

Determining the Appropriate Values of Compactor Parameters of the Enhanced Harrow Leveller

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Received March 10, 2020; Revised April 20, 2020; Accepted May 3, 2020

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Abstract The following items are specified in the article: installation angle with regard of horizon of the enhanced compactor of harrow leveller for the purpose of increasing the work quality and efficiency in land areas harrowing and decreasing the energy-material consumption; length of the working surface and comparison to be forwarded to it, i.e., the results of multi-factor experiments to determine the optimal values of its vertical load corresponding to a coverage width of one meter, which provides the required level of work quality with low energy consumption. Multifactorial trials were implemented based on Hartley-4 plan. In this case the following items are obtained: mean square deviation of unevenness heights of processed land surface as evaluation criteria; degree of soil crumbling, i.e. amount of soil fractions having dimensions less than 25 mm; density of soil at 0-10 cm layer and comparative resistance of traction of the harrow leveller. The information and data obtained in the course of trials was developed based on the "Planexp" programme at the Experiments and Testing Department of the Institute. In this case the following criteria were used: Cochran's test criteria for evaluating the uniformity of dispersion; Student's criteria for evaluation the value of regression coefficients; Fisher criteria for evaluation the adequateness of regression models. The results of trial were developed based on the above specified programme, thus regression equations adequately formulating the evaluation criteria were obtained. They are the average square deviation of the height of the unevenness of the field surface treated for the unit operating speeds of 6.0-8.0 km/h which is less than 2.0 cm, the degree of soil compaction is greater than 80%, the density of the soil in the 0-10 cm layer is 1.1- In the range of 1.2 g/cm³ and the conditions under which the specific resistance of the harrow leveller has a minimum value, the following optimal values of the improved harrow-leveller compactor parameters were determined: installation angle of the compactor relative to the horizon 29-32°, working surface length 31-32 cm and the vertical load applied to it is 2.4-2.6

kN/m.

Keywords Enhanced Harrow Leveller, Leveller, Compactor, Installation Angle of the Compactor with Regard to Horizon, Length of the Working Surface, Comparative Straight Tension, Multifactorial (Trials) Experiments, Regression Equations

1. Introduction

Transfer to intensive methods of agricultural production by introducing the up-to-date agricultural technologies and the provision of farms with high-yield agricultural machinery is the most important direction in the sustainable and efficient development of this sector.

Before sowing the cultures in producing the plenty of yield the agricultural crops it is important to process the lands qualitatively. In the event if the lands are not processed qualitatively, the agricultural crops seeds cannot be sown under the appropriate manner of agrotechnical requirements; the sown seeds will not grow (develop) with plenty and enough seedlings per a hectare which will not be obtained. Thus it outcomes in reducing the crops yield.

It is known that major tasks and assignments in lands presowing tillage are the following: leveling the lands surface; compacting in the appropriate manner and crushing large lumps in it to form fine soil layer [1]. At present, MV-6.0, MV-6.5 and other harrow levellers available on farms are widely used for this purpose in our country [2,3].

But when these harrow levellers are applied in order to till the lands on appropriate level they should pass by the same place for 2-3 times. And it will lead in: increase in labor consumption and other expenditures, including the fuel consumption during lands preparation activities necessary for sowing; excessively soil compacting and losing its moisture; reducing of work effectiveness as well

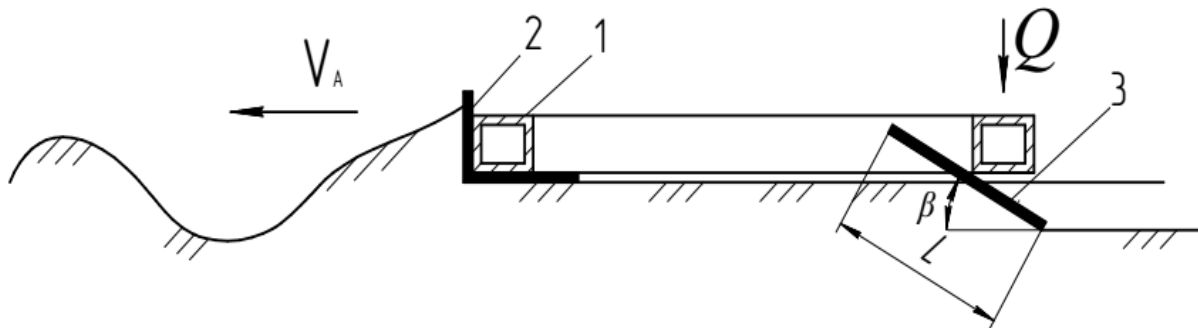
as extension the period the agricultural crops sowing out of date. Besides that, existing harrow levellers are morally very outdated. They do not correspond the up-to-date demands in lands tillage by minimum and under savings, considering above mentioned, the enhanced harrow leveller is developed at the Scientific-Research Institute of Agricultural Mechanization, researches on substantiation of its parameters are being carried out.

Enhanced harrow leveller is manufactured in suspension type and consists of the following items: frame equipped with suspension unit (not shown in the figure); levelling and compacting operation elements (further more accordingly leveller and compactor) mounted to it. In the course working process leveller will align the unevenness on the land surface and compactor will seal (compact) the land surface aligned by leveller (figure 1).

2. Materials and Research Methods

The results of multifactorial trials are in accordance with the Hartly-4 plan, in effort to determine the appropriate values under the terms and conditions with the necessary work quality (fig.1) by less energy consumption of the installation angle of compactor of the enhanced harrow-leveller with regard to horizon - β ; length of working surface - L and comparative straight tension forwarded to it - Q are specified in the article. The factors, their designation, variation intervals and levels are given in the table 1.

In the course of implementation, the multifactorial trials (experiments) the mean square deviation of unevenness height of the tilled field surface; degree of soil crumbling, i.e. amount, density of soil and soil fractions have dimensions less than 25 mm, as well as comparative tension resistance of the harrow levellers were obtained as evaluation criteria; in this case they were determined by applying existing normative documents [4, 5].



1-chassis; 2-leveller; 3-compactor

Figure 1. Technological working process and parameters of the enhanced harrow leveller

Table 1. Intervals and levels of the factors variations

№	Factors and their natural designation	Measurement unit	Factors				
			Coding designation	Variation interval	levels		
					lower (-1)	Main (0)	upper (+1)
1.	Installation angle of the compactor with regards to horizon, β	degree	X_1	10	20	30	40
2.	Length of working surface of the compactor, L	cm	X_2	5	25	30	35
3.	Comparative straight tension power to be forwarded with regard to harrow leveller, Q	kN/m	X_3	0.4	2.0	2.4	2.8
4.	Movement velocity, V	km/h	X_4	1.5	6.0	7.5	9.0

In effort to determine mean square deviation of unevenness height of the tilled field surface after the harrow leveller passes by means of coordinating lath having 5 m length, installed on two poles horizontally, the distances from the field surfaces until upper part of lath with 5 cm interval were measured. According to the measurements data by methods of the mathematic statistics an average arithmetic value from the field surfaces until upper part of lath and its mean square deviation, but then the mean square deviation of unevenness heights of the surface of tilled field area by the harrow leveller.

In the event when we determine the degree of soil crumbling after the harrow levellers passing by means of bottomless box from the 0,25 m² area at the 10 cm depth the samples were taken and by using sieve that has openings of 25 mm diameter, they were divided into fractions having dimensions of more and less than 25 mm. After the degree of soil crumbling was determined as ratio of fractions mass of 25 mm with respect to total mass of sample in percent.

Soil density was determined at the layer of 0-10 cm by using cylinder of 10 cm height and volume of 500 cm³.

Specific traction resistance of small harrow leveller was determined by means of dividing its total traction resistance to the width seizure; and total traction resistance of harrow leveller was determined by means of strain gauging and here tenzofingers (fig.2) installed onto its hinged device were applied. Before and after implementing the trials the tenzofingers were calibrated.



a) tenzofinger, to be installed on the upper point of hinged device of the harrow leveller;



b) tenzofingers, to be installed on the lower points of hinged device of the harrow leveller

Figure 2. Tenzofingers

(1)-(4) When we analyze the regression equations and graphical relations formulated based on them, it can be found out that all the factors have influenced the evaluation criteria significantly (figures 3-5).

For the purpose of reducing the influence of physical and mechanical properties of soil and unevenness height of the tilled field surface as well as the evaluation criteria, the sequence of trials (experiments) implementation is drawn up by using the table of random numbers [6].

Results of multifactorial trials (experiment) are shown at table 2.

The information and data obtained in the course of trials was developed based on the "Planexp" programme at the Experiments and Testing Department of the Institute. In this case the following criteria were used:

- Cochran's test criteria for evaluating the uniformity of dispersion;
- Student's criteria for evaluation the value of regression coefficients;
- Fisher criteria for evaluation the adequateness of regression models.

Table 2. Results of multifactor trial (experiment)

Mean square deviation of unevenness height of the tilled field (\pm cm) by recurrences			Degree of soil crumbling (%) by recurrences			Soil density (g/cm^3) by recurrences			Specific traction resistance (kN/m) by recurrences		
1	2	3	1	2	3	1	2	3	1	2	3
1.906	1.917	1.874	74.36	74.71	73.27	0.971	0.976	0.965	2.408	2.412	2.395
2.052	2.063	2.020	75.20	75.58	74.07	1.063	1.067	1.057	2.760	2.765	2.746
1.067	1.977	1.934	73.82	74.20	72.71	1.09	1.095	1.084	2.512	2.513	2.499
2.113	2.122	2.083	76.26	76.69	75.10	1.099	1.104	1.092	2.972	2.974	2.958
1.036	1.942	1.913	75.30	75.76	74.06	1.090	1.094	1.084	3.392	3.397	3.376
2.082	2.090	2.055	76.49	76.94	75.26	1.118	1.122	1.112	3.00	3.004	2.984
1.405	1.915	1.87	77.71	78.13	76.57	1.093	1.097	1.087	3.572	3.576	3.555
1.635	1.644	1.607	84.51	84.94	83.29	1.037	1.097	1.087	3.072	3.075	3.056
1.871	1.881	1.843	76.04	76.44	74.90	1.094	1.098	1.087	3.073	3.077	3.058
1.913	1.923	1.884	78.86	79.27	77.68	1.112	1.116	1.105	3.053	3.057	3.038
1.754	1.762	1.729	81.76	82.21	80.49	1.133	1.137	1.127	2.691	2.696	2.677
1.563	1.572	1.537	86.45	86.87	85.20	1.159	1.163	1.153	2.885	2.888	2.870
1.788	1.797	1.762	81.34	81.78	80.11	1.114	1.119	1.108	2.420	2.423	2.407
1.566	1.574	1.543	86.65	87.11	85.33	1.156	1.160	1.150	2.956	2.960	2.940
1.764	1.772	1.740	83.46	83.91	82.17	1.158	1.162	1.152	2.699	2.702	2.684
1.514	1.523	1.489	87.49	87.93	86.22	1.133	1.137	1.127	3.119	3.122	3.105
1.639	1.648	1.614	84.77	85.21	83.50	1.153	1.137	1.147	2.829	2.832	2.814

3. The Results of Research and Discussing Them

The following regression equations were obtained that adequately specify the evaluation criteria after developing onto the results according to the set programme:

- by mean square deviations of unevenness height of the tilled field surface, (\pm cm)

$$Y_1 = 1.634 + 0.021X_1 - 0.096X_2 - 0.111X_3 - 0.125X_4 + 0.252X_1^2 - 0.052X_1X_2 - 0.052X_1X_3 - 0.052X_1X_4 + 0.019X_2^2 + 0.05X_2X_3 + 0.051X_2X_4 + 0.038X_3^2 + 0.051X_3X_4; \quad (1)$$

- by degree of soil crumbling, (%)

$$Y_2 = 84.496 + 1.405X_1 + 2.343X_2 + 2.643X_3 + 1.395X_4 - 7.298X_1^2 + 0.899X_1X_2 + 0.586X_1X_3 + 0.498X_1X_4 - 0.666X_2^2 - 0.852X_2X_4 - 0.776X_3^2 - 0.3971X_3X_4 + 0.7X_4^2; \quad (2)$$

- by soil density, (g/cm^3)

$$Y_3 = 1.140 + 0.009X_1 + 0.01X_2 + 0.021X_3 - 0.012X_4 - 0.05X_1^2 - 0.021X_1X_2 - 0.016X_1X_3 + 0X_1X_4 - 0.007X_2^2 - 0.017X_2X_3 - 0.011X_3^2; \quad (3)$$

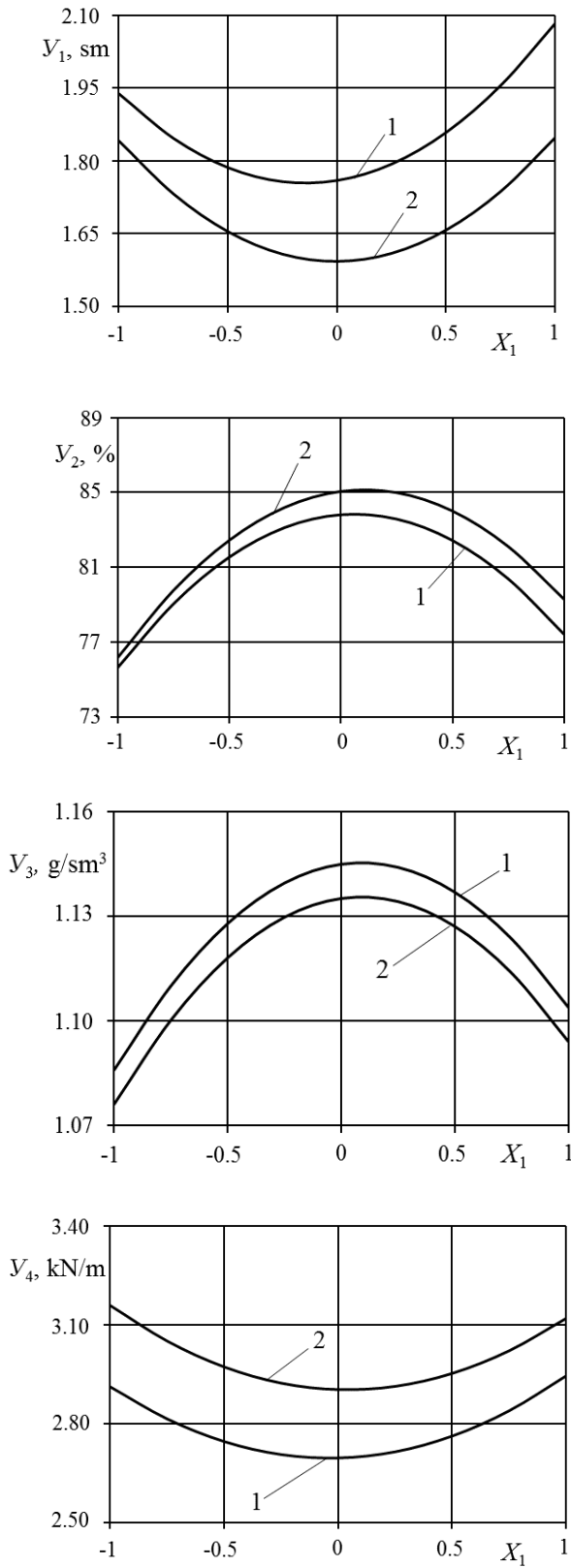
- by the traction comparative resistance of harrow leveller, (kN/m)

$$Y_4 = 2.825 - 0.010X_1 + 0.097X_2 + 0.268X_3 + 0.210X_4 + 0.234X_1^2 - 0.213X_1X_3 - 0.027X_1X_4 - 0.041X_2^2 - 0.218X_2X_3 + 0.03X_2X_4 - 0.07141X_3^2 - 0.026X_3X_4 + 0.08X_4^2. \quad (4)$$

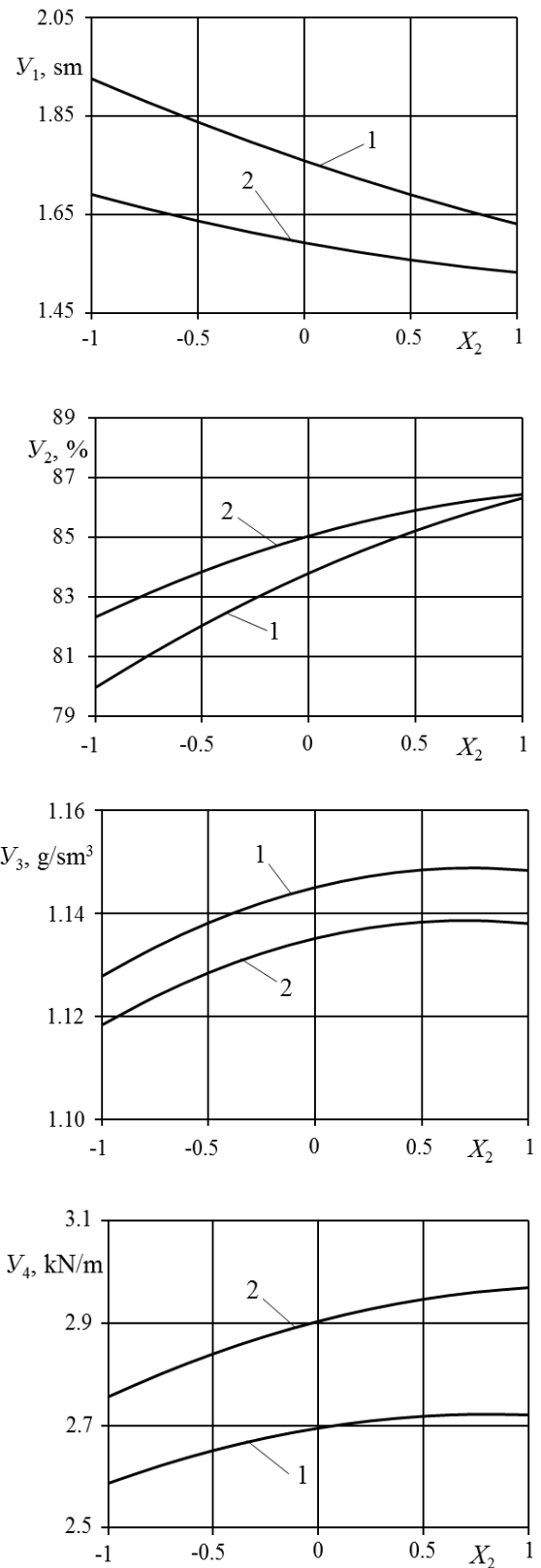
Equations (1)-(4) are applicable in the event if $20^\circ \leq \beta \leq 40^\circ$ $25 \text{ cm} \leq L \leq 35 \text{ cm}$, $2.0 \text{ kN/m} \leq Q \leq 2.8 \text{ kN/m}$, $6.0 \text{ km/h} \leq V \leq 9.0 \text{ km/h}$.

(1)-(4) When we analyse the regression equations and graphical relations formulated based on them, it can be found out that all the factors have influenced the evaluation criteria significantly (figures 3-5).

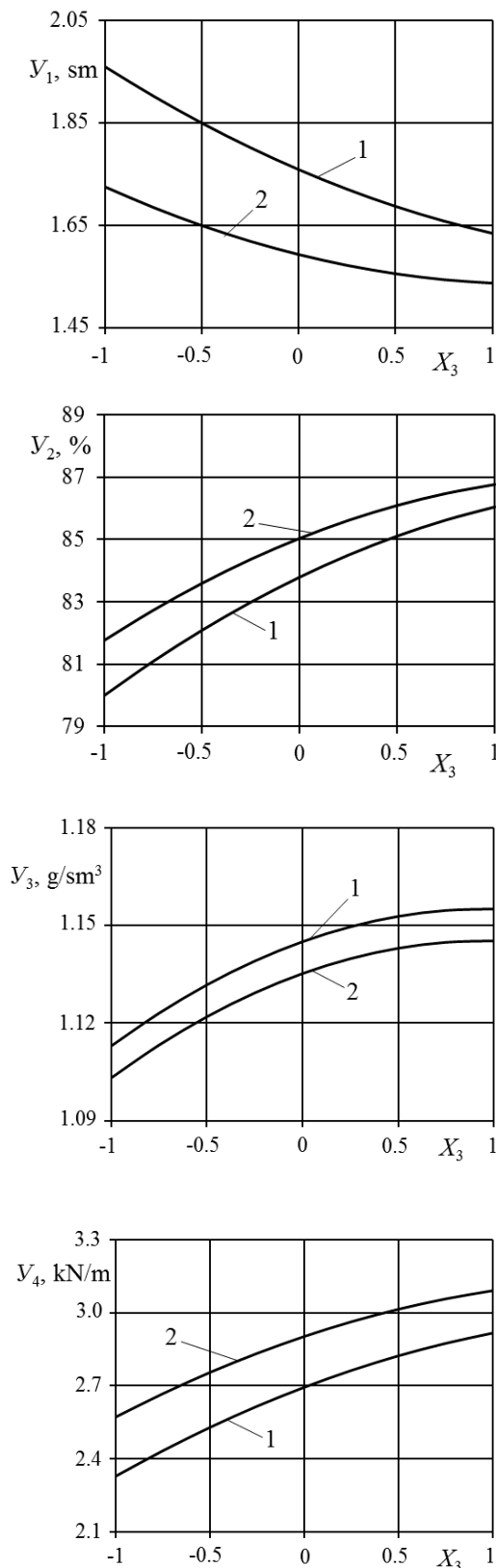
Installation angle of the compactor with regard to horizon, i.e. as the X_1 factor increases Y_1 and Y_4 criteria, that is deviation of height of the mean square unevenness on the field surface and before comparative resistance to the traction decreased, after it has enlarged; Y_2 and Y_3 criteria, i.e. before degree of the soil crumbling and density has reduced, after it increased.



In case when 1 and 2 – accordingly velocity of movement were 6.0 and 8.0 km/hour
Figure 3. Variation curves of Y_1 , Y_2 , Y_3 and Y_4 criteria in relation with X_1 factor



In case when 1 and 2 – accordingly velocity of movement were 6.0 and 8.0 km/hour
Figure 4. Variation curves of Y_1 , Y_2 , Y_3 and Y_4 criteria in relation with X_2 factor



In case when 1 and 2 – accordingly velocity of movement were 6.0 and 8.0 km/hour

Figure 5. Variation curves of Y_1, Y_2, Y_3 and Y_4 criterias in relation with X_3 factor

X_2 factor, i.e. as the length of working surface of compactor increases Y_1 criteria almost decreased based on the straight line laws; and Y_2, Y_3 and Y_4 criteria enlarged, but as X_2 enlarges their increase, intensity has decreased.

Influence forwarded onto the straight comparative tension was as in X_2 criteria to criteria of X_3 factor. And whenever such criteria increases Y_1 criteria has decreased. Y_2, Y_3, Y_4 criteria has enlarged.

(1)-(4) regression equations are less than Y_1 criteria 2,0 cm, Y_2 criteria is more than 80 %; Y_3 criteria bet ween 1,1-1,2 g/cm^3 and Y_4 criteria may be together solved due to that they have minimum values; the following appropriate values for the working velocities – 6.0-8.0 km/h of compactor parameters of the enhanced harrow leveller were found: installation angle of compactor with regard to horizon is 29-32°; length of working surface is 31-32 cm and straight load forwarded to it is 2.4-2.6 kN/m.

Y_1, Y_2, Y_3 and Y_4 criteria accordingly will be 1.53-1.71 cm, 84.49-86.75 %, 1.14-1.15 g/cm^3 and 2.67-3.24 kN/m in the determined above values of the factors.

4. Conclusions

According to the results of implemented multifactorial experiments 6.0-8.0 km/h the following items were pointed out: in effort to ensure performing the necessary tillage on the field surface when the movement velocity of the enhanced harrow leveller compactor by consuming the less energy, in this case the installation angle of compactor with regard to horizon should be between 29-32°; length of the working surface – between 31-32 cm and straight tension forwarded to it should be 2.4-2.6 kN/m.

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