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Yield and Economic Analysis of Maize Production Using Different Combinations of Combined Tillage Machines and Comparison to Conventional Tillage Systems

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Abstract: The study was carried out at the agriculture college research station, University of Basrah, in the 2021 season. This research aimed to investigate the effect of five combinations of combined tillage machines on maize yield, fuel consumption, total cost, total return, and return and benefit-cost return. The economic indicators of combined tillage machines were compared with five conventional tillage systems. The combined tillage machines are The T1 combined tillage machine consists of a subsoiler operating at a depth of 60 cm, a chisel plow, a disk harrow, and a roller. T2 is similar to T1, except the subsoiler operates at a depth of 40 cm. A T3 combined tillage machine consists of a subsoiler operating at a depth of 60 cm and a chisel plow. T4 is similar to T3, except the subsoiler operates at a depth of 40 cm. A T5 combined tillage machine consists of a chisel plow and a disk harrow. The conventional tillage systems include M1, which consists of four passes (subsoiler at a depth of 60 cm + chisel plow + disk harrow + roller), M2 consists of four passes (subsoiler at a depth of 40 cm + chisel plow + disk harrow + roller), M3 consists of two passes (subsoiler at a depth of 60 cm + chisel plow), M4 consists of two passes (subsoiler at a depth of 40 cm + chisel plow), M5 consists of two passes (chisel plow + disk harrow). Each treatment was replicated three times, and the data were analyzed using a randomized complete block design in this experiment. The mean of the treatments for the combined tillage machines and conventional tillage systems were compared using the t-test at the probability level (0.01). The results of the combined tillage machines T1, T2, T3, T4, and T5 comparison with conventional tillage systems M1, M2, M3, M4, and M5 revealed that the maize yield increased by 56.10 and 59.42, 56.48, 35.29, and 35.31% and saved fuel by 54.86 and 60.42, 36.77, 39.77, and 42.20% and decreased the total cost by 24.62, 24.70, 28.70, 27.61, and 16.50%. However, BCR was raised by 96.62, 101.28, 92.44, 68.35.20, and 57.2% respectively. Soil tillage with combined tillage machines improved maize crop yield and fuel consumption.
Keywords: Combined tillage machines, Conventional tillage systems, Maize Yield, Economic analysis

I. INTRODUCTION

One of the most important crops grown worldwide for feed, food, and industrial use is maize (Zea mays L.). Columbus' expeditions at the end of the 15th century brought it from Central America to Europe and other countries. Although maize is mainly used for feed, over these five centuries of maize history, several food specialties were created and have since become conventional food specialties (Revilla *et al.*, 2021). Choosing the best soil tillage method for seed sowing is essential for success in fields where field crops such as maize are cultivated. This will help create a good seed bed according to soil structure, the residual plant before cultivation, the plant that will be cultivated, and the presence of existing mechanization (Noor *et al.*, 2020 a). However, with growing environmental awareness and economic production needs, as well as the importance of energy conservation, many countries have begun to make radical changes in tillage operations (Kan *et al.*, 2018). In order to keep agricultural output sustainable, the tillage system is crucial. Inappropriate tillage results in soil degradation and water and environmental contamination. Reasonable tillage is a key indicator of increasing agricultural productivity and minimizing soil issues. The influence of tillage depends on production sustainability, soil conditions, climate, crop type, and management elements (Kuhn *et al.*, 2016). In the conventional soil tillage system, field traffic is intensive, leading to erosion of soil increases, deterioration of soil physical properties, organic carbon reductions in soil, as well as fuel consumption, is increased. In the conventional soil tillage system, field traffic is intensive, leading to erosion of soil increases, deterioration of soil physical properties, organic carbon reductions in soil, as well as fuel consumption, is increased. Under the intensive production method, further efforts are being made to assure high activity in the utilization (Fernando *et al.*, 2018). In intense production of agriculture, input use increases, cause deterioration of the environment, requires more mechanization and has a detrimental impact on the sustainability of agricultural production (Nassir *et al.*, 2021). Combination tillage equipment may offer a better alternative to lessen the detrimental effects of repeated tillage operations on the soil by lowering the number of passes by combining two or more field activities (Noor *et al.*, 2020 b). Combined tillage machines could be savings of 44 to 55 percent in cost and 50 to 55 percent in time are possible by the use of combination tillage tool for seedbed preparation (Fanigliulo *et al.*, 2021). The energy, time, and cost of operation for combined tillage machines were lower by 65.20 to 70.98, 62.04 to 70.1, and 62.24 to 70.31%, respectively, as compared to the individual tillage machines to get approximately the same quality of tillage (Prem *et al.*, 2016). In agricultural production, increasing productivity has been prioritized as the major goal. In addition, better product quality, lower production inputs, preservation of natural resources, consideration of environmental issues, economic output, and sustainable agriculture. As a result, combination tillage machines are becoming more popular since they dramatically lower production costs when compared to conventional tillage (Apazhev *et al.*, 2019). The notion of a combined machine has been discovered to be crucial for doing many tasks at once, saving time and energy, and reducing labor costs. A few early experiments were conducted to integrate planting machinery with tillage instruments as a minimum tillage combination system (Lotfie *et al.*, 2013). The objective of the study was to evaluate the economics of using a combined tillage machines and to compare it to conventional tillage equipment when preparing the soil for the production of maize crops.

2. Materials and Methods

Combined tillage machine configurations

Soil tillage practices were carried out by a combined tillage machine (Fig.1), which has five combinations:

- Soil tillage by a chisel at depth of 20 cm, deep plowing by subsoiler tine at depth of 60 cm, harrowing by disk harrow at depth of 15 cm, and pulverization and compacting of soil by roller, all operations conducted in one pass (T1).
- Soil tillage by a chisel at depth of 20 cm, deep plowing by subsoiler tine at depth of 40 cm, harrowing by disk harrow at depth of 15 cm, and pulverization and compacting of soil by roller, all operations conducted in one pass (T2).
- Plowing by chisel at depth of 20 cm, deep plowing by subsoiler tine at depth of 60 cm, in one pass (T3).
- Plowing by chisel at depth of 20 cm, deep plowing by subsoiler tine at depth of 40 cm, in one pass (T3).
- Plowing by chisel at depth of 20 cm and, harrowing by disk harrow at depth of 15 cm in one pass (T5).

To compare the combinations of combined tillage machines and separate tillage machines. The following tillage machines were operated in five various conventional tillage systems:

The conventional tillage systems were carried out similarly to the operations of a combined tillage machine, where tillage machines were used separately in seedbed preparation, which consists of

- The conventional tillage system M1 included a subsoiler working at a depth of 60 cm(first pass) followed by a chisel plow (second pass), tandem disk harrow (third pass) and a roller as a fourth pass.

- The conventional tillage system M2 is similar to M1 except for the subsoiler work at a depth of 40 cm.
- The conventional tillage system M3 includes subsoiler work at a depth of 60 cm(first pass) followed by a chisel plow (second pass).
- The conventional tillage system M4 is similar to M3 except for the subsoiler work at a depth of 40 cm. chisel plow (first pass) and tandem disk harrow (second pass).
- The conventional tillage system M5 includes a chisel plow (first pass) and a disk harrow (second pass). The combined tillage machine combinations T1, T2, T3, T4, and T5 operate in the same way as conventional tillage systems M1, M2, M3, M4, and M5. All tillage practices were conducted at speeds of 1.5 and 3 km h^{-1}.

Figure 1. Combined tillage machines T1 and T2

Figure 2. Combined tillage machines T3 and T4

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Figure 3. Combined tillage machines T5

The procedure of the test

The investigation was conducted at the agriculture research station of the college of the agriculture University of Basrah. In order to evaluate the influences of various tillage systems of soil on maize yield and fuel consumption of tractor. A comparative economic analysis between soil tillage by combined tillage machines and conventional tillage systems was also conducted to input and output costs conclusion and to suggest the most advantageous soil tillage system.

The soil physio-chemical properties were estimated before the seeding as demonstrated in Table 1. The soil samples were taken from each treatment plot within soil depths 0-20, 20-40, and 40-60cm. The core sampler was utilized to take samples of soil. The soil samples were fragmented and sieved by a mesh sieve of 2 mm before conducting a physio-chemical analysis of the soil. Soil physical characteristics were estimated at three soil depths of 0-20, 20-40, and 40-60 cm utilizing undisturbed core samples of soil (Yadav *et al.*, 2020) before the beginning of the investigation. Soil analysis results showed the saturation of the test field was 45%, lime content is 15.01% and the texture of the soil was silty clay. Soil EC and pH values were measured in a pH meter device (Schultz *et al.*, 2017). The recommended (120 kg ha^{-1} N, 30 kg ha^{-1} P, and 33 kg ha^{-1} K) were applied to the field.

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Table 1. Physical and chemical properties of the trial field soil.

		Soil depth (cm)		
Soil characteristics	**Unit**	**0-20**	**20-40**	**40-60**
Texture		Silty clay loam	Silty clay loam	clay loam
Bulk density	**Mg m^{-3}**	1.27	1.39	1.58
Organic carbon	**(%)**	1.02	0.81	0.45
SP	**(%)**	34.9	32.7	27.89
pH		7.44	8.22	8.51
EC	**(dS m^{-1})**	10.11	9.35	8.22
Available P	**(mg kg^{-1})**	10.75	8.1	5.2
Available K	**(mg kg^{-1})**	168	122	80.71
Available N	**(mg kg^{-1})**	35.22	24.89	17.71
Available Mn	**(mg kg^{-1})**	4.14	3.22	0.91
Available Zn	**(mg kg^{-1})**	1.3	0.83	0.49
Available Cu	**(mg kg^{-1})**	0.87	0.51	0.11

The experiment was carried out according to a completely randomized design (CRD) in 3 replications for each treatment. The mean of the treatments for the combined tillage machines and conventional tillage systems were compared using the t-test at the probability level (0.01). Sowing was conducted manually for maize seed sowing in the test field. maize was cultivated to be 65 cm between the row and 15 cm between seeds in the same row. Maize crop was sown on the 15 of July, and 100 kg seed of maize per hectare.

A comparison of soil tillage systems was conducted in terms of economic, fuel, and yield parameters. A plot of 1 m x 1 m in the middle of each experimental treatment plot was established to determine the grain yield, when physiological maturity, cobs were harvested as well as straw. The straw was air-dried. The maize grain was hand-threshed and weight was taken after oven drying the grains at 70 C for 24 h until reaching an average moisture content of 15% The yield was determined as Mg ha^{-1}.

The Completion Method was used to determine the consumption of fuel in each tillage system. The rental prices of agricultural equipment used in tillage and sowing techniques were taken into account in the economic analysis to establish total expenses per unit area (Akbamia *et al.*, 2013; Almaliki *et al.*, 2021). The total income (output) per unit area was calculated using the tillage systems' yields and the average sales prices in the area.

Economic Analysis

The economic feasibility of using a combined tillage machine for each combination and conventional tillage systems was calculated by calculating the total costs of producing maize per hectare and subtracting them from the total yield, which was calculated based on the price per ton of maize grain (55000 dinars per ton) and the price per ton of straw (45000). Id tons $^{-1}$ (The Ministry of Agriculture, the Mesopotamian General Company for Seeds, one of the companies of the Ministry of Agriculture, on November 11, 2021). Costs of production are a fixed amount for all tillage treatments (Table 2). When calculating the total costs of producing one hectare of maize crop, as well as calculating the benefit-cost ratio as an economic indicator that depends on the ratio of profits achieved to the total costs. Parameters of economic analysis were calculated from the following equations mentioned in (Molenhuis, 2020).

$$TC = T_{Tc} + MCT_{Tc} \quad (1)$$

TC: Total costs for the mechanized unit (tractor and combined tillage machine) (Id ha^{-1}), MCT_{Tc}: Total costs of the combined tillage machine (Id ha^{-1}), T_{Tc}: Total tractor operating costs (Id ha^{-1}).

$$GMR = [Grain\ yield\ * (P_G + P_S)] \quad (2)$$

GMR: Total return (Id ha^{-1}), $Grain\ yield$: Total production of maize grains (Mg ha^{-1}), P_G: Maize grain price (Id Mg^{-1}), P_S: Straw price (Id Mg^{-1}).

$$NMR = GMR - TC \quad (3)$$

NMR: Net Monetary Returns (Id ha^{-1}).

Variable production factors	**Cost (Id ha^{-1})**
seeds	150000
Fertilizers	620000
irrigation	250000
Harvest	90000
pesticides	40000
scattered	100000
costs of production	12500000

$$BCR = \frac{GMR}{TC} \quad (4)$$

BCR : Benefit-Cost Ratio (%).

Table 2. Variable production costs for different tillage treatments (Id ha^{-1})

3. Results and Discussion

Comparison of the fuel consumption rate of combinations of combined tillage machines with conventional tillage system

Table3. showed that there were highly significant differences (p<0.01) between the tillage treatments of the combined tillage machine and the conventional tillage system according to the t-test. When compared to the conventional tillage treatments M1, M2, M3, M4, and T5, the combined tillage machines T1, T2, T3, T4, and T5 reduced fuel consumption by 54.86 and 60.42, 36.77, 39.77, and 42.20%, respectively. This was due to the combined tillage machine decreasing passes to one pass to the preparation of the seedbed, which contributed to reducing fuel consumption. The conventional tillage system requires four passes in the field for seedbed preparation. The plowing process consumes an additional amount of fuel at each pass, and this quantity accumulates until the completion of the plowing process and the preparation of a suitable seedbed for germination and plant growth. The results clearly show the saving of the amount of fuel consumed in the case using the combined tillage machines compared to the conventional tillage systems. These results are in agreement with the findings of Nasr et al (2016) and Siddiq and AL-Obaidi (2019).

Table 3. Fuel consumption (Lha^{-1}) of combined tillage machines and conventional tillage systems

	T1	M1	T2	M2	T3	M3	T4	M4	T5	M5
Tillage treatments	31.79	70.42	26.65	67.33	28.43	44.96	25.24	41.87	19.35	33.48
t (0.01)	25.5		21.5		22.5		10.5		11.5	

Comparison of the grain yield of combinations of combined tillage machines with conventional tillage system

Table 4. revealed that there were highly significant differences ($p<0.01$) between the tillage treatments by the combined tillage machine and the conventional tillage systems according to the t-test. The combinations of combined tillage machines T1, T2, T3, T4, and T5 surpassed the grain yield by 56.10 and 59. 42, 56.48, 35.29, and 35.31% compared with the conventional tillage systems M1, M2, M3, M4, and M5, respectively. This was due to the reduction of the combined tillage machine to the preparation of the seedbed in one pass in the field. Passes reduction in the field led to the improvement of the soil properties, which positively affected the growth of the maize crop and then increased the grain yield. The M1 was carried out by four passes in the field. Many passes of tillage machines negatively affect the properties of the soil, and this in turn reduces the growth of the maize crop and then reduces the grain yield. These results agree with the findings (Nath, *et al*. 2020) indicated that deep tillage TD was superior by recording the highest grain yield of maize plant amounted to 5.20 Mg ha^{-1}, while the two treatments CT and minimum tillage TR recorded the lowest grain yield of maize plant amounted to 47.70 and 43.30 Mg ha^{-1} They attributed the reason for this to improving the physical properties of the soil, increasing the spread of roots and increasing their ability to absorb nutrients, which led to an increase in plant growth and yield.

Table 4. Grain yield (Mg ha^{-1}) of combined tillage machines and Conventional tillage systems

	T1	M1	T2	M2	T3	M3	T4	M4	T5	M5
Tillage treatments	26.28	4.02	5.50	3.45	5.87	3.75	4.60	3.40	4.10	3.03
t (0.01)	15.57		21.30		30.21		14.70		17.75	

Comparison of the Total costs of combinations of combined tillage machines with conventional tillage system

Table 5. showed that there were highly significant differences ($p<0.01$) between the configurations of the combined tillage machine and the conventional tillage systems in the total costs according to the t-test. It could be seen that the configuration of the combined tillage machine T1 reduced the total costs by 24.62% compared to the conventional tillage system M1. This was because the M1 needed four passes in the field, which are the first pass of a subsoiler, then a second pass of the a chisel plow, then a third pass with the disc harrows, and then the fourth pass with the roller, and this led to an increase in the time required to complete the plowing process as well as an increase in fuel consumption. Many passes in the field may increase the number of working hours when preparing the soil by traditional methods, thus increasing the maintenance and repair costs of the tractor and the tillage machines, which led to an increase in the total costs. These results agree with Prem *et al*. (2016) who found that the plowing with combined tillage machines compared with the single use of tillage tools to prepare the seedbed decreased by 20 to 50%. The configuration of the combined tillage machine T2 reduced the total costs compared to the conventional M2 tillage system by 24.70%. The configuration of the T3 tillage machine outperformed in reducing the total costs by 28.70% compared to the conventional plowing system M3. For the same reason, total costs decreased by 27.61% when comparing T4 with M4. Also, the configuration of the combined tillage machine T5 surpassed in reducing the total costs compared to the conventional tillage system M5 by 16.50%. The reason was that the M5 required two passes to complete the

plowing process, which included a first pass for the chisel plow and then a second pass for the disc harrows. This led to an increase in total costs as a result of the increase in working costs. These results were in agreement with Sarauskis *et al.*, (2014), Afshar and Dekamin (2022), and de Amorim *et al.*, 2022).

Table 5. Total costs (Id ha^{-1}) of combined tillage machines and Conventional tillage systems

	T1	M1	T2	M2	T3	M3	T4	M4	T5	M5
Tillage treatments	1206337	1600000	1189017	1580000	1196575	1540000	1191122	1520000	1186057	1420000
t (0.01)	139.06		71.03		65.01		61.67		39.17	

Comparison of the net return of combinations of combined tillage machines with conventional tillage systems

The data are shown in table 6 that there are highly significant differences ($p<0.01$) between the combinations of the combined tillage machine (T1, T2, T3, T4, T5) and the conventional tillage systems (M1, M2, M3, M4, M5) in the net return according to the t-test. The configuration of the T1 surpassed M1 in increasing the net return by 122.45%, and the net return increased by 124.50% for the combinations of the combined machine T2 compared to the conventional cultivator M2 system. This was because of the decrease in the total costs of the combined tillage machines compared to the traditional tillage system, in addition to an increase in the yield of maize (grain and straw yield) due to the improvement of soil properties as a result of reducing the times of traffic on the soil field, which led to a decrease in soil compaction (Oduma *et al.,* 2020), As a result, using combined tillage machines increased the net return. The T3 combined tillage machines outperformed in increasing the net return by 149.50% compared to the conventional M3 tillage system. When comparing T4 with M4, the net return increased by 188.46%. Also, T5 outperformed in a net increase compared to the traditional M5 tillage system by 143.20%, due to the same previous reasons. These results are in agreement with Wang *et al.* (2020), Swain *et al.,* 2020), and (Foster and Rosenzweig, 2022).

Table 6. Net return (Id ha^{-1}) of combined tillage machines and conventional tillage systems

	T1	M1	T2	M2	T3	M3	T4	M4	T5	M5
Tillage treatments	2990788	1229750	2548858	883600	2763083	1107500	1977878	881000	1649443	741500
t (0.01)	175.45		173.77		136.97		61.67		64.77	

Comparison of the benefit cost ratio of combinations of combined tillage machines with conventional tillage systems

Table 7. showed that there were highly significant differences ($p<0.01$) between the tillage treatments of the combined tillage machine and the conventional tillage system according to the t-test. When compared to the conventional tillage treatments M1, M2, M3, M4, and M5. The combined tillage machines T1, T2, T3, T4, and T5 increased the benefit-cost ratio (BCR) by 96.62, 101.28, 92.44, 68.35.20, and 57.24%, respectively. The was due to the increase in the total yield (Fig. 4) resulting from the increase in the yield (grain yield + vegetative yield) as result of improving soil propertiesو and this led to increasing total return more than the costs, thus increase in the BCR. As a result, using combined tillage machines increased the net return. These results are in agreement with the findings of Muhsin *et al.*,(2021) anShivran *et al.,* (2020) who indicated that BCR increasing by 61.38% for combined tillage machine compared to individual tillage machines.

Table 7. BCR of combined tillage machines and conventional tillage systems

	T1	M1	T2	M2	T3	M3	T4	M4	T5	M5
Tillage treatments	3.48	1.77	3.14	1.56	3.31	1.72	2.66	1.58	2.39	1.52
t (0.01)	32.78		5.82		3.65		5.85		3.36	

3- Conclusions and Recommendations

The economic input of maize yield from various soil tillage methods was compared, and the cost of production input and the income's monetary value were evaluated. It can be concluded from the study that the use of combined tillage machines significantly surpassed conventional tillage systems in increasing grain yield, the net return, and BCR, as well as a reduction in the total cost and saving fuel. On the other hand, the combined tillage machine T1 recorded the highest grain yield, net return, and BCR, reaching 6.28 Mg ha-1, 2990788 Id ha-1, and 3.48%, respectively, while the combined tillage machine of the tillage T5 recorded the lowest grain yield, reaching 4.10 Mg ha-1, 1649443 Id ha-1, and 2.39%, respectively. it can be recommended to use the combined tillage T1 or other T2, T3, T4, and T5 instead of using the conventional tillage systems to reduce costs of production and increase net return.

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