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# Calculating the Total Costs of the Tractor and the Chisel Plow under Variable Speeds and Depth of Tillage

**Ahmed Abd Ali Hamid[1]***

[1]Department of Dormitories Affairs, University of Baghdad, Baghdad, Iraq.

*Corresponding author: ahmed.hamid@uobaghdad.edu.iq

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**Abstract**

Factorial experiments were conducted in a silt clay loam soil with a randomized complete block design with three replications for each treatment. This study aimed to calculate machinery unit costs and some indicators during primary tillage, under variable tractor speeds of 1.8, 3.5 and 5.7 km.h$^{-1}$ and depth of plowing 20, 30 and 40 cm. A higher speed of 5.7 km.h$^{-1}$ is associated with higher practical productivity of 0.9696 ha.h$^{-1}$; specific productivity of tillage 4309 m.h-1; a volume of soil disturbed 2884 m3. h$^{-1}$. The best fixed, management, total tractor, total plow and total machinery unit costs were 2.27, 0.80, 9.02,1.01 and 10.04 \$.ha$^{-1}$ respectively. Additionally, lower fuel consumption was 8.56 l.ha$^{-1}$, and the actual time for plowing one hectare was 1.02 h. The depth of tillage 20 cm recorded a higher productivity of 0.6412 ha.h-1, the specific productivity of tillage was 2849 m.h$^{-1}$, less fuel consumption of 7.74 l.ha$^{-1}$, less actual time of plowing one hectare of 1.95 hThe least fixed, variable, management, total tractor, total plow and total machinery unit costs were 4.32, 4.71, 0.89, 9.94,1.94 and 11.89 \$.ha$^{-1}$ respectively. All interactions among the treatments were significant. The experiment concluded that the plowing depth has a greater effect than speed on all operating costs of the tractor and chisel plow and performance indicators. The correlations among the indicators studied were direct (positive) and inverse (negative) significantly and were also non-significant.

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## Introduction

Tillage is a mechanical soil treatment to prepare a suitable place for seeds and their growth. The chisel plow is one of the most important plows used for primary tillage and fragmentation of the soil without turning it over (Askari *et al*., 2022). Tillage or plowing can be categorized as primary or secondary (Abdul-Munaim, 2013; Himoud, 2018). Most of the agricultural lands in Iraq and other researchers, before planting crops, are primarily plowed using one of the plows such as a chisel, moldboard or disc (Nafawaah and Mageed, 2019; Abdul- Munaim *et al*., 2020; Jaber *et al*., 2020; Jasim *et al*., 2020; Alhasnawi *et al*., 2022; Hamid and Alsabbagh, 2022). Primary tillage involves cutting, breaking, overturning, and pulverization of soil by plows which are strongly affected by the depth of tillage (Ahaneku *et al*., 2011). The quality of soil plowing with a chisel plow depends on the speed and depth of tillage (Marey *et al*., 2020). The tractor is considered the backbone of any agricultural operation, and it is necessary to calculate fuel consumption and costs, especially

When pulling plows (Hamid, 2012; Moitzi *et al*., 2014). Plow productivity is affected by tractor speed, plow width and design, plowing depth and soil conditions (Taha and Taha, 2019; Hamid and Alsabbagh, 2023). Taha (2011) and Abdulla *et al*. (2018) concluded that the maximum practical productivity of a chisel plow can be obtained at the high speed of the tractor, and productivity decreases when the depths of tillage increase. Almaliki (2018) noticed the chisel plow needs more draft when increased the tractor speed and plowing depth, therefore, the fuel consumption will be increasing. In conclusion, fuel consumption tends to increase while productivity decreases when the plowing depths increase (Hamid, 2012; Amir *et al*., 2021; Jebur and Himoud, 2018). Amer (2017) and Hameed and Alani (2022) reported increased productivity of tillage and decreased fuel consumption with increasing speed. Siddiq and Alobaidi (2019) concluded a decrease in the volume of soil disturbed and consumption of fuel an increase in when a tractor speed was increased during plowing with a chisel plow. Increasing tillage depth causes increased consumption of fuel tractor and volume of soil and reduces practical productivity (Alhadithy and Albadry, 2012; Hashim and Juber, 2022; Alnuaimi and Alrejabo, 2020). The cost of operation machines depends on the life of the tractors and plow, fuel and lubbers (Altahan *et al*., 1991; Tahir and Jarad, 2017; Awad *et al*., 2022). Almafrachi (2013) added tractor's speed, tillage depth and moisture of soil during the plowing. Alwash and Al-Aani (2023) reported decreased fuel costs when the tractor speed increased. Jasim and Alhashimy (2015) and Jasim and Juber (2015) concluded that the chisel plow had lower operation costs and fuel consumption than did the disc and moldboard plow.

The objective of the field experiment was to determine the effects of tractor speeds and depth plowing on productivity, fuel consumption, the time of the plowing one hectare, the specific productivity of tillage, soil disturbed volume, and estimated economic cost of machinery unit (tractor and chisel plow) to increase their operating efficiency, and obtain the highest productivity and performance of machinery units at the lowest possible costs.

## Materials and Methods

### Experimental site

The research was carried out in 2023 in southern Baghdad, Iraq, within the coordinates Latitude 33.251389° N, Longitude 44.391944° E. According to the Köppen climate classification, Iraq is located within an arid climate. The height of the experimental field above sea level was 31.6 m, the field was uncultivated, and the field area was 13650 $m^2$ (140 m long and 105 m wide). Five random samples were selected and analyzed from a depth of 50 cm in the upper field soil layer by using core samples (cylindrical shape), and dried by using the oven at 105°C for 24 h; the moisture content of the soil was 16-18% when the field was tilled and the bulk density was 1.39 $g.cm^{-3}$. The soil texture was silty clay loam (425, 445 and 130 $g.kg^{-1}$).

### Technical specifications of the tractor and chisel plow

**ITMCO 285 2WD tractor** constructed in Iran; Four-cylinder direct injection diesel engine with 85 horsepower (63.4 kW), a water cooling system, a maximum of engine revolutions of 2000 rpm, and a torque of 272 N. m at the engine rotates 1200 rpm. Hydraulic steering wheel, and diesel fuel tank capacity 90 liters. The gearbox has 8 forward and 2 rear speeds, power take-off (PTO) shaft speeds of 540 at 1684 rpm, a width and length tractor of 2500 and 4530 mm, respectively, and a total tractor weight of 3110 kg.

**A Chisel plow** made in Turkey, with non-soldered steel rolled iron was used in the chassis and a special alloy steel cast was used for 9 tines with safety pins to prevent plow chassis damage and the tractor. The width of the working was 2250 mm, the maximum depth was 450 mm, and the space of the tines was 250 mm, the weight of 460 kg, the length 2500 mm, the width 1200 mm, and the height of 1285 mm.

### Experiment Design

A factorial experiment was conducted under a randomized complete block design (RCBD) with three replications. Statistical Analysis System (SAS) was carried out using SAS software 9.2 (SAS 2010), employing the least significant difference (L.S.D) method to compare means at the significance of 0.05 and 0.01. The experiment incorporated two factors: tractor speed (1.8, 3.5, and 5.7 $km.\ h^{-1}$) and tillage depth (20, 30, and 40 cm). Nine treatments with three replicated for each one, a total of 27 treatments (3 * 3 * 3 replication = 27 treatments). The treatment area covered 45 m² with dimensions of 20 m long and 2.25 m wide.

## Measurement Indicators

### Practical productivity

The actual field performance rate of the chisel plow was calculated from the following equation (Kepner, 1972):

$$Pp = 0.1 * Bp * Vp * ft \quad (1)$$

where $Pp$ is the practical productivity (ha. h$^{-1}$), 0.1 is the conversion factor, Bp is the actual width of the chisel plow, $Vp$ is the tractor speed during plowing, $ft$ is the utilization time factor for the chisel plow which is equal to 0.75-0.85, and 0.80 is taken as the average in this experiment (ASABE 2006).

### Fuel consumption

The way of refilling the fuel tank tractor which used, this way fills the fuel tank tractor completely to the brim before starting treatment and after, by a graduated cylinder with a capacity of 1000 ml. The amount (quantity) of diesel fuel used at the time of operation was calculated from the following equation (Igoni *et al*., 2020; Hamid and Alsabbag 2022):

$$Q_F = q_l * 3600 \ / \ t \ * 1000 \quad (2)$$

Where $Q_F$ is the fuel quantity consumption (l.h$^{-1}$), $ql$ is a measured quantity of fuel for tillage line treatment (ml), $t$ is the time in (sec) to across one treatment, and 3600 and 1000 factor conversion.

### Specific productivity of tillage

The number of linear meters that are plowed per hour is calculated from the following equation (Al-Awdhi, 1978; Hamid 2015):

$$SPT = (Pp * 10000) \ / \ Bp \quad (3)$$

Where $SPT$ is the specific productivity of tillage (m.h$^{-1}$), and 10000 is the factor conversion.

### Actual time for plowing one hectare

The time spent plowing one hectare of the agricultural field, was calculated from the following equation (Hamid, 2015):

$$ATP = 1 \ / \ Pp \quad (4)$$

Where *ATP* is the actual time for plowing one hectare (h).

### Volume of soil disturbed

Soil raised volume during the plowing process at a given time, is dependent on the depth of plowing and practical productivity, and is calculated from the following equation (Bukhari *et al*., 1988):

$$VSR = Pp * D * 100 \quad (5)$$

Where *VSR* is the volume of soil raised (m$^3$.h$^{-3}$), and *D* is the depth of the plowing (cm).

## Economic cost of machinery units (Tractor and chisel plow)

### Fixed cost

Costs that do not change whether the tractor or plow is working or not, and include the fixed costs of the tractor and plows (Altahan, 1991):

### Depreciation

A continuous gradual decrease in the price value of tractors and plows. Depreciation was calculated according to declining balance depreciation; this method has been adopted in the United States of America since 1945 for calculating the federal income tax on agricultural machinery (Aboud, 1980). The depreciation was calculated from the following equations (Altahan, 1991):

$$Dep = V_n - V_{n+1} \quad (6)$$

$$V_n = P \ (1 - X \ / L \ )^n \quad (7)$$

$$V_{n+1} = P \ (1 - X \ / \ L \ )^{n+1} \quad (8)$$

where *Dep* is the depreciation value annually (\$.Year$^{-1}$), $V_n$ is the value of the remaining tractor in n years, $V_{n+1}$ is the value of remaining tractor in $V_{n+1}$ year (\$.Year$^{-1}$), $P$ is the price of the tractor, $X$ is the depreciation rate ratio ranging between 1 and 2, the value $X$ is assumed to be equal to 1, and $L$ is the operating life of the tractor (10 years).

**Interest on capital**

The interest rate is estimated on the basis of the annual return on fixed assets paid to purchase tractor and agricultural machinery. The interest rate varies from country to country. Interest is calculated from the following equation (Altahan, 1991):

$$Int = [\,(P + V_n) \div 2 / h\,] * Int.Rate \quad (9)$$

Where *Int* is interested in the capital ($. year$^{-1}$), $H$ is the number of annual operating hours of the tractor (1000 hours.year$^{-1}$), and *Int.The rate* is the percentage of interest on capital is 4 % (the interest rate approved by Iraqi banks belonging to the Iraqi Ministry of Finance for the year 2023).

**Taxes, Insurance and Shelter**

Taxes represented a small percentage of capital. Insurance farmers are advised about the risks of accidents and prevent potential risks. A shelter is the sheltering of tractors and plows in shelters to protect them from weather factors such as sun, rain, wind and dust, which increases their operational life. It is calculated from the following equation (Altahan, 1991):

$$T.I.S = (P / h) * T.I.S.Rate \quad (10)$$

Where *T.I.S* represents taxes, insurance and shelter ($. year$^{-1}$), and *T.I.S. Rate* is the percentage of taxes, insurance and shelter 2%.

Then, the fixed costs are calculated by summing the depreciation, interest on capital, taxes, insurance and shelter costs via the following equation (Altahan, 1991):

$$F.C = Dep + Int + T.I.S \quad (11)$$

Where *F.C* is the fixed cost for the tractor ($. year$^{-1}$).

The fixed tractor costs are then converted from a unit of $.h$^{-1}$ to $.ha$^{-1}$ by dividing them by the practical productivity ha.h$^{-1}$.

**Variable costs**

The costs resulting from the operation of tractors or plows increase as operation increases and decrease with decreasing operation; these costs are also called direct costs. It consists of:

**Fuel costs**

The amount of fuel consumed varies per unit area to accomplish agricultural operation, this quantity depends on the engine power, the type of fuel and the type of agricultural operation and it is calculated from the following equation (Altahan, 1991):

$$Fu.c = QF * Fu.pre \quad (12)$$

Where *Fu.c* is the fuel cost ($.ha$^{-1}$), and *QF* is the price of a liter of diesel fuel, is equal to 0.30 $ (400 Iraqi dinars according to the official price of the Iraqi Ministry of Oil for the year 2023).

**Oil costs**

Oil consumption increases with the daily operation of the tractor, so it is related to the number of operating hours. It is calculated from the following equation (Altahan, 1991):

$$O.c = Q.o * O.pre / P.o * Pp \quad (13)$$

where O.c is the cost of oil ($.ha$^{-1}$), Q.o is the oil quantity added after oil is changed, which is 8 liters in the tractor used in the field experiment, *O. pre* is the liter oil price, which is equal to 1.51 $ (2000 Iraqi dinars according to the official price of the Iraqi Ministry of Oil for the year 2023), *P.o* is the oil change period, which was 100 hours according to the manufacture's recommendations.

**Repair and maintenance costs**

The data includes the cost of spare parts, technicians' wages, and the transportation costs of the tractor to the place of repair, and were calculated from the following equation (Altahan, 1991):

$$M.R.c = (P / h * Pp)\, M.R.Rate \quad (14)$$

Where *M.R.c* is the repair and maintenance costs ($.ha$^{-1}$), and *M.R. Rate* is the percentage for maintenance and repair and ranges from 2.2-7.4% of the tractor purchase price, this percentage is 4.5% in this experiment.

**Labor costs**

Operating tractors requires specialized drivers with experience in operation and maintenance, which may occur during field work; these wages are linked to the number of actual operating hours of the tractor and are calculated as daily or monthly wage. The labor cost is calculated from the following equation (Altahan, 1991):

$$L.c = D.L / d * Pp \quad (15)$$

Where *L.c* is the labors cost ($\$.ha^{-1}$), *D.L* is the wage of the worker (driver) in one day, which was 19$ according to the wages followed at the site where the experiment was conducted, and *d* is the number of working hours 8 $h.day^{-1}$.

Then, the variable costs were calculated by summing all the costs (fuel, oil, repair and maintenance, and labor) as follows the equation (Altahan, 1991):

$$V.C = Fu.c + O.c + M.R.c + L.c \quad (16)$$

Where *V.C* is the variable cost ($\$. ha^{-1}$).

**Tractor management costs**

Management costs are calculated as a percentage of 10 % of the total fixed and variable costs, calculated from the following equation (Altahan, 1991):

$$Ma.C = (F.C + V.C) * 0.10 \quad (17)$$

Where *Ma. C* is tractor management costs ($\$.ha^{-1}$).

**Tractor total costs**

It is calculated by summing all costs, which include fixed, variable and management, costs, via the following equation (Altahan, 1991):

$$T.T.C = F.C + V.C + Ma.C \quad (18)$$

Where *T. T. C* is the tractor total cost ($\$.ha^{-1}$).

**Plow total costs**

The fixed and management costs of the chisel plow were calculated using the same method and equations used for calculating the fixed and management costs, respectively, for the case of the tractor, as for the cost variable of the plow, they are calculated at a percentage of 80 % of the fixed costs of the plow, as calculated by the following equation (Altahan, 1991):

$$P.V.C = P.F.C * 0.80 \quad (19)$$

Where *P.V.C* is the variable cost of plowing ($\$.ha^{-1}$), and *P.F.C* is the fixed cost of plowing ($\$.ha^{-1}$).

The total costs of the chisel plow were calculated by summing the costs of the chisel plow as a fixed, variable and management, and these costs were calculated from the following equation (Altahan, 1991):

$$P.T.C = P.F.C + P.V.C + P.Ma.C \quad (20)$$

Where *P.T.C* is the total cost of the chisel ($\$.ha^{-1}$), *P.Ma. C* is the management cost of the chisel ($\$.ha^{-1}$).

**Machinery unit total costs**

It is calculated by summing the total tractor costs and the totals plow costs, is via the following equation (Altahan, 1991):

$$T.C = T.T.C + P.TC \quad (21)$$

Where *T.C* is the total cost of the machinery unit total costs (tractor and chisel plow), ($\$.ha^{-1}$).

**Results and Discussion**

Table 1 show that the practical productivity, specific productivity and volume of soil raised increase with increasing tractor speed, so the best result at the higher speed of 5.7 $km.h^{-1}$ was 0.9696 $ha. h^{-1}$, 4309 $m. h^{-1}$ and 2884.8 $m^3. h^{-1}$, respectively, because the plowing speed is an important factor that affects these characteristics, these results agree with results (Hamid, 2015; Abdalla *et al*, 2018; Siddiq and Al-Obaidi, 2019). Fuel consumption and the time of plowing one hectare decreased when the tractor speed increased, where the lowest values were 8.56 $l.ha^{-1}$ and 1.02 h, respectively. Increasing the tractor speed means making better use of the engine's power and reducing working time, thus reducing the amount of fuel per hectare, these results are the same as those of (Almafrachi, 2013; Alwash and Al-Aani, 2023). Fixed, management, and total costs for the tractor, plow and machinery unit (tractor and chisel plow) are directly affected by the speed of the tractor; these costs decreased to 2.27, 0.80, 9.02, 1.01 and 10.04 \$. $ha^{-1}$, respectively, when increasing the speed to 5.7 km. $h^{-1}$ , the cause is that practical productivity increases when the tractor speed increases, leading to decreased costs when plowing one hectare; These results are the same as those of (Almafrachi, 2013; Jasim and Alhashimy, 2015; Jasim and Juber, 2015).

**Table 1. The effect of tractor speed on the studied attributes**

| studied attributes | Tractor speed km . $h^{-1}$ | | | L.S.D | DF | Anova SS | Mean Square | F value |
|---|---|---|---|---|---|---|---|---|
| | 1.8 | 3.5 | 5.7 | | | | | |
| Practical productivity ha . $h^{-1}$ | 0.2890 | 0.5886 | 0.9696* | 0.004 | 2 | 2.0944 | 1.0472 | 5095 |
| Fuel consumption l. $h^{-1}$ | 11.25 | 9.94 | 8.56*** | 0.427 | 2 | 32.651 | 16.325 | 89.4 |
| Specific productivity m. $h^{-1}$ | 1284 | 2616 | 4309** | 20.13 | 2 | 24371 | 20685 | 5095 |
| Time of plowing one hectare h | 3.46 | 1.69 | 1.02*** | 0.034 | 2 | 28.648 | 14.324 | 1205 |
| Volume of soil raised $m^3$ . $h^{-1}$ | 853.2 | 1748.3 | 2884.8** | 16.82 | 2 | 18660 | 93303 | 3292 |
| Tractor fixed costs \$ . $ha^{-1}$ * | 7.67 | 3.75 | 2.27 *** | 0.070 | 2 | 140.10 | 70.052 | 1399 |
| Tractor variable costs \$ . $ha^{-1}$ | 4.75*** | 5.17 | 5.39 | 0.134 | 2 | 6.3966 | 3.1983 | 176.8 |
| Tractor management costs \$.$ha^{-1}$ | 1.23 | 0.88 | 0.80 *** | 0.03 | 2 | 0.9690 | 0.4845 | 538.6 |
| Tractor total costs \$ . $ha^{-1}$ | 13.68 | 9.82 | 9.02 *** | 0.198 | 2 | 111.66 | 55.831 | 1444 |
| Plow total costs \$ . $ha^{-1}$ | 3.35 | 1.69 | 1.01 *** | 0.107 | 2 | 26.020 | 13.010 | 1118 |
| Machinery unit total costs \$.$ha^{-1}$ | 17.06 | 11.52 | 10.04*** | 0.136 | 2 | 246.61 | 123.25 | 6655 |

* 1 \$ = 1320 Iraqi Dinar according to the Dollar Exchange at the Central Bank of Iraq for the year 2023.
** The higher value is the best.
*** The lower value is the best.

Additionally, the results shown in Table 2 show that practical productivity, and specific productivity decreased with increasing the plowing depth, where the best results were 0.6412 ha.$h^{-1}$ and 2849 m. $h^{-1}$ respectively when the plowing depth was 20 cm. This is because the depth increases which makes the load in front of the chisel plow increase, which leds to a reduction in the tractor speed due to increased slippage; these results are in agreement with previous results (Hamid, 2015; Abo-Hababa *et al*., 2018). Fuel consumption increased when depth increased, where the values were 7.74, 9.50 and 12.51 l.$h^{-1}$ when plowing was increased by 20, 30 and 40 cm, respectively. This is because the plowing depth results in greater agitation of the plowed soil, which results in greater work being accomplished and thus the consumption of a greater amount of fuel; these result are the same as those of other studies (Jebur and Himoud, 2018; Amir *et al*., 2021; Hamid and Alsabbagh, 2022). The costs, as fixed, variable, management and tractor total, plow and machinery unit (tractor and chisel plow) are affected by the plowing depth. These costs were the lowest at 4.32, 4.71, 0.89, 9.94, 1.94 and 11.89 \$. $ha^{-1}$, respectively, when 20 cm was the depth. A reason was a decrease in productivity when the plowing depth increased, which inevitably increased various costs, similar to the findings of the results (Jasim and Alhashimy, 2015; Jasim and Juber, 2015).

**Table 2. The effect of the plowing depth on the studied attributes**

| Studied attributes | Plowing depth cm | | | L.S.D | DF | Anova SS | Mean Square | F value |
|---|---|---|---|---|---|---|---|---|
| | 20 | 30 | 40 | | | | | |
| Practical productivity ha . $h^{-1}$ | 0.6412** | 0.6178 | 0.5882 | 0.004 | 2 | 0.0126 | 0.0063 | 308.9 |
| Fuel consumption l. $h^{-1}$ | 7.74 *** | 9.50 | 12.51 | 0.427 | 2 | 104.62 | 52.313 | 286.6 |
| Specific productivity m. $h^{-1}$ | 2849 ** | 2745 | 2614 | 20.13 | 2 | 25082 | 12541 | 308.9 |
| Time of plowing one hectare h | 1.95 ** | 2.04 | 2.19 | 0.034 | 2 | 0.2680 | 0.1334 | 112.2 |
| Volume of soil raised $m^3$ . $h^{-1}$ | 1282.3 | 1851.3 | 2352** | 16.82 | 2 | 51263 | 25811 | 9107. |
| Tractor fixed costs \$ . $ha^{-1}$ * | 4.32** | 4.53 | 4.85 | 0.070 | 2 | 1.2731 | 0.6365 | 127.1 |
| Tractor variable costs \$ . $ha^{-1}$ | 4.71*** | 5.16 | 5.98 | 0.134 | 2 | 7.4373 | 3.1718 | 205.6 |
| Tractor management costs \$.$ha^{-1}$ | 0.89*** | 0.96 | 1.06 | 0.03 | 2 | 0.1264 | 0.0632 | 70.29 |
| Tractor total costs \$ . $ha^{-1}$ | 9.94*** | 10.67 | 11.91 | 0.196 | 2 | 17.739 | 8.8698 | 229.5 |
| Plow total costs \$ . $ha^{-1}$ | 1.94*** | 2.04 | 2.08 | 0.107 | 2 | 0.0900 | 0.0450 | 3.87 |
| Machinery unit total costs \$.$ha^{-1}$ | 11.89*** | 12.72 | 14.02 | 0.136 | 2 | 20.603 | 10.301 | 556.2 |

* 1 \$ = 1320 Iraqi Dinar according to the Dollar Exchange at the Central Bank of Iraq for the year 2023.
** The higher value is the best.
*** The lower value is the best.

The results as shown in Figures 1, 2, 3, and 4 the interaction tractor speed was 5.7 km. $h^{-1}$ with plowing of 20 cm resulted in higher practical productivity of 1.004 ha. $h^{-1}$, specific productivity of tillage 4464 m.$h^{-1}$, best consumption fuel tractor 6.58 l.$h^{-1}$, minimum time plowing one hectare 0.99 h, while interaction tractor speed 1.8 km. $h^{-1}$ with a depth of 40 cm gave lower productivity which was 0.2670 ha.$h^{-1}$, and the specific productivity of tillage was 1186 m. $h^{-1}$, higher consumption of 14.29 l.$h^{-1}$, and maximum plowing time of one hectare of 3.74 h. The interaction tractor speed is 5.7 km. $h^{-1}$ and plowing depth 40 cm gave a higher volume of soil raised which was 3729 m3.$h^{-1}$, while tractor speed 1.8 and plowing depth 20 cm recorded a lower value, which was 3729 m3.$h^{-1}$, while tractor speed 1.8 and plowing depth 20 cm recorded a lower value, which was 616.8 $m^3$. $h^{-1}$.

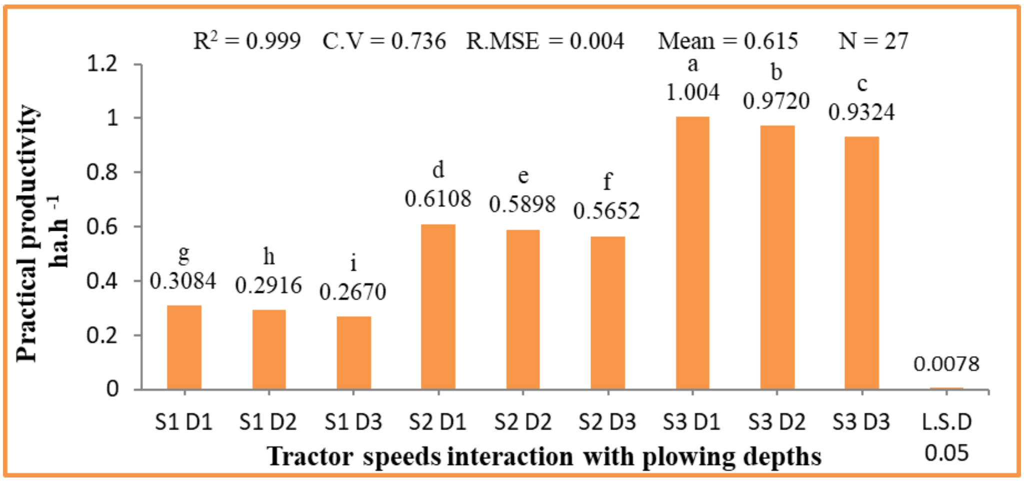


**Figure 1. Effect of interaction tractor speed and plowing depth on practical productivity**
(Means with the same letter are not significantly different), (S1 = 1.8, S2 = 3.5, S3 = 5.7 km.$h^{-1}$, D1 = 20, D2 = 30, D3 = 40 cm).

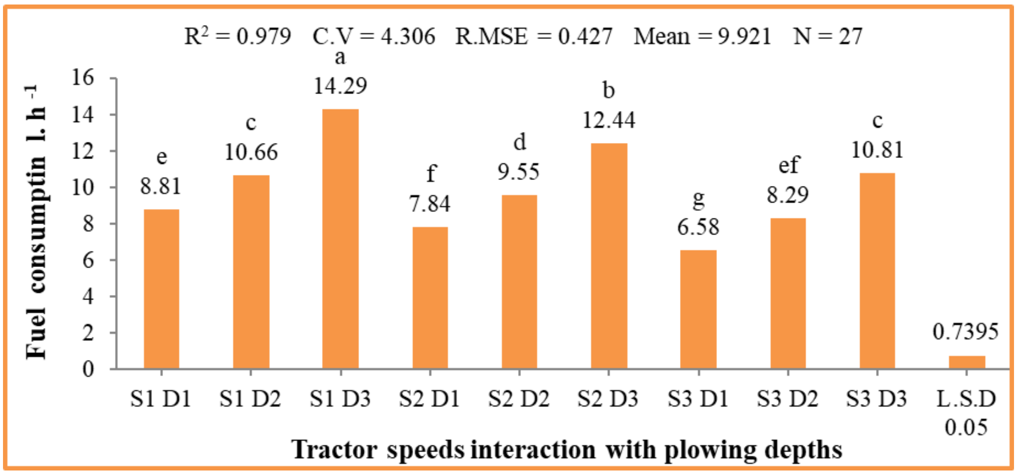


**Figure 2. Effect of interaction tractor speed and plowing depth on fuel consumption**

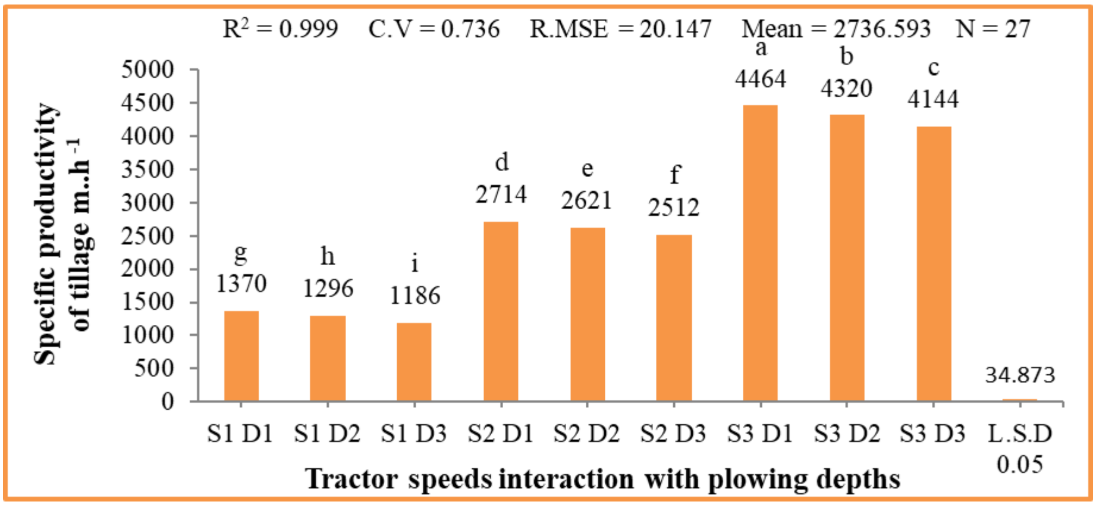


**Figure 3. Interaction tractor speed and plowing depth on the specific productivity of tillage**

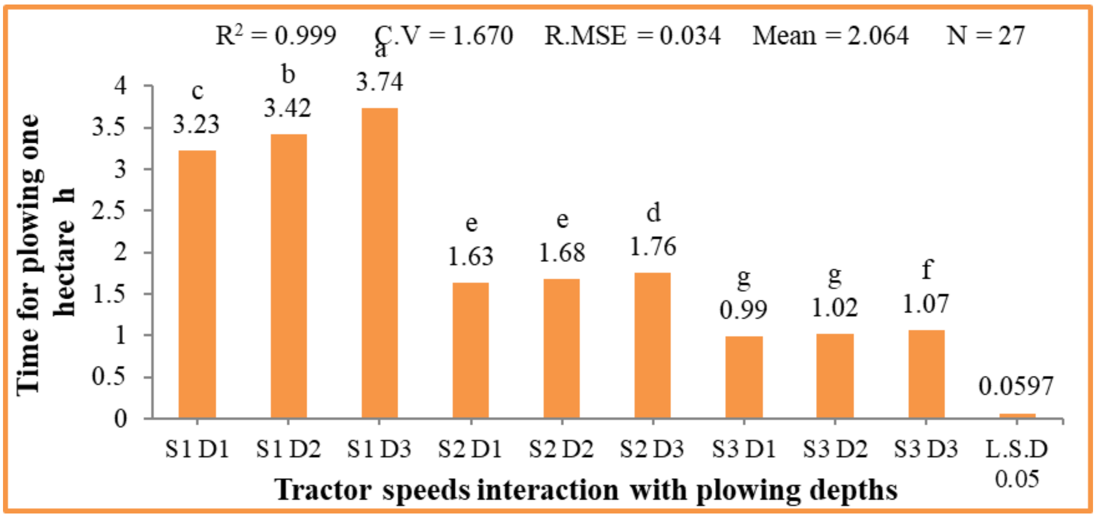


**Figure 4. Interaction tractor speed and plowing depth on time for plowing one hectare**

The Figure 5 clearly shows that from that increasing the depth had a significant impact on the soil volume raised, because depth is an important factor in calculating the soil raised volume.

The results showed in the Figures 6, 8, 9, 10 and 11 an interaction tractor speed of 5.7 km.$h^{-1}$, with plowing 20 cm gave the lowest tractor costs fixed, additionally, the management and total costs for the tractor, plow and machinery unit (tractor and chisel plow) were 2.19, 0.75, 8.41, 0.96 and 9.38 $. $ha^{-1}$ respectively. The reason is that high speeds result in high productivity, which leads to lower costs. The speed is 1.8 km. $h^{-1}$ at 40 cm depth recorded a higher cost tractor costs fixed, management and total costs for the tractor, plow and machinery unit were 8.28, 1.38, 15.28, 3.41 and 18.77 $. $ha^{-1}$ respectively, increasing the plowing depth 40 cm led to reduced productivity, so the cost was greater. The variable costs for the tractor behaved differently from the rest of the all costs, as the speed overlap 1.8 km. $h^{-1}$ with the plowing depth of 20 cm recorded the lowest variable costs for the tractor was 4.08 $. $ha^{-1}$, while the highest costs were when the speed overlapped 5.7 km. $h^{-1}$ with 40 cm depth was 6.49 $. $ha^{-1}$ (Figure 5), because fuel consumption is an important factor in calculating variable costs, as fuel consumption increases when productivity increases, and workers' wages (labors) also increase.

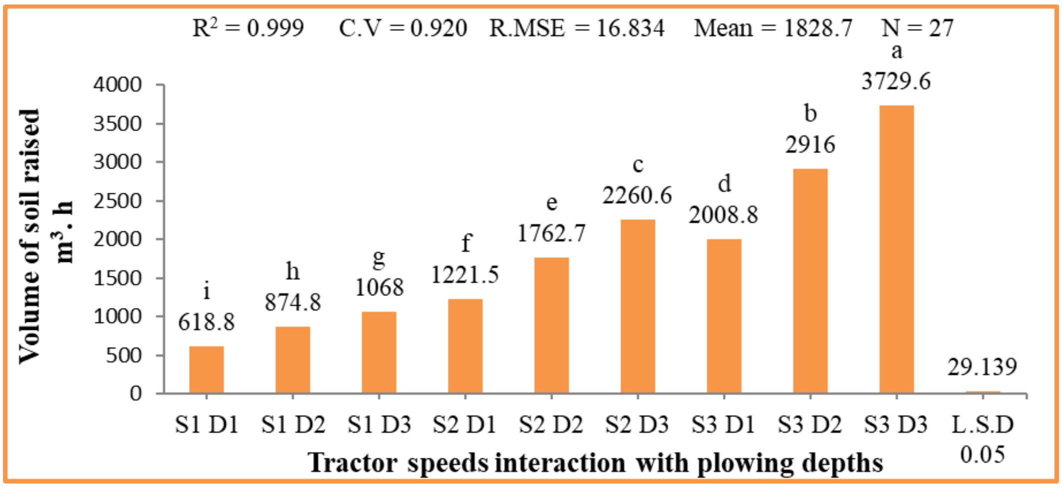


**Figure 5. Effect of interaction tractor speed and plowing depth on volume of soil raised**

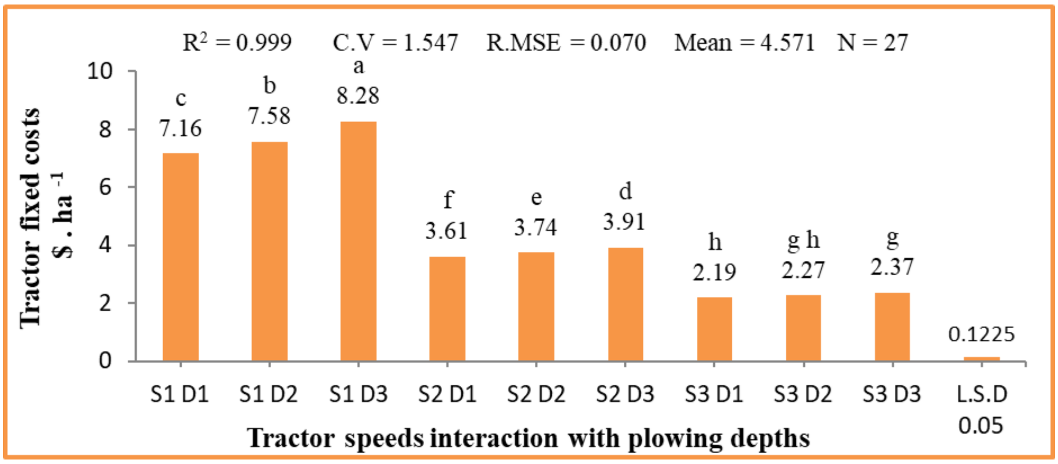


**Figure 6. Effect of interaction tractor speed and plowing depth on tractor fixed costs**

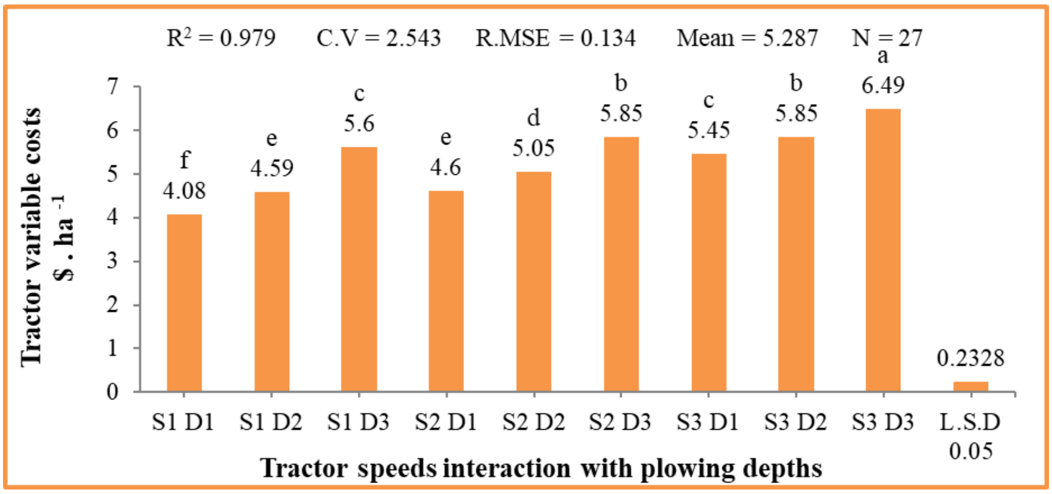


**Figure 7. Effect of interaction tractor speed and plowing depth on tractor variable costs**

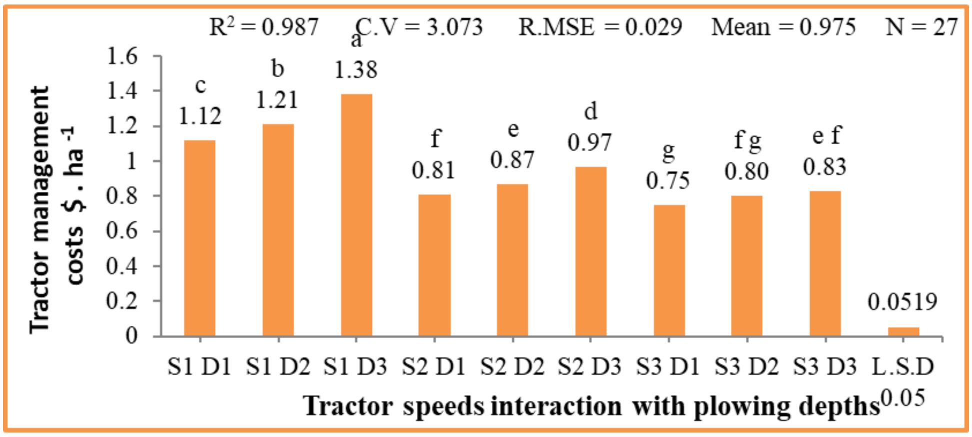


**Figure 8. Effect of interaction tractor speed and plowing depth on tractor management cost**

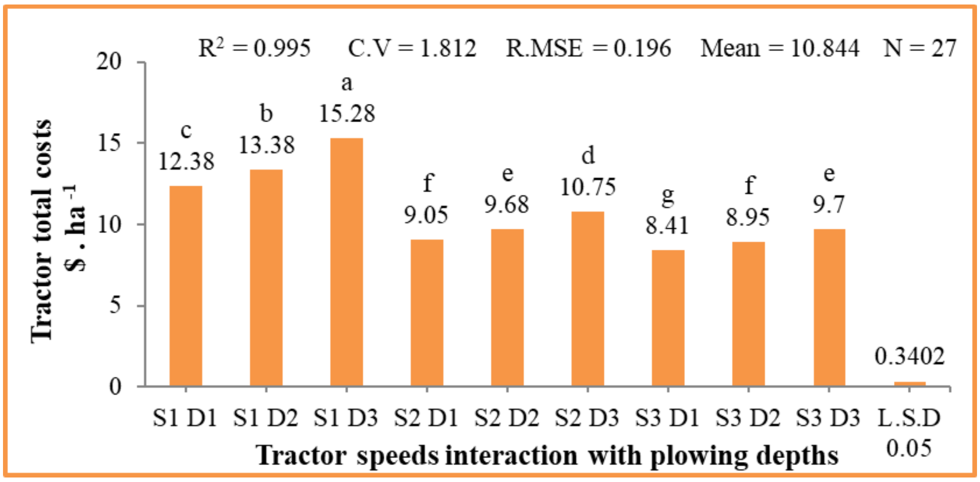


**Figure 9. Effect of interaction tractor speed and plowing depth on tractor total costs**

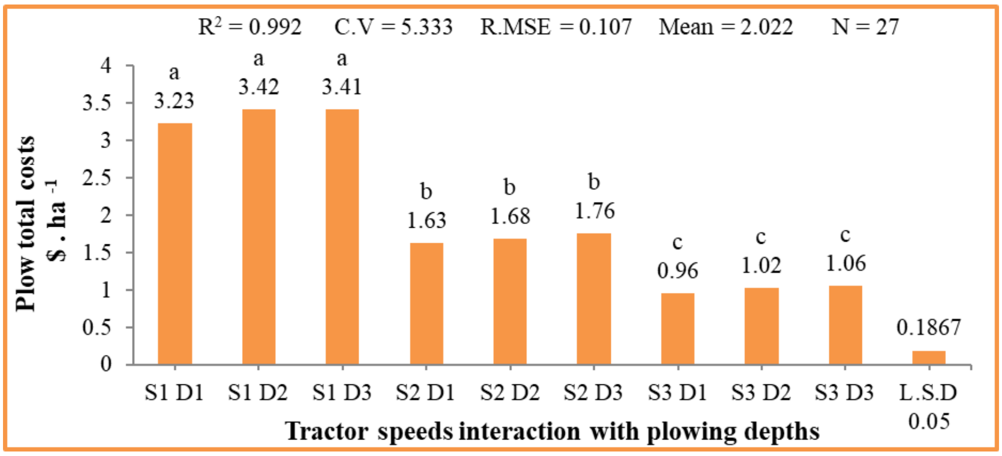


**Figure 10. Effect of interaction tractor speed and plowing depth on plow total costs**

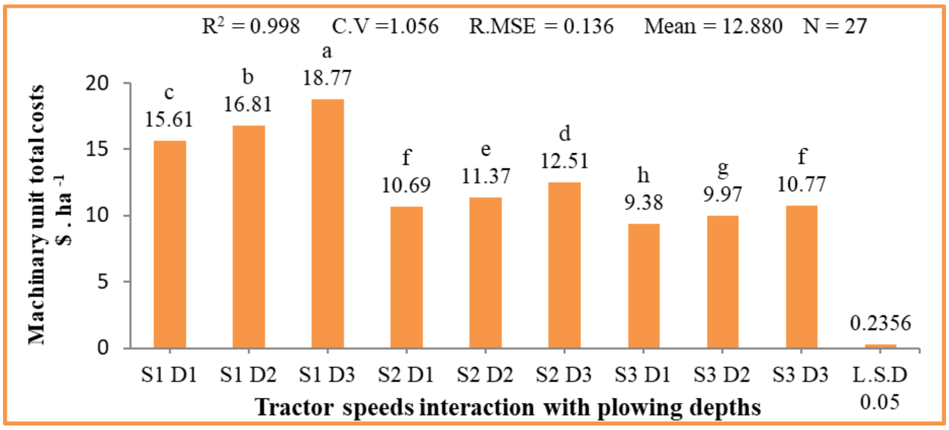


**Figure 11. Effect of interaction tractor speed and plowing depth on machinery unit total costs**

In Table 3 the mean values for all the treatments (N = 27), standard deviations, sum, minimum and maximum values were obtained by applying a statistical analysis system (SAS) for all the performance indicators studied and operation costs in the field experiment.

**Table 3. Simple statistics of the study characteristics**

| Variable | N | Mean | Std.Dv | Sum | Min | max |
|---|---|---|---|---|---|---|
| Practical productivity ha.$h^{-1}$ | 27 | 0.615 | 0.2847 | 16.624 | 0.261 | 1.008** |
| Fuel consumption l.$h^{-1}$ | 27 | 9.921 | 2.3460 | 267.87 | 6.440* | 15.11 |
| Specific productivity m.$h^{-1}$ | 27 | 2737 | 1266 | 73888 | 1160 | 4480** |
| Actual time for plowing h | 27 | 2.064 | 1.0581 | 55.730 | 0.990* | 3.840 |
| Volume of soil raised $m^3.h^{-1}$ | 27 | 1829 | 981.39 | 49377 | 612.0 | 3758** |
| Tractor fixed costs $.$ha^{-1}$ | 27 | 4.571 | 2.3394 | 123.75 | 2.190* | 8.470 |
| Tractor variable costs $.$ha^{-1}$ | 27 | 5.287 | 0.7448 | 142.75 | 3.900* | 6.630 |
| Tractor management costs $.$ha^{-1}$ | 27 | 0.975 | 0.2098 | 26.350 | 0.740* | 1.430 |
| Tractor total costs $.$ha^{-1}$ | 27 | 10.84 | 2.2582 | 292.79 | 8.350* | 15.82 |
| Plow total costs $.$ha^{-1}$ | 27 | 2.022 | 54.600 | 54.600 | 0.910* | 3.650 |
| Machinery unit total cost $.$ha^{-1}$ | 27 | 12.88 | 347.76 | 347.76 | 9.350* | 19.02 |

Min and Max are the minimum and maximum values, respectively, obtained in the field experiment.
*The lowest value for the studied indicators is the best.
**The greater value for the studied indicators is the best.

## Correlation

The correlations between the indicators studied were significant and non-significant, as was the presence of a direct (positive) or inverse (negative) correlation (Table 4). The highest positive correlation was between the actual time for plowing one hectare and the tractor fixed cost of 0.999 at an L.S.D of 0.01; this means that when one of them increases, the other also increases. The direct (positive) correlation between practical productivity and the specific productivity of tillage was 1.000 at L.S.D of 0.01; this is because practical productivity is directly involved in calculating the specific productivity of tillage, and therefore, there is a very strong correlation between them. The maximum inverse (negative) correlations between total tractor costs and practical productivity and specific productivity of tillage was- 0.948 and -0.948, respectively, indicating that the meaning when practical productivity and specific productivity of tillage decrease the total tractor costs. The minimum direct correlation was between fuel consumption and tractor variable costs were 0.339. The minimum inverse (negative) correlation between tractor variable costs and total tractor costs was -0.236; when one of them increased, the other decreased.

**Table 4. Correlations among indicators studied in the field experiment**

| | X 1 | X | X 3 | X 4 | X 5 | X 6 | X 7 | X 8 | X 9 | X 10 | X 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **X 1** | 1.00 | | | | | | | | | | |
| **X 2** | -0.54* | 1.00 | | | | | | | | | |
| **X 3** | **1.00**** | -0.54** | 1.00 | | | | | | | | |
| **X 4** | -0.94** | 0.54* | -0.94** | 1.00 | | | | | | | |
| **X 5** | 0.82** | -0.55 | 0.82** | -0.78** | 1.00 | | | | | | |
| **X 6** | -0.94** | 0.54* | -0.94** | **0.99**** | -0.78** | 1.00 | | | | | |
| **X 7** | -0.60** | **0.33** | 0.60** | -0.52* | 0.86** | -0.52* | 1.00 | | | | |
| **X 8** | -0.86** | 0.72** | -0.86** | 0.95** | -0.61** | 0.96** | -0.26 | 1.00 | | | |
| **X 9** | 0.85** | 0.74** | -0.85** | 0.95** | -0.58* | 0.96** | **-0.23** | 0.99** | 1-00 | | |
| **X10** | **-0.94**** | 0.49* | **-0.94**** | 0.99** | -0.79** | 0.99** | -0.67* | 0.92** | 0.92** | 1.00 | |
| **X11** | -0.90** | 0.68** | -0.90** | 0.97** | -0.65* | 0.97** | -0.34 | 0.98** | 0.99** | 0.96** | 1.00 |

X1 practical productivity, X2 fuel consumption, X3 specific productivity of tillage, X4 actual time for plowing one hectare, X5 volume of soil disturbed, X6 tractor fixed cost, X7 tractor variable costs, X8 tractor manage- ment costs, X9 total tractor costs, X 10 total plow costs, X11 total machinery unit costs.

-----Maximum direct (positive) and inverse (negative) correlations.

- - -Minimum direct (positive) and inverse (negative) correlations.

*Significant at L.S.D 0.05

**Significant at L.S.D 0.01

## Conclusion

In light of the findings of the experiment, it was concluded that increasing the speed of the tractor contributed to increasing the practical productivity, specific productivity of tillage and volume of soil disturbed, but also reduced fuel consumption, the actual time for plowing one hectare, fixed, management, total tractor, total plow and total machinery unit costs. The best tractor speed was 5.7 km.h$^{-1}$, which provided the best results. Increasing the depth of tillage leads to decreasing practical productivity and specific productivity of tillage. Fuel consumption, the actual time for plowing one hectare, the volume of soil disturbed, the fixed, the management, the total tractor, the total plow and total machinery unit costs increased when the tillage depth increased. Additionally, the tillage depth affected all operation costs, and the rest of the indicators were related more to the speed of the tractor. The best interaction was between a tractor speeds 5.7 km.h$^{-1}$, with 20 cm depth tillage. All interactions between treatments were significant. The correlations between the performance indicators and operation costs of the tractor and chisel plow were direct (positive), and the inverse (negative) correlations were also significant and not insignificant.

## Conflict of Interest

The author declares that there are no conflicts of interest regarding the publication of this manuscript.

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