Characteristics of soil tillage for rice after alfalfa

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Abstract. The purpose of the research was to study the effect of harvesting time and methods of using alfalfa biomass on soil fertility and rice yield at different times of the main tillage. Field experiments were conducted in the Kizlyar district of the Republic of Dagestan according to the scheme: 1. autumn plowing after harvesting the 3rd mowing of alfalfa 3 years of use, control; 2. the overlapping of chopped green mass of alfalfa 3rd cut alfalfa 3 years of use; 3. spring plowing after harvesting the 1st cut alfalfa 4 years of use; 4. the overlapping of chopped green mass of alfalfa 1st cut alfalfa 4 years of use. The results shown that the best time for cutting the layer of perennial alfalfa is spring plowing of the green mass of alfalfa 1 mowing, which allows you to get a yield of 6 t/ha without reducing the quality indicators of rice grain. The data on the rice yield shows that in the spring tillage the yield was 5.41 t/ha, and in the autumn tillage only 4.91 t/ha. Carrying out sideration at both terms of the main tillage contributed to an increase in yield by 0.81-1.11 t/ha.

1. Introduction
In the Republic of Dagestan, rice production has always been one of the leading areas of crop production, but the difficult economic conditions of agricultural producers have led to a sharp 3.5-fold reduction in the area (7.3 thousand hectares in 2004) and a 1.5-fold decrease in crop yield (up to 2.1 t/ha). State support in recent years had a significant impact on the revival of the industry and by 2019 the area has increased to 21.5 thousand hectares with the yield of 4.4 t/ha, and by 2025 150 thousand tons of grain per 29 thousand hectares should be produced.

Due to the intensification of rice farming in the Republic of Dagestan, currently the main focus is on improving the technology of rice cultivation in order to increase the productivity of reclaimed hectares based on the use of resource-saving cultivation technologies. One of the directions of resource saving, increasing soil fertility and improving the economic situation in rice production is field sideration, which reduces the chemical load on a hectare of arable land and increases the environmental safety of the technology [1, 2].

In the region, the degradation of landscapes with rice crop rotations is observed, so a special approach to these ecosystems is required [3, 4]. One of the solutions is the introduction of resource-saving, so-called sparing basic soil treatments into production [5, 6, 7].

One of the main elements in the technology of rice cultivation on saline soils with a heavy granulometric composition of lowland Dagestan is high-quality tillage aimed at creating an optimal structure of the arable layer, careful leveling and creating a favorable phytosanitary environment, especially when cultivating rice without the use of herbicides [8, 9, 10]. In this regard, it is very
important to maximize the use of phytomeliorative role of alfalfa as more than just a biological drainage and significantly affect phytosanitary and agrochemical indices of soil fertility.

2. Materials and methods
Currently, there is no consensus on the terms of alfalfa use in rice crop rotations, and in recent years the duration of alfalfa use in rice farms of the republic has increased to 3-4 years. Therefore, the main goal of the research was to study the impact of harvesting time and methods of using alfalfa biomass on soil fertility and rice yield at different times of basic tillage.

The field experiments were carried out in the pilot production farm "Lenin's Way" of the Kizlyar district of the Republic of Dagestan according to the following scheme:
1. autumn plowing after harvesting the 3rd alfalfa mowing of the 3rd year of use, control;
2. plowing the crushed green mass of alfalfa of the 3rd alfalfa mowing of the 3rd year of use;
3. spring plowing after harvesting the 1st alfalfa mowing of the 4th year of use;
4. plowing of the crushed green mass of alfalfa of the 1st mowing of alfalfa of the 4th year of use.

The soil of the experimental site is meadow-chestnut heavy loam, humus content - 2.7%, total nitrogen - 0.21-0.3%, mobile phosphorus according to Machigin - 18-22 mg/kg, exchange potassium according to Protasov - 380-430 mg/kg of soil, pH = 7.3, rice variety - Liman.

3. Results and discussion
The processes that occur in the soil as the result of decomposition of the alfalfa green mass can be observed by the content of the main nutrients in the soil. It was found out that regardless of the variant, after flooding the rice bay with water, the content of nitrate nitrogen in the soil layer of 0...0.2 m decreased and at the beginning of tillering was detected only in the form of "traces". After dumping water from the rice bays and harvesting the rice, nitrates reappeared in this soil layer, which is associated with improved aeration conditions and restoration of the nitrification process (Table 1).

| Variants of the experiment | Timing of soil sampling | before rice sowing | beginning of tillering | stem elongation | after harvesting of rice |
|----------------------------|-------------------------|-------------------|-----------------------|----------------|-------------------------|
|                            | Nitrate and ammonium nitrogen* | 25.0/15.4 | traces/22.0 | traces/21.0 | 31.8/12.0 |
| 1                          |                          | 26.4/17.0 | traces/30.6 | traces/22.5 | 36.5/19.0 |
| 2                          |                          | 25.8/16.2 | traces/34.0 | traces/30.0 | 35.0/13.0 |
| 3                          |                          | 26.7/18.3 | traces/38.7 | traces/36.5 | 38.0/22.4 |
| 4                          |                          | 17.0/400  | 24.2/440   | 18.5/410    | 15.0/390    |
|                            | Mobile phosphorus and exchange potassium** | 18.7/420  | 38.4/460   | 32.1/430    | 29.0/420    |
| 2                          |                          | 21.5/400  | 35.0/460   | 30.5/420    | 25.0/380    |
| 3                          |                          | 23.2/420  | 39.1/490   | 34.0/460    | 30.0/430    |

* In the numerator - nitrate nitrogen, in the denominator - ammonium nitrogen.
** In the numerator - mobile phosphorus, in the denominator - exchange potassium.

The dynamics of the content of ammonia nitrogen in the soil showed a completely different nature. So, before sowing rice the variant after plowing alfalfa of the 3rd mowing of the 3rd year contained: nitrate nitrogen 25.0, and ammonia nitrogen 15.4 mg/kg of soil; when plowing alfalfa crushed green mass of the 3rd mowing in autumn, these indicators were 26.4 and 17.0 mg/kg of soil, i.e. they were higher by 1.4 and 1.6 mg/kg of soil, respectively. In the variants with spring plowing after alfalfa of the 1st mowing of the 4th year and plowing of alfalfa crushed green mass of the 1st mowing, these indicators were even higher. It should be noted that at the beginning of rice tillering, the content of nitrate nitrogen in the soil layer of 0-0.2 m was practically reduced to zero, and the soil under the rice contained only...
the ammonia form of nitrogen. At the same time, the largest amount of ammonia nitrogen was contained during the spring tillage, and the maximum amount (38.7 mg/kg of soil) was contained during soidation. By harvesting, due to the absorption of plants, the content of ammonia nitrogen in the arable layer decreases, but remains higher during spring tillage. Along with this, due to the restoration of nitrification processes, the content of nitrate nitrogen sharply increases, which becomes more than ammonia by 15.6-24.5 mg/kg of soil.

The highest values of mobile phosphorus were 38.4 and 39.4 mg/kg of soil and exchangeable potassium 460 and 490 mg/kg of soil, and they were also observed when the alfalfa crushed green mass was plowed in autumn and spring, i.e. in the second and fourth variants of the experiment and, despite their significant absorption by rice crops, the maximum values (39.1 and 490 mg/kg of soil) these elements contents were noted at the beginning of the tillering phase.

The number of fertile tillers per area unit determines the grain crops yield. The studied terms of plowing the alfalfa layer had a significant impact on the field germination of seeds and the density of plant standing (Table 2). On average, for 3 years of research, the field germination of seeds in the variant where plowing was carried out after harvesting alfalfa of the 3rd mowing in the autumn was 35.4%, when plowing crushed green mass, the 3rd mowing in the autumn, it was 36.2%, or 0.8% higher. When plowing after harvesting alfalfa of the 1st mowing of the fourth year in the spring, the field germination of seeds was 35.8%, and when plowing the crushed green mass of the 1st mowing of the fourth year in the spring, it was the highest and made 37.5%. The maximum number of plants - 187 pcs/m² was also observed during the spring sideration of the alfalfa crushed green mass of the 1st mowing of the 4th year. It should be noted that some rice plants die during the growing season as the result of damage by pests, diseases and frequent winds. In our research, the number of plants from the tillering phase to the milky-waxy ripeness of grain decreased by an average of 14.5...15.4%.

| Variants of the experiment | Field seed germination, % | Number of plants, pcs/m² | The number of productive stems, pcs/m² |
|---------------------------|--------------------------|--------------------------|---------------------------------------|
| 1. Autumn plowing after harvesting of the 3rd mowing of the 3rd year alfalfa, control | 35.4 | 177 | 304 |
| 2. Autumn green manuring of the crushed green mass of alfalfa of the 3rd mowing of the 3rd year | 36.2 | 181 | 345 |
| 3. Spring plowing after the 1st mowing of the 4th year alfalfa | 35.8 | 179 | 322 |
| 4. Spring green manuring of crushed green mass of alfalfa of the 1st mowing of the 4th year | 37.5 | 187 | 394 |

Plant growth and productivity are primarily the result of photosynthetic activity. An important reserve for increasing the photosynthetic productivity is the optimization of plant architectonics, which provides better illumination of leaves of different tiers and reduces plant competition. This is important because the growth of individual plants in crops is largely limited by competition for sunlight. One of the main indicators that characterize the photosynthetic activity of plants is the leaf surface area, the size of which determines the absorption coefficients of the solar radiation energy falling on the crop.

Our studies showed that, despite the absence of a significant difference in the onset of plant development individual phases and the duration of the growing season, the studied terms of plowing the alfalfa layer (autumn and spring) had a significant impact on the formation of the leaf surface area, the photosynthetic potential (PP) of crops and the net productivity of photosynthesis (Table 3).
Table 3. Rice crops photosynthetic activity at different periods of plowing.

| Variants of the experiment | Leaf area, thousand m\(^2\)/ha | Photosynthetic potential, million m\(^2\)/ha × days | The accumulation of organic matter, t/ha | Net photosynthetic productivity, g/m\(^2\) × day |
|----------------------------|--------------------------------|---------------------------------------------------|--------------------------------------|-----------------------------------------------|
| 1                          | 35.4                           | 1.704                                             | 8.48                                 | 4.9                                           |
| 2                          | 36.2                           | 1.758                                             | 9.15                                 | 5.1                                           |
| 3                          | 35.8                           | 1.730                                             | 8.85                                 | 5.0                                           |
| 4                          | 37.2                           | 1.826                                             | 9.86                                 | 5.3                                           |

The maximum values of the leaf surface area were observed in the flowering phase in the second and fourth variants, where these indicators were 36.2 and 37.2 thousand m\(^2\)/ha, by the phase of waxy grain ripeness, the leaf surface area decreased by 14.7-15.2%.

The leaf surface area of plants is the main factor determining the photosynthetic potential of crops. In our research, those variants that contributed to achieving the largest leaf surface area of rice were also more effective for the photosynthetic potential of crops. In the variant where autumn plowing was carried out after harvesting alfalfa of the 3rd mowing of the 3rd year, the PP was 1.704 million m\(^2\)/ha × days, when plowing the crushed green mass of the 3rd mowing in autumn, this indicator was higher by 54 thousand m\(^2\)/ha × days more than in the autumn plowing and 28 thousand m\(^2\)/ha × days less than in the autumn plowing of crushed green mass. The maximum value of PP of the crops (1.826 million m\(^2\)/ha × days) was reached in variant 4, where there was spring sideration of alfalfa crushed green mass of the 1st mowing of the 4th year, which is 3.9-7.1% more than in other variant.

The terms of plowing the alfalfa layer had a significant impact on the accumulation of dry organic matter by rice crops. So, in the variant 1, where plowing was carried out after harvesting alfalfa of the 3rd mowing of the 3rd year in the autumn, the rice accumulated 8.48 t/ha by the phase of waxy ripeness of grain, and in the variant 2 the sideration carried out at the same time contributed to the increase in the accumulation of dry organic biomass by 0.67 t/ha. The highest dry organic mass (9.86 t/ha) of rice crops was accumulated in the 4th variant, where rice was sown after spring sideration. At the same time, the efficiency of spring sideration is higher than that of autumn by 0.34 t/ha, which is associated with a higher daily increase in the organic mass of rice sown on siders. The net productivity of photosynthesis as well as the accumulation of dry organic biomass was the highest 5.3 g/m\(^2\) × day - in the variant with spring sideration.

Increasing the gross rice harvest and increasing the economic efficiency of the industry is impossible without effective weed control. For rice crops, marsh and grass weeds are the most harmful. Due to the intensive growth of weeds and infestation of fields and crops, it is very difficult to meet the need of plants for moisture and nutrients. A sharp decrease in the yield on heavily infested crops is caused by the shading of cultivated plants by weeds and their absorption of a large amount of nutrients and moisture.

In our research, the infestation of rice crops was directly related to the time of plowing the alfalfa layer. So, in the 1st variant, where autumn plowing was carried out after harvesting alfalfa of the 3rd mowing of the 3rd year, there were 34 weeds per 1 m\(^2\), and in the 2nd variant, where rice was sown after autumn sideration of the alfalfa mass of the 3rd mowing of the 3rd year, the infestation decreased by 8.8%. In the variant 3, where plowing was carried out after the 1st mowing of alfalfa of the 4th year, the infestation decreased even more significantly – 17.7%, and the lowest number of weeds was observed on crops with spring sideration - 26 pcs/m\(^2\) (Table 4).

The yield is determined by the number of fertile tillers per unit of sown area, as well as the productivity of an individual panicle and the weight of the grain. Each of these elements is the result of the combination of many processes- the intensity of photosynthesis, root nutrition, movement of
nutrients, tillering of plants, their growth and development, deposition of nutrients in the reserve. One of the limiting factors of rice yield growth is its insufficient resistance to thickening, which is associated with intense competition for light in dense crops, as the result of which the productivity of the panicle sharply decreases, and its resistance to lodging decreases.

Table 4. Infestation of rice crops depending on the terms of plowing the alfalfa layer, pcs/m².

| Variants of the experiment | Total | Including |
|-----------------------------|-------|-----------|
|                            |       | Water grass | Reed | Bolboschoenus |
|                            |       | pc. | %   | pc. | %   | pc. | %   |
| 1. The autumn plowing after harvesting the 3rd alfalfa mowing of the 3rd year, control | 34   | 21  | 63.2 | 7   | 20.4 | 6   | 16.4 |
| 2. The autumn sideration of crushed green mass of alfalfa of the 3rd mowing of the 3rd year | 31   | 19  | 62.8 | 6   | 20.8 | 6   | 16.4 |
| 3. The spring plowing after the 1st mowing of alfalfa of the 4th year | 28   | 18  | 63.1 | 6   | 20.6 | 4   | 16.3 |
| 4. The spring sideration of crushed green mass of alfalfa of the 1st mowing of the 4th year | 26   | 16  | 63.2 | 5   | 20.6 | 5   | 16.2 |

The soil reserves of nutrients available to plants are usually insufficient to realize the genetic potential of rice varieties. Therefore, the use of siderates is one of the most important techniques and factors that contribute to the growth of crop yields.

The results of our research showed that the studied terms of plowing the alfalfa layer at different times of the main tillage (autumn, spring) had a significant impact on the yield of rice. Data on rice yield indicate that at the spring tillage the yield was 5.41 t/ha, and at the autumn tillage it was only 4.91 t/ha. Sideration during both periods of basic tillage contributed to the increase in yield by 0.81–1.11 t/ha, but the maximum yield was observed during the spring sideration and made 6.02 t/ha (Table 5).

Table 5. Yield and quality of Liman rice variety depending on the terms of plowing the alfalfa layer.

| Variants of the experiment | Yield, t/ha | Number of grains in a panicle, pcs | Weight of grain from 1 panicle, g | Weight of 1000 grains, g | Husk content, % | Vitreousness, % | Grain kernel content, % |
|---------------------------|-------------|----------------------------------|---------------------------------|------------------------|----------------|----------------|-----------------------|
| 1 | 4.91 | 68 | 2.2 | 32.1 | 16.5 | 87 | 75 |
| 2 | 5.72 | 69 | 2.3 | 33.4 | 16.4 | 88 | 80 |
| 3 | 5.41 | 68 | 2.2 | 32.6 | 16.5 | 88 | 82 |
| 4 | 6.02 | 71 | 2.4 | 33.8 | 16.4 | 90 | 85 |

When using green mass in autumn, the time interval between sideration and rice sowing increases to 6...7 months. During this period, the nitrogen contained in the green mass of alfalfa is prematurely mineralized and nitrates accumulate in the soil, and are washed out of the arable soil layer at the first flooding of rice. Apparently, for this reason, the rice yield in this variant decreased by 6.7% compared to the optimal variant.

The quality, as well as the yield of rice, is determined by the complex of all agrotechnical and technological operations during its cultivation, harvesting and post-harvest processing of grain. Studies showed that the studied terms of plowing the alfalfa layer had a significant impact on the quality of rice grain. The best indicators for vitreous content - 90%, grain yield - 71%, grain kernel content - 85% and
stress crack - 16% were achieved in the variant where rice was sown after spring sideration of alfalfa crushed green mass of the 1st mowing of the 4th year.

4. Conclusion
The use of crushed green mass of the 1st mowing alfalfa of the 4th year of use in the spring as a green fertilizer with subsequent soil preparation and rice sowing contributes to the increase in soil fertility and yield by 22.6% without reducing the quality indicators of rice grain.

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