

EVALUATION A LOCALLY DESIGNED DEVICE VERSUS A CONVENTIONAL ONE FOR MEASURING FUEL CONSUMPTION AND PERFORMANCE INDICATORS AT VARIOUS SPEEDS AND PLOWING DEPTHS

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ABSTRACT

A field experiment was conducted to test a locally designed device and compare it with a conventional device for measuring fuel consumption and some performance indicators under specific plowing speeds and depths. The experiment took place in the fields of the College of Agricultural Engineering Sciences, University of Baghdad, located in Jadriya, on October 21, 2024. An electronic device was designed to measure the fuel consumption of agricultural tractors and compared to a conventional device. The study examined the effects of three factors. The first factor is the device type electronic and conventional the second factor is the forward speed (2.24 , 3.49 km.h⁻¹). The third factor is the Plowing depth (10–15, 20–25 cm). Measurements included fuel consumption draft power, actual productivity, and cost. The experiment was implemented using a nested design under the randomized complete block design (RCBD) with three replicates. The Least Significant Difference (LSD_{0.05}) test was applied to compare treatment means at a probability level 0.05. The results revealed a significant interaction between the device type and plowing depth. The electronic device outperformed the conventional one at the 10–15 cm plowing depth by recording the lowest fuel consumption, 31.80 l.h⁻¹, the lowest drawbar power, 5.44 kW, and the highest productivity, 0.33 ha.h⁻¹. and The lowest costs amounted to 20,352 Di.ha⁻¹

Keywords: Fuel consumption, electronic device, drawbar power, actual productivity, plowing depth.

تقييم جهاز محلي الصنع مقارنة بجهاز تقليدي لقياس استهلاك الوقود ومؤشرات الأداء عند سرعات وأعماق حرث مختلفة

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الخلاصة

تم تنفيذ تجربة حقلية لأختبار جهاز مصمم محليا ومقارنته مع جهاز تقليدي في قياس استهلاك الوقود وبعض مؤشرات الاداء تحت سرع وأعماق حراثة اعماق حراثة معينة في حقول كلية علوم الهندسة الزراعية /جامعة بغداد الواقعة في الجادرية بتاريخ 2024/10/21 . تم تصميم جهاز الكتروني يستخدم لقياس استهلاك وقود الجرارات الزراعية ومقارنته مع الجهاز التقليدي .تم دراسة تأثير ثلاثة عوامل ,العامل الاول هو نوع الجهاز الكتروني وتقليدي والعامل الثاني هو السرعة الامامية 2.24 و3.49 كم.ساعة⁻¹ والعامل الثالث هو عمق الحراثة 10-25 و 20-25 سم . تم قياس استهلاك الوقود و قدرة السحب والانتاجية الفعلية في هذه التجربة . تم تنفيذ التجربة باستخدام النظام المعشش Nested (Design) تحت نظام القطاعات الكاملة المعشاة (Randomized Complete Block Design) مع ثلاث مكررات حيث استخدم اقل فرق معنوي (LSD_{0.05}) لمقارنة متوسطات المعاملات تحت احتمالية 0.05 . اوضحت النتائج بأن هناك فرق معنوي للتداخل بين نوع الجهاز وعمق الحراثة اذ تفوق نوع الجهاز الالكتروني عند العمق 10-15سم بأعطاء اقل



كمية استهلاك وقود بلغت 31.80 لتر/ساعة¹ وأقل قدرة سحب بلغت 5.44 KW وأعلى انتاجية بلغت 0.33 هكتار/ساعة¹ وأقل تكاليف بلغت 20352 دينار/هكتار¹.
الكلمات المفتاحية : استهلاك الوقود، جهاز الكتروني، قوة السحب، الانتاجية الفعلية، عمق الحراثة.

INTRODUCTION

Improving tractors and agricultural machinery is a critically important subject to minimize energy losses during agricultural operations. Studies have shown that approximately 20–55% of tractor power is wasted due to interactions between the soil surface and the tractor wheels, leading to increased fuel consumption and, consequently, higher production costs (**Jalilnezhad et al., 2023**). Accurate measurement of fuel consumption for various agricultural machines is fundamental for conducting research or testing, as it serves as an indicator of the power required to perform any agricultural operation .

Fuel consumption is typically measured using specific devices integrated into the tractor's fuel system. These devices can be either locally made or imported. However, most of the currently used methods are insufficiently accurate and rely heavily on less reliable techniques. Therefore, it is crucial to develop or assemble highly accurate devices to measure fuel consumption for agricultural machinery and equipment (**Elsbaay & Hegazy, 2016**).

Several agricultural factors influence the fuel consumption of tractors, including soil type, texture, moisture, density, the type of implement being towed or mounted, the type of tractor two-wheel drive or four-wheel drive, tractor size, the compatibility between the tractor and the implement, and the tractor's actual working speed. Consequently, the measured fuel consumption of a tractor using different methods is not constant and varies between tests (**Nielsen & Sørensen, 1993**). The most useful unit for fuel consumption in most agricultural field operations is L.ha⁻¹, as it decreases with the increase in the machine unit's speed over the area. On the other hand, fuel consumption in terms of L.km⁻¹ increases (**Damanauskas & Janulevičius, 2022; Jokiniemi et al., 2012**). Estimating tractor fuel consumption helps select the best practices for maintaining agricultural equipment and extending its lifespan . Most traditional fuel consumption measurement methods used are insufficiently accurate and require significant effort and time to complete the process, in stark contrast to the device that has been designed, which offers high precision and ease of use, saving both effort and time.

Speed has a significant effect on the studied parameters; as forward speed increases, fuel consumption decreases (**Alsharifi et al., 2022**), while drawbar power and actual productivity increase (**Al-Ani, 2024**). Depth also affects these parameters; as plowing depth increases, fuel consumption, drawbar power, and operational productivity all increase (**Sadeeq & Al-Obaidi, 2019; Al-Azzawi et al., 2022**). Most methods currently used to measure fuel consumption remain inadequately accurate. Therefore, this study was conducted to design and construct a fuel consumption measurement device to accurately measure the fuel consumed by agricultural machinery .

MATERIALS AND METHODS

A field experiment was carried out on October 21, 2024, in the fields of the College of Agricultural Engineering Sciences at the University of Baghdad, located in Jadriya, to evaluate a locally designed device and compare its performance with a conventional device in measuring fuel consumption and specific performance indicators at designated plowing depths. An electronic device was designed to measure the fuel consumption of agricultural tractors and was compared to a conventional device. Three factors were studied in this experiment; Device type is electronic and conventional. The second factor is the forward speed of 2.24 and 3.49 km.h⁻¹, and the third factor is the plowing Plowing depth of 10–15 and 20–25 cm.

Measurements included fuel consumption, drawbar power, and actual productivity. The experiment was implemented using a nested design under the randomized complete block design (RCBD) with three replicates. The Least Significant Difference (LSD_{0.05}) test was applied to compare treatment means at a probability level of 0.05.

The experiment utilized two tractors, JINMA and NEW HOLLAND. Both were equipped with a three-bottom moldboard plow manufactured by the General Company for Mechanical Industries in Alexandria. The electronic device was designed using two water flow sensors integrated into an Arduino UNO board. The first sensor measured the flow of fuel entering the injector pump, and the second sensor measured the fuel returning from the injectors and the injection pump to the fuel tank. Fuel consumption was determined as the difference between the values recorded by the two sensors.

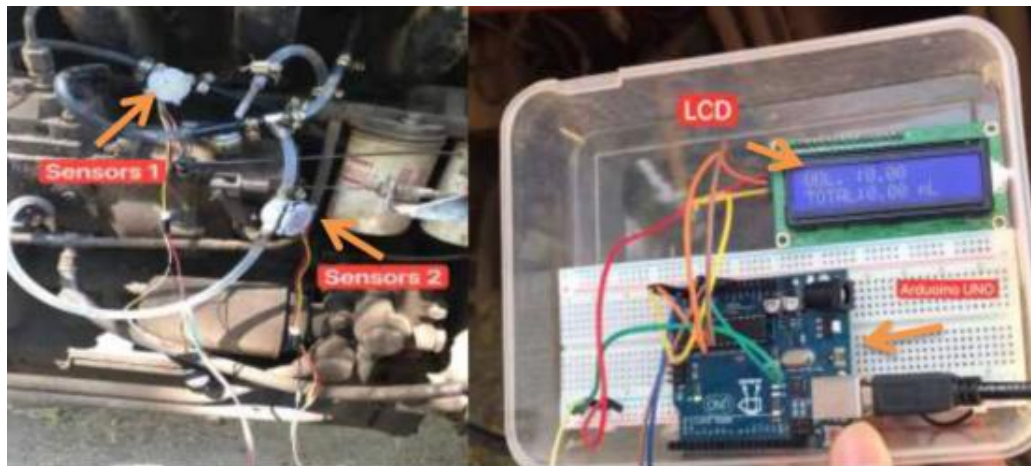


Figure (1): shows the electronic device that was designed.

Studied Parameters

1. Fuel Consumption Rate (L/ha):

The fuel consumption rate was calculated using the following equation proposed by (Al-Jarrah, 1998)



$$V_{co} = \frac{Q \times 10000}{TL \times WP \times 1000}$$

Where:

V_{co} : Fuel consumed per hectare (L.ha⁻¹).

Q: Fuel consumed during the operation (ml).

TL :Operation length (m).

WP: Effective plowing width (m).

2. drawbar power (kw):

The draft force was calculated using the equation proposed by (**Barger et al, 1963**):

$$F_t = F_{pu} - F_{rr}$$

Where:

F_t : Draft force (KN).

F_{pu} : Total thrust force during plowing operation (KN).

F_{rr} : Rolling resistance force when the plow is nearly touching the ground (KN).

3. Actual Field Capacity (ha.h⁻¹):

The actual field capacity was calculated using the equation proposed by(**Kepner et al. 1982 ; Al-Tahan ,1991**):

$$E. F. C = \frac{w \times s}{10} \times \phi t$$

Where:

E. F. C :Actual field capacity (ha.h⁻¹).

w: Effective working width of the plow (m).

s: Operating speed (km.h⁻¹).

ϕt : Time efficiency factor (%).

4. cost (Di .h⁻¹)

Mechanized Unit Costs = Tractor Costs + Agricultural Machine Costs

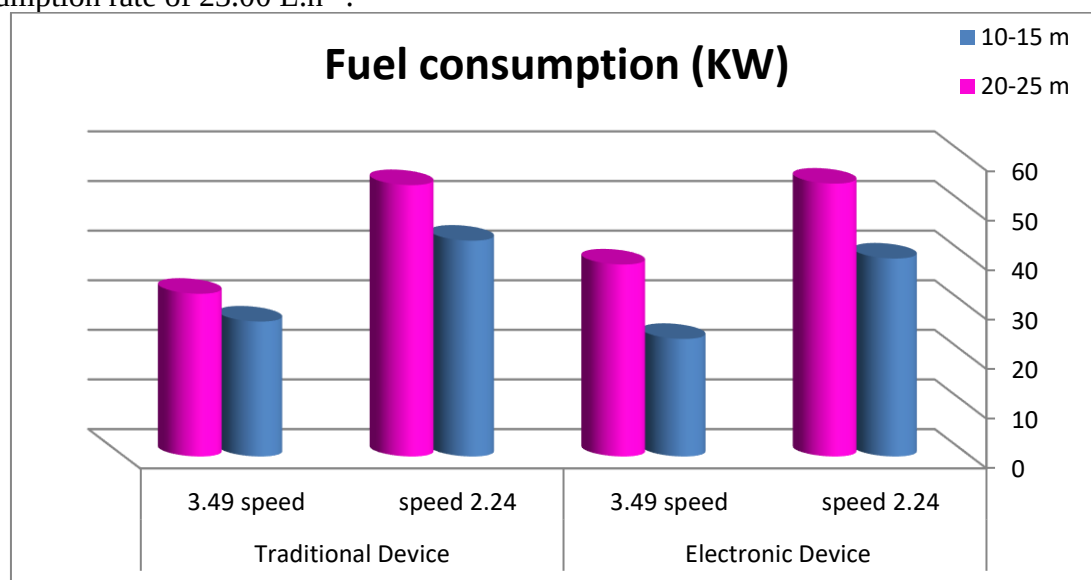
RESULTS AND DISCUSSION

1. Fuel Consumption Rate(L.h⁻¹)

Figure (2) examines the influence of device type, operating speed of the mechanical unit, plowing depth, and their interactions on the fuel consumption rate of the agricultural tractor. The results indicate no significant differences in fuel consumption based on the type of device used. However, significant variations were observed due to tractor speed. As the speed increased from 2.24 to 3.49 km.h⁻¹, the fuel consumption decreased from 48.30 to 30.60 L.h⁻¹. This reduction can be attributed to the improved utilization of the tractor's power at higher speeds, which reduces the time required to complete field operations and, consequently, lowers fuel



consumption. These findings are consistent with those reported by (Laibi & Al-Ani ,2022; Mankhi & Jebur ,2022). The analysis also reveals that plowing depth significantly impacts fuel consumption. Increasing the depth from 10–15 cm to 20–25 cm raised the fuel consumption rate from 33.60 to 45.30 L.h⁻¹. This increase is likely due to the greater volume of soil being tilled at deeper depths, which increases the workload during the operation, thereby leading to higher fuel consumption. These findings align with the results reported by (Amer, 2019). Moreover, the figure highlights a significant interaction effect between device type and operating speed. When operating at a speed of 3.49 km.h⁻¹, the electronic device recorded the lowest fuel consumption rate of 30.00 L.h⁻¹. Similarly, in the interaction between device type and plowing depth, the electronic device achieved the lowest fuel consumption rate of 31.80 L.h⁻¹ at a depth of 10–15 cm. Additionally, the table indicates a significant interaction effect between operating speed and plowing depth, with a speed of 3.49 km.h⁻¹ at a depth of 10–15 cm achieving the lowest fuel consumption rate of 24.45 L.h⁻¹. Finally, in the three-way interaction among device type, operating speed, and plowing depth, the electronic device at a speed of 3.49 km.h⁻¹ and a depth of 10–15 cm demonstrated the most significant advantage, achieving the lowest fuel consumption rate of 23.00 L.h⁻¹.

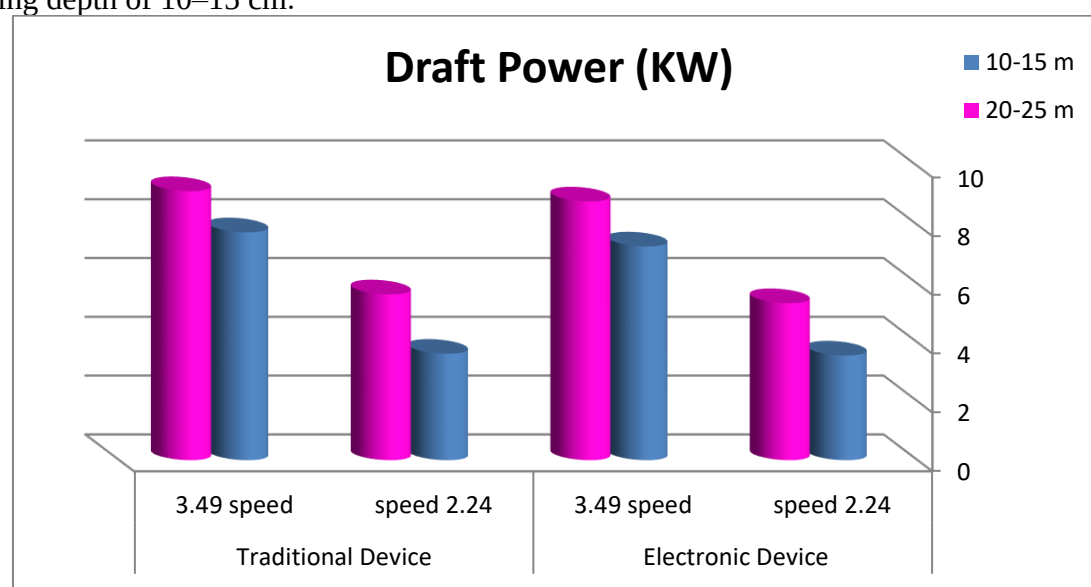


The figure (2): show the effect of device type, forward speed, and plowing depth on fuel consumption.

2- draft power (KW)

The impact of device type, operational speed, plowing depth, and their interactions on draft power is illustrated in Figure (3). The results indicate no substantial differences in draft power based on the type of device employed. However, a significant variation in draft power was observed with changes in tractor speed. For instance, increasing the speed from 2.24 km.h⁻¹ to 3.49 km.h⁻¹ led to a rise in draft power from 4.54 kW to 8.24 kW. This can be attributed to the greater resistance exerted by the soil on the plow blades as the tractor's ground speed increases (Al-Sammarraie, 2023). Additionally, the figure highlights that the plowing depth significantly

influences draft power. A deeper plowing level, such as 20–25 cm compared to 10–15 cm, resulted in an increase in draft power from 5.55 kW to 7.23 kW. This is mainly due to the higher pulling force required to overcome the increased soil resistance and the heavier load on the tractor, as outlined by (Al-Azzawi,2022). Furthermore, the interaction between device type and operational speed showed a marked impact, with the electronic device achieving the lowest draft power of 4.63 kW at a speed of 2.24 km.h⁻¹. Similarly, for the interaction between device type and plowing depth, the electronic device demonstrated superior performance at a depth of 10–15 cm, with a minimum draft power of 5.44 kW. When analyzing the combined effect of operational speed and plowing depth, the lowest draft power recorded was 3.59 kW at a speed of 2.24 km.h⁻¹ and of 10–15 cm depth. Finally, in the three-factor interaction, the electronic device achieved the best result, with the lowest draft power of 3.56 kW at a speed of 2.24 km/h and a plowing depth of 10–15 cm.



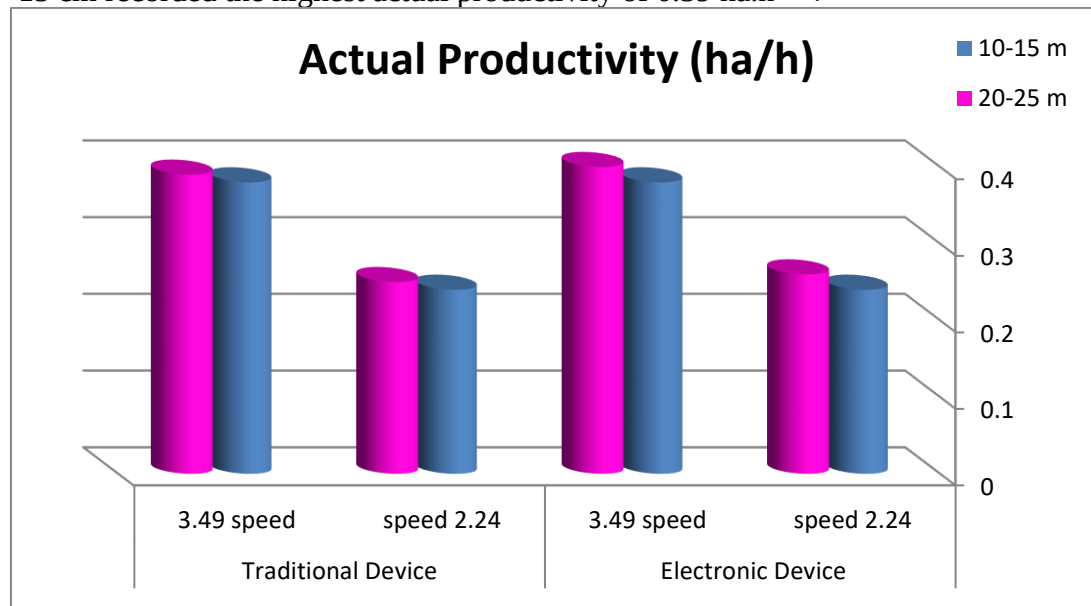
The figure (3): show the effect of device type, forward speed, and plowing depth on Draft Power.

3-Actual Productivity (ha/h)

Figure (4) illustrates the impact of device type, operational speed of the mechanical unit, plowing depth, and their interactions on actual productivity. The figure indicates no notable differences in actual productivity based on the type of device used. However, it reveals significant variations in productivity due to tractor speed. Increasing the speed from 2.24 to 3.49 km.h⁻¹ enhanced productivity from 0.24 to 0.38 ha.h⁻¹ (Omar *et al.*, 2021). Additionally, the figure highlights the significant effect of plowing depth on productivity. Increasing the plowing depth from 10–15 cm to 20–25 cm decreased actual productivity from 0.32 to 0.30 ha.h⁻¹. Furthermore, the interaction between device type and operational speed showed a considerable effect, with the electronic device achieving the highest productivity of 0.24 ha.h⁻¹ at a speed of 2.24 km.h⁻¹. Regarding the interaction between device type and plowing depth, the electronic



device excelled at a depth of 10–15 cm, achieving a maximum productivity of 0.33 ha.h^{-1} . Moreover, the interaction between operational speed and plowing depth showed that a speed of 2.24 km.h^{-1} at a depth of 10–15 cm resulted in the highest productivity of 0.39 ha.h^{-1} . Finally, in the three-factor interaction, the electronic device at a speed of 2.24 km.h^{-1} and a plowing depth of 10–15 cm recorded the highest actual productivity of 0.39 ha.h^{-1} .

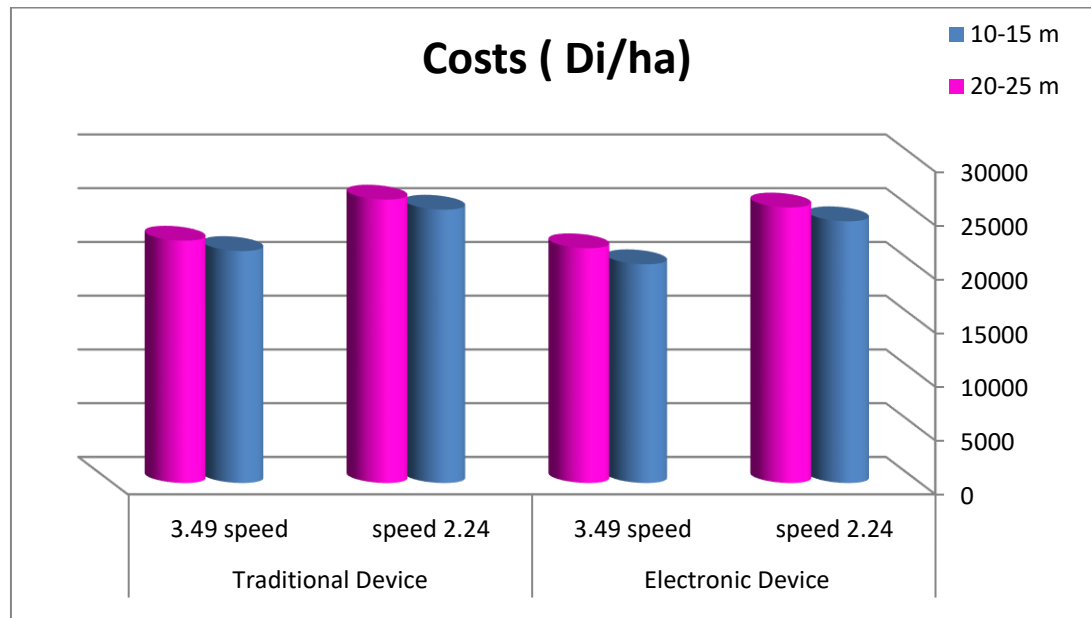


The figure (4): show the effect of device type, forward speed, and plowing depth on Actual Productivity.

4-Costs (Di.ha^{-1}):

Figure (5) demonstrates the effect of device type, operational speed of the mechanical unit, plowing depth, and their interactions on costs. The figure reveals no significant differences in costs based on the type of device used. However, it shows notable differences in costs associated with tractor speed. Increasing the speed from 2.24 to 3.49 km.h^{-1} led to a reduction in costs from $25,446$ to $21,581 \text{ Di.h}^{-1}$. This cost reduction is attributed to the enhanced operational productivity, which lowers overall costs. Additionally, higher speeds decrease the time needed to complete tasks, leading to reduced fuel consumption and associated expenses, thus further lowering total costs. These results align with findings reported by **Al-Azzawi (2022)**. The figure also emphasizes the significant impact of plowing depth on costs. Increasing the plowing depth from 10–15 cm to 20–25 cm raised costs from $22,930$ to $24,098 \text{ Di.ha}^{-1}$. This increase is primarily due to a higher slippage percentage, which slows down operational speed, a key factor in productivity. These observations are consistent with the findings reported by **Saleh (2023)**. Furthermore, the interaction between device type and operational speed showed that the electronic device, achieved the lowest costs at a speed of 3.49 km.h^{-1} , recorded at $21,097 \text{ Di/ha}$. In terms of the interaction between device type and plowing depth, the electronic device excelled at a depth of 10–15 cm, achieving the lowest costs of $22,352 \text{ Di.ha}^{-1}$. The interaction between operational speed and plowing depth also showed significant results, with a speed of 3.49 km.h^{-1}

at a depth of 10–15 cm resulting in the lowest costs, recorded at 20,968 Di.ha⁻¹. Finally, in the three-factor interaction, the electronic device, operating at a speed of 3.49 km.h⁻¹ and a plowing depth of 10–15 cm, achieved the lowest costs, recorded at 20,352 Di.ha⁻¹.



The figure (5): show the effect of device type, forward speed, and plowing depth on Cost

How to Use the Device in Detail:

1. Connecting the Main Components:

- Connect the Arduino board to the screen and sensors using the designated connection wires to ensure a stable connection.

2. Connecting the First Sensor:

- Place Sensor 1 in the middle of the inlet pipe leading to the injector pump, where this sensor measures the fuel quantity or pressure entering the pump.

3. Connecting the Second Sensor:

- Place Sensor 2 in the middle of the return pipe from the injector pump and injectors to the tank, to measure the fuel quantity or pressure returning to the tank.

4. Power Connection:

- Connect the Arduino board to the power source (typically a battery), ensuring the battery is adequately charged to keep the device running continuously.

5. Starting the Device:

- Once the device is turned on, the Arduino board will start collecting data from the sensors.
- The results will be displayed directly on the attached screen, which may include: fuel quantity, pressure, or any other programmed data.



Maintenance Requirements for the Device:

After Each Use:

- Clean the internal and external parts of the device to remove any fuel residues or other deposits.
- Ensure that no outlets or internal pipes are clogged.
- Check the remaining fuel level and refill if necessary.

Periodic Maintenance:

- Conduct regular inspections of the mechanical parts to ensure there is no wear or damage.
- Replace filters and oils (if they are part of the device's design) at specified intervals.
- Review the instruction manual to ensure the recommended maintenance steps are properly followed.

The Beneficiaries of the Research in Iraq:

Agricultural Sector:

- The device can be used to improve irrigation efficiency or agricultural mechanization, contributing to increased productivity and reduced costs.

Industrial Sector:

- If the device is designed for energy efficiency, it can serve small and medium-sized factories.

CONCLUSIONS AND RECOMMENDATIONS

From the obtained results, we conclude that the electronic device type outperformed with an operational speed of 3.49 km.h^{-1} and a depth of 10-15 cm, yielding the best results for the studied characteristics.

We recommend using an electronic device to measure the fuel consumption of agricultural tractors, as it provides the highest measurement efficiency. We also recommend applying the device to all types of agricultural tractors.

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