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A RESEARCH INTO COMBINED EROSION CONTROL TILLAGE

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ABSTRACT:
The method of erosion control tillage through combined simultaneous implementation of furrowing and breaking with dead-furrowing is a new one and there has been insufficient theoretical and practical research into it. The present development determines the parameters of the process and its constitutive operations as well as their interrelation. The expedience of the combined erosion control operations has been analyzed and substantiated and it has also been supported by test results.
KEY WORDS:
absorbing and evaporation, method of combined erosion control tillage, furrowing, breaking with dead-furrowing, combined erosion control tillage equipment.

1. INTRODUCTION

A great number of soil conservation methods and equipment are being used in the arable land of the Republic of Bulgaria for water erosion control. The method of combined implementation of furrowing and breaking with dead-furrowing, developed at the Experimental Station on Erosion Control, Ruse, is one of them. The results obtained from its utilization at growing hoed crops on slopes prove it to be auspicious [1; 2]. However, as it is a relatively new one, it has not been adequately explored. That necessitates carrying out some theoretical research for the purpose of proving the potentialities of the method as well as the directions of its development and improvement, which have to be tested practically.

The aim of this research is to determine the primary elements of the process of furrowing and breaking with dead-furrowing as well as to substantiate and present their influence on the basic indices characterizing this process through analytical interrelation of the basic parameters, i.e., water-holding and absorbing abilities of soil and increase (decrease) in its surface evaporation as compared to the separately performed constitutive operations.

Determining the actual relative increase in water-holding ability and the relative increase in the absorbing ability ensuing from the erosion control tillage necessitates detecting the analytical subordination as there is possible different ratio between the volume of the non-eroded soil to the eroded one as well as divergence in tillage depths and widths. The furrow and breaking cross sections are taken into consideration and the components interrelation is expressed through factors. For the purpose of allowing comparison, this development presents some interrelations between separately carried out field management erosion control techniques such as furrowing and breaking with dead-furrowing. A comparative analysis has been accomplished and it has been confirmed by test data.

2. MATERIALS AND METHODS

The present development determines the interrelation between the components of the combined operation through a comparative analysis of its two constitutive ones – furrowing and breaking with dead-furrowing. The theoretical research has been carried out conditionally but the methods and the possibilities of implementing them practically as well as the reasonable and expedient ranges of parameter changes have been taken into consideration.

The process can be carried out either with bilateral furrowing tools at fixed working width or with unilateral ones with options of changing the furrow width while the breaking width is assumed as constant, about 2 cm. It has also been assumed that the furrow cross-section is trapezium-shaped with angles at the base $\pi/4$ rad. Aside from that it has been assumed that the volume of the washed-out soil is about 50% larger than the volume of the non-eroded soil and that at the movement of the working tools the soil does not get displaced aside and its natural slope is in the same direction as the one of the furrow wall. These parameters add perfectly well to the practically observed cases.

It has also been assumed that the breaking is to be considered without the dead-furrowing which has insignificant effect on the present research. It is logical to maintain that if it was included it would have facilitated the thesis as it has been proved by the tests.

The structure of the equipment implementing the method (fig.1) allows independent change in the working depths of the furrower and the breaker as well as in the width of the furrower, which has been used in this development.

Having in mind the standard interspacing at growing hoed crops and the fact that the method under consideration is carried out as the last inter-row tillage, the possible furrow widths at the base are assumed as b=20 cm and 40 cm and the depths as a=8 cm and 15 cm. The breaking depth is assumed to be twice the furrow depth, which is within the reasonable range (1 to 3 times).

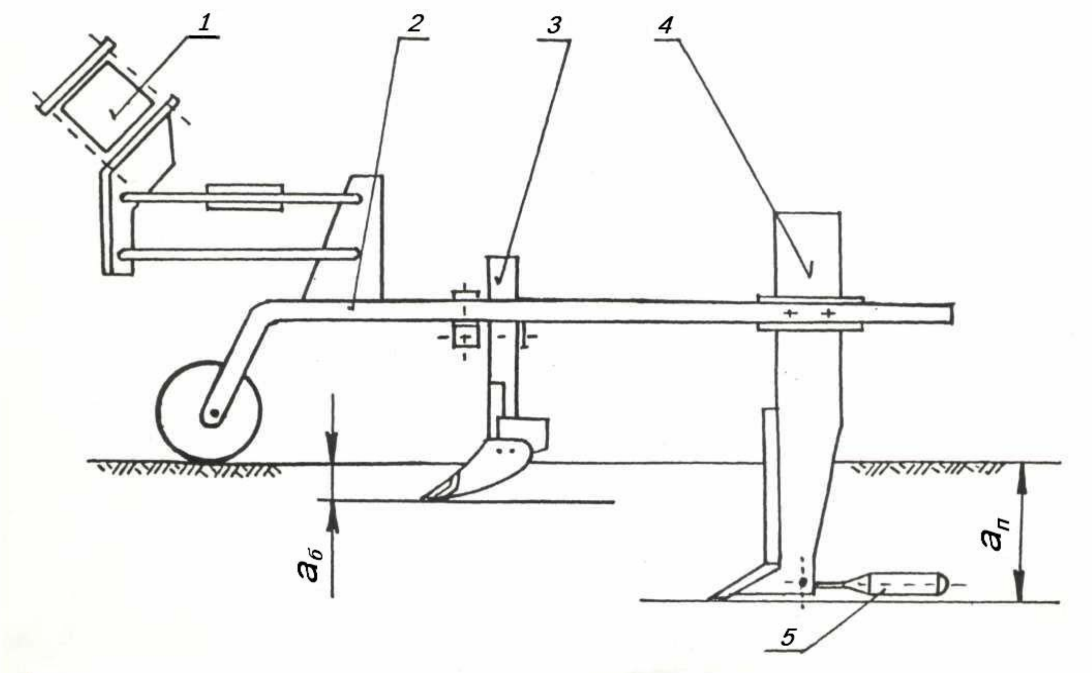

Figure 1. General view of a cultivator with combined soil erosion control equipment
1 – frame; 2 - working section; 3 – plow bottom; 4 – breaker bottom; 5 – dead-furrower.

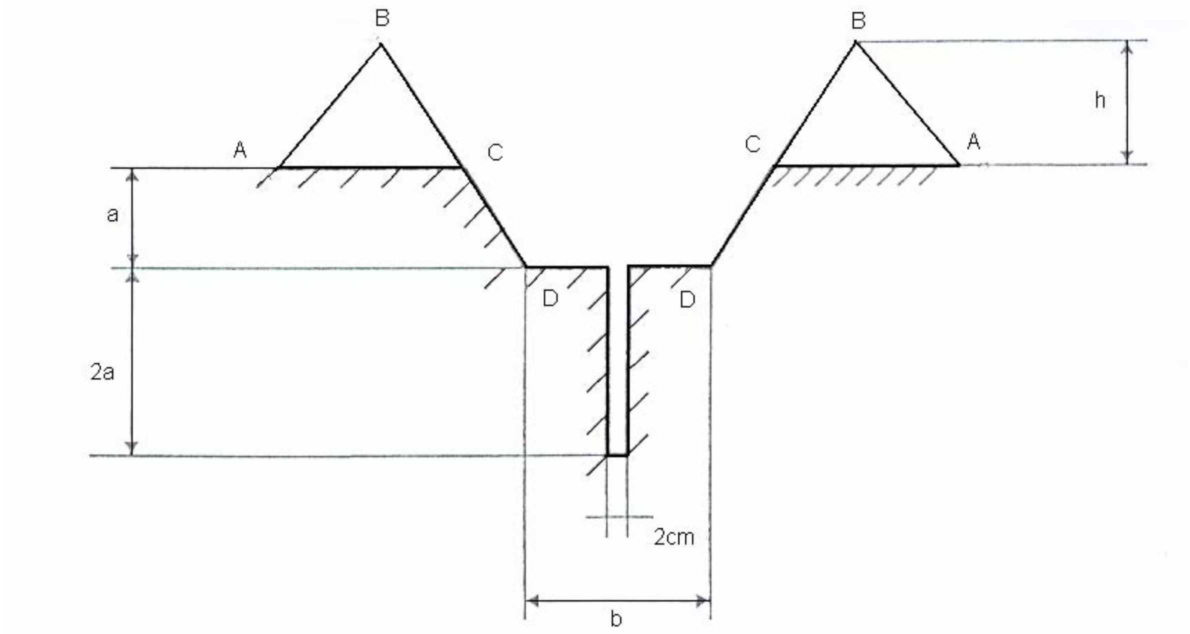

Figure 2. Operating scheme of the equipment carrying out the combined erosion control tillage

To determine the increase in soil surface resulting mainly from furrowing it is necessary to determine the furrow's ridge ***h*** based on the proportionality of the sections of ABC triangle, CDDC trapezium and their concomitant volumes in conjunction with the volume increase factor of the washed-out soil compared to the non-eroded soil k_1, i.e.:

$$2S_{ABC} = S_{CDDC}.k_1$$

then:

$$S_{CDDC} = a.b + 2\frac{1}{2}a^2 = a^2(k_2 + 1),$$

where: $k_2 = \frac{b}{a}$

$$S_{ABC} = h^2 = \frac{1}{2}k_1.a^2(k_2 + 1)$$

$$h = \frac{a}{\sqrt{2}}\sqrt{k_1(k_2 + 1)} \qquad (1)$$

$$AB = BC = CB = BA = \sqrt{2h^2} = \sqrt{2}.h = a\sqrt{k_1(k_2 + 1)}$$

$$CD = DC = \sqrt{2a^2} = a\sqrt{2}$$

If water evaporation in the cut is ignored as it is of significantly less intensity than the one of the furrow surface, then the evaporation can be accepted as proportional to its surface and the respective perimeter of the cross section.

The perimeter is

$$P_{ABCDDCBA} = AB + BC + CD + b + DC + CB + BA$$

or

$$P_{ABCDDCBA} = a\left[2\sqrt{2} + k_2 + 4\sqrt{k_1(k_2+1)}\right] \quad (2)$$

The parameter of the non-eroded soil surface is corresponding to the above one

$$P_{ACCA} = AC + a + b + a + CA$$

$AC = CA = 2h = \frac{2a}{\sqrt{2}}\sqrt{k_1(k_2+1)}$ - at 45° angle of repose of the loose soil.

$$P_{ACCA} = \frac{4a}{\sqrt{2}}\sqrt{k_1(k_2+1)} + 2a + ak_2 = a\left[2 + k_2 + \frac{4}{\sqrt{2}}\sqrt{k_1(k_2+1)}\right] \quad (3)$$

Water-holding ability with the combined method at horizontal movement is determined mainly from the furrow components and does not differ significantly from the one at furrowing, if viewed as an independent operation. The assertion that the same results will be obtained in practice, especially after longer period of time, can be stated with high degree of trustworthiness.

The basic parameters characterizing the combined erosion control tillage method have been determined on the basis of the above stated assertions. The relative increase in the surface evaporation can be judged by the quotient of expressions (2) and (3)

$$\frac{P_{ABCDDCBA}}{P_{ACCA}} = \frac{2\sqrt{2} + k_2 + 4\sqrt{k_1(k_2+1)}}{2 + k_2 + \frac{4}{\sqrt{2}}\sqrt{k_1(k_2+1)}} \quad (4)$$

The absorbing ability of the furrow formed through the combined method can be judged by the area of the surfaces proportional to the furrow parameters **P_{CDDC}** and the cut $P_{пр}$. It can be assumed that the slices to the furrow sides do not take part in the process of water charging in the soil depth, especially at rainfall immediately after the implementation of the combined erosion control tillage.

3. RESULTS AND DISCUSSIONS

The relative increase in the evaporation surface, according to equation (4) at furrow bottom width of 20 cm and two different depths of 8 cm and 15 cm and ratios k_2=2.5 and 1.33 comes out respectively to 31% and 38%.

At twice larger widths and the same depths, the relative increase of the evaporation surface is comparatively smaller (27% and 31%). That indicates that the wider furrows are preferable, which in some cases are more appropriate as they also provide better coverage of the rows with soil.

It is evident from the analysis of subordination (4) that furrow width up to 40 cm affects comparatively less the relative increase in the evaporation surface at smaller depths while at greater depths it is within the same range as the impact of the depths. That indicates that it is more expedient to perform the operation through furrowing tools which allow changes in the working width such as the unilateral or bilateral ones with changeable geometry of the sections.

Proceeding from fig.2 we will obtain the following for the furrow perimeter:

$$P_{CDDC} = CD + ak_2 + DC = 2a\sqrt{2} + ak_2 = a\left(2\sqrt{2} + k_2\right) \quad (5)$$

$P_{пр} = 2.2a$ - perimeter of the breaking.

The relative increase in the absorbing ability, resulting from the combined method, compared to the soil surface prior to the combined erosion control tillage becomes as follows:

$$\frac{P_{CDDC} + P_{пр}}{P_{CC}} = \frac{2\sqrt{2} + k_2 + 4}{k_2 + 2}$$

where P_{CC} is the perimeter of the respective non-tilled soil compared to the furrowing.

By the same analogy we obtain the following equation for the relative increase in the absorbing ability at furrowing only:

$$\frac{P_{CDDC}}{P_{CC}} = \frac{2\sqrt{2} + k_2}{k_2 + 2} \quad (7)$$

and for the breaking only

$$\frac{P_{пр}}{P_{CC}} = \frac{4}{k_2 + 2}, \quad (8)$$

Several calculations have been made on the basis of the above subordinations (6), (7) and (8) and the results from them indicate the relative increase in the absorbing ability of the furrow at the combined method in comparison with the non-tilled soil. The results from the calculations at widths of 20 cm and 40 cm, constant depth $a = 10$ cm and factors $k_2 = 2$ and 4 are presented in table 1.

TABLE 1. Absorbing ability of the furrow at constant depth $a = 10$ cm and factors $k_2 = 2$ and 4

	$k_2 = 2$	$k_2 = 4$
$\frac{P_{CDDC} + P_{пр}}{P_{CC}}$	2,20	1,80
$\frac{P_{CDDC}}{P_{CC}}$	1,83	1,58
$\frac{P_{пр}}{P_{CC}}$	1,00	0,67

The results (table 1) indicate that the absorbing ability of the furrow depends mainly on its depth rather than width.

Therefore the furrow width should be determined in comparison with the technology for implementing the respective operation. The increase in the absorbing ability at increasing the depth can be explained with the cut at the bottom of the furrow.

This indicates that the technological operation of breaking plays a particular role in this case and the question of the advisability of performing only the breaking arises inevitably.

Generally the answer is negative because of two reasons:

- firstly, due to the fact, that as it has been stated before, the furrowing is performed anyway for the purpose of earthing-up for weed control;
- secondly, from erosion control point of view, the furrow is used as water run-off basin while it is absorbed by the soil.

The field test with this combined erosion control method was carried out within the period of 1996-2000 in the experimental field at the Experimental Station on Erosion Control, Ruse in the area of the village of Trastenik, the district of Ruse, in non-irrigated fields with calcareous chernozem of medium erosion and average gradient of 5° . It has been set and completed on an area of 27.5 da, in four versions, with four repetitions, after the method of the Latin Square. It is a single-factor test with soil conservation tillage as a factor.

The four tested versions are as follows:

- corn, grown without erosion control tillage – check
- corn, grown with water run-off furrows in the inter-row spacing;
- corn grown with inter-row breaking;
- corn, grown with water run-off furrows and breaking in the inter-row spacing.

The furrows were implemented with the second version during plant vegetation, at a developmental phase of 5-7 leaves at a depth of 12 cm in each inter-row spacing.

The cuts were implemented with the third version during plant vegetation at a developmental phase of 5-7 leaves, simultaneously with the second hoeing in every other inter-row at a depth of 25 cm.

The combined erosion control tillage consists of simultaneously implemented water run-off furrows and cuts during plant vegetation at a developmental phase of 5-7 leaves (after the second hoeing). The furrows are in each inter-row at a depth of 12 cm while the cuts are at an interspacing of 1.4 m (every other inter-row) at a depth of 25 cm.

Every soil conservation tillage as well as others needed for growing the crop were carried out annually within the periods of the field management terms and transversely to the slope.

The erosion research was carried out via the volume-and-statistics stationary method and the exact quantity eroded soil was precisely determined depending on the relief, rainfall intensity, the amount of the surface water run-off and other factors. The amount of surface water run-off and washed out soil after each rainfall were determined during the test period via draining sites of 50 m^2 surface. They facilitated determining the exact quantity of surface run-off water as well as washed-out soil for each tested version.

The five-year period research into the erosion process and the results from implementing the tillage operations of furrowing and breaking with dead-furrowing simultaneously or separately indicate that the best soil conservation effect, at the same absorbing ability in the conditions of intensive rainfall, is obtained when they are carried out simultaneously and consecutively.

For example, the surface water run-off in areas where the combined tillage of furrowing and breaking with dead-furrowing is 1.6 times less at an average compared to the areas in which only breaking with dead-furrowing was carried out while this decrease comes to 1.4 to 2.4 times for eroded soil. The results from the comparison of the combined method with furrowing are similar. In this case the surface water run-off decreases by 1.8 for the versions with combined tillage while the eroded soil is reduced 2.2 times at average compared to the areas with furrows in the inter-rows only.

4. CONCLUSION

1. The obtained interrelations about the process implementing the combined method for furrowing with breaking and dead-furrowing allows determining its

parameters as well as carrying out comparative analyses of the different means utilized for erosion control tillage.

2. With the combined method the relative increase in absorbing and evaporating surfaces as well as with the implemented separate constitutive operations depends on the ratio between the component quantities.
3. With the combined method for erosion control tillage, at increasing the operating depth the relative increase in water-accumulating ability is larger than the relative increase in the evaporating surface. At the same time, this allows water penetration in depth.

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