The effectiveness of the primary tillage system using green manure, biological products and fertilizers on typical black soil in the Chechen Republic

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Abstract. The results of studies within the framework of the state task on the topic: “To scientifically substantiate a resource-saving system of basic tillage using organic fertilizers and biological products for the sustainable production of crop production, preservation and reproduction of soil fertility on black soil typical of the Chechen Republic,” are presented. The research has been conducted since 2018 at the Chechen Agricultural Research Institute. According to the research phase, soil fertility and crop productivity were studied depending on the main processing system using green manure, biological products and mineral fertilizers. The primary tillage system included: plowing, diskng and chiseling. The results of the experiment showed a positive effect of the primary tillage system and green manure on its fertility, mainly indicators are better when plowing. The humus content in the soil is higher during plowing in the “NPK” variant, where in the arable layer it is 4.1 % (average level), in the arable layer – 3.7 % (low level). The nitrogen content is higher when plowing the soil in the “NPK + biological product” variant, where in the arable layer – 28 mg/kg, in the subsoil layer – 21 mg/kg, which refers to an increased level. Potassium indices are higher for soil chelating in the “NPK + biological product” variant – 220 mg/kg in the arable layer (average content), 130 mg/kg in the sub-arable layer (low content). The phosphorus content is higher when plowing the soil in the “Biopreparation” variant – 28 mg/kg in the arable layer and 17 mg/kg in the arable layer, which refers to the average level.

1. Introduction

The use of scientifically based soil and fertilizer cultivation systems in crop rotation is a necessary condition for further increasing its fertility and crop yields [2].

As a result of the decrease in the volume of application of mineral and organic fertilizers, the yield and quality of the resulting products are reduced. Based on this, the question arose of finding additional sources of supply of plants with nutrients. One of the ways to solve this problem can be the use of
microbial preparations that contribute to the stimulation of plant growth, fixation of molecular nitrogen, phosphate mobilizing, fungicidal and bactericidal activity, anti-stress effect. Recently, fundamental scientifically-based developments have appeared to optimize plant-microbial interaction [7].

2. Relevance
The relevance of the scientific work is due to the problem associated with the continuing decrease in the level of soil fertility and moisture availability in most of the arable land of the Chechen Republic, as a result of which the productivity of agricultural crops has significantly decreased. The main reason for this is the lack of compliance in agricultural production with agrotechnological requirements, including the soil treatment system, the use of organic and mineral fertilizers, as well as the timing of work.

3. Purpose and objectives
The purpose of the research is to develop a scientifically based resource-saving system for primary tillage using organic fertilizers and biological products for the sustainable production of high-quality crop products, preservation and reproduction of soil fertility, lowering energy resources and increasing the profitability of agricultural production, using the example of chernozem typical in the Chechen Republic.

To achieve this goal, the following objectives were solved:
- to conduct a general analysis of the soil cover and climatic conditions of the forest-steppe zone within the borders of the Chechen Republic as an agroecological resource of agriculture;
- control of the soil fertility of the experimental plot, by conducting laboratory analyzes of its agrochemical and agrophysical indicators at the beginning and end of the plant vegetation;
- to give a comparative assessment of the effectiveness of tillage methods against the background of green manure using mineral fertilizers and biological products.

The scientific novelty of the research lies in the fact that for the first time in the Chechen Republic on a typical black soil, the influence of a resource-saving primary tillage system using organic fertilizers and biological products on obtaining a consistently high yield of grain crops, preservation and reproduction of soil fertility is studied.

4. Place, metotics, conditions and materials
The scientific research was carried out on the experimental field of the Chechen Research Institute of Agriculture, located in the forest-steppe natural and climatic zone. The climate of the zone is warm, moderately humid – favorable for the cultivation of crops. Soil of the site – typical chernozem (on the dry land).

Winter is moderately mild, with unstable snow cover, 5–8 cm high, the sum of negative temperatures – –170…–600 °C. The average monthly temperature in January is –3…–5 °C, and the absolute minimum is –36°C. Summer is moderately hot, the average monthly temperature in July is 23°C, the maximum is 41°C, the average annual air temperature reaches 9.6–10.4 °C, the sum of active air temperatures above 10°C is 3400–3600 °C. The average annual wetting ratio is 0.48–0.60. 350–500 mm of precipitation falls during the period of active vegetation, and 450–600 mm during the year. The frost-free period is 185 days. Despite moderate hydration, droughts and dry winds are often observed, the number of days of which from April to October is 50–70 The beginning of the vegetative period of plants is the first decade of April [9].

The soil cover of the forest-steppe zone is very diverse due to the general heterogeneity of natural conditions and soil formation processes. The most widespread are chernozem soils. In mesicosities, where groundwater lies close to the surface, meadow chernozemic and meadow soils are often found [5]. In floodplains, river valleys, and on floodplain terraces, alluvial-meadow soils are common. In the extreme south of the zone, gray forest and dark gray forest soils lie in small contours [3].

The bookmark and organization of field experience, observations and laboratory analyzes, selection of soil and plant samples were carried out according to generally accepted guidelines and recommendations given in the sources [1, 4, 7, 8, 10].
Laboratory analysis of the soil was carried out at the Agrochemical Service Station “Chechen” according to the methods provided for carbonate soils:

- determination of humus – according to the method of Tyurin (GOST 26213-91);
- determination of nitrate nitrogen (N-NO₃) – by the ionometric method (GOST 26951-86);
- determination of mobile compounds of phosphorus (P₂O₅) and potassium (K₂O) according to the Machigin method in the modification of TsINAO – (GOST 26205-91);
- determination of bulk mass – according to the Kaczynsk method;
- determination of the number of structural aggregates (dry sieving) – according to the method of Savvinov;
- determination of the water resistance of structural aggregates (wet sieving) – according to the Andrianov method;

The main tillage was carried out in three ways using agricultural machinery and equipment:
1) plowing to a depth of 25–30 cm with a mounted plow PN-4-35 + VT-100 (tracked tractor);
2) disking to a depth of 10–15 cm with a disk harrow BDM-3 × 4 + KhTZ-17221 (wheeled tractor);
3) chiseling to a depth of 30–40 cm with a chisel-deep-ripper D 380 NS + XT3-17221 (wheeled tractor).

Mineral fertilizers were used:
- the main application on all crops – for the main tillage: ammophos and potassium nitrate in a dose of N30P60K60 (AI);
- top dressing on the phases of plant vegetation with ammonium nitrate: for winter wheat in the tillering phase at a dose of N40 (a.v.) and in the phase of belling at a dose of N30 (a.v.), under spring oats in a tillering phase and at a bumping phase in doses N30 (a.a.), for corn in the phase of the third sheet and throwing panicles in doses of N45 (a.a.).

As organic fertilizers were used:
- semi-rotted manure at a dose of 30 t/ha;
- green manure – spring oats + fodder sorghum, seeding rate of 150 and 10 kg/ha, respectively.

Biological products were used according to the recommendations of the All-Russian Research Institute of Agricultural Microbiology and given in the source [10]. The technology of using biological products: for winter wheat, oats and corn – Bacillus subtilis (strain V417). Presowing seed inoculation is normal 1 l/t, double treatment of winter wheat and oat crops in the tillering and tubing phases, corn in the fifth leaf phase and throwing panicles at a dose of 2 l/ha. Under soybean – pre-sowing seed inoculation with Rizotorfin at a rate of 3 l/t and Extrasol at a rate of 1 l/t, cultivation of crops with Extrasol at a dose of 2 l/ha.

The plot area in the experiment is 50 m², the repetition is 4-fold. Repetitions are placed in a continuous organized manner.

The following were taken for control: 1) a variant of field experience without the use of organic, mineral fertilizers and biological products; 2) plowing by a plow PN-4-35 – for methods of tillage.

The objects of research: the soil of the experimental plot – typical medium-power chernozem chernozem underlain by gravel. Differs in flushing type of the water regime of the soil. The depth of the pebble varies between 50–100 cm. The reaction of the soil solution is neutral (pH 6.9) – optimal for the growth and development of crops.

5. Results
The autumn-winter period of 2018–2019 turned out to be warm, in the absence of precipitation. Winter was snowless. The spring period was characterized by an abundance of precipitation, with an excess of the norm of air temperature by an average of almost one degree and its differences from –3.7 to 19.0 °C. The warmest days with a maximum temperature of 31.9 °C occurred at the end of April.
### Table 1. Influence of methods of soil treatment using sederate, biological products and mineral fertilizers on agrochemical indices in the agriculture and subground layer

| Soil tillage          | Variant                  | Soil layer, cm | Humus (according to Tyurin), % | Nitrate Nitrogen (N-NO₃), mg/kg (ionometric method) | Labile Phosphorus (P₂O₅), mg/kg (according to Machigin) | Labile Potassium (K₂O), mg/kg (according to Machigin) |
|-----------------------|--------------------------|----------------|-------------------------------|---------------------------------------------------|------------------------------------------------------|--------------------------------------------------|
|                       |                          | 0–5            | 2.56                          | 5                                                 | 11                                                   | 130                                              |
|                       |                          | 25–50          | 2.48                          | 3                                                 | 8                                                    | 100                                              |
| Baseline, Fall 2018   |                          |                |                               |                                                   |                                                      |                                                  |
| The beginning of the vegetation period, spring 2019 |                          |                |                               |                                                   |                                                      |                                                  |
| Control               |                          | 0–25           | 2.7                           | 8                                                 | 16                                                   | 110                                              |
|                       |                          | 25–50          | 2.6                           | 7                                                 | 14                                                   | 100                                              |
| NPK                   |                          | 0–25           | 4.1                           | 8                                                 | 18                                                   | 150                                              |
|                       |                          | 25–50          | 3.7                           | 8                                                 | 15                                                   | 100                                              |
| Green manure          | Biological product      | 0–25           | 3.8                           | 8                                                 | 17                                                   | 130                                              |
|                       |                          | 25–50          | 3.4                           | 14                                                | 12                                                   | 100                                              |
| NPK + Biological product |                      | 0–25           | 3.7                           | 28                                                | 17                                                   | 160                                              |
|                       |                          | 25–50          | 3.1                           | 21                                                | 8                                                    | 120                                              |
| Average (green manure)|                          | 0–25           | 3.9                           | 15                                                | 17                                                   | 133                                              |
|                       |                          | 25–50          | 3.4                           | 14                                                | 12                                                   | 100                                              |
| Average (plowing)     |                          | 0–25           | 4.0                           | 13                                                | 18                                                   | 153                                              |
|                       |                          | 25–50          | 3.3                           | 12                                                | 13                                                   | 121                                              |
| Control               |                          | 0–25           | 3.4                           | 7                                                 | 15                                                   | 120                                              |
|                       |                          | 25–50          | 3.1                           | 6                                                 | 12                                                   | 110                                              |
| NPK                   |                          | 0–25           | 4.0                           | 8                                                 | 19                                                   | 140                                              |
|                       |                          | 25–50          | 3.7                           | 7                                                 | 15                                                   | 100                                              |
| Green manure          | Biological product      | 0–25           | 3.6                           | 13                                                | 16                                                   | 140                                              |
|                       |                          | 25–50          | 3.3                           | 10                                                | 14                                                   | 110                                              |
| NPK + Biological product |                      | 0–25           | 3.8                           | 26                                                | 18                                                   | 150                                              |
|                       |                          | 25–50          | 3.4                           | 19                                                | 13                                                   | 120                                              |
| Average (green manure)|                          | 0–25           | 3.8                           | 16                                                | 16                                                   | 137                                              |
|                       |                          | 25–50          | 3.5                           | 12                                                | 13                                                   | 107                                              |
| Average (disking)     |                          | 0–25           | 3.8                           | 14                                                | 22                                                   | 174                                              |
|                       |                          | 25–50          | 3.3                           | 11                                                | 19                                                   | 140                                              |
| Disking (BDM-3x4)     |                          | 0–25           | 3.2                           | 8                                                 | 15                                                   | 120                                              |
| Control               |                          | 25–50          | 2.7                           | 7                                                 | 11                                                   | 100                                              |
| NPK                   |                          | 0–25           | 3.7                           | 8                                                 | 21                                                   | 160                                              |
|                       |                          | 25–50          | 3.4                           | 7                                                 | 16                                                   | 120                                              |
| Green manure          | Biological product      | 0–25           | 3.5                           | 12                                                | 16                                                   | 120                                              |
|                       |                          | 25–50          | 3.1                           | 10                                                | 13                                                   | 110                                              |
| NPK + Biological product |                      | 0–25           | 3.4                           | 17                                                | 12                                                   | 220                                              |
|                       |                          | 25–50          | 3.1                           | 11                                                | 9                                                    | 130                                              |
| Average (green manure)|                          | 0–25           | 3.5                           | 12                                                | 16                                                   | 167                                              |
|                       |                          | 25–50          | 3.3                           | 9                                                 | 12                                                   | 117                                              |
| Average (disking)     |                          | 0–25           | 3.7                           | 13                                                | 18                                                   | 174                                              |
|                       |                          | 25–50          | 3.1                           | 11                                                | 12                                                   | 126                                              |
| Chiselplowing (1 380 NS) |                      | 0–25           | 3.1                           | 8                                                 | 15                                                   | 140                                              |
| For all methods of tillage |                        | 0–25           | 2.8                           | 7                                                 | 12                                                   | 113                                              |
| Average (control)     |                          | 0–25           | 3.8                           | 14                                                | 16                                                   | 146                                              |
|                       |                          | 25–50          | 3.4                           | 12                                                | 12                                                   | 108                                              |
| Average (green manure)|                          | 0–25           | 3.4                           | 12                                                | 12                                                   | 108                                              |
| HCPus                 |                          |                | 0.48                          | 3.6                                               | 4.0                                                  | 14.8                                             |

Analysis performed in the agrochemical service station “chechen”
### Table 1. Part 2

The end of the growing season, Fall 2019

| Soil tillage     | Variant                  | Soil layer, cm | Humus (according to Tyurin), % | Nitrate Nitrogen (N-NO₃), mg/kg (ionometric method) | Labile Phosphorus (P₂O₅), mg/kg (according to Machigin) | Labile Potassium (K₂O), mg/kg (according to Machigin) |
|------------------|--------------------------|----------------|--------------------------------|-----------------------------------------------------|--------------------------------------------------------|--------------------------------------------------------|
|                  |                          | 0–25           | 2.5                            | 3                                                   | 12                                                    | 110                                                   |
|                  |                          | 25–50          | 3.1                            | 4                                                   | 16                                                   | 120                                                   |
|                  |                          | 0–25           | 3.4                            | 4                                                   | 16                                                   | 120                                                   |
|                  |                          | 25–50          | 3.9                            | 5                                                   | 11                                                   | 110                                                   |
|                  | Plowing (PN-4-35)        | 0–25           | 3.2                            | 3                                                   | 28                                                   | 120                                                   |
|                  |                          | 25–50          | 3.7                            | 8                                                   | 17                                                   | 100                                                   |
|                  |                          | NPK            |                                |                                                     |                                                       |                                                       |
|                  |                          | 0–25           | 3.2                            | 9                                                   | 15                                                   | 130                                                   |
|                  |                          | 25–50          | 3.6                            | 16                                                  | 10                                                   | 110                                                   |
|                  | Green manure             | 0–25           | 3.3                            | 5                                                   | 20                                                   | 123                                                   |
|                  |                          | 25–50          | 3.7                            | 10                                                  | 13                                                   | 103                                                   |
|                  | Biological product       | NPK            |                                |                                                     |                                                       |                                                       |
|                  |                          | 0–25           | 3.0                            | 5                                                   | 16                                                   | 121                                                   |
|                  |                          | 25–50          | 3.6                            | 9                                                   | 12                                                   | 107                                                   |
|                  |                          | Biological product |                  |                                                     |                                                       |                                                       |
|                  |                          | 0–25           | 3.1                            | 7                                                   | 9                                                    | 150                                                   |
|                  |                          | 25–50          | 3.4                            | 9                                                   | 7                                                    | 100                                                   |
|                  |                          | NPK + Biological product |            |                                                     |                                                       |                                                       |
|                  |                          | 0–25           | 3.2                            | 8                                                   | 17                                                   | 150                                                   |
|                  |                          | 25–50          | 3.6                            | 13                                                  | 14                                                   | 120                                                   |
|                  | Average (green manure)   | 0–25           | 3.2                            | 6                                                   | 12                                                   | 133                                                   |
|                  |                          | 25–50          | 3.6                            | 9                                                   | 9                                                    | 110                                                   |
|                  |                          | Average (disking)|                  |                                                     |                                                       |                                                       |
|                  |                          | 0–25           | 3.2                            | 5                                                   | 15                                                   | 159                                                   |
|                  |                          | 25–50          | 3.5                            | 7                                                   | 13                                                   | 123                                                   |
|                  |                          | Control        |                                |                                                     |                                                       |                                                       |
|                  |                          | 0–25           | 3.0                            | 3                                                   | 10                                                   | 140                                                   |
|                  |                          | 25–50          | 3.5                            | 5                                                   | 9                                                    | 100                                                   |
|                  |                          | NPK            |                                |                                                     |                                                       |                                                       |
|                  |                          | 0–25           | 3.3                            | 4                                                   | 12                                                   | 170                                                   |
|                  |                          | 25–50          | 3.6                            | 5                                                   | 11                                                   | 140                                                   |
|                  | Green manure             | 0–25           | 3.1                            | 6                                                   | 17                                                   | 160                                                   |
|                  |                          | 25–50          | 3.5                            | 9                                                   | 14                                                   | 127                                                   |
|                  | Biological product       | NPK            |                                |                                                     |                                                       |                                                       |
|                  |                          | 0–25           | 3.1                            | 8                                                   | 18                                                   | 200                                                   |
|                  |                          | 25–50          | 3.5                            | 12                                                  | 14                                                   | 150                                                   |
|                  |                          | Biological product |                  |                                                     |                                                       |                                                       |
|                  |                          | 0–25           | 3.1                            | 6                                                   | 17                                                   | 160                                                   |
|                  |                          | 25–50          | 3.5                            | 9                                                   | 14                                                   | 127                                                   |
|                  |                          | Average (green manure) |          |                                                     |                                                       |                                                       |
|                  | Chiselplowing (D 380 NS) | 0–25           | 3.1                            | 5                                                   | 17                                                   | 177                                                   |
|                  |                          | 25–50          | 3.5                            | 8                                                   | 14                                                   | 137                                                   |
|                  | For all methods of tillage | Average (control) |                  |                                                     |                                                       |                                                       |
|                  |                          | 0–25           | 3.3                            | 4                                                   | 10                                                   | 117                                                   |
|                  |                          | 25–50          | 3.2                            | 6                                                   | 16                                                   | 139                                                   |
|                  | Average (green manure)   | 0–25           | 3.2                            | 6                                                   | 12                                                   | 113                                                   |
|                  |                          | 25–50          | 3.6                            | 9                                                   | 12                                                   | 113                                                   |
|                  |                          | Average (green manure) |            |                                                     |                                                       |                                                       |
|                  |                          | 0–25           | 3.2                            | 6                                                   | 12                                                   | 113                                                   |
|                  |                          | 25–50          | 3.6                            | 9                                                   | 12                                                   | 113                                                   |
|                  |                          | For all methods of tillage |          |                                                     |                                                       |                                                       |
|                  |                          | 0–25           | 3.2                            | 6                                                   | 12                                                   | 113                                                   |
|                  |                          | 25–50          | 3.6                            | 9                                                   | 12                                                   | 113                                                   |

In May, 56 mm of precipitation fell within the annual average. However, during the summer period, the amount of precipitation decreased sharply against the background of a significant increase in air temperature (2.7 °C).
In the period 2018–2019, according to the stage of the research work, the dependence of soil fertility on various tillage methods using siderate, biological products, and mineral fertilizers was studied. In this case, the influence of soil cultivation techniques in combination with the studied factors on its agrochemical and agrophysical properties in the arable and subsurface layer at the beginning and at the end of the growing season was considered.

According to the data of the agrochemical analysis of the soil carried out at the beginning of the growing season, comparatively better indicators of the humus content were noted in the experimental variants using mineral fertilizers (NPK) for all tillage methods, both in the arable field – 0–25 cm and in the subsoil – 25–50 cm (TABLE I).

This indicator is higher when plowing (control by soil cultivation techniques) – 4.1 % in the arable soil layer, which is 1.4, or 34 % higher than in the control version, where the humus content is 2.7 %; the subsoil layer of humus contains – 3.7, 1.1, or 30 % higher than in the control version, where the humus content is 2.6 %. If we compare the methods of cultivating the soil, then the humus content in the arable layer during plowing is 0.1 % higher than during disking and 0.4 % in the arable layer and 0.3 % in the subsoil layer is higher than when chiseling. The same trend was noted at the end of the growing season, while the humus content became higher in the subsurface layer of the soil, compared with the arable layer, which can be caused by the flushing type of water regime of the soil, in which the humus is washed out in its lower layers. So, when plowing in the same version of the experiment with NPK in the arable layer of the soil, the humus content is 3.4 %, which is 0.9, or 26 % higher than in the corresponding control variant, where the humus content is 2.5 %, while in the subsoil layer this indicator is 3.9 %, which is 0.8, or 20 % higher than in the control version, where humus is contained – 3.1 %. When disking and chiseling the soil as compared with plowing, the humus content in the arable layer is lower by 0.1 %, respectively, and in the sub-arable layer by 0.2 and 0.3 % (TABLE I – Part 2).

According to the content of nitrate nitrogen and mobile potassium at the beginning of the growing season for both soil layers, the best results were obtained in the experiment with the use of mineral fertilizers and biological products (NPK + biological product) at all tillage methods. These indicators are higher when plowing the soil, where the nitrogen content in the arable layer is 28 mg/kg of soil, in the subsoil layer is 21 mg/kg, which is 20 mg/kg and 14 mg/kg, or 3.5 times and 3 times more than in the corresponding control variant with a nitrogen content of 8 mg/kg and 7 mg/kg. When disking the soil, the nitrogen content, both in the arable and in the subsoil layer, is 2 mg/kg, and when chiseling is 11 and 10 mg/kg lower than during plowing. According to the potassium content in the arable and subsurface layer of the soil during chiseling the indicators are higher than in the other treatments – 220 mg/kg and 130 mg/kg, which is 100 mg/kg and 30 mg/kg, or almost 2 times and 23 % more than in the control version, where the potassium content, respectively, 120 mg/kg and 100 mg/kg. When plowing and disking, the potassium content in the arable layer is 60 and 70 mg/kg, respectively, and in the sub-arable layer, 10 mg/kg lower than when chiseling (TABLE I). At the end of the growing season, as well as at its beginning, the best indicators for the content of nitrogen and potassium in the soil were obtained in the NPK + version of the biological product at all processing stages. At the same time, as in the case of humus, there was an increase in the content of nitrate nitrogen in the subsurface layer of the soil, compared with the arable layer, which is also due to the flushing type of its water regime. This indicator in both layers of soil is higher on plowing than on other treatments – 9 mg/kg in the arable layer and 16 mg/g in the subsoil, with the corresponding indicators of the control options 3 mg/kg and 4 mg/kg, which is 6 mg/kg and 12 mg/kg, or 3–4 times more. When disking and chiseling, the nitrogen content in the arable layer is 1 mg/kg and 3 and 4 mg/kg lower in the arable layer than during plowing. In terms of potassium, the indicators are higher during chiseling, moreover, in both soil layers, they are 200 mg/kg in the arable layer and 150 mg/kg in the arable layer, which is respectively 60 and 50 mg/kg, or 30 and 33 % higher than control options – 140 and 100 mg/kg. The potassium content in the arable layer of the soil during disking and plowing is lower by 50 and 30 mg/kg, respectively, and in the subsoil layer by 70 and 40 mg/kg than when chiseling (TABLE I – Part 2). At the beginning of the growing season, similarly to humus
indicators, the phosphorus content is higher in the variant with NPK at all cultivation methods and in both soil layers. The indicators are better for soil chiselplowing – 21 mg/kg in the arable layer and 16 mg/kg in the subsoil, which is 6 and 5 mg/kg, or 29 % and 31 % more than in the corresponding control options, where phosphorus is contained 15 and 11 mg/kg. When disk and plowing, the phosphorus content in the arable layer of soil is 19 mg/kg and 18 mg/kg, respectively, the same in the subsurface layer is 15 mg/kg, while it is less than when chiselplowing by 2 and 3 mg/kg, and by 1 mg/kg (TABLE I). At the end of the growing season, the best indicators for the phosphorus content in the soil for both layers and for all treatment methods were achieved in the experimental version using only biological preparations, which was facilitated by its phosphate mobilizing activity. The indicators are relatively higher for plowing – 28 mg/kg in the arable layer and 17 mg/kg in the arable layer, which is respectively 16 mg/kg, or more than 2 times and 5 mg/kg, or 29 % more than in the control variant, where phosphorus is 12 mg/kg in both soil layers. When chiselplowing in the arable and subsurface layers of the soil, phosphorus is contained at 7 and 2 mg/kg less than during plowing. When disk, the phosphorus content in the soil is higher in the NPK – 1 variant biological product. In the arable soil layer, this indicator is 17 mg/kg, in the arable layer – 14 mg/kg, respectively, 7 and 4 mg/kg, or 41 % and 29 % higher than in the control variant, with the content in both layers of soil 10 mg/kg. Compared with plowing, phosphorus is contained in the arable and subsurface soil layer, respectively, 11 and 3 mg/kg less (TABLE I – Part 2).

6. Conclusion

Based on the research results, the following conclusions are made:

- a positive effect of soil cultivation techniques and organic fertilizers on its fertility was revealed, the results are better when plowing the soil;
- in terms of humus content, the best indicators were noted in the experimental variants with the use of mineral fertilizers (NPK) for all tillage methods, both in the arable layer – 0–25 cm and in the subsoil layer – 25–50 cm. This indicator is higher when plowing (control by methods of tillage) – 4.1 % (average content) in the arable layer of the soil, arable layer – 3.7 % (low content);
- on the content of nitrate nitrogen and mobile potassium on both soil layers, the best results were obtained in the experiment with the use of mineral fertilizers and biological products (NPK + biological product) at all methods of soil cultivation. The nitrogen content is higher during plowing, where in the arable layer – 28 mg/kg, in the subsoil layer – 21 mg/kg, which refers to an increased level. Potassium indices are higher when soil is chelated – 220 mg/kg in the arable layer (average content), 130 mg/kg – in the arable layer (low content);
- the best indicators for the phosphorus content in the soil in both layers and at all processing methods were achieved in the experimental version using only biological products, which could be facilitated by their phosphate mobilization activity. The indicators are higher for plowing – 28 mg/kg in the arable layer and 17 mg/kg – in the arable layer, which refers to the average content.

In conclusion, we can say that the obtained results contribute to solving urgent problems on the effective application of the main tillage system, organic and mineral fertilizers, biological products for the conservation and reproduction of soil fertility and sustainable production of crop products.

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