Crop agro-technologies adaptation in organic farming

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Abstract. The materials of long-term field experiments carried out in the forest-steppe of the Ob region of the Novosibirsk region and in the northern forest-steppe of the Kuznetsk basin of the Kemerovo region in various types of crop rotations on leached chernozems were analyzed to assess the possibility of developing organic farming. The most stable crop rotation in relation to weeds is a grain-fallow crop rotation with winter rye, where the coefficient of crop rotation productivity decrease with an increase in infestation by 1 unit of specific weed biomass was 0.205.The number of interstim pests per plant was less on wheat crops placed on vetch-oats, winter rye and rapeseed than on fallow and spring grain predecessors. The most productive crop rotations without the use of fertilizers and pesticides were grain fallow crop rotations with winter rye (2.46 t/ha) and legumes (2.44 t/ha). It has been established that organic farming can only be carried out under conditions of crop diversification (increase in biodiversity within crops of winter rye, cabbage, leguminous grasses and grain legumes), a decrease in the intensity of mechanical impact on the soil, the introduction of organic fertilizers and plant residues of crops, sideration.

1 Introduction

Organic farming arose as a reaction to the industrialization of agriculture and the environmental and social problems associated with it due to the high load on the natural environment due to the excessive amount of chemicals used and intensive tillage [1-3]. Organic farming is also associated with an increase in the sustainability of agriculture in general due to climate change and the need to improve the quality of human nutrition and farm animals [4-6]. The goals of organic farming go beyond food production and include the protection of the environment (landscapes, habitats, biodiversity, air and water) and the well-being of people and animals [7]. Usually organic farming has higher energy efficiency (input/output), but on average shows lower yields and, therefore, reduces productivity compared to traditional farming [8, 9].

Agrotechnology of crop production is the embodiment of the farming system on a specific field in a specific agricultural year. Therefore, the adaptation of agricultural technologies to

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a large extent depends on the adaptation of the entire system of agriculture to the natural and production resources of the economy. In traditional agriculture, this is realized through the organization of the territory, optimization of the structure of crops and crop rotations, the system of tillage, fertilizers, plant protection, anti-erosion measures, etc. [10]. In organic farming, it is supposed to abandon the use of mineral fertilizers and pesticides in plant protection. It is planned to compensate for the lack of nutrients in the soil and their mobilization by preserving the organic residues of previous crops and applying organic fertilizers, while regulating the development of harmful organisms in crops by diversifying cultivated crops and increasing biodiversity [11-14]. In the conditions of Siberia, the principle of biodiversity can be implemented by alternating plants that enrich the soil with nitrogen (both perennial and annual leguminous grasses and grain legumes) with impoverishing (cereals), clogging (spring cereals) with cleansing (perennial and annual grasses, tilled) and others [15].

Crop rotation is an obligatory attribute of any agricultural technology, since a set of crop cultivation operations depends on the previous use of a particular land plot. The structure of sown areas, the placement of crop rotations on the territory of the economy and their types, taking into account the biological requirements and the environmental influence of agricultural crops as various predecessors in accordance with the agro-ecological characteristics of the land, is an integral part of organic farming. In agricultural technologies, it is necessary to make maximum use of positive coenological relationships between crops alternating in crop rotation, which will ensure the fixation of atmospheric nitrogen by symbiotic and free-living soil microorganisms, the biological loosening of the arable and subarable soil layers, the redistribution of nutrients along the soil profile, and the regulation of the vital activity of organisms harmful to plants. Crops of legumes, rapeseed, lupine, perennial legumes can improve the phytosanitary condition of crops, in particular, significantly reduce the damage to cereal crops by root rot. If in monoculture and in crop rotations saturated with crops with a short rotation, one-sided use of mineral nutrition elements is inevitable, then with the correct alternation of crops, elements (including hard-to-reach ones) from different soil horizons are involved in the process of plant nutrition [16,17].

Equally important in the adaptation of agricultural technologies is the choice of tillage method. A long-term study of the main tillage systems in field experiments conducted in Siberia showed that on all zonal soils, non-moldboard and small flat-cut tillage, including zero, increase the weediness of crops compared to plowing. On heavy soils, after grain harvesting, the density of the arable layer reaches values that do not provide sufficient water permeability for the accumulation of autumn-winter-spring precipitation, and deep autumn loosening is required. Fine tillage of sloping lands with a compacted layer of the lower part of the arable layer does not provide anti-erosion resistance. Non-moldboard and shallow flat-cutting treatments reduce the accumulation of mobile nitrogen compounds in the root layer, and also contribute to the differentiation of the upper soil layer in terms of fertility. Deep tillage, especially moldboard cultivation, under conditions of moisture deficiency and winters with little snow, leads to large losses of productive moisture due to diffuse evaporation. Soils of a lighter granulometric composition with normal moisture in autumn have a favorable composition of the arable layer and do not require additional deep loosening [18].

The purpose of the study is to evaluate the results of field experiments conducted in the forest-steppe zone of Western Siberia for the possibility of their use for the adaptation of agricultural technologies of crop production in organic farming.

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2 Materials and methods

For the analysis, the research materials conducted over 10 years were used. They were recorded in the forest-steppe of the Ob region of the Novosibirsk region and in the northern forest-steppe of the Kuznetsk basin of the Kemerovo region in various types of crop rotations on leached chernozems.

The content of humus in the arable layer of the soil of the experimental plot in the forest-steppe of the Ob region was 4.81%, total nitrogen was 0.27%, phosphorus (according to Chirikov) was 18.5 mg/100 g, exchangeable potassium (according to Chirikov) was 7.0 mg /100 g of soil, salt pH was 6.6, granulometric composition was medium loamy. Crop rotations (grain-fallow with spring cereals, grain-fallow with winter rye, grain, grain with legumes, grain with cabbage) during laying unfolded in time and space. The field size of experimental crop rotations is 475 m^2. Varieties of agricultural crops released in the zone were sown. Techniques of the main and pre-sowing tillage were carried out separately in each field of the crop rotation, and the principle of compliance of tillage with optimal crop cultivation technologies was observed. The fallow areas were cultivated with a mouldboard plow, after grain crops, deep non-moldboard loosening with Siberian Research Institute of Mechanization and Electrification of Agriculture tines (plows with cutting shares) to a depth of 28-30 sm was used.

The content of humus in the arable layer of the soil of the experimental plot in the northern forest-steppe of the Kuznetsk basin was 8.2%, phosphorus (according to Chirikov) was 14.3 mg/100 g of soil, exchangeable potassium (according to Chirikov) was 13.4 mg/100 g of soil, Salt pH was 6.0, granulometric composition was heavy loamy. The studies were carried out in grain-row crop rotation (barley with oversowing of clover (minimum tillage) - clover - wheat (zero tillage) - potato), as well as in grain-fallow (pure fallow (green manure fallow) - wheat - peas - pure barley and barley with overseeding of sweet clover) using various tillage systems for crops: moldboard deep (moldboard plowing in autumn), combined deep (non-moldboard deep in autumn), combined minimum (non-moldboard shallow in autumn), mulching minimum (direct sowing without tillage) [20, 21].

3 Results and discussion

In the forest-steppe of the Ob region, in all the years of research, the root-sprout-tap-root-juvenile type of weed infestation of the experimental plot prevailed, and dicotyledonous weeds make up from 31.3 to 68.0% of the total number of weeds, depending on the cultivated crop, of which from 58.8 to 95% was perennial (root shoots and tap roots). In the filling phase, an increase in the production of dicotyledons is consumed in crops of oats, wheat and vetch-oats, more than 80% of them are perennials, and cereal weeds prevailed in crops of rapeseed and barley. The highest relative infestation (mass of weeds to the total mass of agrocenosis) was noted on barley (the trailing crop of crop rotations) with 38.1%, which was more than 3 times higher than the threshold of harmfulness.

To assess the resistance of crop rotations to the most harmful of biotic stressors (weeds), the coefficients were calculated, they determine the magnitude of the decrease in the productivity of crop rotations depending on the development of weeds in crops. To obtain these coefficients, the dependence of the productivity of crop rotations (yield of 100 kg per feed protein unit (CPU) per 1 ha of crop rotation area – B_0) was analyzed without the use of chemicals on the specific biomass of weeds (average values for crop rotation per rotation) using statistical analysis (Table 1).

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Table 1. Evaluation of the resistance of crop rotations to weeds in the forest-steppe of the Ob region.

Crop rotation	B_0, 100kg/ha CPU	WDC	B_1, 100kg/ha CPU
Fallow – wheat – wheat – barley	33.59	2.39	0.417
Fallow – winter rye – wheat – barley	31.26	4.88	0.205
Wheat - oats – wheat – barley	43.19	1.06	0.946
Vetch-oats – wheat – wheat – barley	66.44	1.72	0.580
Rapeseed – wheat – wheat – barley	41.48	2.17	0.460

The coefficient of development of weeds (WDC) shows the value of their specific biomass, accompanied by a decrease in the productivity of crop rotation by 100 kg/ha of CPU crop rotation area. Coefficient B_1 shows how many centners per hectare of CPU the productivity of crop rotations decreases with an increase in weed infestation by 1 unit of specific weed biomass.

An analysis of weed infestation of crop rotations using these coefficients showed that in a grain crop rotation, to reduce the productivity of crop rotations by 100 kg/ha of CPU the smallest increase in the specific biomass of weeds is required with 1.06% of the mass of the acrocyanosis. In order for the grain-fallow crop rotation with winter rye to reduce productivity by the same amount, the specific weediness is 4.6 times higher.

Grain-fallow crop rotations respond to the increase in weediness to a lesser extent by reducing productivity only by 0.20 and 0.42 100 kg/ha of CPU. Crop rotations with legumes and cabbages are included in the second group in terms of resistance and respond to a unit increase in the specific biomass of weeds, reducing productivity by 0.58 and 0.46 100 kg/ha of CPU, respectively, and at a relatively high infestation, they successfully cope with weeds due to the increased competitiveness of crops. The grain crop rotation turned out to be the least balanced and was characterized by the greatest losses in productivity with 0.95 100 kg/ha of CPU.

Leaf and stem infections developed mainly at a level below the threshold of harmfulness, and only in years when moisture exceeded the norm, and the lack of heat in the second and third ten days of July hampered the development of culture, the threshold of harmfulness for Septoria was exceeded only on wheat for rapeseed (development of Septoria on the flag leaf was 26.8%), leaf rust and powdery mildew were practically absent.

In wet years, the accumulation of *Bipolaris sorokiniana* conidia in the soil exceeded the threshold of harmfulness for all predecessors except rapeseed, where the number of spores per 1 g of air-dry soil was 15, the maximum number (65 fungal conidia) and, accordingly, the development of the disease (20%) was on wheat for a couple. This is due to the fact that the final crop of the crop rotation is barley, which destabilizes the phytosanitary situation in a pair before the main crop. In other years, the development of common root rot of spring wheat was below the level of damage threshold for all predecessors.

The number of larvae and puparia of intrastim pests per plant was the highest in wheat crops for fallow and for spring grain predecessors (Table 2).

Table 2. Infection of wheat with intrastim pests depending on predecessors in the forest-steppe of the Ob region.

Predecessor	Number of pests, pcs/plant	Infected, %	
		plants	stems
Fallow	0.80	58.8	30.3
Winter Rye	0.47	38.2	16.8
Oat	0.72	55.9	27.5
Barley	0.68	53.1	23.4
Vetch-oats	0.58	50.0	24.1
Rapeseed	0.34	32.4	20.3

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A smaller number of pests was observed on wheat crops for vetch-oats, winter rye and rapeseed. Despite the relatively high level of infection of plants by intrastim pests, the damage caused by them was insignificant, since by the time of mass oviposition of harmful species, wheat had passed the most vulnerable phase of development (seedlings), and pests inhabited mainly younger lateral stems.

It has been established that without the application of mineral fertilizers, grain-fallow crop rotations are preferable, in which the best predecessor of spring wheat was black fallow, good was for the 1st wheat after fallow and winter rye fallow, satisfactory was for vetch-oats, rapeseed.

In terms of grain yield per hectare of crop rotation area without the application of fertilizers and pesticides, the most productive were grain fallow crop rotation with winter rye (2.46 t/ha) and grain crop rotation with legumes (2.44 t/ha).

In the grain-row crop rotation of the northern forest-steppe of the Kuznetsk basin, when using red clover, not only the preservation, but also the improvement of soil fertility occurs, due to the introduction of organic matter when harvesting clover for seeds, grain crops and the mineralization of their root system. In the variants without basic tillage, for 2.5 rotations of the crop rotation, the content of humus and mobile phosphates increased, the aggregate composition of the soil improved, while the density of the soil, depending on the cultivation technology, did not have significant differences, its indicators were in optimal values (1.08-1.11 g/cm^3). The yield of spring wheat in the grain-row crop rotation, depending on the conditions of the year, with zero tillage was higher in comparison with the deep moldboard by 15-50%. With a minimum tillage system in the same crop rotation, the yield of barley was 3.0-4.0 t/ha, potato was 4.0-6.0 t/ha [22].

The cellulolytic activity of the soil was higher with the preservation of stubble, straw and crop residues on the surface with a minimal mulch tillage system. The decomposition of linen in this variant was at the level of 8.5%, after the combined deep processing system at 5.6%, combined minimum at 5.3%, deep moldboard at 3.0% [23].

The main factor in the formation of the yield of spring wheat in the grain-fallow crop rotation is the moisture supply of plants during the periods of sowing on full tillering (r = 0.9579), the beginning of earing on wax ripeness (r = 0.9611; R = 0.9500). The biological activity and aggregate composition of the soil had a positive effect on the yield of wheat. A direct correlation between these factors and the crop yield was determined (r = 0.6366-0.7298, r = 0.6343-0.7103, respectively). The development of root rot (*Bipolaris sorokiniana* (Sacc.) Shoem) had a negative impact on the formation of wheat yield (r = -0.4808).

It has been established that the tillage systems (72.4%), the predecessor (22.0%) had a significant impact on the yield of spring soft wheat in combination with the identified factors. The optimal conditions in the agrocenosis of spring wheat for the formation of its yield over the years of research were identified for green manure fallow with minimal moldboard and deep moldboard tillage systems (2.72 and 2.78 t/ha, respectively), which is 0.55 and 0.51 t/ha higher in comparison with similar treatments for the predecessor pure fallow (control). The advantage in terms of economic evaluation is the minimum moldboard tillage system with a profitability of 193.6% and a cost of 1 ton of grain of 5.0 thousand rubles [24].

According to experts, wheat as an agricultural crop has the highest potential for the development of organic farming in the regions of Siberia. In the domestic market, the demand for wheat grown using organic farming technologies for therapeutic and prophylactic purposes in the recreational sector is steadily growing. The most promising export markets for the regions of Siberia (primarily the Altai and Krasnoyarsk Territories, Novosibirsk and Omsk Regions) are India and China [25].

4 Conclusion

In organic farming, crop rotation plays a key role in realizing the productive potential of varieties, maintaining soil fertility, especially in regulating the regime of organic matter, the phytosanitary state of crops, and protecting soil from erosion. Organic farming in Siberia can only be carried out under conditions of crop diversification (increasing biodiversity in crops of winter rye, cabbage, leguminous grasses and grain legumes), reducing the intensity of mechanical impact on the soil, applying organic fertilizers and plant residues of crops, green manure.

Adaptation of agrotechnology of crop production in organic farming in Siberia is to reduce the impact of negative factors on the growth and development of cultivated plants in specific soil and climatic conditions based on resource-saving tillage systems using renewable bioresources in crop rotations, ensuring a balance of the necessary nutrients and reducing the impact of harmful organisms.

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