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POTENTIAL CONTAMINATION OF SOYBEAN AGROPHYTOCENOSIS DEPENDING ON THE SYSTEM OF FARMING AND SOIL TILLAGE

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Abstract. This work presents the results of the study of changes of the potential contamination of soybean agrophytocenosis in grain-row crop rotation by using different systems of farming and typical black soil tillage. It was established that in the upper 0–5 cm layer of soil there are on average 393–671 million pieces of weed seeds. which is 33.6–43.0% of the total number in the layer of soil 0–20 cm. It was established that the use of periodical moldboard and superficial basic soil tillage had no impact on reducing the potential contamination of typical black soil compared to the variant of differentiated tillage. During subsurface plowing the total number of seeds in the soil layer 0–20 cm increased by 13.5–25.8% compared to differentiated tillage. In the variants of ecological and biological farming systems the number of weed seeds in the layer 0–5 cm was 11.3–19.6% higher compared to the intensive farming system. Based on monitoring of the species composition of the weed seeds bank it was established that in the arable layer of the soil the largest share are annual dicotyledonous – 48–62%. annual monocotyledonous – 30.2–44.6%. perennial – 0.9–3.3% of the total number. It was proved that under the intensive system of farming the yield of soybean variety Silesia increased on average from 10.2 to 147% compared to the ecological and biological system of farming. During the biological system of farming soybean yield did not exceed 1.0–1.8 t/ha. Therefore. the industrial and ecological system of farming had the greatest impact on reducing the potential weediness of the soybean agrocenosis during the growing season. During the biological system of farming crop yields decrease due to the accumulation of weed seeds in the topsoil and formation of high actual weediness of the soybean agrocenosis.

Key words: potential contamination, tillage, farming system.

INTRODUCTION

Potential stocks of weed seeds in the arable layer of the soil are the main factor that determines the actual weediness of field crops. Therefore. both scientists and producers should pay constant attention to the monitoring of potential weediness of agricultural land (Manko 2000; Jordan et al. 2016). The most important part of modern technologies of growing crops is the protection of crops from weeds. Despite the huge annual costs

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spent on weed control. which exceed 10 billion hryvnias. their number in the fields does not decrease. but even increase (Manko 2000). The reason for this is the extremely high potential soil contamination. According to various data of the authors. the average stocks of weed seeds in the arable soil layer in the forest-steppe zone now range from 1.71 to 14.0 billion units/ha and the ability of weed seeds in the soil to sprouting on average is from 2.4 to 8.1% (Ivashchenko 2004; Makuch 2004; Sosnoskie et al. 2006). This number of seeds without the intensive weed control guarantees a high actual weediness of crops with the appearance during the growing season from 2 to 5 thousand pieces/m^2 of their seedlings (Ryan et al. 2009). The higher the stock of seeds and organs of vegetative reproduction of weeds in the soil. the more it will sprout under favorable conditions in the future. Despite the intensive use of herbicides in the cultivation of crops. the potential weediness of the arable layer does not reduce (Tkachuk 2018).

Soil contamination with weed seeds can cause significant weediness of crops with a decrease of crop yields by 25–30 %. At the same time. it is necessary to take into account the nature of weeds. biological features and the dispersal area of the most harmful weeds (Suchorzewski 2018; Bagavathiannan 2012).

Among the important reasons for the significant increase of the potential weediness of typical black soil are often the following (Shuvar et al. 2018):

- high seed productivity and regenerative ability of weeds due to a lack of effective control of them on arable and uncultivated lands;
- violation of scientifically substantiated crop rotations. optimal terms of field work and tillage system;
- simplification of crop care system and lack of weed control on uncultivated land.

Potential weediness is a reliable biological adaptation of weed sinuses that helps to maintain the evolution of plant species and ensure their survival in both natural and technogenic environments (Uzbek et al. 2010). This stock of weeds creates great competitive problems for cultivated plants in agrocenoses (Storchous 2011; McErlich and Boydston 2013).

The degree of resistance and indifference to provocative factors of germination in the soil of weed seeds exceeds the cultivated plants. which are highly homogeneous in the germination process. Weed seeds can maintain the anabiosis under favorable water and temperature regimes. high and low temperatures. in deep soil layers at different densities and controllability of arable land. withstands herbicide concentrations (Shuvar 2008).

There are several important scientific principles for the effective management of processes of harmfulness control of weeds in various agro-ecospheres. The problem of conservatism and variability of potential weediness of such eco-landscape and techno-biogenic areas as cultivated land has not been fully resolved by that time (Ryan et al. 2010). The problematic directions of transformation of the species composition of weed seeds in the soil and in the field of various technobiogenic objects in the formation of weediness of agrocenoses are expected in time (Gallandt 2006; Gallinat et al. 2015; Benaragama et al. 2016).

The aim of the study is to determine the influence of farming and tillage systems on the weed seed accumulation patterns in the arable soil layer and in the soybean agrophytocenosis.

MATERIAL AND METHODS

Experimental studies were performed during 2017–2019 in a stationary experiment of the Department of Agriculture and Herbology in a separate unit – Agronomic Research Station of the National University of Life and Environmental Sciences of Ukraine.

The variability of weather conditions over the years of the study is expressed by the value of the hydrothermal coefficient of Selyaninov: HTC 2017 – 0.90, 2018 – 0.92, 2019 – 0.90. The soil of the experimental area is typical low-humus medium loam black soil. The humus content in the soil layer is 0–30 cm is 4.5%. the salt pH is 6.9–7.3.

The study was performed in a 2-factor stationary field experiment to study 3 gradations of the farming systems and 3 systems of basic tillage. The crop rotation is as follows: soybeans – winter wheat – sunflower – barley – corn for grain. Soybean was the test crop to determine the change of the potential weediness of agrophytocenosis.

The only logical difference between the options of the farming system is their resourcing for the reproduction of soil fertility and the implementation of technological measures of care for the crops.

Intensive (industrial) system of farming *(control)* – priority use of industrial fertilizers to restore soil fertility with the application of 12 tons of manure per hectare of crop rotation area and intensive use of mineral fertilizers – 300 kg NPK ($N_{92}P_{100}K_{108}$). and pesticides.

Ecological system of farming – priority application of 18 t of organic fertilizers per hectare of crop rotation area for soil fertility reproduction (12 t/ha of manure and 6 t/ha of by-products and weight of post-harvest green manures) and 150 kg of active ingredient of mineral fertilizers ($N_{46}P_{49}K_{55}$). the use of pesticides according to ecological and economic criterion of the threshold of pests presence.

Biological (organic) system of farming – the use of only 17 t/ha of organic fertilizers of natural origin to restore soil fertility without the introduction of industrial agrochemicals and pesticides. but using instead of them biological crop protection products.

The content of the second factor – the systems of basic tillage in crop rotation: within each system of farming. three of its variants are studied:

1) differentiated tillage (control). which is recommended in the forest steppe zone of Ukraine and provides during the crop rotation 3 moldboard tillage. one superficial – for winter wheat and one chisel tillage for barley;
2) periodical moldboard consisting of tiered plowing for sunflower, superficial disking for winter wheat and chisel breaking up of soil for other crop rotations;
3) superficial soil tillage with disc tools for all crops to a depth of 8–10 cm. The arable area is – 280 m^2 accounting area – 192 m^2. Repetition of the experiment is provided four times. the placement of options is consistent.

The potential weediness of the soil was determined by the method of soil sampling by Kalentiev drill on the diagonal of the field in five places of the experimental area. The selected soil sample was washed through a sieve with 0.25 mm diameter holes and a flange 5 cm high above the tank. A salt solution was used to separate the fine seeds that passed through the sieve from the sludge and water. At the same time. heavy mineral

particles of the soil settled to the bottom. and light weed seeds and organic residues rose to the surface. The weed seeds were dried and counted together with the previously sieved seeds. The level of soil contamination by weed seeds was determined by the formula:

$$З = 10\,000 \cdot К / Н \cdot П$$

where:

З – contamination of the soil layer with weed seeds [pc/m²];

10 000 – area [1 m² · cm²];

К – the number of weed seeds in the sample [pc];

Н – the number of samples from which the average sample was formed;

П – the area of the inner surface of the drill [cm²] (Manko et al. 1998).

The accounting of yield was performed by the method of complete harvesting from the accounting area and conversion to moisture and contamination (Manko et al. 2019).

RESULTS AND DISCUSSION

The weed seed accounting in the soil has been tested and the potential contamination of the arable layer has been high. depending on the systems of farming and basic tillage is 1.1–1.5 billion pieces. seeds per 1 ha (Table 1). It was established that the weediness of the soybean agrocenosis depends on the amount of seeds that are placed in the upper 0–5 cm layer of soil. Thus on 1 ha in 0–5 cm of soil layer there are on average 393–671 million pieces of weed seeds. which is 33.6–43.0% of its total amount in the soil layer of 0–20 cm. 100 g of soil in a layer of 0–5 cm contains 63–93 pcs weed seeds. This number of weed seeds in the soil can ensure significant weediness of crops in crop rotation.

According to various data the average reserves of weed seeds in the arable soil layer (0–30 cm) of Ukraine are from 1.7 to 15.0 billion pcs/ha. and the ability of weed seeds in the soil to germinate is on average from 2.3 to 8.2%. This number of seeds without intensive weed control is able to form a high actual weediness of the agrocenosis with the appearance during the growing season from 2 to 5 thousand pcs/m^2 of their seedlings.

Table 1. Potential soil contamination depending on the systems of farming and its tillage (2017–2019)

System of farming (A)	Tillage option (B)	Number of seeds in the soil [mln pcs/ha]		
		in a layer of 0–5 cm	in a layer of 0–20 cm	in 100 g of soil 0–5 cm layer, pcs
Intensive (control)	differentiated (control)	393	1168	62
	periodical moldboard	549	1155	83
	superficial	582	1470	90
Ecological	differentiated (control)	410	1279	64
	periodical moldboard	627	1247	88
	superficial	601	1494	92
Biological	differentiated (control)	483	1374	68
	periodical moldboard	672	1365	91
	superficial	671	1560	93
LSD_{05} A		67	326	31
LSD_{05} B		29	279	18

LSD – least significant difference.

Potential contamination of the soil layer significantly depends on the main tillage systems. Systematic periodical moldboard and superficial tillage had no impact on the reduction in potential soil contamination compared to the variant of differentiated tillage. In the variant of superficial tillage. the total number of seeds in the soil layer 0–20 cm increased on average by 13.5–25.8% compared to the variant of differentiated tillage. In the variant of periodical moldboard tillage. the number of weed seeds is significantly reduced compared to superficial tillage. This is evidence that due to the use of moldboard tillage in the technology of growing crops weed seed growth rates outweigh natural and anthropogenic destruction.

Scientists of Uman National University of Horticulture established that the pattern of significant increase of weed seeds in a layer of 0–10 cm with a decrease of tillage depth from 20–22 to 15–17 cm for both moldboard and nonmouldboard tillage. and with the deepening of arable layer their number decreased. The possible reason was the distribution of weed seeds during deep tillage in a larger volume of soil (Zanin et al. 1997; Blackshaw 2005; Karnauch et al. 2018).

The potential soil contamination in the layer of 0–5 cm was much higher by using periodical moldboard and superficial basic tillage than with differentiated tillage. Thus by using the intensive system of farming the potential soil contamination averaged 39.6–48.1. by using the ecological system – 46–52.9. and by using the biological system – 38.9%.

In the variants of ecological and biological systems of farming. The number of weed seeds in the soil layer 0–5 cm was higher on average by 11.3–19.6% compared to the intensive system of farming. We believe that this result was achieved due to the use of herbicides by the criterion of ecological and economic threshold of harmfulness.

Thus the potential weediness in the farming system is considered to be the main factor that determines the degree of weediness of crops. the harmfulness of weeds and the amount of harvest losses.

Based on our monitoring of the species composition of the weed seeds bank it was established that in the arable layer of the soil the largest share are annual dicotyledonous – 48–62%. annual monocotyledonous – 30.2–44.6%. perennial – 0.9–3.3% of the total number (Fig. 1). The seeds of yellow foxtail (*Setaria glauca*), barn grass (*Echinochloa crus-galli* L.) and meadow grass (*Poa bulbosa* L.) are predominant among the annual monocotyledonous.

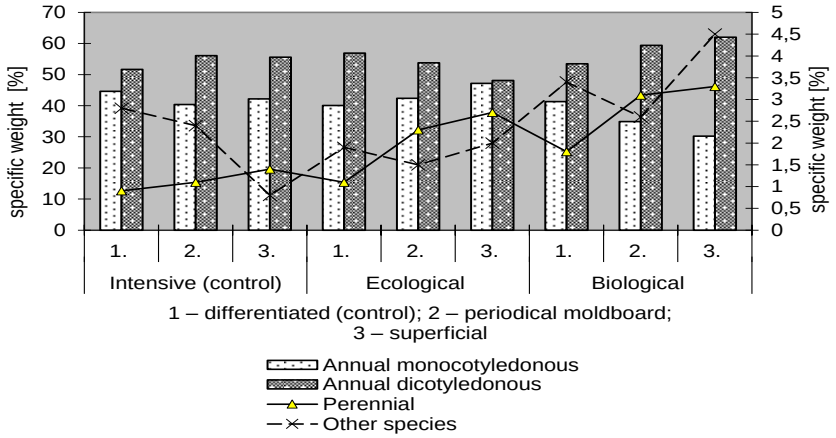

Fig. 1. The structure of the potential contamination of the arable layer of soil with weed seeds (on average within 2017–2019)

By using the intensive system of farming the lowest seeds number of annual monocotyledonous weeds was established due to periodical moldboard tillage. By using the ecological system of farming the largest number of seeds of annual monocotyledonous weeds was established due to superficial tillage – 47.2%. The application of a biological system of farming on the background of superficial tillage helps to reduce the number of annual monocotyledonous weeds (Winston et al. 2014).

Among the annual dicotyledonous weeds the seeds of white quinoa (*Chenopodium album*), redroot pigweed (*Amarantus retroflexus*), catchweed bedstraw (*Gallium aparine*), shepherd's purse (*Capsela bursa pastoris*) and purslane (*Portulaca olerace*) are predominate. The high potential stock of weed seeds of these species in the arable layer of the soil causes their significant distribution in the soybean agrocenosis. It is established that the use of periodical moldboard and superficial tillage causes an increase of seeds of small dicotyledonous and perennial weeds in the arable soil layer compared to the use of differentiated tillage.

Based on the study it was established that the use of farming system and tillage affects the yield of soybeans (Fig. 2). These features must be taken into account in the technology of growing crops. The highest yield (3.8 t/ha) of soybean Silesia over the years of the study was obtained due to the use of intensive farming system.

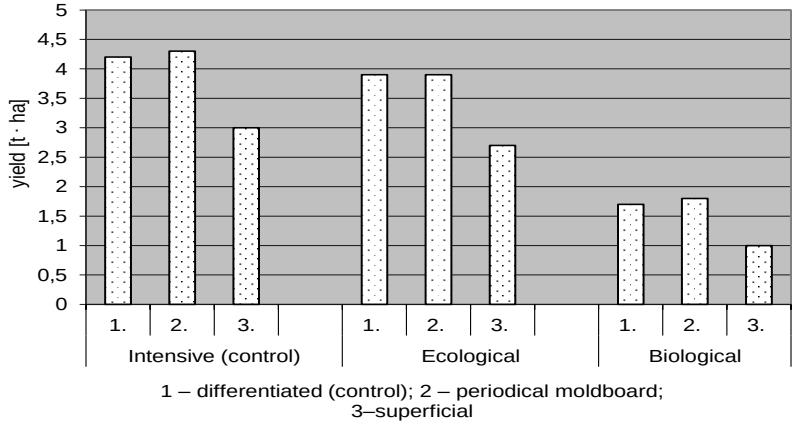

Fig. 2. Soybean yield depending on the system of farming and tillage (average within 2017–2019)

Significantly lower yields were obtained by using the variant of the biological system of farming compared to the industrial and ecological systems. Significant increase of potential and actual weediness has an impact on yield reductions during the use of biological farming system and a complete rejection of chemical protection systems compared to its industrial and ecological systems.

The highest soybean yield was obtained in the variants of differentiated and periodical moldboard basic tillage – 4.2 and 4.3 t/ha. A significant reduction in soybean yield was obtained by using the variant of superficial main tillage.

The correlation between potential weediness and crop yields is one of the closest among other factors. despite the fact that the sale of seed stocks largely depends on ecological voids in agrocenoses. competition at different stages of plant development. soil moisture. synchronicity of agriculture cycles with the cycles of biological awakening of weeds. localization of seeds in a zone of active stimulation or long preservation.

We established an inverse insignificant correlation between the number of weed seeds in the soil layer 0–5 cm and soybean yield (r = –0.54). noted an inverse significant correlation between the number of weed seeds in the soil layer 0–20 cm and soybean yield (r = –0.81).

CONCLUSIONS

The greatest impact on reducing the potential weediness of the soybean field during the growing season on average within 2017–2019 was obtained due to use of industrial and ecological farming systems. The biological system of agriculture contributes to the accumulation of weed seeds in the upper layer of the soil due to the high actual weediness of the agrocenosis and the reduction of crop yields. Among the methods of basic tillage the highest yield of soybeans is provided by differentiated tillage. During the experiment with use of basic periodical moldboard tillage against the background of the industrial system of farming, in which the number of weed seeds in the soil decreased by 25%. the highest yield was obtained – 4.3 t/ha. Further research on establishing the role of tillage in the formation of weed measures on typical black soil of the forest-steppe of Ukraine is promising.

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