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Impact of mulch tillage and fertilization on growth and development of winter wheat plants in clean fallow in Northern Steppe of Ukraine

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In conditions of the northern steppe of Ukraine, while cultivating winter wheat after corn in clean fallow the expediency of shallow mulch tillage (disk, flat-cut (early fallow)) has been justified, which provides obtaining equivalent biometric indicators of plant growth and development, grain yield compared to the fall-plowing (the yield of grains for plowing is 5,24-5,50 t/ha, the disking is 5,17-5,60 t/ha, flat-topping loosening (early fallow) – 5,04-5,52 t/ha) on the organic and mineral background (stubble residues + $N_{30-60}P_{30}K_{30}$). The autumn disk and spring flat-cut cultivation of the fallow field on the background of applying $N_{30-60}P_{30}K_{30}$ ensure the annual yield of high quality grain of the 3d class (protein – 11,6-12,3%, gluten – 22,6-24,6%), and also contribute to fuel economy during soil cultivation – 22-29 l/ha and guarantee high profitability of grain production at the level of 110-123%).
Key words: winter wheat; clean fallow; tillage; stubble residues; plant growth and development; biometric indicators; fertilization; grain yield

Introduction

The priority of stable development of modern steppe agriculture against the background of changing climatic conditions, ecological and economic principles of management, biologization of farming, and the frequent placement of winter wheat after an atypical sunflower precursor due to the expansion of its planting acreage more than 5 million hectares, is the constant protection of soils from the constantly growing erosion processes, excessive man-caused load, deterioration of water regime and humus condition of chernozems. The above mentioned negative factors make it necessary to improve the system of basic soil cultivation under winter wheat in the direction of its minimization, taking into account soil and climatic conditions, the number of stubble residues left by the precursor, fertilizers, phytosanitary state of the crops (Cherenkov et al., 2007, 2008; Rybka et al., 2008; Kozechko, 2014).

Getting full-fledged shoots, optimal growth and development of winter wheat plants depends on a favorable combination of hydrothermal and soil conditions, individual reaction of the culture to environmental factors, as well as the proper condition of the sowing layer in the autumn. The best way to grow winter wheat is to use fertile loamy soils with a deep humus horizon, without excessive sealing, well-aerated, with high water absorbing capacity (Medvediev, Lyndina, 1999). As it is known, significant impact on the condition of the arable and sowing soil layer has the basic cultivation of soil, which is carried out by various types of implements, depending on the conditions of cultivation of the grain crop.

The opinions of various scientists regarding the impact of tillage methods on the growth, development and productivity of winter wheat plants are ambiguous and sometimes contradictory. Thus, according to many scientists (Demeshko, Cheriachukin, 1991; Desiatnyk, Krotinov, 1999; Maksimchuk et al., 1990), the highest yield is provided by a deep moldboard and moldboardless tillage, both of which they recommend to use for the producers of the Steppe. Investigations at Odessa Institute of Aviation have established that the use of moldboard and moldboardless soil cultivation at a depth of 25-27 cm does not have the advantages compared with the small basic work during the preparation of the fallow, because soft winter wheat forms approximately the same biometric indicators and crop yields with shallow and deep cultivation of fallow (Tsandur, 2006). The same opinion is hold by foreign scientists from various research institutions (Maliarchuk, 1992; Tararyko, 1990). And according to A.F. Wind and A.S. Izvekova, moldboardless flat-cut cultivation of soil contributed to the formation of even higher yields of winter wheat grains compared with the moldboard plowing (Viter, 1984; Izvekov, 1988).

In modern conditions, when growing winter wheat shallow mulch tillage is spreading that does not lead to the turning of the arable layer and leaves byproducts of the predecessor on the soil surface (Pabat, 2002; Horobets et al., 2008, 2011; Chumak et al., 2002; Tsyliuryk, 2014, 2017; Cociu, 2012; Jankowski et al., 2015; Norwood, 2000; Olofsson, 1993; Protopish, 2016; Qin et al., 2004; Racz et al., 2015; Shanahan et al., 1985; Sieling et al., 1999). Due to the small amount of information on the impact of shallow mulch cultivation on growth and development of winter wheat plants in the northern steppe, as well as the contradictory attitude of different researchers to one or another tillage, it is necessary to continue research in this direction in order to determine the optimal option of loosening arable land in the technology of growing crops, which provides maximum growth, development and yield of grain with a minimum amount of production costs and high profitability production.

The objective of the research is to determine the influence of different methods of basic soil cultivation and mineral fertilizers when leaving stubble residues of the precursor on the growth and development of winter wheat plants, its productivity and economic efficiency in conditions of the Northern Steppe of Ukraine.

Materials and methods

Experimental researches were carried out during 2011-2015 in the stationary field experiment of the State University Institute of agriculture of the steppe zone of the National Academy of Sciences of Ukraine (now State University Institute of grain crops of the National Academy of Sciences of Ukraine) in five-breed short-range crop rotation: clean fallow – winter wheat – sunflower – spring barley – corn with general-background leaving stubble residues of all field crops. The main soil cultivation under winter wheat in fallow was carried out with a moldboard plow ПО-3-35 at a depth of 25-27 cm (control), moldboardless (disk) soil tillage – with heavy disk harrows of BDV-3 (БДВ-3) on 10-12 cm and moldboardless (flat-cut) spring soil cultivation (early fallow) – with a combined aggregate of KSHN (КШН) – 5,6 "Resident" on 12-14 cm. A variety of winter wheat as Litanivka was sown. Seeds were necessarily cultivated with the herbicide esteron during the tillering phase (905 g/l 2-ethylhexyl ether + 600 g/l 2,4 – dichlorophenoxy octic acid) – 1.2 l/ha for the complete destruction of weeds. The scheme of the experiment also included three fertilizer backgrounds: 1) without fertilizers + stubble residues of the precursor; 2) $N_{30}P_{30}K_{30}$ + stubble residues of the precursor; 3) $N_{60}P_{30}K_{30}$ + stubble residues of the precursor. Mineral fertilizers were introduced in the spring in a scattering way under pre-sowing cultivation. Agrotechnics of growing winter wheat in the experiments is common for the Steppe zone. All experimental studies were conducted in accordance with conventional methods.

The soil of the research area is ordinary heavy loamy black earth with a content of humus in the layer 0-30 cm – 4.2%, nitric nitrogen – 13.2, mobile forms of phosphorus and potassium (according to Chirikov) respectively 145 and 115 mg/kg.

Unfavorable weather conditions for winter wheat cultivation were in 2012. The hydrothermal coefficient during the period of the largest water consumption of plants (May – the first half of June) was in years: 2011 – 0.8, 2012 – 0.6, 2013 – 0.7, 2014 – 0.9, and 2015 – 0.8. HTC index less than 0.7 indicates the presence of soil-air drought, which negatively affects the formation and grain filling.

Results and discussion

Table 1. Biometric indicators of winter wheat plants before entering the winter depending on tillage and fertilization on average for 2011-2015.

Tillage in fallow	Fertilization	Plant height, cm	Quantity, pc./plant			Depth of tillering zone, cm	Area of 1 plant leaves, cm^2	Weight of 100 completely dry plants, g
			[illegible]	[illegible]	[illegible]			
Moldboardless plowing at 25-27 cm	without fertilizers + stubble residues (control)	20.0	3.6	10.6	8.0	2.36	5.60	46.0
	$N_{30}P_{30}K_{30}$ + stubble residues	21.2	3.8	10.8	8.6	2.41	6.13	47.0
	$N_{60}P_{30}K_{30}$ + stubble residues	22.0	4.0	11.2	8.8	2.44	6.20	49.0
Moldboardless (disk) at 10-12 cm	without fertilizers + stubble residues (control)	18.0	3.5	10.4	7.9	2.32	5.52	45.4
	$N_{30}P_{30}K_{30}$ + stubble residues	19.0	3.8	10.8	8.6	2.40	6.16	47.3
	$N_{60}P_{30}K_{30}$ + післяжнивні рештки	20.0	4.1	11.4	8.9	2.48	6.31	49.9
Moldboardless (flat-cut) at 12-14 cm (early fallow)	without fertilizers + stubble residues (control)	17.1	3.5	10.2	7.7	2.26	5.38	44.2
	$N_{30}P_{30}K_{30}$ + stubble residues	18.5	3.7	10.5	8.4	2.34	5.96	45.7
	$N_{60}P_{30}K_{30}$ + stubble residues	19.9	4.0	11.2	8.8	2.44	6.22	49.2

Growth and development of winter wheat plants differed significantly in the years of the research and much depended, first of all, on weather conditions (temperature regime, moisture provision).

It should be specially mentioned about anomalously arid year of 2012, when the slow growth and development of winter wheat plants was noted. In addition to weather conditions, biometric indicators also significantly depended on the dose of mineral fertilizers, the development of the root system, output moisture reserves, agrophysical soil parameters, which are closely related to the methods of basic tillage.

The phase of complete plant emergence on average for five years of research in the areas of moldboard plowing was observed on the 6th day, and in the areas where sowing was carried out on shallow mulch tillage (disk, flat-cut) 2 days later, or on the 8th day, the phase of tillering winter wheat plants began on the 26th and 27th day after emergence.

Data analysis of biometric parameters (height, number of vegetative organs, tillering node depth, leaf area, weight of 100 absolutely dry plants) showed a lag in the growth and development of plants for the moldboardless disk, and especially spring, flat-cut soil cultivation for all biometric indicators in unfertilized plots. The introduction of mineral fertilizers in moderate doses ($N_{30-60}P_{30}K_{30}$) slightly leveled this difference (Table 1). Thus, for example, the difference in height of winter wheat plants before entering the winter in unfertilized variants was 2.0 and 2.9 cm (10.0%, 14.5%), respectively, lower in moldboardless backgrounds than in control (plowing). And when applying fertilizers ($N_{60}P_{30}K_{30}$), the difference was slightly lower for comparatively higher plant height indicators, and was 2.0 and 2.1 cm, or 9.0 and 9.5%, respectively.

It should be noted that in general during the autumn period of vegetation there was a slight lag in the growth and development of winter wheat plants on moldboardless backgrounds compared to moldboard plowing. In our opinion, this is due to the later emergence of shoots on options of disking and spring flat-cut loosening and is caused by poorer moisture and physical condition of the soil.

In general, wheat plants were in good physiological state for the time of autumn vegetation completion, regardless of soil cultivation. They have accumulated enough amount of sugar for winter breeding. both in leaves (24.62-24.70%) and in tillering nodes (31.97-32.98%).

Moderately warm winters during the years of research contributed to a good overwintering of winter wheat. The general physiological state of plants and shoots at the time of renewal of the spring vegetation was assessed as good, which was confirmed by the results of growing winter crops in a monolith.

The phase of plant output into the tube in all variants of the experiment passed almost simultaneously and was noted during the years of research on May 5-15. From this time, the gradual leveling of the difference in the initial individual plant development for all variants of the experiment began. That is, during this period there is alignment of plants according to the habitus is observed in the variants of various methods of basic tillage.

Table 2. The main elements of the yield structure of winter wheat plants depending on the main tillage and fertilization on average for 2011-2015.

Tillage in the fallow	Fertilization	Plant height, cm	Number of productive stems, pcs/m^2	The coefficient of productive tillering	Length of ear, cm	Number of grains from the ear, pc.	Grain weigh from the ear, g	Weight of 1000 grains, g
moldboard plowing at 25-27 cm	without fertilizers + stubble residues (control)	92.4	410.5	1.4	7.1	29.2	1.06	37.1
	$N_{30}P_{30}K_{30}$ + stubble residues	93.3	480.3	1.6	7.1	29.3	1.17	39.9
	$N_{60}P_{30}K_{30}$ + stubble residues	95.5	518.9	1.7	7.2	31.8	1.33	41.8
Moldboardless (disk) at 10-12 cm	Without fertilizers + stubble residues (control)	82.3	405.0	1.3	7.1	28.9	1.04	36.6
	$N_{30}P_{30}K_{30}$ + stubble residues	84.0	482.9	1.6	7.1	29.4	1.17	40.1
	$N_{60}P_{30}K_{30}$ + stubble residues	86.2	528.3	1.8	7.2	32.3	1.35	42.5
Moldboardless (flat-cut) at 12-14 cm (early fallow)	without fertilizers + stubble residues (control)	80.6	394.8	1.3	7.0	28.2	1.01	35.6
	$N_{30}P_{30}K_{30}$ + stubble residues	83.3	467.2	1.4	7.1	28.5	1.14	38.8
	$N_{60}P_{30}K_{30}$ + stubble residues	85.2	520.8	1.6	7.1	31.9	1.33	41.9

The analysis of the structural elements of winter wheat plant productivity, which were determined by sampling the test sheaths in the pre-harvest period, showed that the introduction of moderate doses of mineral fertilizers contributed to an increase in the indicators of the main elements of the yield structure (Table 2). In particular. using the variant of fertilizers with a dose of $N_{60}P_{30}K_{30}$. the number of productive stems on plowing grew by 20.9%. disking – 23.3%. flat-cut loosening – 24.2%. The number of grains from the ear increased by 8,1%; 10,5%; 11,6%. The weight of the ear grain was increased by 20.3%; 22.9%; 24.0%. and the weight of 1000 grains. respectively. was 11.2%; 13.8%; 15.0%. As we can see from the given data, the use of mineral fertilizers on more rigid, moldboardless backgrounds is more efficient and provides the maximum growth of the main elements of the yield structure of the crop compared with the moldboard plowing.

As for the tillage methods, these indicators were practically identical except for spring flat-cut cultivation, where there was a tendency to decrease the main elements of the yield structure compared with the moldboard plowing and disking.

Precipitation in the pre-sowing period, moderately warm winters, almost complete restoration of productive moisture reserves for the time of spring tillering of plants and abundant rains that coincided with the critical period of water consumption of winter wheat, created good preconditions for obtaining high grain yields in 2013, 2014 and 2015 (6.05-6.95. 5.83-7.19 and 5.67-6.93 tons/ha. respectively). Less favorable meteorological situation was in 2011. when the productivity of winter crops ranged within 4.85-5.59 t/ha (Table 3).

A characteristic feature of the spring-summer vegetation of winter wheat in 2012 was extremely dry weather in the third decade of April. the first and second decades of May. when the deviation of air temperature from the average long-term values reached 6.7-7.9 ºC. and its relative humidity in certain hours decreased to 18-21%. June and July were anomalously hot. These phenomena had a negative impact on pollination and fertilization of plants. the formation of reproductive organs. and therefore the grain yield was the lowest for all years of research (2.22-2.69 t/ha).

Differences in hydrothermal conditions, fertility factors, as well as phytosanitary state of crops ultimately determined the level of wheat yield in the areas with different soil treatments and fertilizers.

According to the research results, the average yield of winter wheat in clean fallow after corn depending on the feed background in the variant with plowing was 5.24-5.50 t/ha. disking – 5.17-5.60. the flat-cut loosening of arable land - 5.04- 5.52 t/ha. It should be noted that the decline in plant productivity in the moldboard cultivation (compared to disk and flat-cut) in 2013 and 2014, which is primarily due to the state of crops in the phase of diary and wax ripeness of grain.

Therefore, under certain conditions in relatively favorable years for wintering, in the background of moldboard plowing in clean fallow the dose of nitrogen fertilizers in spring feed should be minimal, taking into account possible losses of the main products.

Table 3. Yield of winter wheat in clean fallow, t/ha

Tillage in the fallow	Fertilization	Years					Average
		2011	2012	2013	2014	2015	
Moldboard plowing at 25-27 cm	without fertilizers	5.48	2.52	6.05	5.83	6.32	5.24
	$N_{30}P_{30}K_{30}$	5.57	2.60	6.22	6.49	6.72	5.52
	$N_{60}P_{30}K_{30}$	5.59	2.69	6.31	6.00	6.93	5.50
Moldboardless (disk) at 10-12 cm	without fertilizers	5.28	2.43	6.20	6.23	5.73	5.17
	$N_{30}P_{30}K_{30}$	5.43	2.54	6.79	6.71	6.29	5.55
	$N_{60}P_{30}K_{30}$	5.48	2.64	6.95	6.38	6.55	5.60
Moldboardless (flat-cut) at 12-14 cm (early fallow)	without fertilizers	4.85	2.22	6.08	6.40	5.67	5.04
	$N_{30}P_{30}K_{30}$	4.97	2.34	6.41	7.19	5.95	5.37
	$N_{60}P_{30}K_{30}$	5.34	2.43	6.77	6.55	6.51	5.52
$HIP_{0.95}$	For tillage	0.32	0.11	0.23	0.22	0.22	-
	for fertilizers	0.32	0.10	0.20	0.23	0.23	-
	for interaction	0.46	0.19	0.40	0.38	0.39	

It should be emphasized that the noted tendency is not constant in time. For example, in 2015, due to relatively high crop productivity, the plant layout was not observed in the experiment. In other words, the decisive role in the development of this phenomenon is evidently played by the degree, nature and combination of factors directly related to the processes of plant nutrition, the pace of accumulation of vegetative weight and the formation of straw with different morphobiological, physical and chemical properties (thickness and fragility of the stem, internode length, the ratio of macro- and trace elements to by-products, etc.). The emergence of crops in the Steppe is also promoted by abnormal weather phenomena, in particular, powerful storms, intense showers, grabbing.

In 2011, 2012, and 2015, by the grain yield mulch tillage a plow on the seed, due, probably, to somewhat worse phytosanitary state of agrocenosis, inhibition of microbiological processes in the presence of a large number of post-dormancy residues in the upper layer of soil and others not fully understood factors of different nature.

On average, during the research period. deep moldboard tillage of black fallow did not have advantages over the small disk treatment. in contrast to the spring flat-cut soil loosening. where lower values within certain fertilizer options (without tufts. $N_{30}P_{30}K_{30}$). were obtained. At the same time. the application of N_{60} in spring. in combination with $P_{30}K_{30}$ under pre-sowing cultivation. provided grain yield at the control level (plowing – 5.50. early steam – 5.52 t/ha).

In moldboard soil cultivation. the application of $N_{30}P_{30}K_{30}$ contributed to an extra grain of 0.28 t/ha. disk – 0.38. flat-cut – 0.33 t/ha. and $N_{60}P_{30}K_{30}$ – 0.26; 0.43 and 0.48 t/ha. respectively. The low growth of grain yield from mineral fertilizers. in particular nitrogen. in 2011 and 2012 is due to the lack of rainfall during the formation of reproductive organs in plants.

It has been established that the best conditions for obtaining high-protein winter wheat grain took place in 2011 and 2014, when the spring-summer vegetation of plants was followed by sufficient sources of productive moisture in a layer of 0-150 cm, warm and moderately humid weather in the period from the beginning of the infusion to the end of the wax ripeness of the grain. Improvement of the quality parameters of the main products in arid 2012 is explained by the formation of small grains, that is, the proportion of proteins in relation to carbohydrates (starch) increased proportionally with lower natural weight.

As is known, winter wheat with a higher yield usually produces less qualitative grain, mainly due to the dominance of the processes of growth dilution of nitrogen-containing compounds. However, in our studies, this pattern was not constant over the years due to the high potential and effective fertility of agricultural background.

During the experiment. the deep plowing of black fallow on all agricultural backgrounds provided food grains with a protein content of 11.6-12.4%. and gluten 23.3-26.2% (average for 2011-2015). Autumn disk and spring flat-cut cultivations of the steam field caused the annual receipt of 3d class grain only when $N_{60}P_{30}K_{30}$ was added (protein – 11.6-12.3%. gluten – 22.6-24.6%). In this case, the fertilization of winter wheat with ammonium nitrate at the rate of N_{60} should be a mandatory agricultural measure, which reduces the probability of fixing nitrogen compounds with the microbial complex and creates the proper conditions for the intense flow of nitrification processes.

According to the averaged indicators when engaging in the cycle of by-products crop rotation, the introduction of $N_{30}P_{30}K_{30}$ under winter wheat, placed in clean fallow. contributed (compared to unfertilized background) to an increase in the protein content in the grains by 0.6-1.0%. gluten – by 1.9 -2.6%. and $N_{60}P_{30}K_{30}$ – by 0.8-1.4% and 2.0-3.0% respectively.

As noted above, the cultivation of winter wheat in fertilized areas (stubble residues + $N_{60}P_{30}K_{30}$) according to the technology of shallow mulch soil cultivation on average over the years of research did not lead to a decrease in crop yields compared to deep autumn plowing. At the same time, the use of less energy-intensive and more productive equipment during the preparation of the fallow in the autumn period against the background of disking and flat-cut soil loosening in the spring contributed to a reduction in production costs in relation to control at 664-1343 UAH/ha. Thus, fuel economy (22-29 l/ha) and high profitability of production (110-123%) were obtained.

Conclusions

The application of moldboardless disking, especially spring flat-cut soil treatment in the technology of growing winter wheat in unfertilized areas helps to reduce biometric indicators to 10.0-14.5% and lag in the growth and development of plants, but the application of mineral fertilizers in moderate doses ($N_{30\text{-}60}P_{30}K_{30}$) neutralizes this difference and promotes further growth of structural elements of plant productivity (the number of productive stems to 23.3-24.2%, the number of grains from the ear to 10.5% - 11.6%, the weight of grain from the ear to 22.9-24.0%, the weight of 1000 grains to 13,8% -15,0%), especially on plots of disk plowing since autumn.

Considering the level of grain yield of winter wheat small mulch tillage soil in fallow (disk, flat-cut (early fallow)) is not inferior to deep moldboard autumn plowing and contributes to significant fuel economy (22-29 l/ha) and high profitability of production (110-123%).

The use of stubble residues of the precursor as a fertilizer against the background of the introduction of mineral fertilizers in a dose of $N_{30}P_{30}K_{30}$ under winter wheat contributes compared with the unfertilized background to an increase in protein content in the grain of 0.6-1.0%, gluten – of 1.9-2.6%, and for using $N_{60}P_{30}K_{30}$ – of 0.8-1.4, and 2.0-3.0%, respectively.

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