Influence of background of mineral nutrition and receptions of major treatment of soil when cultivating spring wheat in conditions of the forest-steppe zone of the middle Volga region

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Abstract. Discussion issues on partial replacement of mineral fertilizers with crushed straw and crop siderate, as well as minimizing soil tillage, are often linked by researchers to an increase in biological and enzymatic activity, at the same time, and with an increase in the number of agronomically important physiological groups of soil-ammonifying, nitrifying, denitrifying bacteria and cellulose-forming microorganisms that contribute to higher yields and lower production costs for the cultivation of crops. In result of the conducted researches we obtained the highest yield of all possible experience (of 3.09 t/ha) and the best indicators of quality of grain of spring wheat also were obtained on the variant with the introduction N60P60K60, chopped straw predecessor and green manure on subsurface loosening. In addition, in this embodiment, the best were the economic indicators, net income – RUB 2369.6 1 ha, and the level of profitability of production amounted to 34.3%.

1. Introduction
About 20 kg of nitrogen, 7.6-8.0 kg of phosphorus and 22-25 kg of potassium per hectare are supplied to the soil when green manures are sown. In grain-steam crop rotation with stubble green manure (rapeseed) the yielding capacity capacity of spring cereals in average fertilized backgrounds increased up to 3.21-3.33 tons, and in grain-grasses - up to 3.07-3.46 tons/ha. Introduction of straw and green manure into the soil increases biological activity, accelerates decomposition of fresh non-humified nutrients, i.e. influences improvement of physical and biological properties of soil [1-3].

Many authors note that agro-ecological, energy-saving and economic efficiency of siding on the fields occupied by grain crops, and especially at stubble sowing of green manures in combination with straw and introduction of small doses of mineral fertilizers synthesis of biological and technogenic means of soil fertility reproduction takes place, and, consequently, the yielding capacity of agricultural crops in crop rotation with good indicators of grain quality increases [4,5].
2. **Research conditions, materials and methods**

In the Zakamskaya filed station of Buinsky district of the Republic of Tatarstan field experiments on leached chernozem were started in 2015-2017. The soil of the pilot plot of average granulometric composition with humus content of 6.3%, alkali-hydrolysable nitrogen - 143-151 mg/kg, mobile forms of phosphorus - 148-151, exchangeable potassium - 122-127 mg/kg of soil, pH of salt extract - 5.6.

For sowing we used the variety of spring wheat Miss, with the norm of sowing 5.5 million seeds pcs./ha. Fertilizers for 4.5 t/ha were calculated by the balance method, while for the rest variants 60 kg of NRC per 1 ha were applied.

Field experience scheme: Factor of A-reception of soil treatment: 1. Clean ploughing, 2. tilting the soil before ploughing.

Facts of B-background feeding: 1. without fertilizers; 2. NPK for 4.5 t/ha (N126 P156 K111); 3. N60P60K60; 4. N60P60K60 + straw; 5. N60P60K60 + green manure; 6. N60P60K60 + straw+ green manure. Tables show the variants with application of mineral fertilizers, straw and green manure will be indicated by numbers from 1 to 6.

Repetition in the experiments was three times, and the plots were placed systematically. The area of the plot was 278 m²; the record area was 210 m². After harvesting winter rye with stubble residue, 1.78 t/ha of dry biomass or N7.8 P4.6 K1.3 kg of B.V., straw - N12.5 P6.3 K2.1 kg of B.V. /ha (2.46 t/ha), green manure - N13.6 P2.3 K16.2 kg of B.V. /ha (3.6 t of green mass from 1 ha) were delivered to the soil.

3. **Results and discussions**

The use of plant biomass as an organic fertilizer created favorable conditions for activation of biological processes, contributed to improvement of soil agrophysical indicators, water and food regimes, and had a positive impact on yielding capacity and qualitative characteristics of spring wheat grains.

The change in the structure of the arable layer depends on the methods of basic tillage and qualitative soil cutting, and the deterioration of its physical, agrochemical and biological properties, which occurs from the impact of heavy machinery and tools on the soil.

Before sowing, the soil density was low, the ploughing in the layer of 0-10 g/cm³ was 1.15-1.17 g/cm³, the ploughing without tilting - 1.14-1.16 g/cm³, and in the layer of 10-20 cm - 1.20-1.23 and 1.19-1.22 g/cm³ respectively (Table 1).

| Feeding background | Before sowing | Before harvesting |
|--------------------|---------------|-------------------|
|                    | 0-10 cm | 10-20 cm | 0-20 cm | 0-10 cm | 10-20 cm | 0-20 cm |
| Ploughing          |         |         |        |         |         |        |
| 1.                 | 1.17    | 1.23    | 1.20   | 1.27    | 1.36    | 1.32    |
| 2.                 | 1.17    | 1.22    | 1.19   | 1.28    | 1.35    | 1.32    |
| 3.                 | 1.17    | 1.23    | 1.20   | 1.27    | 1.35    | 1.31    |
| 4.                 | 1.16    | 1.21    | 1.18   | 1.26    | 1.34    | 1.30    |
| 5.                 | 1.15    | 1.21    | 1.18   | 1.26    | 1.34    | 1.30    |
| 6.                 | 1.15    | 1.20    | 1.17   | 1.24    | 1.33    | 1.29    |
| Tilting            |         |         |        |         |         |        |
| 1.                 | 1.16    | 1.22    | 1.19   | 1.26    | 1.34    | 1.30    |
| 2.                 | 1.16    | 1.22    | 1.19   | 1.26    | 1.33    | 1.30    |
| 3.                 | 1.17    | 1.22    | 1.20   | 1.26    | 1.33    | 1.30    |
| 4.                 | 1.15    | 1.20    | 1.18   | 1.25    | 1.32    | 1.29    |
| 5.                 | 1.14    | 1.20    | 1.17   | 1.25    | 1.32    | 1.29    |
| 6.                 | 1.14    | 1.19    | 1.17   | 1.24    | 1.31    | 1.28    |

More compaction of the soil took place before harvesting on all feeding backgrounds, and the lowest compaction rate was observed on the basis of non-dumping loosening. Comparing the values of soil
density for ploughing in the layer 0-10 cm, we can say that it was 1.24-1.28 g/cm³, in the layer 10-20 cm increased to 1.33-1.36 g/cm³. The indices of soil density on tilting were lower and amounted, respectively, to 1.24-1.26 in the layer of 0-10 cm and 1.31-1.34 g/cm³ in the layer of 0-20 cm. A significant decrease in the density of soil formation occurred with the application of nutrients. 0-20 cm layer of ploughing decreased in comparison with the control by 0.02-0.03 g/cm³, and 0.02 g/cm³ layer of non-dumping loosening.

Therefore, the introduction of stubble and root residues, straw and green manure into the soil contributed to the general decrease in the density of soil formation, thus having a favorable impact on plant development.

Before sowing, we determined the structural-aggregate composition of the soil, which showed that the layer 0-10 cm had more non-deposited tillage than the layer of ploughing by 1.2-2.3%, and the layer 10-20 cm - respectively by 1.4-2.3% (Table 2).

| Feeding background | Structurality 0-10 cm | Structurality 10-20 cm | Structurality 20-30 cm | Structure 0-10 cm | Structure 10-20 cm | Structure 20-30 cm |
|--------------------|-----------------------|------------------------|------------------------|------------------|-------------------|-------------------|
| Ploughing          |                       |                        |                        |                  |                   |                   |
| 1.                 | 43.9                  | 47.8                   | 45.9                   | 0.69             |                   |                   |
| 2.                 | 44.9                  | 49.5                   | 47.2                   | 0.73             |                   |                   |
| 3.                 | 44.3                  | 48.5                   | 46.4                   | 0.70             |                   |                   |
| 4.                 | 46.9                  | 51.7                   | 49.3                   | 0.76             |                   |                   |
| 5.                 | 48.0                  | 53.8                   | 50.9                   | 0.83             |                   |                   |
| 6.                 | 51.2                  | 56.9                   | 54.1                   | 0.86             |                   |                   |
| Tilting            |                       |                        |                        |                  |                   |                   |
| 1.                 | 45.1                  | 49.2                   | 47.2                   | 0.74             |                   |                   |
| 2.                 | 47.2                  | 51.3                   | 49.3                   | 0.77             |                   |                   |
| 3.                 | 46.3                  | 50.2                   | 48.3                   | 0.75             |                   |                   |
| 4.                 | 48.9                  | 53.4                   | 51.3                   | 0.82             |                   |                   |
| 5.                 | 50.6                  | 56.1                   | 53.4                   | 0.87             |                   |                   |
| 6.                 | 53.2                  | 59.2                   | 56.2                   | 0.90             |                   |                   |
| HCP 05             |                       |                        |                        |                  |                   |                   |
| A                  | 0.48                  | 3.84                   | 2.08                   |                  |                   |                   |
| B                  | 1.05                  | 0.86                   | 0.82                   |                  |                   |                   |
| AB                 | 0.69                  | 0.77                   | 0.61                   |                  |                   |                   |

With the application of the previous straw separately their content in the layer 0-20 cm of structural-aggregate composition of the soil increased by 3.4%, from the application of green manure - by 5%, with the joint use of straw and green manure as a biological fertilizer - up to 8.2 percent. The structural-aggregate composition of the soil was higher than that of the landfill ploughing and amounted to 4.1%, 6.2% for the green manure and 9% for the straw + green manure background, respectively, as compared to the control.

Therefore, the incorporation of stubble and root residues, the straw of the previous one and the sowing of green manure contributed to the improvement of the physical properties of the soil structure and the density of soil formation.

The application of the calculated doses of mineral fertilizers by 4.5 t/ha significantly increased the content of nutrients in the soil, 71 mg/kg of easily accessible nitrogen for ploughing, 230 mg/kg of mobile phosphorus and 146 mg/kg of exchangeable potassium in the soil before sowing, and only 41, 177 and 89 mg/kg of soil were controlled. On no-tillage processing these indicators exceeded insignificantly, on 1-3 mg/kg of soil.

Introduction of plant biomass in the form of straw and green manure contributed to the accumulation of nitrate nitrogen in the layer of 0-30 cm before sowing for ploughing 55-61 mg/kg of soil, for non-
dumping loosening - 56-62 mg, in the flowering phase of 33-40 and 35-41 mg/kg of soil, respectively. Before harvesting, there was a significant reduction in the content of nitrate nitrogen in the soil to 25-30 mg and 27-31 mg/kg of soil (Table 3). The content of mobile phosphorus in the soil of these variants before sowing was 198-210 mg, in the flowering phase they decreased to 191-200 mg/kg and before harvesting to 181-189 mg/kg of soil, in the absence of dumping of this indicator in the phases of development of spring wheat was 202-212, 193-202 and 185-194 mg/kg of soil, respectively. The same content and decrease in the yield for harvesting occurred with exchange potassium. The best conditions for plant nutrition were in the variant with the application of calculated doses of mineral fertilizers on 4.5 t/ha.

Table 3. Battery content in soil under spring wheat crops, mg/1000 g

| Feeding background | Before sowing | Blossoming | Full ripeness |
|--------------------|---------------|------------|---------------|
|                    | N-NO₃  | P₂O₅  | K₂O | N-NO₃  | P₂O₅  | K₂O | N-NO₃  | P₂O₅  | K₂O |
| Ploughing          |        |        |     |        |        |     |        |        |     |
| 1.                 | 41     | 177    | 89  | 32     | 168    | 81  | 23     | 159    | 76  |
| 2.                 | 71     | 230    | 146 | 52     | 212    | 138 | 33     | 204    | 131 |
| 3.                 | 55     | 197    | 119 | 36     | 189    | 110 | 25     | 180    | 103 |
| 4.                 | 56     | 198    | 119 | 33     | 191    | 106 | 26     | 181    | 101 |
| 5.                 | 57     | 200    | 120 | 36     | 190    | 109 | 29     | 182    | 102 |
| 6.                 | 61     | 210    | 121 | 40     | 200    | 111 | 30     | 189    | 104 |
| Tilting            |        |        |     |        |        |     |        |        |     |
| 1.                 | 41     | 179    | 91  | 31     | 171    | 84  | 23     | 159    | 78  |
| 2.                 | 72     | 233    | 148 | 51     | 224    | 138 | 35     | 209    | 132 |
| 3.                 | 56     | 200    | 120 | 35     | 191    | 113 | 27     | 183    | 107 |
| 4.                 | 57     | 202    | 121 | 36     | 193    | 110 | 27     | 185    | 103 |
| 5.                 | 58     | 206    | 122 | 36     | 196    | 114 | 29     | 188    | 106 |
| 6.                 | 62     | 212    | 124 | 41     | 202    | 116 | 31     | 194    | 109 |

On average, for 3 years the maximum yielding capacity of grain was obtained by plowing N₆₀P₆₀K₆₀ + straw + green manure – 2.95 t/ha, for non-dumping processing it increased to 3.09 t/ha, yield increase to the control was 1.33 and 1.37 t/ha. Variants with the application of N₆₀P₆₀K₆₀ and plant biomass in comparison with the control allowed to form additionally the grain yielding capacity in the variant with the dump treatment of 0.60-1.33 t/ha, by non-dumped – 0.65-1.37 t/ha.

Therefore, the application of plant biomass (straw and green manure) not only improved the agrophysical indicators of the soil, but also significantly increased the yielding capacity of spring wheat. The quality of the crop was greatly influenced by the introduction of 60 kg of NRC, the predecessor straw and the incorporation of green manure. Weight of 1000 grains in this variant with dump processing increased up to 38.1 g, grain nature - up to 753 g/l, mass fraction of gluten - up to 31.3%, quality of gluten corresponded to the second class, while at the control these indicators were 28.3 g, 732 g/l and 50%, respectively. The increase in these indicators was due to the fact that the soil was not dumped. On this variant the indicators of quality of grain have increased in comparison with the control: weight of 1000 seeds - on 10.7 g, the nature of grain - on 24 g/l, vitreous form - on 15 % and the maintenance of gluten - on 6.7 %. In addition, this variant of gluten quality corresponded to the second class.
Table 4. Wheat yielding capacity depending on fertilizers and basic tillage methods, t/ha

| Feeding background | Years | Average | ± from control |
|--------------------|-------|---------|----------------|
|                    | 2015  | 2016    | 2017           | t/ha | % |
| Ploughing          |       |         |                |      |   |
| 1.                 | 1.26  | 1.38    | 2.24           | 1.62 | - 100.0 |
| 2.                 | 2.44  | 2.37    | 3.83           | 2.88 | 1.26 177.8 |
| 3.                 | 1.59  | 1.58    | 2.83           | 2.00 | 0.38 123.5 |
| 4.                 | 1.77  | 1.79    | 3.09           | 2.22 | 0.60 137.0 |
| 5.                 | 1.96  | 2.03    | 3.22           | 2.40 | 0.78 148.1 |
| 6.                 | 2.38  | 2.40    | 4.08           | 2.95 | 1.33 182.1 |
| Tilting            |       |         |                |      |   |
| 1.                 | 1.34  | 1.43    | 2.38           | 1.72 | - 100.0 |
| 2.                 | 2.55  | 2.52    | 3.94           | 3.00 | 1.28 174.4 |
| 3.                 | 1.70  | 1.78    | 3.09           | 2.19 | 0.47 127.3 |
| 4.                 | 1.88  | 1.93    | 3.31           | 2.37 | 0.65 137.8 |
| 5.                 | 2.18  | 2.24    | 3.48           | 2.63 | 0.91 152.9 |
| 6.                 | 2.49  | 2.57    | 4.21           | 3.09 | 1.37 179.7 |
| HCP_{05} t/ha      | A     | 0.03    | 0.07           | 0.04 |   |
|                    | B     | 0.06    | 0.06           | 0.07 |   |
|                    | AB    | 0.07    | 0.08           | 0.10 |   |

Table 5. Quality indicators of spring wheat grain depending on fertilizers and basic tillage methods

| Feeding background | Weight | Kind, g/l | Vitreousity, % | Mass fraction of gluten, % | Index DCI-1 | Group of the gluten quality |
|--------------------|--------|-----------|----------------|---------------------------|-------------|---------------------------|
| 1.                 | 28.3   | 732       | 50             | 24.2                      | 112         | I-3                       |
| 2.                 | 39.0   | 755       | 63             | 31.1                      | 68          | 2                         |
| 3.                 | 31.1   | 748       | 58             | 28.4                      | 102         | I-3                       |
| 4.                 | 34.2   | 743       | 54             | 27.3                      | 107         | I-3                       |
| 5.                 | 34.0   | 745       | 57             | 28.6                      | 92          | I-3                       |
| 6.                 | 38.1   | 753       | 60             | 31.3                      | 70          | 2                         |
| Tilting            |        |           |                |                           |             |                           |
| 1.                 | 27.9   | 733       | 49             | 24.6                      | 110         | II-III                    |
| 2.                 | 38.1   | 755       | 63             | 31.5                      | 70          | II                        |
| 3.                 | 33.2   | 745       | 58             | 29.1                      | 90          | II                        |
| 4.                 | 33.5   | 742       | 55             | 28.0                      | 103         | II-III                    |
| 5.                 | 36.0   | 749       | 58             | 29.3                      | 87          | II-III                    |
| 6.                 | 38.6   | 757       | 64             | 31.3                      | 58          | II                        |
| HCP_{05}           | A      | 0.70      | 5.78           | 3.60                      | 0.79        |                           |
|                    | B      | 1.24      | 5.84           | 2.47                      | 0.84        |                           |
|                    | AB     | 1.23      | 3.99           | 2.72                      | 0.40        |                           |

Cultivation of spring wheat turned out to be the most effective at the application of N_{60}P_{60}K_{60} + straw + green manure on the variant with a non-dumping loosening, where the profitability of production amounted to 34.3%, and the energy efficiency coefficient of non-dumping loosening - 1.94, against 1.81 on the background without fertilizers.
4. Conclusion
The maximum yield (3.09 t/ha) and the best indicators of grain wheat were obtained by applying N60P60K60, shredded straw of the predecessor and green manure for non-dumping loosening, and the addition to the control was 1.37 t/ha. In the same variant, the economic efficiency indicators were the best, and the profitability level was 34.3%.

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