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Article

Development of a Project of an Improved Row Cultivator that Coordinates The Processes of Row Processing and Feeding

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Abstract: In cotton cultivation, inter-row cultivation and plant nutrition are considered essential agrotechnical measures. Separate execution of these processes leads to an increase in energy consumption, repeated movement of aggregates across the field, and soil re-compaction. In this regard, the creation of resource-saving technical means that combine the processes of inter-row cultivation and plant fertilization with mineral fertilizers is a pressing scientific and practical issue. This article is dedicated to the development of a design for an improved furrow cultivator that simultaneously performs inter-row cultivation and plant nutrition. A structural diagram of the cultivator has been developed, and the main parameters influencing the mutual arrangement of working parts and the effective execution of the technological process have been analyzed. The proposed technical solution allows for the high-quality loosening of inter-row soil, the removal of weeds, and the local application of mineral fertilizers in the layer where the root system develops. As a result, the number of trips of the unit across the field is reduced, fuel consumption is reduced, soil compaction is prevented, and the efficiency of agrotechnical measures is increased.

Keywords: Cotton, Row Spacing, Furrow Cultivator, Fertilization, Mineral Fertilizer, Resource-Saving Technology, Combined Unit, Working Element, Soil Loosening, Agrotechnical Efficiency

1. Introduction

In cotton cultivation, row spacing management and plant nutrition are critical agrotechnical measures directly influencing crop yield and quality. Traditionally, these processes are executed as separate operations, which significantly increases energy consumption, operational costs, and labor requirements. Furthermore, repeated movement of heavy machinery across the field exacerbates soil compaction. This compaction severely degrades the soil's water-physical properties, impeding air and water exchange, restricting root development, and reducing the absorption efficiency of applied mineral nutrients. Consequently, modern sustainable agriculture increasingly demands the transition toward resource-saving, combined technological operations [1].

To address these challenges, agricultural theory emphasizes combining multiple field operations into a single pass to optimize energy efficiency and protect soil structure. While conventional equipment like the KRN-4, KRX-3.6, and KRT-4 rotary cultivators have historically managed basic row cultivation and fertilization, their rigid configurations fall short of modern precision and resource-conservation standards. Past research has focused heavily on individual tillage tools, creating a clear knowledge gap in the synchronized engineering of adaptive row cultivation and deep localized feeding mechanisms [2]. This study addresses this gap by developing an improved furrow cultivator that integrates deep soil loosening, weed eradication, and targeted subsoil fertilizer placement.

The design methodology utilizes a systematic engineering approach structured across five progressive development stages. This includes constructing a double-row square-profile steel base frame, integrating an adaptive parallelogram mechanism to stabilize working depth against terrain unevenness, and configuring specialized central beams equipped with multi-tiered soil-softening elements. Additionally, a mechanical transmission system linked to the support wheels is incorporated to facilitate precise, continuous fertilizer dosing from the integrated bunkers to the active plant root zone. It is expected that the integrated architectural design will mitigate the destructive physical impacts of multiple machinery passes by completing separate agrotechnical measures simultaneously. The structural configuration is anticipated to maintain highly stable immersion depths and precise delivery coordinates, even across variable field terrains [3]. By systematically reducing the tractor's cumulative traction resistance, the engineered layout aims to establish a balanced distribution of mechanical forces during simultaneous deep tillage and nutrient delivery.

The research successfully yields a fully modeled, structurally combined row cultivator characterized by independent section movements and precise mechanical fertilizer dosing. Results demonstrate that three sequentially arranged deep looseners efficiently distribute operational loads while loosening the soil to exact depths of 6…8 cm and 10 cm. The practical implication of this technical solution is a profound advancement in resource-saving cotton cultivation. By minimizing trips across the field, this innovative design prevents soil compaction, cuts fuel consumption, and elevates fertilizer absorption efficiency, offering an economically viable pathway for modern agrotechnical operations [4].

2. Methodology

The structural development of the improved row cultivator follows a scientifically based sequence of five key design stages to ensure high-quality soil processing and synchronized plant feeding. In the initial phase, a heavy-duty double-row base frame is constructed using 100×100 mm square profile steel pipes, reinforced with vertical connecting elements to withstand heavy bending and torsional moments. To optimize tractor balance and stability, a central connection bracket is integrated and strategically offset 400 mm from the front of the frame. The second phase incorporates an adaptive parallelogram mechanism built from 60×60 mm square profile steel pipes to mitigate the impact of vertical vibrations caused by uneven terrain. Movable brackets equipped with lower support wheels ensure that a stable immersion depth is maintained independently across all processing sections.

In the third and fourth phases, the central beams are finalized and mounted to the ends of the movable brackets to establish a flexible yet stable kinematic connection. These central beams feature sliding locks on the cross beams that allow for highly flexible horizontal positioning of the working elements. The soil-engaging assembly includes softeners, irrigation ditch openers, and three sequentially arranged deep looseners spaced 10 cm apart to gradually distribute operational loads and reduce tractor traction resistance [5], [6]. These deep looseners are engineered to isolate soil processing to precise depths of 6…8 cm, 10 cm, and 10 cm. Finally, the assembly integrates auxiliary lifting and locking mechanisms for safe field transport, alongside a mechanical transmission system that directly transfers rotational movement from the support wheels to the bunker dosing axes, ensuring a continuous, uniform fertilizer application rate.

3. Result and Discussion

Cotton Our Republic village farm strategic from networks one is calculated, its productivity increase and cultivation expenses reduce always current from issues one to be came. It is known that timely and high-quality cultivation of inter-rows during the growth and development of cotton is one of the main factors for obtaining high yields. As a result of inter-row cultivation, air exchange in the soil improves, favorable conditions for moisture retention are created, weeds are destroyed, and the development of the plant root system is activated [7]. Therefore, inter-row cultivation is an integral part of cotton growing technology.

For many years, the KRN-4, KRX-3.6 and KRT-4 rotary cultivators have been successfully used in cotton cultivation. These cultivators are capable of cultivating the soil between rows, removing weeds and applying mineral fertilizers to a certain depth. Although their design has proven itself in practice, the requirements of modern agriculture, such as resource conservation, energy efficiency and reducing the number of technological operations, require the development of new constructive solutions.

Today, the widespread introduction of resource-saving technologies in cotton growing is of great importance. In particular, the issues of reducing fuel and lubricant consumption, increasing labor productivity, and performing agrotechnical measures in a short time require special attention. In current technologies, inter-row tillage and plant nutrition processes are often performed as separate operations. As a result, the aggregates have to move across the field several times [8]. This leads not only to additional fuel consumption, but also to soil compaction, reduced labor productivity, and increased technological costs.

Soil compaction under the influence of wheels of agricultural machinery negatively affects its water-physical properties. In compacted layers, the movement of water and air becomes difficult, the development of roots is limited, and the level of absorption of nutrients by plants decreases. As a result, the effectiveness of the applied mineral fertilizers is not fully manifested. Therefore, the implementation of inter-row tillage and fertilizing processes as a single technological operation is one of the important scientific and practical tasks of agricultural production.

Analyses show that during the cotton growing season, the simultaneous application of mineral fertilizers to the layer where the root system is actively developing, along with inter-row tillage, improves the nutritional conditions of plants. Since the soil is in a softened state, the efficiency of fertilizer absorption into the soil and its deposition in the root zone increases [9]. At the same time, the implementation of two technological operations in one unit reduces the number of trips across the field and significantly reduces energy consumption.

One of the promising directions for solving this problem is the creation of an improved tiller that combines the processes of inter-row cultivation and fertilizing. Such a technical tool allows you to loosen the soil between the rows, remove weeds, and place mineral fertilizers at a specified depth and distance. As a result, the quality of agrotechnical measures increases, fuel consumption decreases, soil compaction is prevented, and the economic efficiency of agricultural production increases.

In this regard, the purpose of this research is to develop a structural scheme of an improved row-type cultivator that combines inter-row tillage and feeding processes, to substantiate optimal options for the placement of its working bodies, and to create scientific and technical solutions that allow for the effective implementation of the technological process. The technical tool developed as a result of the research will serve to introduce resource-saving technologies in cotton growing, improve the quality of agrotechnical measures, and create the necessary conditions for obtaining high yields.

this improved tiller is an innovative technical solution being developed for the first time, it was considered necessary to cover its design process and implementation stages in a scientifically based sequence [10].

Stage 1. Base frame construction working exit At this stage, a design of the base frame, which is the main lifting element of the improved rotary cultivator, was created. Based on the analysis of the loads acting on the structure and the stresses transmitted through the working bodies, the frame was designed as a double-row frame of 100×100 mm square profile steel pipes. Vertical connecting elements were installed between the parallel-positioned profiles, increasing the overall rigidity of the structure. This solution provides a high level of resistance to bending and torsional moments that occur during soil cultivation and feeding. A special bracket was installed in the central part of the frame for connection to the three-point suspension mechanism of the tractor. In order to ensure the stability of the unit during operation and convenient placement of the working bodies, the connection points of the suspension mechanism were moved 400 mm from the front of the frame. As a result, a base frame structure was developed that has high strength, allows free placement of the working bodies and reliably operates under high operational loads (Figure 1).

Figure 1. Three-dimensional (3D) computer model of the support frame of the improved tiller.

Stage 2. Development of a mechanism for hanging the working sections. From this stage, all the main mechanisms and parts of the improved tiller were depicted in the form of kinematic diagrams in order to more clearly express the principle of their operation. In order to ensure that the working bodies of the cultivator are less affected by the unevenness of the surface between the rows and to ensure stable maintenance of the working depth, it was envisaged to use a parallelogram mechanism to connect the working sections to the frame.

It is known that when the unit is moving, the tractor wheels are subject to vertical vibrations under the influence of the relief of the inter-row space. If the working bodies are rigidly attached directly to the frame, these vibrations will negatively affect the quality of processing and lead to a change in the depth of soil processing [11]. The parallelogram mechanism ensures free movement of the working sections in the vertical plane, allowing them to operate in a stable position relative to the soil surface. As a result, the quality of processing the inter-row space is improved and the operation of the feeding bodies at the specified depth is ensured.

In the kinematic scheme (Fig. 2), the fixed brackets of the parallelogram mechanism 3 were fixed to the support frame based on the row spacing and the number of working sections. In order to ensure structural strength, the brackets were made of square profile steel pipes 60×60 mm in size with a wall thickness of 3.5 mm. Central beams were attached to the movable bracket 4 of the parallelogram mechanism, and a support wheel 5 was installed in its lower part. The function of the support wheels is to maintain a stable depth of immersion of the working bodies in the soil and increase the stability of the unit during operation.

The length of the parallelogram mechanisms located in the two edge sections of the cultivator was chosen to be greater than that of the central sections. Such a constructive solution allows for the placement of additional transmission and executive mechanisms that will be installed at later stages. In particular, the gap necessary for installing the leading wheels is created opposite the support wheels of the edge sections [12]. These leading wheels are subsequently used to transmit motion to the working elements of the feeding system. As a result, the proposed design ensures independent movement of the working sections, stability of the working depth, and reliable operation of the feeding system.

1-frame, 2-parallelogram mechanism, 3-fixed bracket of the parallelogram mechanism, 4-movable bracket of the parallelogram mechanism. 5- base wheels.

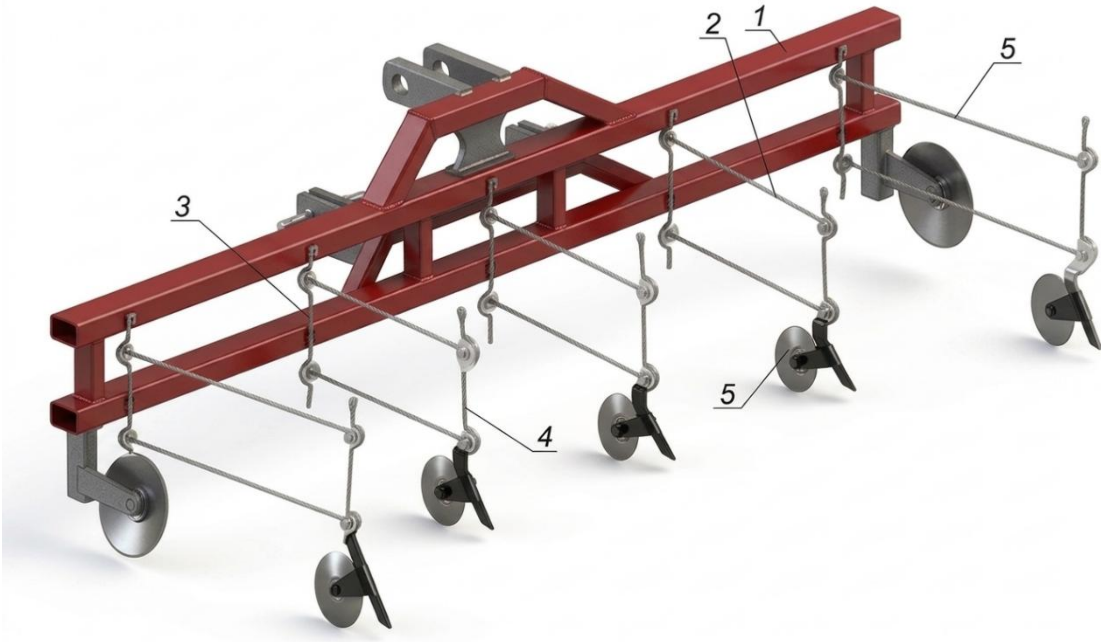


Figure 2. Scheme of the combined parallelogram mechanism with the frame of the improved tiller.

Stage 3. Connecting the working bodies of the parallelogram mechanism and installing the central beams

At this stage, the parallelogram mechanism, which is the main working part of the machine, is transferred to the final assembly process. That is, central beams (working elements) are installed on the lower and outer ends of the movable brackets and a reliable kinematic connection is created with them.

The central harrows are the main working bodies that directly work with the soil, performing functions such as entering between rows, cutting weeds, loosening the soil and leveling the surface. Their installation ensures that the parallelogram mechanism constantly keeps the working bodies at a specified depth and angle during movement [13].

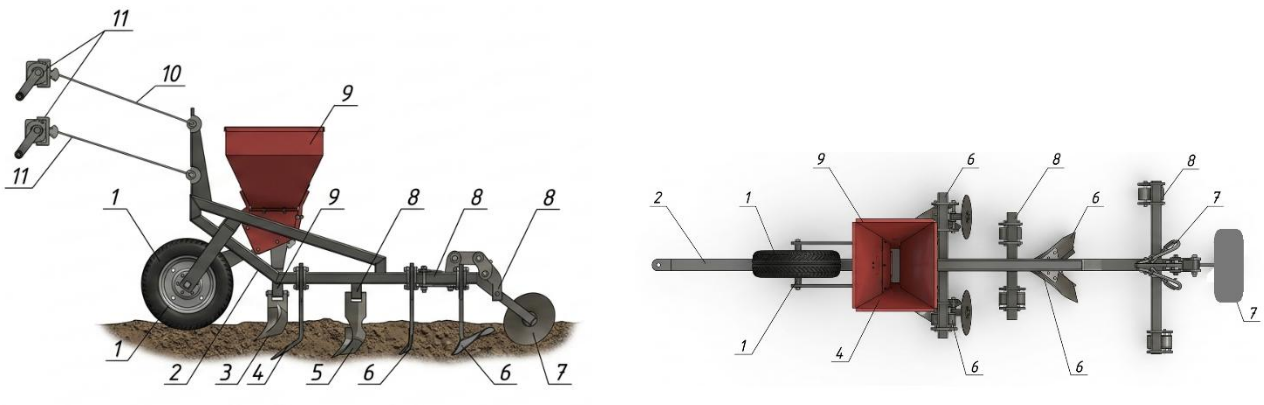
The connection between the movable brackets and the central beams is designed in such a way that they compensate for vertical and horizontal vibrations. As a result, the working bodies adapt to changes in the terrain and maintain a stable operating mode relative to the soil surface. This ensures uniform processing quality and reduced energy consumption.

Figure 3 shows two different structural views of the central beams, which represent the following:

- The first view – a working element in the form of a simple disk or blade;
- The second version is a reinforced, improved version that combines a guiding and cutting function.

The use of these two options is selected depending on the type of soil being cultivated, its moisture level and agrotechnical requirements. As a result, the versatility of the unit increases and it can be used in various

The use of these two options is selected depending on the type of soil being cultivated, its moisture level and agrotechnical requirements. As a result, the versatility of the unit increases and effective operation in various conditions is ensured.



a b

a-side view, b-top view of the central ridge

1-base wheel, 2-central beam, 3,5-rotary softeners, 4,6-deep softeners, 7-water ditch opener, 8-transverse beams, 9-pulleys, 10-parallelogram mechanism, 11-frame, 12-locks

Scheme of the central beam and the location of the working bodies in it

Cross beams 2 are attached to the central beams (60×60 in size), which ensure the strength of the structure and the stable location of the working elements. Each cross beam is equipped with locks 3 that slide in the horizontal direction, which allow flexible positioning of the working elements both in the forward and reverse directions. This increases the quick adaptability of the unit to various agrotechnical conditions.

Softeners 6, deep softeners 7, and irrigation ditch openers 8 are installed in special grooves in the central ridge body, and their location is clearly shown in the side view of the central ridge.

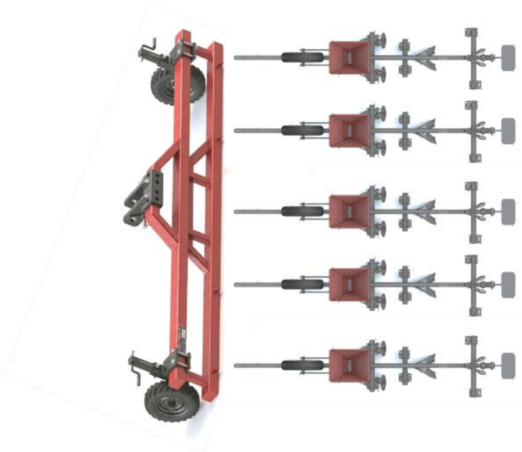
Three successively arranged deep looseners are installed in the central part, which loosen the soil to depths of 6…8 cm, 10 cm and 10 cm, respectively, relative to the surface on which the support wheel moves [14]. These depths remain unchanged regardless of the height at which the support wheel moves above the soil surface, which ensures the stability of the processing quality.

The placement of the deep looseners at a distance of 10 cm from each other serves to gradually distribute the load during operation. As a result, the resistance to each working element is reduced, the demand for traction is reduced, and the overall energy efficiency of the cultivator is increased.

Using locks installed on the cross beams, the working elements used in traditional cultivators can also be adapted and installed, and they will fully fulfill their functions.

The working elements mounted on the central beam are selected depending on the technology of inter-row processing: the necessary elements are brought into working position, and the rest are kept in a raised position during the work process.

Step 4. The front part of the assembled central beam is connected to the end of the movable bracket of the parallelogram mechanism, ensuring the flexible and stable operation of the entire system.



Stage 5. Installation of auxiliary devices and final equipment of the unit. This stage involves the installation of auxiliary mechanisms and devices that serve to increase the working efficiency of the sectional improved tiller. These devices serve to ensure stable, reliable and safe operation of the unit in both transport and working modes.

First of all, special lifting and locking mechanisms are installed to lift the working sections up in the transport position of the unit, firmly fix them, and prevent damage to the working parts during transportation in the field. This mechanism significantly increases the compactness of the unit and transport safety.

A system for implementing the crop feeding process is also integrated. In this system, a mechanical transmission that transmits movement from the support wheel to the dosing mechanism in the bunkers plays a key role [15]. In this case, the rotational movement of the wheel is transmitted to the dosing axis continuously and in a precise ratio, ensuring a stable and uniform distribution of the fertilizer application rate.

The cultivator created on the basis of the developed project is characterized by the complex implementation of the processes of inter-row cultivation of cotton, deep loosening of the soil and simultaneous application of mineral fertilizers. Therefore, it is appropriate to characterize this unit as a structurally combined and improved stubble cultivator.

4. Conclusion

1. The developed improved design of the tiller cultivator is capable of not only ensuring high-quality processing of rows, but also simultaneously performing the feeding process by introducing mineral fertilizers to a specified depth and zone, and serves as a combined unit that performs complex agrotechnical operations.
2. The use of the proposed combined cultivator reduces the number of technological operations in agricultural production, thereby reducing the number of trips of the unit across the field, resulting in significant savings in fuel and lubricants and preventing soil compaction. At the same time, favorable agrotechnical conditions are created for the preservation of the physical and mechanical properties of the soil and the development of the plant root system.

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