



Check for  
updates



## Research Article

# Interactive Effects of Reduced Irrigation and Coated Fertilizer on Nutrient and Water Use Efficiency of Maize

Muhammad Amir<sup>1</sup>, Shakeel Ahmad<sup>1</sup>, Wazir Ahmed<sup>1</sup>, Muhammad Usman Jamshaid<sup>1</sup>, Malik Muhammad Yameen<sup>1</sup>, Hafiz Muhammad Farrukh<sup>2</sup>, Muhammad Atiq ur Rahman<sup>3</sup>, Hafiz Muhammad Rafique<sup>4</sup>, Muhammad Imran<sup>1\*</sup>

<sup>1</sup> Department of Soil and Environmental Sciences, Muhammad Nawaz Shareef University Agriculture, Multan-Pakistan.

<sup>2</sup> Director R & D, Maxim Agri Pvt., Ltd., Multan.

<sup>3</sup> Senior Scientist, Provincial Reference Fertilizer Testing Laboratory, Raiwind, Lahore.

<sup>4</sup> Principal Scientist (Soil fertility), Soil and Water Testing Laboratory, Bahawalpur.

## ABSTRACT

This study investigates the interactive effects of reduced irrigation and coated fertilizer application on nutrient and water use efficiency in maize cultivation. Water scarcity derives the development of resource efficient agricultural practices to maintain crop productivity. In this research, we evaluated the impact of lower levels of irrigation and the application of coated fertilizers on maize growth, yield, and resource use efficiency. Maize is a staple crop with substantial water and nutrient requirements. So, its cultivation optimization is essential for sustainable agriculture in water-limited regions. Various strategies have been explored to enhance nutrient and water use efficiency in maize cultivation. Reduced irrigation involves managing the water application to crops and maintaining growth. Two growing seasons were used for these experiments and the results suggest that a combination of reduced irrigation and coated fertilizers can enhance maize nutrient and water use efficiency, contributing to sustainable maize production. A field experiment was conducted on three irrigation levels i.e., 50% available water content (AWC), 75% AWC and 100% AWC along with two level of fertilizer Normal fertilizer (NF) vs. value added coated fertilizers Zarkhez Plus (ZKZ) on maize followed by randomized complete block design (RCBD) and each treatment was followed with three replication. Our results revealed that the T<sub>6</sub> where 50% available water content was maintained along with ZKZ showed the highest water use efficiency (3.5 kg ha<sup>-1</sup> mm<sup>-1</sup>) with minimum yield reduction (16%). The highest yield (10.5 Mg ha<sup>-1</sup>) was recorded with T<sub>2</sub> (100% available water application along with ZKZ fertilizer) that was statistically at par with T<sub>4</sub> where 75% available water application along with ZKZ fertilizer was applied and produced 10.3 Mg ha<sup>-1</sup> yield. It was also observed that the availability of NPK nutrients was more under reduced irrigation with slow-release fertilizer ZKZ as compared to NF with 100% application of available water content. It was concluded that the application of reduced irrigation along with slow-release nutrients fertilizer is the best strategies to combat water shortage and pollution under climate change.

**Keywords:** Maize, coated fertilizer, reduced irrigation, nutrient use efficiency, water use efficiency, sustainable agriculture.



## Correspondence

Muhammad Imran  
m.imran@mnsuam.edu.pk

## Article History

Received: September 10, 2024

Accepted: December 04, 2024

Published: December 27, 2024



**Copyright:** © 2024 by the authors.  
**Licensee:** Roots Press, Rawalpindi, Pakistan.

This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license:  
<https://creativecommons.org/licenses/by/4.0>

## INTRODUCTION

The world's changing climate patterns pose significant challenges to global food security. Pakistan is currently experiencing severe climate change scenarios. Global warming (GW) is a serious problem that affects every region of the planet (Rasul, 2021). Since 1975, the average global temperature has risen by 1.4°C. It is predicted by the end of the twenty-first century that global temperatures will have risen by 2°C, which would probably have a significant effect on the world economy.

Food production and food security are negatively impacted by the rise in temperature and greenhouse gas emissions brought on by climate change (CC). Temperature rises and a significant alteration in precipitation patterns are predicted for Punjab and Pakistan's Kharif and Rabi seasons. The average lowest and highest temperature are predicted to rise by 2-3°C and 2.1-3.5°C, respectively throughout the course of the Rabi season. Kharif is also predicted to suffer a temperature increase of 1.3–3.3°C and a 25–35% change in the pattern of rainfall (Bokhari *et al.*, 2017). One of the most significant staple crops in the world, maize (*Zea mays* L.) provides industrial raw materials, feed, and food. However, maize cultivation requires substantial water and nutrient inputs, making it vulnerable to water scarcity and environmental degradation (Shafique *et al.*, 2020). To resolve these problems, it is crucial to develop sustainable agricultural practices that optimize resource use efficiency while maintaining crop productivity.

The timing and amount of irrigation, the genetic characteristics of the maize variety, soil type, and the weather effect maize production. A management technique known as reduced irrigation involves crop production with optimum irrigation application without reduction in crop productivity (Feres and Soriano, 2007). Irrigation below crop water requirement resulted in a decrease in yield. The researchers discovered that in years with less rainfall, reduced irrigation had a more detrimental effect on yield (Djaman *et al.*, 2018). Reduced irrigation resulted in a decrease in yield, even if the effect was less pronounced in soils with higher available water content (Imran *et al.*, 2013).

When irrigation was cut by 40% during the vegetative stage, production was hardly affected, but when irrigation was cut by the same percentage during the reproductive stage, production was significantly decreased (Djaman *et al.*, 2018). Additionally, they observed that compared to a less tolerant variety, the drought-resistant maize they employed produced more with less watering (Luo *et al.*, 2016). Inadequate irrigation can impede the growth and productivity of plants. However, the amount, timing, and duration of the irrigation determine how severe the reduction is.

As a result, reduced irrigation during the vegetative stage of maize growth could not affect crop yield when it was applied under vigilant management. This management approach can enable sustaining acceptable agricultural production while protecting water supplies (Pereira *et al.*, 2009). Reduced irrigation affects maize in a complex and variable-dependent way (Pokhrel, 2021). Numerous aspects of agricultural development, productivity, and quality may be impacted, both directly and indirectly, by reduced irrigation. The intricate relationship between coated fertilizer and reduced irrigation on the effectiveness of nutrient and water consumption in maize production involves several physiological and biochemical processes. It was well documented that water stress produced by reduced irrigation at initial stages may promote maize roots development and grow to their full potential (Shahzad *et al.*, 2022). Through the progressive release of nutrients from coated fertilizer, it might enhance root growth and development by giving the roots a consistent supply of nutrients throughout growing period (Shahzad *et al.*, 2022).

Coated fertilizers and other slow-release fertilizers are designed to give nutrients to crops gradually over a long period of time (Subramanian *et al.*, 2015). By using the coating on the fertilizer granules to control the rate and timing of nutrient release, it is feasible to improve the efficiency of nutrient usage and reduce nutrient losses from leaching and volatilization (Lu *et al.*, 2021). The effect of coated fertilizers on maize yield may differ according to a variety of factors, such as soil type, climate, and the amount and timing of fertilizer application. Nonetheless, coated fertilizers may increase agricultural productivity, reduce pollution, and enhance nutrient utilization efficiency, all of which could increase farmers' profits (Lu *et al.*, 2021). The water use efficiency (WUE) of irrigation systems in agriculture is a measurement of how much water plants need to finish their life cycles and yield (Malek and Verburg, 2018). By improving water use efficiency in maize production, crop yield can be raised while water use is reduced. WUE must be enhanced for agriculture to produce sustainably, particularly in areas with scarce water supplies. The capacity of crops to absorb and utilize nutrients for maximum output is known as nutrient usage efficiency or NUE. Therefore, nutrient absorption, assimilation, and utilization are three crucial plant activities that are included in the NUE concept (Mahboob *et al.*, 2023). The use of nutrients attempts to improve the overall performance of cropping systems by economically feeding the crop optimally, limiting nutrient losses from the field, and increasing the sustainability of agricultural systems by improving soil fertility or other aspects of soil quality. Nitrogen, phosphorus, and potassium are among the elements that plants may take and use from the soil to support their growth and development (Johnston and Bruulsema, 2014). Keeping in view of the above discussion, this study was planned to assess the interactive effect of reduced irrigation and coated fertilizer on maize production.

## MATERIALS AND METHODS

This section describes the experimental design, treatments, data collection and analysis for assessing the interactive effects of reduced irrigation and coated fertilizer on the maize NUE and WUE.

## Experimental Site and Conditions

The study was conducted at B-block of MNS-University of Agriculture, Multan, Pakistan from August to November 2022 with a semi-arid climate. The soil at the site was sandy loam and initial soil tests revealed the following characteristics: Organic matter: 0.53%, pH: 8.28, Nitrogen (N): 1.3%, available Potassium (K): 136 mg kg<sup>-1</sup> soil, Phosphorus (P): 8 mg kg<sup>-1</sup> soil.

The maize crop was sown on 16<sup>th</sup> of August, 2022 and harvested on 14<sup>th</sup> November 2022. The average daily temperature of Multan during the month of June was 35.5°C that was the hottest month while January was the coldest month with an average temperature of 13.2°C. The total rainfall was 175 mm during 2022.

## Experimental Design

A Randomized Complete Block Design (RCBD) was used with irrigation and fertilizer type in combinations as explained in treatment plan. The experiment was arranged in three replications.

## Treatments

The experiment was comprised of three irrigation levels i.e., 50 % of available water content (AWC), 75 % AWC and 100% AWC with normal fertilizer vs value added fertilizers. The Normal fertilizer means the recommended rate of NPK (Nitrogen, Phosphorous and Potassium) application was maintained by DAP, MOP and Urea while in coated fertilizer the recommended rate of NPK was applied using Zarkhez plus that was mixture of NPK. The recommended rate of fertilizer for maize was 250 Kg N ha<sup>-1</sup>, 150 Kg P ha<sup>-1</sup> and 100 Kg K ha<sup>-1</sup>, respectively. The treatment plan was given below:

T1 = 100% Available water content + Normal Fertilizer (NF)

T2 = 100% Available water content + Zarkhez plus (ZKZ)

T3 = 75% Available water content + Normal Fertilizer

T4 = 75% Available water content + Zarkhez plus

T5 = 50% Available water content + Normal Fertilizer

T6 = 50% Available water content + Zarkhez plus

## Agronomic Practices

**Soil Preparation:** The soil was tilled using a rotavator once and cultivator twice. Land levelers were used for leveling to ensure uniform application of water.

**Seedbed Preparation:** Then the ridger was used to make ridges. Then the field area was split up into two main plots and each of which was then subdivided into two smaller plots.

**Planting:** "Harmony 636" maize seed were sown at a spacing of 25 cm between plants and 75 cm between rows.

**Fertilizer Application:** Fertilizer was applied in two doses:

**Conventional Fertilizer:** Applied at planting (50% of the recommended rate) and the remaining 50% as top dressing at the V4 growth stage (4th leaf stage).

**Coated Fertilizer:** Applied at planting (100% of the recommended rate) in a single dose.

**Irrigation:** The soil water retention curve (SWRC) was estimated by pedo-transfer functions. The following soil properties bulk density, sand silt and clay percentage were used to estimate the SWRC. Field capacity and permanent wilting point was determined from SWRC then Available water content of soil was calculated. The irrigation treatment was applied 100% of available water content, 75% of available water content and 50% of the available water pump content. The potential of airport transportation evapotranspiration was calculated using the FAO Penman-Monteith approach.

## Data Collection

### Soil Nutrient Analysis

Samples of soil were taken at planting and at harvest from each treatment plot to determine nutrient content. Samples were analyzed for Potassium (K), Phosphorus (P), and available nitrogen.

Samples of soil were taken at top 0–30 cm layer using a soil auger. The samples were dried, ground, and analyzed using standard laboratory procedures.

### Maize Yield and Biomass

**Grain Yield:** Maize was harvested at physiological maturity (when kernels reached their maximum dry weight) from 1 m<sup>2</sup> area per plot. Grain was dried to a constant weight, and yield was recorded in Mg/ha.

**Biomass:** Above-ground biomass (including leaves, stems, and ears) was sampled from 1 m<sup>2</sup> area per plot at maturity to determine biomass.

## Growth Parameters

**Plant Height:** A scale was used to measure the length, width and height of plant.

**Stomatal conductance (gs):** CIRAS was utilized to measure this parameter. Five Plants from each replication were randomly selected and used to measure stomatal conductance ( $\text{mmol m}^{-2} \text{s}^{-1}$ ). A similar procedure was used to measure transpiration rate ( $\text{mmol m}^{-2} \text{s}^{-1}$ ), intrinsic water uses efficiency and photosynthetic rate ( $\text{umol m}^{-2} \text{s}^{-1}$ ).

**Chlorophyll content (SPAD meter value):** SPAD was measured by SPAD 502 plus meter. The measurement was taken from five randomly selected plants of each replication.

**Leaf Area Index (LAI):** Measured at mid-season (around silking stage) using a leaf area meter.

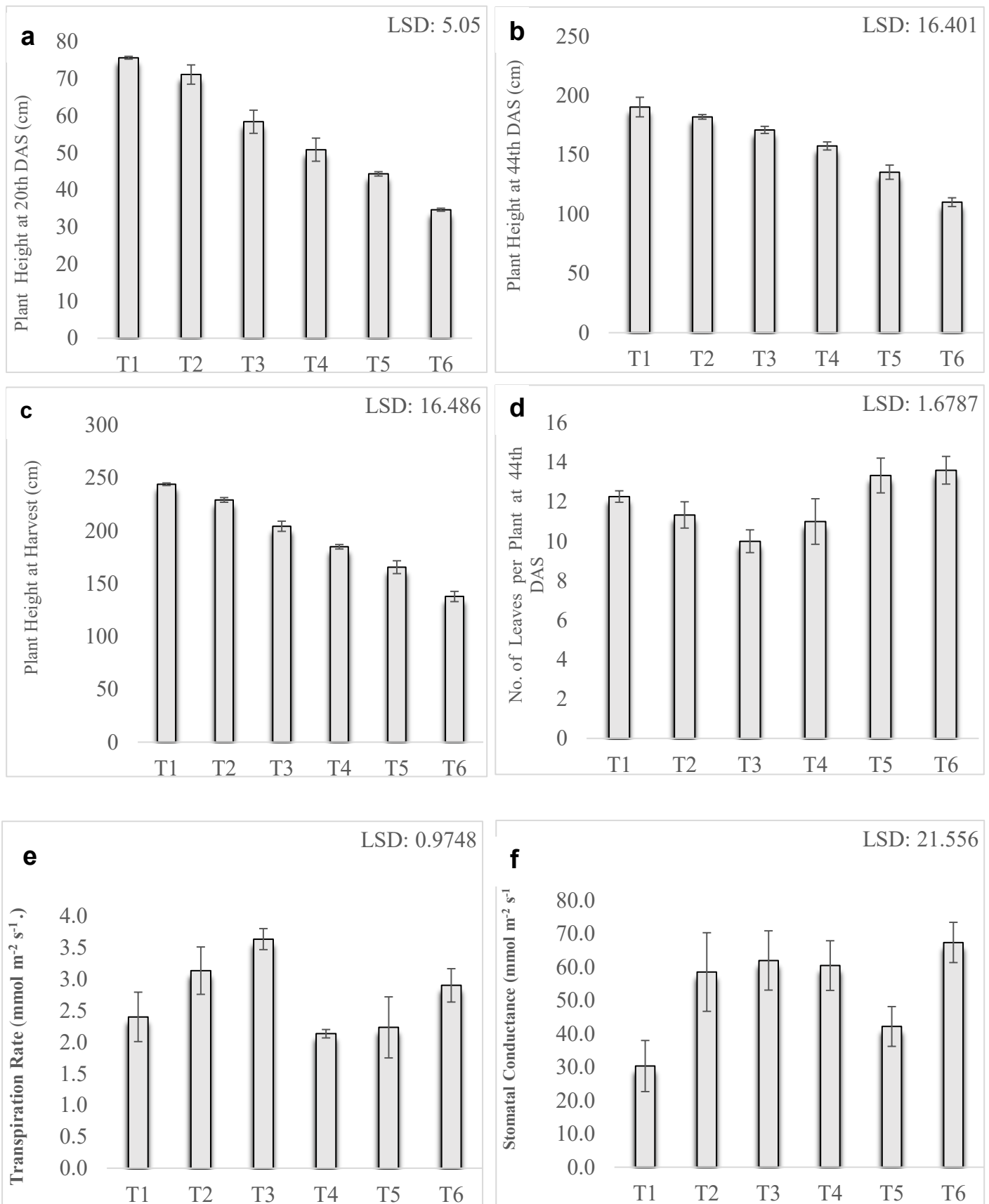
## Statistical Analysis

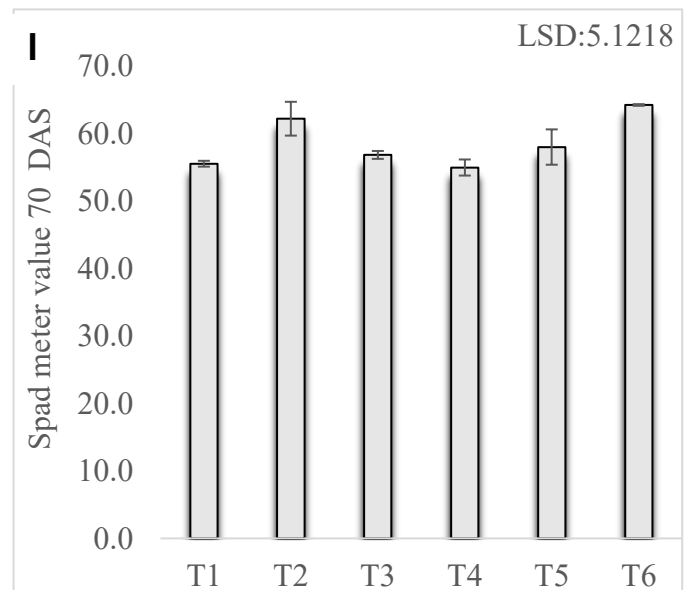
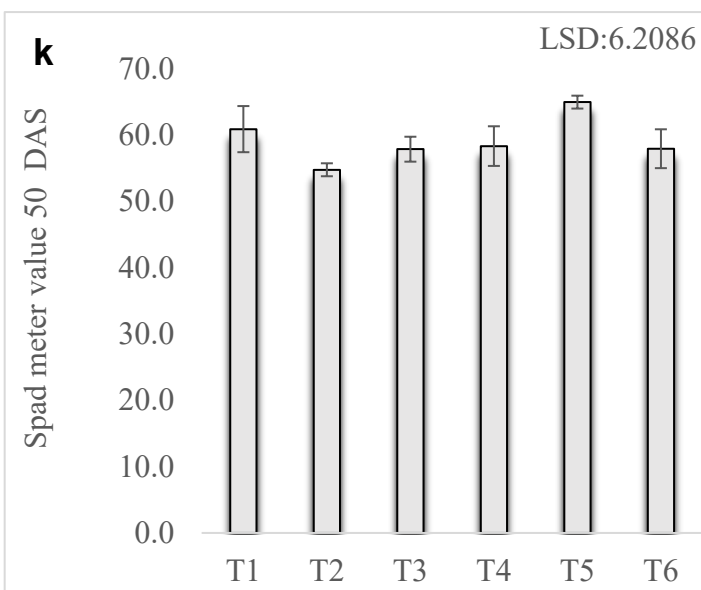
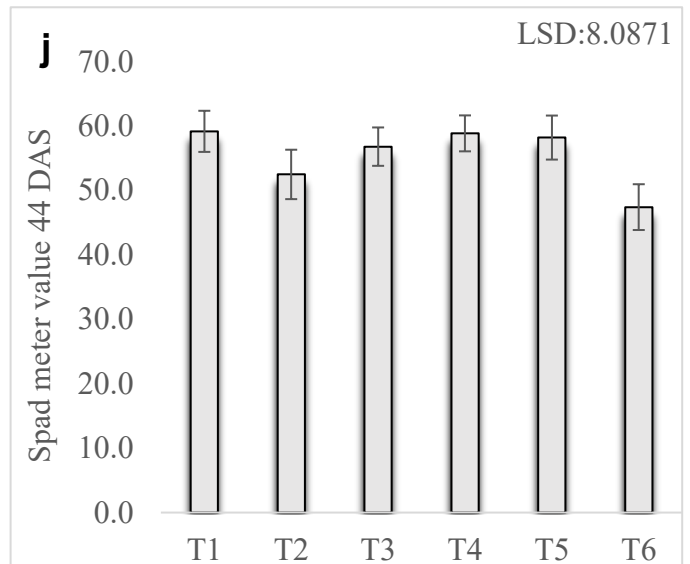
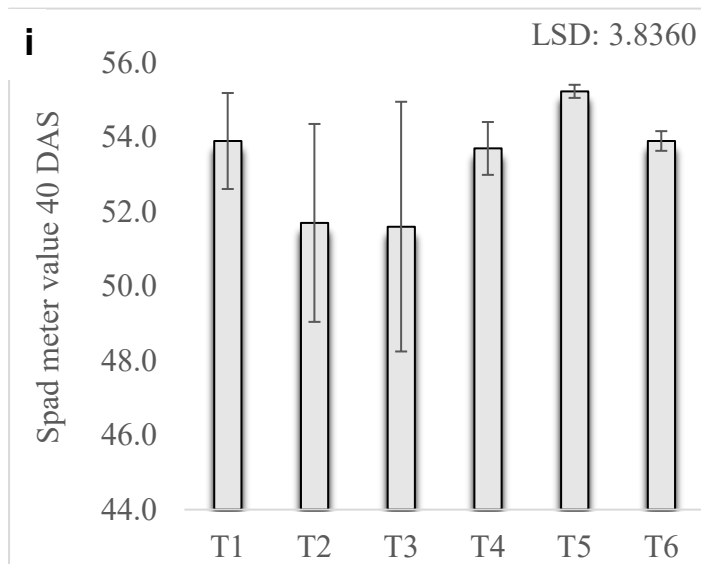
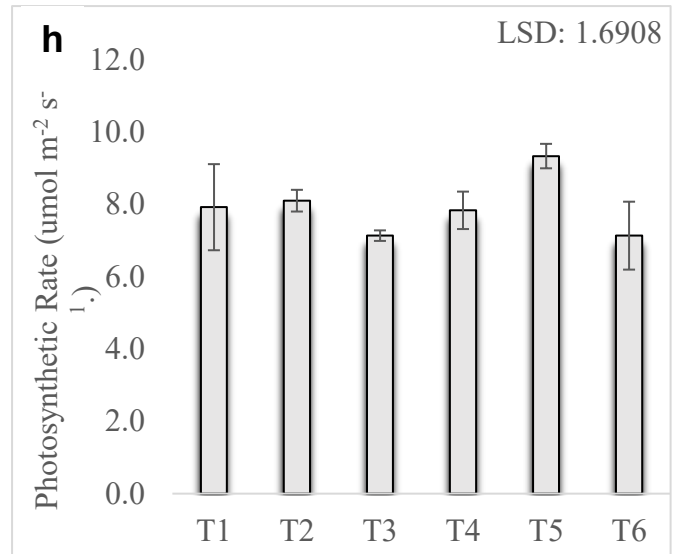
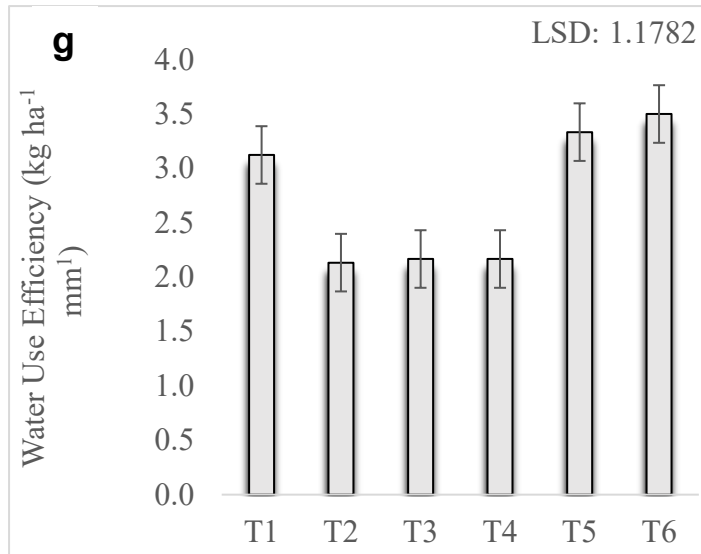
It was decided to use LSD for the mean at a 5% level of probability and to construct an analysis of variance. ANOVA and means comparison were performed using statistical software STATISTIX 8.1 (Steel *et al.*, 1997).

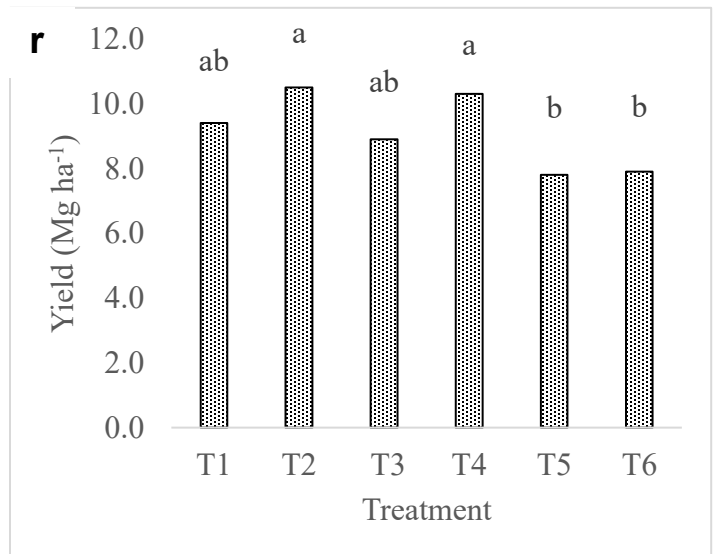
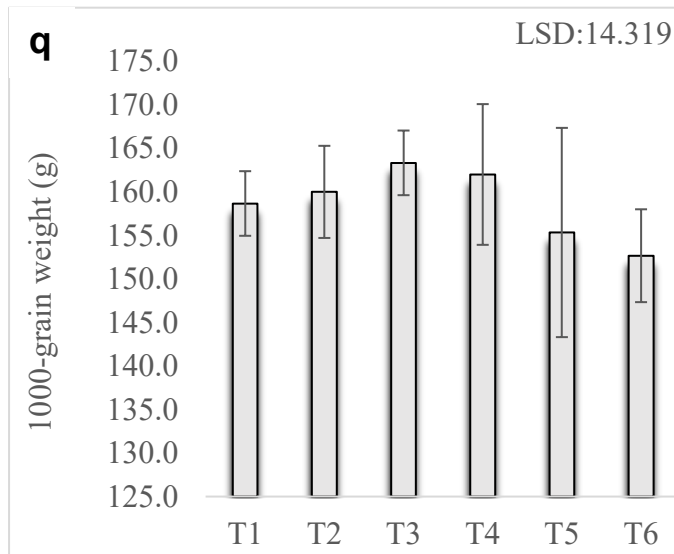
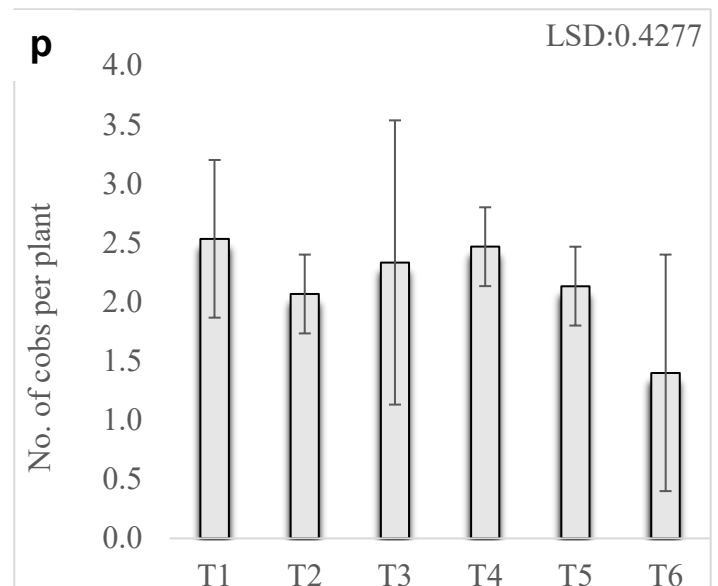
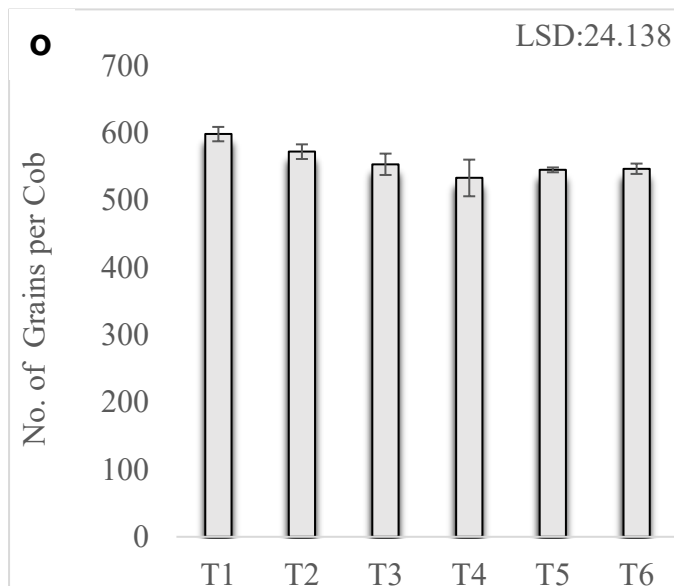
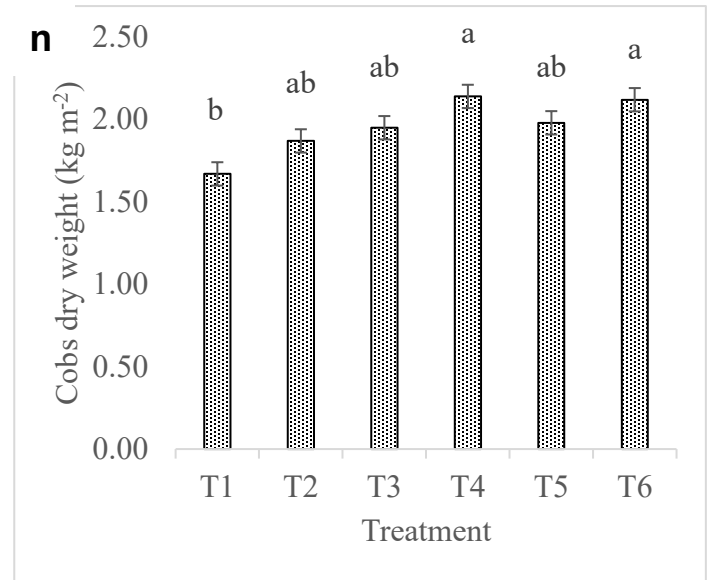
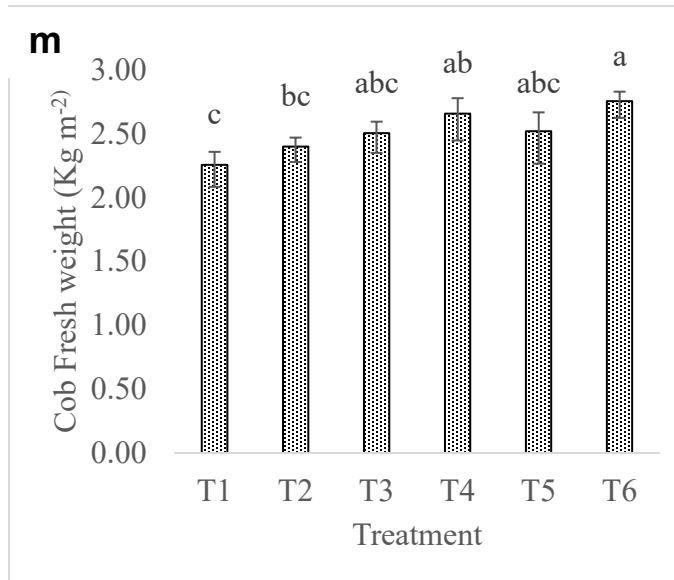
## RESULTS

The reduced irrigation and value-added fertilizer improved the growth and yield parameters of maize. Plant height at 20 DAS (days after sowing) was significantly ( $P < 0.05$ ) effected by reduced irrigation and coated fertilizer and showed maximum plant height in T<sub>2</sub> treatment (73 cm) where 100% irrigation applied with ZKZ and minimum in T<sub>5</sub> treatment (40 cm) where 50% irrigation applied with NF (Figure 1a). A similar trend was observed in Plant height at 44 DAS (Fig.-1b) and 92 DAS (Figure - 1c). Number of Leaves had been significantly affected with Normal Fertilizer (NF) and showed maximum number of leaves in T<sub>6</sub> treatment where 50% irrigation applied with ZKZ and minimum in T<sub>3</sub> treatment where 75% irrigation applied with NF (Figure 1d). Transpiration rate was also significantly affected with reduced irrigation and coated fertilizer (ZKZ) and highest value ( $2.9 \text{ mmol m}^{-2} \text{ s}^{-1}$ ) was observed in T<sub>3</sub> treatment which received 75% irrigation with NF. The lowest value of transpiration rate was recorded ( $2.1 \text{ mmol m}^{-2} \text{ s}^{-1}$ ) in T<sub>4</sub> treatment which received 75% irrigation with ZKZ (Figure 1e). It might be due to the high solubility of mineral fertilizer and its uptake which increased the transpiration rate while ZKZ is slowed released fertilizer which did not enhanced the transpiration rate. Treatments showed significant effect on Stomatal conductance with maximum value ( $67.4 \text{ mmol m}^{-2} \text{ s}^{-1}$ ) in T<sub>6</sub> treatment which received 50% irrigation along ZKZ and minimum ( $30.3 \text{ mmol m}^{-2} \text{ s}^{-1}$ ) in T<sub>1</sub> treatment which received 100% irrigation along NF application (Figure 1f). The highest Water use efficiency was observed ( $3.5 \text{ kg ha}^{-1} \text{ mm}^{-1}$ ) in T<sub>6</sub> treatment which received 50% irrigation ZKZ fertilizer. It was followed by T<sub>5</sub> (Figure 1g). This treatment also showed the highest Photosynthetic rate,  $9.3 \text{ umol m}^{-2} \text{ s}^{-1}$  (Figure 1h). The maximum SPAD value recorded at 40 DAS was 55. 2 in T<sub>5</sub> treatment which received 50% irrigation with NF while minimum was recorded in T<sub>2</sub> and T<sub>3</sub> that were statistically at par (Figure 1i). SPAD values at 44, 50 and 70 DAS were statistically non-significant (Figure 1j, k and L). The fresh weight of cobs showed a significant difference and maximum cobs fresh weight observed ( $0.275 \text{ kg m}^{-2}$ ) in T<sub>6</sub> treatment where 50% irrigation was applied along ZKZ (Figure 1m). The dry weight of cobs observed maximum ( $2.14 \text{ Kg m}^{-2}$ ) in treatment T<sub>4</sub> where 75% irrigation was applied along ZKZ fertilizer and minimum cobs dry weight was observed in treatment T<sub>1</sub> (Figure 1n). The number of grains per cob showed a significant difference and the highest number of grains per cob (585) recorded in T<sub>1</sub> treatment while minimum (533) recorded in T<sub>4</sub> (Figure 1o). The number of cobs per plant has significant difference and maximum number of cobs (2.5) recorded in T<sub>1</sub> and T<sub>4</sub> treatment while minimum (1.4) recorded in T<sub>6</sub> (Figure 1p). In the case of 1000 grains weight, maximum (163g) was recorded in T<sub>3</sub> while minimum (153g) was recorded in T<sub>6</sub> (Figure 1q). The grain yield showed a significant difference between treatments, and the highest yield ( $10.5 \text{ Mg ha}^{-1}$ ) was recorded in T<sub>2</sub> where 100% available water was applied along with ZKZ while minimum yield ( $8.10 \text{ Mg ha}^{-1}$ ) was recorded in T<sub>5</sub> where 50% available water was applied along NF fertilizer (Figure 1r). The concentration of available Nitrogen (N) in soil after harvest was maximum (0.004%) in T<sub>3</sub> and minimum (0.001%) in T<sub>5</sub> (Figure 1s). The concentration of Olsen Phosphorus (P) in soil was maximum (10.9 ppm) in T<sub>2</sub> and T<sub>3</sub> treatment and minimum (9.5 ppm) in T<sub>4</sub> (Figure 1t). The concentration of Potassium (K) in soil was maximum (195 ppm) in T<sub>2</sub> treatment and minimum (171 ppm) in T<sub>5</sub> (Figure 1u). The concentration of Nitrogen (N) in plants was maximum (1.1 %) in T<sub>3</sub> treatment and minimum (0.9%) in T<sub>2</sub>, T<sub>4</sub> and T<sub>6</sub> treatment (Figure 1v). The concentration of Phosphorus (P) in plants was maximum (0.78 %) in T<sub>1</sub> treatment and minimum (0.4 %) in T<sub>6</sub> treatment.

(Figure 1w). The concentration of Potassium (K) in plant was maximum (2.44 %) in T6 treatment and minimum (1.77 %) in T1 treatment.







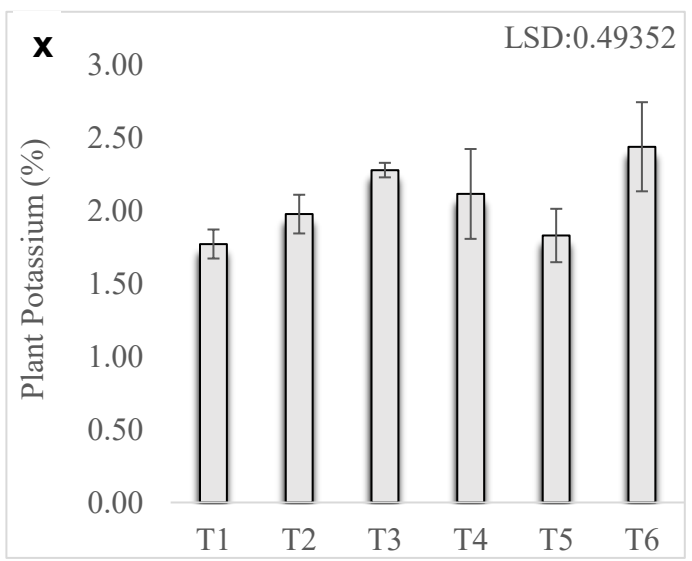
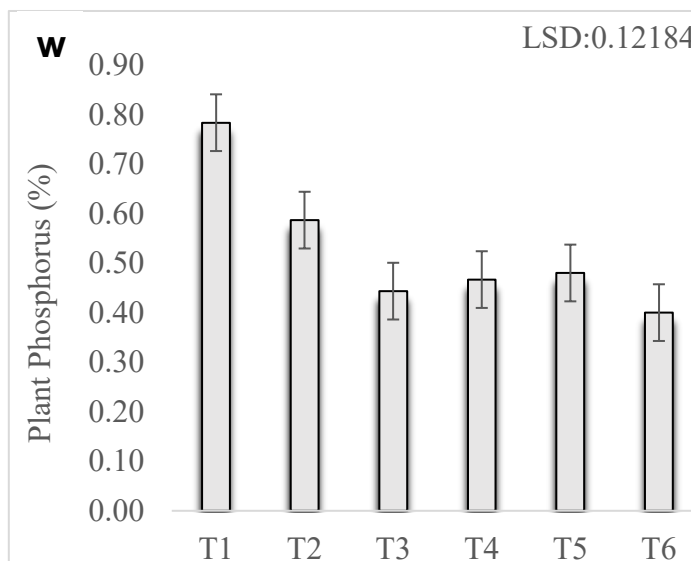
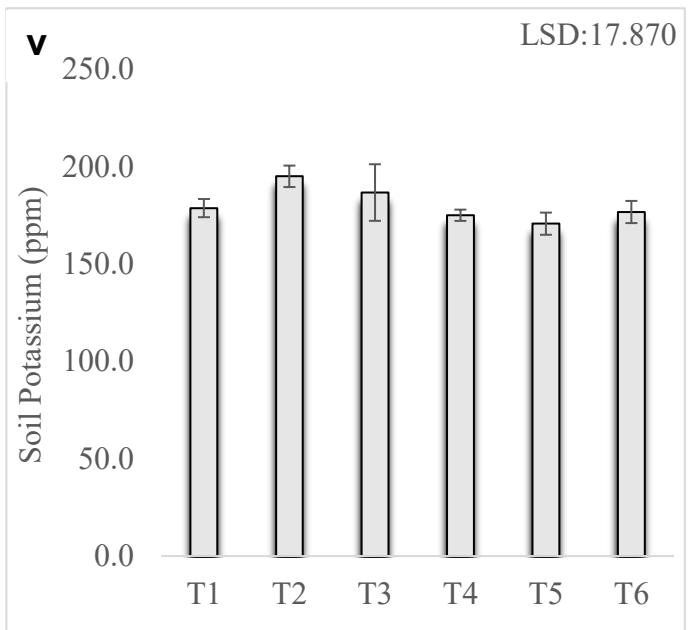
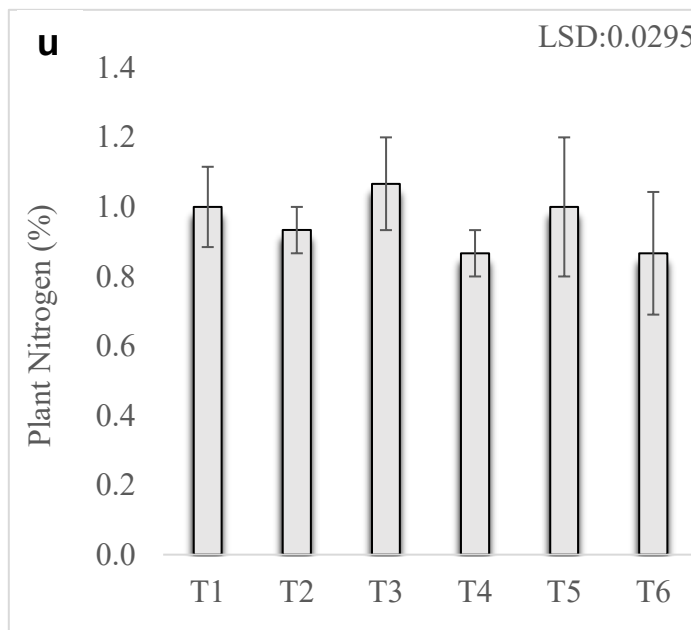
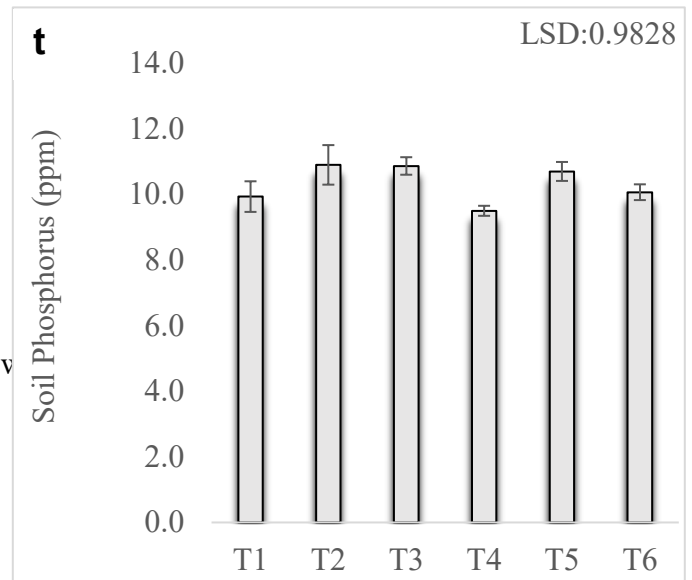
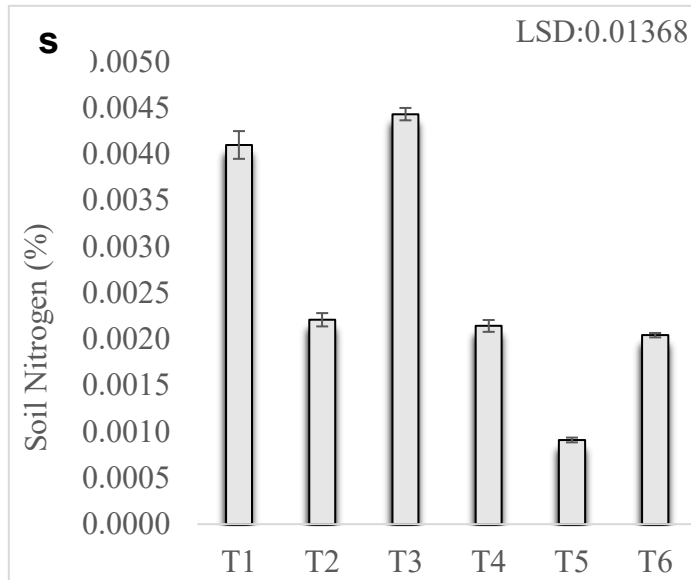


Figure 1. Effect of irrigation scheduling and value-added fertilizer improves the growth and yield parameters of maize on a) Plant Height 20 DAS b) Plant Height 44 DAS c) Plant Height 92 DAS. d) Number of Leaves per plant. e) Transpiration Rate (E). f) Stomatal Conductance(g<sub>s</sub>). g) Water use Efficiency. h) Photosynthetic Rate (A). i) Chlorophyll content 40 DAS. j) Chlorophyll content 44 DAS. k) Chlorophyll content 50 DAS. l) Chlorophyll content 70 DAS. m) Cobs fresh weight. n) Cobs dry weight. o) No. of grains on cobs. p) No. of cobs per plant. q) 1000-grain weight. r) Yield. s) Soil Nitrogen. t) Soil Phosphorus. u) Soil Potassium. V) Plant Nitrogen. w) Plant Phosphorus. x) Plant Potassium.

## DISCUSSION

The availability of moisture content for plant growth, maize plant height was greater when more irrigation and balanced fertilizer were applied. The maximum plant height 90 DAS was observed in T1 where 100% irrigation was applied with NF. The minimum plant height 90 DAS was observed in T6 where 50% irrigation and Zarkhez plus and NF were applied. Numerous researchers asserted that increased maize height of plants because of adequate watering and stable fertilization. The assessment aims to understand the combination of two factors irrigation and fertilizer influence crop performance, resource utilization and overall productivity. Law-Ogbomo and Remison (2009) found that stable application of fertilizers resulted in statistically higher plant heights of maize after two, four and six weeks of sowing Ahmad *et al.*, (1996) and Gill *et al.*, (1996) both observed an increase in the height of plant in maize after using natural feedstock.

Reduced irrigation decreased evaporation losses, resulting in an increase in WUE. Plants use the maximum amount of water. The highest WUE was observed in T6 where 50% irrigation was applied with ZKZ fertilizer. Reduced irrigation might stimulate root development and improved water use efficiency in maize plants. When crops are subjected to limited water availability, they tend to develop deeper and more extensive root systems in search of moisture. This increased root biomass enhances the plants' ability to extract water from deeper soil layer, reducing water loss through evaporation and increasing overall water use efficiency. The integration of the two strategies might reduce the amount of irrigation used in the region. Our results are in line with Giday *et al.*, 2014. In plants the process of photosynthesis is most important which is determined by leaf area index and other elements such as interception of radiation, accumulation of biomass, energy and transpiration are also determinant factors of leaf area. In the limited supply of water, the leaf growth and development are more sensitive associated with root because when the leaf improves then the plant starts vigor growth and photosynthetic characteristics enhanced. The maximum Photosynthetic rate was observed in T6 where 50% irrigation was applied. The minimum photosynthetic rate was observed in T2 where 75% irrigation was applied. The reduction in photosynthetic rate might be due to the low actual amount of water being applied and plant was not showed any stress. The increase in photosynthesis rate in fertilizer treatment may be due to the best combination of the fertilizer being applied. In agreement with Mulumba and Lal (2008), our findings showed that restricted irrigation increased water storage at reduced flow rates by 28 to 70 percent and the amount of accessible water by 17 to 36 percent. It holds great promise for sustainable agriculture. They controlled the release of nutrients from the coated fertilizer and can help to synchronize nutrient availability with crops' requirements. This ensures that nutrients are not lost through runoff or leaching, which often occurs with conventional fertilizer. As a result, maize's nutrient use efficiency can be improved, resulting in the uptake and utilization of vital components for development and growth. Excessive water application in the field of maize can cause negative effects such as loss of water and excessive vegetative growth resulting in lodging ultimately reduction in yield. Present observations are in line with Fereres and Soriano (2007) who described the use of less irrigation saved the maximum loss of water without affecting on the quantity and quality of crops yield. Ertek and Kanber (2003) reported that there was no significance difference in yield by using reduced irrigation in the form of drip irrigation. It was described by Basal *et al.* (2009) in 1000-grain weight and other components which contribute to yield by applying 75% irrigation water associated with maximum water content statistically same. The WUE increased by 50% irrigation because there were no losses of water in the form of ET or drainage beneath the rhizosphere but in case of 100% AWC the water present for 24 hours which was losses through evapotranspiration and/or it was drained out. The other reason was that in 100% irrigation the vegetative growth of plants was maximum as associated with 50% irrigation and weeds competition was maximum in 100% irrigation plots because of accessibility of water for the growth of weeds. In all physiological parameters the net photosynthesis rate is the basic component in the production of crops (Basal *et al.*, 2009). Photosynthesis is not significantly affected by the water stress, but expansion of leaf was affected by water stress. When the irrigation was applied after somewhat stress then the plant recovers the photosynthesis rate quickly for long periods of time. The WUE and yield of crop was also increased (Giday *et al.*, 2014). Reduction in photosynthesis was due to closure of stomata due to reduced irrigation. In early morning the photosynthesis rate was maximum because of less temperature

in nighttime and afternoon the maximum transpiration rate was low and in water shortage conditions the shrinkage of leaf occurred, and rate of water loss was reduced. It was studied in the whole crop cycle and observed that there was no significance difference in main effects of irrigations and varieties. In full irrigation the transpiration rate was maximum associated with 50% available water content irrigation because of high temperature in daytime and extra water was not consumed in plants and water loss occurred in the form of transpiration. As in case of reduced irrigation the actual water was applied, and less loss of water occurred but when the plants were getting maximum height then rate of transpiration was equal to full irrigation. Sustainable maize production is intelligent farming. Sustainable maize production, for example, entails managing resources economically, scheduling planting and watering ideally, and employing the finest practices. Climate change and agriculture must establish a plan to improve farm level water management by enhancing interaction with farmers and partners in cotton-producing river basins to maximize crop per drop and boost yields.

Producing maize in accordance with nature, which eventually improves soil quality and biodiversity, may minimize water pollution caused by maize cultivation due to a greater dependence on naturally occurring insect control agents rather than agro-chemicals. Soil loss and eutrophication can be reduced by carefully managing soil and nutrients. Improving soil quality should result in increased productivity over time. Given the scarcity of water in these areas, the transition to organic farming with a focus on water efficiency and yield improvement, thereby increasing organic farmers' income, is the best long-term strategy to consider.

## CONCLUSIONS

The efficiency of the maize crop's water utilization was also improved through irrigation scheduling. The soil nutrients availability increased because of irrigation schedule, which is critical for greater root penetrations that enhance plant development and output. In times of water scarcity, water may be conserved by using irrigation scheduling on corn crops.

## AUTHOR CONTRIBUTIONS

Not applicable.

## COMPETING OF INTEREST

No conflicts of interest have been disclosed by the authors.

## REFERENCES

- Akhtar, S., Abbas, A., Iqbal, M.A., et al 2021. What determines the uptake of multiple tools to mitigate agricultural risks among hybrid maize growers in Pakistan? Findings from field-level data. *Agri*. 11: 578.
- Fereres, E., Soriano, M.A. 2007. Deficit irrigation for reducing agricultural water use. *J. Exp. Bot*. 58: 147–159.
- Bokhari, S.A.A., Rasul, G., Ruane, A.C., et al 2017. The past and future changes in climate of the rice-wheat cropping zone in Punjab. Pakistan. *Pak. J. Agric. Sci*. 13: 9–23.
- Bouyoucos, G.J. 1962. Hydrometer Method Improved for Making Particle Size Analyses of Soils. *Agron. J*. 54: 464.
- Djaman, K., O'Neill, M., Owen, C.K., et al 2018. Crop evapotranspiration, irrigation water requirement and water productivity of maize from meteorological data under semiarid climate. *Water*. 10(4): 405.
- Johnston, A.M., Bruulsema, T.W. 2014. 4R nutrient stewardship for improved nutrient use efficiency. *Procedia Eng*. 83: 365–370.
- Lu, J., Hu, T., Zhang, B., et al 2021. Nitrogen fertilizer management effects on soil nitrate leaching, grain yield and economic benefit of summer maize in Northwest China. *Agric. Water Manag*. 247: 106739.
- Luo, H.H., Zhang, Y.L., Zhang, W.F. 2016. Effects of water stress and rewatering on photosynthesis, root activity, and yield of cotton with drip irrigation under mulch. *Photosynthetica*. 54(1): 65–73.
- Mahboob, W., Yang, G., Irfan, M. 2023. Crop nitrogen (N) utilization mechanism and strategies to improve N use efficiency. *Acta Physiol. Plant*. 45: 52.
- Malek, Z., Verburg, P.H., et al 2018. Adaptation of land management in the Mediterranean under scenarios of irrigation water use and availability. *Mitig. Adapt. Strateg. Glob. Change*. 23: 821–837.
- Monzon, J.P., Sadras, V.O., Andrade, F.H. 2012. Modelled yield and water use efficiency of maize in response to crop management and Southern Oscillation Index in a soil-climate transect in Argentina. *Field Crops Res*. 130: 8–18.
- Pereira, L.S., Cordery, I., Iacovides, I. 2009. Coping with water scarcity: Addressing the challenges. *South South Coop. Bull. Manag*.
- Pokhrel, S. 2021. Effects of drought stress on the physiology and yield of the maize: a review. *Food Agric. Econ. Rev*. 1(1): 36–40.

- Rasul, G. 2021. Twin challenges of COVID-19 pandemic and climate change for agriculture and food security in South Asia. *Environ. Challenges*. 2: 100027.
- Richards, L.A. 1954. Diagnosis and improvement of saline and alkali soils. *USDA Agric. Handb.* 60, Washington, D.C.
- Shafique, F., Ali, Q., Malik, A. 2020. Effects of heavy metal toxicity on maize seedlings growth traits. *Biol. Clin. Sci. Res. J.* 2020.
- Steel, R.G.D., Torrie, J.H., Dicky, D.A. 1997. Principles and procedures of statistics (A biological approach, 3rd ed.). *McGraw-Hill Book Co.*, New York, USA.
- Subramanian, K.S., Manikandan, A., Thirunavukkarasu, M., et al 2015. Nano-fertilizers for balanced crop nutrition. *Nanotechnol. Food Agric.* 69–80.
- Walkley, A., Black, I.A. 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Sci.* 37: 29–38.