

Machine for Seedbed Preparation for Sorghum Sowing In Burundi

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Abstract: The analysis of sorghum cultivation technology in Burundi has shown a low level of mechanization of the soil preparation process due, first of all, to small forms of farming (up to 0.5 ha per family farm). The conducted theoretical studies allow us to justify the expediency of reducing labor costs for the most labor-intensive operations through the use of small-scale mechanization. The aggregate considered in the article is a machine for performing combined operations of soil preparation. The development of the machine was accompanied by the analysis of drawbacks of existing combined tillage machines taking into account small areas of arable land. The results of calculations of traction resistance of the combined tillage machine on the basis of a motorized block are given. The obtained mathematical dependence of the soil cultivation process and its graphical interpretation show the dependence of energy consumption on various factors.

1 INTRODUCTION

The Republic of Burundi is a small country located in East Africa with a high population density (more than 300 people per square kilometer). The most common type of activity is agriculture, which employs more than 80% of the country's population. At the same time, the development of this sector is at a low level due to the significant use of manual labor. This factor may be the result of small farms (on average up to 0.5 hectares of agricultural land per family farm), which does not make it unprofitable to purchase and use expensive agricultural machinery and power tools.

Burundi's climatic conditions determine the main direction of agricultural activity. The most common export crops include tea, coffee, and cotton. Most of the food crops are beans, rice, potatoes, maize, and bananas. One of the first cereal crops to be cultivated in Burundi was sorghum, a crop used both for human nutrition and animal feed (Khavyarimana, Tarasenko, Karpenko, Drobot, 2023).

Due to the peculiarities of its root system, sorghum is a drought-resistant crop, uses nutrients

from the soil rationally, but requires a well-tilled seedbed.

Sorghum is the fifth largest crop in the world, behind maize, rice, wheat and barley.

As with other crops, high yields in sorghum cultivation depend on site selection and the preceding crop. Rational system of soil tillage, including the technology of preservation and accumulation of moisture in the soil, optimal timing of its implementation can not but affect the yield of the crop under consideration.

Any soil tillage technology is based on the primary requirements that reflect the optimal parameters of thermal and water-air regimes, provide a reduction in the risk of disease infection of the seed layer, destruction of weed vegetation (Drobot, Brusentsov, 2021).

The introduction of modern technologies provides for the use of various kinds of technical means. To reduce the negative impact of their drivers on the soil, it is proposed to reduce the number of passes of machinery on the sowing area through the use of combined aggregates that allow combining several

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operations in one pass of the aggregate (Tarasenko, Orlenko, Dmitriev, Khavyarimana, 2006).

Taking into account the low level of economy we propose the use of low-powered power means like motor-blocks, thus allowing to mechanize agricultural processes and reduce the use of manual labor.

According to the technology of soil treatment in sorghum cultivation in Burundi after harvesting, the complex includes milling operations and additional crumbling of the layer and crushing of the root part of weed organics by means of disk working tools (Tarasenko, Khav'yarimana, Drobot, Rudnev, 2023).

2 RESEARCH METHODOLOGY

The proposed unit for soil preparation (Figure 1) for sorghum sowing in Burundi includes a power sub-motor frame with an engine from a motorcycle Voskhod-3M, ignition system from a scooter Vyatka, fuel tank, forced cooling system fan, a rod made of steel wire to shift gears, the gear lever of the gearbox of the motorcycle engine, muffler, transmission, working shaft, steering wheel with clutch lever and throttle control handle, bracket for connection with a vehicle, wheels, operator's seat, milling working bodies (Tarasenko, Niyomuvunyi, Drobot, Rudnev, Blinova, 2023), whereby according to the utility model, as a vehicle is used a trailer (Figure 2) equipped with wheels with the ability to adjust their height of installation depending on the depth of soil cultivation and mounted behind it removable working bodies in the form of a disk battery. Detachable wheels for power tillers or detachable milling attachments are mounted on the working shaft of the power unit.

The essence of the proposed aggregate for soil preparation for sorghum sowing in Burundi is presented in Figures 1 - 5.

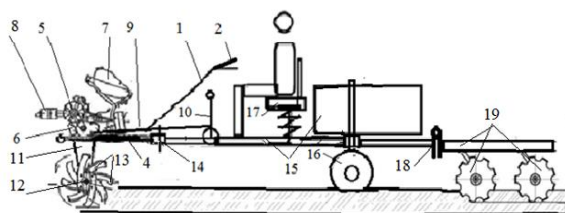


Figure 1: Side view of machine with cutter bar and disk battery.

The machine for soil preparation for sorghum planting in Burundi, includes a power unit containing a steering wheel 1 with a clutch lever 2 and a handle

3 for throttle control and a sub-motor frame 4. Submotor frame 4 is equipped with engine 5 from motorcycle Voskhod-3M with gearbox 6. Engine 5 is equipped with ignition system from scooter Vyatka, forced cooling fan, fuel tank 7, muffler 8. The gearshift box 6 of the motorcycle engine 5 is connected by a rod 9 made of steel wire with a lever 10 to change gears, and through the transmission 11 is connected to the working shaft 12, on which are mounted removable milling work tools 13. The power plant through the sub-motor frame 4 by means of a bracket 14 is coupled with a vehicle, as which is used a trailer 15 with wheels 16 and spring-loaded operator's seat 17. The wheels 16 of the trailer have the possibility of adjusting their mounting height depending on the depth of tillage. At the rear, the trailer 15 is equipped with brackets 18, with the help of which removable disk batteries 19 are attached or hitched (shown conventionally in the diagrams of block attachment). At the same time, removable wheels for power tillers 20 or removable milling working tools 13 are mounted on the working shaft 12 of the power unit.

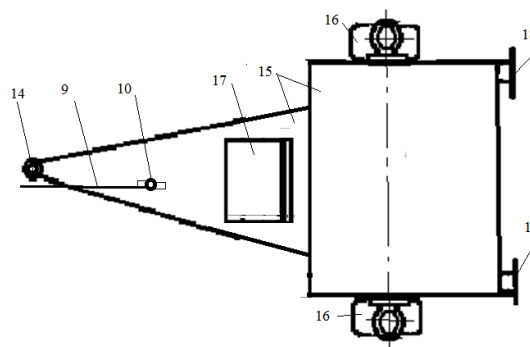


Figure 2: Trailer.

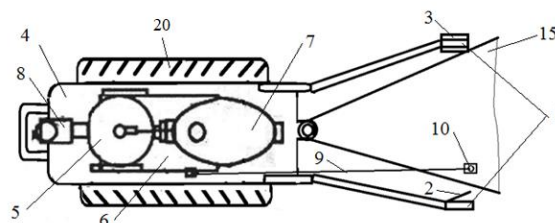


Figure 3: Top view of power unit with wheels for power tillers.

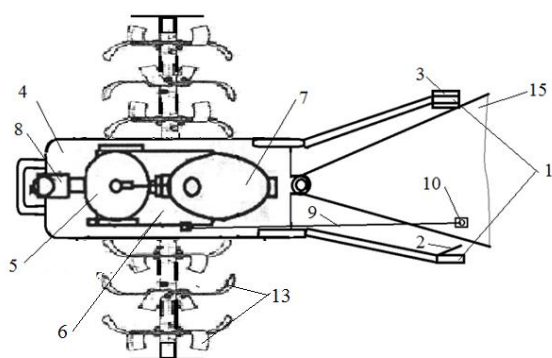


Figure 4: Top view of power unit with milling machine.

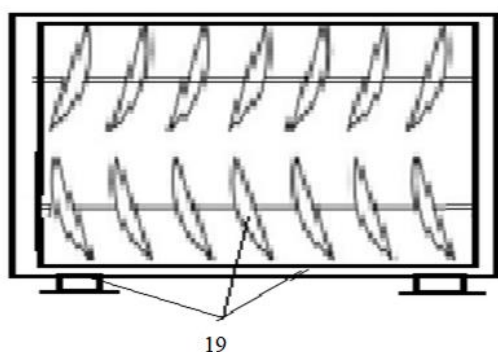


Figure 5: Top view of the disk battery.

The machine operation consists of the following operations.

After harvesting the preceding crops, milling and cultivation with disk cutters is performed. For this purpose the detachable wheels for power tillers on the machine are removed, and instead of them milling working tools are mounted. Then the trailer wheels are fixed at a height according to the depth of processing with disks attached to the brackets of the disk battery. Then the clutch lever is squeezed out on the handlebar and fixed in this position by a latch, the motorcycle engine placed on the under-motor frame with ignition system from Vyatka scooter, with a fan of forced cooling system is started. The engine is checked at idle speed. Then turn on the first gear and removing the latch unlock the clutch lever, after which from the gearbox through the transmission is transferred rotation to the working shaft with fixed on it soil-turning milling cutters, by means of which the

soil is milled, providing intensive loosening and subsequent mixing of the fertile layer. When rotating, the cutters enable the machine to move together with the trailer and the disk unit. batteries. The disks additionally cut and shred the root part of weed organics (Primakov, Nikolenko, 2022; Nikolenko, Drobot, 2023).

The use of this aggregate for soil preparation for sorghum sowing in the conditions of agricultural production in Burundi, will provide the expansion of functional capabilities and improve the quality of soil tillage.

In the practice of using feather working tools, milling cutters with horizontal axis of rotation are the most widespread. The possibility of rotation of working bodies from the drive mechanism, gives us the right to consider them as active rotary working bodies.

In our proposed unit, cutting of soil chips by the cutter blade starts from the field surface, which corresponds to the direct rotation of the rotor.

Taking into account the level of development and socio-economic condition of Burundi, an important issue in the cultivation of any crop is the issue of energy intensity. For a more rational use of rotary working tools, it is necessary to identify analytical dependencies of the required power, analyzing the parameters affecting the energy intensity of processes.

3 RESULTS OF THE STUDY

According to the researches conducted by Dr. F.M. Kanaryov, the power of milling machine can be determined by the expression:

$$N = N_n + N_p + N_o, \quad (1)$$

Where N_n – power spent on overcoming constant resistances;

N_p – power used in the process of cutting off soil chips;

N_o – power spent on throwing away soil particles.

According to the research conducted, a formula for determining the power required by the cutter was derived:

$$N = N_n + \frac{v_n \cdot l_p \cdot n \cdot [k_n \cdot (\delta_c + l_{k,n}) + k_o \cdot S_{k,c}]}{s} + 0,5 \cdot \rho_n \cdot B \cdot h \cdot K_{om} \cdot v_n^3 (\lambda - 1)^2, \quad (2)$$

Where N_n – power spent on overcoming constant resistances, as which we take power losses in the

drive system of the rotating mechanism ($N_n = 3,01 \text{ кВт}$);

v_n – speed of translational motion of the milling machine. It is accepted equal from 0.83 to 1.4 m/s (3...5km/h), which is conditioned by physiological features of the operator of manual motorized equipment;

l_p – length of the cutting arc, depending on the kinematic parameters of the cutter, the angle of cutting start and the height of the ridge in the transverse plane. For the milling cutters with saber-shaped blades, we assume the following ($l_p = 0,18$ m);

n – number of milling cutters in standard version ($n=8$);

k_{π} – soil resistivity, $k_{\pi} = 1,1 \frac{\text{кН}}{\text{м}}$;

δ_c – soil chip thickness ($\delta_c = 0,06$ m);

$l_{\kappa,\lambda}$ – blade length of the knife wing ($l_{\kappa,\lambda} = 0,06 \dots 0,07$ m);

k_o – specific resistance of soil to deformation ($k_o = 120$ кПа);

$S_{\kappa,c}$ – projection of the knife blade on the frontal plane ($S_{\kappa,c} = 0,001183$ m²);

S – the distance traveled by the cutter from the moment the first blade of the cutter disk starts cutting to the moment the second blade starts cutting ($S = 0,08$ m);

p_n – density of the cultivated soil layer ($p_n = 11300$ H/m³);

B – rotor working width ($B = 0,25$ m);

h – working depth (0,06, 0,09, 0,12 m);

k_{om} – soil rejection factor ($k_{om} = 0,7$);

λ – rotor kinematic parameter ($\lambda = 4$).

On the basis of the obtained theoretical dependence of power on the speed of the machine at different depths of cultivation, we construct the graph shown in Figure 6.

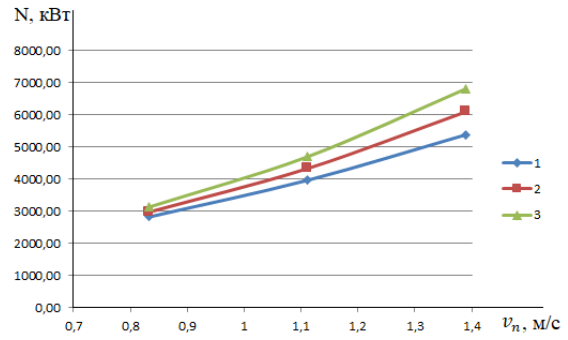


Figure 6: Dependence of power on the speed of machine movement at different working depths: 1 - at a working depth of 0.06 m; 2 - at a working depth of 0.09 m; 3- at a working depth of 0.12 m.

Soil reaction to the machine rotor ($P_{f,N}$) taking into account the total power is determined by the expression:

$$P_{\phi} = \frac{N \cdot S}{v_n \cdot l_p} \quad (3)$$

Dependence of cutter force on machine speed and working depth is shown on the graph (Figure 7).

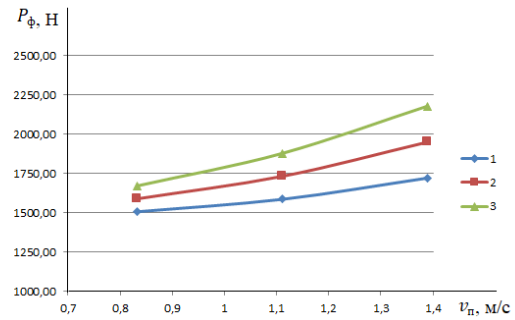


Figure 7: Soil response to the rotor (cutter) of the machine at different speeds and at different tillage depths: 1 - at a tillage depth of 0.06 m; 2 - at a tillage depth of 0.09 m; 3- at a tillage depth of 0.12 m.

For a more detailed representation of the response surface from two factors (speed and depth of machining) we obtained a model with real coefficients (second degree polynomial):

$$P_{\phi} = 2,033 \cdot 10^3 - 339,583 \cdot X_1 - 4,678 \cdot 10^3 \cdot X_2 + 2,442 \cdot 10^3 \cdot X_1 \cdot X_2 + 37,5 \cdot X_1 \cdot X_1 + 2,744 \cdot 10^{-7} \cdot X_2 \cdot X_2, \quad (4)$$

где X_1 – forward speed of milling machine, km/h;

X_2 – working depth, m.

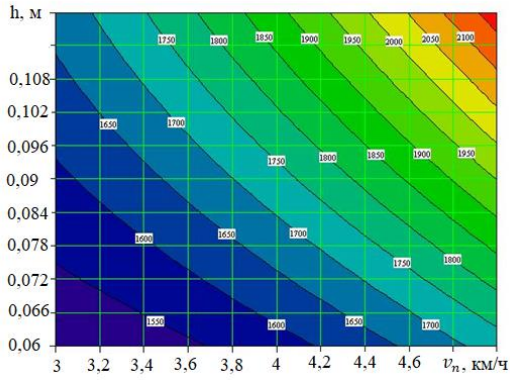


Figure 8: Surface of dependence of soil reaction to the rotor (cutter) of the machine on the speed of movement and depth of cultivation.

Parameters of disk working tools and the soil layer cut off by them have a direct impact on the quality and energy parameters of soil tillage. It is necessary

$$P_d = \lambda \cdot G_M \cdot \frac{\sin \varepsilon_3 \cdot \sin \gamma + f \cdot (\cos^2 \gamma + \cos \varepsilon_3 \cdot \sin^2 \gamma)}{\cos \varepsilon_3 - f \cdot \sin \gamma \cdot \sin \varepsilon_3} + a \cdot b \cdot [k + \varepsilon \cdot v_n^2] + a \cdot b \cdot l \cdot \gamma_{06} \cdot \frac{\sin \beta + f \cdot (\cos \gamma \cdot \text{ctg} \gamma + \sin \gamma \cdot \cos \beta)}{\cos \beta - f \cdot \sin \gamma \cdot \sin \beta} + \frac{a \cdot b \cdot \gamma_{06} \cdot v_n^2 \cdot \sin^2 \gamma \cdot [\sin \beta + f \cdot \sin \gamma \cdot (\text{ctg} \gamma + \cos \beta)]}{g \cdot (\text{ctg} \beta - f \cdot \sin \gamma)} \quad (5)$$

where λ – coefficient, the value of which may not exceed 0,3-0,4;

G_M – disk harrow weight ($G_M = 120$ H);

ε_3 – rear cutting angle ($\varepsilon_3 = 10^\circ - 12^\circ$);

γ – blade bevel angle formed by the blade line with the direction of travel, $\gamma = 4$ hail;

f – coefficient of friction ($f = 0,6$);

a – formation thickness (depth of treatment) ($a = 0,06$ m);

b – layer width ($b = 0,3$ m);

k – coefficient taking into account soil properties (σ – temporary soil tensile strength and φ – friction angle) and geometric shape of the wedge (crumbling angle β); the value of this coefficient should be determined experimentally ($k = 1,9 \dots 2,2$ kH/m);

ε – speed resistance coefficient, depending on soil properties and parameters (geometric shape) of working surfaces of organs ($\varepsilon = 0,05$);

v_n – translational speed (or 0,83 до 1,4 m/s);

l – formation length ($l = 0,45$ m);

γ_{06} – soil volume weight ($\gamma_{06} = 14500$ H/m³);

β – crumbling angle ($\beta = 5$ hail);

g – free fall acceleration ($g = 9,8$ m/s²).

to achieve optimal values of parameters, which will contribute to the reduction of energy consumption to the minimum level (Medovnik, Maslov, Tarasenko, Chebotaryov, Bugayev, Drobot, 2006).

Unfortunately, the mechanics of soil tillage is insufficiently studied, and the significant variation of physical and mechanical properties of soil during tillage prevents the creation of an accurate mathematical model for determining the optimal parameters. It is necessary to resort to a large number of different assumptions (Tarasenko, Tverdokhlebov, Bogatyrev, Medovnik, Gorovoy, Drobot, Poplavkov, Tsybulevsky, 2021).

Analysis of scientific and technical literature allows us to consider the soil reaction to the disk using an analytical expression that establishes the relationship between the horizontal component of the traction resistance of the disk tillage implement and its geometric parameters (Drobot, Tsybulevskiy, 2010):

Soil reaction to the disk implement is determined at different speeds at a constant depth equal to the sorghum sowing depth (0.06 m) according to formula (5). The resulting graph is shown in Figure 10.

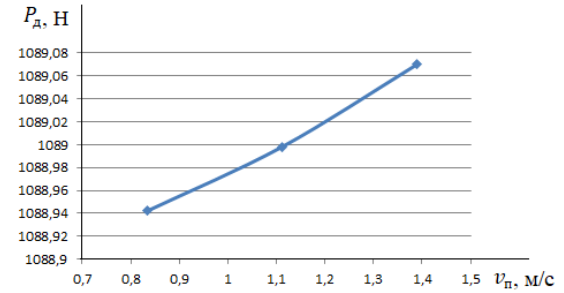


Figure 10: Soil response to disc implements at different travel speeds and constant tillage depths.

Traction resistance of the machine (P) (Nikolenko, 2023) determine by the expression:

$$P = P_\phi + P_d + f \cdot G_a \quad (6)$$

where G_a – unit weight ($G_a = 1670$ H).

The dependence of traction resistance of the machine on the variation factors, taking into account

its weight, is determined by formula 6 and presented in the form of a graph in Figure 11.

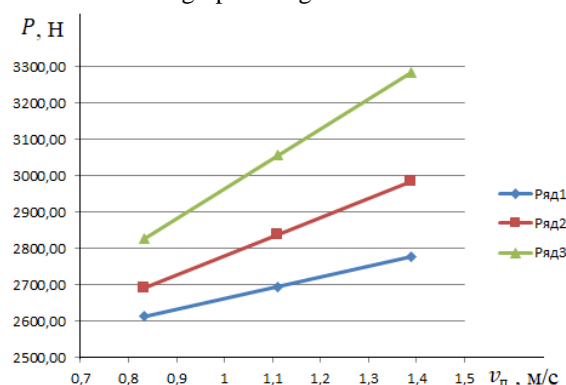


Figure 11: Dependence of traction resistance on the speed of machine movement at different working depths: 1 - at a working depth of 0.06 m; 2 - at a working depth of 0.09 m; 3- at a working depth of 0.12 m.

The response surface of the traction resistance of the machine from the travel speed is considered using a mathematical model (second degree polynomial with real coefficients).

$$P = 3,138 \cdot 10^3 - 338,083 \cdot X_1 - 4,744 \cdot 10^3 \cdot X_2 + 2,442 \cdot 10^3 \cdot X_1 \cdot X_2 + 37,333 \cdot X_1 \cdot X_1 + 370,37 \cdot X_2 \cdot X_2, \quad (7)$$

where X_1 – orward speed of milling machine, km/h;
 X_2 – working depth, m.

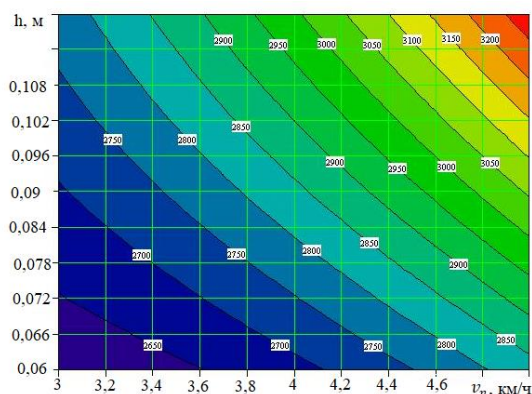


Figure 12: Surface of dependence of machine traction resistance on travel speed and working depth.

4 CONCLUSIONS

According to the received dependencies, on which the graphs are constructed (Figure 8, 12) it is possible to determine the required power of a motorized block on soil cultivation at various variants of a complete set of the unit.

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