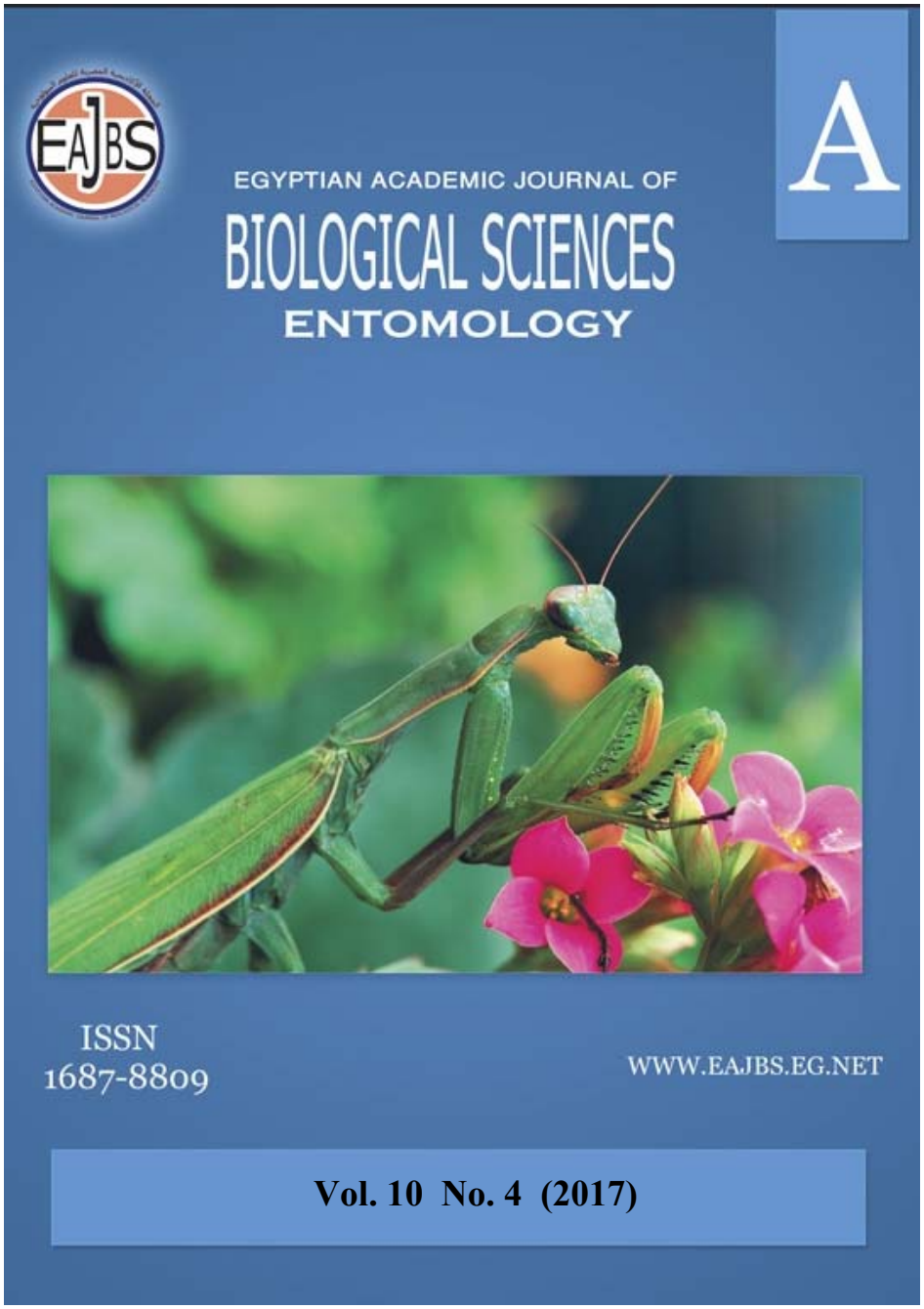

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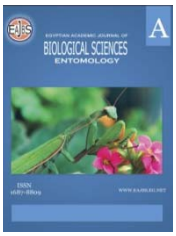

Efficacy of kaolin Foliar Application Aga inst Tomato Whitefly; *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae)

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ABSTRACT

Nowadays, nonchemical pest control replacements are being required. This research aims to study the efficacy of Kaolin (clay mineral) foliar application on the development of whitefly *Bemisia tabaci* (Genndius) (Hemiptera: Aleyrodidae) population on tomato plants. Two field experiments were performed at Qalubiya governorate, Egypt through three successive seasons (2014, 2015 and 2016). The first experiment was carried out in 2014 to evaluate the reduction effect of two Kaolin concentrations (2.5% and 5% W/V)) compared with two recommended pesticides; Acetamiprid (Mospilan SP 20) and Orange oil (Prev-AM) on *B. tabaci*. The results revealed that the initial effect of Acetamiprid and kaolin 5% were superior in activity with 91.6% and 90.1% reduction in whitefly adults population. Similar efficacy for Acetamiprid and 5% Kaolin were found on nymphs (89% and 85.7% respectively). The second experiment was conducted to study the impact of repeated foliar applications of Kaolin; 2.5% and 5% (W/V), compared with the two insecticides; Acetamiprid (Mospilan SP 20) and Orange oil (Prev-AM), on population fluctuation of whitefly stages (adults and nymphs) during summer plantation of 2015 and 2016 seasons. For both studied seasons no significant differences were found between the main numbers of whitefly adults recorded on plants treated with either Acetamiprid (3.5 and 4.1 adult/leaf) or Kaolin 5% (4.6 and 5.0 adult/leaf). Moreover, no significant differences were found between orange oil treatment (9.4 and 10.0 adult / leaf) and Kaolin 2.5% treatment (8.9 and 9.5 adult/leaf). Similar trends were obtained with whitefly nymphs where, Kaolin 5% and Acetamiprid had the same reduction effect. In conclusion, the use of Kaolin foliar application can be considered in a program of agricultural management since it can control a high percentage of whitefly; Kaolin particles act as a barrier repelling infestations.

INTRODUCTION

Tomato whitefly, *Bemisia tabaci* (Genndius) (Hemiptera: Aleyrodidae) is a major pest of economically important crops worldwide; it is considered one of the most intractable and damaging pests that attacking vegetables, crops and ornamentals worldwide (Perring, 2001; carabali *et al*., 2005; Touhidul and Shunxiang, 2007; Abdel-Baky and Al-Deghairi, 2008; Cuthbertson and Vänninen 2015). *Bemisia tabaci* is the most destructive insect pest attacking tomato plant, *Lycopersicon esculentum* (Schuster 2003). Since late 1980's the insect has risen from relative insignificance to become one of the crucial insect pests of agricultural crops (Lin *et al*., 2007) and that may due to not only its direct damage by sucking plant phloem sap but also its transition of various viral diseases (Oliveira *et al*. 2001; Al-Deghairi, 2009).

Chemical control has been widely used for the management of *B. tabaci*. However, applications of chemicals have not been totally effective, due to that frequent and often excessive chemical applications have resulted in development of resistance against these chemicals, with subsequent population outbreaks (Palumbo *et al*., 2001). Chemical applications alone are not sufficiently effective to suppress all developmental stages of the pest. Moreover, natural enemies of *B. tabaci* could be effective but populations of these natural enemies suffer after repeated chemical applications (Gonzalez-Zamora *et al*., 2004). Further, during heavy pest infestations, the activities of natural enemies alone are insufficient to prevent economic losses of the host crops.

Some physical methods such as oils have been used for pre-harvest treatments for decades as novel approaches to control insect pests. Another recently developed method for pre-harvest situations is particle films. Spraying canopies with a suspension of Kaolin clay mineral, cover the plant leaves with a thin Kaoline particle film, consider one of the physical control methods (Vincent *et al*., 2003 and Benhadi-Marín *et al*., 2016). Kaolin is a white, non-porous, non-swelling, non-abrasive alumino-silicate natural clay mineral ($Al_4Si_4O_{10}[OH]_8$) that easily disperses in water and is chemically inert over a wide pH range (Glenn *et al*., 1999 and Glenn and Puterka, 2005). This methodology has efficiently inhibited plant diseases and several plant-feeding and virus-vector arthropods such as *Bemisia argentifolii* (Homoptera: Aleurodidae) on melon (Liang and Liu, 2002); *Circulifer tenellus* (Baker) (Homoptera: Cicadelidae) on chili pepper (Creamer *et al*., 2005); *Aphis spireacola* Patch (Homoptera: Aphididae), *Cacopsylla pyricola* Foerster (Hemiptera: Psyllidae), *Tetranychus urticae* Koch (Acarina: Tetranychidae) and *Empoasca fabae* (Harris) (Homoptera: Cicadelidae) in pear and apple (Glenn *et al*., 1999); *Cydia pomonella* (Linnaeus) (Lepidoptera: Torticidae) in apple and pear (Unruh *et al*., 2000); and boll weevil; *Anthonomus grandis grandis* Boheman (Coleoptera: Curculionidae) in cotton (Liang and Liu, 2002). Moreover, studies carried out on soybean, cotton, melons and peach have shown that kaolin particle films foliar applications reduced plant stress that is important for plant growth and quality (Creamer *et al*., 2005). According to Glenn, (2016) the nature of the film does not seem to affect plant photosynthesis or productivity. In addition, use of Kaolin can have positive effects on the plant physiology (Glenn and Puterka, 2002). It has also been stated that leaf temperature and/or fruit decreased (Wünsche *et al*., 2004) and the chlorophyll content increased with kaolin particle film (Segura-Monroy *et al*., 2015).

Therefore, the main objective of the current study is to assess the impact of Kaolin foliar application on different stages of whitefly *B. tabaci* Genn. populations comparing with recommended insecticides on tomato plants.

MATERIALS AND METHODS

In order to achieve the objective of this investigation, two field experiments were carried out. The experiments conducted at Qalubiya governorate, Egypt during three successive seasons; 2014; 2015 and 2016. The experimental area was 672 m^2 and divided into 20 plots (each plot were 33.6 m^2) cultivated with tomato plants; *Lycopersicon esculentum* Mill.

Tomato seedlings (Super Strain variety) were transplanted in the open field in the first week of May each studied season. The plots were arranged in a randomized complete block design with four replicates for each treatment. Five treatments were

considered. All recommended agricultural practices were followed during the growing season.

First experiment:

This experiment was carried out in summer plantation of 2014 to assess the efficacy of Kaolin, chemical pesticide (Acetamiprid) and essential oil (Orange oil) on the adults and nymphs populations of whitefly; *B. tabaci*. Five treatments were applied, as a single foliar spray, after 21 days of seedling. The treatments were; control (without any insecticide), Acetamiprid (Mospilan SP 20) (25g/100L.) and Orange oil (Prev-AM) 400cm^3/100L.), Kaolin 2.5% and 5% (W/V). Adult and nymph stages of whitefly, *B. tabaci* were counted pre-treatment and after 1, 3, 5, 7 and 10 days of application. The reduction percentage for each treatment was calculated. The methodology of Henderson and Tilton (1955) was followed.

Second experiment:

In order to compare the impact of Kaolin spry with Acetamiprid and Orange oil, the second experiment was conducted during two successive seasons (2015 and 2016). Kaolin suspension (2.5 and 5% w/v), Acetamiprid, Orange oil and control treatments were applied with a Knapsack sprayer until the foliage was thoroughly coated. In the control, fresh water was sprayed with the same sprayer. The applications were repeated every 15 days until the fruit ripening stage.

The plants were visually examined in the field with counting the whitefly mature stage (adults). To count whitefly immature stage (nymphs), 20 leaves were collected randomly from each replicate in paper bag and transferred to the laboratory to examine using binocular. Sampling procedures were started 21 days after seedlings plantation at weekly intervals and continued till the end of season.

Statistical Analyses

Different methods of data analysis have been employed in this study. The reduction for each treatment was calculated according to Henderson's formula (Henderson and Tilton 1955). Also, SAS Institute (2003) was used to compute ANOVA ($P<0.05$).

RESULTS AND DISCUSSION

Effect of single application of some foliar applications on whitefly

Tables (1 and 2) show the percentage of reduction of whitefly populations (adult and nymph) under single application of the studied treatments at 1, 3, 5, 7 and 10 days.

The initial effect (24 hours after spraying) of Acetamipride and Kaolin 5% were superior in whitefly adult population reduction (91.6% and 90%) followed by 2.5% kaolin (77.5 %). The lowest reduction percentage was 63.7% caused by Orange oil (Table 1). Foliar application of Acetamipride and 5% Kaolin showed a similar efficacy on whitefly nymphs (89% and 85.7% respectively). Furthermore, the general reduction percentage cleared that there were no significant differences between Acetamipride and 5% Kaolin applications on both studied whitefly stages (adults and nymphs) (85.1% and 83.5%) and (77.7% and 76.9%), respectively. Also, the differences between the reduction percentages of 2.5% Kaolin and Orang oil (68.8% and 67.9%) and (66.1% and 64.4%) were not significant.

Table 1: Efficacy of some treatments on the percentage of reduction of the whitefly, *Bemisia tabaci* (Gennadius) adults on tomato plants.

Treatments	Pre-treatment	Mean number of adult/ leave: Post treatment observation: 24 hours		3 days		5 days		7 days		10 days		General mean	General reduction
		No	R%	No.	R%	No.	R%	No.	R%	No.	R%	No.	R%
Acetamipride 20% SP	9.4	1.0	91.6	1.3	90.7	2.1	88.6	3.2	82.8	5.4	72	2.6	85.1a
Kaolin 5%	8.3	1.0	90.1	1.4	89.6	2.2	86.7	3.1	81.1	5.1	70	2.56	83.5a
Kaolin 2.5 %	8.9	2.4	77.5	3.3	76.2	5.8	67.5	6.3	64.7	7.7	58	5.1	68.8b
Orange oil	7.8	3.4	63.7	2.1	83.3	4.9	67.1	5.2	65.6	6.4	60	4.4	67.9b
Untreated	6.3	7.6	-	10	-	12.4	-	12.5	-	13.0	-	-	-

a, b mean there is significant difference using ANOVA test at P< 0.05.
R% reduction percentage

Table 2: Efficacy of some treatments on the percentage of reduction of the whitefly, *Bemisia tabaci* (Gennadius) nymphs on tomato plants**.**

Treatments	Pre-treatment	Mean number of larvae/leave: Post treatment observation: 24 hours		3 days		5 days		7 days		10 days		General mean	General reduction
		No	R%	No.	R%	No.	R%	No.	R%	No.	R%	No.	R%
Acetamipride 20%SP	12	1.5	89.0	1.8	87.3	3.3	80.6	4.5	71.2	6.5	60.6	3.5	77.7 a
Kaolin 5%	11.3	1.8	85.7	2.0	86.5	3.0	79.3	5.0	70.3	6.0	62.9	3.6	76.9 a
Kaolin 2.5%	14	6.0	63.3	4.8	70.6	5.3	70.3	6.0	67.1	8.0	59.0	6.0	66 .1 b
Orange oil	13.5	6.3	62.6	5.5	67.4	5.5	71.1	7.0	63.5	8.0	57.3	6.5	64.4 b
Untreated	16	19	-	20.5	-	22.5	-	23	-	23	-		-

a, b mean there is significant difference using ANOVA test at P< 0.05.
R% reduction percentage

Larentzaki *et al*. (2008) demonstrated that Kaolin particle film had significant effects on oviposition, feeding and development of *Thrips tabaci* compared to control. Abd El-Aziz (2013) found that; there was no significant difference between Kaolin and Sumithion treatments on onion thrips; *Thrips tabaci*. Núñez-López *et al*. (2015) stated that, bean plants treated with kaolin showed high efficacy on *Trialeurodes vaporariorum* (Westwood) adult population compared with chemical insecticides.

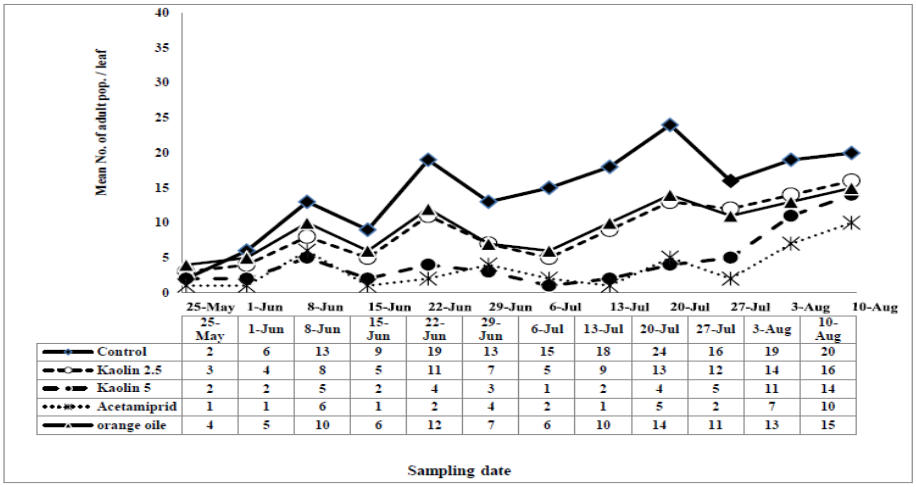
Previous studies found that foliar Kaolin sprays reduced the adults and nymphs of *Agonoscena targionii* (Hemiptera: Psyllidae) in pistachio by 80% (Saour, 2005); the number of eggs and nymphs of *Diaphorina citri* (Hemiptera: Liviidae) on citrus by 85% and 80% (Hall *et al*., 2007) and the nymphs population of *Cacopsylla pyri* (Psyllidae) on pear trees by 85% (Saour *et al*., 2010).

The impact of repeated applications of different treatments on whitefly adult population

The data recorded on the incidence of whitefly adults during 2015-2016 is shown in Figure (1). The data revealed that population of adults was high on control plants compared with the plants under the other four treatments. Moreover; the plants

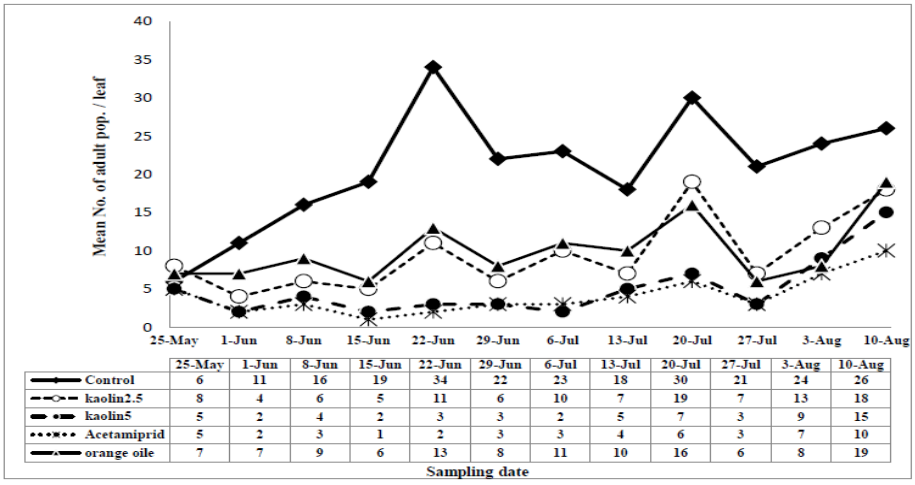
treated with Acetamipride and Kaolin 5% were infested less than those treated with kaolin 2.5% and orange oil. The population of adults recorded only one peak under both Acetamipride and Kaolin 5% (6 and 5 adults/leaf) in June 8th during the first season while two peaks were shown under Kaolin 2.5% and Orange oil treatments in June 8th and 22nd. Likewise, three peaks were observed in control treatment during the first season; first peak was in June 10th while the other two peaks were in June 24th and July 22nd respectively.

The population of whitefly adults in the second season was low on plants treated with Acetamipride and Kaolin 5% and no peaks were observed (Figure 2). On the other hand, two peaks were recorded in June 22nd and July 20th under control treatment (34 and 30 adults/leaf), Kaolin 2.5% (11 and 19 adults/leaf) and orange oil and (13and16 adults/leaf).



	25-May	1-Jun	8-Jun	15-Jun	22-Jun	29-Jun	6-Jul	13-Jul	20-Jul	27-Jul	3-Aug	10-Aug
Control	2	6	13	9	19	13	15	18	24	16	19	20
Kaolin 2.5	3	4	8	5	11	7	5	9	13	12	14	16
Kaolin 5	2	2	5	2	4	3	1	2	4	5	11	14
Acetamiprid	1	1	6	1	2	4	2	1	5	2	7	10
orange oile	4	5	10	6	12	7	6	10	14	11	13	15

Fig. 1: Population of whitefly adults on tomato plants (first season)



	25-May	1-Jun	8-Jun	15-Jun	22-Jun	29-Jun	6-Jul	13-Jul	20-Jul	27-Jul	3-Aug	10-Aug
Control	6	11	16	19	34	22	23	18	30	21	24	26
kaolin2.5	8	4	6	5	11	6	10	7	19	7	13	18
kaolin5	5	2	4	2	3	3	2	5	7	3	9	15
Acetamiprid	5	2	3	1	2	3	3	4	6	3	7	10
orange oile	7	7	9	6	13	8	11	10	16	6	8	19

Fig. 2: Population of whitefly adults on tomato plants (second season)

The statistical analysis results in Table (3) indicate that there were significant differences between control and all other treatments in both two studied seasons 2015 and 2016. Among the different treatments in the two seasons, the lowest effect on the adult stage of whitefly was noticed in plots that treated with orange oil with mean seasonal numbers 9.4 and 10.0 adult / leaf, respectively.

Table 3: Effect of different treatments on the mean numbers of tomato whitefly adults *Bemisia tabaci* (Gennadius); infesting tomato plants during two seasons.

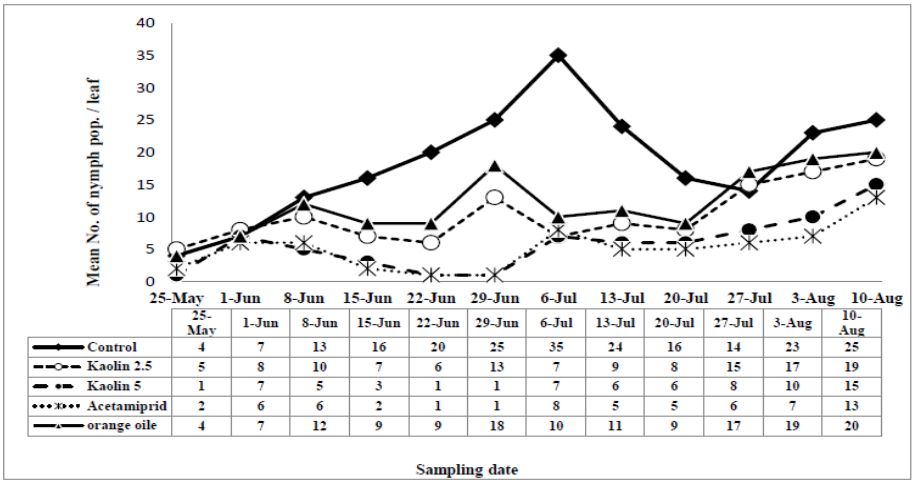
Mean No. of *Bemisia tabaci* (Adults)	Treatments						
	Control	Kaolin 2.5%	Kaolin 5%	Acetamipride 20 Sp	Orange oil	F value	LSD at 5%
1st season 2015	14.5a	8.9b	4.6c	3.5c	9.4b	11.79*	3.90
2nd season 2016	20.8a	9.5b	5.0c	4.1c	10.0b	22.13*	4.10

The mean difference is significant at the 0.05 level.
*significantly difference using ANOVA test at p< 0.05

On the contrary, Acetamipride treatment had the highest reduction effect on whitefly adults with mean numbers (3.5 and 4.1 adult/leaf) followed by Kaolin 5% (4.6 and 5.0 adult/leaf) in both seasons. No significant difference was found between adult mean numbers recorded on plants sprayed with Acetamipride and plants sprayed with Kaolin 5%. Moreover, the differences between Orange oil treatment (9.4 and 10.0 adult/leaf) and Kaolin 2.5% treatment (8.9 found between plants treated with Kaolin 5% and Acetamipride from side and those treated with Kaolin 2.5% and orange oil from other side in both seasons.

The impact of repeated applications of different treatments on whitefly nymph population

The general trend of whitefly nymphs population (Fig. 3) denoted that low population were recorded on treated plants compared to control. Moreover, plants treated with Acetamiprid and Kaolin 5% received fewer whitefly nymphs than those treated with orange oil and Kaolin 2.5%. The nymphs population on Orange oil and Kaolin 2.5% treated plants recorded only one peak in June 29th (18 and 13 nymph/leaf, respectively).



	25-May	1-Jun	8-Jun	15-Jun	22-Jun	29-Jun	6-Jul	13-Jul	20-Jul	27-Jul	3-Aug	10-Aug
Control	4	7	13	16	20	25	35	24	16	14	23	25
Kaolin 2.5	5	8	10	7	6	13	7	9	8	15	17	19
Kaolin 5	1	7	5	3	1	1	7	6	6	8	10	15
Acetamiprid	2	6	6	2	1	1	8	5	5	6	7	13
orange oile	4	7	12	9	9	18	10	11	9	17	19	20

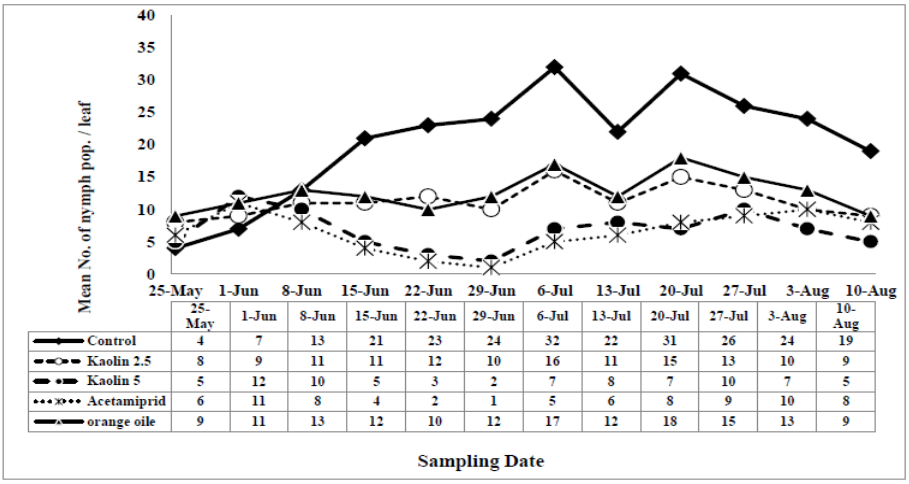
Fig. 3: population of whitefly nymphs on tomato plants (first season)

In control treatment the population increased gradually and recorded a peak in July 6th (35 nymph/ leaf), then declined steadily to reach14 nymph/ leaf in July 27th.

Moderate numbers of whitefly nymphs were recorded at the beginning second season, May 25th. These numbers raised up in the first of June and recorded two peaks in control treatment, the first peak on July 6th (32 nymph/leaf) and the second peak was noted on July 20th (31 nymph/leaf).

The foliar applications were applied after second inspection then population declined and recorded the lowest numbers under Kaolin 5% and Acetamiprid (2

nymph/leaf) and (1 nymph/leaf), respectively. Two peaks were observed on July 6th and July 20th (16, 17 nymph/leaf) and (15, 18 nymph/leaf) under Kaolin 2.5% and Orange oil treatments, respectively (Figure 4). Generally, low population of nymphs recorded under Kaolin 5% and Acetamiprid treatments compared to other treatments during the second season.



	25-May	1-Jun	8-Jun	15-Jun	22-Jun	29-Jun	6-Jul	13-Jul	20-Jul	27-Jul	3-Aug	10-Aug
Control	4	7	13	21	23	24	32	22	31	26	24	19
Kaolin 2.5	8	9	11	11	12	10	16	11	15	13	10	9
Kaolin 5	5	12	10	5	3	2	7	8	7	10	7	5
Acetamiprid	6	11	8	4	2	1	5	6	8	9	10	8
orange oile	9	11	13	12	10	12	17	12	18	15	13	9

Fig. 4: population of whitefly nymphs on tomato plants (second season)

From obtained data in Table (4) it is clear that Kaolin 5% has the same effect of Acetamipride on reducing population of whitefly nymphs. No significant differences were found between the mean numbers of nymphs on plants treated with Kaolin 5% or Acetamipride either in the first season (5.6 and 5.0 nymphs/leaf) or in the second season (6.8 and 6.5 nymph/leaf). Furthermore, during the two seasons the differences between Kaolin 2.5% (10.3 and 12.1 nymph/leaf) and Orange oil (11.3 and 12.6 nymph/leaf) treatments were not significant.

Significant differences were found between control and all other treatments in both seasons (2015 and 2016). These results are in agreement with those of Nateghi *et al*. (2013) who stated that kaolin, as a pest repellant can be an excellent insecticide alternative for *Schizaphis graminum* management in wheat. Núñez-López *et al*. (2015) applied Kaolin as foliar application on bean plants against whitefly, *Trialeurodes vaporariorum* (Westwood) and found that Kaolin reduced the population of whitefly stages by about 80% compared to control.

Table 4: Effect of different treatments on the mean numbers of whitefly nymphs; *Bemisia tabaci* (Gennadius) infesting tomato plants during two seasons.

Mean No. of *Bemisia tabaci* (Nymphs)	**Treatments**						
	Control	**Kaolin 2.5%**	**Kaolin 5%**	**Acetamipride 20 Sp**	**Orange oil**	**F value**	**LSD at 5%**
1st season 2014	18.5a	10.3b	5.6c	5.0c	12.1b	9.33*	4.55
2nd season 2015	20.5a	11.3b	6.8c	6.5c	12.6b	12.12*	4.30

Aa, Bb, Cc, Dd significantly difference against capital litter using LSD at P<0.05
*significantly difference using ANOVA test at p< 0.05

Finally, it could be concluded that Kaolin particles act as a barrier repelling defeating infestations by making the plant visually unrecognizable as a host. Moreover, it hinders insect movement, feeding and other physical activities (Glenn *et al*., 1999). It can be concluded that use of kaolin may be considered as a useful tool in a program of IPM.

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ARABIC SUMMARY

فعالية الرش الورقي بالكاؤلين ضد الذبابة البيضاء للطماطم ؛ *Bemisia tabaci* (Gennadius) ((Hemiptera: Aleyrodidae

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ظهرت حديثا الحاجة إلي إستبدال مبيدات مكافحة الآفات الكيميائية بإخرى غير كيميائية. و قد إستهدفت هذه الدراسة دراسة فعالية رش الكاؤلين (أحد معادن الطين) على أوراق نباتات الطماطم لخفض تعداد الذبابة البيضاء (*Bemisia tabaci* Gennadius) (Hemiptera: Aleyrodidae) . تم تنفيذ تجربتين حقليتين في محافظة القليوبية – مصر- خلال ثلاثة مواسم متتالية (٢٠١٤ و ٢٠١٥ و ٢٠١٦). التجربة الأولى أجريت في عام ٢٠١٤ لتقييم تأثير إستخدام تركيزين من الكاؤلين (٢,٥٪ و ٥٪ و/ح) مقارنة مع اثنين من المبيدات الموصى بها لمكافحة هذه الأفة بمصر أسيتاميبريد (Mospilan SP 20) وزيت البرتقال (Prev-AM) في خفض أعداد الذبابة البيضاء. وأظهرت النتائج أن التأثير الفوري للأسيتاميبريد والكاؤلين ٥٪ كان أعلي خفضاً لطور الحشرة الكاملة للذبابة البيضاء بنسب خفض ٩١,٦٪ و ٩٠,١٪ علي التوالي. كذلك فإن فعالية الأسيتاميبريد و الكاؤلين ٥٪ في خفض اعداد طور الحوريات كان أعلي بنسب خفض ٨٩٪ و ٨٥,٧٪ على التوالي. التجربة الثانية أجريت بهدف دراسة تأثير الرش الورقي المتكرر للكاؤلين (٢,٥ ، ٥ % و/ح) مقارنة بكل من أسيتاميبريد (Mospilan SP 20) وزيت البرتقال (Prev-AM)، على تعداد الذبابة البيضاء (حشرات كاملة وحوريات) خلال العروة الصيفي لموسمي ٢٠١٥ و ٢٠١٦. خلال موسمي الدراسة لم تظهر فروق معنوية بين متوسط أعداد الذبابة البيضاء المسجلة علي أراق النباتات المعاملة بالأسيتاميبريد (٣,٥ و ٤,١ من حشرة كاملة / ورقة) ,والمعاملة بالكاؤلين ٥٪ (٤,٦ و ٥,٠ من حشرة كاملة / ورقة)، من جهة أخري فقد كانت الفروق غير معنوية بين معاملة زيت البرتقال (٩,٤ و ١٠,٠ حشرة كاملة / ورقة) ومعاملة الكاؤلين ٢,٥٪ (٨,٩ و ٩,٥ حشرة كاملة / ورقة) خلال الموسمين. وتم الحصول على تأثير مماثل علي طور الحوريات حيث كان الكاؤلين ٥٪ والأسيتاميبريد ذو تأثير مماثل في خفض أعداد الحوريات. و بصفة عامة يمكن التوصية بإمكانية إستخدام معدن طين الكاؤلين رشا على الأوراق في برنامج الإدارة الزراعية حيث أظهرت الدراسة قدرته علي خفض أعداد الذبابة البيضاء على نباتات الطماطم من خلال عمله كسطح عازل على سطح الأوراق النباتية يؤدي إلى التأثير علي قدرة الأفة علي التعرف علي النبات و اصابته.