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Are Seed Treatments Effective on Overwintered Adults of Sunn Pest, *Eurygaster integriceps* (Hemiptera: Scutelleridae)?

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Abstract. Application of insecticides against overwintered adults of Sunn pest has limitations. To find the new measurement against the insect, two insecticides, imidacloprid and thiamethoxam, as seed treatments, were tested against overwintered adults of Sunn pest in semi-field and field conditions in Alborz province. This project was carried out in a split-plot design with planting dates at 3 levels (at the beginning of wheat cultivation in 2016, Nov. 7, mid- and late-dates in 2016, Nov. 20, and Dec. 4) as the main plots and seed treatments at 5 levels, including imidacloprid 700WS with two concentrations of 1 and 0.5 g/kg of wheat seed and thiamethoxam 350FS with two concentrations of 0.8 and 0.4 g/kg and control (without seed treatment) as the sub-plots. The comparison of the mean efficiency of treatments at different cultivation dates in the semi-field conditions showed that the lowest (9.1%) and the highest (71.66%) efficiencies were observed at the beginning and late cultivation dates, respectively. In seed treatments, thiamethoxam at high concentration had the maximum efficacy (84.4%) 48 days after the last planting date, and the minimum efficacy (5.55%) was related to thiamethoxam at low concentration 116 days after. The results of field conditions showed that the highest (15%) and lowest (1.25%) efficacies of seed treatments were 97 days after the last cultivation date. Thiamethoxam seed treatment at high concentration had the highest efficiency (21.6%) among the treatments at the first sampling date. On other sampling dates, the efficiency of all treatments was less than 10%. The seed treatment with imidacloprid and thiamethoxam did not have acceptable effectiveness against overwintered adults and nymphs of Sunn pest. Also, the change in the cultivation date of seed-treated wheat cannot be effective in reducing the overwintered adult population of Sunn pest.

Keywords: imidacloprid, thiamethoxam, insecticide, chemical control

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Introduction

Wheat is one of the oldest and most widely used crops in the world. This strategic crop has a very high nutritional value for humans, especially in terms of energy supply (carbohydrates). Wheat is cultivated extensively in different parts of the world. The cultivation area of irrigated and dry wheat in Iran is 5.4 million hectares, with a production of 13.3 million tons and an average irrigated yield of 4.3 tons per hectare (Ahmadi et al., 2018).

Sunn pest, *Eurygaster integriceps* (Hemiptera: Scutelleridae), is the most important wheat pest in Iran. The infected areas range from southeastern Iran to southeastern Europe and North Africa. Sunn pest has one generation per year. Overwintering adults of Sunn pest spend the summer, autumn, and winter under the weeds of mountain slopes. When the average temperature reaches about 14 degrees Celsius, they migrate from mountains to fields. The migration period takes 7–30 days, 1-3 times. Overwintering adults travel 20–30 km. After settling in the barley and wheat fields, they feed on the leaves, stems, and final buds. In this stage, crop loss is quantity. Then they mate and lay eggs. After one to 10 days, the nymphs hatch. The nymphs usually feed on the clusters. The crop loss of the new generation is in both quantity and quality, but quality damage to grain is very important. Because the product of wheat fields contains more than 2% of damaged grain, which is not recommended for bakery use (Khanjani, 2004; Javadipouya et al., 2023). In Iran's weather conditions, the earliest and latest times of emigration from the mountains are in February and May. Based on phenological wheat fields, emigration starts at the

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beginning of the pawing period and ends at cluster formation, and most of the emigration occurs when the wheat is in the pawing state (Rajabi, 2000). The emigration time of Sunn pest depends on the topography, altitude, rainfall and the weather conditions of the area each year. The cold weather can cut off flying Sunn pest from mountains to fields (Rajabi, 2000).

The chemical control by seed treatment is not only effective against sucking pests but also reduces those viral plant diseases including Maize dwarf mosaic virus (MDMV) and Barley yellow dwarf virus (BYDV). Seed treatment with thiamethoxam controlled Rhopalosiphum padi and decreased BYDV up to 50%. (Gourmet et al., 1996a and 1996b). Preliminary studies have shown that neonicotinoids are effective on overwintering adults of Sunn pests (Jafarpour et al., 2011).

Due to the lack of sufficient information about the migration behavior of overwintered adults on the fields, there is no optimized strategy for chemical control, and the chemical application on the overwintered adult stage often has less efficacy than on the nymphal stage. The seed treatment can be used in hot spots where Sunn pest infestation happens in those fields every year. It can increase the efficacy of the chemical control against Sunn pest and decrease the total treated area. Therefore, the aim of this study was to determine the effectiveness of chemical control by seed treatment methods with two insecticides, imidacloprid and thiamethoxam, against overwintered adults of Sunn pest in laboratory and field conditions.

Materials and Methods

Insecticides

Insecticides tested were imidacloprid (Gaucho® 700WS, Bayer Crop Science Inc., Germany) at two concentrations of 0.7 and 0.35 g a.i./kg of wheat seeds and thiamethoxam (Cruiser® 350FS, Syngenta Crop Protection, Greensboro, NC, USA) at two concentrations of 0.28 and 0.14 g a.i./kg of seeds that were used as a seed treatment (Gourmet et al., 1996a; Way and van Emden, 2000).

Insect Collection

Overwintered adults of Sunn pest with spent diapause stage and capable of mating and oviposition were collected from Ghara Aghaj Mountains at 2300 to 2200 meters above sea level from under Milk vetch and Artemisia plants in February and March 2016. It is located near Varamin, Tehran province. The collected insects were released into special plastic containers 15×30 and 20 cm high and then transferred to the laboratory and stored in the refrigerator at 3 ±1 °C. They were immediately used to perform biometric tests on the same day or in less than 24 hours.

Laboratory Tests

The wheat cultivar Pishtaz was used for all experiments. On each of the planting dates, 6 pots were planted for each treatment, and 5 seeds were sawed in each pot. The bioavailability and efficacy of treatments were conducted against overwintered adults of Sunn pest on 48, 90, and 116 days after treatment. In each test, the number of overwintering adults was released in each pot, and the mortality was recorded at 48 hours after exposure. The evaluation dates were the same as the field study.

Field Tests

Pishtaz cultivar was planted in experimental plots. The trial was performed in Alborz province under normal field conditions. The field location was at northern latitudes 35°48'38.9" and eastern longitudes 50°57'52.3". Winter wheat, Pishgam, was used for this study. The experiment was set in a split-plot design in a randomized complete block design. The main plot included planting dates in three levels with a 15-day interval: (1) beginning of planting date: 2016. Nov. 6; (2) middle of planting date: 2016. Nov. 19; (3) late planting date: 2016. Dec. 3. The sub-plots comprised insecticide seed treatment at 5 levels, including seed treatment by Gaucho® 700 WS at two concentrations of 1, 0.5 g/kg of wheat seeds, Cruiser 350 FS at two concentrations of 0.8, 0.4 g/kg of seeds, and control (without seed treatment).

Intervals between planting dates were at least 15 days. The block distance was considered to be 3 meters. The experiment was conducted with 15 treatments and three repetitions, and the size of the sub-plots was 50 square meters, which included 9 rows of 10 meters. Irrigation of each subplot was done separately to prevent water from entering from one subplot into the other.

The evaluation of seed treatments was conducted twice, at 25 and 61 Zadoks indexes, which are cereal growth staging scales. The cages with dimensions of 1.5 h× 0.5 w× 0.5 l meters were used in each plot, and 30 overwintered adults of Sunn pest were introduced in each cage. Mortality was recorded 2–4 days after release. The first experiment was synchronized with the migration of the overwintered adults to fields at Zadoks 25, and in the second test at Zadox 61 (flouring stage), 30 overwintering females and 10 males were released in each cage. In the second test, the cages did not move until harvesting time.

Statistical Analyses.

Data on mortality within treatments in laboratorial conditions were analyzed using PROC GLM. Differences between treatments at each location were tested using the Fisher Least Significant Difference (LSD) Test (one-way ANOVA). The difference was considered significant at $P < 0.05$. The data were analyzed by the SAS version for Windows (SAS Institute 2009).

Results

Laboratory Tests

Evaluation of the efficiency of seed treatment in autumn against the overwintered adults of Sunn pest with imidacloprid and thiamethoxam in pots showed that the interaction of planting dates and seed treatment was significant 48 and 90 days after the last planting date, while it was not significant 116 days later. (Table 1).

A comparison of the mean efficiency of seed treatments on different planting dates showed that the lowest efficiency of the treatments was related to the first planting date (9.1%) on 116 days after planting, and the highest efficiency was related to the second (61.66%) and third (71.66%) planting dates on 48 days after the last planting date. Thiamethoxam (84.4%) at a high concentration (0.8 g/kg seed) had statistically significant differences with other treatments (Table 2).

Table 1. The effect of sowing dates on the efficacy of the insecticide seed treatment on the overwintered Sunn pest on different days after the last planting date and the mean comparison based on LSD at laboratory conditions.

Sowing date in 2016	Efficiency (%) of planting date at days after last planting date		
	+48	+90	+116
1st planting date (November 6)	17.5±7.7b	18.33±8.14a	9.1±3.5a
2nd planting date (November 19)	61.66±8.1a	31.6±9.5a	18.33±7.42a
3rd planting date (December 3)	71.66±8.2a	22.5±5.6a	15.83±4.16a
LSD (alpha5%)	*17.1*	*19.1*	*19*

The means in a column followed by the same small letters are not significantly different.

Table 2. The mean effectiveness of the insecticide seed treatments against the overwintered Sunn pest on different days after the last planting date and the comparison based on LSD at the laboratory conditions.

Seedtreatments (g/kg of seeds)	Efficiency (%) of the insecticides at different days after last planting date		
	+48	+90	+116
Gaucho® 700 WS(1)	41.11±10.46bc	11.11±3.09b	10±3.72b
Gaucho® 700 WS(0.8)	28.88±7.15c	7.77±2.22b	10±5.2b
Cruiser® 350 FS (0.8)	84.44±6.8a	61.11±±8.57a	32.22±7.59a
Cruiser® 350 FS (0.4)	46.66±14.5b	16.66±6.45b	5.55±3.37b

LSD (alpha5%)	*13.77*	*15.12*	*16.41*

The means in a column followed by the same small letters are not significantly different.

Field Tests

Data analysis in the field conditions revealed that at all sampling times (97, 116, and 121 days after the last planting date), the interaction between planting dates and seed treatments was significant at the 5% level. Also, the efficacy of seed treatments with insecticides was significantly different at the 5% level. Thiamethoxam treatment (0.8 g/kg seed) had the highest efficiency (21.6%) on the 97 days after the last planting date, and on the next sampling dates, the efficiency of all treatments was often less than 15% (Tables 3 and 4).

On 150 days after the last date, all seed treatments by the neonicotinoid insecticides were not able to reduce the crop losses of Sunn pest in the economic injury level, and all clusters of wheat were white in the cage, and the kernel rate was more than 70% (Table 5).

Table 3. The effect of sowing dates on the efficacy of the insecticide seed treatment in planting dates against the overwintered adults of Sunn pest and the mean comparison based on LSD in field conditions.

Sowing date in 2016	**Efficiency (%) of planting date at different days after last planting date**		
	+97	**+117**	**+121**
1st planting date (November 6)	1.25±1.11c	5.11±1.9a	7.73±1.18a
2nd planting date (November 19)	10±3.3b	6.08±1.47a	5.7±1.2a
3rd planting date (December 3)	15±3.19a	4±1.76a	7.17±1.8a
LSD (alpha5%)	***4.05***	***2.71***	***3.47***

Table 4. The mean effectiveness of the seed treatments against the overwintered adults of Sunn pest on different days after the last planting date and comparison based on LSD in a field condition.

Seed treatments (g/kg of seeds)	**Efficacy (%) of the insecticides at different days after last planting date**		
	+97	**+117**	**+121**
Gaucho® 700 WS (1)	5±1.39bc	7.25±2.4a	8.39±1.5a
Gaucho® 700 WS (0.8)	6.66±2.84b	4.91±1.49ab	2.38±1.17b
Cruiser® 350 FS (0.8)	21.6±4.3a	5.12±1.9ab	9.2±2.1a
Cruiser® 350 FS (0.4)	1.66±0.7c	2.98±2b	7.53±0.95a
LSD (alpha5%)	***4.3***	***4.05***	***3.89***

Table 5. The mean white head, numeric and weight kernel rates (Sunn pest damaged grain) of wheat in insecticide seed treatments on Sunn pest in the cages used in field.

Damage indexes	**Seed treatments**

	Gaucho® 700 WS(1)	Gaucho® 700 WS(0.8)	Cruiser® 350 FS (0.8)	Cruiser® 350 FS (0.4)	Control	*LSD*
white head rate %	2.33±2.33	12.43±8.56	8.27±4.4	20.5±6.35	58.33±1.6	*15.48*
numeric kernal rate %	77.17±23	82.23±17.66	69±31	100	100	*61.86*
weight kernal rate %	77.17±23	77±23	68.9±31	100	100	*64.81*

Discussion

The efficiency comparison of seed treatments in laboratory tests (pots) and field conditions showed that the seed treatment in the pots has higher efficacy than it in the field. So that thiamethoxam at a high concentration had 84.44% efficacy in the pot and 21.6% efficacy in the field in the first sampling time, while the efficacy of imidacloprid at a high concentration was 41.11% and 5%, respectively. Seed treatments with imidacloprid and thiamethoxam insecticides did not have an acceptable efficacy (<10%) on overwintered adults of Sunn pest in the subsequent evaluations in the field. Although seed treatment with imidacloprid and thiamethoxamis is an effective chemical control method against wheat aphids and wheat bulb fly (Way and van Emden, 2000).

Seed treatment is the most important pest management technique. The rate of crop loss by wireworms, ground beetles (*Zabrus tenebrionis* Goege), and aphids in seed treatment methods is lower in comparison to conventional control methods (Adam and Noal, 2014). Growers often use neonicotinoids as seed treatments for controlling early-season pests on crops. It is used mostly in some crops, such as soybeans, corn, cotton and wheat. The usage of insecticide seed treatment has significantly increased in the world since 2003. In the United States, insecticide seed treatment is applied on 40 million hectares (Douglas and Tooker, 2015).

Potato seed treatment with imidacloprid at a concentration of 30 g a.i./kg tubers can protect the plant from sucking pests for 30–38 days. Also, raising the insecticide concentration (60 g a.i./kg seed) can increase the duration of bioeffectiveness (Nault et al., 2004). In the present study, the results of wheat seed treatment by neonicotinoids against overwintered adults of Sunn pest showed that the efficacy was 84–28% on 48 days after planting in laboratory conditions and 7.77–61.6% on 90 days after planting, respectively, whereas in field conditions, the maximum efficacy of insecticide seed treatment was 21.6% at the migration time of overwintered adults to the fields (on 97 days after planting), and at the subsequent month it was decreased to 9.2%. Based on our results and others' , we found that the bioefficacy of insecticide seed treatment could not be persistent until 90 days after planting. The low percentage of efficiency of insecticide seed treatments would be due to the difference in feeding behavior of overwintered adults of Sunn pest and aphids (Rajabi, 2001; Rajabi, 2007). The overwintered adults of Sunn pest feed from more parts of the wheat plant in comparison with aphids, which mostly select foliage ends for feeding. It can reduce the effectiveness of the seed treatment against the overwintered adult Sunn pest. The main reason for the low efficiency of seed treatment against overwintered adults may be the low concentration of neonicotinoids and their metabolites in the plant and their non-uniform distribution in different parts of the wheat plant. Since tested neonicotinoids are systemic, they can be absorbed through the roots and reach all parts of plant green tissues, nectarines, and pollen grains (Laurent and Rathahao, 2003; Schmuck et al., 2001). The residue of thiamethoxam and its metabolites in different growth stages of sunflower plant showed that their concentrations were low in the flowering stage (2.7 ng/cm^2), compared to the early growth stages (15.89 ng/cm2) (Bredeson and Lundgren, 2015). When imidacloprid is used as a seed treatment, most of its residue is found in the soil, so that 23% of imidacloprid can be found in the soil on 97 days after planting (Westwood et al. 1998). The highest amount of imidacloprid was observed in sugar beet plants on 64 days after planting (5.3%), whereas on 97 days it reached 4.5% of the total residue on the seed (Westwood et al. 1998). Imidacloprid may be metabolized for half or slightly more in the plant. Seed treatments of sugar beet (900 µg per seed) showed that the concentration of imidacloprid and its metabolites (olefin) in the sugar beet leaves was 15.2 µg/g on 21 days after planting, but it was reduced to 0.3-0.5 µg/g on 64 and 97 days after planting (Westwood et al. 1998). The residue decrease of imidacloprid until the flowering stage was observed when it was used as chemigation (130 µg/L) in canola fields in the autumn (Reetz et al., 2015). Plants uptake 5–6% of the total neonicotinoid residue in soil and seeds. The neonicotinoid concentration in soil reduces to 60% and 23% on 21 and 97 days after planting (Douglas and Tooker, 2015). The results of seed treatment with imidacloprid and thiamethoxam against overwintered adults of Sunn pest showed that the bioefficiency of this chemical control method is low. It can be due to the reduced concentration of imidacloprid and thiamethoxam and their metabolites in wheat plants at the emigration time of Sunn pest to wheat and barley fields.The treated seeds with neonicotinoids have been planted for many years. The concentration of neonicotinoid in the soil increased until 4-5 years, but it fixed from the sixth year onwards, so the mean concentration of clothianidin in the soil was 7 ng/g in 10 years after planting treated seeds (Westwood et al., 1998; Xu et al., 2016).

In conclusion, seed treatment with neonicotinoids has a lower usage rate of insecticide per hectare than other chemical control methods. On the other hand, the results showed that the wheat seed treatment with the insecticides imidaclopride and thiamethoxam cannot control the wintered adult Sunn pest on winter planting dates, but it needs to be tested on spring planting dates of wheat. We hope that in the future, the new technology of formulations will increase insecticide efficacy against pests and reduce their environmental side effects. However, at the present, the use of insecticide seed treatment on a large scale on overwintered adult Sunn pest does not have effectiveness and is not recommended.

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