Investigating the rationale of dimensional elements in the ripper of a combined unit

Anvar Xudayarov1, Ibrohimjon Nazirjonov1, Ikrom Abdimominov2, Matluba Yuldasheva2

Andijan branch of Research Institute of Forestry, Andijan, Uzbekistan
Andijan Institute of Agriculture and Agrotechnologies, Andijan, Uzbekistan

Abstract. The article describes a technology for minimizing tillage when growing cotton in rows and calculates the dimensions of the ripper parameters of the combined unit that uses this technology. Based on the results of the experiment, these calculations showed that the ripper's working surface length should not be less than 150 mm and its coverage width should not exceed 140 mm in order to ensure soil softening and prevent ditch compaction beneath the processed layer.

1. Introduction

In the world, the production and use of energy-saving, high-performance machines used in the cultivation of agricultural land occupies a leading position. Currently, the agriculture of the entire planet uses 1.8 billion hectares of land cultivated for growing crops, of which an average of 120 million hectares are sown with crops that require cultivation of beds, so we can say that the creation and development of energy-efficient, high-quality and productive machines, used in soil cultivation and cultivation, are of great importance throughout the world.

Worldwide research efforts are focused on developing new scientific and technical underpinnings for combined units that use resource-efficient technologies to prepare cotton fields for planting in a single pass [1-5]. Current tasks in this direction include developing a combined unit that implements the processes of deep softening of the soil without turning it over, layering fertilizers on the softened area, and forming beds on the softened and fertilized layer [6-9], as well as studying the characteristics of its working parts, as well as conducting targeted research to determine the optimal values of the sizes of working bodies [10-12], which will allow resource efficiency in the process of interaction with the soil.

A minimal tillage technique for growing cotton in beds is applied in the fall, when the previous year's cotton-free rows are loosened to a depth of 30–40 cm without being turned over. The loose area is then fertilized in two layers using the belt method, with the top of the loose layer and the bottom at a height of 30–40 cm from it. Old beds are pushed onto these loose and fertilized areas, and new ones, 25–30 cm high, are formed, taking the place of the raised part of the bed. When growing cotton in beds, the proposed technology for field preparation is different from existing methods in that it loosens the soil without tipping plowing and does not require harrowing or crushing. This results in a notable decrease in labor, energy, fuel, and lubricant costs, as well as a sharp reduction in the number of unit passes across the field (from 6-7 to 2 times).

2. Research methods

The established methods for assessing the energy consumption of machines included strain gauge methods, mathematical statistics, theoretical mechanics laws and regulations, agricultural mechanics, mathematical planning of experiments, and testing of agricultural machinery, deep tillage machines and tools, testing procedures and programs, and agricultural technologies.

Experimental studies were carried out on cotton fields freed from the cotton harvest, with a row spacing of 90 cm. The soil of the experimental fields is gray soil of medium-heavy mechanical composition with groundwater occurring at a depth of 10–12 m.

Before conducting the experiments, soil moisture, density and hardness were determined. These indicators were studied in layers of 0–10 cm, 10–20 cm, 20–30 cm and 30–40 cm in rows, beds and outer rows.

*Corresponding author: anvarjon@gmail.com
To conduct experimental studies, the design of a combined unit was developed and its prototype was manufactured (Figure 1), as well as softeners with different geometric shapes of the working surface, length and width.

The traction resistance of the working parts, the quality of soil adhesion, the width and depth of the loosened layer were taken as evaluation criteria during the experiments.

The main working parts of the combined unit are a ripper, which loosens the soil without turning it over, a device for applying fertilizer in a belt manner to the loose layer, as well as shock receivers, which form beds on top of the loose and fertilized layer.

3. Results

Ripper width

Theoretical and experimental results are used to validate the dimensions of a combined aggregate ripper. Research has indicated that soil loosening occurs down to a "critical" depth. Below this depth, a compacted "bottom" with tight walls forms without allowing the soil to come loose, disrupting the soil's water-air balance and requiring unnecessary energy to cultivate (Figure 2).

Consequently, for high-quality loosening of the soil with less energy, the critical loosening depth of the working body $h_{kr}$ must be equal to or greater than the tillage depth $h_{t}$, that is, $h_{kr} \geq h_{t}$. The critical depth of loosening depends on the physical and mechanical properties of the soil, the shape and parameters of the working body and can be found using the following expression:

$$h_{kr} \geq \frac{b_{so}}{m + \tan \alpha_{so}}$$

where, $\sigma_e$ - the specific resistance of soil to crushing; $\xi$ - angle of deviation of the resultant forces acting on the soil relative to the horizon; $n$, $m$ - coefficients without a unit of measurement, depending on the physical and mechanical properties of the soil.

Taking into account expression (1), we can solve expression (2) with respect to $b_{so}$, and thus we obtain:

$$h_{kr} \geq \frac{\frac{\sigma_e}{\xi} (1 + \tan \xi) - n}{m + \tan \alpha_{so}}$$
From this expression it is clear that the width of the ripper depends primarily on the depth of processing, the physical and mechanical properties of the soil and the angle of entry of the working body into the soil. Based on the sources, it was accepted that $m = 4.2; \sigma_e = 1.44 \times 10^6 \text{Pa}$ and $\tau_k = 2 \times 10^4 \text{Pa}$, accepted $n = 2.5$, according to expression (2) it is established that the width of the ripper must be at least 140 mm to ensure softening of the bottom of the bed at a depth of 30-40 cm without the formation of walls of compacted furrows.

Based on the results of theoretical studies, in experiments the width of the ripper coating was tested with changes from 100 mm to 220 mm with an interval of 40 mm (Figure 3).

![Fig. 3. Rippers with wide 100mm (1), 140mm (2), 180mm (3) and 220mm (4)](image)

The tests were carried out at unit speeds of 5.0 and 7.0 km/h. The results of the experiments are reflected in Table 1 and Figure 4 below.

**Table 1. Performance characteristics of rippers of different widths**

<table>
<thead>
<tr>
<th>Width of ripper, mm</th>
<th>Speed, km/h</th>
<th>The number of fractions of the following sizes (mm), %</th>
<th>The depth of the softened layer, cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>5.0</td>
<td>&gt;100</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>7.0</td>
<td>&lt;50</td>
<td>80.80</td>
</tr>
<tr>
<td>140</td>
<td>5.0</td>
<td>&gt;100</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>7.0</td>
<td>&lt;50</td>
<td>81.60</td>
</tr>
<tr>
<td>180</td>
<td>5.0</td>
<td>&gt;100</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>7.0</td>
<td>&lt;50</td>
<td>81.30</td>
</tr>
<tr>
<td>220</td>
<td>5.0</td>
<td>&gt;100</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>7.0</td>
<td>&lt;50</td>
<td>80.80</td>
</tr>
</tbody>
</table>

The results revealed that increasing the width of the ripper (from 100 mm to 50 mm of the treated layer) resulted in a decrease in the quality of the cultivated soil due to an increase in the number of soil blocks (fractions), and in cases...
less than 50 mm, a decrease in the number of fractions. This is explained by the fact that as the width of the loosening coating rises, so does the zone of soil deformation and the probability of growing soil blocks being displaced. However, expanding the ripper's width from 100 mm to 220 mm had no significant influence on the depth of its immersion into the ground; with increasing speed, this indicator decreased in all variants within 0.5-0.8 cm. This can be explained by an increase in the pushing torque unit from the soil, due to the increase in ripper resistance to traction resistance with increasing speed.

According to the data provided, the width of the softener should not be less than 140 mm in order to ensure complete softening of the inner part of the furrow, since \( b < 140 \) mm, the bottom of the treated layer does not soften properly, as shown in Figure (3), a small ditch is formed in it equal to the width of the working body. This kind of bed is deemed inappropriate since it causes the soil’s mechanical and physical qualities to deteriorate and wastes energy.

A decrease in the width of the loose layer with increasing speed is associated with a decrease in the time of the soil’s interaction with the working body, and an increase in resistance to the ripper stretching is associated with an increase in the volume of soil deformed by the working body. Meanwhile, an increase in the ripper’s width is linked to both its tensile resistance and an increase in the width of the loose layer. The results revealed that in order to provide thorough soil softening without compacting the furrows, the width of the ripper coating should be at least 140 mm.

3.1 Ripper working surface length

The softener’s working surface length is determined using the figure shown in Figure (5). It is very evident that the softener’s working surface length \( L \geq AD \) must match or exceed the \( AD \) value:

\[
AD \geq AO \sin \alpha + \psi
\]

When \( AD \leq AO \), the soil is not adequately distorted by the working body, the ensuing tension does not reach a critical point, and the soil is not enough loosened and crushed as a result. Therefore, using the sine theorem, we can derive the following from the triangle \( AOD \):

\[
\frac{AD}{\sin \psi} = \frac{AO}{\sin (\alpha + \psi)}
\]

\[
AD = \frac{AO \sin \psi}{\sin (\alpha + \psi)}
\]

Fig. 5. Soil deformation under the action of the working body and decomposition processes

\[
L \geq AD
\]
\[ L \geq \frac{S \cdot (\alpha + \varphi + \varphi)}{\left[ \alpha - (\varphi + \varphi) \right]} \]

\[ L \geq \sqrt{\frac{\left[ \tau_c \right] \left[ \beta \left( \alpha + \varphi + \varphi \right) + h t g \left( \frac{\pi - \varphi}{2} \right) \right] h \left( \varphi + \varphi - \alpha \right)}{q \left( \alpha + K_v V \right) b \left( \alpha - \varphi + \varphi \right) \left[ \left( \alpha + \varphi \right) + \varphi \right] \left( \alpha + \varphi \right)}} \]

\[ \text{Table 2. Performance characteristics of rippers with different working surface lengths} \]

<table>
<thead>
<tr>
<th>Length of the working surface of the ripper, mm</th>
<th>speed km/h</th>
<th>The number of fractions of the following sizes (mm), %</th>
<th>The depth of the softened layer, cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>5.0</td>
<td>10,87, 13,53, 75,60</td>
<td>&gt;100</td>
</tr>
<tr>
<td></td>
<td>7.0</td>
<td>8,86, 13,56, 77,58</td>
<td>100-50</td>
</tr>
<tr>
<td>150</td>
<td>5.0</td>
<td>8,42, 14,64, 76,84</td>
<td>&gt;50</td>
</tr>
<tr>
<td></td>
<td>7.0</td>
<td>7,03, 14,34, 78,03</td>
<td>50-20</td>
</tr>
<tr>
<td>200</td>
<td>5.0</td>
<td>6,89, 14,77, 78,34</td>
<td>&gt;20</td>
</tr>
<tr>
<td></td>
<td>7.0</td>
<td>6,33, 13,76, 79,91</td>
<td>20-10</td>
</tr>
<tr>
<td>250</td>
<td>5.0</td>
<td>6,50, 14,70, 78,80</td>
<td>&gt;10</td>
</tr>
<tr>
<td></td>
<td>7.0</td>
<td>5,48, 13,85, 80,67</td>
<td>10-0</td>
</tr>
</tbody>
</table>

From the data given in the table, it is clear that increasing the length of the working surface of the ripper from 10 cm to 20 cm led to an improvement in the quality of loosening the soil, an increase in the width of the loosening layer, and also to an increase in the tensile resistance of the working body. These indicators change little when the length of the working surface of the softener increases from 20 cm to 25 cm.

If with an increase in the length of the plasticizer, an increase in its tensile strength, as well as the width of the softened layer, is associated with an increase in the volume of soil deformed by the working element, then with an increase in

Fig. 6. Rippers length 100mm (1), 150mm (2), 200mm (3) and 250mm (4)
4. Conclusion

According to theoretical and experimental results, the breadth of the ripper coating should be at least 150 mm. Analysis of the obtained theoretical and experimental results showed that to ensure loosening of the soil in the lower part of the treated layer without the formation of compressed furrows, the length of the ripper's working surface must be at least 150 mm to ensure soil loosening at the bottom of the treated layer without causing the formation of compacted furrows. Simultaneous manipulations carried out during the main and pre-sowing tillage ar

References

A. Tustakuziev, A.N. Khudoerov. Theory of movement of private soil on the working surface of a spherical disk. Technique in agriculture 2 (2009), 139-142.


