Influence of irrigation on the Sunn pest *Eurygaster integriceps* Put. (Insecta: Heteroptera) in the Central Forest-Steppe of Ukraine

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Abstract. The aim of the research is to establish the influence of watering on the phenological and biological features of winter wheat pests development, in particular Sunn pests. Trials were conducted on winter wheat crops under sprinkler irrigation in 2015-2020 in conditions of the Central Forest-Steppe of Ukraine. The size of the experimental plots in the field experiments was 50 m^2 (10.4x4.8 m) at the 4 times replication. The allocation of plots was randomized. The average numbers of Sunn pest nymphs in 2015-2020 were 0.7-2.7 exemplars/m^2 on non-irrigated winter wheat crops and 0.8-3.8 exemplars/m^2 on irrigated. The share of the factor "presence of irrigation" that impacts on the number of Sunn pests reaches 80.2%. The sums of degree-days necessary for the beginning of different development stages of this phytophagous were calculated. The stage of the revival of Sunn pest nymphs began in mid-May – the first decade of June, which coincided with the phases of development of winter wheat: the end of flowering – soft dough ripening of the grain. The sum of degree-days required for the beginning of this stage was 177.8-233.8°C without irrigation, while in sprinkler irrigation conditions – 275.5-349.1°C. For the beginning of the transformation of the fifth instar nymphs into adults, the required sum of degree-days was 410.5-481.5°C on the non-irrigated crops and 545.7-630.4°C – under conditions of irrigation. Clarifying the sum of degree-days required for different stages of Sunn pest development will allow for predicting the terms of protective measures against this pest in the field conditions under irrigation.

Keywords: winter wheat, sprinkler irrigation, Sunn pest, phytophagous, Central Forest-Steppe of Ukraine.

1. Introduction

Winter wheat is one of the most common crops grown in Ukraine. According to the State Statistics Committee data's, the planting area under this crop over the past 10 years has varied between 5.796-6.851 million hectares and reaches 6.907 million hectares in 2021. It is known that regions with insufficient and unsustainable moisture include 70% of the country's lands. So irrigation is a condition for the stable production of this crop (Lv at al, 2010). After all, at the absence of the possibility for irrigation of crops, the agricultural producer faces with the problem of crop yield failure, despite the supplying of grown plants with all other necessary elements of their cultivation technologies: tillage, quality seeds, fertilizers, pesticides, etc.

More than 360 species of insects and other animal organisms, including nematodes, rodents, birds and representatives of other classes of fauna damage cereals in Ukraine (Fedorenko, 2015). Plants in the growth stages of winter wheat from germination to tillering are infested and damaged by the following phytophagous: Corn ground beetle (*Zabrus tenebrioides* Goeze.), cutworms (Noctuidae), cereal flies (Frit fly, Hessian fly), cereal leafhoppers (Six-spotted leafhopper, European grass-feeding leafhopper), aphids (English grain aphid, Oat grain aphid, Spring grain aphid). With the beginning of spring vegetation, these pests continue to feed on crops, in addition, winter wheat plants are damaged by flea beetles (*Chaetocnema*, *Phyllotreta* spp.), cereal leaf beetles (*Oulema* spp.).

Saturation of crop rotation with cereals (corn, winter wheat) leads to creation of favorable conditions for the development of pests and, accordingly, for growth of their number and harmfulness on winter wheat crops (Melnichuk et al., 2019). Winter wheat crop in the phase of stem extension is infested and damaged by the Sunn pest (*Eurygaster integriceps* Put.) (Zibaee & Bandani, 2009; Canhilal, 2016; Alizadeh et al., 2022). The Sunn pest is negatively affecting the flour quality and cause yield loss at damage of wheat grains (Gotsova & Kontev, 1981; Dizlek & Özer, 2015a; Dizlek & Özer, 2015b; Sabanci et al., 2022).

In the middle of the growing season from the phase of flag leaf sheath opening till grain filling, the generative organs are damaged by cereal aphids and wheat thrips. In the phase of grain filling – soft dough ripening of the grain, winter wheat grain damage is caused by shield-backed bug nymphs. The grain is damaged by the imago of bread beetles (*Anisoplia* spp.) and corn ground beetles (*Zabrus tenebrioides* Goeze.) before harvesting. Pests feeding on winter wheat plants leads to a shortage of grain yield or its complete loses. In particular, damage of the winter wheat stem only by a Sunn pest reduce its yields by 50-54% (Sekun, 2002), damage of the grain reduce its quality significantly (Durić et al., 2014; Torbica et al., 2014).

Implementation of irrigation leads to changes in the structure and chemical composition of the soil, as well as affects its aeration. Artificial irrigation results in a change in the intensity of physiological processes in plants, their biomass, and species composition of weeds in agrocenoses. These factors further significantly affect the species and quantitative composition of the entomofauna of different agrocenoses, including winter wheat (Podkopay, 1964; Melnichuk, 2020). Density of the Sunn pest adults on irrigated crops is maintained at a much lower level (lower by 1.6-2 times) (Kamenchenko, 2006) than at growing without watering, due to low temperatures, high humidity of air and soil. Irrigation creates additional opportunities to protect cultivated plants from pests. Irrigation water itself is an effective protective tool against big number of pests. So the use of irrigation in plant protection gives positive results when the time of watering matches with certain plant growth phases and phenological stages of pest development (Minoranskiy, 1979).

The analysis of literature sources shows us that the influence of irrigation on the biological peculiarities of the phytophagous population development isn't studied completely. Investigations of the effects of irrigation on the development of particular insect species have been conducted by scientists from different countries. It was noted that irrigation provides the prolongation of the growing season of cereals. Greater moisture supply of host plants and soil improves the feeding conditions of phytophagous, promotes the accumulation of fat reserves that are necessary for overwintering and increasing of the adult's fertility (Minoranskiy, 1979).

Influence of watering on the peculiarities of the shield-backed bugs development, in particular Sunn pest, has been insufficiently studied. In the spring, adults migrate on the irrigated and non-irrigated wheat crops almost simultaneously. Sparse sowing and well-heated crops are more attracted for the pest. Combination of watering terms with mass flights of Sunn pest contributes to a lower its population density on winter wheat crops. Drought-induced stress conditions adversely affect the condition of crops under common wheat cultivation and indirectly affect the behavior of pests that are trophically related to host plants. It is known that in arid conditions, the consumption of plant moisture for evaporation increases sharply. This drives shield-backed bugs to migrate on more humid crops (Kamenchenko, 2006).

The population density of shield-backed bugs adults feeding on plants of irrigated fields in the spring, as well as the number of nymphs of the new generation are not exceed an appropriate indicator in non-irrigated areas. Heavy rains and watering during the development of eggs lead to their death. Under sprinkler irrigation, the duration of Sunn pest development from egg to adult stage is prolonged (Dovhan et al., 2008).

The aim of the research is to establish the influence of watering on the phenological and biological features of winter wheat pests development, in particular Sunn pest, and to determine the dependence of fluctuations in its density of population on the presence and absence of crop irrigation.

2. Materials and methods

Field investigations were conducted on winter wheat crops according to generally accepted methods (Paliy, 1970; Omelyuta et al., 1986; Stankevych & Zabrodina, 2016) during 2015-2020 in Boryspil district, Kyiv region, Ukraine. The size of the experimental plots in the field experiments was 50 m^2 (10.4x4.8 m), the replication was 4 times. Allocation of plots was randomized. The entomological butterfly net was used to count and identify insects on plants. The number of small and mobile insects (thrips, aphids, fleas, leafhoppers, ladybirds, shield-backed bugs, bees, lacewings) was determined per 100 stroke-swings. Catching by butterfly net was carried out in all phases of crop development, from the germination of seeds to harvesting of yield.

Observations of winter wheat crops for the detection of adults and nymphs of shield-backed bugs were carried out in the phase of spring tillering – harvesting. On plots, arranged in a checkerboard pattern in 8-time replication, observations were performed using a frame of 50 x 50 cm (0.25 m^2), which was applied to the plants randomly. As a result, the average number of insects per 1 m^2 of crops was defined (Trybel et al., 2001).

For thrips counts, 5 spikelets were selected in 10 places of the plot. Samples were placed in paper bags, then the number of thrips and their average number per one spikelet were counted in the laboratory. The number of cereal aphids was counted on each plot on 100 stems (5 stems in 20 places), taking into account adults and larvaes on leaves, stems and spikelets.

Hydrothermal coefficient of Selianinov (HTC) (Meladze M. & Meladze G., 2017; Stoyanova & Georgiev, 2017) calculated by the formula: $K=R*10/\Sigma t$; where R is the sum of precipitation in millimeters for a period with temperatures above +10°C, Σt is the sum of temperatures in degrees Celsius (°C) for the same time. The lower the HTC, the drier the area.

The degree-days were calculated using the formula for the average daily temperature, calculated from the daily maximum and minimum temperatures, minus the development threshold (Herms, 2004; Iranipour et al., 2010; Gözüaçik et al., 2016; Musayeva & Yaxyayev, 2020). For development threshold for Sunn pest was taken temperature +10°C.

3. Results and discussions

Among the main pests of cereals, from the period of seed germination and throughout the growing season, the greatest damage is caused by about 30 species of insects, several species of mites and nematodes (Bublyk et al., 1999). Phytophages of 34 species were damaged the plants of winter wheat at observations in 2015-2020 (Table 1).

Table 1. Species composition of dominant wheat pests in irrigated agrocenoses of winter wheat in the Central Forest-Steppe of Ukraine (2015-2020).

Period, stage of crop development	Phytophagous
1	2
Autumn. Planted and germinating seeds – the beginning of tillering	*Agrotis (Scotia) segetum* Denis and Schiffermaller *Agriotes sputator* L., *A. obscurus* L., *A. gurgistanus* Fald., *Selatosomus latus* F. *Delia platura* Mg. (*Hylemyia cilicrura* Nar.) *Zabrus tenebrioides* Goeze. *Phyllotreta vittula* T. *Macrosteles laevis* Rib., *Psammotettix striatus* L.
Seedlings – tillering	*Sitobion avenae* F. *Rhopalosiphum padi* L. *Oscinella pusilla* Mg., *Oscinella frit* L. *Mayetiola destructor* Say *Phorbia securis* Tien.

Spring. Tillering – Stem elongation	*Zabrus tenebrioides* Goeze. *Mayetiola destructor* Say *Oscinella pusilla* Mg., *Oscinella frit* L. *Phorbia securis* Tien. *Eurygaster integriceps* Put., *Eurygaster austriacus* Schrank., *Eurygaster maura* L. *Aelia acuminata* L., *A. rostrata* Boh.
Spring-summer period. Tillering – soft dough	*Chaetocnema aridula* Gyll., *Chaetocnema hortensis* Geoffr., *Phyllotreta vittula* T. *Oulema melanopus* L., *Oulema lichenis* Voet. *Sitobion avenae* F.
Summer. Heading – flowering	*Schizaphis graminum* Rond., *Rhopalosiphum padi* L. *Mayetiola destructor* Say *Chlorops pumilionis* Bjerk
Flowering – grain filling	*Haplothrips tritici* Kurd. *Hybolasioptera cerealis* Lind.
Milk – full ripening	*Eurygaster integriceps* Put., *Eurygaster austriacus* Schrank., *Eurygaster maura* L. *Haplothrips tritici* Kurd. *Anisoplia austriaca* Herbst, *A. agricola* Poda., *A. segetum* Herbst *Cephus pygmaeus* L., *Trachelus tabidus* F.

Studies show that the species composition of the main phytophages of irrigated winter wheat crops completely coincides with the species composition in the conditions without of sprinkler irrigation, but the quantitative ratio of species differs significantly (Fig. 1). During the period of research, a higher number of cereal aphids was observed on irrigated crops. The share of wheat thrips in the phytophagous complex also increased. Regarding to the flea beetles and cereal leaf beetles, it was determined the decreasing in the number of these pests and their both shares in the complex.

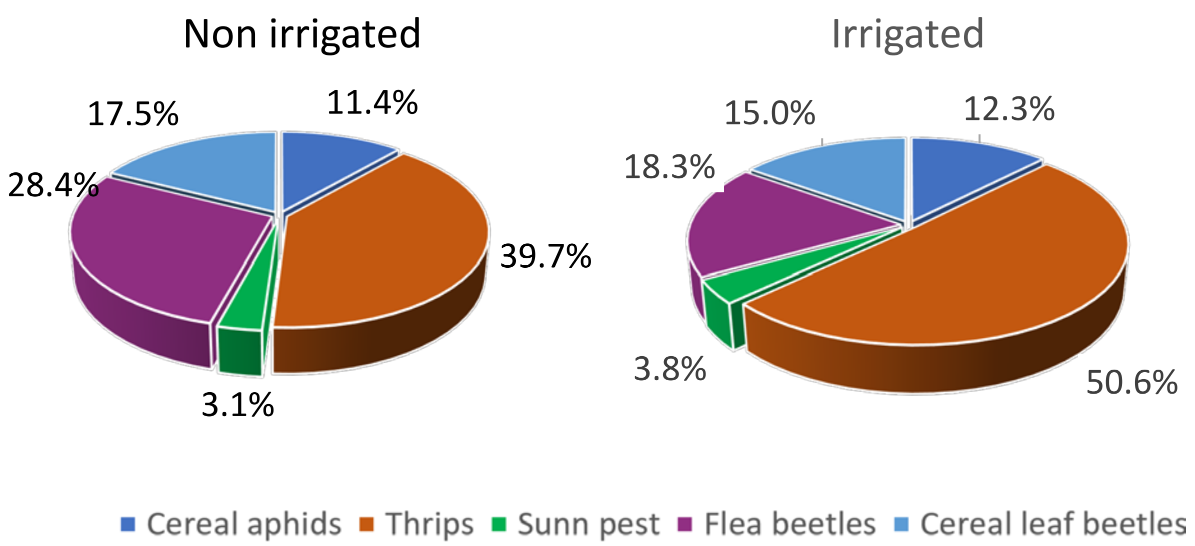

Figure 1. The structure of the main phytophagous complex of winter wheat depending on irrigation (2015-2020).

In the conditions of the Central Forest-Steppe of Ukraine during 2015-2020, the Sunn pest (*Eurygaster integriceps* Put.) was dominated among the shield-backed bugs. Also the other species of shield-backed bugs were found: tortoise bug (*Eurygaster maura* L.), Austrian (*Eurygaster austriaca* Schrank) and others. The average numbers of Sunn pest nymphs in 2015-2020 were 0.7 and 2.7 exemplars/m² on winter wheat crops without irrigation and 0.8-3.8 exemplars/m² on irrigated ones. Depending on the weather conditions of the research years the difference reaches 14.3-33.3%. Thus, in drier (Hydrothermal coefficient (HTC) = 1.0-1.12) years, the difference between the number of phytophagous was increased, in more humid (HTC = 1.43-1.7) – was decreased (Table 2).

Table 2. Influence of sprinkler irrigation on the average number of winter wheat pests in the conditions of the Central Forest-Steppe of Ukraine (2015-2020).

Year	Variants	Number					
		Nymphs of Sunn pest, exemplars/m^2	± to control, %	Flea beetles, exemplars/m^2	± to control, %	Cereal leaf beetle (imago), exemplars/m^2	± to control, %
2015	without irrigation	2.6		20.8		16.4	
	irrigation	3.4	30.8	12.0	-42.3	14.5	-11.6
2016	without irrigation	0.7		8.9		10.2	
	irrigation	0.8	14.3	6.2	-30.3	9.7	-4.9
2017	without irrigation	2.3		19.3		5.8	
	irrigation	2.8	21.7	14.6	-24.4	4.8	-17.2
2018	without irrigation	2.3		18.8		7.1	
	irrigation	2.9	26.1	14.1	-25.0	6.2	-12.7
2019	without irrigation	2.7		23.3		14.3	
	irrigation irrigation	3.6	33.3	13.6	-41.6	11.9	-16.8
2020	without irrigation	0.7		12.3		9.8	
	irrigation	0.9	28.6	8.	-34.1	9.2	-6.1

Two-factor analysis of variance regarding the results of the studies was calculated. The factors of “presence of irrigation” with two gradations (without irrigation and with irrigation) and weather and climatic conditions of the growing season were considered. It was found that the factor “presence of irrigation” had a significant impact on the number of Sunn pest. Its share reaches 80.2% (Fig. 2).

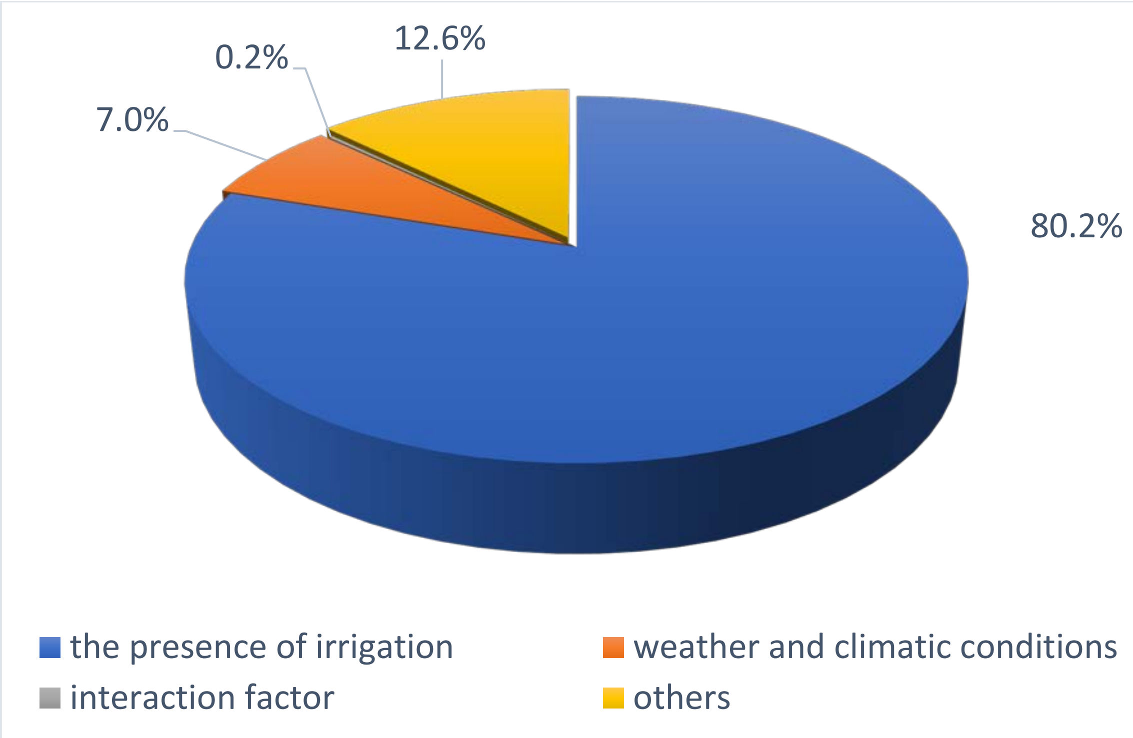

Figure 2. The influence of the studied factors on the number of Sunn pest on winter wheat crops.

Weather conditions, including snowless winters with significant reductions and sharp changes of air temperature, play an important role in reducing of the shield-backed bugs number. The activity of physiological processes of pest increases at warm and dry weather in autumn. It leads to a significant consumption of energy reserves and their lack in the cold season. Warm and dry spring is favor for the development of sexual products and the active laying of eggs by the pest, it accelerates the development of eggs and nymphs. Insufficient nutrition of shield-backed bugs in summer causes their mass death in winter. Weakened overwintered females have reduced fertility, which leads to the population size reducing (Iranipour et al., 2011).

Shield-backed bugs are univoltine and develop in one generation. Adults overwinter in forests, in forest floor, under fallen leaf litter. According to various sources, the migration of overwintered adults to the fields begins at the average daily temperature of + 9.5°C or + 13-14°C. The sum of degree-days in amount of 50.9-68.8°C is required for insects to leave their wintering places (Dovhan et al., 2008; Gözüaçik et al., 2016; Musayeva & Yaxyayev, 2020). In our studies, the beginning of colonization of cereal crops by overwintering shield-backed bugs was observed during May, which coincided with the phase of tillering – stem elongation of winter wheat. In some years, depending on weather conditions, the beginning of mass migration of shield-backed bugs from wintering places to winter wheat crops occurred in the I, II, III decades of the month. So the sum of degree-days in amount of 109.3-141.3°C is needed for the beginning of mass migration of Sunn pest.

During the observations, it was noted that the beginning of shield-backed bug egg laying occurred during the mass flight of adults. It happens usually in 2-6 days after the beginning of the flight of overwintering population. The needed sum of degree-days was 124.5-153.2°C.

The beginning of the revival of nymphs occurred in mid-May – the first decade of June, which coincided with the phases of development of winter wheat: the end of flowering – soft dough ripening of the grain. The sum of degree-days required for the beginning of this stage was 177.8-233.8°C on winter wheat crops without irrigation, while under sprinkler irrigation conditions – 275.5-349.1°C (Table 3). Nymphs of Ist and IInd instars are very sensitive to hydro-meteorological conditions: lower air temperature and abundant rainfall (watering) cause their mass death. Our data had shown that during irrigation, the period of development of shield-backed bug nymphs was prolongated.

Table 3. Influence of sprinkler irrigation on the development of shield-backed bugs on winter wheat, 2015-2020.

Stage of Sunn pest development	Year	Date of stage beginning		Sum of degree-days	
		without irrigation	irrigation	without irrigation	irrigation
Appearance of the first-stage nymphs (n1)	2015	27 May	10 June	199.4	335.9
	2016	21 May	02 June	178.5	275.5
	2017	02 June	12 June	233.8	317.5
	2018	17 May	29 May	219.8	307.8
	2019	25 May	06 June	195.1	327.6
	2020	09 June	21 June	177.8	349.1
	average	-	-	203.9	309.6
Appearance of the new generation of adults	2015	25 June	08 July	481.5	630.4
	2016	19 June	01 July	413.9	590.7
	2017	27 June	09 July	459.1	578.8
	2018	14 June	24 June	451.8	561.9
	2019	13 June	24 June	421.3	571.6
	2020	26 June	07 July	410.5	545.7
	average	-	-	451.5	599.9
Migration of adults to the overwintering places	2015	04 July	17 July	567.3	712.5
	2016	28 June	10 July	548.1	681.6
	2017	05 July	19 July	553.3	672.7
	2018	22 June	04 July	553.0	645.0
	2019	23 June	05 July	558.2	678.0
	2020	05 July	15 July	521.2	612.2
	average	-	-	556.2	688.9

The beginning of winging and the fifth instar nymphs transformation into adults on winter wheat without watering was observed starting from the second decade of June. While on irrigated crops there was a shift of almost 10 days: starting from the middle of the third decade of June. So, the recorded sum of degree-days required for this process was 410.5-481.5°C on non-irrigated crops and 545.7-630.4°C under sprinkler irrigation.

Therefore, it is most effective to apply protection measures on winter wheat crops against Sunn pest during the stages of its development: rebirth of nymphs – before the beginning of appearance of the new generation of adults, at sum of degree-days 203.9-451.5°C in crops without irrigation and 309.6-599.9°C – under irrigation. So, protection against shield-backed bug nymphs on irrigated crops will be shifted by 10-12 days later than in crops without watering.

It is known that the migration of Sunn pest to places of additional feeding and wintering occurs in the phase of full ripening of grain crops, during their harvesting or even after harvest (Iranipour et al., 2010). Therefore, the phase of full maturity of winter wheat was taken as the basis for determining the time of departure of the shield-backed bug adults. Thus, it was found that in the conditions of winter wheat without irrigation the terms of Sunn pest migration were in the third decade of June – the first decade of July, while in the conditions of sprinkler irrigation – in the first and second decades of July. The sum of degree-days required for the beginning of Sunn pest migration to the places of additional feeding and wintering was: in the conditions without watering – 521.2-567.3°C, in the conditions of irrigation – 612.2-712.5°C.

On irrigated crops, the density of shield-backed bugs population before beginning of appearance of the new generation adults was lower. After harvesting of winter wheat crops without watering, shield-backed bugs fly to irrigated crops of other crops, especially spring wheat. It sometimes leads to the increasing of the population density of shield-backed bugs on irrigated crops areas. Additional nutrition on host plants of irrigated crops allows the pest to accumulate fat reserves and, therefore, survive in the cold season.

4. Conclusions

The average number of Sunn pest nymphs in 2015-2020 was 0.7 and 2.7 exemplars/m² on winter wheat crops without irrigation and 0.8-3.8 exemplars/m² on irrigated ones. The difference was 14.3-33.3%, depending on the weather conditions of the research years. Share of factor “presence of irrigation” that impact on the number of Sunn pest reaches 80.2%.

Beginning of mass migration of shield-backed bugs from wintering places to winter wheat crops was occurred in the I, II and III decades of the May. Required sum of degree-days was 109.3-141.3°C. Sunn pest females laid eggs during the mass flight. The needed sum of degree-days was 124.5-153.2°C.

Stage of revival of Sunn pest nymphs began in mid-May – the first decade of June, which coincided with the phases of development of winter wheat: the end of flowering – soft dough ripening of the grain. The sum of degree-days required for the beginning of this stage was 177.8-233.8°C without irrigation, while in sprinkler irrigation conditions – 275.5-349.1°C.

The required sum of degree-days for the beginning of winging and transformation of the fifth instar nymphs into adults was 410.5-481.5°C on the non-irrigated crops. It is occurred in the second decade of June. And the required sum of degree-days for the beginning of this stage under irrigation conditions was 455.7-630.4°C, which happened in the middle of the third decade of June.

In the conditions of winter wheat without irrigation, the beginning of Sunn pest migration to the places of additional feeding and wintering occur in the third decade of June – first decade of July, while in the conditions of irrigation – in the first and second decades of July. The sum of degree-days required for the beginning of migration of this pest was: in the conditions without irrigation – 521.2-567.3°C, in the conditions of sprinkler irrigation – 612.2-712.5°C.

It was established that the most effective to apply protection measures against Sunn pest during the stages of development: rebirth of nymphs before the beginning of appearance of the new generation of adults, at average sum of degree-days 203.9-451.5°C on non-irrigated winter wheat crops and 309.6-599.9°C – on irrigated ones.

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