Using modern technologies to improve the vegetable cultivator

D. R. Norchayev[1], *B.* Sh. Gaybullyev[1], *A.* N. Khayitov[2*], *B.* S. Khusainov[2], and *A.* A. Khudaykuliev[2]

[1]Agricultural Mechanization Scientific-Research Institute, Gulbahor, Uzbekistan
[2]Urgench State University, Urgench, Uzbekistan

Abstract. This paper explores the selection of high-yielding potato varieties suitable for various soil and climatic conditions, the use of modern scientific technologies in their cultivation, the current state and significance of potato cultivation in the soil and climatic conditions of the Republic of Uzbekistan, and the importance of employing specific techniques such as a motoblock for potato cultivation in homesteads or small farms. The paper also presents the results of theoretical and experimental studies conducted on the study of the grinding angle of the cultivator softener paw. The research findings suggest that the optimal grinding angle for the vegetable cultivator softener claw should be within the range of 25º-30º, ensuring the necessary soil quality and minimal resistance of the working body. This study highlights the importance of selecting appropriate potato varieties and utilizing modern scientific technologies for successful potato cultivation in Uzbekistan.

1 Introduction

One of the main directions of the development of agriculture and mechanical engineering is the improvement of resource-efficient technological machine units, mechanisms and devices and the creation of new ones [1-4]. It is known that in order to obtain high and quality products from agricultural crops, it is necessary to properly use soil fertility and climatic conditions, as well as scientifically based agricultural crop cultivation technologies.

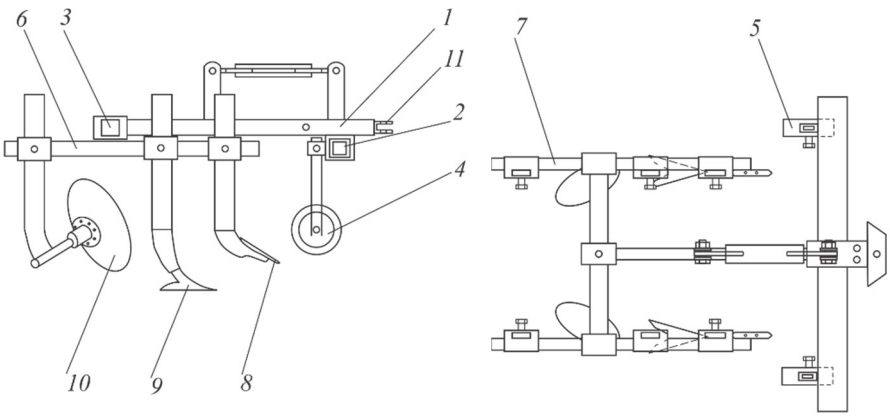
Today, the modern technology of potato cultivation includes the selection of potato species and varieties with valuable economic and biological characteristics suitable for the local soil and climate conditions, rotation, selection of the previous crop for planting, soil tillage system, fertilization, seed production, preparation of seeds for planting, planting method. Moreover, it covers such things as timing, planting rate and planting depth, protection from weeds, diseases and pests, crop care, harvesting and preliminary processing, and the machinery system used in their implementation, etc. [5-6].

Currently, special attention is being paid to the cultivation of potatoes in the homesteads of the Republic of Uzbekistan in the conditions of the soil and climate. Potatoes grown in household plots or small contour fields are mainly done by manual labor. However, the

* Corresponding author: abdullaxayitov250@gmail.com

increase in labor costs and other costs causes the product cost to increase. In the cultivation of potatoes, the process of interrow processing is one of the most complicated processes. Currently, cultivators working on a motoblock (motor cultivator) base are used in small contour fields in the world. There are different versions of them, of which cultivators equipped with arrow-shaped and softening claws are effective. However, the construction of this type of cultivators is complex and bulky, and the possibilities for different soil and climatic conditions during operation are low.

Based on the above, it is necessary to apply small techniques and use them effectively in this situation. In recent years, the widespread use of small machinery in agriculture has become popular all over the world. Currently, the parameters of the techniques used in the cultivation of potatoes and vegetables in the country's homesteads and small farms are suitable for the soil and climatic conditions of the republic of Uzbekistan, and researches on what parameters they have not been conducted before and have not been scientifically substantiated. For this purpose, a vegetable cultivator for a motoblock was developed at the Agricultural Mechanization Research Institute. Work in the form of a cultivator frame 1 (see Fig. 1), front 2 and rear 3 transverse brushes, support wheels 4 and 5, right 6 and left 7 longitudinal brushes, softener 8 and arrow-shaped claws 9 and spherical disk 10 installed on them composed of organs. The cultivator provides adjustment of the position of the support wheels 4 and 5 and the working bodies 8, 9 and 10 in transverse 2 and 3 and longitudinal brushes 6 and 7 in transverse and vertical directions. A special flange 11 is installed on the front part of its frame to connect the cultivator to the motoblock.



side view **top view**

Fig. 1. Construction scheme of vegetable cultivator for motoblock.

In the working process of the developed cultivator, the softener and bullet tines soften the paddy slopes and edges and cut the weeds on them, while the spherical discs push the soil softened by the softener and bullet tines into the paddy and increase its height.

Based on this, this article presents the results of the theoretical and experimental research conducted on the study of the grinding angle of the softener paw of the vegetable cultivator developed for the motoblock.

2 Methods

To determine the grinding angle of the softener, we consider the processes of soil deformation and fragmentation under its influence. It is known from the literature and previous studies [7-9] that the processes of deformation and fragmentation of the soil under

the influence of the softening claw consist of two stages: when the softening blade moves from position I to position II (Fig. 2), the soil is initially compressed (crushed) under the influence of its working surface, and when the stresses generated in it reach a critical limit, they are located at an angle ψ_b relative to the direction of its movement (where ψ_b is the angle of refraction in the longitudinal direction of the soil, °) ABB_1A_1 disintegrates (displaces) along the plane, and $ABB_1A_1DCC_1D_1$ prism-shaped fragment is separated from the soil. In the next movement of the softening paw, these processes are repeated sequentially, and the subsequent pieces are separated.

According to the research conducted by A. Tokhtako'ziev and Q.B. Imamgulov [10], the step of soil decomposition for work bodies in the form of a softening claw can be determined by the following expression:

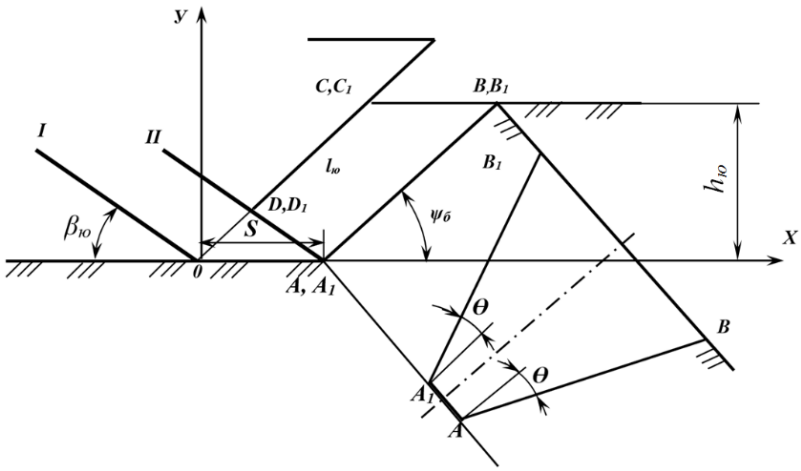


Fig. 2. Deformation and decomposition processes under the influence of a soil softener.

$$S = \sqrt{2}\left\{\kappa_c\left[b_{ю} + h_u tg\left(\frac{\pi}{4} - \frac{\phi_2}{2}\right)\right] h_u \cos\phi_1 \cos\frac{1}{2}(\phi_1 + \phi_2 - \beta_u)\right\}^{\frac{1}{2}} :$$

$$\left[q_0 b_u \cos^3\frac{1}{2}(\beta_u + \phi_1 + \phi_2)\sin\beta_u\right]^{\frac{1}{2}}, \quad (1)$$

where, κ_c – relative resistance of the soil to displacement, Pa;

h_u – the depth of tillage by the softener paw, m;

φ_1, φ_2 – internal and external soil friction angles, respectively, °.

q_0 – volume compression coefficient of the soil, N/m^3.

According to the literature [11-13], the smaller the step of soil fragmentation, the higher the quality of its compaction, the smaller the resistance to traction of the softening pad.

In order to determine the value of the softening blade grinding angle, which ensures that the step of soil decomposition has a minimum value, we can derive from the expression (1) and by setting it to zero and simplifying it, we get the following result,

$$2\sin^2\beta_u + 2\sin(\phi_1 + \phi_2)\sin\beta_u = 1 + \cos(\phi_1 + \phi_2)\cos\beta_u. \quad (2)$$

We solve this expression using the graphical method. For this, we introduce the designations y_1=2sin2β_u+2sin(φ_1+φ_2)sinβ_u and y_2=1+cos(φ_1+φ_2)cosβ_u, and construct graphs of the change of y_1 and y_2 depending on byu at different values of φ_1 and φ_2 (Fig. 3 and Fig.

4). Their intersection points give the values of the angle of grinding of the softening blade, which ensure that the step of soil fragmentation is minimal.

3 Results

According to the graphical connections presented in Figures 3 and 4, when φ_1=25-35° and φ2=35-45°, the step of soil fragmentation has a minimum value and, therefore, it follows that the grinding angle of the softener paw should be in the range of 25-30° in order to ensure its high-quality crushing and to reduce the resistance to traction.

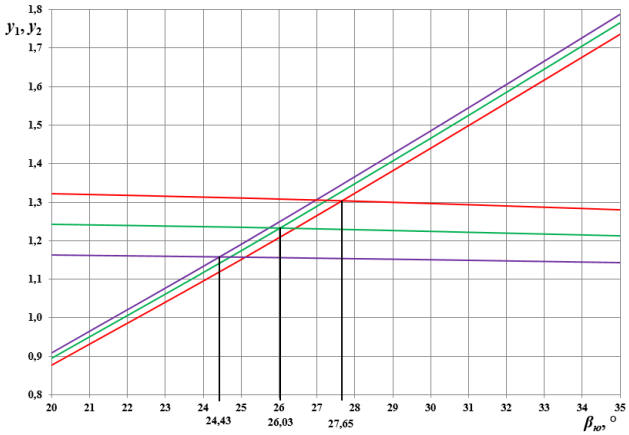


Fig. 3. Graphs of the variation of y_1 and y_2 at different values of φ_1 as a function of β_u.

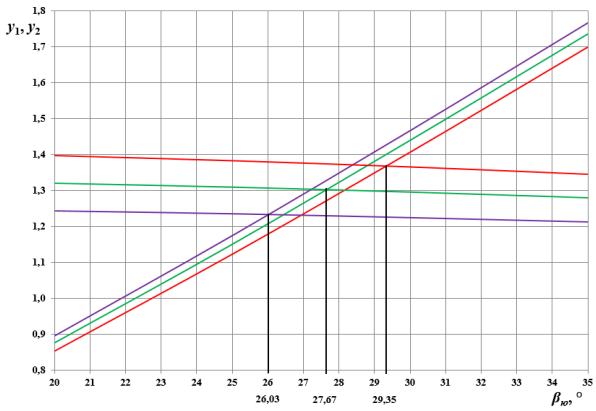


Fig. 4. Graphs of the variation of y_1 and y_2 at different values of φ_2 as a function of β_u.

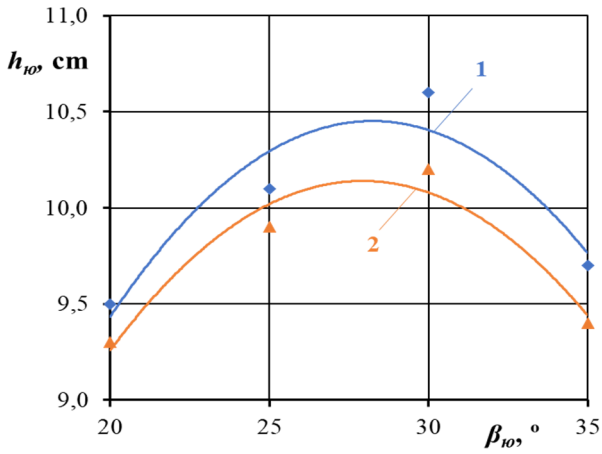
In order to verify the results obtained in theoretical studies, experimental studies were conducted.

In order to conduct experiments, the angle of contact (entry into the soil) of the working body was changed from 20° to 35° with an interval of 5°. In the experiments, the width of the softener paw was 50 mm, the length of the working surface was 17.5 cm, the processing depth was 10 cm, and the operating speeds of the unit were between 0.4 m/s and 0.8 m/s.

The working depth of the working body, soil compaction quality, and the resistance to traction of the working body were taken as the main quality and energy indicators as evaluation criteria during the experiments.

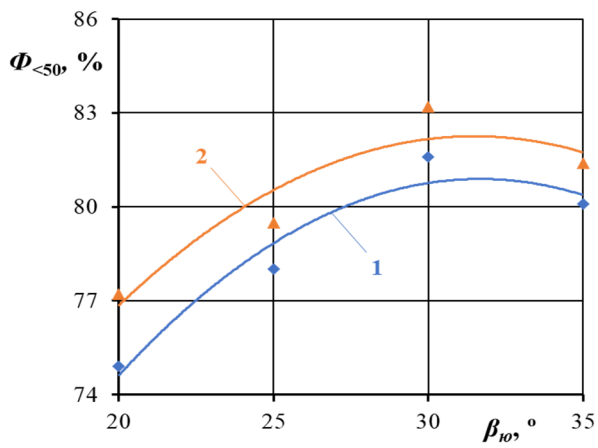
The results of the experiments are presented in Figures 5-7.

The data presented in Figure 5 shows that with the increase in the grinding angle of the softening blade, the processing depth of the working body first increased and then decreased at both movement speeds of the unit. For example, with an increase in the grinding angle of the softener paw from 20° to 30°, at both speeds of movement of the aggregate, it increased from 9.5 cm to 10.6 cm and from 9.3 cm to 10.2 cm, respectively, while the emphasis angle increased from 30° with an increase to 35°, the above values decreased from 10.6 cm to 9.7 cm and from 10.2 cm to 9.4 cm, respectively.



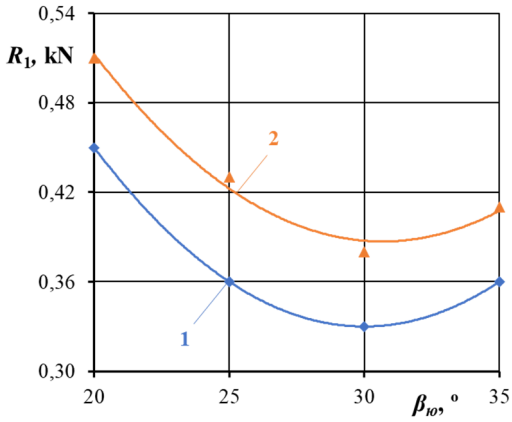
1 – V=0,4 m/s; 2 - V=0,8 m/s

Fig. 5. The graph of the change of the processing depth of the working body (h_u) depending on its angle of entry into the soil (β_u).



1 – V=0,4 m/s; 2 - V=0,8 m/s

Fig. 6. The graph of the variation of the level of soil compaction (F <50) depending on the soil penetration angle (β_u) of the softener paw.



1 – *V*=0,4 m/s; 2 - *V*=0,8 m/s

Fig. 7. A graph of the variation of the pull-out resistance (R_1) of the softening pad as a function of its angle of entry into the soil (β_u).

The level of soil compaction at both speeds of the unit, increasing the compaction angle (β_u) of the softening blade from 20° to 30° improved the level of soil compaction, and increasing it from 30° to 35º caused this indicator to worsen (see Figure 6). This can be attributed to the law of change of the size of the pieces separated from the soil under the influence of the working body, depending on the angle β_u. When β_u =25-30°, the size of the cuts had a minimum value. Increasing the speed from 0.4 m/s to 0.8 m/s led to the improvement of soil compaction quality.

4 Discussion

The traction resistance of the working body first decreased and then increased at both movement speeds as the angle of its entry into the soil increased (Fig. 7), that is, as the pitch angle increased from 20° to 30°, the drag resistance of the working body decreased from 0.45 kN to 0.32 kN and from 0.51 kN to 0.39 kN at both travel speeds, respectively. As the angle increased from 30º to 35°, the above values increased from 0.32 kN to 0.35 kN and from 0.39 kN to 0.44 kN, respectively.

As mentioned above, this can be explained by the reduction of the size of the pieces separated from the soil under the influence of the working body, and the reduction of the amount of energy used to break it up.

The graphs shown in Figures 5-7, which represent the change of the depth of tillage of the working body, the crushing quality of the soil and the traction resistance of the working body depending on its crushing angle, can be expressed by the following empirical formulas determined by the method of least squares [14-15]:

- when the speed of movement is 0.4 m/s,

$$h_u=-1.505 + 0.847\,\beta_u - 0.015\,\beta_u^2,\ \text{cm}; \quad (R^2=0.8806); \quad (3)$$

$$F_{<50} = 30.21 + 3.256\,\beta_u - 0.052\,\beta_u^2,\ \%; \quad (R^2=0.9059); \quad (4)$$

$$R_1 = 1.41 - 0.072\,\beta_u + 0.0012\,\beta_u^2,\ \text{kN}; \quad (R^2=1); \quad (5)$$

- when the speed of movement is 0.8 m/s,

$$h_u=-0.78 + 0.782\,\beta_u - 0.014\,\beta_u^2,\ \text{cm}; \quad (R^2=0.9407); \quad (6)$$

$$F_{<50} = 41.86 + 2.506\,\beta_u - 0.038\,\beta_u^2,\ \%; \quad (R^2=0.8774); \quad (7)$$

$$R_1 = 1.4225 - 0.0675\,\beta_u + 0.0011\,\beta_u^2,\ \text{kN}; \quad (R^2=0.9865) \quad (8)$$

where, β_u – grinding angle of softener paw, °(β_u=20-35°).

5 Conclusion

In conclusion, the results of our theoretical and experimental research have shown that the optimal grinding angle for the vegetable cultivator softener claw is in the range of 25º-30º. This angle ensures that the vegetable cultivator is at the specified depth of cultivation, the quality of soil compaction is at the required level, and the resistance of the working body to the pull is minimal. This finding is significant for the successful cultivation of potatoes in homesteads or small farms using a motoblock, as it allows for efficient and effective soil preparation. Additionally, the selection of high-yielding potato crops suitable for different soil and climatic conditions, and the use of modern scientific technologies in their cultivation, are crucial for the current state and relevance of potato cultivation in the Republic of Uzbekistan. Overall, this study emphasizes the importance of selecting appropriate potato varieties, utilizing modern scientific technologies, and employing the optimal grinding angle for the vegetable cultivator softener claw for successful potato cultivation in Uzbekistan.

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