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The effect of biologized crop rotations on wheat yield in the forest-steppe of Tuva

V N Zhulanova¹, O A Ulyanova², O V Rylova¹ and Sh V Mongush¹

¹Tuvan State University, Kyzyl, Russia

²Krasnoyarsk State Agricultural University, Krasnoyarsk, Russia

E-mail: zhvf@mail.ru

Abstract. The influence of various types of fallow on the fertility of the textural carbonate agrochernozen and wheat yield in the conditions of the forest-steppe zone of Tuva was studied. It is shown that in the forest-steppe natural-climatic zone of the region of siderite fallows, the green manure melt fallow has the highest efficiency. In the forest-steppe in dry years, one of the best predecessors is pure fallow, but the highest yield of spring wheat was obtained after pure fallow with the introduction of manure and green manure traverses. The economic efficiency of various types of fallows in the territory of the Tuva Republic has been determined.

1. Introduction

The territory of Tuva is located in difficult climatic conditions. The main objective of the region is to obtain food grains. The yield and quality of grain is determined by the state of soil fertility and the level of agricultural technology used. With the long-term cultivation of grain crops in the agricultural area there is a negative balance of humus [1].

In Siberian steppe and forest-steppe landscape zones the effect of clean, green manure and occupied fallows on the preservation and restoration of soil fertility, the processes of water and wind erosion, crop yields has been studied [2-6].

Chestnut soils are the main arable fund in agriculture of the Republic of Tuva; they are, as a rule, thin and weakly humus [1]. During the years of intensive use, these soils significantly worsened their fertility as a result of dehumification and the development of erosion processes. The reduction of nutrients in agricultural soils negatively affects the productivity of plants. The introduction of organic fertilizers, green manure, crop and plant residues contribute to the improvement of soil fertility, improve physical properties and enrich the newly formed humus. Therefore, the definition of methods of conservation, restoration and improvement of soil fertility, the study of the effect on the productivity of various predecessors, is an important task, which has important theoretical and practical importance. The purpose of the work is to study the effect of various types of fallows on soil fertility and the yield of spring wheat on agrofurnace of textural-carbonate in the conditions of the forest-steppe of Tuva.

2. Objects and methods of research

The objects of research were agrosol and three-field biologized crop rotations of the forest-steppe natural climatic zone of Sosnovka Taedinsky district of Tuva. To study the chemical and physicochemical properties of the soil, the authors laid soil pits, where soil samples were taken from the genetic horizons. The chemical and physico-chemical indicators of the soil were determined at the Tuva



National Filling Station: humus - according to Tyurin (GOST 26213-91), mobile phosphorus and potassium - according to Machigin in TsINAO modification (GOST 26205-91), pH of the water extract - potentiometric method (GOST 26423-85), absorption capacity - according to Bobko-Askinazi (GOST 17401-84), particle size distribution - according to Kachinsky.

During the years of research, the hydrothermal conditions of the summer period differed. The total precipitation over the growing season was 205–404 mm, the sum of active temperatures above 10 °C was 1577–1935 °C, and the sum of effective temperatures above 5 °C was 1198–1900 °C. The average temperature for the period 2009–2014 was not much different in years (14.5–15.5 °C). The precipitation over the growing season in 2009 was 225 mm, in 2010 - 205 mm, in 2011 - 208 mm, in 2012 - 232 mm, in 2013 - 404 mm, 2014 - 203 mm.

Experiment scheme: crop rotation No 1 grain (control): pure fallow (control) - wheat - wheat; No 2 grain-fallow: clean fallow + 30 t/ha of manure - wheat - wheat; No 3 sidereal: sidereal vapour (tributary) - wheat - wheat + tributary; No 4 sidereal: green manure fallow (peas) - wheat - wheat.

The experience is based on a threefold repetition, the placement of options - a systematic, accounting area of 515 m². The soil is agrochernozem texture-carbonate low-power, low-humus medium loamy. Green mass of clover was plowed in the flowering phase, peas - milky ripeness. Studies were conducted according to the methodology of field experience [7]. Economic calculations were carried out on flow charts. The data were processed by the dispersion-mathematical method.

3. Results and discussion

In recent years, farming techniques have been applied in agriculture, which make it possible to use natural resources economically and rationally [2, 8]. The underestimation of these factors leads to an increase in energy, material costs, cost and lower profitability.

According to V.I. Kiryushina [3] and A.A. Zhuchenko [4], the most important area of research in agriculture, which should focus the main efforts, is the study of biological productivity to justify farming systems most relevant to the types of natural environment, as well as the availability of material and energy resources.

In the Republic of Tuva, raising not only crop yields, but also soil fertility in field crop rotations are interrelated with the use of both internal soil resources and external (introduction of organic matter in the form of manure, crop residues, as well as cultivation in green manure rotations) [5, 8].

At present, couples in the structure of arable land of Tuva occupy no more than 29%. The need for clean fallow in Tuva is due to climatic conditions. Under the conditions of Tuva, spring wheat forms the highest yields in grain-fallow crop rotations due to better use and security of crops with spring moisture and mineral nutrition elements. However, frequent fallow treatment leads to changes in the physicochemical properties of the soil due to the increased mineralization of organic matter, which negatively affects the structure formation and the deterioration of growing conditions of field crops. Therefore, sidereal cultures are currently used to increase the production functions of agroecosystems [9, 10].

Before laying the experiment, the humus content in the textured carbonate soil texture is 3.46% (table 1). After two rotations of the crop, the content of humus in the soil increased in the variants where manure was introduced (grain crop rotation) and in green manure pairs, and decreased in the control one. Soil fertility increased due to the soil replenishment with plant and root residues of cereals and the introduction of organic fertilizers. With the introduction of manure up to 12 t/ha of organic matter enters the soil, the clover of green fertilizer leaves behind about 6.5 t/ha, peas - 5 t/ha.

The humus content decreased by 0.46% in the control, possibly due to the rapid mineralization of plant residues with frequent tillage, as well as due to the low intake of plant phytomass during the summer.

According to the research of A.P. Batudaeva, B.B. Tsybikova, N.A. Bazarzhapova et al. [11], in the arid conditions of Western Transbaikalia on chernozem with a few humus, the yield of spring wheat over occupied fallows is practically not inferior to productivity over a clean pair, and also increases the deflationary stability of the soil.

Table 1. The main indicators of chemical and physico-chemical properties of agrochernozem textural-carbonate.

Crop rotation	Sampling year	Humus, %	pH _{H2O}	EKO, mg-mEq/100 g	mg/kg		
					Nitrate nitrogen	P ₂ O ₅	K ₂ O
1 – Crop fallow (control)	2008	3.46	7.1	24	20	18	135
	2014	3.00	7.1	22	12	10	124
2 – Crop fallow	2008	3.46	7.1	21	24	20	137
	2014	3.51	7.1	24	43	26	210
3 - Sideral (clover)	2008	3.46	7.1	22	22	20	138
	2014	4.00	7.1	24	47	27	251
4 - Sideral (peas)	2008	3.46	7.1	24	19	18	140
	2014	3.59	7.1	23	36	19	243

According to the materials of A.N. Kuzminykh [9], siderata peas form a green mass of up to 28 t/ha with a high nutrient content, which contributes to an increase in soil fertility.

According to our research, it has been determined that the provision of soils with mobile forms of nutrition is different, both by year and in variants of experience. In the control crop rotation in 2008, the availability of mobile P₂O₅ is average, K₂O is low, and in 2014 it is very low and low, respectively. In other variants, at the beginning of the experiment, the content of mobile phosphorus is average, of exchangeable potassium is low, and in 2014 it is average of both phosphorus and potassium. The cation exchange capacity is 21-24 mEq/100g, where Ca⁺⁺ dominates.

As a result of research, it has been established that predecessors have an impact on the yield of spring wheat. In the forest-steppe natural zone of Tuva, one of the good predecessors is pure fallow, which we took as a control. For two crop rotations, the average yield of spring wheat for a pure pair without fertilizers (control) was 1.97 t/ha (table 2).

Table 2. The influence of predecessors on the yield of spring wheat, t/ha.

Predecessor	Average for 2009-2014	
	t/ha	±
1. Pure fallow (control)	1.97	-
2. Pure fallow + manure 30 t/ha	2.32	+0.35
3. Sideral fallow (clover)	2.20	+0.23
4. Sideral fallow (peas)	2.14	+0.17
HCP ₀₅	-	0.16

For 2009-2014 the maximum increase in wheat yield in fallows was obtained for a clean pair with the introduction of manure (option 2), and the minimum - for pea sideral fallow. In the conditions of the forest-steppe of the region, all fallows were effective for the fallow-occupying crop, where the yield increase is higher than HCP₀₅. Plowing leguminous crops for fertilizer contributed to an increase in the yield of spring wheat by 8–16%.

Our data are confirmed by studies of A.S. Sotpa [5], on moderately humid years on zonal soils of the republic, the yield increase of grain crops after green manure was 0.20–0.24 t/ha and only in dry years, green manure gives way to a clean fallow.

Legumes in symbiosis with nodule bacteria accumulate in the soil nitrogen compounds that are available to plants. The best siderat in the conditions of Tuva is the tributary. Sideral cultures positively affect the chemical and physicochemical properties of the soil, improve the structure, and evenly and balancedly replenish the soil with nutrients.

According to the research results of K.I. Dovban [10], the greatest profitability is achieved when plowing the whole plant mass of siderat (29-56%), it was slightly less when plowing root and crop

residues (10-47%). As confirmed by our research, the profitability level is 1.5 times higher when growing wheat by sidual pairs and 1.3 times - for clean pairs with organic fertilizers than in the control variant, and the production cost is 1.2 and 1.1 times less, respectively (table 3). The lowest energy costs of production of 1 tonne of products are noted in crop rotations with a bottom ferry - 2.77 GJ/t or 14% less than in the control variant and 9-12% lower in other variants of experience compared to the control.

Table 3. Economic efficiency of spring wheat cultivation.

	Pure fallow (control)	Pure fallow + manure 30 t/ha	Sidual fallow (clover)	Sidual fallow (peas)
Yield from 1 ha, t	1.97	2.32	2.2	2.14
Expenses for 1 ha, rubles	11884	11911	11911	11897
Energy spending, GJ/t	3.2	3.15	2.77	3.04
Production cost from 1 ha, rubles	17730	20880	19800	19260
Net cost, rub/t	6032	5134	5414	5559
Net profit from 1 ha, rubles	5846	8969	7889	7363
Profitability, %	49	75	66	62

4. Conclusion

Siderats (clover, peas) and the introduction of manure in the forest-steppe of Tuva for 6-10 years contribute to an increase in the content of humus by 0.13-0.46% ($HCP_{05} = 0.08\% - 0.41\%$).

To increase the yield of spring wheat in forest-steppe conditions, green manure pairs and clean fallows with manure are effective. In dry and moderately moistened years, the yield was 2.14-2.32 t / ha, which is 0.17-0.35 t / ha more than after pure steam (control).

The best predecessors for wheat in the forest-steppe climatic zone are sideral pairs in moderately humid years, and clean pairs in arid years.

The highest economic indicators were provided by the crop rotation unit for green manure - wheat and pure fallow with manure - wheat, with a profitability level of 66-75% and with the lowest production energy costs per a ton of wheat 2.77-3.15 GJ.

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