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Study on the efficiency of seeder performance in no-tillage farming system and its impact on selected technical and physical performance indicators and wheat yield

Osama Hassan J. Al-Mashhadany[1,2*], Ziyad Dris[2], Abdulrazzak A. Jasim[3]

[1] Ministry of Agriculture, Iraq
[2] Laboratory of Electromechanical Systems, National School of Engineers of Sfax (ENIS), University of Sfax, Tunisia
[3] College of Agricultural Engineering Sciences, University of Baghdad, Baghdad, Iraq
* Corresponding author e-mail: osamahassan16@yahoo.com

ABSTRACT

Eield experiment was conducted in one of the fields in Baghdad Governorate during the 2021–2022 agricultural season in loamy soil to investigate the feasibility of using no-tillage farming systems for wheat cultivation and their impact on plant growth and yield. The experiment employed a German-made NEWHOLLAND Tractor 80-66S with machinery units,The study examined three factors. Three speeds were tested 4.23, 6.54, and 8.37 km/h. Two seed rates were used 100 kg/ha and 140 kg/ha. Three configurations were evaluated: Osduman seeder alone, Osduman seeder with soil servicing tools, Broadcaster seeds with soil servicing tools. Performance indicators studied included fuel consumption rate, field efficiency, drawbar power, soil moisture content, and biological yield. The least significant difference (LSD) test at a 0.05 significance level was used to compare treatment means. The highest speed 8.37 km/h, at a seed rate of 100 kg/ha and with the Osduman seeder treatment Z, recorded the lowest fuel consumption rate of 4.26 L/ha and the highest field efficiency of 73.42%. At the same speed and seeder configuration treatment Z but with a seed rate of 140 kg/ha, the highest biological yield was achieved 7067 kg/ha. The lowest speed 4.23 km/h, at a seed rate of 100 kg/ha and with the Osduman seeder, recorded the highest soil moisture content 0.247%. At the same speed and seed rate but with the Osduman seeder combined with soil servicing tools treatment Zt, the lowest draft power, was recorded 1.88 kW.

Keywords: fuel consumption, field efficiency, drawbar power, no-tillage farming, seed rate, operational speed.

INTRODUCTION

Agricultural machinery and equipment play a fundamental role in advancing the agricultural process and increasing production per unit area, especially with the growing global population and the rising demand for food. The expansion of cultivated areas makes it difficult to meet this increasing demand using traditional farming methods. Therefore, the integration of modern technology and the development of advanced agricultural machinery with higher capacity and speed have become essential. These machines are capable of performing multiple agricultural operations simultaneously, making them crucial for keeping pace with rapid advancements in other fields, particularly in countries where the agricultural sector still suffers from neglect and outdated practices [1]. The development of mechanical industries has enhanced agricultural capabilities, as seen in the use of tractors. This progress has led to an increase in the number and types of agricultural equipment, including plows, harrows, seeders, planters, sprayers, and harvesters, all of which are directly connected to tractors [2-3]. Composite machines help reduce energy consumption, save fuel and time, improve filtration capacity, minimize runoff, and decrease soil erosion. This ultimately leads to better root growth and increased crop yields compared to conventional machinery used for soil preparation and other farming processes. Traditional equipment often causes soil compaction, increases bulk density, reduces porosity, and raises soil resistance to root growth and seedling emergence [4]. Composite machines contribute to reducing energy consumption, saving fuel and time, improving filtration, and reducing surface runoff and erosion, which enhances root growth and ultimately increases productivity during farming operations [5-7]. Studies have shown that no-till farming has been practiced instinctively since ancient times. Early humans lacked the technical knowledge required for proper tillage. Ancient Egyptians and later South American farmers used sticks to create holes for planting seeds without preparing the soil [8]. Additionally, [9] concluded in a study that a multi-functional composite machine, designed by their research team, had a significant impact on improving soil physical properties and increasing crop yields compared to traditional machines. Farmers must seek sustainable, productive, and profitable agricultural methods that minimize the depletion of non-renewable natural resources. Conservation agriculture is the key solution, as it involves appropriate crop rotation, continuous soil coverage, and reduced tillage to preserve agricultural and natural ecosystems [10]. Agricultural mechanization within the no-till farming system can be defined as the application of mechanical technology at lower costs and reduced power requirements while achieving acceptable crop yields. This technology, particularly modern seeders for both conventional and no-till systems, has advanced the agricultural sector in developed countries. It meets the agro-technical requirements for various crops by ensuring precise seed distribution per unit area and maintaining uniform spacing and depth, resulting in consistent plant density [11]. Climate change in the rain-fed areas of northern Iraq has led to irregular rainfall patterns, with total precipitation decreasing by more than 50% over the past decade. Rainfall timing has also shifted, occurring either earlier (mid-September to mid-October) or later than usual. This variability negatively affects the biological yield of wheat, including both grain and straw production [12]. These climatic conditions have resulted in lower grain yields per hectare and significant depletion of soil straw due to increased demand from livestock farmers. As a consequence, soil cover has been lost, exposing the land to wind erosion, which has sometimes forced farmers to migrate due to desertification [13]. The no-till farming system is a viable and advanced alternative to traditional tillage. This system has proven effective in rainfed areas with varying rainfall levels. Researchers have emphasized the importance of reducing frequent tillage to prevent moisture loss in the root zone and protect plants from drought stress [14]. The use of practical experience was to study the possibility of using no-tillage agricultural systems in the seeds of wheat crops and their impact on the growth and production of the plant The aims of this is research to know the possibility of using no-till farming systems in wheat seeds and to compare between no-till farming systems, disc, chisel, and seed spreader. It also aims to influence the no-till farming systems on some soil characteristics and the growth and production of the wheat crop.

MATERIALS AND METHODS

Experiment field was conducted in one of the fields located in Al-Tarmiyah district, Baghdad Governorate, during the 2021–2022 season. The aim of the experiment was to study the feasibility of using no-till farming systems for wheat seeding and their impact on plant growth and production. The process began with the removal of weeds and cleaning of the field. The land was then leveled and smoothed using a grader. Afterward, the field was marked with 20 cm high earthen ridges and flooded with water to achieve the appropriate moisture level for tillage in some replicates, making the field ready for planting. The field was divided into three sections for conducting the experiment and comparing the replicates. As shown in Figure 1, the experimental field and the random distribution of replicates, along with the mechanism of wheat crop cultivation. The initial plowing was done using a moldboard plow with three bodies to prepare 36 experimental units, followed by secondary tillage using a rotary tiller to smooth the soil. This preparation was specifically for the 36 experimental units that included seeding with the Broadcaster Seeds machine (Ct) in 18 experimental units and seeding with the Osduman seeder and fertilizer machine (Zt) in another 18 experimental units, which operated on the tilled land. The exception was for 18 experimental units dedicated to conservation agriculture using the Osduman seeder and fertilizer machine, which were included in the comparison with the previously prepared experimental units. The Özdeman and broadcast

Figure 1. The experimental field and the wheat crop

seeders were used in the experimental field, as shown in Figure 1 and Figure 2. Three factors were used in the experiment. The first, involved three speeds, 4.23, 6.54, and 8.37 km/h. The second factor, was the seeding rate with two quantities 100 and 140 kg/ha. The third factor, involved the use of three machines: the Osduman seeder and fertilizer machine without tillage, the Osduman seeder and fertilizer machine with tillage, and the Broadcaster Seeds machine (Figure 3), Table 1. shows the symbols used in the experiment and their meanings. The assigned area for each experimental unit was 3 m of width and 45 m of distance. The total number of experimental units in the field was 54, with the experimental units in each replicate being randomly distributed. The total area designated for the experimental field was 5000 m². The experiment was

Figure 2. The Özdeman Fertilizer seed drill

Figure 3. The broadcast spreader

Table 1. Symbols used in the experiment and their meanings

Symbol	Meaning
S1	First operational speed: 4.23 km/h
S2	Second operational speed: 6.54 km/h
S3	Third operational speed: 8.37 km/h
A	Estimated seed quantity: 100 kg
B	Estimated seed quantity: 140 kg
M	Seed machinery system
Z	Osduman seed drill and fertilizer applicator with conservation agriculture
Zt	Osduman seed drill and fertilizer applicator with primary and secondary tillag
Ct	Broadcaster Seeds with primary and secondary tillage
R1, R2, R3	Replicates , experimental units

conducted using a nested design system with a complete randomized block design (R.C.B.D.) and three replications, employing the least significant difference LSD at the 0.05 level to compare the means of the treatments [15]. The factors being tested are organized at nested levels, and a nested design is used because there is a main factor that branches into sub-factors. Each experimental unit is randomly assigned within each sector, which reduces variability between the units and increases accuracy.

STUDIED TRAITS

Fuel consumption

Fuel consumption was measured according to the method followed by [16]:

$$Fc = \left(\frac{Q\,x10000}{TL\,XWp}\right)x1000 \qquad (1)$$

where: Q – amount of fuel consumed during the treatment (ml), T_1 – length of the treatment (m), W_p – actual working width of the plow (m).

Field efficiency of the machine

The field efficiency was calculated using the following equation proposed by [17]:

$$Fe = \left(\frac{Pt}{Pp}\right)\,x\,100 \qquad (2)$$

where: P_p – effective productivity of the machine (ha/h), P_t – theoretical productivity of the machine (ha/h).

Draft power

Draft power was calculated using the method by [18] with the following equation:

$$HP = \frac{Vp\ x\ Ft}{3.6} \qquad (3)$$

where: Vp – operating speed (km/h), Ft – draft force (kn).

Soil moisture content

Soil moisture content was calculated using the gravimetric method before conducting the experiment for all experimental units, as used by [19]. The calculation was performed using the following equation:

$$M = \left(\frac{Mw}{Ms}\right)\ X\ 100 \qquad (4)$$

where: Mw – mass of water (g), Ms – mass of the solid part (g).

Biological yield

The biological yield calculated from the total weight of dry matter (grains + straw) above the soil surface from the harvested plants in the same area used to study yield components. This was converted to tons per hectare according to [20].

RESULTS AND DISCUSSION

Fuel consumption

Experiment and study of the fuel consumption rate revealed the impact of forward operational speed, seeding rate, and seeder machine treatments on fuel consumption. The results show significant differences in fuel consumption due to the use of different speeds for the mechanized unit. The third speed, 8.37 km/h, record the lowest fuel consumption of 21.06 L/ha compared to the first speed, 4.23 km/h, and the second speed, 6.54 km/h, which recorded 33.15 L/ha and 24.67 L/ha, respectively. This reduction in fuel consumption can be attributed to the optimal utilization of tractor power, reduced time required to complete tillage operations per unit area, and increased operational productivity. These findings are consistent with the results reported by [21]. Regarding the average seeding rate, there ere no significant differences, although the 100 kg seeding rate recorded a slightly lower fuel consumption of 26.28 L/ha compared to the 140 kg seeding rate, which recorded 26.31 L/ha. The reason for this is that increasing the seeding rate and tillage operations during the passage of the CT machine slows down the tractor and increases fuel consumption. In contrast, a lower seeding rate allows the machine and tractor to move more quickly, reducing fuel consumption, especially when using the Z machine without tillage operations. Furthermore, the seeder machine treatments had a significant impact on fuel consumption, with the Z machine recording the lowest fuel consumption of 5.89 L/ha, followed by the Zt machine and the Ct machine, which record the highest fuel consumption of 33.93 L/ha and 39.06 L/ha, respectively. The interaction between speed and seeding rate also show significant effects on fuel consumption. The highest fuel consumption record at the first speed of 4.23 km/h with a seeding rate of 140 kg, reaching 33 L/ha, while the lowest value recorded at the third speed of 8.37 km/h with a seeding rate of 100 kg, at 20.70 L/ha. The interaction between speed and seeder machine treatments show significant differences as well. The combination of the third speed, 8.37 km/h, and the Z seeder machine record the lowest fuel consumption of 4.44 L/ha, while the combination of the first speed, 4.23 km/h, and the Ct seeder machine record the highest fuel consumption of 49.30 L/ha. The interaction between seeding rate and seeder machine treatments also affect fuel consumption, with the 100 kg seeding rate combined with the Z treatment recording the lowest fuel consumption of 5.49 L/ha, while the 140 kg seeding rate combined with the Ct treatment recorded the highest fuel consumption of 39.21 L/ha (Figure 4).

Field efficiency

Experiment field show the impact of forward operational speed, seeding rate, and seeder machine treatments on field efficiency, revealing significant differences in field efficiency due to the use of different speeds for the mechanized unit. The third speed, 8.37 km/h, recorded the highest field efficiency at 69.01%, compared to the first speed, 4.23 km/h, and the second speed, 6.54 km/h, which recorded 68.81% and 68.47%, respectively. This increase in field efficiency can be attributed to the increase in speed and the effective working width of the plow, which also leads to increas operational productivity, directly proportional to field efficiency. These results are consistent with those reported by [22]. The 100 kg seeding rate recorded the highest field efficiency at 69.16%, compared to the 140 kg seeding rate, which recorded the lowest field efficiency at 68.37%. Additionally, the seeder machine treatments had a significant impact on field efficiency, with the Z machine achieving the highest field efficiency at 71.88%, followed by the Ct and Zt machines, which recorded the lowest field efficiency at 67.23% and 67.18%, respectively. Furthermore, the interaction between speed and seeding rate show an increase in field efficiency, with the third speed of 8.37 km/h and a seeding rate of 100 kg achieving a field efficiency of 69.66%, while the first speed of 4.23 km/h and a seeding rate of 140 kg recorded the lowest value at 68.05%. The interaction between speed and seeder machine treatments also show significant differences, with the first speed of 4.23 km/h combined with the Z seeder machine achieving the highest field efficiency at 72.28%, while the second speed of 6.54 km/h combined with the Ct seeder machine recorded the lowest field efficiency at 65.98%. The interaction between seeding rate and seeder machine treatments also revealed significant differences in field efficiency. The 100 kg seeding rate combined with the Z treatment recorded the highest field efficiency at 72.58%, while the 140 kg seeding rate combined with the Zt treatment

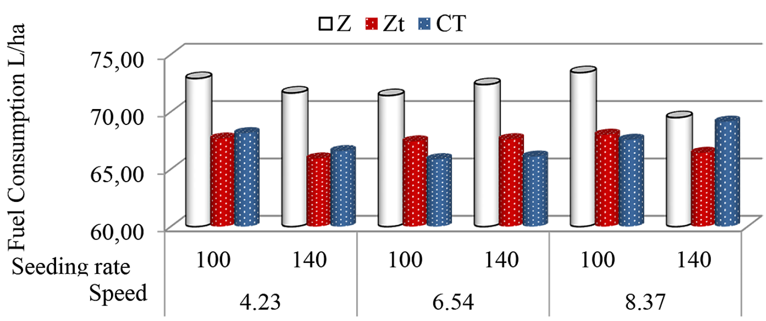

Figure 4. Impact of forward operational speed, seeding rate, and seeder machine treatments on fuel consumption

record the lowest field efficiency at 66.66%. Figure 5 shows that the three-way interaction between speed S1, S2, S3, seeding rate A, B, and seeder machine treatments had a significant impact on field efficiency. The combination of the third speed of 8.37 km/h, a seeding rate of 100 kg, and the Z seeder treatment achiev the highest field efficiency at 73.42%, while the combination of the first speed of 4.23 km/h, a seeding rate of 140 kg, and the Ct seeder treatment recorded the lowest field efficiency at 66.58%.

Draft power

Field experiment reveal the impact of forward operational speed, seeding rate, and seeder machine treatments on draft power, showing significant differences in draft power due to the use of different speeds for the mechanized unit. The first speed of 4.23 km/h, recorded the lowest draft power at 2.19 kW, compared to the second speed of 6.54 km/h and the third speed of 8.37 km/h, which recorded 4.66 kW and 6.47 kW, respectively. This can be attributed to the fact that as speed increases, the movement of soil clods increases, leading to friction between them, which creates resistance in front of the machine and results in an increase in draft power to break up the soil clods. This indicates a direct relationship between speed and draft force, and similarly, between draft force and draft power, where increasing forward speed results in higher draft force and, consequently, increased draft power. These findings are consistent with [23]. Regarding the same trait, significant differences were observed, with the 140 kg seeding rate recording the highest draft power at 4.46 kW, compared to the 100 kg seeding rate, which recorded a slightly lower draft power at 4.41 kW. It was noted that the seeder machine treatments had a significant impact on draft power, with the Z machine recording the lowest draft power at 4.08 kW, followed by the Zt and Ct machines, which recorded the highest draft power at 4.20 kW and 5.03 kW, respectively. The interaction between speed and seeding rate also shows an increase in draft power, with the third speed of 8.37 km/h and a 100 kg seeding rate achieving a draft power of 6.49 kW, while the first speed of 4.23 km/h and a 100 kg seeding rate recorded the lowest value at 1.96 kW. The interaction between speed and seeder machine treatments also showed significant differences, with the first speed of 4.23 km/h combined with the Zt seeder machine recording the lowest draft power at 1.96 kW, while the third speed of 8.37 km/h combined with the Ct seeder machine recorded the highest draft power at 6.49 kW. There was also a significant impact observed in the interaction between seeding rate and seeder machine treatments, with the 140 kg seeding rate combined with the Zt treatment recording the lowest draft power at 3.97 kW, while the same seeding rate of 140 kg combined with the Ct treatment recorded the highest draft power at 5.28 kW. Figure 6 shows that the three-way interaction between the speed S1, S2, S3, the seeding rate A, B, and seeder machine treatments had a significant impact on draft power. The combination of the first the speed of 4.23 km/h, a seeding rate of 100 kg, and the Zt seeder treatment recorded the lowest draft power at 1.88 kW, while the combination of the third speed of 8.37 km/h, a seeding rate of 140 kg, and the Ct seeder treatment recorded the highest draft power at 7.79 kW.

Soil moisture content

Field experiment showed the impact of forward operational speed, seeding rate, and seeder machine treatments on soil moisture content, revealing significant differences in soil moisture

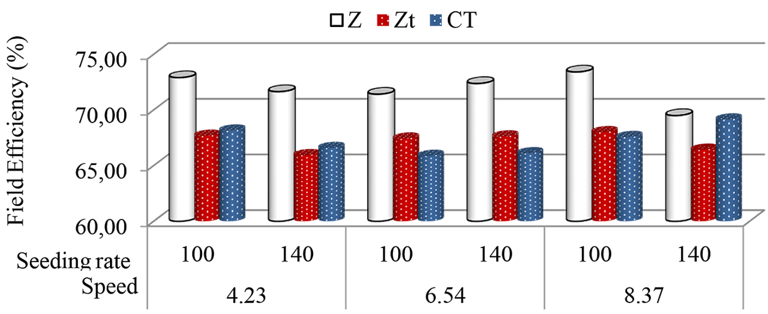

Figure 5. Impact of forward operational speed, seeding rate, and seeder machine treatments on field efficiency

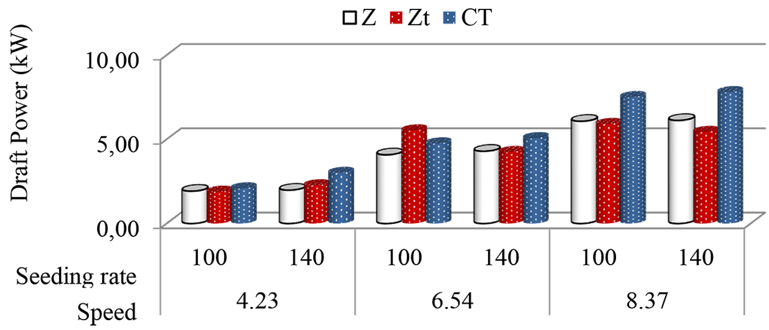

Figure 6. Impact of forward speed, seeding rate, and seeder machine treatments on draft power

content due to the use of different speeds for the mechanized unit. The third speed of 8.37 km/h recorded the lowest soil moisture content at 0.176%, compared to the first speed of 4.23 km/h and the second speed of 6.54 km/h, which recorded 0.228% and 0.207%, respectively. This decrease in soil moisture content at higher speeds can be attributed to the increase in operational tillage speed, which leads to higher soil bulk density and reduced soil porosity. These factors increase soil fragmentation, exposing it more to atmospheric conditions, which in turn increases evaporation and decreases soil moisture content. These findings are consistent with those reported by [24]. No significant differences were observed in relation to seeding rate, although the 140 kg seeding rate recorded a lower soil moisture content at 0.199% compared to the 100 kg seeding rate, which recorded a higher soil moisture content at 0.208%. The seeder machine treatments had a significant impact on soil moisture content, with the Z machine recording the lowest soil moisture content at 0.212%, followed by the Zt and Ct machines, which record the highest soil moisture content at 0.201% and 0.198%, respectively. The interaction between speed and seeding rate did not show significant differences, although the combination of the first speed of 4.23 km/h and a seeding rate of 100 kg achieve the highest soil moisture content at 0.235%, while the combination of the third speed of 8.37 km/h and a seeding rate of 140 kg recorded the lowest soil moisture content at 0.170%. The interaction between speed and seeder machine treatments also did not show significant differences, but the combination of the third speed of 8.37 km/h and the Z seeder machine recorded the lowest soil moisture content at 0.167%, while the combination of the first speed of 4.23 km/h and the Z seeder machine record the highest soil moisture content at 0.243%. The interaction between seeding rate and seeder machine treatments showd that the 100 kg seeding rate combined with the Z treatment achiev the highest soil moisture content at 0.216%, while the 140 kg seeding rate combined with the Ct treatment recorded the lowest soil moisture content at 0.185%. Figure 7 shows that the three-way interaction between speed S1, S2, S3, seeding rate A B, and seeder machine treatments did not show significant differences in soil moisture content. However, the combination of the first speed of 4.23 km/h, a seeding rate of 100 kg, and the Z treatment recorded the highest soil moisture content at 0.247%, while the combination of the third speed of 8.37 km/h, a seeding rate of 100 kg, and the Zt treatment recorded the lowest soil moisture content at 0.162%.

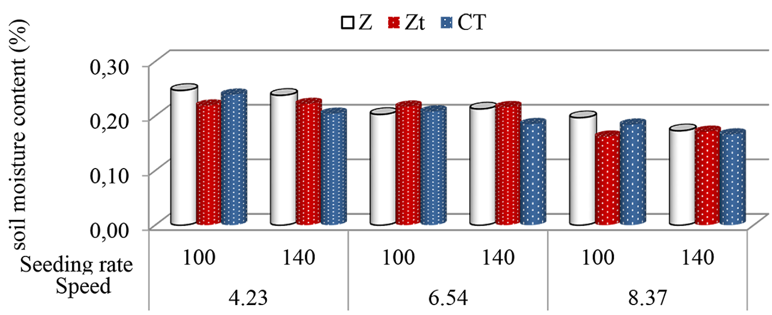

Figure 7. Impact of forward speed, seeding rate, and seeder machine treatments on soil moisture content

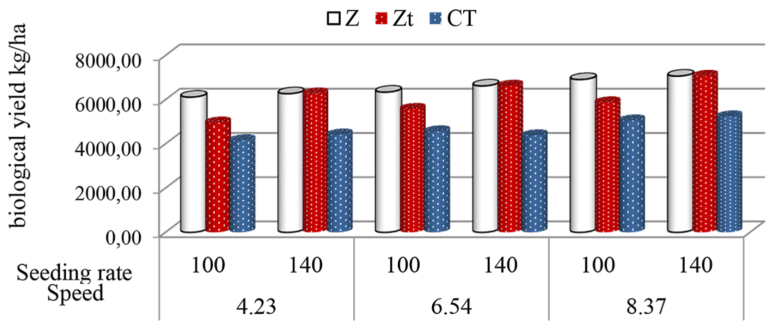

Figure 8. Impact of forward speed, seeding rate, and seeder machine treatments on biological yield, biological yield at 4158 kg/ha

Biological yield

Experiment demonstrated the impact of forward operational speed, seeding rate, and seeder machine treatments on biological yield, revealing significant differences in biological yield due to the use of different speeds for the mechanized unit. The third speed of 8.37 km/h recorded the highest biological yield at 6041 kg/ha, compared to the first speed of 4.23 km/h and the second speed of 6.54 km/h, which recorded 5223 kg/ha and 5538 kg/ha, respectively. There were also significant differences observed in relation to seeding rate, with the 140 kg seeding rate recording the highest biological yield at 5696 kg/ha, compared to the 100 kg seeding rate, which recorded a lower biological yield of 5506 kg/ha. The seeder machine treatments had a significant impact on biological yield as well, with the Z machine achieving the highest biological yield at 6555 kg/ha, followed by the Zt and Ct machines, which recorded lower biological yields of 5613 kg/ha and 4634 kg/ha, respectively. The interaction between speed and seeding rate show an increase in biological yield, with the third speed of 8.37 km/h and a seeding rate of 140 kg achieving a biological yield of 6136 kg/ha, while the first speed of 4.23 km/h and a seeding rate of 100 kg recorded the lowest biological yield at 5078 kg/ha. The interaction between speed and seeder machine treatments did not show significant differences, but the combination of the third speed of 8.37 km/h and the Z seeder machine recorded the highest biological yield at 6990 kg/ha, while the combination of the first speed of 4.23 km/h and the Ct seeder machine recorded the lowest biological yield at 4287 kg/ha. The interaction between seeding rate and seeder machine treatments also did not show significant differences; However, the 140 kg seeding rate combined with the Z treatment recorded the highest biological yield at 6653 kg/ha, while the 100 kg seeding rate combined with the Ct treatment recorded the lowest biological yield at 4591 kg/ha. Figure 8 shows that the three-way interaction between speed S1, S2, S3, seeding rate A, B, and the seeder machine treatments did not show significant differences in biological yield. However, the combination of the third speed of 8.37 km/h, a seeding rate of 140 kg, and the Z treatment recorded the highest biological yield at 7067 kg/ha, while the combination of the first speed of 4.23 km/h, a seeding rate of 100 kg, and the Ct seeder treatment recorded the lowest biological yield at 4158 kg/ha.

CONCLUSIONS

The study demonstrated the superiority of the no-tillage farming system over the conventional farming system in improving mechanical properties by reducing fuel consumption, requiring less draft power, providing higher soil moisture content, and decreasing the time required to complete the agricultural operation. Additionally, it led to an increase in yield production. The no-tillage system also excelled in enhancing crop yield characteristics by achieving the highest biological yield value, as indicated by the study demonstrates that the use of varying forward speeds, seeding rates, and seeder machine treatments significantly impacts key agricultural parameters, including fuel consumption, field efficiency, draft power, soil moisture content, and biological yield in wheat cultivation. The results indicate that higher operational speeds, particularly 8.37 km/h, generally improve field efficiency and biological yield while reducing soil moisture content and increasing draft power requirements. The use of the Z seeder machine consistently resulted in better performance across most parameters, highlighting its efficiency in no-till farming systems. Overall, the findings suggest that optimizing these factors can enhance productivity and resource efficiency in wheat farming, making no-till systems a viable alternative to conventional tillage, especially in areas with varying environmental conditions.

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