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RESEARCH ARTICLE

Weed infestation of winter wheat in organic crop rotation and economic efficiency of its cultivation

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Abstract

Organic farming is an important way to get healthy food and build a healthy nation. There is no alternative to herbicides, so scientists are improving the system of tillage and the use of mulch from plant residues, green manure in organic crop rotations. Under the conditions of chernozem of typical light loamy of the Left-Bank Forest-Steppe of Ukraine (Sumy district), when using no-tillage cultivation in the crop rotation buckwheat - winter wheat - sunflower - spring barley, the weed infestation score in winter wheat crops was determined as average level and high level at sowing time (in average 2020-2022 years): 32 pcs./m^2 when using a heavy cultivator to a depth of 10 cm-12 cm and 6 cm-8 cm - 58 pcs./m^2, when using a disc harrow to a depth of 10 cm-12 cm - 44 pcs./m^2 and 6 cm-8 cm – 50 pcs./m^2. Among the weeds, annual monocots and rhizomes predominated. The yield and quality of winter wheat grain, the conditionally net profit from cultivation using organic technology, were the highest when using a heavy cultivator by 10 cm-12 cm.

Keywords: Wheat, Yield, Tillage, Crop rotation, Weeds, Grain, Organic farming, Economic analysis.

Introduction

Improvement of technologies for growing agricultural products, in particular, winter wheat, which meet the requirements of Organic Standard certification, i.e. without the use of pesticides and mineral fertilizers, is currently relevant in Ukraine and in the whole world. In developed countries with stable economies, people want to have environmentally friendly and high-quality products in their diet (Ilchenko et al., 2023; Rempelos et al 2023; Waqas et al. 2023). In countries with an economic crisis, this issue is also relevant due to high prices for mineral fertilizers, fuel and pesticides, and sometimes manual labor takes place in technologies in small areas. Properly selected technological operations for tillage, the timing of their implementation is an important factor in regulating the weed infestation of crops (Kolisnyk et al. 2020; Hryhoriv et al. 2023). Of course, the selection of winter wheat cultivation technology depends on the type of soil, i.e. its particle size distribution and mineralogical composition, the location of fields in the relief, the meteorological features of the area and many other factors (Dindaroglu et al. 2022; Lopushniak et al., 2021; Voitovyk et al. 2023**)**. The complexity of the relationship between crops and weed communities prompts the invention of new ways to control them, for example, using robotics that recognize plants and remove them mechanically. The method of identifying weeds using spectral images is quite interesting (Wangetal 2023). There is also an opinion that there are so-called "neutral" weeds, and there are aggressive ones, and approaches to regulating their numbers can be different to maintain biodiversity (Esposito et al. 2023). Green manure crops suppress the development of some weeds, but here the question of studying which green manure affects which weeds is more relevant, this issue has not yet been fully investigated (Mishchenko et al. 2019; Weisberger et al. 2023). The rate and timing of sowing crops are also significant factors in monitoring weeds and planning appropriate measures to regulate their abundance (Essman et al. 2023; Kharchenko et al. 2019, 2021; Zakharchenko et al. 2023).

Materials and Methods

A field study was conducted during two growing seasons from 2021 through 2022 at the Institute of Agriculture of the Northern East, geographical coordinates of field plots are N 50.888429, E 34.711497. Soil of experimental plots is chernozem typical leached low-humus medium-loam on loess. Soil pH is 6.5, humus content 4.0 %, mineral nitrogen is 89 mg /100 g soil (by Tiurin), mobile for of phosphorus is 11.75 mg /100 g of soil, exchangeable form of potassium – 10.0 mg /100 g of soil (photometric method by Chyrikov). Sort of winter wheat is Vyshyvanka.

Treatments were arranged in a randomized complete block design with a split-plot randomization restriction with three replications. Obtained results were calculated using Agrostat program.

Winter wheat seeding rate was 4,5 mln. seeds per 1 ha. Seeds were planted in 15 cm raw spacing in the 3 cm depth.

Measurement included calculation of weeds per m^2, in the replicates for each variant. Types of weeds were determined and grouped accordance to their life cycles. Winter wheat seeds were harvested in the middle of July with moisture content 16,3 %.

Studies are carried out in stationary experiments in four-field crop rotation: buckwheat – winter wheat - sunflower - spring barley. The scheme of the experiment is as follows:

1. Cultivation with a heavy cultivator KLD-2.0 to a depth of 10 cm-12 cm.
2. Cultivation with a heavy cultivator KLD-2.0 to a depth of 6 cm-8 cm.
3. Disc processing AG-2.4-20 to a depth of 10 cm-12 cm.
4. Disc processing AG-2.4-20 to a depth of 6 cm-8 cm.

This cultivation scheme is also carried out in crop rotation for spring barley. For sunflower and buckwheat in option 1, plowing is carried out to a depth of 20 cm, in option 2 - deep loosening to 35 cm, in option 3 - disc cultivation with a heavy cultivator KLD-2.0 to a depth of 10-12 cm, in option 4 - disc cultivation AG-2.4-20 to a depth of 12-14 cm. That is, the methods of tillage are studied comprehensively and by crops in particular. The straw of the predecessor remains on the field. After barley and winter wheat, mustard as a cover crop is used in crop rotation.

Meteorological conditions in 2021 differed from 2022 with significant rainfall and high temperatures in June-July.

Results and Discussion

In autumn, during the sowing period of 2021, the largest number of weeds was observed when using a disc cultivator. In the autumn of 2022, the number of weeds was significantly less than the previous year. Early spring annual weeds predominated among the weed groups at the beginning of the growing season such as *Chenopodium album* L., *Poligonum convolvulus* L., *Amaranthus albus* L., *Thlaspi arvense* L., *Galinsoga parviflora* L. etc. Among the late spring weeds - *Setaria glauca* L., *Setaria veridis* L., *Echinochloa crus-gali* L., *Sonchus oleraceus* L. dominated. Among wintering weeds there are such as *Viola arvensis* Murr., *Consolida arvensis* L., *Erigeron canadensis* L., *Centaurea cyanus* L., *Galium aparine* L. Such perennial plants can be found as Elymus repens (L.) Gould etc.

Recently, against the background of changes in the species composition of weeds in crops, grain yield losses are 20-60%. The cool weather of the spring period restrained the germination of spring weeds in crops. Their main number was represented by perennial wintering groups of weeds. Studies on the weed infestation of agrocenosis have shown that non-flange cultivation affects weed infestation, depending on the depth and type of the machine.

On the variant where soil tillage was carried out to a depth of 6-8 cm, their total number was the highest 62 / 57 pcs./m^2 on 2 and 4 variants in 2021 sowing time, and for the harvesting period pcs./m^2, 54 / 44 pcs./m^2 in 2022 sowing time (Table 1).

During the growing season, winter wheat plants bush well and prevent weeds from fully developing, covering the surface of the soil. Therefore, the number of weeds decreases until harvesting time.

Table 1. Biological groups of weed in the winter wheat field.

Variant	Biological groups of weeds								Total	
	Early spring		Late spring		Wintering		Pirennial			
	Sowing	Harvesting	Sowing	Harvesting	Sowing	Harvesting	Sowing	Harvesting	Sowing	Harvesting
1. Cultivation with a heavy cultivator KLD-2.0 to a depth of 10 cm-12 cm	23/16*	3/11	7/5	23/4	5/4	0/1	0/0	2/0	35/29	28/16
2. Cultivation with a heavy cultivator KLD-2.0 to a depth of 6 cm-8 cm	48/45	4/16	7/4	29/2	6/5	0/2	1/0	6/0	62/54	39/20
3. Disc processing AG-2.4-20 to a depth of 10 cm-12 cm	30/27	5/8	9/7	25/3	8/6	0/1	1/0	2/0	48/40	32/12
4. Disc processing AG-2.4-20 to a depth of 6 cm-8 cm	40/32	8/8	10/8	32/5	4/2	0/0	3/2	5/1	57/44	45/14

*2021-2022 years of research

Comparing the depth of cultivation with a heavy cultivator KLD-2.0, it is necessary to note the greater efficiency of the application of cultivation to a depth of 10 cm-12 cm. A positive effect can be seen in reducing the number of early spring weeds. The use of a disc cultivator with cultivation to a depth of 6 cm-8 cm leads to an increase in the number of weeds compared to cultivation with the same cultivator, but to a depth of 10 cm-12 cm. But at the time of harvesting, a smaller number of early spring weeds was noted on these experimental plots.

The data in the table show that the yield of wheat grain for two years in a row had small indicators for the experiment options in 2021 and 2022. As you know, without the use of pesticides and mineral fertilizers, considerable attention should be paid to the system of cultivation and application of organic fertilizers or wrapping green manure, plant residues, based on the alternation of certain technological operations. The use of various methods of basic tillage is one of the important measures to regulate the contamination of soil weeds with seeds. Pre-sowing cultivation in organic farming is carried out as early as possible in order to control seed germination immediately before sowing. The upper horizon of the soil is loosened by mechanized units and their weight, the configuration of the cutting / loosening bits-tines has an impact on the angle of undercutting of the soil layer, the pressure on the soil layer. Deeper tillage can loosen the lower layers better, which gives the plant's roots better access to air and a better soil structure which also confirm the research results of (Tsyuk et al. 2023, Karpenko et al. 2020, Karbivska et al. 2020). The yield in the experiment is lower than in the fields with intensive technology due to the lack of organic fertilizer application in the field. Only the mulch of the predecessor in the crop rotation for wheat and barley, and green manure of mustard for sunflower, and corn acts as an intake of organic material.

As can be seen from the (Table 2), in 2021, up to 0.4 t ha^{-1}, more winter wheat grain yield was obtained using a heavy cultivator to a greater depth of 10 cm-12 cm than using disc cultivators to the same depth. There is no significant difference between variants 2,3,4, the same variants have a significant difference with the first variant. But in 2022, there is no significant difference between the options. A similar situation applies to the protein content – it is the highest in the first option.

The total cost of growing winter wheat in 2021 amounted to USD 436.9- USD 446.3, in 2022 – USD 744.5-843.6. Such a difference in costs over the years is explained by the economic crisis, the collapse of the hryvnia, and the completely destroyed logistics chains as a result of the full-scale invasion of the Russian Federation. The rise in energy and fuel prices has all affected the return on investment in the cultivation of crops. Conditionally, net profit in 2021 was USD 340.4-370.3, in 2022 – USD 227.5-377.5. As you can see, in 2022, the use of a heavy cultivator brings a difference of $29.9 to the use of discs to a depth of 10 cm-12 cm. Comparing the cultivation to a depth of 6 cm-8 cm, we see an increase of only $1.9 when using a heavy cultivator. In 2021, the lowest profit was also received on the version using a disc harrow to a depth of 6 cm-8 cm, which is $33.3. Less with the use of a heavy harrow.

Table 2. Yield and quality of winter wheat grain with the calculation of economic efficiency of cultivation

Variant	Grain yield, t ha^{-1}			Protein content, %			Total cost of growing winter wheat, $		Net profit, $	
	2021	2022	Av.	2021	2022	Av.	2021	2022	2021	2022
1.Cultivation with a heavy cultivator KLD-2.0 to a depth of 10 cm-12 cm	3.49	3.4	3.44	10.8	10.6	10.7	446.6	843.6	370.3	377.5
2.Cultivation with a heavy cultivator KLD-2.0 to a depth of 6 cm- 8 cm	3.12	3.25	3.19	10.6	10.2	10.4	438.8	754.2	349.8	260.8
3.Disc processing AG-2.4-20 to a depth of 10 cm-12 cm	3.16	3.32	3.24	10.3	10.3	10.3	446.3	763.9	340.4	268.4
4.Disc processing AG-2.4-20 to a depth of 6 cm-8 cm	3.08	3.05	3.07	10.2	10	10	436.9	744.5	348.4	227.5
LSD_{05}	0.27	0.39		0.2	0.2					

Conclusions

Methods of surface tillage for winter wheat to a depth of 6 cm-8 cm to 10 cm-12 cm do not significantly affect the weed infestation of crops during the spring resumption of vegetation. At the time of harvesting winter wheat, annual cereals and dicotyledonous weeds prevailed in the crops. The yield of winter wheat in 2022 did not depend much on the method and depth of the main tillage, in 2021 the highest yield with a significant difference from other cultivation options was obtained when using a heavy cultivator with a loosening depth of 10 cm-12 cm as the main cultivation. According to the yield obtained, the profit from the use of the studied technological operations was also the highest on the same option.

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