Agrochemical objectivation of corn root residues accumulation using different methods of soil treatment and fertilizer doses

S D Litsukov, E G Kotlyarova, L N Kuznetsova, A V Akinchin and S A Linkov
Belgorod State Agricultural University named after V. Gorin, Belgorod, Russia

1E-mail: akinchin_av@bsaa.edu.ru

Abstract. Soil treatment and fertilization influenced the amount of root residues in the soil. The greatest amount of root residues mass was obtained by plowing and ranged from 4.45 t/ha in the control to 5.06 t/ha in the variant with the introduction of mineral fertilizers. For all treatments, the application of organic and mineral fertilizers had a positive effect on root residues accumulation, their maximum accumulation was obtained in the variant N130P130K130 + N100 and amounted to 4.67 - 5.06 t/ha. For all processing methods, the highest load of corn root residues is in the 0-10 cm layer. On average over the years of research maize for silage left in a grain-row crop rotation in a soil layer of 0-30 cm on the control for plowing 22.3 kg/ha of nitrogen, 2.8 kg/ha of phosphorus and 7.0 kg/ha of potassium. The use of mineral fertilizers at the rates (NPK) 70 and (NPK) 140 increased these indicators respectively to 28.0-30.2; 3.8-3.9 and 10.9-11.6 kg/ha. Organic fertilizers in the third year of aftereffect practically did not change the amount of nutrients accumulation in comparison with the unfertilized option. Using organo-mineral fertilization system nitrogen remained in the soil with a root mass of 28.0-28.9 kg/ha, phosphorus 4.1-4.2 and 10.9-11.3 kg/ha of potassium. A similar pattern was observed in the variants with soil cultivation without seed turnover and in the variant with the aftereffect of manure after shallow cultivation significantly less nutrients were accumulated compared to plowing. So, on plowed plots there was more nitrogen by 1.8 kg/ha, by 0.4 kg/ha phosphorus and by 0.7 kg/ha potassium. The methods of basic soil treatment in this crop rotation did not have a significant effect on the nutrients’ accumulation.

1. Introduction
In production conditions root and crop residues are the main components of soil enrichment with organic matter and therefore nutrients. Many scientists have found that root residues amount entering the soil is largely determined by the effect of fertilizers and the method of basic soil cultivation affects their distribution over the soil layers.

According to O G Kotlyarova, G I Uvarov, E G Kotlyarova (2004) soil treatment without plowing up led to an increase in the main amount of root residues of field crops in the upper (0-10) soil layer compared to plowing. When flat-cut processing to a depth of 25-35 cm in a layer of 0-10 cm, the amount of corn root residues for silage was 56.1% of the total mass of root residues, in a soil layer of 10-20 cm –28.9% and a layer of 20-40 cm - 15.0%. When plowing - in the 0-10 layer - 47.9% of root residues, in the 10-20 cm layer - 33.8% and in the 20-40 cm layer - 18.3%. According to the minimum soil treatment, the distribution of roots in the soil profile was correspondingly by layers — 54.9%; 30.3%; 14.8%.
Surface treatment provided the accumulation of root residues in the upper soil layer to a greater extent. So, when plowing in a layer of 0-10 cm, it was 46.7% of the total mass of root residues and with surface treatment - 68.6% of the total mass of roots. In the work of M I Salnikov and B A Rybalkin (2001) also noted that when plowing to a depth of 23-25 cm 2/3 of the stubble-root plant residues accumulates in soil layers of 10-20 and 20-30 cm while during flat-cut processing in a layer of 0-10 cm accumulates - 80-85%.

Grigorov M S, Kurbanov S A (1998) noted that the largest amount of root residues in the 0-30 cm soil layer was during moldboard and moldboard-free deep cultivation and the least - with shallow disc cultivation.

The results of Uvarova’s G I research (2007) et al. say that the maximum indicator of root residues mass of grain crops was observed with the combined application of organic and mineral fertilizers where the methods of treatment did not affect this indicator.

Studies on the effect of high doses of poultry manure on the yield and quality of corn have shown that when poultry manure is applied it changes the ratio between the aboveground part of plants and root residues mass. Moreover, the mass of root residues is significantly reduced [1-4].

Shiryaev A V and Kuznetsova L N (2014) note that plants’ root system plays an important role in nutrients absorption, moisture and crop formation by plants. Their growth as well as the formation of aboveground parts proceeds under the complex environment influence and cultivation technologies elements. Today more attention is paid to the study of investigated factors influence on the aboveground parts of plants and the effect on the underground is less studied.

2. Methodology

Researches to study the effect of fertilizers and methods of soil cultivation on corn productivity were carried out under the conditions of two experiments:

1. Field in CJSC "Krasnoyaruzhskaya grain company” Belgorod region.

The soil of the experimental area is typical Chernozem, medium-thick, low-humus, heavy loamy. The arable layer is characterized by the following indicators: humus content - 4.6% (according to Tyurin); pHKCl-6.12; Ng - 2.16; the content of easily hydrolyzable nitrogen - 147 mg/kg, mobile phosphorus and exchangeable potassium (according to Chirikov) - 51 and 89 mg/kg, respectively; sulfur content - 47.6 meq / 100 g of soil, magnesium - 2.5 meq / 100 g of soil, manganese - 5.37 mg/kg, zinc - 0.16 mg/kg.

The experiment is two-factorial, the replication is threefold, the sown area of the plot is 117.6 m², the counting area is 75 m². In crops a hybrid of Rovello maize was studied.

The experiment studied three methods of basic soil cultivation (factor A) and organic and mineral fertilizers (factor B).

Soil treatment methods:

- plowing with a Lemken plow to a depth of 22-25 cm;
- moldboard-free soil treatment to a depth of 22-25 cm with a Gaspardo subsoiler;
- surface tillage was carried out with a Rubin discator to a depth of 10-12 cm.

The scheme of the experiment including options with mineral and organic fertilizers and looked like this:

1) Control (no fertilizer).
2) Poultry excreta 20t/ha.
3) Poultry excreta 20t/ha + N60.
4) Poultry compost 20t/ha.
5) Poultry compost 20t/ha + N60.
6) N₁₃₀P₁₃₀K₁₃₀ + N₁₀₀

2. In a stationary field experiment at the Belgorod Research Institute of Agriculture.
The soil of the experimental area is typical, medium-thick, low-humus, heavy loamy Chernozem on loess-like loam with a humus content (according to Tyurin) 4.7-5.6%, pH of salt extract 5.8-6.3, contain of mobile phosphorus and exchangeable potassium (according to Chirikov) respectively 67-78 and 88-112 mg/kg of soil, the degree of saturation with bases is about 90%. During the stationary experiment the method of split plots was used. The experiment is two-factorial, its replication in time and space is threefold, the sown area of the plot is 120 m², the counting area is 75 m².

During the experiment, two crop rotations were studied: grain-row and grain-steam with the following crops alternation.

Grain-row
1. Peas.
2. Winter wheat.
3. Sugar beet.
4. Barley.
5. Corn for silage.

Grain-steam row
1. Black steam
2. Winter wheat.
3. Sugar beet.
4. Corn for silage.
5. Corn for grain.

Three methods of basic soil treatment (factor A) were studied:

- Plowing to a depth of 25-27 cm with the PLN-5-35 plow which was preceded by disc stubble plowing by 6-8 cm.
- Non-moldboard soil treatment to a depth of 25-27 cm with a Paraplau plow in front of which disc stubble cultivation was carried out by 6-8 cm.
- Surface tillage was carried out with a disc harrow BDT 7 at 6-8 and 10-15 cm.

Studied the rates of fertilization with manure: 0; eight; t/ha of crop rotation area and mineral fertilizers: control - without the use of fertilizers, single rate (NPK) 70 and double rate - (NPK) 140.

The scheme of experiments including options with mineral and organic fertilizers, (factor B), is as follows:

1. Control (used)
2. (NPK) 70
3. (NPK) 140
4. Manure 40 t/ha
5. Manure 40 t/ha + (NPK) 70
6. Manure 40 t/ha + (NPK) 140

3. Results and discussion

As a result of the experiments we found that the amount of root and crop residues in the first experiment on plots with plowing using organic and mineral fertilizers was greater.

The accumulation of root residues in the soil in our experiment was influenced by both the method of basic soil treatment and the applied fertilizers.

Information on root residues accumulation is presented in figure 1.

On plots with non-moldboard and shallow cultivation of root residues less than on plowed plots on the control was accumulated by 0.39-0.56 t/ha, on variants with the introduction of organic fertilizers by 0.25-0.78 t/ha, against the background the use of mineral fertilizers - by 0.29-0.39 t/ha.

The use of both organic and mineral fertilizers contributed to an increase in the studied indicator for all methods of basic soil cultivation compared to the control option where fertilizers were not used - for plowing by 0.31-0.61 t/ha, for alternative treatments by 0.32-0.78 t/ha.

Under the conditions of the second experiment in grain-tilled crop rotation, on average for three years in a soil layer of 0-30 cm the weight of roots on the option without the use of fertilizers was 2.24 t/ha for plowing, 2.08 for non-moldboard and 2.02 t/ha for surface tillage. Mineral fertilizers applied in single and double doses contributed to the growth of this indicator in relation to the control variant.
**Figure 1.** Root residues accumulation under corn for grain depending on the methods of basic soil treatment and fertilizers, t/ha.

**Table 1.** Root residues accumulation of under corn for silage in grain-row crop rotation depending on the methods of basic soil treatment and fertilizers, t/ha.

| Manure, t/ha | Fertilizers kg/ha | Soil treatment method | plowing | non-moldboard | surface tillage |
|--------------|-------------------|-----------------------|---------|---------------|-----------------|
| 0            | control           | 2.24                  | 2.08    | 2.02          |
| 0            | (NPK)$_{70}$      | 3.02                  | 3.03    | 2.98          |
| 0            | (NPK)$_{140}$     | 3.19                  | 3.04    | 3.12          |
| 40           | -                 | 2.40                  | 2.18    | 2.16          |
| 40           | (NPK)$_{70}$      | 3.15                  | 3.13    | 3.07          |
| 40           | (NPK)$_{140}$     | 3.25                  | 3.32    | 3.22          |
|              | HCP$_{05}$ factor A* | 0.23          | -       | -             |
|              | HCP$_{05}$ factor B** | 0.30          | -       | -             |

* - factor A – soil treatment;  
** - factor B - fertilizers

On plowed fields according to these backgrounds, it was equal to 3.02-3.19 t/ha according to non-moldboard and surface tillage respectively, 3.03-3.04 and 2.98-3.12 t/ha.

In the third year of aftereffect organic fertilizers had practically no effect on the root mass in comparison with the unfertilized options. It was 2.16-2.40 t/ha for various treatments.

Using organo-mineral fertilizer system this indicator was equal for plowing - 3.15-3.25 t/ha, for non-moldboard and surface tillage - 3.13-3.32 and 3.07-3.22 t/ha respectively. It should be noted that double rates of mineral fertilizers both in pure form and against the background of the aftereffect of organic fertilizers slightly increased the mass of roots compared with single ones.

Differences between the methods of basic soil treatment in the accumulation of roots were manifested in the variant with manure aftereffect. So, according to plowing against this background of fertilization there were 2.40 t/ha of roots, according to non-moldboard 2.18 and on surface tillage 2.16 t/ha (HCP05 for treatments 0.23 t/ha).
Table 2. Root residues accumulation under corn for silage in grain-and-steam crop rotation depending on the methods of soil treatment and fertilizers, t/ha.

| Manure, t/ha | Fertilizers kg/ha, | Soil treatment methods |
|--------------|--------------------|------------------------|
|              | plowing            | non-moldboard | surface tillage |
| 0            | control            | 2.32          | 2.20          | 2.18          |
| 0            | (NPK)$_{70}$      | 3.09          | 3.07          | 3.03          |
| 0            | (NPK)$_{140}$     | 3.30          | 3.17          | 3.18          |
| 40           | -                  | 2.47          | 2.34          | 2.33          |
| 40           | (NPK)$_{70}$      | 3.19          | 3.18          | 3.16          |
| 40           | (NPK)$_{140}$     | 3.21          | 3.30          | 3.23          |
| HCP$_{05}$ factor A* | 0.14 | -   | -   |
| HCP$_{05}$ factor B** | 0.22 | - | - |

* - factor A – soil treatment;  
** - factor B - fertilizers

In the grain-and-row crop rotation the mass of root residues depended mainly on the background of fertilization. On unfertilized fields it was 2.18-2.32 t/ha. In the second year of its aftereffect organic fertilizers slightly increased this indicator to 2.33-2.47 t/ha.

With mineral and organo-mineral fertilization systems the root mass significantly increased compared to the control respectively, for plowing up to 3.09-3.30, 3.19-3.21 t/ha, for non-moldboard tillage 3.08-3.17, 3.18-3.30 and 3.16-3.23 t/ha, for surface tillage (HCP$_{05}$ for fertilizers 0.22 t/ha).

The ratio of the root mass of root residues along the horizons in the experiment depended both on the processing method and on the fertilizers used.

As a result of our experiments, it was found that under the conditions of the first experiment in a soil layer of 0-10 cm for each method of processing, the content of corn root residues was maximum. For plowing it was 71.1-75.9%, for non-moldboard tillage 74.7-81.6%, for surface tillage 75.4-83.6%.

When moving down the profile the containing of roots by non-moldboard plowing was less than by plowing. In the 10-20 cm layer the number of corn roots (11.3-18.6%) is slightly less than for plowing - 18.0-23.9%. This was influenced by the good conditions for the development of the root system and the fertilizers used.

The full dose of mineral fertilizers over the course of three years of testing contributed to the better development of the corn root system which was reflected in the increase in the relatively unfertilized option for plowing - 12%, for non-moldboard plowing 14.9-16.8%.

Poultry excreta and poultry compost gave an increase of 6.5-11.6%. The mass of roots with the combined application of organic and mineral fertilizers increased by 9.2-14.5%.

Despite the fact that under the conditions of the second experiment soil treatment method in most cases did not have a significant effect on the accumulation of root mass it should be noted that the root mass is somewhat larger for non-moldboard tillage in the 0-10 cm soil layer than for plowing. So, if on the control in the grain-row crop rotation for plowing in the specified layer there were 41% of roots to their weight in the layer 0-30 cm, in 10-20 cm - 37 and in 20-30 cm - 21.8%, then by non-moldboard and surface tillage respectively - 47.5, 36.5, 15.8 and 67.3, 25.7, 6.9%. A similar pattern is observed in fertilized fields.

The above changes also take place in grain-and-row crop rotation.
In the top 0-10 cm soil layer on plowed fields depending on the level of fertilization 39.2-41.5%, in the 10-20 cm layer - 34.8-36.8%, in the 20-30 cm layer - 23.3-26%. For non-moldboard plowing, respectively, 46.8-51.2, 29.2-31.1, 18.7-22.2%, for surface tillage 66.0-68.9, 23.4-25.3, 6.1-13.3%.

Table 3. Root residues mass ratio along the horizons, %.

| Experiment variants | Layer | Soil treatment method |
|---------------------|-------|-----------------------|
|                     |       | plowing | non-moldboard | surface tillage |
| 1. No fertilizers –control | 0-10  | 71.5    | 75.9          | 75.4           |
|                      | 10-20 | 21.3    | 18.6          | 18.0           |
|                      | 20-30 | 7.1     | 5.5           | 6.6            |
|                      | 0-30  | 100.0   | 100.0         | 100.0          |
|                      | 0-10  | 71.1    | 74.7          | 76.8           |
|                      | 10-20 | 23.6    | 19.5          | 17.5           |
| 2. Poultry excreta –20t/ha | 20-30 | 5.4     | 5.8           | 5.7            |
|                      | 0-30  | 100.0   | 100.0         | 100.0          |
|                      | 0-10  | 75.9    | 81.6          | 81.7           |
| 3. Poultry excreta –20t/ha+N₆₀ | 10-20 | 18.0    | 14.1          | 12.7           |
|                      | 20-30 | 6.1     | 4.3           | 5.6            |
|                      | 0-30  | 100.0   | 100.0         | 100.0          |
|                      | 0-10  | 71.4    | 78.5          | 82.5           |
| 4. Compost (poultry)–20t/ha | 10-20 | 23.9    | 14.4          | 12.2           |
|                      | 20-30 | 4.8     | 7.1           | 5.2            |
|                      | 0-30  | 100.0   | 100.0         | 100.0          |
|                      | 0-10  | 75.8    | 81.6          | 81.9           |
| 5. Compost (poultry)–20t/ra+N₆₀ | 10-20 | 18.3    | 13.3          | 13.7           |
|                      | 20-30 | 5.9     | 5.0           | 4.5            |
|                      | 0-30  | 100.0   | 100.0         | 100.0          |
|                      | 0-10  | 72.5    | 80.5          | 83.6           |
| 6. N₁₃₀P₁₃₀K₁₃₀+N₁₀₀ | 10-20 | 19.2    | 13.2          | 11.3           |
|                      | 20-30 | 8.2     | 6.3           | 5.1            |
|                      | 0-30  | 100.0   | 100.0         | 100.0          |

Thus, our studies have shown that using surface tillage and non-moldboard cultivation, nutrients accumulate more in the upper soil layer and the root mass is located mainly in this layer which creates the preconditions for a very sharp differentiation in the fertility of the cultivated layer. Considering that with frequent May and June droughts, the top ten-centimeter soil layer dries up, the process of differentiation of the arable soil layer by fertility can hardly be considered a positive phenomenon.

The organic part of the soil is usually a small fraction of the total soil mass. But it is one of the most important and common soil components and its significance for soil formation and fertility is extremely great.

Thanks to organic matter the soil is inhabited by numerous microorganisms and soil animals with which a variety of complex biochemical processes are associated. The living matter of the soil
determines the biological circulation of substances and the flow of energy thanks to which the existence of life on land is possible.

The main source of primary organic matter entering the soil under natural vegetation is plant remains. Crop stubble and root residues of agricultural crops are an important source of increasing the reserves of nutrients in the soil, they are more easily mineralized than humus and their effect are close to organic fertilizers.

On average, over the years of research, maize for silage left in a row crop rotation the return to the soil of nutrients by the root weight in the control for plowing 22.3 kg/ha of nitrogen, 2.8 kg/ha of phosphorus and 7.0 kg/ha of potassium. The use of mineral fertilizers at the rates (NPK) increased these indicators respectively, to 28.0-30.2; 3.8-3.9 and 10.9-11.6 kg/ha. Organic fertilizers in the third year of atereffect practically did not change the amount of nutrients accumulation in comparison with the unfertilized variant (table 4).

**Table 4.** Return of nutrients with root residues to the soil depending on the methods of basic soil treatment and fertilizers, kg/ha.

| Manure, t/ha | Fertilizers kg/ha | Soil treatment method | Plowing | Non-moldboard | Surface tillage |
|--------------|------------------|----------------------|---------|---------------|----------------|
|              |                  |                      | N       | P2O5          | K2O            |
|              |                  |                      | N       | P2O5          | K2O            |
|              |                  | Grain-row rotation   |         |               |                |
| 0            | control          | 22.3                 | 2.8     | 7.0           | 22.4           |
|              | (NPK)70          | 28.0                 | 3.8     | 10.9          | 27.4           |
|              | (NPK)140         | 30.2                 | 3.9     | 11.6          | 29.6           |
| 40           | -                | 22.9                 | 3.0     | 7.3           | 22.7           |
|              | (NPK)70          | 27.6                 | 4.1     | 10.9          | 28.0           |
|              | (NPK)140         | 29.8                 | 4.2     | 11.3          | 28.9           |
| HCP05 factor A*| 1.7             | 0.3                  | 0.6     | -             | -              |
| HCP05 factor B**| 2.6             | 0.4                  | 0.8     | -             | -              |
| Grain-steam row rotation |
| 0            | control          | 17.1                 | 2.6     | 5.8           | 18.0           |
|              | (NPK)70          | 27.6                 | 3.7     | 9.5           | 26.4           |
|              | (NPK)140         | 28.0                 | 3.8     | 9.8           | 27.9           |
| 40           | -                | 17.6                 | 2.8     | 6.0           | 17.2           |
|              | (NPK)70          | 27.9                 | 3.5     | 9.7           | 27.8           |
|              | (NPK)140         | 28.5                 | 3.8     | 10.0          | 28.4           |
| HCP05 factor A*| 1.3             | 0.3                  | 0.4     | -             | -              |
| HCP05 factor B**| 1.8             | 0.5                  | 0.5     | -             | -              |

* - factor A – soil treatment;
** - factor B - fertilizers

With the organo-mineral fertilization system nitrogen remained in the soil with a root mass of 28.0-28.9 kg/ha, phosphorus 4.1-4.2 and 10.9-11.3 kg/ha of potassium. A similar pattern was observed in the variants with soil cultivation without plowing up and in the variant with the atereffect of manure after surface significantly less nutrients were accumulated compared to plowing. So, on plowed fields there was more nitrogen by 1.8 kg/ha, by 0.4 kg/ha phosphorus and by 0.7 kg/ha potassium.

When having grain-and-row crop rotation the return to the soil of nutrients by the root weight in the control plowing was 36 kg/ha including 27.6 kg/ha of nitrogen, 2.6 kg/ha of phosphorus, and 5.8 kg/ha. With the use of mineral fertilizers the return of nitrogen, phosphorus and potassium significantly
increased and amounted to 39.7-41.6 kg/ha, including 27.6-28.0 kg/ha of nitrogen, 3.7-3.8 kg/ha of phosphorus and 9.5-9.8 kg/ha of potassium which amounted to 161-164 respectively; 142-146 and 164-169% to control.

On fields with manure aftereffect of in the studied soil layer 3% more nitrogen and potassium and 8% more phosphorus remained in comparison with the unfertilized background. Application of mineral fertilizers against the background of organic aftereffects brought these indicators to 27.3-28.5, respectively; 3.5-3.8 and 9.7-10.0 kg/ha.

The methods of basic soil treatment in this crop rotation did not have a significant effect on the nutrients’ accumulation.

Thus, based on the above, we can say that when fertilizers are applied for silage corn, along with a significant increase in green mass yield, the amount of root residues significantly increases which contributes to an increase in nutrients return to the soil.

In general, the mass of root residues depended on the amount of applied fertilizers, both mineral and organic and their distribution in the arable layer depended on soil treatment method.

4. Conclusion
In the first experiment, soil treatment and fertilization influenced the amount of root residues in the soil. The largest amount of the mass of root residues was obtained by plowing and ranged from 4.45 t/ha in the control to 5.06 t/ha in the variant with the introduction of mineral fertilizers. For all treatments, the application of organic and mineral fertilizers had a positive effect on the accumulation of root residues, their maximum accumulation was obtained in the variant N130P130K130 + N100 and amounted to 5.06 - 4.67 t/ha. For all processing methods, the highest content of corn root residues is in the 0-10 cm layer.

In the second experiment, the amount of root residues on fertilized plots in the 0-30 cm soil layer increases in grain-row crop rotation by 4.8-59.6% and by 6.4-50.0% in grain-row steam rotation compared to the control (20.2-22.4 and 21.8-23.2, respectively).

The return of nutrients with root residues in the control in both crop rotations was 25.5-26.2 kg/ha, on fertilized fields this indicator increased in the first crop rotation to 44.6-45.7 and to 42.1-42.3 kg/ha in the second.

References
[1] Turyansky A V, Kotlyarova E G, Litsukov S D, Titovskaya A I and Akinchin A V 2018 Research development trends in the field of soil fertility restoration Ecology, Environment and Conservation 24(3) 1048-52
[2] Litsukov S D, Glukhovchenko A F, Kotlyarova E G, Titovskaya A I and Akinchin A V 2019 Agrochemical substantiation of the inclusion of bird droppings under grain maize at different tillage in terms of the south - western part of the central black earth region Bioscience Biotechnology Research Communications 12(S5) 152-60
[3] Turianskii A V, Dorofeev A F, Akinchin A V, Linkov S A and Stupakov A G 2018 Agroecological and Economic Substantiation Of Agriculture Biologization Elements Research Journal of Pharmaceutical. Biological and Chemical Sciences 9(5) 1370-8
[4] Petrosov D A, Ignatenko V A, Litsukov S D, Feklin V G, Zelenina A N and Kochegarov A V 2019 An application of petri nets in technological process synthesis issues on agriculture International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies 10(11) ISSN 2228-9860 eISSN 1906-9642 http://TuEngr.com
[5] Grigorov M S and Kurbanov S A 1998 Methods of the main soil treatment of medic layer for corn during irrigation Agriculture 2 24-5
[6] Kornilov I M and Rybalkin B A 2001 The System of Reproduction of Soil Fertility in Landscape Agriculture. Materials of the scientific-practical conference (Belgorod) pp 105-6
[7] Kotlyarova O G, Uvarov G I and Kotlyarova E G 2004 Fertility of Agrolandscapes of the Central Black Earth Zone (Monograph) (Belgorod: BelGSKhA Publishing House) p 277
[8] Salnikov M I and Rybalkin B A 2001 The System of Reproduction of Soil Fertility in Landscape Agriculture.
Agriculture. Materials of the scientific-practical conference (Belgorod) pp 190-1

[9] Uvarov G I, Solovichenko V D and Bondarenko M V 2007 Agroecological Aspects of Soil Cultivation in the Central Black Earth Region (Textbook) (Belgorod: Bel State Agricultural Academy) p 100

[10] Shiryaev A V and Kuznetsova L N 2014 The influence of soil cultivation systems on the growth and development of corn for grain Bulletin of the Kursk State Agricultural Academy 9 38-40