Improvement of soybean cultivation technology in the southern forest-steppe of western Siberia

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Abstract. Legumes contribute significantly to the nitrogen balance of agrocenosis and terrestrial ecosystems. They fix the free air nitrogen and convert it into forms available to other plants. Legumes are a powerful biological factory of nitrogen fertilizers. The soils are enriched with available forms of nitrogen up to 80 kg/ha during the growing season. This process occurs due to the soil organic matter, stubble, and root residues left after harvesting soybeans. An increased planted area of soybeans in the rotation promotes a significant improvement in the growing conditions of other crops and increases their yield without additional costs. The crop yield is not significantly affected by soil treatment using herbicides in the conditions of the southern forest-steppe of Western Siberia. It is impossible to reduce the infestation of soybean crops to an economically harmless level with the use of a single herbicide. Due to a single application of herbicide and nitrogen-phosphate fertilizers, the yield of soybeans increases by an average of 0.46 t/ha or 51.7%.

1 Introduction

Legumes contribute significantly to the nitrogen balance of agrocenosis and terrestrial ecosystems. They fix the free air nitrogen and convert it into forms available to other plants. Legumes are a powerful biological factory of nitrogen fertilizers. Soybean is one of the valuable preceding crops for wheat, as the main crop for the Siberian region. The soils are enriched with available forms of nitrogen up to 80 kg/ha during the growing season. This process occurs due to the soil organic matter, stubble, and root residues left after harvesting soybeans. This is of great economic and ecological importance in the cultivation of crops [1].

Soybean (Glycine max L. Merrill.) is a high-oil food and fodder crop of global significance. It is unrivaled except for sunflower. Geographically moving to the northern latitudes, soybeans slow down their development, as it is a short-day plant. Successful acclimatization of soybeans in the West Siberian region is possible only with the correct selection of the genotype [5].

Soybean is very demanding to climatic conditions. The formation of the quantity and quality of beans is more affected by drought than overwatering. Soil moisture deficit affects

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the development of root nodules in the process of nitrogen fixation. The symbiotic fixation of nitrogen in the air stops if the moisture content in the surface soil layer is lower than the moisture content of the capillary breaks (less than 20%). At this point, the nodules are dropped from the roots, and the plants begin to suffer nitrogen starvation due to a lack of nutrition. However, it is known that hypoxia or anoxia in the root layer causes, namely, overwatering. As a result, low crop yields and deterioration of product quality are formed [2,6].

The expansion of soybean crops is restrained by a large instability of yields. The main reasons for the low biological crop yield of soybeans in the region are insufficient soil moisture supply, air drought during the blossom time of crops, and very high infestation [4,10].

2 Objects and methods

The object of the study is the agrotechnology of soybean cultivation of the Sibiryachka variety in the crop rotation: soybean – wheat – rapeseed - barley. The research was performed from 2018 to 2020 in the area of the southern forest-steppe in the experimental fields of the laboratory of resource-saving agrotechnologies of the Omsk Agrarian Research Center. The work was conducted on meadow-black soil (medium-humus medium-thick medium-loamy); pH was 6.4.

Design of stationary two-factor experiment:

Factor A – Tillage system:

1. Moldboard plowing (by 20-22 cm, annually); 2. Combined (plowing by 20-22 cm for soybeans, flat-cutting tillage by 10-12 cm for cereals; no fall tillage for rapeseed); 3. Zero (without basic tillage).

Factor B – Use of chemicals:

1. Control (without chemicals); 2. Herbicides; 3. Fertilizers + herbicides; 4. Complex use of chemicals (fertilizers + herbicides + Ultramag Combi top dressing).

The treatment of crops with Pulsar herbicide was done in the phase of 2-3 true soybean leaves. The treatment of crops with herbicides and fertilizing of complex micro and macro fertilizers Ultramag Combi was performed with a boom sprayer with a working solution consumption of 200 l/ha.

Using a disk drill amorphous $N_{10}P_{52}$ was applied in variants with fertilizers. Pre-planting cultivation to a depth of 5-6 cm was performed with a KPS-4 trash cultivator. Sowing was done at the beginning of the third decade of May by a Bystrica seeder with anchor tools.

In the experiments, a released soybean variety “Sibiryachka” was sown having a seeding rate of 0.8 million viable grains per hectare. Sibiryachka variety was bred by individual selection from a hybrid combination [Mageva x (Maple presto x L 1339/86)] at Omsk Agrarian Research Center. The variety is quickly ripening. The duration of the growing season is about 97 days [3].

The area of the primary plot is 308 m^2 (14*22). The replication in the experiment is fourfold. The crop recording is a single–phase (in the phase of full ripeness with the Sampo-130 combine harvester). The straw was crushed and scattered over the field during the harvesting of all crops in the crop rotation.

3 Results of studies

The agro-climatic conditions of the Omsk region promise to grow quickly ripening varieties of soybeans for grain and cover the needs for it. Weather conditions varied significantly

during the years of research. The growing season of 2018 turned out to be wet. 2019 was close in weather conditions to the average annual indicators. However, it was drier in the second half of the growing season. In 2020, there was a heatwave during the growing season, which caused drought and a significant loss of yield.

Generally, soybeans are relatively moisture-loving plants. To spew and germinate, 130-160% of the moisture from the mass of dry seeds is required. From sprouting to tillering, the absolute water consumption is usually small. As plants grow, water consumption increases, reaching its greatest value in July – August during blossoming and filling. If there is a lack of moisture at this time, it can result in a decrease in soybean yield by 50% or more [7].

During sowing, the reserves of productive moisture in the meter-deep layer of soil during the research period were very high (Table 1).

Table 1. Dynamics of productive moisture reserves (mm) in the soil layer 0-100 cm depending on tillage and use of chemicals in soybean crops (average for three years).

Tillage system	Determination terms					
	dropping		blooming period		harvesting	
	c*	c/ch**	c	c/ch	c	c/ch
Moldboard plowing	195	214	132	152	86	123
Combined	179	199	133	152	95	113
Zero	177	200	117	144	107	98
Average	184	204	127	149	96	111

c* - control (without chemicals); c/ch** - complex use of chemicals

Meanwhile, during the control and complex use of chemicals, significant differences in favor of options with chemicalization were observed only in 2020. As a rule, moisture reserves for sowing are greater in the variant with annual plowing than in the variants with combined and zero tillage.

In the blooming period of the crop, the reserves of productive moisture are significantly reduced. Nevertheless, there is no significant difference between the tillage options. In comparison with the control, the differences in favor of complex chemicalization rise to 17% according to the options of chemicalization. Soybean plants received sufficient moisture for blooming and bean formation during the observation period. During the growing season, the use of complex chemicals in crops had a considerable impact on the reserves of productive moisture in the soil. This is mainly due to a decrease in the infestation of crops and moisture consumption by weeds in variants with herbicides.

The soil density in the arable layer (0-30 cm) after sowing in the plowing variant averaged 1.09 g/cm^3 during the research period. These indicators are typical for the black soils of the region with moldboard plowing. Therefore, the soil density according to the options with moldboard plowing was within the limits of more optimal for the growth and development of soybeans in comparison with zero tillage.

Minimization of tillage almost always results in an increase in infestation in crop rotation fields. The infestation of soybean crops in the control without the use of chemicals was significantly higher than in the other variants of chemicalization. The crops were dominated by offset weeds, such as field milk thistle, yellow thistle, and field bindweed; to a lesser extent, there were bluegrass weeds, mainly chicken and field millet.

In the case of zero tillage, the average infestation in the variants appeared to be the highest and amounted to 60 pcs. /m^2. The infestation in the variant with moldboard plowing was 33.3% lower. Depending on weather conditions and species composition, the

infestation level varies greatly over the years. According to the mass of weeds, the infestation level was very high. The use of herbicide in the phase of 2-3 true soybean leaves decreased the infestation of crops by 2.5 times compared to the control (Table 2).

Nevertheless, the infestation level has reduced only to an average level. A single application of the herbicide does not always guarantee a low infestation of soybean crops. The use of fertilizers contributed to an improvement in the infestation of crops. It is required to further improve the system of crop protection from weeds.

Table 2. Infestation of soybean crops (pcs/m2) depending on the tillage system and the use of intensification means, average for 3 years.

Intensification (factor B)	Tillage system (factor A)			Average for B
	moldboard plowing	combined	zero	
Control (without chemicalization)	69	83	102	85
Herbicides	23	38	40	34
Herbicides + fertilizers	42	39	37	39
Average for A	45	53	60	53

Along with grain quality, its yield is the main measure of evaluation of agricultural technologies and varieties for productivity. Meteorological conditions of the growing season and the genetic potential of the variety have a complex effect on crop yield [8, 9].

The yield of soybeans in the years of research was low. On average, according to the experiment, it amounted to 1.19 t/ha (Table 3).

Table 3. Grain yield (t/ha) of Siberian soybean depending on agricultural technology of cultivation, average for three years.

Intensification variants (factor B)	Tillage system (factor A)			Average for B, HCP_{05} = 0,10
	moldboard plowing	combined	zero	
Control (without chemicalization)	1,01	0,87	0,80	0,89
Herbicides	1,23	1,35	1,00	1,19
Herbicides + fertilizers	1,33	1,47	1,25	1,35
Complex use of chemicals	1,28	1,44	1,22	1,31
Average for A, HCP_{05} = 0,08	1,21	1,28	1,07	1,19

The yield of soybeans significantly depended on the tillage system. According to the chemicalization options, on average, zero tillage reduced productivity by 11.6 and 16.4%, in comparison with the moldboard plowing and combined tillage. If the level of intensification of crop cultivation increases, the yield rise in the variant with combined tillage increases to a greater extent than with zero tillage and moldboard plowing.

The use of herbicides significantly improved the yield (by an average of 33.7%). Against the background of the herbicide, fertilization provided an average yield growth of 13.4%. The herbicides + fertilizers option boosted soybean yields by 51.7% compared to the control. In the conditions of the arid second half of the growing season, Ultramag Combi top dressing did not have a significant effect on the harvest. In the variant of complex chemicalization, the yield growth compared to the control averaged 47.2%.

4 Conclusion

Therefore, in the conditions of the southern forest-steppe of Western Siberia, soybean plants receive a sufficient amount of soil moisture for blooming and bean formation. The soil density in the variants with moldboard plowing was in the optimal range for the growth and development of soybeans. In the case of zero tillage in arid conditions, it exceeds the limits of favorable density. The infestation of soybean crops without the use of chemical weeding is usually very high. A single application of Pulsar herbicide in crops does not eliminate infestation to a harmless level. Offset and young dicotyledonous weeds dominate in all variants.

The tillage system significantly affects yield. In case of a zero tillage system, soybean productivity reduced by an average of 11.6-16.4% in comparison with the moldboard plowing and combined tillage. The use of herbicides and fertilizers significantly enhances crop yield. It is on average by 51.7% or 0.46 t/ha, compared with the control.

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