

New Combined Unit for Small Mechanization and Investigation of its Parameters Using Similarity and Dimensional Theory

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(Presented by Academy Member Alexander Didebulidze)

The paper deals with the designs of technical means of small mechanization that are used in Georgia, namely agricultural machinery installed on motoblocks, the scale and advantages of their use in comparison with powerful equipment, and on the basis of a patent a completely new combined machine for motoblock is proposed, which is currently in demand in the conditions of development of modern technologies for growing crops on small plots and greenhouse farms. The paper offers a constructive description of the combined unit and the principles of its operation. The theory of similarity and dimension is used, functional connection between the optimization parameters and acting factors are determined. © 2023 Bull. Georg. Natl. Acad. Sci.

agriculture, mechanization, walk-behind tractor, unit, new technologies

Both mobile and small mechanization technical means, moto blocks and devices assembled on them are used to perform the operations necessary for the complex mechanization of maintenance and cultivation of agricultural crops [1, 2]. Their use is particularly effective for regions where agricultural areas are small in contour and located in mountainous conditions. For these regions, proposes a combined resource-saving agricultural aggregate based on moto blocks for furrow forming on soil and mulching is proposed.

The combined aggregate allows loosening soil with powered tillage tools, forming furrow, laying

a drip water system, laying plastic mulch, covering it with soil, and drilling laid plastic mulch with one pass through small energy consumption. The proposed aggregate is a significant innovation in terms of both scientific and practical use, it will complement the untapped market segment in terms of the use of equipment in the agricultural sector, where mobile equipment cannot be used and will be in high demand in small and closed ground (greenhouses), among the producers of agricultural crops, growing vegetables, cucurbits and small-fruit crops, which are considered by the Georgian state a priority in the agricultural sectors.

The highland regions of Georgia are distinguished by such features as the location of agricultural lands on the slopes, fragmented narrow contour plots, mountainous conditions, sloping terrain, high air humidity, solar radiation, duplex soils, and more.

Due to the mentioned circumstances, it is not possible to use mobile and heavy equipment in most of the arable lands, there is no mountainous equipment and therefore, the main works are done by hand and use of technical means of small mechanization.

According to the conducted research, the total volume of plots up to 1 hectare is 12.7% of the total arable land, and the volume of plots from 1 to 5 hectares is 19.3%. Just in these areas the smallholder farmers and peasants produce vegetables, cucurbits, and small-fruit crops, and the above-mentioned smallholder farmers and peasants are the main users of small-scale mechanization equipment.

Basic Part

The machine for laying on the soil of plastic tape for mulching contains a frame, connected with the power tool, on which there are installed in sequence the tools for tillage and profiling of surface of furrows, a roll of plastic mulching tape, and soil fillers. The machine is additionally equipped with a drum with a drip irrigation pipe and a mulch tape

perforator. Also, the drum with a drip irrigation pipe reeled on it is installed on the frame after the tool for profiling of furrow surface, which is a bow-shaped shield, and the soil-cultivating tool is made in the form of a rotary tiller with a horizontal shaft mounted on the front of the frame. Also, the power supply is a moto blocks, while the frame has supporting wheels, with the mulch tape perforator placed on the axle of support wheels and positioned between the mulch tape roll and the soil fillers. (Fig.) shows the principle diagram of the proposed aggregate [3].

The aggregate laying of plastic tape on soil for mulching contains the power tool – motoblocks 1 with drive wheels 2 to which frame 3 is connected. On the front part of frame 3, a soil cultivating tool is mounted, which is made in the form of rotary tiller 5 with horizontal shaft 4. The operator's seat 6 is attached to the upper side of frame 3. On the lower side of frame 3, after the rotary tiller 5, a tool for profiling the furrow surface is attached, which is a bow-shaped shield 7. After the mentioned tool 7 for profiling of furrow surface, a drum 8 with drip watering pipe reeled on it, the roll 9 of the mulching tape, the perforator of the mulching tape 10, and soil fillers 11 are mounted on the frame 3 in sequence. Frame 3 is equipped with support wheels 12. The perforator 10 of the mulching tape 9 is placed on the axle of the support wheels 12 and is located between the roll of mulch tape 9 and soil fillers 11.

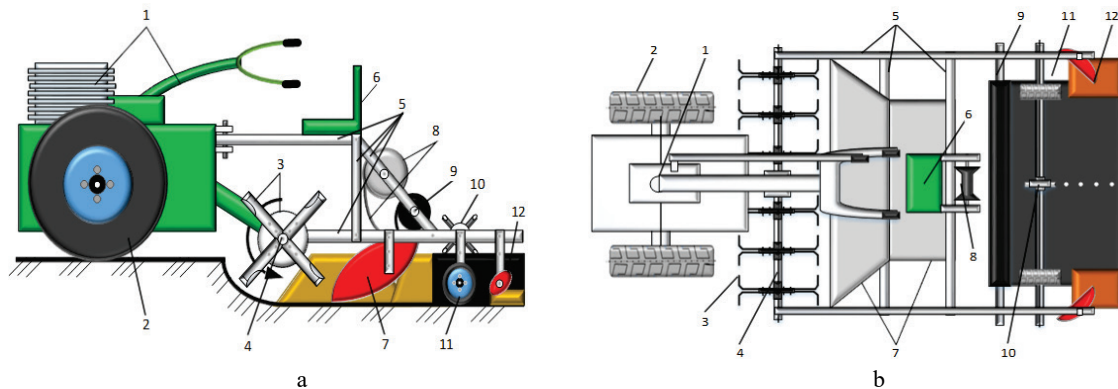


Fig. Innovative combined unit for mulching soil on the basis of moto blocks: a) side view; b) top view.

The aggregate works as follows: after starting the engine of the moto blocks 1, the coupling (not shown in the drawings) of the drive wheels 2 and the rotary tiller 5 is turned on, as a result of which the two-wheel tractor 1 moves forward and the rotary tiller 5 starts working – cutting and loosening the soil layer. The layer of soil cut by the knives of the rotary tiller 5 is thrown back and meets the tool for profiling of furrow surface, which is a bow-shaped shield 7; its shape gives the soil layer cut by the rotary tiller 5 a certain direction and forms a furrow with a smooth surface. At the center of the profiles made by the rotary tiller 5 and the bow-shaped shield 7, a flexible drip irrigation pipe reeled on the drum is unreel, then the pipe is covered with plastic mulch tape 9 from the roll 9 for mulching. The support wheels 12 move on the edges of the mulch tape 9, and the perforator 10, rotating under the action of the axle of support wheels, in the same zone makes holes for planting of saplings, and the edges of the mulch tape 9 are covered by loose soil using soil fillers 11.

The proposed aggregate for laying on the soil of mulching plastic tape is of simple construction, is characterized by low energy consumption, and allows to loosen a soil through a single pass of the moto blocks, to make furrows, unreel flexible drip irrigation pipe, to lay plastic mulch tape on furrows, to make pits for planting of saplings and cover the edges of the mulch tape with soil [3,4].

The experimental unit will be mounted on a high clearance 7 hp two-wheel tractor. This field

will be tested on annual crops in 2023 in the Scientific-Research Center for Agriculture of Georgia [5].

Results of Theoretical Research

Theoretical studies have been carried out, using the theory of similarity and dimension. Present them.

Functional connection between optimization parameter and the factors affecting on it have the following face:

$$N = f(V, \rho, P, R, h, b).$$

This dependence can be expressed as similarity criteria. Their number is determined by π – theorem of dimensional analysis.

$$r = N - n,$$

N – number of values, n – number of main factors. These factors should be selected as follows, to determine the exponents of their dimensions differed from zero. subject to these requirements, as the main factors we accept – the speed of movement of the tractor – V , undercut resistance – P and stem density – ρ .

The dimensions of these quantities can be represented as follows:

$$[V] = LM^0T^{-1},$$

$$[P] = LMT^{-2},$$

$$[\rho] = L^{-3}MT^0.$$

The determinant of the exponents of these quantities is equal to:

Table. The list of factors affecting the power of the motobloks

№	The name of the optimization parameter and factors	Designation	The dimension in the system Si	Dimension, expressions by the symbols of quantities
1	Power	N	Watt	L^2MT^{-3}
2	the speed of movement of the moto blocks	V	m/s	LT^{-1}
3	undercut resistance	P	Newton	LMT^{-2}
4	soil density	ρ	kg/m ³	ML^{-3}
5	radius of trimming machine	R	m	L
6	cutting height	h	m	L
7	cutting width	b	m	L

$$\Delta = \begin{vmatrix} 1 & 0 & -1 \\ 1 & 1 & -2 \\ -3 & 1 & 0 \end{vmatrix} = -2, \neq 0.$$

This means that the main factors are chosen correctly.

Number of similarity criteria:

$$r = N - n = 7 - 3 = 4.$$

It is necessary to obtain characteristic similarity criteria:

$$\pi = NV^\alpha \rho^\beta P^\gamma = 1,$$

$$\pi_1 = RV^{\alpha_1} \rho^{\beta_1} P^{\gamma_1} = 1,$$

$$\pi_2 = hV^{\alpha_2} \rho^{\beta_2} P^{\gamma_2} = 1,$$

$$\pi_3 = bV^{\alpha_3} \rho^{\beta_3} P^{\gamma_3} = 1,$$

where $\alpha_i, \beta_i, \gamma_i$ – Unknown features.

To π_1 – similarity criteria have become dimensionless, the exponents should be as follows, to replace each variable with the appropriate combination M, L, T in the resulting expressions, the exponent of the basic dimension was equal to zero [6].

With this in mind, it is possible to obtain a defined similarity criterion:

$$NV^\alpha \rho^\beta P^\gamma = L^2 M T^{-3} L^\alpha T^{-\alpha} L^{-3\beta} M^\beta L^\gamma M^\gamma T^{-2\gamma} = L^0 M^0 T^0 = 1.$$

We obtain the following linear equations:

$$2 + \alpha - 3\beta + \gamma = 0,$$

$$1 + \beta + \gamma = 0,$$

$$-3 - \alpha - 2\gamma = 0.$$

The solution of these equations gives:

$$\alpha = -1; \beta = -2; \gamma = -1.$$

Accordingly, the defined criterion has the form:

$$\pi = \frac{N}{PV}$$

analogically, we obtain the defining similarity criteria:

$$\pi_1 = RV \sqrt{\frac{P}{\rho}}; \quad \pi_2 = hV \sqrt{\frac{P}{\rho}}; \quad \pi_3 = bV \sqrt{\frac{P}{\rho}};$$

physical meaning of the obtained criteria following:

$$\frac{N}{PV}$$

quality criterion dimensionless engine power. the rest are technological criteria, similarity:

$$RV \sqrt{\frac{P}{\rho}} - \text{defining criterion, radius of trimming}$$

machine;

$$hV \sqrt{\frac{P}{\rho}} - \text{defining criterion, cutting height};$$

$$bV \sqrt{\frac{P}{\rho}} - \text{defining criterion, cutting width.}$$

After field testing of this equipment, the data will be processed to improve the reliability of resource-saving technologies using the theory of similarity and dimensions. Primary reporting features are accepted.

Conclusions

The proposed combined unit, allowing from one pass: loosen the soil, form a furrow, lay a drip water supply system, cover the furrow plastic mulch, cover the edges of the plastic mulch with earth and create holes for planting plants. In essence, the proposed unit is a unit of minimal tillage.

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მექანიკა

მცირე მექანიზაციისათვის საჭირო ახალი კომბინირებული აგრეგატი და მისი პარამეტრების გამოკვლევა მსგავსობისა და განზომილებათა თეორიის გამოყენებით

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ნაშრომში განხილულია საქართველოში გამოყენებული მცირე მექანიზაციის ტექნიკური საშუალებების კონსტრუქციები, კერძოდ, მოტობლოკზე დამონტაჟებული სასოფლო-სამეურნეო ტექნიკა, მათი გამოყენების მასშტაბები და უპირატესობები მძლავრ ტექნიკასთან. შემოთავაზებულია სრულიად ახალი კომბინირებული მანქანა მოტობლოკისათვის, რომელიც ამჟამად მოთხოვნადია ბაზარზე თანამედროვე ტექნოლოგიების გამოყენებით ერთწლიანი თუ მრავალწლიანი კულტურების წარმოებისთვის, კერძოდ, მცირე ნაკვეთებსა და სასათბურე მეურნეობებზე. ნაშრომში მოცემულია შემოთავაზებული კომბინირებული ექსპერიმენტული აგრეგატის აღწერა და მისი მუშაობის პრინციპები, აგრეთვე ჩატარებულია თეორიული კვლევა მსგავსობისა და განზომილებათა თეორიის გამოყენებით.

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