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INFLUENCE OF THE VERTICAL DISTANCE BETWEEN LOWER AND UPPER HITCH POINTS OF AN EXPERIMENTAL PLOW HITCHING DEVICE ON ITS PERFORMANCE INDICATORS

A.R. Rasuljonov

PhD, Senior Researcher

Abstract. This paper presents the results of an experimental investigation into the influence of the vertical distance between the lower and upper hitch points of an experimental plow hitching device on its performance indicators. The studies were conducted within a range of 70–90 cm, with a stepwise variation of 5 cm. During the experiments, working depth, its root mean square deviation, and the draft resistance of the plow were taken as the main evaluation criteria. The analysis of the obtained results shows that variations in the vertical distance have no significant effect on the working depth; however, noticeable changes are observed in the stability of working depth and draft resistance. The most favorable operating condition was identified in the range of 75–80 cm, where stable operation of the arperate and minimum energy consumption were achieved. Based on the experimental results, empirical relationships were developed and optimal design parameters were justified.

Keywords: mounted plow, hitching device, vertical distance, working depth, stability, draft resistance, energy efficiency.

Introduction. The efficiency of primary tillage operations in agriculture is directly influenced by the structural and kinematic parameters of plow implements. In particular, the spatial stability of plows mounted on tractors via a three-point hitch system has a significant impact on work quality, the accuracy of working depth, and overall energy consumption.

The forces acting on soil-engaging tools and the stability of agricultural implements during soil tillage have been widely studied in previous research. McKyes, in his theoretical framework, demonstrated that soil cutting processes and the resistance forces acting on tillage tools depend on both the physical–mechanical properties of the soil and the motion geometry of the working tools [1].

Gill and Vanden Berg further showed that the draft force and stability of tillage systems are strongly influenced by the geometric relationship between the implement and the draft line. Their findings confirm that the spatial equilibrium of the implement has a direct effect on operational performance [2].

Srivastava and co-authors investigated the optimization of structural parameters of agricultural machines and emphasized that the geometry of the three-point hitch system significantly affects both the dynamic stability and energy efficiency of the implement [3].

Zelenin and collaborators developed mechanical models describing soil–tool interaction and demonstrated that implement stability is closely related to soil resistance and the spatial positioning of working tools [4].

In addition, ASABE standards recognize the kinematic analysis of tractor-mounted implements and the geometry of hitch points as key design factors governing operational stability and efficiency [5].

Despite these studies, the influence of the vertical distance between the upper and lower hitch points of a plow mounting system—an important geometric parameter—has not been sufficiently investigated experimentally, particularly in relation to working depth stability and draft force variations. This gap in knowledge highlights the need for a detailed experimental study of this parameter.

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The aim of this study is therefore to experimentally investigate the effect of the vertical distance between the lower and upper hitch points of a plow mounting system within the range of 70–90 cm on operational performance indicators and to determine its optimal value.

Materials and Methods. The present study is aimed at experimentally investigating the influence of the vertical distance between the lower and upper hitch points of an experimental plow mounting device on the operational performance indicators of the aggregate. The experimental investigations were carried out under field conditions at the experimental farm of the Research Institute of Agricultural Mechanization (SRIAM), specifically on field plot No. 3. To ensure uniform agro-technical conditions, the experimental field was prepared in advance by deep plowing, leveling, and full-area irrigation.

The experiments were conducted using the experimental mounted plow and chisel cultivator developed in Chapter 2 of this work, together with the methodological approaches described therein. The soil of the experimental field was classified as medium-heavy textured gray soil, with groundwater located at a depth of 10–15 m. Prior to the experiments, the main agrophysical properties of the soil—moisture content, bulk density, and hardness—were determined for the 0–10, 10–20, 20–30, and 30–40 cm soil layers. The average values of these parameters were found to be within the ranges of 15.2–18.5%, 1.31–1.49 g/cm³, and 1.37–2.81 MPa, respectively. These conditions ensured a relatively stable soil environment throughout the experimental program (Table 1).

Table 1. Characteristics of the experimental field.

	Names of indicators	Values of indicators
	Soil moisture content by layers (cm), %:	
	0-10	15,2
	10-20	17,4
	20-30	17,9
	30-40	18,5
	Soil hardness by layers (cm), MPa:	
	0-10	1,37
	10-20	2,08
	20-30	2,51
	30-40	2,81
	Soil bulk density by layers (cm), g/cm³:	
	0-10	1,31
	10-20	1,35
	20-30	1,42
	30-40	1,49

The main independent variable in the experimental studies was the vertical distance between the lower and upper hitch points of the experimental plow mounting device, which was varied from 70 cm to 90 cm with a step of 5 cm. The initial optimal design value was taken as 74.8 cm, and this parameter was adjusted by vertically shifting the upper hitch pin along the holes of the bracket. The experiments were conducted at two operating speeds, namely 6 km/h and 8 km/h, while all other conditions were kept constant.

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During the experiments, working depth (h_p), its stability expressed as the root mean square deviation ($\pm\sigma_p$), and the draft resistance of the plow (R_p) were recorded as the main performance indicators. Working depth was measured using a mechanical depth gauge, while draft force was recorded using a dynamometric measurement system. Travel speed was controlled using the standard tractor monitoring system.

The obtained experimental data were processed using mathematical and statistical methods, and regression analysis was applied to determine the relationship between the vertical distance between the lower and upper hitch points of the experimental plow mounting device and the performance indicators h_p, $\pm\sigma_p$, and R_p. Based on this analysis, empirical equations describing these dependencies were developed.

Results and Discussion. During the experimental investigations, the vertical distance between the lower and upper hitch points of the experimental plow mounting device was varied from 70 cm to 90 cm at intervals of 5 cm. This was achieved by moving the upper hitch pin upward through the holes provided in the mounting bracket. Throughout the experiments, the vertical distance from the supporting surface to the lower hitch points was maintained at 80 cm, the working depth was set at 35 cm, the support wheel diameter and width were 40 cm and 20 cm, respectively, and the travel speed of the aggregate was maintained at 6 and 8 km/h. Under these conditions, the effect of the vertical distance on working depth, its root mean square deviation, and draft resistance was investigated.

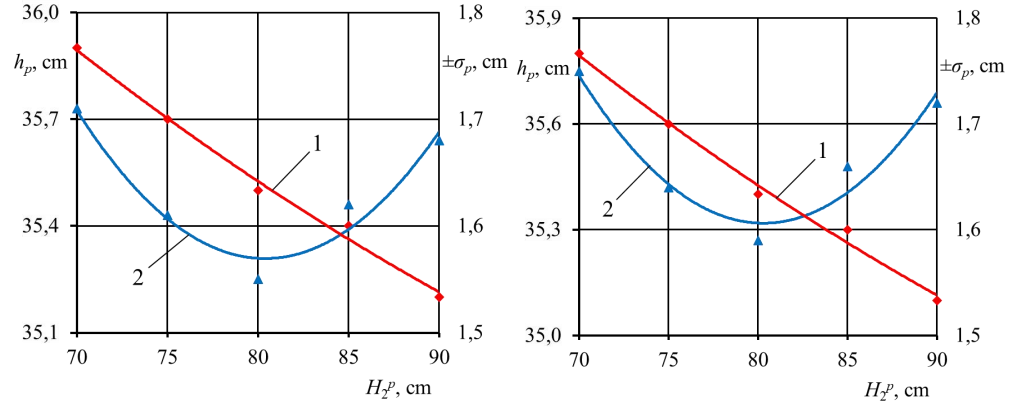
Analysis of the experimental results (Table 2 and Figures 1–2) showed that varying the vertical distance between the lower and upper hitch points within the range of 70–90 cm had no significant effect on the working depth at either travel speed. The working depth remained nearly constant throughout the tested range, indicating that the vertical equilibrium of the aggregate was effectively maintained by the interaction between the support wheel and the soil reaction forces. However, the root mean square deviation of working depth ($\pm\sigma_p$) exhibited a distinct trend. As the vertical distance increased from 70 cm to 75 cm, the deviation decreased; within the range of 75–80 cm it remained nearly unchanged, whereas a further increase from 80 cm to 90 cm resulted in a gradual rise in deviation. This behavior can be attributed to the dynamic equilibrium of the aggregate in the longitudinal–vertical plane. In particular, within the range of 75–80 cm, the instantaneous center of rotation was located close to the line of action of the resultant soil resistance force, leading to improved moment equilibrium and reduced vertical oscillations of the implement.

Table 2. Influence of the vertical distance between the lower and upper hitch points of the experimental plow mounting device on its performance indicators

Vertical distance between the lower and upper hitch points of the mounted plow, cm	Working depth and its root mean square deviation, cm		Draft resistance, kN
	h_p	$\pm\sigma_p$	
V=6 km/h			
70	35,9	1,71	29,1
75	35,7	1,61	28,8
80	35,5	1,55	28,4
85	35,4	1,62	28,1
90	35,2	1,68	27,7

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V=8 km/h			
70	35,8	1,75	30,2
75	35,6	1,64	29,6
80	35,4	1,59	29,3
85	35,3	1,66	29,1
90	35,1	1,72	28,7



а) *б*)

1. $h_p=f(H_2^p)$; 2. $\pm\sigma_p=f(H_2^p)$

Figure 1. Influence of the vertical distance between the lower and upper hitch points of the plow mounting device on working depth (h_p) and the root mean square deviation of working depth ($\pm\sigma_p$): (a) 6 km/h; (b) 8 km/h.

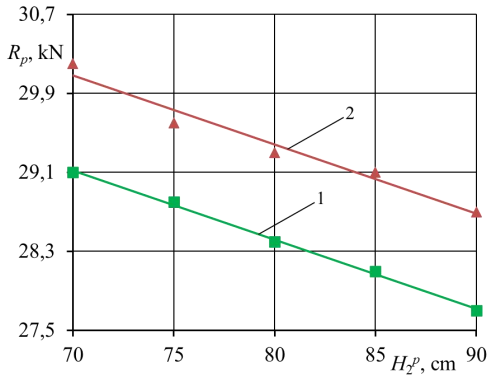


Figure 2. Effect of the vertical distance between the lower and upper hitch points of the plow mounting device on draft resistance (R_p): 1 – 6 km/h; 2 – 8 km/h.

The analysis of draft resistance indicated a decreasing trend with increasing vertical distance. At a travel speed of 6 km/h, draft resistance decreased from 29.1 kN to 27.7 kN, while at 8 km/h it decreased from 30.2 kN to 28.7 kN. This reduction is associated with the downward displacement of the instantaneous center of rotation and the resulting

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redistribution of the normal load acting on the plow bodies. Consequently, the effective component of soil resistance opposing motion was reduced, contributing to lower energy consumption during operation.

Based on the experimental data, empirical regression equations were developed to describe the relationships between the investigated parameter and the performance indicators, including working depth, depth stability, and draft resistance. The obtained models demonstrated high reliability, with coefficients of determination (R^2) ranging from 0.93 to 0.99, indicating good agreement between the predicted and measured values. These results provide a quantitative basis for evaluating the influence of the vertical distance between the lower and upper hitch points on the operational performance of the experimental plow.

Overall, the results indicate that the vertical distance between the lower and upper hitch points is an important geometric parameter affecting both the stability and energy efficiency of the aggregate. The most favorable operating conditions were observed within the range of 75–80 cm, where working depth stability was maximized, the root mean square deviation reached its minimum value, and draft resistance remained relatively low. Therefore, for stable and energy-efficient operation of the experimental plow, a vertical distance of 75–80 cm between the lower and upper hitch points is recommended.

Conclusion. The experimental investigations demonstrated that the vertical distance between the lower and upper hitch points of the experimental plow mounting device has a significant influence on its performance indicators. Although varying this parameter within the range of 70–90 cm had little effect on the average working depth, noticeable differences were observed in working depth stability and draft resistance.

The most favorable operating condition was obtained within the range of 75–80 cm, where the root mean square deviation of working depth reached its minimum value and the draft resistance approached its lowest level. This behavior can be explained by the optimization of the geometric equilibrium of the hitching system and the more favorable distribution of soil–implement interaction forces.

Overall, setting the vertical distance between the lower and upper hitch points of the experimental plow mounting device within the range of 75–80 cm ensures stable operation of the plow together with improved energy efficiency.

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1. McKyes, E. (1985). *Soil Cutting and Tillage*. Elsevier.
2. Gill, W. R., & Vanden Berg, G. E. (1968). *Soil Dynamics in Tillage and Traction*. USDA Agricultural Handbook.
3. Srivastava, A. K., Goering, C. E., Rohrbach, R. P., & Buckmaster, D. R. (2006). *Engineering Principles of Agricultural Machines*. ASABE.
4. Zelenin, A. N., Balovnev, V. I., & Kerov, I. P. (1985). *Machines for Earthmoving Work*.
5. ASABE Standards. *Tractor Hitch Geometry and Implement Performance Guidelines*. American Society of Agricultural and Biological Engineers.