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Machine for carrying works on deep loosening of soil with the simultaneous application of liquid organic fertilizers

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Machine for carrying works on deep loosening of soil with the simultaneous application of liquid organic fertilizers

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Abstract. The situation in the country is analyzed, the amount of fallow lands withdrawn from agricultural use during the period of reforms is estimated. The necessity of carrying out work on deep loosening of mineral soils of III-IV groups of heavy mechanical action to increase water permeability, in order to drain excess surface water into the underlying soil layers, has been substantiated. The ways of achieving a high-quality fine crumbly soil structure to achieve an optimal water-air balance for the subsequent development of plants have been investigated. The efforts of reclamation rippers are considered and a two-row deep-ripping type with front shanks of a volumetric structure and rear curved shanks with additional plowshares is selected. The possibility of simultaneous operations on deep loosening of the soil with the introduction of liquid fertilizers has been substantiated. This will increase the fertility of the soil and qualitatively change its composition. The rates of application of liquid fertilizers to the soil have been investigated and a modified design of the machine for the delivery of organo-containing liquid to an enlarged pore space has been proposed. The resistance of soil development was estimated, the traction and grip qualities of the machine were checked and the possibility of installing additional equipment for applying fertilizers to the root-inhabited vegetation layer was revealed. The movement of an organic fluid in the pore representation is considered, the possibility of creating a homogeneous soil structure and uniform distribution of fluid, organic matter, in the root zone of plants is analyzed. The influence of the ongoing reclamation measures on increasing soil fertility, creating an optimal water and air balance for the growth and development of cultural and expected increase in yield is analyzed.

1. Introduction
The priority direction of agricultural development in the Russian Federation is to increase the number of acreages in order to ensure food safety of the country. Currently, the amount of arable land is 116 million hectares, or 58.7% of the total amount of agricultural lands [1]. Unused lands include 40 million hectares removed from agricultural turnover during the reform period at the end of the last century. These territories mostly abandoned, overgrown with coarse stalked and shrubby vegetation [2]. At the same time, the soil structure, its physical and chemical properties, including water permeability, have changed. These territories are partially waterlogged, covered with hummocks, and swampy. To make these lands suitable for agricultural use, it is necessary to conduct agro-reclamation activities, including deep soil loosening [3]. This will make the soil structure uniform, crumbly, and increase the pore space for the

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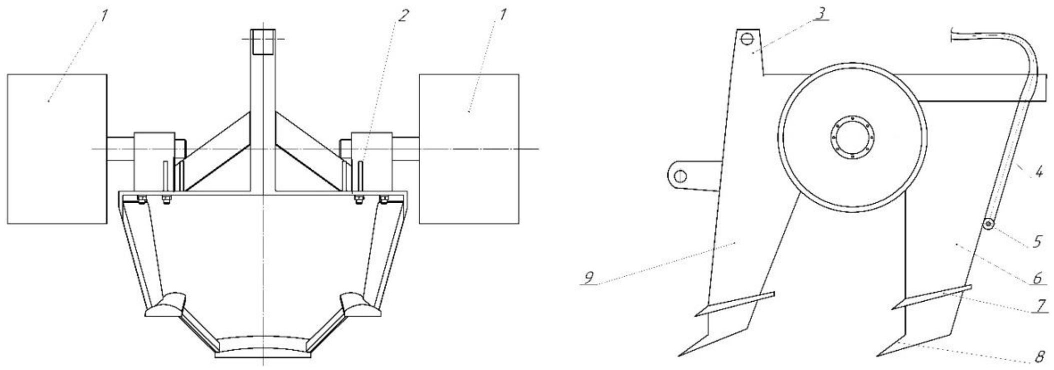
outflow of excess surface water to the underlying soil layers. The measures taken will significantly improve soil aeration by increasing the porosity coefficient from 0.4...0.5 for non-loosened samples to 0.65...0.75 after deep loosening [7]. The advantage of reclamation rippers of the passive type is the absence of mixing of the upper fertile soil layer and the lower underlying one. The quality of work is high for passive bulk rippers, as well as for rack rippers. The advantage of using a working body of this type is the almost complete absence of undeveloped areas in the inter-column space [9, 11]. To improve the soil structure, create optimal water – air balance and nutrient regime of the plant, it is proposed to combine work on deep loosening and applying liquid organic fertilizers to the soil. Once in the loosened soil, liquid fertilizers will be evenly placed in the increased pore space after loosening, creating an optimal regime for plant growth and development.

2. Materials and Methods

The machine designed for deep soil loosening with simultaneous application of liquid organic fertilizers is a passive volume-type Ripper with a width of 2.5 m with two-row curved posts, main and additional ploughshares at different heights, for loosening and fertilizing the soil. The design of the machine provides for the installation of additional equipment for intra-soil application of liquid organic fertilizers to a depth of 0.2 m using a nozzle [6].



a) b)

Figure 1. Subsoiler - fertilizer: a) Front view and b) side view; 1 - guide wheel, 2.3 - brackets for aggregation with the base machine, 4 - pipeline for fertiliser in the soil, 5 - injector, 6 - ripper (rack) of the second row, 7 - the upper chisel, 8 - the lower chisel 9 - the ripper of the first row, 6 - bracket for the base machine, 7 - the lid of the tank

To obtain a uniform crumbly soil and the absence of compacted areas between the pillars, it is necessary to determine the angle of the cone of the chip [5]:

$$\psi = arctg\left(\sqrt[3]{\sin(\alpha + (f + \varphi)) + \sqrt{\cos(\alpha - (f + \varphi))^2 + 1}\ \cdot}\right) \quad (1)$$

where: α - the angle of cutting lemech, hail; f - angle of friction of the ground on metal; φ - the angle of friction of the ground on the ground.

Knowing the angle of the ground cleavage, we determine the required width of the ploughshare to create a uniform soil structure [10]:

$$B_{\text{г}} \geq h_{\text{г}} \cdot \sqrt{\frac{\pi \cdot \cos\psi}{10 \cdot C \cdot \sin^2\psi \cdot \sqrt{1 + tg^2 f}}} \quad (2)$$

where: C - the number of blows densely dorny; $h_{\text{г}}$ - depth of loosening, m.

For the specified parameters of the machine, the soil resistance should be determined [4]:

$$F_{\text{т}} = F_{\text{р}} + F_{v} + F_{\text{тр}} \quad (3)$$

where: $F_р$ – resistance to the ground detachment, kN; F_v – resistance to the ground acceleration, kN, $F_{тр}$ – resistance to soil friction on the surface of the lemech and rack, kN

Decoding each of the terms, we can get next equation:

$$F_т = \frac{0{,}8\pi n \cdot \cos\psi \cdot \sin\alpha \cdot tg\varphi \cdot C \cdot h_г^2}{\sin^2\psi \cdot \sqrt{1 + tg^2 f}} + 10^{-3} b \cdot \rho \cdot k_м \cdot k_{пр} \cdot h_г \left(\frac{v_м^2}{2k_v} + \frac{L \cdot tgf}{g}\right)$$

where: n – the number of ripper shanks; b – loosening width, m; ρ – soil density, kg / m^3; L – ripper length, m; $v_м$ – the working speed of the ripper, m / s; $k_м$ – coefficient of resistance to the rise of the soil mass; $k_{пр}$ – coefficient of loosening completeness; k_v – coefficient of resistance to ground acceleration.

The distance of treatment with fertilizers from one position is determined from the next equation [8]:

$$p_н = p + \frac{10^{-5}\rho_у}{2g}\left(v^2 - v_н^2\left(1 + \vartheta + \lambda\frac{l_п}{d_п}\right)\right) \quad (4)$$

where: p_n - pressure at the exit of the pump, Pa; p - pressure at the entrance to the nozzles, Pa; ρ_y - fertilizer density, kg/m^3; v - speed at the entrance to the nozzles, m/s; v_n - speed at the exit from the pump, m/s; θ - dynamic loss factor; q - coefficient, taking into account local resistance; d_n - total length of pores, m; l_n - length of sprayed fertilizer, m.

After the appropriate transformations, we will get the value of the range of the spray:

$$l_п = \frac{10^{-5}\rho_у \cdot d_п\left(v^2 - v_н^2(1 + \vartheta)\right) - 2g \cdot d_п(p_н - p)}{10^{-5}\rho_у \cdot \lambda \cdot v_н^2} \quad (5)$$

Knowing the amount of pore space for the relevant category of soils, it is necessary to determine the required range of sprayed fertilizers from one position. According to agricultural requirements, organic fertilizers delivered to the soil should be evenly distributed in the space between vertical racks, oversaturated fertilizers and insufficiently fertilized areas should be avoided. To ensure that you've set the indicators, you should choose hydraulic equipment with the required characteristics.

3. Results and Discussion

According to the results of tests, qualitative indicators of the soil structure were obtained after the passage of the machine (Figure 2).

a) b) c)

Figure 2. Loosening by passive working bodies of different types: a) V-shaped; b) volumetric deep loader; c) three-post

Before deep loosening, the porosity coefficient in the studied soils was within the range of 0.4-0.5. After passing the machine, the loosening coefficient was 1.27 – 1.38 on soils of categories III-IV, the volume of pore space increased to 60-75%, which indicates the suitability of the resulting soil for further agricultural development (Figure 3).

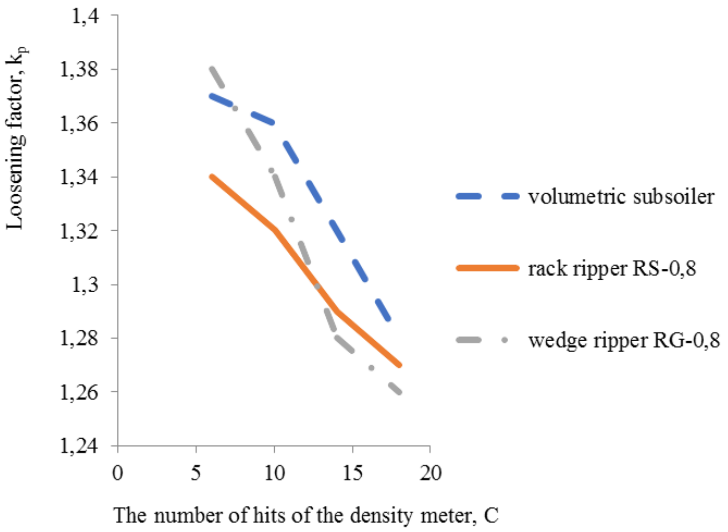


Figure 3. The dependence of the loosening factor on ground density when different types of passive rippers work

In the course of the research, traction resistances were identified. The results showed that working equipment can be aggregated with tractors of traction class 2... 3 (Table 1).

Table 1. Pulling resistance of the voluminous deep-thhitel

Soil type	Resistance to the ground detachment, kN	Resistance to the ground acceleration, kN	Resistance to soil friction on the surface of the lemech and rack, kN	Total traction resistance, kN
sandy loam	1,75	0,59	0,51	2,85
loam	6,42	0,62	0,54	7,58
clay	9,69	0,65	0,57	10,91

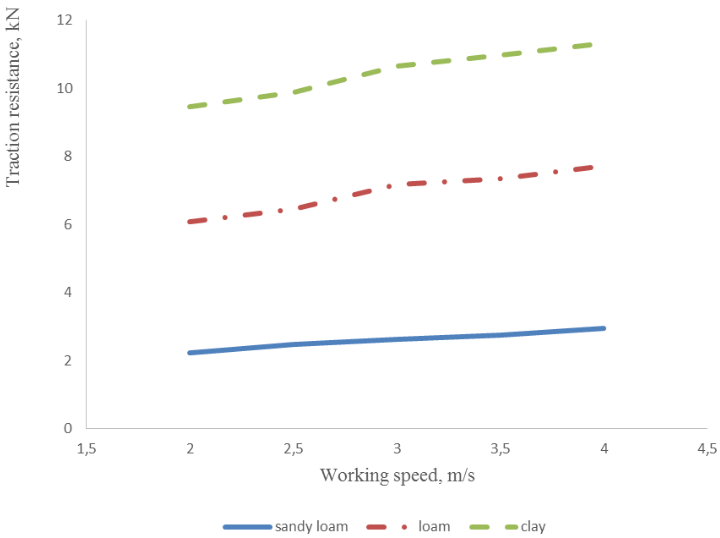


Figure 4. Traction resistance of the volumetric ripper

The experiment showed that the installation of additional equipment for the introduction of liquid organic fertilizers will not lead to a significant increase in traction resistance, the discrepancy with the data of theoretical studies did not exceed 6.2 - 7.6% on the soils of the study categories. The working speed of the machine was 2... 4 m/s depending on the soil category (Figure 4).
Liquid organic fertilizers were added to the soil at the rate of 2... 3 l/m^2, which did not exceed 5% of the formed additional pore space.

Table 2. Length sprayed fertilizer at the passage of the ripper - fertilizer from one rack

Porosity ratio	0,55	0,65	0,75
sandy loam	1.86m	1,94 m	1,97 m
loam	1.65m	1.74m	1.78m
clay	1.56m	1.62m	1,64 m

Thus, fertilizers will be appliedon the entire cultivated surface on the studied soils to the depth of the root-and-a collectable layer.

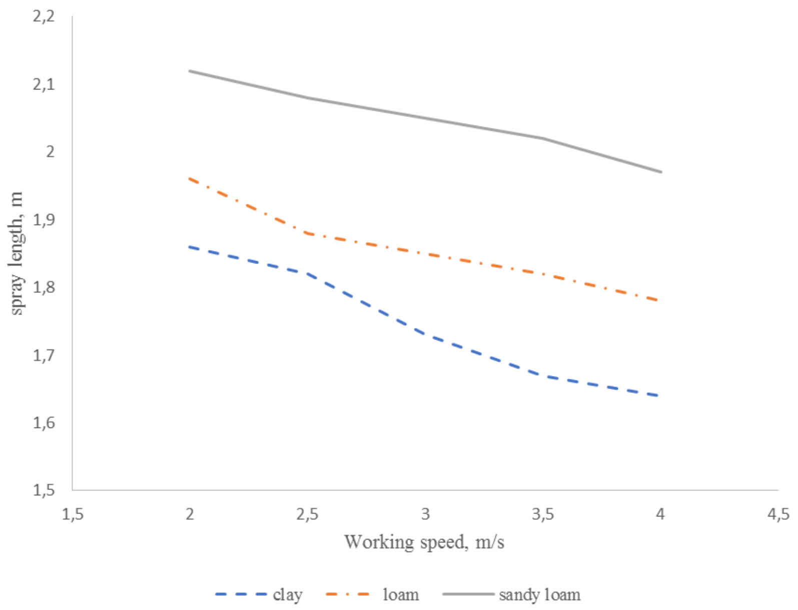


Figure 5. The length was sprayed from one position of the ripper-fertilizer.

As tests have shown, in the studied soil conditions, after the passage of the cultivator - the volumetric fertilizer, a qualitative improvement of the soil structure is observed, the volume of the pore space increased to 0.6 - 0.75, which indicates the suitability for agricultural development. The completeness of application is also ensured at these speed modes; therefore, it can be assumed that the conducted ameliorative measures will not disturb the water-air balance of the soil, having significantly improved it, the expected increase in yield can be up to 15 ... 20%.

4. Conclusions

Deep loosening is carrying to increase the water permeability of mineral soils of groups III-IV, in order to improve the quality of the structure and create favorable conditions for the development of plants. The use of bulk passive rippers of the passive type will allow achieving a uniform fine-lump structure without mixing the upper fertile and lower underlying layers of soil. To increase fertility, you should add liquid organic fertilizers to the increased volume of pores because of loosening. The developed design of the Ripper-fertilizer will allow you to combine deep loosening and application of liquid organic fertilizers, which will reduce the number of passes of the machine, increase productivity, and reduce energy consumption.

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