The influence of field crop rotation on the accumulation of stubble and root residues in the arable layer of sod-podzolic soil

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Abstract. The purpose of the work is to conduct a comparative assessment of the amount of smelted plant residues in various field crop rotations in the conditions of the Mari El Republic. The work was completed in 2013-2018 on a stationary site in a two-factor experiment. The first factor is types of crop rotation and crop rotation. Four crop rotation with a different set of crops. Cereal crops occupy 83\% in the first. The share of cereals was 67\% in the second and third. Cereals occupy 50\% and perennial grasses and potatoes 50\% in the fourth crop rotation. The second factor is mineral fertilizers: 1) without fertilizers; 2) N\textsubscript{60}P\textsubscript{60}K\textsubscript{60}. On average, 3.02 ± 0.06 t / ha of stubble and root residues was received per year according to the results of studies in the control grain-grass crop rotation with a one-year use of clover. There are no perennial herbs, but there are potatoes in the first fruit-bearing. Here, plant residues entered the soil by 41\% less than in the first crop rotation. The accumulation of stubble and root residues was 2.91 ± 0.07 t / ha in the second crop rotation. The decrease is due to the cultivation of potatoes, which does not leave plant residues after harvesting. The largest number of stubble and root residues was formed in the third crop rotation (3.37 ± 0.07 t / ha). The use of mineral fertilizers increased the mass of stubble and root residues in all crop rotations by 0.16 t/ha.

1. Introduction

Sod-podzolic soils are the main part of cultivated land in the Republic of Mari El, their share reaches 86\% in the structure of arable land. The successful development of agriculture depends largely on the optimal level of fertility of sod-podzolic soils and the maintenance of an appropriate level of organic matter in them.

Plant residues of crops are the main source of replenishment of soil organic matter. Stubble, root and leafy residues are included in them, the amount of which is associated with the size of crop yields.

Plant residues entering the soil undergo complex decomposition processes, their mineralization and humification. The degree of intensity and nature of humification depends on various factors [1, 2].

Nutritional resources in the soil can be improved by the use of stubble and root residues in the crop rotation, the need for the use of mineral and organic fertilizers is reduced [3, 4].

I.M. Kornilov notes in his work: “...The amount of plant debris entering the soil for rotation of crop rotation plays an important role in maintaining soil fertility. Decomposition products of plant residues

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undoubtedly have a positive effect on the subsequent culture. Therefore, there is a need to study the accumulation of plant residues by each crop..." [5].

Nitrogen is washed less than that obtained from stubble and root residues than from mineral fertilizers [6]. Therefore, the positive effect of smelling stubble and root residues is more pronounced compared to the application of mineral fertilizers [7].

It was noted in many studies [8, 9, 10, 11] that perennial grasses leave the largest amount of the mass of stubble and root residues in the soil, and therefore nutrients, “...therefore, their introduction into crop rotation is a necessity, as this contributes to the economical increase the flow of organic matter into the soil in the form of plant residues, which will solve the problem of soil humus reproduction to its deficit-free balance against the background of organic and mineral fertilizers…” [11].

The purpose of the research is to conduct a comparative assessment of the amount of smelted plant residues in various field crop rotations in the conditions of the Mari El Republic.

2. Material and methods

The experimental part of the work was performed on a stationary site of the experimental field of the Mari Agricultural Research Institute - branch of Federal Agrarian Research Center of the North-East in 2013-2018 in two-factor experiments laid down in 1996 and 1998.

The first factor is types of crop rotation and crop rotation:

- Grain grass - control (oats + clover, clover 1 year of use, winter rye, vetch oat mixture for grain, spring wheat, barley);
- I crop rotation (vetch oat mixture for green mass, winter rye, barley, potatoes, vetch oat mixture for grain, spring wheat);
- II crop rotation (vetch-oat mixture for grain, spring wheat, potatoes with manure (80 t / ha), barley + clover, clover 1 year of use, winter rye);
- II crop rotation (barley + clover, clover 1 year of use, clover 2 years of use, winter rye, potatoes, oats).

The second factor is mineral fertilizers:

- No fertilizer (control);
- N60P60K60.

The soil of the experimental plot is sod-podzolic medium loamy. The arable layer was characterized by the following agrochemical indicators at the time of laying the experiment: the humus content (according to Tyurin) was 1.72%, the salt pH was 5.67, the hydrolytic acidity index was 1.7 milligram equivalent / 100 g, the sum of the absorbed bases was 7, 9 milligrams-equivalent / 100 g. The availability of mobile phosphorus in the soil was within 270, and with exchange potassium 130 mg / kg.

Crop rotations deployed in time. The repetition of options in the experiment is threefold, the arrangement of plots in the repetitions is systematic. The total and accounting area of the plots is 165 m².

Mineral fertilizers for each crop rotation crop were added to each plot in accordance with the experimental design. Ammonium nitrate was used from nitrogen fertilizers, double superphosphate was used from phosphate fertilizers, and potassium chloride was used from potassium fertilizers. Under the perennial legumes and their predecessors did not make nitrogen fertilizers.

The determination of the number of root and stubble residues was carried out by the framework method according to N. Z. Stankov with a frame size of 30.2 x 33.3 cm [12]. The size of the frame was increased on row crops, maintaining the same ratio between the row and row-spacing as on the entire sowing area. Studies were carried out according to generally accepted methods. Accounting and
observations, statistical data processing carried out by B.A. Dospehov [13]. Weather conditions for years of research differed in temperature, the amount of precipitation and their distribution during the growing season, and for the most part were satisfactory for the growth and development of the tested crops in crop rotation. The growing season of field crops was characterized as wetter in 2017 (total precipitation was 313.3 mm), 2013, 2014, 2015, 2018 were less wet (243, 165.3, 246.1 and 159 mm of precipitation fell during the growing season, respectively) The year 2016 was relatively dry (total precipitation is 117.5 mm). The hydrothermal coefficient by years was: 2013 - 1.21, 2014 - 0.84, 2015 - 1.29, 2016 - 0.56, 2017 - 1.85, 2018 - 0.87.

3. Results and its discussion
Studies have shown that the accumulation of stubble and root residues of field crops was largely determined by the type of crop rotation, crop and the use of mineral fertilizers (table 1-4). Accounting for the dry mass of stubble and root residues showed that the soil received the least amount of organic matter in crop rotation with a high saturation of crops and potatoes.

Table 1. The accumulation of stubble and root residues of field crops in the arable soil layer (grain-grass crop rotation), 2013-2018, t/ha.

| The culture of crop rotation | No fertilizer | NPK | Average |
|-----------------------------|--------------|-----|---------|
| Spring wheat                | 2.39±0.17    | 2.56±0.11 | 2.48±0.12 |
| Barley                      | 1.41±0.12    | 1.66±0.11 | 1.54±0.10 |
| Oats                        | 2.02±0.03    | 2.15±0.03 | 2.09±0.02 |
| Winter rye                  | 3.62±0.07    | 3.86±0.15 | 3.74±0.12 |
| Vetch / oats (grain)        | 2.55±0.05    | 2.71±0.08 | 2.63±0.06 |
| Clover 1 year of use        | 5.60±0.03    | 5.67±0.06 | 5.64±0.05 |
| The average for the year of crop rotation | 2.92±0.06 | 3.10±0.07 | 3.02±0.06 |

Our studies in the grain-grass rotation showed that the plant mass in the 0-20 cm layer remained the most after clover of 1 year of use - 5.64 tons per 1 ha. Winter rye exceeded for this index among cereal crops.

Table 2. The accumulation of stubble and root residues of field crops in the arable soil layer (I crop rotation), 2013-2018, t/ha.

| The culture of crop rotation | No fertilizer | NPK | Average |
|-----------------------------|--------------|-----|---------|
| Spring wheat                | 2.46±0.16    | 2.84±0.14 | 2.65±0.13 |
| Barley                      | 0.95±0.07    | 1.08±0.08 | 1.02±0.07 |
| Winter rye                  | 4.00±0.08    | 4.12±0.05 | 4.06±0.06 |
| Vetch / oats (grain)        | 2.22±0.07    | 2.38±0.09 | 2.30±0.08 |
| Vetch / oats (green mass)   | 1.65±0.01    | 1.74±0.02 | 1.70±0.01 |
| Potatoes                    | 1.08±0.02    | 1.15±0.02 | 1.12±0.02 |
| The average for the year of crop rotation | 2.06±0.05 | 2.21±0.05 | 2.14±0.04 |

The largest amount of plant debris was after winter rye - 4.06 t / ha in the first crop rotation. All other cultures lagged strongly in this indicator. The minimum amount of stubble and horse residues remains after potatoes and barley in the soil. Perennial grasses are absent in this crop rotation. As a result, the average amount of plant residues was 1.4 times less compared to the grain-grass rotation in this rotation.
Table 3. The accumulation of stubble and root residues of field crops in the arable soil layer (II crop rotation), 2013-2018, t/ha.

| The culture of crop rotation | No fertilizer | NPK | Average |
|------------------------------|---------------|-----|---------|
| Spring wheat                | 2.80±0.04     | 2.97±0.06 | 2.89±0.05 |
| Barley                       | 1.33±0.05     | 1.43±0.04 | 1.38±0.05 |
| Winter rye                   | 3.81±0.09     | 4.21±0.13 | 4.01±0.11 |
| Vetch / oats (grain)         | 2.57±0.09     | 2.70±0.10 | 2.64±0.09 |
| Clover 1 year of use         | 5.10±0.10     | 5.17±0.13 | 5.14±0.11 |
| Potatoes                     | 1.48±0.00     | 1.40±0.03 | 1.44±0.01 |
| The average for the year of crop rotation | 2.84±0.06 | 2.98±0.08 | 2.91±0.07 |

The introduction of clover contributed to an increase in the content of stubble and root residues in the soil in the second crop rotation. Subsequently, these plant residues had a positive effect on other crops. Our studies showed that there was more organic matter compared to other crop rotations after potatoes.

Table 4. The accumulation of stubble and root residues of field crops in the arable soil layer (III crop rotation), 2013-2018, t/ha.

| The culture of crop rotation | No fertilizer | NPK | Average |
|------------------------------|---------------|-----|---------|
| Barley                       | 1.28±0.12     | 1.42±0.13 | 1.35±0.13 |
| Oats                         | 2.23±0.05     | 2.36±0.07 | 2.30±0.06 |
| Winter rye                   | 4.05±0.22     | 4.49±0.31 | 4.27±0.25 |
| Clover 1 year of use         | 5.60±0.09     | 5.86±0.03 | 5.73±0.04 |
| Clover 2 year of use         | 5.40±0.03     | 5.45±0.07 | 5.43±0.04 |
| Potatoes                     | 1.12±0.04     | 1.15±0.06 | 1.14±0.04 |
| The average for the year of crop rotation | 3.28±0.07 | 3.45±0.10 | 3.37±0.07 |

The largest number of stubble and root residues was formed due to the cultivation of clover for 2 years of use in the third crop rotation. There is obtained the largest number of plant residues after winter rye compared with other rotations.

The amount of root and stubble residues entering the soil after harvesting depends on the type of crop. Perennial grasses leave the greatest amount of organic matter in the soil, among cultivated plants cultivated in various crop rotations. The amount of stubble and root residues entered the soil from 5.10 t / ha to 5.86 t / ha after clover. Clover in the first year leaves more organic matter compared to the second year.

On average, 3.02 ± 0.06 t / ha of stubble and root residues was received per year in a grain-grass crop rotation with a one-year use of clover. The largest amount of organic matter remained in the soil after clover. The largest number of plant debris was after winter crops, among crops. Spring crops were distinguished by stubble and root residues. 2.48-2.89 t / ha remained after spring wheat, 2.09-2.30 t / ha after oats and 1.02-1.54 t / ha after barley. After potato, plant debris remains low in the soil.

The least amount of residues was formed in the first crop rotation (2.14 ± 0.04 t / ha). In this crop rotation, 41% less residues were formed than in the control due to the replacement of clover with potatoes. The results of the analysis of variance (smallest significant difference 05 (SSD_05) factor A - 0.21) confirm the reliability of this statement. The accumulation of stubble and root residues was 4% less than in the control variant in the second crop rotation. The mathematical processing data is not significant between these crop rotations. The third crop rotation (3.37 ± 0.07 t / ha) left behind the
largest number of stubble and root residues. It exceeded the grain-crop rotation by 0.35 t / ha (SSD<sub>0.05</sub> of factor A - 0.21). There were noted the best development of the root system of crops and the improvement of the phytosanitary condition of the soil and crops in this crop rotation. Our studies have shown that less damage to crops by root rot and, therefore, higher development of plants and increase their productivity in the fourth crop rotation. So the difference in the spread of root rot was 24.8%, with the level of SSD<sub>0.05</sub> - 6.4, in our previous studies, on this crop rotation compared with the control at the end of the growing season [14].

The use of mineral fertilizers increased the mass of stubble and root residues in all crop rotations. So, the average annual amount of stubble and root residues was 2.78 ± 0.06 t / ha against the background without fertilizers. It increased the mass of stubble and root residues by 0.16 t / ha with the use of mineral fertilizers, at the level of SSD<sub>0.05</sub> factor B - 0.15.

Crops for the accumulation of plant debris in various crop rotations are arranged in the following order: perennial grasses, winter, spring grain and leguminous plants; potatoes.

4. Conclusions
The first crop rotation with annual herbs and potatoes leaves behind the smallest amount of stubble and root residues - 2.14 t / ha. In grain-grass crop rotation with a one-year use of clover, an average of 3.02 ± 0.06 t / ha of dry biomass of stubble and root residues is received per year on average, which significantly exceeds the first fruit-crop rotation. The third crop rotation leaves behind (3.37 ± 0.07 t / ha), the largest number of stubble and root residues. The largest number of stubble and root residues entered the soil after perennial grasses, the smallest - after potatoes and oats.

The application of mineral fertilizers increases the biomass of stubble and root residues of cultivated crops by 0.16 t / ha. When fertilizers were added, crops formed a larger crop and more organic matter entered the soil.

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