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A Study related to the influence of the speed of a Machine-tractor aggregate and soil moisture on plowing depth

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GOAL OF THE STUDY

The aim of the present study is to trace out the working stability of a machine-tractor aggregate during soil plowing according to the momentous soil moisture at two aggregate`s speeds.

METHODOLOGY OF THE INVESTIGATION

1. Experimental design

An experiment was carried out on a parcel (42º09`07``N25º20`54``E) on the territory of Chirpan Region in the central part of Bulgaria. The experimental field was divided into two plots with sizes 1000 m length and 45 m width (Fig. 1). The soil in the examined parcel was of the *chernozem* type. The study was carried out in December 2021.

The work of the machine-tractor aggregate set to plow at a depth of 28-30 cm has been studied. Tillage was performed with a five-corpus turning plow, aggregated to a tractor of 200 hp. The aggregate's speed used on the first plot was 4,5 km/h, and on the other - 6 km/h.

The actual depths of plowing in the aggregate`s operation with the relevant speeds in the particular plots were measured using linear mether as follows: 50 measurings every 20 m along the length of the furrow. Using a soil moisture-meter AM-128 SOIL the instantaneous soil moisture was measured in the relevant points of both plots.

2. Data analysis

Data analysis includes the obtaining of the basic descriptive statistics and One-Way ANOVA aiming at establishing significant differences between the studied plowing depths at the relevant speeds of the machine-tractor unit. A correlation analysis was conducted to investigate the power and direction of relations between the observed parameters Soil Moisture, Aggregate`s Speed, and Plowing Depth at a significant level $p < 0.01$.

A multivariate regression analysis was applied to examine the changes in depth at soil plowing depending on the machine aggregate`s speed and soil moisture at $p < 0.05$. Two types of models were used – Linear (1) and Non-linear (2). The second model included the interaction between the factors. The general look of the models was as follows:

$$a = b_0 + b_1 x + b_2 y \quad (1)$$

$$a = b_0 + b_1 x + b_2 y + b_3 xy + b_4 x^2 + b_5 y^2 \quad (2)$$

where a is the depth of aggregate`s operation, [m]

x – soil moisture, [%]

y – speed of aggregate`s motion, [km/h]

b_0, b_1, b_2…….b_n - coefficients of the model.

MAIN RESULTS FROM THE STUDY

A. Descriptive statistics, ANOVA and Correlation analysis

Table 1. Crosstab correlation between the examined parameters Aggregate's Speed, Soil Moisture, and Depth of Plowing.

Tillage depth (a, cm) n=50	Soil moisture (W, %)	Aggregate speed (V, km/h)	Depth of Plowing (a, cm)
Soil moisture (W, %)	1	- 0.943*	- 0.860*
Aggregate speed (V, km/h)	-	1	0.923*
Depth of Plowing (z, cm)	-	-	1

Table 2. Descriptive statistics and ANOVA of the observed depths of Plowing.

Depth of Plowing (a, cm) (n= 50)			
Aggregate speed (km/h)	$\bar{x} \pm SD$	**min**	**max**
4.5	23.31±1.13 [a]	21	25
6	29.04±1.27 [a]	27	32

[a-a] - Same superscripts within the same column represent significant differences at the level of significance $p < 0.05$; SD – Standard deviation; n – number of the observations

B. Regression analysis

Table 3. Linear Regression Model showing the dependence of plowing depth from the aggregate`s operational speed and soil moisture.

Regression Summary for Dependent Variable: Tillage depth, cm Multiple R=0.984; R^2 = 0.9683; Adjusted R^2= 0.9625; p < 0.00 (Corrected Model)				
No. of cases: 50	Coef.	Std. error of estimate	F (df = 2;11)	p-value
Intercept	75.634	1.463	168.034	0.000
Soil moisture (W, %)	- 0.29			0.000
Aggregate speed (v, km/h)	- 4.95			0.000

The equation of the Linear model is:

$$a = 75.63 - 0.29W - 4.95v$$

Table 4. Non-linear Regression Model expressing the dependence of tillage depth from the aggregate`s operational speed and soil moisture

Regression Summary for Dependent Variable: Tillage depth, cm Multiple R=0.988; R^2 = 0.9770; Adjusted R^2= 0.973; p < 0.00 (Corrected Model)				
No. of cases: 50	Coef.	Std. error of estimate	F (df = 2;11)	p-value
Intercept	62.345	1.245	234.075	0.000
Soil moisture (W, %)	- 0.0015			0.000
Aggregate speed (v, km/h)	- 4.95			0.000

The equation of the Non-linear model is:

$$a = 62.5 - 4.95v - 0.0015W^2$$

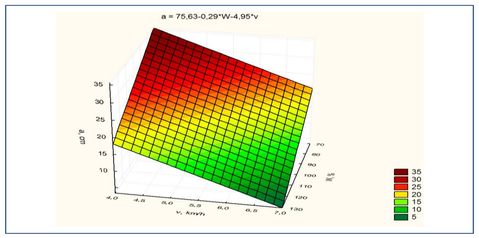

Fig. 1. Plot`s surface a = f (v, W) for the Linear model

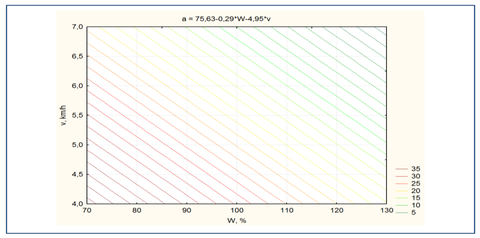

Fig. 2. Lines of equal surface a = f (v, W) for the Linear model

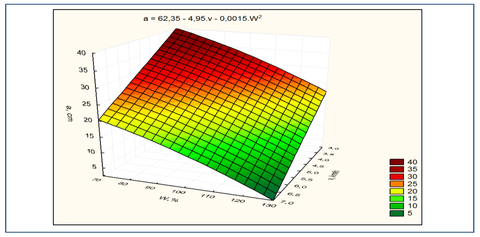

Fig. 3. Plot`s surface a = f (v, W) for the Non-linear model

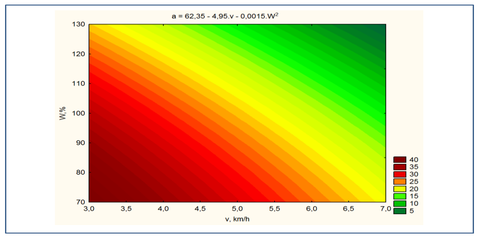

Fig. 4. Lines of equal surface a = f (v, W) for the Non-linear model

CONCLUSIONS

- A motor-tractor aggregate for plowing was examined by the qualitative indicator Tillage Depth at parametric instability. Data received from the field experiment were statistically processed and the following results were obtained:
- A very strong positive correlation between the parameters Aggregate`s Speed and Depth of Plowing (r = 0.923) was registered, i.e. the increase of aggregate`s speed leads to an increase in the uniformity of plowing depth.
- There were very strong, but negative correlations between the Soil moisture and Aggregate`s speed (r = - 0.943), as well as between Soil moisture and Depth of Plowing (r = - 0.860). It can be concluded that the increase of soil moisture leads to a decrease of aggregate`s speed, which decreases the plowing depth. Thus, the tractor begins to slip.
- Statistically significant differences between the average values of the parameter Depth of Plowing at both Aggregate`s speeds were established. The higher operational speed (6 km/h) and the lower momentous soil moisture lead to values of the actual measured plowing depths closer to the set ones for the unit.
- Two models were examined – Linear and Non-linear. It was reported that the Non-linear model was more comprehensive and described better the studied process.
- The regression equations were visualized with a 3D graphic of the plot`s surface a = f (v, W), as well as a 2D graphic consisting of lines on equal levels. It was evident from the graphics that the maintenance of the corresponding plowing depth in this particular case can be obtained at moisture between 70 - 80% and an aggregate`s speed of 4.5-5 km/h.