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ЭФФЕКТИВНОСТЬ СИСТЕМ ОСНОВНОЙ ОБРАБОТКИ ПОЧВЫ ПРИ ВОЗДЕЛЫВАНИИ ЯЧМЕНЯ

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Установлена эффективность длительного применения различных систем основной обработки темно-серой лесной почвы в условиях Северного Зауралья. Определено их влияние на эффективность при возделывании ячменя по зерновому предшественнику (яровая пшеница) и зернобобовому (вика на зерно). Исследования проведены в стационарном опыте по изучению отвальной, безотвальной, комбинированной, дифференцированной, плоскорезной и поверхностной систем основной обработки почвы. Опыты проходили в течение третьей – шестой ротаций (1996–2018 гг.) двух зернопаровых севооборотов, развернутых во времени и в пространстве. Первый севооборот: чистый пар – озимая рожь – яровая пшеница – яровая вика – яровой ячмень, второй: чистый пар – озимая рожь – яровая пшеница – яровая пшеница – яровой ячмень. При возделывании ячменя по зернобобовому предшественнику (яровой вике) экономически целесообразным оказалось применение систем основной обработки с элементами минимизации. В нее входили безотвальная и комбинированная обработки с безотвальным рыхлением стойками СибИМЭ на глубину 20–22 см; дифференцированная с плоскорезной на 12–14 см и дискование на 10–12 см. Данные приемы обеспечили близкие отвальной системе условия формирования продуктивности и практически одинаковую урожайность ячменя, получение чистого дохода и коэффициента энергетической эффективности. На фоне без удобрений урожайность составила 2,97–3,03 т/га, с применением $N_{40}P_{40}P_{40}$ – 3,47–3,65 т/га. При размещении ячменя по повторной пшенице самой эффективной оказалась отвальная система обработки с чистым доходом 14,67 тыс. р./га на фоне без удобрений и 22,75 тыс. р./га на фоне их применения с энергетическим коэффициентом 2,65 и 2,75. Применение ресурсосберегающих приемов обработки по повторной пшенице приводило к снижению урожайности зерна ячменя на 0,09–0,40 т/га, снижению чистого дохода при возделывании ячменя в сравнении с зернобобовым предшественником на 31,0–44,1%.

Ключевые слова: система основной обработки, севооборот, предшественник, яровой ячмень, урожайность, эффективность производства

EFFICIENCY OF BASIC TILLAGE SYSTEMS IN THE CULTIVATION OF BARLEY

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The effectiveness of long-term use of various basic tillage systems of dark grey forest soil in the conditions of the Northern Trans-Urals was established. Their impact on the efficiency of barley cultivation depending on the grain (spring wheat) or legume forecrop (vetch for grain) was determined. The research was carried out in a stationary experiment covering moldboard, non-moldboard, combined, differentiated, stubble-mulch and surface systems of basic soil tillage. The experiments took place during the third–sixth rotations (1996–2018) of two grain-fallow crop rotations spread in time and space. The first crop rotation was: bare fallow – winter rye – spring wheat – spring vetch – spring barley, the second crop rotation: bare fallow – winter rye – spring wheat – spring wheat – spring barley. When cultivating barley following the legume forecrop (spring vetch), it was economically feasible to use basic tillage systems with the elements of minimization. It included non-moldboard and combined tillage with subsurface loosening by a plow with SibIME tines to a depth of 20-22 cm differentiated with stubble-mulch at 12-14 cm and disk harrowing at 10-12 cm. These methods provided conditions for the formation of productivity close to the moldboard system and practically the same yield of barley, net income and energy efficiency coefficient. Without fertilizers, the yield was 2.97-3.03 t/ha, with the use of $N_{40}P_{40}P_{40}$ it was 3.47-3.65 t/ha. When planting barley following wheat sown twice, the most effective was moldboard tillage system with a net income of 14.67 thousand rubles/ha without fertilizers and 22.75 thousand rubles/ha with fertilizers and energy coefficient of 2.65 and 2.75. The use of resource-saving tillage methods with repeated wheat led to a decrease in the yield of barley grain by 0.09–0.40 t/ha, and a decrease in the net income of barley cultivation compared to the legume forecrop by 31.0–44.1%.

Keywords: basic tillage system, crop rotation, forecrop, spring barley, yield, production efficiency

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INTRODUCTION

In the Tyumen region, the crop production area under barley occupies 22% of the sowing of grain and leguminous crops. The demand for this crop is due to the high fodder qualities of grain for animal husbandry and the processing industry, good adaptive ability to natural factors, increased responsiveness to fertilization, which leads to high productivity of crop cultivation [1-3].

In the Northern Trans-Urals, in production conditions, during the main soil cultivation, methods of moldboard-free and flat-cut cultivation and disking which are energetically less expensive than plowing are increasingly used. Scientific studies on this issue do not give an unambiguous answer on the comparative efficiency of technologies of different intensity, as well as on their influence on the efficiency of barley production in comparison with the traditional technology based on plowing [4–10].

The purpose of the study is to determine the effectiveness of long-term use of various systems of the main processing of dark gray forest soil in the conditions of the Northern Trans-Urals during the cultivation of barley for grain (spring wheat) and leguminous (vetch for grain) predecessor.

MATERIAL AND METHODS

The studies were carried out in the stationary experiment of the Scientific Research Institute of Agriculture of the Northern Trans-Urals - a branch of the Tyumen Scientific Center of the SB RAS in 1996–2018. The scientific experiment took place during the third - sixth rotations of two grain-fallow crop rotations spread in time and space. The first crop rotation: clean

fallow - winter rye - spring wheat - legumes (vetch for grain) - spring barley, the second: clean fallow - winter rye - spring wheat - spring wheat - spring barley. The soil is dark gray forest heavy loamy. The depth of the humus horizon is 25–27 cm, the humus content is 4.2–5.0%, the pH of the salt extract is 6.0–6.4. The total absorbed bases in the plowing layer is 18.6–25.6 mEq. / 100 g of soil.

The tillage systems were as follows:

– moldboard: the main cultivation for barley and other crops of crop rotation with the Lemken plow to a depth of 20-22 cm;

– non-moldboard: annual loosening with SibIME tines to a depth of 20-22 cm;

– combined: for barley and wheat for winter rye, loosening with SibIME tines to a depth of 20-22 cm, for winter rye, spring vetch and second wheat - plowing with a Lemken plow by 20-22 cm;

– differentiated: for winter rye, in steam and for spring wheat for winter rye, loosening with a flat cutter Smaragd-6 to a depth of 12-14 cm, for vetch and second wheat - plowing with a Lemken plow by 20-22 cm, for spring barley and after harvesting surface processing by disking of a large barrel drum 2.5 x 10–12 cm.

Pre-sowing treatment for all studied systems of the main treatment consisted in early spring harrowing with BZSS-1.0 tooth harrows in four tracks, pre-sowing cultivation with the Smaragd-6 cultivator to the depth of seeding. Sowing of Acha variety barley was carried out with a SZP 3.6 seeder. The seeding rate is 5 million viable seeds / ha. Mineral fertilizers, according to the method, were applied before presowing cultivation with a rate of $N_{40}P_{40}K_{40}$ kg of ai. per 1 hectare of crop rotation area. For the destruction of weeds, herbicides were used in all studied variants.

The plot area was (5.5–6.0 × 63 m) 346–378 m^2, the accounting area was 100 m^2. According to the meteorological conditions of the growing season, 6 years were dry, 17 years - close to the average long-term conditions. The laying technique and the experiment were carried out according to the method of B.A. Dospekhov[1] using computer programs of O.D. Sorokin[2], the bioenergetic and economic efficiency was calculated according to methodological recommendations[3,4].

RESULTS AND DISCUSSION

In the grain-fallow crop rotation, when placed on leguminous crops, resource-saving processing systems provided almost equal barley yield to the moldboard system. Without fertilizers, it amounted to 2.97–3.03 t / ha, with the use of fertilizers - 3.47–3.65 t / ha (see Table 1). This can be explained by the fact that favorable agrophysical conditions and conditions for plant nutrition, especially nitrogen, were formed by resource-saving backgrounds and by the moldboard processing system [11].

The replacement of leguminous crops in the grain-fallow crop rotation with second wheat and its use as a precursor for barley has led to a steady decrease in barley yields for non-moldboard, stubble- mulch and for disking. In comparison with the plowing system without mineral fertilizers, it decreased by 0.09-0.27 t / ha (3.8-11.4%), with the use of fertilizers - by 0.07-0.40 t / ha (2.0-11.1%). This is explained by the deterioration of the nitrogen nutrition of plants for non-moldboard and shallow treatments, especially for the repeated grain precursor [12–15].

Indicators of economic and energy efficiency indicate that they to a decisive extent depended on the value of the yield, which, in turn, depended on the tillage system, the predecessor and the background of fertilization. So, with a decrease in direct costs for resource-saving processing systems without fertilizers by 1.2-4.1%, with the use of fertilizers by 0.33-2.8%, the cost of gross barley production without and with the use of fertilizers for the legume predecessor as well as the yield were close to the control vari-

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Табл. 1. Урожайность, прямые затраты и чистый доход при возделывании ячменя в зернопаровых севооборотах в зависимости от систем основной обработки почвы (1996–2018 гг.)

Table 1. Yield, direct costs and net income of barley cultivation in grain-fallow crop rotations depending on basic tillage systems (1996-2018)

Basic tillage system	Fertilizer background	Yield, t/ha		Direct costs, thousand rubles/ha	Net income, thousand rubles/ha	
		vetch	wheat		vetch	wheat
Moldboard	Without fertilizers	2,97	2,37	8,88	20,63	14,67
	With fertilizers	3,53	3,60	13,022	22,06	22,75
Non-moldboard	Without fertilizers	3,02	2,10	8,75	21,26	12,12
	With fertilizers	3,65	3,27	12,89	23,38	19,61
Combined	Without fertilizers	3,03	2,23	8,75	21,36	13,41
	With fertilizers	3,60	3,53	12,89	22,89	22,19
Differentiated	Without fertilizers	2,94	2,14	8,74	20,44	12,49
	With fertilizers	3,47	3,31	12,98	21,48	19,91
Surface tillage	Without fertilizers	3,06	2,10	8,77	21,64	12,10
	With fertilizers	3,59	3,20	12,98	22,70	18,82
Stubble-mulch	Without fertilizers	2,92	2,28	8,52	20,50	14,14
	With fertilizers	3,54	3,46	12,64	22,52	21,73
LSD_{05}	Without fertilizers	0,11	0,20			
	With fertilizers	0,14	0,26			

ant of the technology based on plowing. On the contrary, with a decrease in the yield of barley for recycled wheat, the decrease in the cost of gross production for resource-saving processing systems without fertilizers was 3.8-11.4%, with the use of fertilizers - 1.9-11.1% (see Table 1, 2).

For the legume predecessor with similar yield values, the net income, the energy coefficient for the studied processing systems were also similar. Without and with the use of fertilizers, the differences in net income (20.5–21.6 and 21.5–23.4 thousand rubles / ha, respectively) between the moldboard and resource-saving processing systems did not exceed, respectively, the background of fertilizers 0.6– 3.7% and 2.6–6.0%. According to this predecessor, in grain-fallow crop rotation for barley, along with the moldboard system, the use of non-moldboard loosening with SibIME tines to a depth of 20–22 cm is economically justified; with non-moldboard and combined systems the use of the Smaragd cultivator to a depth of 12–14 cm and processing of BDT-2.5 to a depth of 10–12 cm with stubble- mulch and surface processing systems is appropriate. The energy coefficient for these processing systems without fertilizers was 3.43–3.46, with fertilizers - 2.78–2.81, for the moldboard system, respectively, the fertilizer backgrounds were 3.23 and 2.69, i.e. exceeded the control variant of the moldboard system by 0.09–0.14.

Cultivation of barley after repeated wheat, especially without fertilization, significantly reduced the profitability of its cultivation in comparison with the legume predecessor. Thus, the decrease in net income in this case for the moldboard processing system was 28.9%, for resource-saving systems - 31.0-44.1%. With the use of fertilizers with a moldboard processing system, there was no decrease in net income, depending on the predecessor, for resource-saving processing systems, a decrease of 3.0–17.1%.

When barley was placed on repeated wheat with a moldboard system of main processing, the net income without fertilizers amounted

Табл. 2. Экономическая и энергетическая эффективность возделывания ячменя в зернопаровых севооборотах при различных системах основной обработки почвы (1996–2018 гг.)

Table 2. Economic and energy efficiency of barley cultivation in grain-fallow crop rotations with different systems of basic soil tillage (1996-2018)

Basic tillage system	Fertilizer background	Energy coefficient		Cost price 1 tone of grain		Gross product value, thousand rubles/ha	
		vetch	wheat	vetch	wheat	vetch	wheat
Moldboard	Without fertilizers	3,32	2,65	2,99	3,75	29,51	23,55
	With fertilizers	2,69	2,75	3,69	3,62	35,68	35,78
Non-moldboard	Without fertilizers	3,43	2,38	2,89	4,17	30,01	20,87
	With fertilizers	2,81	2,52	3,53	3,94	36,27	32,50
Combined	Without fertilizers	3,44	2,53	2,89	3,92	30,11	22,16
	With fertilizers	2,78	2,72	3,58	3,65	35,78	35,08
Differentiated	Without fertilizers	3,33	2,42	2,98	4,10	29,22	21,27
	With fertilizers	2,67	2,55	3,74	3,92	34,46	32,89
Surface tillage	Without fertilizers	3,46	2,38	2,87	4,18	30,41	20,87
	With fertilizers	2,76	2,46	3,62	4,06	35,68	31,80
Stubble-mulch	Without fertilizers	3,41	2,66	2,92	3,74	29,02	22,66
	With fertilizers	2,78	2,72	3,57	3,66	35,18	34,38

to 14.67 thousand rubles / ha, with their use - 22.75 thousand rubles / ha. At the same time, without fertilizers, this indicator turned out to be the closest to the moldboard processing system during stubble- mulch processing and processing with SibIME tines to a depth of 20–22 cm in the combined system (lower than the control by 3.6–8.6%).

With the use of fertilizers, the combined and stubble- mulch processing systems were inferior to the moldboard in terms of net income by only 2.5–4.5%. For the rest of the studied soil cultivation options, the net income was lower than with the moldboard system: without fertilizers by 2.18–2.57 thousand rubles / ha (14.8–17.5%), with the use of fertilizers by 2, 84-3.93 thousand rubles / ha (12.5-17.3%). Our data on productivity and economic efficiency are largely consistent with the results of studies obtained in the European part of Russia [16, 17].

CONCLUSION

1. It is economically most expedient to use the main processing systems with elements of minimization on the dark gray forest soils of the northern forest-steppe of the Northern Trans-Urals during the cultivation of barley as the final crop in the grain crop rotation according to the legume predecessor (spring vetch): non-moldboard and combined with non-moldboard loosening by SIBIME tines at 20-22 cm, differentiated with stubble- mulch processing by 12-14 cm and disking by 10-12 cm. These processing systems after legumes for barley provided the formation of almost equal to the moldboard processing system barley yield: without fertilizers - 2.97-3, 03 t / ha, using N40P40P40 - 3.47–3.65 t / ha, net income.

2. The use of resource-saving methods of processing in grain crop rotation clean fallow - winter rye - spring wheat - spring wheat - spring barley for repeated wheat led to a decrease in the yield of barley grain by 0.09–0.40 t / ha, a decrease in net income when cultivating barley

in comparison with the legume predecessor by 31.0–44.1%.

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