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# EFFICIENCY OF SOIL CULTIVATION AND AGROTECHNOLOGY TO MINIMIZE FIELD CROP RESOURCE EXPENSES IN A CROP ROTATION PROGRAM

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We discuss basic soil cultivation and fertilizer influences on dynamics of productive moisture and nutrients in soil, as well as the efficiency of various categories of crop technologies and care of crops against a background of various cultivations and application of fertilizers in order to maximize production quality and economic efficiency in a crop rotation program.

**Key words:** crop rotation, soil cultivation, fertilizers, categories of technologies, productivity, energy efficiency.

In the recent decade, the rate of growth of agrotechnology has been increasing in the entire world, and in a number of countries the limit of average crop yield of 5 t/ha has been exceeded. Thus, the average crop yield for the last decade of the 20th century amounted to 6.3 t/ha in Germany and 7.0 t/ha in France [1]. At the same time, yield increases occurred with reduced rates of application (220 kg per ha of crops). Return on cost via yield improvement increased up to 15 kg of grain per 1 kg of fertilizer application thanks to the rise in scientific application and accuracy of agrotechnology.

Within the regional agricultural system, this issue required solution in our country as well, because the experience in development of intensive grain cultures technology (basically, winter cereal crops) in the 1990s is indicative of the fact that the payback on inputs actually obtained was often 2–2.5 times lower than the planned grain yield [2]. The low payback in the Central Black Earth Region is due mainly to the yield-limiting factor of insufficient moisture in the growing period.

In later investigations performed by us under conditions of the South-East of the Central Black Earth Region, a trial was undertaken to determine the efficiency of various categories of field crop cultivation technologies in crop rotation related to the specific soil / climatic conditions in order to achieve the planned yield and production quality with regard to ecological compatibility of the applied chemical inputs and economic efficiency.

The trial plot soil is the typical heavy-loamy chernozem: pH ~ 6.9; humus content in the 0–40 cm layer according to Tyurin ~ 7.1%; total nitrogen ~ 0.340%; total phosphorus ~ 0.165%; total potassium ~ 1.74%; labile phosphorus ~ 95–118 mg/kg of soil; exchangeable potassium ~ 111–151 mg/kg of soil; hydrolytic acidity 1.4–2.0 mg/100 g of soil; total absorbed bases 54–55 mg-equivalent/100 g of soil; degree of soil saturation with bases 96.5–97.5%.

The investigation objects were the eight-course crop rotation cultures: black fallow - winter wheat – corn for grain; barley – pea – winter rye – sunflower – millet. The following cultivars were used in the trials: winter wheat – Donskaya Bezostaya, rye – Talovskaya 15, barley – Odessky 100, pea – Uran, sunflower – Voronezhsky 436, millet – Saratovskoye 6, corn hybrid – Voronezhsky 3 MV.

Three systems of primary soil cultivation in the crop rotations, three systems of mineral fertilizers application, and three methods of sowing and care of the crops during the growing period were studied.

The first system of main cultivation ($O_1$) included low input, principally nonmouldboard (mulching) cultivation. Plowing by a plow PN–4–35 was carried out only in one crop rotation field (12.5% of the area) for fallow at a depth of 25–27 cm. Nonmouldboard cultivation was applied for sunflower and grain corn using "paraplow" type tools at 25–27 cm, for peas using SIBIME columns at 20–22 cm, for barley and millet using a blade cultivator KPG-250 at 20–22 cm. Surface cultivation was applied for winter rye using BDT-3 at 8–10 cm.

The second combined system for the primary cultivation in the crop rotation ($O_2$) was combining mouldboard, mulching and surface cultivations (plowing 50% of the crop rotation area). Plowing for fallow, corn and sunflower used a plow PN–4–35 at 25–27 cm and for pea at 20–22 cm; nonmouldboard cultivation - for millet and barley by a blade cultivator KPG-250 at 20–22 cm; and surface cultivation – for winter rye using BDT-3 at 8–10 cm.

Different rates of mineral fertilizers were studied ($U_1$; $U_2$; $U_3$) for the crop rotation cultures as compared to organic fertilizers: manure, 40 t/h in the fallow, non-grain part of the yield of winter rye and wheat - under corn and sunflower.

$U_1$ – minimum - only nitrogen fertilizers applied at a rate of 15 kg per t of winter wheat straw being scattered – for corn and rye – for sunflower ($N_{20}$ per 1 ha of the crop rotation area).

$U_2$ – calculated rates of fertilizers for increment of the grain yield: winter wheat, barley and millet – 1.0 t of each/ha; pea – 0.5 t/ha; sunflower – 0.3 t/ha ($N_{54}P_{34}K_{32}$ per 1 ha of the crop rotation area on average).

$U_3$ – mineral fertilizers rates calculated for the planned crop rotation cultures yield with regard to content of the nutrition elements in the soil: winter wheat 6.5 t/ha, corn for grain 6.0 t/ha, barley 4.5 t/ha, pea 3.5 t/ha, winter rye 4.5 t/ha, sunflower 2.5 t/ha, millet 4.0 t/ha (N73P63K47 per ha of the crop rotation area at an average).

The technologies of field cultures cultivation with various intensification levels ($T_1$; $T_2$; $T_3$) were tested against differently fertilized backdrops.

$T_1$ – extensive (with the minimum use of pesticides and other chemical agents). With these technologies, herbicides were used only in the millet crops for mitigating sunflower fruit drop. In relation to the other cultures, only seed treatment was performed before sowing; to control weeds when cultivating corn and sunflower, cutting guiding slots were used when sowing, and mechanical inter-row weeding along the guiding slots with the minimum protection zone and the use of feeler units.

$T_2$ – normal technology, nitrogen extra nutrition of winter rye and wheat, herbicides, insecticides and retardants – with regard to the phytotoxicity threshold and time of resumption of spring growth; soil herbicides were applied in corn and sunflower; in barley crops, extra nitrogen for leaf growth was used when necessary (at a rate of 25–30 kg per 1 ha) and crop treatment with herbicides; in pea – seed treatment with microelements (Mo and Mn); in millet crops – herbicide 2,4-D.

$T_3$ – intensive technology; the integrated protection with regard to the plant disease, phytotoxicity threshold based on the forecast of pests appearing in the crops.

The tests have shown that no significant differences in moisture content in the plowing and meter layers of the soil with the different main tillage systems were observed (Table 1).

Plowing during the entire growing period had an advantage in moisture accumulation in the meter soil layer of the corn and sunflower crops.

On average for all the cultures, no significant differences were observed in available moisture in the soil with the various main cultivation systems from the start of vegetation until blossoming. More underused moisture in the soil remained when applying plowing only up to harvest.

The nutrient content with the minimum use of fertilizers in the crop rotation (only nitrogen from decomposition of the non-grain part of the winter rye and wheat yield) was almost independent on the main cultivation system in the crop rotation (Table 2).

**Table 1. Influence of main cultivation systems in crop rotation on dynamics of supplied moisture in soil (average in 1991—1993), mm**

| Crop rotation cultures | Soil layer, cm | Resource-saving (mulching) soil cultivation in crop rotation ($O_1$), (plowing on 12.5% of the area) | | | Combined cultivation in crop rotation ($O_2$), (plowing on 50% of the crop rotation area) | | |
|---|---|---|---|---|---|---|---|
| | | shoots | blossoming | harvesting | shoots | blossoming | harvesting |
| corn | 0—20 | 19.4 | 33.1 | 26.5 | 26.7 | 40.1 | 46.7 |
| | 0—100 | 116 | 216 | 124 | 167 | 229 | 202 |
| barley | 0—20 | 25.4 | 18.2 | 19.2 | 24.7 | 18.8 | 18.2 |
| | 0—100 | 169 | 99.4 | 95.7 | 164 | 91.9 | 90.3 |
| pea | 0—20 | 22.7 | 12.5 | 9.6 | 21.4 | 10.4 | 12.0 |
| | 0—100 | 154 | 94.2 | 72.1 | 150 | 98.0 | 91.1 |
| sunflower | 0—20 | 14.7 | 12.0 | 21.6 | 22.5 | 9.0 | 22.1 |
| | 0—100 | 112 | 73.0 | 105 | 121 | 63.2 | 86.5 |
| millet | 0—20 | 26.1 | 10.3 | 13.9 | 22.5 | 4.2 | 13.5 |
| | 0—100 | 141 | 84.3 | 87.0 | 131 | 82.3 | 92.1 |
| Average for cultures | 0—20 | 21.7 | 17.2 | 18.2 | 23.6 | 16.5 | 22.5 |
| | 0—100 | 138 | 113 | 96.8 | 147 | 113 | 112 |

**Table 2. Nutrient content in 0–40 cm soil layer depending on main cultivation system and fertilizers (average over crop rotation in 1991–1993)**

| System of fertilizers application in crop rotation | Plants development phase | Main cultivation system | | | | | |
|---|---|---|---|---|---|---|---|
| | | $O_1$ | | | $O_2$ | | |
| | | $N—NO_3$ | $P_2O_5$ | $K_2O$ | $N—NO_3$ | $P_2O_5$ | $K_2O$ |
| $N_{20}$* $(U)_1$ | shoots | 18.2 | 11.8 | 15.1 | 18.6 | 11.0 | 13.2 |
| | blossoming | 17.8 | 10.5 | 12.5 | 15.8 | 10.7 | 12.1 |
| | harvesting | 18.4 | 9.5 | 12.7 | 19.6 | 9.3 | 11.1 |
| $N_{54}P_{34}K_{32}$* $(U)_2$ | shoots | 19.6 | 15.6 | 16.4 | 22.3 | 13.0 | 13.4 |
| | blossoming | 17.2 | 12.3 | 13.6 | 17.7 | 12.3 | 15.0 |
| | harvesting | 21.1 | 9.9 | 16.5 | 19.8 | 11.4 | 11.5 |
| $N_{75}P_{63}K_{47}$* $(U)_3$ | shoots | 17.1 | 15.2 | 15.7 | 19.9 | 14.5 | 14.7 |
| | blossoming | 16.3 | 12.6 | 14.8 | 17.9 | 12.3 | 14.1 |
| | harvesting | 22.0 | 12.0 | 15.1 | 19.8 | 10.7 | 12.7 |

* Average dose for each crop rotation culture; $N—NO_3$ — mg/kg; $P_2O_5$ and $K_2O$ — mg/100 g of absolutely dry soil

As the dose of the introduced fertilizers grows, the rise in content of the nitrate nitrogen in the soil is firstly noted compared to the combined cultivation, and the content of phosphorus and potassium with mulching cultivation.

This trend is observed with the calculated rates for the yield increase and for the planned crop capacity.

Nitrate content with combined main cultivation from the beginning until the end of the growing period tends to decline; whereas with mulching cultivation, it tends to rise. However, the contents of labile phosphorus and exchangeable potassium were usually reduced by the end of the growing period with either type of cultivation in the crop rotation.

Mineral fertilizers introduced into the soil increased the content of nutrients available to the plants by 11.2–32.3%. The phosphorus and potassium reserves increased to the greater extent. The difference as compared to the option of minimum fertilizer application remains till harvesting.

When introducing manure and nitrogen fertilizers in the fallow, with scattering and embedding straw in the soil, a relatively high yield of the first two cultures of winter wheat and grain corn crop rotation results: 4.36 and 5.75 t/ha, respectively, as compared to the primarily mulching main cultivation system in the crop rotation, and 4.32 and 5.62 t/ha as compared to the combined main cultivation system in the crop rotation (Table 3).

These cultures use soil nutrients to the maximum extent and deliver high yield as compared to minimum doses of mineral (nitrogen) fertilizers. Their productivity appeared to be 24.6–64.3% higher than the expected value.

**Table 3. Planned and actual crop capacity of field cultures depending on tillage and use of fertilizers in the crop rotation, t/ha (average over 1991—1993)**

| Cultures | $U_1$ | | | $U_2$ | | | $U_3$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | planned | actual | | planned | actual | | planned | actual | |
| | | $O_1$ | $O_2$ | | $O_1$ | $O_2$ | | $O_1$ | $O_2$ |
| Winter wheat | 3.5 | 4.36 | 4.32 | 4.5 | 4.57 | 4.74 | 6.5 | 4.48 | 4.58 |
| Grain corn | 3.5 | 5.75 | 5.62 | 4.5 | 5.68 | 5.48 | 6.0 | 5.78 | 6.37 |
| Barley | 2.5 | 1.96 | 1.86 | 3.0 | 2.33 | 2.16 | 4.5 | 2.09 | 2.05 |
| Pea | 2.0 | 1.56 | 1.54 | 2.0 | 1.48 | 1.61 | 3.5 | 1.81 | 1.78 |
| Winter rye | 3.0 | 3.89 | 4.0 | 4.0 | 4.98 | 5.0 | 6.0 | 5.02 | 5.06 |
| Sunflower | 1.5 | 1.17 | 1.26 | 1.8 | 1.08 | 1.24 | 2.5 | 1.18 | 1.25 |
| Millet | 2.5 | 1.70 | 1.73 | 3.0 | 1.97 | 1.95 | 4.0 | 1.98 | 1.96 |

The rise in the fertilization level of the winter wheat did not result in an increase in yield. Thus, increased application rate of mineral fertilizers to winter wheat, as calculated for a grain yield increase of 1.0 t/ha on average for three years, increased only from 0.21 to 0.42 t/ha as compared to the minimum fertilization. The mineral fertilizers rates calculated for a wheat yield of 6.5 t/ha increased productivity by 0.12–0.25 t/ha as compared to the minimum rate.

Obviously, with other rate-limiting factors, the winter wheat sown in the manured clear fallow under insufficient moisture conditions is not able to provide higher yield with increasing doses of the mineral fertilizers.

When cultivating grain corn, significant yield increase is achieved with the rates of the fertilizers for a planned yield of 6.0 t/ha as compared to the combined tillage in the crop rotation which was 0.37 t/ha higher than the planned value. However, taking into account that $N_{64}P_{30}K_{51}$ was additionally introduced in the soil as compared to the minimum fertilizer application, the payback on the fertilization was very low: 2.6 kg of grain/kg in rate of application of NPK, with the rated value of – 7- 8 kg of grain per kg in rate of application.

The barley, sunflower, pea, and millet productivity was lower than the planned value.

Generally, the crop rotation productivity balance between the planned and actual yield calculated in feed units was positive with the minimum application of mineral fertilizers and with the calculated rates for the yield increments of +0.87 and +0.1 t/ha of feed units, respectively, while with the calculated rates for the planned yield, the balance appeared to be negative (–1.52 t/ha of feed units). The achieved result is indicative of the fact that it is reasonable to manage with the minimum rates of application of mineral fertilizer (nitrogen fertilizers as calculated for 15 kg in rate of application/t of straw being scattered) under conditions of the South-East of the Central Black Earth Region, in the soils with average and raised levels of content of nutrients accessible by plants, provided that 5 t/ha of manure and about 1 t/ha of non-grain part of the winter rye and wheat yield are introduced per ha of crop rotation area in biologically oriented agriculture.

In general, the efficiency of different levels of intensity of the technologies applied for the crop rotation can be judged from the productivity parameters of the crop rotation area unit (Table 4).

The average productivity of the crop rotation with different options of application of mineral fertilizers, the main cultivation systems and the level of intensity of the sowing and care technologies fluctuates within statistically insignificant bounds: 3.46 to 4.00 t/ha of feed unit. With the minimum application of mineral fertilizers ($U_1$), the main tillage method and the measures on sowing and care of the crops had no considerable impact on their efficiency. The energy efficiency coefficients in all types of technologies as compared to different main cultivation systems were practically equal. Thus, with extensive technology,

**Table 4. Productivity and energetic efficiency of crop rotation cultures cultivation depending on agrotechnologies elements (average in 1991—1993)**

| Sowing and care technologies | Systems of fertilizers application in crop rotation | | | | | |
|---|---|---|---|---|---|---|
| | $U_1$ | | $U_2$ | | $U_3$ | |
| | feed units, t/ha | Energetic efficiency co-efficient | feed units, t/ha | Energetic efficiency co-efficient | feed units, t/ha | Energetic efficiency coef-ficient |
| Primarily mulching tillage in crop rotation | | | | | | |
| $T_1$ | 3.48 | 2.01 | 3.74 | 1.77 | 3.78 | 1.56 |
| $T_2$ | 3.59 | 1.85 | 3.86 | 1.70 | 3.91 | 1.49 |
| $T_3$ | 3.56 | 1.80 | 3.73 | 1.60 | 3.80 | 1.42 |
| Average | 3.54 | 1.9 | 3.78 | 1.7 | 3.83 | 1.5 |
| Combined tillage in crop rotation | | | | | | |
| $T_1$ | 3.46 | 1.97 | 3.74 | 1.76 | 3.92 | 1.61 |
| $T_2$ | 3.56 | 1.81 | 4.00 | 1.75 | 3.97 | 1.51 |
| $T_3$ | 3.63 | 1.82 | 3.97 | 1.68 | 3.98 | 1.47 |
| Average | 3.55 | 1.9 | 3.90 | 1.7 | 3.96 | 1.5 |

it amounted to 2.01 and 1.97, respectively, as compared to primarily mulching combined with main tillage systems in the crop rotation. When normal technology was applied, the parameters were 1.85 and 1.81, respectively, while in case of intensive technology, 1.80 and 1.82, respectively.

Increase in the rates of the fertilizers being introduced in the crop rotation ($U_2$) results in slightly greater increase in productivity of the crop rotation with normal and intensive technologies vs. the combined main tillage in comparison with the primarily mulching system. At the same time, however, a tendency towards reduction of energy efficiency as compared to the main cultivation is observed.

Thus, with the minimum doses of the mineral fertilizers application as compared to the higher backdrops of the cultures' fertilization, the intensive methods of crop care are energy-inefficient. With the minimum system of application of fertilizers and plant protection means, from the bioenergetic point of view, the resource-saving (mulching) system of main tillage in the crop rotation is the most reasonable.

With the increase in the rates of the fertilizers being introduced in order to raise the cultures productivity, with the relatively high energy efficiency coefficient, it is more reasonable to apply the combined main tillage system and the normal agrotechnology of sowing and care in the crop rotation during the growing period; it ensures along with the agrotechnical and biological measures, moderate application of chemical agents providing protection of against crop injury and formation of high-quality and high yield.

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## INFLUENCE OF AGROTECHNICAL METHODS ON FRACTIONAL COMPOSITION OF LEACHED CHERNOZEM

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Changes of fractional structure of humus in leached chernozem caused by application of mineral fertilizers and calcium ameliorant are investigated. It was established that with application of mineral fertilizers, an intensive destruction of all high molecular weight fractions of humic acids occurs. Addition of a calcium component promotes humus stabilization.

**Key words:** humic acids, fulvic acids, fractional composition, potentiometry.

Under conditions of intensive cultivation, the increased anthropogenic influence on the soil results in a considerable change in its properties. Thus, as a consequence of introduction of mineral fertilizers, soil acidification occurs, andhydrolytic and exchange acidities are increased; while the prolonged use of lands with no restoration of biophylic elements results in reduction in efficiency of productivity and decalcification, causing a change in hydration characteristics and structure of the soil aggregates [1]. Reclamation measures also influence the content and physical-chemical properties of the soil.

All anthropogenic changes to soil are related to humus as the basic part of the soil-absorbing complex (SAC). Therefore, evaluation of the cause-and-effect relationship between the level of anthropogenic influence and the quantity and quality of humus in the soil is important. It is also useful to examine how agrotechnical means can affect the relationship between various forms of organic substance in the soils being investigated.

The fractional composition of the humus of the plowing (0–20 cm) leach layer of chernozem was studied. The following options were studied: absolute control; options for application of $N_{120}P_{120}K_{120}$, and application of calcium ameliorant. The soil samples were treated according to the standard method [2] with a solution of pyrophosphate and sodium hydroxide each with a concentration of 0.1 moles/l, with the ratio of soil mass: solution = 1:5 for 24 hours. The obtained suspension was then centrifuged and the liquid phase (alkaline extract) was acidified with hydrochloric acid to a pH of 1.5–2.0. The poorly soluble humic acid precipitates (HA) were separated by centrifuging from the acid solution containing fulvic acids (FA), washed, air dried, and weighed. According to the method [2], the fulvic acid solution was passed through columns of absorbent carbon where their sorption occurred. The fulvic acids were then divided into fractions by successive water desorption. (Fraction A was the low molecular weight organic substances of non-specific nature), water-acetone mixture (fraction C was the ligno-fulvic acids), and 3% solution of ammonium hydroxide (fraction E was the actual FA). The solutions were dried, and the generated dry mass of fulvic acids was collected and weighed. Total humus content in the soil was determined according to the method of Tyurin [2]. The pH value of water and salt extract was determined by the same method [2]. The nonrecoverable component of the humus – humic acid in the soils was calculated from the difference between the total content of humus and the sum of humic acids and fulvic acids fractions. The samples of humic acids and fulvic acids fractions were titrated potentiometrically according to the standard method [3]. Concentration of the functional groups in the E preparations (mmole/g) was calculated from the formula:

$$E = \frac{C \bullet (V_n - V_{n-1})}{m},$$

where C – titrant solution concentration, mole/l; V – its volume, ml; m – sample mass, g; n – number of leap on the titration curve.

Table 1 represents the content of various humus fractions in the soil samples of the options being studied.

| Table 1. Humus fractional composition | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Option | Humus, % | pHwater | $pH_{CHI}$ | % of the total humus content | | | | | | |
| | | | | HA | FA | | | | HA+E | Humin |
| | | | | | Σ | A | C | E | | |
| Control | 4.43 | 6.94 | 6.46 | 29.4 | 43.0 | 10.9 | 11.7 | 20.4 | 49.8 | 27.6 |
| $N_{120}P_{120}K_{120}$ | 3.50 | 5.86 | 5.74 | 19.7 | 32.6 | 8.0 | 17.9 | 6.7 | 26.4 | 47.7 |
| Calcium ameliorant | 4.79 | 7.14 | 6.45 | 8.5 | 19.8 | 10.8 | 4.3 | 4.7 | 13.2 | 71.7 |

Change of relationship of mass content of HA:FA in soils depending on fertilization options is presented in Figure 1. For all options, the FA fraction is higher than HA. This appears to be associated with HA destruction by agrotechnical methods.

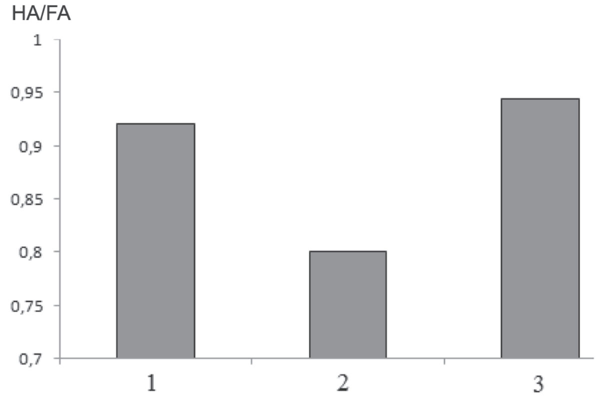


***Figure 1. Relation of content of HA (masses): FA (C and E fractions). 1 – absolute control, 2 – option with application of $N_{120}P_{120}K_{120}$, 3 – option with calcium ameliorant application***

The relationship of HA:FA content shows a sharp difference between the control sample and the calcium ameliorant option on one side, and the option of $N_{120}P_{120}K_{120}$, on the other side, which indicates the extensive degradation of humus due to the hydrolytic and oxidative impact of mineral fertilizers. The effect of nitrogen fertilizers on HA destruction has been shown by us previously [4]. Comparison of control and calcium ameliorant application demonstrates the close relationship of the HA:FA values. The higher parameters for these options vs. the option with mineral fertilizers indicate the higher stability of humus.

The considerable growth of the humic content in the row: control < option with introduction < option with calcium ameliorant is seen, as well as reduction of humic acids content. The reason for the humus content increase in the soil in the option with calcium ameliorant is fixation of the calcium humates generated by interaction of humic acids with carbonates in the mineral matrix of the soil (Fig. 2).

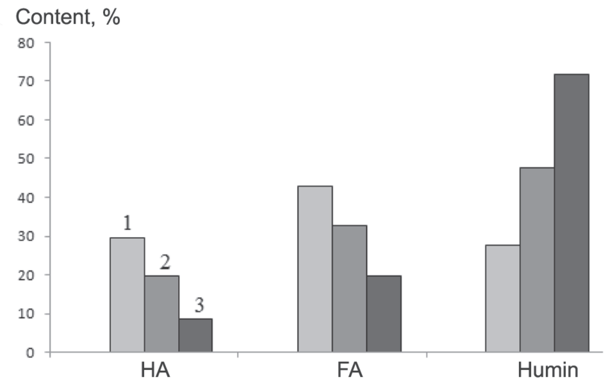


***Figure 2. HA, FA and humin content in the plowing layer soils of various options. 1 – absolute control, 2 – option with introduction $N_{120}P_{120}K_{120}$, 3– option with calcium ameliorant***

In our opinion, apart from HAs which are the main components, the soil absorbing complex comprises C and E fractions of FA as having relatively higher molecular weight and more complicated structure as compared to the A fraction. Therefore, in the following, when evaluating the absorbing capacity of the soils, we considered content of HA and these FA fractions, as well as their functional structure.

On the basis of the potentiometry data, the content of carboxyl groups and phenol hydroxyls in the humic acids of the soils of the options being studied was determined (table 2)

| Table 2. Functional groups content in HA and Fa molecules | | | | | | |
|---|---|---|---|---|---|---|
| Option | FA | | | | HA | |
| | C fraction | | E fraction | | | |
| | Carboxyls | Phenol hydroxyls | Carboxyls | Phenol hydroxyls | Carboxyls | Phenol hydroxyls |
| Control | 2.62 | 11.94 | 1.90 | 3.20 | 4.38 | 3.34 |
| $N_{120}P_{120}K_{120}$ | 1.46 | 8.70 | 1.04 | 3.47 | 3.34 | 2.66 |
| Calcium ameliorant | 8.58 | 7.52 | 4.10 | 4.10 | 3.52 | 2.29 |

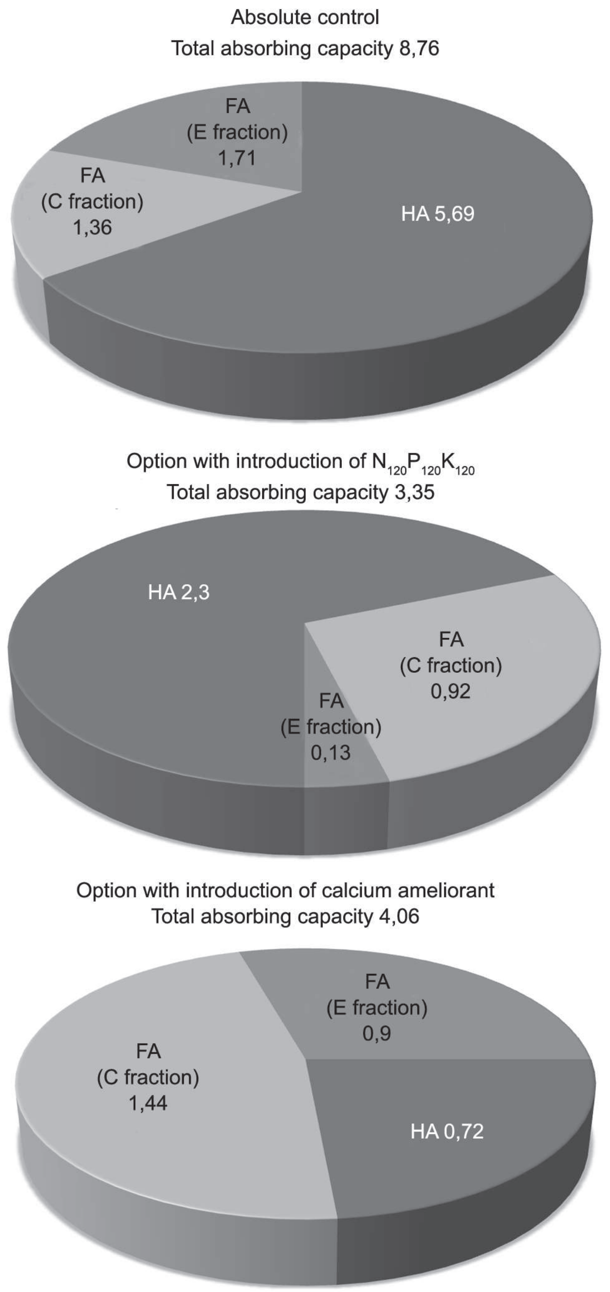


***Figure 3. Shares of individual humus fractions (Ek•m) in the total soil absorbing capacity (U)***

The total absorbing capacity of the soils can be described by the product of content of the functional groups (E) of HA and FA for their mass (m). Comparison of the obtained values for different options of the test enables reveals the absorbing capacity of the soil absorbent complex at the expense of these humus components. Table 3 demonstrates calculation of the absorbing capability (E•m).

**Table 3. Content of HA and FA in the soil (m, g/100 g of soil), product of content of highly dissociated (carboxyl) and weakly dissociated (phenol) proton-donor groups and the FA and HA masses and their sums (U)**

| Option | E*m | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | FA | | | | HA | | U | |
| | C fraction | | E fraction | | | | | |
| | Carboxyl | Phenol | Carboxyl | Phenol | Carboxyl | Phenol | Carboxyl (HA + FA) | Phenol (HA + FA) |
| Control | 1.36 | 6.20 | 1.71 | 2.88 | 5.69 | 4.34 | 8.76 | 13.42 |
| $N_{120}P_{120}K_{120}$ | 0.92 | 5.48 | 0.13 | 0.45 | 2.30 | 1.83 | 3.35 | 7.76 |
| Calcium ameliorant | 1.72 | 1.50 | 0.90 | 0.90 | 1.44 | 0.94 | 4.06 | 3.34 |

Let us consider which of the functional groups of HA and FA acts the determinative role in the absorbing capacity of the soils.

The soil pastes and extracts from the soils are weak acids or neutral (Table 1); it should be assumed that the cationic exchange in the soils is mainly due to the relatively weak carboxyl groups.

In terms of the sum E•m of the carboxyl groups (Table 3), the plowing layer of control exceeds all other options. However, comparison of data for the options with the double dose of mineral fertilizers and with the calcium ameliorant shows the superiority of the last option.

At the same time, in spite of the higher value of E•m in the weakly dissociating proton-donor groups in control and the mineral fertilizers option, with the resulting pH values of the soil extracts, they should not participate in the ion-exchange process.

It is possible to determine which of the humus fractions being studied has the highest capability of ion-exchange interaction due to participation of highly dissociated functional groups in it. Figure 3 presents a graphic display of soils' absorbing capacity distribution in the humic acids fractions.

On the basis of the acquired data, it was established that the maximum capacity for ion-exchange interaction is displayed by HA, which is associated with high molecular weight and more complex chemical structure as compared to FA. In the mineral fertilizers option, apparently, an extensive destruction of all high molecular weight fractions of humic acids occurs (not only HA, but also FA fractions E). With the use of calcium ameliorant, higher uniformity is noted in distribution of the absorbing capacity in fractions.

The presented results suggest that the use of calcium ameliorant is effective for stabilization of the qualitative and quantitative humus content.

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## THE INFLUENCE OF CROP ROTATION ON CROP PRODUCTIVITY AND SOIL FERTILITY

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Winter triticale preceding crops — clear fallow, red clover, mixed oats with vetch, silage crop, green manure mustard, and green manure lupine have identical influence on yield. Barley and lupine for grain as preceding crops reduced yield of winter triticale by 2,5 to 5,3% at an average.

**Key words:** crop rotation, soil fertility, humus, green manure fallow, grain predecessor, yields.

The influence of clear, occupied, green manure fallows, lupine for grain, silo cultures, barley as a winter triticale predecessor, their impact and aftereffect on yield of the subsequent cultures in the crop rotation were studied in NIICH CRNZ. The test was established in 2001–2003 on the soil-podzol medium-loam soil in the EKH Nemchinovka of the Odintsovo District of the Moscow Region. The agrochemical characteristics of the soil are the following: pH=5.4–6.0, $P_2O_5$ – 300–320 mg/kg of soil, $K_2O$ – 120–190 mg/kg of soil, humus content 2.0–2.5%. Plots were replicated fourfold. The site size was 240 m$^2$, the control area was 140 m$^2$. The winter triticale predecessors were clear fallow (option I), clover fallow (II), mixed oats with vetch (III), green manure fallow – mustard (IV), green manure fallow – lupine (V), lupine for grain (VI), barley for grain (VII), silage mix – sunflower + vetch with oats (VIII). Barley, first and second year grasses, and winter wheat in all options folowed the winter triticale. The main tillage for spring crops included plowing the fall-plowed field by a plow with skim colters at the depth of 20–22 cm with previous mowing of stubble. In spring, the fall-plowed field was harrowed, with presowing cultivation at a depth of 6–8 cm, and treatment with the aggregate RVK-3.6 before sowing was performed. Mineral fertilizers ($N_{60}P_{60}K_{90}$) were applied as a general background by a seeding machine SZT-3.6. Under the winter triticale, after harvesting the predecessors, the soil was disked in two traces, then it was tilled with a plow with skim colters at the depth of 20–22 cm, and the presowing cultivation and treatment were carried out with the aggregate RVK-3.6. The winter triticale was sown within the optimum time by a mounted seeding machine CN-16. The spring crops were sown as the soil was maturing. In the crop rotations, the following were used: barley Suzdalets (5.5 mil. pcs./ha of germinating seeds), lupine Ladny (1.4 mil. pcs./ha), clover Moskovsky 1 (12 kg/ha), mustard (10 kg/ha), vetch (80 kg/ha), oats (100 kg/ha), low-grade sunflower (15 kg/ha) mixed with vetch and oats, winter triticale Antey (5 mil. pcs./ha), winter wheat Moskovskaya 56 (5.5 mil. pcs./ha). In the winter culture crops, the following were used: Agritoks (0.7 l/ha), Granstart (10 l/ha), Danadim (0.8 l/ha), and Tilt Premium (330 g/ha); in the spring culture crops, the following were used: Lintur (100 g/ha), Laren (8 g/ha), and Bi-58 Novy (1 l/ha).

Observations and investigations were performed in two non-adjacent replicates according to the guidelines of Gossortset, VIZR, NIICH CRNZ [1].

Weather conditions during the growing seasons of 2001–2007 were different in terms of moisture provision and air temperature. So, 2001, 2002, 2006, and 2007 were noted to have elevated temperature along with lack of precipitation; 2003, 2004, and 2005 had a considerable amount of rainfall and air temperature close to the average multi-year value.

In the period of spring resumption of tillering and start of booting of triticale, the soil humidity was sufficient for the growth and development of plants. Content of available moisture during spring tillering in 2002 was 27.3–39.0 mm, in 2003 – 29.2– 50.8 mm, in 2004 – 49.7–60.6 mm (Table 1). By the middle of the growing period, the available moisture content was reduced due to consumption and weather conditions, especially in 2002.

The density of the soil composition in all options in the triticale spring regrowth phase amounted to 1.23–1.32 g/cm$^3$ (in the 0–10 cm soil layer) and 1.19–1.30 g/cm$^3$ (in the 10–20 cm layer). In the middle and by the end of growth, a tendency towards increased soil compaction was observed (1.38–1.47 g/cm$^3$). The hardness data show the soil compactness. By the middle of the growth period, soil hardness under the triticale plants amounted to 11.0–23.0 kg/cm2 in the 0–5 cm layer, 23.0– 40.0 kg/cm$^2$ in the 0–10 cm layer, 50.0–60.0 kg/cm$^2$ in the 0–15 cm layer, and 67.0–80.0 kg/cm$^2$and over in the 0–20 cm layer. Under winter wheat (the sixth culture of the crop rotation), in the spring regrowth phase, the soil humidity in the 0–10 cm layer amounted to 16–19% (Table 1).

By the middle of the growing period, the soil humidity had risen due to the moisture consumption by the plants and amounted to 15.3–18.9%. The lowest soil humidity indicators (11.4–15.9%) were registered prior to harvesting which is associated with the insufficient precipitation.

***Table 2. Agrochemical soil indicators for the sixth year of crop rotations (2006—2007)***

| Option | Soil layer, cm | pH (KCl) | Hr, mg-equivalent/ 100 g of soil | Humus, % | $P_2O_5$, mg/kg of soil | $K_2O$, mg/kg of soil | Ca, mg-equivalent/ 100 g of soil | Mg, mg-equivalent/ 100 g of soil | S (base), % |
|---|---|---|---|---|---|---|---|---|---|
| I | 0–10 | 5.18 | 3.96 | 2.21 | 261.0 | 88.0 | 9.37 | 0.99 | 72.3 |
| | 10–20 | 5.41 | 3.25 | | 250.0 | 89.0 | 10.1 | 0.97 | 77.4 |
| II | 0–10 | 5.18 | 3.82 | 2.19 | 273.0 | 93.0 | 8.87 | 0.90 | 71.9 |
| | 10–20 | 5.06 | 4.14 | | 268.0 | 79.0 | 8.77 | 0.92 | 70.0 |
| III | 0–10 | 5.22 | 3.71 | 2.10 | 291.0 | 91.0 | 8.90 | 0.95 | 72.6 |
| | 10–20 | 5.18 | 3.96 | | 282.0 | 77.0 | 8.52 | 0.89 | 70.4 |
| IV | 0–10 | 5.34 | 3.56 | 2.29 | 255.0 | 95.0 | 8.35 | 0.88 | 71.1 |
| | 10–20 | 5.42 | 3.19 | | 250.0 | 82.0 | 8.37 | 0.96 | 74.5 |
| V | 0–10 | 5.40 | 3.05 | 2.29 | 227.0 | 120.0 | 8.02 | 0.91 | 74.5 |
| | 10–20 | 5.02 | 2.92 | | 216.0 | 89.0 | 7.77 | 0.87 | 74.7 |
| VI | 0–10 | 5.42 | 3.19 | 2.48 | 236.0 | 146.0 | 7.95 | 1.03 | 73.7 |
| | 10–20 | 5.10 | 4.23 | | 250.0 | 75.0 | 7.35 | 0.89 | 66.4 |
| VII | 0–10 | 5.20 | 3.79 | 2.21 | 252.0 | 95.0 | 7.52 | 0.93 | 69.0 |
| | 10–20 | 5.12 | 4.14 | | 230.0 | 109.0 | 7.62 | 0.96 | 67.4 |
| VIII | 0–10 | 5.18 | 3.82 | 2.13 | 259.0 | 107.0 | 7.95 | 0.93 | 69.9 |
| | 10–20 | 5.27 | 3.56 | | 225.0 | 88.0 | 8.22 | 0.95 | 72.0 |

***Table 1. Humidity and density of soil under winter wheat plants (in the 0—20 cm layer)***

| Option | Humidity, % | | | | | | Density, g/cm3 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Spring regrowth | | Earing | | Before harvesting | | Spring regrowth | | Earing | | Before harvesting | |
| | 2006 | 2007 | 2006 | 2007 | 2006 | 2007 | 2006 | 2007 | 2006 | 2007 | 2006 | 2007 |
| I | 16.3 | 19.4 | 15.3 | 7.8 | 11.4 | 13.8 | 1.33 | 1.32 | 1.33 | 1.36 | 1.44 | 1.38 |
| II | 19.0 | 20.6 | 15.7 | 8.2 | 13.2 | 14.2 | 1.30 | 1.34 | 1.30 | 1.32 | 1.35 | 1.34 |
| III | 17.0 | 19.2 | 17.8 | 7.8 | 14.4 | 13.2 | 1.37 | 1.36 | 1.37 | 1.34 | 1.39 | 1.36 |
| IV | 16.7 | 18.6 | 17.9 | 8.0 | 12.3 | 14.0 | 1.31 | 1.30 | 1.31 | 1.30 | 1.32 | 1.28 |
| V | 17.3 | 18.0 | 17.4 | 8.6 | 13.6 | 13.8 | 1.28 | 1.32 | 1.28 | 1.30 | 1.30 | 1.30 |
| VI | 16.0 | 17.8 | 18.9 | 8.9 | 13.7 | 14.2 | 1.27 | 1.28 | 1.27 | 1.32 | 1.27 | 1.34 |
| VII | 16.8 | 18.0 | 17.7 | 7.8 | 14.1 | 13.6 | 1.27 | 1.30 | 1.27 | 1.34 | 1.34 | 1.38 |
| VIII | 16.8 | 18.4 | 17.5 | 7.8 | 15.9 | 14.0 | 1.37 | 1.34 | 1.37 | 1.32 | 1.35 | 1.30 |

The soil compaction density in all options in the spring regrowth phase amounted to 1.26–1.30 g/cm$^3$, while prior to harvesting, this parameter equaled 1.27–1.44 g/cm$^3$. The compaction density was changing during vegetation, but it was optimal for growth and development of the winter wheat.

Due to the weather conditions in 2007 (raised temperature conditions and lack of precipitation), the soil humidity indicators in the period of booting and earing of the winter wheat plants were low (7.8–8.9%); however this did not affect the yield, since the winter cultures in the autumn-spring development period acquired enough moisture.

Accumulation of available nutrients in the soil provided winter wheat plants with a sufficient quantity of absorbable forms of phosphorus and potassium during the growing periods (Table 2).

Determination of agrochemical soil parameters in 2006–2007 showed that the soil in the 0–20 cm layer consisted of 2.20–2.48% humus, 193–282 mg/kg $P_2O_5$, 77–146 mg/kg $K_2O$, $pH_{KCl}$– subacid (5.1–6.0), the hydrolytic acidity lay within 2.92 to 4.23 mg-equivalent/100 g. The sum of absorbed bases (Ca + Mg) was 8.24–11.14 mg-equivalent/100 g of soil, while the degree of saturation with bases was 67.4–77.4%. This demonstrates the average cultural state of the soil.

The low biological activity of the soil was demonstrated by the slow decomposition of straw in all options of the test. Decomposition in 2007 for 85 days of growth of winter wheat in the 0–10 cm soil layer amounted to 23.5–42.1%, while in the 10–20 cm layer it was 21.0–41.7%. A lower decomposition was observed in the option IV.

Humus accumulation in the soil was closely associated with the mass of the root and stubble residues supplied to the plowing layer soil [2]. The amount of these residues in its turn depends on the type of the triticale predecessors being cultivate, their aftereffect on other cultures in the crop rotation, yield, and growth of green mass of break cultures.

The total supply of root and stubble residues of the plants for 7 years (in the first establishment of the test) amounted to 24.43–33.54 g/ha of dry substance. 3.5–4.7 t/ha of dry substance falls on a single year at an average.

It should be noted that the plowed stubble remains often do not compensate for the humus loss from the soil, because 70–80% of plant residue supplied into the soil are mineralized to the final products $CO_2$, $NO_4$, $NO_3$, while only 20–30% of them turn into the organic substance of the soil. In addition, the important factor is an increase in the humification coefficient of root and stubble remains, which is possible owing to creation of the optimum ratio of carbon and nitrogen in the vegetable residues due to application of nitrogen fertilizers and cultivation of green manure and interplanted cultures.

The yield of the cultures being cultivated in the test depends largely on the phytosanitary condition of the crops. No substantial infestation was observed in our test with the intensive farming culture. The quantity of annual weeds in terms of the triticale shoots amounted to 9–21 pcs./m$^2$, while the quantity of perennial weeds was 1–3 pcs./m$^2$. By the time of harvesting, the quantity of weed declined due to the influence of the well-developed haulm stand of the cultures being cultivated and equaled 3–9 pcs./m$^2$. Chickweed, Field Pansy, Hemp Nettle, Fumitory, Lamb's-Quarters, Chamomile, and Sowthistle were most common in the weed population.

With the established weather conditions, the following yield of the winter triticale predecessors was obtained on average for 3 years (three establishments): clover – 19.12 t/ha of green mass, mixed oats and vetch – 42.08 t/ha, mustard and lupine as the green manures for green fertilizer – 30.77

**Table 3. Culture yield within the test, t/ha (in three establishments)**

| Option | Winter triticale | | | Barley + perennial grasses | | | First year perennial grasses (hay) | | | Second year perennial grasses (hay, one cutting) | | | Winter wheat | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2002 | 2003 | 2004 | 2003 | 2004 | 2005 | 2004 | 2005 | 2006 | 2005 | 2006 | 2007 | 2006 | 2007 |
| I | 6.13 | 4.78 | 3.16 | 4.22 | 3.72 | 4.26 | 7.15 | 9.12 | 8.72 | 4.73 | 4.08 | 5.60 | 6.33 | 5.11 |
| II | 6.13 | 4.73 | 3.79 | 4.48 | 3.70 | 4.24 | 7.21 | 9.04 | 9.36 | 4.73 | 3.33 | 5.60 | 6.70 | 5.00 |
| III | 6.19 | 4.98 | 3.39 | 4.30 | 3.79 | 4.19 | 7.89 | 9.54 | 7.70 | 4.61 | 3.24 | 5.69 | 6.40 | 5.58 |
| IV | 6.10 | 4.94 | 3.92 | 4.30 | 3.68 | 4.24 | 6.31 | 9.48 | 8.59 | 4.64 | 4.22 | 6.04 | 6.51 | 5.43 |
| V | 6.14 | 4.49 | 4.33 | 4.30 | 3.88 | 4.37 | 8.19 | 8.97 | 7.93 | 4.61 | 3.87 | 5.88 | 6.51 | 4.96 |
| VI | 5.69 | 4.64 | 3.87 | 3.70 | 4.02 | 4.40 | 8.40 | 9.36 | 7.47 | 5.37 | 3.58 | 6.09 | 6.20 | 4.91 |
| VII | 5.62 | 4.69 | 3.04 | 3.95 | 3.50 | 3.78 | 7.36 | 9.34 | 9.97 | 4.26 | 2.52 | 5.40 | 6.35 | 5.18 |
| VIII | 6.36 | 4.69 | 3.22 | 4.48 | 3.69 | 3.95 | 8.52 | 9.23 | 9.91 | 6.00 | 3.19 | 6.13 | 6.54 | 5.42 |
| $HCP_{05}$ | 0.46 | 0.25 | 0.53 | 0.52 | 0.46 | 0.43 | 1.34 | 0.76 | 1.54 | 1.22 | 1.04 | 0.98 | 0.52 | 0.53 |

and 74.73 t/ha, respectively, lupine for grain – 1.61 t/ha, barley – 3.26 t/ha, silage cultures for green mass – 39.0 t/ha (Table 3).

The yield of the winter triticale in the test was high. The yield of the triticale in 2004 was lower than in the previous years, because the triticale plants were thinned due to a poor wintering and adverse weather conditions. It should be noted that the influence of predecessors upon the triticale yield was preserved, and the difference in the options was considerable.

With the grain predecessor option, the triticale yield amounted to 30.4 c/ha, with lupine for green fertilizer – 43.3 c/ha. In the clear fallow option, the triticale yield was reduced due to plants lodging. The grain was less plump; the weight of 1000 grains was lower than in other options, except for the grain predecessor.

The negative aftereffect of the triticale grain predecessors appeared in barley. The barley yield in 2003 in the options with lupine and barley for grain reduced by 10.0–17.5%. The same trend was observed in 2004 as well.

In 2006–2007, the subsequence of the predecessors for the sixth crop rotation culture – the winter wheat of the grade Moskovskaya 56 was studied.

The degree of density of the winter wheat plants in the phase of shoots in autumn of 2006 amounted to 176-263 pcs./$m^2$. The wintering was good and the plant death was at the level of 2–3%.

The winter wheat yield in 2007 was lower than in the previous year (Table 3). It should be noted that the aftereffect of predecessors upon the winter wheat yield was preserved, but the difference in the options was insignificant. Thus, in the option with the grain predecessor, the winter wheat yield amounted to 49.1 c/ha, while in the options with the silage predecessor, the parameter was 54.2 c/ha with $HCP_{05}$ of 5.3 c/ha. In the option with the clear fallow, the yield reduced due to the less plump grain and the weight of 1000 grains which was lower than in other options.

Therefore, in terms of the influence on the winter triticale grain yield, the predecessors of clear, clover and mixed oats and vetch fallows, green manure fallows with mustard, lupine, and silage cultures were equivalent. The grain predecessors (lupine and barley) reduced yield of triticale by 2.5 to 5.3% at an average. The aftereffect of the predecessors on the yield and quality of the winter wheat grain of Moskovskaya 56 grade is preserved in the sixth year of the crop rotation as well. However, it should be noted that with the preserved tendency towards increased yield, no significant difference between the options is observed. Introduction of green manure fallows into the crop rotation assisted in the greater supply of vegetable residues (24.43–33.54 t/ha for 7 years of the crop rotations).

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## PROBLEMS AND POSSIBILITIES OF PROLONGED APPLICATION OF MINIMUM TILLAGE

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The results of 30-years of research (1978–2007) on minimum tillage in sod-podzolic soils have shown that it is possible only with a high standard of farming, perfection of its systems, and thorough evaluation of suitability of soils to the use of minimum tillage. The minimum period of the crop rotation should not exceed three years in succession. Simultaneously, minimum tillage produces the problems of deterioration of phytosanitary state of crops and soils, the differentiation of an arable layer is accelerated, pesticides oppress microbiological activity, water retention in drought years is worsened, erosive processes are not eliminated, and environmental preservation is not improved.

**Keywords:** minimization, agrotechnologies, erosion, phytosanitary state, harmfulness, differentiation, efficiency, yield.

Soil productivity enhancement, protection against erosion and degradation, prevention of environmental quality deterioration, and improvement of agronomical landscapes are fundamental goals in modern agriculture [8, 14, 16]. Priority is placed on resource saving and energy saving technologies, and, first of all, on minimum tillage. The discussions concerning the issue "to plow or not to plow" are often one-sided. Thus, the nonrecurring replacement of plowing with ground treatments during 1–2 years is performed, and on the basis of the observed results, conclusions are drawn on the considerable economic effect on expenses. No complex evaluation of minimum till is performed. However, serious problems with minimum till occur subsequently. For example, sometimes the technologies applied abroad are recommended. It is appropriate to recall the words of K.A. Timiryazev: "Nowhere, probably in no other activity, is it required to weigh so many various conditions of success; nowhere is such complex information required, nowhere can a one-sided perspective result in such a great failure as in agriculture" [17]. Many scientists emphasize that agriculture was, is, and will be a local activity, i.e. the things that suit some regions and countries may not suit others.

The purpose of this investigation is detection of positive and negative sides of minimum tillage; studying the influence of multi-year application of soil-protective technologies, crop rotation, fertilizers, and herbicide systems on erosion processes, humus content, phytosanitary condition, soil phytotoxicity, microbiological soil activity, entomological and phytopathological evaluation and yield of cultures.

The investigations were carried out within the long-term stationary field 2-factor (4*5) test established in 1977 by an offer of Professor B.A. Dospekhov on the experimental field of the Soil-Agronomical Plant n.a. V.R. Williams in the Podolsk District of the Moscow Region. The test was established in the 4-course field grain-grass soil protective crop rotation: barley with intercropping of perennial grasses – perennial grasses of the first year – winter wheat, 4 – oats. The test was established in the section with the one-sided southern slope of 3.0–3.5°.

The test outline included the following options:

Tillage (A factor): 1 – plowing (control), 2 – combination of plowing and blade cultivation, 3 – blade cultivation, 4 – minimum. All tillage and cultures sowing operations were performed across the slope: plowing – 20–22 cm, blade cultivation 25–27 cm, minimum till (dehulling) – 6–8 cm.

– Herbicide system (B factor): 1 – with no herbicides, 2 – 25% saturation (in the first field of crop rotation), 3 – 50% (in two fields), 4 – 75% (in three fields), 5 – 100% (in four fields). The herbicide system included both widely used and new prospective preparations: 2,4-D, 2M-4H, Simazine, Dialen, Lontrel, Cowboy, Difezan, Fenfiz in recommended dozes.

Mineral fertilizers were introduced as a general background for the planned crop capacity; organic fertilizers – 40 t/ha per rotation.

All calculations and analyses were carried out in compliance with relevant Russian State Standards (RSS) and methods accepted in scientific institutions. The experimental data were processed by the dispersion analysis method for multifactor field and vegetation tests.

It was established that the long-term study of minimum till and the surface tillage in the test had not confirmed the positive effect of the soil protection. The minimum till did not provide the necessary decompaction of the plowing layer. As compared to minimum till, surface run-off was increased with no interflow, as was soil loss. According to the averaged data, the water reserves before snow melt amounted to 75–80 mm, while the run-off coefficient was 0.30. The soil loss also fluctuated within extended bounds in terms of plowing with paraplowing: on average, the annual soil loss amounted to 72 to 233 kg/ha, while with the minimum till, 116 to 456 kg/ha.

Therefore, minimum tillage and the surface tillage can not serve as a reliable soil protective method. This was confirmed in the research of the Russian Institute for Agriculture and Soil Protection Against Erosion, the Soil Institute n.a. V.V. Dokuchaev, and other institutions.

As a result of the prolonged application of soil protective crop rotation with perennial grasses, soil protective tillage methods, herbicides, organic and mineral fertilizers, considerable changes occurred in both the total humus reserves and its content in the layers of plowing and subsurface horizons. The humus content in 1978 in the initial samples did not exceed 1.4%, while in the following years, the humus content raised up to 1.63 to 2.04% due to accumulation and distribution of root and stubble remains of the cultures being cultivated.

Thus, in the plots with the use of nonmouldboard cultivation, humus mass growth of 10–15% was observed in the top layers over the 30-year period (Table 1). On the contrary, the use of herbicides caused a reduction in the humus content due to decrease of the organic remains entering the soil, which is related to the weed mass reduction.

**Table 1. Influence of tillage methods and herbicides on humus content in the 0—20 cm layer, t/ha**

| Option | Saturation with herbicides, % | Initial sample (1978) | 1981 | 1990 | 1997 | 2005 |
|---|---|---|---|---|---|---|
| Plowing (control) | 0 | 18.3 | 21.8 | 25.9 | 25.2 | 26.1 |
| | 50 | | 21.8 | 26.1 | 24.3 | 23.1 |
| | 100 | | 22.7 | 25.1 | 24.0 | 22.0 |
| Blade cultivation | 0 | 18.9 | 22.7 | 27.5 | 26.0 | 26.0 |
| | 50 | | 22.0 | 26.9 | 25.2 | 24.1 |
| | 100 | | 22.4 | 27.2 | 25.4 | 23.2 |
| Minimum till | 0 | 18.0 | 21.5 | 25.9 | 25.1 | 25.1 |
| | 50 | | 21.5 | 25.5 | 24.2 | 24.2 |
| | 100 | | 21.6 | 26.8 | 22.7 | 21.5 |

Numerous investigations of minimum till methods are accompanied by an increase of the abundance weed plants [3, 10, 11, 16]. The floristic composition of weed plants and the forecast of their appearance over the 30-year period correlated with the reserve of fertile seeds.

The initial potential soil infestation with the seeds did not exceed 216–250 millions pcs./ha. This indicator grew more than twofold after one crop rotation. Significant influence was exerted by the tillage methods, especially in the 0–10 cm layer. When conventional tillage was applied, the seed reserve amounted to 395 million pcs./ha; in case of the blade cultivation the indicator equaled 745 million seeds; while when minimum till was applied, the seed reserve was 606 million pcs./ha. The sharp increase in potential infestation can be explained by an enhancement of weed growth and development due to introduction of mineral and organic fertilizers and allocation of seeds according to the plowing layer profile.

The actual average infestation for the first 3 crop rotations with conventional cultivation amounted to 179 pcs./m$^2$, with blade cultivation – 259, with minimum till – 248 pcs./ m$^2$ which is many times larger than the Economical Harmfulness Threshold. With minimum till, the proportion of noxious perennial varieties (Canada Thistle, Devil's Grass, Yellow Sow Thistle) in the weed population increased. Minimum till changed the ecological conditions of the growth of these weeds, while the infestation level exceeded the Economical Harmfulness Threshold (EHT) by the factor of 10–20 [4, 5, 10].

Even with good development of the cultivated plants, the weeds consume a considerable amount of nutrients from the soil and fertilizers. In highly competitive winter wheat, the carry-over of nutrients by the culture in the tillering phase equaled 70.8 kg/ha, the carryover by the weeds – 7.2, while in the blossoming phase this indicator was 183.6 and 115.4, and in the milk stage – 137.3 and 154.7 kg/ha, respectively.

The total decrease in grain due to weeds in the test, depending on the cultivation technology, amounted to 0.8–1.1 t/ha at maximum with the use of blade cultivation and minimum till. The crop capacity reduction remained during the entire vegetation period. Weed control was necessary; the earlier it was performed, the more efficient it was (Table 2) [3, 4].

**Table 2. Influence of cultivation methods and weeding time on crop productivity (at an average for 5 years)**

| Option | Amount of weeds, pcs./m$^2$ | Weed dry weight, g/m$^2$ | Crop capacity, t/ha |
|---|---|---|---|
| Conventional tillage | | | |
| Control (without weeding) | 80 | 50.3 | 2.04 |
| Regular weeding (reference value) | | | 3.45 |
| Weeding in the full seedling period | 183 | 5.5 | 3.39 |
| Weeding in the tillering phase | 156 | 15.1 | 3.07 |
| Weeding in the booting phase | 91 | 35.8 | 2.47 |
| Minimum tillage | | | |
| Control (without weeding) | 52 | 56.0 | 2.36 |
| Regular weeding (reference value) | | | 3.67 |
| Weeding in the full seedling period | 195 | 14.7 | 3.23 |
| Weeding in the tillering phase | 203 | 42.7 | 3.11 |
| Weeding in the booting phase | 54 | 47.4 | 2.43 |

The soil-protective surface and blade cultivation operations favored the stable trend in differential distribution and accumulation of labile phosphorus (58%) and available potassium (62%). During plowing, no more than 50% of nutrients were accumulated in this layer. Behavior of nitrogen was of an opposite nature. Content of nitrate nitrogen was lower by 14.1% with blade cultivation and by 11.9% with minimum tillage as compared to conventional cultivation. The reason for this could be an intensive immobilization of nitrogen from decomposition of plant residues on the soil surface.

According to our information, out of the total quantity of plant residues of grains and meadow clover, over 60% of root residues are concentrated in the 0–10 cm layer. In the meadow clover crops in the 0–40 cm soil layer, up to 5.32 t/ha of absolutely dry mass were accumulated, 3.61 t/ha in the winter wheat crops, and up to 3.0 t/ha in the spring crops.

The special investigations have established the amount of root residues of weed plants – 0.4 to 0.6 g/ha of dry substance. Their distribution practically did not differ from the cultivated plants.

Consequently, minimum till promotes the process of plowing layer differentiation in terms of fertility.

During minimum till, the use of herbicides becomes an integral part of the crop cultivation technology. However, even with this, a number of unsolved problems arise – unfavorable shift toward accumulation of stable weeds, insufficient selectivity, absence of necessary preparation generations, prolonged inactivation, negative consequences of herbicides, environmental pollution [1, 9, 10].

Development and adaptation of herbicide systems in the cropping pattern is a priority. It has been established that the complex application of all cropping pattern elements, e.g. crop rotation, tillage, fertilizers, reclamation measures, can help to achieve high biological and economical efficiency of herbicides; herbicide systems developed with a crop rotation saturation of up to 50–100% showed the highest biological efficiency (Table 3).

**Table 3. Herbicide system efficiency (%) depending on tillage system**

| Crop rotation saturation with herbicides, % | First rotation | Second rotation | Third rotation | Average |
|---|---|---|---|---|
| Common tillage (LSD05 — 81 pcs./m² (Least Significant Difference)) | | | | |
| 0* | 102 | 219 | 215 | 179 |
| 50 | 16 | 58 | 67 | 47 |
| 100 | 41 | 85 | 82 | 69 |
| Blade cultivation ($LSD_{05}$ — 50 pcs./m²) | | | | |
| 0* | 125 | 326 | 327 | 259 |
| 50 | 31 | 58 | 69 | 53 |
| 100 | 39 | 73 | 84 | 65 |
| Minimum till ($LSD_{05}$ — 46 pcs./m²) | | | | |
| 0* | 129 | 285 | 330 | 248 |
| 50 | 32 | 61 | 79 | 57 |
| 100 | 60 | 77 | 77 | 71 |

* Amount of weeds, pcs./m²

The most reasonable is the herbicide system with the 50% saturation (tillage every second year), with which the herbicide load on the soil biota is considerably reduced, as well as the volumes of application of the preparations.

Herbicide systems combined with tillage systems allow influence on the process of reduction of the potential infestation (Table 4).

Use of the minimum technologies without herbicides results in significant increase in the weed seeds reserve in the soil and considerable deterioration of its phytosanitary condition.

Experience shows that the herbicide systems in general assisted the reduction of the potential infestation by a factor of 1.5–2; it depended on the tillage system and the degree of crop rotation saturation with herbicides. Reduction of potential infestation by 39.6% is observed in the 0–30 cm layer in all tillage systems with the use of herbicides in two fields, and by 46.9% in four fields, respectively.

**Table 4. Influence of tillage system and herbicides on potential infestation, million seeds/ha***

| Tillage system | Crop rotation saturation with herbicides, % | | | Average |
|---|---|---|---|---|
| | 0 | 50 | 100 | |
| Common tillage | 900/595 | 538/205 | 486/213 | 671/306 |
| Blade cultivation | 1346/745 | 860/504 | 706/443 | 901/620 |
| Minimum till | 1101/606 | 817/495 | 709/416 | 943/633 |
| Average in the herbicide system | 1184/583 | 716/365 | 629/334 | |

* a/b, where a – in layer 0–30 cm, b – in layer 0–10 cm

Consequently, under current conditions and from the environmental aspect, chemical methods of weed control must be considered as a part of the cropping pattern providing an increase in land capability, rise in its fertility, and obtainment of high-quality production with the minimum hazard of the environment pollution.

The maximum effect from herbicide systems with minimum till can be achieved with an annual application of herbicides (the weed death amounted to 70–75%). When herbicide systems based on the early-generation active ingredients are used (combination of 2,4-D and 2M-4H with Simazine, Dicamba, Lontrel, Dialen, Fenfiz, Difezan, Cowboy and the sulphonylurea-based products) [4, 9, 10], efficiency equaled 85–95%.

The plant and stubble residues with minimum till are concentrated in the 0–10 cm soil layer. On average, the amount of plant residue in the crop rotation amounted to: 4.03 t/ha with conventional tillage, 3.93 t/ha with blade cultivation, and 4.13 t/ha with minimum till. The quantity of root and stubble residues of weed plants was 0.4–0.6 t/ha of dry substance in the options without the use of herbicides.

Minimum till combined with herbicide system results in a favorable effect on fertility indicators, including the agrophysical factors (Table 5).

**Table 5. Influence of tillage systems on agrophysical parameters of soil fertility**

| Option | Moisture reserve in soil, mm | | Density, g/cm²/ porosity, % | | Hard-ness, kg/cm² | Water-stableag-gregatescontent, % | |
|---|---|---|---|---|---|---|---|
| | 0–20 cm | 0–100 cm | 0–20 cm | 20–40 cm | 0–20 cm | 0–20 cm | 20–40 cm |
| Conventional tillage | 43.5 | 277.0 | 1.38/47.3 | 1.48/42.8 | 20.0 | 44.6 | 38.0 |
| Conventional tillage + paraplowing | 44.2 | 281.7 | 1.37/46.8 | 1.48/43.0 | 19.3 | 48.3 | 39.7 |
| Blade cultivation | 42.5 | 285.8 | 1.38/46.6 | 1.50/42.3 | 23.2 | 50.2 | 35.4 |
| Minimumtill (dehulling) | 43.4 | 276.4 | 1.38/46.5 | 1.47/43.4 | 23.8 | 50.5 | 39.4 |

Minimum till combined with herbicides considerably reduced the number of bacteria and microfungus. The inhibitory action of herbicides was strengthened in minimum till; this was shown by the study of phytotoxicity determined by development of bacteria in test cultures. The length of roots of the plants being tested was reduced by 44–46.5% in the options of minimum till combined with herbicides.

Minimum till technologies affected the number of earthworms differently. In the plots with minimum till, their number was certainly higher as compared to conventional cultivation. Systematic application of herbicides resulted in a certain reduction of the number of worms (26 spec./m²) as compared to the plots without herbicides or with the episodic application of herbicides (38 and 33 spec./m²). All the minimum till technologies created specific difficulties with incorporating organic fertilizers and their necessary location along the plowing layer profile. It should be noted that the manufacture of basic organic fertilizer is sharply decreasing (the forecast value is 70 million tons maximum, i.e. 0.5 t/ha). Manure replacement is possible with the introduction of shredded straw and cultivation of break and interplanted crops. However, with straw introduction, weed infestation is increased due to the seeds mixed with chaff. In case of minimum till, embedding the break and interplant crops is complicated with the high yields of their green mass. With straw introduction, addition of nitrogen fertilizers is necessary, which requires additional expenses.

As a result of the multi-year investigations, application of the specialized crop rotation, various tillage technologies and herbicide systems enabled obtaining the planned crop capacity (3.5–4 t/ha).

After assessing the economic efficiency of the minimum till without herbicides, we should note the considerable reduction of yield of winter wheat, barley, oats and their productivity within the range of 0.7–0.8 feed units/ha. The effect of herbicide systems was large; depending on saturation of the crop rotation with them, it amounted to 7–17% with conventional cultivation, 2–14% with conventional cultivation with paraplowing, 6–13% with blade cultivation, and 6–16% with minimum till.

The results enable changing the strategy and tactics of herbicides application to a considerable extent; a possibility of ecologization and biologization of soil-protective farming is being opened up. The science-based application of herbicide systems allows elimination of systematic (annual) use of herbicides even in specialized crop rotation, while applying them every second year with the 50% saturation of crop rotation with the conventional cultivation, conventional cultivation with paraplowing, and blade cultivation. Annual application of herbicides is required with the minimum till.

Energy consumption for fertilizers, tillage, pesticides, and transport equal 80–90% of total expenses during crops cultivation. It is assumed that up to 40% and over are consumed for tillage, while with the minimum till, these costs are reduced to 10–15%. Simultaneously, a share of costs for pesticides rises up to 25%.

The economic efficiency of minimum till as compared to plowing in terms of prime cost was 13.1–17.4 % lower, the net profit rose by 88.7–98.2, the profitability – by 48.9– 52.3, the labor productivity – by 32.1–37.5, while the costs dectreased by 22.9–30.5% (subject to the strict observance of elements of the farming pattern, complex chemical use, application of integrated plant protection).

Thereby, the results of 30 years of investigations (1978–2007) on minimum till in the sod-podzol soils showed that the application of energy-resource-saving technologies is possible with strict observance of elements of the farming pattern, complex chemical use, integrated plant protection within three successive years maximum in the crop rotation. Simultaneously, the problems with deterioration of phytosanitary condition of crops and soil arise – the plowing layer differentiation accelerates, the pesticides depress the microbial activity, the entomological activity is reduced, the water schedule is impaired in rainless years, and environmental condition is not improved. It is reasonable to use minimum till only with intensive farming culture, improvement of its systems and careful evaluation of suitability of soil for the minimum till. The minimum mechanical till period in the crop rotation should not exceed three successive years which should be interrupted by deep cultivations, i.e. by the system of the science-based various-depth tillage.

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## DYNAMICS OF SPECIES COMPOSITION AND ABUNDANCE OF WEEDS ON THE SEQUENCE PLOW LAND; LONG FALLOW; PLOWLAND*

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The article shows that after reclamation of seven-year long fallow the number of weed species was increased. Among them were detected a great number of annual weed species that were not detected in long term fallow. It was concluded that they persisted after previous plowing. Also present were native species.

**Key words:** long fallow, wild grasses, reclamation.

In the past 20 years, the structure of lands for agricultural use in Russia has undergone significant changes. There has been an increase in long term fallow in farmland since 1996. By 2006, the area of long term fallow has risen to 3.4 million ha with total agricultural land amounting to 191.7 million ha [9]. In general, these fields are populated by different types of weeds, mainly permanent grasses. In a few years, the natural vegetation from surrounding lands begins to populate the fields [1,2,3,4,5,8]. Persistent weeds (*Cirsium arvense*, field sow thistle, *Triticum repens*) do not disappear. Annual and perennial segetalis species also persist.

With reclamation of long-term fallows, it is necessary to plan measures for weed control within the new agrocoenosis. If it is known what types of agrobiological groups were present in seeding before the long term fallow, as well as how the species composition of coenosis was changed during the period of long term fallow, then it is possible to accurately predict what kind of weed species distribution will be found during re-cultivation of the field.

Studies of species distribution and weed population have been conducted in MSU UOPETs Chashnikovo in June 2001 and in 2007–2008 at one of the crop rotation fields by routing

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method. 50 x 50 cm frameworks for recording of weed species were laid at equal distances. In 2001, weeds were recorded at 100 points, at 2007 at 200 points, in 2008 at 58 points. In 2007–2008 the coordinates of points were recorded using GPS (Garmin Legend).

Preparation of the specified field was carried out in 2001; the field was seeded with a vetch-oat mixture with undersown perennial grasses (*Phleum pratense*, meadow clover, Fescue grass).

In the survey of the vetch-oat mixture made in 2001, 37 species of weeds were found. Almost all species were wild grasses [6, 11]. They are widespread and typical for the nonchernozem belt area. The most frequent species were *Viola arvensis* and *Thlaspi arvense* (table 1). Their average and maximum numbers per unit area were the highest.

**Table 1. Statistical characteristics of weeds (pcs/m²), 2001**

| Rank* | Species | Occurrence, % | Average per 1 sq. m. | Lower quartile | Median | Upper quartile | Maximum |
|---|---|---|---|---|---|---|---|
| 1. | *Viola arvensis* Murr. | 80 | 11.97 | 28 | 40 | 77 | 300 |
| 2. | *Thlaspi arvense* L | 74 | 8.06 | 8 | 16 | 24 | 600 |
| 3. | *Tripleurospermum inodorum* (L.) Sch. Bip | 72 | 8.28 | 12 | 28 | 45 | 800 |
| 4. | *Chenopodium album* L. | 70 | 4.3 | 16 | 20 | 28 | 92 |
| 5. | *Agropyron repens* (L.) Beauv | 65 | 17.68 | 44 | 80 | 132 | 460 |
| 6. | *Myosotis arvensis* Hill | 63 | 2.78 | 8 | 12 | 20 | 160 |
| 7. | *Capsella bursa-pastoris* (L.) Medik. | 61 | 2.31 | 8 | 12 | 16 | 100 |
| 8. | *Matricaria discoidea* DC | 59 | 4.68 | 12 | 28 | 44 | 100 |
| 9. | Stelaria media | 58 | 3.54 | 8 | 18 | 28 | 120 |
| 10. | *Cirsium arvense* (L.) Scop. | 51 | 1.66 | 8 | 12 | 16 | 40 |

* number of the species in the list ranked by decrease of occurrence

Plants of average occurrence group (9 species) have a small difference in this indicator. The largest numbers is noted for *Triticum repens*, which is typical for rhizome plants which in case of soil treatments disseminate along the field.

With a notable occurrence, *Chenopodium album* shows small, average, and maximum values per unit area; however previous research has shown that *Chenopodium album* had the highest seedbank in the soil of this crop rotation [7]. The remaining 25 species belong to the group of rare occurrence. Decrease in their occurrence and in the number per unit area is found. The number of annual and perennial species is almost equal in this group.

The field has not been processed since 2002. The seeded cereals have formed the basis of the new phytocoenosis. Red clover has almost come out, with only rare plants remaining. Over these years the species composition of the vegetation has changed. Wild species have not disappeared, because the seedbank in soil is large enough [7]; however their number and occurrence have decreased. Among the 42 species found in the field, just 7 were annual, and none of them had a frequent occurrence. Plants typical for natural coenosis had appeared in the vegetative cover (1/5 of the total number): *Stellaria longifolia*, clump speedwell, common sage, meadow knapweed, hawkweed, blood root, common tansy and silvery cinquefoil. Appearance of these plants may be considered as the initial stage of transition from agrocoenosis to natural coenosis.

There are only 2 common species – *Taraxacum officinale* and *Cirsium arvense* (table 2). These species increased in frequency relative to 2001. *Taraxacum officinale* occurrence was doubled, and its density per 1 sq. m. was increased by 30 times.

The remaining 40 species of rare occurrence and sporadic. The occurrence of *Agropyron repens* decreased by three times, with average and maximum numbers almost unchanged. The 1.5 x increase of occurrence and 10x average number of *Cirsium arvense* shows that such a period of non-cultivation is not sufficient to achieve a density of plow layer fatal for root sucker plants. Probably for the same reason, an increase in number of *Sonchus arvensis* was found with continued occurrence.

**Table 2. Statistical characteristics of weeds (pcs/m²), field 4, 2007**

| Rank | Species | Occurrence, % | Average per 1 sq. m. | Lower quartile | Median | Upper quartile | Maximum |
|---|---|---|---|---|---|---|---|
| 1 | *Taraxacum officinale* Wigg | 82.5 | 31.94 | 16 | 28 | 40 | 140 |
| 2 | *Cirsium arvense* (L.) Scop. | 73.5 | 10.68 | 0 | 12 | 16 | 56 |
| 6 | *Agropyron repens* (L.) Beauv | 21.0 | 20.68 | 0 | 0 | 0 | 320 |
| 10 | *Sonchus arvensis* L | 11.5 | 16.0 | 0 | 0 | 0 | 32 |

In comparison with 2007, the species diversity of weeds in agrocoenosis in 2008 has shown a slight increase (table 3). 46 species of plants were found, of which 40 are wild grasses, mostly annual weeds. After processing, some individual plants of natural coenosis remained: *Tanacetum*, *Chamaenerium angustifolium*, *Lysimachia nummularia*, *Crassula Glechoma hederacea*.

**Table 3. Statistical characteristics of weeds (pcs/m²), field 4, 2008 г.**

| Rank | Species | Occurrence, % | Average per 1 sq. m. | Lower quartile | Median | Upper quartile | Maximum |
|---|---|---|---|---|---|---|---|
| 1 | *Thlaspi arvense* L | 87.9 | 24.48 | 8 | 24 | 36 | 80 |
| 2 | *Cirsium arvense* (L.) Scop. | 87.9 | 10.34 | 4 | 12 | 16 | 24 |
| 3 | *Viola arvensis* Murr. | 82.8 | 22.55 | 11 | 50 | 32 | 80 |
| 4 | *Taraxacum officinale* Wigg | 77.6 | 13.31 | 5 | 12 | 20 | 64 |
| 10 | *Sonchus arvensis* L | 34.5 | 7.86 | 0 | 0 | 8 | 100 |
| 14 | *Agropyron repens* (L.) Beauv | 29.3 | 12.76 | 0 | 0 | 20 | 200 |

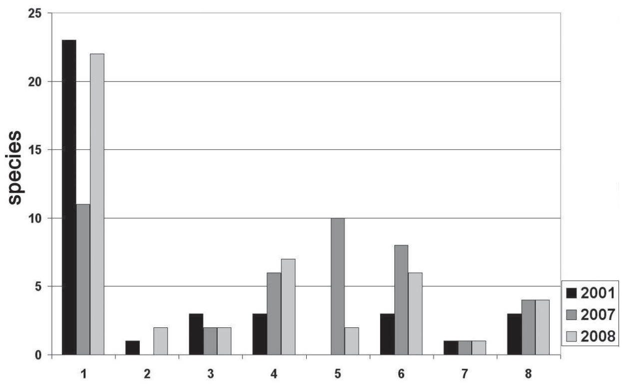
Species with frequent occurrence after treatment have increased – they are *Thlaspi arvense* L, *Cirsium arvense*, *Viola arvensis* Murr. and *Taraxacum officinale* Wigg (table 3). The proportion of species with average occurrence changed slightly (11 species). Remaining weeds are of rare occurrence and individual. It is noted that occurrence of *Taraxacum officinale* Wigg remained at a high level; however its average density per area unit decreased by almost three times.

After processing, the occurrence of root sucker plants — *Cirsium arvense* (L.) Scop. and *Sonchus arvensis* L increased. The number of *Cirsium arvense* per area unit remained unchanged and the number of *Sonchus arvensis* increased by eight times. This is typical for root sucker weeds because while processing, the root system is damaged and new plants grow from root fragments. The corresponding indices for *Agropyron repens* remained almost unchanged.

Grouping weeds species by lifetime and structure of root system helps to create effective schemes to control them. With long term fallow reclamation it is necessary to have information on changes in number of types inside each group. With such information, it is possible to predict the species composition of weeds during new cultivation of long term fallow lands.

The number of annual bilobed weeds in 2001 and 2008 is almost the same (figure). With cultivation of long term fallows, reactivation of these species from the seedbank began. In comparison with 2001, there was increase in the proportion of root weeds (*Tussilago farfara*, *Achillea millefolium*, *Artemisia vulgaris* L, *Mentha* arvensis).

The dramatic increase in the number of root plants of natural ecotope is noted. These species appeared in the long term fallow not due to the stock of diaspore in the farm field, but as a result of penetration from the field sides, from overgrown ravines and hedgerows. After a single treatment the number of such species deceased five times, but they remained in seedings as outlier plants.




***Qualitative change species of weeds in years of treatment***
Agrobiological groups of weeds are numerated: 1 — annual bilobed; 2 — annual monocotyledonous; 3 — offset; 4 — root wild grasses; 5 — root of natural ecotope; 6 — vertical roots; 7 — root in clusters; 8 — creeping roots, tuberous, incrassate spindle-shaped roots.

Knowledge about species composition of agrocoenosis ruderal component makes no assumptions about the quantitative extent of weeds of agricultural lands. Quantitative data may be transferred in scoring. If we know weed scores for each weed agrocoenosis group, it is possible to plan the necessary soil treatments.

In the studied field in 2001 the maximum score of number [10] was for the group of root weeds (table 4). After plowing of the long term fallow, the highest score was for, as expected, the group of other perennial (not wild perennial plants).

Perhaps the described phenomenon is of temporary nature for which reason more attention should be paid to the scoring of such persistent weeds as perennial root offset weeds. Underestimation of this fact may result in further increase in the number of plants of this group. One may see retention of the high score for annual bilobed species. With continuation of treatment, the population of this group will be replenished through the seedbank.

***Table 4. Scoring of weed infestation or oats crops (scale 1 to 5)***

| Agrobiological groups | 2001 | 2007 | 2008 |
|---|---|---|---|
| Annual bilobed | 3.52 | 1.06 | 2.8 |
| Annual monocotyledonous | 0.22 | – | 0.13 |
| Perennial offset | 3.45 | 4.17 | 4.31 |
| Perennial root | 4.13 | 3.39 | 2.91 |
| Other perennial | 1.65 | 4.89 | 4.71 |

These results indicate the need to plan in advance activities for control of the most numerous and harmful types of weeds.

A large number of annual bilobed weeds is typical for agrocoenosis. As a natural result, there is their decrease during long term fallow and sharp increase with cultivation of the latter.

In our case, the proportion of annual species of weeds within the total number of species is as follows by year: 0.64–0.26–0.52. It can be seen that the proportion of annual species of weeds almost recovers if the long term fallow is plowed in 5 years.

Thus, the increase in the number of non-wild types in phytocoenosis of long term fallow does not mean that when it is plowed there won't be a lot of annual species of weeds in seeding. The seedbank provides for the occurrence of annual wild grasses in territories which are very similar to natural habitats. This fact may be used for approximate determination of long fallow duration.

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## SPATIAL VARIABILITY OF AGROCHEMICAL PROPERTIES WITHIN AN AGRICULTURAL FIELD (AGROGREY SOILS)*

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The need to study the spatial variability of agrochemical properties and weed infestation within one field is shown in the example of typical agricultural land of Bryansk Opolje.

**Key words**: precision agriculture, Bryansk Opolje, agrogrey soils, mobile forms of nitrogen, phosphorus and potassium, weed contamination of arable lands, spatial variation.

Technologies of precision agriculture are expanding throughout the world. They are designed to increase production efficience. With implementation of precision agriculture technologies production efficiency, reduce the cost of commodity production and for preservation of the environment. These objectives are achieved through the use of modern information technology [5]. With implementation of precision agriculture, assessment of soil and productivity of cultivated plants can be made for individual agricultural fields [5,6]. At present, minimum area, characterized by a mixed model with agrochemical examination depends on the soil-climatic zone and level of fertilizers application, is within the range from 1 to 25 hectares [2]. For the purposes of precision agriculture, this is not enough. Therefore, the study of patterns of variability of individual agricultural properties within an individual agricultural field is relevant. Another factor limiting crops is weed contamination. As weeds are located at the field by blocks, extensive treatment of crops with herbicides does not

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always have the desired effect, and can result in unnecessary environmental pollution.

The objective of this work is to study spatial variability of agrochemical properties of agrogrey soils and weed contamination as exemplified by one typical agricultural field in Bryansk Opolje (high plains).

**Facilities and methods.**

The experimental site was located at a distance of 25 km from Bryansk on the territory of Bryansk State Agricultural Academy within landscape and typological group of Bryansk Opolje (high plains). The site area is 16 ha. The landscape is gently undulating, altitude difference is 2–2.5 m. Slopes are closed, round or prolate form. The parent material is strong pulverescent loess loam, with boiling found at a depth of 1.5–2 m. The basic soils are agrogrey soils in hill sites, and agrogrey with a second humus horizon located in the low sites [4]. All soils have more or less erosion features, and in deep low sites there may be gleic differences.

The field was seeded with oats in the year of research. Remote sensing survey has shown that there is a significant diversity of vegetation in the cover crop, the most noticeable in the red part of the spectrum. Spotting could be due both to the original heterogeneity of soil cover (visible as light and dark gray spots on adjacent territory) and unequal fertilizer application.

For the study of spatial variation of soil agrochemical properties more than 150 soil samples were taken from the plough layer. Sampling points were located along the field almost evenly with the mesh 33 x 33 m. Weed control within the limits of 50 x 50 cm was made at sampling points. Location of samples was controlled by Garmin GPS receiver. Location accuracy was 4–5 m. Determination of agrochemical properties was made on the basis of generally accepted techniques [1]. Processing of the results was carried out using the STATISTICA 6 and ArcGis 8 packs. Interpretative maps were created using ordinary kriging, taking into account the parameters of semmivariogramms.

**Results**

If we are basing on average values, then the agricultural field has optimal parameters of crop-producing potential for the given natural zone (table 1). Thus, if we use a generally accepted soil grouping [3], then soils may be classed by their average pH value to subacid, and by provision of phosphorus and potassium to soils with high level of phosphorus and extremely high level of potassium respectively. However, as is seen from the same table, agrochemical properties of the plough horizon have a noticeable variability which is shown in quite high coefficients of variation. Minimum values found at this agricultural field are in the field of non-provision to the plants with these recourses, and maximum values (higher than the upper quartile) significantly exceed limits required for optimal development of plants.

**Table 1. Statistical characteristics of distribution of agrochemical properties at the agricultural field (n = 150)**

| | Humus, % | $pH_{KCl}$ | $P_2O_5$, mg/100 g | $K_2O$, mg/100 g | $NO_3^-$, mg/100 g |
|---|---|---|---|---|---|
| Average | 3.42 | 5.4 | 34.6 | 39.5 | 7.0 |
| Standard deviation | 0.59 | 0.6 | 15.0 | 14.8 | 2.8 |
| Variation coefficient, % | 17 | 10 | 43 | 38 | 39 |
| Minimum | 1.20 | 4.8 | 2.2 | 8.3 | 1.4 |
| Lower quartile | 3.06 | 5.1 | 22.8 | 28.5 | 4.9 |
| Median | 3.46 | 5.3 | 31.7 | 37.5 | 6.8 |
| Upper quartile | 3.76 | 5.7 | 42.5 | 47.7 | 8.6 |
| Maximum | 4.98 | 7.2 | 93.6 | 89.3 | 16.6 |

Hence it appears that if this agricultural field is not fertilized, there will be areas in the field with insufficient nutrition for favorable development of plants. With even application of fertilizers, however, there will be areas with excess nutrients. The size of these spots will be larger as more as the rate of fertilizer is increased, resulting in relative economic losses.

In order to localize sites with different levels of available nutrients, interpretative maps of the distribution of basic agricultural properties within the experimental field were prepared (figure). It is seen from the figure that zones with different level of available nutrients are localized in two natural parallel areas elongated from north to south. A zone of low potassium occupies the entire eastern part of the field, and low phosphorus values are recorded in the north eastern part of the field. Thus, for different elements necessary for plant nutrition, zones of high, average and low content do not match. This allows planning and performing differential fertilizer application.

Control of weed plants has shown significant weed contamination of the agricultural field (table 2). Among the annual weeds bristle grasses and hemp-nettles prevail, among perennials sow-thistle, wheat-grass and horsetail prevail. High coefficients of variation indicate extreme inequality of weeds distribution in space. For each of the dominant weed species interpretation maps of weed contamination were created.

**Table 2. Statistical characteristics of basic weeds occurrence at the agricultural field (pc/m²)**

| | bristle grasses | sow-thistle | hemp-nettles | wheat-grass | horsetail |
|---|---|---|---|---|---|
| Average | 67 | 37 | 25 | 14 | 6 |
| Standard deviation | 68 | 33 | 30 | 15 | 12 |
| Variation coefficient, % | 102 | 90 | 122 | 107 | 202 |

Such maps provide the ability to control the dynamics of distribution of certain types of weed vegetation. Zones with numbers exceeding the economic limit of harm may be treated with herbicides.. Thus on the basis of the typical agricultural field located at the with herbicides. Treatment of the rest of the territory is not required. This approach allows a decrease of almost 2x the required amount of preparation.

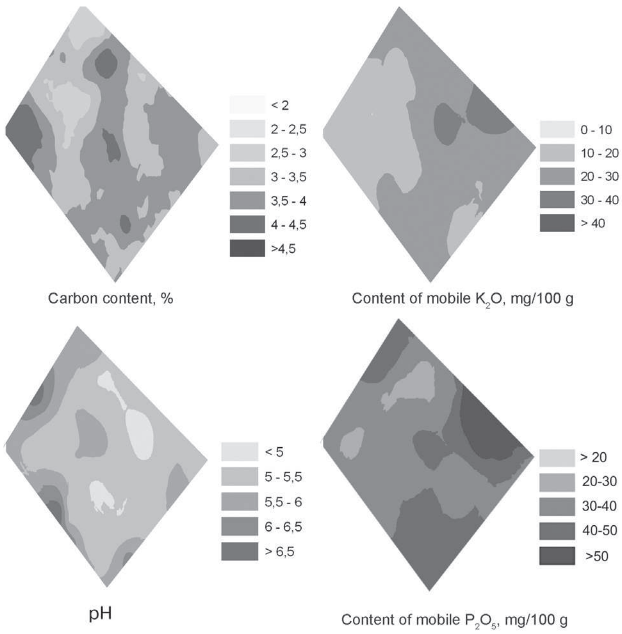


***Figure. Interpretation maps of distribution of basic agricultural properties within the experimental field***

Thus, on the basis of the typical agricultural field located in the territory of Bryansk Opolje, we show the value of study within the individual field of the spatial variability of soil agrochemical properties and localized weed infestation.

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## THE INFLUENCE OF BIOLOGICAL FACTORS ON THE PHYTOSANITARY CONDITION OF THE SOIL FOR THE CULTIVATION OF BARLEY

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Phytosanitary conditions of soil improve with cultivation of barley using organic substances and mineral fertilizers. A plowing of clover green manure and chopped straw of the preceding culture increased the quantity of antagonists and reduced the number of pathogenic fungi in the soil. It is established that optimization of a phytosanitary condition of soil reduces damage due to barley root rot.
**Key words**. Pathogens, saprotrophs, organic and mineral fertilizers, barley, root rot, soil moisture.

There has been a reduction in planting acreage and decrease in yield of cereals, including barley, in recent decades in nonchernozem belt of the Russian Federation. An important cause of the decrease in yield is deterioration of the phytosanitary condition of sowing and seed stock resulting from nonobservance of cultivation technologies [3]. Introduction to cereals crop rotation as a predecessor of feeding lupine, clover, vetch-oat mixture, spring and winter rape reduces infection of cereals with root rot by 5–6 times [2].

Perennial grasses provide the possibility to replenish organic matter and improve the phytosanitary condition of the soil. The condition of contamination with soil pathogens is a biological phenomenon and one defining phytosanitary condition of soil. Soil infection functions at a community agricultural ecosystem level.

Plant residues added to soil serve as an additional medium for microorganism-antagonists that suppress agents of root rot of agricultural crops. Trophic competition between pathogens and saprotrophic fungi in soil is an important factor for reduction of the population density of pathogenic species of fungi and, consequently, improves the soil suppressiveness [1].

Development of barley root rot is present every year in Mari El Republic. The importance of organic matter addition into the soil in modern adaptive farming agriculture technology as a factor improving the phytosanitary condition of the soil is increasing. Therefore, the objective of our work is to examine the influence of addition of organic matter in the form of shredded straw and clover green manure on formation of the soil phytosanitary condition.

**Material and techniques**. Research was performed under the conditions of experimental field of the State Scientific Institution "MarNIISCh Rosselkhozacademy" of Mari El Republic and in the laboratories of the Plant protection academic Department of Mari State University in 2005–2009.

The experiment had 2 factors. Factor A, addition of organic matter: 1. Control (without green manure); 2. With green manure. Factor B, addition of mineral fertilizers: 1. Control (without fertilizers); 2. $N_{60}P_{60}K_{60}$.

The experiment was conducted in triplcate with systematic arrangement of plots. Total area of plots was 330 sq. m. (30 x 11 m). Record plot area was 100 sq. m. Clover green manure was plowed immediately after mowing of clover at a height of 20 cm. Clover was removed from the field and the stubble field was plowed. Besides the clover green manure, the shredded straw of the previous crop of spring wheat was plowed into the soil.

Spring barley was cultivated in the field in 6-course rotation with 83% saturation of cereals (oats + clover – clover 1 g. p. – winter rye – + vetch + oats for grain – spring wheat – barley,). Background – pre-sowing seeds were treated with Dividend Star, KC (rate of application 30 g/l of difenoconazole + 6.3 g/l of ciproconazole) at the recommended dose of 1.0 kg/t. The Rakhat variety of barley was used for sowing.

Phytosanitary diagnostics and records of the barley affected by root rot were made by route inspection method [5]. Accounting of species and quantitative composition of myxomycetes in soil was made in the following periods: in the early vegetation (sprouts), in the middle of vegetation (coming to ear) and at the end of vegetation (milky ripeness) using a generally accepted method of VIZR. In order to identify the qualitative and quantitative composition of the ecology-trophic groups of microorganisms the Czapek Dox growing medium was used.

**Research results and discussion**. Under the influence of fertilizers there is change in the quantity and composition of the rhizosphere microflora. The results of the analyses carried out show the following composition of micromicetes: fungi of genus *Fusarium* (*F. culmorum* Sacc., *F. oxysporum* Sch., *F. graminearum* Sch.); *Bipolaris sorokiniana* Sacc.; *Alternaria alternate* Fr.; from genus Aspergillus (*As. niger* van Tiegh, *As. clavatus* Desm); *Rizopus nigricans* Her.; *Mucorpiriformis* Fisch.; from genus *Penicillium* (*Penicillum freguintans* Westl., *Penicillum funiculosum* Thom., *Penicillum viridicatum* Westl.) and antagonist fungi *Trichoderma lignorum* Tode. Harz.

Most of fungi were fungi of *Penicillum* genus. The proportion of *Penicillum* genus fungi was 55–60% of the total number. Fungi of this genus are typical for derno-podzolic soil.

Addition of green manure significantly changes the micromicete composition of soil even at the beginning of barley vegetation. The proportion of pathogenic fungi (*Fusarium* spp., *Alternaria* spp.) in the soil decreases. Antagonist fungi *Trichoderma* appear. *Penicillium* spp fungi increased almost two-fold. The number of these fungi increased more with addition of mineral fertilizers as well as green manure. Occasionally found in this soil were fungi *B. sorokiniana*. The frequency of occurrence was 3–5% depending on experiment variants.

Small doses of mineral fertilizers ($N_{60}P_{60}K_{60}$) have a stimulating effect on the number of soil microorganisms. Thus, in replicates with the use of mineral fertilizers, the number of microorganisms increased in all phases of barley plant development (table 1).

Biological factors play a positive role in the development of micro-organisms in the soil. When crushed straw and clover green were added, the number of microorganisms increased in comparison with replicates without green manure. The greatest number of fungi is found when green manure and mineral fertilizers are added. In variants with green manure antagonist fungi *Trichoderma lignorum* (Tode) Harz are found in the soil.

Development of barley root rot depended on the number of pathogenic microorganisms in the soil, which in turn depended on the number of saprotrophs and antagonists. The number of microorganisms in the soil increased in replicates with green manure and mineral fertilizers due to increase of saprotrophs fungi.

**Table 1. Dynamics of micromicet in rhizosphere of barley, thousand units oflive matters/g of soil**

| Variants | | Total fungi | Including pathogens | | | Including saprotrophs | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Factor A | Factor B | | Fusarium spp. | B. sorokiniana | Alternaria spp. | Aspergillus spp. | Rizopus | Mucor | Penicillium spp. | Trichoderma |
| Sprouts | | | | | | | | | | |
| Without green manure | Control | 58.4 | 18.3 | 1.8 | 1.0 | 7.3 | 8.8 | 4.5 | 16.7 | — |
| | $N_{60}P_{60}K_{60}$ | 75.3 | 21.9 | 0.8 | 1.1 | 12.2 | 5.4 | 6.2 | 27.7 | — |
| Green manure | Control | 78.3 | 7.8 | — | 1.0 | 13.5 | 4.5 | 6.6 | 40.4 | 4.5 |
| | $N_{60}P_{60}K_{60}$ | 83.1 | 6.1 | 0.9 | 0.5 | 18.9 | 5.5 | 6.6 | 32.5 | 12.1 |
| Coming to ear | | | | | | | | | | |
| Without green manure | Control | 96.4 | 29.2 | 1.8 | 2.3 | 15.3 | 7.7 | 8.8 | 31.3 | — |
| | $N_{60}P_{60}K_{60}$ | 108.5 | 29.2 | 1.5 | 0.8 | 22.4 | 12.2 | 6.1 | 36.3 | — |
| Green manure | Control | 107.8 | 13.5 | 1.3 | 1.6 | 24.3 | 10.2 | 6.6 | 39.3 | 11.0 |
| | $N_{60}P_{60}K_{60}$ | 126.4 | 15.1 | 1.5 | 1.5 | 18.4 | 14.6 | 12.1 | 39.0 | 24.2 |
| Milky ripeness | | | | | | | | | | |
| Without green manure | Control | 128.6 | 34.5 | 2.7 | 3.5 | 24.8 | 12.1 | 10.4 | 40.6 | — |
| | $N_{60}P_{60}K_{60}$ | 145.1 | 32.6 | 2.3 | 3.1 | 28.7 | 12.5 | 16.4 | 47.3 | 2.2 |
| Green manure | Control | 145.4 | 13.3 | 2.4 | 13.3 | 24.5 | 13.3 | 8.8 | 45.3 | 24.5 |
| | $N_{60}P_{60}K_{60}$ | 175.3 | 19.9 | 1.6 | 19.9 | 27.7 | 15.5 | 10.2 | 48.4 | 32.1 |

As a result of the decrease in the number of pathogens in the soil, plants developed better and increased root secretions, which feed saprotrophs.

Thus, due to reduction in competition for nutrients, the number of saprotrophs increased, which in turn had a positive effect on soil fungistasis and phytopathogenic potential.

It can be assumed that the effect of barley under field conditions is associated mainly with the development of soil pathogens.

Addition of mineral fertilizers reduces development of barley root rot (table 2). Significant reduction was observed when adding mineral fertilizers as well as organic matter.

We have found that addition of mineral and organic fertilizers increases humidity and supply of productive soil moisture, which contributes to activation of the micromicete complex in the surface layer of soil and a significant change in phytosanitary condition of planting and soil. Multiple correlation coefficients have shown that development of root rot is dependent on soil moisture (–0.76–0.81). Details of our research support the opinion of F. Peresypkin [4]. Under conditions of sufficient soil moisture, plants are less affected by the disease. When soil moisture is insufficient, robust development of root rot is found in the soil.

**Table 2. Dissemination and development of barley root rot, %**

| Variants | | Sprouts | | Coming to ear | | Milky ripeness | |
|---|---|---|---|---|---|---|---|
| Factor A | Factor B | p | R | P | R | P | R |
| Without green manure | Control | 60 | 17.5 | 70 | 27.5 | *80* | 30 |
| | $N_{60}P_{60}K_{60}$ | 30 | 7.5 | 40 | 17.5 | 60 | 22.5 |
| Green manure | Control | 30 | 7.5 | 50 | 15 | *60* | 20 |
| | $N_{60}P_{60}K_{60}$ | 10 | 2.5 | 30 | 7.5 | 40 | 12.5 |
| $HCP_{05}$ | | 4.127 | 0.162 | 4.334 | 1.974 | 3.312 | 1.615 |

Note: P — distribution of root rot, %; R —development of the disease, %

**Conclusions**

1. Addition of green manure in the form of shredded straw and stubble clover contributes to increase in micromicetes in the soil. When adding green manure antagonist fungi appear in the soil. The number of antagonist fungi by the end of barley growth is increased by 2.5–5 times in comparison with the beginning of vegetation.
2. The number of pathogenic fungi in soil with addition of green manure is reduced at the beginning of the growth period by 2.4 times in comparison with control without green manure.
3. Organic matter in the soil increases the ratio of saprotrophs to pathogenic fungi.
4. Extension and development of barley root rot is significantly reduced with addition of mineral fertilizers as well as organic fertilizer.
5. Increased moisture contributes to activation of the micromicete complex in the surface layer of soil and a significant change in phytosanitary condition of soil.

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## CORN WATER CONSUMPTION DEPENDS ON MOISTURE IN DIFFERENT YEARS AS AFFECTED BY AMELIORATION IN THE DRY-STEPPE OF ZAVOLZHYE

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Based on long-term research, water consumption of corn for silage dependant on moisture during the growing period and influenced by irrigation, chemical use, and forest amelioration on red-brown soils of Zavolzhye are revealed.

**Key words**: water consumption, amelioration, arid-steppe areas, regularity, irrigation, dependence, red-brown soil, covariance analysis.

Water consumption is one of the most important components of promotion of the yield of agricultural and irrigation is intended to compensate for the deficit of moisture needed by the plants. Use of fertilizers plus irrigation aims to promote high yield [3,13]. Overhead irrigation is not always operationally practicable; its use is not possible when wind speeds exceed 5–7 m/s due to drift, and the watering time frames are shifted [12]. The problem can be mitigated by creation of forest belts (FB) in the lands being irrigated. These can form a microclimate in spaces between belts. In particular, they reduce the wind speed by up to 30%, and in case of the gusts, by up to 60%.

Investigations of the influence of moisture during the growing period, irrigation, forest and chemical ameliorations on water consumption on corn silage mass were carried out in the red-brown soils of AO Novoye (the former work-study unit No. 1 SGAU n.a. N.I. Vavilova) and OPH VolzhNIIGiM of the Engels District of the Saratov Region.

The investigations took place in the period of 1992–2009. In terms of the moisture levels during the warm period, the years during the investigations were as follows: 3 years were drought and acute drought (1998, 1999, 2009), 8 years were medium dry (1992, 1995, 1996, 2000, 2001, 2002, 2005, 2007), 2 years were medium humid (2004, 2006), and 5 years were humid (1993, 1994, 1997, 2003, 2008). Irrigation was conducted using Sprinkling Machine Fregat in various modifications. The irrigation rate varied from 115 mm in humid years to 345 mm in drought years.

Two-factor test options were studied for determination of water consumption of corn for silage with three rates of mineral fertilizers (1st factor) over the different distance from the forest belts (2nd factor).

The options with the mineral fertilizers doses: 1. $N_{90}P_{60}K_{30}$; 2. $N_{180}P_{120}K_{60}$; 3. $N_{270}P_{180}K_{90}$. Nitrogen was introduced with the irrigation water in the form of anhydrous ammonia (fertigation), phosphorus and potassium for the main treatment. The options over the different distance from the FB were : 1. 1H (17 m); 2. 3H (51 m); 3. 5H (85 m); 4. 10H (170 m); 5. 20H (340 m) (H – FB height. H = 17 m). Forest belts with a width of 18 m consist mainly of Siberian Elm, accompanied by green ash. Observations were carried out in accordance with the methods of the leading research institutes of the RF [8, 9, 11] and of B.A. Dospekhov [6].

Statistical analyses included analysis of covariance with the use of standard computer programs and graphical analytical methods for determination of significance of parameters of microclimate, growing period moisture, water consumption, yield, etc. [4,5,10]:

$P = 100\ m\ /\ (n + 1)$, (1)

where P – level of significance of the parameters being investigated, %.

m – order number in the ranked observation series;

n – series members number (number of years of observations).

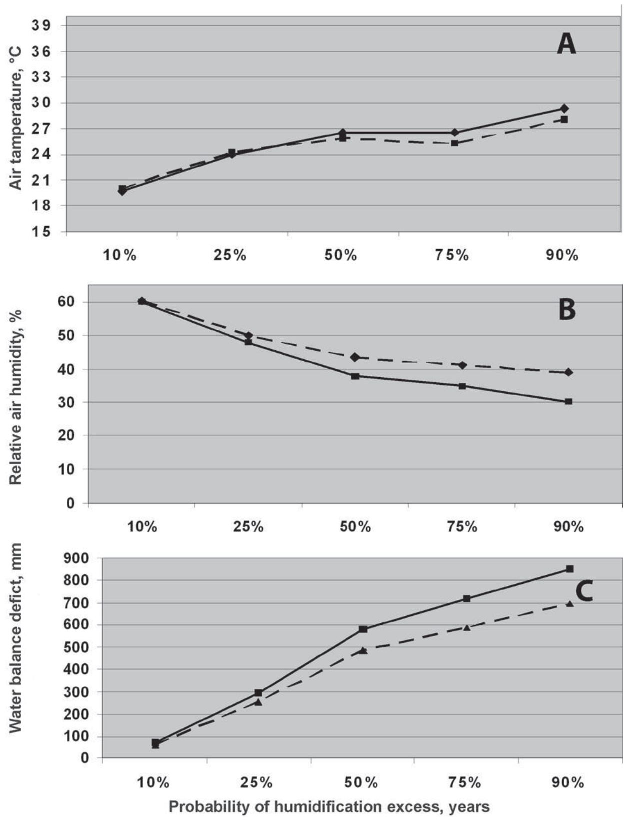
Creation of favorable microclimate in the space between belts along with precipitation, water balance deficit and moisture accumulation in the soil are significant part in yield of corn for silage.

In the humid years, air temperature and relative humidity under the influence of forest belts of various structures are less variable. In the acute drought years, the air humidity under the influence of forest belts increases by 9%, while in the medium humid years, when the maximum crop yield occurred, this parameter increases by 4.2%. The water balance deficit (evaporability minus precipitation) grows with the increase of the aridity of the crop growing period, with the difference in the dry years as compared to the humid years of up to 780 mm. Forest belts reduce this parameter depending on the structure to 690–708 mm, or by 9.2–11.5% (Fig. 1).

The daily evaporability in the control corn crops gained 5.3 mm (7.1 mm in the drought days), while among the forest belts, this parameter reached only 4.0 mm and was appropriately reduced with increased moisture to 2.9 mm for middle years and to 2.4 mm for humid years. At the same time, an insignificant influence of the forest belts on the evaporability was noted in the humid years (less than 0.1 mm per day).

The water balance deficit for the growing period among the forest belts in the corn crops in the acute drought years reduced by 55–100 mm, and in the humid years by 2–10 mm. Optimal structure of the forest belts (laced or blown-off) results in reduction of non-productive evaporation in the acute drought years by 25–45 mm or by 2.9–5.3%, while in the medium humid and humid, by 7.0–11.5% (Fig.). In the same years, the maximum corn yield results with the maximum plant transpiration and the minimum water consumption coefficient.

Yield increments of corn for silage with irrigation are appropriately reduced with the increased moisture in both absolute value and specific weight irrespective of the forest belts structure.




Dotted line — under influence of forest belts; solid line — with no influence of forest belts.

***Fig. Influence of forest belts on temperature (A), air humidity (B), and water balance deficit (C) depending on humidification of vegetation period***

The maximum yield increments are typical for forest belts with the laced or blown-off structure: 42.3 to 48.4% in the acute drought years and 1.7 to 2.9% in the humid years.

When cultivating corn for silage, the influence of the amelioration type on yield was analyzed: chemical, irrigation, and forest (Table).

The influence of the amelioration type as the effector of yield of corn for silage was studied and analyzed: A factor, chemical ameliorations; B factor, irrigation ameliorations, C factor, forest ameliorations.

A factor: up to 55%; B factor: up to 33%; C factor: up to 18%, depending on moisture during the growing period of the corn for silage crop. With increased drought, the effect of B factor increases more than two to threefold; the effect of C factor increases by 1.2 to 1.4 times.

Combination of the factors shows the following effects: A+B, up to 70 %; B+C, up to 21% ; A+C, 17%; A+B+C, up to 73%. In the humid years, the influence of the B factor (irrigation) is reduced, while the influence of precipitation and soil moisture increases as the total water consumption elements. The total water consumption of corn for silage in the humid years raises by 30% as compared to the acute drought years due to reduction of physical evaporation.

In the presence of forest belts, with fertilizer rates reduced three-fold reduct, the irrigation water discharge per 1 t of corn silage increases by 6.2 $m^3/t$ or by 9.0% in the acute drought years; with a × rate of mineral fertilizers, the parameter increases by 3.5 $m^3/t$ or by 5.1%, respectively.

- During extreme weather, when a relative air humidity of less than 20% is observed, the air temperature difference under the influence of the forest belts achieves 3.4°C;
- The forest belts raise the relative air humidity depending on moisture during the growing period by 0.2–4.2% in the humid years and by 7.6–9.0% in the drought years;
- In the drought days with the air humidity of less than 20%, the forest belts reduce daily evaporability to 1.9 mm or by 26.8% due to decrease in non-productive evaporation;

**Water consumption of silage corn mass depending on humidification of vegetation period and fertilizers under influence of forest belts (denominator) in liver-colored soils of dry-steppe Zavolzhye**

| Vegetationperiodhumidification | Precipitation | | Soil moisture (in the 0.6 m layer) | | Irrigation rate (with soil humidity of 0.7 of Field Moisture Capacity) | | Total water consumption, mm | Fertilizers dose, kg in rate of application/ha | Crop capacity, t/ha $HCP_{05}$ = 0.5 t/ha | Water consumption coefficient, $m^3/t$ | Irrigationwaterdischarge, $m^3/t$ | Water saving by forest belts, mm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | mm | % | mm | % | mm | % | | | | | | |
| Drought P > 85% | 60/60 | 12.0/12.5 | 95/105 | 19.0/21.9 | 345/305 | 69.0/65.6 | 500/470 | $N_{90}P_{60}K_{30}$ | 50.0/53.8 | 100.0/87.4 | 69.0/56.7 | 40 |
| | | | | | | | | $N_{180}P_{120}K_{60}$ | 63.0/67.0 | 79.4/70.1 | 54.8/45.5 | |
| | | | | | | | | * $N_{270}P_{180}K_{90}$ | 89.0/91.0 | 56.2/51.6 | 38.8/33.5 | |
| Medium P = 50% | 75/75 | 17.8/18.8 | 115/125 | 27.4/31.2 | 230/200 | 54.8/50.0 | 420/400 | $N_{90}P_{60}K_{30}$ | 55.0/57.3 | 76.4/69.8 | 41.8/34.9 | 30 |
| | | | | | | | | $N_{180}P_{120}K_{60}$ | 67.2/70.1 | 62.5/57.1 | 34.2/28.5 | |
| | | | | | | | | * $N_{270}P_{180}K_{90}$ | 91.9/93.0 | 45.7/43.0 | 25.0/21.5 | |
| Humid P < 15% | 110/110 | 31.4/31.4 | 125/125 | 35.7/35.7 | 115/115 | 32.9/32.9 | 350/350 | $N_{90}P_{60}K_{30}$ | 52.0/52.4 | 67.3/66.8 | 22.1/21.9 | 1 |
| | | | | | | | | $N_{180}P_{120}K_{60}$ | 60.2/60.8 | 58.1/57.6 | 19.1/18.9 | |
| | | | | | | | | * $N_{270}P_{180}K_{90}$ | 83.1 83.6 | 42.1 41.9 | 13.8/13.8 | |

P — probability of humidification excess, %.* Nitrogen was introduced with irrigation water in the form of ammonia (fertigation)

- With increased dryness during the growing period, the water balance deficit increases from 60–242 mm in humid years up to 660–850 mm in drought years;
- Depending on the structure and the moisture during the growing period, the forest belts reduce the water balance deficit by 2–32 mm in humid years and by 28–100 mm in drought years. The water saving extreme in the acute drought years under the influence of the forest belts of the laced and blown-off structures reaches 80–100 mm which is 25–45 mm higher than for the dense structure;
- The moisture content in the soil among the forest belts and beyond in the humid years amount to 65–75% of Field Moisture Capacity. In the drought years, they drop to values of humidity of wilting in the spaces between belts and lower without the influence of the forest belts;
- The long-term cyclones in the humid years determine the lower air temperature as of 13 o'clock as compared to the drought years by 8–10°C,as compared to the medium humid by 2–4°C which influences the corn yield;
- In the medium humid years, the corn yield was higher than in the humid years by 30% when the lower air temperatures prevent normal development of the generative members of the culture; in addition, depending on the structure, the forest belts raise the productivity up to 10%.
- With increased moisture in the silage corn growing period, the yield increment under the influence of forest belts declines and practically stays within the test error for the humid years;
- In the total water consumption, the influence of precipitation and soil moisture with increased drought declines from 35.7 to 12%, while the effect of irrigation water increases from 32.9 to 69%. Moreover, the forest belts increase the effect of the moisture content in the soil by 3.8%, and reduce the irrigation rate by 4.8% in water consumption of corn for silage. In the humid years, the forest belts do not practically influence water consumption, which is confirmed by the evaporability observations;
- The forest belts decrease the total water consumption of corn for silage to 30 mm in the drought years and to 20 mm in the medium years;
- The rate of mineral fertilizers cardinally changes the silage corn yield and the water discharge per the culture's yield unit. As the rate mineral fertilizers increases, the silage corn yield appropriately increases irrespective of the growth period moisture; however, it is slightly lower for the humid years, because the low temperature conditions formed with cyclones shift the formation of the plants' vegetative mass. The highest yield of up to 93–98 t/ha of silage corn was obtained with fertigation, when nitrogen in the form of anhydrous ammonia was introduced fractionally with the irrigation water in the dose $N_{270}$. At the same time, the effect of the forest belts gained 1.1–2.9 t/ha which is associated, first of all, with an observance of silage corn watering time frames, i.e. in the days when the strong wind (over 7 m/s) disabled watering;
- The water consumption coefficient and the irrigation water discharge appropriately decrease with the increase in moisture during the growing period, the irrigation water discharge per yield unit reduce by the factor of 1.7–1.8. This regularity persists with an enhancement of the growing period drought. The direct irrigation water content decreases with the improvement of the natural humidification from 69 $m^3/t$ in the acute drought years up to 13.8 $m^3/t$ in the humid years, or by the factor of 3 to 4;
- The water consumption coefficient and the irrigation water discharge appropriately decrease with the increase in the moisture during the growing period. Moreover, with the two to threefold increase in the rate mineral fertilizers, the irrigation water discharge per yield unit decreases by a factor of 1.7 to 1.8. This regularity persists with an enhancement of the vegetation period drought. The direct irrigation water content decreases with the improvement of the natural humidification from 69 $m^3/t$ in the acute drought years up to 13.8 $m^3/t$ in the humid years, or by the factor of 3–4;
- Irrigation in forest belts systems enables saving irrigation water when drought conditions are worse: from 1 mm for humid years to 40 mm for dry years;
- The variance analysis shows that the considerable increments of the corn yield depending on the forest belts structure occur for all years in terms of humidification. In the acute drought years, the considerable differences in the culture yield increments exist irrespectively of the structures, for the other years – only in relation to the dense structures;
- The regression dependencies of the corn yield on the vegetation period humidification are described by the cubic equation with the coefficient of determination of 0.80–0.82: up to 82% of yield fluctuations are caused by fluctuations in change of the vegetation period humidification;
- The maximum irrigation water saving by the forest belts is associated with an enhancement of drought of the cultures cultivation vegetation period – in the acute drought years, the forest belts save up to 55 m of irrigation water during irrigation of the corn for silage.

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## EFFICIENCY OF CHEMICAL AMELIORANTS AT CULTIVATION OF GRAIN CROPS ON SOD-PODZOL SOILS OF CHUVASHIYA

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The article shows that liming and application of nitric fertilizers at rates of 30, 60 and 90 kg/hectare allows improvement of fertility of sod-podzol soils of the Chuvash Republic and to produce consistently high yields of grain crops.
**Key words**: sod-podzol soils, nitric fertilizers, liming, *triticum aestivum*, *hordeum sativum*, *secale cereale*.

One of the most important tasks in creating favorable conditions for sustainable economic development of the Russian Federation and provision of food and environmental security is efficient use and protection of agricultural land as a major national wealth. At the same time, one of the most acute problems in agriculture is a growing phenomenon of degradation of natural resources, first of all soil, which is due to high anthropogenic load.

At the present time, lack of energy and capital investment, including reduction of application of organic and mineral fertilizers and chemical amelioration in agricultural production, coupled with increase in the use of natural resources order to obtain a short-term maximum economic effect, have caused adverse effects of agronomic and environmental nature: reduction in agricultural crop yields, further increasing water and wind erosion, silting-up of waters, and deterioration of water balance.

All of this creates preconditions for deterioration of soil quality: humus content, mobile compounds of nutrient elements are annually reduced, soil acidity is increasing. Thus, according to the Federal State Institution "State Centre of Agrochemical Service "Chuvash", as of January 1, 2007 just in Chuvash Republic, there were 134.6 thousand ha with low content of phosphorus, 270.0 thousand ha of acidic soils and soils with low exchange of potassium.

At the present stage of agricultural production development, the typical features of sod-podzol soils in Chuvash Republic are weak top humus horizon; acidic reaction of medium and weak structure, which has a negative effect on water and air and nutrition mode; erosion resistance of the tilth-top soil; and, as a result, reduced yield of agricultural crops [1].

With development, this type of soil may gain properties favorable for cultivation of agricultural crops, but with insufficient investment of energy resources, may lose it quickly [1.2]. Therefore, at present, of important scientific and practical value is an increase of the fertility of sod-podzolic soils and improvement of their quality by means of chemicals

The objective of our research was assessment of influence of liming and different doses of nitrogen fertilizer on the fertility of sod-podzolic soils and cereal crop productivity.

Therefore it was undertaken to study agrochemical, agrophysical and biological indicators of soil fertility of sod-podzolic soils, and to evaluate effects of liming and rates of nitrogen fertilizer on yield and quality of spring wheat, winter rye, and barley.

Studies were performed in 2005–2008 at the territory of Cheboksary and Kanashskogo districts of the Chuvash Republic in crop rotation with the following sequence of plants: winter rye – spring wheat – barley. Forecrops of cereal crops were annual grasses for hay (vetch with oat). Replication was four-fold, with arrangement of trail plots by the method of randomized repetitions in two tiers. Area of plots was100 $m^2$ (5 x 20 m).

Experimental trials were: 1) without fertilizers (control); 2) $K_{30}P_{30}$ background; 3) background + $N_{30}$; 4) background + $N_{60}$; 5) background + $N_{90}$; 6) background + $N_{30}$+ lime; 7) background + $N_{60}$ + lime; 8) background + $N_{90}$ + lime.

All potash fertilizers were applied while plowing; 75% of phosphorus fertilizers were applied while plowing, and 25% while seeding; Nitrogen fertilizers in accordance with the experimental trials were applied at pre-seeding cultivation, taking into consideration the phase of spreading of cereal crops. Spraying of crops was performed with herbicide "Cowboy" at 200 mg/ha rate with simultaneous fertilizing of soil with ammonium nitrate at a rate of 10 kg/ha of nitrogen. Liming of soil with lime flour at a dose of 4 t/ha was conducted in autumn of 2005.

We have studied Prokhorovka spring wheat varieties, Elf barley varieties and Bezenchukskaya 87 rye varieties with seeding norm 5.5; 5.5 and 5.0 million germinable seeds per hectare (in the calculation 210; 200 and 180 kg/ha), respectively. Before sowing, seeds of spring crops were pretreated with TMTD at a rate of application of 4 kg/t and winter rye with Ferazim KS at the rate of 1.5 l/t seeds.

Cultivation technology of the studied cereals was based on primary tillage of the forecrops at a depth of 4–6 cm BDT-3; moldboard plowing PLN-4-35 at a depth of 18–20 cm, preseed cultivation KPS-4 at a depth of 406 cm with simultaneous harrowing BZSS-1.0, seeding with seed planter SZ-3.6 and further compacting 3KKLU-6. Harvesting of cereal crops was made directly by combine harvester "Don-1500".

Field studies and laboratory analysis were performed during tests and examinations: humus content was determined on the basis of Tyurin methods as modified by CINAO (Russian State Standard (RSS) 26213-91), mobile forms of phosphorus and potassium in accordance with Kirsanov method (RSS 26207-91), nitrates on the basis of calorimetric method with chromotrope acid, pHKS1n, based on potentiometer method (RSS 2648-85); the density of soil consistency by repeat sampling using Nekrasov sampler, structural-aggregate soil composition based on N.I. Savvinov method, soil-water filtration rate based on square frameworks; soil biological activity based on activity of cellulose-decomposing microorganisms by the method of application.

Results of agrophysical studies showed that the maximum (1.31 g/$cm^3$) average values of texture density of tilth-top soil in traditional cereal crop cultivation technologies were found in control plots, and the minimum (1.24 g/$cm^3$) average values in plots with soil liming and application of 90 kg/ha of nitrogen as well as phosphoric-potash nutrition (table 1).

The maximum average content agronomically valuable aggregate (69.8%) was found in the tilth-top soil in the plots with liming and annual application of 90 kg/ha of nitrogen against along with phosphoric-potash, and the minimum (61.8%) average content was in control plots.

**Table 1. Agrophysical properties of the plough layer of sod-podzol soils (average values for 2005—2008)**

| Variants | Texture density, г/см³ | | Content of aggregation 0.25—10 мм, % | | Contents of the water-resistant aggregation, % | | Filtration speed, mm/min | |
|---|---|---|---|---|---|---|---|---|
| | Seeding | Harvesting | Seeding | Harvesting | Seeding | Harvesting | Seeding | Harvesting |
| 1 | 1.05 | 1.31 | 58.5 | 61.8 | 17.4 | 19.8 | 1.37 | 1.16 |
| 2 | 1.05 | 1.30 | 59.2 | 63.2 | 18.0 | 21.2 | 1.37 | 1.19 |
| 3 | 1.05 | 1.28 | 61.9 | 66.6 | 20.1 | 22.9 | 1.37 | 1.20 |
| 4 | 1.05 | 1.26 | 62.2 | 67.2 | 20.6 | 23.3 | 1.37 | 1.22 |
| 5 | 1.05 | 1.25 | 62.9 | 69.0 | 20.9 | 24.2 | 1.37 | 1.24 |
| 6 | 1.05 | 1.27 | 62.0 | 66.9 | 20.4 | 23.0 | 1.37 | 1.20 |
| 7 | 1.05 | 1.26 | 62.6 | 67.8 | 20.8 | 23.7 | 1.37 | 1.23 |
| 8 | 1.05 | 1.24 | 63.4 | 69.8 | 21.5 | 24.5 | 1.37 | 1.26 |
| $HCP_{05}$ | — | 0.10 | 4.06 | 4.18 | 2.34 | 2.60 | — | 0.06 |

According to the results of our experiments, the average maximum number of water-resistant aggregates (24.5%) was also formed in plots with lime application and 90 kg/ha of nitrogen along with phosphoric-potash nutrition. Minimum (19.8%), was formed in control plots without application of fertilizers. Increased content of agronomically valuable and water-resistant aggregates is due to the fact that when applying fertilizer and lime to the soil the speed of reproduction of soil microorganisms producing mucus that binds the individual soil aggregates is increased.

It was found in the course of examination that filtration properties of soil are improved with annual application of only phosphorus / potassium fertilizer at 0.02–0.03 mm/min, together with different doses of nitrogen at 0.03–0.10 mm/min, and with liming at 0.04–0.11 mm/min.

Results of agrochemical research in CJSC "SKhPK Chuvashagromarket" have demonstrated that in plots without the use of fertilizers when cultivating cereal crops based on traditional technology, deterioration in soil fertility of sod-podzolic soils is found which results in humus content reduction by 0.1%, mobile phosphorus and potassium by 13 and 11 mg/kg respectively, nitrates by 0.4 mg/kg; in an increase of acidity by 0.1 unit in comparison with the values as of the time of study initiation. This was also shown by the results of our studies in the collective farm "Civil". There is decrease of humus content in the control variant by 0.1%, mobile phosphorus and potassium – by 10 and 9 mg/kg respectively, nitrates – by 0.3 mg/kg, the increase in acidity was by 0.1, compared with the original data (table 2).

At the same time, the annual application of nitrogen fertilizers at rates of 30, 60 and 90 kg/ha liming at 30 and 60 kg/ha along with phosphoric-potash nutrition contributes to preservation of humus in the soil and application of nitrogen fertilizers at the dose of 90 kg/ha with liming along with phosphoric-potash increased humus content by 0.1%.

Therefore, with application of 90 kg/ha of nitrogen to the soil there is genesis of humus to the extent that newly-formed volume exceeds volume of degradation, while in case of absence of nitrogen fertilizers, the opposite is true, i.e degradation exceed synthesis, as was confirmed by results of the research.

Application of phosphoric fertilizers at a rate of 30 kg/ha contributed to an increase of phosphorus content available for plants in tilth-top soil, except for trials with applications of 90 kg/ha of nitrogen at the collective farm "Civil", whereas cultivation of cereals without fertilizers has resulted in its decline.

Study of potash mode has shown that application of nitrogen fertilizers and lime reduced its content in soil by 7–8 mg/kg compared to the original value. Maximum content of potassium exchange in soil was also found at the background sites.

**Table 2. Agrochemical indicators of tilth-top soil of sod-podzol soil CJSC "SKhPK Chuvashagromarket" and collective farm "Civil" (2005—2008)**

| Variants | Humus, % | Content, mg/kg | | $pH_{KCl}$ | Nitrates, mg/kg |
|---|---|---|---|---|---|
| | | $P_2O_5$ | $K_20$ | | |
| CJSC "SKhPK Chuvashagromarket" — beginning of the experiment (august 2005) | | | | | |
| Initial | 1.9 | 165 | 137 | 5.2 | 7.2 |
| End of the experiment (august 2008) | | | | | |
| 1 | 1.8 | 152 | 126 | 5.1 | 6.8 |
| 2 | 1.8 | 184 | 145 | 5.1 | 6.9 |
| 3 | 1.9 | 181 | 140 | 5.1 | 7.0 |
| 4 | 1.9 | 179 | 135 | 5.0 | 7.4 |
| 5 | 2.0 | 172 | 132 | 5.0 | 7.7 |
| 6 | 1.9 | 177 | 135 | 5.4 | 7.2 |
| 7 | 1.9 | 174 | 132 | 5.4 | 7.5 |
| 8 | 2.0 | 170 | 129 | 5.4 | 7.8 |
| $HCP_{05}$ | 0.05 | 14.64 | 11.42 | 0.14 | 0.22 |
| Collective farm "Civil" — beginning of the experiment (august 2005) | | | | | |
| Initial | 2.1 | 182 | 131 | 5.3 | 8.0 |
| End of the experiment (august 2008) | | | | | |
| 1 | 2.0 | 172 | 122 | 5.2 | 7.7 |
| 2 | 2.0 | 196 | 140 | 5.2 | 7.6 |
| 3 | 2.1 | 190 | 138 | 5.2 | 8.0 |
| 4 | 2.1 | 185 | 133 | 5.1 | 8.2 |
| 5 | 2.1 | 179 | 126 | 5.1 | 8.2 |
| 6 | 2.1 | 188 | 136 | 5.7 | 8.1 |
| 7 | 2.1 | 183 | 130 | 5.6 | 8.3 |
| 8 | 2.2 | 176 | 124 | 5.5 | 8.3 |
| $HCP_{05}$ | 0.05 | 14.82 | 11.18 | 0.18 | 0.26 |

According to the agrochemical analysis data, soil liming provided the possibility to reduce acidity in experimental plots by 0.2–0.4 units, while in plots where there was no liming, the acidity conversely increased: by 0.1 unit in control and background trials and in trials with application of 30 kg/ha of nitrogen; and by 0.2 units in variants with application of 60 and 90 kg/ha nitrogen respectively. The data are consistent that annual application of mid-and high-doses of nitrogen fertilizer contributes to strengthening of soil acid properties.

Content of nitrates in the soil without application of nitrogen fertilizers decreased by 0.3–0.4 mg/kg in control and background trials; with application of 30 kg/ha of nitrogen it decreased by 0.2 mg/kg, while together with liming it remained at the same level. Only with use of 60 and 90 kg/ha of nitrogen was there an increase by 0.2–0.5 mg/kg. Moreover, liming increased the amount of increase by more 0.1 mg/kg, as lime fertilizes soil with calcium, required for binding of nitrate in the form of $Ca(NO_3)_2$.

The main indicator of biological activity of the soil is activity of cellulose-decomposing microorganisms, which is determined by the degree of decomposition of linen. In average, the intensity of the linen decomposition in the control sites without application of fertilizers was minimal – 53.6% (Figure).

Maximum intensity of linen decomposition, 70.7%, was detected at sites with liming and annual application of nitrogen fertilizers at the rate of 90 kg/ha along with phosphorus potash. This may be explained by the fact that with lime, the efficiency of nitrogen-assimilating bacteria (nitrogen bacteria, clostridium, etc.) and nodule bacteria, activity of nitrifying agent (*Nitrosomonas* and *Nitrobacter*) is stimulated.

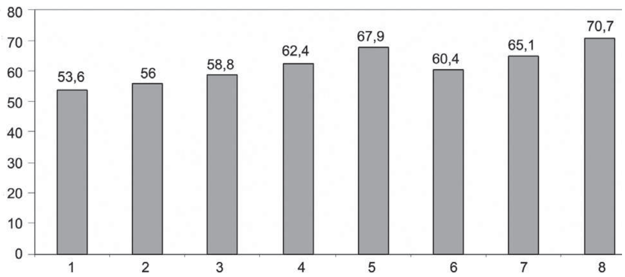


***Figure. Intensity of the linen decomposition under cereal crops by experiment variants, % (average for 2006—2008)***

On average, on nutrient-poor soil CJSC "SKhPK Chuvashagromarket" without fertilizer we have got 11 centner/ha of grain. As a result of nitrogen fertilization and liming at a dose of 90 kg/ha yield of cereal crops was increased by more than 2 times and amounted to 23 centner/ha on average during the years of research.

The highest return of mineral (8.4 kg/kg) and nitrogen (13.5 kg/kg) fertilizers during cultivation of grain crops in the first rotation of crops rotation was obtained at variant with liming at a dose of 60 kg/ha along with potash nutrition (table 3).

***Table 3. Average yields of grain crop rotation in CJSC "SKhPK Chuvashagromarket" (2006—2008)***

| Variants of experiment | Yield | | | | | Return, Kg/kg | |
|---|---|---|---|---|---|---|---|
| | In average, Centner/ha | Increase | | | | | |
| | | Centner/ha, to | | %, to | | | |
| | | Control | Background | Control | Background | NPK | N |
| 1 | 11.0 | — | — | — | — | — | — |
| 2 | 12.9 | 1.9 | — | 17.3 | — | 3.2 | — |
| 3 | 16.3 | 5.3 | 3.4 | 48.2 | 26.3 | 5.9 | 11.3 |
| 4 | 20.1 | 9.1 | 7.2 | 82.7 | 55.8 | 7.6 | 12.0 |
| 5 | 21.9 | 10.9 | 9.0 | 99.1 | 69.8 | 7.3 | 10.0 |
| 6 | 16.9 | 5.9 | 4.0 | 53.6 | 31.0 | 6.6 | 13.3 |
| 7 | 21.0 | 10.0 | 8.1 | 90.9 | 62.8 | 8.4 | 13.5 |
| 8 | 23.0 | 12.0 | 10.1 | 109.1 | 78.3 | 8.0 | 11.2 |
| $HCP_{05}$ | 3.78 | | | | | | |

On average we have obtained 12.5, 12.8, and 12.3 centner/ha of winter rye grain, spring wheat and barley in collective farm "Civil" without the use of chemicals. As a result of liming nitrogen fertilization at a dose of 90 kg/ha the yield of cereal crops increased by 1.8–2.1 times and reached 23.7, 26,8, and 24.4 centner/ha respectively (table 4).

The highest return on mineral fertilizers during cultivation of winter rye (7.8 kg/kg) and barley (8.3 kg/kg) was found in trials with liming and application of nitrogenous fertilizers in dose of 60 kg/ha with phosphorus potash nutrition and during cultivation of spring wheat (9.3 kg/kg) in the trials with liming and annual application of nitrogen fertilizers at a rate of 90 kg/ha along with phosphorus potash.

Maximum return on nitrogen fertilizer during cultivation of all studied cereal crops was found in trials with liming and application of 30 kg/ha nitrogen. With increased nitrogen fertilizer rates, their return with yields of cereal crops increase has declined.

On average, a minimum (15.4%) amount of gluten was contained in caryopsis of spring wheat cultivated without fertilizer. Liming and annual application of mineral fertilizers contributed to increase in gluten content of the grain. Maximum (23.5%) amount of gluten was contained in caryopsis of spring wheat, cultivated at site with liming and nitrogen fertilizer application 90 kg/ha along with phosphorus-potash nutrition.

Qualitative indicators of barley grains met the requirements for brewing of RSS 5060 "Brewer's barley", and analysis of qualitative indicators of winter rye grain has shown its compliance with 2 grade requirements specified for rye flour production.

***Table 4. Average yields of grain crops in collective farm "Civil" (2006—2008)***

| Variants of experiment | Yield | | | | | Return, kg/kg | |
|---|---|---|---|---|---|---|---|
| | Increase | Increase | | | | | |
| | | centner/ha, to | | %, to | | | |
| | | Control | Background | Control | Background | NPK | N |
| Winter Rye | | | | | | | |
| 1 | 12.5 | — | — | — | — | — | — |
| 2 | 14.1 | 1.6 | — | 12.8 | — | 2.7 | — |
| 3 | 18.1 | 5.6 | 4.0 | 44.8 | 28.3 | 6.2 | 13.3 |
| 4 | 21.3 | 8.8 | 7.2 | 70.4 | 51.0 | 7.3 | 12.0 |
| 5 | 23.5 | 11.0 | 9.4 | 88.0 | 66.6 | 7.3 | 10.4 |
| 6 | 18.4 | 5.9 | 4.3 | 47.2 | 30.4 | 6.6 | 14.3 |
| 7 | 21.9 | 9.4 | 7.8 | 75.2 | 55.3 | 7.8 | 13.0 |
| 8 | 23.7 | 11.2 | 9.6 | 89.6 | 68.0 | 7.5 | 10.7 |
| $HCP_{05}$ | 4.50 | | | | | | |
| Spring wheat | | | | | | | |
| 1 | 12.8 | — | — | — | — | — | — |
| 2 | 15.6 | 2.8 | — | 21.8 | — | 4.7 | — |
| 3 | 19.3 | 6.5 | 3.7 | 50.7 | 23.7 | 7.2 | 12.3 |
| 4 | 23.2 | 10.4 | 7.6 | 81.2 | 48.7 | 8.7 | 12.7 |
| 5 | 26.4 | 13.6 | 10.8 | 106.2 | 69.2 | 9.1 | 12.0 |
| 6 | 19.9 | 7.1 | 4.3 | 55.4 | 27.5 | 7.9 | 14.3 |
| 7 | 23.7 | 10.9 | 8.1 | 85.1 | 51.9 | 9.1 | 13.5 |
| 8 | 26.8 | 14.0 | 11.2 | 109.3 | 71.7 | 9.3 | 12.4 |
| $HCP_{05}$ | 4.72 | | | | | | |
| Barley | | | | | | | |
| 1 | 12.3 | — | — | — | — | — | — |
| 2 | 14.6 | 2.3 | — | 18.6 | — | 3.8 | — |
| 3 | 18.9 | 6.6 | 4.3 | 53.6 | 29.4 | 7.3 | 14.3 |
| 4 | 22.0 | 9.7 | 7.4 | 78.8 | 50.6 | 8.1 | 12.3 |
| 5 | 24.0 | 11.7 | 9.4 | 95.1 | 64.3 | 7.8 | 10.4 |
| 6 | 19.4 | 7.1 | 4.8 | 57.7 | 32.8 | 7.9 | 16.0 |
| 7 | 22.3 | 10.0 | 7.7 | 81.3 | 52.7 | 8.3 | 12.8 |
| 8 | 24.4 | 12.1 | 9.8 | 98.3 | 67.1 | 8.1 | 10.9 |
| $HCP_{05}$ | 4.44 | | | | | | |

Thus, results of field experiments made on the sod-podzol soil with main grain crops common in the Chuvash Republic allow conclusions about the efficiency of liming and application of nitrogen fertilizers at rates of 30, 60 and 90 kg/ha, which contribute to the reliable improvement of agrochemical, agrophysical and biological indicators of soil, providing consistently high quality yield of grain crops.

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# THE STABILITY OF THE PHYSICAL STATE OF ALLUVIAL SOILS IN VOLGA DELTA LANDSCAPES

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The influence of long-term irrigation on physical and hydrological properties of irrigated soils is revealed. The increase in natural existing cycles of wetting – drying leads to illimerization of oozy particles and soil compaction results. Under the influence of illimerization and shrinkage there is a consolidation not only of the subsurface horizon, but also of deeper layers. Absorbing ability of soils of vaporous moisture and wilting point decrease. Water permeability of soils during this process increases over time. A high positive correlation between the size of swelling and the content of smectite component in oozy fraction (r=0.751) has been noted. Recommended soil moisture content is within the limits of 18–21% of soil weight. It is recommended to make moldboard plowing with pan busting 1 time in two-three years.

**Key words**: granulometric composition, illimerization, carbonates, volume weight, consolidation, total porosity, aeration porosity, minimum moisture capacity, humidity wilting point, swelling, smectite, stickiness, optimum humidity of processing.

The Volga River delta belongs to alluvial and deltoid semidesertic plain landscapes which resulted from erosive and follow-up accumulative activity of river waters. Under water influence, the topography of deltoid space is created, qualitative and quantitative structure of the alluvium influences development of vegetation and activity of microorganisms, and the course of soil-forming processes, and the variety of floodplain soils, delta and sub-steppe lakes are determined.

Features of Volga's hydrological mode are caused by the variety of topography of deltoid islands. The flat character of primary islands as the result of their integration is differentiated and becomes complicated. Peripheries of islands tower as corniform high deltaic levees deposited by waters. The central parts of islands which have grown together around kultuk have deep depressions. Flat sites are quite often cut by courses of dried shallow channels and longitudinal manes. Each primary deltoid island in the deltaic part is composed of sand or sandy loams, and in the central sites, by loams and clays. In both cases, the deposits of delta fronts or kultuks of the earlier period of development in which granulometric composition changes from sands to clays, act as the lithological base. During the modern period of development of deltoid space, the general regularities of formation are shown. High dynamism of soil-forming processes causes diversity of even well formed soils. The central lower parts of islands are covered with deposits of heavier granulometric composition, and sites close to deltaic area, with light sediments [3,7].

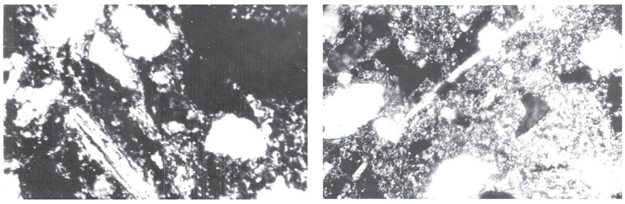
The area of investigation is in the raised western (hilly and flat) part of the delta proper [5] and occupies the southern part of the island washed by the rivers Tarnovaya, Tabola, Krutoberezhnaya and Kigach. The topography is characterized by considerable uniformity. The flat character is interrupted by separate zone elevations, "Ber's hillocks". From the North, the territory is limited by hillocks Bolshoy and Maliy Esenke, and from the South by the Argymak hillock. They represent narrow elevations with height of 10–15 m. The width of hillocks reaches 250–300 m, and the length fluctuates from 1500 to 2000 m. Slopes at the foot of hillocks give way to terraces in the form of half rings which tower one over another by 0.5–1.5 m. The usual number of terraces is three. The Kultuchnaya plain represents one of the modern topographical forms composed of alluvial and diluvial deposits. The plain soil cover is primarily alluvial meadow black soils (classification of S.A. Vladychensky).

Monitoring of delta landscapes soils has been carried out in the territory of an experimental farm of the GNU of all-union scientific research institute of irrigated vegetable and melon growing. We examined more than 200 profiles over an area of 400 hectares. Over a range of profiles we tended to capture all main soil differences. In addition, the binding to profiles which were taken while carrying out reclamation works in 1959 by the Astrakhan branch of "Yuzhgiprovodkhoz" was considered. This allowed characterization of the composition and the properties of alluvial meadow black soils, including physical and hydrologic properties, in connection with their long use for vegetables and melon growing.

The probes showed that in the territory of the experimental farm of GNU of all-union scientific research institute, alluvial meadow black soils of mainly average (profile 2), heavy clay loam (profile 10 and 13), and clay (profile 18), granulometric composition prevail, which at a depth of 50–100 cm are interleaved with sandy loam and light clay loam deposits (Table 1). Fractions of fine sand (22–77%) and oozy (9–35%), being in inversely proportional dependence, prevail. The volume of physical clay makes to 17–66%. The wide range of variation of specified fractions is explained by features of formation of deltoid islands and, first of all, by initial heterogeneity of deposited river alluvium with the annually changing hydrological mode of the Volga River. The soil profile has a multinomial structure where the regularity of alternation of alluvial deposits is practically absent. In heavy soil differences (profile 10, 13, 18), which are in the lower central part of the Kultuchnaya plain, the content of pulverescent and oozy particles prevails. Light soil differences (profile 2) in which the raised content of sand is noted, are typical for deltaic area, and the dispersion factor on soil profile changes from 11 to 20%. In heavy clay loam and clay soils the size of the dispersion factor is the smallest – 0.2–5.8 %. This testifies to their strong microstructure, first of all, owing to oozy fraction. It actively participates in the physical and chemical processes going on in soil, including the cementation of soil units. The strong microstructure is caused by chemical bonds both in colloidal and chemical units, and between micro units. Carbonates play an important role assisting the cementation of micro units. The micromorphological analysis carried out by us indicates that carbonate grains increase with depth where soil plasma is plentifully inlaid with fine-grained calcite (Fig. 1).

***Table 1. Granulometric composition and dispersion factor of alluvial meadow black soils***

| Profile № | Depth, cm | Particle size (mm) and its concentration (%) | | | | | | | Dispersion factor, % |
|---|---|---|---|---|---|---|---|---|---|
| | | 1–0.25 | 0.25–0.05 | 0.05–0.01 | 0.01–0.005 | 0.005–0.001 | <0.001 | >0.01 | |
| 10 | 0–30 | 0.2 | 35.2 | 11.1 | 5.9 | 12.6 | 35.0 | 53.5 | 0.19 |
| | 30–47 | 0.1 | 21.6 | 12.0 | 9.7 | 16.4 | 40.2 | 66.3 | 0.19 |
| | 47–72 | 0.1 | 30.3 | 18.8 | 9.6 | 11.5 | 29.7 | 50.8 | 0.30 |
| | 72–94 | 0.1 | 60.0 | 13.1 | 4.3 | 5.6 | 16.9 | 26.8 | 0.66 |
| | 94–120 | 0.1 | 33.1 | 5.0 | 8.2 | 14.4 | 39.2 | 61.8 | 0.41 |
| | 120–150 | 0.1 | 58.4 | 1.6 | 4.2 | 5.8 | 29.9 | 39.9 | 0.43 |
| 2 | 0–28 | 1.6 | 36.1 | 20.1 | 4.0 | 13.9 | 24.3 | 42.2 | 11.62 |
| | 28–40 | 1.7 | 51.7 | 7.2 | 4.0 | 12.2 | 23.2 | 39.4 | 15.50 |
| | 40–55 | 2.5 | 56.4 | 3.5 | 6.0 | 8.2 | 23.4 | 37.6 | 16.33 |
| | 55–70 | 1.5 | 58.6 | 3.9 | 4.5 | 12.1 | 19.4 | 36.0 | 11.42 |
| | 70–95 | 0.7 | 66.2 | 4.4 | 2.5 | 8.7 | 17.5 | 28.7 | 19.87 |
| | 95–150 | 1.1 | 65.6 | 3.7 | 3.7 | 7.7 | 18.2 | 29.6 | 16.51 |
| 13 | 0–27 | 0.2 | 23.4 | 26.3 | 10.4 | 11.7 | 28.0 | 50.1 | 1.96 |
| | 27–45 | 0.5 | 48.3 | 19.3 | 2.7 | 9.8 | 19.9 | 32.4 | 0.33 |
| | 45–92 | 0.5 | 77.3 | 4.3 | 3.0 | 5.5 | 9.4 | 17.9 | 0.51 |
| | 92–150 | 0.2 | 53.6 | 10.5 | 6.6 | 10.6 | 18.5 | 35.7 | 2.29 |
| 18 | 0–30 | 0.7 | 22.0 | 15.5 | 10.5 | 16.0 | 35.3 | 61.8 | 5.76 |
| | 30–55 | 1.1 | 40.0 | 10.0 | 6.0 | 11.9 | 31.0 | 48.9 | 0.49 |
| | 55–85 | 0.7 | 54.3 | 10.3 | 8.3 | 10.9 | 15.5 | 34.7 | 0.28 |
| | 85–98 | 0.6 | 70.0 | 8.2 | 4.5 | 8.6 | 8.1 | 21.2 | 0.29 |
| | 98–150 | 0.7 | 60.8 | 2.5 | 7.3 | 9.5 | 19.2 | 36.0 | 0.32 |



20—30 cm, nicols X (profile 2) 80—90 cm, nicols X (profile 2)

***Fig. 1. Microstructure of alluvial meadow black soils (magnification 7x9)***

The analysis of results of granulometric composition of alluvial meadow black soils received by us and by the Astrakhan branch of "Yuzhgiprovodkhoz" during the period of their development showed the following. Long agricultural use (more than 30 years) of soils under intensive irrigation and exit of deltoid islands out of the influence of inundated processes as a result of their bordering and canalization of the bed of the Volga causes illimerization of oozy particles out of the profile limits (150 cm) and to accumulation of a fine sand fraction (Table 2). The pulverescent fraction remains unchanged. The process of illimerization is most clearly observed in profile 77 which corresponds with profile 10 (tab. 2) studied by us. Development of deltoid soils, as the sizes of dispersion factor shows, promotes hardening of microstructure of the top half-meter layer of soil (profile 77). Here the dispersion factor decreases from 12–30 to 0.2 % (profile 10). It is caused, as was noted earlier, by accumulation of carbonates in irrigated soils and the intensification of aging processes in soils.

When studying physical and hydrologic properties, the arable layer was divided into layers through each 10 cm as the surface layer of soils is exposed to the maximum anthropogenic influence (Table 3).

***Table 2. Granulometric composition and dispersion factor of alluvial meadow black soils ("Yuzhgiprovodkhos", 1959)***

| Profiles № | Depth, cm | Particle size (mm) and its concentration (%) | | | | | | | Dispersion factor, % |
|---|---|---|---|---|---|---|---|---|---|
| | | 1—0.25 | 0.25—0.05 | 0.05—0.01 | 0.01—0.005 | 0.005—0.001 | <0.001 | >0.01 | |
| 71(18) | 0—22 | — | 4.39 | 18.48 | 9.18 | 15.74 | 52.21 | 77.13 | — |
| | 25—45 | — | 2.65 | 34.79 | 8.62 | 12.39 | 41.55 | 62.56 | — |
| | 60—75 | — | 19.93 | 12.07 | 7.09 | 14.44 | 46.47 | 68.00 | — |
| | 90—110 | — | 73.88 | 4.24 | 0.80 | 12.00 | 9.08 | 21.88 | — |
| | 125—150 | — | 21.56 | 20.20 | 7.70 | 10.29 | 40.52 | 58.51 | 12.99 |
| 77(10) | 0—20 | — | 1.52 | 17.82 | 11.71 | 17.84 | 51.11 | 80.66 | 30.21 |
| | 20—50 | — | 3.77 | 24.56 | 7.96 | 14.98 | 48.73 | 71.67 | — |
| | 55—80 | — | 1.33 | 25.89 | 8.42 | 13.87 | 50.49 | 72.78 | — |
| | 90—115 | — | 0.67 | 30.07 | 11.33 | 13.15 | 44.78 | 69.26 | — |
| | 135—160 | — | 76.58 | 11.77 | 1.59 | 2.61 | 7.45 | 11.65 | — |
| 30(2) | 0—12 | — | 2.62 | 16.90 | 9.09 | 14.17 | 57.22 | 80.48 | — |
| | 30—45 | — | 21.11 | 16.71 | 7.07 | 9.52 | 45.59 | 62.18 | — |
| | 65—90 | — | 8.34 | 30.04 | 6.52 | 10.71 | 44.39 | 61.62 | — |
| | 170—200 | — | 33.22 | 37.57 | 2.66 | 4.96 | 21.59 | 29.21 | — |

Note: in brackets No. of profiles assigned by us and corresponding to profiles of "Yuzhgiprovodkhoz" are specified.

The cultivated soils are characterized by dense structure that shows adverse conditions for cultivated crops. The smallest values of firmness of 1.35–1.43 g/cm$^3$ are characteristic for the top 10 cm of a layer of the arable horizon; firmness sharply increases to 1.50–1.68 g/cm$^3$ with depth. It is quite difficult to observe the regularity of packing of horizons. It is possible to explain this by features of soil formation and alternation of soil formations, and also by long term intensive use of lands in irrigated agriculture. Light soil differences (profile 2) for which the dense packing of sandy particles is characteristic, have the greatest packing.

Firmness of the top 10 cm layer of the cultivated soils increased to 0.34 g/cm$^3$, in the layer of 20–30 cm to 0.38 g/cm$^3$; deeper, on average to 0.15 g/cm$^3$ (profiles 77 and 10).

***Table 3. Water-physical properties of alluvial meadow black soils***

| Profile № | Depth, cm | Specific gravity, g/cm$^3$ | Density of soil solid phase, g/cm$^3$ | Total porosity, % | Aeration porosity, % | Minimum moisture capacity, % | Maximum hygroscopicity, % | Humidity wilting point, % | Maximum permissible volume weight, g/cm$^3$ |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 0—10 | 1.43 | 2.65 | 46.0 | 3.6 | 34.1 | 10.1 | 15.2 | 1.18 |
| | 10—20 | 1.50 | 2.65 | 43.4 | 1.2 | 32.6 | 9.4 | 14.1 | 1.21 |
| | 20—30 | 1.57 | 2.67 | 41.2 | 2.5 | 29.0 | 10.0 | 15.0 | 1.28 |
| | 47—72 | 1.45 | 2.61 | 44.5 | 4.5 | 30.4 | 6.5 | 9.8 | 1.23 |
| | 72—94 | 1.58 | 2.68 | 41.0 | 1.0 | 28.7 | 7.7 | 11.6 | 1.27 |
| | 94—120 | 1.51 | 2.63 | 43.0 | 4.1 | 27.3 | 5.0 | 7.5 | 1.30 |
| 2 | 0—10 | 1.41 | 2.72 | 48.2 | 9.4 | 26.5 | 6.0 | 9.0 | 1.34 |
| | 10—20 | 1.53 | 2.66 | 42.0 | 10.8 | 23.0 | 6.0 | 9.0 | 1.40 |
| | 20—30 | 1.60 | 2.65 | 39.6 | 7.6 | 22.8 | 6.4 | 9.6 | 1.40 |
| | 55—70 | 1.58 | 2.68 | 41.0 | 10.3 | 21.9 | 5.6 | 8.4 | 1.41 |
| | 70—95 | 1.68 | 2.70 | 37.8 | 2.4 | 23.2 | 5.0 | 7.5 | 1.40 |
| | 95—120 | 1.67 | 2.69 | 37.9 | 2.3 | 23.5 | 5.2 | 7.8 | 1.42 |
| 13 | 0—10 | 1.38 | 2.64 | 48.0 | 10.3 | 30.4 | 7.1 | 10.7 | 1.25 |
| | 10—20 | 1.52 | 2.68 | 43.0 | 2.1 | 29.7 | 6.5 | 9.8 | 1.27 |
| | 20—30 | 1.40 | 2.63 | 46.8 | 10.6 | 28.6 | 6.3 | 9.2 | 1.28 |
| | 45—92 | 1.48 | 2.70 | 45.2 | 10.7 | 25.8 | 5.8 | 8.6 | 1.35 |
| | 92—150 | 1.49 | 2.65 | 43.8 | 7.8 | 26.9 | 6.4 | 9.6 | 1.30 |
| 18 | 0—10 | 1.35 | 2.66 | 49.0 | 7.6 | 33.8 | 7.4 | 11.1 | 1.19 |
| | 10—20 | 1.51 | 2.71 | 44.3 | 2.4 | 30.5 | 6.8 | 10.2 | 1.26 |
| | 20—30 | 1.48 | 2.62 | 43.5 | 4.7 | 28.8 | 6.0 | 9.0 | 1.27 |
| | 55—85 | 1.49 | 2.63 | 43.3 | 7.0 | 26.8 | 5.3 | 8.0 | 1.31 |
| | 85—98 | 1.57 | 2.66 | 41.0 | 3.1 | 27.8 | 8.5 | 12.8 | 1.30 |
| 77 (10) | 0—10 | 1.09 | 2.71 | 59.7 | 21.3 | 41.2 | 13.7 | 20.6 | 1.09 |
| | 20—30 | 1.19 | 2.75 | 56.7 | 20.6 | 36.1 | 13.3 | 20.0 | 1.17 |
| | 50—65 | 1.30 | 2.77 | 50.1 | 21.1 | 28.7 | 14.7 | 22.1 | 1.31 |
| | 65—80 | 1.38 | — | 50.1 | 14.1 | 31.9 | 13.4 | 20.1 | — |
| | 80—95 | 1.47 | 2.79 | 47.3 | 9.7 | 31.4 | 12.6 | 18.9 | 1.26 |
| | 110—130 | 1.49 | — | 44.8 | 4.9 | 28.3 | 3.5 | 5.3 | — |

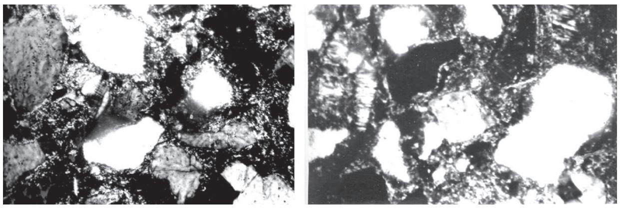
* Note: profile 77 – the results of probes of "Yuzhgiprovodkhoz" (1959). in brackets there are No. of profiles assigned by us and corresponding to profile on virgin soil.

It is possible to explain this packing, first, by an increase over natural existing cycles of wetting / drying during irrigation, and also the sizes of peaks of these parameters. Fast transition from dry condition to wet and rather fast drying promotes the packing of soil. The same process, but less expressed, is also observed in lower layers (deeper than 50 cm). Secondly, under the influence of shrinkage, there is packing not only of the subsurface horizon, but also of deeper layers, though this influence is more apparent in the former. It should be noted that the formation of plough-pan is relatable not only to irrigation, but primarily to the intensive processing of soils which leads to partial collapse of structure, strengthening of mineralization of the vegetative residue, and shrinkage. Thirdly, the accumulation of carbonates in soil profile during irrigation and the increase of free silica, that together with other physical and chemical processes lead to packing of irrigated soils are important [1]. The results of micromorphological probes also demonstrate an accumulation in the soil profile of fine-grained calcite and dense packing of soil particles

The degree of total porosity in all studied soil is in the range of 41–49%. On the Kachinsky scale, it belongs to unsatisfactory for an arable layer. With depth, this indicator decreases to

37–43%. During processing of soil and irrigation, there is a decrease of total porosity in arable horizon of 14.6%, and deeper , 7%.

The reduction of total porosity is mainly due to aeration pores. Micromorphological probes showed that in studied soil, the pores are of inappropriate, branching, channel shape, (Fig. 2). This is a characteristic sign of irrigated soils formed in hydromorphic conditions.



10—20 cm, nicols X (profile 10) 120—130 cm, nicols X (profile 10)

***Fig.2. Microstructure of alluvial meadow black soils (magnification 7x9)***

The prevalence of capillary pores in soil reveals a negative water to air ratio for soil aeration, low water return, and increased values of humidity wilting point. The majority of pores are filled with hard-to-reach water, so that most of the moisture is in a bound state. In heavy soil varieties, the concentration of air is notably low (profile 10, 18). In light soil varieties (profile 2) the volume of pores filled with air increases to 7—10% at minimum moisture capacity. The comparison of agronomical soil landscapes with soils of virgin landscapes demonstrates the decrease in the content of soil air in the arable horizon from 20–21 to 1–4%, deeper – from 5–14 to 1–5% with minimum moisture capacity. In this regard, inter-row processing used in technologies of cultivation of vegetable and melon crops allow an increase in the volume of air of 10–15% of soil volume. These limits provide normal development of vegetable and melon crops.

The calculation of the maximum permissible soil density made by us according to Dolgov demonstrates the reconsolidation of soil of agronomic landscapes; in virgin soil, the content of soil air corresponds to norm.

The minimum moisture capacity (MMC) varies within limits of 22–34 %. Water-retaining capacity of the top layers of heavy soil varieties has the greatest values (profile 10, 18). With increasing depth the MMC decreases to 22–27%; the minimum values are observed in sandy layers. Agricultural use of soils led to decrease of the MMC in the arable horizon for 7%; deeper, the changes are insignificant. The maximum hygroscopic moisture and humidity wilting point of studied soils are within limits respectively of 5–10 and 8–15%. Anthropogenic factors promote reduction of absorbing ability of soils of vaporous moisture and humidity wilting point.

The permeability of alluvial soils varies greatly. It depends on granulometric composition and mineralogical structure of soils and their age. Alluvial meadow black soils created on the Kultuchnaya plain have rather low permeability: on the average, after 6 hours, this varies within 0.61–1.10 mm/min (Table 4). Absorption in the first hour fluctuates in a wide range of values of 68–153 mm. The lowest values of water permeability are peculiar to heavy loam clay and clay soil varieties (profile 13 and 18).

The permeability of meadow soils in development increases with age. In soil profiles of meadow thin layered soils, there can be sharp transitions from low permeability to high permeability horizons. Sharp changes among layers of granulometric composition create increased resistance to filtered water and reduce permeability. Even a layer of small capacity with low permeability weakens the filtering capability of soils. In meadow black soils the meadow soil-forming process slightly leveled the lamination by depth so increaseing their filtering capability [4].

***Table 4. Permeability of alluvial meadow black soils, mm/minute (load sites method)***

| Place of definition | Permeability | | | Decrease of permeability, % | Absorbed after 1 hour in mm | Average permeability after 6 hours |
|---|---|---|---|---|---|---|
| | For the first 10 minutes | Final at the 6th hour | Average in 1 hour | | | |
| Profile 10 | 2.00 | 0.90 | 1.52 | 55 | 119.2 | 1.10 |
| Profile 2 | 2.80 | 1.01 | 2.17 | 64 | 153.6 | 1.36 |
| Profile 13 | 1.58 | 0.48 | 0.93 | 70 | 68.3 | 0.61 |
| Profile 18 | 1.91 | 0.52 | 1.29 | 73 | 76.8 | 0.71 |

The presence in soil profiles of heavy clay layers results in a sharp decrease in degree of permeability. Sandy layers are distinguished, on the contrary, by high permeability. An exception to this is cemented condensed sands. Prevalence in soil the capillary pores, which are narrowed when soils are swelling and can be blocked by airlock, also reduces the permeability. The increase of absorbing capability of meadow black soils is explained by the higher moisture capacity of their top layers which causes rapid water absorption. The existence of fissuring in soil surface to 20 cm in dry conditions, and the presence of root tracks and rhizomes of plants, supplements high water absorbing capability in the first 10 minutes by 1.6 to 2.8 mm/minutes. The decrease of permeability to 30% by the end of the first hour is explained by the rapid moistening and subsequent swelling of soils.

The swelling of soil samples of various horizons reaches 5 to 12% of initial volume and it is noted at the end of the seventh hour after the initial wetting. The majority of swelling is characteristic of the top layers; when depth increases, the indicator decreases and reaches a minimum in sandy layers of 5%.

Studies of the fine-grained portion of soil demonstrated the qualitative and quantitative characteristics of clay minerals influencing swelling of alluvial soils. The main components of the oozy fraction of soils are mixed layered mica -smectite formations with prominence of clathrates of mica, chlorite, and kaolinite. Associating minerals include and feldspar. The smectite proportion is 20—80%, the proportion of hydromica, 10–70%, kaolinite and chlorite, 10– 25%. In heavy loam clay varieties, the quantities of smectite and hydromica are respectively within 19 to 55 and 33 to 65 % and is inversely proportional to depth to 19 and 65 %. In medium clay loam varieties of soils, the smectite proportion is 71 to 82%, which does not change significantly with depth. It is known that features of the structure of an elementary smectite cell, consisting of two tetrahedral layers between which there is an octahedral, explains high swelling capability of the mineral. We discovered a high correlation between the degree of swelling and the content of the smectite component in the oozy fraction of soils (g=0.751).

Increased content of water-soluble salts in soil also promotes swelling.

We did not determine the dependence between the content of waterproof soil aggregates and the volume of smectite in oozy (g =-0,407), and in soil (g =-0,028). It is evident that during irrigation there is smectite swelling and, in consequence, destruction of waterproof soil aggregates.

We have no data on permeability of soils of virgin sites within the studied territory. On the basis of literature data [2,6,8] and our research, it is possible to assume that the speed of water filtration in soils decreases as the result of consolidation of subsurface horizon and illimerization of oozy fraction out of soil profile studied by us to 150 cm (Table 1, 2, 3).

Alluvial meadow black soils as classified by Kachinsky, belong to the mid-viscosity category (Table 5). The beginning of sticking corresponds to humidity of 25–29% from soil weight. The maximum degree of stickiness is noted in the top 10 cm layer at 41–49% moisture per soil weight. The presence of a raised content of smectite component can be explained by qualitative and quantitative features of the oozy fraction of studied soils. As the results show, a wide range of fluctuations of stickiness in profiles of the top 30 cm layer of soil is not observed.

**Table 5. Stickiness of alluvial meadow black soils, g/cm²**

| Depth. cm | Humidity, % | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 25 | 29 | 33 | 37 | 41 | 45 | 49 | 53 | 57 | 61 |
| Profile 10 | | | | | | | | | | |
| 0—10 | 0.3 | 3.9 | 4.8 | 5.5 | 5.6 | 6.8 | 7.5 | 6.3 | 5.7 | 3.0 |
| 10—20 | — | 1.7 | 3.6 | 8.5 | 6.0 | 6.3 | 5.0 | 4.1 | 3.0 | — |
| 20—30 | — | 1.8 | 3.4 | 7.3 | 7.6 | 8.3 | 6.3 | 4.4 | 3.4 | — |
| Profile 2 | | | | | | | | | | |
| 0—10 | 0.2 | 4.2 | 5.1 | 5.6 | 5.0 | 7.0 | 7.7 | 6.6 | 6.1 | 3.2 |
| 10—20 | — | 1.8 | 3.4 | 8.9 | 6.4 | 6.3 | 5.2 | 4.2 | 2.8 | — |
| 20—30 | — | 1.7 | 3.7 | 7.0 | 7.5 | 8.1 | 6.5 | 4.7 | 3.3 | — |
| Profile 13 | | | | | | | | | | |
| 0—10 | — | 1.9 | 3.4 | 4.2 | 9.3 | 8.8 | 6.9 | 4.0 | 3.1 | 2.3 |
| 10—20 | — | 0.6 | 1.7 | 4.5 | 4.3 | 8.1 | 6.8 | 5.9 | 3.8 | 2.8 |
| 20—30 | — | 2.4 | 6.9 | 7.6 | 5.7 | 5.0 | 2.5 | 1.7 | 0.5 | — |
| Profile 18 | | | | | | | | | | |
| 0—10 | — | 1.5 | 3.3 | 4.0 | 9.2 | 8.9 | 6.9 | 4.2 | 2.9 | 2.0 |
| 10—20 | — | 0.5 | 1.7 | 4.5 | 4.4 | 8.3 | 7.0 | 6.3 | 3.9 | 3.0 |
| 20—30 | — | 2.5 | 6.7 | 7.6 | 5.6 | 5.1 | 2.6 | 1.5 | — | — |

Thus, the present study demonstrated the following. The illimerization of oozy particles negatively affects the physical and chemical reactivity of soils and mobilization of nutrients. Accumulation of carbonates promotes hardening of the microstructure.

Long use of intensive irrigation changes the physical and hydrological properties of alluvial meadow black soils. In this regard, the system chosen for main and inter-row soil processing allows reduction of density and improvement of aeration conditions. As a result, the water capacity and the permeability of loosened layers increase. Thus, 5–10% of pores participate in soil air exchange that is more than before processing. Thus, the porosity in aeration areas is withinin optimum limits for vegetable and melon crops. The content of macro and meso pores increases, and the quantity of small pores decreases. To improve aeration and increase permeability of the subsurface horizon, pan-busting should be carried out once every 2 to 3 years.

The studied soil properties considerably depend on qualitative and quantitative structure of the oozy fraction. The prevalence of the smectite component limits the high end of swelling and stickiness.

When developing recommendations for soil processing, it is necessary to consider the physical and hydrological properties of specific soil types. In areas cultivated with crop rotations, it is necessary to consider the diversity of soil surface, and to use energy saving and soil protective technology. The recommended soil moisture is within 18 to 21% of soil weight for optimal soil aggregation.

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## WATER CONSUMPTION AND EFFICIENCY OF CARROTS WITH DRIP IRRIGATION

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In this article, questions of efficiency of carrots (cultivar Shantene 2461) in different modes of drip irrigation and rates of chemical fertilizers are considered. Correlations between water consumption and productivity of carrots with variations of water and fertilizer ris noted.

**Key words:** water consumption, efficiency, carrots, drip irrigation, rate of fertilizers, productivity.

Carrots are a valuable vegetable culture in the Volgograd region. The special value of carrots for human nutrition is that orange root crops have a significant quantity of carotene (provitamin A). There are also vitamins $B_1$, $B_2$, $B_6$, C, E, Pp and a lot of salts of calcium, magnesium, sodium, phosphorus and iron. Flavour and sugar content in carrots make them a nutritive, valuable, dietary product [1,2,3].

Planting area of carrots in the world is about 1 million ha; in Russia, about 100 to 200 thousand ha, and in Volgograd oblast, 3.8 thousand ha. Average carrots crop yield does not exceed 22 tons/ha; however the potential yield of modern varieties and hybrids of carrots is about 90 tons/ha [4,5]. One of the main factors limiting crop efficiency of planted table carrot in ameliorated chestnut soils is insufficient and often incorrect application of fertilizers without due regard to irrigation regime and biological characteristics of varieties and hybrids. In these circumstances, research on the use of drip irrigation systems and fertilizer application to significantly increase yields of carrots is important.

Studies were performed in PFE "V.D. Vybornova" of the Leninsky district of the Volgograd region in 2007–2008.

Field experiments were designed to study the following factors: factor B – level of mineral nutrition levels for different levels of projected yields of carrot.

Experimental design for soil moisture (factor A) provides the following factors: A1 – maintenance of pre-irrigation limit of soil moisture in the layer of 0.4 m, differentiated 70% FMS of planting prior to root crop formation, 80% FMS from the beginning of root crop forming to technical ripeness, 70% FMS from the technical ripeness to harvesting; A2 – 70–80–80% FMS; A3 – 70–90–80% FMS; A4 – 70–80–90% of FMS.

Soil fertility amendments included addition of mineral fertilizers in doses calculated on the basis of planned yield levels of 40, 50, 60 and 70 t/ha. B1 – addition of mineral fertilizers in dose $N_{100}P_{90}K_{70}$ for a planned carrots yield level of 40 t/ha; B2 – $N_{140}P_{120}K_{140}$ for 50 t/ha; B3 – $N_{180}P_{150}K_{210}$ for 60 t/ha; B4 – $N_{220}P_{180}K_{280}$ for 70 t/ha.

Studies were performed on carrot varieties Shantenae 2461. All variables, including topography, soil, and hydrological conditions were identical. To exclude the influence of soil variety, experiments were conducted in quadruplicate. The experimental field area was 1 ha. Each plot for testing irrigation mode was 0.25 hectares, and for fertilization, 150 $m^2$.

***Yield of carrots depending on doses of fertilizers and irrigation mode***

| Dose of mineral fertilizers, kg rate of application/ha | Level of preirrigation soil moisture, % FMS | Yield of carrots by years of research/ha | |
|---|---|---|---|
| | | 2007 г. | 2008 г. |
| $N_{100}P_{90}K_{70}$ | 70–80–70 | 39.5 | 40.2 |
| | 70–80–80 | 44.8 | 46.3 |
| | 70–90–80 | 45.5 | 45.9 |
| | 70–80–90 | 42.1 | 43.8 |
| $N_{140}P_{120}K_{140}$ | 70–80–70 | 47.3 | 48.8 |
| | 70–80–80 | 56.5 | 57.2 |
| | 70–90–80 | 57.4 | 56.7 |
| | 70–80–90 | 50.2 | 51.7 |
| $N_{180}P_{150}K_{210}$ | 70–80–70 | 55.8 | 57.3 |
| | 70–80–80 | 65.6 | 66.2 |
| | 70–90–80 | 66.7 | 67.8 |
| | 70–80–90 | 59.1 | 60.3 |
| $N_{220}P_{180}K_{280}$ | 70–80–70 | 58.0 | 59.2 |
| | 70–80–80 | 68.1 | 67.8 |
| | 70–90–80 | 69.4 | 69.3 |
| | 70–80–90 | 61.6 | 61.3 |
| $HCP_{05}$ for private secondary | | 2.0 | 1.7 |
| $HCP_{05}$ factor A | | 1.0 | 0.83 |
| $HCP_{05}$ factor B | | 1.0 | 0.83 |

Carrot panting rate was 1 million seeds/ha in 4-line belts. Planting was made on June 01 using a vacuum seeder "Gaspardo'' (Italy). "Eurodrip" (Greece) drip equipment set was used for irrigation, with a distance between drippers of 40 cm and a rate of 1.6 l/h per linear meter.

Taking into account the hydrological properties of soil and the local moisture at the site in order to maintain the limit of preirrigation soil moisture in the 0.4 m layer, 70% FMS irrigation was performed with norm 184 $m^3$/ha, 80 % FMS – 166 $m^3$/ha, 90% FMS – 82 $m^3$/ha.

The greatest influence on the mode of the drip irrigation of carrots is soil water mode parameters. To maintain the lower preirrigation moisture level 70–80–70% of FMS in varying precipitation years, 20–23 watering was needed with irrigation norm 3338–3872 $m^3$/ha. Where preirrigation moisture level was maintained at the level of 70–80–80% FMS was maintained by 22–24 watering with irrigation norm 3670–4002 $m^3$/ha. Maintenance of preirrigation moisture level 70–90–80% FMS was ensured by 43–48 watering with irrigation norm 3796–4290 $m^3$/ha. Lower preirrigation moisture level 70–80–90% of FMS was maintained by 23–29 watering with irrigation norm 3584–4160 $m^3$/ha. Minimum values for total water consumption of 4870–5390 $m^3$/ha were found at sites where moisture level was maintained at the level of 70% FMS from seeding to sprouting preirrigation, from sprouts to technical ripeness, 80% FMS, and from the beginning of technical ripeness up to harvesting 70% FMS Mineral fertilizers were applied $N_{100}P_{90}K_{70}$, calculated for obtaining 40 t/ha of carrots. Increase of preirrigation soil moisture level up to 80% FS within the period from the beginning of technical ripeness up to harvesting exceeded water consumption by crops up to 4640–5580 $m^3$/ha, which on average exceeded 40 $m^3$/ha in variant A1 (70–80–70% FMS). The greatest consumption of moisture by carrots was in variant A3 (70–90–80% FMS) and was in total 5190–5720 $m^3$/ha. Maintenance of the set level of soil moisture combined with application of mineral fertilizers ensured achievement of the planned yield (table).

On the basis of mathematical analysis of experimental data using statistical software and computers we found a correlation describing association of changes in water consumption and yields of carrot under the controlled conditions of water and mineral nutrition of plants (figure).

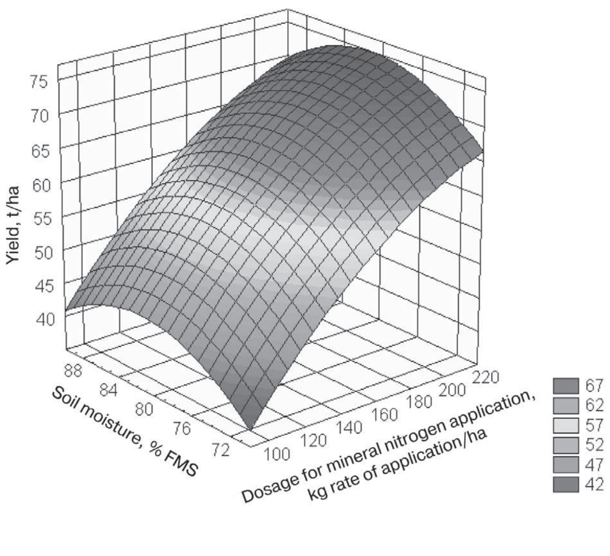
Dependencies are shown as polynomial equations of the following type:

$$K = 927.9 - 1.409N - 17.51V + 0.003N^2 + 0.1069V^2 + 0.0021NV;$$

where K – water consumption coefficient; N – dosage for mineral nitrogen application, kg rate of application/ha; V – soil moisture, % FMS.

$$Y = -444 + 0{,}541N + 11{,}065V - 0{,}001N^2 - 0{,}068V^2 - 0{,}0001NV;$$

where Y – level of the formed carrot yield, t/ha.




***Changes in yields of carrot under the controlled conditions of water and mineral nutrition of plants***

The obtained analytical dependences are characterized by a high degree of reliability. Value of determination of the coefficient equal to the square of correlation coefficient was 0.92 for the yield and for coefficient of water consumption 0.91.

Thus in the course of the research the statistically significant influence of conditions of water and mineral nutrition of plants on carrot yield was revealed.

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# GLOBAL POISONING WILL ELIMINATE OUR CIVILIZATION BEFORE GLOBAL WARMING DOES

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The world's fate in the XXI century is defined by the genetic consequences of anthropological counter-evolution in nature, and not by the global economy.

**Key words**: globalism, natural globalization, anthropogenic globalization, technical-engineer, technically modified, criterion $LD_{50}$

Globalization, global warming and global economic crisis are the most discussible problems in the world. people cannot find a solution is not the case; the case is that According to scientists, politicians and economists, they comprise the global problem of human survival. However, as the famous English writer Gilbert Keith Chesterton noted, "The fact that people cannot find a solution is not the case; the case is that they usually cannot see the problem

Anthropogenic globalization, or more exactly transglobalization is the policy of establishment and arrangement of the new world public-economic order on the basis of global technologies. It is performed through the economic, politic, legislative, science-technical, technological and cultural integration of the world; using unification, standardization and labor migration processes, capital, human and manufacturing resources; by vulgarized culturalisation of the world in order to change the consciousness of the people, expansion of global world-view and world-order, standardization of lifestyle, primitivization of every human personality.

A global event has occurred at the turn of XX and XXI centuries without being noticed. Anthropogenic globalization came into collision with natural globalization, i.e. global warming. So, the world entered the age of global natural, anthropogenic and economic shocks which globally change the order of civilization development existing since the Iron Age.

The natural globalization is the global warming tangible by living creatures and shown in figures in a number of intergovernmental documents. A group of experts on climate change (Intergovernmental Panel on Climate Change) headed by Albert Gore, published estimation reports and forecasts related to climate change on Earth in 2007 and got the Nobel Peace Prize. According to the results of multi-annual climatic simulations and direct measurements carried out by scientific climatologists (over 2500 scientists from approx. 130 countries of the world were involved), the experts marked out the following main factors of growth of global warming from a huge data array, and predicted its consequences [1]:

- There exists "a very high level of certainty" in the fact that anthropogenic activity since 1750 has been promoting the global warming of the Earth;
- the average global near-surface air temperature over the last 100 years has grown by 0.74°C; it currently amounts to 14.4°C and is growing with the rate of 0.177°C each 10 years;
- the carbon dioxide ($CO_2$) concentration growth in the atmosphere due to acceleration of the industrial development of the world is the most important factor conditioning growth of the global temperature;
- in case of $CO_2$ stabilization at the level of 958 ppm (the integral equivalent of $CO_2$ is currently about 430 ppm), the increase in the average global temperature by 4°C is expected as compared to 1980–1999;
- this will result in reduction of the global food production, increase of the risk of species extinction, melting of the ice sheets of Greenland and the Western Antarctic ice sheet, and an increase in the sea level by 4–6 m.

Consequently, in case of development of the anthropogenic scenario with the greenhouse effect of $CO_2$ at a level of about 958 ppm and the increase of the near-surface temperature by 4°C, the irreversible processes of bio-ecological catastrophe of life on Earth will start in nature as soon as the 2090s.

However, there are many scientists in the world who do not agree with an anthropogenic reason for the warming climate on Earth. Thus, the leading scientist-geophysicist of the Institute of Oceanology n.a. P.P. Shirshov of the Russian Academy of Sciences O.G. Sorokhtin writes in his book "Life of the Earth" [3], that the accumulation (or reduction) of carbon dioxide, methane and some other so-called "greenhouse" gases does not affect the Earth climate at all. Moreover, change of $CO_2$ concentration, increase or decrease of the partial pressure in the atmosphere are not the reasons, but the consequence of the temperature changes of the climate. With the rise of the oceanic waters temperature, transfer of a part of $CO_2$ from the ocean to the atmosphere always occurs. On the contrary, in case of the fall of temperature, solubility of $CO_2$ in the oceanic waters raises. This implies that the climatic warming is always preceded by an increase of the partial pressure of $CO_2$ in the atmosphere, and the cooling is preceded by its reduction.

The true reasons for temperature fluctuations of the Earth climate lie in other processes and occurrences, for example, in precession of the Earth's rotation, in irregularity of solar radiation, in instability of the ocean currents, etc. The Earth is currently at the peak of its relatively small local warming which soon (in relatively few years) will be replaced by the regular deep cooling – the predecessor of the next Ice Age.

The reason for the upcoming cooling is related to reduction of the Earth's precession angle and decrease of the total pressure of the Earth atmosphere due to the vital activity of the nitrogen-consuming bacteria which constantly remove nitrogen from the air and mineralize it. However, these processes are uncontrollable and people will unlikely be able to do anything to affect them (using such documents as the Kyoto Protocol).

Subsequences of the anthropogenic globalization.

Since the late Neolithic Age, the horse was the historical driver of constantly progressing humanity. Although people had started using oil already in the 6th millennium B.C.E., they have learnt to retrieve anthropogenic energy from it only 100–150 years ago. Then the Age of the Horse was replaced by the Age of Motors, Man-made Biota and Anthropogenic Energy which total reactive mass expressed in hundreds of megatons of toxigenic waste – the by-products of this mass:from carbon dioxide to radionuclides – currently creates a destruction of the global bioenvironmental stability of the biosphere. At present, the level of development of any government is determined by the level of energy consumption, and not by the energy consumption efficiency! According to the forecasts of scientists, the century dream of the energetically concerned humanity will be achieved in 2040 and people will finally create a practically inexhaustible energy source, i.e. the fusion reaction. People will be even able to reduce the $CO_2$ emissions into the atmosphere by 50%. Unfortunately, it will be too late. The global energetic and bioenvironmental world crises are unavoidable. While the first crisis will start in about 20 years according to the estimations of some scientists, and in half a century by the evaluations of others, the second crisis has already approached. Although both crises are the results of primitive technologies using traditional raw material types and energy in the classical model of the scientific-technological advance (TA).That is why the issue of the environmentally reasonable use of raw materials and energy in the living matter food chains is already a global problem.

With the present extent and low scientific-technical level, as well as the anti-environmental, i.e. the counter-productive results of dispersion of the traditional raw material and energy types with the efficiency of $< 0.1$, in combination with the results of the continuous pesticidization and transgenization of biocenosis, – in only 30–40 years, the natural order of species selection, heredity, and ecology of the most fragile planet inhabitants (plants, insects, and microorganisms) established during millions of years will be completely destroyed. Then global genetic degradation will come, and the regressive metamorphosis will guide the evolution of living nature according to some other latent orders not envisaged by nature or people, but in strict compliance with the $LD_{50}$ criterion [2]. The living matter rotation will take place until the total synergetic dose of all poisons participating in the processes of bioaccumulation, biotransformation, and mutual toxification will obtain the lethal value $LD_{50}$, which will unavoidably result in death of 50% of all biological molecules taking part in the living matter rotation through the nutrition.

Out of the huge number of global anthropogenic factors which steadily draw nearer this $LD_{50}$, we will mark out the most important ones:

- the rate of ingress of the anthropogenic poisons in nature in 1986–1990 obtained the exponential character and advanced the rate of detoxification by nature;
- the quantity of anthropogenic manipulations of humans with nature became extremely high and tends (theoretically) to the number of options which can be searched by nature itself for the survival;
- pesticides are the fatal phenomenon of the material reality, while the polydisperse methods of their spraying as the similar technologies of burnup of the carbon fuel types represent the dead branch of civilization life-support;
- people can adapt to low caloric intake and insufficient food, however they can never adapt to the chronically toxic food.

As a result, the proportion of genetically defective, mentally retarded and socially dangerous people per each thousand citizens of the planet is constantly growing. They reproduce and will further reproduce more radical descendants which are similar to them and socially dangerous.

However, these factors indicating the genetic regress of humans do not disclose the most difficult question which has been discussed for so long in the scientific communities concerning pesticides, they only emphasize it: for example, why people live longer in Japan than in Russia, though the amount of pesticides applied in Japan exceeds the Russian parameter by a factor of 40? Of course, we assume that the figure is scientifically correct. Indeed, no comparative data on types, groups and rates of consumption of the preparations per 1 ha exists. This is in the first place. In the second place, exactly those people live longer whose genes were inherited from a pre-pesticide nature which was not yet poisoned by industry and chemistry. It was nature which surrounded people until the Second World War. The evolutional selection of human material was originated at the gene level, and about 50–60% of genetically acquired properties drive from historical heredity. In the third place, along with the life standard of life and food quality of Japan (which consists of no-yet-poisoned seafood at the level of 70–80%), this country has the highest pesticides introduction in the world culture of labor. At the same time, the question "how long will average Japanese who are currently at the age of 10–15 live with the progressive decline of environmental quality" is far from being rhetorical.

According to all scientific-anthropogenic signs, the Carthage of civilization shall be destroyed: a human in the ecologically poisoned nature cannot remain genetically and biologically valuable! This indicates the bio- and ecological cause-effect relation of results of the human and nature historical collision. It is disclosed by the authors of the scientific discovery made in 1979: "There was established the earlier unknown phenomenon of change of the immunological and functional condition of human organism and the biological life of human population consisting in loss of the bacterial internal environment adapted to the microorganism, and in destruction of the ecosystem formed within the evolution process and natural selection: microorganism is the pre-symbiotic bacteria causing diseases and reduction of human vitality"*.

The stronger biological community, and usually the most deleterious one, tends to win every niche in nature. Being genetically modified under constant synergetic influence of various anthropogenic poisons, living nature tends to the interpopulation survival, while human nature tends to self-destruction through invention and introduction of more and more poisons and super-poisons with qualitatively new toxicological properties. Although, the quintessence of living nature as well as the quintessence of human nature are formed by the world of plants, insects and microorganisms. We'll say one more time, that life is supported by it, and it has been serving as a "perpetual motion machine" for the biological matter rotation through nutrition for millions of years.

Being a biological creature, a human is what he/she eats, drinks and breaths. We, people and animals, eat ecologically contaminated food, drink dirty water and breathe poisoned air at the present time. The regressive metamorphosis and the bioenvironmental disharmony of the world of plants, insects, and microorganisms lead to facing principally new atypical epiphytotics, epizootics, pest infestation of people (and people already face them); these are the new kinds and forms conditioned by change of the development cycles in phytopathogenes, reproduction and injuriousness nature. The plants, animals and, undoubtedly, people will have other diseases – atypical diseases.

In order to suspend the future in which the past disappears, world science should not be concerned with the hypothetical global warming, but the reduction of the Earth's raw materials specific consumption:

- in order to spend minimum energy per unit of the final anthropogenic production;
- perform the task with the same economical effect, but simultaneously with the abrupt reduction of the anthropogenic load on the biosphere;
- thereby, change the relation of rates of poisons ingress in nature and the speed of their detoxification by nature.

For example, the monodisperse application (instead of the polydisperse) of the dispersion (capable of drop dispersion) chemical energies of carbon fuel types and pesticides will immediately reduce the anthropogenic load on the biosphere by 30–40%. However, in order to do this, the scientific-technological advance must converge with the scientific-ecological advance. Otherwise, global warming will destroy civilization together with the scientific-technological advance. There is no third option…

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