (Fig. 3b and d). During the dry season, a few individuals were also captured with yellow pan traps, and most of them at 1.5 m.

The largest numbers of leafhoppers captured during these studies were with yellow sticky card traps at 1.5 m at 70 to 77 d after emergence in the rainy season, and at 77 to 84 d after emergence in dry season.

Table 1. Estimated corn leafhopper densities (mean ± SE insects per trap per day) from yellow sticky card and yellow pan traps positioned at 2 heights in corn grown during the rainy and dry seasons at Teresina, Piauí, Brazil, in 2013.

Period	Height (m)	Type of Trap	Mean ± SE insects per trap per day
Rainy season	0.5	Sticky card	4.7 ± 0.34
		Pan trap	0.1 ± 0.05
	1.5	Sticky card	9.1 ± 1.38
		Pan trap	1.2 ± 0.51
Dry season	0.5	Sticky card	41.9 ± 3.78
		Pan trap	0.8 ± 0.51
	1.5	Sticky card	156.2 ± 7.43
		Pan trap	4.0 ± 1.19

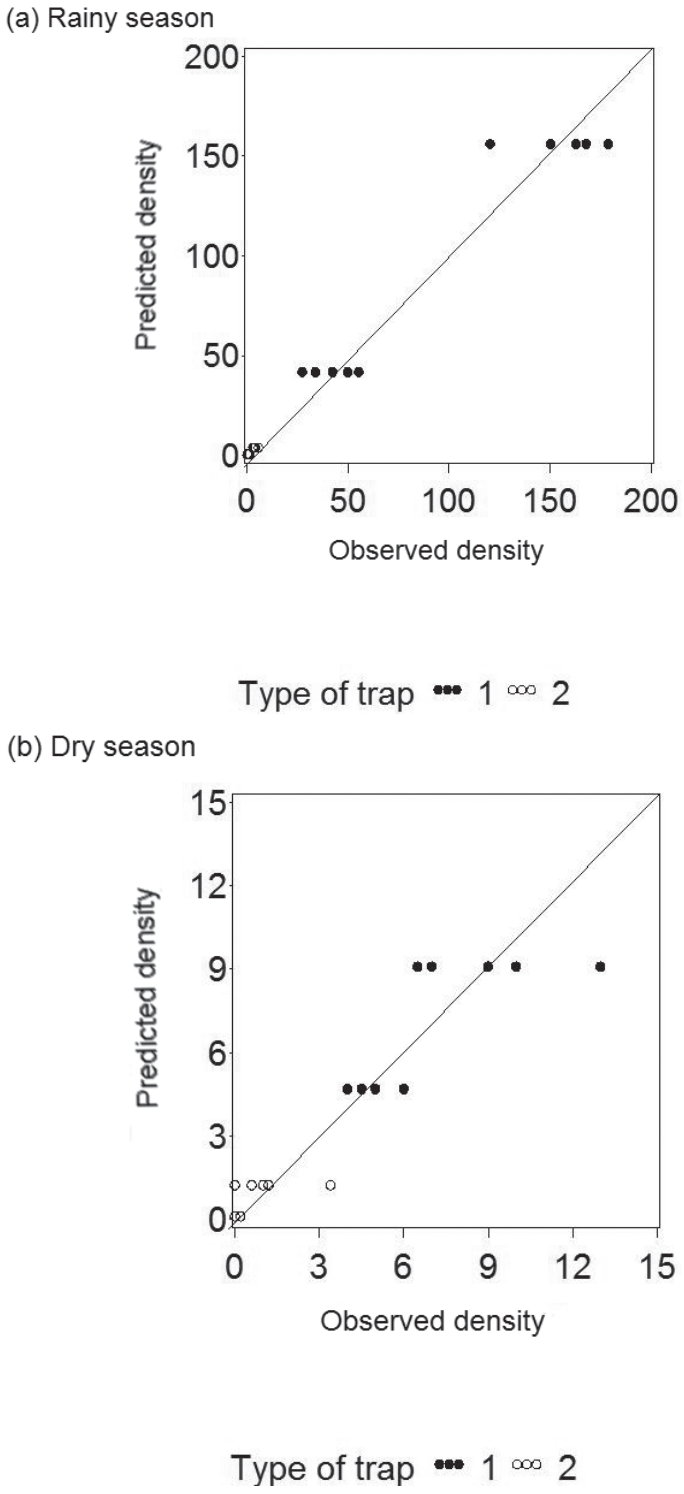

Fig. 2. Quality of fit of generalized linear mixed models used to assess the effect of trap type on capture of *D. maidis* at 2 heights, expressed as the ratio of values observed to values predicted by the models. Type 1 = yellow sticky card and type 2 = yellow water pan. (a) Rainy season. (b) Dry season.

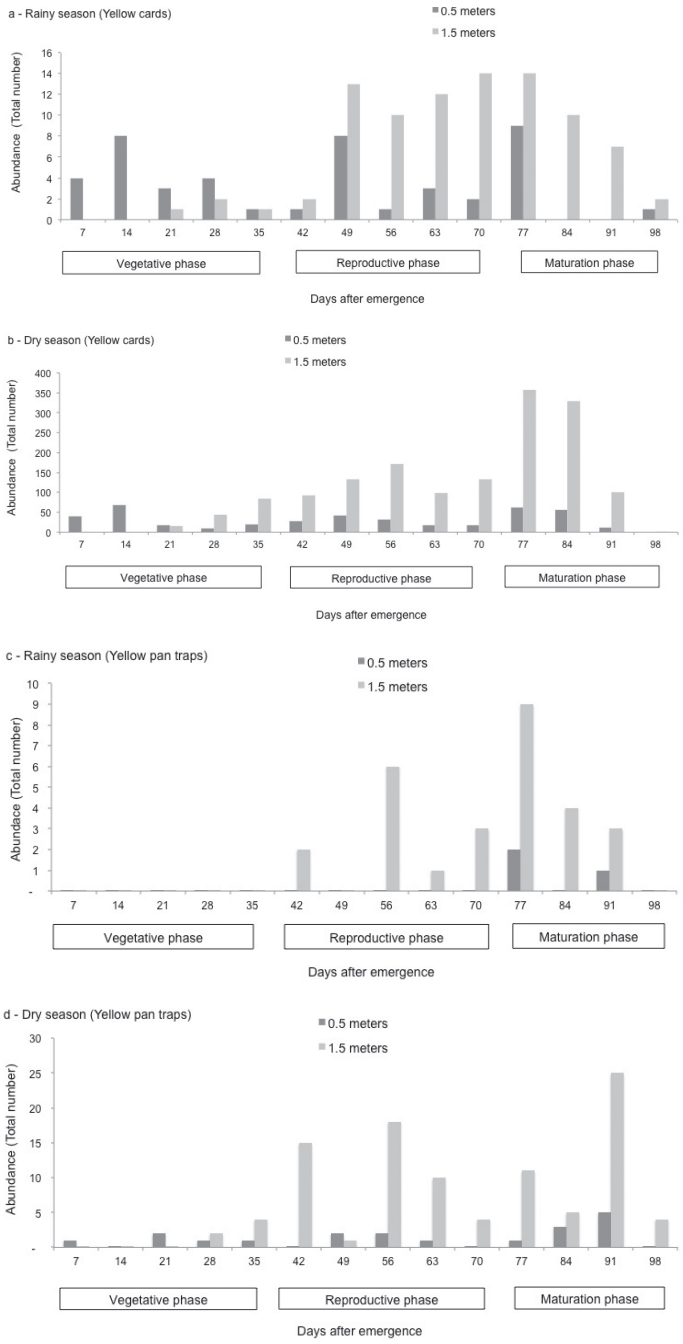

Fig. 3. Abundance of *Dalbulus maidis* from yellow sticky card and yellow pan traps positioned at 2 heights in corn grown during (a, c) the rainy season and (b, d) the dry season.

Discussion

Our study on the population dynamics of *D. maidis* in 2 cropping seasons showed the population of *D. maidis* in the dry season to be much larger than the population of this leafhopper in the rainy season. The increase in *D. maidis* populations in the drier months (Aug, Sep, and Oct) seems to be the pattern observed in Brazilian regions. In Mato Grosso do Sul, Brazil, population peaks of *D. maidis* were also reported in Sep, during the dry season (Ávila & Arce 2008), and the same behavior was observed in Brasília (Federal District) and in the state of Minas Gerais (Oliveira CM, Embrapa, personal communication). The increase in corn leafhopper abundance could be explained by several factors, including the nearly continuous availability of food allowing the population to increase, the favorable microclimate provided by irrigation, a reduced complex of natural enemies during the dry season, or influx of leafhoppers to an irrigated field from nearby dry vegetation.

In general, corn crops occur throughout the year, although the planted area is smaller during the dry season. Thus, the prolonged availability of corn fields could favor the occurrence of late-season population peaks. A similar pattern was also observed in a 2 yr period in the state of Minas Gerais, where populations of *D. maidis* were larger in Brazil's 2nd corn crop, or 'safrinha' corn fields, as compared with summer corn (Oliveira E et al. 2015). Stunt diseases transmitted by *D. maidis* in southeastern and central-western Brazil are a more serious problem and bring more significant losses to irrigated and 'safrinha' corn as compared with summer corn (which is not irrigated) (Oliveira E et al. 1998, 2002a, 2002b).

Larger numbers of *D. maidis* leafhoppers can be captured with yellow sticky cards than with yellow pan traps. Although some studies have suggested that *D. maidis* and other cicadellids can be satisfactorily collected using yellow pan traps (Vega & Barbosa 1990; Hickel et al. 2001; Trebicki et al. 2010), sticky cards have been shown to be a more efficient capture method for species of Cicadellidae in various habitats (Giustolin et al. 2009; Miranda et al. 2009; Ringenberg et al. 2010). Many researchers in Brazil and Mexico have been using sticky cards to study the population dynamics of *D. maidis* (Larsen et al. 1992; Oliveira CM et al. 2013a).

The vertical distribution of *D. maidis* suggests that corn leafhoppers are captured at different heights according to the development stage of the corn plants. As a result, during the initial phases of growth, when the corn plants are smaller, traps positioned at a height of 0.5 m will be within the field of vision of the leafhoppers and, because this species shows a strong orientation to yellow (Todd et al. 1990a,b), these traps will capture more specimens. As the plants grow, the traps positioned higher (1.5 m) start collecting a larger number of insects. This behavior of *D. maidis* was also observed during studies conducted in the state of Mato Grosso do Sul (Oliveira CM et al. 2002). Hence, single-height sampling may underestimate the population size of insects, with potentially critical effects on integrated pest management programs (Vega & Barbosa 1990). Another fact to be considered is that the lower leaves of a corn plant will become senescent as the plant grows. The more nutrient-rich plant tissues will be located higher up, near the whorl—which is the site preferred by *D. maidis*, causing the populations of this leafhopper to migrate vertically onto the upper part of the plants (Todd et al. 1991).

The variation in the ability of traps positioned at different heights to capture leafhoppers suggests that monitoring protocols should be modified during the growing season. Because early-season detection is important for initiation of control measures to reduce the population of these insect vectors, the traps initially should be installed at 0.5 m. Then, traps could be installed at 1.5 m for monitoring leafhoppers at the later stages of corn phenology.

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