Influence of treatments on the productivity of grain crops in the conditions of the Lower Volga region

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Abstract
The research was carried out in the fields of the Lower Volga Research Institute of Agricultural Sciences. Work was carried out in 2017-2020. The soil of the experimental site is light chestnut, heavy loam, with a humus content in the arable layer of 1.74 %. The average annual precipitation was 339.7 mm. The technology of cultivation of these crops was generally accepted for the research area. The placement of options (A) is sequential and options (B) are arranged in blocks in three tiers. The following types of basic soil treatments were studied in the experiment: moldboard, moldless, surface, as well as a system of crop rotations, which includes: grain-steam (4x-full sowing with the SZ – 3.6 seeder)-control and grain-steam (4x-field similar to the control with the rejection of the main treatments for spring crops, sowing with the Omichka SZS-2.1 seeder). Records and observations were carried out according to the recommendations. The largest reserves of productive moisture in the meter layer of the soil in winter wheat for the spring vegetation period were on the moldless and moldboard variants when sowing with the SZS-2.1 seeder and amounted to 73.2 and 69.5 mm. By the time of sowing of spring wheat with a higher content of productive moisture reserves, stubble variants showed, where moisture reserves varied from 101.2 mm on a surface background to 133.8 mm on a variant with a moldboard-free background. In the variants with sowing with the SZS-2.1 seeder, winter wheat had a denser stalk and amounted to 356 units/m^2 for moldboard processing, 388 units/m^2 for non-moldboard processing and 334 units/m^2 for surface processing, which ultimately had a positive effect on the yield of winter wheat. In spring wheat and spring barley, the difference in the results of the stalks was small for the variants, it differed in the number of productive stalks in favor of the main treatments for crops and averaged 297 pcs/m^2 for spring wheat at SZ-3.6 versus 245 pcs/m^2 at SZS-2.1, for barley 332 pcs/m^2 and 268 pcs/m^2, respectively. On average, over four years, the level of profitability in a 4-field crop rotation without processing for spring crops had a profitability higher by 28.8-31.5% depending on the background and amounted to 72.7% for moldboard, 96.4% for moldless and 54.1% - surface treatment.

Key words: productive moisture; tillage; grain crops; grain productivity; economic efficiency

INTRODUCTION

Modern agricultural production in the region, under the influence of repeated tillage, is characterized by a powerful technogenic effect on the soil and plants, increased erosion processes, decreased soil fertility and, as a consequence, a drop in yield and grain quality (Azizov, 2004; Dorozhko, 2017; Sukhov, 2011; Semichenko, 2021). According to studies of recent years show, intensive mechanical cultivation leads to the drying of the fertile soil layer, disrupts the structure and leads to soil depletion.

In addition, costs increase and the cost of production increases. Achievements in the field of plant protection and the development of complexes of modern tools for direct sowing, it is advisable to develop a transition to new technologies based on the principles of minimum tillage (Kulintsev & Dridiger, 2016; Lentochkin et al., 2016).

Currently, farmers actively use surface and minimal tillage with disk tools, but such treatment leads to the loss of a large amount of soil moisture, which is in great deficit in arid climates (Lu, et al., 2018; Shurygin, 2017; Zelenev et al., 2018).

The main task of the farmer is to get the maximum output per hectare at the minimum cost. Moisture is a strategically important limiting factor in rainfed agriculture (Belyakov & Solonkin, 2012; Kashtanov, 2008; Shavrukov et al., 2017). In real life, you can buy everything except precipitation, so their accumulation should be subordinated to the entire technological chain of cultivation of agricultural crops. In our zone, the tendency of moisture accumulation from treatments is confirmed by practice in favor of a stubble background, and it is more noticeable in dry years, where the accumulation of moisture in winter on stubble is much greater than in open soil, which has a positive effect on the spring moisture reserve in favor of fields with stubble residues (Sukhov, 2011; Tagirov et al., 2018; Churzin & Kubrakov, 2018).

Purpose of the work: To substantiate agrotechnological methods with minimizing the main soil cultivation for the highest yield of crop production in the soil and climatic conditions of the Lower Volga region.

MATERIALS AND METHODS

The research was carried out at the experimental site of the LOWER VOLGA RESEARCH INSTITUTE of AGRICULTURE-a branch of Agroecology of the Russian Academy of Sciences in the conditions of dry-steppe lowland agricultural landscapes. The site is located in a hollow catchment system on the slope of the western exposure with a slope of up to 2° on an area of 12 hectares. The soil of the experimental site is light chestnut with a humus content in the arable layer of 1.74%, total nitrogen and phosphorus of 0.12% and 0.11%, respectively. According to the Kaczynski classification, the soil is silty-coarse-silty heavy loam according to its mechanical composition: it contains 49.3% of physical sand and 50.7% of physical clay). The reaction of the soil solution in the arable layer is pH-8.1. The soils are alkaline in their composition.

The study of the problem of minimizing the main and pre-sowing tillage in the crop rotation was carried out in a multi-factor stationary experiment. The object of research is crop rotations (factor A), variants of the main tillage (factor B) and crops superimposed on the variants of tillage with the SZS-2.1 seeder (Omichka, anchor coulter) and SZ-3.6 (disks). Placement of options (A) sequential and options (B) in blocks in three tiers. The following types of basic soil treatments were studied in the experiment: moldboard to a depth of 25...27 cm with a plow PN-4-35, moldless to a depth of 25...27 cm with a “Ranch” tool, surface to a depth of 8-10 cm with a BDM-3 tool, as well as a crop rotation system that includes: grain-steam (4x-field sowing with a SZ – 3,6 seeder)-control and grain-steam (4x-field similar to the control with the rejection of the main treatments for spring crops, sowing with an Omichka SZS-2,1 seeder). Records and observations were carried out in accordance with the Recommendations for the methodology for conducting observations and studies in the field experience (Dospekhov, 1985; Smirnov, 1973). The Omichka stubble seeder helps to maintain an optimal level of moisture in the soil when planting crops. Contributes to the creation of conditions for protection from soil erosion. Technical features allow you to save fuel even with a high load on the unit. The large loading tank allows you to work on large areas without additional backfilling of seeds.

RESULTS AND DISCUSSION

An active means of improving the water regime of the soil is its mechanical treatment, by which it is brought into a state in which, on the one hand, the penetration of precipitation moisture into the soil is facilitated and, on the other, its unproductive losses as a result of runoff, snow removal and physical evaporation are reduced.

All technological operations performed in the process of tillage affect its water regime to one degree or another, but loosening and wrapping is especially noticeable. The depth of soil loosening has a direct and indirect positive effect: direct-increases water permeability, water compatibility and water yield of the soil, indirect-a deep cultivated layer is formed, on which plants develop a more powerful root system and use its water resources more fully, weeds that consume soil moisture are more actively destroyed, the nutrient regime of the soil improves, and plants use moisture more economically.

Analyzing the data on the reserves of productive moisture in one meter soil profile, we can draw the following conclusions:

The greatest reserve of productive moisture is observed in the early spring period after snowmelt, both after a swell, and on a stubble background.

During the spring growing season of winter wheat, the highest productive moisture reserves in the meter layer of the soil were on the moldless and moldboard variants when sowing with the SZS-2.1 seeder and amounted to 73.2 and 69.5 mm, and on the surface 54.9 mm, which exceeded the variant of sowing with the SZ-3.6 seeder by 5.8-1.7 mm. By the end of the harvest, the humidity for all variants of winter wheat was practically absent, and was in the range of 0.1-1.1 mm.

The highest accumulation of moisture occurred on stubble variants of the field, under the sowing of spring wheat, where all the studied variants came to the time of sowing wheat with a more significant content of productive moisture reserves. Moisture reserves ranged in the variants from 101.2 mm on the surface background to 133.8 mm on the variant with non-surface backgrounds. At the same time, less moisture accumulated on the variants with the main soil treatment, and it was 112.7 mm on the moldboard treatment, 123.4 mm on the moldless treatment and 97.5 mm on the surface. For barley, the moisture trend continued. By harvesting spring crops, the available moisture remained from 2.7 to 9.6 mm.

The greater accumulation of productive moisture in the soil with the technology without treatment in winter is due to the better retention of snow by plant residues remaining on the surface of the field. So the average depth of snow cover over the years of research on this technology was 20.2 cm, and according to traditional technologies, depending on the treatment – 9.5-16.9 cm, which is 3.3-10.7 cm less than without tillage. A deeper snow cover formed on untreated soil, when positive air temper-

Table 1. Effect of technology on the content of productive moisture in the soil, mm (2017-2020)

Culture	Type of processing	Soil layer, cm	Term of determination			
			April	May	June	July
4-field grain-fallow crop rotation with basic tillage						
Winter wheat	moldboard	0-100	63,8	42,6	11,4	0,4
	moldless	0-100	61,5	59,2	19,3	0,1
	surface	0-100	49,1	34,4	14,6	0.7
Spring wheat	moldboard	0-100	112,7	77,1	29,1	3,7
	moldless	0-100	123,4	83,5	22,5	7,8
	surface	0-100	97,5	69,2	26,0	5,2
Barley	moldboard	0-100	103,3	74,8	28,7	4,9
	moldless	0-100	116,8	81,4	25,3	5,1
	surface	0-100	91,5	64,1	34,8	7,3
4-field grain-fallow crop rotation without main processing						
Winter wheat	moldboard	0-100	69,5	42,1	16,5	0.3
	moldless	0-100	73,2	50,3	12,0	0,8
	surface	0-100	54,9	28,9	13,3	1,1
Winter wheat (without processing)	moldboard	0-100	121,5	90,3	33,5	6,2
	moldless	0-100	133,8	113,4	44,2	7,8
	surface	0-100	101,2	86,9	36,4	9,6
Barley (without rocessing)	moldboard	0-100	107,0	88,1	31,5	5,3
	moldless	0-100	121,1	108,0	34,1	2,7
	surface	0-100	95,7	84,3	35,2	6,0

atures occurred, melted for 10-12 days longer than on treated soil. That is, when there was still snow on the plots with plant residues, there was no snow on the plots with cultivated soil, and there was an involuntary loss of moisture due to its physical evaporation from the surface of the uncovered soil with plant residues.

At the same time, if we compare the main tillage, the greatest accumulative capacity is shown by deep moldless tillage, in comparison with moldboard and surface tillage. Moreover, the drier the year, the more the moisture-accumulative ability of moldless treatment is manifested.

According to the forms of the crop structure, the yield of grain crops consists of three elements - the density of the productive stalk and the mass of 1000 grains.

According to the results of the sheaf analysis of grain crops, the influence of various methods of basic tillage and sowing on the density of productive stems and the number of stems was established.

Analysis of the data showed that the result of the sheaf analysis of grain crops with different methods of basic tillage and sowing with seeders SZ-3.6 and SZ-2.1 affected the density of the productive stalk and the number of stems. Denser stalk growth was on the variants with seeding with the SPS-2.1 seeder on winter wheat was 356 pcs/m^2 for moldboard processing, on moldless processing 388 pcs/m^2 and surface 334 pcs/m^2, on the same variant more productive stems were formed where the productive bushiness was 1.5 when seeding with the SPS-2.1 versus 1.2 when seeding with the SZ-3.6 seeder, which ultimately affected the yield of winter wheat.

On the variants of sowing spring crops, a slightly different picture has developed, so the density of the stalk was when sowing with the SZ-3.6 seeder on the dump treatment for spring wheat 358 pcs/m^2, for barley 382 pcs/m^2; on the non-dump 316 pcs/m2 and 360 pcs/m^2, on the surface 301 pcs/m^2 and 321 pcs / m^2, respectively. In direct sowing with the SZS-2.1 seeder, these indicators were for the

Table 2. Structural analysis of grain crops depending on tillage, (average for 2017-2020)

Crops	Type of processing	Number of stems, pcs/m^2		Weight of grain from a sheaf, g	Number of grains per ear, pcs	Biological yield, t / ha	Weight of 1000 grains, g
		All	Products.				
Winter wheat	moldboard	329	400	397,1	43,5	4,0	39,1
Spring wheat		358	298	102,9	21,7	1,0	21,4
Barley		382	362	229,2	41,1	2,3	20,9
Winter wheat	moldless	380	456	446,2	42,7	4,5	43,7
Spring wheat		316	334	157,7	31,86	1,6	24,6
Barley		360	396	262,6	50,70	2,6	20,1
Winter wheat	surface	304	410	381,4	42,4	3,8	34,4
Spring wheat		301	261	85,5	27,3	0,85	20,8
Barley		321	238	133,24	41,5	1,3	20,0
Winter wheat	moldboard	356	514	524,4	42,8	5,2	35,0
Spring wheat	without tillage	342	286	102,9	27,3	1,0	21,4
Barley	without tillage	362	288	149,8	40,4	1,5	17,1
Winter wheat	moldless	388	582	561,3	44,1	5,6	47,9
Spring wheat	without tillage	361	226	93,9	28,9	0,94	22,1
Barley	without tillage	326	302	181,9	39,8	1,8	17,5
Winter wheat	surface	334	460	426,1	41,8	4,3	37,9
Spring wheat	without tillage	337	224	73,36	24,4	0,73	18,2
Barley	without tillage	342	215	126,6	43,4	1,3	16,9

background of dump treatment of 342 pieces/m^2 on spring wheat and 362 pieces/m^2 on barley, for non-dump 361 pieces/m^{-2} and 326 pieces/m^2 and surface 337 and 342 pieces / m^2, respectively. Although the difference in the results of the stalk was small in terms of options, it differed in the number of productive stems in favor of the main treatments for crops and averaged 297 pcs/m^2 for spring wheat on SZ-3.6 versus 245 pcs/m^2 on SZ-2.1, for barley 332 pcs/m^2 and 268 pcs/m^2, respectively, which affected the yield.

According to the results of the biological yield of grain crops, the highest yield was on the non-dump treatment of winter wheat and amounted to 5.6 t / ha, where the sowing was carried out with the seeding machine SZS-2.1, on the dump treatment the yield was 5.2 t/ha with the same sowing and the lowest on the surface treatment of 4.3 t/ha, when sowing with the seeding machine SZ-3.6, the yield was 4.5, 4.0, 3.8 t/ha, respectively. For spring wheat, the advantage was with the main non-dump treatment with sowing with the SZ-3.6 seeder, where the yield was 1.6 t/ha, which exceeded the same option but without treatment by 0.6 t / ha, for the options of dump and surface treatment and their backgrounds, the difference was not significant. On barley, the yield is the same for both seeders with surface treatment. However, the difference between the dump and non-dump was 0.3 t/ha. We attribute the low yield of spring crops on the variants without processing to late sowing due to the prevailing climatic conditions, when the average temperature in April was 10^{0}C, while precipitation fell 51.5 mm, which did not allow sowing spring crops in the optimal time, and due to the high contamination of crops.

Data based on the results of the analysis of economic efficiency for 2017-2020 are presented in the table. The cost of production is the average selling price of wheat 7500 rubles / t, barley 6300 rubles / t. The costs of the options for sowing spring crops without treatments are reduced due to (lack of basic processing, cover harrowing, pre-sowing cultivation, rolling crops, depreciation and labor compensation). So the cost of moldboard processing will decrease by 1870 rubles, without moldboard 1502 rubles, and surface 1113.0 rubles.

After analyzing the data (Table 3) it was found that the costs per one conditional hectare of crop rotation area for crops of 4-field crop rotation with the main tillage for all crops on average amounted to 27593.0 rubles for the dump area; 26203.0 rubles for the non – dump area; 24484.0 rubles for the surface area. On the crop rotation without the use of basic processing for spring crops, the costs were - 23563.0; 23103.0; and 22510.0 rubles, respectively.The level of profitability of treatments on average for crops of a crop rotation was: dump - 42.1%; without dump - 64.9% and surface - 25.3%. 4-field crop rotation without processing of spring crops had a profitability higher by 28.8%. 31.5% depending on the background and amounted to: for the dump - 72.7%; without dump - 96.4% and surface tillage - 54.1%. At the same time, the crop rotation for the dump-free background exceeded the similar ones by 23.7 - 42.3%.

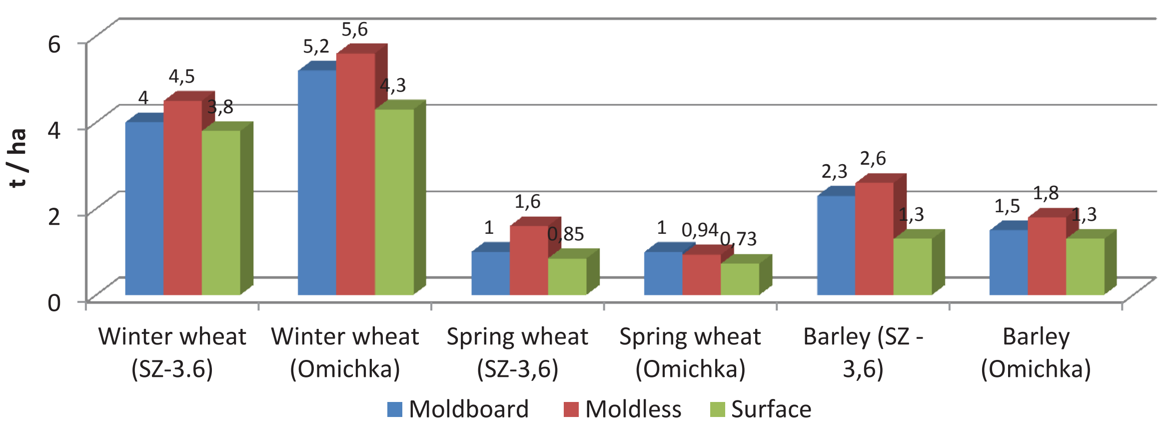

Figure 1. Crop yield depending on the soil treatment and the method of sowing, t/ha, (average for 2017-2020)

Table 3. The impact of basic processing and direct sowing in 2017-2020 on the economic efficiency in 4-field crop rotations

Treatment and seeding options		Average yield, c/ha	Production cost, rub/ha	Costs per rub/ha	Crop rotation costs, RUB	Net profit on crop rotation, RUB	Average profitability by crop rotation, %
Moldboard tillage SZ-3,6	Winter wheat	23,5	17625,0	11269,0	27593,0	11623,0	42,1
	Spring wheat	11,4	8550,0	8750,0			
	Barley	20,7	13041,0	7574,0			
Moldless tillage SZ-3,6	Winter wheat	26,8	20100,0	10809,0	26203,0	17024,0	64,9
	Spring wheat	13,7	10275,0	8300,0			
	Barley	20,4	12852,0	7094,0			
Surface tillage SZ-3,6	Winter wheat	20,3	15225,0	10216,0	2/4484,0	6194,0	25,3
	Spring wheat	9,6	7200,0	7737,0			
	Barley	13,1	8253,0	6531,0			
Moldboard tillage	Winter wheat	28,3	21225,0	10979,0	23563,0	17144,0	72,7
SZS-2,1	Spring wheat	12,2	9150,0	6880,0			
SZS-2,1	Barley	16,4	10332,0	5704,0			
Moldless tillage	Winter wheat	31,5	23625,0	10519,0	23103,0	22271,0	96,4
SZS-2,1	Spring wheat	13,2	9900,0	6880,0			
SZS-2,1	Barley	18,5	11655,0	5704,0			
Surface tillage	Winter wheat	24,1	18075,0	9926,0	22510,0	12178,0	54,1
SZS-2,1	Spring wheat	9,5	7125,0	6880,0			
SZS-2,1	Barley	14,2	8946,0	5704,0			

CONCLUSIONS

The use of moldboard-free tillage in crop rotation increased its productivity from a unit of crop rotation area. The highest productivity of grain crops, on average in terms of crop rotation, had winter wheat, which was 2 - 3 times higher in yield than spring crops. The level of profitability for treatments on average for crops of the crop rotation was 42.1% on the dump, 64.9% without dump and 25.3% on the surface, a four-field crop rotation without processing of spring crops had a profitability higher by 28.8 ... 31.5% depending on processing and amounted to 72.7% for dump, 96.4% for non-dump and 54.1% for surface treatment.

REFFERENCES

Azizov, Z. M. (2004). Resource-saving systems of basic soil cultivation in the upland-lowland landscape and dry steppe of the Trans-Volga region. Collection of scientific works NVNIISKh: Volgograd, pp. 12-18.

Belyakov, A. M., & Solonkin, A.V. (2012). Regional adaptive-landscape system of agriculture in the Lower Volga region. *Print: Volgograd*, pp. 22-24.

Dorozhko, G. R. (2017). Influence of long-term use of direct sowing on the main agrophysical factors of soil fertility and yield of winter wheat in an arid zone. *Zemledelie* (7), pp. 7-9.

Dospekhov, B. A. (1985). Field experiment technique (with the basics of statistical processing of research results). *M.: Agroproimzdat,* 315 p.

Zelenev A .V. Pleckachev Y. N. & Seminchenko E. V. (2018). Crop rotations ensuring the greatest yields under dry conditions of tne lower Volga region water – saving irrigation regimes for vegetable crop production under conditions of Volga – don intereluve. *Bulletin of the Peoples' Friendship University of Russia. Series: Agronomy and Livestock, 13*(3), pp. 216-223.

Kulintsev V. V., & Dridiger, V. K. (2016). Scientific support of the farming system without tillage in the Stavropol Territory. *Collection of reports of the All-Russian scientific and practical conference GNU VNIIZiZPE, September 10-12, pp.* 37-38.

Kashtanov, A. I. (2008). Agriculture. *Selected Works. Russian Agricultural Academy - Moscow,* 685 p.

Lentochkin, A. M., Shirobokov, P. E., & Lentochkina, L. A. (2016). Zero, minimal or moldboard tillage. *Agriculture*, (3), pp.9-13.

Lu W., Adamowicz, W., Jeffrey, S., Goss, G., & Faramarzi, M.. (2018). Crop Yield Response to Climate Variables on Dryland versus Irrigated Lands. *Canadian Journal of Agricultural Economics*, 66, pp. 283-303.

Sukhov, A. N. (2011). Agrophysical indicators of light chestnut soils and their regulation by methods of basic tillage. *Bulletin of the Nizhnevolzhsky agro-university complex, Volgograd* (1), pp.72-78.

Shurygin, A. V. (2017). Moisture in rainfed agriculture is a gift. *Farmer,* (2), pp. 28-30.

Shavrukov, Y., Kurishbayev, A., Jatayev, S., Shvidchenko, V., Zotova, L., Koekemoer, F., De Groot, S., Soole, K., & Langridge, P. (2017). Early flowering as a drought escape mechanism in plants: How can it aid wheat production? *Frontiers in Plant Science,* 8 (17), p. 1950.

Smirnov, B. M. (1973). Recommendations for the methodology of observation and research in the field experiment. *Saratov,* 223 p.

Semichenko, E. V. (2021). Influence of treatments on the physical and chemical properties of the soil in the Dry-Steppe zone of the Lower Volga region. *Rastenievadni nauki, 58*(2) pp. 79-85 (Bg).

Tagirov, M. Sh., Shakirov, R. S., & Gilaev, I. G. (2018). Influence of basic tillage methods on water-physical parameters of soil and productivity of spring wheat. *Agriculture* (8), pp.20-21.

Churzin, V. N., & Kubrakov, E. V. (2018). The role of the main soil cultivation methods in the accumulation of soil moisture and the use of atmospheric precipitation when growing winter wheat on light chestnut soils of the Volgograd region. *Bulletin of the Nizhnevolzhsky agrouniversity complex: science and higher professional education, 4*(52), pp. 128-133.

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