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Impact of agricultural and tillage systems on the main pests of winter wheat

Abstract. The intensification of agriculture has some adverse consequences, and the preservation of land resources during their active exploitation is a vital issue today, given the ever-increasing need to increase food supply. The world practice of organic farming shows limited regulation of the number of pests of agricultural crops. Artificially increasing natural enemies and altering the landscape to enhance biological control is not a popular solution and has controversial effectiveness. The number of winter wheat entomocomplex was monitored according to generally accepted methods on 48 plots, where 12 variants were placed in 4 repetitions during 2019-2021. This paper presents the results of a study indicating a substantial impact of agricultural systems on the main pests of winter wheat and the ability to control their numbers according to the ecological system at the level of the economic threshold of harmfulness. Tillage variants did not regulate the number of *Schizaphis graminum* R., *Eurygaster integriceps* R. and *Oulema melanopus* L., while chisel tillage at 20-22 cm regulated the number of *Anisoplia austriaca* N. and *Haplothrips tritici* Kurd at the level of the control (ploughing) in all years of observations. In the case of surface cultivation of the soil to a depth of 6-8 cm, the number of these pests increased substantially, and was on average at 2.0 and

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14.4 specimens/m^2, respectively. Thus, the highlighted data confirm the effectiveness of reducing the multiplicity of insecticidal treatments of winter wheat in the ecological system without increasing the risks of crop loss due to pest damage to plants in combination with chisel tillage

Keywords: phytophages; chisel; ploughing; disking; ecological cultivation of winter wheat

RELEVANCE

According to the UN forecast, by 2050, population growth will lead to an increase in demand for food, including cereals, up to 46% (M.C. Hunter *et al.* 2017). The productivity of winter wheat depends on the use of modern intensive cultivation technology, where one of the determining factors is the management of the dynamics of harmful organisms and the use of modern plant protection products. However, the choice of intensive tillage and application of insecticides can adversely affect the functional diversity of soil communities and their abundance (J.G. Zaller *et al.*, 2016.)

Given the tendency to minimize the main tillage and reduce the use of pesticides, there is a need to find new, balanced approaches to solving the problem of protecting winter wheat from pests and increasing its productivity.

ANALYSIS OF RECENT STUDIES AND PUBLICATIONS

The difficulty in making decisions regarding the protection of crops from pests lies in the lack of monitoring and the uneven understanding of the economic threshold of harmfulness (ETH) according to different phenological phases of plant development, the effectiveness of preparations and various natural zones (V.M. Chaika *et al.*, 2014). According to some data (S. Stankevich, 2016), the ETH of cereal aphid on winter wheat in the earing phase is 5-10 pcs./stem, and according to others – 20-25 specimens/ear (V.P. Omelyuta, 1986). The economic threshold of harmfulness of the imago of a sunn pest in the phase of stem elongation in these authors also ranges from 1 to 4 specimens/m^2. Therefore, agricultural producers often introduce insecticides in response to any potential economic threat, rather than as a last resort. The intensity and excessive use of chemical plant protection products creates adverse consequences for the environment, including the destruction of beneficial entomofauna. According to the authors (Sabluk *et al.*, 2021), the number of the latter in the sowing of crops under the organic farming system was substantially higher than in the industrial system, which ensured that the pest population was reduced by half. Many field studies on the effectiveness of the implementation of the practice of intercropping flowering plants to create a shelter and additional food source for entomophages and, as a result, increase their number and regulation of phytophages showed somewhat inconsistent and sometimes inconclusive results (Schipanski *et al.*, 2014; Gontijo *et al.*, 2018). Researchers (Buchanan & Hooks, 2018) found that mixed cover crops of barley and clover did not attract entomophages and did not regulate pest populations, while increasing the abundance of the *Carabidae* family in organic farming systems did not provide sufficient regulation of phytophagous populations (Birkhofer *et al.*, 2008). Research in organic crop rotation at PE "Agroecology" shows a reduction in winter wheat crop losses from *Heteroptera* bugs and *Anisoplia austriaca* due to sowing with spring wheat, the grain of which is used for fodder (V.M. Pysarenko *et al.* 2020).

The results of some studies show that often the authors do not correlate the increase in the number of natural enemies with the decrease in damage to plants by phytophages (Cloyd, 2020). The study results regarding the influence of the depth and method of soil cultivation as a factor that can reduce the number of phytophages are equally ambiguous. The study (O.M. Yakovenko, 2017) showed that the population of *Elateridae* under the conventional tillage system was 5.2 specimens/m², under systems with mini-till elements – 8.0 specimens/m², while the conservation tillage system reduced the number of phytophages to 4.6 specimens/m².

An analysis of 30 publications from 1990 to 2017 (Rowen *et al.*, 2020), despite the expectation that soil pests would be particularly sensitive to habitat change, did not reveal any considerable differences in pest numbers in systems with different methods and depth of tillage, even using no-till technology. An interesting fact is that pests whose life cycle does not pass in the soil and most of which are r-strategists were considerably inferior in numbers in systems with low intensity of cultivation and increased the population in conventional systems.

Understanding the specific features of the biology of winter wheat pests allows identifying the optimal and critical stages of their development, which, together with crop rotation, tillage, and greening of agriculture, enables effective regulation of their number.

The purpose of this study was to establish the impact of minimizing the main tillage under various farming systems on the number of main phytophagous winter wheat.

MATERIALS AND METHODS

The study was conducted during 2019-2021 in the conditions of the stationary field of the Detached Division of the National University of Life and Environmental Sciences of Ukraine "Agronomic Research Station". The species composition and number of pests of Linus winter wheat were determined according to generally accepted entomological methods (V.P. Omelyuta, 1986; S. Stankevich, 2016) according to species. Scheme of a two-factor experiment: factor A – three farming systems: industrial, ecological, and biological. Factor B – variants of the main tillage of the soil: ploughing at 20-22 cm (control), tillage without shelves (chiselling at 20-22 cm), shallow tillage at 10-12 cm (disc harrow), surface tillage at 6-8 cm (disc harrow).

The insecticide "Pirinex Super" (chlorpyrifos, 400 g/l + bifenthrin, 20 g/l) was applied in the BBCH phase 31 (first node) and BBCH 53 (30% of inflorescence emerged) at the rate of 1 l/ha under the industrial farming system, marginal spraying with the preparation of plots under ecological conditions – 0.8 l/ha. The biological system of agriculture did not make provision for the introduction of chemical protection preparations.

The soils of the experimental plots are typical medium-loamy chernozem. The content of humus in the arable layer of the soil is 4.38-4.53%, the pH of the salt extract ranges from 6.9 to 7.3.

The experiment was based on the method of split areas. There were 48 sections in total, where 12 variants were placed in 4 repetitions. The total area of the experimental plot is 93.6 m², and the accounting plot is 75 m².

The typicality of the weather conditions of the northern Forest-Steppe of Ukraine is determined by three elements, such as the sum of active temperatures (SAT), the amount of precipitation, and a general indicator – the hydrothermal coefficient (HTC) (Table 1).

Table 1. Distribution of key weather conditions indicators, 2019–2021

Indicator	2019	2020	2017	Average over the years of the experiment	Average multi-year rate
SAT, >10 °C	3,090.0	3,099.3	2,897.3	3,028.8	3,007.5
Total precipitation, mm	352	326	299	325.6	310.3
HTC	1.14	1.05	1.03	1	1.04

RESULTS

Entomocomplexes of winter wheat are constantly in a dynamic state depending on the average annual temperature indicators, precipitation, farming systems, crop rotation, etc. The analysis of HTC according to the adequacy indicator (K_i) showed that the years of experiment differed substantially in terms of monthly values. Specifically, the spring months of 2019 were excessively wet (K_i = 1.7 and 0.8), which is not typical of multi-year data, while June and August were dry (K_i = -0.2), which is optimal for this period. April and May 2020 were excessively wet, while K_i = 0.9 and K_i = 2.0 were substantially and extremely different from the long-term norm. The summer months were tendentiously dry (K_i= -0.4; -0.3; -0.5).

The beginning of the growing season of 2021 according to HTC indicators was comparable with 2019 with an extremely wet April (K_i = 4.2), June is tendentiously dry (K_i = -0.9), while July and August showed optimal conditions to multi-year indicators (K_i = 0.0 and 0.2).

The rate of development of the sunn pest depends on the hydrothermal conditions of the spring-summer period, dry summer months can lead to the death of 75-95% of the eggs of the *Anisoplia austriaca*, therefore the analysis of weather conditions is an essential factor in preventing outbreaks of pests.

The species composition of phytophages can vary due to migration from other biotypes and vary depending on the phase of wheat development, so for the choice of chemical protection, it is primarily important to identify constant and dominant species that cause considerable crop losses. According to the study results, the main pests of winter wheat in the spring and summer period were identified as follows: wheat aphids *(Schizaphis graminum R.)*, sunn pest *(Eurygaster integriceps R.)*, cereal leaf beetle *(Oulema melanopus L.)*, *Anisoplia austriaca N.* and *Haplothrips tritici Kurd.* (Fig. 1).

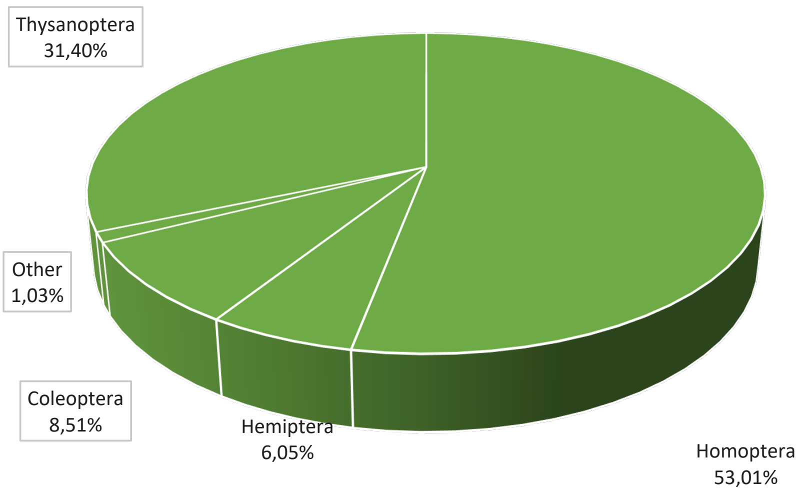

Figure 1. The structure of the entomocomplex of the main pests of winter wheat in the Detached Division of NULES of Ukraine "Agronomic Research Station", 2019-2021

The analysis of the species composition of pests shows that, in percentage terms, the main number of phytophages belonged to the orders *Homoptera* and *Thysanoptera* – 53.01% and 31.4%, respectively. Representatives of the *Coleoptera* order were less numerous – 8.51%, specifically 53.47% of the order was accounted for by Oulema melanopus, the rest by *Anisoplia austriaca*. The smallest number over the years of observation was the sunn pest of the *Hemiptera* order – 6.05%. Such phytophages as *Cephus pygmeus* and *Zabrus tenebrioides* were sparsely present in winter wheat crops and did not pose a threat to the crop.

It is generally accepted that the main tillage has a considerable impact on the regulation of the number of pests of agricultural crops, and tillage, as an independent agrotechnical method of controlling winter wheat phytophages, is not used in modern crop cultivation technology. However, farmers introduce insecticides in response to any potential economic threat, and not as a last resort, and systematically work to prevent exceeding the threshold of harmfulness. Statistical analysis of the obtained data showed that the number of all pests was significantly affected by agricultural systems (factor A). The industrial model turned out to be the best farming system in terms of its impact on the number of pest populations. The biological system showed the inability to effectively control the population of winter wheat phytophages (Table 2). According to the authors' observations, populations of natural enemies without increasing the availability of flowering plants, landscape diversity or the use of cover crops are incapable of effective regulation of insect pests, which confirms the data of other researchers (McGuire, 2017).

Table 2. Total pest density of winter wheat under various farming systems (2019-2021)

Agriculture system (Factor A)	Main tillage variants (Factor B)	Aphid count, specimens/plant	Number of *Heteroptera*, specimens/m^2	Number of Oulemas, specimens/m^2	Number of beetles, specimens/m^2	Number of Thysanoptera, specimens/m^2
Industrial (c)	Ploughing at 20-22 cm (control)	2.4	0.6	0.2	0.1	0.8
	Chiselling at 20-22 cm	2.8	1.0	0.3	0.0	0.7
	Shallow 12-14 cm	2.5	0.8	0.3	0.1	1.0
	Surface area 6-8 cm	3.4	1.3	0.2	0.2	1.4
Ecological	Ploughing at 20-22 cm (control)	17.4	1.6	1.2	0.6	6.3
	Chiselling at 20-22 cm	16.8	1.9	0.9	0.8	7.8
	Shallow 12-14 cm	16.6	1.8	1.2	0.8	10.6
	Surface area 6-8 cm	18.7	2.2	1.0	1.3	11.5
Biological	Ploughing at 20-22 cm (control)	28.7	3.1	3.1	2.3	13.2
	Chiselling at 20-22 cm	32.9	3.1	3.0	2.4	13.0
	Shallow 12-14 cm	29.6	2.9	3.4	2.4	25.6
	Surface area 6-8 cm	34.5	3.3	3.1	4.4	30.2
LSD_{05} (A)		3.2	0.6	0.7	0.6	2.8

Table 2. Continued

Agriculture system (Factor A)	Main tillage variants (Factor B)	Aphid count, specimens/plant	Number of *Heteroptera*, specimens/m²	Number of Oulemas, specimens/m²	Number of beetles, specimens/m²	Number of Thysanoptera, specimens/m²
LSD_{05} (B)		$F_f<F_{05}$	$F_f<F_{05}$	$F_f<F_{05}$	0.7	3.2
LSD_{05} (AB)		$F_f<F_{05}$	$F_f<F_{05}$	$F_f<F_{05}$	1.2	5.6

There was a significant influence of the main tillage options on limiting the number of beetles and Thysanoptera, while the number of Aphidoidea, *Heteroptera*, and cereal leaf beetles for all tillage options was within random deviations. On average, over the years of the experiment, the number of *Anisoplia austriaca* increased substantially on the variant of disc tillage at 6-8 cm, while the variants of chiselling and disc tillage at 10-12 cm limited its number to 1.1 specimens/m², which is at the control level, with slight deviation towards increase.

The numerical advantage of aphids and *Heteroptera* for surface cultivation at 6-8 cm, without a statistically significant difference, is explained by the increase in the mass of weeds in this variant, which serve as a reservoir of diseases and an added habitat for pests.

Analysis of data on the influence of Factor B on the population size of *Haplothrips tritici* Kurd. shows that reducing the depth of tillage in shallow and surface tillage variants substantially increases the average pest population to 12.4 and 14.4 specimens/m² (LSD_{05} = 3.2). The use of chisel tillage proved the absence of a statistically significant difference compared to ploughing (control) and ensured the regulation of the phytophagous population at 7.1 specimens/m².

CONCLUSIONS

According to the present study, the main tillage considerably affects the number of *Thysanoptera* and *Anisoplia austriaca* H., whose females lay eggs to the depth of the arable layer, and the larvae of the *Anisoplia austriaca* H. can penetrate the soil to a depth of 80 cm. Variants of chiselling at 20-22 cm and shallow cultivation at 12-14 cm showed the result at the control level, and reducing the depth of cultivation to 6-8 cm substantially increased the number of *Anisoplia austriaca H.* to 2.0 specimens/m². The distribution of Thysanoptera in the Right-Bank Forest-Steppe zone of Ukraine was substantially affected only by the chiselling variant, with an average pest population of 7.1 specimens/m². Modern farming lies in controlling the number of pests at a level that does not lead to a substantial decrease in the yield of winter wheat, and not at a level close to zero. It is due to the reduction of the rate of insecticide application and merely marginal treatment of the plots that the ecological farming system appears as the best variant in terms of the numbers of all pests below the levels of ETH.

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Вплив систем землеробства та обробітку ґрунту на основних шкідників пшениці озимої

Анотація. Інтенсифікація сільського господарства має низку негативних наслідків, а збереження земельних ресурсів за їхньої активної експлуатації є важливим питанням сьогодення, з огляду на дедалі більшу потребу в збільшенні продовольства. Світова практика ведення органічного землеробства показує обмеженість в регулюванні чисельності шкідників сільськогосподарських культур. Штучне збільшення природних ворогів та зміна ландшафту для підсилення біологічної боротьби не є популярним рішенням та має суперечливу ефективність. Моніторинг чисельності ентомокомплексу пшениці озимої проводився згідно із загальноприйнятими методиками на 48 ділянках, де розміщено 12 варіантів у 4 повторностях упродовж 2019-2021 рр. У статті наведені результати дослідження, що свідчать про істотний вплив систем землеробства на основних шкідників пшениці озимої та здатність до контролю їхньої чисельності за екологічної системи на рівні економічного порогу шкідливості. Варіанти обробітку грунту не регулювали чисельність *Schizaphis graminum* R., *Eurygaster integriceps* P. та *Oulema melanopus* L., тоді як чизельний обробіток на 20-22 см забезпечував регуляцію кількості *Anisoplia austriaca* H. та *Haplothrips tritici Kurd* на рівні контролю (оранка) у всі роки спостережень. За поверхневого обробітку грунту на глибину 6-8 смчисельністьцихшкідників істотно збільшувалась, та була в середньому на рівні 2,0 та 14,4 екз./м^2. Отже, висвітлені дані підтверджують ефективність зменшення кратності інсектициднихобробокпшеницiозимої заекологічної системибезпідвищенняризиків втрати врожаю через пошкодження рослин шкідниками в поєднанні з чизельним обробітком ґрунту

Ключові слова: фітофаги; чизель; оранка; дискування; екологічне вирощування пшениці озимої