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Sunflower productivity response to tillage depth and harrowing speed

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ABSTRACT

The field experiment was conducted in one of AL-Kahlaa station' fields - Agricultural Directorate of Maysan Province within soil classified as silty clay loam. Three tillage' depths of (12, 17, and 22 cm) with three harrowing forward' speeds of (2.54, 3.61, and 4.32 km.hr^{-1}) of combined equipment (which performs three agricultural operations simultaneously, namely plowing, harrowing, and leveling) were studied during this experiment. The trial findings showed an increase of slippage percent, fuel consumption, disturbed soil volume, flower disc diameter, and oilseed yield which were 7.702%, 22.411 L. ha^{-1}, 596.66 m^{3}. hr^{-1}, 12.555 cm, and 3.693 ton.ha^{-1}, respectively, when the tillage depth was increased from 12 to 17 and then to 22 cm. Whilst, the lowest average of slippage percent, fuel consumption, disturbed soil volume, flower disc diameter, and seed yield were at the lowest tillage depth' level of 12 cm which were 6.750%, 20.036 L.ha^{-1}, 527.44 m^{3}.h^{-1}, 11.586 cm, and 3.326 ton.ha^{-1}, respectively. Moreover, the lowest slippage percentage (4.778%), and largest diameter of flower disc (13.877 cm) and seed yield (4.295 ton.ha^{-1}) were occurred at the slow forward speed of 2.54 km.hr^{-1} while the lowest fuel consumption (16.506 L.ha^{-1}) and highest disturbed soil volume (734.55 m^{3}.hr^{-1}) were achieved through the high forward speed of 4.32 km.hr^{-1}.

أستجابة أنتاجية زهرة الشمس لعمق الحراثة وسرعة التنعيم

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الخلاصة

أجريت تجربة حقلية في أحد حقول منطقة الكحلاء التابعة الى مديرية زراعة ميسان في تربة مزيجيه طينية غرينيه, تضمنت ثلاثة أعماق للحراثة (12 , 17 و 22 سم) وثلاثة سرع أمامية (2.54 و3.61 و4.32 كم ساعة$^{-1}$)، باستخدام الة مركبة ثلاثية الغرض (تجري عملية حراثة, تنعيم و تسويه)، أظهرت النتائج زيادة في معدل استهلاك الوقود ونسبة الأنزلاق وحجم التربة المثار وقطر قرص زهرة الشمس وحاصل البذور بلغ 22.411 لتر هـ$^{-1}$ و 7.702 % و 596.66 م^{3} ساعة$^{-1}$ و 12.555 سم و 3.693 طن هـ$^{-1}$ على التوالي عند زيادة عمق الحراثة من 12 إلى 17 ثم إلى 22 سم. بينما أقل معدلاً لها بلغ 20.036 لتر هـ$^{-1}$ و 6.750 % و 527.44 م^{3} ساعة$^{-1}$ 11.586 سم 3.326 طن هـ$^{-1}$ على التوالي عند العمق 12 سم. علاوة على ذلك، فإن أقل نسبة انزلاق (4.778 %)، وأكبر قطر لقرص الزهرة (13.877 سم) وإنتاجية البذور (4.295 طن هـ$^{-1}$) حدثت عند السرعة الأمامية البطيئة البالغة 2.54 كم ساعة$^{-1}$ في حين أن أقل معدل للوقود. تم تحقيقه (16.506 لتر هـ$^{-1}$) وأعلى حجم تربة مثار (734.55 م^{3} ساعة$^{-1}$) من خلال السرعة الأمامية العالية البالغة 4.32 كم ساعة$^{-1}$.

الكلمات المفتاحية: استهلاك الوقود, عمق الحراثة, وقطر قرص زهرة الشمس.

INTRODUCTION

Helianthus annuus. L is an important oleaginous crop that widely cultivated around the world since it suits various environmental conditions (Gayithri et al., 2017). Locally, the cultivation of sunflower occupies large areas of Iraqi' arable land (Tawfiq, 2019), which estimated at approximately 22600 dunums (CSO, 2016 & 2018). The sunflower belongs to the Asteraceae' family, which natively to North America (Zobiole et al., 2010). Cause its seeds contain a high percentage of oil up to 50%, so it used as food and in cooking oil and soap' manufacture (Skoric and Marinkovic, 1986). Furthermore, its residues used as animal feed that rich in protein up to 35% (Drouin et al. 2010), oleic and linoleic acid up to 25.1% and 66.2%, respectively (Vick and Dorrell, 1997). In spite of its importance, CSO (2018) reported that the achieved annual production of sunflower was sharply declined from 7500 tons in 2010 to around 500 tons in 2017 and this is totally consistent with what Muhsin et al., (2021) pointed out recently.

The reluctance to provide agricultural production requirements by the government represented by the Ministry of Agriculture to farmers, as well as raising their awareness regarding the importance of increasing production and achieving self-sufficiency, may be considered one of the main reasons of agricultural production decline (Alsharifi et al., 2022; Alaamer et al., 2022 and Makawi. Z. A. and Suhad Y. Jassim., 2023). According to Hameed and Jebur. (2022), soil degradation as a result of poor management of crop and soil considered one of the most important reasons for poor production, which requires intensive efforts to study the factors related to soil and crop' performance to increase crop productivity. Combined equipment' selection regarding own operations' sequence, especially those equipment which functional in preparing of seedbed, considered a very important issue (Al-Zaidi. and Al-Jumaili 2022). Regarding the used tractor' horsepower, Jebur and AL-Halfi (2022) stated that it should suit the combined equipment' draft requirement, operation conditions, and yield type, which in turn will increase farm profits and reduce operating costs through increasing the cultivated area productivity.

In the same way, Hachim and Jebur (2022) have mentioned that the equipment's performance efficiency comes from its compatibility with the used tractor and thus achieving economic feasibility through reducing operation costs and increasing crops' yield. Undoubtedly, the tillage operation brings about a significant amelioration on soil physical properties such as bulk density, porosity, aeration, water movement, and soil strength or penetration resistance ... etc. (Li et al., 2018). The slippage considers a real indicator that reflects the operating conditions' correctness, machinery unit performance efficiency, as well as tractor suitability to tillage equipment, whether was mounted or towed (Amer et al, 2021). Jebur and Himoud (2018) also stressed that slippage should be studied in most of tillage trials, as it has a direct influence on tractor' fuel consumption and its average economic life, consequently will reflect the operation' expected gains. Moreover, Amer et al, (2020) have concluded that slippage is a sign of tractor energy waste during the agricultural process, and they also documented that the slippage percentage increases with increasing tillage depth as a result of increasing the target soil' resistance to shear.

With regard to studying the sunflower crop performance indicators, Muhsin et al., (2021) concluded that the available information regarding this crop is insufficient and they recommended to conducting more research to enrich the scientific library. The aim of this study was therefore to study the effect of tillage depth and harrowing speed on some growing properties and yield sunflower (*helianthus annuus. L*).

MATERIAL AND METHODS

The experiment was conducted in one of AL-Kahlaa station' fields - Agricultural Directorate of Maysan Province (31°39'40"N 47°32'53"E) to study the effect of a three-purpose locally manufactured combined equipment (which carry out tillage, harrowing and leveling in one pass of the machinery unit) on performance of machinery unit, soil, and crop. The combined equipment was connected to the tractor' three linkage hitch. In this study, three tillage' depths of (12, 17, and 22 cm) with three harrowing forward' speeds of (2.54, 3.61, and 4.32 $km.hr^{-1}$) of the combined equipment and their effect on the tractor' fuel consumption and slippage percent, soil' disturbed volume, and sunflower' disc diameter were investigated. The site soil was classified as silty clay loam, and its physical properties are shown in table 1. The experiment was carried out using the split plot system under the randomized complete design (RCD) with three replications. The *helianthus annuus. L* sunflower cultivar was planted in this study.

Table 1: The physical properties of the site soil

Particle size analysis ($gm.kg^{-1}$)	Sand	165
	Clay	336
	Silt	499
Bulk density ($gm.cm^{-3}$)	0 - 10 cm	1.320
	10 - 20 cm	1.362
	20 - 30 cm	1.485
Texture	Silty Clay Loam	
Particle density ($gm.cm^{-3}$)	2.65	
Porosity (%)	47.90	
Electrical conductivity ($ds.m^{-1}$)	3.90	
pH	7.4	
Water content (%)	18.6	
Hydraulic conductivity ($cm.hr^{-1}$)	4.812	

Calculate and measure the studied performance indicators

1. **Slippage percentage**: It was calculated according to Jebur and Himoud (2018) equation:-

Sp = (Vt - Vp / Vt) × 100 ……………………………. (1)

Where:
Sp = slippage percentage (%),
Vt = theoretical velocity ($km.hr^{-1}$), and
Vp = practical velocity ($km.hr^{-1}$).

2. **Fuel consumption**: It was calculated via the locally manufactured device and according to the suggested equation by the (Mankhi and Jebur 2022), as follow:

$$\boldsymbol{F.C} = \frac{\boldsymbol{f \times 10000}}{\boldsymbol{w \times s \times 1000}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

Where:
F.C = Fuel consumption ($L.ha^{-1}$),
F = the amount of consumed fuel for one treatment (mL),
W = the actual operation width (m), and
S = the treatment' length (m).

3. **The volume of disturbed soil**: It is the volume of disturbed soil by the tillage equipment during the operation time. It depends on both of practical productivity and practical tillage depth of the tillage equipment. It was calculated using the following equation (McKyes, 1985):

D.S.V = Pp × Dp ………………………………………. (3)

Where:
D.S.V = disturbed soil volume ($m^3.\ hr^{-1}$),
Pp = practical productivity ($m^2.\ hr^{-1}$), and
Dp = practical tillage depth (m).

4. **Flower disc diameter**: It was measured via a measure tape at the maturity stage, by measuring the part that includes flower disc for ten plants per row then averaged.

5. **Seed yield**: it was extracted from the middle rows of each plot. After checking the grain moisture content and its readiness for harvest (moisture content less than (25 - 30%) (Simonyan et al., 2007; Kanoosh et al., 2019) the recommended method for cereal sampling by Hudson (1939) cited in AL-Halfi (2021) was used. The flower discs of the plants of 5 m of the two middle rows were manually harvested. After threshing the flower discs, grain yield results were then corrected according to the standard moisture for commercialization of sunflower grain which is 11% (GTA, 2017). Equation 4 was used to measure the harvested area. Dry grains yield was expressed in kg.m^{-2}. After, the yield was converted from kg.m^{-2} to ton.ha^{-1}.

Harvested Area (m^2) = harvested row length (m) × row spacing (m) ………. (4)

RESULTS AND DISSCUSION

Table (2) shows the effect of tillage depth and tractor forward speed and their overlapping on slippage percentage. It can be seen from the table that when the tillage depth and tractor front speed increased, the slippage % was increased significantly. Shifting the tillage depth from 12 to 17, then to 22 cm, and the operation forward speed from 2.54 to 3.61, then to 4.32 km.hr^{-1}, have led to a significant increase in the slippage percentage from 6.750 to 7.295, then to 7.702%, and from 4.778 to 7.224 and then to 9.745%, respectively. The reason may be attributed to the fact that increasing tillage depth means increasing the tilled soil layer thickness and this means increasing the load on the plow' shanks and tips, so the slippage percentage will increase. Another reason is that increasing the depth means increasing soil bulk density and this means increasing of soil resistance to shear and accordingly, the slippage value will increase. Regarding increasing the forward speed, it will lead to create a weak connection (traction) between the tractor' driving wheels and soil surface, as well as a lower in tractor pulling force which in turn will lead to increase the percent of slippage. Also, from the table it is clear that the overlapping between the tillage depth and operation front speed had a significant effect on the slippage percent. The highest slippage percent was at the depth of 22 cm and the high forward speed (third) of 4.32 km hr^{-1}, which was 10.137%, while the lowest slippage percent was 4.367%, which resulted from overlapping of the shallow tillage depth of 12 cm and the slow forward speed (first) of 2.54 km hr^{-1}.

Table 2: Effect of tillage depth, tractor forward speed, and their overlapping on slippage percentage (%)

Tillage depth (cm)	Forward speed (km. hr^{-1})			Av. tillage depth (cm)
	2.54	**3.61**	**4.32**	
12	4.367	6.727	9.157	6.750, a
17	4.697	7.247	9.943	7.295, b
22	5.270	7.700	10.137	7.702, c
Av. forward speed (km. hr^{-1})	4.778, a	7.224, b	9.745, c	LSD = 0.05

Note: Variation in letters and their mismatch are evidence of the significant effect, while the similarity of letters indicates that the effect is not significant.

Table (3) presents the effect of tillage depth, tractor forward speed with their interaction on consumed fuel liters per hectare. Changing the tillage depth level from 12 to 17 and then to 22 cm has led to increase fuel consumption from 20.036 to 20.907 and then to 22.411 $L.ha^{1}$, significantly. On the contrary, shifting from first (slow) to second (medium) and then to third (high) speed has led to a significant decrease in the amount of consumed fuel from 26.227 to 20.621 and then to 16.506 $L.ha^{-1}$. It is likely that the reduction reason in the consumed fuel liters at the shallow tillage depth is a result of lowering of the tractor' draft force requirement as a result of reducing the thickness of tilled soil layer as well as its bulk density value and therefore a decrease in tractor engine fuel consumption. The reason for the lower fuel consumption at high forward speed may be due to the short required time to finish the operation, which in turn means less consumed fuel. Also, the interaction of the tillage depth with tractor forward speed had a significant effect on the fuel consumption amount. The lowest fuel consumption resulted from overlapping the shallow tillage depth (12 cm) with high speed (4.32 $km.hr^{-1}$), which amounted to 15.757 $L.ha^{-1}$, while the largest amount of fuel consumption was 27.170 $L.ha^{-1}$, which resulted from overlapping the tillage depth of 22 cm and high forward speed of 4.32 $km.hr^{-1}$.

Table 3: Effect of tillage depth, tractor forward speed, and their overlapping on fuel consumption ($L.\ ha^{-1}$)

Tillage depth (cm)	Forward speed ($km.\ hr^{-1}$)			Av. tillage depth (cm)
	2.54	**3.61**	**4.32**	
12	25.170	19.183	15.757	20.036, a
17	26.343	20.317	16.063	20.907, b
22	27.170	22.363	17.700	22.411, c
Av. forward speed ($km.\ hr^{-1}$)	26.227, a	20.621, b	16.506, c	LSD = 0.05

Note: Variation in letters and their mismatch are evidence of the significant effect, while the similarity of letters indicates that the effect is not significant.

The effect of tillage depth, tractor forward speed, and their overlapping on the volume of the disturbed soil are shown in Table 4**.** The table shows the soil behavior towards increasing of both operation depth and its velocity. The table values show that increasing the tillage depth from 12 to 17, then to 22 cm, and the tractor speed from 2.54 to 3.61, then to 4.32 $km.hr^{-1}$, were significantly increased the volume of disturbed soil from 527.44 to 567.22, then to 596.66 $m^{3}.hr^{-1}$ and from 387.44 to 575.33 then to 734.55 $m^{3}.hr^{-1}$, respectively. The reason may be attributed to the fact that by increasing the tractor forward speed, the soil disturbance action will also increase. As for the tillage depth, the accepted reason is that with increasing depth level, the volume of disturbed soil by the penetrating plow shanks and tips will increase too**.** Also, the bi-interactions had a significant effect on the disturbed soil volume. The overlapping of the third tillage depth (22 cm) with high tractor velocity (4.32 $km.hr^{-1}$) was superior in achieving the highest disturbed soil volume of 747.67 $m^{3}.hr^{-1}$, while the lowest volume of disturbed soil (345.00 $m^{3}.hr^{-1}$) was resulted from the slow tractor forward speed (2.54 $km.hr^{-1}$) with shallow depth (12 cm) interaction.

Table 4: Effect of tillage depth, tractor forward speed, and their overlapping on the disturbed soil volume (m^3. hr^{-1})

Tillage depth (cm)	**Forward speed (km. hr^{-1})**			**Av. tillage depth (cm)**
	2.54	**3.61**	**4.32**	
12	345.00	518.33	719.00	527.44, a
17	385.33	579.33	737.00	567.22, b
22	432.00	610.33	747.67	596.66, c
Av. forward speed (km. hr^{-1})	387.44, a	575.33, b	734.55, c	LSD = 0.05

Note: Variation in letters and their mismatch are evidence of the significant effect, while the similarity of letters indicates that the effect is not significant.

The flower disc diameter' average values as a result of the influence of tillage depth and tractor forward speed and their overlap are presented in Table 5. From the table, it can be seen that when the practical speed increased from 2.54 to 3.61 and then 4.32 km.hr^{-1}, the diameter of the flower disc decreased significantly from 13.877 to 12.216 and then to 10.072 cm. On the contrary, the table values document that when the tillage depth increased from 12 to 17 and then to 22 cm, the flower disc diameter values increased from 11.586 to 12.025 and then 12.555 cm, significantly. The acceptable and reasonable explanation for the table results is that increasing tillage depth means more improving of the soil' physical properties through decreasing its bulk density and strength and increasing water infiltration and thus its availability in the scarcity time, all of which will facilitate crop' roots elongating to reach the water sources and nutrients and thus improve the growth of vegetative plant. As for the speed, its increasing means increasing the slipping percentage and fine soil particles, and then a great chance for soil to compact, and this means creating unsuitable conditions for plant growth. Moreover, it is not possible to reach the target tillage depth at high speeds, especially the deep tillage levels, and these reasons, in turn, will limit the plant growth and improvement its production. The differences between the flower disc diameter mean values as a result of the tillage depth and the operation speed interaction were also significant, as the interaction of the third depth (22 cm) with the slow speed (2.54 km.hr^{-1}) was superior in producing the largest diameter of the flower disc of 14.513 cm, while the less diameter of flower disc was due to the overlapping of the high speed (4.32 km.hr^{-1}) and shallow depth 12cm, which was 9.676cm.

Table 5: Effect of tillage depth, tractor forward speed, and their overlapping on flower disc diameter (cm)

Tillage depth (cm)	**Forward speed (km. hr^{-1})**			**Av. tillage depth (cm)**
	2.54	**3.61**	**4.32**	
12	13.163	11.920	9.676	11.586, a
17	13.956	12.083	10.036	12.025, b
22	14.513	12.646	10.506	12.555, c
Av. forward speed (km. hr^{-1})	13.877, a	12.216, b	10.072, c	LSD = 0.05

Note: Variation in letters and their mismatch are evidence of the significant effect, while the similarity of letters indicates that the effect is not significant.

Table (6) shows the effect of tillage depth and tractor forward speed and their overlapping on sunflower seed yield. It can be seen from the table that changing the tillage depth level from 12 to 17 and then to 22 cm has led to increase seed yield significantly from 3.326 to 3.435 and then to 3.693 ton.ha^{-1}. On the contrary, shifting from 2.54 to 3.61

and then to 4.32 km.hr^{-1} has led to a significant decrease in sunflower seed yield from 4.295 to 3.493 and then to 2.667 ton.ha^{-1}. Since the diameter of the flower disc is an index of the grain yield so, the same mentioned earlier reasons of the flower disc diameter can be adopted in interpretation of the Table 6 results. Also, from the table it is clear that the overlapping between the tillage depth and operation front speed had a significant effect on the seed yield. The highest yield was at the depth of 22 cm and the slow forward speed (2.54 km.hr^{-1}), which was 4.551 ton.ha^{-1}, while the lowest yield of seed was 2.494 ton.ha^{-1}, which came out from overlapping of the shallow tillage depth (12 cm) with the high forward speed (4.32 km.hr^{-1}).

Table 6: Effect of tillage depth, tractor forward speed, and their overlapping on seed yield (ton. ha^{-1})

Tillage depth (cm)	Forward speed (km. hr^{-1})			Av. tillage depth (cm)
	2.54	**3.61**	**4.32**	
12	4.112	3.373	2.494	3.326, a
17	4.221	3.413	2.672	3.435, b
22	4.551	3.692	2.834	3.693, c
Av. forward speed (km. hr^{-1})	4.295, a	3.493, b	2.667, c	LSD = 0.05

Note: Variation in letters and their mismatch are evidence of the significant effect, while the similarity of letters indicates that the effect is not significant.

CONCLUSION

Performing more than one operation within one pass via farming equipment is an effective technique to reduce soil compaction, increase the production and sustainable it, save time and costs, and thus increase economic gains. However, field research related to investigating of such equipment still limited and insufficient. The speed of the agricultural equipment and operating depth are among the most influential factors on the performance of arable lands, cultivated crop and machinery unit efficiency. In this study, the highest tillage depth was the best in achieving the highest product of the disturbed soil volume, flower disc diameter, and seed yield respectively. As for the slippage %, it was within the acceptable limits. Regarding the large fuel consumption compared to the first and second depths, it is very likely that its costs to cover by increasing the yield. Increasing tillage speed can increase the tilled hectares quantity per hour, but the tillage quality is very likely to be poor. Although it had low fuel consumption with the largest disturbed soil volume in this experiment, the diameter of the high speed' plots flowers disc and seed yield were less compared to the medium and slow speeds' plots at this study. Depending on the study findings, it is better to adopt slow or medium tractor speeds with deep tillage depths, provided that it is not to be within the critical depth boundaries and to ensure a profitable production and healthy soils. We recommend conducting more experiments related to combined equipment and comparing it acting with individual equipment economically, technically, and study their impact on soil and crop behavior for long-term periods

CONFLICT OF INTEREST

The authors declare no conflicts of interest associated with this manuscript.

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