The influence of green-manured and complete fallow on soil fertility and wheat productivity in Tuva

V N Zhulanova¹, O A Ulyanova², T F Zharova¹ and A D Sambuu³

¹Tuva State University, 36 Lenin St., Kyzyl, 667000, Russia
²Krasnoyarsk State Agrarian University, 90 Mira Av., Krasnoyarsk, 660049 Russia
³Tuva Institute for the exploration of natural resources Siberian Branch of the Russian Academy of Science, 117A Internatsional’nyaya St., Kyzyl, 667007, Russia

E-mail: zhvf@mail.ru

Abstract. The influence of complete, seeded, and green manured fallows on the chemical and agrophysical properties of dark chestnut soil in the conditions of the forest steppe of Tuva is studied. It was determined that the humus content in green manured fallows increased by 0.13% – 0.64% during rotation. It was revealed that various types of fallows do not have a strong effect on the density of composition and structural composition of dark chestnut soil. The highest biological activity of soils is observed in crop rotations with green manured and complete manured fallows with organic fertilizers. It was determined that complete manured fallow with manure and green manured fallows increase spring wheat yield.

1. Introduction

Tuva is a mountainous area. Steppe landscapes are located on the bottoms of intermountain basins at heights of 500-1200 m [1]. The climate in the steppe territories is sharply continental. The average annual temperature in the Tuvan steppes is negative, which significantly distinguishes them from the steppes of the European Plain and Kazakhstan but brings them closer to the steppes of Central and Eastern Siberia.

Land resources are one of the main assets in agricultural production. The rational use of soil resources is of great importance in the economy of the region. Obtaining agricultural products is associated precisely with the fertility of the soil cover and the conditions for its use. In recent decades, in agriculture, green manure is used as sources of increasing soil fertility and obtaining stable crop yields in addition to manure [2, 3, 4, 5, 6].

The soil cover of the region’s steppe in the second half of the 20th century was subjected to intensive agricultural use, which led to an increased manifestation of degradation processes and a decrease in the humus state of soils [7]. Erosion disturbed the natural equilibrium prevailing in soils, as a result of which the content and reserves of humus decreased.

In Tuva, farming is carried out in difficult bioclimatic conditions. However, there is a clear need for food grain and livestock feed. The increase in yield and gross yield of crops is determined by the state of soil fertility and the level of agricultural technology used. With intensive cultivation of field crops in the last century, a negative humus balance of -845 kg / ha is observed on arable land [7]. Therefore, the study of the chemical, physico-chemical and biological properties of agricultural soils, obtaining
modern materials of the qualitative state of agricultural land is relevant. In the region, the use of green manure is not yet sufficiently substantiated, which is an important factor in improving soil fertility.

The purpose of the work is to study the effect of various types of fallows on the chemical and physico-chemical properties of dark chestnut soil and the productivity of spring wheat in the conditions of the forest-steppe zone of Tuva.

2. Objects and research methods

The studies were carried out in three-field rotation according to the field experiment methodology [8]. The objects of research were dark chestnut soils of village Sosnovka of the Tandinsky district of the Ulug-Khem basin.

Humus was determined according to Tyurin, mobile phosphorus and exchangeable potassium were determined according to Machigin, and nitrate nitrogen was determined by the ionometric method (GOST - 20951-86). The soil density was determined according to N.A. Kachinsky, the structural composition of the soil - according to the method of N.I. Savvinov. The biological activity of the soil was studied by linen to a depth of 0-20 cm [9]. The research results were processed by statistical methods of variance analysis [8] using software packages Microsoft Excel.

During the study, the weather conditions of the growing season varied significantly from year to year. During the study period, the amount of precipitation during the growing season was 203-315 mm, the sum of active temperatures above 10 °C was 1577-1924 °C, and the sum of effective temperatures above 5 °C was 1198-1899 °C. The amount of precipitation during the growing season in 2014 was 203 mm, in 2015-315 mm, in 2016-208 mm.

The soil cover of the experimental plot is represented by dark chestnut light loamy soil. At the beginning of the experiment, the humus content in the arable layer of the soil is low (3.30-3.46%), total nitrogen - 0.20%, mobile phosphorus - 18-20 mg / kg of soil, exchangeable potassium - 120-148 mg / kg of soil.

The study of the influence of fallow types on soil fertility and spring wheat productivity was carried out in three-field crop rotation: 1. grain-fallow (control): complete fallow (control) - wheat - wheat; 2. grain - fallow: complete fallow + 30 t / ha of manure - wheat - wheat; 3. green manure: green manure (melilot) - wheat - wheat + melilot; 4. cereal with seeded: clover for green mass - wheat - wheat + clover; 5. green manure: green manure (peas) - wheat - wheat.

Cloves were plowed for green manure in the flowering phase, and peas in milk ripeness.

3. Results and discussion

Soil fertility is considered to be all the properties and processes that occur in the soil, which provide plants with nutrients. Changes in fertility occur due to intensive anthropogenic impact on the soil. In the cultivation of crops, the main place is occupied by such elements as tillage and fertilizing. The main reason for the decline in the fertility of agricultural soils is the insufficient use of fertilizers.

During the intensification of agriculture in Tuva (1980-1990), the use of mineral fertilizers reached 42.1-49.1 kg ai / ha, organic fertilizers 0.60-0.85 t / ha [7]. Currently, mineral fertilizers are applied in the amount of 0.1 kg a.a. / ha, and organic fertilizers - 0.2-0.6 t / ha [10]. Therefore, under these conditions, there is an annual deficit in the balance of humus. In the region, manure is used to preserve and increase soil fertility. Break crops contribute to the intensity of humus accumulation and humus reserves, and in Tuva it is a clover [5, 6].

The data of the initial survey before laying and after rotation of crop rotation make it possible to trace how the chemical and physicochemical properties of soils have changed. At the beginning of the study, the humus content in the upper layer of dark chestnut soil is 3.30-3.46% (table 1). After passing the rotation of the crop rotation, the humus content increased in the grain-fallow by 0.20%, green sweet clover-by 0.64%, green pea-by 0.13%, and decreased in the grain-control by 0.46%. The humus content remained at the same level in the crop rotation with grain occupied by fallow (option 4). This can be explained by the fact that the largest amount of crop and root residues leaves clover for green manure...
up to 6.3 t / ha, peas - 5.0 t / ha, manure application - up to 12 t / ha of organic matter. Melilot on the green mass gives 3.2 t / ha of organic matter.

The decrease in humus in a crop rotation with complete fallow without the application of organic fertilizers (control) is probably due to the rapid mineralization of organic matter during annual soil cultivation.

Quantitative estimates of the nitrate nitrogen content and the cation exchange capacity in soils depend on the humus content and particle size distribution. The cation exchange capacity is 21-24 mEq / 100g. The composition of the exchange cations is dominated by Ca + 2.

The provision of soils in 2008 with mobile P2O5 is average, and in 2016 in the control fallow grain and grain with seeded fallow it is exceptionally low, in the rest it is average. In 2008, the exchange K2O security is average, and in 2016 in green and grain-fallow with manure 30 t / ha crop rotation is high.

**Table 1.** The main indicators of dark chestnut soil chemical and physico-chemical properties.

| Crop rotation     | Year of sampling | Humus, % | pH H2O | ECO mEq /100 g | mg / kg Nitrate nitrogen | P2O5 | K2O |
|-------------------|------------------|----------|--------|----------------|-------------------------|------|-----|
| 1 - Grain fallow  | 2008             | 3.46     | 7.1    | 24             | 20                      | 18   | 138 |
| (control)         | 2016             | 3.00     | 7.1    | -              | 12                      | 10   | 104 |
| 2 – Grain fallow  | 2008             | 3.31     | 7.1    | 21             | 24                      | 20   | 137 |
|                   | 2016             | 3.51     | 7.1    | -              | 43                      | 26   | 210 |
| 3 - Green (sweet clover) | 2008         | 3.36     | 7.1    | 22             | 22                      | 20   | 148 |
|                   | 2016             | 4.00     | 7.1    | -              | 47                      | 27   | 251 |
| 4 - Seeded with cereal | 2008        | 3.30     | 7.1    | 21             | 15                      | 18   | 120 |
|                   | 2016             | 3.30     | 7.1    | -              | 12                      | 10   | 120 |
| 5 - Green (pea)   | 2008             | 3.46     | 7.1    | 24             | 19                      | 18   | 150 |
|                   | 2016             | 3.59     | 7.1    | -              | 36                      | 19   | 243 |

The influence of different types of fallows on the dark chestnut soil density of the composition was considered. Before laying the experiment, the addition density in the 0–10 cm layer varied within 1.33–1.43 g / cm³, and in the 10–20 cm layer — 1.35–1.41 g / cm³. In the control variant, the addition density in the 0–10 cm layer was 1.33 g / cm³ in the 10–20 cm layer — 1.35 g / cm³; in other variants, 1.34–1.43 and 1.37–1.41 g / cm³, respectively.

According to the precursor to complete fallow (option 1), the soil compaction density in the 0-20 cm layer under wheat slightly increased by 2-4%, and in other cases it decreased by 3-8%. The largest decrease in the density of addition was noted after pea green manure fallow (option 5) (8%) and complete fallow + manure 30 t / ha (option 2) (4%). The loose state of the arable layer of soil under wheat in these variants is due to annual tillage that impedes self-compaction, as well as the effect of rotted manure and an annual leguminous crop (pea).

Dark chestnut light loamy soil in various types of crop rotation in terms of composition and structural composition is characterized by favourable agrophysical properties.

A qualitative assessment of the structural state of soils is assessed by the content of aggregates of agronomically valuable fractions (AVF) of 10-0.25 mm in size. In the arable layer of dark chestnut soil in all test variants, the content of AVF is 64-68%, which indicates a good state of aggregation (table 2). The structure of the experiment variants does not change significantly and remains in the same category according to the content of the AVF.

**Table 2.** The structural composition of dark chestnut soil in a layer of 0-20 cm, %.

| Predecessor          | Diameter of fractions, mm | Structural coefficient |
|----------------------|---------------------------|------------------------|
|                      | >10  | 10-0.25 | <0.25 |                    |
| 1. Complete fallow (control) | 22.5 | 64.2    | 13.3  | 1.8                 |
| 2. Complete fallow + manure 30 t / ha | 20.2 | 67.2    | 12.6  | 2.0                 |
The largest amount of AVF is contained in the arable soil layer in the variants with seeded fallow and clover green manure (67.8–67.9%), the smallest - in the grain-fallow rotation (control) (64.2%).

The structural coefficient is within 2, which also indicates a good state of aggregation of the soil.

Our data are confirmed by previous studies of V.N. Zhulanova, N.L. Kurachenko [11], that dark chestnut and chestnut soils of light loam and sandy loam granulometric composition have excellent structure. In a layer of 0–20 cm of these soils, the content of aggregates of agronomically valuable fractions reaches 72–94%. Further, with depth, the level of structure decreases significantly. Depending on the subtype of soils, particle size distribution and the nature of their agricultural use, it varies from excellent to satisfactory. Dark chestnut loamy soils have optimal composition only in the 0-20 cm layer (1.08-1.20 g / cm³). Below with depth, intensive and uniform impregnation with carbonates contributes to soil compaction to 1.21-1.29 g / cm³.

When growing crops, soil fertility also depends on the activity of beneficial microflora and other components of soil biota. The level of biota activity in the soil is supported by the crop residues of annual plants, the cultivation of perennial grasses, green manure, and the organic fertilizers application.

An addition to the characterization of the soil physicochemical properties is the determination of its biological activity. The cellulose activity of dark chestnut soil was studied using the application method of decomposition of linen for 45 days.

In all cases, the intensity of fibre destruction is weak. The degree of decomposition of linen in the experimental versions of the experiment was 1.3-1.6 times higher than in the control (complete fallow). The highest degree of web decomposition was observed in green pea (17.2%) and clover green (16.4%) pairs, the smallest - in complete fallow (control) (10.8%). In other variants, the degree of decomposition differs little from each other (14.5–14.8%). The difference in the intensive decomposition between the options can be explained by the method of incorporating fertilizers into the soil, as well as by the moisture of the plowed organic matter.

As a result of research, it was found that precursors affect the yield of spring wheat. Complete fallow served as control, as one of the best predecessors for the forest-steppe zone of the region. The average yield during the spring wheat experiment for the control without fertilizers was 19.1 c / ha (table 3).

On average, over the years of research, the highest wheat yield in fallows was obtained in option 2 after complete fallow + manure 30 t / ha. The minimum yield of wheat was obtained after clover seeded fallow. The clover green manure proved to be effective for the fallow-grown crop, and wheat gave an increase of less than HCP₀₅ for the pea green manure.

| Predecessor | Average for 2014-2016 c / ha |
|-------------|-----------------------------|
| 1. Complete fallow (control) | 19.1 ± -            |
| 2. Complete fallow + manure 30 t / ha | 21.3 ± +2.2  |
| 3. Green fallow (sweet clover) | 21.0 ± +1.9    |
| 4. Seeded fallow (sweet clover on green mass) | 18.5 ± -0.6 |
| 5. Green fallow (pea) | 20.4 ± +1.3 |
| HCP₀₅ | - ± 1.4 |

4. Conclusion

Green fallow and complete fallow in the Tuva forest-steppe conditions increase soil fertility during rotation by 6-19%. Fallow with sweet clover preserves the fertility of the soil, and complete fallow without the application of organic fertilizers reduces.
Different types of predecessors during one rotation of the crop rotation do not significantly affect the agrophysical properties of dark chestnut light loamy soil.

The biological activity of soils in green-manured fallow is 1.3–1.6 times higher than in complete fallow (control).

The best predecessors for spring wheat in the forest-steppe landscape-climatic zone of Tuva are green manured and complete fallows with manure. Clover and green manured with pea fallows were not highly effective.

Acknowledgments

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