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Impact of weather factors and certain insecticides on the population density of cotton whitefly, *Bemisia tabaci* (Genn.) (Homoptera: Aleyrodidae)

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Abstract

Field experiments were conducted to study the impact of weather factors and certain insecticides on the population of cotton whitefly, *Bemisia tabaci* (Genn.) (Homoptera: Aleyrodidae) under cotton field conditions during 2013 and 2014 seasons. The cotton whitefly population started with average number of 0.83 and 0.33 insects/ plant in the 4th and the 2nd weeks of April and progressively increased throughout May and June during both seasons. The peak population of cotton whitefly reached 3.12 and 2.53 insects/ plant in average the 4th week of May and the 1st week of June. The results revealed that the relative humidity showed high significant negative correlation with the whitefly population, whereas, the maximum and minimum temperatures showed non-significant positive correlation. The foliar application of selected insecticides on the cotton whitefly under field conditions showed that all treatments caused significant reduction to whitefly population at 1, 7, 15 and 21 days after treatment as compared to the control. Thiamethoxam, malathion, and pirimicarb showed non-significant differences between them; and gave high efficiency reduction in whitefly population, as compared to acetamiprid, imidacloprid and dinotefuran. Thiamethoxam induced a maximum reduction in whitefly population with an average reduction of 80.72%. Malathion and pirimicarb showed similar effect with an average reduction of 50.23 to 46.82%. In contrast acetamiprid and dinotefuran showed intermediate results and were statistically similar in their efficiency with an average reduction of 20.08 and 38.88% during 2013 season. During 2014 season, imidacloprid and thiamethoxam caused the highest population reduction with an average 70.43 and 60.63%, whereas, acetamiprid and dinotefuran showed intermediate effect and were statistically similar in their efficiency with an average reduction of 44.78 and 45.48%. Results of this study indicated that the foliar application of neonicotinoid insecticides were highly effective against cotton whitefly, followed by pirimicarb and malathion in cotton fields.

Keywords: cotton whitefly, weather factors, insecticides efficiency, cotton.

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Introduction

The cotton whitefly, *Bemisia tabaci* (Homoptera: Aleyrodidaeis) is a virus-transmitting hemipteran herbivore with a wide host range (Brown et al., 1995). It is among the world's most invasive species and has devastating effects on cotton, vegetable and ornamental plant species (Vázquez et al., 1997; Williams et al., 1996). This insect not only inflicts direct damage to plants through phloem consumption, honeydew secretion, and triggering uneven ripening of fruits (Schuster, 2001; Matsui, 1992), but also causes indirect damage by vectoring more than 100 different viruses and by promoting the growth of a saprophytic fungi on the leaves (Valverde et al., 2004; Oliveira et al., 2001). Besides the variety of reasons of the low yield of cotton, the insect pests cause heavy qualitative and quantitative losses varying from 40-50% (Naqvi, 1976). Among sucking insect pests, *B. tabaci* is designated as a key pest, responsible for cotton leaf curl virus (CLCV) and development of sooty mould on the leaves of cotton, interrupting photosynthesis and contributing for low yield (Umar et al., 2003). In Egypt, *B. tabaci* had two peaks of abundance during June 20th and August 23rd (El-Ghobary, 2011), and at El-Gharbia Governorate the infestation of white fly started with low numbers in the 2nd week of April for the three planting dates. The population tended to increase gradually reaching a maximum in the 1st week of September (Radwan et al., 1997). El-Dewy (2006) at Kafr El-Sheikh, recorded two *B. tabaci* peaks on cotton plants by late August and late September. Then after, a sharp decline was recorded towards the end of the cotton season. Chemical control is an essential component of crop protection in modern agriculture, although over-reliance on insecticides has resulted in resistance problems, ecological disturbances and higher costs to the growers (Horowitz & Ishaaya, 1996). In addition, difficulties in the registration of new insecticides have led to a decrease in the number of insecticides available for controlling whiteflies in many countries. For the last two decades, *Bemisia* control was based exclusively on conventional insecticides such as organochlorines, organophosphates, carbamates and pyrethroids (Sharaf, 1986). However, conventional insecticides did not, in many cases, achieved comprehensive control because of the presence of immature stages and adults of whitefly on the underside of the leaves and of rapid development of resistance to these insecticides (Henneberry, 1993; Henneberry & Butler, 1992; Johnson et al., 1982). At the beginning of the 1990s, insecticides with novel modes of action and selective properties, such as buprofezin, pyriproxyfen, diafenthiuron and imidacloprid, were found to be very effective for controlling developmental stages of *Bemisia* in cotton and other crops (Horowitz et al., 1994). However, to delay the onset of resistance in *Bemisia* to novel insecticides as well as to the effective conventional types, management strategies should be implemented in multi-crop systems (Horowitz & Ishaaya, 1996). Imidacloprid (Admire®, Confidor®), a nitromethylene analog, is a highly effective systemic insecticide for controlling sucking insects including *Bemisia*, with low mammalian toxicity (Leicht, 1993; Mullins & Engle, 1993; Elbert et al., 1990). It acts as an agonist by binding to the nicotinergic acetylcholine receptor in the post-synaptic region of the insect nerve and causes sodium ion channels to open, thus exerting a lethal effect (Bai et al., 1991). Due to its systemic properties, imidacloprid is suitable for seed treatments and drench applications, although foliar sprays are also effective under field and greenhouse conditions (Mullins & Engle, 1993; Elbert et al., 1990; Oetting & Anderson, 1990). New compounds of the same chemical class, such as acetamiprid (Takahashi et al., 1992) are under development. The present study was undertaken to determine the impact of weather factors and the efficiency of foliar treatment of four neonicotinoid insecticides acetamiprid, imidacloprid, thiamethoxam and dinotefuran in comparison with the commonly used malathion (organophosphate) and pirimicarb (carbamate) on the population density of cotton whitefly under cotton field conditions.

Materials and methods

Population fluctuations of cotton whitefly: An area (ca. ¼ feddan) (feddan= 4200 m^2) was cultivated by Egyptian cotton (*Gossypium barbadense*) cultivar Giza 90 (the most commonly grown variety in Assiut governorate) and divided into 36 plots, 3.5 meter long by 3-meter wide (1/400 feddan). This area was planted by the cotton variety on March 15, 2013, and on March 21, 2014. The normal agricultural practices were performed. The direct count was used as a sampling method. When the plants started to appear, samples at weekly intervals consisted of 30 seedlings (i.e. 10 seedlings/ plot) were taken at random for counting the cotton whitefly (*B. tabaci*). Seedlings were placed individually in muslin bags, and transferred to the laboratory for examination and counting the adults of whiteflies. Investigations took place as soon as the plants appear above the ground and continued until the end of the seedling stage. Then 30 cotton plants (i.e. 10 plants/ plot) were chosen at random and the cotton whitefly were counted directly in the field every week till the end of the season.

Effect of three weather factors on population fluctuations of cotton whitefly: Direct count technique was used for counting the adults of whitefly. The daily records of the day maximum temperature, minimum temperature and daily mean relative humidity were obtained from the meteorological station located close the experimental area at the University of Assiut Experimental Farm, Egypt. Correlation coefficient values (r) were first estimated by SPSS software ver. 16.

Pesticides used on cotton whitefly on cotton plants: Tested pesticide trade names, formulation types, the percentage of active ingredients, and application rate are listed in Table1. The pesticide concentrations used in this study were based on the labeled recommendation rate. Tested neonicotinoid (acetamiprid, imidacloprid, thiamethoxam and dinotefuran), carbamate (pirimicarb) and organophosphate (malathion) insecticides were distributed in a randomized complete block design (RCBD) in three treated replications and untreated control. A knapsack sprayer with one nozzle covering 200 liters per feddan (feddan= 4200 m^2) was used in the application. Insecticides were applied on April 7 and on April 28 for cotton whitefly during 2013. In 2014 season the same insecticides were applied on April 15 and on May 6. Ten plants were randomly selected from each replicate before and after treatment at periods of 1, 7, 15 and 21 days of treatment for evaluating the efficiency and the residual activity of these insecticides on cotton whitefly population. To determine the field efficiency of the tested insecticides (after 1, 7, 15 and 21 days of spraying). The percentages of cotton whitefly reduction were calculated according to Henderson & Tilton's equation (1955).

$$\text{Reduction \%} = \left(1 - \frac{\text{n in Co before treatment} * \text{n in T after treatment}}{\text{n in Co after treatment} * \text{n in T before treatment}}\right) * 100$$

Where: n = insect population, T= treatment, Co= control

Data presentation and statistical analyses: Data were analysed using one-way ANOVA and presented as mean ± S.E.M (Standard Error of Mean). Means were separated by Duncan's Multiple Range Test (DMRT) and Tukey's Multiple Comparison Test (TMCT). Figures and statistical analysis were done using Graph Pad Prism 5^{TM} (San Diego, CA) and SPSS ver. 16 software.

Table 1: Descriptions of the insecticides used against sucking insect pests and their insect predators under cotton field conditions.

Active ingredient (a.i.)	Trade name	% (a.i.) and formulation type*	Manufacturer	Recommended rate
Acetamiprid	Mospilan®	20% SP	Nippon Soda Ltd.	25mg L^{-1}
Imidacloprid	Confidor®	20% SC	Bayer CropScience	0.5ml L^{-1}
Thiamethoxam	Actara®	25% WP	Syngenta Agro	50mg L^{-1}
Dinotefuran	Ochin®	20% SG	Mitsui Chemicals	50mg L^{-1}
Malathion	Malathon®	57% EC	Sinochem Ningbo Chemicals	5ml L^{-1}
Pirimicarb	Aphox®	50% DG	Syngenta Agro	31.2mg L^{-1}

*SP: Soluble powder, SC: Suspension concentrate, WP: Wettable powder, SG: Soluble granules, EC: Emulsifiable concentrate, DG: Dispersible granules.

Results and Discussions

Population density and fluctuation of cotton whitefly: Data of population fluctuation of the cotton whitefly, *B. tabaci* adult stages throughout the cultivated period during 2013 and 2014 seasons are presented in Figures (1 A, B, C and D). During 2013 season, the cotton whitefly population started with an average of 0.83 insect/ plant at the 4th week of April (Max. temp. 39.06 °C, Min. temp. 19.94 °C and RH 51%) and progressively increased throughout May and June. The peak population of cotton whitefly reached 3.12 insects/ plant at the fourth week of May (Max. temp. 40.66 °C, Min. temp. 21.29 °C and RH 35%) (Fig. 1 A, B). In 2014 season, cotton whitefly started with low numbers in the 2nd week of April (0.33 insect/plant in average) (Max. temp. 32.66 °C, Min. temp. 14.14 °C and RH 45.29%). The population increased gradually to reach its maximum at the 1st week of June with 2.53 insects/ plant in average (Max. temp. 39.60 °C, Min. temp. 21.54 °C and RH 33.93%) (Fig. 1 C, D). Several studies indicated that, *B. tabaci* had two peaks of abundance during June 20th and August 23rd (El-

Ghobary, 2011), and at El-Gharbia governorate the infestation of white fly started with low numbers in the 2nd week of April for the three planting dates. The present results are in contradiction with those obtained by Radwan et al. (1997) who found that, the population of *B. tabaci* tended to increase gradually reaching the maximum at the 1st week of September. Whereas, El-Dewy (2006) at Kafr el-Sheikh, recorded two *B. tabaci* peaks on cotton plants by late August and late September. Then after, a sharp decline was recorded towards the end of the cotton season. Arif et al. (2006) at Pakistan reported that *B. tabaci* had two peaks on cotton during the fourth week of August and the first week of September. In China, Zhang et al. (2013) studied the density seasonal dynamics of *B. tabaci* on cotton and six other co-occurring common plants and found that weeds esp. the common ragweed (*Ambrosia artemisiifolia* L.) around cotton fields increase the population density of *B. tabaci* on cotton, while sunflower could act as a trap crop for decreasing pest pressure on cotton.

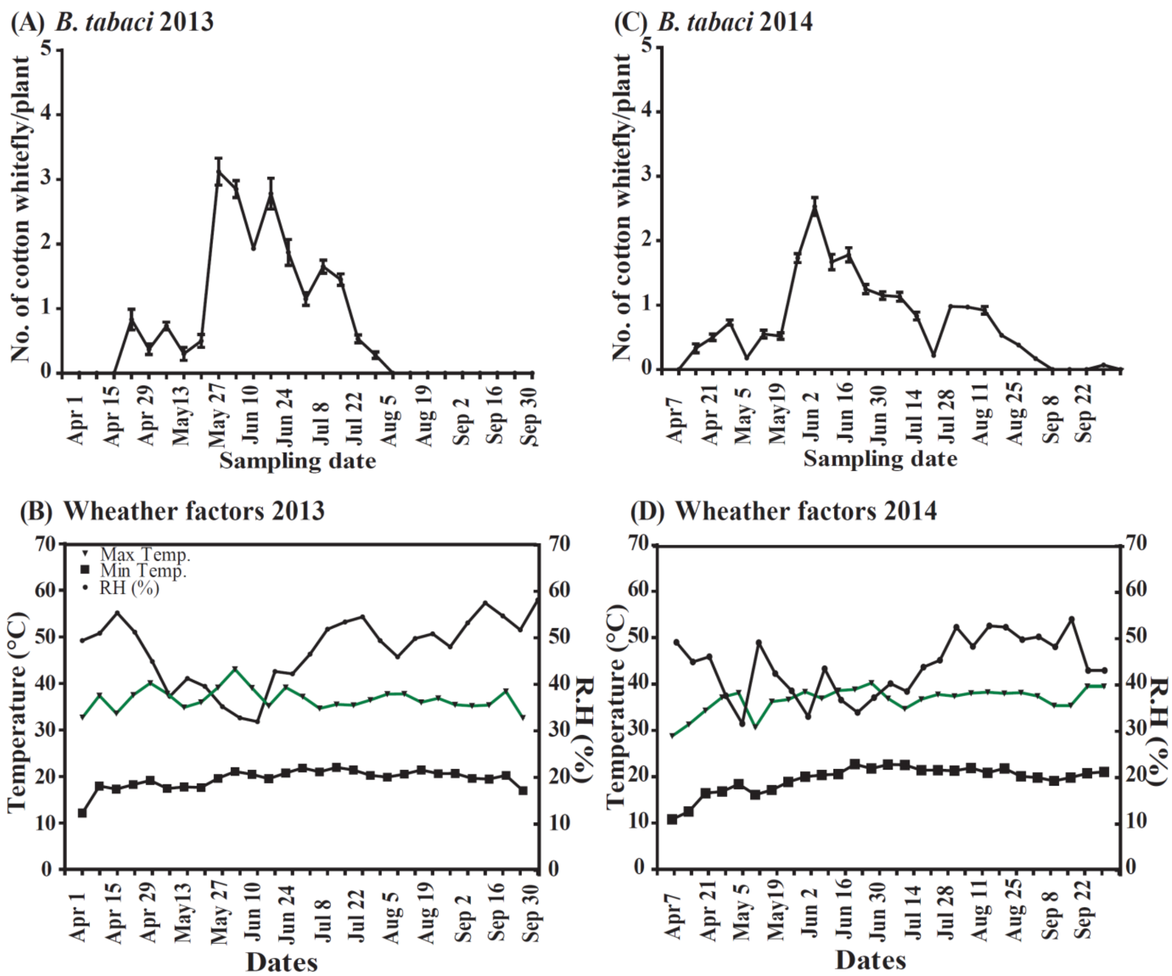

Figure 1: Population fluctuation of cotton whitefly, *B. tabaci* and weather factors during 2013 (A, B) and 2014 (C, D) seasons in Assiut governorate, Egypt.

Mogahed (2016) reported that, the population of cotton whitefly, *B. tabaci* had three main peaks in growing season (July, August and September) with Temp. (26.2-26.6 °C), R. H. (68.3-69.0 %), wind speed (0.77-0.90 m/sec.) and sunshine duration (12.4-13.9 hr), however, the lowest population of whitefly was recorded in May with Temp. 23.0 °C), R. H. (51.7 %), duration (13.6 hr). The difference in the results of present studies and the others may be due to the weather factors and/or the distribution of the host plants of whitefly and the weeds around the cotton fields and biotic factors.

Effect of weather factors on population of cotton whitefly: During 2013 season, the results revealed that, the relative humidity showed significant negative correlation (r = -0.627**)** with the whitefly population, whereas, the maximum (r = 0.463**)** and minimum (r = 0.293**)** temperatures showed non-significant positive effects. The effect of maximum temperature had non-significant (r = 0.229) positive effects on the whitefly population during 2014 season. Whereas the minimum temperature had significant positive effect (0.338). Relative humidity showed high significant and negative correlation (r = -0.352) with whitefly population (Table 2). Akram et al. (2013) reported that, the Bt cotton genotypes, maximum and minimum temperature showed significantly and positive effect on whitefly population, whereas relative humidity exhibited negative effect during 2010. During 2011, the effects of all studied weather factors were non-significant. On a cumulative basis, there was a positive correlation between the population of whitefly and minimum temperature. But in the case of non-Bt, it has negative with maximum temperature whereas relative humidity had a positive effect on whitefly population. Riaz et al. (1987) studied the influence of environmental conditions on the sucking insect pests of cotton and their chemical control. The temperature had a momentous and positive effect on whitefly population with r-values of 0.86. Non-significant effect existed among relative humidity and insect pest populations. On whitefly the combined effect of temperature and relative humidity was high (86.50 and 75.00 %). Wahla et al. (1996) studied the effect of seven physical environmental factors viz., maximum temperature, minimum temperature, temperature fluctuations, mean temperature, relative humidity, sun shine hours and rainfall on the population dynamics of sucking insect pests of cotton variety “FH-87”. They found that change in temperature was positively correlated to the population of sucking insect pests as against those in the minimum temperature as well as that in the relative humidity, which was negatively correlated.

Table 2: The relationship between the weather factors, maximum, minimum temperature and relative humidity and the population density of cotton whitefly, *B. tabaci* during 2013 and 2014 seasons.

Seasons	Correlation coefficient values “r”		
	Max. Temp. (°C)	Min. Temp. (°C)	RH (%)
2013	0.463 ns	0.293 ns	-0.627**
2014	0.229 ns	0.338*	-0.352**

ns: non-significant p >0.05, *p< 0.05, **p<0.01.

Impact of selected insecticides on the population of cotton whitefly: The results of the efficacy of selected insecticides for control of cotton whitefly, *B. tabaci* at 1, 7, 15 and 21 DAT during 2013 season under field conditions are shown in Figures 2 and 3. Foliar application of selected insecticides on the cotton whitefly under field conditions showed that all treatments caused a significant reduction in whitefly population at 1, 7, 15 and 21 DAT as compared with the control. Thiamethoxam, malathion and pirimicarb showed non-significant differences between them; and gave high efficiency reduction against whitefly compared to acetamiprid, imidacloprid and dinotefuran. Thiamethoxam induced a maximum reduction in whitefly population, 98.32, 56.49, 78.07 and 90.01% after 1, 7, 15 and 21 days, respectively, and with average reduction 80.72%. Malathion caused 74.91, 65.52, 48.49 and 12.11%; malathion and pirimicarb had a similar effect with an average reduction of 50.23 to 46.82%. In contrast acetamiprid and dinotefuran showed intermediate results and were statistically similar in their efficiency ranged from -5.75 to 53.41% and from -10.08 to 73.38% at different dates respectively, with an average reduction 20.08 and 38.88% during the 1st treatment (Fig. 2). For the 2nd treatment all of the insecticides induced a low reduction percent at different dates (Fig. 3).

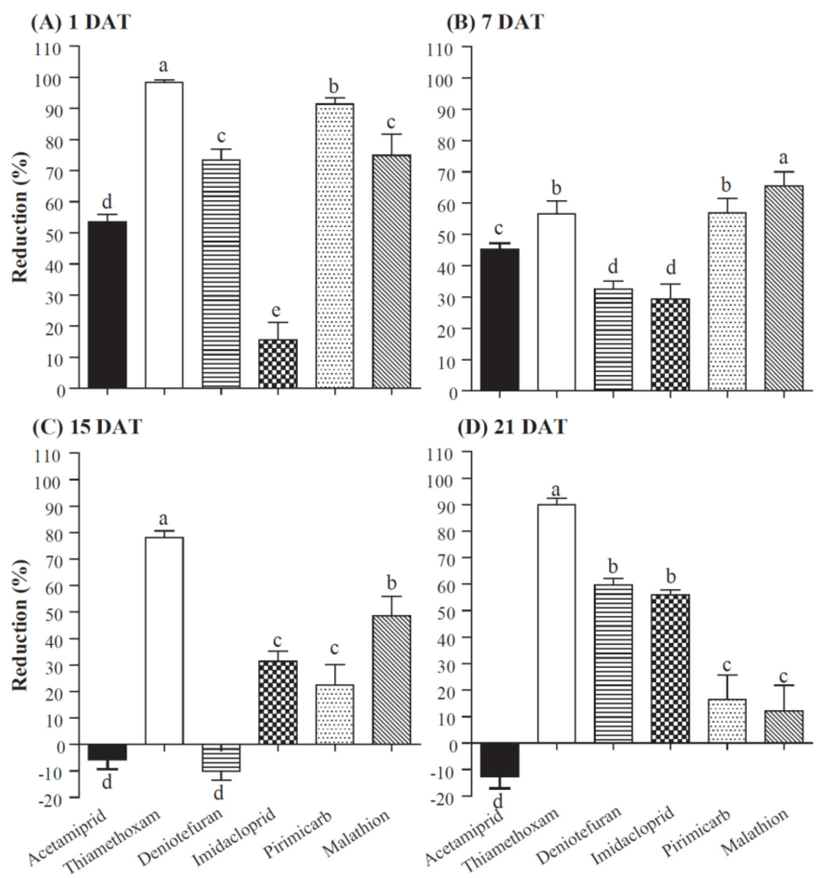

Figure 2: Efficacy of selected insecticides for control of cotton whitefly, *B. tabaci* at 1 DAT (A), 7 DAT (B), 15 DAT (C) and 21 DAT (D) during 2013 season (1st treatment) under field conditions. Data are expressed as means ± standard error (SE) of three replicates at each insecticide. DAT: Day after treatment. Columns headed by the same letter (s) within the same figure are non-significantly different ($P \leq 0.05$) according to DMRT.

The average reduction percentage in cotton whitefly population caused by acetamiprid, thiamethoxam, dinotefuran, imidacloprid, pirimicarb and malathion were 36.45, 22.91, 16.51, 19.84, 6.88 and 23.29% respectively. The reduction percentage in the population decreased over the time may be as the whitefly was more tolerant to these insecticides or because of the residual activity of these insecticides decreased due to environmental factors over time. However, conventional insecticides did not, in many cases, achieved comprehensive control because of the presence of immature stages and adults on the underside of the leaves and of rapid development of resistance to these insecticides (Henneberry, 1993; Henneberry & Butler, 1992; Johnson et al., 1982). Other non-conventional chemicals such as benzoylphenyl ureas (Ishaaya et al., 1989; Ascher & Eliyahu, 1985), fenoxycarb (Lindquist & Casey, 1991) and abamectin mixed with oil (unpublished data), acetamiprid (NI-25) showed high efficacy against whiteflies (Takahashi et al., 1992).

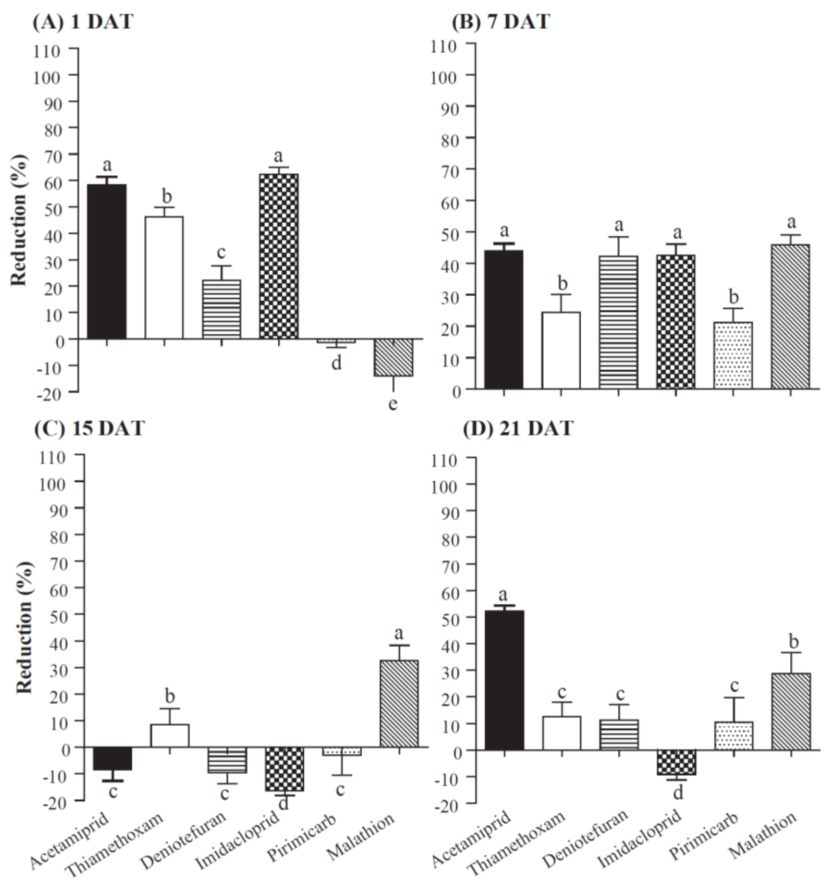

Figure 3: Efficacy of selected insecticides for control of cotton whitefly, *B. tabaci* at 1 DAT (A), 7 DAT (B), 15 DAT (C) and 21 DAT (D) during 2013 season (2nd treatment) under field conditions. Data are expressed as means ± standard error (SE) of three replicates at each insecticide. DAT: Day after treatment. Columns headed by the same letter (s) within the same figure are non-significantly different ($P \leq 0.05$) according to DMRT.

The population reduction of the cotton whitefly population showed a significant variation after 1, 7, 15 and 21 days when treated with acetamiprid, thiamethoxam, dinotefuran, imidacloprid, pirimicarb and malathion during 2014 season. The average reduction of *B. tabaci* population ranged from 44.78 to 70.43% through the 1st spray (Fig. 4). Imidacloprid and thiamethoxam caused the highest population reduction with an average of 70.43 and 60.63%. Whereas, acetamiprid and dinotefuran showed intermediate effects and were statistically similar in their efficiency which ranged from -9.58 to 72.39% and from -6.26 to 69.94% at the different date, respectively, with an average reduction of 44.78 and 45.48% during the 1st treatment (Fig. 4). For the 2nd treatment similar trend was observed on the efficiency of selected insecticides on the population reduction at different dates (Fig. 5). Acetamiprid, thiamethoxam, dinotefuran, imidacloprid, pirimicarb and malathion caused significant reduction percentages with an average ranged from 19.27 to 68.15%. Acetamiprid caused the highest reduction (68.15%) followed by malathion (55.83%) and dinotefuran (48.74%). In contrast, imidacloprid and thiamethoxam showed the lowest reduction with an average of 19.27 and 12.33%.

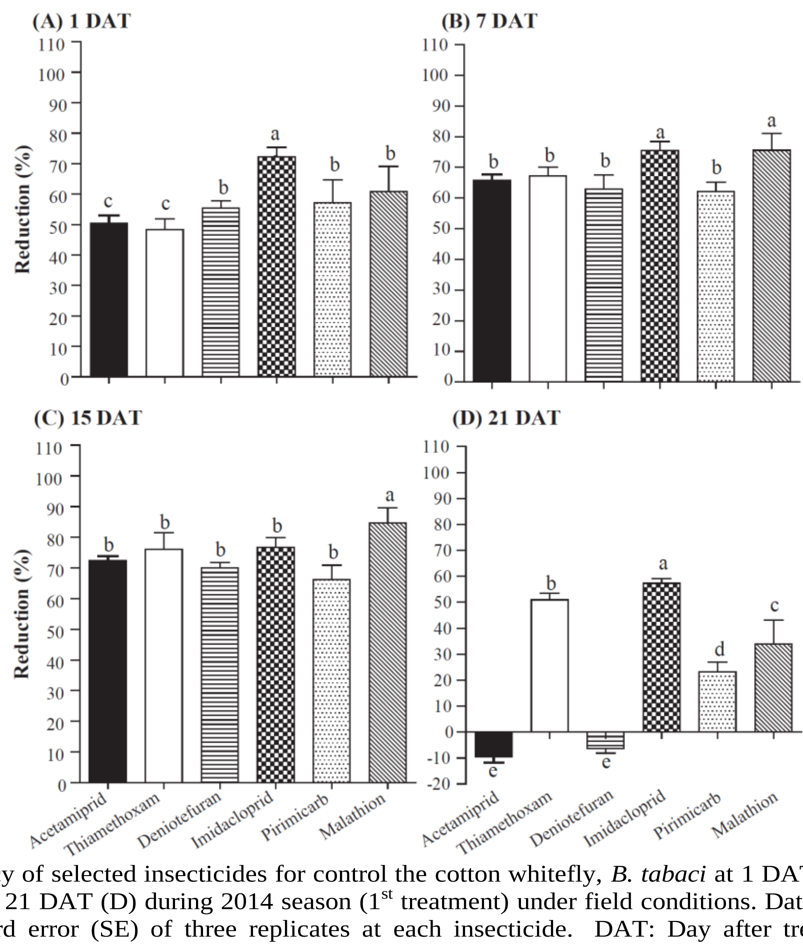

Figure 4: Efficacy of selected insecticides for control the cotton whitefly, *B. tabaci* at 1 DAT (A), 7 DAT (B), 15 DAT (C) and 21 DAT (D) during 2014 season (1st treatment) under field conditions. Data are expressed as means ± standard error (SE) of three replicates at each insecticide. DAT: Day after treatment. Columns headed by the same letter (s) within the same figure are non-significantly different ($P \leq 0.05$) according to DMRT.

Contradictory results in comparison to the present study were obtained by Amjad et al. (2009), who reported that confidor (imidacloprid) gave effective control of whitefly population while in our study confidor proved to be the intermediate insecticide for the control of whitefly. As a result, it has developed a high level of resistance to conventional (organophosphates and carbamates) as well as to neonicotinoids and insect growth regulators (IGRs) (Nauen & Bretschneider, 2002; Elbert et al., 1998; Cahill et al., 1996; Horowitz & Ishaaya, 1994). In many cropping systems, the capacity of *B. tabaci* to evolve resistance has precipitated a classic treadmill of increasing numbers of applications and rapid depletion of ejective control agents (Denholm et al., 1998; Dennehy & Williams, 1997; Denholm et al., 1996; Horowitz et al., 1994; Byrne et al., 1992; Dittrich et al., 1990). The use of insecticides against *B. tabaci* is common; however, they are not very effective because the adult insects are located on the abaxial surfaces of leaves. Moreover, the insects rapidly develop resistance against these products (Luan et al., 2013; Horowitz & Ishaaya, 1995).

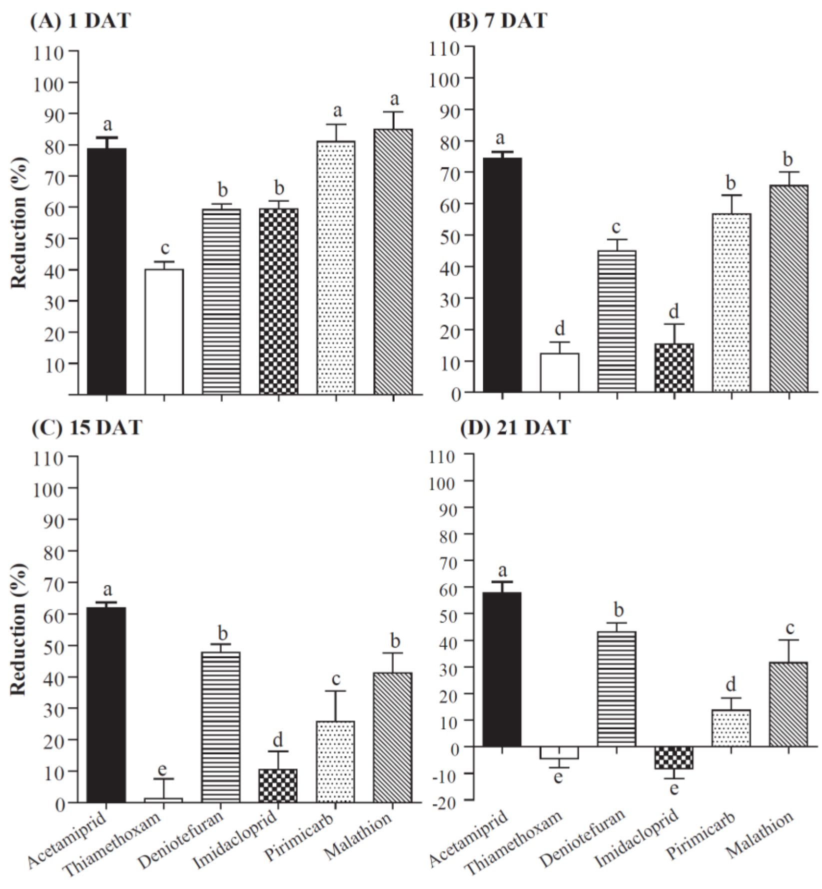

Figure 5: Efficacy of selected insecticides for control the cotton whitefly, *B. tabaci* at 1 DAT (A), 7 DAT (B), 15 DAT (C) and 21 DAT (D) during 2014 season (2nd treatment) under field conditions. Data are expressed as means ± standard error (SE) of three replicates at each insecticide. DAT: Day after treatment. Columns headed by the same letter (s) within the same figure are non-significantly different ($P \leq 0.05$) according to DMRT.

The obtained results showed that the effects of the insecticides on cotton whitefly can strongly vary depending upon various factors, such as the application methods, the insecticide chemical family and the insecticide concentration considered climatic condition and host plants. Generally, it could be concluded that the neonicotinoid insecticides acetamiprid, thiamethoxam, dinotefuran and imidacloprid can be used to control cotton whitefly, *B. tabaci*, followed by carbamate (pirimicarb) and organophosphorus (malathion) in cotton fields. Regarding the residual effect of these insecticides which they were highly persistent up to 21 DAT. These insecticides could be arranged in ascending order as follows: thiamethoxam > acetamiprid > imidacloprid > dinotefuran > pirimicarb > malathion for controlling the cotton whitefly. Thus, the neonicotinoid insecticides still provide a good efficiency against cotton whitefly under field conditions but, the problem is that this pest can develop resistance very quickly for these insecticides. Therefore, these insecticides should be used in an orderly manner and applied in a control program to prevent whitefly to develop resistance.

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