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Impact of Bottoms Number on Draft Force Requirements and Stability of Moldboard Plow at Various Tillage Depths and Forward Speeds

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

The study aimed to evaluate the bottom effect of the numbers of different moldboard plows, namely single bottom (MB1), two bottoms (MB2), three bottoms (MB3), and four bottoms (MB4), three levels of forward speeds (3.17, 4.78, and 6.43 km h^{-1}), and three levels of plowing depths (15, 20, and 25 cm) for the moldboard plow, and the interaction between these factors on draft force, fuel consumption, and longitudinal and lateral deflection of the moldboard plow. The experiments were carried out in the Basrah governorate (29° 31′N, 46° 48′ E). The experiment used a randomized complete block design with a split plot method for a factorial experiment (4 × 3 × 3) with three replicates. The results showed that increasing the number of bottoms from MB1 to MB4 reduced the draft force per bottom from 5.55 to 3.22 kN, fuel consumption from 18.83 to 14.72 L ha^{-1}, lateral deflection from 4.58% to 2.22% and longitudinal deflection from 8.04% to 2.76%. Although

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increasing the speed from 3.17 to 6.43 km h^{-1} increased the draft force by 64.3%. Increasing the plowing depth from 15 to 30 cm increased the draft force from 3.50 to 7.84 kN, fuel consumption from 14.00 to 23.69 L ha^{-1}, longitudinal deflection from 2.31% to 6.27%, and lateral deflection from 2.43% to 3.22%. The best performance was recorded when using the MB4 at a speed of 6.43 km h^{-1} and a depth of 15 cm, achieving the lowest draft force (3.22 kN), the lowest fuel consumption (10.00 L ha^{-1}), and lateral and longitudinal deflection of 0.78% and 2.76%, respectively.

Keywords: Moldboard Plow; draft force; fuel consumption; longitudinal deflection; lateral deflection.

1. INTRODUCTION

The moldboard plow is one of the most important and widely used primary soil preparation machines because it achieves the objectives of plowing, which are cutting, turning the soil, and breaking up the soil and thus providing a suitable bed for seed germination and growth (Mahatale *et al*., 2017). Soil preparation for planting and providing a suitable bed for the seed requires more than 60% of the energy expended on all agricultural operations (Nassir *et al*., 2023). Therefore, part of the energy expended in plowing operations can be reduced by using different designs of shears or bottoms because of their effect on the process of cutting and turning the soil (Guul-Simonsen *et al*., 2002).

Plowing depth, soil conditions, and forward speed are some of the variables that affect moldboard plow stability and traction needs. Modifying these variables can enhance field efficiency, lower energy usage, and maximize moldboard plow performance. It is essential to comprehend these dynamics in order to choose the best plow design and operating parameters for certain field circumstances (Ranjbar *et al*., 2013)

The traction force of the plough depends on the soil properties and conditions such as moisture content, bulk density, and cohesive strength as well as operating conditions such as forward speed and tillage depth (Kim *et al*., 2021). The draft force required for moldboard plows differs considerably with tillage depth, forward speed, and soil circumstances (Kim *et al*., 2021). Taha and Taha (2019) found that the draft force increased by 65.25% when increasing plowing depth from 15 to 20 cm; they also reported that increasing forward speed from 3.77 to 6.45 led to an increased draft force by 80%.

The draft force and the effectiveness of the plowing operation are directly correlated with fuel consumption. According to a study comparing several moldboard plow designs, a helical (long) bottom design used 6% less fuel than a cylindrical (short) one (Plouffe *et al*., 1999). Fuel consumption is also affected by operating speed; greater speeds often result in reduced fuel consumption per hectare because of the improved field capacity (Hamid & Alsabbagh, 2024). Several factors, including cropping systems, tillage depth, tractor speed, plow type, and soil conditions, impact fuel consumption in moldboard plowing. This improvement in area efficiency is due to higher speeds that cover more ground per unit of time, allowing the primary fuel consumption to be distributed over a larger working area (Chenarbon, 2022). Fuel consumption increases considerably with plowing depth; for instance, increasing 10 cm to 30 cm can increase fuel consumption by more than 50% because of increased soil resistance and tractor workload (McLaughlin *et al*., 2024).

Effective soil preparation, particularly when it comes to keeping a constant plowing depth, depends on the stability of the plowing operation. The uneven soil conditions caused by varying plowing depths may have an impact on later sowing activities. The stability of the plowing depth declines with decreasing depth, and the coefficient of variability is higher at lower depths (Plouffe *et al*., 1999). Furthermore, stability may be significantly impacted by plow design elements like landside, with longer landside offering superior lateral stability as well as an increased number of bottoms (working width), which led to reduced stability of plow (Zaidan, 2012). In addition, challenges with depth stability worsen at depths greater than 15 cm. Optimizing plowing depth may increase stability and plowing efficiency, which leads to reduced fuel consumption and specific draft force dropping with shallower plowing settings (Al-Shamiry *et al*., 2020).

The working width of the moldboard plow, represented by the number of bottoms, has a great impact on the requirements of traction, fuel consumption, and lateral and vertical deviation (Kim, 2022). Therefore, the study aimed to estimate the traction force, fuel consumption, lateral and vertical deviation of the moldboard plow based on one bottom, two bottoms, three bottoms and four bottoms and to answer the questions: Does the single-body plough need the same power requirements as one bottom of the plough bottoms in the case of multiple bottoms?

2. MATERIALS AND METHODS

2.1 Description of the Site, Design of the Experiment, and Tillage Methods

The study was carried out in December 2023 at the University of Basrah's agricultural college's agriculture station study facility (30° 30′ N, 47° 49′ E) in southern Iraq. With a long-term average yearly rainfall of 250 mm, this area has a semi-arid climate (Al-Lami *et al*., 2021). Most of the rainfall occurs in the winter in this region. The average monthly temperature ranges from 12°C in January to a high and low of 45°C in July. In the experimental field, the top layer (0–35 cm) had a clay loam soil texture class (50% clay, 30% silt, and 20% sand), The surface soil layer's bulk density, moisture content and penetration resistance of soil were measured and found to be 1.24 Mg 19.47%, and 0.98 MPa, respectively with three replications. The experiment was organized as a split-plot randomized complete block design. Four different plowing methods were arranged in the main plots consisting of MB1 (single bottom), MB2 (two bottoms), MB3 (three bottoms), and MB4 (four bottoms). Three plowing depths of 15, 20, and 25 cm were arranged in subplots. Three forward speeds of 3.17, 4.78, and 6.43 km h^{-1} were arranged in the sub-subplot. The plot area was adjusted to 200 m × 2 m.

2.2 Moldboard Plow

The moldboard plow deep digger type was used in the experiments. The distance between each bottom and the other is 35 cm, and each bottom is provided with a 42 cm landside and a cutting shear with an area of 35 x 5 cm. The shear front is pointed to facilitate the penetrating process of the soil. The total height of the plow is 95 cm. The total weight of the plow is 500 kg (4.905 kN). This plow is characterized by the ease of removing or adding the bottoms, and this feature makes it easy to use the plow with one bottom, two bottoms, three bottoms, and four bottoms. On this basis, the working width of the plow varies according to the plowing treatment. Therefore, the working width for single bottom plow, two bottom plow, three bottom plow, and four bottom plow are 35, 70, 105, and 140 cm, respectively.

2.3 Fuel Consumption

Fuel consumption was measured for single, double, triple, and quadruple bottom plow by filling the tractor tank perfectly with diesel fuel. The distance of the experimental unit was determined at 200 m. When the tractor, loaded with the moldboard plow, covers this distance, the tractor engine is stopped, and an additional amount of fuel is added using a graduated cylinder of known volume to the fuel tank to fill it to its previous position. This added amount is considered the amount of fuel consumed. The fuel consumed in units of litter per hectare was calculated from the following equation mentioned in Nassir *et al*. (2023).

$$F.C = \frac{Q}{A} \times 10^4 \quad (1)$$

where, $F.C$ is fuel consumption (L ha^{-1}), Q is fuel consumption required to cover the plot area (L), A is plot area (m^2) (The distance of the experimental unit is 200 m multiplied by the working width.), and 10^4 is convert the area from m^2 to hectare.

2.4 Tractors Used and Draft Force Measurement

A load cell (model H3-C3-3.0t-6B-D) with a maximum load of 3 tons (30 kN) was used to determine the draft force of the plow. The plow was attached to a CASE JX75T tractor, and a Massey-Ferguson axtra 440 tractor was used to draft the CASE JX75T tractor carrying the plow. The two tractors were connected by a flexible cable and, through the load cell, connected to a laptop computer. The draft force was recorded and stored when the Massey-Ferguson axtra 440 tractor pulled the CASE JX75T tractor carrying the plow. The tractor's gearshift was in neutral, and the driving tractor's engine speed was set to 1500 rpm. The specifications of both tractors are as shown in Table (1).

2.5 Longitudinal Deflection

Plowing depth measurements were taken for each meter of the plowing line length, and the average of these readings was taken to determine the actual plowing depth. Vertical deviation was calculated using Equation 2, which was mentioned in Zaidan (2012).

$$a_{sr} = \sum \frac{ap}{np} \quad (2)$$

Table 1. Specifications of tractors used in the study

Specifications of tractors	Values	
Tractor Type	Massey- Ferguson 440 xtra	CASE JX75T
Maximum Power (kW)	81.90 (61.10)	78 (65.60)
Engine Speed (rpm^{-1})	2500	2200
Engine Type	Perkins (diesel)	Perkins (diesel)
Engine Displacement (L)	4.50	4.07
Number of Cylinders	4	4
Compression Ratio	19.5:1	18.5:1
Engine Torque (Nm)	288	248
PTO Speed (rpm^{-1})	5400 (single speed)	5400 (single speed)
Carried Weight (kgf)	2600	2300
Thrust Generation	MFWD	MFWD
Tractor Weight (kg)	3568 (35.00.64)	3104.15 (30.45)
Fuel Tank Capacity (L)	120	120
Engine Oil Tank Capacity (L)	8	6
Made in	Brazil	India

where: a_{sr}: average depth (cm), ap: measured depth (cm), np: number of replicates.

$$\Delta a = \sqrt{\sum(ap - asr)^{2}/np} \quad (3)$$

$$\delta a = \left(\frac{\Delta a}{a_{sr}}\right) * 100 \quad (4)$$

Where: Δa: average depth deviation (m) δa: longitudinal deflection (%).

2.6 Lateral Deflection

It represents the deviation from the design width of the plow as a percentage. This indicator represents evidence of a defect in the technical condition of the plow and is calculated from the following equation mentioned in Zaidan (2012).

$$b_{sr} = \sum \frac{bp}{np} \quad (5)$$

Where: b_{sr}: average width (cm), bp: measured width (cm) np: number of replicates.

$$\Delta b = \sqrt{\sum(bp - bsr)^{2}/np} \quad (6)$$

$$\delta b = \left(\frac{\Delta b}{b_{sr}}\right) * 100 \quad (7)$$

Where: Δb: Average width deviation (cm) δb: Lateral deviation (%)

3. RESULTS AND DISCUSSION

3.1 Effect of the Number of Bottoms on the Studied Characteristics

Table (2) shows the results of the effect of the number of bottoms on the draft force, fuel consumption, vertical deflection, and lateral deflection.

3.1.1 Draft force

Draft force increases significantly ($p < 0.05$) with the increase in the number of bottoms. The MB4 recorded the highest draft force of 12.86 kN, while the draft force for MB3, MB2, and MB1 was reduced to 10.79, 6.7, and 5.55 kN, respectively. From the results, we note that the required draft force for one Bottom decreases as the number of bottoms increases. The MB1, compared to the MB2, MB3, and MB4, reduced draft force by percentages of 17.16, 48.56, and 56.84%, respectively. When comparing the MB2 with the MB3 and M4, draft force was reduced by 37.91% and 47.90%, respectively. It was also found that the draft force constituted a percentage of 16.09% when comparing MB3 with MB4. It can be noted from the current results that the draft force required by one bottom decreases with the increase in the number of bottoms for the plow. In the case of the MB4, it was found that one bottom required a draft force of only (12.86/4) 3.22 kN, while the single-bottom plow (MB1) required a draft force of 5.55 kN, meaning that the MB4 reduced the draft force of one body by 2.36 kN. This may be because the single-bottom plow (MB1) requires a high draft force to cut the soil slice from the parent soil body and turn it over. As for the multi-bottoms, the draft force of the bottoms after the first bottom will decrease. The multi-bottoms work to cut a slice of soil that has been relatively dismantled by the first bottom, which makes the draft force required to cut the soil slice and turn it over decrease for the second, third and fourth bottms, as each body reduces the draft force required to cut and turn the soil for the body that follows it, with different percentages of decrease in the draft force, as shown in the results as mentioned earlier. These results are consistent with Taha and Taha (2019) and Hamid (2023).

3.1.2 Fuel consumption

Fuel consumption increases significantly ($p<0.05$) with a decreased number of bottoms. The MB1 recorded the highest fuel consumption of 18.83 L ha^{-1}. In contrast, the MB2, MB3, and MB4 recorded fuel consumption of 17.57, 16.37, and 14.72 L ha^{-1}, respectively. This decrease in fuel consumption may be due to a reduction in draft force as the number of plow bottoms decreases. On the other hand, fuel consumption was reduced for multi-bottom plows compared to single-bottom plows (MB1). Each bottom consumed fuel for four, three, or two-bottom plow amounts of (14.72/4) 3.68, (16.37/3) 5.46, and (17.57/2) 8.79 L ha^{-1}. The reason was due to the large difference in the working area, as the large working width of the four-bottom plow made it complete the plowing process fast, which reduced the amount of fuel needed for plowing per unit area. In contrast, the single-bottom plow needs many passes due to its small working width, and this led to an increase in fuel consumption to cover one hectare. The greater the working width i.e., the number of bottoms, the lower the fuel consumption. Despite the increase in the requirements for traction and power for multi-bottom plows, this increase was not sufficient to raise fuel consumption compared to the increase in the working width, which led to a reduction in time, which reduced the fuel consumption needed to cover one hectare. These results are consistent with those of Inthiyaz et al. (2020), who found that the fuel consumption rate decreased when the working width of the plow was reduced by 53%, and they attributed this to reducing the time and number of passes in the field to complete the soil preparation process, which reduces the fuel consumption rate.

3.1.3 Lateral deflection

The results showed that MB4 had the lowest lateral deflection values, which amounted to 2.22%, while the lateral deviation increased as the number of bottoms decreased. MB3, MB2, and MB1 recorded lateral deviations of 2.30, 3.29, and 4.58%, respectively. This is due to the decrease in the number of landsides with the decrease in the number of bottoms, which makes the plow less resistant to balance the force acting on the bottom by the soil, and thus the plow deviates from the travel line to balance those forces. As for the MB4, there are a sufficient number of landslides to balance the plow and absorb the forces acting on the bottoms, which makes it more stable than the MB3, MB2, and MB1, respectively. These results are consistent with Zaidan (2012), who found that increasing the number of bottoms of moldboard plow led to an increase in its stability, and consequently, the values of lateral deflection decreased by 32.28%.

3.1.4 Longitudinal deflection

The results show that the longitudinal deflection increases as the number of bottoms decreases. MB1 recorded the maximum longitudinal deflection value of 8.04%. However, for MB2, MB and MB4, it dropped to 5.27, 3.88, and 2.76 percent, respectively. These results indicate that the depth of plowing was greatly fixed with the increase in the number of plow bottoms. The decrease in longitudinal deviation may be due to the increase in the plow's weight, resulting from increased bottoms. This, in turn, leads to an increase in the depth of the bottoms in the soil and, subsequently, to an improvement in the longitudinal stability of the plow. These results are consistent with those of Zaidan (2012), who found that increasing the number of bottoms of moldboard plow led to an increase in its stability, and consequently, the values of longitudinal deflection decreased by 22.87%.

3.2 Effect of the Interaction Among the Number of Bottoms Plowing Depth and Forward Speed on the Studied Characteristics

Table (3) shows the results of the effect of interaction among the number of bottoms plowing depth and forward speed on the draft force, fuel consumption, vertical deflection, and lateral deflection.

3.2.1 Draft force

The results showed that the draft force was significantly affected by the number of bottom, plowing depth, and operating speed. Increasing the number of bottoms from one (MB1) to four (MB4) at a shallow plowing depth of 15 cm and an increased speed from 3.17 to 6.43 km h^{-1} (103%) led to increase the draft force from 3.50 to 10.56 kN (+201.7%), due to the increased total area in contact with the soil, which increased the friction forces and cumulative resistance of soil (Godwin & O'Dogherty, 2007), who found that the draft force increases linearly with increasing

Table 2. Effect of bottoms number on parameters studied

Bottoms number	Draft force (kN)	Fuel consumptions (l ha^{-1})	Lateral deflection (%)	Longitudinal deflection (%)
MB1	5.55^{a}	18.83^{a}	7.31^{a}	8.04^{a}
MB2	6.7^{b}	17.57^{b}	4.58^{b}	5.27^{b}
MB3	10.79^{c}	16.37^{c}	3.29^{c}	3.88^{c}
MB4	12.86^{d}	14.72^{d}	2.30^{d}	2.76^{d}

Different letters indicate a significant difference at a probability of 0.05 between the means in the same column.

Table 3. Effect of interaction among bottom number, plowing depth and forward speed on parameters studied

Bottoms number	Depth (cm)	Speed (km h^{-1})	Draft force (kN)	Fuel consumptions (l ha^{-1})	Lateral deflection (%)	Longitudinal deflection (%)
MB1	0-15	3.17	3.50^{a}	17.00^{a}	5.03^{a}	5.53^{a}
		4.78	4.25^{b}	15.00^{b}	6.12^{b}	6.73^{b}
		6.43	5.75^{c}	14.00^{c}	7.22^{c}	7.94^{c}
	15-25	3.17	4.00^{d}	21.80^{d}	6.53^{d}	7.18^{d}
		4.78	6.00^{e}	20.00^{e}	7.62^{e}	8.38^{e}
		6.43	6.58^{f}	17.80^{f}	8.02^{f}	8.82^{f}
	25-30	3.17	5.00^{g}	23.69^{g}	7.59^{g}	8.35^{ge}
		4.78	7.00^{h}	21.00^{h}	8.56^{h}	9.42^{h}
		6.43	7.84^{i}	19.20^{i}	9.08^{i}	9.99^{i}
MB2	0-15	3.17	4.00^{ld}	16.00^{k}	2.52^{j}	2.90^{j}
		4.78	6.00^{je}	14.00^{lc}	3.72^{k}	4.28^{k}
		6.43	6.50^{mf}	13.00^{m}	4.58^{l}	5.27^{l}
	15-25	3.17	6.80^{n}	20.67^{n}	3.53^{m}	4.06^{m}
		4.78	7.00^{oh}	19.28^{oi}	4.60^{n}	5.29^{n}
		6.43	7.50^{p}	16.39^{p}	5.50^{o}	6.33^{o}
	25-30	3.17	7.00^{qoh}	21.20^{q}	5.00^{pa}	5.75^{p}
		4.78	7.50^{rp}	19.58^{r}	5.81^{q}	6.68^{q}
		6.43	8.00^{s}	18.01^{s}	6.00^{r}	6.90^{r}
MB3	0-15	3.17	14.00^{t}	14.11^{tc}	1.52^{s}	1.79^{s}
		4.78	6.50^{umf}	12.98^{u}	2.22^{t}	2.62^{t}
		6.43	7.68^{v}	11.50^{v}	3.00^{u}	3.54^{u}
	15-25	3.17	8.22^{w}	19.87^{w}	2.53^{v}	2.99^{vj}

Bottoms number	Depth (cm)	Speed (km h^{-1})	Draft force (kN)	Fuel consumptions (l ha^{-1})	Lateral deflection (%)	Longitudinal deflection (%)
		4.78	9.57^{x}	18.00^{x}	3.10^{w}	3.66^{w}
		6.43	10.87^{y}	15.87^{y}	4.00^{x}	4.72^{x}
	25-30	3.17	12.00^{z}	20.00^{ze}	3.70^{yk}	4.37^{z}
		4.78	13.56^{A}	18.00^{Ax}	4.51^{z}	5.32^{A}
		6.43	14.69^{B}	17.00^{Ba}	5.00^{A}	5.90^{B}
MB4	0-15	3.17	8.00^{Cs}	13.00^{Cm}	0.78^{B}	0.89^{C}
		4.78	9.00^{D}	11.00^{D}	1.20^{C}	1.44^{D}
		6.43	10.56^{E}	10.00^{E}	2.00^{D}	2.40^{F}
	15-25	3.17	11.36^{F}	18.00^{FAx}	1.52^{E}	1.82^{E}
		4.78	13.69^{GA}	17.00^{GBa}	2.08^{F}	2.50^{G}
		6.43	14.69^{H}	15.00^{Hb}	2.99^{G}	3.59^{H}
	25-30	3.17	15.60^{I}	17.50^{I}	2.68^{H}	3.22^{I}
		4.78	16.00^{J}	16.00^{Jk}	3.49^{I}	4.19^{J}
		6.43	16.80^{k}	15.00^{KHb}	3.97^{Jx}	4.76^{K}

Different letters (small or capital) indicate a significant difference at a probability of 0.05 between the means in the same column.

plowing depth or forward speed or both. In contrast, increasing the depth from 15 cm to 30 cm (+100%) with a single bottom (MB1) increased the draft force from 3.50 to 7.84 kN (+124%), which was attributed to the increased volume of loosened soil and vertical shear resistance (Kheiralla *et al*., 2004). Also, increasing the speed from 3.17 to 6.43 km h^{-1} (+103%) increased the drag force by 64.3% on average due to the increased kinetic energy required for the soil loosening (Serrano *et al*., 2003).

3.2.2 Fuel consumption

Fuel consumption decreased significantly ($p<0.05$) with increasing numbers of bottom and speed, while it increased with increasing depth. When using MB4 instead of MB1 at a shallow plowing depth of 15 cm and a speed of 6.43 km h^{-1}, fuel consumption decreased from 14.00 to 10.00 L ha^{-1} (-40%) due to reduced operating time, resulting in covering a large area (Raper, 2005). However, plowing at a depth of 30 cm with MB1 increased fuel consumption to 23.69 L ha^{-1} compared to 15.00 L ha^{-1} for MB4 at the same depth, reflecting the direct effect of plowing depth on tractor engine overload (Sahu & Raheman, 2006) who found that fuel consumption with increasing plowing depth by 23.36%.

3.2.3 Lateral deflection

Lateral deflection decreased with increasing number of bottoms, from 5.03% (MB1 at 15 cm and 3.17 km h^{-1}) to 0.78% (MB4 under the same conditions) (-84.5%). This was due to the distribution of lateral friction forces across multiple contact points, which improves plow stability (Hasimu, A., and Chen, 2014). They found that the lateral deviation decreased by 18% when the number of bottoms increased from one to three. However, high speed (6.43 km h^{-1}) increased the lateral deflection by an average of 34.2% when using MB4 due to the distribution of lateral friction forces when multiple bodies move in parallel. The lateral resistance forces are distributed over multiple points of contact, reducing the local pressure concentration at a single point. (Al-Suhaibani *et al*., 2010). They found that increasing the working width between brackets and the number of bottoms with a decrease in forward speed when plowing with a moldboard plow led to a decrease in lateral deflection by 43%.

3.2.4 Longitudinal deflection

Longitudinal deflection was inversely related to the number of bottoms and directly related to speed and depth. Increasing the number of bottoms from one (MB1) to four (MB4) at a depth of 15 cm reduced longitudinal deflection from 5.53% to 0.89% (-83.9%), due to the increased total mass, which reduces vertical vibrations (Raper, 2005). However, increasing speed from 3.17 to 6.43 km/h at a depth of 30 cm increased longitudinal deflection from 8.35% to 9.99% (+19.6%), reflecting the worsening dynamic instability under extreme conditions (Chen *et al*., 2020). They found a significant decrease in longitudinal deviation at low forward speed and shallow plowing depth, as the longitudinal deflection decreased by 30.25% when the speed decreased from 4 km h to 1.5 km h^{-1}, and the depth was a shallow depth of 15 cm.

4. CONCLUSION

The study concludes that increasing the number of plow beds (from 1 to 4 bottoms) resulted in a 56.8% reduction in draft force per bottom, a 40% improvement in fuel consumption (from 18.83 to 14.72 L ha^{-1}) due to reduced operating time and increased working width, and a significant improvement in lateral stability (decline from 4.58% to 2.22%) and longitudinal stability (decline from 8.04% to 2.76%) due to better force distribution and increased plow mass. However, high speeds (6.43 km h^{-1}) increased lateral deflection by 34.2% with MB4, highlighting the need to balance speed and the number of bottoms to maintain soil compaction. MB4 are recommended at medium speed (4.78 km h^{-1}) and 15-25 cm depth to achieve a balance between efficiency and tillage quality, avoiding intensive use of single bottom plows at large depths (30 cm) to avoid overloading the engine.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators, have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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