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Article

Evaluation of The Performance of Locally Manufactured Crawler Combing Machines in Some Field Performance Indicators

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Abstract: This study included manufacturing a combing machine with two types of creeping teeth with shapes (circular and rectangular) by drawing and designing the machine and the shapes of its creeping teeth using the (Solidworks) program according to the measurements and dimensions required for the design, and then manufacturing the machine by the researcher and evaluating its field performance through a factor experiment with three factors, the first factor is the two types of reciprocating ploughs (patchwork and disc), the second factor is the forward speed at two levels (8.20, 13.02) km / h, the third factor is the shapes of the creeping teeth at two levels (circular and rectangular) in silty mixed soil, and its effect on the studied characteristics, which are the width of fragmentation, actual field productivity, and performance efficiency. The results showed that the rectangular tooth was significantly superior in recording the highest values for all studied characteristics, significantly superior in its interaction with the reciprocating plough in recording the highest values for all studied characteristics, and significantly superior in its interaction with the forward speed (8.20) km / The hour recorded the highest value for the width of the fragmentation and the efficiency of the performance and its moral superiority in its interaction with the forward speed (13.02) in recording the highest value for the field productivity. As for the triple interaction, the rectangular tooth was morally superior in its interaction with the rotary plough at the forward speed (13.02) km/h in recording the highest value for the field productivity, while the triple interaction did not show any significant differences in the characteristics of the width of the fragmentation and the efficiency of the performance.

Keywords: Crushing width, Actual field productivity, Performance efficiency

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1. Introduction

The process of ploughing with soil preparation equipment for primary treatments, especially the tipper ones, is not enough alone to obtain a suitable bed for the seed because it leaves strips of large soil clods and a less flat surface and a rough ploughing appearance that is not suitable to be a bed for seeds. It is necessary to use soil preparation equipment for secondary treatments that cannot be dispensed with, especially the combs to crush, break and fragment those soil clods through their teeth and level the ploughed soil through their forward movement, which ensures obtaining a bed that ensures good germination of the seeds. The combs with creeping teeth are one of the combs that contain several rows, each row has a set of teeth mounted on it and are placed vertically and overlapping between one row and another to ensure the efficiency and width of the best fragmentation of those teeth. Among the most important factors that ensure good actual field productivity are the design width of those combs and their forward speed and the type of soil in addition to the soil that is ploughed and loosened better by the tipper ploughs, which ensures maintaining the necessary speed and the working width by the combing machine with creeping teeth and thus reaching efficiency Better, increasing the forward speed of the combing with increasing the depth of fragmentation leads to increased slippage and thus the combing machine loses its stability and deviates to one side, which negatively affects the width of fragmentation and thus reduces field productivity because the width of fragmentation is one of the components included in calculating productivity, but when the depth of fragmentation decreases with the same increase in speed, field productivity increases (Oduma, 2021). Choosing the appropriate plough also plays a role in achieving better productivity and efficiency, as using the rotary-blade plough with increased forward speed increases actual field productivity compared to the rotary-blade plough because the design width of the rotary-blade plough is larger compared to the rotary-blade plough. One of the reasons for the low productivity of the rotary-blade plough is its large weight compared to the rotary-blade plough, which increases the slip rate and thus reduces its field productivity (Amer, 2024). The good design of the harrowing machine, especially the shapes of its teeth and the large design width of the machine, is considered a positive factor that is calculated in favour of field productivity, as the harrows with spring-like creeping teeth outperformed the rest of the harrows due to the large area of their teeth in contact with the soil and the design width of the machine (At-Talabani, 2012). One of the factors that increase actual field productivity is increasing the forward speed of harrowing within certain limits because speed is one of the components included in calculating productivity, but increasing it above the permissible limits leads to increased slippage and thus reduces field productivity (Eni-like et al. (2024). From the above, the study aims to evaluate the performance of locally manufactured creeping tooth combs of circular and rectangular shapes and to know their effect on the following characteristics: fragmentation width, field productivity and performance efficiency.

2. Materials and Methods

The experiment was conducted in the autumn agricultural season (2024) in one of the agricultural fields south of Nineveh Governorate, where the area of the exploited field was (3) hectares; in silty mixed soil, a Turkish-made (MASSEY-FERGUSON) tractor (MF - 285S) was used, and two types of reversible ploughs (sprinkler and disc) were used to plough the soil, and a combing machine was used with two types of crawling tooth shapes (circular and rectangular) manufactured locally to comb the soil to break up its large lump, which was designed using the ((Solidworks program according to the measurements and dimensions shown in Figure (1, 2) and shown in a three-dimensional view in Figure (3, 4), as the researcher manufactured it after a test was conducted on the metal at the University of Mosul / College of Engineering / Laboratories of the Department of Mechanical Engineering. Table (1) shows the chemical composition, and Table (2) shows the mechanical properties of the metal from which the combing machine was made And her crawling teeth.

Table 1. Shows the chemical composition of the metal.

No.	Specimen	C	Mn	Si	Cr	Mo	Ni	P	S	Ti	V	Grade Designation
1	Circular tooth	0.255	0.452	0.074	0.034	0.063	0.036	0.005	0.005	0.001	0.005	AISI 1025
2	Rectangular tooth	0.113	0.423	0.065	0.036	0.057	0.046	0.006	0.003	0.003	0.002	AISI 1010
3	U-shaped metal	0.062	0.346	0.034	0.024	0.038	0.045	0.004	0.002	0.001	0.003	AISI 1005

4	**square metal**	**0.059**	**0.335**	**0.026**	**0.025**	**0.032**	**0.049**	**0.003**	**0.004**	**0.002**	**0.001**	**AISI 1005**

Table 2. Shows the mechanical properties of the metal.

No.	Specimen	Yield strength (MPa)	Tensile strength (MPa)	Hardness HRB	Standard
1	**Circular tooth**	**375**	**465**	**73**	**AISI 1025 CS**
2	**Rectangular tooth**	**298**	**375**	**60**	**AISI 1010 CS**
3	**U-shaped metal**	**210**	**327**	**50**	**AISI 1005 CS**
4	**square metal**	**215**	**334**	**53**	**AISI 1005 CS**

Note: The results showed that the samples are made of carbon steel and comply with ASTM A512-17.

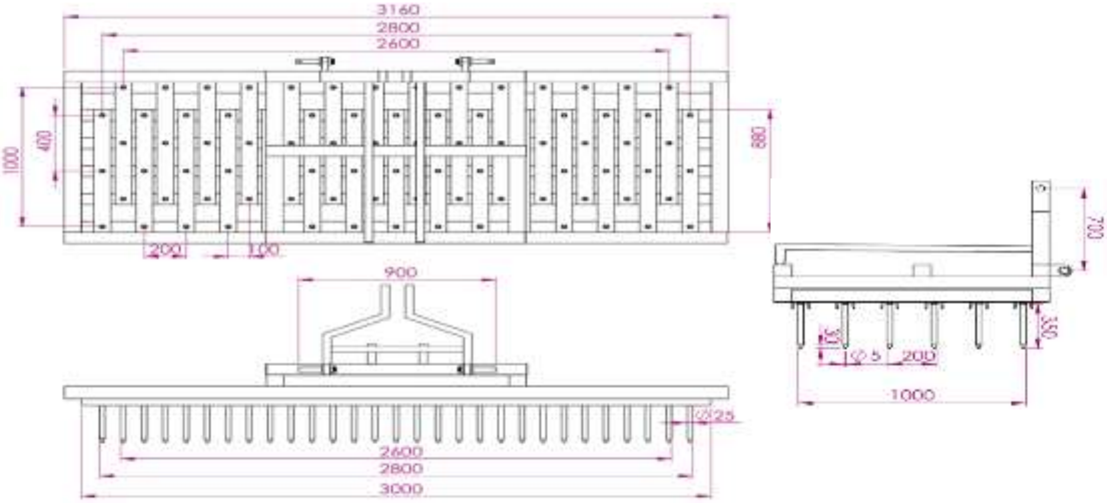

Figure 1. Front, side and horizontal view showing the measurements and dimensions of the circular crawler tooth combing machine.

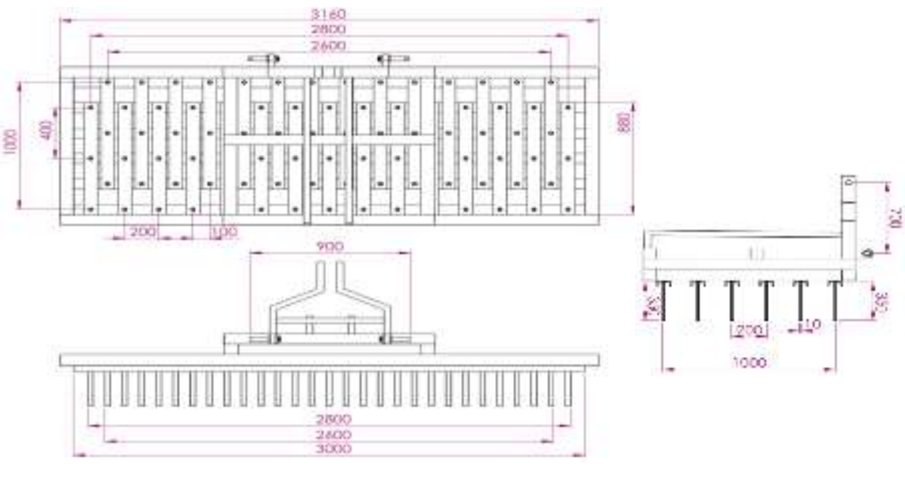

Figure 2. Front, side and horizontal view of the dimensions and measurements of the rectangular crawler combing machine.

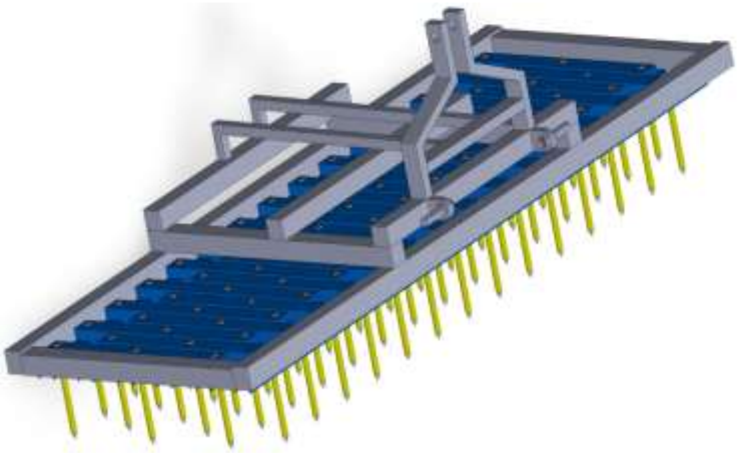

Figure 3. Three-dimensional view of the circular crawler tooth combing machine.

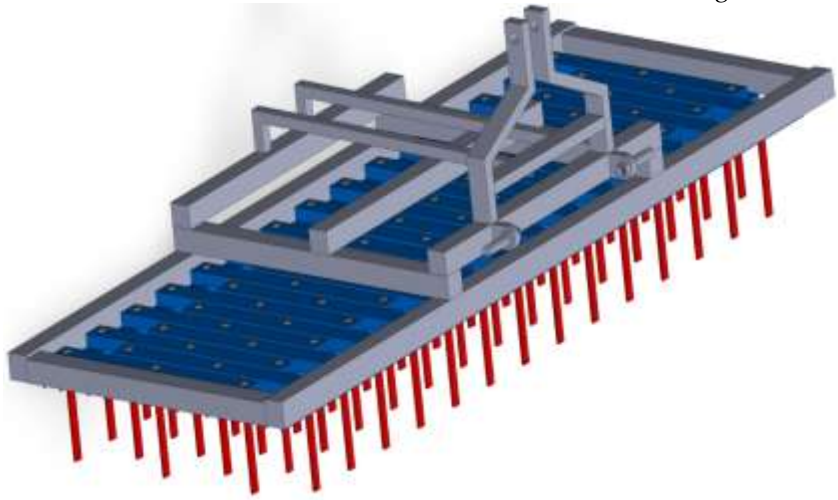

Figure 4. Three-dimensional view of the rectangular crawler combing machine.

The experimental field was divided according to the Randomized Complete Block Design (RCBD) system. The Split plot Design method was used (Dawood & Elias, 1990), which includes two main factors, which are the ploughs (disc and rotary) and two secondary factors, which are the forward speed (8.20, 13.02) and two sub-secondary factors, which are the creeping teeth (circular and rectangular). Each level has three replicates, i.e. 24 experimental units. The experiment was carried out according to the following stages.

Studied characteristic

Crushing width

The ripping width was measured randomly for each treatment and for three replicates of the speeds and tooth shapes used after ripping by the combing machine using a 5 m long ruler from one end of the working width to the other. The average for each treatment was extracted, which represents the actual width achieved.

Actual field productivity

It is defined as the actual machine performance rate in the field or when trading a crop at a specific time, or it is the actual area (number of hectares) that the machine accomplishes at a specific time, and it can be calculated from the following equation: (Al-Tahhan et al., 1991).

$$EFC = 0.1 * Wp * Vp * St$$

E

FC Actual productivity (hectare/hour).

wp: Actual (practical) working width of the plough (meters).

vt: Actual speed (km/hour).

st: Time utilisation factor (field efficiency).

Performance efficiency

It is the ratio between actual field productivity and theoretical productivity and can be calculated using the following equation (Al-Tahhan et al., 1991).

$$FE = \left(\frac{EFC}{TFC}\right) \times 100$$

FE: Field performance efficiency (%)
EFC Actual productivity (hectares/hour).
TFC: Theoretical productivity (hectares/hour).

3. Results

Crushing width

Effect of reversible plows

Figure (5) shows that the reversible plough was significantly superior to the reversible disc plough in recording the highest value of the crushing width (2.70) meters. In contrast, the reversible disc plough recorded the lowest value of the crushing width (2.65) meters. The reason for this is that the combing machine that works in the soil ploughed by the reversible plough maintains its stability because the reversible plough loosens the soil and causes it to be agitated, thus reducing its resistance to penetration and fragmentation of the soil masses, thus preserving the actual working width of soil fragmentation, unlike the reversible disc plough that leaves a strip of large, undisturbed soil masses that increases the resistance to penetration and fragmentation of the soil masses, which caused a lower crushing width for the combing machine.

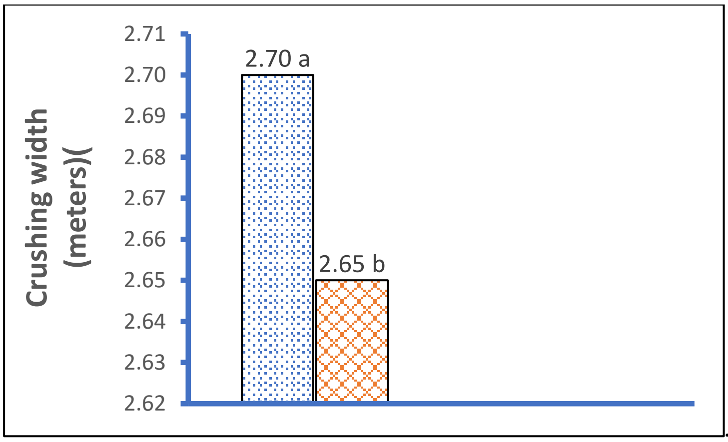

Figure 5. Effect of types of rotary ploughs

Forward speed effect

Figure (6) shows that the forward speed (8.20) km/h was significantly superior to the forward speed (13.02) km/h in recording the highest value for the ripping width (2.74) meters. In contrast, the forward speed (13.02) km/h recorded the lowest value for the ripping width (2.61) meters. Increasing the forward speed leads to instability for the combing machine concerning both the vertical and lateral levels, directly reflected in the ripping width in the ploughed soil for both ploughs.

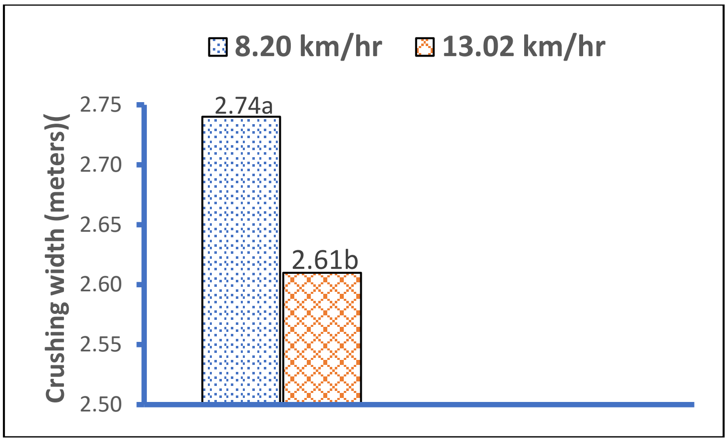

Figure 6. Effect of forward speed

Effect of creeping tooth shapes

Figure (7) shows that the rectangular tooth is significantly superior to the circular tooth in recording the highest value of the crushing width (2.69) meters. In contrast, the rectangular tooth recorded the lowest value of the crushing width (2.65) meters. The reason for this is that the rectangular teeth have a larger surface area of contact and crushing of the ploughed soil than the surface area of contact of the circular teeth, which allows them to achieve a larger and better soil crushing width.

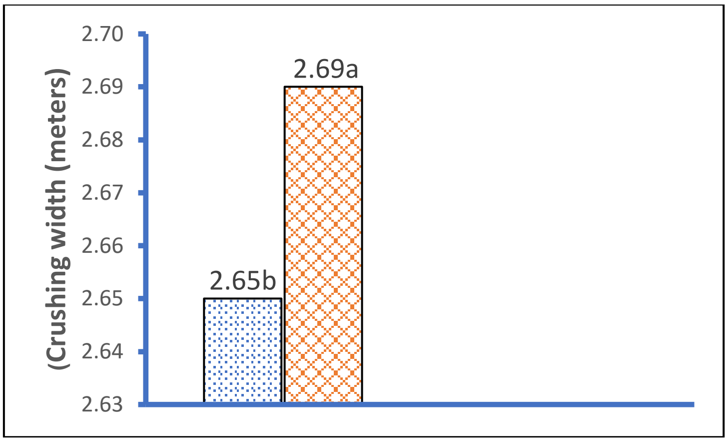

Figure 7. The effect of the shapes of the creeping teeth

The effect of the two-way interaction between the types of plows and the shapes of the creeping teet

Figure (8) shows that the interaction between the rotary plow and the rectangular tooth was significantly superior to the interaction between the rotary disc plow and the circular tooth in recording the highest value of the ripping width (2.71) meters, while the interaction between the rotary disc plow and the circular tooth recorded the lowest value of the ripping width (2.62) meters. The reason is that the rectangular teeth of the combing machine that work in the soil plowed by the rotary plow do not go deep into the soil due to the width and tip of the tooth in contact with the soil plowed by both plows, especially the rotary plow, which gave the highest ripping width because the rotary plow has a greater ability to disintegrate and excite than the rotary disc plow, and this excitation helps the combing machine with rectangular teeth with a wider width than the circular teeth.

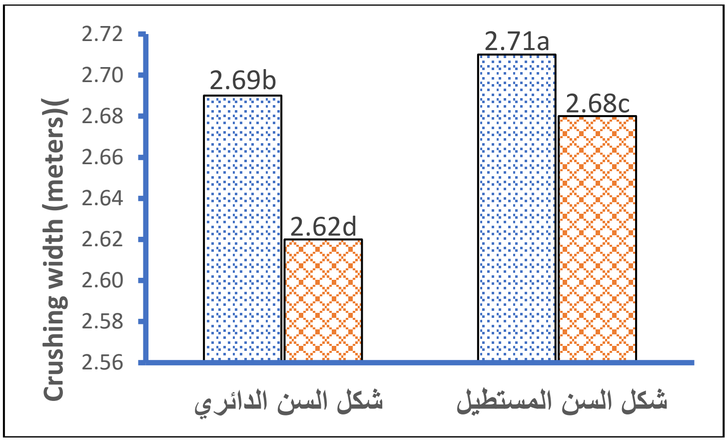

Figure 8. Overlap between types of plows and creeping tooth shapes

Actual field productivity

Effect of reversible plows

Figure (9) shows the moral superiority of the reversible plough over the reversible disc plow in recording the highest value of field productivity (0.236) hectares/hour, while the disc plow recorded the lowest value of field productivity (0.230) hectares/hour. The reason for this is that the reversible plough was more stable vertically and laterally while working in the soil, which was proven by the working width and what is reflected in the fragmentation width of the disc plow, and because the working width is one of the components included in calculating productivity and thus increasing its actual productivity.

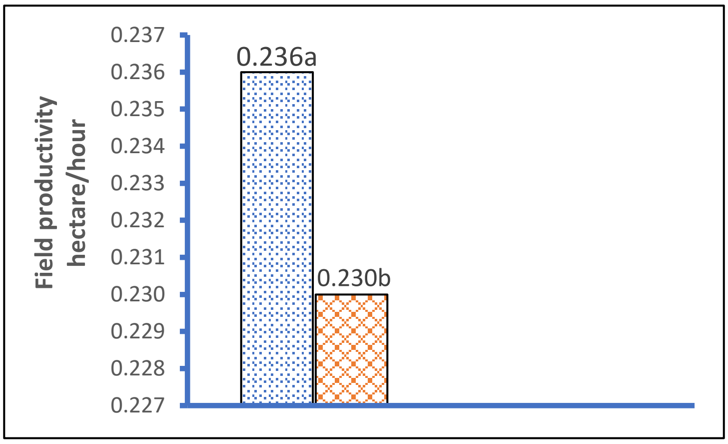

Figure 9. Effect of types of rotary ploughs

Forward speed effect

Figure (10) shows that the forward combing speed (13.02) km/h was significantly superior to the forward speed (8.20) km/h in recording the highest field productivity value (0.277) hectares/hour. In contrast, the forward speed (8.20) km/h recorded the lowest field productivity value (0.189) hectares/hour. The reason for this may be attributed to the fact that the forward speed represents one of the productivity components, so an increase follows any increase in speed in productivity.

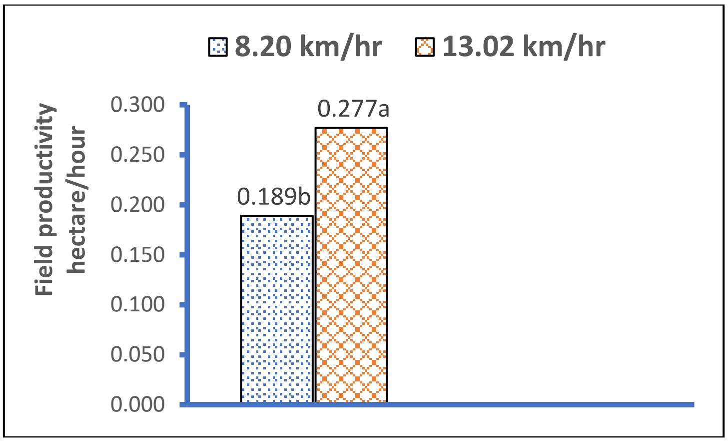

Figure 10. Effect of forward speed

The effect of the shapes of the creeping teeth

Figure (11) shows that the rectangular tooth was significantly superior to the circular tooth in recording the highest field productivity value (0.236) hectares/hour, while the circular tooth recorded the lowest field productivity value (0.230) hectares/hour. The reason for this is that the combing machine with rectangular crawling teeth gave the highest fragmentation width, which is considered one of the productivity components, so it will increase.

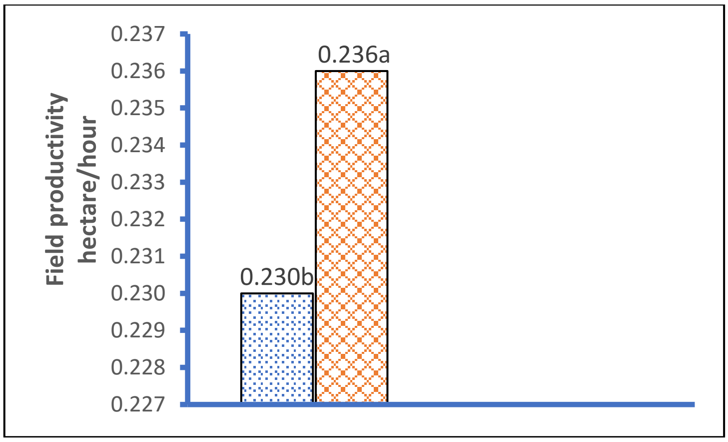

Figure 11. The effect of the shapes of the creeping teeth

The effect of the interaction between the types of rotary ploughs and the shapes of the creeping teeth

Figure (12) shows that the interaction between the rotary plough and the rectangular tooth was significantly superior to the interaction between the disc plough and the circular tooth in recording the highest value of actual field productivity (0.234) hectares/hour, while the interaction between the rotary plough and the circular tooth recorded the lowest value of field productivity (0.187) hectares/hour. This is due to the fact that the combing machine with the creeping teeth of a rectangular shape when working in the soil plowed by the rotary plough maintains its lateral stability and thus maintains the actual fragmentation width due to the small depth of the rectangular teeth in the soil due to the large area of the tip of the tooth in contact with the soil, as the larger the area of the part in contact with the soil, the less its depth in the soil, thus maintaining the fragmentation width, which is considered one of the components included in calculating productivity, which leads to an increase in actual productivity.

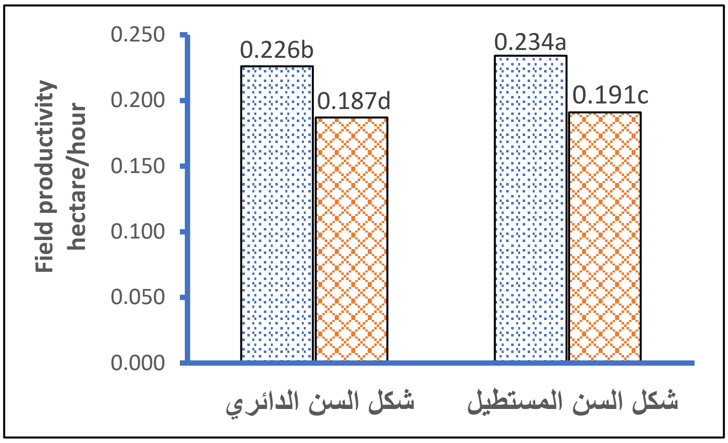

Figure 12. Overlap between types of ploughs and creeping tooth shapes

Binary interaction between forward speed and extrusive tooth shapes

Figure (13) shows that the overlap between the forward speed (13.02) km/h and the rectangular tooth was significantly superior to the overlap between the forward speed (8.20) km/h and the circular tooth in recording the highest value for actual field productivity (0.281) hectares/hour, while the overlap between the forward speed (8.20) km/h and the circular tooth recorded the lowest value for field productivity (0.187) hectares/hour, and this is due to the same reasons mentioned above.

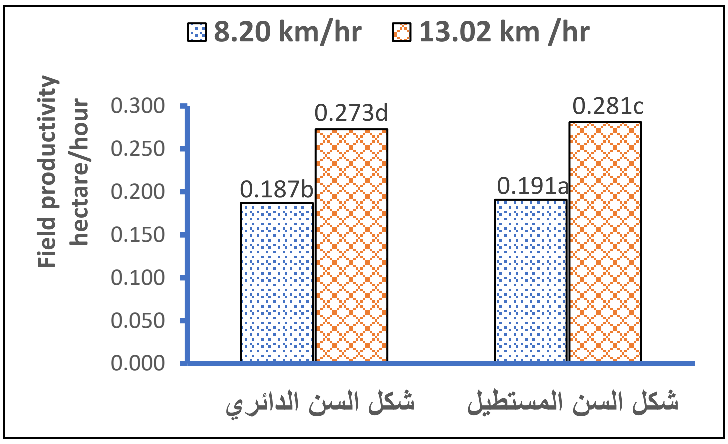

Figure 13. Interference between forward speed and creeping tooth shapes

Effect of triple interaction between plow types, forward speed and creep tooth shapes.

Figure (14) shows a significant superiority for all three interactions, as the interaction between the rotary plough and the rectangular tooth at the forward speed (13.02) recorded the highest value of field productivity (0.283) hectares/hour, while the interaction between the rotary disc plough and the circular tooth at the forward speed (8.20) km/hour recorded the lowest value of field productivity (0.184) hectares/hour. The reason for this is that the combing machine with the creeping teeth of a rectangular shape that works in the soil plowed by the rotary plough that loosens the soil and reduces its resistance, and also the rectangular tooth does not go deep into the soil due to the large area of contact of its tip with the plowed soil. Therefore, the combing machine maintains its lateral stability, which maintains the actual working width in addition to increasing the forward speed, as the actual productivity increases, considering that the working width and the forward speed are two factors included in calculating the actual productivity. As they increase, the actual productivity increases.

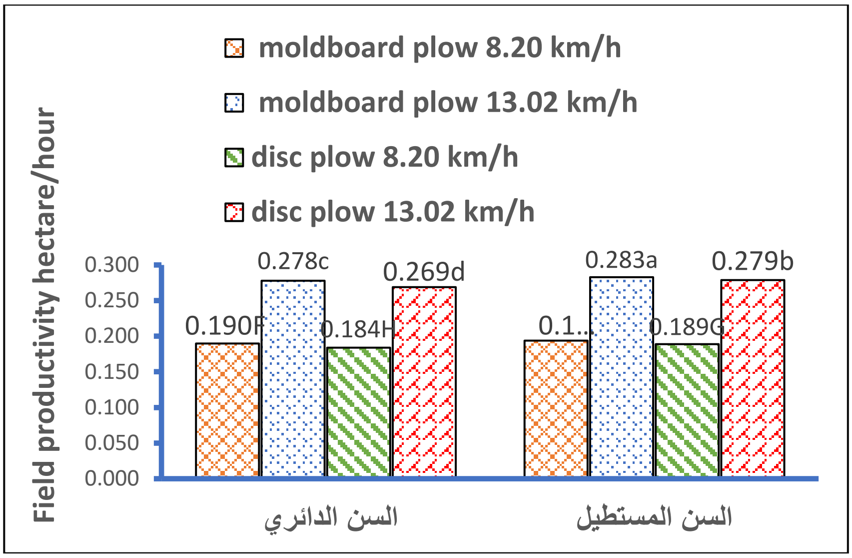

Figure 14. The triple interaction between the studied factors and their impact on field productivity

Performance efficiency

Effect of types of reversible plows

Figure No. (15) shows that the reversible plough was significantly superior to the disc plough in recording the highest value of performance efficiency (80.87)%, while the disc plough recorded the lowest value of performance efficiency (78.73)%. This is due to the fact that the increase in actual field productivity with the reversible plough is accompanied by an increase in performance efficiency because the relationship between them is directly proportional.

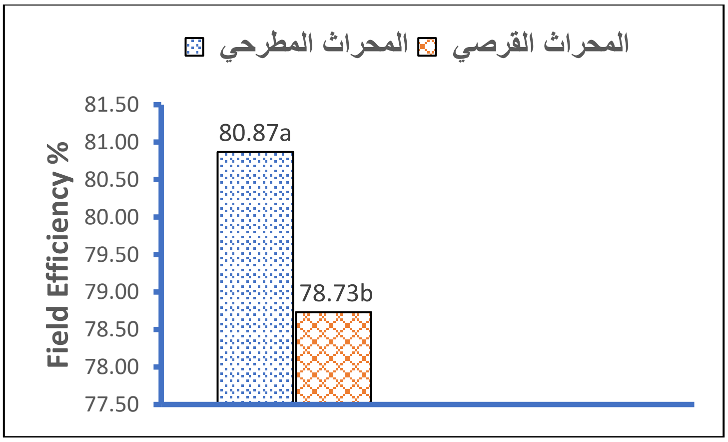

Figure 15. Effect of types of rotary ploughs

Effect of forward speed

Figure (16) shows that the forward speed of combing (8.20) km/h is significantly superior to the forward speed (13.02) in recording the highest value of performance efficiency (82.45) %, while the forward speed of combing (13.02) km/h recorded the lowest value of performance efficiency (77.14) %

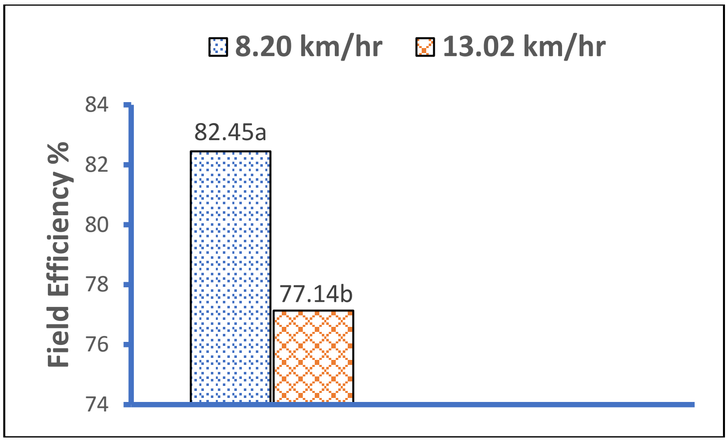

Figure 16. Effect of forward speed

The effect of the creeping tooth shapes

Figure (17) shows that the rectangular tooth shape is significantly superior to the circular tooth shape in recording the highest value of performance efficiency (80.84)%, while the circular tooth recorded the lowest value of performance efficiency (78.75)%. This is due to the fact that the more the actual field productivity increases, the more performance efficiency is accompanied by this, and this is what happened with the combing machine with rectangular teeth.

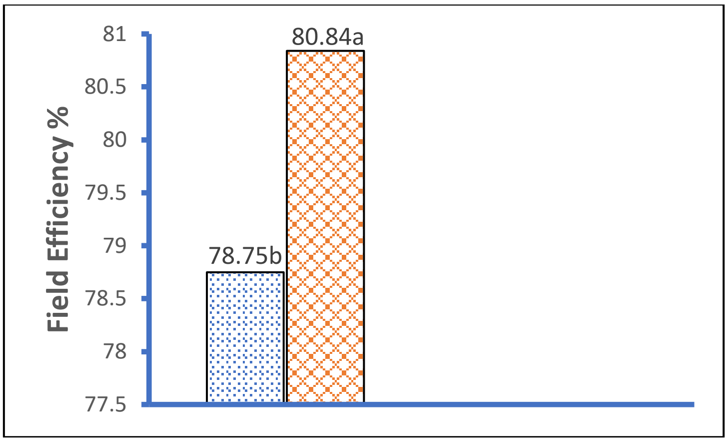

Figure 17. The effect of the shapes of the creeping teeth

The interaction between the types of reversible ploughs and the shapes of the creeping teeth

Figure (18) shows that the interaction between the reversible plough and the shapes of the creeping teeth was significantly superior to the interaction between the reversible disc plough and the shapes of the creeping teeth, as the interaction between the reversible plough and the rectangular tooth recorded the highest value of performance efficiency (81.66)%, while the interaction between the reversible disc plough and the circular tooth recorded the lowest value of performance efficiency (77.43)%, and this is due to the same reasons in the previously mentioned paragraphs.

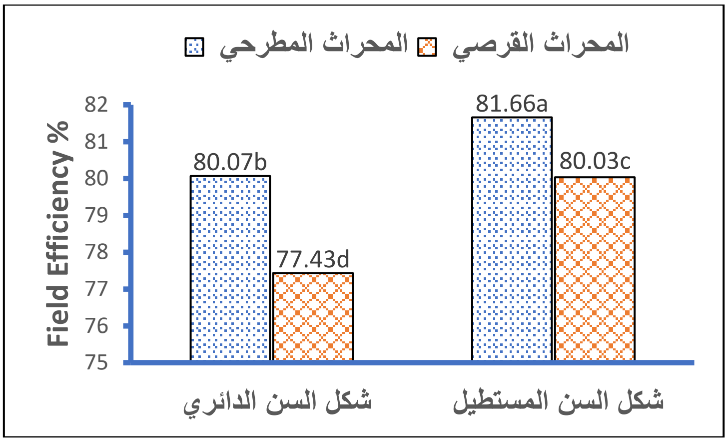

Figure 18. Overlap between types of plows and creeping tooth shapes

4. Discussion

The findings of this study highlight the impact of various factors on the field performance of locally manufactured crawler combing machines. The results demonstrate that the type of plough, forward speed, and the shape of the creeping teeth significantly influence key performance indicators, including crushing width, actual field productivity, and performance efficiency.

The reversible plough showed superior performance in all measured indicators compared to the reversible disc plough. This can be attributed to the fact that the reversible plough effectively loosens and agitates the soil, reducing resistance and allowing for greater soil fragmentation. In contrast, the reversible disc plough left undisturbed soil strips, which increased penetration resistance and reduced the effectiveness of the combing machine. This result aligns with previous studies on soil tillage, which suggest that deeper soil disturbance facilitates better fragmentation and machine efficiency.

Forward speed played a crucial role in determining both crushing width and field productivity. The results indicated that a lower forward speed (8.20 km/h) resulted in a wider crushing width due to better stability of the combing machine. However, a higher forward speed (13.02 km/h) contributed to increased field productivity, as it allowed more area to be covered within a specific timeframe. This finding suggests that selecting an optimal balance between speed and stability is critical to achieving maximum performance efficiency.

The shape of the creeping teeth also had a noticeable effect on performance. Rectangular teeth exhibited better crushing width and field productivity compared to circular teeth, likely due to their larger surface contact area with the soil. This resulted in a more effective fragmentation process and improved machine efficiency. The interaction between plough type and creeping tooth shape further confirmed that rectangular teeth in combination with a reversible plough provided the highest field performance indicators.

Moreover, performance efficiency was observed to be highest when using the reversible plough, the rectangular creeping tooth shape, and a lower forward speed. This suggests that maintaining machine stability and optimizing the interaction between tillage and combing mechanisms can significantly enhance efficiency. The triple interaction analysis further reinforced these findings, indicating that the combination of a reversible plough, rectangular teeth, and a higher forward speed resulted in the highest actual field productivity.

Overall, this study emphasizes the importance of optimizing plough selection, machine speed, and crawling tooth shape in improving the efficiency of locally manufactured crawler combing machines. These findings provide valuable insights for farmers and agricultural engineers in selecting the most effective machine configurations for different soil conditions, ultimately enhancing agricultural productivity. Future studies should focus on further refining machine designs and evaluating their performance across different soil types and climatic conditions to ensure broader applicability.

5. Conclusion

We conclude that the rectangular teeth of the harrow gave the best field performance than the circular teeth to achieve the highest ripping width at the speed (8.20) km/h, and the highest field productivity at the forward speeds (8.20, 13.02) km/h in the soil plowed by the rotary-blade plow.

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