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CROPS WEEDINESS DEPENDING ON BASIC SOIL CULTIVATION SYSTEMS AND SOIL FERTILIZATION LEVELS IN CULTIVATED CROP ROTATION IN THE CENTRAL FOREST-STEPPE OF UKRAINE

S. Obrazhiy, Cand.of Agr. Scs.
Bila Tserkva National Agrarian University

The paper presents the results of studies on investigating soil infestation with weed seeds and weed-infested sown areas under different crops, depending on the system of basic soil tillage and fertilization levels in five-field cultivated crop rotation. It has been found out in the research that in the Central Forest-Steppe of Ukraine soil infestation with weeds seeds and crop rotation weediness during the period of sowing and harvesting are the lowest under combined cultivation and the highest under systematic subsurface one. These figures are slightly higher under systematic surface and durable shallow cultivation compared to the combined cultivation treatment. Soil infestation with weed seeds and sown areas weediness decrease considerably when fertilizing level increases. To improve the phytosanitary condition of cultivated crop rotation it is recommended to use a durable shallow tillage alongside with application of 12 tons of manure + $N_{57}P_{75}K_{75}$.

Keywords: cultivated crop rotation, basic cultivation, fertilization rate, soil weediness, weed seeds, crops weediness.

The problem definition. Weeds emergence of and their adaptation to specific crops is related evolutionarily to agriculture origination. Humans have been selecting the most productive and valuable in the food and economic terms, plants forms and have been growing the crops on the cultivated areas. Under such conditions, undesirable species affecting the primary culture negatively emerged along with cultivated plants. Weeds seeds and vegetative reproductive organs concentrated in cultivated soil after falling or getting into the soil from the surrounding areas [1].

Weeds constantly compete with cultivated plants. Weeds cause particularly significant damage in the early growing season when there is enough resources available for life support. Plants shade is another negative consequence of weeds affect, which cause underdevelopment of mechanical tissue, less carbon dioxide is absorbed and less organic matter is accumulated. Soil temperature decreases under crops shade, which affects their growth adversely [2].

The main reason for weed components emergence in agrocenoses is a high grade of croplands soil weediness. The presence of a great number of weeds in crops and their negative impact on crop yields is becoming an increasingly urgent problem, which reduces the significant potential of our country as a manufacturer and exporter of crop production [3].

Increase in weed-infested cultivated crops areas under flat hoe and surface tillage without herbicide application can be explained by seeds large quantities of weed seeds in the topsoil layer surface covering with organic fertilizer containing a great number of high germinable weed seeds accumulation and [4].

Most scientists consider substitution of plowing with superficial or flat toe tillage as possible only on the weeds clean fields, or under systematic application of herbicides [5].

But according to other sources, better conditions for clearing arable soil of weed seeds are available under holding subsurface tillage. A higher number of weed seeds in arable soil layer is revealed under holding different depth of plowing – 845.8 million per hectare, under subsurface different depth cultivation their number was 607 million per hectare, and 543 million under shallow cultivation with flat and disc harrows [6].

Lower crops weediness under surface and flat hoe tillage surface is explained by better topsoil moisture provision and more active seeds germination, seedlings and shoots of which are destroyed under further cultivations. Soil infestation remains in dynamic equilibrium under

plowing, as the amount of weed seeds carried out to the surface and furrowed into is approximately the same [7].

Subsurface and shallow tillage in unfavorable years allows better weed clearing in the upper (0-10 cm) soil layer and obtaining winter wheat yield increase of 2,2-2,4 kg/ha [8].

The study aimed at determining the most efficient system of basic tillage under different fertilization levels and their effect on the soil and crop weediness level in cultivated crop rotation.

Research Methods. The research was conducted during 2007-2012 biennium at a stationary field experiment on the experimental field of Bila Tserkva NAU in five-field crop rotation with 100% saturation with grains and legumes. The soil type was deep rich humus, low humus, light loams.

The experiments repeatedness – three times, repetitions placing in the area – complete, with first-order plots (tillage) placed in a circle consistently, systematically, while the second order sections (level of fertilization) were placed sequentially in four tiers. Sown area of first-order plots made 684 m^2 (9x76), accounted area made 448 m^2 (7x64), sown area of second-order sections made171 m^2 (9x19), the accounted one made 112 m^2 (7x16).

Four variations and four basic soil fertilization systems were investigated in the rotation. Levels of yearly fertilizers application level per 1 ha of arable crop rotation were the following: zero – no fertilizer, the first – 4 tons of manure + $N_{57}P_{75}K_{75}$; second – 8 tons of manure + $N_{38}P_{50}K_{50;}$ third – 12 tons of manure + $N_{57}P_{75}K_{75}$.

Surface soil cultivation of 15-17, 20-22 and 25-27 cm depth was performed with a plow PLN-3-35; subsurface (flat hoe) soil tillage to the depth of 10 -12, 15 -17, 20-22 and 25-27 cm was performed with flat hoe CPG -250, shallow ploughing to 10-12 cm depth was performed with subsurface plows PL-5-25 and BDV-3,0disc harrow cultivation. Fertilizers applied were ammonium nitrate, granular superphosphate, potassium salt and semi-rotten cattle manure.

Assessment of the crops weed-infesting was performed with quantitative gravimetric method and soil infesting with weed seed – with the method of washing the samples on sieves with apertures of 0.25 mm in diameter, taken with Kalentyev drill.

Results. In our experiments by the time of peas harvesting the topsoil weed seeds infestation increased under subsurface cultivation to 30.5% on unfertilized areas; to 30.6% on the plots of single level of fertilization; to 29.1% on double level of fertilization and to 20.6% on plots of triple level of fertilization compared to surface cultivation (Table 1).

Table 1

Contamination of soil arable layer with weed seeds and pea crop weediness during the vegetation under different tillage systems and fertilization levels, average for 2007-2012

Soil cultivation system	Fertilizers level	Soil infestation with weeds seeds, mln pcs/ha		Actual weed infestation	
		sowing	harvesting	harvesting	
				pcs/m^2	Crude mass, g/m^2
Regular surface (control)	no fertilizers	7,7	7,3	30,2	7,2
	4 t of manure + $N_{19}P_{25}K_{25}$	7,3	7,0	23,1	6,6
	8 t of manure + $N_{38}P_{50}K_{50}$	7,1	6,8	19,0	6,1
	12 t of manure +$N_{57}P_{75}K_{75}$	6,6	7,3	13,3	5,0
Regular subsurface	no fertilizers	10,7	10,5	52,2	13,0
	4 t of manure + $N_{19}P_{25}K_{25}$	10,6	10,1	41,4	11,0
	8 t of manure + $N_{38}P_{50}K_{50}$	10,1	9,6	32,6	10,3
	12 t of manure +$N_{57}P_{75}K_{75}$	9,6	9,2	24,4	9,1

Combined	no fertilizers	7,2	6,8	28,6	7,0
	4 t of manure + $N_{19}P_{25}K_{25}$	7,0	6,4	21,7	6,4
	8 t of manure + $N_{38}P_{50}K_{50}$	6,5	6,0	17,5	6,0
	12 t of manure +$N_{57}P_{75}K_{75}$	6,1	5,7	12,7	4,8
Durable shallow	no fertilizers	7,6	7,2	31,9	7,3
	4 t of manure + $N_{19}P_{25}K_{25}$	7,1	6,7	24,6	6,8
	8 t of manure + $N_{38}P_{50}K_{50}$	6,7	6,3	20,7	6,4
	12 t of manure +$N_{57}P_{75}K_{75}$	6,1	5,8	15,0	5,6
MSD_{05} for A factor		0,2	0,2	0,2	1,0
MSD_{05} for B factor		0,2	0,2	0,2	1,0
MSD_{05} for AB factors interaction		0,5	0,4	0,4	2,0

Under combined and durable shallow tillage the difference reached 0.5 and 0.1 million pcs/ha on the unfertilized plots; 0.6 and 0.3 million pcs/ha on the single, 0.8 and 0.5 million pcs/ ha on dual, 1.6 and 1.5 million pcs./ha on triple fertilization level compared with the combined cultivation. Crude weight of weeds was 42.5% higher under subsurface cultivation compared to the combined one and 40.2% higher compared to regular surface cultivation.

The biggest difference in weed-infestation, depending on tillage systems, was observed in winter wheat crops. By the time of the crops harvesting weed infestation was 40.3% higher under surface cultivation, 5.4% higher under durable and shallow cultivation and 6.4% lower than under combined cultivation (Table 2).

Table 2

Change in winter wheat weeds infestation under different cultivation systems and fertilizing levels, average for 2007-2012

Soil cultivation system	Fertilizers level	Soil infestation with weeds seeds, mln pcs/ha		Weed infestation	
				harvesting	
		Sowing	harvesting	pcs/m^2	Crude mass, g/m^2
Regular surface (control)	no fertilizers	7,8	7,4	27,0	4,3
	4 t of manure + $N_{19}P_{25}K_{25}$	7,1	6,8	20,2	3,8
	8 t of manure + $N_{38}P_{50}K_{50}$	6,9	6,4	18,3	3,6
	12 t of manure +$N_{57}P_{75}K_{75}$	6,7	6,2	9,1	2,0
Regular subsurface	no fertilizers	9,9	9,5	46,5	6,2
	4 t of manure + $N_{19}P_{25}K_{25}$	9,8	9,5	37,6	6,0
	8 t of manure + $N_{38}P_{50}K_{50}$	8,9	8,6	26,4	4,9
	12 t of manure +$N_{57}P_{75}K_{75}$	8,2	7,8	17,6	3,7
Combined	no fertilizers	7,8	7,5	26,8	4,1

	4 t of manure + $N_{19}P_{25}K_{25}$	6,8	6,3	18,4	3,6
	8 t of manure + $N_{38}P_{50}K_{50}$	6,6	6,3	16,6	3,3
	12 t of manure +$N_{57}P_{75}K_{75}$	6,6	6,3	8,7	1,9
Durable shallow	no fertilizers	8,5	8,0	27,5	4,2
	4 t of manure + $N_{19}P_{25}K_{25}$	7,3	7,0	19,9	3,8
	8 t of manure + $N_{38}P_{50}K_{50}$	7,0	6,6	17,4	3,6
	12 t of manure +$N_{57}P_{75}K_{75}$	7,0	6,7	10,5	2,2
MSD_{05} for A factor		0,4	0,4	0,4	0,2
MSD_{05} for B factor		0,4	0,3	0,4	0,2
MSD_{05} for AB factors interaction		0,6	0,5	04	0,4

Fertilization provided reducing the number of weeds in application of all tillage systems. The reason is that fertilizers contribute to the formation of a strong root system and aboveground mass. Due to its significant vegetative mass winter wheat shades and suppresses weed growth and development.

During the growing season of winter wheat seeds the soil weed infestation and crop weediness decreased under all tillage systems. The use of systematic surface cultivation caused reduction in the number of seeds in the arable soil layer during the period from sowing to harvesting crops by 0.3-0.5 mln/ha. A similar trend was noted during the combined cultivation as well.

Substituting regular surface systematic cultivation for subsurface one in the soybean by the germination period contributed to the increase of weed seeds content in the arable soil layer (Table 3).

Table 3

Cultivation systems and soil fertilizing level impact on soybean crops weediness during the growing season of, average in 2007-2012

Soil cultivation system	Fertilizers level	Soil infestation with weeds seeds, mln pcs/ha		Weed infestation	
		Sowing	harvesting	Harvesting	
				pcs. /m^2	Crude mass, g/m^2
Regular surface (control)	no fertilizers	8,1	7,8	31,0	134,4
	4 t of manure + $N_{19}P_{25}K_{25}$	7,7	7,4	24,3	124,8
	8 t of manure + $N_{38}P_{50}K_{50}$	7,5	7,2	20,5	109,3
	12 t of manure +$N_{57}P_{75}K_{75}$	7,2	6,9	15,4	83,5
Regular subsurface	no fertilizers	11,2	10,8	54,3	223,7
	4 t of manure + $N_{19}P_{25}K_{25}$	10,8	10,5	42,4	205,3
	8 t of manure +	10,3	9,8	34,6	172,4

	$N_{38}P_{50}K_{50}$				
	12 t of manure $+N_{57}P_{75}K_{75}$	9,7	9,2	26,8	126,6
Combined	no fertilizers	7,5	7,1	29,5	129,8
	4 t of manure + $N_{19}P_{25}K_{25}$	7,5	7,2	22,3	121,7
	8 t of manure + $N_{38}P_{50}K_{50}$	6,8	6,4	18,4	92,1
	12 t of manure $+N_{57}P_{75}K_{75}$	6,5	6,1	13,8	75,0
Durable shallow	no fertilizers	7,8	7,9	28,3	120,3
	4 t of manure + $N_{19}P_{25}K_{25}$	7,6	7,7	26,6	115,2
	8 t of manure + $N_{38}P_{50}K_{50}$	7,5	7,5	22,8	102,8
	12 t of manure $+N_{57}P_{75}K_{75}$	7,4	7,2	20,7	98,3
MSD_{05} for A factor		0,4	0,4	0,4	5,6
MSD_{05} for B factor		0,4	0,4	0,4	5,6
MSD_{05} for AB factors interaction		0,6	0,6	0,6	11,2

In the control variant without fertilizers, their number amounted to 8.1 million pcs/ha, single fertilization level – 7,7 mln/ha, double layer – 7,5 mln/ha triple – 7.2 mln/ha. Under regular subsurface cultivation these figures exceeded 34,7-40,3%. Applying the combined tillage cultivation provided reduction in soil infestation with weed seeds under different fertilization levels of 0.6, 0.2, 0.4 and 0.7 million pcs/ha compared with a control variant. During soybean growing season weed seeds content in arable soil layer decreased and during the crops harvesting under subsurface systematic cultivation it made 10.8, 10.5, 9.8 and 9.2 million pcs/ ha.

Applying the combined cultivation system for corn grain caused decrease in soil infestation with weed seeds by planting time in the variant without fertilizer by 15.7%, on the single fertilization – by 11.8%, on the dual – by 10.8%, on the triple –one by 7 5% compared with the control (Table 4).

Table 4

Indicators of corn grain crops weed infestation under different cultivation systems and fertilization levels, average in 2007-2012

Soil cultivation system	Fertilizers level	Soil infestation with weeds seeds, mln pcs/ha		Weed infestation	
		Sowing	harvesting	Harvesting	
Regular surface (control)	no fertilizers			pcs/m^2	Crude mass, g/m^2
	4 t of manure + $N_{19}P_{25}K_{25}$	8,5	8,2	29,6	131,4
	8 t of manure + $N_{38}P_{50}K_{50}$	8,3	7,7	23,4	115,2
	12 t of manure $+N_{57}P_{75}K_{75}$	8,0	7,6	17,8	89,7
Regular subsurface	no fertilizers	12,5	12,0	57,6	232,7
	4 t of manure + $N_{19}P_{25}K_{25}$	12,1	11,7	46,7	201,4

	8 t of manure + $N_{38}P_{50}K_{50}$	11,6	11,3	35,6	175,3
	12 t of manure +$N_{57}P_{75}K_{75}$	11,0	10,6	24,8	126,8
Combined	no fertilizers	7,5	7,3	34,6	132,0
	4 t of manure + $N_{19}P_{25}K_{25}$	7,5	7,4	27,3	121,2
	8 t of manure + $N_{38}P_{50}K_{50}$	7,4	7,1	21,4	117,4
	12 t of manure +$N_{57}P_{75}K_{75}$	7,4	7,1	15,1	85,3
Durable shallow	no fertilizers	8,6	8,3	32,3	142,1
	4 t of manure + $N_{19}P_{25}K_{25}$	8,4	8,2	25,5	120,0
	8 t of manure + $N_{38}P_{50}K_{50}$	8,0	8,1	19,8	101,5
	12 t of manure +$N_{57}P_{75}K_{75}$	7,7	7,4	15,7	78,4
MSD_{05} for A factor		0,3	0,2	0,2	5,8
MSD_{05} for B factor		0,3	0,3	0,2	5,8
MSD_{05} for AB factors interaction		0,7	0,5	0,4	11,6

Indicators of the soil weed seeds infestation and weed-infested corn during a durable shallow cultivation remained at the level of the control variant.

During the growing season of barley seeds the soil weed infestation on all variants of tillage and fertilization levels decreased by 0.3-0.5 mln/ha (Table 5). By harvesting time the crop weediness under applying the combined durable cultivation and shallow tillage remained close to that of the control variant, and under the systematic subsurface tillage it was 19,7-32,4% higher.

Table 5

Barley crops weediness during the growing season under different soil tillage systems and fertilization levels, average for 2007-2012

Soil cultivation system	Fertilizers level	Soil infestation with weeds seeds, mln pcs/ha		Actual weed infestation	
		Sowing	harvesting	Harvesting	
				pcs /m^2	Crude mass, g/m^2
Regular surface (control)	no fertilizers	8,3	8,0	37,2	38,1
	4 t of manure + $N_{19}P_{25}K_{25}$	7,6	7,2	30,3	31,4
	8 t of manure + $N_{38}P_{50}K_{50}$	7,4	7,0	22,5	25,2
	12 t of manure +$N_{57}P_{75}K_{75}$	6,8	6,5	16,1	18,1
Regular subsurface	no fertilizers	10,4	10,0	49,8	53,2
	4 t of manure + $N_{19}P_{25}K_{25}$	9,1	9,6	39,6	43,7
	8 t of manure + $N_{38}P_{50}K_{50}$	9,5	9,1	31,4	35,6
	12 t of manure +$N_{57}P_{75}K_{75}$	9,0	8,7	22,2	25,8

Combined	no fertilizers	7,7	7,3	33,3	35,4
	4 t of manure + $N_{19}P_{25}K_{25}$	7,2	6,8	26,4	27,2
	8 t of manure + $N_{38}P_{50}K_{50}$	6,9	6,6	20,6	22,3
	12 t of manure +$N_{57}P_{75}K_{75}$	6,5	6,2	13,4	14,9
Durable shallow	no fertilizers	8,9	8,5	39,8	40,4
	4 t of manure + $N_{19}P_{25}K_{25}$	8,3	8,1	32,6	33,9
	8 t of manure + $N_{38}P_{50}K_{50}$	8,1	7,8	24,9	27,9
	12 t of manure +$N_{57}P_{75}K_{75}$	7,4	7,1	18,4	21,4
$НІР_{05}$ для фактора А		0,2	0,2	0,2	3,0,
$НІР_{05}$ для фактора В		0,2	0,2	0,2	3,0
$НІР_{05}$ для взаємодії факторів АВ		0,4	0,4	0,5	6,0

Higher crop weediness was noted under flat hoe tillage compared with surface cultivation system: by 30.5% on the peas field, by 42.5% on winter wheat, by 57.7% – on soybeans, by 53.7% on corn and by 74 2% on the barley field.

Contamination of soil on all the crops in crop rotation by the date of harvesting under systematic surface, durable combined and shallow tillage systems made 6,0-12,0 million pcs/ha. Crops weediness under the proper cultivation reached 8,7-49,8 pcs/m^2. These parameters increased under systematic subsurface cultivation.

We have not found significant effect of different tillage systems on change in crude weight of one segetal plants of the weeds. Thus, on the peas field the figure was 4,8-13,0 g, on winter wheat – 1,9-6,2 g, on soya – 75,0-223,7 g, on corn – 85,3-232,7 g, on barley – 14,9-40,4 g. Contamination of soil arable layer in April 2009, as compared with April 2005, decreased by 5.1% under the control cultivation, by 1.6% under flat hoe tillage, by 5.5% under combined one and 3.7% under durable shallow cultivation.

The amount of weeds in July 2012 compared with July 2007 was lower by 3.4, 13.5, 17.2 and 19.2% (Table 6).

Table 6

Change in soil weed-infestation and crops infestation under the influence of tillage and fertilization levels

Soil cultivation systems	Fertilizers level			
	no fertilizers	4 t of manure + $N_{19}P_{25}K_{25}$	8 t of manure + $N_{38}P_{50}K_{50}$	12 t of manure +$N_{57}P_{75}K_{75}$
Contamination of soil arable layer in April 2007, mln pcs/ha				
Regular surface (control)	8,4	7,7	7,6	7,2
Regular subsurface	10,6	10,1	9,7	9,0
Combined	8,3	7,5	7,3	7,0
Durable shallow	8,2	7,7	7,4	7,1
Contamination of soil arable layer in April 2012, mln pcs/ha				
Regular surface (control)	7,9	7,2	7,1	7,1

Regular subsurface	10,4	9,8	9,6	8,9
Combined	7,7	7,2	7,1	6,8
Durable shallow	7,8	7,3	6,9	6,9
Contamination of soil arable layer in July 2007, mln pcs/ha				
Regular surface (control)	34	27	22	16
Regular subsurface	47	41	31	21
Combined	32	25	20	14
Durable shallow	33	27	21	16
Contamination of soil arable layer in July 2012, mln pcs/ha				
Regular surface (control)	30	24	22	17
Regular subsurface	41	35	31	22
Combined	27	20	19	14
Durable shallow	29	22	21	17

Fertilizers provided suppression of weeds by accelerating the growth and development of crops in the crop rotation and thus increase in fertilization level caused decrease in the amount of weeds. Under the control cultivation system and triple fertilization level application on peas, winter wheat, soybeans, corn and barley the crops infestation be the period of harvesting decreased respectively by 57, 63, 52, 54 and 53% compared with zero fertilization.

A similar pattern was observed in other tillage systems in cultivated crop rotation.

In the phase of full ripeness of the weight of a segetal weed plant reduced with the increase in the fertilizers application level. Application of triple level of fertilization on peas, winter wheat, soybeans, corn and barley, compared with zero one, provided the reduction in weight per plant under the combined system of soil by 5, 18, 26, 48 and 6%.

Conclusions and recommendations for further research. Soil and crops weediness by the period of sowing and harvesting are the lowest under the combined cultivation and it is the highest under systematic subsurface cultivation. Under regular surface and durable shallow cultivation these figures are slightly higher compared with the combined one. Increase in fertilizers level provides decrease in soil and crops weediness significantly.

Thus, the results of our research have shown that substitution of regular surface cultivation system with regular systematic subsurface cultivation causes increase in weed-infested crops in crop rotation. Under the combined system of cultivation, this figure is lower compared with the control, and under durable shallow cultivation crop weediness was on the level of the control.

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