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SELECTION OF INPUT MAGNITUDE FOR INVESTIGATING KINEMATIC AND STRUCTURAL PARAMETERS OF VSH PTM ELLIPTICAL DRUM COTTON PICKING APPARATUS

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Abstract: This article investigates the selection of an input indicator for studying the kinematic and structural parameters of an elliptical drum in a vertical-spindle cotton-picking apparatus. The relevance of the study is associated with the need to improve the completeness and quality of mechanised cotton harvesting. The aim is to substantiate apparatus parameters through an assessment of field agrotechnical conditions. The research is based on field observations conducted during the 2025 harvesting season. The number of cotton plants and open bolls was recorded in three-metre row sections. The least-squares method was applied to process the collected data. A positive linear relationship between plant number and open-boll count was identified. The scientific novelty lies in proposing a regression-based approach that uses field indicators to select elliptical-drum parameters.

Keywords: cotton-picking apparatus, elliptical drum, vertical spindle, kinematic parameter, structural parameter, open boll, experimental design, least-squares method, regression model.

Annotatsiya: Mazkur maqolada vertikal shpindelli paxta terish apparati elliptik barabanining kinematik va konstruktiv parametrlarini tadqiq etish uchun kirish ko'rsatkichini tanlash masalasi ko'rib chiqilgan. Tadqiqotning dolzarbligi paxtani mexanizatsiyalashgan usulda sifatli va to'liq terish zarurati bilan izohlanadi. Ishning maqsadi paxtazorning agroteknik holatini baholash orqali apparat parametrlarini asoslashdan iborat. Tadqiqot 2025-yilgi dala kuzatuvlari ma'lumotlari asosida amalga oshirildi. Uch metrli qator kesimlaridagi paxta o'simliklari va ochilgan ko'saklar soni o'rganildi. Ma'lumotlarga eng kichik kvadratlar usuli qo'llanildi. Natijada o'simliklar soni va ochilgan ko'saklar soni o'rtasida ijobiy chiziqli bog'lanish aniqlandi. Ilmiy yangilik elliptik baraban parametrlarini tanlashda dala agroteknik ko'rsatkichlariga asoslangan regressiya yondashuvi taklif etilgani bilan belgilanadi.

Kalit so'zlar: paxta terish apparati, elliptik baraban, vertikal shpindel, kinematik parametr, konstruktiv parametr, ochilgan ko'sak, eksperimentni rejalashtirish, eng kichik kvadratlar usuli, regressiya modeli.

Аннотация: В статье рассмотрен вопрос выбора входного показателя для исследования кинематических и конструктивных параметров эллиптического барабана вертикально-шпиндельного хлопкоуборочного аппарата. Актуальность исследования связана с необходимостью повышения полноты и качества механизированной уборки хлопка. Цель работы состоит в обосновании параметров аппарата на основе оценки агротехнического состояния хлопкового поля. Исследование выполнено по материалам полевых наблюдений 2025 года. На трёхметровых

участках рядов определялись количество растений хлопчатника и число раскрытых коробочек. Для обработки данных использован метод наименьших квадратов. В результате установлена положительная линейная связь между числом растений и количеством раскрытых коробочек. Научная новизна заключается в применении регрессионного подхода, основанного на полевых агротехнических показателях, при выборе параметров эллиптического барабана.

Ключевые слова: хлопкоуборочный аппарат, эллиптический барабан, вертикальный шпиндель, кинематический параметр, конструктивный параметр, раскрытая коробочка, планирование эксперимента, метод наименьших квадратов, регрессионная модель.

INTRODUCTION

The quality of picking performed by vertical-spindle (VS) cotton picking machines (CPM) is shaped largely by the design of the spindle drum, the machine's principal working unit. How the spindles interact with cotton bolls - spindle dimensions and rotational speed, the gaps left between neighbouring spindles, their orientation relative to the bolls, among other traits - governs picking quality to a large degree [4,5,6]. At the same time, cotton agrotechnology has changed considerably in recent years, so understanding how field agronomic conditions affect the required structural characteristics of the machine has become just as important for using picking equipment efficiently.

Prior work has shown that a VS picker's efficiency hinges on two things: how many spindles are engaged in the picking zone at any given moment, and how much contact area those spindles maintain with the plant [1,2,5]. Extensive research and design experience further indicate that the spindle drums built into current VS machines constrain how freely spindle trajectory, kinematic mode, and spacing - all decisive for picking efficiency - can be adjusted. Packing more spindles into a drum of fixed diameter forces the gaps between them to shrink, which in turn lowers cotton quality and raises material costs for the drum; enlarging the diameter instead to fit additional spindles pushes both material use and energy consumption upward, and a wider drum is also harder to fit between the cotton rows [7].

One promising route toward better picking completeness and work quality is to replace the standard spindle drum with an elliptical one. Our earlier work already showed that reworking the vertical-spindle drum mechanism structurally can raise both picking completeness and overall work quality [7]; by varying the dimensions of the redesigned components, we were able to identify workable spacing between spindle centres and suitable kinematic parameters. That earlier study, however, stopped short of relating the factors that matter for picking efficiency to actual field agronomic conditions.

Fitting a picking apparatus with elliptical spindles is expected to improve picking completeness because more spindles operate simultaneously and their kinematic modes can be tuned more freely. But as noted above, an elliptical-drum machine's performance is not governed by structural and kinematic design alone - field agronomic conditions matter too, including cotton variety, boll size, plant architecture, degree of leaf drop, boll density along the row, and the spacing between bolls. Because these traits vary somewhat randomly from field to field, they need to be accounted for when the drum is designed [8].

A body of research links machine picking completeness and quality directly to the number of spindles working at once and their spacing [5,7,9,10]. Spacing of 60–80 mm between spindles has previously been associated with both high picking completeness and good cotton quality [9]. Conventional vertical-spindle drums, limited in how many spindles can work simultaneously and in their contact area with cotton, often struggle to reach adequate picking completeness once yields climb to 40 c/ha or beyond [5]. Elliptical drums get around this: spindle spacing varies through the rotation, so the 60–80 mm spacing is preserved in the zone of contact with the cotton, while the contact area and the number of actively engaged spindles both rise by 20–25%. This makes the elliptical-drum apparatus a realistic option even under high-yield conditions.

An experimental prototype built around an elliptical drum was assembled at the Department of Ground Transport Systems, Tashkent State Technical University, and went through initial field trials during the 2025 harvest. These trials confirmed that the machine works as intended, and a preliminary look at the results puts average picking completeness at 91–93%.

Because the parameters of an elliptical drum vary and each one affects picking completeness in its own way, gauging the size of these effects calls for field experiments built on formal experimental design and statistical analysis. Efficient mechanized cotton picking also depends on the bolls being ready for machine harvesting and on the field carrying sufficient yield potential [8]. The conventional way to judge a field's readiness - counting plants along several 3-metre row sections and estimating average yield from that - is sensitive to the exact timing of the count and does not always track true yield conditions closely.

A better approach takes the plant's developmental stage into account: building a regression relationship between the number of bolls counted in a 3-metre section and the number of those bolls already open lets us

estimate actual yield and use that estimate as an input when choosing rational machine parameters.

REVIEW OF LITERATURE ON THE SUBJECT

The technological foundations of cotton-picking-machine working units have been investigated in numerous studies. Azarov and Arzumanyants considered devices for adapting cotton-picking-machine apparatuses to ridge topography [1]. Abdazimov, Radjabov, and Omonov developed methods and software tools for the rapid computer-aided assessment of agronomic indicators related to cotton-picking machines [2].

Rizaev investigated the development of high-efficiency cotton-picking working units and identified design characteristics that influence harvesting performance [5]. Ravutov justified the main parameters of the cotton-picking zone in spindle apparatuses with elliptical drums, providing a scientific basis for the development of elliptical-drum harvesting units [6].

Shpolyanskij established technological principles for selecting working-unit parameters and cotton-picker schemes. His findings indicate that spindle spacing and the interaction between spindles and cotton bolls are important factors affecting picking completeness and seed-cotton quality [9]. Sablikov also examined the structural and technological characteristics of cotton-picking machines, including the operation of spindle-based harvesting units [10].

Ravutov, Rizayev, and Rajapbaev analysed ways to improve the efficiency of vertical-spindle cotton-picker spindles and stressed the role of rational geometric and kinematic parameters [7]. Studies of drum-drive systems have additionally identified the limitations of multistage mechanical transmissions and proposed electrified solutions that allow more flexible control of drum speed [11].

Kuldoshev and Djurayeva examined the mechanical action of the spindle and stripper on cotton-seed damage, demonstrating that optimisation must address both picking completeness and seed-cotton quality [12]. Baratov's research on spindle kinematic schemes also confirms the need to evaluate spindle trajectories and operating modes when selecting cotton-picker parameters [13].

The reviewed literature shows that the construction, spindle arrangement, drive system, and kinematic mode of vertical-spindle units have been widely investigated. However, the use of field-based indicators, particularly the relationship between plant density and open-boll count, as an input variable for substantiating elliptical-drum parameters has received insufficient attention. This study addresses that issue by linking field conditions with the experimental investigation of the elliptical-drum apparatus.

RESEARCH METHODOLOGY

Field experiments were carried out during the 2025 cotton-harvesting season in the cotton fields of "GTG AGROSERVICE" LLC. The experimental design included 50 replications, where each replication represented a three-metre row section. The purpose of the measurements was to characterise field conditions and obtain an input indicator for subsequent studies of the elliptical-drum cotton-picking apparatus.

The relationship between the number of cotton plants in a three-metre row section and the number of open bolls in the same section was examined. In this study, n_p denotes the number of cotton plants per three metres and n_b denotes the number of open bolls per three metres.

A linear relationship was assumed in the form:

$$n_b = a + b \cdot n_p$$

ANALYSIS AND RESULTS

The field measurements for ten three-metre row sections are presented in Table 1. The data include the number of cotton plants and the corresponding number of open bolls (Table 1).

Table 1. Field measurement results for three-metre row sections¹

Indicator	1	2	3	4	5	6	7	8	9	10
Number of cotton plants, n_p	40	25	31	27	35	28	33	25	30	34
Number of open bolls, n_b	641	572	558	567	634	476	597	486	622	638

The least-squares calculations produced the following aggregate values:

$$\Sigma x = 308, \quad \Sigma y = 5791, \quad \Sigma x^2 = 9694, \quad \Sigma xy = 180268.$$

The normal equations for the linear regression model were formulated as follows:

¹ Source: Compiled by the author.

$$9694b + 308a - 180268 = 0$$

$$308b + 10a - 5791 = 0$$

Solving the system resulted in $b = 9.18$ and $a = 296.3$. The regression equation was therefore obtained as:

$$n_b = 296.3 + 9.18 \cdot n_p$$

The positive coefficient $b = 9.18$ indicates that, on average, one additional cotton plant in a three-metre row section corresponds to an increase of approximately 9.18 open bolls. This result indicates a positive relationship between plant density and the number of open bolls under the observed field conditions (Figure 1).

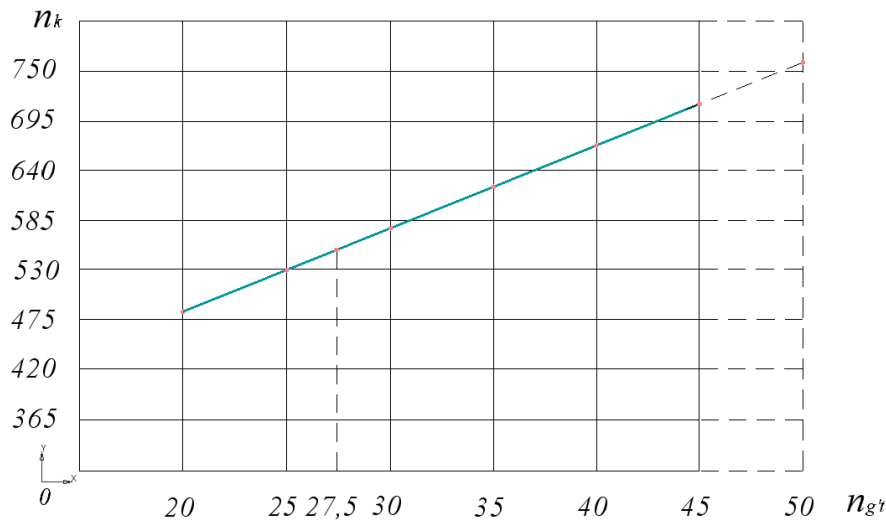


Figure 1. Regression graph of the dependence of the number of bolls per 3 m (n_k) on the number of cotton plants per 3 m² (n_{gt})

The regression model can be used as an input parameter when planning experiments on elliptical-drum cotton-picking apparatuses. It provides a practical means of estimating the boll-opening condition of a field based on plant-density observations. Such an estimate can support the selection of rational drum geometry, spindle spacing, spindle rotational speed, and other operating parameters.

The experimental prototype of the elliptical-drum apparatus was assembled at the Department of Ground Transport Systems of Tashkent State Technical University and underwent preliminary field trials during the 2025 harvesting season. The trials indicated that the apparatus operated as intended, with preliminary average picking completeness reported at 91–93%. Further experiments should assess how the number of active spindles, spindle spacing, drum geometry, and rotational speed jointly influence picking completeness and seed-cotton quality under different plant-density and yield conditions.

CONCLUSIONS AND SUGGESTIONS

The study established a linear relationship between the number of cotton plants and the number of open bolls in three-metre row sections. The relationship was determined using the least-squares method and is expressed by the regression equation $n_b = 296.3 + 9.18n_p$.

The positive regression coefficient indicates that an increase in the number of cotton plants is associated with an increase in the number of open bolls under the observed field conditions. This relationship can be used to estimate the field condition before harvesting and to generate input data for the experimental investigation of cotton-picking apparatuses with elliptical spindle drums.

The proposed approach links agrotechnical field indicators with the structural and kinematic parameters of the harvesting unit. It can support the selection of rational spindle spacing, drum geometry, rotational speed, and the number of spindles operating in the picking zone.

Future research should use the complete dataset from all 50 field replications and apply multifactor experimental design to quantify the combined effects of plant density, drum geometry, spindle motion, spindle spacing, and rotational speed on picking completeness, seed-cotton quality, and seed damage.

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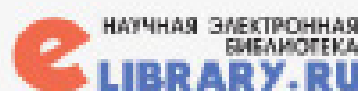
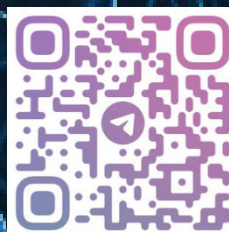
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