EVALUATION OF THE HORIZONTAL AND VERTICAL FORCE OF REVERSIBLE MOLDBOARD PLOW IN SILTY LOAM SOIL.

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Abstract: The aim of the study was to evaluate the horizontal and vertical force of reversible moldboard plow at various operation depth and speed. A complete randomized block design was used with three replications, the first treatment was tillage depth with three levels 15, 20, 25 cm and the second treatment was the forward speed with two levels 3.9, 6.3 km·h⁻¹. The result showed that both forces were increased as increased of tillage depth and speed, however, the operation depth was more effective than speed, on the other hand, the horizontal force was more affected than vertical force by increasing both of depth and speed.

KEY WORDS: VERTICAL, HORIZONTAL FORCE, MOLDBOARD PLOW, TILLAGE

1. Introduction

Tillage is a process that is created suitable soil conditions for seed germination and crop growth (Al-Suhaibani and Ghaly, 2010). Primary tillage in many cases is important for successful crop establishment, pest and weed control (Nielsen, et al. 2017). It is the base operation in the agriculture and its energy represents a considerable part of the energy utilized in crop production (Askari & Khalifahamzeghhasem, 2013). The most common implement in the world for plowing is a moldboard plow, ranging from the simplest type for animal traction, up to the highly advanced, large plows for tractors (Celik et al., 2007). It is widely used as a primary tillage tool (Mari et al., 2014). It was stated that draft force of moldboard plow was about 2.14 and 1.8 times as much as the chisel plow and disk harrow respectively (Askari & Khalifahamzeghhasem, 2013). The amount of force required to pull or push the implement through the soil is called horizontal or draft force (Godwin, 2007), while the vertical force of implement is assisting or preventing the penetration into the soil (Manuwa et al., 2012). Forward speed and tillage depth have considerable effect on the horizontal and vertical force. The vertical force increased with the increase in the tillage depth, this effect occurred due to the fact that at higher depths a greater soil volume is considered (Ibrahim et al., 2014; Manuwa, 2009). It is clearly that tillage forces varied according to the shape of the tools, forward speed and depth of plowing (Godwin & Dogherty, 2007). The relationships between draft and speed showed that with increasing forward speed, draft increased (Safari & Gazor, 2014; Rosa & Wulfssohn, 2008). For the moldboard plow, when forward speed increased from 1.5 to 3 km·h⁻¹, the draft requirement increased from 9 to 10 kN and was not doubled. This increment occurred for all plows. In the sense of doubling the forward speed, the draft requirement increased but was not doubled (ASABE Standards, 2009). Also the ploughing depth has a greater effect on the horizontal force than on the vertical force (Al-Suhaibani & Ghaly, 2013). The objective of this study was to estimate the horizontal and vertical force of reversible moldboard plough in silty loam at different tillage forward speed and depth using new three hitch point (frame).

2. Materials and method

2.1 Treatments and Experimental Design

The trial was conducted at Czeslawice field in Lublin province (Poland) which belong to the farm of the University of Life Science in Lublin at a latitude of N51° 18’ 23”", N51° 13’ 27”, the soil texture was classified as a silt loam.

A complete randomized block design was used with three replications, the first treatment was tillage depth with three levels 15, 20, and 25 cm, the second treatment was the forward speed with two levels 3.9, 6.3 km·h⁻¹. Statistical software (Statistica ver. 13.1) was used for the statistical analysis of the results obtained. A two-way analysis of variance (ANOVA) with interaction was performed assuming 0.05 as the level of significance.

2.2 Forces measurements

The three-point hitch dynamometer (Figure 5) was built in the form of an inverted U–shape and calibrated at the same company (Industrial Institute of Agricultural Engineering, Poznan, Poland). It was designed and fabricated to be used for measuring the horizontal and vertical force of the soil engaged tools. It was placed between the tractor and the implement. The force sensing elements comprise five extended transducers. Moreover, the data acquisition system consists of a program data logger and serial cable. A notebook computer was also used for the monitoring and processing of data in the system.

3. Result and discussion

3.1. Effect of tillage depth on the horizontal and vertical force

The results (Figure 2) indicated that change of tillage depth of plow was effective on the both horizontal and vertical force (p < 0.05).

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Fig. 1. Three hitch dynamometer (frame)

Fig. 2. Effect of tillage depth on the horizontal and vertical force
The maximum horizontal and vertical force (14.01 and 2.25 kN) occurred at tillage depth of 25 cm, while the minimum values (9.53 and 1.87) occurred at tillage depth of 15 cm. The forces increased with the operational depth of the plow was probably due to the greater depth of plow penetration, therefore, the larger surface area and greater soil resistance which requires more force to cut the soil and turn it over during plowing operation, this agreed with the findings of Deshpande et al. (2015)

3.2. Effect of forward speed on the horizontal and vertical force

The results (Figure 2) indicated that forward speed of plow was effective on the both horizontal and vertical force. The maximum horizontal and vertical force were occurred at forward speed 6.3 km h\(^{-1}\), and minimum values occurred at forward speed of 3.9 km h\(^{-1}\). these were agreed with finding of Manuwa (2009) who confirmed that horizontal force increased as forward speed increased, this is mainly due to the acceleration of the soil, which in turn, increased the reaction at the interface of tools, therefore, the higher sliding resistance

\begin{table}
\centering
\begin{tabular}{|c|c|c|}
\hline
Plow forces & Vertical force [kN] & Horizontal force [kN] \\
\hline
6.3 km h\(^{-1}\) & 9.35 & 2.08 \\
3.9 km h\(^{-1}\) & 12.05 & 2.08 \\
15 km h\(^{-1}\) & 2.08 & 12.05 \\
20 km h\(^{-1}\) & 2.08 & 12.05 \\
25 km h\(^{-1}\) & 15.17 & 12.05 \\
\hline
\end{tabular}
\caption{Effect of forward speed on the horizontal and vertical force}
\end{table}

3.3. Effect of interaction of tillage depth forward speed on the horizontal and vertical force

The results (Figure 4) indicated that the interaction of change tillage depth and forward speed of moldboard plow was effective on the horizontal and vertical force the effect was significant at \(p < 0.05\). The highest horizontal and vertical force were obtained by forward speed of 6.3 km h\(^{-1}\) and tillage depth of 25 cm, while the minimum values were obtained by forward speed of 3.9 km h\(^{-1}\) and tillage depth of 15 cm.

\begin{table}
\centering
\begin{tabular}{|c|c|c|c|c|}
\hline
Tillage depth & Vertical force [kN] & Horizontal force [kN] \\
& 3.9 & 6.3 & 3.9 & 6.3 \\
\hline
15 cm & 2.08 & 9.35 & 15.17 & 9.35 \\
20 cm & 2.08 & 15.17 & 9.35 & 15.17 \\
25 cm & 2.08 & 15.17 & 9.35 & 15.17 \\
\hline
\end{tabular}
\caption{The interaction effect of tillage depth forward speed on the horizontal and vertical force}
\end{table}

4. Conclusions

The horizontal and vertical forces of reversible moldboard plow are increased as forward speed and working depth increased. The effect of plowing depth was higher on the forces than effect of plowing speed. Moreover, the increasing in the horizontal force was higher than the increasing in vertical force.

5. References