Substantiation of the parameters of the rotary ripper of the machine for pre-seeding treatment of ridges

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Abstract. Taking into account the fact that the ridge technology of cultivating crops is becoming widespread in the country, and there are no special technical means for pre-sowing treatment, a machine has been developed for processing ridges along their entire profile in one pass, consisting of a frame and support wheels mounted on it, lancet paws, rotary rippers and slatted rollers. The article presents the results of theoretical and experimental studies to substantiate the parameters of the rotary cultivator of the developed machine. According to the results of the research, it was found that for the qualitative implementation of the technological process of processing the slopes of the ridges and ensuring the required quality of soil crumbling on them, the length of the bar of the rotary cultivator must be at least 320 mm, the small and large diameters of its conical rollers, respectively, within 200-250 mm and 400- 450 mm, the number of its slats is 12-14 pieces, the width of the slats is 30-32 mm, as well as the vertical load on it in the range of 0.50-0.60 kN, the longitudinal distance between the lancet share and the rotary ripper is 60 cm .

1. Introduction

According to the Ministry of Agriculture of the Republic of Uzbekistan, in recent years, cultivation of agricultural crops on ridges has become widespread in the country. Increased soil temperature on the ridges, better aeration, as well as optimal soil density create favorable conditions for early and friendly shoots, as well as plant growth and development.

As a rule, the ridges for the cultivation of crops are formed in the fall, and in the spring, pre-sowing treatment is first carried out, and then the seeds are sown on their top [1].

At present, pre-sowing treatment of ridges is carried out mainly by mounted harrows in an aggregate with row-crop tractors. But they do not provide processing of ridges along their entire profile. As a result, a moisture-saving mulch layer is not created on the slopes and in the furrows of the ridges and weeds are not completely destroyed. This leads to weed clogging of the ridges and loss of moisture. In addition, the use of tooth harrows leads to the destruction of the profile of the ridges and, especially, to a decrease in their height. This negatively affects the uniformity of seed germination, the development and productivity of agricultural crops.

Based on the foregoing, we have developed a machine for pre-sowing treatment of ridges, protected by patents of the Republic of Uzbekistan No. FAP 00753, No. FAP 00888, No. FAP 01071

and No. IAP 05829 [2-5]. The machine consists of a frame and lancet shares mounted on it, processing the bottom of the furrow of the ridges to a depth of 8-12 cm, rotary rippers and slatted rollers, processing the slopes and tops of the ridges, respectively, to a depth of 4-6 cm (figure 1).

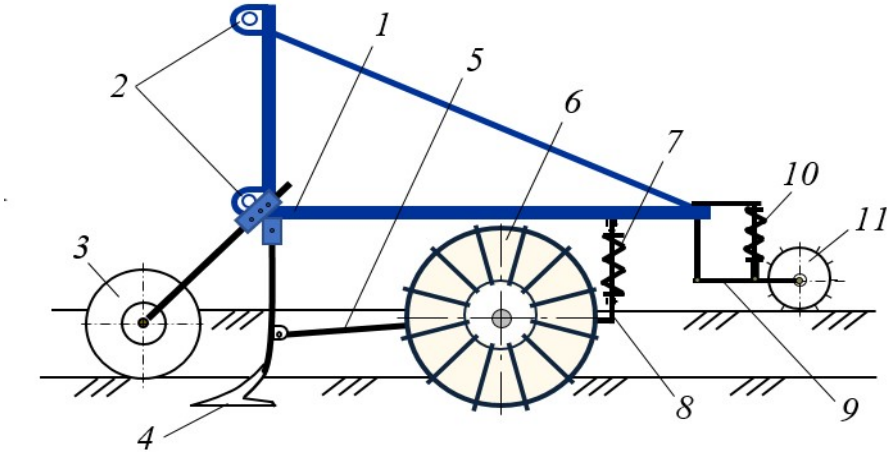


Figure 1. Structural scheme of the machine for pre-sowing ridges processing: 1 - frame; 2 - hinged device; 3 - support wheel; 4 - lancet paw; 5, 9 - thrust; 6 - rotary ripper; 7, 10 - pressure spring; 8 - guide; 11 - slatted roller.

The lancet paws of the developed machine are rigidly mounted on the frame, and the rotary rippers and slatted rollers are hinged by means of rods.

The rotary ripper (figure 2) of the machine consists of left and right conical rollers, axles on which they are installed, bases with small and large diameters (discs), slats, and in the process, they process the slopes of adjacent ridges.

The following are the main parameters of the rotary ripper: small *(d)* and large *(D)* diameters of the rotary ripper cone rollers; length (l_s), width (h_s) and number (n) of the rink slats; vertical load on the rotary ripper (Q_p), as well as the longitudinal distance (L) between the wing share and the rotary ripper.

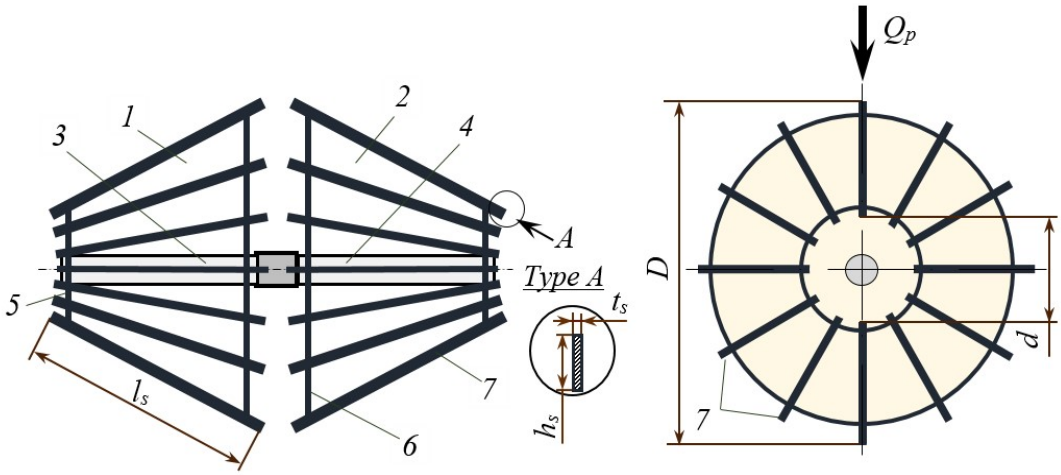


Figure 2. Scheme and parameters of a rotary ripper: 1, 2 - left and right conical rollers; 3, 4 - axes for installing rollers; 5 – base with small diameter; 6 - base with a large diameter; 7 – slats.

2. Materials and methods

In the process of research to justify the parameters of the rotary cultivator, the developed machine, the laws and rules of theoretical mechanics, mathematical statistics, as well as the methods given in the existing regulatory documents [6-8] were applied.

3. Results and Discussion

The length of the slats of the rollers of the rotary ripper was determined from the condition of ensuring complete processing of the slopes of the ridges and the following expression was obtained:

$$l_{nл} \geq \frac{h_{max}}{\sin\varepsilon} - \frac{(0.5B + hctg\psi)\sin\psi}{\sin(\psi - \varepsilon)}, \quad (1)$$

Where h_{max} – is the maximum height of the ridges during spring processing, m; B – sweep width of the lancet paw, m; ψ – angle of lateral shearing of the soil, degree; ε – is the angle of the slope of the ridge to the horizon, degree.

To determine the small and large diameter of the conical rollers of a rotary cultivator, from the condition of rolling them over the encountered lumps, the following expressions were obtained:

$$d = \frac{\left[1 + \cos(\varphi + \rho)\right]\ d_k + 2h}{1 - \cos(\varphi + \rho)} - l_s \sin\varepsilon \quad (2)$$

And

$$D = \frac{\left[1 + \cos(\varphi + \rho)\right]\ d_k + 2h}{1 - \cos(\varphi + \rho)} + l_s \sin\varepsilon \quad (3)$$

Where φ, ρ – are the external and internal soil friction angles, degrees; d_k – is the average diameter of lumps encountered on the path of the rink, m; h – depth of immersion of the slats of the rink in the soil, m.

The number of slats of the rotary ripper rollers is determined from the condition of ensuring their reliable rotation during operation and the following expression is obtained:

$$n \geq 360\ ^\circ : \left(\arccos \frac{\left[\frac{(d + D)}{2}\right] + l_s \sin\ \varepsilon - 2h}{\left[\frac{(d + D)}{2}\right] + l_s \sin\ \varepsilon} \right) \quad (4)$$

The vertical load applied to the rotary ripper was determined from the condition of immersion of its conical rollers to a given processing depth according to the expression (figure 3).

$$Q_p = 2q_0(1 + k_v V)\left\{h + \left[h - \left(0.5\frac{(d + D)}{2}\right)\left(1 - \cos\frac{360\ ^\circ}{n}\right)\right]\cos\frac{360\ ^\circ}{n}\right\} \times l_s t_s \cos\varepsilon \quad (5)$$

Where q_0 – is the coefficient of static volumetric soil collapse; k_v – is the coefficient of proportionality; V – is the unit movement speed, m/s; $t_{nл}$ –is the thickness of the slats of the rollers, m.

The performed calculations according to expressions (1)-(7) at h_{max}=0.26 m, h=0.1 m, h=0.05 m, B=0.14 m, d_k=0.1 m, φ=30°, ρ=40°, q_0=2·10^6 N/m^3, t_s=0.006 m, m_p=20 kg and ε=32º showed that the length of the slats of the rollers should be at least 320 mm, and their minimum and maximum

diameters, respectively, should be at least 180 and 440 mm, the number of slats should be at least 10 pieces, the vertical load applied to the rotary cultivator during operation speeds of 1.7-2.5 m/s (6-9 km/h) should be within 0.53-0.66 kN.

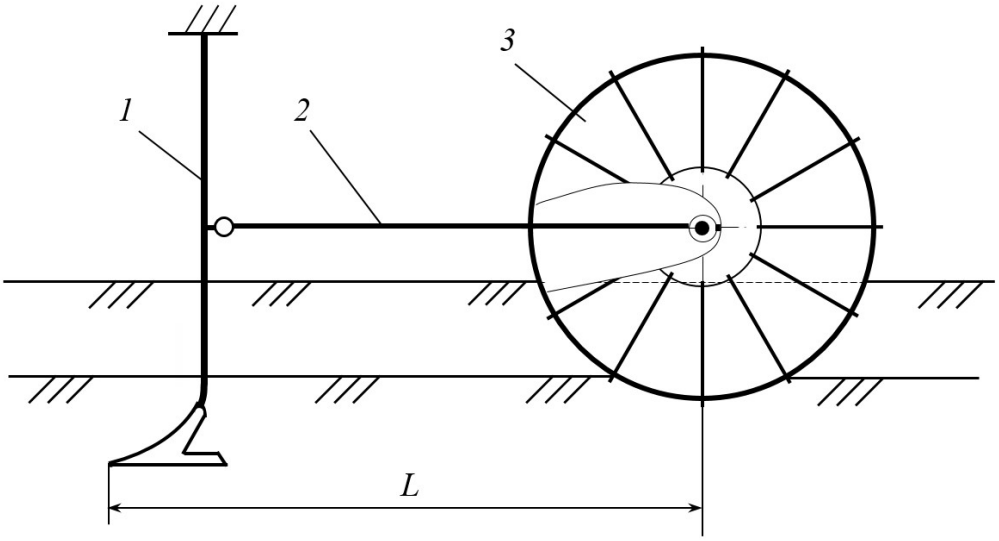


Figure 3. Scheme for determining the vertical load on a rotary cultivator: 1 - lancet paw; 2 - longitudinal thrust; 3 - rotary ripper.

The longitudinal distance between the lancet share and the rotary ripper was determined from the condition that the rollers of the rotary cultivator act on the soil particles coming off the lancet share after they fall to the bottom of the furrow or the slope of the ridge, because otherwise, the technological process of the tool operation will be disrupted, as a result, the soil particles coming off the lancet paw are not sufficiently loosened by the rotary cultivator. Taking into account the above, to determine the distance L, the following expression is obtained:

$$L \geq \frac{V}{g\cos\varphi}\left\{1-\frac{\sin arctg\,(tg\beta\sin\gamma)}{\cos\varphi}\sin\left[arctg\,(tg\beta\sin\gamma)+\varphi\right]\right\}\times$$
$$\times\left\{ V\sin arctg\,(tg\beta\sin\gamma)\cos\left[arctg\,(tg\beta\sin\gamma)+\varphi\right]+\right.$$
$$\left.+\sqrt{V^2\sin^2\beta\cos^2\left[arctg\,(tg\beta\sin\gamma)+\varphi\right]+2gh\cos^2\varphi}\;\right\}+ \quad (6)$$
$$+\frac{1}{2}\sqrt{D^2-d^2}+l_y\cos arctg\,(tg\beta\sin\gamma).$$

Where β – is the angle of crumbling of the lancet paw, degree; γ – is half the angle of opening of the wings of the lancet paw, degree; l_y –is the length of the toe of the lancet paw.

Assuming β=25º, φ=25º, γ=35º, V=2.0 m/s, g=9.81 m/s^2, d=0.2 m, D=0.4 m and l_y=0.14 m according to expression (8), we obtain that the longitudinal distance between the lancet share and the rotary ripper at a working speed of 2.0 m/s should be at least 68.3 cm.

In order to verify the results of theoretical studies, experimental studies were carried out to study the influence of the parameters of the rotary cultivator of the machine for seedbed treatment of ridges on its performance.

Before carrying out experimental studies in horizons of 0-10 and 10-20 cm, soil moisture content on ridges and furrows was, respectively, within 11.41-18.91 and 15.12-19.45%, density - within 1.16-1 .35 and 1.20-1.52 g/cm^3, and hardness is within 0.32-1.02 and 0.53-1.41 MPa [6]. The height of the ridges by the period of spring cultivation compared with the period of autumn formation decreased by an average of 3.76-6.75 cm, the angle of the slopes of the ridges to the horizon decreased by 5-6º, weed infestation during the period of pre-sowing cultivation averaged 24.3 -42.7 pieces/m^2.

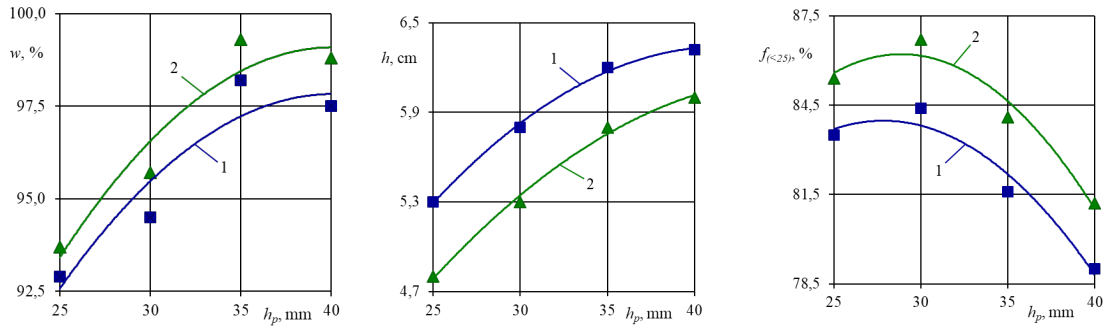
To conduct experimental research on a rotary ripper, its experimental sample was developed and manufactured, which allows changing the small and large diameters of the rollers, as well as the number and width of the slats on it.

When conducting experimental studies [7-8], the degree of weed destruction, the depth of cultivation and the degree of crumbling of the soil were taken as an evaluation criterion, that is the content of fractions smaller than 25 mm on the slopes of the ridges [9-10]. The experiments were carried out at unit speeds of 1.7 and 2.5 m/s.

The results of experimental studies are shown in the table, as well as in figures 4-7.

Table 1. Influence of small and large diameters of rotary rollers ripper on the performance of its work.

Rotary ripper roller diameters, mm		The degree of destruction of weeds, %	Depth of processing, cm		Soil crumbling quality, %		
					fraction sizes, mm		
min	max		M_{av}	±σ	>50	50-25	<25
			V= 1.7 m/s				
100	300	91.5	6.4	0.60	3.7	6.8	89.5
150	350	94.0	5.2	0.63	2.2	5.4	92.4
200	400	95.8	4.8	0.76	1.7	5.6	92.7
250	450	96.5	4.6	1.21	2.1	5.9	92.0
			V= 2.5 m/s				
100	300	92.4	6.2	0.88	2.7	4.7	92.6
150	350	95.2	5.1	0.92	0.9	4.6	94.5
200	400	97.3	4.6	0.97	1.5	4.3	94.2
250	450	97.8	4.3	0.74	1.8	4.4	93.8



a) b) c)

Figure 4. Graphs of changes in the degree of destruction of weeds (a), the depth of processing (b) and the degree of crumbling of the soil (c) depending on the width of the slats of the rotary cultivator rollers: 1 and 2 - respectively, at the unit speed of 1.7 and 2.5 m/s.

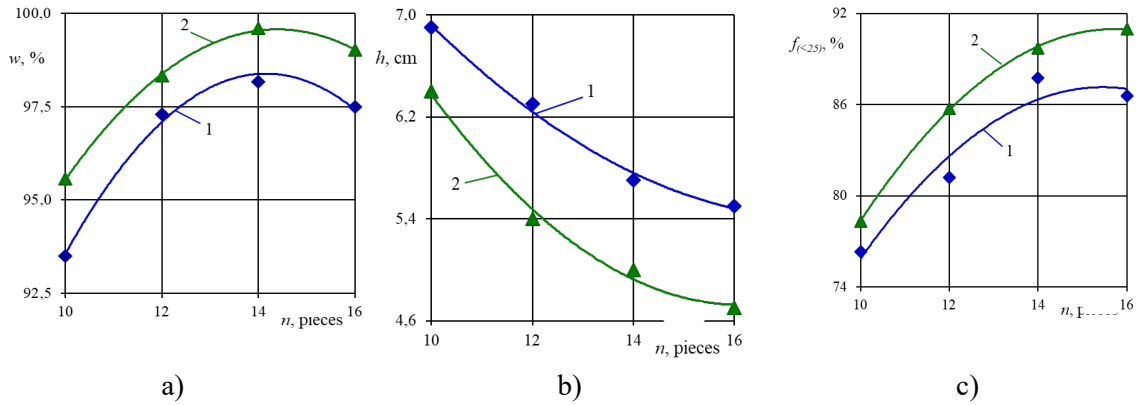


Figure 5. Graphs of changes in the degree of weed destruction (a), the depth of processing (b) and the degree of crumbling of the soil (c) depending on the number of slats of the rotary cultivator rollers: 1 and 2 - respectively, at the unit speed of 1.7 and 2.5 m/s.

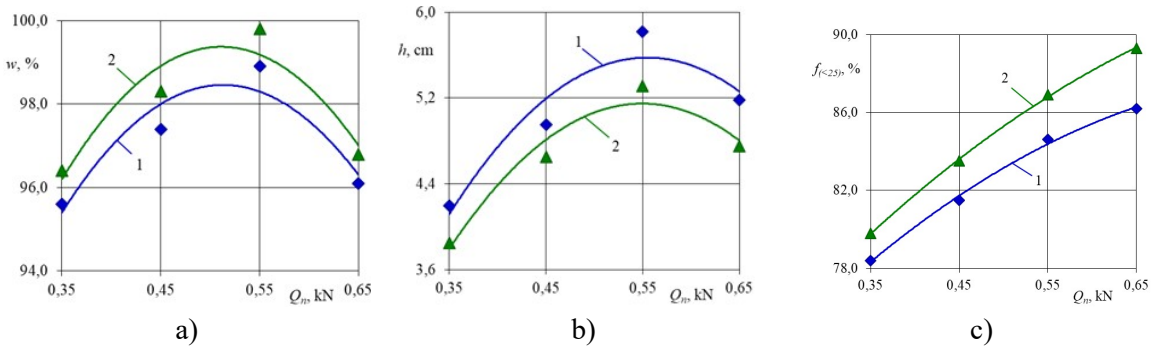


Figure 6. Graphs of changes in the degree of destruction of weeds (a), the depth of processing (b) and the degree of crumbling of the soil (c) depending on: 1 and 2 - respectively, at the unit speed of 1.7 and 2.5 m/s.

Analysis of the results of the experiments showed that with the length of the slats of the conical rollers of the rotary cultivator at least 320 mm, their small and large diameters in the range of 200-250 mm and 400-450 mm, respectively, the number of slats is 12-14 pieces, their width is 30- 32 mm, vertical load on the rotary cultivator in the range of 0.50-0.60 kN provides the required degree of weed control, tillage depth and degree of soil crumbling, that is the content of fractions with sizes less than 25 mm on the slopes of the ridges. These obtained results fully correspond to the results of theoretical studies.

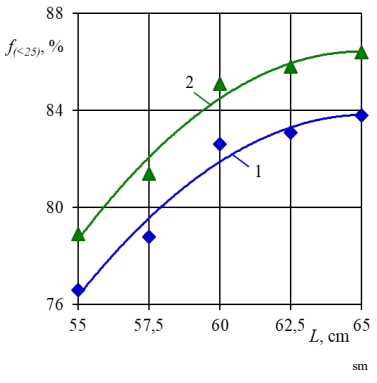


Figure 7. Graph of change in the degree of crumbling of the soil (F<25) depending on the longitudinal distance (L) between the lancet share and the rotary cultivator: 1 and 2 - respectively at a speed movement unit 1.7 and 2.5 m/s.

From the results of studying the effect of the longitudinal distance between the lancet share and the rotary ripper on the performance of the tool, it follows (figure 7) that this distance should be at least 60 cm. Otherwise, soil particles coming off the working surface of the lancet share will interact with rollers of a rotary cultivator until they fall to the bottom of the furrow and, as a result, the degree of crumbling of the soil worsens.

4. Conclusion

As the results of the theoretical and experimental studies show, with the length of the slats of the conical rollers of the rotary ripper at least 320 mm, its small and large diameters, respectively, 200-250 mm and 400-450 mm, the number of its slats 12-14 pieces, the width of the slats 30-32 mm , as well as a vertical load on it in the range of 0.50-0.60 kN, the high-quality implementation of the technological process of processing the slopes of the ridges is ensured, and also with a longitudinal distance between the lancet share and the rotary ripper of at least 60 cm, the possibility of high-quality crumbling of the soil on the slopes of the ridges is created.

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