

Study The Effect of Soil Mulching and Irrigation Systems on Some Physical Properties of The Soil and Growth and Yield of Maize

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Abstract: A field experiment was carried out in the field of the Faculty of Agriculture / University of Wasit located at a longitude 45° 50' 33.5" east and N 29° 36' 49.8" norths for the 2019 growing season, the soil texture was Sandy loam, to study the effect of types of mulching and irrigation systems on some physical properties of soil, growth and yield of maize. The study was carried as factorial experiment in RCBD design with three replications, the first factor was mulching (control, wheat straw, palm fronds, and black nylon), and the second factor was irrigation methods (basin, and furrow). Maize crop was planted on 20/7/2019, and harvesting was completed on November 20, 2019. The physical properties of the study treatments were measured before planting, mid-season and at the end of the season, which included bulk density, saturated hydraulic conductivity, and soil temperature. The growth characters of the maize were measured at 100% flowering, which include plant height, leaf area, weight of 500 grains, total yield, and water use efficiency. The most important results obtained can be summarized as follows:

1. The bulk density values at the beginning of the season were not significantly affected by soil mulching, as the values of bulk density rates were 1.23, 1.23, 1.23 $\mu\text{g m}^{-3}$ for control, frond, and black nylon mulching compared to their pre-planting values 1.23 $\mu\text{g m}^{-3}$. Whereas, there were significant differences in the mid-season in the bulk density values of the control treatment, as they reached 1.24 $\mu\text{g m}^{-3}$. While the mulching of fronds and black nylon did not significantly affect the values of bulk density in the middle of the season compared with the values before planting. While it is evident that there was a significant effect mulching on the values of the bulk density of the control, frond, and black nylon mulching at the end of the season, which amounted to 1.24, 1.25, and 1.26 $\mu\text{g m}^{-3}$, respectively, compared to their values before planting. Also, it is noticed that the values of the bulk density rates of straw mulching treatment decreased at the beginning, middle and end of the season, as the values were 1.21, 1.22, and 1.22 $\mu\text{g m}^{-3}$, respectively, compared with their value before planting.
2. There was no significant effect of the two irrigation methods on the bulk density values at the beginning, middle and end of the season compared with the bulk density values before planting.
3. The presence of a significant effect of mulching on water conductivity, as the values of the water conductivity decreased compared to their values before planting, and became 2.68×10^{-3} , 2.69×10^{-3} , and 2.73×10^{-3} cm sec^{-1} for control, fronds, and nylon, respectively. While the treatment of straw mulching, the water conductivity values increased at the end of the season compared to their values before planting.
4. The presence of the effect of the irrigation method on water conductivity, and led to a decrease in the values of the water conductivity compared to its values before planting, as it reached 2.76×10^{-3} - 2.75×10^{-3} cm sec^{-1} for the two irrigation treatments in basin and furrow, respectively.
5. A slight decrease in the temperature in the middle of the season during the months of September and October, and the decline continued until the end of the season in the month of November. The highest temperatures were recorded for the treatment mulched with black nylon and control, followed by the palm fronds and the lowest temperature for the straw mulch treatment. The irrigation method did not affect soil temperature during the crop growth stages.
6. The presence of a significant effect of mulching on plant height, the mean values of plant height were 184.05, 169.25, 149.6, 177.5 cm for control, straw, fronds, and black nylon respectively, as well as the absence of a significant effect of the irrigation method on plant height, the averages of the two methods of irrigation of basins and furrows were 169.95 and 170.25 cm, respectively.
7. The presence of significant differences between mulching treatments for the leaf area (4205, 5381, 4385, 3564 cm^2 for straw, frond, control, and nylon mulching respectively. as well as, the absence of significant differences between the two irrigation methods on the leaf area.

8. The presence of significant differences between mulching treatments for the grain yield, reaching 5260, 4028, 3520, and 4625 kg ha⁻¹ for control, straw, fronds, and nylon mulching, respectively. As well as significant differences between the two irrigation methods on the grain yield, reaching 4014,4703 kg ha⁻¹ for the treatment of irrigation of basins and furrows, respectively.
9. The presence of significant differences between mulching treatments for weight of 500 grains (91.1, 103.8, 113.9, 99.8 gm for the control, straw, fronds, and black nylon respectively, as well as the presence of significant differences between the two irrigation methods on the weight of 500 grains, which amounted to 105.4 98.8 gm for irrigation with basins and furrows respectively.
10. Mulching soil surface with straw and fronds increased water use efficiency compared to the control treatment, reaching 1.104, 0.849, and 0.708 kg m⁻³, respectively. There were also no significant differences between the two irrigation methods on the water use efficiency.

Keywords: physical properties; mulching; systems irrigation; soil.

I. Introduction

Soil mulching has been defined as a practice used by organic growers, as it depends on the material used in the application. Mulching mulch plays a positive role when used in covering the soil surface by rationing irrigation water and minimizing the loss of nutrients as a result of washing operations with abundant irrigation and it helps in maintaining the physical properties of the soil as a result of rain and walking on it [1]. One of the main reasons for mulching the soil is to maintain soil moisture and increase water storage [2] and [3], explained that organic mulch such as Plant residues, straw, and weeds had an important role in adding some elements necessary for plant growth such as organic nitrogen and improving soil properties. He also explained that the mulching effect was evident when the soil was exposed to a one-month drought period during the growing season. [4], found that there is a variation in the effect of soil surface mulching on the moisture distribution, as the treatment mulched with corncob kept the highest soil moisture content, especially in the surface layer, compared to the treatments of black oil and paraffin.

Irrigation is one of the essential elements in raising the level of agricultural production in various countries of the world, and its importance increases in arid and semi-arid areas where the rain is insufficient for crops to grow and reach the harvest stage. In view of the increase in the demand for water due to the increasing human activity in the various aspects of life, it was therefore necessary to reconsider how to use, distribute and rationalize water consumption in the most appropriate and efficient manner. Soil and water management are considered the two main factors, especially choosing the appropriate irrigation method that achieves the highest efficiency in water use and maintains the physical properties of the soil as well as provides suitable conditions for plant growth [5]. Maize (*Zea mays*, L.) is one of the most important strategic and economic crops in the world, and it ranks third in importance after wheat and rice. Iraq cultivates maize on a large scale, with the area cultivated for the year 2016 about 76,000 hectares, with a production rate of 3,416 µg. hectare⁻¹ [6]. Maize crop is one of the most important cereal crops for the production of fodder, starch, oil and fuel, and its economic importance has increased at the therapeutic level, the production of dyes, or its use as a promising alternative to traditional auto fuel or other uses [7]. Therefore, this study aims to study the effect of types of mulching and irrigation systems on some physical properties of soil, growth and yield of maize.

II. Materials and Methods

The experiment was conducted in sandy loam soil. A factorial experiment was implemented according to the RCBD with three replications. The experiment land was plowed, smoothed, amended, and divided into 24 experimental units with dimensions 4 x 3.75 m, leaving a distance of 1 m between blocks and 1 m between the experimental units. Some physical and chemical properties of the field soil were measured before planting (Table 1 and 2), as well as the chemical properties of irrigation water (Table 3). The experiment consists of the following factors:

A. Soil Mulching: Three types of mulching have been used, namely:

1. Black mulching, the plots were completely covered with black nylon, and as for the furrows, it was completely covered with black nylon, leaving the bottom of the furrow uncovered.
2. Mulching Fronds, the plots were covered with fronds, and as for the furrow, the side facing the sun was covered with palm fronds where the crop was grown.
3. Straw mulching, the plots were covered with straw and, for furrow, the side facing the sun on which the crop was grown.
4. Without Mulching (Control).

B. Irrigation method: It includes two types of irrigation methods, namely:

1. Basins Irrigation (B)
2. Furrow Irrigation (F)

The eight treatments were allocated randomly to the experimental units of each block. The planting was carried out on July 20, 2019 in lines in basins (plots) and in the upper third in furrow, the distance between furrow was 75 cm, and in the hole, the distance between one hole and another 25 cm³ seeds were placed in each hole. thinning was carried out two weeks after planting and the plants were reduced to one plant per hole. After reaching a height of 15-20 cm. Weeding was carried out according to the needs of the plants, and urea was added before planting as a first batch, the second batch after two months of planting, and potassium sulfate and triple superphosphate before planting according to the recommendations of the Ministry of Agriculture. The corn stalk borer insect was controlled by using the granular pesticide of diazinon (10%) by placing it in the apical meristem of the plant. The first irrigation (the germination irrigation) was given immediately after planting on 7/20/2019, all the experiment treatments were irrigated equally until germination, after which the irrigation was done on the basis of depletion of 50% of the available water for the plant. Where the depth of water required to reach soil moisture to the field capacity limits was added based on soil moisture tension curve data.

$$d = (\Theta_{f.c} - \Theta_w) \times D \text{-----(1)}$$

d = depth of irrigation water to be added (cm)

$\Theta_{f.c}$ = volumetric moisture at field capacity cm³ / cm³

Θ_w = volumetric moisture before subsequent irrigation cm³ / cm³

D = soil depth (cm), where a depth of 10 cm was used for the stage of germination and vegetative growth, then it was increased to 20 cm for the stage of flowering, then it was increased to 30 cm in the stage of maturity and harvesting, depending on the field follow-up to deepen the root system of the crop.

The volume of added water (V) was calculated for each experimental unit and the irrigation time (T) according to the equations in [8] and [9] and as follows:

$$V = d \times A \text{----- (2)}$$

$$T = V / Q \text{----- (3)}$$

d = depth of irrigation water (m)

A = The area of the experimental unit (plots or furrows) m²

Q = discharge (liters / s)

Soil bulk density was measured for all experiment treatments before planting and at the beginning, mid and end of the season and at five depths (0-10) (10-20) (20-30) (30-40) (40-50) cm from the soil surface using the method of Cylinder Core Sample. The soil water conductivity was measured for all the experiment treatments at the end of the season and at five depths (0-10) (10-20) (20-30) (30-40) (40-50) cm from the soil surface using a constant water column on non-disturbed soil according to the method [10] and according to the following equation:

$$K = \frac{V L}{A t \Delta H} \text{.....(4)}$$

As: _

K: saturated hydraulic conductivity (cm h⁻¹).

V: The volume of leachate (cm³).

L: Length of the column of soil (cm).

A: The area of the running section (cm²).

t: water collection time (hour).

Δh : The change in the water voltage between its entry and exit point (cm).

Soil temperature was measured for all experiment treatments throughout the growing season and at depths of 0-30-20-20-10 cm from the soil surface by electronic thermometers every 6 hours on a daily basis throughout the experiment period. Crop growth characters were measured during the 100% flowering stage, where five plants were randomly taken from each experimental unit in the experiment and the following characters were measured:

1. Plant height (cm) was calculated by means of a long, graduated ruler from the soil surface to the node of the male flowering at physiological maturity [11].

2. The leaf area (cm²) was calculated using the formula proposed by (11) as follows:

$$\text{Leaf Area} = (\text{Sheet Length})^2 \times 0.75 \text{----- (6)}$$

3. Weight of 500 grains: It was calculated by weighing 500 grains from the grains of five plants randomly taken from each experimental unit after correcting the weight for the moisture content of 14.5% [11].

4. Total grain yield (ton / hectare) was calculated from the average weight of one plant's yield taken as an average of five harvested plants from each experimental unit multiplied by the plant density [12].

5. The water use efficiency was calculated from the following equation [13].

$$\text{WUE} = \text{Yield (kg ha}^{-1}\text{)} / \text{amount of irrigation water added (m}^3\text{ ha}^{-1}\text{)} \text{ ----- (7)}$$

Statistical analysis:

Data were analyzed statistically according to the method of analysis of variance, and comparisons were made between the arithmetic means according to the test of the least significant difference (L.S.D) at a probability level of 0.05.

Table 1. Physical characteristics of the study soil before planting.

water conductivity cm sec ⁻¹	Porosity%	True density μg m ⁻³	bulk density μg m ⁻³	Texure	Particle Size distribution			Soil Depth (cm)
					Clay gm Kg ⁻¹	Silt gm Kg ⁻¹	Sand gm Kg ⁻¹	
0.00291	55.9	2.63	1.16	Sandy loam	63	360	577	0 -10
0.00288	54.5	2.64	1.20		76	375	549	10-20
0.00283	53.6	2.65	1.23		89	360	551	20-30
0.00279	52.1	2.65	1.27		93	350	557	30-40
0.00272	52.4	2.67	1.27		95	335	570	40-50

Characters were analyzed according to the methods presented in [14].

Table 2. Chemical properties of field soil before planting.

Organic matter %	C mol/l								(pH)	Ec (dsm ⁻¹)	Soil depth(cm)
	SO ₄ ⁻²	HCO ₃ ⁻	Cl ⁻	CO ⁻²	K ⁺	Na ⁺	Mg ⁺²	Ca ⁺²			
0.65	1.31	4.8	12.8	0	2.2	3.11	4.4	9.2	7.15	1.89	0 -10
0.58	1.28	4	12.5	0	2.0	2.92	3.8	8.9	7.13	1.79	10-20
0.58	1.1	3.6	10.6	0	1.81	2.70	3.1	7.7	7.11	1.49	20-30
0.55	1.4	3.1	10	0	1.63	2.63	2.6	6.4	7.09	1.34	30-40
0.53	1.2	3.0	10	0	1.62	2.61	2.6	6.3	7.11	1.32	40-50

Table (3) Chemical properties of irrigation water.

SO ₄ ⁻²	Cl ⁻	HCO ₃ ⁻	CO ⁻²	K ⁺	Na ⁺	Mg ⁺²	Ca ⁺²	PH	Ec
C mol/l									
1.5	7	5	0	0.641	3.6	4	5.6	6.76	1.4

III. Results and Discussions

1. The physical properties of the soil

1.1. Bulk Density

1.1.1 The effect of coverage on bulk density

Figure 1 shows the effect of the soil mulching on the values of bulk density at the beginning, middle, and end of the season compared to their values before planting, it became clear that the bulk density values at the beginning of the season were not significantly affected by the mulching, as the values of bulk density rates reached 1.23, 1.23, 1.23 μg m⁻³ for control, frond, and black nylon mulching treatments compared to their pre-planting values, which were 1.23 μg m⁻³, while there were significant differences in the mid-season in the bulk density values of the control treatment, reaching 1.24 μg m⁻³, with an increase of its amount. 0.81% compared to the bulk density of the soil before planting, the reason for this may be attributed to the breakdown and shattering of soil masses during irrigation, which results in the deposition of fine particles in large pores, thus reducing the total porosity and increasing the bulk density and this is consistent with what [15] and [16] found. Whereas, frond and black nylon mulching did not affect the bulk density values in mid-season compared to pre-

planting values, as the values reached 1.23 and 1.23 $\mu\text{g m}^{-3}$ respectively, and this is consistent with what [17] found. While it is evident that there was a significant effect of the mulching treatments on the values of the bulk density of the control, frond, and black nylon mulching at the end of the season, which amounted to 1.24, 1.25, 1.26 $\mu\text{g m}^{-3}$, respectively, compared to their values before planting. The reason for the increase in bulk density values at the end of the season for black nylon treatment may be due to the fact that completely covering the soil surface with black nylon significantly reduces water loss through evaporation and provides moisture in a large amount, which leads to the loss of salts and some bonding materials that may have a role in Formation of organic bonds between soil aggregates, which led to an increase in the bulk density values. The reason may also be due to the effect of the covering on the activity of the aerobic micro-organisms, which reduces their secretions, which play an important role in building soil and reducing the bulk density, and this is consistent with what [18] found. It is noticed from Figure 1 that the values of bulk density rates were decreased for straw mulching treatment at the beginning, middle and end of the season, where the values were 1.21, 1.22, 1.22 $\mu\text{g m}^{-3}$, respectively, the percentage of decrease in the bulk density values was 0.81% at the beginning and middle of the season and% 1.63 at the end of the season compared to its pre-planting value. The reason for this is that the addition of wheat residues (straw) causes an increase in the pore volume, which leads to a decrease in the values of bulk density and an increase in the total porosity of the soil, and this is consistent with his findings [17]. There is another reason for the decrease in bulk density, which is the result of the effect of growth and branching of the roots of maize plants, which helped to improve the properties of the soil by linking its particles and increasing the porosity, as well as the presence of soil microbiology and the substances it secreted from the materials that help in improving the building of the soil and this is consistent with what was found by [19-21].

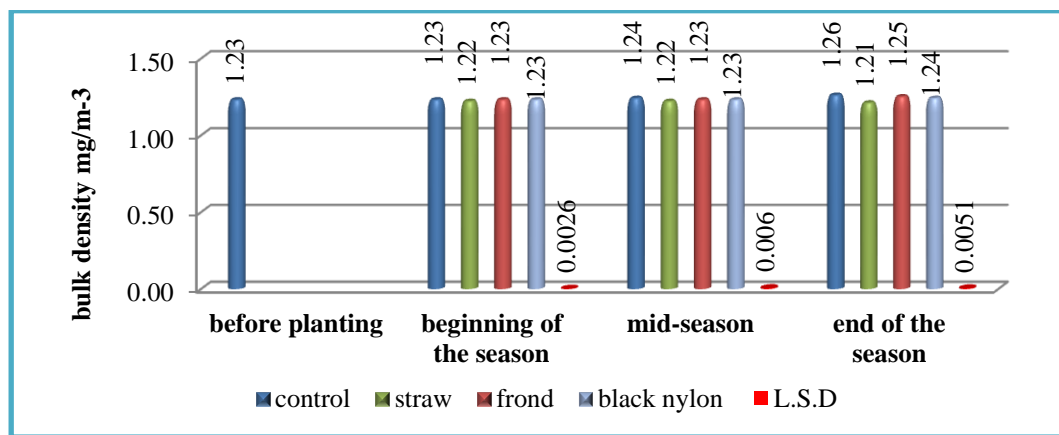


Fig.1. The effect of mulching on soil bulk density during the stages of the crop growing season

2.1.1. Effect of irrigation method on bulk density

It is noticed from Figure 2 that there was no significant effect of the two irrigation methods on the values of bulk density at the beginning, middle and end of the season compared to the bulk density values before planting, the results showed a slight increase in the soil bulk density values at the end of the crop growing season compared to its value before sowing, The reason for this is that the flood irrigation methods lead to the movement of fine particles due to irrigation, which led to the breakdown and collapse of the soil masses and their deposition inside the soil pores, which leads to a decrease in porosity and an increase in the bulk density and this is consistent with what [15] and [16] reached. Also, the continuation of irrigation operations led to a weakening of the aggregates stability, which led to their fragmentation and sedimentation of mud particles in the large pores, which caused an increase in the bulk density values [22].

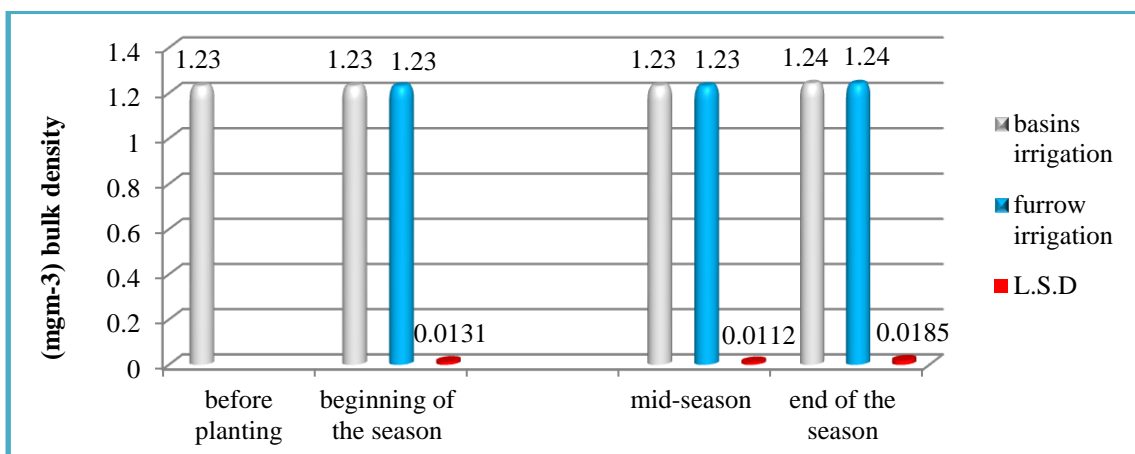


Fig.2. The effect of irrigation method on soil bulk density during crop growth stages

1.2. water conductivity

1.2.1. The effect of coverage on water conductivity

It is noticed from Figure 3 that there is a significant effect of mulching on the values of the water conductivity, as the values of the water conductivity decreased compared to their pre-planting values, which were $2.8 \times 10^{-3} \text{ cm sec}^{-1}$, which became 2.68×10^{-3} , 2.69×10^{-3} , $2.73 \times 10^{-3} \text{ cm sec}^{-1}$ for control treatments and mulching with fronds and nylon respectively, and the reason for this is due to the repeated irrigation process, which caused the dispersion, separation and sedimentation of soil particles in large pores and the formation of a compact layer of low permeability and with a high bulk density [23,24], the reason may also be due to the gradual deterioration that takes place in large soil aggregations and their transformation into smaller ones, as well as the dispersion of colloidal soil particles during irrigation operations, which led to a decrease in the large pores responsible for the movement of water in the soil and thus the decrease in water conductivity [25]. Whereas, for the treatment of straw mulching, the water conductivity values increased slightly at the end of the season compared to their pre-planting values, which amounted to $2.92 \times 10^{-3} \text{ cm sec}^{-1}$. This leads to an increase in capillary tubes that conduct water and as a result the water conductivity increased, and this is consistent with what [25].

1.2.2. The effect of the irrigation method on the water conductivity

It is noticed from Figure 4 the effect of the irrigation method on the values of the water conductivity, as it led to a decrease in the values of the water conductivity compared to its values before planting, it was recorded 2.76×10^{-3} , $2.75 \times 10^{-3} \text{ cm sec}^{-1}$ for the two irrigation methods of basins and furrows, respectively. The reason for this is the continuation of irrigation operations, especially irrigation in basins, which leads to deterioration of soil properties and a decrease in its ability to conduct water, and this is what appeared in some of the treatments that are irrigated by the method of basins [22].

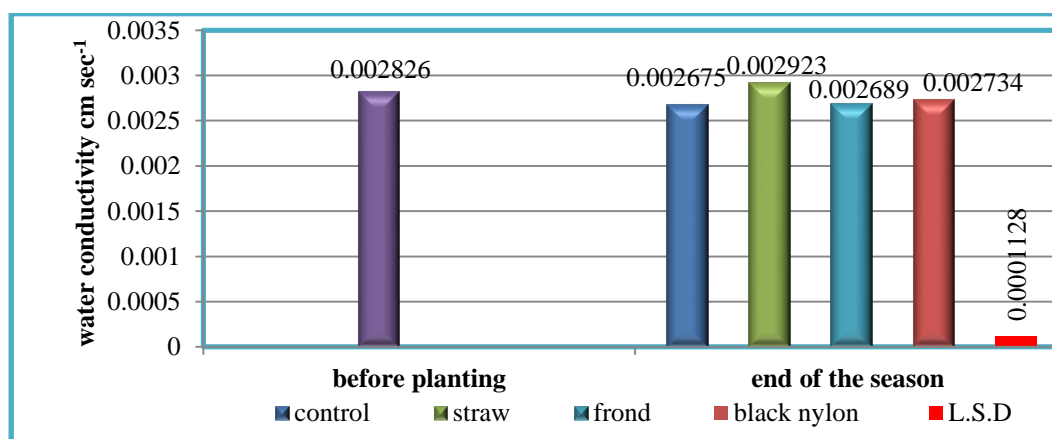


Fig.3. The effect of mulching on the rate of water conductivity of the soil after the end of season.

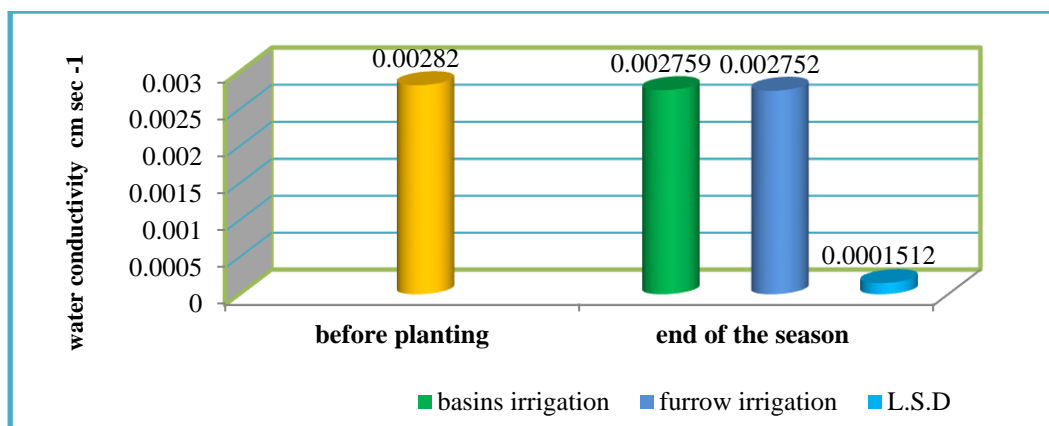


Fig.4. The effect of irrigation method on the rate of soil water conductivity after the season ends

1.3. Soil Temperature

1.3.1. The effect of mulching on soil temperature during the growing season

It is noticed from Figure 5 the effect of mulching on the soil temperature during the growing season of the maize crop, as the highest soil temperatures were recorded during the first months of the growing season (July and August), then a slight decrease in the temperature occurred in the middle of the season (September and October) and the decline continued until the end of the season. (November), the highest average temperatures were recorded for treatments mulched with black nylon and control, followed by palm fronds and the lowest temperature for the straw treatment, At the start of the season, it reached (35.64, 34.06, 32.28, and 31.49) degrees Celsius, as the soil mulching has an effect on soil temperature, as it works either to raise or lower the soil temperature according to the growing season and environmental conditions of the region [26], the reason for the high temperature of the soil covered with black nylon is due to its ability to absorb sunlight and the possibility of storing it in the soil, and this is consistent with what was found by [27]. It is also noticed that mulching with black nylon raises soil temperature to two degrees Celsius compared with uncovered soils, and this is in agreement with (28), It was observed that the soil temperature increased from 1-5 ° C for the nylon-mulched treatment compared to the soil temperature for the straw-mulched treatment and this is consistent with what was found by [29]. The treatments mulched with palm fronds gave a lower temperature compared to the uncovered soil, with a significant difference compared to the treatments mulched with black nylon, and this is consistent with the findings of [30]. Whereas, for the lowest temperature recorded during the season, it is for straw-mulched treatments due to its transparent color that works to reflect sunlight and preserves soil moisture and maintains a suitable temperature for plant growth, and this is consistent with what [31], have reported.

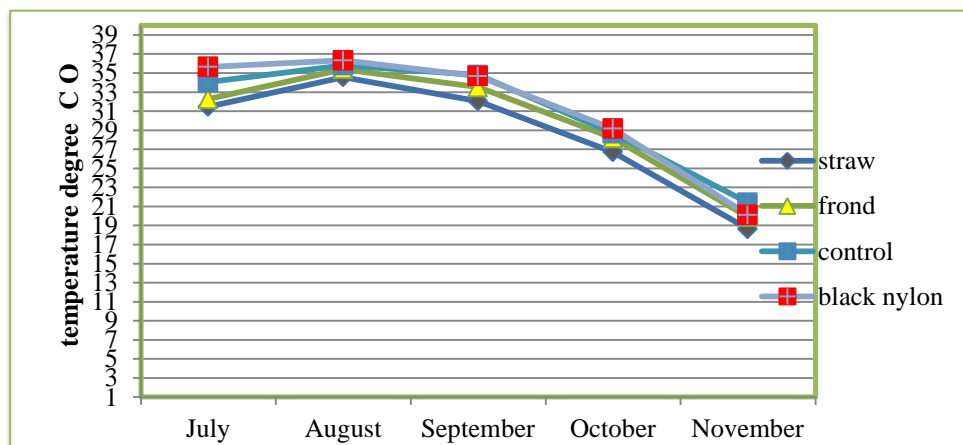


Fig.5. The effect of mulching on the average soil temperature during the crop growing season.

1.3.2. The effect of irrigation method on average soil temperature during the growing season of the crop

Figure 6 shows the effect of the irrigation method on the soil temperature during the growing season, where it is noticed that there are no significant differences between the two irrigation methods (basins and furrow) on the soil temperature during the months of crop growth. As there was a gradual rise in soil temperature in the months (July and August), reaching 33.51-35.56 °C for the basin irrigation method for the months of July and August respectively, and 33.22 and 35.52 °C for the irrigation of furrows for the months of July and August respectively, this is attributed to the environmental conditions of the region, as the increase in air temperature leads to an increase in the soil temperature [32], a gradual decrease in soil temperature is observed upon completion of the flowering phase, where plant growth is complete, which leads to shading the soil surface, and this in turn reduces water evaporation from the soil surface and preserves its moisture and low temperature, at the end of the season a clear decrease in soil temperature is noticed and the reason for that is to weather conditions where the air temperature decreases, which leads to a decrease in the soil temperature.

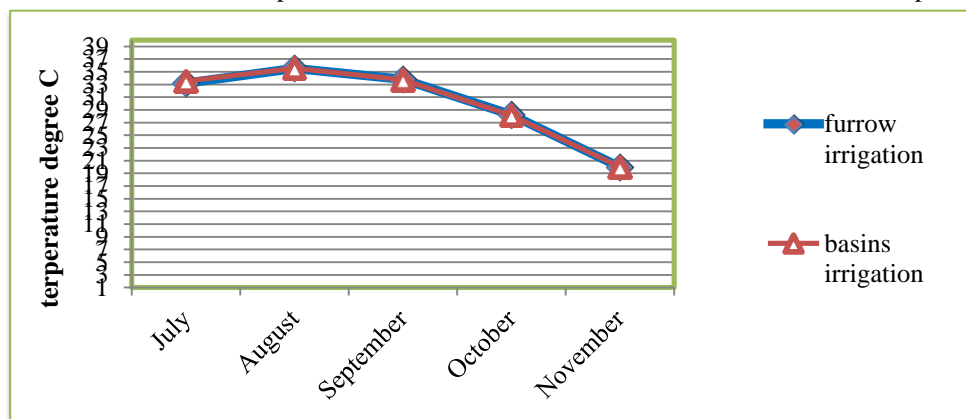


Fig.6. Effect of irrigation method on soil temperature during the crop growing season.

2. Growth characters of maize

2.1. Plant height

Figure 7 shows the significant effect of mulching on plant height. The mean values of plant height were 184.05, 169.25, 149.6, and 177.5 cm for control, straw, fronds, and black nylon respectively, the straw mulching treatment significantly outperformed the two treatments of black nylon and control, while the differences were not significant with frond mulching. The reason for this is attributed to the role of straw in contributing to creating good conditions for plant growth, improving some physical properties of the soil, such as construction, bulk density and preserving the moisture content of the soil, which increases the growth and spread of roots, which in turn provide suitable moisture for the growth and increase of plant height and leaf area as a result of the water relationship with cell division, this is consistent with his findings of [33]. It is noticed from Figure 10 that there are no significant differences between the treatment of straw and palm fronds in terms of plant height because of the role of palm fronds in maintaining the soil with moderate temperature compared to the two treatments of black nylon mulched and control, as the treatment of black nylon led to an increase in the soil temperature, and this consistent with his findings of [34], in that the covered soils retain more moisture than exposed soils due to soil moisture balance, as well as its effect on the soil thermal system due to the color or ability of the soil to conduct heat, which in turn affects the incident and reflected rays, which is negatively reflected on plant height. Figure 8 shows that there was no significant effect of the irrigation method on plant height, as the averages of basin and furrow irrigation methods were 169.95 and 170.3 cm, respectively. The reason for this is that the treatments were irrigated depending on the moisture content of the soil of the treatments, so all plants took their sufficiency of water in the stage of vegetative growth and flowering, and this in turn increased the amount of water absorbed by the plant and increased the amount of nutrients absorbed by the plant, which led to the encouragement of plant growth [35] and then increase its height [36].

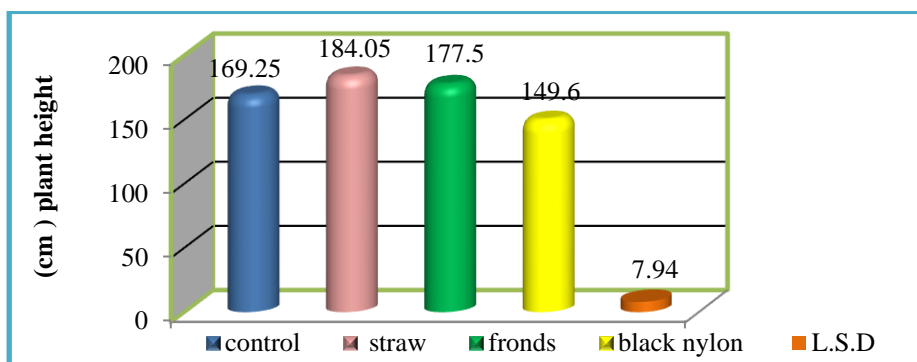


Fig.7. The effect of mulching on plant height.

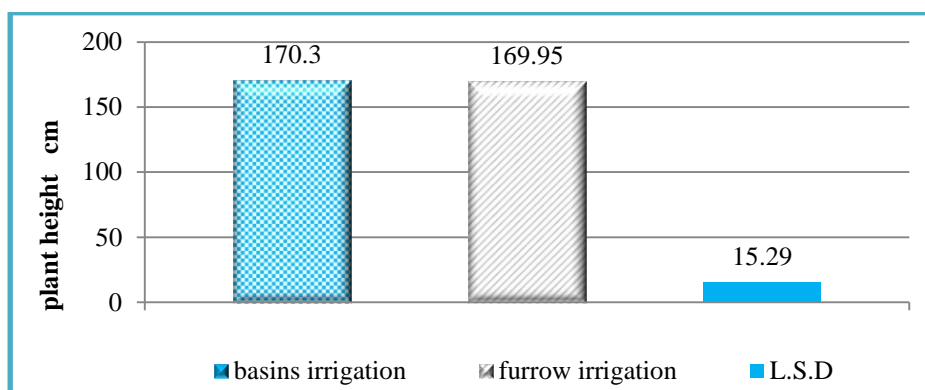


Fig.8. The effect of irrigation method on plant height.

2.2 Leaf area

Figure 9 shows the presence of significant differences between mulching treatments for the leaf area, where the values of the leaf area rates reached 5381, 4385, 4206, and 3565 cm² for the straw, frond, control, and black nylon mulching respectively, and the reason for this is that straw maintains soil moisture, as a result of reducing evaporation from the soil, which increases the ability of the roots to absorb nutrients, which leads to an increase in leaf area and an increase in carbohydrates production, and this is consistent with what [37] found, While the black nylon treatment obtained the lowest rate of the leaf area, the reason for this is that covering with black nylon leads to an increase in the moisture content of the soil after the irrigation process, and this may lead to a decrease in ventilation because it does not have openings or pores, and an increase in the washing of nutrients in the root zone, Which reflected negatively on the vegetative growth of the plant, and this is consistent with what was reached by [38]. Likewise, the plants grown under organic mulching treatments (straw, fronds, etc.) did not suffer from moisture or heat stress, and on the contrary, the plastic mulch (black nylon) led to a decrease in the vegetative growth character of plants as a result of these plants being exposed to heat stress, especially in the emergence stage. This is consistent with what was reached by [38]. The reason for heat stress is that black nylon does not have holes or pores as in other mulching such as straw and fronds, so the process of gas exchange that takes place between the soil and the air is minimal and thus the soil aeration process is necessary to increase the vegetative growth character of the plant. Figure 10 shows The results also indicated that there were no significant differences between the two irrigation methods on leaf area, and the reason for this was due to the sufficiency of irrigation in the vegetative growth and flowering stages, which in turn led to an increase in plant height and an increase in the depth of roots, which increased the absorption of water and nutrients and thus improved growth of Plant, which in turn increased the leaf area [36] and [39].

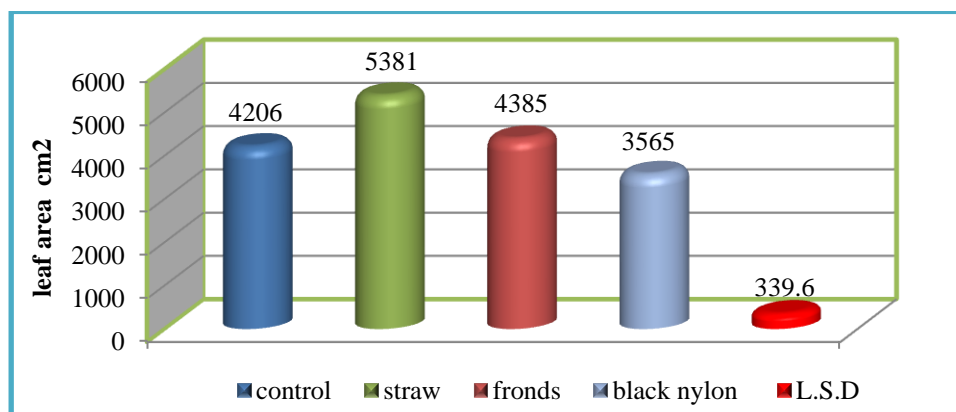


Fig.9. The effect of mulching on leaf area.

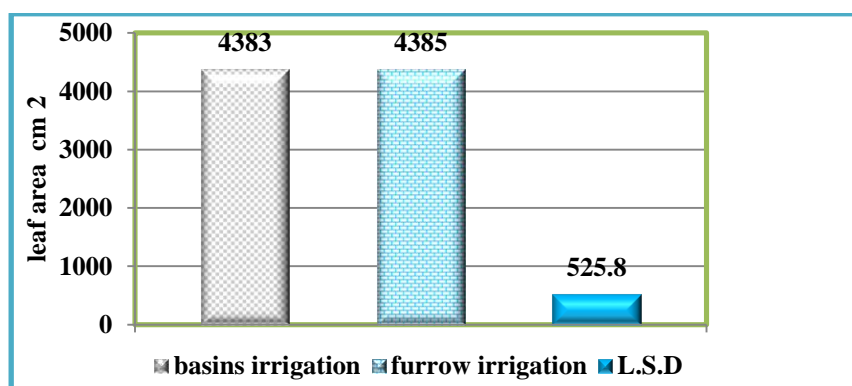


Fig.9. The effect of irrigation method on leaf area.

2.3 Total grain yield

The total

The results showed significant differences between mulching treatments for the grain yield, reaching 3520, 4625, 5260, 4028 kg ha⁻¹ for control, straw, fronds and nylon treatments respectively (Figure 11). Where the highest grain yield rate was for straw mulching, followed by frond mulching and then nylon cover and control treatment, and the reason for this is that mulching with plant residues increases the ability of the soil to hold water, which leads to an increase in water absorption, which in turn affects the absorption of the largest amount of plant nutrients that have a major role in the vital activities of plants [40]. The reason may be attributed to the increase in the leaf area when covering with straw because the increase in the leaf area increases air exchange and exposure to solar radiation and increases the dry matter, which in turn increases the period of filling of the grain, which increases its weight and then increases the yield [41]. The reason for the decrease in the yield of the mulching with black nylon may be attributed to the fact that the coverage greatly reduces the amount of the yield due to the constant rise in air and soil temperatures in the middle of the summer, as the plants suffer from heat stress, so it is sometimes necessary to remove the coverage when temperatures rise to reduce heat stress to which plants are exposed [38]. Figure 12 shows the existence of significant differences between the two irrigation methods in grain yield, with mean value of 4014, and 4703 kg ha⁻¹ for the treatment of irrigation with basins and furrows respectively. The reason for the superiority of the irrigation treatment in basins is due to its positive role in providing sufficient water for the plants. The low yield of the furrow irrigation may be attributed to the fact that the quantities of irrigation water added by the method of irrigation with furrows are small compared with the quantities of water added by basin irrigation. The depth of irrigation water added to basins for control, straw, fronds, and nylon reached 594.78, 519, 559.5, 498.9 mm, respectively, and the furrows amounted to 545.68, 428.35, 528.65, 380.93 mm for control, straw, fronds and nylon treatments

respectively. As water is the only solvent inside plant cells, as it helps in the process of transferring photosynthetic products from the source (leaves and stem) to the seeds, especially during the seed filling stage, which determines the seed weight. Therefore, the amount of water available to the plant during this critical stage of the plant’s life is what determines the amount of yield, and this is consistent with finding of [41].

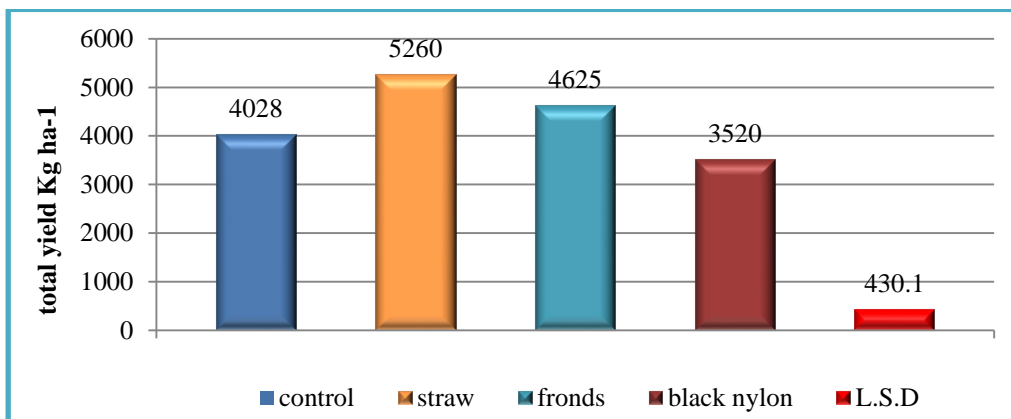


Fig.11. The effect of mulching on the total yield.

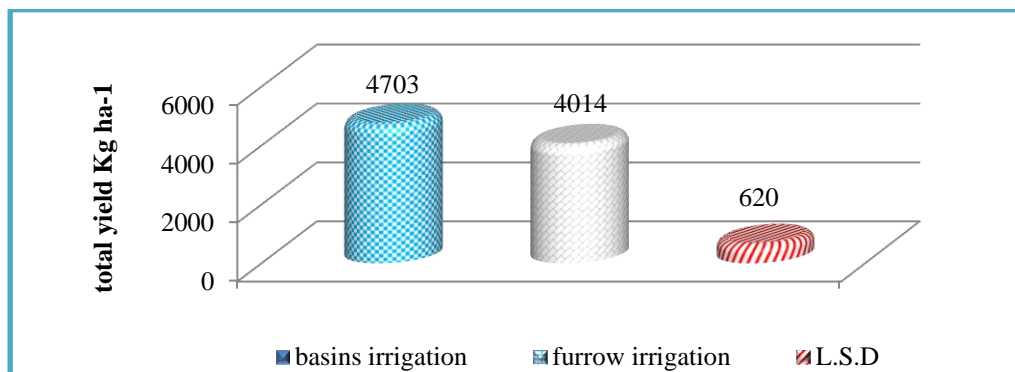


Fig.12. The effect of irrigation method on the total yield.

2.4 Weight of 500 grain

The results showed significant differences between mulching treatments for 500 grain weight, reaching 99.8, 113.9, 103.8, and 91.1 gm for control, straw, fronds, and black nylon mulching treatments respectively (Figure 13). Where the treatment of straw mulching achieved the highest rate, followed fronds and control, then black nylon. The reason for this may be attributed to the preservation of soil moisture for a longer period, which leads to an abundance of water, which in turn affects the growth and division of plant cells, which leads to improving the efficiency of the photosynthesis process and as a result gives an opportunity for the largest amount of nutrients to be stored inside the seed and thus increase the weight of 500 grains [33]. The weight increase of 500 grains of the frond mulching treatment may be attributed to the role of fronds in maintaining soil moisture and moderate temperature for a certain period, which leads to accumulation of dry matter in the grains, high protein content and an increase in the weight of 500 grains [30]. While the mulching with black nylon gave the lowest rate due to the high temperature under the cover in addition to the high air temperature, this may affect the plant growth in general. It is noticed from Figure 14 that there are significant differences between the two irrigation methods on the weight of 500 grains, which amounted to 105.4 and 98.9 gm, for irrigation with basins and furrow, respectively. The reason for this may be attributed to the fact that flood irrigation (basins) provides a large amount of water for the crop, which leads to the consumption of more water and this leads to the absence of physiological disturbances for the plant, especially in the stage of flowering and fertilization, which provided the opportunity to complete the process of

photosynthesis and manufacture its products exported to growing grains, which in turn increases the weight of 500 grains [43].

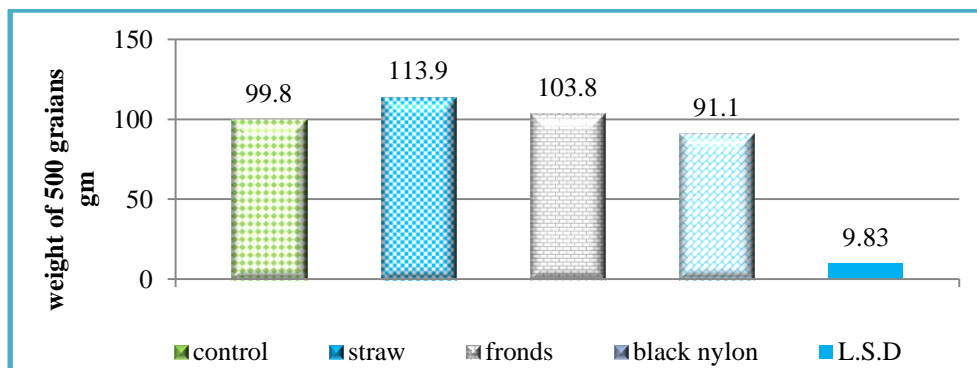


Fig.13. The effect of mulching on the weight of 500 grains.

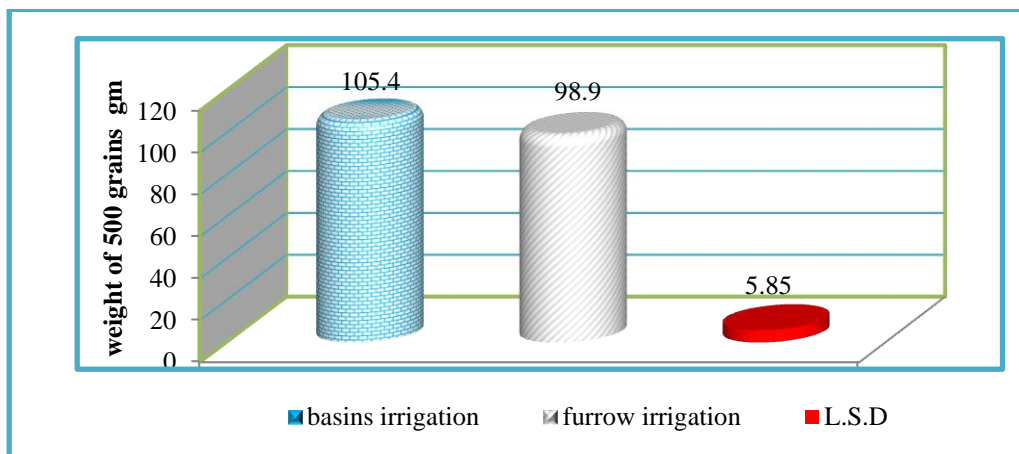


Fig.14. The effect of the irrigation method on the weight of 500 grains.

3. Water use efficiency (WUE)

3.1 Effect of mulching on water use efficiency

The results showed significant differences between mulching treatments for WUE, mulching with straw increased the efficiency of water use, followed by fronds, and black nylon compared to control treatment, reaching 1.104, 0.849, 0.806, and 0.708 kg m⁻³ respectively Figure 15. The reason for this is attributed to the preservation of soil moisture for a longer period, which led to an increase in the plant yield while reducing the amount of water used to irrigate the straw mulching treatment, and hence increased the efficiency of water use. Also, the reason may be attributed to the decrease in the bulk density values due to covering the soil surface with straw. This encouraged better root growth and high efficiency in absorbing nutrients, and this in turn reflected positively on the yield and the increase in the productivity of the unit of water used in irrigation, and this is consistent with what was reported by the [36] and [44]. The reason for this may also be due to the fact that mulching with straw and palm fronds reduced the impact of environmental factors on the soil such as heat, wind and solar radiation, which leads to a decrease in water evaporation from the soil, and thus increased utilization of water and nutrients in the root zone, which in turn leads to increase the plant yield, which increases the efficiency of water use [45], as this new method of mulching has a clear effect on increasing economic returns on the one hand and on the other hand it works to improve the physical properties of the soil, which contributes to rationalizing the amount of water consumed by the plant. Whereas, for mulching with black nylon, the efficiency of water use was low, because black nylon covers the entire surface of the soil, which reduces water evaporation and condenses water and returns it back to the soil, which causes an increase in soil moisture and less oxygen, in addition to a higher soil temperature under cover [38], all

these factors may be the reason for reducing the plant yield, which negatively affected the efficiency of water use when compared with mulching with straw and fronds, as it is known that the efficiency of water use is directly proportional to the increase in crop yield and inversely with the total amount of water added during the full growing season [18]. However, the efficiency of water use in the treatment of nylon mulching is better than the control treatment, and this is consistent with the findings of [38], that mulching with black nylon led to an increase in the efficiency of water use compared to control treatments, but it was of little efficiency as when was compared with the treatments of straw and frond mulching, although it provided greater quantities of water compared to the rest of the treatments, but its effect was negative on the grain yield, so it is not considered to be of good efficiency and this is in agreement with [46]. The reason for the lower efficiency of the control treatment is that fine soil particles are deposited inside the soil pores, due to irrigation, which leads to reduced porosity and high bulk density, and then the development of a surface crust that in turn reduces infiltration in the soil, and this is consistent with what found by [22]. This, in turn, negatively affects the plant yield, in addition to the fact that the quantities of water added to the control treatment are large compared to the rest of the treatments, which in turn affects the efficiency of water use [47]. The reason for the low efficiency of water use in the control treatment is also attributed to the increase in the amount of water used in relation to its production from grain yield compared to the rest of the study treatments, and this is consistent with what [48] found. Whereas, using a large water depth reduces the efficiency of water use, in other words, increasing the irrigation water depth reduces the efficiency of water use [49].

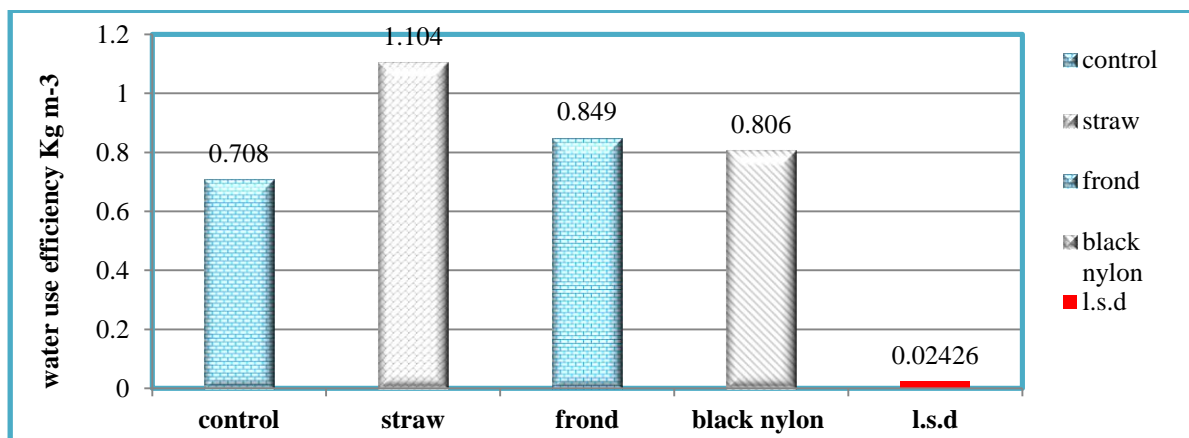


Fig.15. The effect of mulching on water use efficiency.

3.2. The effect of irrigation method on water use efficiency

The results showed no significant differences for irrigation methods on WUE, reached 0.871, 0.862 kg. m⁻³ for basins and furrow irrigation respectively (Figure 16), as it is known that the efficiency of water use is directly proportional to increase the amount of the yield and inversely with the total amount of water added in the irrigation method during the growing season of the crop, as the amount of water used in furrow irrigation method was less compared to the amount of water used in the basins, while the efficiency of water use was higher in basin irrigation, these results were consistent with [50], and the reason for the slight variation in increasing the efficiency of water use with the different irrigation methods used (basin and furrows) may be due to the physiological nature of the plant, where the plant makes great effort in trying to benefit from all the water available for it during the irrigation process to gives normal production, and this is consistent with what he [51] reached.

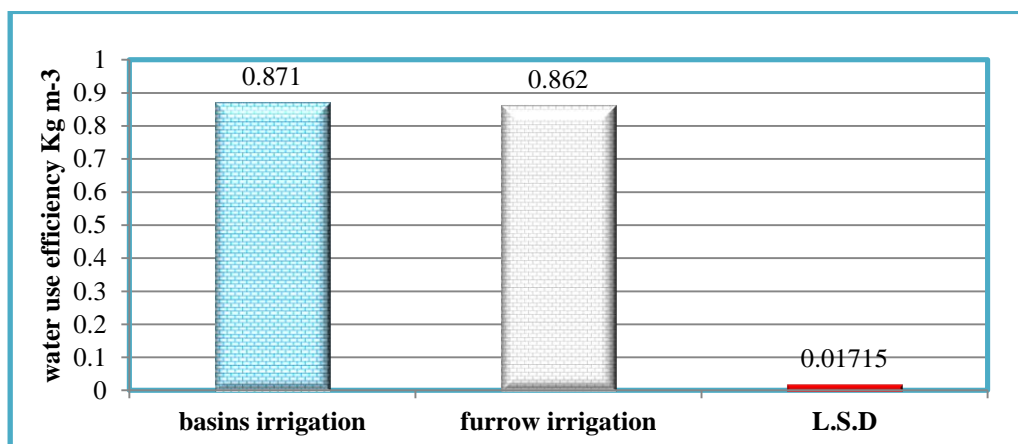


Fig.16. The effect of irrigation method on water use efficiency.

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