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EFFECT OF IRRIGATION PERIODS AND MULCHING ON THE GROWTH AND YIELD-RELATED TRAITS OF MAIZE (*ZEA MAYS* L.)

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SUMMARY

The field experiment on maize (*Zea mays* L.) during the autumn of 2020 revealed the effects of irrigation periods and mulching on its growth and yield-related traits. The study, held at the Bad'at al-Musayyab region, Babylon province, Iraq, had the experiment laid out in a randomized complete block design (RCBD) with factorial arrangement, two factors, and three replications. The first factor was the irrigation intervals (4, 8, and 12 days), while the second comprised two mulching methods (straw mulching and no mulching). The irrigation intervals, mulching treatments, and their interactions revealed significant differences for most growth and yield-related traits in maize. The least irrigation interval (four days) excelled in achieving the highest mean values for plant height (195.00 cm), leaves per plant (16.31), leaf area (697.9 cm^2), chlorophyll index (63.16 SPAD), ears per plant (1.88), grains per ear (602.5), and grain yield (12.55 t ha^{-1}), compared with the maize crop irrigated with a 12-day interval. The latter recorded the lowest means for the above-mentioned traits. The soil mulching treatment also excelled for the traits compared with non-mulching, which recorded the minimum values.

Keywords: Maize (*Zea mays* L.), irrigation intervals, soil mulching, interactions, growth and yield traits, physiological traits

Key findings: Maize (*Zea mays* L.) planting with straw mulching and irrigated every four days, promoted the growth and, eventually, boosted the yield components and grain yield of corn.

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INTRODUCTION

Maize (Zea mays L.) is one of the principal strategic grain crops in the world and Iraq, in particular, due to its best nutritional values and main inclusion in animal feed. For area and yield, it ranks third place worldwide, behind wheat and rice. Accordingly, in 2020, about 101,000 hectares of land were under corn cultivation, which produced 419,030 tons of grains and an average production of 4,137.20 kg ha^{-1} in Iraq (CSO, 2020).

The agricultural sector globally is under extreme pressure to use less water. It is because of rising water prices and climate change, with frequent droughts, making it difficult to grow the most basic crops and even have lower quality (Homayonfar et al., 2014; Al-Khafagi *et al*., 2020). Iraq is in arid and semi-arid parts of the world, having less green spaces becoming vulnerable to climate change, especially in the coming years. With this, the country needs to seriously consider how to control the use of water in agriculture, especially for summer crops like yellow corn requiring more of it. Therefore, it is vital to look for different ways to get edible plants to use less water and produce quality crops with limited water (Al-Aboudi and Al-Shatti, 2014).

Better farming methods have made a big difference in growing more quality crops. The past years, however, saw population increase and the changes in climate utilized more soil and water supplies, creating new problems. The limited water needed for irrigation, producing less food, is the challenge. Despite these concerns, a balanced yield can result from managing soil and water resources well and planning irrigation at proper timing. This is one of the strategic issues related to the growth and productivity of crop plants (Depar et al., 2014).

Using more than one method for field practices to lower water use has become essential for people who work in agriculture. For example, covering the soil's surface can change its temperature and lower water loss from its surface. This is also a management technique creating a good environment, which later shows in the growth and development of food plants. The makeup, biological system, organic matter, and amount of macro- and microelements in the soil all have a huge effect on how well it conducts electricity. These factors also affect the yield components and, finally, the crop grain yield (Pakdel et al., 2013).

According to Al-Roumi (2017), giving yellow corn five or 10 days of watering had a vast effect on its green growth and a bad influence on its yield components. Abd et al., (2014) also said five and 10 days of irrigation directly alter the number of grains in the ears and the weight of the grains, which, in turn, had an effect on the corn crop's end yield. Thus, the point of this study aimed to find out how different amounts of watering and covering (with plant waste) affected the growth and output of maize in the central parts of Iraq. Similarly, it sought how they influenced the amount of water that plants needed.

MATERIALS AND METHODS

In the fall of 2020, some tests went on in a corn crop at the Bad'at al-Musayyab area in Babylon Province, Iraq (longitude 45.49° and latitude 36.16°). Using a rotating plow broke the dirt into two separate plows. The urea fertilizer addition was in two batches, with 690 kg ha^{-1} used at planting and the other third used 45 days later (Hamdan and Bektash, 2011). Applying the DAP fertilizer (18:46 N: P) to the soil at 440 kg ha^{-1}ensued during preparation. Then, the soil's straightening and smoothing out continued before planting. The corn grain's sowing commenced on July 20, 2020. The land used for the experiment bore splitting into three equal areas. The experimental unit was 4 m^2 × 3 m^2, with 12 replicates. The lines and plants were 75 cm and 25 cm apart, respectively. There were five rows in the trial machine. A 1.5 m space existed between the plates and 1.5 m between the replications, preventing water to leak between the follicular units, as the movement of water affects the process of holding it back.

A randomized complete block design (RCBD) with factorial arrangement comprised two factors and three replications. The first factor was irrigation intervals (4, 8, and 12 days), while the second factor was two mulching treatments (straw mulching and no mulching), with an emphasis on conducting conventional tillage before mulching. When the plant reached its fifth true leaf, applying powdered diazinon helped kill the corn stem borer bug. Once the corn fully matured, picking the cobs proceeded and placed them into different piles. The measurement of output components continued for 10 plants randomly chosen from each experimental unit and then averaged. The assessment of chemical and physical qualities of field soil samples ran in the lab of the Department of Soil and Water Resources, College of Agriculture, Al-Qasim Green University, Al-Qasim, Iraq (Table 1).

Vegetative growth traits

These traits' measurement started at the beginning of the appearance of male inflorescences for more than 50% of the plants in the experimental units. Plant height (cm) measuring began from the soil surface to the end of the node bearing the male inflorescence, using a steel measuring tape (Al-Sahuki, 1990). The counting of number of leaves per plant continued for 10 randomly selected plants in each experimental unit and averaged. The leaf area (cm^2) of the leaf on the main stem emerging from the axil underwent measuring according to the following equation (EL-Sahookie, 1985):

Leaf area (cm^2) = leaf length (cm) × maximum leaf width (cm) × 0.75

Leaf chlorophyll content (SPAD) estimation used a SPAD-502 chlorophyll meter prepared by the Japanese company Minolta. The reading went on for 10 randomly selected plants in each experimental unit, with three readings for three leaves in each plant, and then averaged. The measurement used the SPAD unit based on the methodology of Jemison and Williams (2006).

Yield components and grain yield

Measurements of the yield components proceeded at harvest, when signs of the physiological maturity appeared on the plants. A random sample of ten plants, taken in each experimental unit, received markings to carry out the measurements as follows: The number of ears per plant counted in the random samples of plants, and then averaged; the number of grains per ear counted in 10 ears, drawn randomly from the random sample, and then averaged; and for the 500-grain weight (g), separating the cobs of the randomly selected plants had a random sample of 500 grains counted and then weighed on an electric balance after drying the grain and holding the constant moisture (15.5%) (Al-Sahuki, 1990). The grain yield (t ha^{-1}) resulted from setting the humidity to 15.5% and multiplying the grain output per plant by the number of plants in a certain area.

Statistical analysis

All the recorded data for various parameters bore analysis using a randomized complete block design (RCBD) with split-split arrangement. The arithmetic means received further comparison using the least significant difference ($LSD_{0.05}$) test through the Genstat Edition-6 program (Steel and Torrie, 1980).

Table 1. Estimation of some physical and chemical properties of soil samples before planting.

Traits	Values
pH	7.1
Electrical conductivity (dSm^{-1} EC)	3.2
Organic matter g kg^{-1}	1.3
Clay g kg^{-1}	359
Silt g kg^{-1}	340
Sand g kg^{-1}	301
Soil texture	Silty loam
Nitrogen mg kg^{-1}	40.7
Phosphorus mg kg^{-1}	15.3
Potassium mg kg^{-1}	191

Table 2. Effect of withholding irrigations, soil mulching, and their interactions on the plant height in maize.

Withholding Irrigations (days)	Soil mulching		Means (cm)
	Without mulching	With mulching	
4	193.67	196.93	195.00
8	186.30	190.67	188.48
12	168.73	173.07	170.90
Means (cm)	186.69	182.90	
$LSD_{0.05}$ Withholding irrigations: 3.53, Soil mulching: 2.89, Interactions: N.S.			

Table 3. Effect of withholding irrigations, soil mulching, and their interactions on the leaves per plant in maize.

Withholding irrigations (days)	Soil mulching		Means (#)
	Without mulching	With mulching	
4	16.06	16.56	16.31
8	14.59	15.86	15.23
12	12.88	13.93	13.29
Means (#)	14.51	15.37	
$LSD_{0.05}$ Withholding irrigations: 0.49, Soil mulching: 0.40, Interactions: N.S.			

RESULTS AND DISCUSSION

Plant height

The irrigation intervals and soil mulching treatments revealed a significant effect on the plant height in maize crops (Table 2). The treatment with irrigation interval of four days showed the tallest maize plants (195.00 cm), compared with withholding irrigation for 12 days, which gave the shortest plant height (170.90 cm). According to soil mulching, the mulching treatment resulted with the highest mean for the said trait (186.69 cm) versus the plants grown on the soil without mulching, giving the lowest mean (182.90 cm). The reason for the decrease in plant height may be due to the lack of moisture and nutrients necessary for the elongation of the cells and their division with longer irrigation period (Dawood, 2016). Another study agreeing with these results was by Hameedi et al., (2015), who said soil mulching helps plants grow taller by keeping fertilizers, especially nitrogen, in the top layer. This is because these fertilizers help Zea mays L. cells grow longer and divide (Yi et al., 2010). The same table (Table 2) shows the interaction between the two experimental factors and plant height with no significant changes.

Leaves per plant

For leaves per plant, the irrigation intervals and soil mulching treatments exhibited noteworthy differences in maize crops (Table 3). The irrigation with four days interval excelled in achieving the best number of leaves per plant (16.31). It also significantly differed from every eight and 12 days withholding treatments, with the least leaves per plant (15.23 and 13.29, respectively). The mulching treatments also substantially affected this trait, where the soil mulching treatment recorded with the most leaves per plant (15.37), with a notable contrast with the no-mulching treatment (14.51 leaves plant^{-1}). The decrease in the leaf number could refer to withholding irrigation longer, which creates less water in leaf cells, considered the main element increasing the number of cells needed by the plant to form new tissues, including leaves. Soil mulching also maintains a balanced temperature, accelerating the formation of cells and their elongation, which eventually promote crop growth and development (Bu et al., 2013).

Table 4. Effect of withholding irrigations, soil mulching, and their interactions on the leaf area in maize.

Withholding irrigations (days)	Soil mulching		Means (cm^2)
	Without mulching	With mulching	
4	692.5	703.4	697.9
8	643.4	666.5	655.0
12	571.1	611.7	591.4
Means (cm^2)	635.7	660.5	
$LSD_{0.05}$ Withholding irrigations: 20.0, Soil mulching: 16.4, Interactions: N.S.			

Table 5. Effect of withholding irrigations, soil mulching, and their interactions on the leaf chlorophyll content in maize.

Withholding irrigations (days)	Soil mulching		Means (SPAD)
	Without mulching	With mulching	
4	62.49	63.83	63.16
8	57.03	59.23	58.13
12	48.96	53.56	51.26
Means (SPAD)	56.16	58.87	
$LSD_{0.0}$ Withholding irrigations: 4.56, Soil mulching: N.S., Interactions: N.S.			

Leaf area

The irrigation intervals and soil mulching treatments displayed considerable variations for leaf area in maize crops (Table 4). The maize crop irrigation with every four days outshone in achieving the broadest leaf area, amounting to 697.9 cm^2. It differed significantly from the irrigation with every eight and 12 days treatments, recording the lowest means for the said trait (655.0 cm^2 and 591.4 cm^2, respectively. The soil mulching treatment also remarkably influenced leaf area, and the mulching treatment with wheat straw recorded the optimum leaf area (660.5 cm^2), compared with the no-mulching treatment, with the least leaf area (635.7 cm^2). The lack of other biochemical processes, like cell extension and division, which hurt the leaf area in maize plants could be the reason. Water stress can make leaves grow and spread out. Additionally, one way plants deal with abiotic pressures is by decreasing the size of their leaves. This lowers the amount of water they lose through evaporation (Moradi, 2016). These results matched what Al-Mohammadi et al. (2015) found in a corn crop. They stated leaving the soil bare led to a lot of water loss because the soil was extremely hot. This stopped it from growing, causing faster aging. Bu et al. (2013) confirmed covering the soil with wheat straw, especially during the vegetative growth stage, greatly increased the leaf area of yellow corn, which later manifested in the crop's biological and total yield.

Leaf chlorophyll content

For leaf chlorophyll content, the irrigation intervals and soil mulching treatments indicated noticeable differences in maize crops (Table 5). The treatment of withholding irrigation every four days was superior to the rest of the treatments, as it recorded 63.16 SPAD. Meanwhile, the treatment with withholding irrigation every 12 days provided the lowest mean for the chlorophyll content (51.26 SPAD). Meaningful variations occurred between the two treatments, i.e., soil mulching and no mulching. The soil mulching treatment appeared with the best mean for the chlorophyll index (58.87 SPAD), compared with the control treatment, indicating the lowest mean for chlorophyll content (56.16 SPAD). This could refer to the fact that exposing the plants to high stress also affected the chlorophyll synthesis, and cell shrinkage occurred as a result of drought, increasing the enzyme activity responsible for chlorophyll. The rupture of the carana and plastid membranes inside the cell also accelerates its aging, causing a decrease in the chlorophyll content of the leaves in maize crops (Elgamaal and Maswada, 2013).

Stress from flooding also lowers the relative water level of the leaves. It stops the carbon absorption process because the stomata closes partially or completely, and there is no second exchange. The increase in chloroplasts resulted from carbon dioxide, lowering the abundance of pigments, such as chlorophyll, in maize (Ahmed, 2007). According to Al-Qaisi (2017), the corn crop's chlorophyll level dropped because of adverse effects of irrigation times. Researchers also found adding soil mulch kept the soil's structure and makeup the same, raising the percentage of organic carbon, enriching the leaf chlorophyll percentage (Jordán et al., 2010).

Ears per plant

The irrigation intervals and soil mulching treatments exhibited significant differences for ears per plant in maize (Table 6). Withholding irrigation every four days caused a marked increase in the number of ears (1.88 ears plant^{-1}), compared with the irrigation treatment every 12 days, which achieved the lowest mean for the said trait (1.46 ears plant^{-1}). The reason for the decrease in the number of ears could be the longer interval of irrigation, which directly affects plant growth. Thus, it influences the efficiency of photosynthesis and some other physiological processes, decreasing the number of ears per plant in maize (2006; Al-Roumi, 2017). Soil mulching also had a considerable effect on increasing the number of ears, and mulching treatment recorded with 1.74 ears plant^{-1} versus without mulching (1.62 ears plant^{-1}). These results were consistent with the findings of Xu et al. (2015), who reported soil mulching significantly increased the number of ears per plant in maize. The results also authenticated remarkable diversities in the interactions between irrigation intervals and soil mulching treatments for the said trait.

Grains per ear

For grains per ear, the irrigation periods and soil mulching treatments showed substantial variations in maize (Table 7). The withholding irrigation every four days recorded the maximum average number of grains (602.5 grains ear^{-1}) compared with the treatment of withholding irrigation every 12 days, which was the lowest (535.7 grains ear^{-1}). Limited water during the flowering period causes a disturbance in the physiological processes of plants, which affected the available pollen grains to fertilize the ovaries, reducing the number of grains in the ear due to the failure of fertilization (Setter et al., 2001). This was also consistent with findings of Munyiri et al. (2010), who observed water stress at the flowering stage alters the flowering process and fertilization.

As for mulching treatments, soil mulching with hay was the best, recording an average mean of 583.7 grains ear^{-1} compared with leaving the soil bare, giving the lowest mean number of grain, amounting to 562.4 grains ear^{-1} (Table 7). The superiority of mulching points to its positive role in improving soil, benefitting yield components. Inhibiting the evaporation of moisture from the soil surface increased the accumulation of dry matter in cob stages, supporting later stages. The results further indicated a significant binary interaction emerged between the factors of withholding irrigation and mulching. The irrigation treatment every four days with soil mulching surfaced with the topmost mean number of grains (608.4 grains ear^{-1}), significantly differing from the rest of the interactions. The interaction of withholding irrigation every 12 days with no soil mulching demonstrated the lowest mean for the said trait (516.8 grains ear^{-1}). Xu et al. (2015) also confirmed mulching the soil in dry seasons increased the number of grains in the ear of maize (Zea mays L.).

Table 6. Effect of withholding irrigations, soil mulching, and their interactions on the ears per plant in maize.

Withholding irrigations (days)	Soil mulching		Means (ears plant^{-1})
	Without mulching	With mulching	
4	1.83	1.93	1.88
8	1.62	1.77	1.70
12	1.41	1.51	1.46
Means (ears plant^{-1})	1.62	1.74	
$LSD_{0.05}$ Withholding irrigations: 0.09, Soil mulching: 0.13, Interactions: 0.07			

Table 7. Effect of withholding irrigations, soil mulching, and their interactions on the grains per ear in maize.

Withholding irrigations (days)	Soil mulching		Means (grains ear^{-1})
	Without mulching	With mulching	
4	596.6	608.4	1.88
8	573.9	588.2	1.70
12	516.8	554.5	1.46
Means (grains ear^{-1})	562.4	583.7	
$LSD_{0.05}$ Withholding irrigations: 6.92, Soil mulching: 5.65, Interactions: 11.78			

Table 8. Effect of withholding irrigations, soil mulching, and their interactions on the 500-grain weight in maize.

Withholding irrigations (days)	Soil mulching		Means (g)
	Without mulching	With mulching	
4	146.60	147.00	1.88
8	147.39	146.14	1.70
12	148.67	148.17	1.46
Means (g)	147.55	147.10	
$LSD_{0.05}$ Witholding irrigations: N.S., Soil mulching: N.S., Interactions: N.S.			

The 500-grain weight

For 500-grain weight in maize, the irrigation regimes and soil mulching treatments revealed nonsignificant effect (Table 8). However, these results were contrary with the findings of Yi et al. (2010, 2011), who reported mulching with straw caused notable variations in grain weight, which also directly affected the grain yield in corn. Kong's et al. (2020) observations also enunciated soil mulching enhanced the 100-grain weight compared with leaving the soil without mulching. The outcomes further disclosed there were nonsignificant differences for the bi-interaction between withholding irrigation and mulching treatments for the average 500-grain weight. The reason for the lack of substantial disparities between the factors of withholding irrigation and soil mulching and their interactions is the existence of the phenomenon of compensation, occurring mostly among the yield components in maize.

Grain yield

On grain yield, the irrigation intervals and soil mulching treatments exhibited meaningful differences in maize crops (Table 9). Withholding irrigation every four days produced the best average grain yield (12.55 t ha^{-1}), while the lowest yield was visible in withholding irrigation for 12 days (9.57 t ha^{-1}). The reason for the decrease in yield is the decline in one of its components, as limited water, high temperature, and low relative humidity during the growth period and formation of the ovaries could have affected the vegetative traits. Consequently, it caused the lack of photosynthetic carbon synthesis products and their insufficient capacity to form

Table 9. Effect of withholding irrigations, soil mulching, and their interactions on the grain yield in maize.

Withholding irrigations (days)	Soil mulching		Means (t ha^{-1})
	Without mulching	With mulching	
4	12.38	12.72	12.55
8	11.08	12.00	11.54
12	9.30	9.54	9.57
Means (t ha^{-1})	10.92	11.52	

$LSD_{0.05}$ Withholding irrigations: 0.40, Soil mulching: 0.33, Interactions: 2.8

the largest number of grains in maize. It also leads to small-sized and sprinkled grains, which subsequently influencing the grain weight. These results greatly agreed with the findings of Al-Shubar (2021) and Desoky et al. (2021), who also found irrigation periods remarkably modified the grain yield per unit area. The soil mulching with hay recorded with the best mean (11.52 t ha^{-1}), with the lowest grain yield obtained in the soil without mulching (10.92 t ha^{-1}).

Soil mulching also considerably helped increase the grain yield, which may be due to preserving soil moisture in the critical stages of plant growth and the presence of an impediment to its loss toward the top. This was evident in raising the moisture content during flowering and reducing the temperature, and, thus, enhancing the grain yield-attributing traits reflected in the total grain yield. These observations also got support from past findings where soil mulching significantly boosted the grain yield by 20%–30% compared with leaving the soil bare (Li et al., 2013; Atta et al., 2022; Kudaibergenova et al., 2023).

The results further demonstrated major variances in the interaction between withholding irrigation and soil mulching treatments. The interaction of irrigation period every four days and soil mulching with hay outperformed by giving the highest mean for grain yield (12.72 t ha^{-1}) compared with the lowest mean (9.30 t ha^{-1}) obtained with the interaction irrigation every 12 days and with no soil mulching.

CONCLUSIONS

Soil mulching with plant residues, especially with wheat straw, causes a significant reduction in soil surface water loss and runoff at the vegetative growth stages, thus, modifying the crop's growth environment and increasing its production. Therefore, the authors recommend using different mulching materials, such as, leguminous and cereal and other residues layers to achieve the maximum benefit from the conserved moisture in the soil. In addition to preserving the soil composition and moisture conservation, it is necessary to enhance the readiness of nutrients for absorption by crop plants, especially for crops grown in summer in Iraq, mostly facing the scarcity of moisture and nutrients.

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