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Effect of the developed moldboard plow on the pulverization index of soil under various forward speeds

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Abstract: A field experiment was conducted at the Agricultural Research Station, College of Agriculture, University of Basrah, Karmat Ali site. To study the effect of the developed moldboard plow to pulverization index of soil. The experiment was designed according to a complete randomized block design using the split-split plot method in a factorial experiment with three factors (two types of moldboards, three additions of finned harrows and three levels of forward speeds). Adding fins to the moldboard significantly affected the soil pulverization index, with the finned moldboard (M2) achieving a lower index of 33.95 mm compared to the traditional plow (M1) at 47.84 mm. Needle harrows also influenced soil fragmentation, where double fins harrows (H2) achieved the lowest pulverization index of 23.13 mm, followed by single needle harrows (H1) at 32.59 mm, while no harrows (H0) had the highest index at 66.96 mm. Increased forward speed reduced the pulverization index from 46.49 mm at 1.5 km/h to 36.06 mm at 3.5 km/h. The combination of forward speed and needle harrows further impacted soil fragmentation. The lowest pulverization index of 21.8 mm occurred with the finned plow and double fin harrows (M2*H2), while the traditional plow without harrows (M1*H0) showed the highest index at 81.62 mm. The interaction of speed, plow type, and needle harrows (S3*M2*H2) yielded the lowest pulverization index of 18.48 mm, while the highest index, 86.26 mm, was recorded for the combination (S1*M1*H0).

Keywords: forward speed, moldboard plow, needle harrows, soil pulverization.

Introduction

The moldboard plow is one of the most widely used types of plows in the world, particularly for plowing heavy soils, as the plow moldboard cuts and breaks the soil and converts it into large blocks, which requires plowing the soil with secondary harrowing machines after primary tillage many times in the field (Muhsin, 2017a). The soil adequately prepared the suitable conditions for seed germination in the soil and choosing an inappropriate tillage system, particularly clay soils leads to the deterioration of soil properties such as increasing soil compaction thereby not preparing the appropriate conditions for seed germination and plant growth (Kahlon *et al*., 2013). Separate use of tillage machines and harrowing machines in the process of preparing the soil for cultivation results in an increase in the number of machines used. Increasing the traffic of tillage machines leads to an increase in time and costs for completing the tillage operations (Hamid, 2024). The degree of soil fragmentation is measured by the Mean Weight Diameter (MWD) (Pulverization Index (PI)) which is considered a standard for the degree of soil smoothing (Li *et al*., 2023). The lower the values of the Pulverization Index (PI), the higher the degree of soil fragmentation. That is, the relationship is inverse between smoothing (degree of soil fragmentation) and the Pulverization Index (PI). Nasser (2014) found that one of the factors that help reduce the values of the Pulverization Index (PI) is the use of pulverization machines after the primary tillage operations, as the Pulverization Index decreases when using a reversible plow and then a Disk Harrow. Javadi and Hajiahemed (2009) obtained the lowest mean weight diameter (MWD) using two passes of the harrows, as the Pulverization Index (PI) was 11.5 mm, while the disc harrow equipped with an edge had about 12.3 mm, followed by the disc harrow with a single pass of about 13.7 mm. Aday & Nassir (2009) reported that using a combined tillage machine (chisel plow with two soil pulverizes) resulted in a decrease in the pulverization index by 34% compared to traditional chisel plow. Combined tillage machines significantly reduce the pulverization index compared to individual use of machines and reduce the time required to complete agricultural operations (Prem et al., 2016; Sarkar *et al*., 2021; Nassir *et al*., 2022). The geometric design of the moldboard plow is one of the important factors that reduce the values of the pulverization index (Alwan, 2019). Adding a rigid harrow to the moldboard plow reduces the pulverization index in a single pass in the field. The degree of soil pulverizing depends on the geometric design of the harrows, whether disc, reciprocating, or rigid (Mwiti *et al*., 2023; Nassir *et al*., 2023). The forward speed of the tractor plays an important role in the difference in the values of the fragmentation index, which, when increased, reduces the soil pulverization index through the collision of soil masses with each other and with the plow blade due to the kinetic energy resulting from the increase in practical speed. Speed also reduces soil compaction by shortening the time during which the plow body passes over the soil (Zhao *et al*., 2021).

Many studies have been conducted to evaluate the effectiveness of tillage methods or types of plows on the soil fragmentation index of soil under different operating conditions, but studies on the plow are still rare. Therefore, the study aimed to investigate the effect of the developed plow on the soil fragmentation index, given the importance of this feature in the evaluation of the plow, as well as its effect on different soil properties.

Materials & Methods

Description of developed moldboard plow

The traditional moldboard plow was developed by fins fixing on moldboard and adding a rigid harrow for increasing breaking up soil (Fig. 1). The development of the plow was performed in the workshop of the Department of Agricultural Machinery and Equipment in the College of Agriculture of the University of Basrah, A double-moldboard plow manufactured by the General Company for Mechanical Industries. The moldboard is of the semi-helical type. Each moldboard had a width, height, and concavity of 45 cm, 40 cm, and 5.6 degrees respectively. These moldboards are characterized by their high ability to break up the soil. The moldboards are equipped with a cutting shear with dimensions of (9*44) cm. The shear cutting angle is 28 degrees. The six fins were fixed on the surface of the moldboard. The fins with dimensions and measurements were determined through a field experiment. The plow was also provided with a tandem of mutually rigid harrows connected to the plow body in a hinged manner. The first row was placed 20 cm away and parallel to the line of the two plows. The second row was placed 15 cm away from the first row. The length of each harrow was 180 cm with 13 rigid tines.

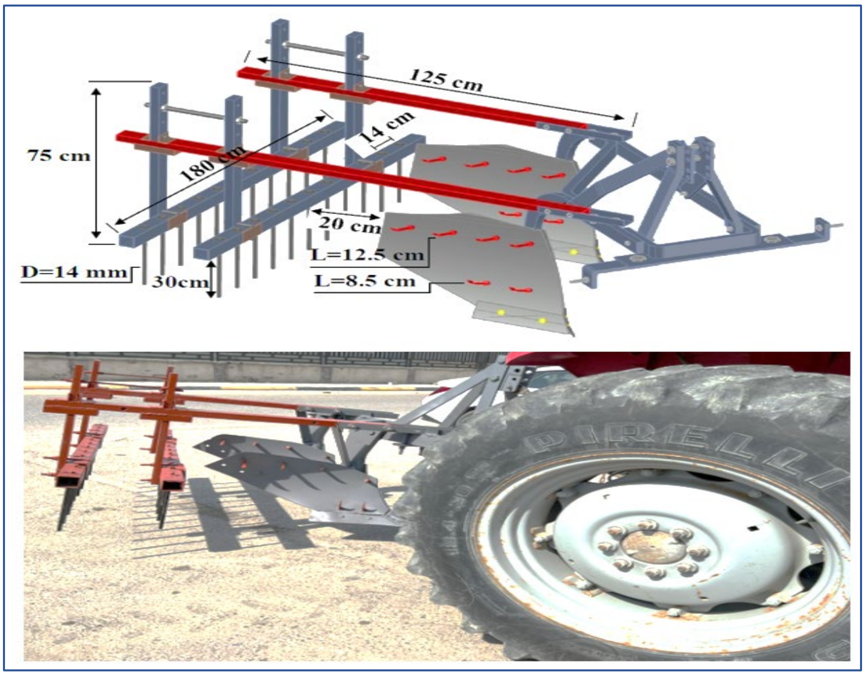

Fig. (1): Developed moldboard plow

The pulverization index of soil

The pulverization index was measured after conducting experiments using the developed moldboard plow. The soil samples of the plowed soil were collected in a square section with dimensions (1 m^2) with three replicates for each treatment. Then the samples were transferred to the laboratory and left to air dry, after which they were sifted using a sifting device that contains a set of sieves with different diameters (100, 75, 50, 22, 16, 8, 2 mm). As for the soil blocks whose size exceeds 175 mm, their diameter was measured using a measuring tape. After completing the sifting process, the soil on each sieve was weighed separately, and the total weight of the sample was calculated by adding the weights of the soil collected on all the sieves. Then the percentage of each weight on each sieve was calculated according to the method mentioned in Hillel (1980) from equation (1).

$$PI = \frac{\sum_{i=1}^{n} Wi * \bar{d}i}{W_{total}} \qquad (1)$$

Where: PI: pulverization index (mm), wi: Percentage of soil masses remaining on each sieve after sieving (mm), W_{total}: Total soil sample mass (kg), $\bar{d}$: Average diameter of two consecutive sieves (mm). (For example, the diameter of the previous sieve is 100 mm and the next sieve is 70 mm, so the average = (100+70) \2 = 85 mm).

Soil properties and texture

The soil moisture content and soil density were determined by taking samples from the field at soil depths of 0-15, 15-20, and 20-25 cm with three replicates for different; soils using the Core. The samples were dried in the oven at a temperature of (105°C) for 24 hours, then the moisture percentage was calculated based on dry weight, and the apparent density of the soil was calculated according to the method described in Black (1965). The soil texture was estimated by the absorbent method according to the method mentioned in Black et al., (1965) to determine the soil texture in which the experiments were carried out and all the results are shown in Table (1).

Table (1): Initial soil properties and texture

Soil properties	Soil depth		
	0-15	**15-20**	**20-25**
Soil moisture content (%)	10.23	16.47	24.68
Bulk Density (Mg m^{-3})	1.29	1.33	1.41
Porosity (%)	11.5	14.80	22.70
Penetration Resistance (kN m^{-2})	1948.57	2147.36	2344.73
Cohesion (kN m^{-2})	15.41	11.39	13.58
Adhesion (kN m^{-2})	0.15	0.18	0.26
Soil texture (Silty loamy)	Clay	Silt	Sand
	35%	47%	18%

Experimental design

The experimental field was divided according to the complete randomized block design and the split-split panel method was used in a factorial experiment with three factors (2 types of moldboard * 3 addition of rigid harrow * 3 forward speed levels of 1.5, 2.5 and 3.5 km h^{-1}) and with three replications where the moldboard type factor was put in the main plots and the addition of rigid harrow factor in the subplots, and the forward speed factor in sub-sub plots. The treatments were distributed randomly in the sectors, as the number of treatments reached (54) experimental units and the length of the experimental unit was 20 m. The data for all treatments were analyzed statistically using the statistical software Gen State Version 4. The means of the treatments were compared using the least significant difference test RLSD at a significance level of 0.05.

Results & Discussion

Effect of the moldboard types on pulverization index

Figure (2) shows a significant effect of the moldboard type on the pulverization index values. The moldboard with finned blade (M2) was superior in achieving the lowest soil pulverization index (increased soil pulverizing) value of 33.95 mm compared to traditional moldboard (M1) which recorded the highest pulverization index (decreased soil pulverizing) which reached 47.84 mm. This may be attributed to the role of the fins fixed on the surface of the moldboard in intercepting the soil blocks of soil cut by the moldboard shear and thus increasing its disintegration, which improves soil fragmentation and reduces the pulverization index compared to the plow with the traditional moldboard. These results agree with Alwan (2019).

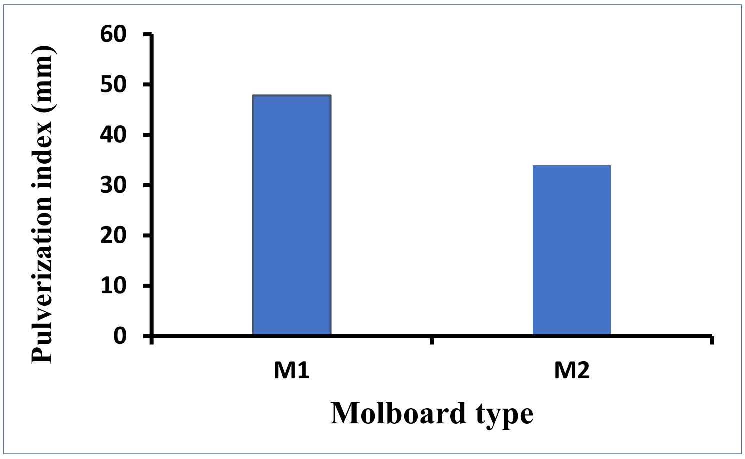

Fig. (2): Effect of the moldboard types in the soil pulverization index

Effect of the rigid harrow types on pulverization index

Figure (3) shows that the treatment of adding double rigid harrows (H2) to the moldboard plow was superior to achieving the lowest soil pulverization index (highest soil fragmentation) value of 23.13 mm, followed by the treatment of adding single rigid harrows (H1), which recorded a pulverization index value of 32.59 mm, while the treatment of using the traditional moldboard plow without adding harrows (H0) recorded the highest pulverization index value of 66.96 mm. This could be attributed to the role of the double rigid harrows added to the plow and their contribution to increasing the smoothness of the soil clods plowed by the plow, which reduces the soil pulverization index compared to the single harrows and the plow without adding the harrows, as the plow alone without adding the rigid harrows (H0) recorded the highest pulverization index. This shows the positive effect of adding rigid harrows to the plow in increasing soil fragmentation. These results agreed with what Turgut and Boydas (2007) reached since they found that adding rotary harrows to the plow led to an increase in soil smoothness and a decrease in soil fragmentation index by 23.98%.

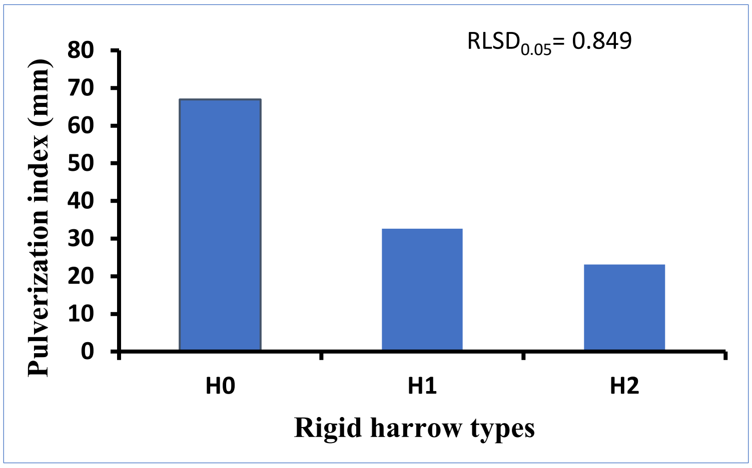

Fig. (3): Effect of rigid harrow types in the soil pulverization index

Effect of forward speed in pulverization index

The results shown in Figure (4) show a decrease in the pulverization index (increased fragmentation of soil) from 46.49 to 40.12 and 36.06 mm when the forward speed increased from 1.5 (S1) to 2.5 (S2) and 3.5 (S3) km h-1, respectively. The reason for the decrease in the pulverization index with the increase in the forward speed is that the increase in the forward speed increases the acceleration of the soil blocks plowed by the plow and increases the collision of the soil blocks with each other, which increases the loosening and smoothing of the soil and thus reduces the rate of the soil friability index. These results are consistent with those of Muhsin (2017b) and Nassir *et al.* (2024). They noted a decrease in the soil pulverization index and an increase in its smoothness with increasing forward speed. Gilandeh *et al.* (2022) also showed that increasing the forward speed during plowing increases the kinetic energy of soil masses due to increased collisions with each other and with the plow blades, which causes an increase in soil fragmentation.

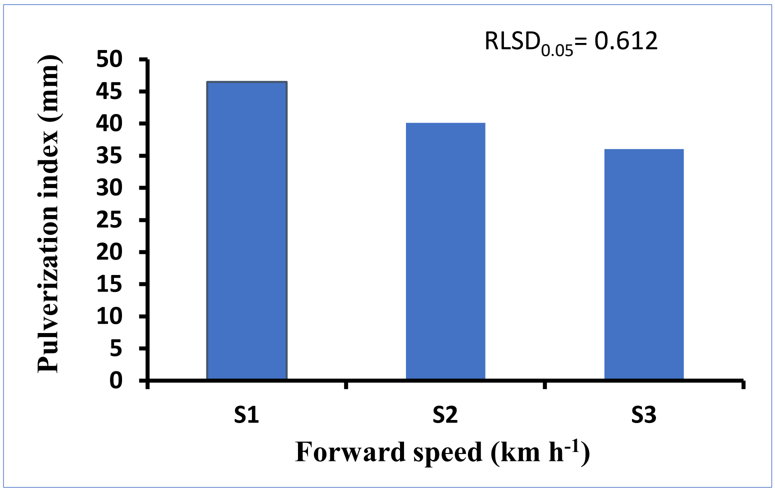

Fig. (4): **Effect of forward speed in the soil pulverization index**

Interaction between the type of moldboard and the rigid harrows

There was a significant effect of the interaction between the type of moldboard and the addition of rigid harrows to the plow on the soil pulverization index. The results shown in Figure (5) show that the lowest rate of pulverization index (highest soil fragmentation) was recorded by (M2*H2) reaching 21.8 mm. In comparison, the highest pulverization index (lowest soil fragmentation) was recorded by (M1*H0) reaching 81.62 mm. The reason for the superiority of the (M2*H2) in achieving the lowest soil pulverization index was attributed to the use of a combined plow that led to increasing the pulverization and smoothing of the soil plowed by the plow, which reduces the sizes of soil blocks to small clods thereby leads to a reduction in the rate of soil pulverization index, unlike the overlapping treatment (M1*H0), in which the soil pulverization process is limited to the traditional moldboard, which leaves large soil blocks after plowing, and this is negatively reflected in increasing the pulverization index.

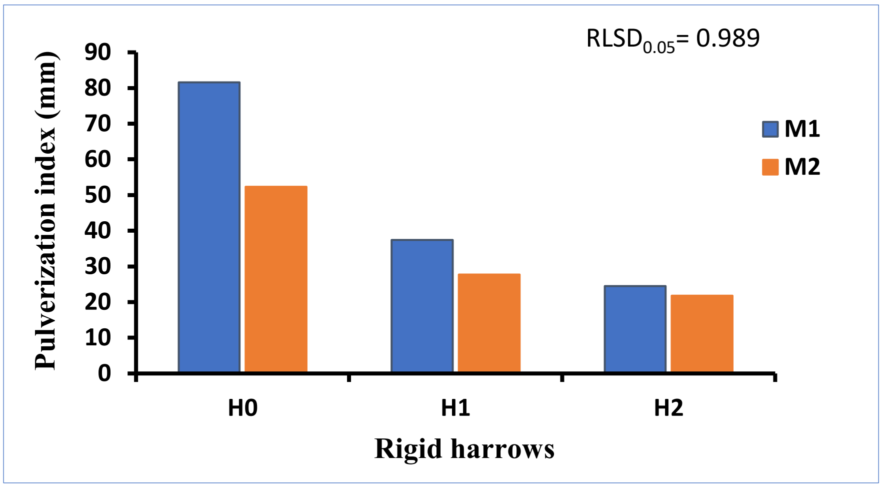

Fig. (5): **Effect of interaction between the type of moldboard and the rigid harrows**

Interaction between the rigid harrows and forward speed

The interaction between adding rigid harrows and forward speed had a significant effect on the soil pulverization index (Fig. 6). The interaction treatment (H2*S3) achieved the lowest soil pulverization index value of 19.66 mm, while the interaction treatment (H0*S1) recorded the highest soil pulverization index value of 72.81 mm. The reason for the superiority of the (H2*S3) in achieving the lowest soil pulverization index was due to the combined plow and the increased forward speed in increasing the loosening and fragmentation of soil blocks during the plowing operation, which is reflected in the decrease in the pulverization index, while the treatment (H0*S1) recorded the highest pulverization index. This is due to the lack of adding needle combs and thus their lack of contribution to the process of smoothing soil clumps and leaving large soil blocks during the plowing operation by the rototiller, especially with the decrease in forward speed, which in turn reduces soil smoothing and increases the pulverization index.

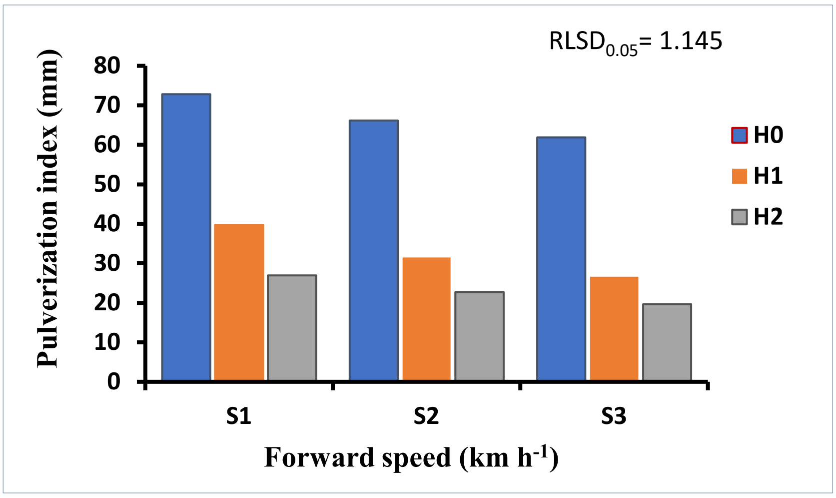

Fig. (6): **Effect of interaction between the rigid harrows and forward speed**

Interaction among the types of moldboard, rigid harrows and forward speed

Table (2) showed a significant effect of the interaction between the types of moldboard, rigid harrow, and the forward speed of tillage on the soil pulverization index. The treatment (M2*H2*S3) achieved the lowest pulverization index value of 18.48 mm, while the interaction treatment (M1*H0*S1) recorded the highest pulverization index value of 86.26 mm. The reason for the superiority of the interaction treatment (M2*H2*S3) in achieving the lowest soil pulverization index was due to the using the developed plow with high forward speed and their contribution to the process of fragmenting and pulverization the soil blocks plowed by the plow, in addition to the role of increasing the forward speed in increasing the acceleration movement of the soil masses and its contribution to increasing their disintegration, which increases the soil softening and reduces the rate of soil pulverization index, unlike the interaction treatment (M1*H0*S1), which leaves large soil masses by the plow with the traditional plow, especially with the decrease in the plowing speed, which is negatively reflected in increasing the soil interaction.

Table (2): Interaction among the types of moldboard rigid harrows and forward speed

Types of moldboard	Rigid harrows	Forward speed (km h^{-1})		
		S1	S2	S3
M1	H0	86.26	81.73	76.85
	H1	45.56	36.33	30.44
	H2	28.28	24.28	20.84
M2	H0	59.36	50.6	46.93
	H1	33.82	26.57	22.85
	H2	25.69	21.23	18.48
RLSD $_{0.05}$			1.499	

Conclusion

The type of moldboard, harrow addition, and forward speed significantly influenced the soil pulverization index. The finned moldboard (M2) achieved superior soil fragmentation with the lowest pulverization index of 33.95 mm, compared to the traditional moldboard (M1), which recorded 47.84 mm. Adding double rigid harrows (H2) to the plow further improved soil fragmentation, achieving a pulverization index of 23.13 mm, while single rigid harrows (H1) recorded 32.59 mm. The plow without harrows (H0) showed the highest pulverization index of 66.96 mm, indicating minimal fragmentation. Increasing the forward speed from 1.5 km/h (S1) to 2.5 km h^{-1} (S2) and 3.5 km h^{-1} (S3) reduced the pulverization index from 46.49 mm to 40.12 mm and 36.06 mm, respectively, demonstrating that higher speeds enhance soil disintegration. The optimal configuration was the combination of the finned moldboard, double rigid harrows, and the highest forward speed (M2*H2*S3), which achieved the lowest pulverization index of 18.48 mm. Conversely, the traditional moldboard without harrows and at the lowest speed (M1*H0*S1) had the highest pulverization index of 86.26 mm, reflecting poor soil fragmentation.

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Contributions of authors

A.S.J.: Methodology and responsible for data collection; writing the review and the editing and conducting field experiments., **S.J.M**.: Statistical analysis and prepare the final version of manuscript.

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Conflicts of interest

As for the requirements of the publishing policy, there is no potential conflict of interest for the authors

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تأثير المحراث المطرحي المطور على دليل تفتيت التربة تحت سرع أمامية مختلفة

علي ستار جبر المنصوري صادق جبار محسن

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المستخلص : تم إجراء تجربة حقلية في محطة الأبحاث الزراعية، كلية الزراعة، جامعة البصرة، موقع كرمة علي. لدراسة تأثير المحراث المطرحي المطور على صفة دليل تفتت التربة. تم تصميم التجربة وفقًا لتصميم القطاعات العشوائية الكاملة بأسلوب القطع المنشقة مرتين في تجربة عامليه من ثلاثة عوامل (نوعان من المطارح * ثلاث إضافات من الامشاط الابرية * ثلاث مستويات من السرع الأمامية). أثر إضافة الزعانف إلى مطرحة المحراث بشكل كبير على دليل تفتت التربة، حيث حققت المطرحة ذات الزعانف (M2)اقل معدل لدليل تفتيت التربة بلغ 33.95 ملم مقارنة بالمحراث ذو المطرحة التقليدية (M1) التي حققت معدل للصفة بلغ 47.84 ملم. كما أثرت الامشاط الابرية على دليل تفتت التربة، حيث سجلت معاملة اضافة الامشاط الابرية المزدوجة (H2) اقل معدل للصفة بلغت 23.13 ملم، تلتها معاملة اضافة الامشاط الابرية المفردة (H1) التي حققت معدل لدليل تفتيت التربة بلغ 32.59 ملم، بينما سجلت معاملة المحراث بدون اضافة الامشاط (H0) أعلى معدل للصفة بلغ 66.96 ملم. أدى زيادة السرعة الأمامية من 1.5 الى 3.5 كم ساعة$^{-1}$ إلى انخفاض معدل دليل التفتت من 46.49 ملم إلى 36.06 ملم. سجل اقل معدل لدليل تفتيت التربة (زيادة تفتيت التربة) بلغ 18.48 ملم لمعاملة التداخل بين مع المحراث ذو المطرحة ذات الزعانف واضافة الامشاط المزدوجة والسرعة الامامية 3.5 كم ساعة$^{-1}$(S3M2H2) بينما حققت معاملة التداخل بين المحراث ذو المطرحة التقليدية وعدم اضافة الامشاط الابرية والسرعة الامامية 1.5 كم ساعة$^{-1}$ (S1M1H0) بلغ 86.26 ملم.

الكلمات المفتاحية : السرعة الامامية، المحراث المطرحي، الامشاط الابرية، تفتيت التربة.