SUITABILITY CRITERIA FOR HARVESTING BY COTTON PICKERS WITH VERTICAL SPINDLE

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Abstract. The issues of increasing productivity and improving the cotton harvesters manufactured nowadays are discussed in the paper. The main factors affecting the technological process are the characteristics and criteria for assessing the suitability of different cotton varieties for machine harvesting. Research conducted in this direction is presented. The criteria of the estimation adaptation cotton plants to machine harvesting with vertical spindle harvesting apparatuses: by wide of the cotton plant's bush; by height of location of the lower boll of cotton and by dimension of feature of green and opened boll.

Keywords: adaptation, machine harvesting, cotton plant, bushes and bolls, cotton picker, criterion, sagging arrow, bolls diameters.

Introduction. In the agricultural engineering industry of the Republic of Uzbekistan, large-scale measures are being taken to increase the efficiency of use and development of agricultural machinery equipped with special working bodies designed for certain conditions. The Development Strategy of the Republic of Uzbekistan for 2017-2021 provides for, in particular, "...modernization and intensive development of agriculture ...widespread introduction of intensive methods in agricultural production, primarily modern water and resource-saving agricultural technologies, the use of high-performance agricultural equipment" [1].

To accomplish these tasks, it is important to determine the suitability for mechanized harvesting of zoned and promising cotton varieties in Uzbekistan; to develop the criteria for the adaptiveness of these varieties for machine harvesting and to increase the efficiency of cotton harvesting machines (CHM) and picking units that provide high-quality harvesting and are equipped with modern smart systems of automatic control and management.

Many scientific researchers in our republic and abroad are engaged in research on improving the design of cotton-picking machines, studying performance indices, substantiating the parameters, assessing the suitability of CHM working bodies for different cotton varieties [2].

However, the properties of new cotton varieties introduced in farms in conditions of modern market and ownership relations have not been sufficiently studied in these researches. Poorly studied are the issues of developing the suitability criteria of cotton varieties for machine harvesting [3], of machine equipping with modern systems of automatic control and management, substantiation of parameters and modes of cotton harvesting apparatus.

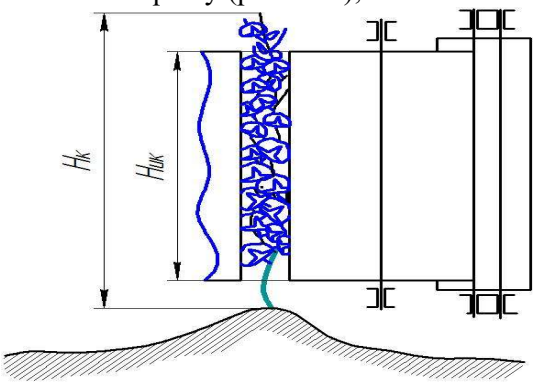
Currently, the agricultural industry of the Republic of Uzbekistan is gradually moving into a cluster-based production system. This involves the design, manufacture and operation of competitive, modern agricultural machinery of various brands with high productivity and reliability, meeting the technical requirements of the clusters. For the farms in our republic, it is advisable to produce the CHM that meet the requirements of adaptability of working bodies parameters to cotton varieties, yield, harvesting time, row spacing, CHM with vertical-spindle (VS), equipped with Systems of Automatic Control and Management (SAC and M), providing crop retrieval and quality.

At increasing completeness of harvesting by CHM with VS and gain quality indexex of harvesting cotton yield it should be reconsidered all factors such as disposition of spindles, width of working chamber, action and state of cotton balls in process of harvest, meeting cotton balls with spindle and time and state of collecting cotton of opened balls by spindle, dimensions of cotton bush and cotton balls in the working chamber, as well as physical and mechanical properties of cotton balls, generally each of all factors which participate in the technological process of CHM. At fulfillment of such difficult multiplex and factor task we used method of system approach [2]. Thus item outputs estimating conformity to CHM (q_1,...,$q_к$) – are criterions. They may be of different quantitative and qualitative indexes depending on type of CPM, most of them have one side limitation.

Methods. Item output of the model (q_1,...,$q_к$) criterions – estimating conformity to harvesting of CPM of sort are as follows:

q_1 – height of cotton plant $H_к$, on width (breadth) $B_г$ and on form - cotton plant must be taller from working chamber of apparatus cotton picker at least to 200...250mm, i.e. $\frac{H_к}{H_{ик}} \le 1{,}2...1{,}3$, if it will increased this height, cotton plant will enter to the working chamber with big bend and will cause detrimental effect to agronomic indexes. For harvesting the cotton by spindles to the maximum it will be purposeful that cotton plant will be near the cylinder form (picture 1);

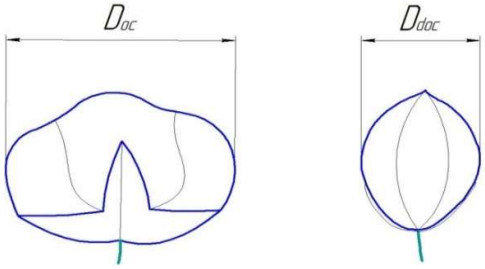
q_2 - $H_{пк}$ – location of cotton balls in cotton plant – height of the lowest ball on the cotton plant from surface of cultivation furrow should not be less than $H_{lb} \ge 80$ mm and it is purposeful that location of balls be along the height of cotton plant distributed equally (picture 1);



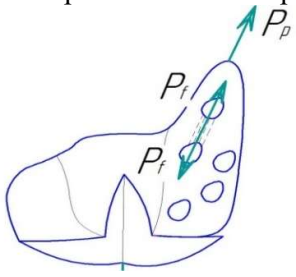
Picture 1. Diagram of location the cotton plant and cotton balls refer to harvesting apparatus

q_3 - $t_{ко}$ – ball's quickness of opening - opening of almost all balls of cotton plant in short term ($t_{qo} \le 10$ day) opening is one of the criterions of estimation of conformity for machine harvesting;

q_4 – O_{bok} – ratio coefficient ball's of opening – it is purposeful that the ratio of diameter of opened ball's to not opened ball diameter to be $\frac{D_{ob}}{D_{gb}} \ge 1{,}6$, depending on the most higher degree of this ratio the possibility of meeting the spindles with opened balls will raise, the damage of green balls will be decreased, this criterion also is valuable for CHM with VS (if it will operate in the field where balls did not opened to 100%) (picture 2);



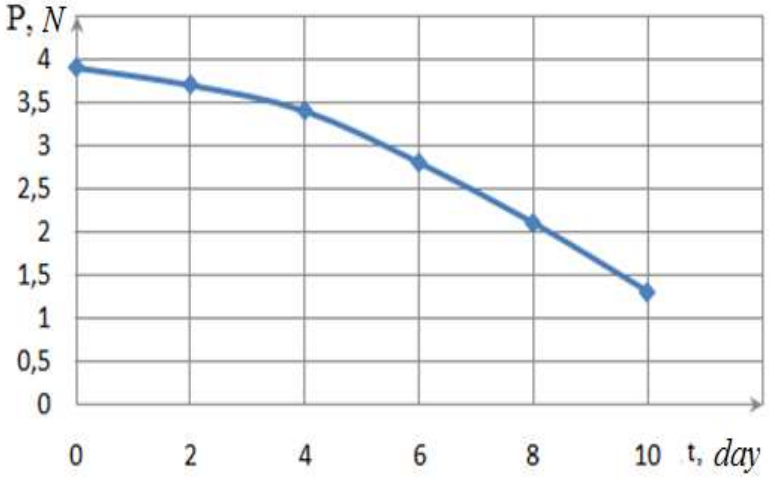
Picture 2. Diagram of dimensions of opened and don't opened (green) cotton balls



Picture 3. Diagram of forth of connection between cotton-seeds in balls and cotton plate

q_5 – P_f – mutual connection forth of cotton-seeds and of piece of cotton in balls and in cotton plate – forth of connection between the cotton-seeds in cotton balls P_f and forth of connection of cotton plate with cotton ball must be 1,3...1,4 times bigger re P_p ($\frac{P_f}{P_p} \geq 1{,}3$), if this condition will be fulfilled the cotton will be taken out from cotton balls without tear it off (picture 3).

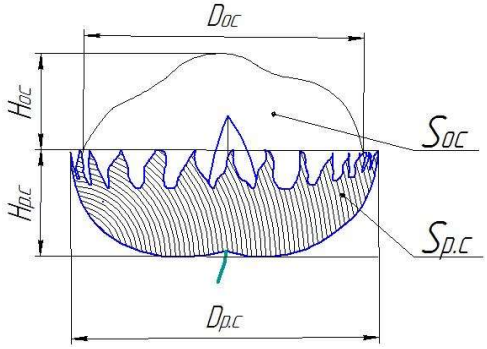
q_6 - P_p – stability of forth of connection of seed with cotton plate (speed of decreasing) – decreasing this force during 10 days must not exceed to 3 times re the day of cotton opening, otherwise natural falling out of cotton plate in the piece of ball will happen (picture 4);



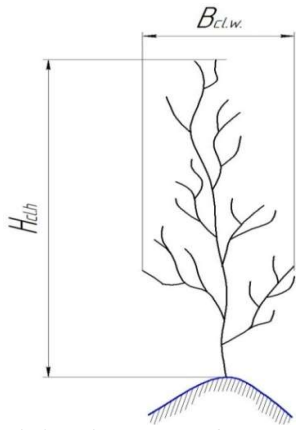
Picture 4. Diagram of time dependence of the dependence forth of cotton plate with cotton ball (speed of decreasing)

q_7 – $S_{p.c.}$– degree of closing of opened balls with petals – aggregate of petals total surface re total surface of opened cotton must be ($\frac{S_{p.c}}{S_{oc}} \leq 30\%$) less to 30 %, thus the less this percent will be, the possibility of meeting spindle with opened balls will be increased, if otherwise the degree of closing of balls by petals is high, spindles will grasp petals together with cotton in balls and dirtiness of harvested cotton will increased (picture 5).

q_8 - B – lateral development of cotton plant (monopodial or sympodial) – if the amount of side boughs grown from the main plant of cotton (monopodia) is less or cotton balls are grown out of the main bines (sympodia), the crop of this sort shall meet qualitative effective harvesting with BS of CHM (at a agrotechnical requirements degree) (picture 6).



Picture 5. Diagram of definition of closing ratio of opened balls by petals



Picture 6. Diagram of lateral development of cotton plant (monopodial or sympodial)

Theoretical research was made out of the above given criterion on estimation of conformity of different sorts of cotton to harvesting by machines on criterion of difference of dimensions and forms of cotton plant, height of the lowest cotton ball from the surface of a furrow, diameters of disclosed or closed balls.

It is known that the diameters of opened and green bolls obey the law of normal distribution [3]. According to this criterion, to assess the suitability of cotton varieties for machine harvesting, the calculated diameters of the bolls are obtained, which ensure absolute accuracy according to the law of normal distribution from its center to B_{min} $3.9\sigma_{ob}$, $\frac{\alpha - \overline{d}_{gb}}{\sigma_{gb}} = 1.89$ and as a result, $\alpha - \overline{d}_{gb} = 1.89\sigma_{gb}$ is obtained.

The resulting expression for determining the boll estimated diameter D_{ob}^{o} by assessing the suitability of various varieties of cotton for machine harvesting has the following form

$$D_{ob}^{o} \geq \overline{d}_{gb} + 1.89\sigma_{gb} + 3.9\sigma_{ob} \quad (1)$$

Here σ_{gb} –is the mean square deviation of the diameter of green bolls; $\overline{d}_{gb}$ - is the diameter of a green boll; $\overline{d}_{gb}$ - is the average value of the diameter of green boll; σ_{ob} - is the standard deviation of the diameter of open bolls.

The suitability criterion for machine harvesting according to the diameters of bolls of certain selective varieties is established by the following expression

$$K_d = \frac{\overline{D}_{ob}}{D_{ob}^{o}} \geq 1. \quad (2)$$

Here $\overline{D}_{ob}$ –is the average value of the diameter of open bolls.

Results. The results of studies of dimensional characteristics based on the suitability criteria of the cotton variety crops harvested by machines. The suitability of certain zoned cotton varieties was assessed: early-ripening ones - Sultan, Namangan-77, An-Bayaut 2, S-4727; mid-ripening ones - Bukhoro-6, S-6524 and the promising one - UzPITI-201 to be harvested by CHM with VS. The criterion was assessed based on the determination of statistical indices of cotton bush according to the height of the lowest bolls from the bed surface and to the size of open and green bolls.

Based on the developed criteria, the suitability coefficients (K_d) for more than 20 cotton varieties were determined by the difference in diameters of open and unopen bolls. It was established that the cotton varieties Sultan, Namangan-77, S-4727, Porlok-1, Porlok-2, Bukhoro-6, Bukhoro-8, UzPITI-201, Gulbakhor-2 have a greater suitability coefficient than other varieties, i.e., the suitability of these varieties for the harvesting by the CHM with VS is higher.

Based on the study of the bonding force between the cotton slivers and the valves and the bond between the pappi, an improved laboratory setup was designed and manufactured to determine the bond breaking

strength of the sliver and the valves and the bond strength between the pappi; the experiments were carried out on this setup. The experiments showed that the requirements of criterion $P_p > P_s$ for the need that the value of the bonding force between the slivers and pappi P_p should exceed the value of the bonding force between the valve and the slivers P_s are fulfilled after the 6th day of the cotton bolls opening.

The condition of the agricultural background during the harvesting process (cotton variety, size, degree of bolls opening and their size, height of the lowest bolls, leaves, etc.) significantly affects the agrotechnical indicators of the CHM. The main technological parameters of the CHM are the accuracy of the harvesting machines motion along the row-spacing, the height from the bed surface; correct choice of the width of working gap ensures an increase in agrotechnical indicators and in reliability of the CHM technological process. Due to the fact that CHM are still equipped with SAC and M with low reliable mechanical measuring transducers (MT) in order to replace then with non-mechanical ones, i.e. contactless optical MT, for these systems (controlling the CHM motion along the row-spacing, the working gap and height of the harvester relative to the field surface), it became necessary to select the input values. Research was conducted to determine the mutual correlation dependences of the parameters of the cotton bush.

According to the suitability criteria for machine harvesting, the average value of the distance from the top of the bed to the lowest boll h_a, and the standard deviation (σ) were determined by the height of the lower bolls on the cotton bush relative to the bed surface to assess the suitability of the cotton variety for machine harvesting. That is, we can proceed to determine Δ of the lower bolls, located lower than 80 mm from the bed surface. Numerical integration was used to determine Δ

$$\Delta = \int_0^{80} \frac{1}{h\sigma\sqrt{2\pi}} e^{-\frac{(\ln h - h_a)^2}{2\sigma^2}} . \quad (3)$$

The Δ value thus determined is the value of the part of bolls of their total number N = 1. In many varieties, the location of the lowest bolls (80 mm) differs from the standard one, so this criterion is of comparative nature.

According to the results of studies, it was determined that there is a high correlation between the height of the cotton bush and the height of the lowest bolls.

The results obtained make it possible to adopt the height of the highest bolls as an input parameter for modern contactlessly operating optical sensors. Recommendations were developed on the choice of input values for CHM automatic driving systems along the beds and adjusting the working gap.

For the control and management of technological parameters, it is advisable to commercially produce the CHM with VS equipped with the following main SAC and M:

The height of the harvester from the bed surface;

Automatic driving system for driving along the cotton rows;

System of automatic adjustment of the working gap width of the harvester;

Kinematic parameters of the unit;

Hopper and pneumatic transport filling system.

At present, the work is underway with the author's participation to substantiate the schemes and parameters of smart SAC and M of the CHM with VS, to create trial models and conduct tests; these studies will continue in the future.

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