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EFFECT OF THIAMETHOXAM SEED TREATMENT ON INSECT PEST PREVALENCE AND GRAIN YIELD IN WINTER WHEAT (*TRITICUM AESTIVUM* L.)

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SUMMARY

Winter wheat (*Triticum aestivum* L.) yields are gradually increasing in Russian plains, though a limited yield exists, which could point back to insect pest incursion in wheat fields. However, in the past up to the present, yield losses due to insect pest invasion were approximately 20% annually. The latest study aims to determine the effectiveness of the insecticide Thiamethoxam (350 g/l) used in controlling insect pests through wheat seed treatment. The experiments laid out in 2019 and 2020 in the foothill zone of Abinsky, Astrakhan region, Russian Federation. The randomized complete block design (RCBD) used with four replications and a plot size of 100 m^2. The treatment included one winter wheat variety and four treatments: T1 = Kaytoks, KS @ 0.5 l/t, T2 = Kaytoks, KS @ 1.0 l/t, T3 = Cruiser, KS @ 1.0 l/t, and T4 = the control (untreated). Based on the crop season evaluation, a significant increase resulted in the pest population (4.74 to 26.57 adults/m^2) in the control plots. The plots amended with insecticide Thiamethoxam (350 g/l) at the rate of 0.5 l/t showed lesser pest population (0.25 to 1.25 adults/m^2), and plots with 1.0 l/t ranged from 0 to 0.5 adults/m^2. Results also revealed that insecticides of the manufacturers, i.e., Kaytoks, KS, and Cruiser, KS, proved effective in pest control, ranging from 80 to 100%. The wheat seeds treated with Kaytoks, KS (0.5 l/t) and (1.0 l/t) increased their yield compared with control by 9.3 to 14.8% (2019) and 15.6 to 17.3% (2020). Thus, to achieve insect pest control and yield increase in wheat varieties, seed treatment using Thiamethoxam (Kaytoks, KS) at an application rate of 1.0 l/t can be a vital crop protection tool for cereal crops and an eco-friendly method.

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Key findings: Seed treatment with Thiamethoxam (350 g/l) significantly reduced the incidence of five key insect pests and increases winter wheat grain yield in the Astrakhan region, Russia. Thus, Thiamethoxam (350 g/l) can be a recommended option to the farming community for better pest control and increased grain yield.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is among the world's most significant grain crops, and in Russia, it is one of the country's leading food grain baskets. In recent years, reports indicated that Russian wheat production ranked 60 to 70% compared with other grain products (Zimnyakov *et al*., 2020). In the Russian Federation, the Volgograd, Astrakhan, Republic of Kalmykia, and the Central Volga are the main sowing areas for winter wheat production, where 75 to 85% of the area is for agriculture practices. In the Astrakhan Oblast region, due to pests (aphids, leafhoppers, Swedish fly, striped wheat flea, and cereal ground beetles), the winter wheat yield losses have reached estimates of 20-30% annually (Zhuikova and Batalova, 2022). Past studies revealed that aphids (*Sitobion avenae* F.), Swedish fly larvae (*Oscinella frit* L.), flea beetle (*Phyllotreta vittula Redt*), cereal ground beetle larvae (*Zabrus tenebrioides* Goeze), and larvae leafhopper [*Psammotettix striatus* (L.)], are the critical pests affecting winter wheat yield in these regions (Radchenko, 2019; Zhang *et al*., 2022).

The grain aphid (*Sitobion avenae* F.) is the most invasive and risky pest of wheat grains, which significantly reduces cereal production by causing direct damage via feeding and indirectly as a vector for the transmission of harmful viruses (Wang *et al*., 2015). The mentioned pest harms plants by sucking its sap, which interferes with grain filling and excreting honeydew, delaying photosynthesis. Resulting from an insect pest attack caused discoloration on the winter wheat leaves and death; during the flowering stage, the pest affects grain formation, thus reducing the number of grains and the grain size per plant, decreasing yield. *Sitobion avenae* can cause significant losses in Russian farming system and the economy by lowering winter wheat yield by 20% (Radchenko, 2019; Zhang *et al*., 2022). According to Xu *et al*. (2011), *S. avenae* damaged approximately 13 million hectares yearly, lowering China's wheat yield by 40%.

The Swedish fly (*Oscinella frit* L.), belonging to the family Chloropidae, is one of the most widespread cereal pests, causing damage to crops by boring in wheat shoots. It is primarily widespread during the germination and early tillering stages. Its larvae also cause considerable damage to winter wheat crops in all Russian regions (Illarionov *et al*., 2020; Zhuikova and Batalova, 2022). The said fly crawls on the leaf sheaths, penetrating the shoots and working their way up to the auricles, where they feed. When the larvae attacked the wheat plants, the plants quickly turned yellow, and the central leaf withered; thus, plants became stunted, leading to a gradual dieback. Past findings reported yield losses (1.5 to 15.0%) due to Swedish flies, which are continuously increasing every year (30 to 50%) (Illarionov *et al*., 2020; Zhuikova and Batalova, 2022).

The striped wheat flea beetle (*P. vittula* Redt.) is a vector belonging to the Chrysomelidae family. Adults appear in winter wheat during the early stages of plant development and harm the cereal crops in Russia (Zargar *et al*., 2017a; Kozulina *et al*., 2021; Makarova *et al*., 2022). During feeding, the beetles scrape the parenchyma of the wheat plant leaves between the veins in small oblong stripes resembling solid yellowish-gray spots during severe damage. In hot and dry crop seasons, the economic threshold damage of the grain yield might be more than 15% (Zargar *et al.,* 2018; Makarova *et al*., 2022).

The cereal ground beetle (*Z. tenebrioides* Goeze) belongs to the family Carabidae and is one of the most dangerous insect pests that feed on cereal crops. Recently, it has become a severe pest in Russia, causing damage (8 to 40%) in winter wheat (Demenko *et al*., 2022). According to Jasim *et al*. (2022), the Zabrus insect is one of the critical pests of winter wheat in the territory of Orel Oblast, at the eastern border of Astrakhan province and Kazakhstan (Georgescu *et al*., 2017). In spring, the larvae feed on winter wheat leaves, dragging them into their burrows, where they pupate. The sites where the larvae accumulated had formations of 'threadbare spots.' The damage caused by this insect is most often evident in the wheat spikes (Taşkesen *et al*., 2021). Each beetle can feed on up to 25 grains during infestation, leading to considerable grain losses.

Leafhopper (*P. striatus* L.) belongs to the family Cicadellidae, and it is an economic pest threatening wheat production in Russia, with significant production losses due to persistently propagating wheat blue dwarf (WBD). This insect also causes severe plant stunting, with numerous short tillers forming at the plant's base. Infected plant leaves have chlorotic mottling and curling. The lower leaves and stems become deep blue-green, stiffened, and thickened with time. In severely infected wheat plants, spikes appear malformed and sterile and may not grow (Wu *et al.,* 2010; Hollingsworth *et al*., 2008). The larvae are vectors of viral and phytoplasma diseases of winter wheat mosaic, white mosaic, common dwarfism, and pale green dwarfism of wheat (Zhao *et al*., 2010; Abt *et al*., 2018). These viruses cause significant wheat yield losses worldwide (Khorina *et al*., 2023). Most of the damage caused by these pests is visible during the early seedling stages of winter wheat development in Astrakhan province. Therefore, pre-seed insecticide treatment can be a key option for protecting wheat seed materials and seedlings. This method allows reliable and permanent crop protection from various soil-borne and terrestrial pests, including insects carrying viral infections.

Thiamethoxam [5-methyl-3-(2-chlorothiazol-5-ylmethyl)-1,3,5-oxadiazinan-4-ylidene-N-nitroamine] are chemicals that have active ingredient of pesticides (neonicotinoid), with typical uses are to control insect pests of winter wheat and other cereal crops (Beres *et al*., 2016; Zargar *et al*., 2017b). The plant absorbs the Thiamethoxam during seed germination and moves along the xylem to untreated parts of plants. This mechanism of action belongs to acetylcholinesterase agonists, causing the opening of sodium channels in the chain of nerve impulse transmission, triggering over-excitation and paralysis, leading to feeding arrest and insect death (Macedo and e-Castro, 2011). Other regions of Russia conducted studies using insecticides to control cereals' insect pests (Abd-Ella, 2016; Ding *et al*., 2018). Thus, the presented research aims to evaluate the efficacy of Thiamethoxam in controlling insect pests and assess the winter wheat yield in the Astrakhan region, Russian Federation.

MATERIALS AND METHODS

Experimental location and procedure

Experiments conducted in the wheat cropping seasons of 2019 and 2020 in an open field at the foothill zone in District Abinsky, Astrakhan region, Russian Federation. The winter wheat cultivar 'Nikolash' was the sample used in this study. All recommended agronomic practices following the Guidelines for registration tests of insecticides, acaricides, molluscicides, and rodenticides in agriculture by St. Petersburg (Dolzhenko, 2009) were applicable. The experiments were done in a randomized complete block design (RCBD) with four replicates within a plot size of 100 m^2. The soil of the experimental plots was Southern leached chernozems, with a pH of 6.5 to 7.0. Plowing continued at 24-25 cm depths, and a seed sowing rate was 220 kg/ha.

The study used systemic insecticide seed treatment Kaytoks, KS (Thiamethoxam – 350 g/L) from AGROMIR LLC Company and Cruiser, KS (standard) (Thiamethoxam – 350 g/L) from SYNGENTA LLC Company. The study evaluated the efficacy of these chemicals on five key pests (striped flea beetles, Swedish fly larvae, aphids, cereal ground beetle larvae, and leafhopper larvae) affecting winter wheat yields in this region. Seeds treatment used a PS-10 treater with a mixer operating with water, with a working fluid flow rate of 7 l/t, and the operation finished within 12 min; all seeds treatment followed this procedure. The four treatments used at varying levels in the experiment were the following: T_1 = Kaytoks, KS (0.5 l/t), T_2 = Kaytoks, KS (1.0 l/t), T_3 = Cruiser, KS (1.0 l/t), and T_4) control (untreated). During both cropping seasons, the Astrakhan climate was temperate, sharply continental - with high temperatures in summer, low in winter, large annual and summer daily amplitudes of air temperature, low precipitation, and high evaporation. Precipitation falls only 150-175 mm annually, including only 100-200 mm with air temperature above 10 °C. Favorable temperatures ranged from 3450 °C to 3600 °C. No extreme weather conditions (hail, frost, and heavy rains) existed during the crop experimental seasons.

Data collected and statistical analysis

Data collection strictly followed the observation guide, i.e., counting the number of ground insect pests and the damage caused to wheat plants according to the methodology adopted by Dolzhenko (2009). The obtained data analysis used Dolzhenko's guidelines (2009). Counting the larvae was in four samples of 0.5 linear meters in a row for each repetition. A total collection of 20 plant samples from each replication bore probing where applicable, including infested stems. Flea beetles, Stem fly, cereal ground beetles, and aphids entailed counting on the days after planting (DAP), first, third, seventh, and 14^{th} days after larvae emergence in the plots, and bread beetle larvae (leafhopper) counting in the autumn during the germination stage and in spring during the tillering phase. Determining the biological efficacy of insecticides against all pests was according to the Abbott formula (Chulkina *et al*., 2007).

$$X = \frac{A - B}{A} \times 100$$

Where:
X = pest population reduction (%), A = average pest population in the control, and B = average in the experimental variant.

Statistical analysis of all the collected data followed the methodology proposed by Dospekhov (1986), using the least significant difference (LSD) at the 0.05 to separate the means.

RESULTS

Effect of Thiamethoxam (350 g/l) on *P. vittula* population

After planting in May for both experimental years (2019 and 2020), the flea beetle (*P. vittula*) began invading the wheat crops in the first ten days. On the first day of data recording, the number of insect pests in the control plot was 7.75 adults/m^2 in 2019 and 4.75 adults/m^2 in 2020 (Table 1). Wheat seeds

Table 1. Biological effectiveness of Thiamethoxam (350 g/l) against striped flea beetle (*P. vittula*) on winter wheat in the Astrakhan region, Russia.

Crop seasons	Treatments	The average number of adults per one m^2 after the emergence of pests on the survey day				Decline in numbers relative to control (%) from the day of recording pest emergence			
		1	3	7	14	1	3	7	14
2019	Kaytoks KS (0.5 l/t)	0.25	0.5	1.0	1.25	96.7	95.6	93.7	93.7
	Kaytoks KS (1.0 l/t)	0	0.25	0.25	0.5	100	97.8	98.4	97.5
	Cruiser KS (1.0 l/t)	0	0.25	0.25	0.5	100	97.8	98.4	97.5
	Control	7.75	11.5	16.0	20.0				
2020	Kaytoks KS (0.5 l/t)	0	0.5	1.0	1.25	100	95.1	94.0	94.3
	Kaytoks KS (1.0 l/t)	0	0.25	0.25	0.5	100	97.5	98.5	97.7
	Cruiser KS (1.0 l/t)	0	0.25	0.25	0.5	100	97.5	98.5	97.7
	Control	4.75	10.25	16.75	22.25				

treated with insecticide Kaytoks, KS (350 g/l Thiamethoxam) at the consumption rate of 0.5 l/t and 1.0 l/t, pest invading levels were 0.25 adults/m^2 and 0 adults/m^2, respectively. Kaytoks (KS) has revealed that seed treatment at the rate of 1.0 l/t was more effective by 96.7 to 100%. The evaluated insecticide standard Cruiser, KS's effectiveness at the highest application rate (1.0 l/t) was also effective (Table 1). Pest assessment continued on the third day of counting; the number of *P. vittula* increased to 11.5 adults/m^2 and 10.25 adults/m^2 in 2019 and 2020, respectively, in control plots. It was also evident that using Thiamethoxam (350 g/l) with application rates of 0.5 l/t and 1.0 l/t significantly reduced the pest population by 95.1 and 97.8%, respectively.

On the seventh day of observations, in all the treatments, the number of *P. vittula* continued to increase with Thiamethoxam (350 g/l) at the rate O.5 l/t, from 0.25 to 1.0/m^2 and at 1.0 l/t, from 0.0 to 0.25 adults/m^2 in the two study seasons. However, in the control plots, there were 16.0 adults/m^2 and 16.75 imago/m^2 in 2019 and 2020, respectively. Notably, there were no significant differences in the efficacy among the treatments within the seven days of data collection. In the 14th day of observations, the number of flea beetles increased in plots with Thiamethoxam (350 g/l) from 0.25–1.0 adults/m^2 in both study seasons. However, in the control plots, there were 20.0 adults/m^2 and 22.25 imago/m^2 in 2019 and 2020, respectively. The effectiveness of the new insecticides varied (from 94.3 to 98.4%) according to the applied concentration rates, while the biological efficiency of Cruiser (KS) was 94.7 to 97.7% (Table 1).

Effect of Thiamethoxam (350 g/l) on *O. frit* population

The Swedish fly (*O. frit* L.) larvae predominated during the winter wheat cultivation phases. In the control plots, their population on the first day of counting after the emergence of *O. frit* was 8.5 and 8.25 larvae/linear meter (lm) in 2019 and 2020, respectively, which reduced to 0.5 and 0.0 larvae/lm with the treatment application rates of 0.5 and 1.0 l/t, respectively. According to the application doses, the biological effectiveness of Thiamethoxam (350 g/l) was 93.9 to 100%. The results further revealed that for the standard Cruiser KS insecticides, the efficiency was 100% (Table 2). In the third day of counting, the number of larvae of *O. frit* in the treatment at 0.5 l/t reached 0.5 larvae/lm, and at 1.0 l/t, it reached 0.25 larvae/lm. However, in the control plots, the number of larvae of *O. frit* was 14.5 and 15.5 larvae/lm in 2019 and 2020, respectively.

At the same time, the efficiency of the insecticide Kaytoks, KS, at the application rate of 1.0 l/t, was equal in efficacy level as the standard Cruiser, KS insecticides. In subsequent observations, an increase in larvae number was noteworthy in all experimental treatments. By the seventh day of recording,

Table 2. Biological effectiveness of Thiamethoxam (350 g/l) against Swedish fly larvae (*O. frit* L.) on winter wheat in the Astrakhan region, Russia.

Crop seasons	Treatments	Average number of larvae per one linear meter from the day of survey as the pests appear				Decline in numbers relative to control (%) from the day of recording pest emergence			
		1	3	7	14	1	3	7	14
2019	Kaytoks KS (0.5 l/t)	0.5	0.5	1.0	1.5	94.1	96.5	95.1	94.1
	Kaytoks KS (1.0 l/t)	0	0.25	0.5	1.0	100	98.2	97.5	96.1
	Cruiser KS (1.0 l/t)	0	0.25	0.5	0.75	100	98.2	97.5	97.0
	Control	8.5	14.5	20.5	25.75				
2020	Kaytoks KS (0.5 l/t)	0.5	0.5	1.0	1.25	93.9	96.7	95.3	95.2
	Kaytoks KS (1.0 l/t)	0	0.25	0.5	0.75	100	98.3	97.6	97.1
	Cruiser KS (1.0 l/t)	0	0.25	0.25	0.75	100	98.3	98.8	97.1
	Control	8.25	15.5	21.5	26.5				

the amount of *O. frit* decreased from 20.5 to 0.5/ lm in the treatments, Kaytoks 1.0 l/t and Cruiser KS 1.0 l/t. The treatment Kaytoks (0.5 l/t) had the most negligible efficacy, with 1.0/lm in 2019. In contrast, for 2020, the larvae/lm declined from 21.5 to 0.25 using Cruiser KS (1.0 l/t), 0.5/lm with Kaytoks (1.0 l/t), while Kaytoks (0.5 l/t) caused the same reduction level as in 2019 at the value of 0.5/lm. Both insecticides (Kaytoks, KS and Cruiser, KS - with application rates of 0.5 and 1.0 l/t) were effective (95.1–98.8%). In the 14th day after the appearance of Swedish fly larvae, the effectiveness of Thiamethoxam (350 g/l) was 94.1–97.1% (Table 2).

Effect of Thiamethoxam (350 g/l) on *S. avenae* population

In the first day of observation, in control plots, *S. avenae* was 7.0 and 8.75 aphids per 10 net sweeps in 2019 and 2020, respectively. The biological effectiveness of Kaytoks, KS, was 89.2 to 100%. In the third day, the control plots exhibited 11.5 and 14.25 pieces/10 strokes of *S. avenae* in 2019 and 2020, respectively. However, the effectiveness of the insecticide Kaytoks, KS, at the application rate of 1.0 l/t, was slightly higher than the efficiency level of the standard Cruiser, KS. On the seventh day of observation, the number of aphids in the control plots was 19.25 pieces/stroke in 2019 and 18.75 pieces/10 strokes in 2020, and the effectiveness of Kaytoks, KS was 94.8% to 97.4% (Table 3). By the 14th day of data recording, seed treatment with Thiamethoxam (350 g/l) proved more effective in protecting the wheat crop from aphids by 93.6–96.0%, respectively.

Effect of Thiamethoxam (350 g/l) on *Z. tenebrioides* population

During the germination stage of the winter wheat, in the treatment using insecticide Kaytoks, KS, the reduction was remarkable in the number of cereal ground beetle (*Z. tenebrioides*) larvae with the application rate of 1.0 l/ha, which was slightly lower than the Cruiser level insecticide. In the tillering stage, treatment with the insecticide Kaytoks, KS, indicated a decrease in ground beetle larvae at the application rate of 1.0 l/t. In contrast, the treatment with the Cruiser level insecticide with the same application rate differed. By using the insecticide Kaytoks, KS, at the application rate of 0.5 l/t, the number of cereal ground beetle larvae was lower during tillering by 78.3% than that of Cruiser (1.0 l/t), KS treatment by 94.5% (Table 4).

Table 3. Biological effectiveness of Thiamethoxam (350 g/l) against *S. avenae* on winter wheat in the Astrakhan region, Russia.

Crop seasons	Treatments	Average number of aphids per 10 net sweeps from the day of survey as the pests appear				Decline in numbers relative to control (%) from the day of recording pest emergence			
		1	3	7	14	1	3	7	14
2019	Kaytoks KS (0.5 l/t)	0.75	1.0	1.0	1.5	89.2	91.3	94.8	93.6
	Kaytoks KS (1.0 l/t)	0	0.25	0.5	1.0	100	97.3	97.4	95.7
	Cruiser KS (1.0 l/t)	0.25	0.5	0.5	0.75	96.4	95.6	97.4	96.8
	Control	7.0	11.5	19.25	23.75				
2020	Kaytoks KS (0.5 l/t)	0.5	0.75	0.75	1.5	94.2	94.7	96.0	94.0
	Kaytoks KS (1.0 l/t)	0	0.25	0.5	1.0	100	98.2	97.3	96.0
	Cruiser KS (1.0 l/t)	0	0.5	0.5	0.75	100	96.1	97.3	97.0
	Control	8.75	14.25	18.75	25.0				

Table 4. Biological effectiveness of Thiamethoxam (350 g/l) against *Z. tenebrioides*'s larvae on winter wheat in the Astrakhan region, Russia.

Crop seasons	Treatments	Average number of larvae per m^2		Decline in numbers relative to control (%)	
		in autumn, during the germination stage	in spring, during the tillering stage	in autumn, during the germination stage	in spring, during the tillering stage
2019	Kaytoks KS (0.5 l/t)	8.0	4.0	60.5	78.3
	Kaytoks KS (1.0 l/t)	1.25	0.75	93.8	95.9
	Cruiser KS (1.0 l/t)	1.5	1.0	92.5	94.5
	Control	20.25	18.5		
2020	Kaytoks KS (0.5 l/t)	6.5	3.25	65.3	79.3
	Kaytoks KS (1.0 l/t)	1.0	0.5	94.6	96.8
	Cruiser KS (1.0 l/t)	0.75	0.5	96.0	96.8
	Control	18.75	15.75		

Table 5. Biological effectiveness of the insecticide Kaytoks, KS (350 g/l) against *Z. tenebrioides* population on winter wheat in the Astrakhan region, Russia.

Crop seasons	Treatments	Average number of damaged plants (main stems) (m^2)		Reduced plant damage relative to control (%)	
		in autumn, during the germination stage	in spring, during the tillering stage	in autumn, during the germination stage	in spring, during the tillering stage
2019	Kaytoks KS (0.5 l/t)	10.5	7.25	64.1	62.3
	Kaytoks KS (1.0 l/t)	5.75	1.0	80.3	94.8
	Cruiser KS (1.0 l/t)	6.0	1.0	79.4	94.8
	Control	29.25	19.25		
2020	Kaytoks KS (0.5 l/t)	11.25	6.25	55.8	64.7
	Kaytoks KS (1.0 l/t)	2.0	0.75	92.1	95.7
	Cruiser KS (1.0 l/t)	2.25	0.75	91.1	95.7
	Control	25.5	17.75		

Effect of Kaytoks, KS (350 g/l) on *Z. tenebrioides* population

As shown in Table 5, the efficiency of Kaytoks, KS, and Cruiser, KS, at the application rate of 1.0 l/t, shows nonsignificant differences in both years. Kaytoks effectively reduced plant damage by 80.3% and Cruiser by 79.4% in 2019 and 2020, by 92.1% and 91.1% in the germination and tillering stage of crop development. Data from the two-year observations allowed us to conclude that the insecticide Kaytoks, KS (350 g/l) at the application rate of 1.0 l/t was not inferior to Cruiser, KS, in reducing the number of ground beetle larvae and their damage to winter wheat plants.

Effect of Thiamethoxam (350 g/l) on *P. striatus* population

By counting leafhoppers (*P. striatus*) at the first day after their appearance, in the control plots, their average number was 8.0 pieces/10 strokes of the net. The biological effectiveness of the insecticide Kaytoks, KS, and Cruiser, KS, at an application rate of 1.0 l/t, have equal efficiency levels. At Kaytoks, KS, with a 0.5 l/t application rate, the *P. striatus* population was 0.75 pieces/10 strokes in 2019 and 0.5 pieces/ 10 strokes in 2020. On day three observation, the number of leafhoppers in the treatment with the tested insecticides reached 1.0 and 1.25 pieces/10 strokes (0.5 l/t) and 0.25 and 0.75 pieces/10 strokes (1.0 l/t) in 2019 and

Table 6. Biological effectiveness of Thiamethoxam (350 g/l) against leafhoppers (*Psammotettix striatus* L.) in winter wheat in the Astrakhan region, Russia.

Crop seasons	Treatments	Average number of leafhoppers per 10 net sweeps from the day of survey as the pests appear				Decline in numbers relative to control (%) from the day of recording pest emergence			
		1	3	7	14	1	3	7	14
2019	Kaytoks KS (0.5 l/t)	0.75	1.0	2.0	4.75	90.6	93.3	91.6	82.7
	Kaytoks KS (1.0 l/t)	0.25	0.25	1.0	4.0	96.8	98.3	96.8	85.4
	Cruiser KS (1.0 l/t)	0.25	0.5	0.75	4.0	96.8	96.6	96.8	85.4
	Control	8.0	15.0	24.0	27.5				
2020	Kaytoks KS (0.5 l/t)	0.5	1.25	2.5	5.0	94.5	91.3	88.6	81.3
	Kaytoks KS (1.0 l/t)	0.5	0.75	2.0	4.0	94.5	94.8	90.9	85.0
	Cruiser KS (1.0 l/t)	0.25	0.75	1.75	4.0	97.2	94.8	92.0	85.0
	Control	9.25	14.5	22.0	26.75				

Table 7. Effect of insecticide Kaytoks, KS, Thiamethoxam (350 g/l) for the grain yield of winter wheat in the Astrakhan region, Russia.

Crop seasons	Treatments	Productivity by repetition (t/ha)					Increase (%)	
		1	2	3	4	Average	t/ha	Compared to control
2019	Kaytoks KS (0.5 l/t)	1.42	1.38	1.40	1.40	1.40	0.12	9.3
	Kaytoks KS (1.0 l/t)	1.45	1.49	1.47	1.49	1.47	0.19	14.8
	Cruiser KS (1.0 l/t)	1.47	1.42	1.50	1.43	1.46	0.18	14.1
	Control	1.31	1.27	1.25	1.20	1.31	-	-
2020	Kaytoks KS (0.5 l/t)	1.40	1.43	1.45	1.40	1.33	0.20	15.6
	Kaytoks KS (1.0 l/t)	1.47	1.50	1.45	1.45	1.38	0.25	17.3
	Cruiser KS (1.0 l/t)	1.48	1.45	1.52	1.41	1.40	0.27	17.8
	Control	1.11	1.18	1.12	1.11	1.13	-	-

2020, respectively. In the control plots, the average number was 15.0 in 2019 and 14.5 pieces/10 strokes in 2020. However, the effectiveness of Kaytoks, KS, with an application rate of 1.0 l/t, was slightly higher than the Cruiser, KS insecticide efficiency level. In the seventh day, the number of leafhoppers in the control plots was 24.0 in 2019 and 22.0 pieces/10 strokes in 2020. Plots amended with insecticide Kaytoks, KS (0.5l/t), had 2.0 pieces/10 strokes in 2019 and 2.5 pieces/10 strokes in 2020. The effectiveness of both insecticides at a 1.0 l/t application rate had a nonsignificant difference. In the 14th observation, the insecticide treatment on wheat seed protected the wheat plants from leafhoppers by 82.7–85.4% (Table 6).

Effect of Kaytoks, KS, Thiamethoxam on wheat grain yield

Generally, noninsecticidal application in the control plots of winter wheat exhibited grain yields of 13.1 t/ha in 2019 and 11.3 t/ha in 2020. However, insecticidal seed treatments using the Kaytoks, KS (350 g/l) at the rate of 0.5 to 1.0 l/t significantly increased the grain yield of the crop from 9.3 to 14.8% and from 15.6 to 17.3% in 2019 and 2020, while Cruiser, KS (1.0 l/t) was 14.1 and 17.8%, respectively (Table 7).

DISCUSSION

The results showed that all insect species of different families observed in this study, in their early development stages, could affect winter wheat in the Astrakhan region of Russia. The leading winter wheat pests investigated in the pertinent research belonged to Chrysomelidae, Chloropidae, Aphididae, Carabidae, and Cicadellidae. These results agree with Pavlushin *et al.* (2015), stating that these insect families can destroy 60% of seedlings under favorable conditions and considerably reduce winter wheat yields (Pavlushin *et al*., 2015). Depending on the crop season and the evaluation time, in 2020, the population of *P. vittula* varied from 7.5–20.0 and 4.75–22.25 adults/m^2, and for *O. frit* larvae from 8.5–25.75 and 8.25–26.5. The presented results were analogous to the findings which reported similar effects of insecticidal seed treatment on cereal aphids in wheat cultivars (Abd-Ella, 2016; Illarionov *et al*., 2020; Ismailova and Azizov, 2022; Bakhadirov *et al*., 2024).

Findings showed an increase in Swedish fly larvae from 8.5–27.75 larvae/linear meter in 2019 and 8.25–26.50 larvae/linear meter in 2020 during observation time. These results are similar to the findings of Boika *et al.* (2020) in Belarus, where Swedish flies usually dominated winter wheat crops in the initial period of plant development stages in autumn. Among these insects include cereal flies, barley flies (*O. pusilla* Mg.), ranging from 77.8–83.6%, and oat flies (*O. frit* L.), from 22.2–16.4% annually (Boika *et al.,* 2020). According to Boika *et al*. (2022), the research results indicated that at the 2-leaf stage (BBCH 12), an average of 2.0–44.0 wasps/100 strokes of an entomological net (hereafter, wasps/100 strokes of the net) incurred mowing, and the pest damage was 3.9-22.0%. In 2019 and 2020, a significant increase in winter wheat yield was attained, ranging from 9.3 to 14.8% and 15.6 to 17.3%, respectively.

In the treatments with insecticide Kaytoks, KS (350 g/l) at the rate of 0.5 to 1.0 l/t, despite the pest damage, according to the research of Pavlushin *et al.,* they observed a considerable increase in yield notwithstanding pest damage in their wheat field in the Volga region, Russia (Pavlushin *et al.,* 2015); this result agrees with the latest study that observed a significant increase in winter wheat yield from 9.3 to 14.8% and from 15.6 to 17.3% in 2019 and 2020, respectively.

Seed treatments are among the crop protection measures that could achieve a maximum positive environmental impact. Protecting the plant during its early growth and development stages from pests is necessary to increase crop yield. The efficacy of Thiamethoxam (350 g/l) varied according to the pest and the application rate compared with the control. The insecticidal potential of Kaytoks, KS was not significantly different from that of the Cruiser, KS insecticide; thus, their efficiency ranged from 80 to 100%. These results are in agreement with the findings of Pavlushin *et al*. (2015), Abd-Ella (2016), and Boika *et al*. (2022) in the evaluation of diverse seed treatments in winter wheat genotypes using Cruiser KS insecticide at an application rate of 2.0 l/t. A similar study of insecticidal-fungicidal mordant Questor Forte, KS, with an application rate of 2.0 l/t, based on Thiamethoxam (150 g/l), showed that the insecticide reliably provides protection of grain crops from larvae of click beetles and cereal flies in grain crop seedlings (Boika *et al*., 2022).

CONCLUSIONS

Assessing the biological effectiveness of the insecticide Thiamethoxam for seed treatment revealed that both application rates have a significant impact on reducing insect pest populations at a favorable economic threshold. It was also evident that the insecticide efficacy at the application rate of 0.5 l/t was slightly lower than the efficiency attained through Cruiser, KS rate (1.0 l/t). Both insecticides, Kaytoks, KS, and Cruiser, KS, performed better at the standard application rate of 1.0 l/t, with remarkable performances in controlling pests. Seed treatment with Kaytoks, KS, and Cruiser, KS, can be a recommended superior protection measure to minimize the insect pest population and increase the grain yield in winter wheat.

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