



Research Article

Theoretical Justification of the Parameters of a Rotary Loosening Blade for Inter-row Tillage in Potato Cultivation

Bayboboev Nabijon G'ulomovic¹ , Komilov Ne'matilla Muxammadjonovich¹ ,
Xamzayev Asrorxon Akmalxonovich², Matyoqubov Doston Zohidjon O'g'li^{1,*}

¹The Department of Mechanization agriculture, Namangan State Technical University, Namangan, Uzbekistan

²The Department of Transport Engineering, Namangan State Technical University, Namangan, Uzbekistan

Abstract

In potato cultivation, mechanical inter-row tillage plays an important role in loosening the soil, eliminating weeds, crushing soil clods, and creating favorable soil conditions for the development of the plant root system. The effectiveness of inter-row tillage largely depends on the geometric and kinematic parameters of the working tools and their interaction with the soil. The aim of this study is to theoretically substantiate the main geometric and kinematic parameters of a rotary loosening blade designed for inter-row tillage in potato cultivation. The study analyzes the principal geometric parameters of the rotary blade, including the bending angle, lateral angle, bending line angle, tangential edge height, bending radius, rotational radius, working width, and cutting-edge characteristics. For the theoretical analysis, the rotational radius of the rotary loosener was assumed to be 0.17 m, with four blades mounted on one side of the disc. The blade wing length was taken as 0.07 m, while the sharpening angle of the cutting edge was set at 30°. Based on the obtained theoretical relationships, the main kinematic parameters of the rotary loosener were determined for different operating conditions. At a rotor rotational speed of 120–140 rpm, the corresponding angular velocity was calculated as 12.57–14.66 rad/s, while the peripheral velocity of the blade tip ranged from 2.14 to 2.49 m/s. At an aggregate travel speed of 3–5 km/h, the kinematic operating mode coefficient varied from 1.54 to 2.99. The obtained results provide a theoretical basis for selecting appropriate geometric and kinematic parameters of rotary loosening blades and can be used in the design and improvement of mechanical inter-row tillage equipment for potato cultivation.

Keywords

Potato, Row Spacers, Rotary Ripper, Knife, Geometric Parameter, Rotation Radius, Rotational Speed, Kinematic Coefficient

1. Introduction

The main geometric parameters of the rotary loosening blade include the bending angle β , lateral angle δ , bending line angle α , tangential edge height, bending radius, rotational radius, working width, initial radius of the lateral cutting edge, and final radius of the lateral cutting edge. The mechanisms

by which the main structural parameters influence the operation of the loosener during potato inter-row tillage are as follows [1-5].

The bending angle β , defined as the spatial angle between the tangential plane and the lateral cutting plane of the rotary

*Correspondence: Matyoqubov Doston Zohidjon O'g'li (dostonmatyoqubov515@gmail.com)



loosening blade, has a significant effect on its operational characteristics. Excessively large values of β may cause the tip of the rotary loosening blade to come into contact with the soil or potato roots prematurely, resulting in increased mechanical loads, reduced service life, and possible damage to potato plants [5-10].

2. Materials and Research Results

The angle δ is defined as the angle between the lateral cutting surface and the central line of the blade and affects the pressure exerted on the rotary loosening blade during inter-row tillage. As δ decreases within the considered range, the pressure on the blade increases.

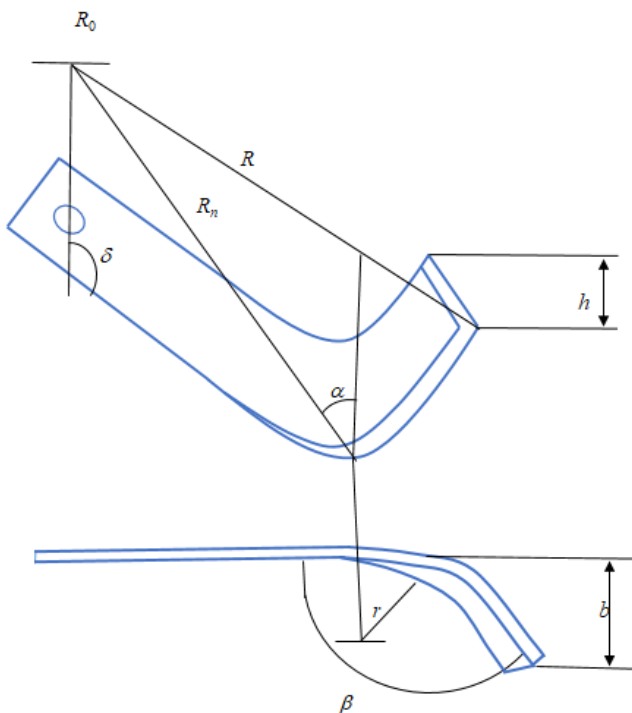


Figure 1. Ridge-forming cultivator-fertilizer applicator.

A. E. Zimmerman developed a new working unit of the seeder-cultivator for subsurface broadcast sowing to eliminate these shortcomings (Figure 2).

The angle of the bending line α affects the relative acceleration between the soil particles and the blade surface. A small value of α increases the accelerating effect on the soil; however, it also increases the resistance to penetration into the soil.

If the tangential edge height is too small, the quality of soil throwing and crumbling decreases. However, if the height is excessively large, the tillage resistance increases, and the bent section becomes more susceptible to breakage [10-17].

If the bending radius is too small, the strength of the soil-mixing blade at the bending point decreases, which may result in increased soil adhesion and a reduction in service life. However, when the radius is excessively large, soil unevenness at

the bottom of the furrow increases.

The sharpening angle of the blade cutting edge is assumed to be 30° based on the condition that the cutting edge should not become blunt too quickly.

Blade pitch. The corresponding points of the trajectories of two adjacent blades of the rotary loosener are horizontally displaced from each other by a distance S on the field surface (Figure 2). This distance is referred to as the blade pitch. It can be determined using the following expressions [3]:

$$S = \frac{2\pi V}{z_f \omega} \quad \text{or} \quad S = \frac{2\pi R}{z_f \lambda}. \quad (1)$$

This parameter is one of the most important parameters determining the degree of inter-row tillage performed by the rotary loosener and the amount of energy required for its operation.

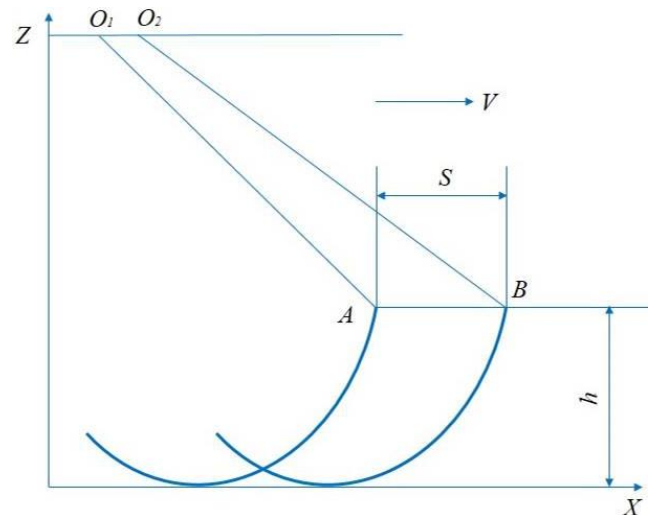


Figure 2. Schematic diagram for determining the blade pitch.

An increase in the blade pitch leads to a decrease in the degree of tillage and a reduction in energy consumption.

Based on the conducted studies, the blade pitch is assumed to be 0.0267 m. An increase in the blade pitch reduces the quality of inter-row tillage in potato cultivation, whereas a decrease in the pitch results in increased energy consumption.

The rotational speed of the rotary loosener is determined from the values of its peripheral velocity V_0 and radius R using the following expression:

$$n_f = \frac{30v_0}{\pi R}. \quad (2)$$

Substituting the above-mentioned values of ω and R into this expression, it is determined that the rotational speed of the drum should be within the range of 120-140 rpm. The bending

angle of the blade wing is assumed to be 90° based on the condition that the rotary loosener should ensure uniform tillage depth across the entire working width [1].

Thus, based on the results of the conducted studies, the rotary loosener should have the following parameters: four blades installed on one side of the disc; a radius of 0.17 m; a peripheral velocity of 2.14 m/s; a blade pitch of 0.0267 m; a kinematic operating mode coefficient of 4; an aggregate operating speed of 3-5 km/h; a blade-wing installation angle of 72° ; a length of 0.34 m for one section of the rotary drum; a blade cutting-edge sharpening angle of 30° ; a blade wing length of 0.07 m; a rotary loosener rotational speed of 120-140 rpm; and a blade-wing bending angle of 90° .

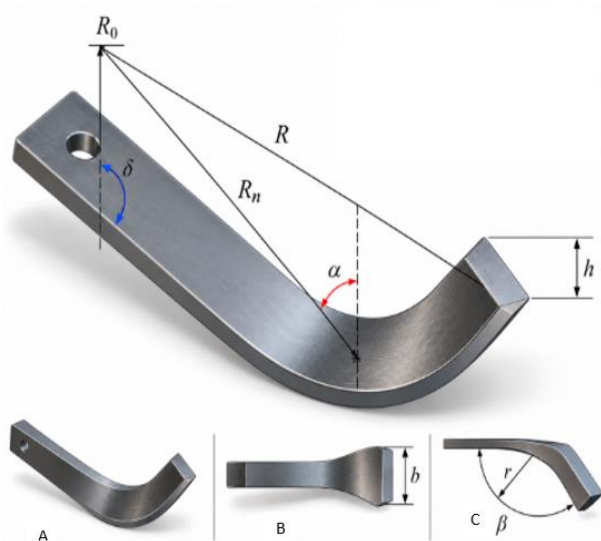


Figure 3. Parameters of the rotary loosening blade.

Table 1. Values.

R_0 - Central point	α - Bending line angle
R - Rotational radius	β - Bending angle
R_n - Bending radius	r - Bending radius
δ - Lateral angle	h - Tangential edge height
	b - Working width

The operational efficiency of the rotary loosener cannot be adequately evaluated solely based on the rotor rotational speed or an individual geometric parameter of the blade. The technological process is determined by the interaction between the rotor radius (R), rotational speed (n), forward travel speed of the aggregate (V), number of blades (z), tillage depth (h), and the geometric angles of the blade. Therefore, it is appropriate to consider these parameters as a unified kinematic system.

As a result of the theoretical investigation of the geometric

and kinematic parameters of the rotary loosening blade designed for inter-row tillage in potato cultivation, the main parameters determining its interaction with the soil and operating mode were identified. It was theoretically substantiated that the bending angle β , lateral angle δ , bending line angle α , tangential edge height, bending and rotational radii, and working width of the blade directly affect soil crumbling, displacement, and tillage resistance.

According to the calculation results, when the rotational radius of the rotary loosener is 0.17 m and its rotational speed is 120-140 rpm, the angular velocity is 12.57-14.66 rad/s, while the peripheral velocity of the blade tip is 2.14-2.49 m/s. At an aggregate forward travel speed of 3-5 km/h, the variation in the kinematic operating mode coefficient ensures active interaction between the blade and the soil. This relationship shows that, when the rotor radius remains constant, the peripheral velocity of the blade changes in direct proportion to the rotational speed.

For the investigated design, when ($R = 0.17$) m, the calculated parameters for rotational speeds of 120, 130, and 140 rpm are as follows:

Table 2. Rotational speed.

n , rpm	ω rad/s	V_0 m/s
120	12,57	2,14
130	13,61	2,31
140	14,66	2,49

It was established that the absolute motion of the blade tip is formed by the superposition of the forward motion of the aggregate and the rotational motion of the rotor, and that its trajectory can be described by a trochoidal law. This makes it possible to evaluate the processes of blade entry into and exit from the soil, the tillage pitch, and the intensity of soil crumbling.

Based on the theoretical analysis, it was determined that it is appropriate to install four blades on one side of the rotary loosener disc, with a rotor radius of 0.17 m, a blade wing length of 0.07 m, a cutting-edge sharpening angle of 30° , and a rotor rotational speed in the range of 120-140 rpm.

The obtained results provide a theoretical basis for selecting the structural and kinematic parameters of the rotary loosener for potato inter-row tillage. Determining the optimal values of the identified parameters and evaluating their effects on the degree of soil crumbling, tillage depth, protective zone, energy consumption, and the degree of damage to potato plants should be carried out in subsequent experimental studies.

3. Conclusions

The theoretical analysis of the geometric and kinematic parameters of a rotary loosening blade designed for inter-row tillage in potato cultivation made it possible to substantiate the main design and operating parameters of the working element. It was established that the absolute motion of the blade tip is formed by the combined effect of the forward motion of the aggregate and the rotational motion of the rotor, resulting in a trochoidal trajectory. This motion pattern determines the conditions of blade entry into and exit from the soil, the tillage pitch, and the intensity of soil crumbling.

Based on the theoretical calculations, the recommended design parameters of the rotary loosener were determined. The rotor radius was taken as 0.17 m, the number of blades installed on one side of the disc was four, the blade wing length was 0.07 m, and the sharpening angle of the cutting edge was 30°. At a rotor rotational speed of 120-140 rpm, the angular velocity was determined to be 12.57-14.66 rad/s, while the peripheral velocity of the blade tip was 2.14-2.49 m/s. For an aggregate travel speed of 3-5 km/h, the kinematic operating mode coefficient varied within the range of 1.54-2.99.

Abbreviations

R_0	Central Point
R	Rotational Radius
R_n	Bending Radius
δ	Lateral Angle

Author Contributions

Bayboboev Nabijon G'ulomovic: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Methodology, Resources, Software, Validation, Writing – original draft, Writing – review & editing

Komilov Ne'matilla Muxammadjonovich: Conceptualization, Project administration, Supervision, Visualization, Writing – review & editing, Visualization

Xamzayev Asrorxon Akmalxonovich: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Resources, Software, Validation, Writing – original draft, Writing – review & editing

Matyoqubov Doston Zohidjon O'g'li: Investigation, Methodology, Resources, Software, Validation, Writing – original draft, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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Biography



Bayboboev Nabijon G'ulomovich is a highly respected Doctor of Technical Sciences and a professor, renowned for his extensive contributions to the field. He has conducted extensive research in the field of agricultural machinery, particularly in fertilizer application and potato cultivation technologies. Currently, he works as a professor at the Department of Agricultural Mechanization at the Namangan State Technical University. He is also the chairman of the specialized academic council for doctoral dissertations in technical sciences. Bayboboev is the author of more than 100 scientific publications, including monographs, articles, and teaching manuals. He holds several patents for inventions that have been practically implemented in Uzbekistan's agricultural sector.



Komilov Ne'matilla Muxammadjonovich is a respected PhD-qualified associate professor at the Namangan State Technical University, with specialized expertise in agricultural mechanization—particularly in soil tillage and fertilizer application technologies. His impactful work in both theoretical and applied research supports ongoing innovations in Uzbekistan's mechanized agriculture sector.



Xamzayev Asrorxon Akmalxonovich is a researcher specializing in agricultural engineering and agricultural machinery. His research interests include the design, development, and optimization of agricultural machines and working implements for soil tillage and crop cultivation. His scientific activities focus particularly on mechanization technologies for potato and other row crops, rotary tillage implements, soil-engaging working elements, and the theoretical and experimental investigation of their operating parameters.



Matyoqubov Doston Zohidjon O'g'li is currently student an PhD. at the Namangan State Technical University in Uzbekistan. His academic focus is on post-harvest processing technology and the drying of vegetables.

Research Field

Bayboboev Nabijon G'ulomovich: Agricultural Mechanization, Design of Fertilizer Application Systems, Potato Harvesting Technologies, Development of Resource-efficient Machinery for Soil Cultivation

Komilov Ne'matilla Muxammadjonovich: Soil Tillage Mechanization, Fertilizer Distribution Systems, Theoretical and Experimental Studies of Rotary and Disk-based Working Tools, Kinematics of Granular Fertilizer Flow

Xamzayev Asrorxon Akmalxonovich: Mechanization of Harvesting Processes, Baler-collector Design, Humate-treated Forage Harvesting Technologies, Optimization of Machine Parameters for Crop Handling

Matyoqubov Doston Zohidjon O'g'li: Post-harvest Processing, Vegetable Drying Methods, Food Technology, Optimization of Drying Parameters for Quality Preservation in Agricultural Products