E3S Web of Conferences **377**, 03002 (2023) https://doi.org/10.1051/e3sconf/202337703002
ICECAE 2022

Study on the selection of the type and parameters of moldboard plow for combined tillage system

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Abstract. This article highlights information on the development of new techniques for preparing the planting area of nurseries for growing seedlings of ornamental trees and rare flowers. In forestry, the use of modern energy-saving agricultural machinery to create optimal conditions for plant growth allows for high volumes of product with minimal labor and material costs. Agricultural machines used today do not fully meet the agrotechnical requirements of technological operations. Therefore, it became necessary to improve the design of the combined tillage used, which in one pass carry out various work on preparing the soil for sowing, and for this, first of all, it is necessary to improve their working bodies that will produce a good air-water soil exchange. In the proposed technology, the furrow former of the complex tillage system reduces the accumulation of soil clods under the working body, forming optimal furrows for planting ornamental trees and seedlings of rare flowers. And since a complex operation is carried out in one run, it reduces the other cost. A plow with two moldboard bodies, of a combined tillage system, must comply with the requirements for use, and at the same time, the height of the moldboard plow opening furrows must be at least 20.5 cm, opening angle of the share wings is 60-65º, the angle of entry into the soil is 35-40º, the angle of the side cut of the wings of the working body is 37-40º, the width of the share wings is not less than 41 cm, the body length of plow must be not less than 78 cm.

1. Introduction

The basis of the technical support of soil cultivation should be an effective system of machine technologies that prevent soil degradation as a result of overconsolidation by movers, excessive spraying and violation of the water-air regime of soils [1]. This technological policy requires the introduction of modern highly efficient equipment that meets zonal agrotechnical requirements and increases crop yields at the lowest labor costs [2]. In many developed countries, the manufacture of high-performance combined machines and equipment for tillage in forest plantations has recently assumed a prominent role. Considering that forestry companies manage around 131 million hectares of land annually worldwide to prepare the soil for planting ornamental trees, rare flowers, and medicinal plants [3], the quality of developing productive and energy-saving complex machines and equipment is an important task. In addition, many agricultural machines used today do not fully meet the agrotechnical requirements of technological operations. Thus, much attention has been paid to developing combined tillage to prepare the soil for planting forest plantations [4]. Based on advanced technologies, the development and use of high-performance combined units in Uzbekistan are also given special attention to reducing labor and energy costs when growing ornamental trees, seedlings, and rare flowers in forest nurseries. The use of combined units that implements more than one tillage operation for planting in a single run is of great importance for the preparation of forest plantations [5]. Because when using such aggregates, due to the small number of passes the soil is less compacted, and this creates the basis for good development of the root system of future crops. In addition, the need for various types of agricultural machines and direct operating costs will decrease, and productivity will increase [6, 7].

The technical support of tillage involves solving the following most pressing issues:

– reduction of technogenic load on the soil;
– expansion of families of soil-cultivating working bodies adapted to various soil conditions;
– creation of unified machines with a set of interchangeable working bodies;
- creation and use of tools with combined working bodies in order to effectively use the power of energy-saturated tractors;
– reduction of material consumption and energy consumption.

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Development of the design of tillage machines, optimization of their parameters and modes of operation, providing agrotechnical requirements at the lowest cost, requires system analysis and synthesis for making technical decisions on a given agrotechnological task, which became the goal of the study.

2. Methods

Studies were carried out using standard methods, which determine the size of seeds, seedlings, and the root system length of seedlings prepared for planting in the greenhouse. Methods using physical and mathematical modeling have also been used.

The share and the moldboard are designed concurrently in this investigation, as they were in several other earlier studies. The graphical methods that are the foundation of all plough bottom design methodologies are cumbersome and imprecise. A moldboard plough bottom might be viewed as a wedge-shaped surface according to Goriyachkin theory. Three triangular prisms make up this wedge, which is a trilateral pyramid with one edge perpendicular to the base. The soil is broken up, the furrow-slice is inverted, and the soil is displaced laterally to cover plant residue, respectively, using prisms with angles of α, β and γ.

3. Results

As a result of the analyses and studies, a new technology (Figure 1) for preparing land for growing ornamental trees, rare flowers, and medicinal plants in forest plantations were developed, as well as a combined aggregate for its implementation.

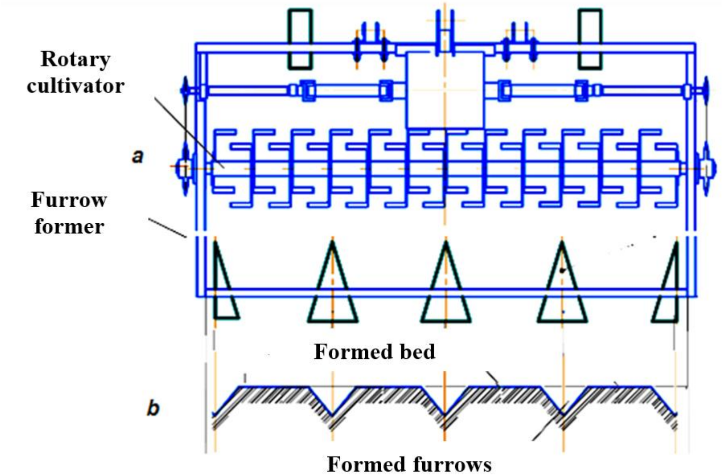


Fig. 1. Scheme of the combined aggregate technological process of preparing forest land for planting: a-technological process of the machine; b- bed and furrow produced by the aggregate

According to the proposed technology, they plow in the fall and loosen in the spring, the soil is cut, pulverized, mixed, and leveled with a (Figure 1, a), irrigation channels are opened and the land is prepared for sowing (Figure 1, b). When compared to currently employed methods, the suggested technology for preparing forest nursery lands for planting reduces labor expenses as well as considerably saves time, fuel, and energy because the area is prepared with no need for other harrowing, planking, and harvesting.

The combined machine consists of a frame, a rotary ripper, a moldboard plow that serves as a furrow former, a protective device also, support beams, support wheels, and a hitch. Once plowed with the help of such an aggregate, the soil is crushed, opening irrigation canals and forming beds [8]. The use of the manufactured combined tillage machine makes it possible to reduce the number of separate inputs of the aggregates for performing the processes carried out during the preparation of the land for sowing, as well as the consumption of fuels and lubricants and operating costs [9, 10, 11].

The results of the studies carried out on the selection of an operating part of a combined unit for forming furrows are presented.

Plowshares and moldboards in the complex unit are used to open the furrow. During operation, a certain height of the ridges, and certain size seedbeds must be formed so that the lower part of the plant can be filled with soil. The landside of the plow moves the soil between the rows to the sides without burying the plants and creates a grid between the rows of a given size. The shares and the landside are used for different purposes, even though they perform the same operation. It has been established that the shape and size of other plowshares that are produced are not able to form beds that meet the relevant agro technical requirements, that is, they do not fully meet modern requirements. In the course of comparing disc and moldboard furrow openers in the studies, it was found that the quality of the beds and furrows, obtained with moldboard furrow openers meets agro technical requirements compared to those obtained with others. When using a spherical disc plow, a large amount of soil is scattered to the bottom of the furrow, which means that they are unsuitable when using irrigation lines.

Based on the results of the study of seeds and development of seedlings of ornamental trees and rare flowers produced by the combined unit, it was determined that the width of the row spacing of the seedlings should be at least 60 cm. The shape of the furrow should be an inverted trapezium or triangle 20 cm wide and at least 15 cm deep.

The impact of water on the soil is seen in a change in its agronomic features, including changes in temperature, air exchange, and microbiological traits in addition to variations in moisture saturation. Crop development and productivity are both significantly increased by irrigation. Hence, the design of the furrow openers with two moldboard bodies was used to determine the appropriate form of the furrow. To create irrigation gates at the required level, their scheme was chosen to develop the design of various forms based on existing units (Figure 2).

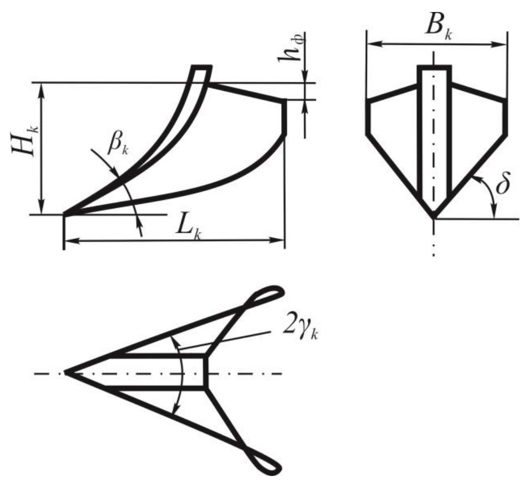


Fig. 2. Parameters of the moldboard plow

Below are the main parameters of the working element that opens furrows (Figure 2):

- the height of the mouldboard $H_к$;
- width of Share wings $B_к$;
- setting angle $\beta_к$;
- mouldboard side angle $\delta_к$;
- body length $L_к$;
- opening angle of the share wings 2 $\gamma_к$;

The height of the working element was determined based on the known value of the depth of its immersion in the ground using the following expression:

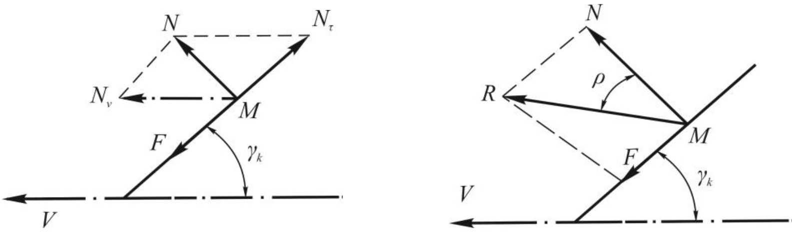
$$H_k \geq (1+K)\frac{h_б}{\sqrt{2}}\left(1+\sqrt{2}\right). \tag{1}$$

Here, K - coefficient of soil accumulation in front of the working element taking into account the value $h_б$, (1) the expression will have the following form:

$$H_k \geq (1+K)\frac{\left(1+\sqrt{2}\right)(b+2a)b}{4\sqrt{2}(b+a)}tg\varphi. \tag{2}$$

Taking as K = 0.5, substituting the above values b, a, and φ into expression (2), we determine that the height of the mouldboard should be at least 20.5 cm.

To determine the opening angle of the wings of the working body, consider the grinding of soil clods in a horizontal plane under the action of its right-wing (Figure 3).



a) b)

Fig. 3. Scheme of influencing forces to crush the soil clods, in a horizontal plane under the action of the right wing of the working body

In the horizontal plane, the normal reaction force N and the friction force F=Ntgρ (where ρ is the friction angle of the soil clods on the wing of the working body) act on the soil clods by the wing of the working element (Figure 3a). Than to divide the force N into components N_V and N_τ, where N_V is directed in the direction of motion, and the force N_τ is directed parallel to the surface of the wing of the working body (Figure 3a)

From the scheme presented in Figure 3 we determine that $N_V = N/\sin\gamma_k$. (3)

and

$$N_V = Nctg\gamma_k. \tag{4}$$

Under the action of the force N_V, the soil particles move in the direction of movement, and under the action of the force Nτ move along the surface of the working body. But for $N_\tau < F$,

that is $\gamma_\kappa > \frac{\pi}{2} - \rho$, soil particles cannot move along the wings of the working element, they can only move forward. This builds up a large amount of earth in front of the working element, increasing its resistance. Furthermore, in this case, the adhesion of dirt to the surface of the plow is observed. This results in poor furrow opening and even greater plow resistance.

With the possibility of moving pieces of soil along the wings of the working body, the above disadvantages are not observed. To do this, $N_\tau > F$, or $\gamma_\kappa < \frac{\pi}{2} - \rho$

In this case, the pieces of soil under the action of the working body move in the direction of the force R, the resultant of the forces N and F (Figure 3b). For this case, the absolute speed of movement of soil particles in the horizontal plane V_a can be found using the following formula (Figure 4):

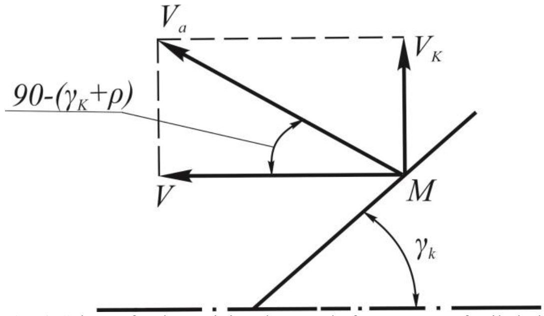
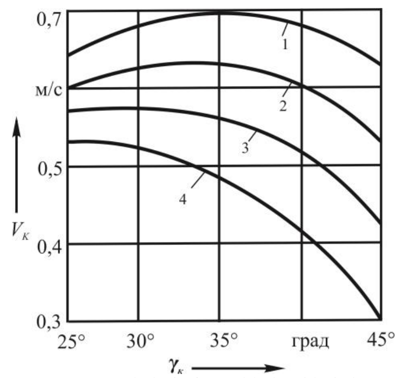


Fig. 4. Scheme for determining the speed of movement of soil clods

$$V_a > V\,\frac{\sin\gamma_k}{\cos\rho}, \tag{5}$$

Here, V is the speed of movement of the combined tillage, and we determine the transverse component of the speed V_a, that is, the perpendicular direction.

$$V_K > V\,\frac{\sin\gamma_k}{\cos\varphi}\cos(\gamma_\kappa + \rho). \tag{6}$$



1, 2, 3, 4- φ= 20, 25, 30, 35º

Fig. 5. Graphs of the dependence of the speed V_K on the angle γ_K

The higher the speed V_K, the less accumulation of soil in front of the working body, and the absence of the adhesion of the soil on the wings of the working body is ensured. Figure 5 shows graphs of the change in velocity V_K depending on the angle at V = 2 m/s and at various values of the friction angle γ_K.

As can be seen from the graphs, the V_K velocity has a maximum value at certain values of the angle γ_K. Therefore, it can be said that with these values of the soil embankment in front of the working body and the resistance to its frontal resistance will be the smallest, and high-quality cutting of the furrow will be achieved. We determine the maximum values of the angle γ_K and provide the maximum speed V_K. To do this, we examine expression (6) for an extremum, that is, we take the derivative of its right side concerning the angle γ_K and equate the result to zero.

$$\frac{dV_t}{d\gamma_k} = V\left[\cos\gamma_k \cos(\gamma_k + \rho) - \sin\gamma_k \sin(\gamma_k + \rho)\right] / \cos\rho = 0. \quad (7)$$

Solving this expression concerning γ_K, we obtain the following:

$$\gamma_к = \frac{\pi}{2} - \frac{\rho}{2}. \quad (8)$$

Substituting certain values of ρ (25º–30º) into this resulting expression, we determine that the opening angle of the working body is within $2\gamma = 60^\circ - 65^\circ$.

And determine the angle of entry of the working body into the soil from the following condition:

$$\beta_k + \rho < 90^\circ. \quad (9)$$

When this condition is met, the clod slides up along the working surface of the working element, preventing the compaction of the soil in front of it. (9)

Solving the equation for βк and substituting the maximum value ρ (35°) [12] into the resulting equation shows that the entry angle of the workpiece into the ground should not exceed 55°. As a final result, we accept βк = 35–40º [13, 14].

The angle of the mouldboard side angle is equal to 2-3° less than the natural inclination of the ground. In this case, the likelihood of reburying the soil excavated by the working body in the open furrow is reduced. Based on the above, we accept $\delta_к$ = 35-38º.

The width of Share wings is determined by the following expression based on the diagrams shown in Figure 2.

$$B_к \geq 2H_к ctg\delta \quad (10)$$

Or meaning (2)

$$B_к \geq 2\left[(1+\kappa)\frac{(1+\sqrt{2})(b+2a)b}{2\sqrt{2}(b+a)} tg\varphi - h_ф\right] ctg\delta, \quad (11)$$

Where, $h_ф$ - is the height difference between the front and rear parts of the wings, m.

Assuming the values of k, b, a, φ and δ defined above and assuming $h_ф$ = 5 cm, calculations using expression (11) showed that the width of Share wings should be at least 41 cm.

The length of the body of the working element can be determined by the following expression [11] :

$$L \geq \frac{H_k\left(1+\sqrt{1+f}\right)}{\sin\delta}, \quad (12)$$

here f- is the coefficient of friction of soil clods on the wings of the working body.
If we take f=0.7 and substitute the values of $H_к$ and δ defined above into expression (12), then it follows that the length of the body of the working body must be at least 78 cm.
So, according to the results of the research, the height of the moldboard plow opening furrows is at least 20.5 cm, opening angle of the share wings is 60-65º, the angle of entry into the soil is 35-40º, the angle of the side cut of the wings of the working body is 37-40º, the width of the share wings is not less than 41 cm, the body length of plow must be not less than 78 cm [13, 14].

4. Conclusions

a) As a result of the research, a new technology for preparing land for planting ornamental trees and seedlings of rare flowers in forest nurseries has been developed.
b) When compared to current technology for preparing nursery lands for planting in forestry, the proposed technique allows for labor and other cost savings because the land is prepared without harrowing, chopping, or weeding.
c) It was determined that the working body of the combined unit that forms the beds meets the requirements for the use of bed formers with two moldboard bodies.
d) The the height of the moldboard plow opening furrows is at least 20.5 cm, opening angle of the share wings is 60-65º, the angle of entry into the soil is 35-40º, the angle of the side cut of the wings of the working body is 37-40º, the width of the share wings is not less than 41 cm, the body length of plow must be not less than 78 cm.

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