ZANCO Journal of Pure and Applied Sciences
The official scientific journal of Salahaddin University-Erbil
https://zancojournals.su.edu.krd/index.php/JPAS

ISSN (print):2218-0230**, ISSN (online):** 2412-3986**, DOI:** **http://dx.doi.org/10.21271/zjpas**

RESEARCH PAPER

Interactive effect of irrigation strategies and mulching on yield, water use efficiency and crop response factor of maize (*Zea mays L.*) in a semiarid climate

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A B S T R A C T:
With growing water scarcity and increasing competition for water, there will be more need for development of sustainable and efficient irrigation strategies, especially in areas that are arid and semi-arid. The adoption of other practices In conjunction with deficit irrigation techniques, further enhance both crop yield and the effectiveness of its irrigation. Accordingly, a study was initiated following a factorial experiment in randomized complete block design with three replications to evaluate the interactive effect of deficit irrigation (DI) and type of mulching (M) on yield, irrigation water use efficiency and crop response factor for corn during the growing season of 2021. The deficit irrigation encompassed three strategies: 1.0 of full irrigation supply (100%FI), 0.75 of full irrigation supply (75 %FI) and 0.5 of full irrigation supply (50% FI) and mulching included: no mulch (M1), wheat straw mulching (M2) and plastic mulching (M3). The results indicated that irrespective of mulch type the yield increased linearly as there is an increase in total Amount of water required. It was also noticed that there was a steady increase irrigation water use efficiency (IWUE) with a decrease in the amount of applied water. Overall, there was an improvement in IWUE upon mulching. The treatment combination M_3I_3 offered the highest water use efficiency. Under all mulching types, the k_y –values were less than 1.0, indicating that DI combined with M is an effective and practical management strategy to combat water shortage in the study location. Furthermore, crop sensitivity to drought tended to decrease with mulching.

KEY WORDS: Deficit irrigation, mulching, Maize water use efficiency, crop response factor
DOI: http://dx.doi.org/10.21271/ZJPAS.35.3.9
ZJPAS (2023) , 35(3);98-109 .

1. INTRODUCTION:

Improving water productivity is considered as the main challenge for water management and consequently sustainable crop production (Tufa et al., 2022). In regions where rainfall amount is decreasing, irrigation is the alternative choice for growing crops. The success of farming in these regions depends on the ability of the growers to properly manage scare water resource for agricultural use. (Suleiman et al., 2021).

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Article History:
Received: 12/09/2022
Accepted: 24/10/2022
Published: 15/06 /2023

One strategy to increase yields per irrigation water unit used is to maximize water use efficiency. is the practice of deficit irrigation. Under this practice, the grown crop is subjected to a particular extent of deficit irrigation during a specific stage or during the whole growing period (Nagaz et al., 2012). The potential of this practice in conserving limited water resources and increasing farm productivity has been documented (Kirdra, 2020). Zhang et al. (2017) reported that a less expensive water-saving irrigation method is deficit irrigation. approach for growers, permitting crops will only experience minor water stress. Huang et al. (2022) demonstrated that crop yield and water stress are related type of crop and soil and the prevailing climatic conditions.

Mulching is a central agronomic practice increase crop yield and water use efficiency of crops as it reduces evaporation of soil water and soil water conservation weed control and soil temperature increase are both benefits (Allen et al., 1998; Igbadun et al., 2012). Crop yield and water use efficiency may both rise as a result of combining mulch and irrigation scheduling with limited irrigation water, especially in arid regions.

Kırnak and Demirtas (2006) highlighted that limiting soil evaporation with mulches is a key action to take to save irrigation water and to improve water use efficiency and irrigation water use efficiency. Under drip irrigation, mulching causes an increase in water use efficiency, regulates the soil's temperature, suppresses evaporation losses. Additionally, it reduces weeds and enhances fruit yield and quality (Saridas et al, 2021). Different types of mulch create specific conditions that have a substantial effect on growth, fruit (Casierra-Posada et al., 2011). Apart from this, it was observed that, Inappropriate irrigation scheduling could reduce crop yields on mulched cropland by making some growth stages more severely water stressed for its effect of increasing leaf area index in mulching fields (Xie et al., 2005, Chen et al., 2015).

Maize (*Zea mays* L.) is considered as among the most essential crops, now ranking third in the world production behind all of rice and wheat (WMO, 2012). It can significantly improve food security because of its versatility as a food source, feed source, and fuel source (Greaves and Wang, 2017). Apart from this, insufficient water for irrigation purposes, is one of the challenges faced by many developing countries in production of this crop (WMO, 2012).

The response of a crop to its soil moisture environment is measured through Ky. So, the Ky - approach provides a dependable means of simulating crop yield in response to water stress for a specific area (Shrestha et al., 2010). The Ky-values were reported for a number of crops by Doorenbos and Kassam (1979). Since this parameter is affected by a host of conditions such as localized climate, soil and water management conditions, its existing values for a given crop cannot be transferred (Ferreira and Goncalves, 2007). Consequently, there is an urgent it is necessary to develop and evaluate the performance of Ky for various crops and in specific environments to support in sustainable development of irrigation water management techniques.

To this point, studies conducted to rate the interacted effects of irrigation regimes and different types of mulching on growth, yield and irrigation water use efficiency of maize grown in the Mediterranean region of Iraqi Kurdistan Region are lacking.

In this context, the current research was commenced to evaluate the interactive effects of deficit irrigation level and mulching type on growth, yield and irrigation water use efficiency of maize in the semiarid environment of Iraqi Kurdistan region.

2. Materials and Methods

Nearly a level parcel of land was selected for this study at the experimental farm of Girdarasha, College of agricultural Engineering Sciences, university of Salahaddin, which is about 7 km to the south of Erbil city (36^{o} 11$'$ 35.6$''$N and 44^{o} 01$'$ 9.87$''$). The experiment was carried out on a clay loam soil (clay= 32.8%, silt=42.0%, sand =25.2%; ECe = 0.8 dS m^{-1} and pH= 7.9, θ_{FC}=26.29%, θ_{pwp}=16.06% on mass basis and ρ_b= 1.38 g cm^{-3}). The soil exhibited moderate swelling potential and categorized as Fine Clay, Active, Mixed Thermic, Typic chromoxererts. The climate of the study area is of Mediterranean type. The rainfall has a unimodal distribution with no rainfall during the summer months of the year. The hottest and coldest months of the year are August and January (Fig.1). The experimental field preparation before sowing, it was twice plowed and well leveled to ensure that the water would be applied consistently. Based on experimental design total 27 plots with dimensions of 3 m × 3 m were prepared. To avoid interaction between treatments, the blocks were bounded with a buffer zone 2 m in width. Each plot consists of four rows of planting. Maize (Zea mays L.) hybrid Talan was directly sown on 1st August in the growing season growing seasons 2021. Plants were spaced 25cm×75cm within and between rows, respectively which made a plant population of (53333) plant ha^{-1}. Prior to sowing, 80 kg ha^{-1} N and 80 kg ha^{-1} P_2O_5 (Urea + Triple superphosphate) were applied to all plots. During the cropping season, diseases and insects were strictly controlled, and plots were hand-weeded as needed.

The experiment was laid out following a 3 x 3 factorial experiment design in a randomized complete block arrangement with three deficit irrigation levels: I_1= 100% Full irrigation or 100%FI; I_2= 75%FI; I_3= 50% FI and three types of mulching: M_1=No mulch; M_2 = chopped wheat straw mulching at a rate of 0.7 kg m^{-3}; M_3 = plastic mulching in form of transparent polyethylene sheets with a thickness of 1.5 mil. The experiment was conducted in triplicate. The depth of irrigation was applied according to 0.50, 0.75 and 1.00 of readily available water and the irrigation interval was set such that the percent of available water depletion be 55%. The percent of depletion was checked by taking soil samples throughout the root zone by a small auger. Equations 1 through 5 were used to calculate the depth and volume of soil moisture deficit and time of operation of the pump during each irrigation according IA, (2005):

$$SMD = \left(\frac{\theta_{FC} - \theta_i}{100}\right) D_{rz} A_s f \qquad [1]$$

$$\theta_i = P*TAW(\%) + \theta_{PWP} \qquad [2]$$

$$TWA = \theta_{Fc} - \theta_{PWP} \qquad [3]$$

where SMD = soil moisture deficit (mm)
θ_{FC} and θ_{pwp} = Soil moisture content of the root zone at field capacity and permanent wilting point on mass basis
θ_i= Soil moisture content of the root zone prior to irrigation on mass basis. It was obtained from:
P = depletion fraction (0.55 for maize)
D_{rz} = root zone depth at the time of irrigation (mm). The root depth was determined periodically by pulling out plants prior to each irrigation
As = apparent specific gravity (-) and given by

$$As = \frac{\rho_b}{\rho_w} \qquad [4]$$

Where ρ_b and ρ_w are soil bulk density and water density using the same unit

TAW = Total available water (%)
f = a coefficient to impose different levels of deficit irrigation, 1.0, 0.75 and 0.50 for I_1, I_2, I_3, respectively
The source of irrigation water was a nearby well (EC = 0.6 dS m^{-1} and pH= 7.7). The time required to achieve the desired irrigation depth for each plot was calculated. from:

$$IWUS = \frac{Y_a}{I} \qquad [5]$$

T = time of operation in minutes

a= plot area (9 m^2)

q = Hose discharge in (l/min). A flow meter Model was in line with hose for measuring hose discharge.

Ea = irrigation application efficiency. Based on the slope of the land and the basic infiltration rate a value of 0.60 was selected (Karim and Karim, 2001).

The inflow rate was measured with a flow meter Model SOTERA digital flow meter, installed at a few meters upstream from the experimental plots' inlet.
Full irrigation (FI)) under no mulch was used as a control for the other plots (Kiptoo et al., 2019). Before maize emergence, to avoid water deficits, all plots received the same irrigation water. afterward irrigation was done as per the deficit level up to the end of October, 2021.
The crop was harvested on 29th Nov.2021 and the grain yield in kg was obtained from two central rows of each experimental unit (sub-plot) and then adjusted into ton per hectare. Furthermore, the value of this parameter was adjusted based on 15.5% grain moisture content.
The yield response factor (*Ky*) was calculated to quantify the effect of deficit irrigation on maize yield according to (Doorenbos and Kassam, 1979):

$$1 - \frac{Y_a}{Y_{max}} = K_y \left(1 - \frac{ET_a}{ET_{max}}\right) \qquad [6]$$

where *Ya* and ET*a* are, the actual yield and actual ET for the deficit treatments respectively; *Ymax* and ET*max* are the maximum yield and maximum ET obtained from the fully irrigated treatment respectively;
The irrigation water productivity or the irrigation water use efficiency (IWUE, kg m^{-3}) was determined from:

$$T = \frac{SMD \times a}{q\,Ea} \qquad [7]$$

where I is the total irrigation water applied

3. Results and Discussion

3.1. Grain yield

Fig.2. display that the maize yield was as affected by the interaction between deficit level and mulching type. As can be noticed, there is a steady decrease in grain yield with an increase level of deficit or water stress under no mulch. Similar trend was noticed under plastic and straw mulches. Additionally, the results indicated under the same level of deficit, the straw mulch offered the highest performance followed by plastic mulching. These results are in line with the findings of Greaves and Wang (2017), who noticed that the corn Grain yields decreased as irrigation water application decreased. These results indicate that the volume of applied water under deficit irrigation was not adequate to offer favorable soil moisture level for optimum production even under mulching.

The results of the variance analysis revealed that the grain yield was affected significantly (P0.05) by deficit irrigation and mulching type (Table 1). Furthermore, Duncan's multiple range test revealed that with no exception, the grain yield under a given deficit differed significantly from the rest of the deficit levels.

Table 1. Analysis of variance showing the effect of deficit irrigation levels and mulching types and the interaction between them on yield of maize.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Deficit level	107.436	2	53.718	64.757	.000
Mulch Type	6.333	2	3.167	3.817	.044
Deficit level * Mulch Type	1.223	4	.306	.369	.827
Replicates	2.340	2	1.170	1.410	.273
Error	13.273	16	.830		
Total	2364.782	27			
Corrected Total	130.605	26			

3.2. The relation between grain yield and total depth of applied water

The grain yield was plotted versus the volume of applied water under all types of mulches and the results were presented in Fig.3. As can be observed, irrespective of type of mulching there is a steady increase in grain yield as the volume of applied water increases over the imposed ranges of water stress. At a given deficit level the grain yield with plastic mulching was superior to those under the remaining types. It is also evident from Fig.3 that the straw mulch offered the second highest performance.

The percentages of reduction in grain yield under I_2 and I_3 under no mulching were 21% and 46% respectively compared with I_1(Table 2). On the other hand, the percentages of reduction in grain yield were 26 and 38% under straw mulching. It was also noticed that the percentages of reduction in grain yield under plastic mulching with one exception fell between these two extremes. The least yield depression for deficit treatments I_2 and I_3 under straw mulching indicates that maize under these treatment combinations was less severely stressed compared with plastic and no mulching, particularly under I_3.

The results of the variance analysis revealed that the IWUE was significantly ($P \leq 0.05$) affected by deficit irrigation and mulching type (Table 3). This result is similar to that reported by Elzubeir and Mohamed (2011), but it differs from the findings of Karasu et al. (2015), who found that water stress reduced the number of rows per ear in deficit irrigated maize.

Imposing deficit levels under I_2 and I_3 offers water-saving opportunities at each irrigation event. In other words, using this water application depth saves water 25 and 50% respectively (Table 2) compared to the fully irrigated treatment with moderate yield penalty. This assumes that increasing the irrigated areas with the saved water could compensate for any yield loss due to deficit irrigation (Tufa et al., 2022).

It is interesting it should be noted that in this study the treatment combination M_1I_1 was considered as the reference to define the time of irrigation during the growing season. This implies the soil under this treatment was monitored to define the time of irrigation. This is the reason for the fact that under a given deficit irrigation level, the no mulch, plastic mulch and straw mulch treatment received the same quantity of total water was applied to irrigation. The idea behind this practice was to show the contribution of mulching in mitigating the bad consequence of deficit irrigation. Lower yield and lower total volume of applied water are expected when each plot under full irrigation belonging to different mulching materials is monitored separately to define different times of irrigation, i.e., each mulch has its own time of irrigation. Accordingly, the second idea is recommended as a proposal for a new study.

Table 2. Additional cultivated area and additional yield that can be obtained under the interactive effect of deficit irrigation and mulching.

Treatment combination	Grain yield(t/h)	Volume of applied water		Water use efficiency (kg m^{-3})	Irrigation water saved (%)	Yield Reduction (%)	Additional area that can be cultivated with corn(ha)	Additional yield(t/ha) under 100%FI
		mm	m^3					
M1 100%FI	11.02	789.00	7101.00	1.55	0.00	0.02	0.00	0.00
M1 75%FI	8.67	591.78	5326.00	1.63	25.00	21.28	0.25	2.75
M1 50%FI	6.00	394.56	3551.00	1.69	50.00	45.55	0.50	5.51
M2 100%FI	11.47	789.00	7101.00	1.62	0.00	-4.08	0.00	0.00
M2 75%FI	8.99	591.78	5326.00	1.69	25.00	18.38	0.25	2.87
M2 50%FI	6.51	394.56	3551.00	1.83	50.00	40.97	0.50	5.74
M3 100%FI	12.34	789.00	7101.00	1.74	0.00	-11.95	0.00	0.00
M3 75%FI	9.19	591.78	5326.00	1.73	25.00	0.26	0.25	3.08
M3 50%FI	7.68	394.56	3551.00	2.16	50.00	0.38	0.50	6.17

3.3. Irrigation Water Use Efficiency

Irrigation water use efficiency (IWUE) was determined for all the treatment combinations as ratio of the crop yield (kg/ha) and total amount of water required (m^3/ha) and the results are presented in Fig.4a. The highest water use efficiency (2.16 kg m^{-3}) was achieved under I_3M_3. Conversely, the lowest value (1.55 kg m^{-3}) under I_1M_1. The results are in line with those obtained by Greaves and Wang (2017) who observed values for this parameter ranged between 1.63 and 2.41 kg m^{-3} in 2014/2015, while for the 2015/2016 season, the range was between 2.95 and 4.53 kg m^{-3}. They attributed the difference in IWUE to crop yield potential, crop environment, and climatic characteristics of a region. As shown in Fig.4a, there is a steady increase in IWUE with a decrease in volume of applied water over the range of imposed water stress. The results found in current study are parallel with the studies of Lovelli et al. (2007) and Ertek et al. (2006) for vegetable crops.

Additionally: it can be observed upon reconfiguring Fig.4a that mulching with wheat straw outperformed the two remaining types in term of IWUE (Fig.4 b).

Like grain yield, the irrigation deficit had a significant (P0.05) effect on water use efficiency. irrigation and mulching type, while it was unaffected significantly by the interaction among them. (Table 3).

Table 3. Analysis of variance showing the effect of deficit irrigation levels and mulching types and the interaction between them on irrigation water use efficiency (IWUE) of yield of maize.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Deficit level	.339	2	.169	3.871	.043
Mulch Type	.300	2	.150	3.425	.058
Deficit level * Mulch Type	.125	4	.031	.713	.595
Replicates	.119	2	.059	1.358	.285
Error	.700	16	.044		
Total	82.945	27			
Corrected Total	1.582	26			

3. 4. Crop Response factor

The relationship between relative maize reduced yield and a deficit in relative evapotranspiration are shown in Figs. 5 through 7. It was observed that the obtained Ky values were less than 1.0 under all types of the applied mulches. According to Araya et al. (2011) Ky-values below 1 reveal that the crop can tolerate some levels of deficit irrigation during its growing season. Also, the obtained result is agreeing with the findings of Greaves and Wang (2017), who noticed that corn yield response to water stress was less than one, suggesting the environmental conditions are favorable for implementing DI strategies. These results also conform to Karam et al., 2003; Kuscu et al., 2013 who reported ky – values of less than 1.0. Apart from this, the obtained values from this study were significantly lower than the values reported by each of Doorenbos and Kassam (1979), Cakir (2004) and Payero et al. (2009) for maize. Variability in the yield response factor (Ky) might be noticed under different irrigation practices, such as method of cultivation method, extent of deficit irrigation and stage of the crop deficit irrigation imposed

Yield response factor (Ky) reflects the complicated relationship between crop production and water use. This relationship may reflect a remarkable validity and allowable procedure for quantifying the impact of water deficit on economic yield. (Mekonnen and Sintayehu, 2020). Therefore, relative yield reduction was less than the relative evapotranspiration deficit when deficit irrigation scheduling was induced over the whole stage of growth. The results also revealed that the straw and plastic mulches offered the highest and lowest performance in term of ky (0.808 versus 0.899). However, the order of effectiveness being:

Straw mulch > plastic mulch > no mulch.

The lower sensitivity of the grown crop under mulching to drought compared to no mulch could be attributed to reduced evaporation, suppressed weed growth and moderated soil temperature, which enhanced plant growth.

4. Conclusions

It can be inferred from the obtained results that maize plant is tolerant of a lack of available soil water throughout the growing season under the semiarid environment of Erbil city but different results may be obtained when the extent deficit irrigation changes. The performance of the maize crop is better under mulching in term of irrigation water use efficiency and crop response factor.

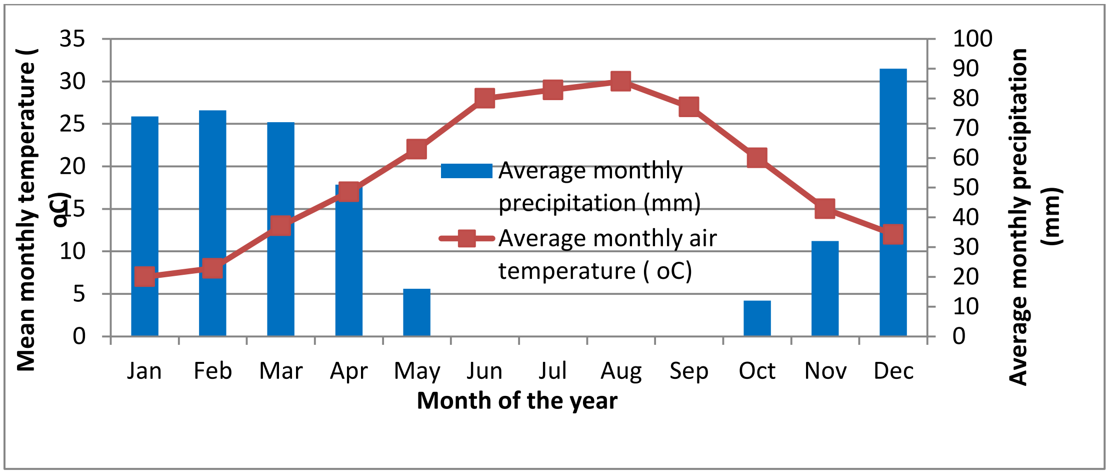

Fig.1. Long term distribution of monthly air temperature and precipitation over the months of the year at the experimental site.

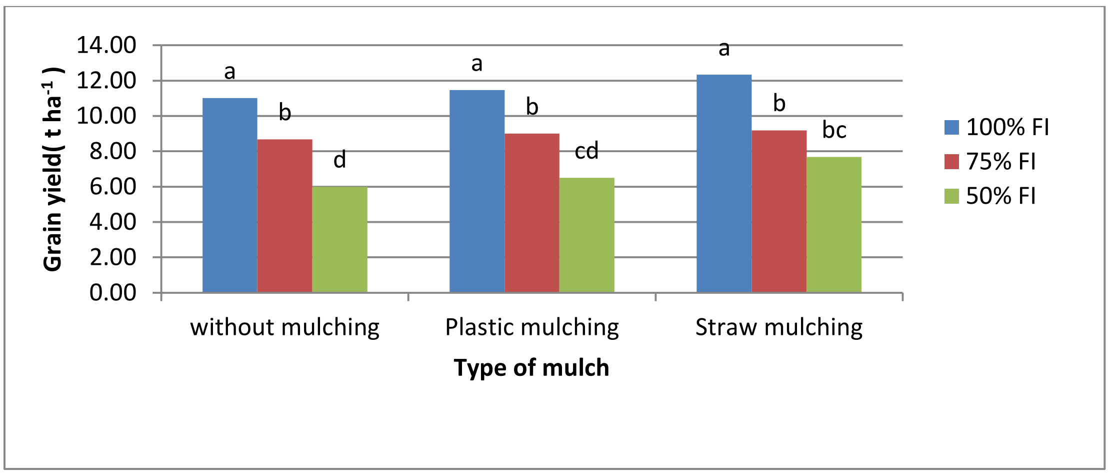

Fig.2. Maize yield as affected by interactive effect of deficit irrigation level and type of mulch

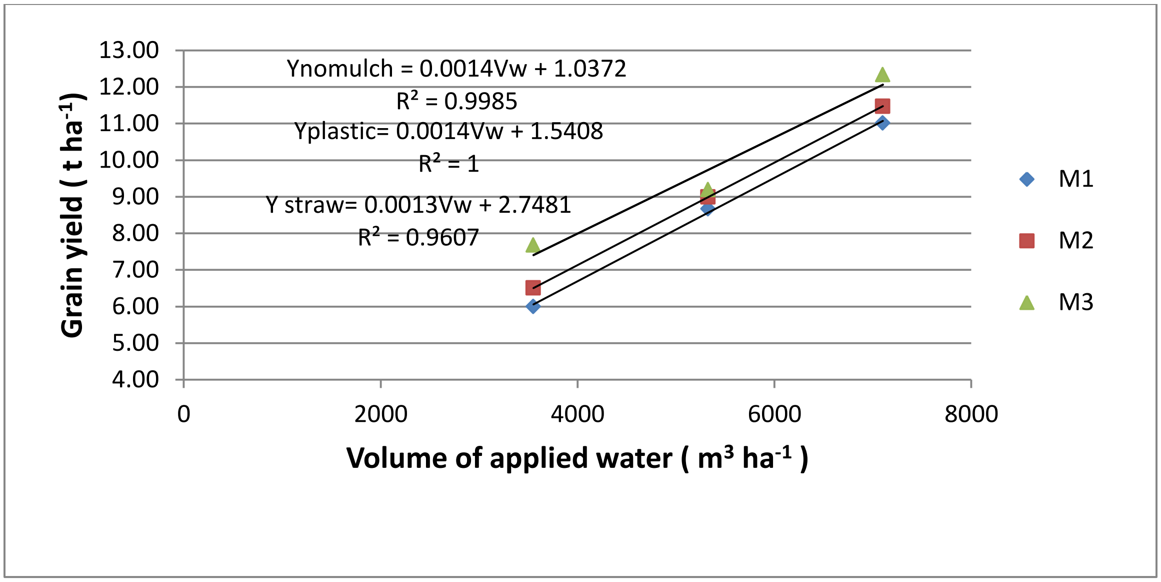

Fig.3. Plot of grain yield versus volume of applied water under different mulching treatments

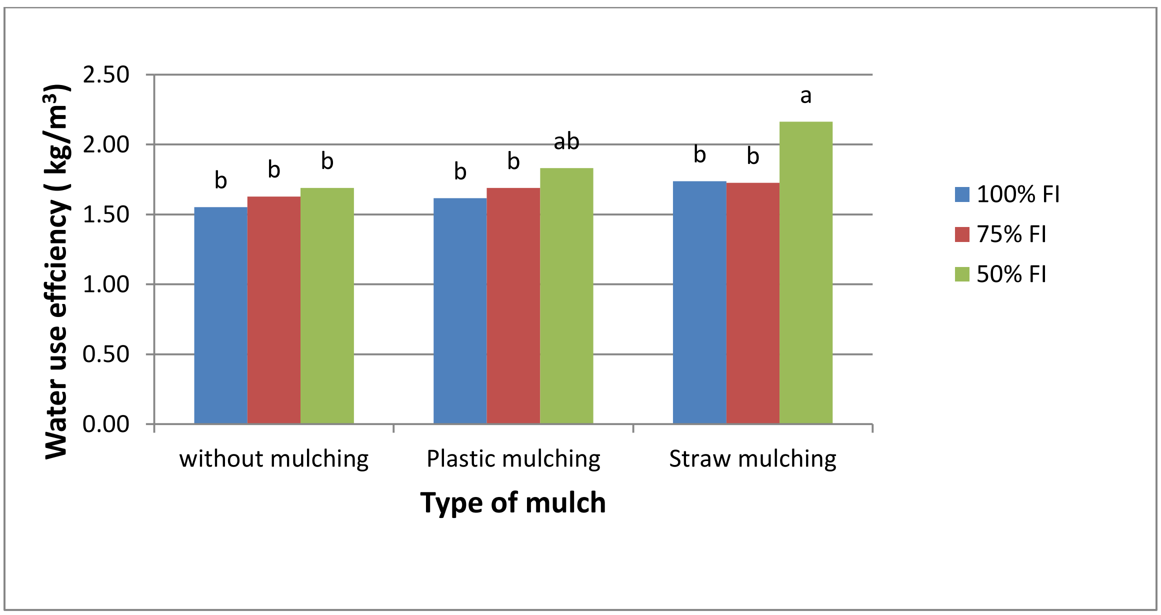

Fig.4a. Corn water use efficiency as affected by interactive effect of deficit irrigation level and type of mulch

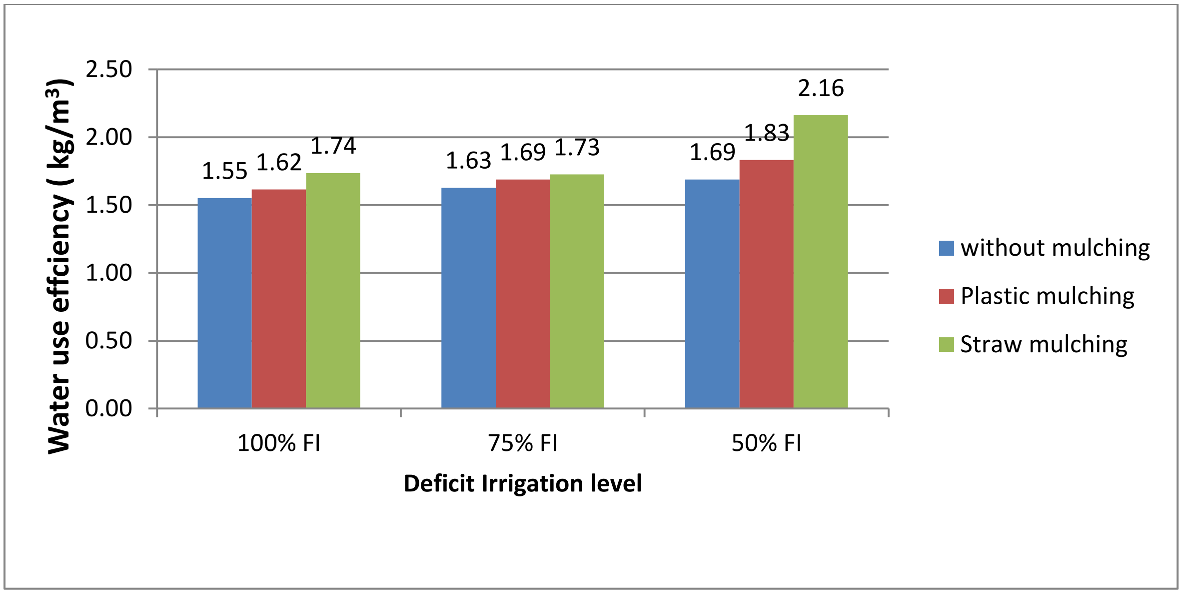

Fig.4b. Corn water use efficiency as affected by interactive effect of deficit irrigation level and type of mulch

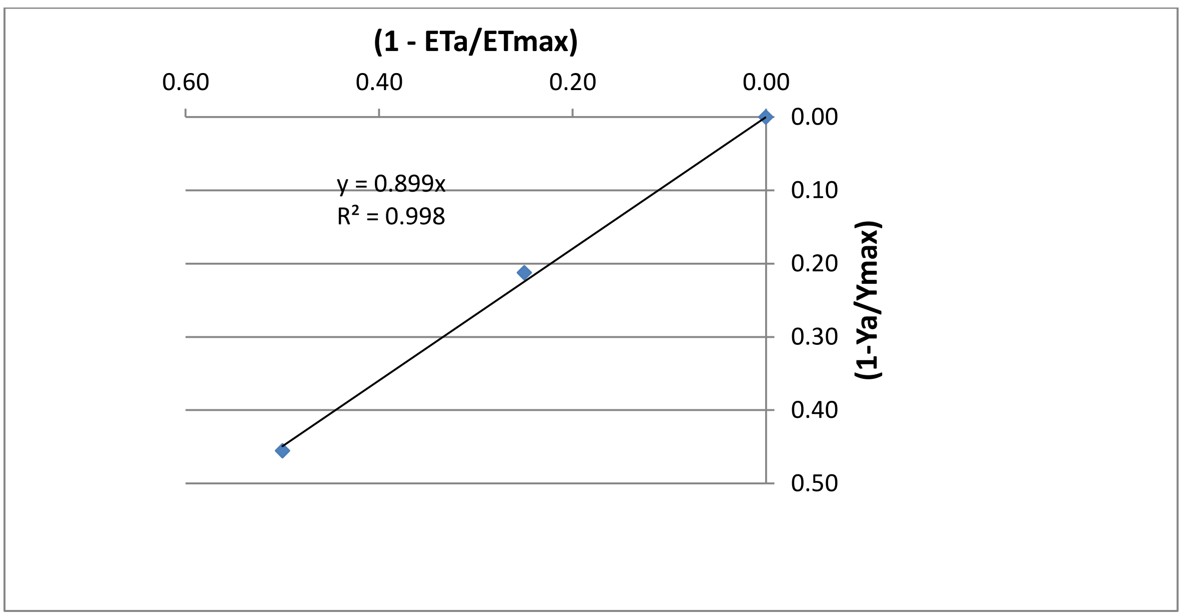

Fig.5. Crop yield response factor for corn without mulching

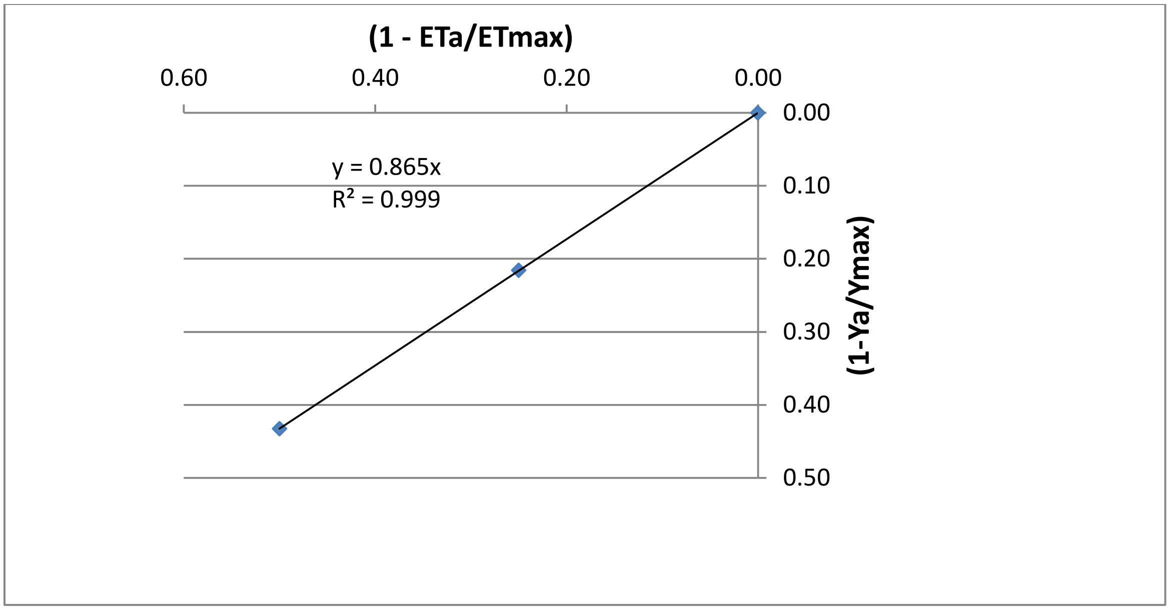

Fig.6. Crop response factor for corn under plastic mulching

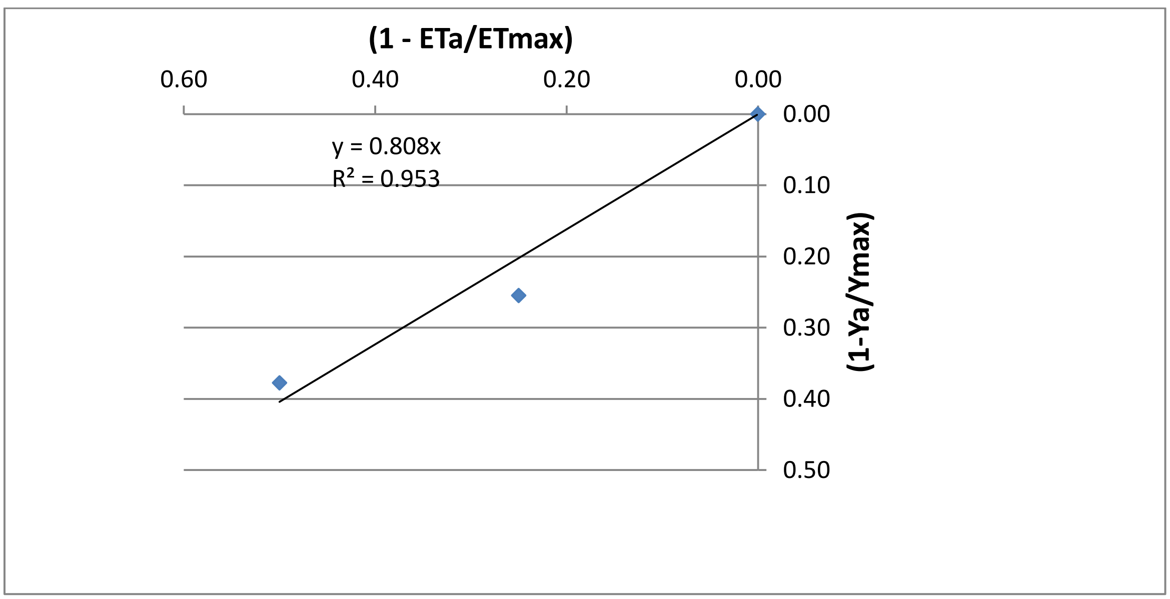

Fig.7. Crop response factor for corn under straw mulching

5.Reference:

Allen, R.G., Pereira, L.S., Raes, D. & Smith, M. (1998). *Crop evapotranspiration*. Guidelines for computing crop water requirements. FAO Irrig. Drain, Paper No. 56. FAO. Rome, Italy. 300pp. 1998.

Araya, A., Stroosnijder, L., Girmay, G., and Keesstra, SD. (2011). Crop coefficient, yield response to water stress and water productivity of teff. *Agricultural Water Management, 98*: 775–783.

Cakir, R. (2004). Effect of water stress at different development stages on vegetative and reproductive growth of maize. *Field Crops Research*, *89*(1), 1–16.

Casierra-Posada, F.; Fonseca, E.; Vaughan, G. Fruit quality in strawberry (Fragaria sp.) grown on colored plastic mulch. Agron. Colomb. 2011, 29, 407–413.

Chen, R., W. Cheng, J. Cui, J. Liao, H. Fan, Z. Zheng and F. Ma. (2015). Lateral spacing in trickle-irrigated wheat: The effects on soil moisture, yield, and water productivity. *Field Crops Research,* 179: pp.52-62.

Doorenbos, J., & Kassam, AH. (1979). *Yield response to water* (Irrigation and Drainage Paper No.33). Rome: Food and Agriculture Organization of the United Nations.

Elzubeir, A. O. and Mohamed, A. E. (2011). Irrigation scheduling for maize (Zea mays L.) under desert area conditions:North of Sudan. *Agriculture and Biology Journal of North America, 2*, 645–651.

Ertek A, Sensoy S, Kucukyumuk C, Gedik I. (2006). Determinations of plant-pan coefficients for field-grown eggplant (Solanum melongena L.) using class A pan evaporation values. Agric.Water Manage., 85:58–66.

Ferreira, T. C., and Goncalves, D. A. (2007). Crop-yield/water use production functions of potatoes (Solanum tuberosum, L.) grown under differential nitrogen and irrigation treatments ina hot, dry climate. *Agricultural Water Management. 90*: 45–55.

Greaves, G. E. and Wang, Y. (2017). Yield response, water productivity, and seasonal water production functions for maize under deficit irrigation water management in southern Taiwan. Plant Production Science, VOL . 20, NO . 4, 353–365

Huang, Y., Zhang, Z., Li, Z. Dai, D and Li, Y. (2022). Evaluation of water use efficiency and optimal irrigation quantity of spring maize in Hetao irrigation district using the Noah-MP Land surface model. Agricultural Water Management. Volume 264, 30.

Irrigation Association [IA]. 2005. Landscape Irrigation Scheduling and Water Management. Available at: http://www.irrigation.org/gov/pdf/IA_LISWM_MARCH_2005.

Igbadun, H. E., A. A. Ramalan and E. Oiganji. 2012. Effects of regulated deficit irrigation and mulch on yield, water use and crop water productivity of onion in Samaru, Nigeria. *Journal of Agricultural Water Management*, 109: 162–169.

Karam, F., Breidy, J., Stephan, C., & Rouphael, J. (2003). Evapotranspiration, yield and water use efficiency of drip irrigated maize in the Bekaa Valley of Lebanon. *AgriculturalWater Management, 63*, 125–137.

Karasu, A., Kuscu, H., Oz, M., and Bayram, G. (2015). The effect of different irrigation water levels on grain yield, yield components and some quality parameters of silage maize (Zea mays indentata Sturt.) in Marmara region of Turkey. *Notulae*

Karim, T.H., Karim, K. (2001). Water demand of crops at Smaquly Watershed/ Koya. FAO Representation in Iraq. – FAO Coordination Office for Northern Iraq, Erbil. Iraq.

Kiptoo S., Kipkorir E. C and Kiptum C. K. (2019). Effects of deficit irrigation and mulch on yield and quality of potato crop. African Journal of Education, Science and Technology, Vol 4, No. 4:65-77.

Kirnak, H. and Demirtas, N. (2006). Effects of different irrigation regimes and mulches on yield and macronutrition levels of drip-irrigated cucumber under open field conditions. Journal of Plant Nutrition , Volume 29, 2006 - Issue 9.

Kuscu, H., Karasu, A., Oz, M., Demir, A. O., & Turgut, I. (2013). Effect of irrigation amounts applied with drip irrigation on maize evapotranspiration, yield, water use efficiency, and net return in a sub-humid climate. *Turkish Journal of Field Crops, 18*, 13–19.

Lovelli S, Perniola M, Ferrara A, Di Tommaso T (2007). Yield response factor to water (Ky) and water use efficiency of *Carthamus tinctorius L.* and *Solanum melongena L.* Agric. Water Manage, 92: 73–80.

Mekonnen, S.A and Sintayehu, A. (2020). Performance evaluation of Sesame under regulated deficit irrigation application in the low land of Western Gondar, Ethiopia International Journal of Agronomy; New York.

Nagaz, K., Masmoudi, M.M., and Mechlia, N.B. (2012).Yield response of drip-ririgated onion under full and deficit irrigation with saline water in arid regions of Tunisia. International Scholarly Research Notices, Volume 2012 |Article ID 562315 | https:// doi.org/10.5402/2012/562315**.**

Payero, J. O., Tarkalson, D. D., Irmak, S., Davison, D., & Petersen, J. L. (2009). Effect of timing of a deficit-irrigation allocation on maize evapotranspiration, yield, water use efficiency and dry mass. *Agricultural Water Management, 96*, 1387–1397.

Sarıdas, M.A., Kapur, B., Celiktopuz, E., Sahinar, Y. and Kargi. (2021). Land productivity, irrigation water use efficiency and fruit quality under various plastic mulch colors and irrigation regimes of strawberry in the eastern Mediterranean region of Turkey. Agricultural Water Management, Volume 245, 28.

Shrestha, N., Geerts, S., Raes, D.,Horemans, S., Soentjens, S., Maupas, F., & Clouet, P. (2010). Yield response of sugar beets to water stress under Western

European conditions. Agricultural Water Management, 97, 346–350.
Suleiman, M.A., Oyebode, N. M. Yahaya1 , U. D. Idris1 and J. O. Ajikashile. (2021). Effect of mulch and deficit irrigation on yield and water use effciciency of cowpea (Vigna unguiculata L. Walp) under gravity drip irrigation. FUW Trends in Science & Technology Journal, Vol. 6 No. 1 pp. 296 – 300
Tufa, K.N., Abebe, Y.A., and Ahmed, F.A.(2022). Effect of deficit irrigation and mulch levels on growth, yield and water productivity of onion (Allium cepa. L.) at Water Middle Awash Valley, Ethiopia, Plant 10(1)26-35.
WMO World Meteorological Organization. (2012). Agrometeorlogy of some selected crops. In Guide to Agricultural Meteorological Practices (GAMP) (2010 ed., pp. 1–128). Geneva: Chair Publications Board.
Xie, Z.K., Y.J. Wang and F.M. Li (2005). Effect of plastic mulching on soil water use and spring wheat yield in arid region of northwest China. *Agricultural water management*, 75(1): pp.71-83.
Zhang, H., Xiong, Y. Huang, G., Xu, X. and Huang, Q (2017). Effects of water stress on processing tomatoes yield, quality and water use efficiency with plastic mulched drip irrigation in sandy soil of the Hetao Irrigation District. Agricultural Water Management, 2017, vol. 179, issue C, 205-214

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