ANTI-EROSION TWO-STAGE TILLAGE BY RIPPER

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Abstract
The aim of the research is to develop a technology and a two-stage ripper for protection of soil from wind and water erosion, as well as improves the accumulation and preservation of soil moisture. The authors proposed a technology of two-stage moldboardless loosening slopes' soil and a cultivator for its implementation. The design of the developed two-stage ripper with the working bodies of the "paraplau" type is given. The type of working bodies and their mutual arrangement were substantiated via theoretical studies. It has been established that the plow scheme with the upper and lower working bodies alternation with the lower bend of the rack is the most rational design scheme of a two-stage ripper with working bodies of "paraplau" type. High-quality loosening with the lowest energy costs is provided with longitudinal and transverse distances between the working bodies of 0.50-0.60 m and 0.35-0.40 m, and field board's width and length are 0.7 m and 0.16 m respectively. The rational values of the loosening plate's parameters were substantiated by theoretical and experimental studies: the maximum plate's installation angle to the surface of the rack is 25°, the plate's length and width are 0.12-0.15 m and 0.9-0.12 m respectively.

Key words: *wind erosion; slope; paraplau; chissel; soil protection.*

INTRODUCTION

Soil erosion is a major environmental threat to the sustainability and productive capacity of agriculture. During 40 years in 1955-1995, nearly one-third of the world's arable land has been lost by erosion. Potential for water and wind erosion of soil is highest in arid and semiarid regions in which located Uzbekistan. In recent years, erosion has caused considerable damage to Uzbekistan's agriculture. Excessive soil tillage in cultivating different crops leads to the spread of wind and water erosion of soil. Because of soil erosion in individual farms, crop yields are sharply reduced. The lightening of the mechanical composition and repeated blowing, in the strong wind zones is result in a sharp decrease in humus, nitrogen and phosphorus in soil. Wind erosion in arid and semiarid zones also increase ambient air pollution by particulate matters *(Lal, 2017; Amonov, Pulatov, & Colvin, 2006; Stetler, & Saxton, 1996; Pimentel, Harvey, Resosudarmo, Sinclair, Kurz, McNair, & Blair, 1995; Khamraev, Nasriddinov, & Nasriddinov, 1989; Mirzajonov, 1981)*.

In this regard, research is aimed to improving the tillage process by developing new technologies for moldboard less tillage of eroded soils and creating technical means to protect the soil from wind and water erosion. In addition, new tillage technology reducing energy costs of tillage, improving the accumulation and preservation of soil moisture.

MATERIALS AND METHODS

The work was carried out using the basic principles and methods of classical mechanics, statistics, and experiment based on mathematical planning, as well as general methods to determine the machines' agro technical, energy and economic performance.

In order to prevent wind and water erosion on sloping lands, a new technology was developed that allows obtaining a stepped bottom of the furrow, which contributes to the retention and accumulation of soil water, especially during heavy rainfall. A two-stage ripper with upper and lower loosening working bodies of the "paraplau" type was developed for implementation of this technology *(Mamatov & Mirzayev, 2013; Mirzaev, Mamatov, Avazov, & Mardonov, 2019; Mirzaev, Mamatov, & Tursunov, 2019)*. It includes a frame 1, on which working bodies 2 and 3 are successively and alternately installed (Fig. 1). Each working body of the "paraplau" type consists of a rack 4 inclined in the transverse vertical plane and a knife 5, chisels 6, a field board 7 and a loosening plate 8 fixed on it.

Each working body of the “paraplau” type consists of a rack 4 inclined in the transverse vertical platan where knife 5, chisels 6, field board 7 and loosening plate 8 are fixed on it. The rack’s inclined part of the working body 2 is made with a smaller height, and the inclined part of the working body 3 is made with a greater height. On the working body 3 with a greater height, the loosening plate is fixed at the level of the loosening plate of the working body with a lower height.

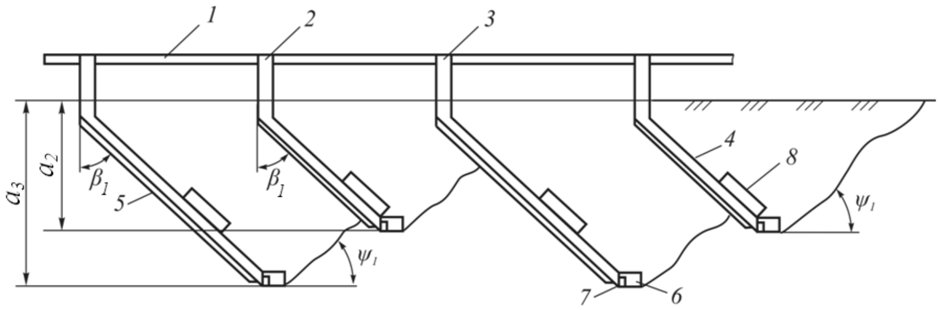

Fig. 1 Technological working process of a two-stage ripper

A stepped bottom of the furrow with periodic indentations (intra soil ridges) intersecting a densified sole is obtained after passing a two-stage ripper. Intrasoil ridges contribute to the complete retention and accumulation of soil water (particularly after heavy rainfall) and water erosion is prevented accordingly.

RESULTS AND DISCUSSION

The loosening plate’s angle ε of installation to the rack’s surface, its length l_R and width b_R, length l_{pd} and width b_{pd} of the field board, the value of the inter-legged working bodies *M* and the longitudinal distance *L* between them are the main parameters of the ripper with working bodies such as "paraplau" (Fig.2.). Loosening technological parameters that determine its effectiveness are the depth and quality of the loosening, the distance between the loosened strips, the width and depth of subsoil stage loosened at the bottom of furrow.

The area of soil’s loosened zone of the arable and subsurface layers affects, on the one hand, the energy intensity of tillage, and on the other hand, the ability to retain and accumulate of soil water. Therefore, to select the layout of the working bodies and other parameters of a two-stage cultivator, we investigated their effect on the loosening fullness, the depth of the step and the distance between the loosened strips.

The quality of soil loosening was assessed by fullness of loosening, i.e. the loosening coefficient η, representing the ratio of the loosened soil zone area F_1 to the total area *F*, located in platan perpendicular to the direction of ripper’s movement, limited by working width of grip B_p and maximum loosening depth, i.e. depth processing a_h of the lower working body, i.e. $\eta = F_1/F$ *(Mamatov & Mirzayev, 2014a).*

The energy intensity of tillage was evaluated by the two-stage ripper’s resistivity, i.e. $K=P/F$, where *P* – two-stage ripper’s traction resistance; *F* – total area of the arable and subsurface layers loosened part *(Mamatov & Mirzayev, 2014c).*

The angle that meets these conditions is determined from the following relation: $\varepsilon \leq (\pi/2 - \varphi_{\max})/2$, where $\varphi_{\max}$ – maximum angle of soil friction with the plate’s working surface, at $\varphi_{\max} \approx 40^{\circ}$ angle $\varepsilon \leq 25^{\circ}$.

The loosening plate’s greatest length l_R was found (condition: excluding soil loading in front of the plate and moving the soil by the plate to the surface of arable land) by the following expressions *(Mamatov & Mirzayev, 2014b):*

$$l_R \leq \frac{2\sigma \cos\varphi}{q \sin(\varepsilon + \varphi)}, \quad (1)$$

q – coefficient of volumetric crumpling of soil, N/m^3; σ – temporary soil resistance to compression, Pa; φ – soil friction angle on metal, gr.

Taking into account the conditions for ensuring agrotechnical requirements for the ridges' height formed between the aisles of upper working bodies, the below formula was obtained to determine a lateral distance between the working bodies:

$$M = 2na_2 ctg\psi_1 + b_d, \qquad (2)$$

where n – ridge's permissible height ratio to the depth processing of the upper working body.
While determining the longitudinal distance between the working bodies, the tool's condition from being clogged by plant residues and soil was taken into account. (Fig. 3). Below equation was obtained to determine the minimum distance between the working bodies of a two-stage ripper:

$$L_2 \geq (a_3 - a_1)ctg\psi + \frac{\sigma}{\gamma g(1+\frac{W}{100})} ctg(\alpha_d + \varphi)\cos\alpha_d + (a_3 - a_1 - h)tg\beta_1, \qquad (3)$$

where a_1 – depth of the rack's straight part immersion into the soil, m; ψ – soil spalling longitudinal ; W – soil moisture, %; h – lift height chisels, m; α_d – crumbling chisels angle, gr.

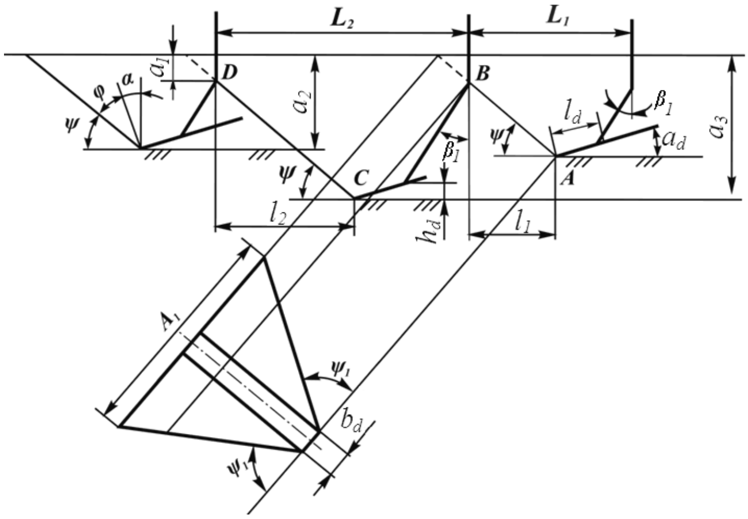

Fig. 2 Scheme for defining the soil deformation zone by the working bodies of a two-stage ripper

Field boards play a central role to support a two-stage ripper and ensure the stability of its travel across the grip's width and the straightness of the unit's movement in a horizontal platan. The field board's width should be less than or equal to the chisel's height h, otherwise the soil coming from the chisel will fall on it, which will lead to an increase in the ripper's resistance. Thus, we have: $b_{pd} \leq h = 0{,}072m$, $b_{pd} = 0{,}07$ m.

The field board length was determined based on the condition that its pressure on the furrow's wall does not exceed a permissible value:

$$l_{pd} \geq \frac{\eta K a_m b_k \sin(\alpha + \theta)\cos\varphi}{[p]\cos\theta\cos(\alpha + \varphi)}, \qquad (4)$$

where K – soil resistivity while loosening, Pa; η – ripper's coefficient; φ –friction angle on field board, gr; a_m – average depth of processing ripper, m; b_k – grip width of the working body, m; $[p]$ – permissible value of the field board's specific pressure on the furrow wall, Pa; α – the ripper thrust line angle , gr; θ – angle between the resultant force direction on the working body and the translational motion of the ripper, gr.
35 m, $[p]=5\cdot10^4$ Pa; $K=5\cdot10^4$ Pa; $\theta=20^\circ$ length $l_{pd} \geq 0{,}16$ m.
To select a type of working body with an inclined rack, the experimental studies of two types of working bodies were carried out: with upper inflection of the rack (above the surface of tillage); with lower inflection of the rack (under the surface of tillage). The studies demonstrated that both types of working bodies on agrotechnical and energy indicators differ slightly from each other. Therefore, we have chosen a working body with a lower inflection, since it is possible to install a disk knife vertically in front of it.
The results from experimental studies showed that soil crumbling, stubble conservation, soil surface

crests and specific traction resistance, as well as the reliability of the ripper, depend on the transverse and longitudinal distances between the working bodies. With a transverse distance between the working bodies of 0.35 and 0.40 m and a longitudinal distance of 0.50-0.60 m, all agrotechnical indicators of a two-stage ripper were observed, the clogging of its working bodies did not occur.
Comparative experimental studies of various schemes for a two-tiered ripper revealed that a two-stage ripper with alternating upper and lower working bodies is the most appropriate. As well as, two-tier ripper with alternating upper and lower working bodies has a lower specific traction resistance by 21.75% compared to a ripper with two lower working bodies.
The results also showed that initially, the working body's traction resistance slightly increased with increasing angle ε of the loosening plate to the rack surface from 5 to 15º, a further increase in the angle ε led to its intensive increase. The drag resistance increased more intensively at high speeds by increasing angle ε. As the angle increased from 5 to 25º, the degree of soil loosening improved. However, a soil displacement towards the furrow was observed with a further increase in the angle of more than 25º, the height of the ridges was beyond the limits of acceptable agrotechnical requirements.
Analysis of the results indicated that the traction resistance of the working body increased rapidly with an increase in the plate width from 0.05 to 0.15 m, and the quality of loosening improved. A further increase in the plate width slightly affected the amount of traction resistance. Increasing the plate width from 0.05 to 0.12 m did not significantly affect the height of the ridges. A further increase in width led to an intense increase in the height of the ridges. In this case, its values were beyond the limits of permissible.
It has been established that the rational width and length of the plate should be selected in the range of 0.09-0.12 m and 0.12-0.15 m.

CONCLUSIONS

It has been established that the most rational design scheme of a two-stage ripper with inclined racks was a plow scheme with alternating upper and lower working bodies with the lower inflection of the rack; high-quality loosening with the lowest energy costs was ensured at the longitudinal and transverse distances between the working bodies of 0.50-0.60 m and 0.35-0.40 m and the field board's width and length of 0.07 m and 16 m respectively. The rational values of the loosening plate parameters were within the following limits: the maximum angle of the loosening plate to the rack surface was 25º, the plate length and width were 0.12-0.15 m 0.9-0.12 m respectively.

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