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WINTER WHEAT PRODUCTIVITY DEPENDING ON THE PRIMARY TILLAGE SYSTEMS AGAINST THE BACKGROUND OF SHORT-TERM CROP ROTATIONS IN THE SOUTH OF UKRAINE

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Topicality. *In the current agricultural environment, there is a trend towards simplification of tillage, wrong crop rotation sequences, narrowing of specialisation of most agricultural enterprises, and therefore the role of the predecessor and tillage systems as one of the least costly ways to optimise winter crop cultivation will only increase. For this reason, the development and research of various schemes of primary tillage on the background of short-term crop rotation will continue to be a topical issue and will always be subject to scientific and practical interest.* ***Purpose.*** *Our research aimed to development of environmental friendly technologies for competitive production of high-quality crop production in the Black Sea Steppe of Ukraine.* ***Methods.*** *The field method was the main method, which was supplemented by analytical studies, measurements, calculations and observations in accordance with generally accepted methods and guidelines in agriculture and crop production. In the experiment, the systems of crop rotations and primary tillage were studied.* ***Results.*** *The influence of different systems of primary tillage on the winter wheat yield in short-term crop rotation was studied. It was found that in the conditions of the Southern Steppe of Ukraine, the moldboardless tillage created the best conditions for the formation of winter wheat yield in the 1st, 2nd and 4th crops. The highest yields were in all experimental variants after such predecessors as black fallow and green manure fallow with winter vetch.* ***Conclusions.*** *For all experimental variants, the best results in terms of yield were observed after black fallow and green manure fallow with winter vetch in the 1st and 4th crops. In the 2nd crop, green manure fallow with winter vetch had an advantage of 4.9 % compared to black fallow. In winter wheat, a positive effect on the formation of yields was manifested by moldboardless tillage*.

Key words: *crop rotation, predecessors, primary tillage system, yield, winter wheat*

Introduction. In agriculture, in recent decades, a new direction of improving crop cultivation technologies in agriculture and crop production has been formed by introducing innovative elements that consist of the development, implementation and application of resource-saving technologies, chemicals of biological origin.

For the rational utilisation of material and energy resources of agricultural production, it is necessary to adapt crop cultivation technologies to the agrometeorological conditions in Ukraine.

For high and sustainable yields of winter cereals with high grain quality in Southern Ukraine, improved agricultural production technologies, optimisation of crop rotations and tillage systems are required.

Significant changes in market conditions led to a shift in the ratio of crop and livestock production, and a change in the structure of sown areas, which caused a reduction in the area under peas and perennial legumes, which are the best predecessors for winter wheat [1].

In present agricultural conditions, there is a trend towards simplification of tillage, disruption of crop rotations, a narrower specialisation of most agricultural enterprises, and the role of the predecessor as one of the least costly ways to optimise winter crops will only grow [2]. Therefore, the development and research of various schemes of primary tillage on the background of short-term crop rotation will continue to be relevant issues and will always have scientific and practical interest.

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Management of the moisture regime of the soil, the introduction of scientifically grounded crop rotations, proper tillage, rational fertiliser rates and timely liming provide favourable conditions for sustainable winter wheat yields.

Data obtained by our station coincide with the results of studies by other institutions [3] in the fact that black fallow is recognised as the best predecessor of winter wheat. So, we obtained grain yield of 100 % on fallow land, while after the following predecessors: vetch-oat mixture – 95 %, grain legumes – 90 %, rape – 82 %, resown wheat – 76 %.

In the context of a market economy, the violation of traditional crop rotations has required to study different methods and techniques of tillage of southern chernozem in The Odesa State Agricultural Experimental Station of the Institute of Climate-Smart Agriculture of NAAS proposes to introduce green manure fallow alongside with black fallow [4, 5]. This is one of the reserves of adaptation to drought, as green manure fallows provide yields at the level of black manure or even higher, and they also increase soil fertility, i.e. increase the reserves of humus and nutrients.

Materials and Methods. The research was carried out over 2021–2022 in the fields of the Odesa State Agricultural Experimental Station of the Institute of Climate-Smart Agriculture of NAAS. A field method was the main method, which was supplemented by analytical studies, measurements, calculations and observations in accordance with generally accepted methodologies and recommendations in agriculture and crop production.

The experiment studied the system of crop rotation (Table 1) and the system of primary tillage (Table 2).

The total area of one field was 3.6 hectares and the area of field trial is 18 hectares. Plot area both for tillage and for predecessors was 2025 m^2. Experiment was replicated 4 times. Variants were arranged using the split-plot method.

Table 1. Crop rotation schemes

Field No.	Crop Rotation No.		
	1	2	3
5	Black fallow	Green manure fallow (winter vetch)	Peas + white mustard for green manure
4	Winter wheat	Winter wheat	Winter wheat
3	Winter wheat	Winter wheat	Winter wheat
2	Oats	Oats	Oats
1	Winter wheat	Winter wheat	Winter wheat

Plots with tillage variants are placed in the north-south direction, plots with variants of predecessors – in the east-west direction.

The experiment was carried out in four crop rotations, which differed only in the first field, i.e. the first crop rotation started with black fallow, the second – with green manure fallow with vetch, the third – with a mixture of pea + white mustard for green manure and the fourth – with peas for grain. The last fields in all crop rotations were planted with the same crops. This was aimed to determine the aftereffects of fallow and non-fallow predecessors. Winter wheat, which was the first crop after fallow and peas, was sown in the second year, and the second wheat crop on the same field was sown in the third, fourth, and fifth years. Oats were sown as a phytosanitary crop and were the third crop in the experiment.

The mass of green manure crops was chopped and partially mixed with the soil with a heavy disc harrow. To determine the effect of fallow and non-fallow predecessors on wheat yields, it was decided to sow wheat again after oats (at the end of the crop rotation). Crop rotations were overlaid on four systems of primary tillage (moldboard – MSSMS, moldboardless – DSSDS, surface – SSSSS, differentiated – SSSMS). The tillage system was as follows: in the first variant, ploughing was carried out to a depth of 22–24 cm with PLN-5-35 ploughs (differentiated tillage -1); in the second variant, combined (differentiated tillage -2) ploughing was used, i.e. alternating between moldboard and surface tillage; in the third variant, deep moldboardless tillage (moldboardless multidepth tillage) was used to a depth of 22–24 cm

Table 2. Scheme of the primary tillage system in crop rotation

Abbreviations for the primary tillage system*	No. of crop rotation field, crop and fallow			
	5	4	3	2
	Black fallow, Green manure fallow	Winter wheat	Winter wheat	Oats
MSSMS (first variant)	moldboard, deep 22–24 cm (M)	surface, moldboardless, 8–10 cm (S)	surface, moldboardless, 8–10 cm (S)	moldboard deep, 22–24 cm (M)
SSSMS (second variant)	surface, moldboardless, 8–10 cm (S)	surface, moldboardless, 8–10 cm (S)	surface, moldboardless, 8–10 cm (S)	moldboard, deep, 22–24 cm (M)
DSSDS (third variant)	moldboardless, deep, 22–24 cm (D)	surface, moldboardless, 8–10 cm (S)	surface, moldboardless, 8–10 cm (S)	moldboardless, deep, 22–24 cm (D)
SSSSS (fourth variant)	surface, moldboardless, 8–10 cm (S)	surface, moldboardless, 8–10 cm (S)	surface, moldboardless, 8–10 cm (S)	surface, moldboardless, 8–10 cm (S)

Note: M – moldboard deep tillage (22–24 cm), S – surface moldboardless tillage (8–10 cm), D – deep moldboardless tillage (22–24 cm).*

with a PRN 5–35 plough (analogue of the paraplough), in the fourth variant, surface tillage (surface multidepth tillage) was carried out to a depth of 8–10 cm with use of heavy disk harrow BDT-7 type and cultivator KRU-3.

Harvesting was carried out using the direct method with a Sampo-500 combine harvester. The bunker weight of grain obtained during the harvest was recalculated for 14 % moisture and 100 % purity [6].

Results and Discussion. The results of the two years research allow us to conclude that black fallow and green manure fallow with winter vetch create the most favourable conditions for the winter wheat growth and development and formation of its yield (Table 3).

Table 3. Yield of winter wheat grain of Knopa variety depending on the aftereffect of predecessors and primary tillage systems, t/ha, (average for 2021–2022) (the first crop after fallow and peas)

Primary tillage system (A)*	Predecessor (B)				Average, t/ha
	black fallow	green manure fallow		peas for grain	
		winter vetch	peas + mustard		
MSSMS	4.05	4.10	3.92	3.35	3.86
SSSMS	3.55	3.69	3.22	2.84	3.33
DSSDS	4.39	4.56	4.21	3.93	4.27
SSSSS	3.78	3.82	3.51	3.21	3.58
Average	3.94	4.04	3.72	3.38	3.77
% to black fallow	100	102.5	94.4	85.8	-
LSD_{05} t/ha: A = 0.12; B = 0.12; AB = 0.24					

Note: M – moldboard deep tillage (22–24 cm), S – surface moldboardless tillage (8–10 cm), D – deep moldboardless tillage (22–24 cm).*

These variants produced almost the same grain yield, which averaged 3.94 and 4.04 t/ha over the two years, respectively. The difference between the yields has not been mathematically proven, i.e. it is insignificant. However, after green manure fallow with winter vetch, there is a tendency to increase grain yield. The advantage of green manure fallow was 2.5 % compared to black fallow. After the pea for grain, yield decreased by 14.2 % compared to the black fallow. Its yield was the lowest in the experiment – 3.38 t/ha.

The moldboardless tillage system (DSSDS) created the best conditions for the formation of winter wheat grain yields (3.77 t/ha), which is 10.6 % more than under moldboard tillage (MSSMS). The lowest grain yield was obtained after differentiated tillage (SSSMS). Under this tillage scheme, the yield of winter wheat was 3.33 t/ha, i.e. 13.7 % less than under the moldboard tillage.

In the second crop, the grain yield was 3.25 t/ha, which is 13.8 % less than in the first crop (Table 4). The yield after all the predecessors was lower than in the first crop.

The aftereffect of the predecessors on the second crop after fallow and peas for grain was almost identical against the background of green manure (winter vetch) and black fallow. Yields after black fallow and green manure fallow with winter vetch were almost at the same level and amounted to 3.94 and 3.04 t/ha. The difference in yield after the mixture of peas and mustard was 5.6 % compared to black fallow. At the same time, after peas for grain, there was a significant decrease in grain yield by 14.2 % compared to black fallow.

Table 4. Yield of winter wheat grain of Knopa variety against the background of different predecessors and primary tillage systems, (average 2021–2022) (2nd crop after fallow and peas)

Primary tillage system (A)*	Predecessor (B)				Average, t/ha
	black fallow	green manure fallow		peas for grain	
		winter vetch	peas + mustard		
MSSMS	3.35	3.34	3.20	2.93	3.21
SSSMS	3.02	3.07	3.04	2.69	2.96
DSSDS	3.57	3.91	3.49	3.27	3.56
SSSSS	3.17	3.43	3.31	3.09	3.25
Average	3.28	3.44	3.26	3.00	3.25
% to black fallow	100	104.9	99.4	92.3	-
LSD_{05} t/ha: A = 0.13; B = 0.13; AB = 0.26					

Note: M – moldboard deep tillage (22–24 cm), S – surface moldboardless tillage (8–10 cm), D – deep moldboardless tillage (22–24 cm).*

Analysis of the aftereffects of primary tillage reveals the same pattern as in the first crop. The moldboardless system of primary tillage (DSSDS) again created the best conditions for the formation of winter wheat grain yield, which averaged 4.27 t/ha over 2 years, which is 10.6 % more than under moldboard tillage (MSSMS). The variant with differential tillage (SSSMS) had the worst yields. Under this tillage scheme, the yield of winter wheat was 3.33 t/ha, which is 13.7 % lower than under the moldboard tillage. Under surface tillage, the yield indicators decreased by 7.3 % compared to the moldboard tillage.

In the fourth crop, the same pattern was observed in terms of predecessors as in the first and second crops. The highest yields were also obtained after green manure fallow with winter vetch, which was 2.55 t/ha. In the variants with the predecessor – black fallow, the yield decreased by 4.1 %. However, the difference between them was not significant.

The lowest winter wheat yield was obtained after peas for grain, which was 2.13 t/ha.

The primary tillage for the fourth crop after fallow and peas (winter wheat) was the same – surface tillage (disking and pre-sowing cultivation). In all variants, the grain yield was obtained on average at the level of 72.9 % of the first crop (Table 5).

Mathematically, it was proved that the most effective way of tillage was the moldboard tillage with the highest yield (2.65 t/ha) compared to other tillage schemes. Moldboardless tillage in the crop rotation did not decrease the yield, and on the contrary, the yield (2.57 t/ha) was higher than under the surface (2.20 t/ha) and differentiated (2.05 t/ha) tillage schemes.

The summary data for different predecessors show (Table 6) that the average yield in rotation after green manure fallow with winter vetch was the highest (3.34 t/ha).

In the variant with the predecessor (black fallow), this indicator decreased by 3.7 % compared to green manure fallow (winter vetch).

Table 5. Winter wheat grain yield of Knopa variety against the background of different predecessors and primary tillage systems, (average 2021–2022) (4th crop after fallow and peas)

Primary tillage system (A)*	Predecessor (B)				Average, t/ha
	black fallow	green manure fallow		peas for grain	
		winter vetch	peas + mustard		
MSSMS	2.76	2.83	2.69	2.31	2.65
SSSMS	2.10	2.19	2.01	1.89	2.05
DSSDS	2.62	2.81	2.54	2.30	2.57
SSSSS	2.30	2.36	2.14	2.00	2.20
Average	2.45	2.55	2.35	2.13	2.37
% to black fallow	100	104.1	95.9	86.9	-
LSD_{05} t/ha: A= 0.13 ; B= 0.13 ; AB= 0.26					

Note: M – moldboard deep tillage (22–24 cm), S – surface moldboardless tillage (8–10 cm), D – deep moldboardless tillage (22–24 cm).*

The variant with green manure fallow (mixture of peas with white mustard) was 3.4 % behind the black fallow and 12.4 % behind the variant with the predecessor – peas for grain.

The data presented in Table 6 convincingly prove that good conditions for the formation of winter wheat yields in the first crop are created when placed after black and green manure fallow with winter vetch, as evidenced by their average yields of 3.94 and 4.04 t/ha.

Table 6. Harvesting winter wheat grain in crop rotation against the background of different systems of primary tillage and predecessors, t/ha

Primary tillage system (A)*	Crop after fallow	Predecessor (B)				Average for factor A, t/ha
		black fallow	green manure fallow		peas for grain	
			Winter vetch	peas + mustard		
MSSMS	1	4.05	4.10	3.92	3.35	3.86
	2	3.35	3.34	3.20	2.93	3.21
	4	2.76	2.83	2.69	2.31	2.65
Average		**3.39**	**3.42**	**3.27**	**2.86**	**3.24**
SSSMS	1	3.55	3.69	3.22	2.84	3.33
	2	3.02	3.07	3.04	2.69	2.96
	4	2.10	2.19	2.01	1.89	2.05
Average		**2.89**	**2.98**	**2.76**	**2.47**	**2.78**
DSSDS	1	4.39	4.56	4.21	3.93	4.27
	2	3.57	3.91	3.49	3.27	3.56
	4	2.62	2.81	2.54	2.30	2.57
Average		**3.53**	**3.76**	**3.41**	**3.17**	**3.47**
SSSSS	1	3.78	3.82	3.51	3.21	3.58
	2	3.17	3.43	3.31	3.09	3.25
	4	2.30	2.36	2.14	2.00	2.20
Average		**3.08**	**3.20**	**2.99**	**2.77**	**3.01**
Average for factor B	t/ha	3.22	3.34	3.11	2.82	3.13
	%	100	103.7	96.6	87.6	-

Note: M – moldboard deep tillage (22–24 cm), S – surface moldboardless tillage (8–10 cm), D – deep moldboardless tillage (22–24 cm).*

The second and fourth crops had lower yields in all variants of the experiment compared to the first crop.

The most effective tillage for the first, second and fourth crops was the DSSDS (moldboardless) tillage. In this variant, the highest yield was obtained compared to the others.

Conclusions. The data of the research results can be summarised as follows: for all variants of the experiment, the best yield results were observed after black fallow and green manure fallow with winter vetch in the first and fourth crops. In these variants, the difference is not mathematically proven. In the second culture, the advantage was observed for green manure with winter vetch, which was 4.9 % compared to black fallow.

It should be noted that in the first and fourth crops, there was a tendency to increase yields after green manure fallow with winter vetch.

The increase was 2.5 and 4.1 %, respectively, compared to the black fallow as a predecessor. On all winter wheat crops, a positive effect on yield formation was manifested in moldboardless tillage.

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Сергєєв Л. А. , Когут І. М. , Мельник О. Т., Почколіна С. В. Продуктивність пшениці озимої залежно від систем основного обробітку ґрунту на тлі короткоротаційних сівозмін в умовах Півдня України. *Зернові культури. 2023. 7 (1). 173–178.*

Одеська державна с.-г. дослідна станція Інституту кліматично орієнтованого сільського господарства НААН, вул. Маяцька дор., 24, смт Хлібодарське, Одеський район, Одеська область, 67667, Україна

Актуальність. В сучасних умовах ведення сільського господарства спостерігається тенденція до спрощення обробітку ґрунту, порушення сівозмін, звуження спеціалізації більшості аграрних підприємств і роль попередника і систем обробітку ґрунту, як одних з найменш затратних способів у оптимізації вирощування озимини, буде тільки зростати. Тому, розробка і дослідження різних схем основного обробітку ґрунту на тлі короткоротаційної сівозміни й надалі залишатимуться актуальними питаннями і завжди будуть мати науковий та практичний інтерес. **Мета.** Розробка екологічно-безпечних технологій конкурентоспроможного виробництва високоякісної продукції рослинництва в Причорноморському Степу. **Матеріали і методи.** Основний метод – польовий, який доповнювався аналітичними дослідженнями, вимірами, підрахунками і спостереженнями відповідно до загальноприйнятих методик та методичних рекомендацій у землеробстві і рослинництві. У досліді вивчалися система сівозмін і система основного обробітку ґрунту. **Результати.** Досліджено вплив різних систем основного обробітку ґрунту на урожайність пшениці озимої у короткоротаційній сівозміні. Встановлено, що в умовах південного Степу України безполицева система основного обробітку ґрунту створила найкращі умови для формування урожаю пшениці озимої у 1-й, 2-й та 4-й культурах. Найвищу урожайність отримали на всіх варіантах досліду після попередників: чорного пару і пару сидерального з викою озимою. **Висновки.** За всіма варіантами досліду найкращі результати за урожайністю спостерігалися після чорного пару і сидерального з викою озимою в 1-й і 4-й культурах. У 2-й культурі перевага була за сидеральним паром з викою озимою, і становила 4,9 % порівняно з чорним паром. На пшениці озимій позитивний вплив на формування урожайності проявився за безполицевого обробітку.

Ключові слова: *сівозміна, попередники, системи основного обробітку ґрунту, урожайність, пшениця озима*