

Allelopathic properties of winter wheat varieties in the phase of full maturity in the steppe zone of Ukraine

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Abstract. The direction of organic farming is one of the most promising and relevant in the field of agriculture. Organic agriculture assumes the priority role of grain production, for which a significant share of organic land is allocated from the total area, but compared to other European countries, it is a much smaller indicator. One of the reasons for this is the low yield of crops, which is due to the cessation of the use of chemical plant protection agents and mineral fertilizers. The phenomenon of allelopathy is taken into account when developing the structure of crop rotation and mixed crops in order to avoid soil fatigue in monocultures and weed control. Accordingly, it is appropriate to research and study the allelopathic properties of new varieties of winter wheat from different breeding centers of Ukraine. Therefore, the purpose of this work is to establish the allelopathic activity of various types of winter wheat, which will make it possible to identify varieties relevant for organic farming. To confirm the allelopathic activity of various types of winter wheat in 2019-2020, field research was carried out in the field of the Educational-Scientific-Practical Center of Mykolaiv National Agrarian University. The article presents the results of research into the allelopathic activity of water-soluble secretions from the soil rhizosphere and vegetative organs of winter wheat plants of new varieties of domestic breeding. It was established that water extracts from the organs of winter wheat plants of Koshova and Garantiya Odeska varieties inhibited the germination of watercress seeds more than other studied varieties. The variety Shchedrivka Kyivska has high allelopathic activity, and the varieties Vidrada and MIP Assol are neutral to the germination of watercress seeds

Keywords: winter wheat, allelopathic activity, varieties, water extracts, rhizosphere zone

INTRODUCTION

Organic farming is one of the priority areas of agriculture in the world. Organic agriculture in Ukraine is dominated by grain production, for which 43.2% of organic land (133,440 thousand ha) is allocated, but this is about 0.9% of the total area allocated for these crops in the country, which is significantly less than in Austria – 15.6%, Italy – 10.4%, Germany – 4.8%, Belgium –

3.8% [1]. It is believed that the main reason for the slow expansion of organic cultivated areas is the low yield of crops, which is due to the cessation of the use of mineral fertilizers and chemical plant protection agents.

One of the most important tasks of modern agricultural science is solving the problem of biologicalization of agriculture, increasing the profitability and

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stability of agrophytocenoses, obtaining stable harvests of high-quality products [2; 3].

When developing the structure of crop rotations and mixed crops in order to prevent soil fatigue in monoculture, fight against weeds and phytopathogenic organisms, etc., the phenomenon of allelopathy or chemical interaction of plants, which was first discovered by the Australian scientist H. Molish in 1937, is taken into account [4]. Allelopathy, as a scientific direction, due to the multifaceted nature of its approaches to the study of various biological phenomena, is intensively developing all over the world, including in Ukraine [5-10].

Currently, the need for alternative methods of weed control and the search for biological plant growth regulators is becoming increasingly urgent [11-14]. It has been established that an allelopathically active culture can potentially be used for weed control by sowing a variety with allelopathic properties, thus reducing the rates of synthetic herbicides [15-17]. Many crops have been identified that produce substances poisonous to weeds.

Soft winter wheat is one of the most common agricultural crops in the world and has an allelopathic potential for fighting weeds, pests and diseases, which contributes to its cultivation according to organic technologies [18; 19].

According to V.A. Derevyanka, L.D. Yurchak, B.O. Ivanytska, A.K.M.S. Kabir and others. [19-21; 22], the phytoimmunity of wheat plants and other crops largely depends on the allelopathic regime of the soil, and the constant cultivation of cultivated plants in one place leads to inhibition of growth and a decrease in resistance to damage by diseases and pests.

Based on the results of the research, it was established that there is a difference in the allelopathic activity of soft winter wheat varieties when grown in the Steppe zone of Ukraine [23; 24].

Currently, research, testing and selection of winter wheat varieties with high potential for organic cultivation are important, but their allelopathic properties are not always taken into account.

Therefore, the study of allelopathic properties of eight new varieties of winter wheat from different breeding centers of Ukraine is relevant.

V.A. Derevyanko (2003) believes that allelopathic parameters should also be taken into account in the characteristics of a wheat variety as an integral part

of the variety's passport, since plants show different tolerance to allelopathically active substances [19]. Therefore, one of the promising directions for the development of allelopathy is the screening test of various varieties and varieties of cultivated plants in order to study their allelopathic potential or resistance to allelopathically active substances [9; 19-24].

It is known that varieties of extensive use must have high allelopathic activity in order to create their own allelopathic regime in the crop and to counteract the penetration of weeds. Varieties of intensive use should have a low allelopathic activity [20].

As a result of numerous studies [18; 23; 24; 26] it was established that winter wheat varieties have different allelopathic properties against weeds, therefore, when they are alternated in crop rotation, the yield reduction in monoculture will be significantly less than when one variety is grown for a long time.

Research on genetic markers associated with wheat allelopathy and gene transfer into modern varieties for resistance to weeds is currently being conducted [25; 26].

It is known that the allelopathic effect of root secretions increases during plant aging [20]. According to B.O. Ivanytska [21], plant leaves and their secretions are more toxic; less – roots and root extracts; stems occupy an intermediate position. Other scientists [27] claim that aqueous extracts from leaves and stems have a higher inhibitory effect on rice seed germination than root extracts because they contain more phenolic compounds. Taking into account the spread of winter wheat and insufficient study of its allelopathic properties, the research topic is relevant.

The purpose of the article is to establish the allelopathic activity of various varieties of winter wheat, which will allow identifying varieties suitable for organic farming.

MATERIALS AND METHODS

In order to establish the allelopathic activity of various varieties of winter wheat in 2019-2020, field research was conducted in the field of the Educational, Scientific and Practical Center of the Mykolaiv National Agrarian University. The technology of growing winter wheat was generally accepted for the Southern Steppe zone of Ukraine. The predecessor is field peas. The research material was eight varieties of winter wheat recommended for cultivation in the conditions of the Steppe of Ukraine (Table 1).

Table 1. Characteristics of winter wheat varieties

Varieties	Type	By height	Resistance to disease	Grain quality
Vidrada	<i>erithrospermum</i>	medium growth	average	strong
Koshova	<i>erithrospermum</i>	medium growth	above average	strong
Shchedrivka Kyivska	<i>lutescense</i>	medium growth	above average	valuable
Krasa laniv	<i>erithrospermum</i>	medium growth	above average	strong
Kvitka poliv	<i>lutescense</i>	medium growth	above average	valuable
MEP Assol	<i>lutescense</i>	medium growth	high	filler
Guarantia Odesa	<i>erithrospermum</i>	medium growth	high	strong
Shedrist Odeska	<i>erithrospermum</i>	a half-dwarf	high	valuable

Variants in the experiment were placed by the method of split plots, repetition four times. The area of the accounting plot is 25 m². The soil of the experimental sites is low-humus, light-loam southern chernozem on the loess of wide poorly drained watershed plateaus, which is typical for the Southern Steppe zone of Ukraine. The content of humus in the arable layer of the soil is 2.4%, easily hydrolyzed nitrogen is 16 mg/kg, mobile phosphorus is 160 mg/kg, and exchangeable potassium is 187 mg/kg of soil.

To determine the allelopathic properties of winter wheat varieties suitable for distribution in the Steppe zone of Ukraine, the bioassay method of A.M. Grodzynskiy [28] was used. Watercress (*Lepidium sativum* L.) was taken as the test object, as it is highly sensitive to allelopathic substances. The growth of the roots of the test object in distilled water was taken as the control (100%).

Laboratory research was carried out in 2020 in the laboratories of the department of plant breeding and horticulture of the Mykolaiv National Agrarian University.

The effect of aqueous extracts of the basal soil layer, roots, leaves and stems of winter wheat plants of different varieties on the growth of seedling roots and the germination of watercress seeds was evaluated.

Since the largest amount of growth inhibitors accumulates in the phase of full grain maturity of winter wheat plants, soil and plant samples of each of the investigated varieties were taken precisely in this phase of development.

Vegetative organs of winter wheat plants (roots, stems, leaves) were separated in laboratory conditions.

The selected samples were dried at a temperature of +65°C to a constant mass and ground. An average weight of 1 g was taken, which was extracted in 100 ml of distilled water in a thermostat during the day at a temperature of +25°C.

One-day-old seedlings were placed in sterile Petri dishes with a diameter of 9 cm on sterile filter paper soaked in 3 ml of filtrate watercress seeds (seeds were considered germinated if the root length was 1 mm). In the control variant, seedlings were grown on distilled water. Petri dishes with watercress seedlings were placed in a thermostat at a temperature of +25°C for one day. The length of the roots was measured using a digital caliper DIGITAL CALIPER 391110 with an accuracy of 0.02 mm. The experiment was completely randomized, four-fold repetition of studies with 100 seeds each was used.

RESULTS AND DISCUSSION

As a result of the conducted research, it was established that water-soluble secretions from the rhizosphere of winter wheat plants of the majority of studied varieties had a stimulating effect on the growth of watercress roots, except for the varieties Shchedrivka Kyivska, Garantia Odeska and Shchedrist Odeska. A longer root length was established in the seedlings of the test culture in the version with water extraction of the soil of the rhizosphere of the Kvitka poliv (14.27 mm) and Koshova (11.22 mm) varieties, which is 5.72 mm and 2.67 mm more than in control. A smaller stimulating effect was observed in varieties Krasa Laniv (9.37 mm), MIP Assol (9.69 mm) and Vidrada (8.77 mm), which by 9.6; 13.3; 2.6% more than in the control (Table 2).

Table 2. Effect of water extracts from the rhizosphere zone and vegetative organs of plants of winter wheat varieties on the root length of watercress seedlings, mm

Type (factor A)	Water extraction (factor B)				Average by factor B
	soil	roots	stems	leaves	
Distilled water (control)	8.55	8.55	8.55	8.55	8.55
Krasa Laniv	9.37	4.55	7.30	7.43	7.16
Vidrada	8.77	7.21	8.47	8.01	8.12
Kvitka poliv	14.27	4.45	7.43	7.71	8.47
Koshova	11.22	2.60	10.41	6.64	7.72
Shchedrivka Kyivska	7.44	4.87	3.83	7.88	6.02
MIP Assol	9.69	9.49	7.43	9.92	9.13
Garantia Odeska	7.10	3.20	6.21	8.32	6.21
Shchedrist Odeska	6.05	3.55	7.43	8.86	6.47
Average by factor A	9.55	4.99	7.31	8.10	7.41

Research has established that water extracts from the roots of plants of most studied varieties inhibited the growth of watercress roots by 15.7-69.6%, the length of the roots of the seedlings ranged from 2.60 mm (Koshova) to 7.21 mm (Vidrada). Stimulation of the growth of watercress roots was detected using water extract from the roots of winter wheat plants of only one studied variety – MIP Assol (9.49 mm), which exceeded the control by 11.0%.

It was determined that the water extract from the stems of plants of most winter wheat varieties studied had an inhibitory effect on the germination of the seeds of the test culture, while the length of the roots of the seedlings ranged from 3.83 mm for the Shchedrivka Kyivska variety to 8.47 mm for the Vidrada variety, which by 1.0-55.2% less than the control. A water extract from the stems of plants of the Koshova variety had a stimulating effect on the germination of watercress seeds. The length of the roots was 10.41 mm, which is 1.86 mm or 21.8% more than in the control.

A more inhibitory effect of water-soluble extracts from the leaves of winter wheat plants of the Koshova variety on the growth of watercress roots was revealed, which is 22.3% lower than the control. A slight stimulating effect on root growth was exerted by water extractions of the varieties Shchedrist Odeska (8.86 mm) and MIP Assol (9.92 mm), which was 16.0 and 3.6% higher, respectively, than in the control variant.

Thus, the average length of watercress roots by varieties (factor A) was the smallest (4.99 mm) under the action of water extraction from the roots, and the largest – 9.55 mm under the action of water extraction from the basal layer of the soil of winter wheat plants.

On average, according to factor B (water extract), the MIP Assol variety had a slight stimulating effect on the growth of watercress roots, and all other varieties had an inhibitory effect.

It was established that the greater growth of the roots of the test culture was under the influence of water extraction from the basal layer of the soil of plants of the Kvitka poliv variety, which is 166.9% compared to the control. Watercress seed treatment

extracts from the vegetative organs of winter wheat plants of the same variety inhibited the growth of the primary root, which amounted to 52.1 (roots); 86.9 (stems) and 90.2% (leaves) relative to the control (Fig. 1).

A similar pattern was observed in the varieties Krasa Laniv and Vidrada, that in the version with water extraction from the soil of the rhizosphere of plants, the growth of roots was 109.6 and 102.6%, respectively, relative to the control, while in the variants with water extraction from the roots – 53.2 and 84.3%; from stems – 85.4 and 99.1 and water extract from leaves – 86.9 and 93.4% relative to the control.

Water extracts from the soil of the rhizosphere and from the stems of winter wheat plants of the Koshova variety had a stimulating effect on the growth of the roots of the studied test crop – 131.2 and 121.8% relative to the control, respectively.

It was determined that the water extract from the leaves of winter wheat plants of the Odesa Generosity variety insignificantly stimulated the growth of the roots of watercress seedlings – 103.6% compared to the control, while the extracts from the basal layer of the soil, roots and stems, on the contrary, inhibited it (70.8; 41.5 and 86.9% relative to the control).

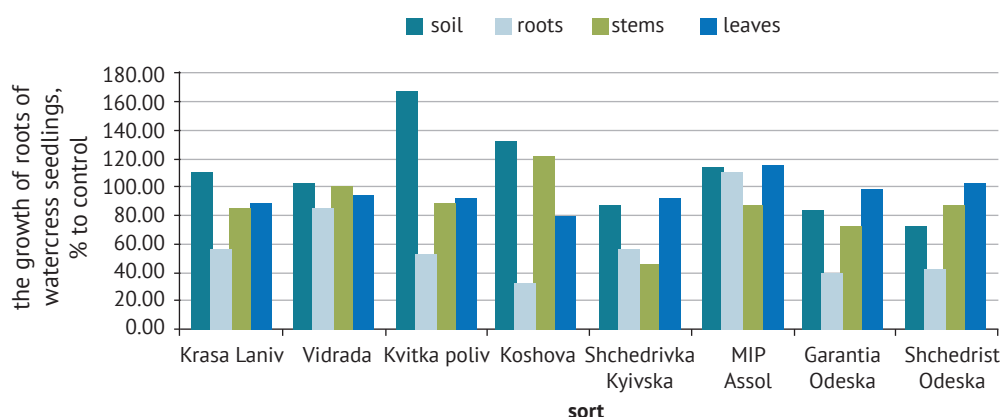


Figure 1. The influence of water extracts from the soil of the rhizosphere and vegetative organs of plants of winter wheat varieties on the growth of roots of watercress seedlings, % to control

It was established that all investigated variants of water extracts from plants of the Garantia Odeska and

Shchedrivka Kyivska varieties had an inhibitory effect on the growth of the roots of seedlings of the test culture, which is from 37.4 to 97.3% relative to the control. The water extract from the leaves of both studied varieties had less inhibition of root growth – 92.2% (Shchedrivka Kyivska) and 97.3% (Odesa Guarantee). The

results of our research showed that allelopathic activity towards watercress seedlings was revealed by the water-soluble secretions of plant roots of the majority of winter wheat varieties studied. The greatest inhibitory effect is characteristic of the varieties Koshova (-69.59%) and Garantia Odesa (-62.57%) (Table 3).

Table 3. Allelopathic activity of water-soluble secretions in the rhizosphere zone and vegetative organs of plants of different varieties of winter wheat, % to control

Type(factor A)	Water Extractor (Factor B)			
	soil	roots	stems	leaves
Krasa Laniv	9.57	-46.78	-14.62	-13.10
Vidrada	2.56	-15.67	-0.94	-6.32
Kvitka poliv	66.87	-47.95	-13.10	-9.82
Koshova	31.23	-69.59	21.75	-22.34
Shchedrivka Kyivska	-12.99	-40.04	-55.20	-7.84
MIP Assol	13.33	10.99	-13.10	16.02
Garantia Odeska	-16.60	-62.57	-27.37	-2.69
Shchedrist Odeska	-29.25	-54.48	-13.10	3.63

A significant inhibitory allelopathic effect of the water extract from the stems of winter wheat plants of the Shchedrivka Kyivska variety was observed (-55.20%), while in the Koshova variety of this extract, it was stimulating (21.75%).

Thus, it was determined that high allelopathic activity in the phase of full ripeness of the grain had a high allelopathic activity in the studied water extracts of soil and plant organs of winter wheat of the Shchedrivka Kyivska variety (from -7.84 to -55.2%), and the lowest – Vidrada varieties (from -0.94 to -15.62%) and MIP Assol (+16.02 to -13.10%).

It was established that among all studied varieties of winter wheat, the water extract from the leaves

of plants of the Koshova variety had the greatest allelopathic activity (-22.34%); from stems – Shchedrivka Kyivska variety (-55.2%); from the roots – the Koshova variety (-69.59%) and from the soil – the Odesa Generosity variety (-29.25%).

The winter wheat variety Shchedrivka Kyivska has a high allelopathic activity in the phase of full grain ripeness (from -7.84 to -55.2%), and the lowest is the Vidrada variety (from -0.94 to -13.50%) and MIP Assol (+16.02 to -27.95%).

It was determined that different parts of the plants of each of the researched varieties exert different inhibitory or stimulating effects on the germination of watercress seeds. As a result of the research,

it was established that the water extract from the leaves of winter wheat plants had a greater negative effect on the germination of watercress seeds, which on average was 74.4% (80.9% of the control) by variety. This is 5.6% less than in the option with water extraction from leaves and 11.8% less than in the option using water extraction from stems (Table. 4) It was determined that the water extract from the roots of winter wheat plants of the Koshova variety had a more inhibitory effect on the germination of watercress seeds (54.8%), which is 94.3% compared to the control. The germination of the seeds of the studied test crop was reduced less by the varieties Krassa Laniv - 88.3% (96.0% to the control), MIP Assol - 88.8% (96.5% to the control), Vidrada - 86.8% (94.3% before the control), Shchedrivka Kyiv - 85.8% (93.3% before the control) and Shchedrist Odesa - 84.3% (91.6% before the control).

Water extracts from the leaves of plants of the Koshova variety had a more negative effect (68.3%) on the seed germination of the test culture, while the extract from the leaves of plants of the MIP Assol variety had a positive effect (105.2%). Aqueous extracts from the stems of winter wheat plants reduced the germination of watercress seeds less compared to extracts from roots and leaves, which is an average of 92.7% for the varieties compared to the control. The lower seed germination (68.3%) was obtained after processing with its extraction from the stems of winter wheat of the Shchedrivka Kyivska variety - 74.2% before the control. Water extracts from the stems of plants of the varieties Vidrada and Kvitka of the fields had a slight stimulating effect on the germination of the seeds of the test culture, which was 104.1 and 107.4%, respectively, of the control.

Table 4. The effect of water-soluble secretions in the rhizosphere zone and vegetative organs of winter wheat plants of different varieties on the germination of watercress seeds, %

Type (Factor A)	Water Extractor (Factor B)							
	Soil	%. To control	roots	%. To control	stems	%. To control	leaves	%. To control
Distilled water (control)	92.0	100.0	92.0	100.0	92.0	100.0	92.0	100.0
Krassa Laniv	83.3	90.5	88.3	96.0	74.3	80.8	90.3	98.2
Vidrada	66.7	72.5	86.8	94.3	95.8	104.1	66.0	71.7
Kvitka poliv	59.7	64.9	67.8	73.7	98.8	107.4	70.3	76.4
Koshova	77.8	84.6	54.8	59.6	88.0	95.7	62.8	68.3
Shchedrivka Kyivska	66.7	72.5	85.8	93.3	68.3	74.2	70.3	76.4
MIP Assol	79.0	85.9	88.8	96.5	83.3	90.5	96.8	105.2
Garantia Odeska	66.7	72.5	71.5	77.7	76.3	82.9	72.0	78.3
Shchedrist Odeska	66.1	71.8	84.3	91.6	82.0	89.1	73.0	79.3
Average on types	70.8	77.0	79.6	86.5	85.3	92.7	74.4	80.9

Analyzing the amplitude of the allelopathic activity of water-soluble secretions of plants of domestic varieties of winter wheat from the rhizosphere

zone and vegetative organs, we found that a higher indicator is characteristic of the Kvitka poliov variety - 114.82% (soil) (Fig. 2).

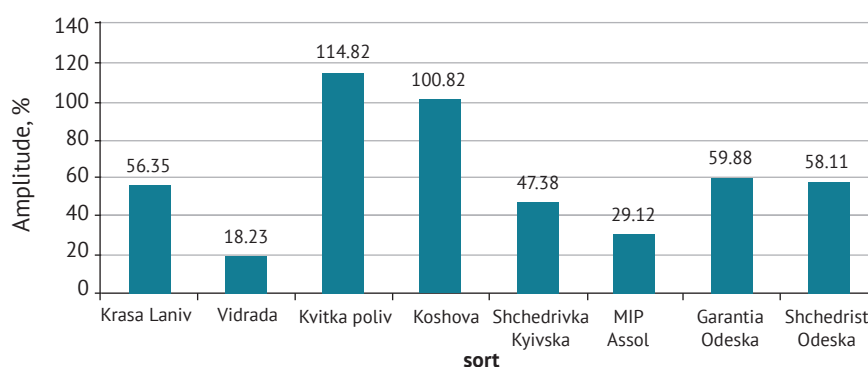


Figure 2. Amplitude of allelopathic activity of water-soluble secretions of water extracts from rhizosphere soil and vegetative organs of winter wheat plants

The average indicators of the amplitude of allelopathic activity are typical for Shchedrivka Kyivska varieties (47.38%), water-soluble secretions in the rhizosphere zone and all vegetative organs of which had inhibitory properties of varying intensity. The amplitude of allocation of plants of the Krasa Laniv variety is 56.35% and ranges from intense inhibitory (water extract from the roots) to slight stimulating (water extract from the rhizosphere soil). The varieties Shchedrist Odeska and Garantiya Odeska are also characterized by average indicators of the amplitude of allelopathic activity (58.11 and 59.88%, respectively), a significant share of which is contributed by the release of roots that have a high inhibitory effect. Plants of Vidrada and MIP Assol varieties are characterized by the smallest amplitude of allelopathic activity (18.23 and 29.12%, respectively), that is, it is close to neutral. However, there is a difference, which is manifested in the fact that in the latter variety, only the release of leaves has a slight inhibitory effect, and for the Vidrada variety, the inhibitory effect of different activity is characteristic of the water-soluble secretions of all vegetative organs, and only the release into the soil of the rhizosphere has a slight stimulating effect.

Due to the fact that Vidrada and MIP Assol varieties show tolerance, we consider it important to analyze the change in allelopathic activity from inhibitory to stimulating. It was established that the change in the allelopathic activity of water-soluble secretions for the Vidrada variety has the following form: "water-soluble secretions of roots < leaves < stems < secretion into the rhizosphere"; for the MIP Assol variety – "water-soluble secretions of stems < roots < secretion into the rhizosphere < leaves". It can be assumed that this phenomenon is associated with the accumulation of a greater amount of phenolic compounds in the roots of plants of the Vidrada variety and the stems of plants of the MIP Assol variety.

As a result of the conducted correlation-regression analysis, it was established that there is a very weak inverse relationship between seed germination

and cress root growth under the influence of water extracts of vegetative organs of plants of different varieties of winter wheat – in the varieties Krasa Laniv and Shchedrist Odeska (-0.0349 and -0.2469, respectively) to a weak straight line – in Shchedrivka Kyivska (0.1450), MIP Assol (0.2217) and Kvitka Poliv (0.4555) varieties. A moderate dependence is observed in winter wheat plants of Garantia Odeska and Koshova varieties (0.6445 and 0.7631, respectively). Only the Vidrada variety is characterized by a high correlation between seed germination and watercress root growth – 0.9069.

CONCLUSIONS

As a result of the conducted research, it was established that the character of the metabolites of the studied varieties of winter wheat, which are released into the rhizosphere zone, have stimulating and inhibitory effects on seed germination and the growth of watercress seedlings.

It was determined that water extracts from the organs of winter wheat plants of the Koshova and Garantiya Odeska varieties suppress the germination of the seeds of the test crop more than the other studied varieties. The water extract from the roots of plants of the Koshova variety had the most inhibitory effect on the growth of watercress roots. It was established that the Shchedrivka Kyivska winter wheat variety has high allelopathic activity, while the Vidrada and MIP Assol varieties are neutral to the germination of watercress seeds. A high correlation (0.9069) was determined between seed germination and cress root growth under the action of water extraction from the rhizosphere soil and vegetative organs of Vidrada variety plants. We assume that with a smaller amplitude of allelopathic activity of water-soluble secretions of winter wheat plants of the Vidrada and MIP Assol varieties, they are tolerant to the reduction of the aftereffects of the cultivation of these varieties and soil fatigue. In the future, the researched varieties will be subjected to a more detailed check at different stages of development and with other test cultures.

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Алелопатичні властивості сортів пшениці озимої у фазі повної стиглості в зоні степу України

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Анотація. У статті представлено результати досліджень алелопатичної активності водорозчинних виділень з ризосфери ґрунту та вегетативних органів рослин пшениці озимої нових сортів вітчизняної селекції. Встановлено, що водні витяжки з органів рослин пшениці озимої сортів Кошова та Гарантія одеська більше пригнічували схожість насіння крес-салату, ніж інші досліджувані сорти. Високу алелопатичну активність має сорт Щедрівка київська, а сорти Відрада та МІП Ассоль є нейтральними до проростання насіння крес-салату

Ключові слова: пшениця озима, алелопатична активність, сорти, водні витяжки, зона ризосфери