The crops influence on the nutrients content in the soil dynamics in the crop rotation links

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Abstract. The article discusses the issues of the crop rotations productivity increasing due to the selection of high-ranking agricultural crops and the green manure crops use as independent and stubble crops. The input into the soil of nitrogen, phosphorus and potassium biologically related substances with organic matter of crop residues in different links of the crop rotation were analyzed. It is shown that the largest mass of organic matter enters the soil after winter wheat (12.4...12.6 t/ha). In Sarepta mustard cultivated for green manure, the total mass of organic matter entering the soil is up to 11.6 t/ha in stubble crops after winter wheat, and up to 12.6 t/ha in spring crops. The increased application of organic matter to the soil in the amount of 24.1 t/ha was ensured by green manure - Sarepta mustard, cultivated in the intermediate crops of the first and second fields of the crop rotation third link. The cultivation of Sarepta mustard as a siderate in the crop rotation led to the increase in the content of the main elements of plant nutrition in the soil.

1. Introduction

The challenge for global agriculture is to provide food for the world's growing population. A significant obstacle to this is the limitation of the agricultural land productivity growth, including due to climate aridization and the decrease in soil fertility.

Irrigation is an effective way to mitigate the arid climate change negative influence. Under irrigation conditions, negative soil processes are accelerated, which leads to depletion of the soil in humus and other nutrients. Long-term intensive exploitation of chestnut soils led to the imbalance between potential and effective fertility. According to the Rostov region soils agrochemical survey, during which the dynamics of organic matter in chestnut soils was studied, it was found that in chestnut soils during the irrigation over the past 30 years, the humus content decreased by 1% or more.

There is also an opinion that on irrigated lands the decrease in the humus content occurs in the first years of irrigation, as the soil moisture regime changes, then the humus content in the soil stabilizes, and later, subject to scientifically grounded farming systems, there is even a slight increase [1, 2, 3, 4].

The scientists established the decrease in the amount of humus in the topsoil and some increase in the subsoil, a change in the qualitative composition of humus by increasing the fraction of fulvic acids to the detriment of humic (more valuable) acids [5, 6, 7]. To reduce the negative impact, it is recommended to use organic fertilizers with high coefficients of humification: humic preparations, uglegumates, organomineral composts [8, 9, 10].

The main reason for dehumification remains the decrease in the cattle and other animals manure
application due to the sharp reduction in their livestock. Under the current conditions, it is possible to compensate for the lack of organic matter by incorporating the entire stubble organic mass of cultivated crops into the soil and sowing catch crops for use as green manure.

At the same time, we observe the change in the specialization of agricultural enterprises towards the production of market-demanded crops, which is reflected in the change in the composition and crops succession in crop rotation. For the reproduction of the chestnut soils fertility, the scientists propose to use 7 ... 8-field rotations, saturated with perennial grasses and intermediate crops, which, during the rotation, are able to create a positive balance of organic matter in the soil and humus [11, 12, 13]. According to Yu. A. Laptina et al. [14], when replenishing the deficit of organic matter in the soil, it is necessary to take into account that the efficiency of 1 ton of green manure for the crop rotation is equivalent to 1 ton of bedding manure. So, for example, 150 ... 200 centners of the legume crop green mass plowed in late autumn, in terms of their fertilizing effect, are equivalent to 20 tons of manure applied per hectare. Alfalfa contributes to the accumulation of 1.0 ... 1.5 t/ha of organic matter per year, and with 1 ton of chopped straw, rods and roots, up to 800 kg of organic matter, 15 kg of nitrogen, 8 kg of potassium are introduced. The most valuable catch crop is Sarepta mustard, which is capable to form a large organic mass in a short time, dissolving and converting insoluble nutrients into available ones for plants. It also has the ability to provoke the microflora pathogenic elements germination that are dangerous for potatoes; after germination, they die due to the absence of vegetative potato plants, on which they parasitize and develop [15].

We assume that the optimal selection of predecessors in crop rotations of high-ranking agricultural crops, as well as the use of green manure crops as independent and stubble crops, will increase the productivity of crop rotations and provide the increase in organic matter, as well as the main nutrients of agricultural plants in the soil.

2. Materials and methods

The research was carried out in LLC "Mayak" of the Semikarakorsk district in the Rostov region for 3 years (2011-2013) with alternation of various predecessors and crops in six crop rotations links, consisting of three fields. The predecessor of all links in the crop rotation in 2010 was winter wheat in terms of the perennial grasses layer turnover. The experiment scheme is shown in Table 1.

The cultivation of potatoes and other crops was carried out according to the technology recommended by the zonal farming systems. Option 1 (crop rotation link) was adopted for the control one. Watering was carried out by sprinkling with a sprinkler of DDA-100VH type. The experiment was repeated three times, the size of the plot was 550 m² (50 × 110 m), and the recorded one was 225 m².

At the spring planting period, the late Lasunok potato variety (Belarus), zoned in the Rostov region, was planted with the vegetation period under irrigation conditions from germination to ripening of 120 ... 127 days. During the summer planting, an early ripe variety Colette was planted with vegetation period from germination to technological ripeness under irrigation conditions of 80 ... 85 days.

Variants of crop rotation links were studied for the selection of favorable potato precursors, in order to ensure the effective and possible full use of solar radiation and create conditions for maintaining soil fertility.

The selection of crops in the crop rotation should provide sufficient income to achieve the level of production profitability on the extended basis.

All the organic mass of plants in the form of crop residues remaining after the main part of the harvest was embedded in the soil. Mustard was cultivated in intermediate crops to use green mass as green manure, so it was mowed, crushed and scattered over the soil surface, and after drying in 4 ... 5 days were imbedded and plowed by disc cultivators.

When setting up field experiments and conducting observations, the generally accepted methods of setting up and conducting field experiments were used. The types of agrochemical studies of the soil were determined according to E.V. Arinushkina, F.A.Yudin. In the experiments, the presence of nutrients in the soil layer of 0.4 m was determined in the spring before sowing (planting) of all crops and in the summer before planting potatoes. The analyzes of soil samples for the plot agrochemical
characteristics were carried out in the All-Russian Research Institute of Irrigated Agriculture analytical laboratory, humus and mobile forms of easily hydrolysable nitrogen - according to Tyurin, mobile phosphorus - according to Machigin, potassium photocolometrically in ammonium carbon extract - according to Protasov.

3. Results and discussion

The largest mass of organic matter enters the soil after winter wheat and Sarepta mustard for green manure. After winter wheat, it enters the soil 12.4–12.6 t/ha, including about 75% with straw and chaff and 25% with the remains of the root system. In mustard, the mass of organic matter entering the soil in stubble crops after winter wheat is up to 11.6 t/ha, and in spring crops - up to 12.6 t/ha in the third link (Table 1).

Table 1 - Biologically nitrogen, phosphorus and potassium substances related with crop residues organic matter entering the soil, 2011–2013.

| № of the link | № of the field, crop | Variant | Year | Received absolutely dry organic matter, t/ha | Intake of macronutrients to the soil, kg/ha |
|---------------|----------------------|---------|------|---------------------------------------------|-------------------------------------------|
| 1 Winter wheat | 1                   | 2011    |      | 12.4                                        | 98                                       |
| 2 Spring planting potatoes | 2 | 2012    |      | 5.0                                         | 116                                      |
| 3 Onion       | 3                   | 2013    |      | 4.2                                         | 42                                       |
| 1 Winter wheat | 4                   | 2011    |      | 12.4                                        | 98                                       |
| + mustard for siderate | 5 | 2012    |      | 11.8                                        | 421                                      |
| 2 Spring planting potatoes | 6 | 2013    |      | 5.3                                         | 124                                      |
| 3 Onion       | 7                   | 2011    |      | 12.4                                        | 98                                       |
| + mustard for siderate | 8 | 2012    |      | 11.5                                        | 411                                      |
| 2 Spring mustard for green manure + summer potatoes | 9 | 2012    |      | 12.6                                        | 450                                      |
| 3 Onion       | 10                  | 2013    |      | 4.4                                         | 44                                       |
| 1 Winter wheat | 11                  | 2011    |      | 12.4                                        | 98                                       |
| + mustard for siderate | 12 | 2012    |      | 11.5                                        | 411                                      |
| 2 Spring mustard for green manure + summer potatoes | 13 | 2012    |      | 12.6                                        | 450                                      |
| 3 Onion       | 14                  | 2013    |      | 4.4                                         | 44                                       |
| 1 Winter wheat | 15                  | 2011    |      | 12.4                                        | 98                                       |
| + mustard for siderate | 16 | 2012    |      | 11.6                                        | 414                                      |
| 2 Onion       | 17                  | 2012    |      | 3.8                                         | 38                                       |
| 3 Spring planting potatoes | 18 | 2013    |      | 6.4                                         | 149                                      |
| 1 Soybean     | 19                  | 2011    |      | 8.1                                         | 202                                      |
| 2 Spring planting potatoes | 20 | 2012    |      | 6.2                                         | 145                                      |
| 3 Onion       | 21                  | 2013    |      | 4.3                                         | 43                                       |
| 1 Soybean     | 22                  | 2011    |      | 8.1                                         | 202                                      |
| 2 Spring mustard for green manure + summer potatoes | 23 | 2012    |      | 10.6                                        | 378                                      |
| 3 Onion       | 24                  | 2013    |      | 4.3                                         | 43                                       |

The largest amount of organic matter was received for 3 years of research in the third link (48.4 t/ha, or on average 16.1 t/ha for 1 year, against 21.6 and 7.2 t/ha in the control one). The increased application of organic matter to the soil in the amount of 24.1 t/ha was ensured by green manure - Sarepta mustard, cultivated in the intermediate crops of the first and second fields of the crop rotation third link.

It was established that organic residues and green manures embedded in the soil replenish the soil not only with organic matter, but also with other nutrients, for example, nitrogen, phosphorus and potassium.
Most of all, biologically related mineral substances with the green mass of mustard are embedded in the soil in the crop rotation third link. For 3 years of sowing (in 2011 after winter wheat and in the spring of 2012 before summer planting potatoes), the soil was embedded with organic crop and root residues: 450 + 411 kg/ha of nitrogen, 38 + 42 kg/ha of phosphorus and at 304 + 333 kg/ha of potassium. Potatoes with crop residues also leave many substances in the soil, for example, in the third link up to 175 kg/ha of nitrogen, 35 kg/ha of phosphorus and 80 kg/ha of potassium. Least of all residues and minerals is remained after the onion.

In the experiment, mustard was cultivated in the second, fourth, and sixth links in one field, and in the third link, in two fields of the crop rotation link: after winter wheat in 2011 and in the spring of 2012 before summer potatoes planting.

With the coefficient of 0.15 organic crop residues humification on southern chestnut soils, the amount of humus that can be formed from the entire mass of organic matter (48.7 t/ha) in the third link is about 7.3 t/ha. Apparently, this explains the increase in the humus content in the soil when comparing the data obtained during the analysis of soil samples in spring, 2011 and after the end of the links study in spring, 2014 (Figure 1).

![Figure 1](image)

**Figure 1** - Change in the humus mass in the soil layer of 0.4 m in various crop rotations links, spring 2011 - spring 2014.

These graphs show that the variant of links with mustard intermediate sowing contributed to the increase in the organic matter content in the soil layer of 0.4 m by the end of the rotation in the third link from 4.75 to 4.83% and from 4.73 to 4.75% in the sixth link, while there is a decrease in its content from 4.78 to 4.58%. in the control one. The humus reserves in the soil changed accordingly. In the third link, the increase in the humus mass over 3 years is observed from 228 to 232 t/ha, i.e., the increase was 3.84 t/ha, or 1.7%. A positive humus balance is also observed in the sixth link, where the legume soybeans were cultivated and mustard was used as intermediate crops (the increase was 0.96 t/ha). On the control plot, the humus deficit for 3 years was 8 t/ha.

Nitrate and ammonia forms of nitrogen in the soil are the indicators of the plants supply with nitrogen. However, they are to a large extent exposed to the influence of soil temperature and at low temperatures the indicators of nitrification capacity are underestimated, while those of ammonia are overestimated, therefore, in our observations, the presence of easily hydrolysable nitrogen was determined.

The data shown in the Figure 2 show that the amount of easily hydrolysable nitrogen decreased in the control one by spring, 2012 from 66.1 to 62.3 mg/kg of soil and recovered by spring, 2014 after potatoes and onions (Figure 2).
Higher rates were observed in the third link (71.2 mg/kg) after the intermediate sowing of mustard in 2011 and in 2012 (72.4 mg/kg) after the green manure application into the soil before planting summer potatoes. In spring, 2014, the nitrogen balance was positive with the increase of 21 kg/ha in the third link. In the fields where the soybean legume was cultivated, the increase in easily hydrolysable nitrogen was also observed by 5 kg/ha in the sixth link and 3 kg/ha in the fifth link of the crop rotation, apparently, nitrogen was formed as the result of the symbiotic activity of nodule bacteria. The control showed a negative nitrogen balance for the period of 2011–2014. (minus 5 kg/ha).

![Figure 2](image.png)

*Figure 2* - Dynamics of the easily hydrolysable nitrogen mass in the soil layer of 0.4 m in various crop rotations links for the period from spring, 2011 to spring, 2014

Observations on the mobile phosphorus content dynamics in the soil showed that the applied calculated doses of mineral fertilizers allowed maintaining the phosphorus content at the same level, although there was a deficit of mobile phosphorus in spring, 2014 compared to spring, 2011 in the amount of 4 kg/ha on the control one and by 3 kg/ha in the crop rotation fifth link (Figure 3).

In all links, where the catch crop was sown, the increase in the phosphorus content was observed, and especially in the third link, where mustard was sown twice. Before the summer potato planting in 2012, the phosphorus content in the third link increased from 29.2 to 39.4 kg/ha compared to spring, 2011. The mass of mobile phosphorus increase before the summer potato planting was 50 kg/ha, and the overall positive balance for 3 years is equal to 19 kg/ha.
Observations on the dynamics of the mobile potassium content in the soil (Figure 4) showed that the greatest positive balance (198 kg/ha) in all years of research is observed in the crop rotation third link, where intermediate sowing of mustard was carried out twice, in the fourth and second links (84 and 93 kg/ha, respectively).

4. Conclusion
The greatest mass of organic matter enters the soil after winter wheat (12.4 ... 12.6 t/ha, including with straw and chaff about 75% and residues of the root system 25%). In Sarepta mustard cultivated for...
green manure, the total mass of organic matter entering the soil is up to 11.6 t/ha in stubble crops after winter wheat, and up to 12.6 t/ha in spring crops.

The cultivation of Sarepta mustard as a green manure in the crop rotation led to the increase in the plant nutrition main elements content in the soil, namely:
- easily hydrolysable nitrogen is up to +21.0 kg/ha;
- mobile phosphorus is up to +39.4 kg/ha;
- mobile potassium is up to 198.0 kg/ha.

The increase in the nitrogen content was also provided by the cultivation of soybeans in the crop rotation up to 5.0 kg/ha.

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