Justification of machine parameters for ridge forming with simultaneous application of fertilizers

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Justification of machine parameters for ridge forming with simultaneous application of fertilizers

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Abstract. The technologies used to prepare the soil for sowing cotton seeds in Uzbekistan have a number of significant drawbacks. Therefore, reducing labour and energy costs, as well as saving resources when cultivating crops based on advanced technologies and developing high-performance agricultural machines is of current interest. The aim of this study is to substantiate the machine parameters for forming ridges in the cotton fields with a simultaneous application of fertilizers. New technology has been developed for the formation of ridges with a simultaneous application of fertilizer in the fields with harvested cotton stalks, which loosens the soil in the middle of existing furrows of the cotton-plant, loosening the existing ridge with simultaneous application of fertilizers and forming new ridges in their place in one pass. An improved chisel – cultivator – fertilizer with ridge – forming agents were developed to implement the proposed technology. It has been established that the formation of a high – quality ridge is ensured with local fertilizer application along with a sowing line of a required degree with the following relative positions of the machine's working bodies: a minimum longitudinal distance from the cultivator to the support wheel is 20 cm, a minimum longitudinal distance of the ridge former to the cultivator coulter is 31.3 cm, the distance between adjacent rippers 60 or 90 cm, the transverse distance from the cultivator to the support wheel is 30 or 45 cm.

1. Introduction

The development and use of energy-resource-saving and high-performance machines for tillage and preparing it for sowing has the leading place in the world. At the same time, much attention is paid to the development of machines that perform all the technological processes of soil cultivation and preparing it for the sowing of row crops on ridges in one pass along the field [1, 2, 3, 4, 5, 6]. The development of energy and resource-saving technologies and machines with high-quality performances and productivity is an important task for preparing the soil for sowing the cotton seeds on ridges.

Studies on improving the soil preparation technologies for sowing row crops on ridges, developing the machines to prepare the soil for sowing on ridges, justifying the designs and parameters of their working bodies were carried out by a number of researchers.

Kurdyumov and Zykin [2, 3] substantiated the technology and means of ridge cultivation mechanization of row crops for the Russian Federation conditions. Batirov, Mamatov and others[4, 6]

developed the three-tier fertilizing technology with simultaneous formation of ridges, and Mamatov and Kadirov [5] developed a machine for preparing the soil for sowing potatoes on ridges. Mamatov, Mirzaev, and Ergashev [7, 8, 9, 10, 11, 12, 13] studied the issues connected with anti-erosion tillage before sowing industrial crops. Mamatov and Berdimuratov justified the parameters of the ridge moulder. Mamatov and Khudayarov justified the parameters of the combined aggregate for preparing the soil of cotton fields with cotton stalks for sowing on ridges [14]. Lichman [15] addressed the issue of soil fertilization. The studies carried out by Abdulkhaev [16] were aimed at developing tools for loosening the ridges and destroying weed vegetation, as well as the formation of a mulching layer on their surface. All these studies were aimed at improving traditional technologies and technical means to prepare the soil for sowing industrial crops, including cotton, which does not meet the modern requirements of agricultural production. These studies did not address the issues of soil cultivation with the simultaneous formation of ridges in cotton fields with uneven terrain and local fertilizer application in one pass of the unit. The above disadvantages can be eliminated by developing an improved chisel-cultivator-fertilizer with ridge formers. We have proposed a new method of soil preparation for cultivating cotton on ridges to reduce the number of machines' passes across the field, to maximize the use of fertilizers, to reduce the energy intensity to prepare the soil for sowing and to save resources.

The aim of the study is to justify the machine's parameters for forming ridges in the cotton fields with the simultaneous application of fertilizers.

2. Methods

The proposed method was carried out in the autumn in the cotton fields after harvesting the cotton stems fig.1 highlights the technology of forming the ridges in the cotton fields with simultaneous application of fertilizers. Initially, the middle of the existing row-spacing was loosened by ripper 1 to a depth of a1 and width of b1 (Figure 1b). Then the middle of the existing ridge 4 was loosened by cultivator 2 with a coulter to a depth of 18-20 cm and at the same time, a mixture of mineral and organic fertilizers was applied in the form of a strip 15-20 cm wide at this depth (fig. 1c). Afterwards, new ridges 5 are formed by ridge divider 3 instead of existing ridges 3 by displacing the loosened soil from the middle of the existing row spacing from the irrigation furrow (fig. 1c). At the same time, the number of soil preparation operations for ridge sowing was sharply reduced.

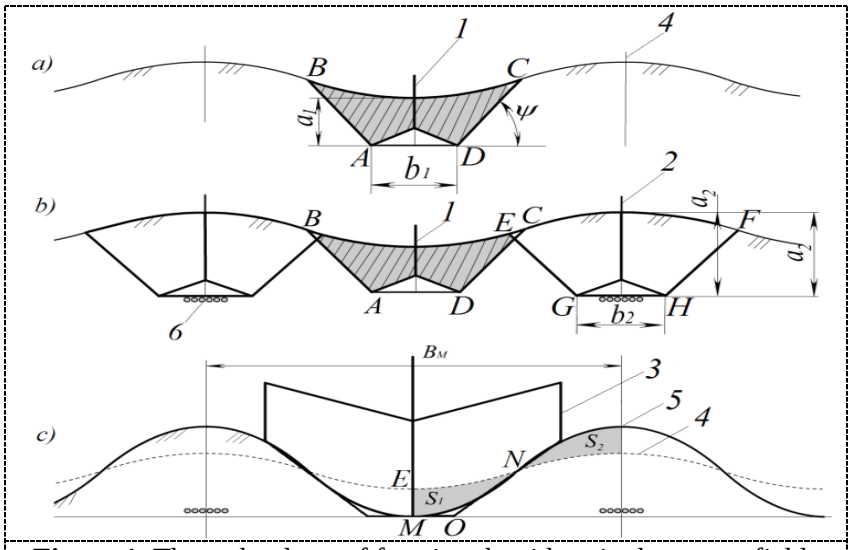

Figure 1. The technology of forming the ridges in the cotton fields with simultaneous application of fertilizers: *a* is the cross-section of the field after loosening the soil in the middle of the existing row

spacing; *b* is the cross-section of the field after loosening the middle of an existing ridge with simultaneous application of fertilizers; *c* is the cross-section of the field after the formation of new ridges.

The proposed technology is equipped with the following working bodies: cultivators 1 for loosening the soil in the middle of the row – spacings, cultivators 2 with piping for loosening existing ridges with simultaneous application of fertilizer along the sowing line and ridge 3 for forming new ridges instead of existing ridges (Figure 1).

Soil preparation for sowing on ridges can be carried out in cotton fields with a row spacing of 60 or 90 cm. Installation of cultivators in front of the fertilizer coulters helps to reduce traction resistance [17, 18, 19].

In spring, strip processing of the ridges was carried out and the seeds were sown without fertilizing. As a result, the spreading of fertilizers for plowing and early spring harrowing with shortage were excluded, and the labour-intensive plowing operation with a turnover of the working body is replaced by moldless loosening with fertilizer application and ridges were simultaneously formed [20, 21, 23]. Tape local fertilizer application helps to reduce fertilizer consumption and increase the utilization rate of plants.

To ensure the proposed technology, based on the existing chisel-cultivator-fertilizer, we developed the experimentally improved universal chisel-cultivator-fertilizer ChKU-4M.

A technological process of the improved chisel-cultivator-fertilizer proceeds as follows. First, cultivator 1 loosens the ABCD soil (Figure 1b) in the middle of the existing row spacing to a depth of a1, then a cultivator 2 with a fertilized coulter loosens the soil EFGH of the middle of the existing ridge 4 to a depth of a2 and simultaneously apply fertilizer 6 to this depth (Figure 1b). The width of the strip of fertilizer is equal to 18-20cm. Afterwards, combing agent 3 displacing the soils of MNEO of the loosened soil in the middle of the row spacing to the existing ridge 4 forms a new ridge 5 and a furrow (Figure 1c).

Due to the symmetrical arrangement of the working bodies, stability of movement of the machine in the horizontal platan is ensured. In one pass, the machine is formed by four aisles with a width of 2.4 m or 3.6 m. Due to the formation of ridges from loosened layers of soil, a crumbling of the ridges was small-sized. An advanced universal chisel-cultivator-fertilizer can prepare the soil for sowing on ridges in the cotton fields.

3. Results and Discussions

High-quality soil preparation and the reliability of the machine depends mainly on the relative position of the working bodies and their parameters. The following parameters included the parameters related to the unit design: width of the rippers, longitudinal and transverse distance between the working bodies.

The width of cultivator capture 1 (Figure 1) was determined based on the conditions of loosening the soil in the aisle and removed by the ridge former to form a new ridge. Therefore, this parameter was justified after determining the cross-sectional area of the layer and removed by the ridge for the formation of a new ridge.

The longitudinal distance between the support wheel and the cultivator is determined from the condition that the cultivator should move the soil unhindered towards the wheel, i.e. the soil shear plane arising under the influence of the plowshare of the cultivator should not reach the support wheel.

The following formula was obtained from figure 2:

$$L_к \geq l_p + a_1 tg(\alpha + \varphi), \quad (1)$$

here: l_p is the distance from the toe of the cultivator to its stand, cm; a_1 is the cultivator depth, cm; α is the crumbling angle of the cultivator, gr; φ is the soil friction coefficient, gr.

Substituting in (1) a_1=12 cm, α=250, l_p=12.5 cm and φ=250, L_k=26.8 cm is received.

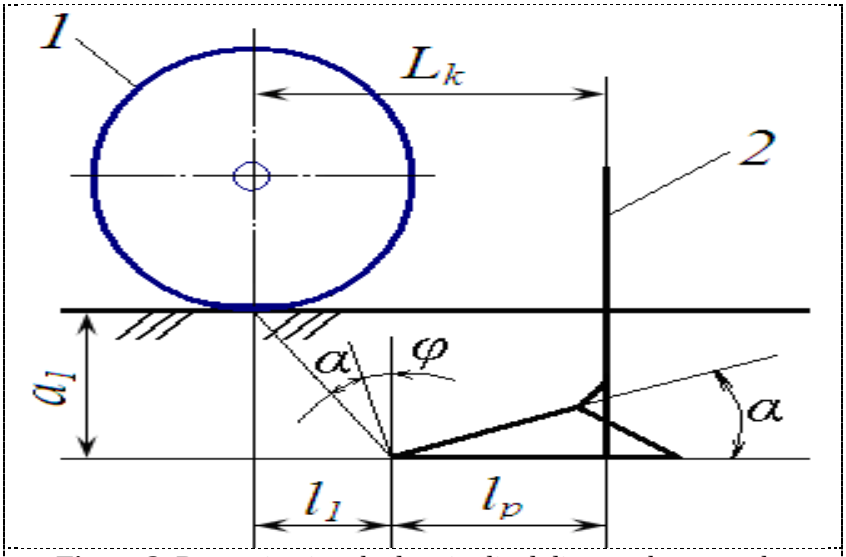

Figure 2. Determination the longitudinal distance between the support wheel and the cultivating paw: 1 – support wheel; 2 – cultivating paw

When determining a longitudinal distance between the ridging and cultivating machines with the fertilizer coulter, the ridging machine needs to move the soil unobstructed in the direction of a zone loosened by the previous working body, i.e., a soil shear platan arising under the influence of the ridging machine should not reach the coulter.

The following formula is obtained from figure 3:

$$L_c \geq l_c + \frac{B_M}{2} tg(\gamma + \phi) \quad (2)$$

here: l_c is the distance from the toe to the rear of coulter, cm; B_m is the width of row spacing, cm; γ is the installation angle of the toe ridge former to the direction of movement, gr.

Substituting in (2) α_c=25^0, l_c=33 cm and φ=25^0 and B_m=90 cm distance, L_c=86.69 cm is received, and by B_m=60 cm distance, L_c=68.76 cm is received.

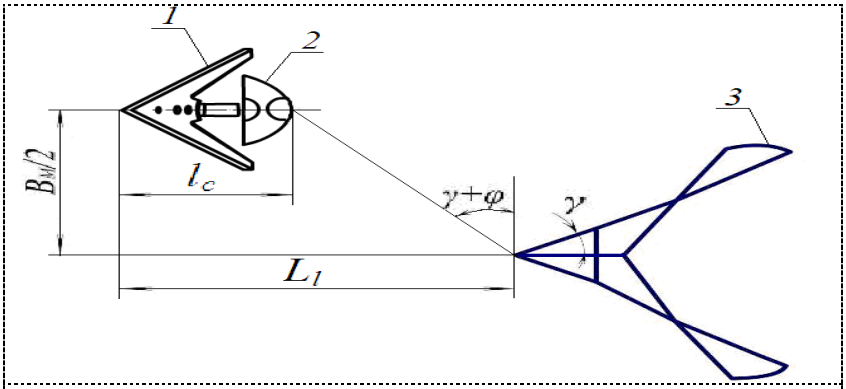

Figure 3. Determination the longitudinal distance between the ridge former and the fertilizer coulter of the cultivator: 1is cultivator; 2 is coulter; 3 is ridge former

To select the parameters of the cultivator, ridge former and ridges, it is theoretically necessary to determine a cross-sectional area of the layer, shifted from the middle of the existing row spacing to form a new ridge instead of the existing one. Numerous studies have established that the cotton relief after harvesting cotton stems has the shape of a sinusoid (figure 4).

It is necessary to move the soil with a cross-sectional area S_1 to the upper surface of the existing ridge to form a new ridge with a height H, instead of an existing ridge with a height h. From the condition of equal areas S_1 and S_2, desired parameters can be found according to the calculation scheme shown in fig. 4, we determined a layer's size moved by the working bodies and the formed ridge, i.e. cross-sectional areas S_1 and S_2.

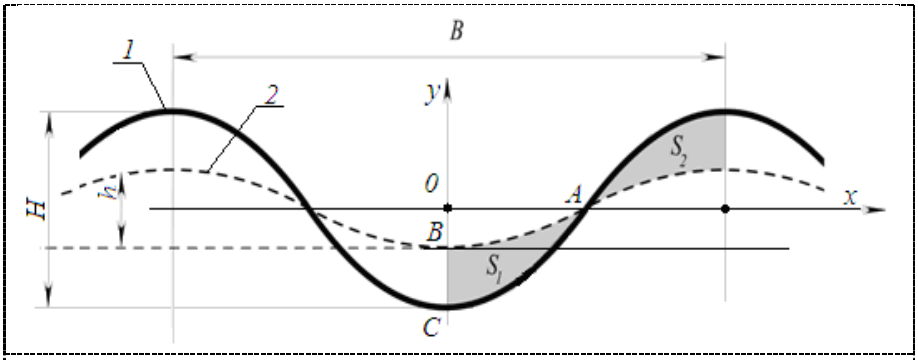

Figure 4. Relief of an existing (2) and formed ridge (1)

The following formula is obtained from Figure4:

$$S_1 = S_2 = \frac{B}{4\pi}(H - h) \tag{3}$$

here: h and H is the average height of existing and new ridge, m; B is the width of row spacing, m.

With an average value of h=12 cm and H=30 cm and with B=90 cm, cross-sectional areas S_1=S_2 is equal to 128.98 cm^2.

The depth of soil loosening of the mid-row spacing is determined from Figure 5

$$a_p = \frac{H - h}{2} \qquad (4)$$

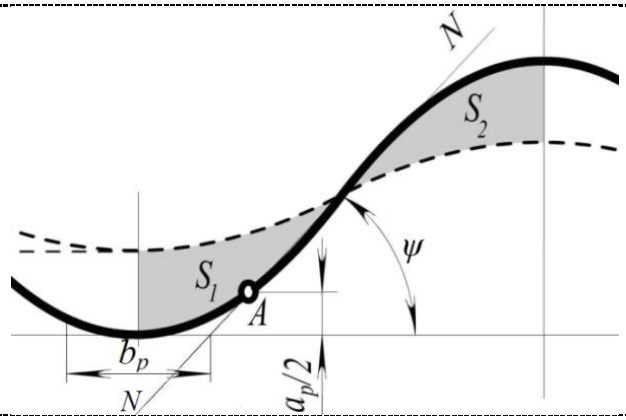

Figure 5. Determination the ripper width for loosening the middle of the furrow

With H = 30 cm and h_{sr}=12 cm, the depth of cultivation should be at least 9 cm. Considering a_r=10cm, a width of the ripper capture is determined from the condition of loosening the soil with cultivator of the moved soil from the middle of the furrow to the ridge. The following formula is obtained from Figure 5:

$$b_p = \frac{B}{4} - a_p ctg\,\psi, \qquad (5)$$

here: ψ is the lateral cleavage angle of soil, gr.

According to the formula (5), with a row spacing of 90 cm and a cultivating depth of 12 cm, the minimum ripper grip width is 12.5 cm.

4. Conclusions

- New technology for preparing cotton fields for sowing on ridges with the use of an improved chisel-cultivator-fertilizer in one of its passes involves loosening the soil in the middle of existing furrows, as well as loosening the existing ridge with the simultaneous application of fertilizers and the formation of new ridges in their location.
- A formation of a high-quality ridge with the introduction of fertilizers along the sowing line of the required degree can be achieved with the following mutual arrangement of the unit's working bodies: minimum longitudinal distance from the cultivator to the support wheel is 20 cm, minimum longitudinal distance from the ridge former to the cultivator coulter is 31.3 cm, transverse distance between adjacent rippers 90 cm, and transverse distance from the ripper to the support wheel 45 cm.

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