Saudi Journal of Biological Sciences 28 (2021) 7152–7159

Contents lists available at ScienceDirect

Saudi Journal of Biological Sciences

journal homepage: www.sciencedirect.com

Original article

# Yield and yield components of maize and soil physical properties as affected by tillage practices and organic mulching

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ARTICLE INFO

*Article history:*
Received 9 November 2020
Revised 1 August 2021
Accepted 2 August 2021
Available online 9 August 2021

*Keywords:*
Bulk density
Maize
Soil water content
Straw mulching
Tillage practices
Yield and yield components

ABSTRACT

Maize (*Zea mays* L.) is an important grains cereal crop. Lots of farmers using tillage and mulching practices influence the final yield, to maintain up with the growing demand for food, fuel and feed. Field experiments were conducted to investigate the effects of tillage practices (i.e. conventional tillage CT, reduced tillage RT, deep tillage DT) and wheat straw mulching (i.e. no mulch and wheat straw mulch of 4, 8 and 12 Mg ha$^{-1}$, SM0, SM1, SM2 and SM3 respectively) on the growth, yield and yield components of maize and some of soil physical properties. The results showed that compared with RT, DT and CT decreased soil bulk density, as well as led to increase soil water content. Application of mulch treatments increased soil water content. DT and CT have been associated with greater plant height, yield components, grain and biomass yield than RT treatment. Plant height, yield components, grain and biomass yield as well as soil water content increased following mulching treatments. Mulching treatment of SM2 had the largest positive effects on maize yield. DT and CT that have potential to break the compacted zone in soil leading to a better soil environment and crop yield. The application of wheat straw mulch could be an efficient soil management practice for corn production in arid subtropical climate region.
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## 1. Introduction

Maize (*Zea mays* L.) is a widely grown crop, with respect to area cultivated and production, it exemplify among cereal crops the third important crop in the world after wheat and rice (Ansari et al., 2015; Božović et al., 2018; 2020). The cultivated area in Iraq for the year 2019 was about 128790 ha with a production rate of 3673.2 kg ha$^{-1}$ (The Central Organization of Statistics, 2019).

Maize is cultivated for animal provender and used in industrial products like starch, glucose and dextrose (FAO, 1999). Application of the diverse management practices that influence crop performance is a vital procedure in maize production. Tillage practices and mulching treatments are varied among many management aspects of growing a maize crop. The characteristics of different soil types and weather diversification at planting time differ between seasons. Planting maize early at the spring (February) may expose it to temperature rise during tasseling stage, which can reduce viability, production, and the release of pollen grains, while late planting at autumn (August) may affect uniformity of pollination, delay maturity and exposure the crop to rain, and consequently damage at the end of the season. Tillage practices considered one of the important factor among several factors accountable to maize yield (Rosner et al., 2008). Soil tillage is substantial factor in maize production as it representing setting up of any crop production method. It can maintains the reachable structure or enhances the poorly structured soils.

An organic loose covering that is placed on the soil surface can be considered as mulches. It assistances to reserve moisture, suppress weed germination, improving the soil consistency, modification soil temperature, protecting roots from high temperatures (Zamir et al., 2013). Mulch can reduce evaporation from the soil due to forming a cover shields (Mupangwa et al., 2007). Although the positive impact of straw mulching on plant growth and yield is well known, only a limited number of studies have been conducted to research the effect of different levels of application of straw mulching on plant growth in the southern area of Iraq under different tillage treatments.

Various tillage operations, in addition to crop residues application that ameliorate soil physicochemical characteristics and microbial activity are considered to be essential characteristics of productive farming (Reddy et al., 2002). In view of this, the current

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Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

https://doi.org/10.1016/j.sjbs.2021.08.005
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research was developed to study the impact of tillage and various levels of straw mulch on the yield of maize in silty clay soil, and to detect optimum tillage practice and rate of mulch under two different growing seasons.

## 2. Materials and methods

### 2.1. Description of study site

The study site was at Al-Qurna town, which is located in the Northwest of Basrah Province, Iraq. The area has warm-temperate continental monsoon climate characteristics. The wettest weather is in December. The study site was previously under wheat.

### 2.2. Experimental design and treatments

The experiment was established in 2020 and carried out for two vegetation seasons. The experiment arrangement was using a split plot in a randomized complete block design of three replications. The main plots consisted of RT (Reduced tillage with solid tine cultivator 10 cm), DT (Deep tillage with subsoiler up to 40 cm and mouldboard plowing 30 cm) and CT (Conventional tillage with mouldboard plow 20 cm). Each main plot was divided into four mulch subplots, with no mulch, and wheat straw mulch of 4, 8 and 12 Mg ha$^{-1}$ (SM0, SM1, SM2 and SM3 respectively).

Fertilizer was added in the form of urea (46 % N) at the rate of 300 kg ha$^{-1}$, half of the quantity was added at planting and all superphosphate fertilizer (46% $P_2O_5$) at a rate of 200 kg ha$^{-1}$ was added in one batch before planting, and the other half of nitrogen fertilizer added at the 40 cm plant height.

The main plot size was split into four 3 × 4.5 m subplots. Every subplot consisted of six rows with inter-row distance 0.70 m and distance between plants was 0.22 m. A 1 m wide open space separated the blocks. Maize (Zea mays L. var. LG30.179) was sown manually, three seeds per hill. Thinning was done four weeks after germination to a single plant per hill. Maize was planted on March 1, 2020 for the first season, and July 1, 2020 for the second season.

Wheat straw was added to all mulched treatments as surface mulch, which is equivalent to 4, 8 and 12 Mg ha$^{-1}$ during the first and second season. The second season experiment was done in the same field. All plots were hand-weeded using a hand hoe during the cropping periods as practiced by the farmers.

### 2.3. Climate data

The climate data of the experimental seasons were gathered from the closest meteorological stations (Table 1).

### 2.4. Sampling and laboratory study of soil

Table 2 and Table 3 give the physical and chemical properties of the soil at the experiment site. Composite soil samples (6 treatments per replication) were collected randomly at a depth of 0–40 cm to determine the physico-chemical characteristics of the soil prior to the experiment. The soil samples were obtained in the first and second seasons, one week before planting. On 1:2.5 soil / water suspensions with a glass electrode pH meter, the pH was calculated. According to the Olsen method (Olsen et al., 1954), usable phosphorus was calculated. Using atomic absorption photometers, exchangeable calcium and magnesium were estimated, while potassium was determined by flame photometry (Black et al., 1965). The study of soil texture was conducted using the Boycous hydrometric system (Black et al., 1965).

Soil sampling for tillage and mulch treatments effects was done at crop harvest. To measure soil bulk density and water content at 0–40 cm soil depth, with an interval of 10 cm, three randomly separate locations were chosen in each plot. By the core process, soil bulk density was measured (Jabro et al., 2021). During the first and second seasons of the experiment, soil cores were taken to a depth of 40 cm in each plot and cut into increments of 10 cm. For determination of bulk density and gravimetric soil water quality, the cores were dried in the oven at 105 °C for 48 h.

The bulk density was calculated according to Eq. (1).

$$\rho_b = m/v \tag{1}$$

where $\rho_b$ is the bulk density of the soil, g cm$^{-3}$, $m$ is the dry weight of the soil, g and $v$ is the sample volume, cm$^3$.

Water content was determined from cores samples, which were collected by core sampler (Black et al., 1993).

$$\theta g = \frac{W_{wet} - W_{dry}}{W_{dry}} \times 100 \tag{2}$$

where:

$\theta g$ = water content (%)

$W_{wet}$ = weight of the wet soil sample (g)

$W_{dry}$ = weight of the dried soil sample (g)

The soil physical and the chemical properties are presented in Table 2 and Table 3.

### 2.5. Agronomic data and measurements

The plant sampling was done at crop harvest. Crop was grown up to maturity. The plants were harvested on June 26, 2020 in the first season and on October 21, 2020 in the second season. The agronomic data collected include plant height (cm), number of cobs plant$^{-1}$, number of grains cob$^{-1}$, number of rows cob$^{-1}$, 500 grain weight (g), grain yield (kg ha$^{-1}$), biological yield (kg ha$^{-1}$), harvest index (%) and shoot and roots dry weight (g). Plant height was measured from the ground level to the base of the tassel for five randomly selected plants per plot.

After harvesting the entire plot, the grain yield was measured in kg ha$^{-1}$ and modified to a 14 percent grain moisture content. The biological yield was reported by weighing all the plants harvested and then converted into kg ha$^{-1}$ from each plot.

The cobs harvested for grain yield were also used by taking five cobs randomly from each subplot sample to estimate the number of cob$^{-1}$ grains, then dried and shelled to count the cob$^{-1}$ grains. By counting 500 grains at random, data concerning 500 grain weight was registered and then weighed with an electronic balance.

Five whole plants were randomly sampled from each sub-plot at the stage 5 of maize vegetative growth, and then the plant shoot and roots were separated and drayed to determine biomass.

**Table 1**
Mean precipitation, air temperature and humidity during two growing seasons.

| | Temperature C ° | | | |
|---|---|---|---|---|
| | Max | Min | Humidity % | Rainfall mm |
| Mar | 27.72 | 12.28 | 18.69 | 17.7 |
| Apr | 35.30 | 19.90 | 11.92 | 0.00 |
| May | 41.75 | 24.00 | 7.95 | 0.00 |
| Jun | 46.16 | 26.92 | 5.31 | 0.00 |
| Jul | 49.37 | 29.51 | 4.51 | 0.00 |
| Aug | 45.46 | 26.51 | 9.00 | 0.00 |
| Sep | 42.34 | 25.91 | 11.80 | 0.00 |
| Oct | 37.76 | 15.50 | 5.90 | 0.00 |

**Table 2**
Physical characteristics of soil at the experimental site before planting.

| Depth cm | $\theta g$ % | $\rho b$ g cm$^{-3}$ |
|---|---|---|
| | 1st season | |
| 0–10 | 10.15 | 1.497 |
| 10–20 | 9.65 | 1.495 |
| 20–30 | 11.76 | 1.529 |
| 30–40 | 15.21 | 1.492 |
| 40–50 | 20.22 | 1.508 |
| 50–60 | 21.72 | 1.479 |
| 2nd season | | |
| 0–10 | 10.26 | 1.495 |
| 10–20 | 10.36 | 1.497 |
| 20–30 | 11.98 | 1.524 |
| 30–40 | 16.28 | 1.487 |
| 40–50 | 20.37 | 1.503 |
| 50–60 | 21.97 | 1.484 |

### 2.6. Statistical analyses

The statistical analyses were implemented using GenStat. version 12. The collected data was analyzed statistically using the analysis of variance (ANOVA). The means of measured agronomic traits were compared by the least significant difference (LSD) test at 5% significance level. The data was analyzed as a split plot arrangement in a randomized complete block design for agronomic traits, and as a split-split plot arrangement in a randomized complete block design for bulk density and water content data (Cochran and Cox, 1957). Only significant effects were discussed.

## 3. Results

### 3.1. Plant height

Plant height as a major aspect of the biomass partitioning patterns, reflects the development achieved during the growth period. The data showed that plant height was significantly affected by tillage systems (Table 4). The tallest plants were recorded in DT and CT (183.45, 182.00 cm and 184.27, 180.48 cm in the 1st and 2nd season respectively). Short plants were recorded in RT (170.23 and 169.69 cm in the 1st and 2nd season respectively).

Respecting mulch level, the results showed a significant effect on the plant height. In the 1st season, the highest values were 184.47, 181.77 and 179.49 cm for SM3, SM2 and SM1, respectively, without statistically significant, compared to the SM0 treatment, which gave the lowest plant height of 168.51 cm. The mean maximum height in the 2nd season 186.66 cm of plant was obtained at SM3 mulch treatment, whereas minimum plant height of 170.03 cm was obtained in control treatment (SM0).

The interaction between tillage systems and mulch was significant in the 1st season. Higher plants (195.65 cm) was recorded for CTxSM3 as compared to RTxSM0 (159.61 cm).

### 3.2. Number of grain per cob

The statistical data analysis showed that cob$^{-1}$ grains were significantly impacted by tillage systems, mulch levels ($P < 0.01$) and their interaction ($P < 0.05$) (Table 4). Higher number of grains cob$^{-1}$ (316.76 and 368.82 in the 1st and 2nd season respectively) were recorded in DT as compare with RT (266.14 and 318.44 in the 1st and 2nd season respectively).

It was found from ANOVA that number of grain per cob was significantly affected by mulch treatments. It can be seen from Table 4 that all mulch levels experienced higher number of grain cob$^{-1}$ compared to control treatment SM0 at the both season.

Interaction between tillage systems and mulch was also remained significant in both vegetation seasons (Table 4). In the 1st season, the interaction treatments DTxSM1 and DTxSM3 gave the highest number of grain per cob of 334.38 and 329.19 grain cob$^{-1}$ compared with RTxSM0 which it gave the lowest value (243.73 grain cob$^{-1}$). Higher number of grain per cob (387.63 and 386.31 grain cob$^{-1}$, respectively, without differences between them) was recorded in DTxSM1 and DTxSM3 in the 2nd season than RTxSM1 and RTxSM0 (314.02 and 297.51 grain cob$^{-1}$, respectively, without differences between them).

### 3.3. 500-Grain weight

Tillage systems had significant effects on 500-grains weight ($P < 0.05$) in 1st season and ($P < 0.01$) in 2nd season (Table. 4). The highest weight were obtained from the DT treatment (118.72 g and 121.63 g in the 1st, and 2nd season respectively) compared to the RT which was not different from CT (104.35 g and 106.81 g in the 1st, and 2nd season respectively).

Mulch significantly ($P < 0.01$) in 1st season and ($P < 0.05$) in 2nd season affected 500-grain weight of maize. In the 1st season the SM2 mulching treatment recorded higher 500-grain weight of 117.32 g while it was 105.73 g and 102.83 g for SM3 and SM0, respectively, without differences between them. The 500-grain weight in the 2nd season were maximum (115.35 g, 113.48 g, 112.31 g) when mulch was applied at SM2, SM1, SM3, respectively, without differences between them, while minimum value of (106.91 g) was obtained from control treatment (SM0).

### 3.4. Number of cobs per plant

The tillage systems, mulching treatment and interaction between tillage systems and mulching treatment had non-significant effect on number of cobs per plant throughout the both cropping season (Table 4).

### 3.5. Number of rows per cob

The data regarding the number of rows per cob revealed that tillage systems, mulching treatments and interaction between them significantly affected the number of rows per cob. In the 1st season, the greatest number of rows per cob was 15.31 rows cob$^{-1}$ at the CT, comparing with 14.06 rows cob$^{-1}$ for RT (Table 4). The DT and CT treatments significantly increased number of rows per cob (14.44 rows cob$^{-1}$ and 14.04 rows cob$^{-1}$, respectively, without differences between them), compared to RT (13.77 rows cob$^{-1}$), in the 2nd season, while there was not a significant difference between the RT and CT treatments.

**Table 3**
Physical and chemical properties of the soil at experimental site.

| Seasons | Physical Properties | | | | Chemical Properties | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sand % | Silt % | Clay % | Texture | EC[†] dS m$^{-1}$ | PH | Soluble cation (mEq L$^{-1}$) | | | | Soluble anion (mEq L$^{-1}$) | | |
| | | | | | | | $Na^+$ | $Ca^{++}$ | $Mg^+$ | $K^+$ | $HCO_3^-$ | $Cl^-$ | $SO_4$ |
| 1st season | 13.75 | 42.32 | 43.93 | Silty Clay | 10.12 | 7.60 | 36.32 | 36 | 32 | 4.45 | 1.8 | 85.4 | 19.22 |
| 2nd season | 14.34 | 41.42 | 44.24 | Silty Clay | 8.42 | 7.66 | 34.74 | 32 | 25 | 4.61 | 1.4 | 75.6 | 17.47 |

† Electrical conductivity.

**Table 4**
Effect of tillage systems, mulching treatments and their interactions on the studied traits of corn at both cropping seasons.

| Treatments | Plant height cm | Number of grain per cob | 500 grain weight g | No. of cobs per plant | Number of rows per cob | Grain yield kg $h^{-1}$ | Biomass yield kg $h^{-1}$ | Harvest index % | Shoot biomass g | Root biomass g |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1st Season | | | | | |
| RT | 170.23 | 266.14 | 104.35 | 1.55 | 14.06 | 3410.2 | 12742.2 | 26.61 | 19.09 | 7.01 |
| DT | 183.45 | 316.76 | 118.72 | 1.56 | 14.55 | 4553.6 | 13290.5 | 34.17 | 19.34 | 7.19 |
| CT | 182.00 | 284.15 | 104.77 | 1.69 | 15.31 | 3923.8 | 13252.1 | 29.73 | 19.26 | 7.14 |
| LSD | 5.99** | 14.77** | 10.38* | ns | 0.41** | 770.7* | 336.3* | 5.39* | 0.091** | 0.0831** |
| SM0 | 168.51 | 268.78 | 102.83 | 1.42 | 13.42 | 2948.6 | 12517.9 | 23.53 | 18.78 | 6.64 |
| SM1 | 179.49 | 298.39 | 111.24 | 1.57 | 14.35 | 4114.5 | 13004.4 | 31.66 | 19.15 | 6.85 |
| SM2 | 181.77 | 294.09 | 117.32 | 1.67 | 15.50 | 4447.3 | 13358.7 | 33.27 | 19.35 | 7.24 |
| SM3 | 184.47 | 294.81 | 105.73 | 1.74 | 15.29 | 4339.7 | 13498.8 | 32.20 | 19.63 | 7.72 |
| LSD | 6.71** | 11.81** | 5.09** | ns | 1.46* | 829** | 713.6* | 6.70* | 0.096** | 0.112** |
| RTxSM0 | 159.61 | 243.73 | 97.01 | 1.29 | 12.71 | 1998.8 | 12318.4 | 16.18 | 18.75 | 6.61 |
| RTxSM1 | 178.65 | 262.85 | 106.93 | 1.57 | 13.67 | 3541.1 | 12585.3 | 28.11 | 19.08 | 6.75 |
| RTxSM2 | 170.37 | 287.82 | 114.06 | 1.53 | 15.12 | 4292.3 | 13043.4 | 32.85 | 19.24 | 7.02 |
| RTxSM3 | 172.29 | 270.15 | 99.4 | 1.81 | 14.74 | 3808.4 | 13021.6 | 29.28 | 19.28 | 7.65 |
| DTxSM0 | 171.67 | 288.33 | 113.19 | 1.42 | 13.76 | 3611.6 | 12430.8 | 29.04 | 18.82 | 6.54 |
| DTxSM1 | 186.13 | 334.38 | 123.16 | 1.47 | 13.48 | 4682.4 | 13167.3 | 35.51 | 19.23 | 6.78 |
| DTxSM2 | 190.54 | 315.14 | 127.59 | 1.60 | 15.59 | 4920.2 | 13788.5 | 35.75 | 19.46 | 7.55 |
| DTxSM3 | 185.46 | 329.19 | 110.93 | 1.73 | 15.37 | 5000.1 | 13775.5 | 36.37 | 19.85 | 7.91 |
| CTxSM0 | 174.25 | 274.29 | 98.29 | 1.55 | 13.78 | 3235.3 | 12804.4 | 25.38 | 18.76 | 6.78 |
| CTxSM1 | 173.69 | 297.93 | 103.62 | 1.65 | 15.91 | 4119.8 | 13260.5 | 31.36 | 19.16 | 7.03 |
| CTxSM2 | 184.42 | 279.30 | 110.30 | 1.88 | 15.78 | 4129.3 | 13244.2 | 31.22 | 19.37 | 7.14 |
| CTxSM3 | 195.65 | 285.09 | 106.87 | 1.69 | 15.78 | 4210.7 | 13699.3 | 30.96 | 19.76 | 7.61 |
| LSD | 10.9* | 20.77* | ns | ns | ns | ns | ns | ns | 0.157** | 0.178** |
| | | | | | 2nd Season | | | | | |
| RT | 169.69 | 318.44 | 106.81 | 1.40 | 13.77 | 4091.0 | 14284.3 | 28.58 | 21.09 | 8.02 |
| DT | 184.27 | 368.82 | 121.63 | 1.38 | 14.44 | 5062.3 | 14772.1 | 34.28 | 21.58 | 8.30 |
| CT | 180.48 | 335.78 | 107.6 | 1.57 | 14.04 | 4850.7 | 14659.3 | 33.11 | 21.44 | 8.21 |
| LSD | 7.03* | 7.36** | 4.55** | ns | 0.41* | 703.0* | 362.7* | ns | 0.237** | 0.1319** |
| SM0 | 170.03 | 320.37 | 106.91 | 1.38 | 13.74 | 3591.4 | 14057.5 | 25.55 | 20.66 | 7.56 |
| SM1 | 176.18 | 351.93 | 113.48 | 1.39 | 14.17 | 5038.1 | 14475.0 | 34.84 | 21.01 | 8.20 |
| SM2 | 179.72 | 345.29 | 115.35 | 1.53 | 14.33 | 5103.1 | 14801.3 | 34.46 | 21.72 | 8.36 |
| SM3 | 186.66 | 346.46 | 112.31 | 1.52 | 14.11 | 4939.5 | 14953.8 | 33.13 | 22.09 | 8.57 |
| LSD | 5.34** | 13.49** | 5.35* | ns | 0.4* | 1193.1* | 643.7* | ns | 0.157** | 0.1374** |
| RTxSM0 | 162.41 | 297.51 | 102.06 | 1.37 | 14.25 | 3136.6 | 13859.7 | 22.48 | 20.63 | 7.53 |
| RTxSM1 | 170.75 | 314.02 | 108.37 | 1.40 | 13.39 | 4308.0 | 14172.1 | 30.46 | 20.88 | 7.86 |
| RTxSM2 | 171.23 | 336.93 | 109.04 | 1.46 | 13.82 | 4425.9 | 14488.7 | 30.53 | 21.06 | 8.10 |
| RTxSM3 | 174.37 | 325.29 | 107.77 | 1.36 | 13.65 | 4493.7 | 14616.6 | 30.86 | 21.80 | 8.56 |
| DTxSM0 | 172.22 | 337.39 | 116.54 | 1.19 | 13.52 | 3614.5 | 14246.2 | 25.34 | 20.74 | 7.63 |
| DTxSM1 | 181.70 | 387.63 | 124.16 | 1.40 | 14.56 | 5796.9 | 14669.2 | 39.66 | 21.17 | 8.44 |
| DTxSM2 | 187.61 | 363.97 | 125.95 | 1.50 | 14.87 | 5617.5 | 14985.0 | 37.52 | 22.13 | 8.52 |
| DTxSM3 | 195.55 | 386.31 | 119.85 | 1.44 | 14.81 | 5220.3 | 15187.8 | 34.62 | 22.25 | 8.61 |
| CTxSM0 | 175.46 | 326.22 | 102.14 | 1.57 | 13.44 | 4023.0 | 14066.4 | 28.83 | 20.60 | 7.53 |
| CTxSM1 | 176.08 | 354.15 | 107.90 | 1.36 | 14.56 | 5009.5 | 14583.7 | 34.40 | 20.97 | 8.30 |
| CTxSM2 | 180.31 | 334.97 | 111.06 | 1.62 | 14.29 | 5265.8 | 14930.1 | 35.32 | 21.97 | 8.45 |
| CTxSM3 | 190.06 | 327.79 | 109.32 | 1.75 | 13.86 | 5104.5 | 15056.8 | 33.91 | 22.21 | 8.55 |
| LSD | ns | 20.81* | ns | ns | 0.66** | ns | ns | ns | 0.296** | 0.2261* |

*, ** Significantly different at 0.05 and 0.01 probability levels, respectively ns: not significant.

The results indicated that mulching treatments significantly ($P < 0.05$) affect the number of rows $cob^{-1}$ (Table 4). The maximum number of rows per cob in the 1st season 15.50 rows $cob^{-1}$, 15.29 rows $cob^{-1}$ and 14.35 rows $cob^{-1}$ recorded at SM2, SM3 and SM1, respectively, without significant differences between them, whilst SM0 and SM1 gave the lowest values of 13.42 and 14.35 respectively without significant differences between them. The results also showed that the higher number of rows per cob in the 2nd season was 14.33, 14.17 and 14.11 was found in SM2, SM1 and SM3 respectively without differences between them, while the minimum number of rows per cob 13.74 rows $cob^{-1}$ was observed in control treatment (SM0).

The interaction between tillage systems and mulching treatments was significant ($P < 0.01$) in the 2nd season. Higher number of rows per cob (14.87 rows $cob^{-1}$, 14.81 rows $cob^{-1}$, 14.56 rows $cob^{-1}$, 14.56 rows $cob^{-1}$, 14.29 rows $cob^{-1}$ and 14.25 rows $cob^{-1}$ respectively, without differences between them) were recorded in DTxSM2, DTxSM3, CTxSM1, DTxSM1, CTxSM2 and RTxSM0, respectively, while lower number of rows per cob (13.39 rows $cob^{-1}$, 13.44 rows $cob^{-1}$, 13.52 rows $cob^{-1}$, 13.65 rows $cob^{-1}$, 13.82 rows $cob^{-1}$, 13.86 rows $cob^{-1}$ and 14.25 rows $cob^{-1}$) which were recorded in RTxSM1, CTxSM0, DTxSM0, RTxSM3, RTxSM2, CTxSM3 and RTxSM0, respectively, without differences between them.

### 3.6. Grain yield

Tillage systems ($P < 0.05$) and mulching treatments ($P < 0.01$ for the 1st season, $P < 0.05$ for the 2nd season) have statistically significantly grain yield. During the 1st season, the DT and CT treatments gave the highest maize yield of 4553.6 kg $h^{-1}$ and 3923.8 kg $h^{-1}$ without differences between them compared to RT, which it gave 3410.2 kg $h^{-1}$ which in turn doesn't different from CT. Correspondingly, in the 2nd season, the maize yield was highest at DT and CT

(5062.3 kg $h^{-1}$ and 4850.7 kg $h^{-1}$ without differences between them) compared to RT (4091.0 kg $h^{-1}$).

In general, adding mulch increased grain yield significantly compared with control treatment. The highest mean of grain yield was recorded under SM2 of 4447.3 kg $h^{-1}$ and 5103.1 kg $h^{-1}$ in the 1st and 2nd season, respectively, which does not differ from SM3 and SM1 in the 1st season and SM1 and SM3 in the 2nd season.

### 3.7. Biomass yield

Different tillage systems had significant effect ($P < 0.05$) on biomass production (Table 4). DT and CT treatment had higher biomass production of 13290.5 kg $h^{-1}$ and 13252.1 kg. $ha^{-1}$, respectively, in 1st season, and 14772.1 kg $h^{-1}$ and 14659.3 kg. $ha^{-1}$, respectively, in the 2nd season, compared to 12742.2 kg $h^{-1}$ and 14284.3 kg $ha^{-1}$ in the 1st and 2nd season, respectively, for RT treatment.

Biomass production varied significantly ($P < 0.05$) due to different mulching treatments of maize. It was observed that biomass production increased gradually and significantly by increasing mulch levels. The maximum biomass production was observed in wheat mulch of SM3, SM2 and SM1 without differences between them (13498.8, 13358.7 and 13004.4 kg $ha^{-1}$ in the 1st season and 14953.8 kg $h^{-1}$, 14801.3 kg $h^{-1}$ and 14475.0 kg $ha^{-1}$ in the 2nd season) whereas the minimum mean was recorded for SM0 (12517.9 and 14057.5 kg $ha^{-1}$ in the 1st and 2nd season respectively).

### 3.8. Harvest index

Tillage systems had significant effects ($P < 0.05$) in the 1st season on harvest index (Table 4). The highest value of 34.166% was recorded from the DT treatment; meanwhile it was 26.605% for the RT treatment.

Harvest index was affected significantly ($P < 0.05$) by the mulching treatments in the 1st season (Table 4). The maximum mean of harvest index was 33.270%, 32.202% and 31.661% observed in SM2, SM3 and SM1 treatments that did not differ significantly from each other, whereas minimum mean value of 23.532% was observed in control treatment SM0.

### 3.9. Shoot biomass

Table 4, showed that tillage systems, mulching treatments and interaction between them significantly ($P < 0.01$) affected shoot dry weight of maize. The highest value (19.34 and 21.58 g in the 1st and 2nd season, respectively) was obtained at DT, while the lowest value (19.09 g and 21.09 g in the 1st and 2nd season, respectively) was obtained at RT.

The highest shoot dry weight (19.63 g and 22.09 g for the 1st and 2nd season, respectively) was found in SM3, which was significantly higher than the other mulching levels. The lowest shoot dry weight (18.78 g and 20.66 g for the 1st and 2nd season, respectively) was recorded in SM0.

The highest shoot dry weight was 19.85 g and 22.25 g in the 1st and 2nd season respectively for DT × SM3 treatment, while the lowest shoot dry weight was 18.75 g in the 1st season for RT × SM0 and 20.60 g in the 2nd season for CT × SM0 (Table 4).

### 3.10. Root biomass

It was observed that root dry weight was significantly ($P < 0.01$) variable among different tillage practices (Table 4). The maximum root dry weight (7.19 g and 8.30 g for the 1st and 2nd season, respectively) was found in DT, while the minimum root dry weight (7.01 g and 8.02 g for the 1st and 2nd season, respectively) was noted in RT.

Among mulching levels treatments, SM3 performed better in improving the root dry weight over all tillage practices as compared to SM0, for the both years (Table 4). During the 1st, and 2nd season, significant effect was recorded for root dry weight with highest value of 7.72 g and 8.57 g for the 1st and 2nd season, respectively for SM3 compared with 6.64 g and 7.56 g for the 1st, and 2nd season under SM0 treatment. In the same direction, the interaction was significant in the 1st ($P < 0.01$) and 2nd ($P < 0.05$) season, respectively, for the root dry weight. A highest value was 7.91 g and 8.61 g for DT × SM3, while the lowest was 6.54 g and 7.53 g for DT × SM0 and CT × SM0 respectively, for two consecutive growing seasons (Table 4).

### 3.11. Bulk density

Bulk density, as a mass-related soil compaction sign, represents an important indicator of soil hardness (Liu et al., 2020). Soil bulk density was significantly ($P < 0.05$) affected by soil tillage (Table 5). It was lower for the DT (1.38, 1.36 g $cm^{-3}$ in 1st, and 2nd season, respectively) and CT (1.42 g $cm^{-3}$, 1.39 g $cm^{-3}$ in 1st, and 2nd season, respectively) treatments without differences between them, compared to the RT treatment (1.45 g $cm^{-3}$, 1.43 g $cm^{-3}$ in 1st, and 2nd season, respectively). The RT treatment, in turns, does not deferent from CT in the both seasons.

The effect of mulching treatments on soil bulk density are presented in Table 5. It was observed that soil bulk density in the 2nd season decreased gradually with increasing mulch level from SM0 to SM3. However, result indicated that higher mean values of bulk density were recorded under SM0, SM1 and SM2 of 1.45 g $cm^{-3}$, 1.43 g $cm^{-3}$ and 1.37 g $cm^{-3}$, respectively, without differences between them, compared with lowest mean value of 1.32 g $cm^{-3}$ which was recorded under SM3 treatment which in turns doesn't deferent from SM2.

Soil depth affected statistically significantly ($P < 0.01$) for the first season, and ($P < 0.05$) for the second season on bulk density. Soil bulk density increased gradually with increasing soil depth. The higher mean value (1.47 g $cm^{-3}$ and 1.46 g $cm^{-3}$ in 1st, and 2nd season respectively) were recorded at the subsurface soil layer of (40 cm) depth and lower mean value (1.36 g $cm^{-3}$ and 1.33 g $cm^{-3}$ in 1st, and 2nd season, respectively) were at the surface layer (10 cm) as indicated on (Table 5). The interaction of tillage systems and mulching treatments is not significant (Table 6).

**Table 5**
Effect of tillage practices, organic mulching and depths on soil bulk density at both cropping seasons.

| | Bulk density (g $cm^{-3}$) | |
|---|---|---|
| Treatments | 1st Season | 2nd Season |
| RT | 1.45 | 1.43 |
| DT | 1.38 | 1.36 |
| CT | 1.42 | 1.39 |
| LSD | 0.045* | 0.0506* |
| SM0 | 1.47 | 1.45 |
| SM1 | 1.40 | 1.43 |
| SM2 | 1.41 | 1.37 |
| SM3 | 1.38 | 1.32 |
| LSD | ns | 0.0858* |
| 10 | 1.36 | 1.33 |
| 20 | 1.38 | 1.37 |
| 30 | 1.45 | 1.42 |
| 40 | 1.47 | 1.46 |
| LSD | 0.0635** | 0.0902* |

*, ** Significantly different at 0.05 and 0.01 probability levels, respectively ns: not significant.

The results also showed that bulk density decreased significantly compared with the values before conducting the experiment (Table 2), (t Stat = 0.0390*) in 1st season, and (t Stat = 3.633*) in 2nd season respectively.

### 3.12. Soil water content

Tillage practices significantly ($P < 0.05$) affected soil water content at both seasons (Table 7). In the 1st season the higher soil water content of 30.53% and 27.03% were recorded under DT and CT, respectively, without significant differences between them, while it was 22.31% for RT treatment, which in turns does not differ significantly from CT treatment. The higher soil water content (at harvest) in the 2nd season was found under DT and CT without significant differences between them (27.83% and 26.38%, respectively) compared to 21.79%, which was recorded under RT. The statistical analysis of the data revealed that soil water content was significantly ($P < 0.01$) affected by mulching treatments (Table 7). In general, soil water content increased as increasing mulch levels. The highest water content in the 1st season was recorded for SM3 and SM2 mulching treatments, which it gave 32.57% and 27.73%, respectively without differences between them, compared to 20.28%, which was recorded under SM0 treatment. In the 2nd season, the highest water content was recorded under SM3 mulching treatment (31.26%), while it was 20.35% and 23.42% under SM0 and SM1 treatments, respectively, without differences between them. No significant interaction between tillage practices, organic mulching and soil depths was observed (Table 8).

The results also showed that soil water content increased significantly compared with the values before conducting the experiment (Table 2), (t Stat = 16.041**) in 1st season, and (t Stat = 7.104**) in 2nd season respectively.

## 4. Discussion

Higher plants under DT and CT systems could be due to encouraging the emergence and early growth of plants compared with RT. Similar result was also reported by Qamar and Khan (2014), where they noticed that higher plants were recorded in deep tillage and lower plant height was found in minimum tillage in maize. The increase in plant height due to mulching effects could have resulted from more soil moisture retention over the growth period in combination with lower soil temperature.

The increase in the number of grains per cob might be due to lower bulk density under DT, that might have facilitated plant root proliferation in the soil and increased the rate of water, air and nitrogen movement. The last plays an important role in tissue development, cell division, enhance plant growth, and thereby increased number of grains per cob. The results of this study were in accordance with results of Zamir et al. (2014) who reported that mulching materials had a significant effect on the number of grains per cob, with maximum number of grains per cob (459.89) obtained where stalk mulch was used followed by grass clipping mulch, while the plots without mulch gave the minimum number of grains per cob (340.29).

The higher grains weight per cob for DT might be due to alleviation of soil compaction causing increased uptake of the essential nutrient. Adding mulch increased grain weight and such findings

**Table 7**
Effect of tillage practices, organic mulching and depths on soil water content at both cropping seasons.

| | Water content % | |
|---|---|---|
| Treatments | 1st Season | 2nd Season |
| RT | 22.31 | 21.79 |
| DT | 30.53 | 27.83 |
| CT | 27.03 | 26.38 |
| LSD | 5.641* | 3.22* |
| SM0 | 20.28 | 20.35 |
| SM1 | 25.91 | 23.42 |
| SM2 | 27.73 | 26.31 |
| SM3 | 32.57 | 31.26 |
| LSD | 5.319** | 4.08** |
| 10 | 25.72 | 24.68 |
| 20 | 26.59 | 27.31 |
| 30 | 26.48 | 24.90 |
| 40 | 27.71 | 24.45 |
| LSD | ns | ns |

*, ** Significantly different at 0.05 and 0.01 probability levels, respectively ns: not significant.

**Table 6**
Soil bulk density (g $cm^{-3}$) as affected by interaction effect of tillage practices, organic mulching and soil depths during both cropping seasons.

1st Season

| | | | | | |
|---|---|---|---|---|---|
| | SM0 | SM1 | SM2 | SM3 | |
| CT | 1.488 | 1.437 | 1.456 | 1.341 | |
| DT | 1.431 | 1.380 | 1.356 | 1.368 | |
| RT | 1.527 | 1.395 | 1.422 | 1.437 | |
| | 10 | 20 | 30 | 40 | |
| CT | 1.365 | 1.396 | 1.430 | 1.492 | |
| DT | 1.274 | 1.401 | 1.419 | 1.441 | |
| RT | 1.428 | 1.355 | 1.509 | 1.488 | |
| | 10 | 20 | 30 | 40 | |
| SM0 | 1.423 | 1.478 | 1.496 | 1.477 | |
| SM1 | 1.342 | 1.304 | 1.473 | 1.497 | |
| SM2 | 1.347 | 1.388 | 1.434 | 1.477 | |
| SM3 | 1.311 | 1.366 | 1.407 | 1.443 | |
| | | SM0 | SM1 | SM2 | SM3 |
| CT | 10 | 1.477 | 1.39 | 1.372 | 1.251 |
| | 20 | 1.404 | 1.365 | 1.558 | 1.257 |
| | 30 | 1.464 | 1.491 | 1.401 | 1.364 |
| | 40 | 1.476 | 1.502 | 1.495 | 1.493 |
| DT | 10 | 1.289 | 1.33 | 1.256 | 1.222 |
| | 20 | 1.559 | 1.345 | 1.324 | 1.376 |
| | 30 | 1.463 | 1.367 | 1.354 | 1.490 |
| | 40 | 1.413 | 1.478 | 1.490 | 1.383 |
| RT | 10 | 1.534 | 1.306 | 1.412 | 1.460 |
| | 20 | 1.47 | 1.202 | 1.283 | 1.465 |
| | 30 | 1.562 | 1.561 | 1.547 | 1.368 |
| | 40 | 1.541 | 1.510 | 1.445 | 1.454 |

2nd Season

| | | | | | |
|---|---|---|---|---|---|
| | SM0 | SM1 | SM2 | SM3 | |
| CT | 1.451 | 1.433 | 1.364 | 1.312 | |
| DT | 1.452 | 1.391 | 1.358 | 1.239 | |
| RT | 1.456 | 1.464 | 1.389 | 1.416 | |
| | 10 | 20 | 30 | 40 | |
| CT | 1.263 | 1.372 | 1.472 | 1.453 | |
| DT | 1.332 | 1.365 | 1.334 | 1.410 | |
| RT | 1.392 | 1.367 | 1.46 | 1.506 | |
| | 10 | 20 | 30 | 40 | |
| SM0 | 1.416 | 1.431 | 1.441 | 1.523 | |
| SM1 | 1.356 | 1.420 | 1.475 | 1.467 | |
| SM2 | 1.319 | 1.344 | 1.372 | 1.447 | |
| SM3 | 1.224 | 1.277 | 1.400 | 1.388 | |
| | | SM0 | SM1 | SM2 | SM3 |
| CT | 10 | 1.386 | 1.264 | 1.250 | 1.150 |
| | 20 | 1.433 | 1.406 | 1.393 | 1.257 |
| | 30 | 1.481 | 1.540 | 1.337 | 1.529 |
| | 40 | 1.504 | 1.521 | 1.475 | 1.313 |
| DT | 10 | 1.441 | 1.376 | 1.336 | 1.175 |
| | 20 | 1.460 | 1.418 | 1.356 | 1.226 |
| | 30 | 1.377 | 1.362 | 1.387 | 1.211 |
| | 40 | 1.528 | 1.409 | 1.355 | 1.346 |
| RT | 10 | 1.422 | 1.429 | 1.372 | 1.347 |
| | 20 | 1.400 | 1.434 | 1.283 | 1.350 |
| | 30 | 1.466 | 1.524 | 1.391 | 1.461 |
| | 40 | 1.536 | 1.47 | 1.512 | 1.505 |

**Table 8**
Effect of interaction of tillage practices, organic mulching and depths on soil water content (%) at both cropping seasons.

| | 1st Season | | | | | | 2nd Season | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | SM0 | SM1 | SM2 | SM3 | | | SM0 | SM1 | SM2 | SM3 | |
| CT | 18.23 | 28.8 | 27.29 | 33.80 | | CT | 21.82 | 23.98 | 27.28 | 32.45 | |
| DT | 24.88 | 28.58 | 31.8 | 36.85 | | DT | 22.10 | 26.72 | 28.92 | 33.58 | |
| RT | 17.73 | 20.36 | 24.12 | 27.05 | | RT | 17.12 | 19.55 | 22.73 | 27.76 | |
| | 10 | 20 | 30 | 40 | | | 10 | 20 | 30 | 40 | |
| CT | 27.70 | 27.50 | 26.74 | 26.17 | | CT | 25.73 | 28.57 | 25.8 | 25.42 | |
| DT | 30.42 | 29.66 | 29.76 | 32.24 | | DT | 26.29 | 28.74 | 27.65 | 28.64 | |
| RT | 19.03 | 22.6 | 22.93 | 24.70 | | RT | 22.02 | 24.63 | 21.23 | 19.28 | |
| | 10 | 20 | 30 | 40 | | | 10 | 20 | 30 | 40 | |
| SM0 | 21.39 | 21.24 | 18.94 | 19.54 | | SM0 | 21.17 | 21.97 | 19.39 | 18.85 | |
| SM1 | 22.99 | 25.65 | 25.58 | 29.43 | | SM1 | 23.02 | 25.62 | 23.51 | 21.51 | |
| SM2 | 27.00 | 26.99 | 29.46 | 27.49 | | SM2 | 24.91 | 28.73 | 25.22 | 26.38 | |
| SM3 | 31.49 | 32.46 | 31.96 | 34.36 | | SM3 | 29.63 | 32.93 | 31.45 | 31.05 | |
| | | SM0 | SM1 | SM2 | SM3 | | | SM0 | SM1 | SM2 | SM3 |
| CT | 10 | 22.52 | 23.38 | 28.94 | 35.98 | CT | 10 | 22.58 | 23.79 | 24.7 | 31.87 |
| | 20 | 20.88 | 27.93 | 28.21 | 32.96 | | 20 | 24.39 | 25.90 | 29.68 | 34.31 |
| | 30 | 15.29 | 30.71 | 28.77 | 32.17 | | 30 | 21.32 | 22.91 | 26.08 | 32.90 |
| | 40 | 14.21 | 33.16 | 23.24 | 34.08 | | 40 | 18.98 | 23.31 | 28.68 | 30.73 |
| DT | 10 | 25.36 | 28.85 | 30.80 | 36.65 | DT | 10 | 22.13 | 25.18 | 26.77 | 31.10 |
| | 20 | 23.75 | 27.57 | 30.14 | 37.18 | | 20 | 22.38 | 28.49 | 29.65 | 34.43 |
| | 30 | 26.30 | 25.6 | 31.23 | 36.03 | | 30 | 21.31 | 26.53 | 28.29 | 34.49 |
| | 40 | 24.12 | 32.30 | 35.02 | 37.52 | | 40 | 22.60 | 26.67 | 30.96 | 34.31 |
| RT | 10 | 16.29 | 16.73 | 21.26 | 21.84 | RT | 10 | 18.81 | 20.08 | 23.26 | 25.92 |
| | 20 | 19.10 | 21.46 | 22.62 | 27.22 | | 20 | 19.15 | 22.47 | 26.85 | 30.04 |
| | 30 | 15.23 | 20.44 | 28.37 | 27.67 | | 30 | 15.55 | 21.09 | 21.31 | 26.97 |
| | 40 | 20.29 | 22.83 | 24.22 | 31.46 | | 40 | 14.96 | 14.56 | 19.50 | 28.11 |

are also in line with those of Zamir et al. (2014), who concluded that the plots receiving maize stalk mulch at the rate of 5 tones $ha^{-1}$ is attributed to the highest (248.64 g) 1000-grain weight, while the lowest 1000 garins weight (213.87 g) was found in a plots receiving no mulch treatment.

The lowest amount of rows per cob obtained by RT may be due to increased soil bulk density that adversely affected root growth. DT and CT treatments, on the other hand, could provide plants with sufficient water and nutrients by promoting moist movement through soil profile, leading to increased movement of nutrients into the rhizosphere, and in turn favoring plant growth and performance. These results are also in accordance with Shahid et al. (2016) who reported that tillage had significant effect on the number of rows per cob, as it was 16.80, 15.40 and 13.90 for deep tillage, conventional tillage and minimum tillage, respectively.

The response in the growth parameters of crop that originated from soil physical properties amelioration may reflected on maize yield increase under DT and CT treatments. Increasing grain yield under DT and CT practices comparing to RT, probably due to deep root distribution and higher root activity under these plots. Mulch treatments increased the storage of soil water compared with control treatment, thereby significantly raising the maize yield. This was possibly attributed to decreased evaporation of soil water, increased water into the soil and improved preservation of soil water while applying straw mulching during the time of the experiment. The findings showed that the content of soil water was higher compared to control treatment by using mulch treatments. Straw mulching is likely to have created favorable soil moisture conditions for the growth of maize. Sime et al. (2015) reported similar results, finding that mulching had a 23–33 percent higher grain yield than no mulch.

Deep and conventional tillage can remediate subsoil compaction. This layer is less permeable for roots, water and oxygen, that probably limits root growth and subsoil penetration, which may lead to delayed plant growth due to limited water and nutrient uptake, resulting in reduced crop growth. It was reported that maize crop under deep tillage gave higher straw yield than minimum tillage and conventional tillage (Qamar and Khan, 2014). The increased production of biomass in mulched crops could be attributed to more soil moisture storage, probably a favorable hydrothermal condition for plant growth and biomass production. These results are in accordance with the findings of Zamir et al. (2014) that biological yield of maize increased by applying mulches (14.01 t $ha^{-1}$) compared to treatment with no mulch (11.38 t $ha^{-1}$), which suggested that growth factors as well as nutrient content were provided by organic mulching.

Directing dry matter produced during the growing season to the sinks, in addition to sink strength, helps to improve yield. The increase in grain yield resulting from the increase in its components by the effect of the DT and CT systems in comparison to the RT system might have been due to the alleviation of soil characteristics that limited the growth and development of the roots. The differences in harvest index may be explained by improvement of growth environment, by increasing the absorption of water and nutrients necessary for growth. Increasing the absorption causes a variation in the reallocation of dry matter from plant tissue to the cob. Higher values of yield components as affected by mulch treatments in comparison with no mulch resulted in increasing grain yield. Yield increase could be connected to increased availability of water for the growth and development of the roots. Such improvement in availability of water reflects on the environment of growth that increases the absorption of water and nutrients necessary for dry matter production and translocate it to the sinks. Yin et al. (2016) reported that crops on No-till with 25 to 30 cm straw covering had higher harvest index of maize, an increase of 8.2 to 21.6% than conventional monoculture maize without straw mulch.

The responses of roots to tillage practices was observed. The increase in the root biomass under the deep and conventional tillage systems may be due to the decrease in soil compaction and affinity of its particles as a result of the decrease in bulk density, which facilitated the growth and spread of roots and increased their branching, and might lead to facilitating nutrient capture by plants.

The lower mass density of soil with increased depth of tillage may be due to increased soil disturbance through soil profile, with the solid layer with high bulk density, due to the nature of the plow geometry and, therefore, the differences in soil disturbance. These results are also in accordance with Hassan et al. (2019) who reported that tillage had significant effect on soil bulk density, as it was 1.48 mg $m^{-3}$, 1.44 mg $m^{-3}$ and 1.38 mg $m^{-3}$ for zero tillage, conventional tillage and deep tillage respectively. Higher bulk density with increasing depth, could be a result of the upper soil layers pressure exerted on the lower layers, consequently, increasing soil compaction and convergence of soil particles from each other. The decrease in the soil bulk density across the soil profile after tillage compared to the bulk density before conducting the experiment was due to the loosening of the soil and consequently the increase in the pores between the soil particles.

Soil water content increased after mulch application. The increase in the moisture content may be due to reduced evaporation from the soil surface. Simsek et al. (2017) reported that the lowest water content of 3.661% is observed in 0 t $ha^{-1}$ of wheat straw mulch dosage while the highest is of 5.096% in 16 t $ha^{-1}$ mulch dose. The results showed an increase in the moisture content across soil profile after tillage operations compared to the initial condition of the soil, which is due to loosening soil, increasing its porosity, water penetration to greater depths, and increasing its ability to conserve water, as well as the effect of mulch application.

## 5. Conclusion

The findings of two seasons field study on maize showed were that deep tillage provides greater agronomic benefits compared to conventional tillage and reduced tillage. Deep tillage increased the productivity of maize by more conventional tillage and reduced tillage. The most probable reasons for the reduced tillage yield depression may be related to the generally lower yield components and because increased weed density. In addition to reduced tillage, deep tillage and conventional tillage decreased the bulk density. Conventional tillage had better performance than reduced tillage, and for farmers who lack easy access to powerful tractors for deep tillage practices, it can be a potential alternative. Mulching improved agronomic characteristics of maize compared to no mulch treatment irrespective of tillage practices. Mulching has been able to enhance the quality of soil water for productive plant use. Thus, in conclusion, deep tillage improved soil physical characteristics and increased maize grain yield with SM2 mulching treatment.

## 6. Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Acknowledgements

The author would like to acknowledge and thank University of Basrah, College of Agriculture, for providing the laboratory facilities to conduct this research.

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