DEVELOPMENT OF THE TWO-WHEEL TRACTOR COMPOUND TO ENHANCE THE EFFICIENCY OF AGRICULTURAL TASKS IN SMALLHOLDING

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ABSTRACT

A field experiment was conducted at the Al-Raed Research Station, located 25 km west of Baghdad, to investigate the effects of machine speed and plowing depth on various performance indicators of a mechanized unit. A combined implement was utilized to simultaneously perform multiple agricultural operations. The experiment employed two main factors: forward speed of the mechanized unit, with three levels (1.004, 2.03, and 3.048 km h-1), and plowing depth, with three levels (5, 8, and 10 cm). The performance indicators studied included slip percentage, operating costs (IQD ha^{-1}), the number of soil clods larger than 22 mm in diameter, and Emergence percentage. Through the results obtained in the experiment The initial operational speed of 1.004 km h^{-1}outperformed other treatments in terms of minimal slip (5.48%), reduced soil clod size (17.00 clods/m² > 22 mm), and higher maximum Emergence (85.30%). Nevertheless, it incurred the highest operational cost of 17807 dinars ha^{-1}. Conversely, a plowing depth of 5 cm resulted in the lowest slip (7.42%), cost (15408 dinars ha^{-1}), and soil clod count (18.30 clods/m²), while maintaining a high Emergence rate (84.90%). nested design with a completely randomized block design (RCBD) was adopted.

Keywords: speed, depth, mechanical properties, Emergence.

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تطوير مجمع الجرارات ذات العجلتين لتعزيز كفاءة المهام الزراعية في الحيازات الصغيرة

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المستخلص

اجريت تجربة حقلية في محطة أبحاث الرائد تبعد 25كم غرب مدينة بغداد لدراسة تأثير سرعة الوحدة المكينة وعمق الحراثة في بعض مؤشرات الاداء للوحدة المكنية باستعمال معدة مركبة لإنجاز عدة عمليات زراعية مختلفة في ان واحد. استعملت في التجربة، عاملين الاول هي السرعة الامامية للوحدة المكنية واشتملت على ثلاث سرع هي ((1.004–2.03–3.048). كم ساعة$^{-1}$ والثاني هو اعماق الحراثة اشتمل على ثلاثة اعماق الحراثة هي (5 – 8 –10) سم وتم دراسة مؤشرات الوحدة المكنية والتي) تشمل النسبة المئوية للانزلاق، التكاليف التشغيلية (دينار هكتار$^{-1}$)، عدد الكتل الترابية ذات الأقطار الأكبر من 22 ملم، بالإضافة الى دراسة نسبة الانبات (%) (. من خلال النتائج المستحصل عليها في التجربة تفوقت السرعة العملية الاولى 1.004 كم ساعة$^{-1}$ أذ عطت اقل نسبة مئوية للانزلاق اذ بلغت 5.48% واقل عدد للكتل الترابية ذات الأقطار الأكثر من22 ملم اذ بلغت 17.00كتلة بالمتر المربع الواحد واعلى نسبة الانبات بلغت 85.30% في حين أعطت اعلى معدل للتكاليف وبلغت 17807 دينار هكتار$^{-1}$. بينما تفوق عمق الحراثة 5سم في الحصول على اقل معدل للنسبة المئوية للانزلاق اذ بلغ (% 7.42) واقل معدل للتكاليف اذ بلغ (15408) دينار هكتار$^{-1}$واقل معدل لعدد الكتل الترابية (18.30) كتلة بالمتر المربع واعلى نسبة الانبات أذ بلغ (84.90%).

الكلمات المفتاحية: السرعة، العمق، الصفات المكنية، الانبات

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INTRODUCTION

Agricultural machinery is fundamental to enhancing agricultural processes and increasing yield per unit area, especially given the growing global population and rising food demand. Combined implements can perform multiple agricultural operations simultaneously, while tillage and seeding tools are essential for crop productivity (5 ,16) and (19) .In Iraq, there is a notable shift toward agricultural mechanization, marked by the adoption of advanced technologies and a growing emphasis on research and development. However, challenges such as increased slip percentage at higher operating speeds and depths, soil clod formation, and seed loss rates at varying ground speeds have been identified (8, 13, 20). Increasing the tractor speed from 2.5 to 6 km h^{-1} resulted in a rise in slip percentage from 9.52 to 14.66% due to reduced contact force between tires and the soil (4) (6) (10) (3). [12] Reported that increasing tillage depth from 15 to 20 cm resulted in an increase in slip percentage from 7.90 to 10.422%. This is because increasing depth enhances soil resistance to rotation, necessitating a greater driving force to overcome this resistance, thereby increasing slip with greater depth and speed. (2,15) (16)Confirmed that increasing the operating speed of the mechanical until. From (24.4‹51.5‹27.7 km h^{-1}) led to a reduction in total operating costs from (80675-57885-41612) dinars h^{-1}. Additionally, increasing the plowing of treatment had a significant impact on the total costs of the mechanical unit, as increasing the depth from (10-20-30) cm led to an increase in total costs from (16720-19150-24569) dinars hec^{-1}. Increasing the tractor's operating speed from (4.27-5.51-7.27) km h^{-1} led to a decrease in the rate of soil clods with a diameter greater than (10) cm/m² from (10.386-7.222-5.728) clods/m², this is because increasing the tractor's operating speed leads to increased collisions between the plowshares and the soil, resulting in increased fragmentation of soil clods. Moreover, it was found that increasing the plowing depth from (5-9) cm led to an increase in the number of soil clods from (5.482-9.778) clods/m² (16,17). In a study conducted by (14, 21, 22) indicated that when increasing the ground speed from (24.2to51.5 to72.7) km h^{-1} the seed loss lowest from(%75to70%) rate seed loss was recorded at a ground speed of 2.4 km h^{-1}, reaching 0.51%, while the highest rate was recorded at a ground speed of 6.1 km h^{-1}, reaching 2.78%. This is because increasing the ground speed reduces the number of seeds dropped per row. Given the critical role of mechanization in modern agriculture, this study aims to develop and evaluate a combined machine capable of performing multiple agricultural operations efficiently.

MATERIALS AND METHODS

A field experiment was conducted on 1/8/2024 for the 2024-2025 agricultural season at one of the fields belonging to the Al-Raed Research Station located in the Arkov area along Abu Ghraib Road. Initially, the field has been divided and marked, and iron stakes were placed to indicate the beginning and end of the field, with a total area of 960 m² (40 m long and 24 m wide). In addition, wooden stakes were placed at the beginning and end of the experimental units, with three replications for three different depths (10, 8, and 5 cm) and three speeds (1.004, 2.030, and 3.048 km h-1). Random samples were taken from the three depths to determine some of the physical and chemical properties of the soil, as shown in Table (1). A small agricultural tractor, also known as a walking tractor or two-wheel tractor with a 20-horsepower rating, was used to conduct the experiment. The type of plow used was a small rotary plow, which performs both plowing and leveling operations. For the seeding and fertilization stage, a row crop planter was used, which places seeds at equal distances between adjacent rows, while the spacing within each row is random. The rotary plow was connected to the seed and fertilizer applicator via an electric motor to facilitate the raising and lowering of the seed with a control device near the operator

Table 1. Physical and chemical characteristics of field soil and its separates before planting

Soil depth (cm)	Soil separation g/kg			soil texture	Soil resistance to penetration	Bulk density of soil mg/m^3		pH	Volumetric moisture content at wilting point%	Volumetric moisture content at field capacity%
	Sand	silt soil	Clay							
0-30	120	530	350	Sandy clay loam	1.10	1.39	8.15	7.7	20.46	44.46

Study traits and their calculation method

Slippage Percentage (Sp. %)

The percentage of slippage was calculated using the following equation, as suggested by (7):

$$S\% = \frac{Vt - Vp}{Vt} * 100 \ldots\ldots (1)$$

Given that:

S: The percentage of slip (%).

Vt: The theoretical velocity (km h^{-1}).

Vp: The practical velocity (km h^{-1}).

Tractor Total Cost's (T.T.c)

This refers to the total of fixed, variable, and administrative costs associated with a tractor. It is calculated using the following equation:

T.T.c = F.c. + V.c + Ma.C……. (2)

Total Tractor Costs (TTC) per hectare (11)

Percentage of soil clods with diameters greater than 22 mm

Is the percentage by weight of soil clods with diameters less than or equal to (22 mm) that pass through a (25 mm) sieve, relative to the total weight (kg) of the soil sample taken from the tilled soil. It is calculated using the following equation: Soil fineness percentage = ((Weight of soil clods with diameters less than or equal to (22 mm) that passed through a 25 mm sieve) / (Total weight of sample)) × 100……… (3)

Seed Emergence percentage (%): Emergence Percentage Field Emergence percentage = (Number of seeds germinated in a unit area) / (Number of seeds sown in a unit area) * 100…… (4)

RESULTS AND DISCUSSION

Slippage Percentage: Table (2) illustrates the effect of depth, operating speed, and their interaction on the percentage of slippage (%). The (Table2) indicates a significant effect of operating speed on the percentage of slippage (%), as observed when increasing the operating speed from (1,004–2,03–3,048) led to an increase in the percentage of slippage by 5.48%, 8.66%, and 11.06%, respectively. This could be attributed to the fact that increasing the operating speed increases the load on the plow due to the increased cutting speed of the plowshare in the soil, leading to reduced wheel-soil traction and consequently increasing the percentage of slippage. These results align with the findings of (5).From the same table shows that there are significant differences in depth, the first depth recorded the lowest percentage of slippage at 7.42%, the second depth recorded a percentage of slippage of 8.38%, while the third depth (10 cm) recorded the highest percentage of slippage at 9.39%. This could be because increasing the depth increases soil penetration resistance, leading to an increase in the percentage of slippage. These results agree with the findings of (1)

Table 2. Effect of depth and speed and interaction between them on slippage percentage (%)

Speed	Depth (cm)			Means speed
	5	8	10	
First speed	4.21	5.82	6.40	5.48
Second speed	7.93	8.18	9.86	8.66
Third speed	10.13	11.15	11.90	11.06
LSD 0.05		0.42		0.30
Means depth	7.42	8.38	9.39	
LSD 0.05		0.24		

Total operating cost per mechanized unit (in Iraqi IQD hec^{-1}): The total operating cost per mechanized unit (in Iraqi IQD hec^{-1}) is presented in (Table 3). shows the effects of depth, operating speed, and their interactions on the operating cost per mechanized unit. The results indicate a significant effect of operating speed on the operating cost per mechanized unit. When increasing the operating speed from (1.004 to 2.03 and then to 3.048) km h^{-1}, the operating cost per mechanized unit decreases from (17,807 to 16,167 and then to 14,097) Iraqi IQD hec^{-1}, respectively. This decrease is likely to be due to the increase in operational productivity at higher speeds, leading to a reduction in operating costs per mechanized unit. These findings agree with the results of (18) Increasing the depth also leads to an increase in operating costs per mechanized unit. The first depth level (5 cm) recorded the lowest operating cost per mechanized unit at (15,408.0) Iraqi IQD hec^{-1}, while the second depth level (10 cm) recorded the highest operating cost per mechanized unit at (16,463.0) Iraqi IQD hec^{-1}. This is because increasing the depth reduces productivity, and since there is an inverse relationship between productivity and total costs, the overall operating cost per mechanized unit increases. These results agree with the results. (4) .

Table 3. Effect of depth, speed and interaction between them on operating cost of the mechanized unit (dinar/hectare)

Speed	Depth (cm) 5	8	10	Means speed
First speed	16537	17930	18955	17807
Second speed	15612	16586	16303	16167
Third speed	14076	14083	14132	14097
LSD 0.05		870		768
Means depth	15408	16200	16463	
LSD 0.05		394		

Number of soil blocks less than 22 mm

Table (3) illustrates the effect of operating speed, depth, and interaction on the number of soil clod exceeding 22mm in diameter. The Table (4) reveals a significant effect of operating speed on the quantity of soil clods larger than (22mm). When the operating speed increases from (1.04) to (2.03) and then to (3.048) km h^{-1}, the number of soil clouds larger than (22mm) correspondingly increases from 17 to 19.6 and then to 21.2 clods per square meter. This can be attributed to the reduced impact of the tillage tools with the soil at higher speeds, resulting in a greater number of soil clods. These findings align with those of [1] and (9). Furthermore, the table demonstrates a significant difference related to depth. Increasing the depth leads to an increase in the number of soil clods. The third depth (10 cm) recorded the highest number of soil clods at 20.4 clods per square meter, followed by the second depth (19.1 clods/m²) and the first depth (18.3 clods/m²). This can be ascribed to the rotary plow's ability to pulverize the soil and provide a fine tilth. These results corroborate the findings of (1)

Table 4. Effect of depth, speed and interaction between them on number of soils blocks less than22 mm

Speed	Depth (cm) 5	8	10	Means speed
First speed	16.30	16.90	17.80	17.00
Second speed	19.10	19.40	20.30	19.60
Third speed	19.40	20.90	23.20	21.20
LSD 0.05	1.15			0.85
Means depth	18.30	19.10	20.40	
LSD 0.05	0.65			

Seed Emergence percentage (%)

Table (5) indicates the effect both planting depth and operational speed, as well as their interaction having a significant effect on seed Emergence percentage. It was observed that Table (5), operational speed exerts a notable influence on Emergence rates. The first speed of (1.004 km h^{-1}) yielded the highest Emergence percentage of 85.30%, while the second speed of (2.03 km h-1) resulted in an Emergence percentage of 83.60%. The third speed of 3.048 km h^{-1} produced the lowest Emergence percentage at 66.00%. This can be attributed to the fact that a lower operational speed of the machinery leads to an increased number of seeds shown per unit area. Furthermore, the (Table 5) reveals significant differences in Emergence rates across planting depths. The first depth (5 cm) resulted in the highest Emergence percentage of 84.90%, followed by the second depth of 8 cm with a rate of 76.70%. The third depth of 10 cm yielded the lowest Emergence percentage of 73.30%. This can be explained by the fact that as planting depth increases, seedlings find it more difficult to penetrate the soil, and soil temperature at deeper depths tends to be lower. These findings are consistent with those reported by (9).

Table 5. Effect of depth and speed and interaction between them on Emergence rate %

Speed	Depth (cm) 5	8	10	Means speed
First speed	91.30	83.70	80.90	85.30
Second speed	89.80	81.50	79.50	83.60
Third speed	73.60	65.00	59.40	66.00
LSD 0.05	N. S			2.58
Means depth	84.90	76.70	73.30	
LSD 0.05	3.31			

Conclusion

The results of this field experiment clearly demonstrate that both operating speed and tillage depth have a significant influence on the performance indicators of the mechanical unit and the resulting soil condition. The lowest slip percentage, lowest number of soil clods, and highest germination percentage were all achieved at the lowest operating speed (1.004 km h^{-1}), although this speed also resulted in the highest operational cost. Conversely, increasing speed led to higher slip and soil clod formation but contributed to reduced operational costs, indicating a trade-off between performance efficiency and economic feasibility.

Similarly, shallow tillage depth (5 cm) proved superior in achieving optimal soil fragmentation, reduced slip percentage, lower operational costs, and improved seed germination, compared to deeper tillage depths. These results confirm that minimizing tillage depth and reducing forward speed enhances both soil physical conditions and seeding performance, especially when using a combined implement capable of performing multiple agricultural operations at once.

Overall, the study concludes that the combination of low operating speed (1.004 km h^{-1}) and shallow tillage depth (5 cm) provides the best balance between machine performance, soil condition, and plant establishment. The developed combined machine demonstrates strong potential for increasing field efficiency and improving the quality of agricultural operations, particularly under the soil and environmental conditions of central Iraq. Further research is recommended to test the machine across different soil textures, moisture levels, and crop types to expand its practical applicability.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

DECLARATION OF FUND

The authors declare that they have not received a fund.

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