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Evaluation of certain neonicotinoid insecticide seed treatments against cereal aphids on some wheat cultivars

A. A. Abd-Ella*

Plant Protection Department, Faculty of Aggriculture, Assiut University, 71526 Assiut, Egypt

Abstract

Field experiment was conducted to find out the comparative efficacy of four commercial neonicotinoid insecticide seed treatments imidacloprid, thiamethoxam, acetamiprid and dinotefuran against cereal aphids, *Rhopalosiphum padi* L., *Schizaphis graminum* Rondani, and *Rhopalosiphum maidis* Fitch (Homoptera: Aphididae) infesting three wheat cultivars Bani Suef, Sids 1 and Misr 1 at Assiut Governorate, Egypt during 2014/2015 season. *R. padi* was the most abundant species with an average (62.33, 32.50 and 25.00), followed by *S. graminum* (28.40, 22.67 and 19.00) and *R. maidis* (9.17, 8.16 and 6.17aphids/tiller) on the three wheat cultivars respectively. There were significant differences in the number of aphids among the wheat cultivars, Bani Suef, Sids 1 and Misr 1. In early season until the second week of March imidacloprid, thiamethoxam, acetamiprid and dinotefuran seed treatments reduced significantly the aphid population densities. After the second week of March there were no significant differences between all insecticide treatments compared to the untreated control. The application of neonicotinoid insecticides as seed treatments under field conditions to suppress the wheat aphid's population increased the yield production of wheat cultivars about 23.04–64.98%. In addition, it was an incontrovertible notice that imidacloprid and thiamethoxam seed treatments caused a significant increase in the average yield/feddan in the three wheat cultivars compared to untreated control, whereas acetamiprid and dinotefuran gave a lower increase in the yield production. It might be concluded that, imidacloprid and thiamethoxam had a better efficiency against wheat aphids than acetamiprid and dinotefuran. As a result of which, neonicotinoid insecticide seed treatments are an integral component and friendly tactic of integrated pest management programs for aphids control in wheat.

Key words: neonicotinoids, seed dressing, cereal aphids, *Triticum* spp.

* **Corresponding author:** A.A. Abd-Ella,
Tel.:+20882412825, Fax :+20882331384
E-mail: aly.abdella@agr.au.edu.eg

Introduction

Cereal aphids are the major insect pests attacking wheat plants (*Triticum aestivum* L.) in Egypt. The Bird cherry-oat aphid, *Rhopalosiphum padi* L., the greenbug, *Schizaphis graminum* Rondani, and the corn leaf aphid, *Rhopalosiphum maidis* Fitch (Homoptera: Aphididae) are the main aphid species recorded on wheat plants in Egypt (El-Hariry, 1979; Megahed et al., 2002), and causing yield losses of 7-23% when infestations substantially exceed damage thresholds (El-Heneidy, 1994). The appearance of these aphids resulted in a dramatic increase in insecticide use in cultivated wheat. Many different control methods have been developed to put down the population of aphid pests, e.g. the use of ryegrass strips in wheat fields and wheat–oilseed rape intercropping to enhance the number of natural enemies (Wang et al., 2009; Dong et al., 2012), the use of resistant wheat varieties (De Zutter et al., 2012) and the application of insecticides. At present known, the application of insecticides (foliar sprays and seed treatments) is one of the most important control options for reducing the damage caused by wheat aphids and vector-borne disease (Ahmed et al., 2001; Royer et al., 2005; Zhang et al., 2015). The use of neonicotinoid insecticide as a seed treatment has recently become an important management option for protection against wheat aphids (Ahmed et al., 2001; Royer et al., 2005; Zhang et al., 2015). Insecticides commercially available for use in wheat as seed treatments include imidacloprid (Gausho 20% SC), thiamethoxam (Actara 25% WP), acetamiprid (Mospilan 20% SP) and dinotefuran (Ochin 20% SG). These are all neonicotinoid-based insecticides with similar physical and molecular properties, and a mode of action as agonists at the insect nicotinic acetylcholine receptor (nAChR) analogous to nicotine (Zhang et al., 2000; Tomizawa & Casida, 2003; Kanne et al., 2005; Hollingworth & Treacy, 2006). Neonicotinoid insecticides applied as seed treatments are highly effective against piercing-sucking insects, such as aphids, mired bugs, whiteflies and planthoppers (Burd et al., 1996; Liu et al., 2005; Shi et al., 2011). In wheat, Ahmed et al. (2001) found that imidacloprid applied at 0.175 and 0.263 g a.i./kg seeds efficiently controlled the maize aphid, *Melanaphis maidis* (Zehntner) and suppressed the green bug, *S. graminum* for 6–8 weeks after sowing, and also reduced the yield loss, these findings agree with the results of Burd et al. (1996). Liu et al. (2005) also found that imidacloprid seed treatments at a rate of 2.24–4.80 g a.i./kg efficiently controlled wheat aphids throughout the wheat growing season, and increased wheat production. Therefore, the objective of the present study is to evaluate the efficacy of four commercial neonicotinoid insecticides as seed treatments, imidacloprid, thiamethoxam, acetamiprid and dinotefuran to control wheat aphids, *R. padi*, *S. graminum* and *R. maidis* in three wheat cultivars Bani Suef, Sids (1) and Misr (1), also the effect on germination percent and yield of wheat cultivars under field conditions.

Materials and methods

Insecticides: Four neonicotinoid insecticides were obtained from the local market and tested as wheat seed treatments; (trade name, percentage of active ingredient, formulation type and application ratio, a.i. g kg^{-1} seeds): imidacloprid (Gausho 20% SC, 7g kg^{-1}), thiamethoxam (Actara 25% WP, 2 g kg^{-1}), acetamiprid (Mospilan 20% SP, 3.3g kg^{-1}), and dinotefuran (Ochin 20% SG, 3.3g kg^{-1}).

Field Study: Seeds of the three wheat cultivars viz., Bani Suef, Sids (1) and Misr (1) were purchased from the Egyptian Ministry of Agriculture and Land Reclamation, and were planted on 25th November, 2014 at Assiut University Experimental Farm, Assiut, Egypt. Regular agricultural practices were applied, except using the neonicotinoid insecticides seed treatments. The experimental area was divided into plots 3.5 ×3 m (1/400 Feddan where Feddan = 0.42 hectare). Tested insecticides were distributed in a randomized complete block design and each insecticide replicated three times. Before sowing, the wheat seeds were treated with the diluted insecticides at a rate of imidacloprid 7g a.i. kg^{-1} seed, thiamethoxam 2g a.i. kg^{-1}, acetamiprid 3.3g a.i. kg^{-1}, and dinotefuran 3.3 a.i.g kg^{-1} and then dried in air. Three untreated replicates were served as control. The numbers of wheat aphids (adults and nymphs) on 20 randomly selected wheat tillers (five locations for every plot, 4 plants for each location) were counted (No. of aphids/tiller) from 7th January, 2015 until the maturity of the wheat plant cultivars. The bird cherry-oat aphid, *R. padi* began to appear on the lower level of wheat plants, while the greenburg aphid, *S.graminum* and the corn leaf aphid, *R. maidis* were observed on the upper level of the wheat plants.

Germination (%) in the field: To study the effects of neonicotinoid insecticides as a seed treatment on the germination of wheat seed cultivars, 100 seeds per plot were sowed between rows of the same plots for each wheat cultivars and the control. The germination count was taken after 14 days from sowing date and expressed as a percentage according to the following equation described by Ruan et al. (2002):

$$\text{Germination (\%)} = \frac{\text{Number of germinated seed}}{\text{Total number of seed tested}} \text{x} 100$$

Yield of wheat cultivars: Wheat was harvested on 10th June, 2015. Average yields of wheat (kg $feddan^{-1}$) were assessed using the harvest from the entire wheat plants of each plot for each wheat cultivars and the control. **Y**ield increase percentage calculated according the following equation: Yield increase (%) = [average yield (kg) in treatment – average yield (kg) in control/ average yield (kg) in control] x 100.

Data analysis: Statistically significant mean values (P <0.05) were calculated as mean ± SEM (standard error mean) using analysis of variance (ANOVA) and separated by Tukey's Multiple Comparison Test (TMCT) using Graph Pad Prism 5TM software (San Diego, CA).

Results

Germination (%) of wheat seeds with different treatments in the field: As shown in Figure 1, the germination (%) of wheat seeds cultivars, Bani Suef, Sids 1 and Misr 1 treated with imidacloprid at a rate of 7g a.i. kg^{-1}, thiamethoxam at a rate of 2g a.i. kg^{-1}, acetamiprid at a rate of 3.3g a.i. kg^{-1} , and dinotefuran at a rate of 3.3g a.i. kg^{-1} were ranging from 84 to 86.5%, 81 to 83.5% and 85.5 to 87% respectively, and there were no significant differences compared to untreated seeds.

Efficacy of neonicotinoid insecticides seed treatment against aphids on Bani Suef wheat cultivar: The insecticidal activity of imidacloprid, thiamethoxam, acetamiprid and dinotefuran applied as a seed treatment against wheat aphids, *R. padi*, *S. graminum* and *R. maidis* were evaluated under field conditions. As shown in Figure 2A, the bird cherry-oat aphid, *R. padi* began to appear on the lower level of wheat plants particularly on the roots on 28 January with an average of 2.57±0.23 aphids/tiller and then the aphids moved from roots to stems and lower leaves, where the population reached a maximum of 62.33±2.14 aphids/tiller on 11 March (Figure 3A). The efficacy of neonicotinod insecticides seed treatments against this aphid species showed that imidacloprid, thiamethoxam, acetamiprid and dinotefuran significantly reduced the maximum population densities on Bani Suef wheat cultivars with the average of 11.03±1.52, 18.75±0.25, 25.07±0.52 and 29.80±2.69 aphids/tiller respectively compared with untreated plots, (62.33±2.14 aphids/tiller).

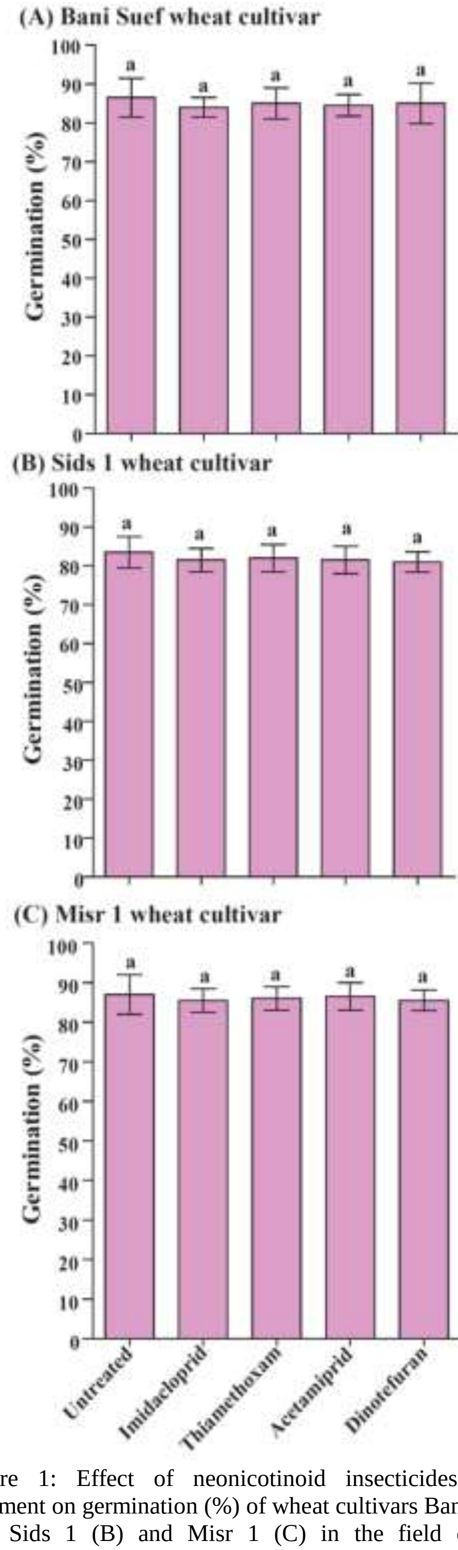

Figure 1: Effect of neonicotinoid insecticides seed treatment on germination (%) of wheat cultivars Bani Suef (A), Sids 1 (B) and Misr 1 (C) in the field during 2014/2015 season. Columns headed by the same letter (s) within the same figure are insignificantly different (*P* <0.05) according to Tukey's Multiple Comparison Test (TMCT).

These results indicated that, imidacloprid at a rate of 7g a.i. kg^{-1} and thiamethoxam at a rate of 2g a.i. kg^{-1} were significantly higher than acetamiprid at a rate of 3.3g a.i. kg^{-1} and dinotefuran at a rate of 3.3g a.i. kg^{-1} in reducing the aphid population densities. Each of the four neonicotinoids provided a significant reduction to the maximum numbers of *R. padi* during the early season compared to the untreated plots, whereas at the end of the season beginning of March 25, there was no significant difference between all insecticide treatments and the untreated plants (Figure 3A). The population of the greenbug aphid, *S. graminum* was nearly the same as that of *R. padi* and showing approximately the same trend. *S. graminum* began to appear on the upper level of wheat plants (Figure 2B) on 28 January with an average of 1.73±0.64 aphids/tiller and the population reached a maximum of 28.40±1.17 aphids/tiller on 11 March. The seed treatments of imidacloprid, thiamethoxam, acetamiprid and dinotefuran significantly reduced the maximum population densities of this species on Bani Suef wheat cultivars with an average of 8.17±1.01, 13.53±0.74, 15.037±0.81 and 17.23±1.25 aphids/tiller respectively compared to the untreated plots (28.40±1.17 aphids/tiller) whereas, at the end of the season beginning of March 25, there was no significant differences between all of insecticide treatments and the untreated plants (Figure 3B). According to the population density, the corn leaf aphid, *R. maidis* was relatively low with a maximum of 9.17±0.44 aphids/tiller on 25 March (Figure 2C). The seed treatments of imidacloprid, thiamethoxam, acetamiprid and dinotefuran against this species reduced the population with an average of 3.70±0.85, 5.23±0.54, 5.78±0.55 and 6.11±0.67 aphids/tiller respectively compared to the untreated plots (9.14±0.44 aphids/tiller) but there was no significant difference between all of insecticides treatments because the population was relatively low compared to other species (Figure 3C).

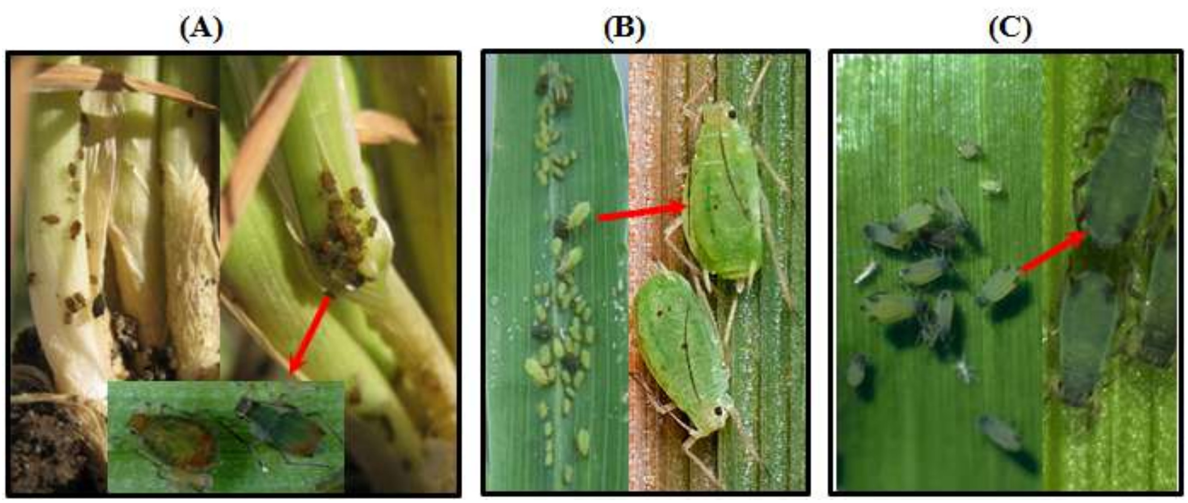

Figure 2: Aphid spices on wheat plants, the bird cherry-oat aphid, *R. padi* on the lower level of wheat plants **(A),** the greenbug aphid, *S. graminum* **(B)** and the corn leaf aphid, *R. maidis* **(C)** on the upper level of the wheat plants. All the photos were taken from Assiut University Experimental Farm, Assiut, Egypt by a Canon Camera (12,1 Mega Pixels, digital IXUS 96015, 15 X, Japan).

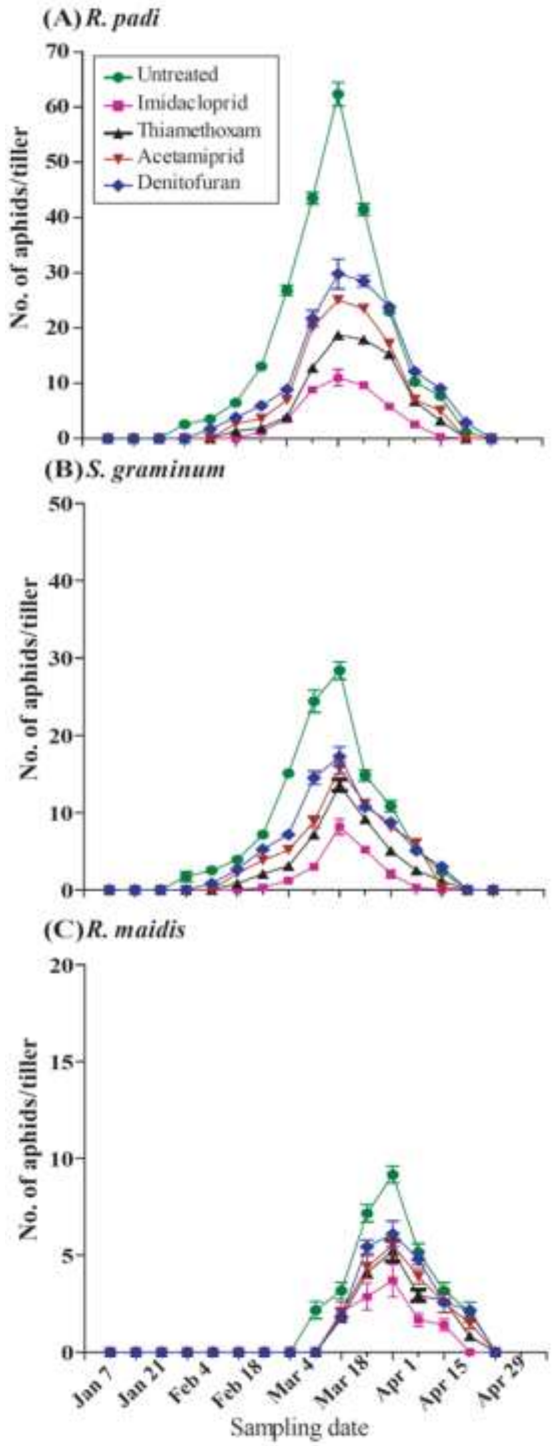

Figure 3: Effect of neonicotinoid insecticides seed treatment against aphids on wheat cultivar Bani Suef during 2014/2015 season.

Efficacy of neonicotinoid insecticides seed treatment against aphids on Sids 1 wheat cultivar: Data represented in figure 3 summarize the effect of imidacloprid, thiamethoxam, acetamiprid and dinotefuran applied as a seed treatment against wheat aphids, *R. padi*, *S. graminum* and *R. maidis*, on wheat cultivar Sids 1 during 2014/2015 season under field conditions. Results showed that all treatments caused a significant reduction in aphid's population as compared with untreated plots. The maximum population of *R. padi*, *S. graminum* and *R. maidis* were 32.50±1.61, 22.67±1.20 and 8.17±0.61 aphids/tiller on 18 March for *R. padi*, *S. graminum* and on 25 March for *R. maidis* in the untreated wheat plants. These results showed that, *R. padi* was the highest population followed by *S. graminum*, whereas, *R. maidis* was the lowest population on wheat cultivar Sids 1. Imidacloprid, thiamethoxam, acetamiprid and dinotefuran reduced the maximum population of *R. padi,* with an average of 11.43±1.73, 13.98±0.57, 16±1.53 and 18.33±1.20 aphids/tiller, *S. graminum* with an average of 10.67±0.88, 13.67±1.20, 14.00±0.53 and 15.67±0.88 aphids/tiller and *R. maidis* with an average of 2.53±0.84, 3.43±0.47, 4.17±0.67 and 5.27±0.37 aphids/tiller, respectively compared to the untreated plants (Figure 4 A, B, C). Moreover, there were no significant differences between treated and untreated wheat plants during the end of season.

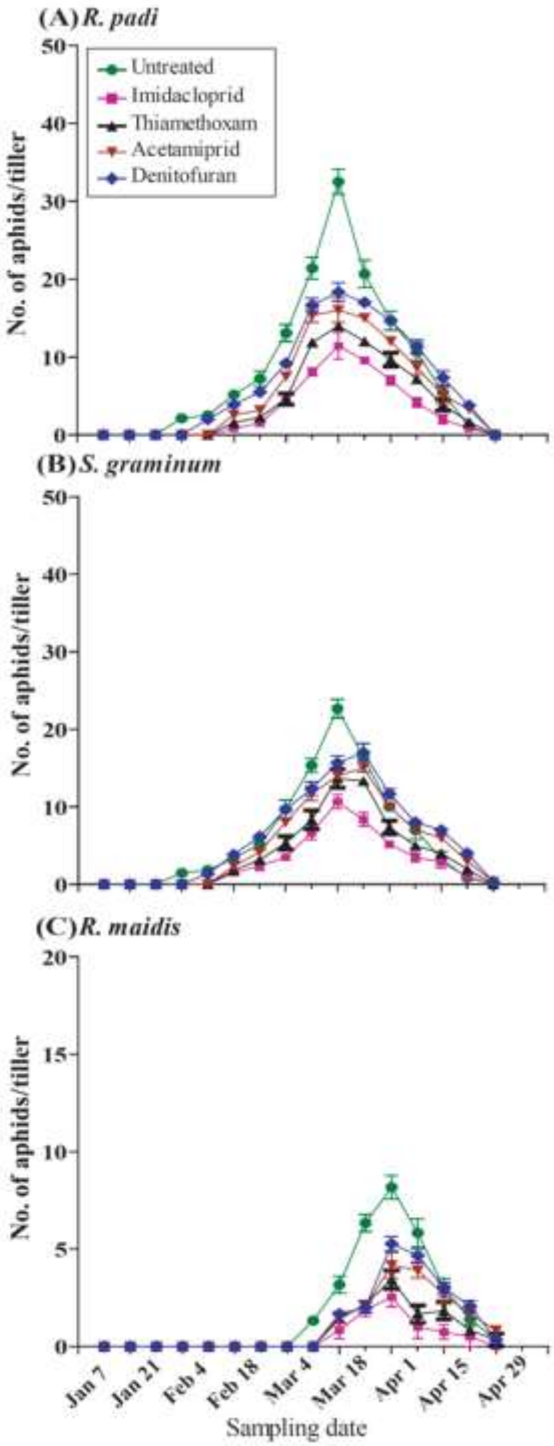

Figure 4: Effect of neonicotinoid insecticides seed treatment against aphids on wheat cultivar Sids 1 during 2014/2015 season.

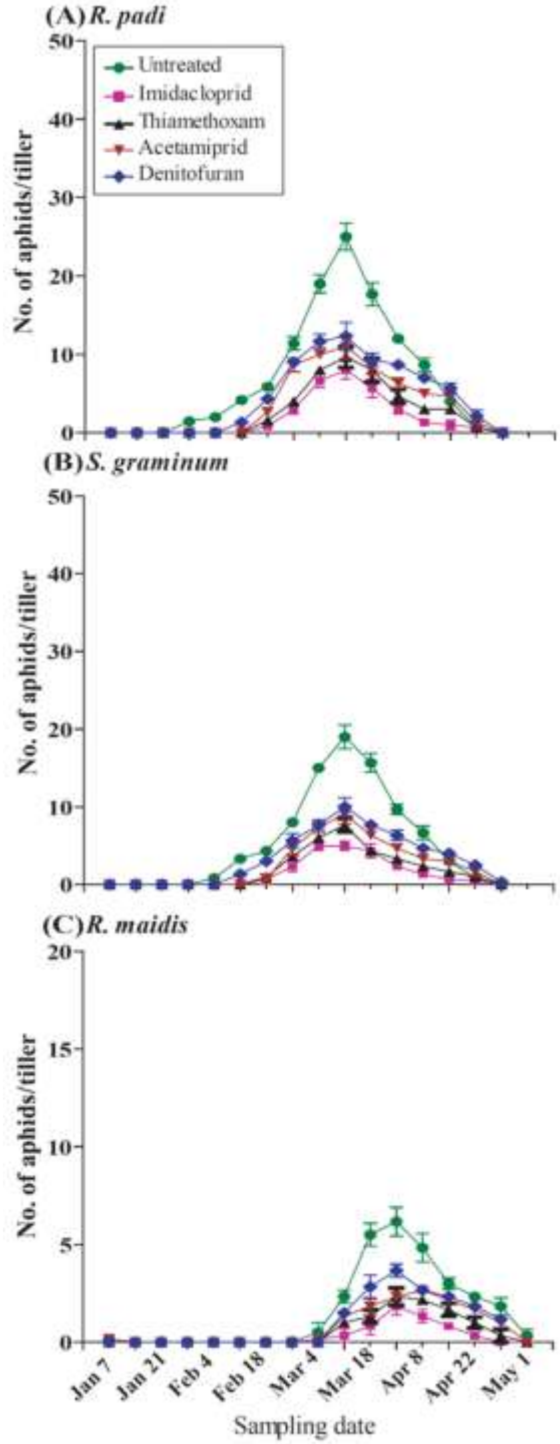

Figure 5: Effect of neonicotinoid insecticides seed treatment against aphids on wheat cultivar Misr 1 during 2014/2015 season

Efficacy of neonicotinoid insecticides seed treatment against aphids on Misr 1 wheat cultivar: For wheat cultivar Misr 1, data illustrated in Figure 5 showed that *R. padi* was the most abundant species with an average of 25.5±1.73 aphids/tiller followed by *S. graminum* with an average of 19.25±1.53 aphids/tiller on 18 March, whereas, *R. maidis* was the lowest abundant with an average of 6.17±0.73 aphids/tiller on 25 March. All insecticides tested as seed treatments significantly reduced the aphid population densities on wheat cultivar Misr 1 during 2014/2015 season under field conditions. Imidacloprid, thiamethoxam, acetamiprid and dinotefuran reduced the maximum population of *R. padi*, with an average of 8.22±1.15, 9.67±1.33, 11.25±1.35 and 12.33±1.76 aphids/tiller, *S. graminum* with an average of 5.00±0.57, 7.67±0.82, 9.00±1.16 and 10.00±1.16 aphids/tiller and *R. maidis* with an average of 1.83±0.44, 2.33±0.45, 3.33±0.17 and 3.67±0.33 aphids/tiller, respectively compared to the untreated plants (Figure 5 A, B, C). However, there were no significant differences between all of insecticides treatment.

Effect of neonicotinoid insecticide seed treatment on yield of wheat cultivars: For wheat cultivar Misr 1, data illustrated in Figure 5 showed that *R. padi* was the most abundant species with an average of 25.5±1.73 aphids/tiller followed by *S. graminum* with an average of 19.25±1.53 aphids/tiller on 18 March, whereas, *R. maidis* was the lowest abundant with an average of 6.17±0.73 aphids/tiller on 25 March. All insecticides tested as seed treatments significantly reduced the aphid population densities on wheat cultivar Misr 1 during 2014/2015 season under field conditions. Imidacloprid, thiamethoxam, acetamiprid and dinotefuran reduced the maximum population of *R. padi*, with an average of 8.22±1.15, 9.67±1.33, 11.25±1.35 and 12.33±1.76 aphids/tiller, *S. graminum* with an average of 5.00±0.57, 7.67±0.82, 9.00±1.16 and 10.00±1.16 aphids/tiller and *R. maidis* with an average of 1.83±0.44, 2.33±0.45, 3.33±0.17 and 3.67±0.33 aphids/tiller, respectively compared to the untreated plants (Figure 5 A, B, C). However, there were no significant differences between all of insecticides treatment.

Discussion

Wheat aphid is one of the major pests of wheat in Egypt, and instituting control measures to prevent the harm they cause will be significant in reducing the associated economic damage. This study, conducted during 2014/2015 season, demonstrated that imidacloprid (7g a.i. kg^{-1}), thiamethoxam (2g a.i. kg^{-1}), acetamiprid (3.3g a.i. kg^{-1}) and dinotefuran (3.3g a.i. kg^{-1}) seed treatments had no effect on the germination percentage of wheat cultivars, increase the average yield production and reducing the wheat aphid infestations throughout the wheat growing season (Figs. 1 to 5 and Table 1). Three aphid species found infesting the three different wheat cultivars during the wheat growing season. The current results reveal that there were significant differences in the number of aphids among the wheat cultivars, Bani Suef, Sids 1 and Misr 1. Maximum numbers of aphids per tiller were the highest in Bani

Suef cultivar with an average of (62.33±2.14) and lowest in Misr 1 cultivar with average (25.00±1.73). Thus, Sids 1 seems to be more susceptible with an average of (32.50±1.73) while Misr 1 was more resistant. Variations in the aphid populations among the different cultivars has been reported by several researchers (Zhang et al., 1989; Aslam et al., 2005; Aheer et al., 2007; Helmi & Rashwan, 2013). Up to 15 weeks after sowing, imidacloprid and thiamethoxam were last in wheat plants, which provided long-term protection for the wheat cultivars against wheat aphids (Figs. 3 to 5). These results were in agreement with the work of Liu et al. (2005), who found that imidacloprid and thiamethoxam seed treatments were effective in suppressing the wheat aphid population in wheat plants under field's conditions throughout the growing season.

Table 1: Estimated average yield per feddan in kilograms of wheat and percentage of increase yield in the control and after neonicotinoid insecticides seed treatment against aphids on wheat cultivars Bani Suef, Sids 1 and Misr 1 during 2014/2015 season.

Insecticides	Rate (a.i. gm/kg seeds)	Bani Suef cultivar		Sids (1) cultivar		Misr (1) cultivar	
		Average yield/ feddan (kg±SE)	Yield increase (%)	Average yield/ feddan (kg±SE)	Yield increase (%)	Average yield/ feddan (kg±SE)	Yield increase (%)
Control	0	2568.25±12.33e	-	2288.67±16.30e	-	2629.33±13.82e	-
Imidacloprid	7	3308.00±22.45a	28.80a	3776.00±18.00a	64.98a	3840.00±11.50a	46.04a
Thiamethoxam	2	2959.33±15.85b	15.23b	3662.50±12.50b	60.03b	3180.00±14.00b	20.94b
Acetamiprid	3.3	2720.00±13.18c	7.85c	3416.00±11.00c	49.26c	3040.00±12.00c	15.62c
Dinotefuran	3.3	2652.00±14.22d	3.26d	2816.00±19.00d	23.04d	2928.00±25.00d	11.36d

Notes: Feddan = 0.42 hectare, yield increase (%) = [average yield (kg) in treatment - average yield (kg) in control/average yield (kg) in control] x100. Means followed by the same letter(s) within the same column are insignificantly different according to TMCT (p-vale < 0.05).

However, acetamiprid and dinotefuran had lower effect as seed treatments against wheat aphids compared to the untreated control. An intense wheat aphid's peaks occurred at the beginning of the second or the third week of March and continued until mid or late April. However, it was apparent that wheat aphids on wheat cultivars in the plots which were treated by imidacloprid and clothianidin less abundant than in the untreated control. In early season until the second week of March, imidacloprid, thiamethoxam, acetamiprid and dinotefuran seed treatments reduced significantly the aphid population densities. After the second week of March, there were no significant differences between all of insecticide treatments compared to the untreated control, this may attributed to wheat aphid's migration to new emerged wheat ears and the wheat plants grew rapidly from the jointing stage to the heading stage (Zhang et al., 2015). In addition, during this period, the concentration of imidacloprid, thiamethoxam, acetamiprid and dinotefuran decreased in the wheat plants and less insecticide was available in the soil, so it was not translocated to new plant parts of wheat. The lower insecticidal concentration in the soil and plant was adverse to the control of the wheat aphids, especially under a serious occurrence of aphids during a later growth period (Magalhaes et al., 2009; Zhang et al., 2015). Imidacloprid, thiamethoxam, acetamiprid and dinotefuran have similar mode of action and molecular structures, and they interact likewise with the nicotinic acetylcholine receptors (nAChRs) of the central and peripheral nervous systems (Yamamoto, 1996; Zhang et al., 2000; Tomizawa & Casida, 2003; Kanne et al. 2005; Hollingworth & Treacy, 2006). In the present study, reasonable population of wheat aphids, *R. padi*, *S. graminum* and *R. maidis* control and yield augments were achieved using the neonicotinoid insecticide seed treatments under field conditions. However, the application at the same rate (3.3g kg^{-1}), acetamiprid provided a lower population density of wheat aphids than dinotefuran in wheat cultivars during the growing season, which was due to the differences in metabolites in wheat plants, water solubility, degradation and insecticide–soil interactions of acetamiprid and dinotefuran (Wu et al., 2012; Kong et al., 2012; Zhang et al., 2015) . These results needs further research studies in view of the extended period of systemic activity of neonicotinoid insecticides in wheat aphids. Although, aphids was considered the important pests attacking wheat plants and causing sever reduction in the yield **(**Slman, 2002). These pests cause serious damages to the plants either directly by sucking plant juice or indirectly as a vector of diseases. Aphids are the limiting factors in wheat production in Upper Egypt which cause severe damage and reduce the yield from 7-23% (El-Heneidy, 1994) and from 4.24 to 21.89 % (Amin et al., 2007). In addition, it was an obvious observation that imidacloprid and thiamethoxam seed treatments caused a significant increase in the average yield/feddan in the three wheat cultivars Bani Suef, Sids 1 and Misr 1 compared to the untreated control (Table 1), meanwhile, acetamiprid and dinotefuran gave a lower increase in the yield production. It might be concluded that, imidacloprid and thiamethoxam had a better efficiency against wheat aphids than acetamiprid and dinotefuran because probably, they have a high systemic effect especially through the root system. Similarly, studies of the efficacy of imidacloprid dressing of winter wheat in North America suggest that yield benefits are small compared to untreated plants and often exceeded by the cost of the pesticide (Royer et al., 2005). Suhail et al. (2013) stated that, imidacloprid and thiamethoxam as seed treatments reduced the population of aphid, *Sitobion avenae* F. and resulted significant increase in wheat crop yield compared to all other treatments. By contrast, Wilde et al. (2001) evaluated thiamethoxam and imidacloprid seed treatments for insect control in wheat fields in Kansas and found no yield benefit in the field experiments, which had low to no pest pressure, and control of early season pests was demonstrated in greenhouse experiments with infested plants, but late season pest control was less effective and inconsistent. The same author noted that, seed treatment could be useful in fields with chronic pressure from several pests, and the use of seed treatments is economically risky where insect populations are variable. In conclusion, the results of the present study clearly showed that, imidacloprid, thiamethoxam, acetamiprid and dinotefuran seed treatments provided early protection against wheat aphids *R. padi*, *S. graminum* and *R. maidis* with greater yield in wheat cultivars Bani suef, Sids 1 and Misr 1 under field conditions. Neonicotinoid insecticides seed treatments are excellent means for the management of wheat aphids on wheat plants. Therefore, imidacloprid and thiamethoxam seed treatment could be used in integrated pest management programs for controlling the wheat aphid.

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