Qualitative Indexes of a Plane Cutter for Shallow Tillage with Optimized Parameters

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Abstract. The levelling of the field surface after shallow tillage with a planar cutter, characterized by such a qualitative indicator as combiness, is within the limits allowed by agrotechnical requirements. We have developed an original design of a plane cutter for shallow tillage. The planar cutter for shallow tillage has various options for the sharpening angle of the rack and mortar, which have been optimized. Optimal according to the criterion of minimum energy consumption while observing the quality of minimal tillage, the following parameters of the plane cutter were selected: the angle of sharpening the rack 50 degrees, the angle of the solution 104 degrees. Thus, the removal of wet layers to the soil surface was not observed during shallow tillage with a planar cutter. The amount of erosive-hazardous particles after tillage with a planar cutter does not increase, even slightly decreases (within 0.4%), which corresponds to agrotechnical requirements. The obtained qualitative indicators, shown in Table 1, were determined on a stubble background pretreated by disk working bodies. Thus, the technological process of a combined unit with sequentially arranged disks and a plane cutter was simulated.

1 Introduction

Shallow tillage is carried out by working bodies without turning the soil layer to a depth of 8-16 cm.

Qualitative parameters of the technological process of fine tillage performed by working bodies include obtaining a finely lumpy structure of the treated layer; uniformity of the depth of loosening; removal of the lower wet layer to the surface of the field is not allowed.

In addition, in regions affected by erosion processes, it is necessary to control the amount of dust particles, the size of which does not exceed 1 mm, on the soil surface (0-5 cm), which will reduce the loss of the fertile layer from the effects of wind and water flows [1-11].

Due to the interaction of the soil with the working bodies, dust-like particles can form, they are also already contained in the untreated soil layer.

By creating a finely lumpy soil structure, dust-like particles located on the surface of the untreated field and formed during interaction with the working body wake up inside the soil layer.

The control of the amount of erosive and dangerous dust particles is carried out during the tillage of the soil by working bodies.

At the same time, it is necessary and sufficient that the number of erosive and dangerous dust particles does not increase after tillage.

The working organs that allow dust-like particles to wake up inside the soil layer during tillage include a plane cutter.

2 Materials and methods

The original design of the planar cutter for shallow tillage has been developed. The planar cutter for shallow tillage (Figure 1) has various options for the sharpening angle of the rack and mortar (Figures 2 and 3), which have been optimized. Optimal according to the criterion of minimum energy consumption while observing the quality of minimal tillage, the following parameters of the plane cutter were selected: the angle of sharpening the rack 50 degrees, the angle of the solution 104 degrees.

Fig. 1. Flat cutter for shallow tillage

Fig. 2. Sharpening angle of the plane cutter rack

Fig. 3. Angle of the flat-cut solution

3 Results and discussion

The obtained qualitative parameters of shallow tillage with a planar cutter are shown in Tables 1 and 2.

Table 1. Qualitative parameters of a plane cutter for shallow tillage on the treated stubble background

The name of the index	The value of the index								
Set speed, km/h	6,84	8,20	11,37	6,84	8,20	11,37	6,84	8,20	11,37
Set depth, cm	8,0	8,0	8,0	12,0	12,0	12,0	16,0	16,0	16,0
Actual depth on average, cm	9,8	9,6	9,2	13,6	12,8	12,6	16,8	17,0	17,2
The greatest depth deviation from the set one, ± cm	2,0								
Depth standard deviation, ± cm	0,45	0,89	0,45	0,89	0,84	0,89	0,84	1,0	2,0
Depth variation coefficient, %	4,56	9,32	4,86	6,54	6,56	7,06	5,0	5,88	11,63
Crest on average, cm	3,7	3,7	3,7	3,6	3,8	3,7	3,9	3,8	3,9
Soil crumbling – the number of lumps less than 25 mm in size, %	84	82	84	85	84	84	83	82	83
Soil crumbling – the number of lumps much than 25 mm in size, %	16	18	16	15	16	16	17	18	17
Moisture content inside the formation before tillage, %	25,4								
Moisture content inside the formation after the passage of the working bodies, %	25,1	25,3	25,6	25,4	25,4	25,5	25,2	25,1	25,5
The amount of erosive-hazardous particles in the surface layer of the soil before treatment, %	23,8								
The number of erosive-hazardous particles in the surface layer of the soil after the passage of the working bodies, %	23,5	23,6	23,4	23,5	23,6	23,4	23,5	23,6	23,4

From the analysis of the obtained data given in Table 1, it follows that the planar cutter qualitatively performs the specified depth of tillage with an acceptable deviation (up to 2 cm).

The maximum deviation value is observed at the greatest depths and speed of movement of the working body (16 cm and 11.37 m/s, respectively), which does not exceed the permissible.

In the above mode, the highest coefficient of variation of this indicator is observed (11.63%).

The levelling the field surface after shallow tillage with a planar cutter, characterized by such a qualitative indicator as combing, is within the limits allowed by agrotechnical requirements (less than 4 cm) and amounted to 3.6-3.9 cm.

According to the soil crumbling (the number of lumps of the permissible size), the planar cutter fulfills agrotechnical requirements.

The number of lumps up to 25 mm in size was 82-85% after the passage of the working body, with the required not less than 80%.

The value of this qualitative index, as well as the previous one, is approximately in the same range for all variants of the experience of shallow tillage with a planar cutter.

There is practically no change in the moisture content inside the soil layer before and after shallow tillage with a planar cutter, which indicates its preservation inside the soil layer, which is provided by the design of the working body.

Thus, the removal of wet layers to the soil surface was not observed during shallow tillage with a planar cutter.

The amount of erosive-hazardous particles after tillage with a planar cutter does not increase, even slightly decreases (within 0.4%), which corresponds to agrotechnical requirements.

The obtained qualitative indicators, shown in Table 1, were determined on a stubble background pretreated by disk working bodies.

Thus, the technological process of a combined unit with sequentially arranged disks and a plane cutter was simulated.

A series of experiments on untreated stubble background was also carried out (Table 2).

Comparing the data obtained in Tables 1 and 2, it should be noted that the qualitative indicators of shallow tillage with a plane cutter to a depth of 8-16 cm when operating on an untreated stubble background have not changed much, they are still at a high level corresponding to agrotechnical requirements.

It should be noted that there is a lower content of erosive and dangerous dust particles in the upper soil layer of an untreated field on a stubble background compared to a disk one.

Prior to the passage of the plane-cutter, erosive-dangerous dust-like particles with a size of less than 1 mm were contained almost 2 times more in the 0-5 cm soil layer pretreated with disk working bodies compared to the untreated stubble background.

In other words, the disk working bodies lead to the spraying of the soil, and the plane cutter provides an anti-erosion structure of the upper fertile layer.

Table 2. Qualitative parameters of a plane cutter for shallow tillage on an untreated stubble background

The name of the index	The value of the index								
Set speed, km/h	6,84	8,20	11,37	6,84	8,20	11,37	6,84	8,20	11,37
Set depth, cm	8,0	8,0	8,0	12,0	12,0	12,0	16,0	16,0	16,0
Actual depth on average, cm	8,6	9,8	9,2	12,6	13,6	13,6	16,8	16,8	16,8
The greatest depth deviation from the set one, ± cm	2,0								
Standard deviation of the depth, ± cm	0,89	0,45	2,0	0,89	0,89	0,89	0,84	0,84	0,84
Depth variation coefficient, %	10,40	4,56	15,21	7,06	6,54	6,54	5,0	5,0	5,0
Crest on average, cm	3,9	3,9	4,0	4,0	3,9	4,0	4,0	4,0	3,9
Soil crumbling of the soil – the number of lumps less than 25 mm in size, %	85	83	84	85	84	84	83	82	85
Soil crumbling of the soil – the number of lumps over 25 mm in size, %	15	17	16	15	16	16	17	18	15
Moisture content inside the formation before tillage, %	30,1								
Moisture content inside the soil layer after the passage of the working bodies, %	29,9	29,8	29,8	30,0	30,4	29,9	29,8	29,8	30,0
The amount of erosive-hazardous particles in the surface layer of the soil before treatment, %	12,6								
The number of erosive-hazardous particles in the surface layer of the soil after the passage of the working bodies, %	12,5	12,5	12,3	12,5	12,9	12,5	12,5	12,1	12,8

Thus, the plane cutter can function qualitatively on an untreated stubble background as part of a combined unit not equipped with disk working bodies. Excessive crushing of the soil layer by disk working bodies can lead to desiccation, loss of structure and degradation of over-dried soil.

Excessive grinding of the soil layer by working bodies has a negative impact on the development of cultivated crops, resulting in a decrease in their yield [12-19].

Therefore, the proposed planar cutter as part of a combined unit without disk working bodies has undeniable advantages. At the same time, the metal consumption and traction resistance of the unit are significantly reduced due to the simplification of the design.

4 Conclusions

The plane cutter qualitatively performs the specified depth of tillage with an acceptable deviation.

The crest is within the limits allowed by agrotechnical requirements was 3.6-3.9 cm.

The number of lumps up to 25 mm in size was 82-85% after the passage of the working organ.

The removal of wet layers to the soil surface was not observed during shallow tillage with a planar cutter.

The planar cutter provides an anti-erosion structure of the upper fertile soil layer.

The plane cutter can function qualitatively on an untreated stubble background as part of a combined unit not equipped with disk working bodies.

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