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The Effect Of Soil Cultivation On Contamination Of Sunflower Crops In The Result Of Technology Intensification In The Last 40 Years In The Central Black Earth Region.

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ABSTRACT

Due to the large macroeconomic importance of sunflower for crop production in the Central Black Earth region, the study of the influence of the main methods of soil cultivation, taking into account the trend of its minimization in recent years, on the level of contamination of crops is very relevant. Earlier studies (1980-1991) showed that compared with plowing, soil cultivation without soil layer turnover led to an increase in the contamination of sunflower crops at the beginning of the vegetation by 25-44%, the lack of soil cultivation – by 2.4 times. The low efficiency of these variants is particularly noticeable in relation to perennial weeds, whose number increased, respectively, by 2 and 6 times (to 11.6 PCs/m²). The observed trend continued towards the end of the growing season. The air-dry mass of weeds increased by 2.5-3.2 times in case of abandonment of the soil layer turnover, while in the absence of soil cultivation – by 4.5 times (up to 42 g/m²). Modern studies (2011-2013) confirmed the effectiveness of plowing, the advantage of which was emphasized by a much more devastating effect on perennial harmful vegetation throughout the growing season. The efficiency of subsoil tillage decreased with the reduction of its depth, and the strengthening of the main soil cultivation based on plowing with additional stubble by 12-14 cm allowed reducing the number of perennial weeds by 1.8 times, and their mass by 2.2 times. The systematic use of herbicides in the production has led to a significant reduction in the contamination of sunflower crops (by 7-15 times) and differences in the influence degree of the main methods of soil cultivation on it recently, especially with regard to the most harmful perennial vegetation and the total weight of weeds (2016-2018). This makes it possible, depending on the economic situation, to make a more effective choice between mechanical and chemical methods of weed control.

Keywords: sunflower, soil cultivation, juvenile and perennial weeds, contamination, herbicides, intensification, Black Earth region.

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INTRODUCTION

Currently, sunflower is one of the most cost effective and highly profitable crops in Russia. In most farms, where its crops occupy about 7-9% of the arable land, the profit from its cultivation reaches 25-35% of the total profit of crop production. Based on this, many farmers today rely on the expansion of sunflower seed production, primarily by increasing its seeding area. Data of Federal State Statistics Service show that over the past 10 years the area of arable land sown with sunflower in Russia increased by 25.1%, and in relation to 1990 – by 2.6 times [10]. In Central Black Earth region, the area of sunflower crops occupy about 20% of the total area sown by this crop in the Russian Federation, and its share in the structure of the region's crop area reaches 15%.

The main and, perhaps, the most problematic link in the technology of sunflower cultivation is the protection of crops from weeds. A wide-row method of sowing and slow growth of crop plants at the beginning of vegetation make its crops in this period the most vulnerable from weed plants. With insufficient attention to the purity of sunflower crops, especially at the beginning of vegetation, 35-40% of its harvest can be missed [12]. In this regard, the issues of improving the technology of protection of its crops from weeds remain very relevant.

The subject of discussion for a long period of time is the optimal choice of soil treatment intensity in the sunflower cultivation and its combination with herbicides for the most rational control of weed vegetation and resource conservation. The opinions of various researchers of this problem are contradictory. According to some researchers, deep soil ploughing provides the least contamination of crops [3, 5, 9]. Other scientists [4, 11, 16, 18], on the contrary, believe that at the application of subsoil tillage, shallow and surface soil cultivation weed crops are below. It is also noted that the minimization of soil cultivation and No-till in the absence of additional methods for weed control lead to an increase in weed contamination [2, 3, 6, 7, 14, 15, 17, 19]. There are research materials that indicate no significant differences in the number of weeds depending on the methods of basic soil cultivation [8].

Currently, the production at the cultivation sunflower uses widely technology Clearfield that is a combination of herbicide Euro-lightning and high-yield hybrids resistant to this herbicide. This allows minimizing soil cultivation up to refusal from it [13]. The purpose of this work is to summarize the results of experiments carried out in different periods of the last four decades to study the effectiveness of the regulatory impact of soil cultivation on the weed component of sunflower agrophytocenosis as a result of changes in the intensity of its cultivation technology.

CONDITIONS AND METHODS OF RESEARCH

The studies were conducted in the agro-ecological conditions of the Central Black Earth zone – the most important agricultural region of the country, the share of farmland in which is 80% (13.2 million hectares). The region is characterized by temperate continental climate with an average annual temperature of 5-6.4° C, the sum of the average daily temperatures above 10° about 2300-3000°, the average annual precipitation 450-550 mm.

Field studies were conducted in stationary experiments of the Department of Agriculture in V.V. Dokuchayev Research Institute of Agriculture of the Central Black-Earth Zone (Voronezh region) in 1980-1991. The soil of experimental area is a common chernozem medium-thick heavy-loamy. The content of humus – 6.84%; total nitrogen – 0.277%; total phosphorus – 0.20%; total potassium – 1.85%; pH_{KCl} 7.02.

In the 80s of the last century, research intensified in connection with the development of new tillage tools based on different principles of the layout of the cultivated soil layer and their different intensity. It should be noted that these tools for soil cultivation are still widely used in production.

In the first experiment (1988-1991), the phytosanitary value of the main methods of basic soil cultivation was studied: 1 – plowing PM-4-35 to a depth of 20-22 cm; 2 – chiseling PM-2.5 to 20-22 cm; 3 – chiseling PM-2.5 to 45 cm; 4 – paraplau cultivation tool for 20-22 cm; 5 – cultivation with SRIAME stands 20-22 cm; 6 – without the main soil cultivation. The study of soil cultivation techniques was carried out on two

backgrounds of fertilization: a – without fertilizers; b – $N_{60}P_{60}K_{60}$ in the main technique. The area of the sowing plot was 360 m², accounting – 210 m², three times repeatability, placement of plots is systematic.

In the second stationary experiment (1980-1991) systems of main soil cultivation in crop rotation were studied (peas – winter wheat – sunflower, corn – barley): 1 – common in the area, two-phase – peeling disk for 6-8 cm + ploughing to 20-22 cm for crops sowing solid and 25-27 cm for sunflower; 2 – the improved, three-phase – peeling disk for 6-8 cm + peeling moldboard on 12-14 cm + ploughing. The area of the sowing plot in the experiment is 172.8 m², accounting – 70.4 m², the repeatability is fourfold. In the experiments, a zoned sunflower variety – Voronezh 436 was sown. Agricultural technology of crop cultivation corresponded to the generally accepted for the zone.

Research in 2011-2013 was conducted on the experimental fields of the Department of Agriculture of Belgorod State Agricultural Academy (Belgorod region). Soil – typical chernozem medium-thick heavy-loamy. Humus content was 5.0%, pH_{KCl} – 6.14; content of mobile phosphorus and potassium (by Chirikov), respectively 125-167 and 128-133 mg/kg of soil.

The methods of the main soil cultivation were studied: 1. plowing (control) – PSM-5-35 to a depth of 28-30 cm, 2. deep moldboard cultivation – PCH-2.5 to a depth of 40-42 cm, 3. small moldboard cultivation CHE-3.8 to a depth of 14-16 cm.

The predecessor of the sunflower varieties Yason was winter wheat, placed after peas. The general background for the main cultivation was the peeling of stubble with disk harrows to a depth of 6-8 cm after the cleaning of the predecessor. The study of the methods of the main soil cultivation was carried out against the background of the main mineral nutrition (azophoska) by 30 kg of the active substance NPK per hectare. Placement of plots in the experiment is systematic, repeatability is triple. Sowing area of plots – 53.2 m², and the accounting area – 50.4 m². During the sunflower growing season, two inter-row cultivations were carried out at a depth of 6-8 cm with a cultivator CPM-4.2.

Field experiments in 2016-2018 were conducted on the basis of “Krasnoyaruszhsky grain company Ltd.” (Belgorod region). The soil of the area is typical chernozem, humus content of 4.9%, pH_{KCl} – 6.4, content of mobile phosphorus and potassium, respectively 134 and 234 mg / kg of soil.

The contamination of sunflower crops, the predecessor of which was winter wheat, cultivated after soybean, was studied depending on the methods of the main soil cultivation: 1. plowing (control) – PSM-4-35 to a depth of 25-27 cm, 2. deep subsoil cultivation – SunFlower to a depth of 25-27 cm, 3. without cultivation – No-till. The impact of soil cultivation methods was also estimated with the use of organic fertilizers: 1. without fertilizers; 2. green manure – white mustard; 3. compost straw-noticeable (20 t/ha).

Placement of plots in the experiment is systematic, repeatability is triple. Sowing area of plots is 100 m², and the accounting area – 50 m². Before sowing of green manure and composting, the disk harrow (post-harvest stubble peeling) of Amazone-Catros was treated, excluding the option with zero soil cultivation. Sowing of green manure crops was carried out by the seeder SGL – 3.6, in the variant with zero soil cultivation – centrifugal spreader Amazone - ZA. Sowing of sunflower was carried out by seeder Massey Ferguson with seed hybrid NK Neeoma company Syngenta. In the phase of 4-6 leaves of sunflower, cultivation with Euro-lighting herbicide, IBS in the norm of 1.0 l/ha, the flow of working fluid 200 l/ha was carried out.

The registration of contamination was carried out by the quantitative-weight method by applying a frame of 1 m², on two non-adjacent repetitions in three places, equidistant at plot diagonals.

Meteorological conditions during the years of research were characterized by certain fluctuations, which undoubtedly reflected on the level of contamination of crops. However, it should be noted that deviations from the mean annual values were typical for the zone of experiments, which can serve as an objective factor in the evaluation of the conducted experiments.

RESULTS AND CONSIDERATION

Contamination of sunflower crops at different methods of basic soil cultivation

In agrocenoses at conducting our research in soil and climatic conditions of the South-East of CBEZ (Voronezh region) in species composition such weeds were dominated as green foxtail (*Setaria viridis* (L.) Beauv), cockspur grass (*Echinochloa crusgalli* (L) Beauv), cleavers (*Galium aparine* L.), wild mustard (*Sinapis arvensis* L.), red-root amaranth (*Amaranthus retroflexus* L.), white goosefoot (*Chenopodium album* L.), field pennycress (*Thlaspi arvense* L.), field bindweed (*Convolvulus arvensis* L.), creeping thistle (*Cirsium arvense* (L.) Scop.), field sowthistle (*Sonchus arvensis* L.), brittlestem hempenettle (*Galeopsis tetrahit* L.), wild buckwheat (*Polygonum convolvulus* L.). Shepherd’s purse (*Capsella bursa-pastoris* (L) Medik.) and drug fumitory (*Fumaria officinalis* L.) were met.

The results of our studies show that the exclusion of the main soil cultivation and subsoil tillage methods led to a sharp increase in the weed contamination of sunflower crops by annual and perennial weeds in quantitative and weight ratio compared to the plowing (table. 1). On average, during the years of research on subsoil tillage at the beginning of sunflower vegetation, the weed contamination of crops, regardless of fertilizer background, was higher in chiseling with the depth of 20-22 cm by 25.2%, for soil cultivation with paraplau tools – by 43.7%, with SRIAME stands – by 38.7%, in the version without basic soil cultivation – by 2.4 times, including perennial weeds more than 2 times - for subsoil tillage, and excluding the main soil treatment – by 6 times. The increase in weed contamination at minimizing soil cultivation was mainly due to cereal weeds (bristles), and there was also an increase in the number of perennial root-spray weeds. Increasing the depth of subsoil tillage (chiseling to a depth of 45 cm) did not reduce the contamination of sunflower crops.

Despite the two inter-row cultivations during the sunflower vegetation, the same pattern in the weed contamination at different methods of the main soil cultivation remained until the end of the sunflower vegetation, both in the number of weeds and their weight. Air-dry mass excess of weeds in sunflower crops at ripening period at subsoil main tillage techniques compared to the plowing was: at chiseling to a depth of 20-22 cm – by 2.6 times, at paraplau soil cultivation – by 2.5 times, with SRIAME stands – by 3.2 times, without main soil cultivation – by 4,5 times. Regardless of the fertilization background in the absence of cultivation weight of weeds was the maximum and was 41.6 g / m² with a significant proportion of the most malicious perennial weeds (over 30% in weight). The decrease in the efficiency of this option in comparison with the use of plowing, where the share of this group of weeds was 6-9% is especially significant.

Higher weed contamination by perennial weeds for subsoil tillage and at the exclusion of the main cultivation is due to the lack of soil layer turnover, weak soil crumbling and small injury to the root system of weeds. Increasing the depth of cultivation – chiseling to a depth of 45 cm resulted in some reduction of weed contamination of crops compared to other subsoil tillage techniques. The application of fertilizer N₆₀P₆₀K₆₀ for the sunflower did not have any impact on the contamination of crops either the number of weeds, or for their mass.

Table 1: Contamination of sunflower crops at different methods and depth of the main soil cultivation in combination with

Fertilizers (1989-1991), PCs / m²

Soil cultivation and depth	Backg	2-4 pairs of real leaves			Before harvesting			Air-dry weight, g / m ²		
		total	among them		total	among them		total	among them	
			juvenile	perennial		juvenile	perennial		juvenile	perennial
Plowing 20-22 cm (control)	a	61.5	59.7	1.8	38.0	37.2	0.8	9.0	8.4	0.6
	b	62.5	61.8	0.7	45.7	44.8	0.9	9.4	8.6	0.8
Chiseling 20-22 cm	a	80.8	79.4	1.4	62.0	60.3	1.7	23.8	20.3	3.5
	b	74.4	72.9	1.5	62.8	60.8	2.0	24.6	21.7	2.9
Chiseling 45 cm	a	85.2	82.0	3.2	55.9	53.9	2.0	16.4	13.6	2.8
	b	80.8	79.1	1.7	58.9	57.4	1.5	15.4	12.7	2.7
Paraplau cultivation	a	92.3	90.2	2.1	56.2	54.3	1.9	23.5	19.8	3.7
	b	85.9	84.7	1.2	59.6	57.2	2.4	22.3	18.0	4.3

20-22 cm										
SRIAME stands cultivation 20-22 cm	a	92.8	90.1	2.7	71.3	67.9	3.4	29.0	21.1	7.9
	b	79.3	76.9	2.4	65.0	62.1	2.9	29.6	23.5	6.1
Without main soil cultivation	a	150.1	138.5	11.6	89.0	74.9	14.1	42.2	28.5	13.7
	b	140.0	124.6	15.8	91.9	77.6	14.3	41.0	27.1	13.9

NB: a – without fertilizers, b – N₆₀P₆₀K₆₀

Phytosanitary value of main soil cultivation systems

According to long-term observations on sunflower crops, about 20 species of weeds germinate at the beginning of vegetation, regardless of the intensity of the main soil cultivation. Juvenile dicotyledonous species, which account is 88-91%, have the advantage in abundance among them. At the same time, studies show that the generally accepted technology of sunflower cultivation, consisting of pre-emergence harrowing and two inter-row cultivations can interrupt the development cycle of most types of weeds of this biogroup.

More adapted to the technology of row crops cultivation are perennial root-spray species of weeds. It is known that the basic principle of the fight against deep-rooting root-spray perennials is based on the depletion of nutrients in the roots by systematic cutting. To do this, at the time the improved (layered) soil cultivation system was developed.

Our long-term (12 years) studies have revealed an ambiguous effect of improved cultivation for different types of root-spray weeds. The most sensitive to its action was the field sowthistle. The number of shoots for two peeling with subsequent plowing was decreased relative to soil cultivation with one plowing by 56.0%, and creeping thistle – by 31.5% (table 2).

Table 2: Number and weight of perennial weeds in sunflower crops at different intensity of the main soil cultivation systems (1980-1991)

Soil cultivation system	Term of determination *	Number of weeds per 1m ²				Weed air-dry mass, g/m ²
		creeping thistle	field sowthistle	field bindweed	total	
Common in the zone	1	5.4	7.5	0.5	13.4	
	2	9.0	1.4	1.1	11.5	36.4
Improved	1	3.7	3.3	0.3	7.3	
	2	4.9	0.9	1.3	7.1	16.7

LSD₀₅=14.5

* 1 – 2-4 pairs of real leaves; 2 – before harvesting.

In general, on biogroup additional peeling in the main soil cultivation system reduced the number of perennial weeds stems in its crops on the average by 1.8 times, and their weight by 2.2 times. At the same time, the positive effect of this soil cultivation system was observed in the aftereffect on barley crops, providing a decrease in the mass of root-spray weeds in its crops by 2.2 times.

Influence of the main soil cultivation intensity on the weed contamination of crops

Currently, protection of sunflower crops from weeds continues to be a problem in the technology of cultivation due to the previously mentioned reasons (high soil contamination potential, wide-row sowing, slow development of the crop at the beginning of vegetation). Despite the significant use of herbicides in recent years [1], due to their high cost soil cultivation is considered as an economic alternative. In turn, the different methods of basic soil cultivation on costs for their execution differ significantly. The search for solutions to the problems of resource saving in modern agriculture is carried out including in the direction of minimizing soil cultivation.

Our studies found that despite the low level of contamination of sunflower crops, it is still largely dependent on the main methods of soil cultivation (table 3).

Table 3: Contamination of sunflower crops (2011-2013)

Main soil cultivation method	Number of weeds, PCs/m ²			
	juvenile		perennial	Total number
	monocotyledons	dicotyledons		
before the first inter-row soil cultivation				
Plowing (control)	7.9	6.5	2.3	16.7
Shallow subsoil tillage	13.5	21.1	6.6	41.2
Deep subsoil tillage	11.1	14.0	3.7	28.8
LSD ₀₅	2.3	4.6	1.2	-
before harvesting				
Plowing (control)	1.8	2.9	0.2	4.9
Shallow subsoil tillage	4.1	10.4	6.2	20.7
Deep subsoil tillage	2.3	9.3	2.1	13.7
LSD ₀₅	0.8	2.1	1.3	-

With regard to the species composition of annual monocotyledonous weeds were common wild oat (*Avena fatua* Thell.), foxtail (*Setaria glauca* L.), annual dicotyledons were mainly represented by cleavers, field pansy (*Viola arvensis* Murr.), wild buckwheat, red-root amaranth, common mallow (*Malva neglecta* Wallr.) and other. Among perennial dicotyledonous weeds creeping thistle and field sowthistle were dominated.

On average, the lowest level of contamination at the beginning of the growing season has been observed in plowing for three years. The total number of weeds was 16.7 PCs/m², with the predominance of juvenile dicotyledonous and monocotyledonous – 86%. Subsoil tillage, shallow and deep, compared with the control, were characterized by a much higher contamination: at cultivating the soil – by 2.5 times, and at using the chisel – by 1.7 times.

The contamination with the most harmful perennial weeds by plowing was significantly lower than at using resource saving cultivation – by 1.6-2.9 times. Worst cultivation option by the number of all considered groups of weeds was shallow subsoil tillage.

The two inter-row cultivations affected the decrease in the number of weeds that appeared in the second half of their vegetation. However, the previously noted nature of the impact of the studied cultivations on this indicator remained.

The total number of weeds on plowing decreased by 3.4 times, on plots treated with a cultivator and a chisel by 2 times. The contamination of sunflower crops on cultivated plots was 4.2 times more than on plowed ones and 1.5 times more than on processed with chisel. Particularly bright positive effect of deep plow tillage was manifested by its impact on perennial weeds. If the reduction of annual weeds for harvesting for different cultivation options was approximately the same: monocotyledonous weeds – by 3-5 times, dicotyledons – by 1.5-2 times, the reduction of perennial weeds against the background of plowing was tenfold, while against the background of deep subsoil tillage their number decreased only by 1.8 times compared to the first accounting period. It should be emphasized that shallow subsoil cultivation had no impact on the distribution of this group of weeds: before inter-row cultivations 6.6 PCs/m², after – 6.2 PCs/m².

Currently, in the advanced farms especially highly specialized, for example, grain direction, herbicides are widely used. It is in this farm in 2016-2018 researches having been conducted to study the effectiveness of main soil cultivation methods and with the use of organic fertilizers – compost and green manure. Records of weeds were carried out only in the phase 2-4 pairs of real leaves, as the sunflower was cultivated according to the Clearfield system with the use of the herbicide Euro-lightning, which excluded the necessity of accounting in the harvesting period.

Data analysis showed that at the systematic use of herbicides in the production there is a decrease in the total level of contamination to 8-11 PCs/m² (table 4), which is lower from 2-4 to 7-15 times compared to previous periods (table 1, 2, 3). This allows minimizing soil cultivation up to refusal from it. Nevertheless, the total level of contamination is significantly less by 1.7-1.8 PCs/ m² or 20-22% when using the main soil cultivation than without it.

Table 4: Influence of basic soil cultivation methods and organic fertilizers on the contamination of sunflower crops (2016-2018)

Soil cultivation (factor A)	Fertilizer (factor B)			Average (A)
	without fertilizers	compost	green manure	
Juvenile weeds, PCs/m ²				LSD ₀₅ =0.7
Plowing	5.7	5.7	5.2	5.3
Deep subsoil tillage	5.3	5.7	5.9	5.6
Without cultivation (No-till)	7.3	6.2	6.6	6.7
Average (B), F _{real} <F _{theor.}	6.1	5.9	5.9	
Perennial weeds, PCs/m ²				F _{real} <F _{theor.}
Plowing	2.9	2.8	2.6	2.8
Deep subsoil tillage	2.3	2.8	2.5	2.5
Without cultivation (No-till)	2.8	2.9	3.2	3.0
Average (B), F _{real} <F _{theor.}	2.7	2.8	2.8	
Total number of weeds, PCs/m ²				LSD ₀₅ =1.2
Plowing	8.6	8.6	7.8	8.3
Deep subsoil tillage	7.6	8.5	8.5	8.2
Without cultivation (No-till)	10.1	9.2	10.7	10.0
Average (B), F _{real} <F _{theor.}	8.8	8.8	9.0	
Weed air-dry mass, g/m ²				F _{real} <F _{theor.}
Plowing	1.5	1.8	1.7	1.7
Deep subsoil tillage	1.5	1.8	1.9	1.7
Without cultivation (No-till)	1.9	1.9	2.0	1.9
Average (B), F _{real} <F _{theor.}	1.6	1.8	1.9	

The same conclusion applies to juvenile weeds. The absence of soil cultivation leads to a significant increase in weed contamination by this group of weeds – by 1.1-1.4 PCs/m² or 20-26%.

The influence of fertilizers on the number of juvenile weeds and the general contamination was not established. As well as the number of perennial weeds and air-dry weight of weeds. The last two indicators did not depend on the main soil cultivation methods. As a trend, we can only note some of their increase without the use of basic soil cultivation.

Obviously, the differences in biological features (fertility and, especially, the way of reproduction) of juvenile and perennial weeds cause the difference between mechanical and chemical methods of weeds contamination control, when the system application of herbicides makes differences between the main soil cultivation methods by the impact on the most harmful perennial weeds unreliable. This is emphasized by the insignificance of differences in air-dry weight of weeds.

CONCLUSION

As a result of studies covering a long period, since 1980 to the present time, it was found that “stable” weeds in sunflower crops are such as species of foxtail (*Setaria Beauv.*), cleavers (*Galium aparine L.*), wild buckwheat (*Polygonum convolvulus L.*), red-root amaranth (*Amaranthus retroflexus L.*) from annual, from perennial dicotyledonous weeds creeping thistle (*Cirsium arvense (L.) Scop.*) and field sowthistle (*Sonchus arvensis L.*) dominated.

Both earlier and modern studies show that in soil and climatic conditions of CBEZ deep plow cultivation creates the most favorable phytosanitary conditions for sunflower growing. The exception of main soil

cultivation and subsoil tillage methods led to an increase in the contamination of sunflower crops by juvenile and perennial weeds in quantity and weight.

The intensification of technologies in the direction of systemic use of herbicides contributed to a significant decrease in the level of contamination of crops – an average of 8-11 PCs/ha (7-15 times over the past 40 years) and the use of resource-saving methods of soil cultivation. This creates the possibility of flexible response to the ever-changing economic situation in the choice of mechanical or chemical method of harmful vegetation control.

Neither mineral nor organic fertilizers, tested in our experiments, had a significant impact on the degree of contamination of sunflower crops.

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