Effectiveness of biologization predecessors and methods in increasing grain crops productivity and field crop rotations productivity in Nizhneje Povolzhje region

A V Zelenev, O G Chamurliev, Yu A Laptina, L V Gubina, O N Romenskaya and L A Feofilova

Volgograd State Agrarian University, 26 University Avenue, Volgograd, 400002, Russia

E-mail: Zelenev.A@bk.ru

Abstract. Researches on the study of predecessors and biologization techniques in field crop rotations were carried out in 2018-2020 in the dry steppe zone of the chestnut subzone of light chestnut soils of the Nizhneje Povolzhje region. It is necessary to grow biennial melilot for green manure as a fallow-growing crop in a grain-steam five-field crop rotation in order to increase the organic matter input into the soil. A significant increase in yield was achieved in chickpeas for winter wheat, its straw was plowed into the soil. The highest increase in the spring barley yield was provided during the chickpeas and sorghum cultivation, which straw entered the soil. When growing spring barley on safflower, its straw was plowed into the soil, the yield was also higher than the control variant. The highest grain yield was achieved in the control grain-fallow four-field crop rotation with complete fallow, where the cultivated crops straw was removed from the field and grain-fallow-grass green manure seven-field crop rotation with seed fallow, where straw and melilot were plowed into the soil. Grain-fallow seven-field and grain-fallow-grass-cultivated green manure seven-field crop rotations, where oats and phacelia straw and green manure mass entered the soil, were inferior to the control.

1. Introduction

The cultivation of agricultural products according to world standards is the main direction of the agricultural industrial complex development in the arid Nizhneje Povolzhje region. Unfortunately, most of the farms in the region use outdated technologies for the grain crops cultivation, which often lead to the decrease in grain production and its collection from a unit of crop rotation area [1, 2, 3].

Recently, there is an increase in the organic matter mineralization processes, a decrease in the fertility of zonal soils due to the transition of farms in the Volgograd region to short-rotation crop rotations, where complete fallow, grain and row crops predominate mainly in their structure. Therefore, the development of modern rational field crop rotations, taking into account local conditions, selection of good predecessors, ensuring the soil fertility preservation and stabilization, increasing the grain crops productivity with minimal labor and funds energy consumption is an important condition for solving problems of food security in the country [4, 5, 6].

The increase in organic matter in the soil by traditional methods turned out to be insufficient, therefore, in recent years, special attention was paid to its production directly in field crop rotations. Moreover, it is very important to obtain organic matter from cheap, affordable, and environmentally
friendly sources of biologization, such as stubble-root residues and straw of grain crops grown in field crop rotations, as well as green fertilizers. In addition, the crop rotations biologization presupposes the introduction into the structure of the crop rotation area instead of pure seed fallow, leguminous crops and perennial grasses [7, 8, 9].

Straw is an essential biological technique that stabilizes soil fertility. The straw introduction into the soil positive effect on the agricultural crops and grain harvest yield in field biologized crop rotations was established in different soil and climatic zones of our country, but it is of particular importance in arid regions. Straw is a low-value non-commercial part of the crop, but at the same time, it is a cheap and affordable source of organic matter. The use of straw as an organic fertilizer makes it possible to increase the yield of grain crops [10, 11, 12].

Another source that increases soil fertility, grain yield and grain harvest in field crop rotations is green manure, which, when it enters the soil, quickly decomposes to form humus. They improve microbiological processes in the soil and reduce soil fatigue. As the result of the green fertilizers use, the agrophysical and agrochemical properties of the soil are improved [13, 14, 15].

The research of the increasing soil fertility issues in field crop rotations through the use of stubble-root residues, straw of grain crops, green fertilizers and their combinations in the conditions of the dry steppe zone of the chestnut subzone of light chestnut soils of the Nizhneje Povolzhje region is relevant and requires further study.

2. Materials and methods

Researches on the study of predecessors and biologization techniques in field crop rotations were carried out in 2018-2020 in the dry steppe zone of the chestnut subzone of light chestnut soils of the Nizhneje Povolzhje region at the experimental site of the Federal State Budgetary Scientific Institution of the Federal Research Center of Agroecology and Complex Reclamation of the Russian Academy of Sciences. The soil on the territory of the experimental site was light chestnut, heavy loamy one. The arable 0.0-0.3 m layer contained 1.74% of humus. The content of easily hydrolyzable nitrogen in this layer is low, at the level of 32-36 mg/kg according to Tyurin and Kononova; mobile phosphorus according to Machigin - average, 18-21 mg/kg and exchangeable potassium also according to Machigin - increased, within 330-370 mg/kg of absolutely dry soil. In the arable layer, the reaction of the soil solution was slightly alkaline and corresponded to the value of 8.1. The unfavorable water-physical properties of the soil were due to the salinity of the parent rock and the varying degrees of soil profile alkalinity. The exchange activity of the soil is low - the sum of absorbed bases was equal to 25.7 mg/eq. per 100 g of soil. The variants in the experiment were placed in a randomized way in one tier with three repetitions. The area of the experimental plot was 900 m² (the length was 50 m, the width was 18 m), registration one - 782 m² (the length was 46 m and the width was 17 m). The mass of stubble-root residues of green manure crops was taken into account by the method of monoliths (0.33 × 0.3 × 0.3 m) according to N.Z. Stankov in an eightfold repetition after harvesting. The wet and air-dry aerial weights of green manure crops, alfalfa, and sainfoin were determined by sampling sheaves from 0.25 m² plots in four repetitions and weighing them in the laboratory. The grain crops economic yield was determined by the weight method using a continuous combine harvesting of each plot. Then it was brought to the standard moisture content of 14% and 100% purity. Subsequently, the grain harvest was calculated in field biologized crop rotations from 1 hectare of the crop rotation area.

The amount of precipitation in 2017-2018, 2018-2019 and 2019-2020 agricultural years was 391, 388.3 and 376.7 mm, respectively, which was 51.3 higher than the average long-term value of 339.7 mm, respectively; 48.6 and 37 mm or 15.1; 14.3 and 10.9%. 119.3 mm precipitated for the period April - August in 2018, and in May - 12.7 mm, June - 7.2 mm and August - 0.8 mm. During the same period in 2019, 149.7 mm precipitated, in June and August there were respectively 13.9 and 3.8 mm. All this affected the yield of field crops. The year 2020 was more favorable in terms of moisture supply; 163.4 mm precipitated for the period April-August.

The predecessors and biologization techniques of were studied in field specialized crop rotations deployed in time and space, including four options:
1) four-field grain fallow: complete fallow - winter wheat - chickpea - spring barley (control), in this rotation, complete fallow and leguminous plants took 25% each and grain crops took 50% of the crop rotation area;

2) grain-fallow green manure five-field: seed fallow (melilot for green manure) - winter wheat - chickpea - spring barley - mustard + melilot, here the seed fallow, legumes, oil-seeds each took 20% and grain crops took 40% of the arable land;

3) grain-fallow-grass green manure seven-field: seed fallow (oats for green manure) - winter wheat - mustard - chickpea - dyeing safflower - spring barley - sainfoin (emergency field), in this crop rotation, seed fallow, leguminous crops, legumes occupied 14.3% each, and also grain and oilseeds took 28.5% each of the crop rotation area;

4) grain-fallow-grass-cultivated green manure seven-field: seed fallow (phacelia for green manure) - winter wheat - spring wheat - chickpea - grain sorghum - spring barley - alfalfa (emergency field), in which seed fallow, legumes, row crops, legumes occupied 14.3% each and grain crops took 42.8% of arable land.

The technology of cultivation of agricultural crops in the experiment is generally accepted for the research area, except for the studied methods. In the first control variant, all the straw of the cultivated grain crops was removed from the field, here only their stubble-root residues entered the soil. In the second, third and fourth variants, the straw of grain crops was left on the field and embedded in the upper soil layer by the heavy disc harrow BDT-3 to the depth of 0.08-0.1 m. Deep chiseling was carried out by an OCHO-5-40 tool on the depth of 0.3-0.32 m with a turnover of the surface layer by the mouldboard to the depth of 0.2-0.22 m as the main tillage in all variants. This tool is equipped with multifunctional working bodies of the modular RANCHO type (mouldboard and wide chisel). Nitrogen fertilizer in the form of ammonium nitrate at the rate of 10 kg of active ingredient per 1 ton was applied before winter and spring wheat, chickpea, spring barley, safflower mustard, sorghum straw disking. Green manure crops, melilot were sown by binary sowing with mustard, and oats and phacelia were single-crop sown in spring. Further, phacelia and yellow melilot in the budding phase were sown in June, and oats in the heading of panicles phase were crushed and embedded in the soil as a green fertilizer by the heavy disc harrow BDT-3 to the depth of 0.1-0.12 m. The remaining crops were sown at optimal agrotechnical terms: winter wheat Kamyshanka 5 at sowing rate of 3 million, chickpea Privo 1 - 500 thousand, spring barley Medicum 139 - 3.5 million, Flagman Sarepta mustard - 1.5 million, spring wheat Kamyshinskaya 3 - 3.5 million, safflower Alexandrite - 300 thousand, grain sorghum Kamyshinskoe 64 - 300 thousand, sainfoin Peschaniy 1251 - 6 million, alfalfa Vega 87 - 5 million, Phacelia Ryazan - 4 million, Astor oats - 3.5 million, yellow melilot Koldybinsky - 6 million germinable seeds per hectare. Winter wheat was sown in the usual row-by-row method with 0.21 m row spacing by the Don-114 grain seeder to the depth of 0.05-0.07 m, which can work according to traditional, minimum and zero soil tillage. Before sowing, the seeds of all crops were treated by seed disinfectants.

3. Results and discussion
Studies have found that green manures are not inferior to traditional organic fertilizers in terms of their influence on the grain crops yield, and the effectiveness of their use is much higher, since their cultivation requires much less costs. Green manure is the most important biological resource for replenishing organic matter on seed fallows. With the average green manure yield of 25 t/ha, 474 million tons of green mass can be obtained from the entire planned area, which will contain about 5 million tons of basic nutrients. In addition, it is important to select promising green manure crops that would satisfy local soil and climatic conditions. Melilot is a winter-hardy, drought-resistant crop and during the development cycle it can form the yield of green mass at the level of 54.8 t/ha, hay - 13.8 t/ha, seeds - 0.55 t/ha, accumulate 560 kg/ha of nitrogen, phosphorus and potassium in biomass. The yield of the phacelia air-dry mass when grown in arid regions can reach 1.55 t/ha, while it contains 1.57% of nitrogen, 1.27% of phosphorus, and 0.31% of potassium. The yield of green manure mass of oats is 3.6 t/ha of dry matter, which contains 2.78% of nitrogen, 0.48% of phosphorus and 3.35% of
potassium. As the result, 108.2, 18.1, and 117.6 kg/ha [16, 17, 18] of the main nutrients enter the soil with its biomass, respectively. In our experiment, the amount of organic matter entering the soil of seed fallows from green manure air-dry aboveground and root mass of melilot, phacelia and oats, which were the predecessors of winter wheat, was determined (Table 1).

**Table 1.** Aboveground, root wet and air-dry weight of green manure crops in crop rotations, t / ha (average for 2018-2020).

| № variant | Crop          | Wet weight | Air-dry weight |
|-----------|---------------|------------|---------------|
| 2         | Melilot 2-years old | 4.5 1.92 6.42 | 1.17 0.74 1.91 |
| 3         | Oat           | 3.39 1.15 4.54 | 1.07 0.53 1.6 |
| 4         | Phacelia      | 3.98 1.2 5.18 | 1.09 0.62 1.71 |

It can be seen from the data in the table that, on average, over three years of research, the highest aboveground wet weight was provided for melilot - 4.5 t/ha, the lowest was for oats - 3.39 t/ha. Phacelia occupied an intermediate position between them and formed 3.98 t/ha of wet aboveground mass. Wet root weight of oats and phacelia was at the same level, 1.15 and 1.2 t/ha, respectively, and of melilot it was the highest - 1.92 t/ha. The largest total wet weight was provided for yellow melilot in the second year of life - 6.42 t/ha, which is higher than in phacelia and oats by 1.24 and 1.88 t/ha, or 23.9 and 41.4%, respectively.

With the aboveground air-dry mass, the melilot organic matter was most of all introduced into the soil - 1.17 t/ha, oats and phacelia were less, 1.07 and 1.09 t/ha, respectively. The root air-dry mass in the soil remained the most in melilot - 0.74 t/ha, lower in phacelia - 1.62 t/ha, and the lowest in oats - 0.53 t/ha. The largest total air-dry mass, which entered the soil in the form of organic matter, was provided by yellow melilot in the second year of life - 1.91 t/ha, the lowest for oats - 1.6 t/ha, which is less by 0.31 t/ha or 16.2% than for melilot. From the total green manure air-dry mass of phacelia, 1.71 t/ha of organic matter entered the soil, which is 0.2 t/ha or 10.5% lower than that for melilot.

The researches established that the winter wheat highest yield was obtained when it was cultivated on sainfoin green manure fallow - 4.9 t/ha. Green manure mustard fallow due to lower quality organic matter plowed into the soil and the decrease in moisture reserves in the soil for sowing winter wheat due to its consumption for mustard growth, worsens the conditions for the growth and development of winter wheat, reduces its yield compared to the control option – black fallow, by 0.5 t/ha. The introduction of leguminous grasses (yellow melilot, blue alfalfa) into crop rotations for green fertilization contributed to the increase in soil fertility and the yield of grain crops [19, 20, 21, 22]. In our experience, the input of organic matter into the soil in the form of stubble-root residues, straw and green manure contributed to the increase in crop yields (Table 2).

It can be seen from the data in the table that the most productive year was 2020, in which winter wheat formed the yield at the level of 3.17-3.54 t/ha, spring barley 2.27-3.15 t/ha, chickpea 1.51-2.12 t/ha, and only mustard had a lower yield at the level of 0.94-1.06 t/ha compared to 2018, in which the yield of this crop was 1.24-1.26 t/ha. The year 2019 was unfavorable in terms of yield for spring barley (0.18-0.27 t/ha), mustard (0.13-0.17 t/ha), spring wheat (0.18 t/ha), safflower (0.35 t/ha) and grain sorghum (0.23 t/ha), 2018 - for winter wheat (0.59-0.71 t/ha) and chickpea (0.17-0.23 t/ha).

On average, over three years of research, winter wheat was the most productive crop in field-bioligized crop rotations - 1.68-1.8 t/ha, and here the increase in yield was insignificant between the options, within the experimental error. Therefore, the occupied coupling, as the predecessors of winter wheat, were equal in yield to each other. The second most productive crop was spring barley. The highest yield of this crop was provided when cultivated for chickpeas and grain sorghum, which straw was plowed into the soil, respectively 1.48 and 1.46 t/ha, which is higher than the control, where the predecessor was chickpea, which straw was alienated from the field, by 0.34 and 0.32 t/ha or 29.8 and 28.1%. When growing spring barley on safflower, which straw was also plowed into the soil, the yield...
was 1.32 t/ha, which is higher than the control variant by 0.18 t/ha or 15.8%. Moreover, the increase in barley yield was significant in all variants of the experiment. In chickpea, the significant increase in yield was observed in the variant where it was cultivated only for winter wheat, which straw was plowed into the soil, compared with the control by 0.11 t/ha, which was 14.5%. According to the predecessor, spring wheat, which straw remained in the field, chickpeas formed the yield at the level with the control - 0.74 t/ha. For mustard, which straw was plowed into the soil, the yield of chickpeas was significantly inferior to the control variant, winter wheat, where straw was alienated from the field, by 0.12 t/ha or 15.8%. The average yield of other crops was low, for mustard 0.78-0.82 t/ha, spring wheat - 0.78 t/ha, safflower - 0.65 t/ha, and grain sorghum - 1.01 t/ha.

Table 2. Field crops yield depending on biologization predecessors and methods, t/ha.

| № variant | Predecessor, biologization technique | 2018  | 2019  | 2020  | Average |
|-----------|-------------------------------------|-------|-------|-------|---------|
| Winter wheat | Complete fallow | 0.59  | 1.28  | 3.54  | 1.8     |
|           | Seed fallow (melilot on green manure) | 0.71  | 1.22  | 3.46  | 1.8     |
|           | Seed fallow (oat) | 0.64  | 1.24  | 3.17  | 1.68    |
|           | Seed fallow (phacelia) | 0.71  | 1.3   | 3.32  | 1.78    |
|           | HCP05 | 0.11  | 0.18  | 0.11  | 0.12    |
| Cheak-pea | Winter wheat | 0.17  | 0.36  | 1.76  | 0.76    |
|           | Winter wheat (straw) | 0.23  | 0.25  | 2.12  | 0.87    |
|           | Mustard (straw) | 0.19  | 0.22  | 1.51  | 0.64    |
|           | Spring wheat (straw) | 0.22  | 0.3   | 1.69  | 0.74    |
|           | HCP05 | 0.04  | 0.1   | 0.09  | 0.07    |
| Spring barley | Cheak-pea | 0.97  | 0.18  | 2.27  | 1.14    |
|           | Cheak-pea (straw) | 1.07  | 0.22  | 3.15  | 1.48    |
|           | Safflower (straw) | 1.06  | 0.24  | 2.66  | 1.32    |
|           | Doura (straw) | 1.13  | 0.27  | 2.97  | 1.46    |
|           | HCP05 | 0.07  | 0.08  | 0.12  | 0.08    |
| Mustard   | Spring barley (straw) | 1.26  | 0.13  | 0.94  | 0.78    |
|           | Winter wheat (straw) | 1.24  | 0.17  | 1.06  | 0.82    |
| Spring wheat | Winter wheat (straw) | 0.42  | 0.18  | 1.73  | 0.78    |
|           | Safflower | 0.44  | 0.35  | 1.17  | 0.65    |
|           | Doura | 0.73  | 0.23  | 2.07  | 1.01    |
|           | Sainfion for hay | -     | 1.19  | 1.94  | 1.04    |
|           | Alfalfa for hay | -     | 0.87  | 2.29  | 1.05    |

The research established a stable relationship between the regular use of biological resources in field crop rotations and the increase in grain harvest in them. In the first rotation of the crop rotation with green manure fallow, productivity was at the level with complete fallow, in the second rotation, productivity increased by 7-12%, during the third rotation with green manure embedded in the soil.
together with straw, the productivity of the agrocoenosis increased by 19%. In grain-fallow crop rotation with complete fallow, the use of only straw is not enough to increase its productivity, and the combined use of biological resources of the crop rotation, including seed fallows, leads to the increase in the crop rotation productivity [23, 24, 25]. In our experiment, to assess the effectiveness of field biologized crop rotations, we calculated the grain harvest per 1 hectare of the crop rotation area (Table 3).

**Table 3. Grain harvest in field biologized crop rotations, t/ha of crop rotation area.**

| № variant | Crop rotation                              | Biologization technique                      | 2018 | 2019 | 2020 | Average |
|-----------|-------------------------------------------|----------------------------------------------|------|------|------|---------|
| 1 (control) | Grain-fallow four-field                   | Stubble-root residues                         | 0.43 | 0.46 | 1.89 | 0.93    |
| 2         | Grain-fallow green manure five-field      | Stubble-root residues, Melilot for green manure, straw | 0.66 | 0.36 | 1.93 | 0.98    |
| 3         | Grain-fallow-grass green manure seven-field | Crop-root residues, oats for green manure, straw | 0.51 | 0.32 | 1.37 | 0.73    |
| 4         | Grain-fallow-grass cultivated green manure seven-field | Stubble-root residues, phacelia for green manure, straw | 0.46 | 0.33 | 1.68 | 0.82    |
| LSD05     |                                           |                                               | 0.05 | 0.07 | 0.11 | 0.08    |

It can be seen from the data in the table that the highest grain yield from 1 hectare of the crop rotation area was provided in 2020: in the grain-fallow green manure five-field crop rotation - 1.93 t/ha, in the control grain-fallow four-field crop rotation - 1.89 t/ha, in the grain-fallow-grass green manure seven-field crop rotation - 1.68 t/ha and in the grain-fallow-grass green manure seven-field crop rotation - 1.37 t/ha. In 2018 and 2019, the grain harvest was low. On average, over three years of research, the highest grain yield was achieved in the control four-field grain-fallow crop rotation, in which all the straw of the cultivated crops was removed from the field, and the grain-fallow green manure seven-field crop rotation, where straw and melilot were plowed into the soil for green manure, respectively 0.93 and 0.98 t/ha of crop rotation area. Seven field grain-fallow-grass and grain-fallow-grass-cultivated green manure crop rotations, where straw and green manure mass of oats and phacelia entered the soil, were significantly inferior to the control variant, by 0.2 and 0.11 t/ha, or 21.5 and 11.8%, respectively.

**4. Conclusion**

In the dry steppe zone of the chestnut subzone of light chestnut soils of the Nizhneje Povolzhje region, in order to increase the input of organic matter into the soil by 19.4%, it is necessary to grow two-year-old yellow melilot for green manure in a grain-fallow five-field crop rotation as a fallow-grown crop. Cultivation of winter wheat on seed fallows occupied by melilot, oats and phacelia does not reduce the yield of this crop in comparison with complete fallow. A significant increase in yield of 14.5% was achieved in chickpeas after the predecessor, winter wheat, which straw was plowed into the soil. The highest increase in the yield of spring barley at the level of 28.1-29.8% was provided during the cultivation of chickpeas and grain sorghum, which straw also entered the soil. To stabilize the harvest of grain from 1 hectare of the crop rotation area, it is necessary to introduce a grain-fallow...
five-field crop rotation with plowing organic matter into the soil in the form of melilot for green manure, stubble-root residues and grain straw into production.

References
[1] Voronov S I, Pleskatchev Yu N and Ilyashenko P V 2020 Fundamentals of high-quality winter wheat grain production Fertility 2(113) 64-66
[2] Zelenev A V 2020 Employed pairs as predecessors of winter wheat in organic farming in Nizhneje Povolzhje region Dairy Economical Bulletin 2(38) 80-94
[3] Postnikov P A 2013 The vapors role in stabilizing soil fertility and grain yield Proc. of the Orenburg State Agrarian University 6(44) 41-43
[4] Balabanov S S, Timofeeva N M, Kartamyshev N I and Besedin N V 2013 Biologization of agriculture and soil density in grain-row crop rotation Bulletin of the Kursk Agricultural Academy 1 12-16
[5] Kozlova L M 2014 Efficiency of field crop rotations under various conditions of agriculture intensification in the Kirov region Agrarian Science of the Euro-North-East 2(39) 30-33
[6] Novoselov S I, Kuzminykh A N and Eremeev R V 2019 Soil fertility and crop productivity depending on the main tillage and crop rotation Fertility 6(111) 22-25
[7] Egorova G S, Shiyano K V and Nesmiyanova E A 2015 Microbiological activity of soil in winter triticale crops, depending on the predecessors and methods of basic tillage Fertility 2(83) 39-40
[8] Komarova N A 2018 The value of different vapors in the change in the light gray forest soil and the crops yield density in crop rotation Agrarian Science of the Euro-North-East 2 58-63
[9] Zopka A S 2014 Effect of vapor species on the dark chestnut soil properties in Tuva and wheat yield Siberian Bulletin of Agricultural Science 3 5-12
[10] Dzyuin A G and Dzyuin G P 2015 The aftereffect of green manure and straw in crop rotation Agrarian Science of the Euro-North-East 6(49) 38-42
[11] Lifanenkov T P and Bizhnoe R V 2019 The role of biological resources in the irrigated ordinary chernozem fertility reproduction in the central Caucasus Agriculture 2 20-23
[12] Rusakova I V 2013 Biological properties of sod-podzolic sandy loam soil with straw prolonged use for fertilization Soil Science 12 1485
[13] Borisova E E 2015 The use of green manure in the world Bulletin of Nizhny Novgorod State Engineering and Economic University 6(49) 24-33
[14] Ovsyannikova G V, Yankovskiy N G and Krivosheeva E D 2016 The role of black and seed fallows in increasing the winter wheat productivity and maintaining soil fertility Agrarian Science of the Euro-North-East 3(52) 27-32
[15] Tsvetkov D P 2016 Influence of seed fallow and green manure fallow on the winter wheat yield and fertility indicators of light gray forest soil of the Nizhny Novgorod region Bulletin of Nizhny Novgorod State Engineering and Economic University 6 92-102
[16] Nenaydenko G N, Sibiryakova T V and Okorkov V V 2013 Influence of fertilizers on yield, chemical composition and consumption of the main nutrients by the phacelia tanacetifolia Achievements of Science and Technology of the Agro-Industrial Complex 4 24-26
[17] Novikov M N, Tamonov A M, Frolova L D and Ermakova L I 2013 Sidersates in agriculture in the Non-Chernozem zone Agrochemical Bulletin 4 20-26
[18] Smurov S I and Popova T V 2015 Assessment of crops various types and their combinations as fallow-occupying green manure Achievements of Science and Technology in the Agro-Industrial Complex 11 74-77
[19] Grebenikov V G, Shipilov I A and Khonina O V 2019 Winter wheat yield and environment-forming potential of perennial legumes as the factor in agriculture biologization Agrarian Bulletin of the Urals 10(189) 2-8
[20] Dedov A V, Nesmeyanova M A and Kuznetsova T A 2014 Binary crops with legumes Perm Agrarian Bulletin 2(6) 10-18
[21] Zhulanova V N and Zharova T F 2018 Green manure pairs in the forest-steppe conditions of the Ulug-Khem depression in Tuva Bulletin of Higher Educational Institutions. North Caucasian region. Series: Natural Sciences 2(198) 69-74
[22] Zelenev A V 2013 Dynamics of productive moisture reserves in the soil and the grain crops yield in biologized crop rotations of the Volgograd region Proc. of the Nizhnevolzhsky Agrouniversity Complex: Science and Higher Professional Education 4(32) 26-31
[23] Galeev R F and Shashkova O N 2019 Assessment of biologization and chemicalization methods on the productivity of forage crop rotation in the forest-steppe of Western Siberia Achievements of Science and Technology in the Agricultural Industrial Complex 10 22-25
[24] Sirotina E A, Sorokin I B and Petrovskaya O A 2015 Agroecosystems biological resources influence on the grain crops yield in the Siberian sub-boreal forest zone Achievements of Science and Technology in the Agricultural Industrial Complex 1 17-19
[25] Sosnina I D 2013 Organic and mineral fertilizers types influence on grain yield, arable land productivity and soil fertility preservation Achievements of Science and Technology in the Agricultural Industrial Complex 5 32-36