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Technology of protection of winter wheat from harmful biota in the Northern Forest-Steppe of Ukraine

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Abstract. Winter wheat protection technology is aimed at preventing the mass spread of harmful biota and the possibility of its rapid restriction. Therewith, the main choice of pesticides and their timely use is precisely at the period when harmful organisms are in a sensitive stage to protective products, and plants are in the phase of forming and laying productivity elements. The purpose of the study is to examine the effectiveness of the proposed compositions of chemical preparations against harmful biota in improving the technology of winter wheat protection. When monitoring harmful organisms, generally accepted methods in phytopathology (Strakhov and Geschele scales), entomology (butterfly net, accounting site methods), and herbology (quantitative-weight) were used. The results of the study obtained during a production experiment to examine the effectiveness of product mixtures for a comprehensive system of protection of winter wheat crops are presented. Changes in the species and quantitative composition of winter wheat weed *Synusia* depending on the protection technology are established. The total number of weeds in the areas where the protection



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system was used decreased by 61.2 pcs./m² compared to the control option. Changes in the number of pests are presented (a decrease in the Hessian fly by 26 specimens/100 w.s. (wheat stem), Swedish fly – 31 specimens/100 w.s., grass aphids – 20 specimens per stem, Haplothrips tritici – 34 specimens/100 w.s., bread carabus – 6 beetles/m²) when spraying winter wheat in the phases of exit into the tube and milk ripeness with insecticides Aktara 25 WG, 0.10 kg/ha + Karate seon 050 CS, 0.2 L/ha. The technical effectiveness of insecticides against pests was 73.8-89.5%, depending on the insect. It is proved that reliable protection against dominant diseases in the farm is achieved by using a combination of fungicides Alto Super 330 EC, 0.5 L/ha and Topsin M, WP, 1.0 kg/ha in the phase of entering the tube and Amistar extra 280 SC, 0.5 L/ha + Rex Duo, SC, 0.4 L/ha in the earing phase–beginning of flowering. The technical effectiveness of double spraying with recommended anti-disease products ranged from 77.1% to 86.8%. The proposed technology for protecting winter wheat from harmful organisms is effective, has passed production testing, and can be implemented in farms of all forms of ownership

Keywords: weeds; diseases; pests; herbicides; fungicides; insecticides; yield

INTRODUCTION

In Ukraine, one of the main tasks of agriculture is to obtain stable and high-quality grain yields. Increasing grain production and improving its quality belongs to winter wheat. Now in Ukraine, the export of wheat grain is one of the main economic instruments of the foreign policy of the country (Tsilurik *et al.*, 2017). According to its biological characteristics, winter wheat is one of the most productive agricultural crops. This is the most productive crop among the grain group of crops which makes the most use of photosynthetic active radiation. However, the potential yield of the crop is realised under certain conditions, such as normal overwintering of plants, the use of agricultural techniques that ensure good field preparation, accumulation of moisture, and the introduction of sufficient fertilisers and plant protection products from harmful organisms (Bakalova *et al.*, 2019; Lollato, 2019). Today, changes in climatic conditions and non-compliance with scientific cultivation technologies lead to a deterioration in the phytosanitary condition of the wheat field.

Planned management of agocenosis is necessary to effectively prevent crop losses. The plant protection system is a rather complex technological process and is implemented by consistently conducting a set of agrotechnical measures aimed at increasing plant productivity, considering their impact on harmful organisms and special chemical means of protection from pests, diseases, and weeds. The tactics of chemical protection against harmful biota have their own characteristics, so the decision to use pesticides against them is made based on various criteria (Secun *et al.*, 2018; Markovska *et al.*, 2018).

As noted by researchers Pisarenko *et al.* (2021), limiting the development of weeds, diseases, and pests through chemical protection products is an important agrotechnical measure, the effectiveness of which depends on the appropriate and correct choice of fungicides and insecticides from a wide range of drugs, compliance with regulations for their use to maximise the impact on harmful organisms without polluting the natural environment. According to V. Gamajunova *et al.*

(2022), selecting products for the protection of field crops, including winter wheat, should be conducted according to the “List of pesticides and agrochemicals allowed for use in Ukraine” (2022) for current years.

Harmful biota causes great harm to plants. Various methods and means of protection are used to protect winter wheat crops. Therewith, it is important to ensure that individual measures are conducted in the determined time frame, considering the biological, morphological, and physiological characteristics of the development of pests, weeds, and pathogens. In this regard, there is a need to constantly monitor the harmful biota of the wheat field to control their abundance, spread, and harmfulness, which is the basis for improving the technology of plant protection against a complex of harmful organisms and adapting them to the modern agroecological situation (Kosylovych *et al.*, 2017). Despite the constant updating of the range of pesticides and the technology of their application, in recent years the potential losses of the winter wheat crop have not changed radically (Liskovskyi *et al.*, 2020). Therefore, the need to use herbicides, fungicides, and insecticides in each specific case should be comprehensively justified. The criterion for such justification is to account for the number of harmful biota in each field and compare them with the economic thresholds of harmfulness (ETH) and the nature of the population of the field.

Thus, the purpose of the study is to examine the effectiveness of the proposed mixtures of pesticides in industrial winter wheat crops from a complex of harmful organisms in the conditions of the Northern Forest-Steppe of Ukraine. The following tasks were set to achieve this goal: identify the specific and quantitative composition of weeds, diseases, and pests; offer tank mixtures of fungicides and insecticides with the addition of microfertilisers for the effective destruction of a complex of diseases, pests, and various biological groups of weed vegetation without harming the growth and development of winter wheat and the environment; determine the technical effectiveness of joint use of pesticides and their tank mixtures.

LITERATURE REVIEW

T. Rozhkova *et al.* (2022) note that the use of non-certified seeds, reduced rotation of grain crops, violation of the terms of sowing, tillage, and fertiliser systems led to an increase in the development of fungal diseases, an increase in the number of phytophages, and substantial contamination of crops. Ukrainian researchers O. Derecha *et al.* (2018) claim that among the leaf diseases of winter wheat, septoriosi, brown leaf rust, and powdery mildew are the most harmful. Crop losses from leaf septoriosi can reach 30-40%, and losses from brown leaf rust with damage up to 40% are 0.3-0.4 t/ha, and more than 40% – exceed 1 t/ha. L. Kryuchkova and N. Hrytsyuk (2014) prove that root rot of various etiologies dominates among root diseases, crop shortages from them can reach 30%, symptoms of root rot damage can manifest themselves in all phases of plant growth and development, while the intensity of the disease varies substantially over the years depending on environmental and agrotechnical conditions.

In the research area, depending on the study area, all six types of root rot were identified – *Pseudocercospora*, *Rhizoctonia* root rots, *Fusarium*, *Gaeumannomyces*, *Bipolaris sorokiniana*, *Pythium* root rot. I. Bakay *et al.* (2019) confirmed that *Fusarium* root rot is the most common. G. Slobodianyuk *et al.* (2022) and O. Markovska *et al.* (2018) in their papers note that substantial reserves of pathogenic microflora and phytophage larvae accumulate in the soil, which, without proper sanitary treatment of seed material, lead to damage to seeds and seedlings of winter wheat. The most practical and cost-effective method of protecting against wheat diseases is pre-sowing seed treatment with approved pesticides. In addition, the positive effect of seed treatment is that much less effort is spent on wheat care during the growing season. It is also a preventive measure using a mixture of insecticidal and fungicidal mordants, which reduces the number of sprays of crops during the growing season, which, in turn, reduces the toxic load on agrocenoses.

V. Sakhnenko *et al.* (2018) reported that siphoning phytophages, especially cicadas, grass flies, and grass aphids, pose a substantial threat to winter wheat crops. The harmfulness of these pests is often underestimated due to unnoticeable damage. However, when sucking out nutrients, insects can introduce toxic compounds that disrupt metabolic processes, inhibit plant growth and development, and worsen winter hardiness and drought resistance. In addition, grass aphids and leaf beetles carry viral diseases of crops. A. Fedorenko *et al.* (2021) claim that grain is damaged by bread beetles – *Anisoplia agricola* P., *Anisoplia austriaca* H., *Anisoplia segetum* H., *Eurygaster integriceps* Put., *Zabrus tenebrioides* Goese.

Researchers O. Kurdyukova *et al.* (2019) and I. Storchous (2019) confirm that weeds compete with cultivated plants for light, water, and nutrients, reducing potential crop yields, and crop contamination can reduce yields by up to 60%, depending on its degree. In addition, failure to comply with the necessary isolation over time and substantial saturation of arable land with winter crops leads to the accumulation of a substantial number of specific cereal weeds in the fields, such as windgrass (*Apera spic aventi* L. Pal Beauv.), including wintering weeds species: cleavers (*Galium aparine* L.), tumbleweed mustard (*Sisymbrium loeseli* L.), flixweed *Deuscurainia Sophia* L. Webbex Prantl), horseweed (*Erigeron Canadensis* L.), drug fumitory (*Fumaria officinalis* L.)

MATERIALS AND METHODS

The technology of winter wheat protection was investigated based on previous studies of the authors, (Derecha *et al.*, 2018) and new ideas were implemented in the production experiment of the SE Experimental Farm Nova Peremoha of the Polissia National University of the National Academy of Agrarian Sciences of Ukraine in the Stara Chortoriia village, Zhytomyr district, Zhytomyr region during 2019-2021 according to such a scheme:

1. Without a protective system (control)
2. Security system (Table. 1)

Table 1. Winter wheat protection system, 2019-2021

Processing term and method	Preparation, a tank mixture	Consumption rate	Harmful organism
Seed treatment	Lamardor 400 FS + Gaucho Plus 466 FS	0.2 (1 L/t) 0.6 (1 L/t)	Loose, stinking, black smuts, seed mould, <i>Cochliobolus sativus</i> , <i>Fusarium</i> root rot. Grass flies, cicadas, ground beetle, thrips, fleas
Tillering phase (BBCH 21-29)	Granstar Pro 75, WG + Apiros 75 WG	20 g/ha + 15 g/ha	Annual and perennial dicotyledons, including weeds resistant to 2,4-D and cereals
Stem elongation phase (BBCH 30-39)	Alto Super 330 EC, + Topsin M, WP + Aktara 25 WG Orakul, s.	0.5 L/ha + 1.0 kg/ha + 1.0 kg/ha 1.0 L/t	Powdery mildew, brown leaf rust, leaf septoriosi, pyrenophorosis, cercosporellosis; cereal leaf beetle, grass aphids, thrips; increased disease resistance and yield
Booting-flowering phases (BBCH 41-69)	Amistar extra 280 SC+ Rex Duo, SC,	0.5 L/ha 0.4 L/ha	Ear diseases (<i>Fusarium</i> , septoriosi, alternariasis), powdery mildew, rusty diseases

Table 1, Continued

Processing term and method	Preparation, a tank mixture	Consumption rate	Harmful organism
Milk phase grain ripeness (BBCH 71–77)	Aktara 25 WG + Karate zeon 050 CS	0.1 kg/ha+ 0.2 L/ha	Spraying when the economic threshold of harmfulness is exceeded ETH: 2-3 larvae of the Eurygaster integriceps bug per 1 m ² ; 40-50 specimens of Haplothrips tritici per ear, 20-30 specimens/w.s. of wheat aphid 3-5 specimens/m ² of bread carabus

Source: compiled by the authors

The soils under the experimental plots are mainly chernozems and dark grey podzolic, which are characterised by the following indicators: the humus content ranged from 3.43 to 4.45%, hydrolytic acidity 2.3-3.0 mg-eq/100 g of soil and pH of salt extract 5.5-6.0, easily hydrolysed nitrogen compounds (75-124 mg/kg), increased mobile phosphorus content (185 mg/kg), average exchange potassium content (102 mg/kg).

Its predecessor is clover of the second year of use. The main tillage was conducted in the third decade of August – ploughing to the depth of the arable layer. Pre-sowing tillage was conducted to a depth of 6 cm with combined tillage units. Sowing was conducted on September 15-20 with an SZ-3,6 seed drill with treated Artemis seeds. They were sown in rows to a depth of 4-5 cm, with a seeding rate of 5.5 million germinating seeds per 1 hectare with row spacing of 15 cm. Mineral fertilisers in the main fertilising N₆₀P₆₀K₆₀ (ammonium nitrate, monokalium phosphate) were applied. Early spring root feeding was conducted with ammonium nitrate at a rate of 30 kg of the active substance. Repetition in the experiment is threefold, the area of the sown area is 190 m², accounting – 100 m² placement of options is systematic. The norm for working fluid consumption is 250-300 litres per 1 ha when spraying plants with protective products, in the control version, the plants were treated with an equivalent amount of water. Agricultural technology in the experiment was generally accepted for the Forest-Steppe zone.

In the course of the study, the following observations and records were conducted:

1. Phenological observations of wheat plant growth and development.

2. Accounting of winter wheat crops for leaf diseases was conducted at the first signs of diseases on the leaves, and subsequent ones – after 10-15 days, using Strakhov and Geschele scales. Root rot was recorded during the waxy ripeness phase according to the method of sampling sheaves. Sheaves were selected in four places from two adjacent rows with a length of 0.5 m. After selection, the plants were carefully examined and evaluated on a scale: 0 points – the plant is healthy; 1 point – up to 15% of the root system is affected; 2 points – 15-30% of the roots are affected; 3 points – 30-60% of the roots and base of the stem (Derecha et al., 2018).

3. When considering the colonisation of wheat plants by dominant pests (grass flies, wheat thrips), the

butterfly net method was used. The method of accounting for ground beetles was used. Accounting was conducted using a frame with a size of 0.25*0.25 m, which was applied to plants, after which they were examined, the number of pests was counted and recalculated for 1 m². When accounting for grass aphids, the method of plant tests was used (Trybel et al., 2001; Omeliuta et al., 1986).

4. Accounting for actual contamination was determined by the quantitative and weight method in two phases of crop development: tillering (BBCH 21-29), stem elongation (BBCH 30-39) (Hrytsaenko et al., 2003). The species composition of weeds was determined in two repetitions of the experiment using atlases and reference books (Veselovskiy et al., 1993).

5. The yield of winter wheat was determined by the method of threshing and weighing grain from each site.

RESULTS AND DISCUSSION

An integral part of optimising the main factors of growth and development of winter wheat plants is the protection technology, which includes integrated or comprehensive protection of plants from diseases, pests, and weeds.

The most harmful diseases of winter wheat in the region of research identified Fusarium (pathogens fungi from the genus *Fusarium*), helminthosporiosis (*Bipolaris sorokiniana*) root rot, brown rust (*Puccinia recondita* f. sp. tritici Rob. ex Desm), septoriosis (*septoriosis tritici* Rob. et Desm.), powdery mildew (*Erysiphe graminis* DC. f. tritici), Ustilago smut (*Ustilago tritici* Pers., Jens), which lead to substantial crop losses, and sometimes to complete plant death. An effective and universal method for these diseases is seed treatment, especially using complex drugs that destroy the infection or prevent its development in the soil, on the surface, and inside the seed. Preparations and mixtures of pesticides were selected considering the forecast of the development of diseases and pests using data from the phytosanitary examination of winter wheat crops on the farm.

The first stage in the proposed protection system is the treatment of winter wheat seeds with a two-component (prothioconazole, 250 g/L + tebuconazole, 150 g/L) systemic preparation Lamardor 400 FS, with a norm of 0.2 L/t together with insecticidal mordant Gaucho Plus 466 FS at a rate of 0.6 L/t (imidacloprid, 233 g/L + clothianidine, 233 g/L), protection from cereal flies, cicadas, ground beetle, thrips, fleas.

The next step is to conduct protection from weeds. Ultimately, one of the main factors limiting the collection of high yields of agricultural crops, namely wheat, is substantial contamination of crops, which is determined by a supply of weed seeds and their vegetative organs in the soil. The weed control system includes compliance with agricultural techniques for growing crops and favourable conditions for plant growth and development. All methods of mechanical tillage should be conducted in the phase of weed germination. The experience of farming proves that it is not always possible to clear the fields of weeds only by agrotechnical measures. At the moment, weed control is most effective when combining agrotechnical and chemical measures. Notably, the trend of using tank mixtures of

pesticides is currently one of the key ones, since such application can substantially reduce the cost of treatments and increase labour productivity.

Winter wheat crops were sprayed in the spring tillering phase (II-III decade of April) against annual and perennial dicotyledonous weeds with herbicides Granstar Pro 75, WG (tribenuron-methyl, 750 g/kg) with a norm of 20 g/ha in a tank mixture against cereal weeds with Apiros 75 WG (sulfosulfuron 78%) with a norm of 15 g/ha. The first symptoms of weed suppression appeared 7-10 days after spraying, and their complete death occurred in 3-4 weeks, depending on the type of weed. Treatment of crops with this combination of drugs led to a good cleaning of crops of annual monocotyledonous, dicotyledonous, and growth retardation of perennial weeds (Table 2).

Table 2. Species composition of weeds of winter wheat agroecosis, pcs./m² (average for 2019-2021)

Type of weed	Economic threshold of harmfulness (spring tillering phase)	Without a protective system (control)	Protection system
Monocotyledons			
Common windgrass	8-10	20.5	6.2
Yellow bristle-grass	10-15	7.3	-
Couch grass	4-6	4.0	1.0
Dicotyledones			
Cornflower	3-6	10.4	1.6
Scentless mayweed	5-7	8.1	0.4
Field mustard	5-8	6.3	-
Wild pansy	10-12	9.5	1.2
Field bindweed	8-10	5.0	0.5
Total		72.1	10.9

Source: compiled by the authors

During the phytosanitary examination of the wheat field, the following weeds were identified on the farm. Among monocotyledons (cereals), the following varieties prevailed: common windgrass (*Apera spic-aveni* L.), yellow bristle-grass (*Setaria glauca* L.), couch grass (*Elytrigia repens* L.); dicotyledonous – cornflower (*Centaurea cyanus* L.), scentless mayweed (*Matricaria perforata* Merat.), field mustard (*Sinapis arvensis* L.), wild pansy (*Viola tricolor* L.), field bindweed (*Convolvulus arvensis* L.). Winter wheat crop losses with such contamination (72.1 pcs./m²) amounted to 26%. The total number of weeds in the areas where the protection system was used decreased by 61.2 pcs./m² compared to the control option. In addition, the flag leaf can retain the assimilation surface and stay green longer, which contributes to the overall health of plants and the formation of higher productivity.

In the stem elongation phase (BBCH 30-39), a tank mixture of fungicides Alto Super 330 EC, (ciproconazole 80 g/L + propiconazole 250 g/L) was used to protect crops from powdery mildew, brown leaf rust, leaf

septorios, cercosporellosis at a normal rate of 0.5 L/ha and Topsin M, WP (thiophanate-methyl, 700 g/kg) at a normal rate 1.0 kg/ha. Since the number of pests exceeded the economic thresholds of harmfulness (ETH: cereal leaf beetle 15-20 specimens/m², grass aphids – 10 specimens/stem, thrips – 8-10 imagoes/stem) in this tank mixture, insecticide Aktara 25 WG (thiamethoxam, 250 g/kg) with a norm of 0.10 kg/ha was also added. For plant resistance to diseases and increased yield, micro-fertiliser Orakul, s., 1.0 L/t was added to the tank mixture.

The second fungicidal treatment was conducted in the earing phase – the beginning of wheat flowering BBCH 41-69 with a mixture of Amistar Extra 280 SC, 0.5 L/ha (ciproconazole 80 g/L + azoxystrobin 200 g/L) and Rex duo, SC, 0.4 L/ha (epoxiconazole 187 g/L + thiophanate-methyl 310 g/L) to protect crops from ear diseases (*Fusarium*, septorios, alternariasis) and powdery mildew, rusty diseases. The use of fungicidal treatments in the BBCH 30-39 and BBCH 41-69 phases substantially increased the resistance of winter wheat plants to diseases (Table 3).

Table 3. Development of winter wheat diseases, % (2019-2021)

Disease	Affected organ	Phase of manifestation of the disease	Without a protective system (control)		Protection system		Technical efficiency, %
			*P	*R	P	R	
Powdery mildew	Leaves Stems Ear	Shoots-waxy ripeness	45.8	31.0	15.4	7.1	77.1
Brown rust	leaves	Stem elongation	52.2	28.1	13.3	4.4	84.3
Septoriosi	Leaves Stems Ear	Stem elongation-milk ripeness	37	19	10	2.5	86.8
Loose smut	Ear	The beginning of waxy ripeness	0.4	0	0	0	-
Fusarium-helminthosporous root rot	Roots, base of the stem	Shoots-waxy ripeness	29.0	18.5	7.8	2.6	85.9

Note: *P – spread of the disease, *R – development of the disease

Source: compiled by the authors

Thus, the spread and development of powdery mildew decreased by 30.3 and 23.9%, brown rust – by 38.9% and 23.7%, and septoriosi – by 27% and 16.5%, respectively, compared to the control variant. Ustilago smut was identified only in non-cultivated areas. The spread of Fusarium-helminthosporous root rot decreased to 7.8%, and its development – to 2.6%. Therewith, the technical effectiveness of double spraying with recommended anti-disease products ranged from 77.1% to 86.8%.

These products provided up to 90% protection of crops from diseases that prevailed on the farm, while in the control areas, the degree of disease damage was higher than the threshold of harmfulness. Spraying of crops is conducted in the phase of milk ripeness BBCH 71-77 with insecticides Aktara 25 WG, 0.10 kg/ha + Karate seon 050 CS, 0.2 L/ha (lambda-cyhalothrin 50 g/L)

to prevent substantial crop losses from bread beetles (ETH – 5-6 beetles per 1 m²), bread bugs (ETH – 1-2 larvae per 1 m² on crops of strong and valuable wheat, 4-6 specimens per 1 m² – on the rest of the wheat fields), bread carabus (ETH – 8 specimens per 1 m²), grass aphids (10-20 specimens per stem), thrips (40-50 specimens per ear).

Notably, in recent years, due to substantial warming in May-June, there is a tendency to increase the number of pests on winter wheat crops (Table 4). During the survey of crops in the spring tillering phase, 35 specimens/100 w.s. of the Hessian fly and 42 specimens/100 w.s. were detected; in the stem elongation phase, 25 specimens/w.s. of wheat aphid, 38 specimens/100 w.s. of Haplothrips tritici; in the phase of milk ripeness – 7 specimens/m² of bread carabus.

Table 4. Population of winter wheat agrocenosis with pests, specimens (2019-2021)

Pest	Settlement organ	Damage phase	ETH	Without a protective system (control)	Protection system	Technical efficiency, %
Hessen fly	Internodes	Shoots-tillering	30-40 for 100 net swings	35	9	74.3
Swedish fly	Stem	Shoots-tillering	30-40 for 100 net swings	42	11	73.8
Grass aphids	Leaves, stems	Stem elongation-milk ripeness	10-20 specimens per stem	25	5	80
Wheat thrips	Ear, grain	Stem elongation-waxy ripeness	20-30 imagoes per 100 w.s.	38	4	89.5
Bread carabus	Ear, grain	Milk ripeness	3-5 beetles/m ²	7	1	85.7

Source: compiled by the authors

The results showed that the proposed insecticides reduced the number of phytophages: the Hessian fly – by 26 specimens/100 w.s., Swedish fly – 31 specimens/100 w.s.,

grass aphids – 20 specimens per stem, Haplothriw.s. tritici – 34 specimens/100 w.s., bread carabus – 6 beetles/m². The technical effectiveness of insecticides against pests

was 73.8-89.5%, depending on the insect. Competition from weeds, reducing the development of diseases, and

the number of pests contributed to improving the growth and development of winter wheat (Table 5).

Table 5. Winter wheat crop structure (2019-2021)

Experiment scheme	Number of stems, pcs./m ²	Number of grains per ear, pcs.	Grain weight per ear, g	Weight of 1000 seeds, g	Yield, t/ha
1. Without a protective system (control)	380	23	1.1	34.8	3.1
2. Protection system	531	34	1.8	46.9	5.4
HIP _(0.05) (t/ha)	2.8	0.7	0.04	1.0	0.2

Source: compiled by the authors

When using the protection technology, the number of stems increased by 151 pieces per 1 m², the number of grains in the ear – by 11 pieces; the weight of one grain from the ear – by 0.7 g, the weight of 1000 grains – by 12.1 g compared to the option where the protection system was not used. The increase in the yield structure had a positive effect on the yield of winter wheat, which was 5.4 t/ha, which is 2.3 t/ha higher than in the control version. The results of the studies are consistent with the experiments of a number of foreign and Ukrainian researchers.

Czech researchers A. Hanzalová & O. Zelba, (2022) report that brown leaf rust (*Puccinia triticina* Eriks) is quite common in the south-eastern part of the country in warm and dry years, so the authors recommend including a number of varieties with the gene of resistance to this disease Lr 37, Lr 24, Lr 28 in the winter wheat protection system. This is a very useful recommendation that should be considered in further studies.

Other researchers A.A. Bajwa *et al.* (2020) argue that climate change has affected the growth, virulence, reproduction, and spread of the most dangerous wheat pests. Canadian researchers R. Aboukhaddour *et al.* (2020) note that over the course of 100 years, due to changing climatic conditions, the pathogenic complex of winter wheat diseases has changed. Climate change has a direct negative impact on the effectiveness of existing pest and disease protection measures. Therefore, it is necessary to select new compositions of tank mixtures of protective products so that they are more effective against harmful organisms, do not cause resistance of pathogens and pests to pesticides, and also have a positive impact on the environment. This study considers all the above factors when selecting pesticide mixtures in winter wheat protection technology.

Researchers G. Kosylovych and Yu. Golyachuk (2017) recommend the autumn use of herbicides in the phase of 1-2 leaves of the crop (BBCH 11-12), using urea derivatives + dinitroanilines (a.s. isoproturon + pendimethanil), and in the phase of 3-5 leaves (BBCH 13-21) – sulfonylureas with metribuzin. In production experiments, herbicides were used once in a combination of Granstar Pro 75, WG 20 g/ha + Apiros 75 WG,

15 g/ha in the tillering phase (BBCH 21-29) because herbicides during spring application can negatively affect the development of the crop itself. Pisarenko *et al.* (2021) prove that the combination of fungicides Falcon (0.6 L/ha) and Titul Duo (0.2 L/ha) with herbicides Monitor (20 g/ha) improved the effectiveness of fungicides because fields without weeds have higher resistance to diseases due to better aeration of the stem. In contrast to these studies, a mixture of herbicides was used in production experiments without combining them with other drugs, which led to the destruction of annual and delayed growth of perennial weeds.

The obtained results of the conducted studies are generally consistent with the results of researchers O.V. Gurmanchuk *et al.* (2021), where the technical efficiency of a mixture of herbicides Granstar Pro 75 + Apiros 75, with norms of 0.025+0.013 kg/ha was 94.6%. The difference was observed in the species composition of weed vegetation, which is explained by different zones of experiment.

Jam (2019) demonstrates that the Zhytomyr region has a high level of colonisation of winter wheat grain by fungi of the *Fusarium* spp. genus, namely *F. graminearum*, *F. culmorum*, *F. poae*, *F. avenaceum*. In this regard, the author recommends using fungicides Follicur BT, EC (1.2 L/ha), Magnello 350 EC, (1.0 L/ha), a mixture of the fungicide Magnello 350 EC, (0.75 L/ha), and the biological product Gaupsin, s. (0.2 L/ha). In the proposed technology of protection against *Fusarium* infection, a mixture of Amistar Extra 280 SC, 0.5 L/ha + Rex Duo, SC, 0.4 L/ha is recommended.

In the technology of winter wheat protection against leaf diseases, tank mixtures of fungicides Alto Super 330 EC (0.5 L/ha) + Topsin M, WP (1.0 kg/ha) are proposed. In the papers by V.I. Martynenko, O.I. Logvenok (2018) the technical effectiveness of fungicides Soligor 425 EC, Falcon, EC, Vareon, EC, and Rex Duo, EC to powdery mildew was indicated in the range of 46.7-49.7%. V.P. Turenko (2018) proposed the fungicide Derozal SC (0.5 L/ha) against Septoriosiis with a technical efficiency of 60.7%.

In general, the conducted studies are consistent with the papers of foreign and Ukrainian researchers,

but there are some differences with the results of other authors, which is explained by changes in the climatic factors of the research area.

CONCLUSIONS

Powdery mildew, brown rust, septoriosi, Ustilago smut, fusarium-helminthosporous root rot were detected during the monitoring of winter wheat production crops of the SE Experimental Farm Nova Peremoha of the Polissia National University of the National Academy of Agrarian Sciences of Ukraine over the years of research. Among the pests grass flies, namely Hessian and Swedish flies, grass aphids, Haplothrips tritici, and bread carabus were identified. All the above-mentioned diseases and pests exceeded the thresholds of economic harmfulness.

Seeds were treated with a mixture of preparations containing active fungicidal and insecticidal action substances to protect plant seedlings from diseases and pests. In the spring tillering phase (BBCH 21-29), considering the species and quantitative composition of the factual contamination, wheat crops were sprayed with a mixture of herbicides Granstar Pro 75, WG, 20 g/ha + Apyros 75 WG, 15 g/ha. Maximum effectiveness against diseases of winter wheat was provided by the use of tank compositions of fungicides Alto Super 330 EC, 0.5 L/ha + Topsin M, WP, 1.0 kg/ha in a mixture with microfertiliser Orakul, s., 1.0 L/ha and in the phase BBCH 41-69 a mixture of fungicides Amistar Extra 280 SC, 0.5 L/ha + Rex duo, KS, 0.4 L/ha. The technical

effectiveness of these drug mixtures ranged from 77.1% to 86.8%, depending on the disease. Against pests, the insecticide Aktara 25 WG, 0.10 kg/ha was added to the mixture of fungicides in the phase of stem elongation, while the technical efficiency was 73.8-89.5%

The use of a comprehensive system of protection of winter wheat crops increases the productive indicators of the crop structure by 20-30%. Consequently, the yield increased by 2.3 t/ha compared to options without the protection system.

Further research should focus on a combination of agrotechnical and chemical measures to protect winter wheat from harmful biota. Namely, due to changes in the climatic conditions of the Forest-Steppe zone of Ukraine, the timing of wheat sowing should be considered more and a pattern between the timing of sowing and the development of harmful organisms should be established. Optimal wheat sowing times for the area under study should be established, thereby minimising the number of pesticide treatments.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Технологія захисту пшениці озимої від шкідливої біоти у північному Лісостепу України

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Анотація. Технологія захисту пшениці озимої спрямована на запобігання масовому поширенню шкідливої біоти та можливість її швидкого обмеження. При цьому є головним вибір пестицидів та вчасне їх застосування саме у той період, коли шкідливі організми знаходяться у чутливій стадії до засобів захисту, а рослини – у фазі формування і закладання елементів продуктивності. Мета роботи передбачає вивчення ефективності запропонованих композицій хімічних препаратів від шкідливої біоти при удосконаленні технології захисту пшениці озимої. При моніторингу шкідливих організмів були використані загальноприйняті у фітопатології (шкали Страхова, Гешеле), ентомології (метод ентомологічного сачка, метод облікових ділянок), гербології (кількісно-ваговий) методи. Наведено, результати досліджень, отримані при проведенні виробничого дослідження з вивчення ефективності сумішей препаратів для комплексної системи захисту посівів пшениці озимої. Встановлено зміни у видовому та кількісному складі бур'янової синузії пшениці озимої залежно від технології захисту. Загальна кількість бур'янів на ділянках, де застосовували систему захисту, зменшилася на 61,2 шт./м² порівняно з контрольним варіантом. Представлено зміни чисельності складу шкідників (зменшення гессенської мухи на 26 екз./100 п.с., шведської мухи – 31 екз./100 п.с., злакові попелиці – 20 особин на стебло, пшеничного трипса – 34 екз./100 п.с., хлібного туруна – 6 жуків/м²) при обприскуванні пшениці озимої у фазах виходу у трубку та молочної стиглості інсектицидами Актара 25 WG, ВГ, 0,10 кг/га + Карате Зеон 050 CS, СК, 0,2 л/га. Технічна ефективність інсектицидів проти шкідників становила 73,8-89,5 % залежно від шкідливої комахи. Доведено що, надійного захисту від домінуючих хвороб у господарстві досягнуто застосуванням комбінацією фунгіцидів Альто супер 330 ЕС, к.е., 0,5 л/га та Топсін М, ЗП, 1,0 кг/га у фазі виходу у трубку та Амістар Екстра 280 SC, КС, 0,5 л/га + Рекс Дуо, КС, 0,4 л/га у фазі колосіння – початок цвітіння. Технічна ефективність подвійного обприскування рекомендованими препаратами проти хвороб становила від 77,1 % до 86,8 %. Запропонована технологія захисту пшениці озимої від шкідливих організмів є ефективною, пройшла виробничу перевірку та може бути впроваджена у господарствах всіх форм власності.

Ключові слова: бур'яни; хвороби; шкідники; гербіциди; фунгіциди; інсектициди; урожайність