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Research Article

Population of *Bemisia tabaci* and Incidence of Yellow Disease in Chili Intercropped with Corn

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ABSTRACT

Bemisia tabaci is one of the limiting factors in chili farming, because it can cause damage both directly and indirectly as a vector for the *Pepper yellow leaf curl virus* (PepYLCV). Intercropping chili with corn is one of the efforts to control *B. tabaci*. Physically, corn plants are able to withstand the presence of *B. tabaci*, in addition to producing volatile compounds that are repellent to *B. tabaci*. This research was conducted to determine the optimal age of corn plants to be intercropped with chili plants. The research was conducted in Pleret District, Bantul Regency by testing five different ages of corn: 2 weeks after planting, 6 weeks after planting, 8 weeks after planting, 10 weeks after planting and control (without intercropping with corn). Weeks after planting are counted from the first day the corn seeds were planted. Yellow sticky trap (YST) was used to determine the presence of *B. tabaci* population in each treatment plot. YST was tied to bamboo sticks and placed on treatment beds with as many as 2 (two) traps per treatment plot. The distance between the yellow sticky trap and the plant was 30 cm, so the height of the trap was always adjusted according to the height of the plant. Observation of *B. tabaci* population was carried out every 5 days by counting the number of *B. tabaci* caught in yellow sticky traps. The results showed that the population of *B. tabaci* in the chili plots intercropped with corn was lower than that in the control plot, especially at the age of 6 weeks after planting (WAP). However, the intercropping of chilies and corn had no significant effect on the incidence of yellow disease in chilies.

Keywords: *Bemisia tabaci*; corn; intercropping; yellow disease

INTRODUCTION

Chili is one of the leading horticultural commodities that is widely cultivated and has the highest price fluctuations in Indonesia (Adriani *et al*., 2019). The harvested area for red chilies in 2019 ranks at the top compared to other vegetable commodities (Centre for Agricultural Data and Information Systems, 2020). Chili productivity in Indonesia is still relatively low compared to other countries in Asia. Several factors have contributed to the low productivity of Indonesian chilies, including the use of inferior seeds, inefficient cultivation techniques and pest and disease attacks (Soelaiman & Ernawati, 2013). One of the pests that attack red chili plants is the whitefly, *Bemisia tabaci* Gennadius.

Damage caused by *B. tabaci* attack on chilies can occur directly or indirectly. Direct damage occurs when whitefly causes leaves to become chlorosis and drop, or plants become stunted due to feeding activity; Meanwhile, indirect damage occurs when the honeydew released by whitefly grows sooty fungi which can reduce the rate of the photosynthesis process thereby reducing fruit quality (McAuslane & Smith, 2015). In addition, the whitefly *B. tabaci* is a vector that can transmit or spread the *Pepper yellow leaf curl virus* in chilies (PepYLCV), the higher the population of whitefly, the higher the distribution of PepYLCV. Whiteflies can persistently spread the virus, which means once it feeds on a viral-loaded plant, it will persist in the insect's body throughout its life. Thus, the virus can be transmitted even after the vector is shed (Nigam, 2021). This virus can cause huge production loss (Ashwathappa *et al*., 2020). Yellow disease incidence causing high yield loss, especially in chili pepper (Zaidi *et al*., 2017). Yield loss due to yellow disease may reach 100% (Kenyon *et al*., 2014).

One strategy to suppress *B. tabaci* populations is to use border plants. Friarini *et al*. (2016) proved that corn was quite effective in reducing the spread of *B. tabaci* in red chili planting plots, which in turn was also able to inhibit the spread of the yellow virus in red chilies. Meanwhile, Udiarto *et al*. (2023) also proved that cultivating corn as a limiter and in combination with sunn-hem can reduce the incidence of chili yellow disease by up to 49.94 – 50.80%.

Corn was known to produce volatile organic compounds that were not favored by *B. tabaci* (Tyasningsiwi *et al*., 2019). Corn leaves are known to contain volatile compounds with carbon groups, namely (Z)-3-hexenol (2-7%), (Z)-3-hexenyl acetate (3-14%), (Z)-4-hepten-2-one (2-8%) and (Z)-4-hepten-2-ol (2-4%) (Buttery & Ling, 1984). Konstantopoulou *et al*. (2004) showed that the volatile compounds of corn plants quantitatively affect the egg laying behaviour of female *Sesamia nonagrioides*, filter paper containing volatile compounds with higher aldehyde groups has fewer eggs than those with lower aldehyde groups. In addition, corn silk also contains a wide range of bioactive compounds in the form of volatile oils, steroids, and other natural antioxidants, such as polyphenols and flavonoids (Bhuvaneshwari & Sivakami, 2017; Singh *et al*., 2022; Žilić *et al*., 2016). Tyasningsiwi *et al*. (2019) reported that corn grown in a greenhouse produces different volatile compounds at each age stage. The most optimal age of corn in producing repellent compounds is 12 weeks after planting (WAP), with a rejection rate of *B. tabaci* of 83.72%. However, information on the ability of corn plants to resist *B. tabaci* at the field scale is still limited. Therefore, this study aims to examine the ability of corn plants to resist *B. tabaci* in the field.

MATERIALS AND METHODS

The research was conducted at the chili plantation field in Pleret District, Bantul Regency, Yogyakarta and The Laboratory of Pest Science, Department of Plant Pests and Diseases, Faculty of Agriculture, Universitas Gadjah Mada from August 2022 to August 2023.

Field Experiment

The corn variety used in this study was BISI-2, while the chili variety used in this study was LABA. The study was conducted to test the ability of corn to resist *B. tabaci*. The treatment used was the age of the corn plant. Corn plants at the age of two, six, eight, and ten weeks after planting (WAP) compared to controls (no corn plants at a radius of 30 meters). WAP are counted from the first day the seeds were planted. Each treatment was repeated five times. Chili and corn plants were planted in beds measuring 100 cm × 500 cm with a distance of 40 cm between the beds. Two beds of chili plants are flanked by one bed of corn plants according to the treatment used. To prevent the influence of corn plants on other plots, each treatment plot was spaced 10 meters apart (Figure 1). Corns were planted earlier than chilies according to the treatment used. Transplanting chilies were carried out when the chilies were 4 weeks old with a planting distance of 40 cm × 50 cm.

Yellow sticky trap (YST) was used to determine the presence of *B. tabaci* population in each treatment plot. YST was tied to bamboo sticks and placed on treatment beds with as many as 2 (two) traps per treatment plot. The distance between the yellow sticky trap and the plant was 30 cm, so the height of the trap was always adjusted according to the height of the plant.

The parameters observed in this test were the number of *B. tabaci* caught in the yellow sticky trap and the incidence of yellow diseases. Observation of the number *B. tabaci* was conducted during dry season of September – October 2022 and carried out every five days until the chili plants are 60 days old. Observation of the incidence of yellow diseases was carried out every 15 days since the age of chili 30 days after planting to 75 days after planting (DAP). Disease incidence was calculated using the formula (Masnilah *et al*., 2020):

$$DI = \frac{n}{N} \times 100\% \qquad (1)$$

Remarks:

DI : Percentage of yellow disease incidence

n : Number of plants affected

N : The number of plants observed

The data obtained were analyzed by analysis of variance (ANOVA) and the differences between treatments were determined using the Tukey test at the 5% level.

Mass Rearing of *B. tabaci*

Mass rearing of *B. tabaci* was carried out based on the method of Rinaldi *et al*. (2016) with modification by researchers. The imago of *B. tabaci* were caught from eggplant, chili and tomato plantations. The imago of *B. tabaci* obtained from the field were placed in cages made of wood covered with gauze measuring 150 cm × 150 cm × 150 cm and filled with eggplant plants as host plants. Twenty (20) polybags of host plants aged ± 4 WAP were placed in cages. An infected plant was replaced with a new healthy plant. The imago of *B. tabaci* used in this test were 10 females starting from the second generation (F2) after collection from the field for each treatment in each replication. The use of *B. tabaci* females, based on Hasyim *et al*. (2016) where female whiteflies have a higher level of virus transmission efficiency compared to male insects.

Test of Corn Volatile Compounds as a Repellent for *B. tabaci* Using Olfactometer

This test was carried out using corn plant which give best repellency result in field test. Corn plants were placed in plastic box sizing 40 cm × 40 cm × 150 cm for about 24 hours to collect the volatiles produce by the plant. Collected volatile compounds in the plastic box then be transferred to olfactometer using aerator. Volatile compounds were drained from inside the plant cover using an aerator and connected to an olfactometer. The olfactometer test used a Y-shaped glass tube with a diameter of 1.3 cm, with a long base and two hands of 10 cm each. Each end of the Y tube was covered using gauze. One of the tube hands was perforated to be connected to the aerator hose so that gas from inside the hood can be channel into the olfactometer tube. Then faced with a small fan to blow air slowly so that it directs *B. tabaci* towards the two hands of the tube. This test was carried out in a closed room with even lighting between the right and left Y-tube hands. This is to prevent *B. tabaci* response bias due to light factors. Imago of *B. tabaci* chose the smell on one of the Y-tube hands. *B. tabaci* was allowed to choose and waits for 10 minutes to walk towards the Y-tube hand 7 cm long from the base of the hand and stays for approximately one minute at that location. If *B. tabaci* did not make a selection for 10 minutes, it was considered no response (Meilin, 2012). The parameters observed in this experiment were the number of *B. tabaci* which avoids volatile compounds of corn plants at various ages. The percentage of repellent was calculated based on the formula of Sjam *et al.* (2010):

$$\text{Percentage of repellent} = \frac{(A-N)}{A} \times 100\% \qquad (2)$$

Remarks:
A: imago on control
N: imago on corn volatile compound

Classification of repellent level is as follows:
Class 1 = 0.1–20%
Class 2 = 20.1–40%
Class 3 = 40.1–60%
Class 4 = 60.1–80%
Class 5 = 80.1–100%

RESULTS AND DISCUSSION

Population of *B. tabaci*

The field test results for the rejection of *B. tabaci* in corn showed that the corn crop caused a decrease in the population of *B. tabaci* in chili plants. The population of *B. tabaci* on chili crops accompanied by corn crops was significantly different from the control, namely chili crops which were not accompanied by corn crops. The age of the corn crops used to accompany the chili crops also has an influence on the population of *B. tabaci* which is trapped in the yellow sticky trap. The most optimal age of corn crops used to accompany chili crops is corn aged 6 WAP, because the population of *B. tabaci* was significantly lower (P <0.05) than the treatment at corn ages 2, 8 and 10 WAP (Figure 2).

The high population of *B. tabaci* in the 2 WAP corn treatment could be due to the fact that the corn crops were still too young so that they had not been able to provide optimal assistance effects both physically and in terms of the production of volatile compounds repelling *B. tabaci*. According to Arimura *et al*. (2004), in general, vegetative tissues release volatile compounds in small quantities, which can be caused by mechanical damage and infection by herbivores or pathogens. The most optimal repellent ability was found in the treatment of corn aged 6 WAP. At this age, corn crops had entered the tasselling and silking phase, where physically, the leaves of the corn plant are fully opened and produce male and female flowers. The results of the study by Knudsen *et al*. (2006) stated that the most diverse mixtures with the highest abundance of volatile compounds were released mainly from flowers in most flowering plants. This is in accordance with the research of Tyasningsiwi *et al*. (2019), which showed that the composition of volatile compounds was higher as the age of the corn crops get older.

The repellent ability of corn plants at the age of 8 WAP and 10 WAP were not high even though at these ages they had also entered the tasselling and silking phases. Corn plants aged 8 and 10 WAP could not optimally accompany chili plants because the time period was narrower than corn plants 6 WAP. The harvesting age of corn crops was 15 WAP so that when chilies reach the optimal age for the development of *B. tabaci*, they are no longer accompanied by corn crops. According to Yuliani *et al*. (2006) stated that the population of *B. tabaci* is increasing and reaches its peak when the chili is 63–77 DAP, then the population of *B. tabaci* will decrease again. The population decline was due to the chili plants at that age no longer having young leaves or their vegetative growth had stopped making them less suitable to be used as hosts for *B. tabaci* again.

The ability of corn crops to produce volatile compounds that were repellent to *B. tabaci* is strengthened by data on the catch of *B. tabaci* before and after the corn crops were harvested. Based on the observations, it was known that there was an increase in the population of *B. tabaci* after the corn plants were harvested at the age of 6, 8, and 10 WAP treatments, on the contrary there was a decrease in the *B. tabaci* population after the corn plants were harvested in the 2 WAP treatment (Figure 3). There was no significant difference in the population of *B. tabaci* before and after the corns were harvested at the age of 2 and 6 WAP. This could be due to the corn harvest time in the two treatments which had entered the rainy season. Corn harvest for treatments aged 2 WAP and 6 WAP were carried out in

October and November where the rainfall was higher than in September (harvest time for treatments 8 WAP and 10 WAP). Based on data from the Yogyakarta Climatology Station, in October and November, rainfall in Pleret District reached 380.4 mm and 666.6 mm (Meteorological, Climatological, and Geophysical Agency, 2023). This rainfall is much higher than when harvesting corn treatment aged 8 and 10 WAP which was carried out in September, namely 19.5 mm. According to Sudiono and Purnomo (2009), rainfall affects the population of *B. tabaci*, the higher the rainfall, the whitefly population decreases. The high intensity of rain causes the population of *B. tabaci* to naturally stress, drives insects away from the plants and can also affect microclimatic conditions through cooling (Dobkin *et al*., 1987; Kamata & Igarashi, 1994).

Incidence of Yellow Disease

The observation results showed that the incidence of yellow disease increased at each observation interval. The results of the analysis showed that the incidence of yellow disease in chili aged 30 and 60 DAP was not significantly different between the four treatments but significantly different from the controls. The incidence of yellow disease increased at the age of 45 DAP and there was no significantly difference between the corn treatment and the control. The incidence of yellow disease at the end of the observation (75 DAP) was not significantly different between the four treatments, but was significantly different between the 2 and 6 WAP corn treatments and the control (Table 1).

The incidence of chili yellow disease increased with the age of chili in all treatments and controls. Age treatment of corn crops did not affect the incidence of yellow disease. Based on statistical analysis, the incidence of yellow disease was significantly different in treatments 2 and 6 WAP compared to the control (without corn). The lowest incidence of yellow disease occurred in the chili plants accompanied by corn age 6 WAP. According to Jeger (2020), the occurrence of disease incidents in plants is influenced by several things such as virus virulence or the ability of viruses to cause disease, the influence of plant genotypes or varieties, and most importantly the influence of the abundance of insect vectors supported by environmental conditions. One of the factors that play a very important role in the spread of yellow disease caused by this virus is the presence of the insect vector of the virus, namely the whitefly (*B. tabaci*). The higher the population of *B. tabaci*, the higher the incidence of yellow disease (Narendra *et al*., 2017; Taufik *et al*., 2023; Temaja *et al*., 2022). *B. tabaci* transmits the yellow virus persistently from diseased plants to healthy plants. *B. tabaci* acquires the virus when it takes food from diseased plants or plants that have been infected with the yellow virus. The virus taken from diseased plants enters through the digestive tract, penetrates the intestinal wall, circulates in the insect's body fluids (hemolymph) and then in the salivary glands. When *B. tabaci* sucks food from healthy plants, the virus that has been in the salivary glands will indirectly enter the body of the plant along with the fluids from the insect's mouth.

The incidence of yellow disease increased at the age of 45 DAP and there was no significantly difference between the corn treatment and the control. This can be caused by transmission of yellow virus disease which has occurred since the vegetative phase, both in the treatment and control. The success of Gemini virus transmission is closely related to the vector insect and the incubation period. Selangga *et al.* (2019) stated that the incubation period for Gemini virus in chili plants ranges from 7–28 days after the plants are inoculated with the virus.

Results of the Repellent Test of Corn Volatile Compounds against *B. tabaci* Using an Olfactometer

The olfactometer test was only carried out on corn plants aged 6 WAP where the results of observations showed that the population of *B. tabaci* was the lowest compared to other corn age treatments. The results of the corn volatile compound repellent test against *B. tabaci* are shown in Table 2.

The percentage of repellent of corn volatile compounds against *B. tabaci* was 68.57 ± 27.53 (%) and entered class 4. The resulting repellent index comes from the greater number of *B. tabaci* in the control hand than the *B. tabaci* in the corn volatile compound treatment hand. The large number of *B. tabaci* in the control hand was because corn plants contain compounds that act as insect repellents. Repellent volatile compounds are produced from plant secondary metabolites, including: monoterpenes, diterpenoids, aromatic esters, flavonoids, and alkaloids. These compounds are obtained from all parts of the plant, namely flowers, leaves, shoots, and nectar (Pohan, 2014). The results of Tyasningsiwis *et al.*'s research (2019) which was conducted on a greenhouse scale showed that corn plants aged 6 MST produced citronellyl acetate compound which was repellent to *B. tabaci* with a rejection rate of 36.19 ± 10.50 in n-hexane solvent and 47.62 ± 5.83 in ethanol solvent.

CONCLUSION

Corn crops were able to resist the presence of *B. tabaci* on chili crops, and corn aged 6 WAP was proven to provide the most optimal rejection effect. However, the presence of corn crops did not significantly affect the incidence of yellow disease in chilies.

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APPENDIX

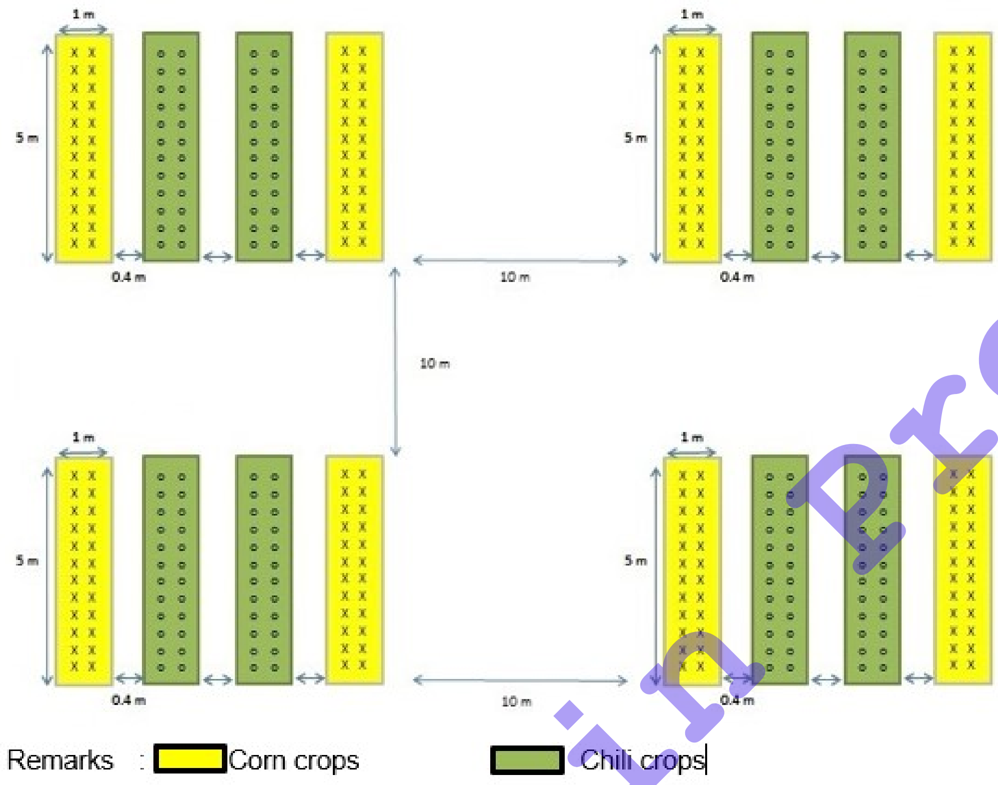

Figure 1. Chili and Corn Planting Design

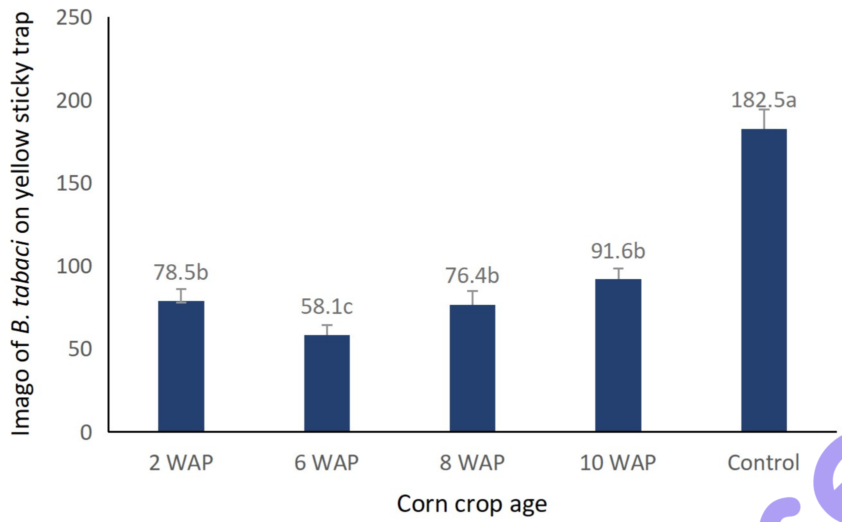

Figure 2. The population of *Bemisia tabaci* caught in the yellow sticky trap at each age treatment of corn crops. Numbers followed by different letters were significantly different according to Tukey Test (α = 0.05); WAP = weeks after planting

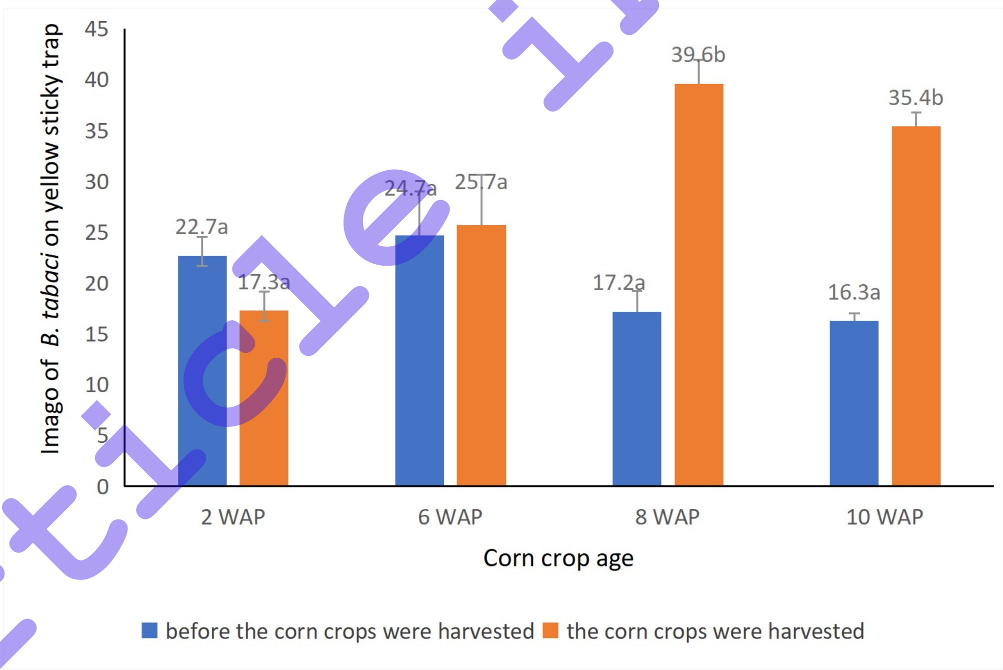

Figure 3. The population of *Bemisia tabaci* before and after the corn plants were harvested at each age treatment of the corn crops. Numbers followed by different letters were significantly different according to t-Test (α = 0.05); WAP = weeks after planting

Table 1. Incidence of yellow disease at various ages of corn planting

Age of Corn Planting	Incidence of yellow disease in chili crop (%)			
	30 DAP	45 DAP	60 DAP	75 DAP
2 WAP	2.67 ± 0.94^b	10.00 ± 0.78^a	20.33 ± 0.85^b	26.67 ± 1.67^b
6 WAP	2.33 ± 0.62^b	6.33 ± 0.88^a	15.67 ± 0.62^b	25.67 ± 1.10^b
8 WAP	2.67 ± 0.19^b	9.00 ± 0.62^a	18.33 ± 1.11^b	36.67 ± 0.78^{ab}
10 WAP	4.33 ± 0.24^b	8.00 ± 0.78^a	28.67 ± 0.78^b	45.33 ± 0.75^{ab}
Control	18.25 ± 0.95^a	19.00 ± 0.64^a	55.00 ± 1.51^a	60.00 ± 1.43^a

Remarks: Number followed by the same letter were not significantly different according to Tukey Test ($\alpha = 0.05$); WAP = weeks after planting; DAP = days after planting

Table 2. Results of the rejection test for corn volatile compounds against *Bemisia tabaci* with an olfactometer

Test	Imago on control (A)	Imago on corn volatile compound (N)	No response imago	Percentage of repellent (%)
1	6	2	2	66. 67
2	8	1	1	87.5
3	4	3	3	25
4	6	3	1	50
5	10	0	0	100
6	8	1	1	87.5
7	6	4	0	33.33
8	6	3	1	50
9	7	1	2	85.71
10	6	0	4	100
Average±SE				68.57±27.53