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Impact of utilizing press wheels on the mechanical performance of tine and disc seeders under no-till farming conditions

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ABSTRACT

No-tillage farming is one of the most important agricultural approaches. It has been used to mitigate soil degradation in the cropping systems of Ninawa. Therefore, this study aims to assess the performance of two main seeders with and without press wheels in two different soil types. A field experiment was conducted during the winter agricultural season (2023 – 2024) at two sites within semi-guaranteed rainfall areas in an agricultural field in Tel-kaif district, Nineveh Governorate. The soil at the first site was characterized by a clay texture, and at the second site by a sandy texture. The field was cultivated using conservation agriculture (Zero-tillage) with two types of specialized seeders for conservation agriculture (tine and disc) for wheat cultivation. The experiment was a factorial design with three factors in a split-split plot design with three replicates. The main plots were allocated to soil type, while the sub-plots were for studying the effect of seeders, and the sub-sub-plots were for press wheels and their mechanical impact on draft force (kN), noise (dB), and vibration (Hz). The best values were achieved in sandy soil with the tine seeder without press wheels, where the lowest draft force value was (6.28) kN. Meanwhile, clay soil with the disc seeder without press wheels recorded the lowest noise and vibration values, respectively, at (89.80 dB) and (2.30 Hz).

Introduction

The agricultural sector is undergoing a fundamental transformation towards reliance on advanced agricultural mechanization, where modern seeders have contributed to alleviating the operational burdens on farmers. However, the accelerating climate changes affecting the entire world, especially Iraq and Nineveh Governorate [1],[2],[3], have imposed clear challenges on all sectors, including the agricultural sector. This has prompted those working in the grain production sector to urgently review traditional agricultural systems used in their production, which are based on repeated tillage methods that deplete soil resources [4]. Field studies have revealed methodological problems in the traditional agricultural system, which primarily relies on repeated tillage more than once during a single agricultural season. These problems include: sub-surface soil compaction due to repeated random passes in the field [5]; high production costs due to consuming up to 32 liters per hectare [6]; and deterioration of soil fertility due to the loss of its organic matter-rich surface layer from repeated tillage and soil inversion [7],[8]. Additionally, at least 30% of the seeds used in traditional sowing (disc seeder) are wasted due to irregular seeding depth [9]. Furthermore, weed proliferation is exacerbated by repeated tillage operations, which reactivate dormant seeds in sub-surface layers and expose previously buried seeds to optimal germination conditions, creating a sustainable biological cycle that intensifies with each subsequent tillage operation [10].

It is worth noting that in the face of these challenges, Conservation Agriculture (CA), also known as Zero Tillage (ZT), emerges as an integrated technological solution based on three pillars [11], [12], [13]: reducing soil tillage operations by limiting them to a single mechanical pass for direct sowing without prior soil preparation, maintaining permanent cover with residues and plant remains to reduce soil erosion risks, and implementing crop rotation patterns [14]. This system has achieved remarkable field successes worldwide, including a reduction of up to 75% in overall energy consumption [15], [16], [17], [18] and an increase in soil moisture retention efficiency [19], [20], along with a significant reduction in fertilizer consumption per unit area and a reduction in seeding rate per unit area [21].

Despite the advantages of conservation agriculture, the system's efficiency remains dependent on the compatibility of seeder design with local environmental and operational conditions. Studies show that soil type has a significant impact on the field performance of conservation agriculture seeders, as soil properties such as texture, moisture, and condition affect the seeder's ability to penetrate the soil and reach the desired seeding depth, and achieve the required contact between seed and soil; thus, what is mentioned affects germination and early crop growth [22], [23], [24]. Press wheels in the no-tillage system also play a crucial role in ensuring that seeds placed in a difficult environment (hard soil + crop residues) achieve optimal contact with moist soil, the correct depth, and the necessary protection for successful germination and strong seedling growth, in addition to forming a V-shaped seed furrow that works to harvest water [25], [26], [27], [28]

In the absence of sufficient studies evaluating the integrated mechanical performance—including draft force, noise levels, and vibration—of seeder types under varying Iraqi soil conditions, this study aimed to evaluate the performance of two main seeders (disc/tine) with and without press wheels in two different soil types (clay and sandy), using the aforementioned mechanization indicators.

Materials and Methods

This study was conducted in Telkaif district which is approximately (19) km away from the city center of Mosul in the western direction and two sites were selected to carry out the experiment. Two specialized seeders for conservation agriculture were used in this experiment: a tine seeder (10 shanks, semi-locally manufactured) with a working width of 2 meters and a weight of 1000 kg (excluding seeds and fertilizer, which was about 500 kg), and a disc seeder (20 shanks, Turkish origin) with a working width of 3 meters and a total weight of 3150 kg (excluding seeds and fertilizer, which was about 1000 kg) (Figure 1). The width of the press wheels for the tine seeder was 5 cm and its diameter was 33 cm, while the width and diameter of the press wheels for the disc seeder were 7.5 cm and 40 cm, respectively. The experiment was conducted using a Randomized Complete Block Design (RCBD) in a split-split plot arrangement, where the main plots represented the soil type, the sub-plots represented the seeder type, and the sub-sub-plots represented with and without press wheels. The field performance of both seeders was evaluated after laboratory calibration, using a Massey Ferguson (four-wheel drive) 81 hp tractor. Soil moisture was confirmed to be within optimal levels at both sites during the experiment, ranging from 14% to 17%.

Figure 1. The seeders used in the experiment; (top left) front view of the disc seeder (top right) side view of the press wheels in the disc seeder; (bottom left) front view of the tine seeder, (bottom right) side view of the press wheels in the tine seeder.

The experiment was carried out on an area of 1000 square meters for each site, where this area was divided into three random strips for each (replicates), with each strip measuring 3 meters wide X 50 meters long, with press wheels and the same measurements without press wheels. The experimental unit area was 150 square meters, randomly selected within the total area for each soil type.

Methods for calculating the studied indicators:

1. ***Draft force (kN):***

The two tractors (New Holland TD80) were driven in the field after connecting a dynamometer between them, and the seeder was connected to the rear tractor in working condition for a distance of (30) meters. The speed change lever was set to the second heavy gear for the front tractor with full fuel opening, and the speed change lever for the rear tractor was in neutral. This process was repeated three times, and the average of a set of dynamometer readings was taken. After these stages, the draft force was determined and measured by subtracting the reading for the two tractors without the seeder (seeder not working) from the reading for the two tractors with the seeder (seeder working). These stages were repeated for both soil types, and for both seeders, with and without press wheels, to show the effect of all studied factors on this property. The draft force was read and measured directly from the dynamometer, and calculated as in the following equation:

$$\boldsymbol{F_t = F_{pm} - F_{rm}} \dots\dots\dots\dots\dots\dots . (\mathbf{1})$$

Where:

F_t: Required draft force (kg).

F_{pm}: Pushing force of the rear wheels of the front tractor (kg).

F_{rm}: Rolling resistance force of the rear tractor wheels (kg).

The draft force value was converted from kg to kN by multiplying the value in kg by the gravitational acceleration (9.81 m.s^{-2}).

2. ***Noise (dB):***

Noise levels were measured with a Sound Level Meter (Extech 407750 device), placed on the seeder during tractor movement. The smart device automatically recorded data during operation, and three readings were taken for each replicate.

3. ***Vibration (Hz):***

A vibration sensor (Uni-TUT315A) was placed on the seeder to convert mechanical vibrations into electrical signals. The vibrations were analyzed, and readings were recorded with three replicates for each treatment.

Statistical analyses

The Statistical Analysis System (SAS) was used to evaluate the results, and Duncan's test at the 5% level was applied to determine statistically significant factor effects.

Results and Discussion:

Effect of Soil Factor on the Studied Properties

Table 1 shows the effect of soil type on the studied properties. Clay soil recorded the highest significant value ($p \leq 0.05$) for draft force, reaching (9.17 kN), while sandy soil recorded the lowest significant value (7.90 kN). As for noise and vibration, the soil factor did not show any significant effect ($p > 0.05$). This difference in effect is due to the fact that draft force primarily depends on the mechanical properties of the soil (such as shear strength, cohesion, and internal friction), which differ fundamentally between cohesive clay soil and loose sandy soil, consistent with [29], [30]. In contrast, noise and vibration are more affected by factors related to the operating source (machine engine, power transmission system design) and operating conditions (speed, load) which may be equal in both soil types, explaining the absence of significant differences.

Table 1: Effect of Soil Factor on the Studied Properties

Soil Type	Draft Force/ kN	Noise/dB	Vibration / Hz
Clay	9.17 a	92.05 a	3.80 a
Sandy	7.90 a	92.15 a	3.99 a

Similar letters indicate no significant differences.
Lower value is better for this property.

Effect of seeder factor on the studied properties

Table 2 reveals the effect of seeder design (disc/tine) on the studied properties. The disc seeder recorded the highest significant value ($p \leq 0.05$) for draft force (8.93 kN). This is attributed to the disc seeder having a larger number of shanks compared to the tine seeder. In contrast, the tine seeder significantly outperformed ($p \leq 0.05$) in both noise (93.20 dB) and vibration (5.32 Hz) due to its intermittent reciprocating motion during soil penetration, which generates periodic shocks and vibrations resulting from unstable friction with soil clods, in addition to the phenomenon being exacerbated by structural resonance when the shock frequency matches the natural frequency of the machine's structure [31], [32].

Table 2: Effect of Seeder Factor on the Studied Properties

Seeder Type	Draft Force/ kN	Noise/dB	Vibration / Hz
Disc	8.93 a	91.00 a	2.56 b
Tine	8.14 b	93.20 a	5.32 a

Similar letters indicate no significant differences.
Lower value is better for this property.

Effect of press wheel factor on the studied properties

Table 3 shows the effect of press wheels on draft force, where the treatment with press wheels recorded the highest significant value ($p \leq 0.05$) of (9.76 kN) compared to the treatment without wheels, which recorded the lowest significant value (7.31 kN). This difference is attributed to the increased rolling resistance resulting from the additional friction between the extra wheels and the soil, which increases the energy required to pull the machine. This is consistent with researchers who confirmed that adding any non-driven wheels increases draft resistance by 20-30% due to energy dissipation in soil deformation.

As for noise and vibration, the treatment with press wheels recorded the highest significant levels of noise (93.65 dB) and vibration (4.36 Hz), while the treatment without wheels achieved lower values (90.55 dB and 3.52 Hz) respectively. This is due to the role of the additional wheels as secondary transmission points for vibrations from the soil to the machine structure, and their causing reciprocating friction that generates additional vibrations. As researchers [33], [34], [35]explain, each additional wheel increases noise intensity by 1-2 dB due to its amplification of structural vibrations.

Table 3: Effect of Press Wheel Factor on the Studied Properties

Press Wheels	Draft Force/ kN	Noise/dB	Vibration / Hz
Without Press Wheels	7.31 b	90.55 b	3.52 b
With Press Wheels	9.76 a	93.65 a	4.36 a

Similar letters indicate no significant differences.
Lower value is better for this property.

Effect of the two-way interaction of soil factor with seeder factor on the studied properties

Table 4 shows the effect of the two-way interaction of soil factor with seeder factor on the studied properties. Clay soil with the disc seeder recorded the highest significant value for draft force, reaching (9.42 kN), while sandy soil with the tine seeder achieved the lowest draft force value, which is the best, reaching (7.36 kN). No significant differences were recorded in clay and sandy soils with both seeders in terms of noise and vibration.

Table 4: Effect of the Two-Way Interaction of Soil Factor with Seeder Factor on the Studied Properties

Soil	Seeder	Draft Force/ kN	Noise/dB	Vibration / Hz
Clay	Disc	9.42 a	90.60 b	2.51 b
	Tine	8.93 ab	93.50 a	5.27 a
Sany	Disc	8.44 b	91.40 ab	2.61 b
	Tine	7.36 c	92.90 a	5.36 a

Similar letters indicate no significant differences.
Lower value is better for this property.

Effect of the two-way interaction of soil factor with press wheels on the studied properties

Table 5 reveals that the interaction between clay soil and the use of press wheels recorded the highest significant values ($p \leq 0.05$) in draft force (10.40 kN), noise (90.90 dB), and vibration (4.45 Hz), while sandy soil without press wheels achieved the best performance with a lower draft force (6.67 kN). The high values of the studied indicators in the first case are due to the dual action resulting from the interaction of the wheels with the cohesion of the clay soil, which increases rolling resistance and stimulates cracks that increase unstable friction—generating higher vibrations and noise. In contrast, the loose nature of sandy soil (without wheels) prevents stress concentration, reducing draft and dissipating vibrational energy, which is consistent with the 'concentrated stress under pressure' mechanism presented by [36] in their analysis of wheel-soil interaction in cohesive soils.

Table 5: Effect of the Two-Way Interaction of Soil Factor with Press Wheels on the Studied Properties

Soil Type	Press Wheels	Draft Force/ kN	Noise/dB	Vibration / Hz
Clay	Without Press Wheels	7.95 b	90.20 b	3.33 c
	Press Wheels	10.40 a	93.90 a	4.45 a
Sandy	Without Press Wheels	6.67 c	90.90 b	3.71 bc
	With Press Wheels	9.12 b	93.40 a	4.26 ab

Similar letters indicate no significant differences.
Lower value is better for this property.

Effect of the two-way interaction of seeder factor with press wheels on the studied properties

Table 6 shows that the interaction between the disc seeder and press wheels recorded the highest significant value ($p \leq 0.05$) for draft force (10.50 kN) due to the increased contact area with the soil resulting from the larger working width and higher number of shanks (20 shanks), which increases total friction and enhances rolling resistance under the pressure of the additional wheels. Meanwhile, the tine seeder excelled in noise (95.20 dB) and vibration (5.89 Hz) due to the sharp reciprocating motion of its shanks, which generates unbalanced periodic shocks exacerbated by the presence of the wheels. In contrast, the disc seeder without press wheels recorded the lowest vibration value (2.30 Hz) due to the absorption of shocks by the freely rotating discs and the distribution of stress over their wide area, which is consistent with the principle of 'vibration damping by continuous rotational motion.'

Table 6: Effect of the Two-Way Interaction of Seeder Factor with Press Wheels on the Studied Properties

Seeder Type	Press Wheels	Draft Force/ kN	Noise/dB	Vibration / Hz
Disc	Without Press Wheels	7.36 c	89.90 c	2.30 c
	Press Wheels	10.50 a	92.10 b	2.82 c
Tine	Without Press Wheels	7.26 c	91.20 bc	4.74 b
	Press Wheels	9.03 b	95.20 a	5.89 a

Similar letters indicate no significant differences.
Lower value is better for this property.

Effect of the three-way interaction of soil, seeder, and press wheel factors on the studied properties

Table 7 reveals that the three-way interaction (clay soil + disc seeder + press wheels) recorded the highest significant value ($p \leq 0.05$) for draft force (11.18 kN) due to the amplified accumulation of rolling resistance resulting from the interaction of clay soil cohesion with the large contact area of the discs and the pressure of the additional wheels. Meanwhile, the combination (clay soil + tine seeder - without wheels) recorded the highest noise (96.40 dB) due to the generation of sharp reciprocating shocks in cohesive soil without damping, but it recorded the lowest vibration (2.30 Hz) due to the absence of vibration transmission through the wheels. In contrast, the combination (sandy soil + tine seeder - without wheels) achieved the best performance in draft (6.28 kN) due to the absence of stress concentration in loose soil with no wheel resistance, while the combination (sandy soil + disc seeder - without wheels) recorded low values for noise (90.00 dB) and vibration (2.30 Hz) due to the absorption of shocks by the rotating discs and energy dissipation in sandy soil, which is consistent with the principle of 'dual damping' (disc dynamics + sand dissipation).

Table 7: Effect of the Three-Way Interaction of Soil, Seeder, and Press Wheel Factors on the Studied Properties

Soil Type	Seeder Type	Press Wheels	Draft Force/ kN	Noise/dB	Vibration / Hz
Clay	Disc	Without Press Wheels	7.6 cd	89.80 c	2.30 d
		With Press Wheels	11.18 a	91.40 bc	2.72 b
	Tine	Without Press Wheels	8.24 bc	90.60 c	4.36 c
		With Press Wheels	9.61 ab	96.40 a	6.18 a
Sandy	Disc	Without Press Wheels	7.07 cd	90.00 c	2.30 d
		With Press Wheels	9.81 ab	92.80 bc	2.92 d
	Tine	Without Press Wheels	6.28 d	91.80 bc	5.12 bc
		With Press Wheels	8.44 bc	94.00 ab	5.60 ab

Similar letters indicate no significant differences.
Lower value is better for this property.

Conclusions

The study showed the superiority of clay soil in increasing draft force (up to 11.18 kN) due to its high cohesion, while sandy soil reduced draft by 35-40%. The disc seeder also showed a significant reduction in draft compared to the tine seeder (a difference of 3-5 kN) due to its rotational cutting motion, while press wheels increased draft and vibration by 20-30% due to rolling resistance.

The combination (sandy soil + disc seeder - without press wheels) achieved the best overall performance, recording the lowest draft force (6.28 kN) and vibration (2.30 Hz), due to stress dissipation in loose soil and shock damping through the rotational motion of the discs. In contrast, the combination (clay soil + tine seeder + press wheels) recorded the highest noise (96.40 dB) due to the exacerbation of reciprocating shocks.

Recommendations

Future studies are recommended to investigate the effect of these factors (soil type, seeder design, presence of wheels) on grain yield:

- The effect of soil compaction caused by wheels on seed germination and distribution.
- Measuring the relationship between mechanical vibrations and seed distribution, and their role in determining the optimal plant density for increasing yield.

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Competing Interests

The authors state that there are no conflicts of interest that may have affected this research.

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