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DETERMINATION OF THE NECESSARY VERTICAL LOAD ON THE LITTLE LEVELER

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Abstract

The article presents theoretical calculations for determining the required vertical load on the leveler. It has been established that the change in the specific load on the leveler depends on the total depth of immersion of the leveler in the soil at different unit speeds. To determine the required vertical load on the leveler, a mathematical calculation method was used. As a result, it was obtained that to ensure the required depth of submersion of the leveler into the soil (1.7-3.1 cm), which ensures the required soil density (1.2-1.3 g/cm^3) and leveling of the field surface, the specific load on the leveler should be within the range of 2.459 - 2.822 kN/m.

Keywords

soil, density, vertical load, field surfaces, leveler, specific load, immersion depth, movement speed, normal reaction.

Introduction. The field prepared for sowing should have a level surface, a fine-grained layer of the plowing layer, especially the upper horizon (0...10 cm), sufficient moisture, and be free from weeds and plant residues.

In the system of measures aimed at obtaining high yields of cotton and other agricultural crops, one of the important places is occupied by pre-sowing soil cultivation, including loosening and leveling the field surface, as well as compacting the soil to optimal values.

With high-quality implementation of these operations, favorable conditions are created for the emergence of closely spaced seedlings, growth, and development of plants during the growing season, which positively affects the yield of the cultivated crops. In addition, pre-sowing leveling creates the necessary conditions that ensure the high-quality execution of subsequent technological operations at increased speeds [1, 2].

Materials and methods. The main parameters of the ridger-leveler, which significantly influence the qualitative and energy indicators of its operation, are the specific vertical load *(Q_y)*, i.e., the vertical load per unit width of the tool's grip.

To determine this parameter, let's consider the interaction of the leveler working element with the soil surface.

Let the working element move along the surface of the field, immersing itself in the soil to a depth of H_p (fig. 1).

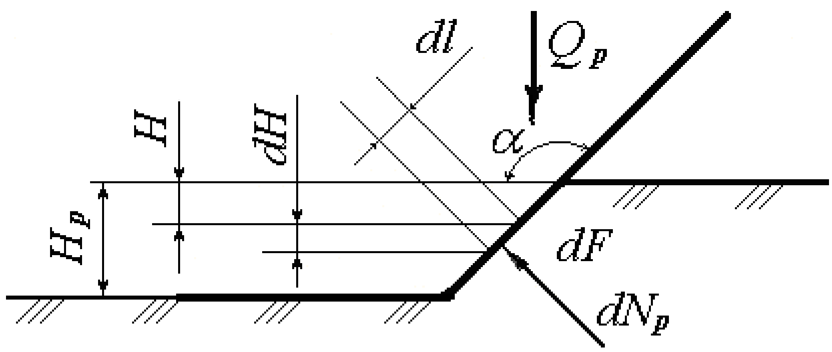

Fig.1. Diagram for determining the magnitude of the vertical load on leveler

Let's determine the vertical load Q_p required to immerse the working body in the soil to a depth of H_p. For this, we will allocate an elementary area $ds=Bdl$ on the working surface of the working body, which is in contact with the soil (where B is the working width of the leveler; dl is the elementary segment allocated on the surface of the working body).

Elementary normal reaction acting on area ds

$$dN_p = qBdl \quad , \qquad (1)$$

where: q - crushing stress (specific pressure) of the soil.

Taking $q = q_0 H$ (where q_0 is the volumetric crushing coefficient of the soil) and considering that $dl = dH/\sin\alpha$, we obtain

$$dN_p = q_0 BH \frac{dH}{\sin\alpha} . \qquad (2)$$

Integrating this expression within the range from 0 to H gives the following expression

$$N_p = q_0 B \frac{H_p^2}{2\sin\alpha}. \qquad (3)$$

Let's determine the friction force arising from this force.

$$F_p = fN = fq_0 B \frac{H_p^2}{2\sin\alpha}, \qquad (4)$$

where f - is the coefficient of soil friction with metal.

Projecting the forces N_p and F_p onto the vertical axis and considering that $f = tg\varphi$ (where φ - is the angle of soil friction with the metal), we obtain the following formula for determining the vertical load on the working body of the leveler.

$$Q_p = N_p \frac{\cos[\pi - (\alpha + \varphi)]}{\cos\varphi}. \qquad (5)$$

or taking into account expression (3)

$$Q_p = q_0 B H_p^2 \frac{\cos[\pi - (\alpha + \varphi)]}{2\sin\alpha\cos\varphi}. \qquad (6)$$

The developed harrow-leveler has three leveling and compacting working bodies arranged stepwise. Therefore

$$Q_{общ.} = Q_1 + Q_2 + \ldots + Q_n, \qquad (7)$$

where: Q_{total} - total vertical load on the leveler;

$Q_1, Q_2, \ldots, Q_n$ - vertical loads, respectively, on the first and subsequent working bodies.

The vertical load on the first and subsequent working bodies according to (6) can be determined by the formulas

$$Q_1 = q_0 B H_1^2 \frac{\cos[\pi - (\alpha + \varphi)]}{2\sin\alpha\cos\varphi}; \qquad (8)$$

$$Q_2 = q_0 B\left(2H_1H_2 + H_2^2\right)\frac{\cos[\pi - (\alpha + \varphi)]}{2\sin\alpha\cos\varphi}; \qquad (9)$$

$$Q_n = q_0 B\left[2\left(H_1H_n + H_2H_n + \ldots + H_{n-1}H_n\right) + H_n^2\right]\frac{\cos[\pi - (\alpha + \varphi)]}{2\sin\alpha\cos\varphi}, \qquad (10)$$

where H_1 , H_2, … , H_{n-1} , H_n – soil immersion depth, respectively, of the first, second,... , pre-final and final working bodies of the leveler.

Substituting the values of Q_1, Q_2, … и Q_n into (7) we obtain

$$Q_{общ.} = q_0 B\Big[\, 2\left(H_1H_2 + \ldots + H_1H_n + H_2H_3 + \ldots + H_2H_n + \ldots + H_{n-1}H_n\right) + \\ + H_1^2 + H_2^2 + \ldots + H_n^2 \,\Big] \frac{\cos[\pi - (\alpha + \varphi)]}{2\sin\alpha\cos\varphi}. \qquad (11)$$

From the mathematics course [3], it is known that

$$2\left(H_1H_2 + \ldots + H_1H_n + H_2H_3 + \ldots + H_2H_n + \ldots + H_{n-1}H_n\right) + \\ + H_1^2 + H_2^2 + \ldots. + H_n^2 = H_0^2, \qquad (12)$$

where: H_o - total depth of the leveler's immersion in the soil.

Taking into account (12) the expression (11) has the following form

$$Q_{общ} = q_0 B H_o^2 \frac{\cos[\pi - (\alpha + \varphi)]}{2\sin\alpha\cos\varphi}. \qquad (13)$$

Dividing both sides of this expression by B, we obtain the specific load on the leveler.

$$Q_y = \frac{Q}{B} = q_0 H_0^2 \frac{\cos[\pi - (\alpha - \varphi)]}{2\sin\alpha\cos\varphi}. \qquad (14)$$

As is known [4, 5], the value of q_0 depends on the speed of movement, i.e.

$$q_0 = q_0^1(\kappa_n V^2 + d)\ , \qquad (15)$$

where q_0^1 – is the volumetric crushing coefficient of the soil at a speed movement 1.1 m/s;

κ_n – proportionality coefficient;

d – dimensionless coefficient.

From (15) it follows that with an increase in the speed of movement, the volumetric crushing coefficient of the soil increases in a parabolic dependence.

Taking into account (15) the expression (14) has the following form

$$Q_y = q_0^1(\kappa_n V^2 + d) H_0^2 \frac{\cos[\pi - (\alpha + \varphi)]}{2\sin\alpha\cos\varphi}. \qquad (16)$$

According to agrotechnical requirements, the density of the arable soil layer prepared for cotton sowing should be within 1.2-1.3 g/cm^3. Based on this and knowing the soil density before the leveler pass, it is possible to determine the permissible amount of its immersion in the soil [6, 7], i.e.

$$H_0 = H_1\left(1-\frac{\rho_0}{\rho}\right), \qquad (17)$$

where: ρ - density of the loosened soil layer, g/cm³;

ρ_0 – density of the loosened soil layer before the passage of the working body, g/cm3;

Taking into account (17), the expression (16) for determining the specific load on the leveler finally has the following form:

$$Q_y = q_0^1(\kappa_n V^2 + d)\left[H_1(1-\frac{\rho_0}{\rho})\right]^2 \frac{\cos[\pi-(\alpha+\varphi)]}{2\sin\alpha\cos\varphi}. \qquad (18)$$

Figure 2 shows graphs of changes Q_y depending on H_0 and V at q_0^1 = 5 H/cm³, κ_n=0,08 c²/m² and d = 0,9, α = 145° and φ = 30°, constructed using formula (16).

From the data presented in Figure 2, it follows that with an increase in H_0 and V, the vertical load on the leveler should be increased.

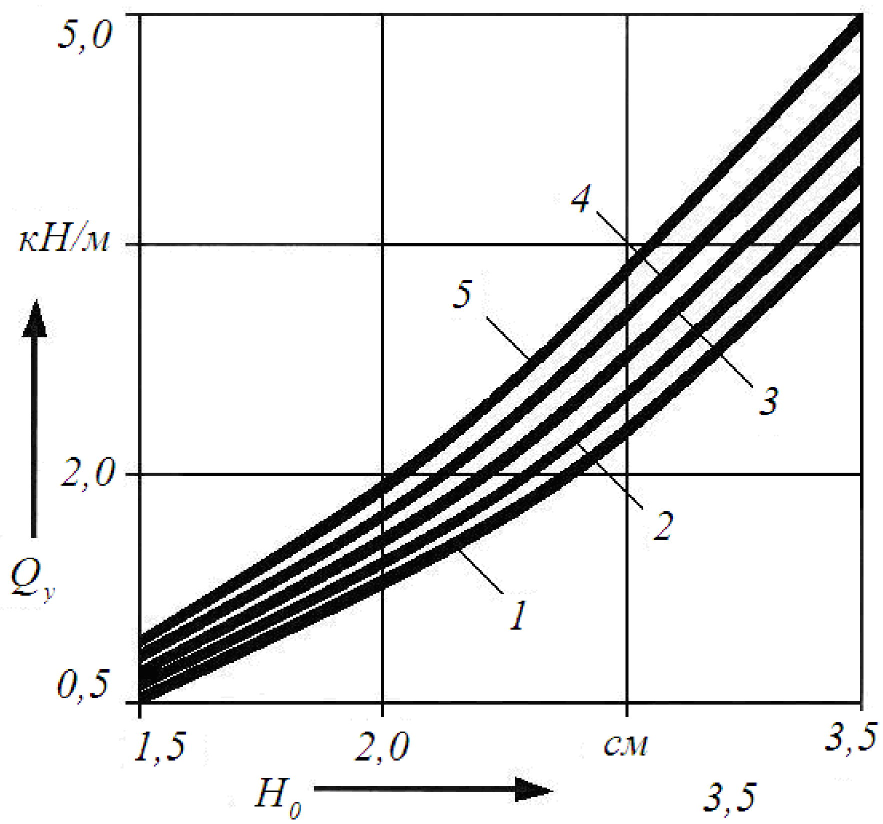

Fig.2. Change in Q_y depending on H_0 at different values of V.
1,2,3,4 and 5 - respectively at V = 1.50; 1.75; 2.00; 2.25 and 2.50 m/s.

Conclusion. Calculations (taking H_1 = 20 cm, ρ_0 = 1,1 g/cm³ and ρ = 1,2-1,3 g/cm³), carried out according to formula (18), also established that when operating at a speed of 2.0-2.5 m/s, to ensure the required depth of submersion of the leveler into the soil (1.7-3.1 cm), which ensures the required soil density (1.2-1.3 g/cm^3) and leveling of the field surface, the specific load on the leveler should be within the range of 2.459 - 2.822 kN/m.

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