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OPTIMISATION OF PARAMETERS AND OPERATING MODES OF AN IMPROVED TOOTH CULTIVATOR FOR PROCESSING COTTON ROW SPACINGS

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Abstract
In order to study the combined influence of the parameters of the improved tooth cultivator for processing cotton row spacings, which were studied in theoretical and single-factor experiments, on its performance indicators and to determine their optimal values, multifactor experiments were conducted using the mathematical planning method [1–2]. It was assumed that the influence of factors on the evaluation criteria was fully covered by a second-degree polynomial, and the experiments were conducted according to plan B5 [3–10].

Introduction

During the experiments, the length of the teeth of the improved toothed cultivator for processing cotton row spacings *l*, the longitudinal and transverse distances between them l_b, a_t, the vertical pressure force on the toothed cultivator *Q*, and the speed of the unit *V* were taken as the factors most influencing its quality and energy performance. They are conditionally designated as:

X_1 - length of the ripper teeth, cm;
X_2 - longitudinal distance between the ripper teeth, mm;
X_3 - transverse distance between the ripper teeth, mm;
X_4 - vertical load applied to the toothed ripper, N;
X_5 - speed of the unit, km/h.

Based on the above theoretical studies and single-factor experiments, the values of the conditional designation, level and intervals of variation (change) of factors were determined (Table 1)

When conducting multi-factor experiments, the depth of processing (Y_1, cm), the degree of soil crumbling (Y_2, %) and the traction resistance of the device (Y_3, N) were taken as evaluation criteria.

Table 1 Levels of influencing factors and their variation intervals

№	Name of factors	Unit of measurement	Factors				
			desig-nation	range of variati-on	уровни		
					(-1)	(0)	(+1)
1.	Length of the ripper teeth	cm	X_1	2	13	15	17
2.	Longitudinal distance between the ripper teeth	mm	X_2	20	120	140	160
3.	Transverse distance between the ripper teeth	mm	X_3	10	40	50	60
4.	Vertical load applied to the toothed ripper	N	X_4	50	100	150	200
5.	Speed of the unit	km/h	X_5	1,5	5,0	6,5	8,0

In order to reduce the influence of uncontrollable factors on the evaluation criteria, the sequence of experiments was established using a random number table [11–12].

The data obtained in the experiments were processed using the PLANEXP programme developed in the experimental planning laboratory of the SRIAM. The Cochran criterion was used to assess the homogeneity of variance, the Student's criterion was used to assess the values of the regression coefficients, and the Fisher criterion was used to assess the adequacy of the regression models.

After processing the experimental results in the established manner, the following regression equations were obtained, adequately describing the evaluation criteria:

by processing depth (cm):

$$Y_1 = 8{,}856+1{,}475\ X_1+1{,}027\ X_2-1{,}205\ X_3+0{,}671\ X_4-0{,}787\ X_5-0{,}258\ X_1^2+ \\ +0{,}151\ X_1X_2-0{,}288\ X_1X_3+0{,}326\ X_1X_4+0{,}07\ X_1X_5+0{,}312\ X_2^2-0{,}104\ X_2X_3+ \\ +0{,}144\ X_2X_4+0{,}325\ X_2X_5+1{,}240\ X_3^2-0{,}295\ X_3X_4-0{,}113\ X_3X_5-0{,}457\ X_4^2+ \\ +0{,}075\ X_4X_5-0{,}548\ X_5^2 \qquad (1)$$

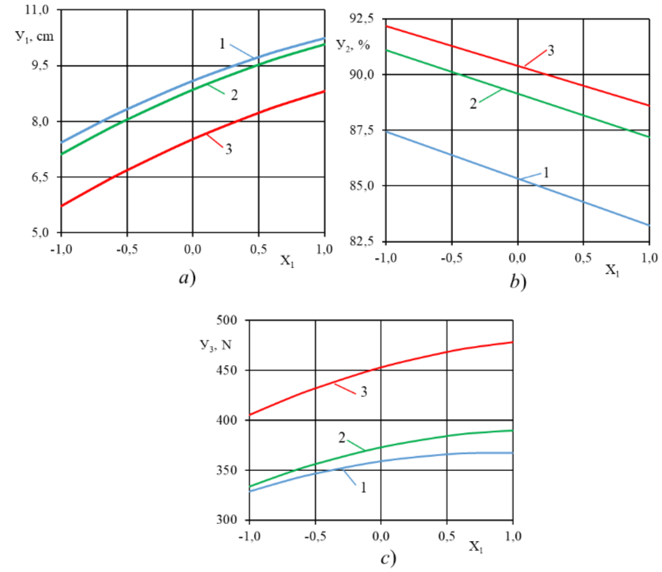
by soil crumbling degree (%):

$$Y_2 = 89{,}133-1{,}949\ X_1+2{,}853\ X_2-3{,}158\ X_3+2{,}426\ X_4+2{,}529\ X_5-0{,}277\ X_1X_2+ \\ +0{,}239\ X_1X_3+0{,}626\ X_1X_5-0{,}799\ X_2^2+0{,}239\ X_2X_4-0{,}676\ X_2X_5-0{,}951\ X_3^2- \\ -0{,}502\ X3X4+0{,}639\ X3X5-0{,}751\ X42-0{,}390\ X4X5-2{,}269\ X52 \qquad (2)$$

by traction resistance of the device (N):

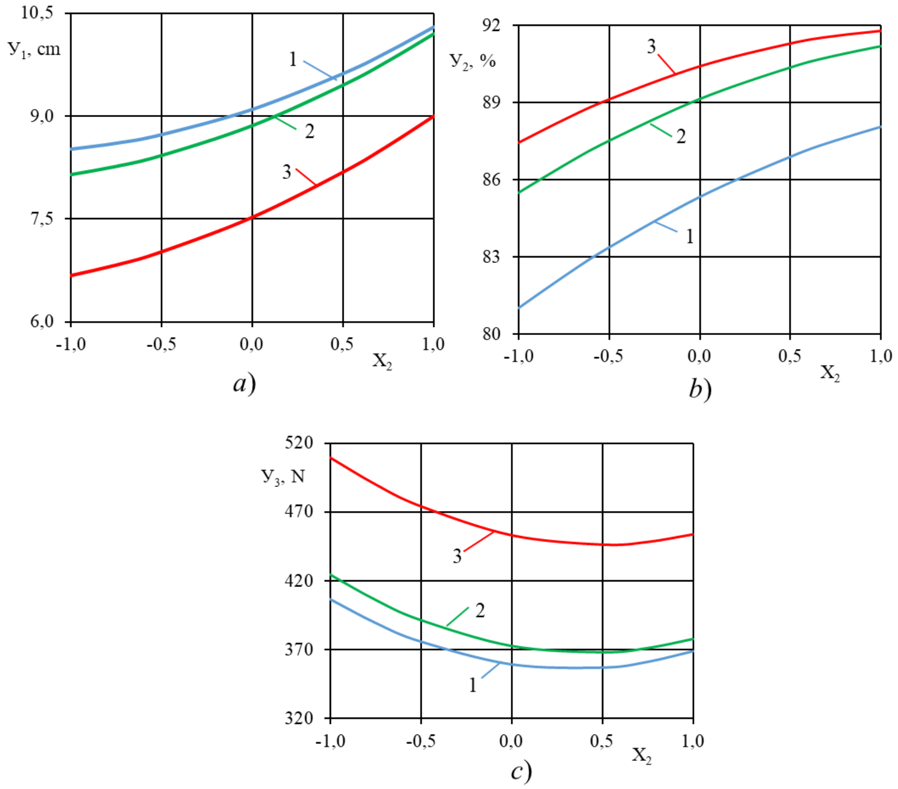
$$Y_3 = 372{,}814+27{,}944\ X_1-23{,}352\ X_2-35{,}907\ X_3+31{,}870\ X_4+46{,}963\ X_5-11{,}207\ X_1^2+ \\ +7{,}958\ X_1X_2+4{,}333\ X_1X_3+9{,}458\ X_1X_4+8{,}375\ X_1X_5+28{,}459\ X_2^2-8{,}417\ X_2X_3- \\ -3{,}375\ X_2X_4-4{,}458\ X_2X_5+5{,}46\ X_3^2-4{,}917\ X_3X_4-7{,}833\ X_3X_5+ \\ +12{,}459\ X_4^2+33{,}293\ X_5^2 \qquad (3)$$

Analysis of the obtained regression equations (1)–(3) and the graphical dependencies constructed based on them (Figures 1–4) shows that all factors had a significant impact on the evaluation criteria.



1, 2 and 3 respectively X₅ -1; at 0 and 1

Fig. 1. Change in processing depth (a), soil crumbling degree (b) and traction resistance (c) depending on the X_1 factor



1, 2 and 3, respectively X_5 -1; at 0 and 1

Fig. 2. Change in processing depth (a), soil crumbling degree (b) and traction resistance (c) depending on the X_2 factor

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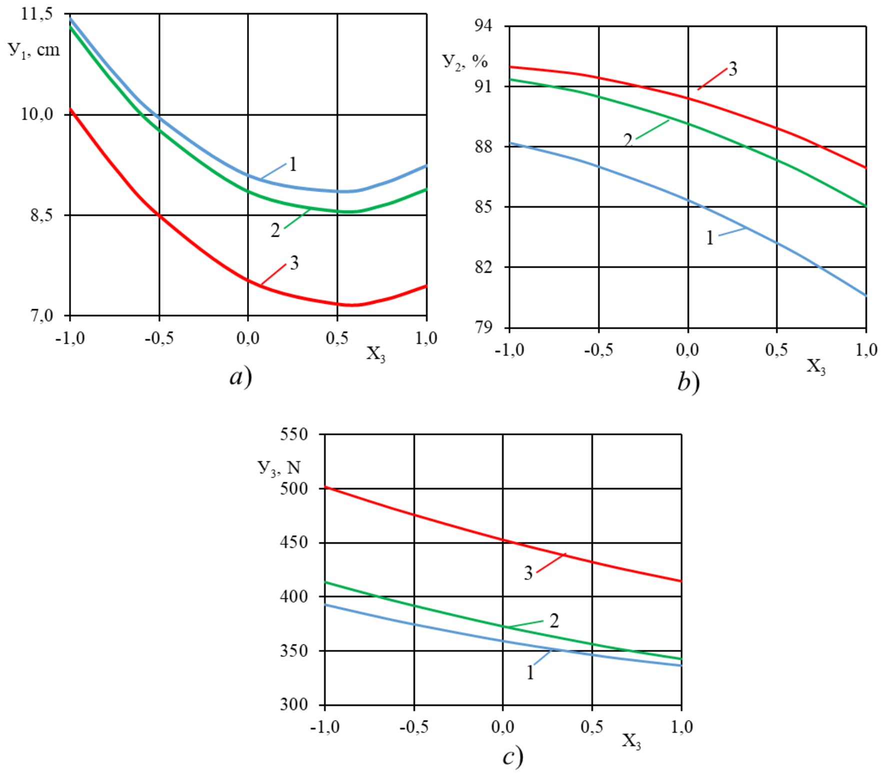
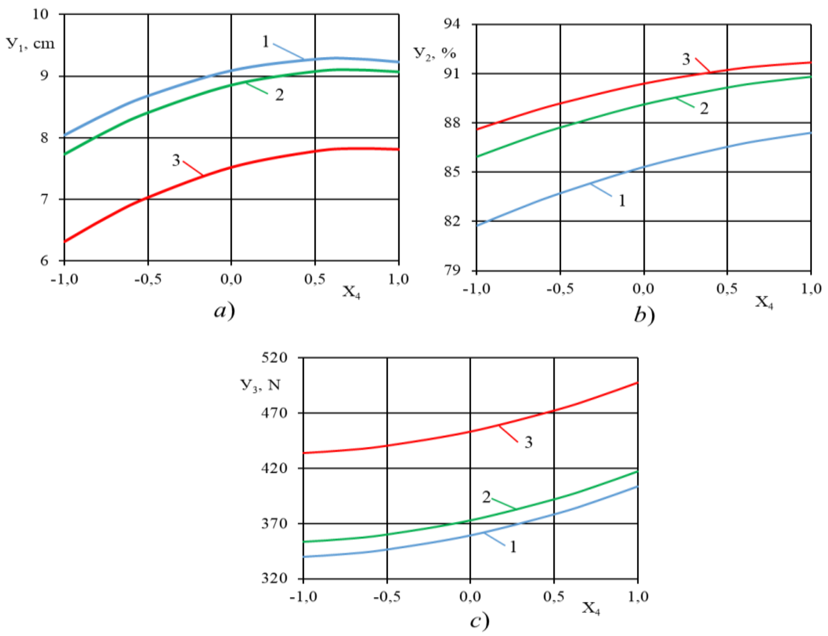


1, 2 and 3, respectively X_5 -1; at 0 and 1

Fig. 3. Change in processing depth (a), soil crumbling degree (b) and traction resistance (c) depending on the X_3 factor



1, 2 and 3, respectively X_5 -1; at 0 and 1

Fig. 4. Change in processing depth (a), soil crumbling degree (b) and traction resistance (c) depending on factor X4

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(1)–(3) regression equations were solved from the conditions of the "Y_1" criterion, processing depth of 8-10 cm, "Y_2" criterion, soil crumbling degree should be greater than 85%, and "Y_3" criterion, traction resistance of the device should have a minimum value, and the following values of factors ensuring the fulfilment of these conditions were determined (Table 2).

Table 2 Optimal values for the improved roller

X_5		X_1		X_2		X_3		X_4	
cod.	orig.	cod.	orig.	cod.	orig.	cod.	orig.	cod.	orig.
1	8,0	0,1086	15,22	0,9742	159,48	0,3842	53,84	0,2742	163,71
0	6,5	-0,074	14,85	0,8140	156,28	0,2345	52,35	-0,148	142,59
-1	5,0	-0,196	14,61	0,4812	149,62	-0,384	46,16	-0,395	130,24

To ensure the required level of quality with minimum energy consumption at unit speeds of 5-8 km/h, the length of the cultivator tines should be within the range of 14.61-15.22 cm, the longitudinal distance between the cultivator tines should be 149.62-159.48 mm, the transverse distance between the cultivator tines should be 46.16-53.84 mm, and the vertical pressure force on the cultivator should be within the range of 130.24-163.71 N.

With these values, the working depth is 9.12-9.45 cm, the degree of soil crumbling is 86.36-89.99%, and the traction resistance is 355.06-447.21 N.

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