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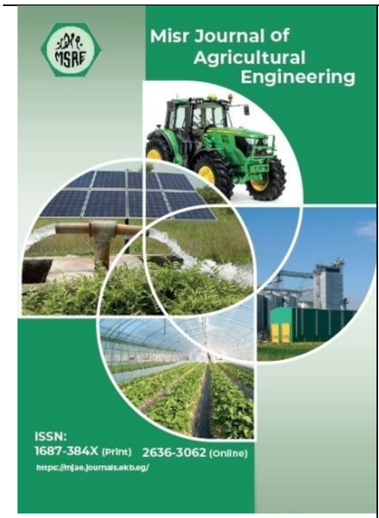
DEFICIT IRRIGATION LEVELS EFFECT ON TOMATO FRUIT USING FURROW SURFACE IRRIGATION WITH THREE FERTILIZER SOURCES

A. M. Almoayyad[1&*]

[1]Assoc. Prof. at Ag. Dept., Fac. of Ag., Thamar U., Yemen.
* E-mail: ahmedalmoayyad2022@gmail.com, ahmedalmoayyad@tu.edu.ye



Keywords:
Deficit irrigation; Fertilization types; Furrow surface irrigation.

ABSTRACT

During the 2023 - 2024 spring season, this experiment was conducted in the Government Thamar Special Farm. There are no appreciable differences between the various irrigation levels in the tomato fruit length; the highest value in the length recipe was obtained at the 100% ETc, with an average length of 21.949 mm, and the lowest value was obtained at the 60% ETc, with an average length of 19.836 mm. Consequently. The tomato crop's diameter measured at the 100% irrigation yielded the maximum average fruit diameter of 37.926 mm, while the lowest average fruit diameter measured at the 60% under-irrigation was 30.893 mm. At a significance threshold of $P < 0.05$, there were significant variations between the amounts of deficit irrigation for the tomato fruit diameter (4.1610). In addition, the 100% ETc the highest value for the efficiency of fertilizer use to produce the tomato crop, with an average of 35.248 kg of tomatoes per kilogram of fertilizer; the 60% deficit ETc the lowest value, with an average of 5.193 kg of tomatoes per kilogram of fertilizer.

INTRODUCTION

According to agricultural census data, the tomato fruits grown in all governorates with varying areas ranging from 12 to 2,000 hectares. Yemen's productivity of this fruit during the year 2021 amounted to 162,634 tons from a cultivated area estimated at 8,392 hectares, with an average productivity per unit area of 19.380 ton/ha. Therefore, productivity is considered very low compared to global productivity, which reached 80 tons/ha. (Annual Agricultural Statistics Book - Ministry of Agriculture – YEMEN - 2021).

The most important obstacles facing tomato cultivation are lack of water, high fuel prices, high labor and pesticide costs, sudden decline in tomato prices in some seasons, lack of storage for tomatoes during low prices, and regulating issues of supply and demand.

The research aims to do the following:

1- Raising tomato productivity per unit area by using furrow surface irrigation methods and optimal use of agricultural fertilizers.

2- Improving Water use efficiency, as well as Improving the fertilizers efficiency.

Yayah A. M. et al (2020) explained that a deficit irrigation level of 100% has the least efficient use of water 4.76 kg/m^3 of water. The results also show that the effect of the interaction between irrigation systems and under-irrigation levels had a significant effect at the 0.01 level on water consumption, While productivity and water use efficiency were not significantly affected, as the belt-in drip system at the 50% water supply level recorded the lowest water consumption of 264.78 mm, while the furrow surface irrigation system at the 100% water supply level gave the highest water consumption of 795 mm, Also the furrow surface irrigation system with polymer at the 100% water supply level recorded the highest tomato fruit productivity of 37,667 kg/ha, While the furrow surface irrigation system at the water supply level of 50% gave a lower productivity of 19,887 kg/ha. Then the drip-on irrigation system at the 50% water supply level recorded the highest water use efficiency of 7.78 kg/m^3 of water, while the furrow surface irrigation system at the 100% water supply level gave the lowest water use efficiency of 3.47 kg/m^3 of water.

Knaj (2015) proved that, in comparison to the furrow irrigation method, surface and subsurface drip irrigation promote greater plant development (leaf number and area), flowering, and fruit output. The surface drip irrigation method resulted in better plant productivity (4.75 kg/plant), with no significant difference when compared to the subsurface irrigation method and a significant difference when compared to the furrow irrigation method (3.95 kg/plant). In comparison to furrow surface irrigation, where these numbers were 7.18%, 4.98%, and 20.96 mg/100g, surface drip irrigation produced fruits with higher quality (8.28% dry material, 5.02% TSS, and 28.23 mg vitamin C/100g) in fresh matter.

Wabela (2018) The application of 50% urea during the transplanting phase and 50% during the development period yields a higher yield (39.33 ton/ha). After applying 25% of urea during transplanting and 75% throughout the development phase, a higher yield of 33 tons per hectare was seen. With no treatment with fertilizer, the minimum output was noted. The yield of split applied treatments is higher than that of 100% urea applied throughout the development or transplanting phase.

Bekele (2017) revealed that varied amounts of deficit irrigation and the furrow system had a significant impact on tomato fruit yield at a significance level of ($p<0.05$). The tomato fruit output from an alternative furrow irrigation system was comparable to that from a standard furrow irrigation system or permanent furrow irrigation. according to statistical analysis. However, compared to traditional furrow irrigation systems, permanent furrow irrigation systems differ significantly. A yield of 75% ETc was also statistically comparable to that of 100% ETc and 50% ETc irrigation levels; however, the application of the 50% ETc deficiency level differed significantly from the 100% ETc level. The findings regarding water productivity indicate a statistically significant distinction between the furrow system and deficit application levels at ($p<0.05$). Water was conserved by 25% when a 75% ETc level was applied.

Islam (2023) demonstrated that as compared to the yield of 77.70 t/ha and 82.04 t/ha, respectively, it resulted in a significantly greater yield (96.46 t/ha and 102.19 t/ha). When compared to no mulch, the application of grass straw mulch (87.15 t/ha and 91.76 t/ha) produced a noteworthy yield as well. Unit fruit weight, marketable fruit production, fruit size at 16, 18, and 20 weeks after transplanting, plant water consumption, and water usage efficiency were all highly impacted by all three of these parameters. The water usage efficiency (WUE) of tomato production was significantly impacted by the interaction of mulching, irrigation scheduling, and raised-bed furrow irrigation. In a two-row fruit cultivation design, the raised-bed furrow irrigation method was statistically equal in terms of WUE if it was run with black polyethylene mulch and irrigated every 3 days.

Gebru et al (2018) showed that, in comparison to the control, the yields of pepper, tomato, and Swiss chard increased by up to 51%, 32%, and 30%, respectively, in the bar-shaped clay pot irrigation system. Additionally, compared to the control, water savings for the corresponding crops improved significantly by 40.6%, 41.2%, and 41.7%. Likewise, the water productivity of pepper, tomato, and Swiss chard were 1.8 kg m^{-3}, 4.2 kg m^{-3}, and 10.9 kg m^{-3}, respectively. It is advised to conduct more research on the suitability of bar-shaped clay pot irrigation for different soil types and fruit types.

MATERIALS AND METHODS

This experiment was carried out at the special farm of the Thamar government during the spring season of 2023/2024. The physical soil analysis and soil moisture content were assessed, and the summarized data is presented in the table (1).

Table (1): physical soil analysis and soil moisture content of the experimental area.

Physical Soil Analysis				
Sand %	Silt %	Clay %	Textural class	Balk Density Kg m^{-3}
20.57	48.57	30.86	Loamy clay	1.46
Soil Moisture content				
Field Capacity % volumetric	Welting Point % volumetric	Available Water % volumetric	Saturation point %	
42.35	17.82	37.65	51.5	

1- Materials:

Furrow surface irrigation was used, where water was delivered to the beginning of the field by Upvc pipe. It created a main channel, from which water enters sub-main channels from which it feeds the agricultural furrows surrounded by a fence to prevent water from escaping from the irrigation furrows. The area of the experimental plots is 100 m^2 and the length of the irrigation furrows is 10 m.

Use three sources of fertilizers (animal manure, chemical and poultry fertilizer) and a control treatment without fertilizer.

A digital scale was used to weigh the tomato crop, as well as a digital caliper to measure the length and diameter of the tomato fruit yield.

2- The Experimental Design

The study employed a randomized complete block design, arranging three fertilizer treatments across the main plots, while three deficit irrigation treatments (100%, 80%, and 60%) were allocated to the sub-main plots. The experimental site covered an area of 1800 m^2 (40 x 45 m), with each plot measuring 100 m^2. This layout is illustrated accordingly Figs. (1,2).

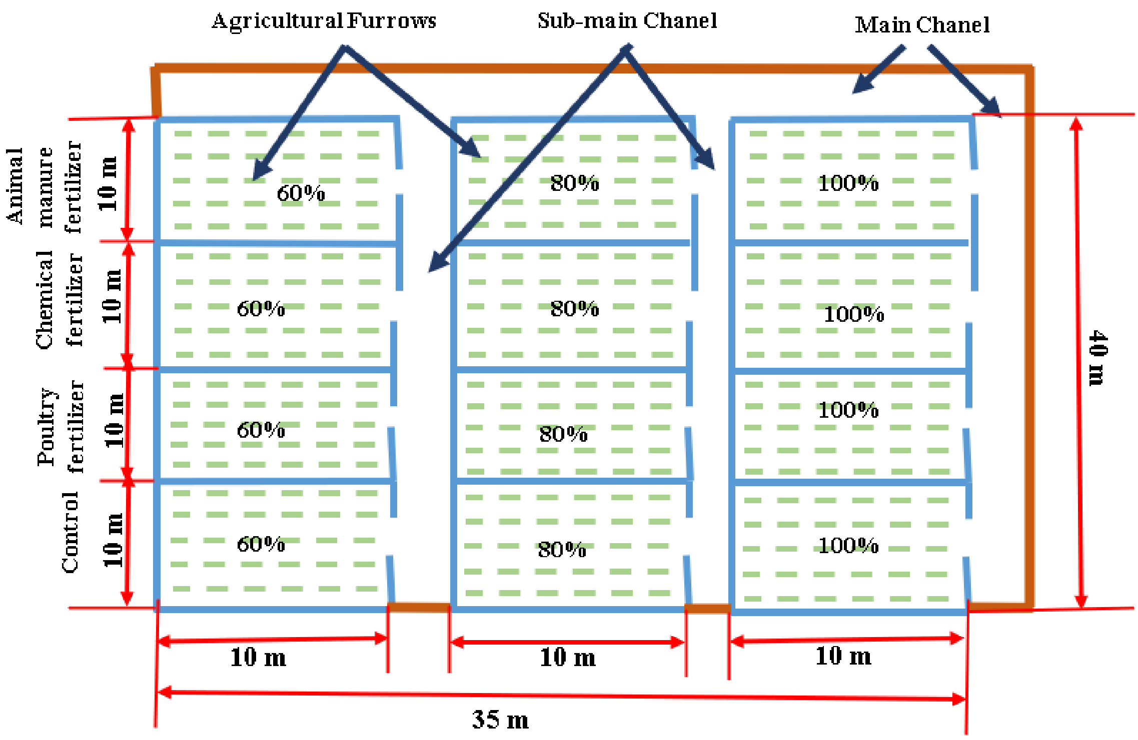


Fig. (1) Distribution of Experimental Treatments Planning

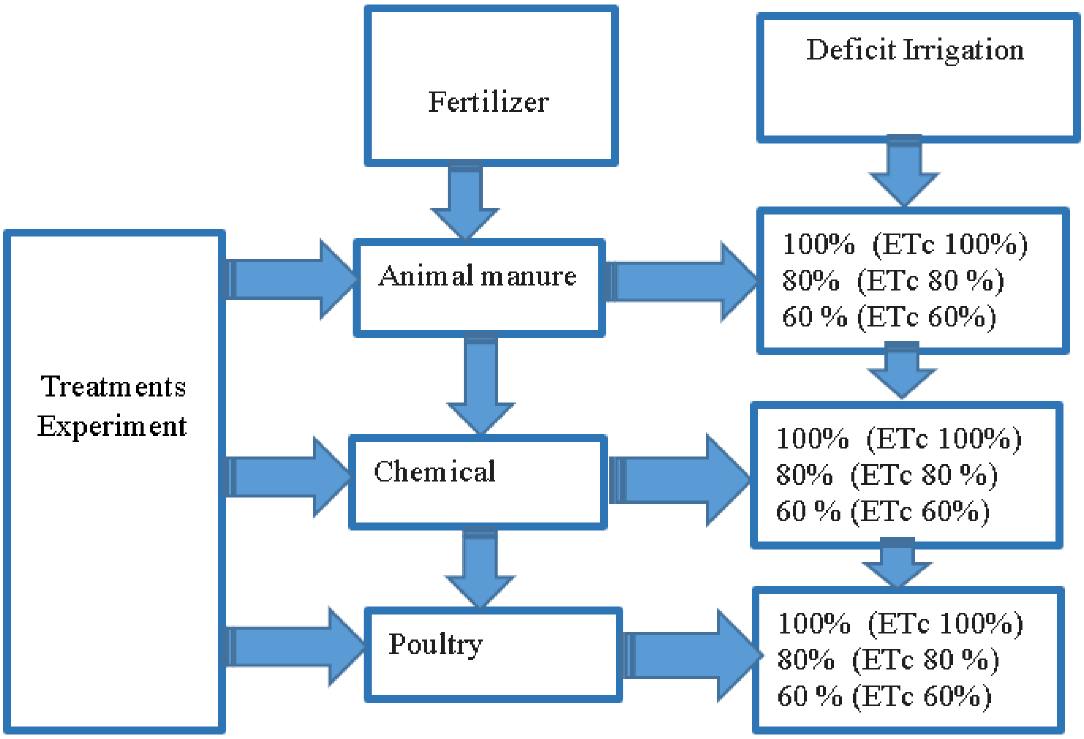


Fig.(2) Planning of Experimental Treatments

3- Amount of Water Applied for Each Irrigation

The amount of irrigation water applied was measured prior to each irrigation session for all treatments. For tomato plants, the irrigation water depth was determined based on the water consumed during the irrigation intervals, calculated as the difference between the soil's moisture content at field capacity and its moisture content right before the next irrigation. Additionally, 21% of the estimated water volume was included as a leaching requirement. The depth of water applied for each treatment was calculated using the following equation:

$$d_n = \left(\frac{\theta_{f.c} - \theta_{b.i.}}{100}\right) * \gamma_s * D_{rz}$$

where;

d_n Net full irrigation water depth,(mm).
$\theta_{f.c}$ Volumetric soil water content at field capacity,(%).
$\theta_{b.i.}$ Volumetric soil water content before irrigation,(%).
γ_s Soil specific bulk density (gm/cm^3).
D_{rz} The root zone depth (mm).

Table (2) Tomato fruit characteristics in terms of yield coefficient and the period between growth stages (FAO 56, 2006)

	Growth Stage			
Yield Coefficient	Init.	Dev.	Mid	Late
	0.6	1.5[2]	1.5[2]	0.80
Planting Period (day)	35	40	50	30

The interval between successive irrigations was four days. The full irrigation treatment 100% ($ETc_{100\%}$) was equivalent to the ETc of the tomato fruit. The deficit irrigation treatments ETc 80% and ETc 60% were 80 and 60 % from the full irrigation of 100% ETc. The root depth of Tomato fruit is 0.70 – 1.5 m.

The Gala tomato variety is a high-yielding, hardy hybrid tomato with attractive red fruits weighing 180-200 grams It is tolerant of harsh environmental conditions and resistant to viral, fungal, and soil diseases.

4- Fertilizer Use Efficiency

The Chemical fertilizer use efficiency (FUE) is the ratio of fruit yield to the amount of applied fertilization, also called the partial factor productivity of applied fertilizer (PFPN). (Dobermann, 2005).

Sharma and Banik (2012) indicated that PFPN can be calculated from the equation:

$$PFPN = \frac{Y}{F}$$

where; PFPN %

Y is fruit yield (kg/ha).

F is the amount of fertilizer applied (kg/ha).

All Fertilizer Sources of fertilizers were added to the soil at a rate of 3 ton/ha, of animal manure, 300 Kg/ha chemical fertilizer (20,20,20) and 2 ton/ha poultry fertilizer.

5- Tomato Production

The total tomato produced per hectare was calculated as follows:

$$\text{Tomato Production } \left({}^{\text{Kg}}/_{\text{ha}}\right) = \frac{\text{Tomato Yield (kg)} \times 10000}{\text{Area Sample (m}^2\text{)}}$$

6- Water Use Efficiency (WUE)

The water productivity of tomato yield was calculated as follows:

$$\text{WUE } \left({}^{\text{kg}}/_{\text{m}^3}\right) = \frac{\text{Tomato yield } \left({}^{\text{kg}}/_{\text{ha}}\right)}{\text{water applied } \left({}^{\text{m}^3}/_{\text{ha}}\right)}$$

RESULTS AND DISCUSSION

Data in Table (3) The 100% from ETc gave the highest value in length, the average length was 21.949 mm, while the lowest value was 19.836 mm at 60% irrigation level, and there are no significant differences between the different irrigation levels in the tomato fruit length.

Also, the data shows that the chemical fertilizer treatment gave the highest value in the length of the tomato fruit with an average of 24.364 mm, compared to the other fertilizer treatments and the control treatment (without fertilization), which gave the lowest value in the length of the tomato fruit with an average of 18.394 cm. There were significant differences between the different fertilizer treatments under study in the length of the tomato fruit1.0355 at a significance level of $P < 0.05$.

Also, the data show that the interactions between the deficit irrigation treatments and the different fertilizers gave the highest value in tomato yield length between the 100% irrigation level treatment and the chemical fertilizer treatment with an average of 27.682 cm, while the lowest value was between the 60% irrigation level and the control treatment (without fertilization) with an average of 17.509 cm. There are significant differences between the interactions between the treatments, where the value of the differences between the interactions of fertilizer treatments x the treatments of deficit irrigation levels was 2.0917 and the value of the differences between the interactions of deficient irrigation level treatments x fertilizers treatments was 2.6412 at a significance level of $P < 0.05$.

Table (3): Tomato Fruit Length (mm) as affected by Irrigation Level and Fertilizer sources under Surface Furrow Irrigation System

Irrigation Levels	Fertilizer sources				Mean
	Control	Animals Manure	Chemical fertilizers	Poultry	
100%	19.763	19.944	27.682	20.409	**21.949**
80 %	17.910	20.438	22.943	20.045	**20.334**
60 %	17.509	18.760	22.468	20.607	**19.836**
Mean	18.394	19.714	24.364	20.354	**20.706**

Table (4) shows that the 100% from ETc gave the highest value for tomato fruit diameter with an average of 37.926 mm, while the lowest value for the diameter of the tomato fruit gave the 60% under-irrigation level with an average of 30.893 mm. There were significant differences between the levels of deficit irrigation for the diameter of the tomato Fruit 4.1610 at a significance level of $P<0.05$.

Also, the data show that the chemical fertilization treatment gave the highest value for tomato fruit diameter, with an average of 45.087 mm, compared to the different fertilization treatments and the control treatment (without fertilization), which gave the lowest value for tomato fruit diameter, with an average of 23.638 mm. There were significant differences between the different fertilizer treatments for tomato fruit diameter of 4.6577 at a significance level of $P<0.05$.

As well as, the data show that the interactions between the deficit irrigation treatments and the different fertilizers gave the highest value in the diameter of the tomato fruit between the 100% irrigation level treatment and the chemical fertilizer treatment with an average of 52.181 mm, while the lowest value was between the 60% deficit irrigation level and the control treatment (without fertilization) with an average of 21.517 mm, and there are no significant differences between the interactions between the deficit irrigation levels treatments and the fertilizer treatments under study.

Table (4): Tomato fruit diameter (mm) as affected by Irrigation Level and Fertilizer sources under Surface Furrow Irrigation System

Irrigation Levels	Fertilizer sources				Mean
	Control	Animals Manure	Chemical fertilizers	Poultry	
100%	25.476	32.398	52.181	41.648	37.926
80 %	23.920	28.2٤4	43.517	41.593	34.319
60 %	21.517	28.857	39.563	33.637	30.893
Mean	23.638	29.833	45.087	38.959	34.379

Table (5) shows that the 100% from ETc gave the highest value for tomato fruit productivity, with an average of 29.379 ton/ha, while the 60% deficit irrigation level gave the lowest value for tomato fruit productivity, with an average of 24.322 ton/ha. There were significant differences between the levels of deficit irrigation for tomato fruit productivity of 0.5581 at a significance level of $P < 0.05$.

According to the results of the table (5), The chemical fertilization treatment gave the highest value for tomato fruit productivity, with an average of 33.435 ton/ha, compared to the various fertilizer treatments and the control treatment, which gave the lowest value, with an average of 18.919 ton/ha. There were significant differences between the different fertilizer treatments in tomato fruit productivity of 0.3770 at a significance level of $P < 0.05$.

AS well as, The table data showed that the interactions between the treatments of deficit irrigation levels and the different fertilizer treatments gave the highest value for tomato fruit productivity between the 100% irrigation level and the chemical fertilizer treatment, with an average of 36.695 ton/ha. There are significant differences between the interactions between fertilizer treatments and deficient irrigation level treatments, 0.7269, and between the interactions between deficient irrigation treatments and fertilizer treatments, 0.7874, at a significance level of $P < 0.05$.

Table (5): Production of Tomato fruit (ton/ha) as affected by Irrigation Level and Fertilizer sources under Surface Furrow Irrigation System

Irrigation Levels	Fertilizer sources				Mean
	Control	Animals Manure	Chemical fertilizers	Poultry	
100%	20.576	26.862	36.695	33.384	29.379
80 %	18.864	25.464	33.467	29.656	26.863
60 %	17.316	23.252	30.142	26.577	24.322
Mean	18.919	25.193	33.435	29.872	26.855

Table (6) shows that the 60% deficit irrigation level gave the highest value for the efficiency of irrigation water use in tomato fruit productivity, with an average of 295.167 kg/m^3, while the 100% irrigation level gave the lowest value for the efficiency of irrigation water use, with an average of 251.058 kg/m^3. For tomato fruit productivity, there were significant differences between the levels of deficit irrigation and the efficiency of irrigation water use in tomato fruit productivity 10.3005 at a significant level of $P < 0.05$.

Also, the table showed that the chemical fertilizer treatment gave the highest value for the efficiency of using irrigation water for tomato fruit productivity with an average of 392.389 kg/m^3, compared to the other fertilizer treatments and the control treatment (no fertilizer), which gave the lowest value for the efficiency of using irrigation water for tomato fruit productivity with an average of 136.166 kg/m^3. There were significant differences between the different fertilizer treatments for irrigation water use efficiency for tomato fruit productivity 6.3122 at a significance level of $P < 0.05$.

Also, from the table we note that the interaction between the deficit irrigation treatments and the different fertilizer treatments was the highest value for the efficiency of irrigation water use for tomato fruit productivity between the chemical fertilizer and the deficit irrigation level of 60% with an average of 427,500 kg/m^3, while the lowest value was for the efficiency of irrigation water use for tomato fruit productivity was between the Control treatment (no fertilizer) and irrigation level 100% with an average of 125.733 kg/m^3. There were significant differences between the interactions of the different fertilizer treatments and the levels of deficit irrigation, as it was between the interactions of the treatments of the deficit irrigation levels and the different fertilizer treatments, 13.8621, and between the different fertilizer treatments and the levels of deficit irrigation, it was 12.3287 at a significance level $P < 0.05$.

Table (6): Water Use Efficiency of Tomato Yield (Kg/m^3) as affected by Irrigation Level and Fertilizer sources under Surface Furrow Irrigation System

Irrigation Levels	Fertilizer sources				Mean
	Control	Animals Manure	Chemical fertilizers	Poultry	
100%	125.733	207.533	363.167	307.800	251.058
80 %	132.733	235.033	386.500	311.100	266.342
60 %	150.033	263.933	427.500	339.200	295.167
Mean	136.166	235.500	392.389	319.367	270.856

Table (7) shows that the 100% irrigation level gave the highest value for the efficiency of fertilizer use to produce the tomato crop, with an average of 35.248 kg $_{tomatoes}$/kg $_{fertilizer}$, while the lowest value for the efficiency of fertilizer use to produce the tomato fruit was for the deficit 60% from ETc, with an average of 5.193 kg $_{tomatoes}$/kg $_{fertilizer}$. There were significant differences between the levels of deficit irrigation and the efficiency of using fertilizer to produce tomato crops 1.0799 at a significance level of $P < 0.05$.

Also, the table (7), shows the chemical fertilizer treatment gave the highest value for the efficiency of using fertilizer to produce a tomato crop, with an average of 101.497 kg $_{tomatoes}$/kg $_{fertilizer}$, while the lowest value for the efficiency of using fertilizer to produce a tomato fruit was for the animal manure fertilizer treatment with an average of 6.053 kg $_{tomatoes}$/kg $_{fertilizer}$. There were significant differences between the different fertilizer treatments for the efficiency of using fertilizer to produce tomato crops, 0.8986, at a significance level of $P < 0.05$.

Also, the table (7), shows the interactions between the levels of deficit irrigation and the different fertilizer treatments, where the highest value of the interaction was between the level of 100% from ETc and the chemical fertilizer treatment for the efficiency of using fertilizer to produce tomato crops, with an average of 119.067 kg $_{tomatoes}$/kg $_{fertilizer}$, while the lowest value of the interaction was between the level of deficit irrigation 60% from ETc and the treatment of herbivorous farm animal manure for the efficiency of using fertilizer to produce a tomato fruit with an average of 5.193 kg $_{tomatoes}$/kg $_{fertilizer}$. There were significant differences between the interactions of deficit irrigation levels and different fertilizer treatments, as the difference between the different fertilizer treatments and deficit irrigation levels was 1.6888 and between the deficit irrigation levels and different fertilizer treatments was 1.7130, at a significance level of $P < 0.05$.

Table (7): Fertilization Use Efficiency of Tomato Yield (Kg $_{yield}$/Kg $_{ferti.}$) as affected by Irrigation Level and Fertilizer sources under Surface Furrow Irrigation System

Irrigation Levels	Fertilizer Sources				Mean
	Control	Animals Manure	Chemical Fertilizers	Poultry	
100%	0.000	6.800	119.067	15.123	35.248
80 %	0.000	6.167	101.350	12.223	29.935
60 %	0.000	5.193	84.073	10.003	24.818
Mean	0.000	6.053	101.497	12.450	30.000

CONCLUSIONS

The objectives of this Study were to evaluate the effect of deficit irrigation levels and fertilization sources on the production of tomato fruit, water use efficiency and fertilization use efficiency under furrow surface irrigation. The results of this study showed that:

1- The deficit irrigation strategy is useful to save the irrigation water for the agricultural purposes.

2- The irrigation level of 100% (full of ETc) gives the highest productivity of the tomato crop, and the deficit irrigation levels of 80% and 60% (of ETc) give the lowest productivity of the tomato crop, but in return it saves quantities of irrigation water and reduces energy costs.

3- Deficit irrigation levels of 60% and 80% (of ETc) give the highest water use efficiency, 60% > 80% ‘respectively, compared to a water level of 100% (Full ETc).

4- The chemical fertilizer treatment (20,20,20) gave the highest values for tomato fruit productivity, irrigation water use efficiency, and fertilizer use efficiency, compared to the animal’s manure fertilizer and poultry fertilizer treatments.

RECOMMENDATION

1- Recommend, using modern cultivators such as mulch to reduce weeds and reduce labor costs. As well as using high-yielding tomato varieties from reliable sources of seeds or seedlings.

2- Also, introducing modern irrigation systems such as drip to protect irrigation water from being lost in areas outside the root zone. Raising fruit productivity and better use of agricultural inputs.

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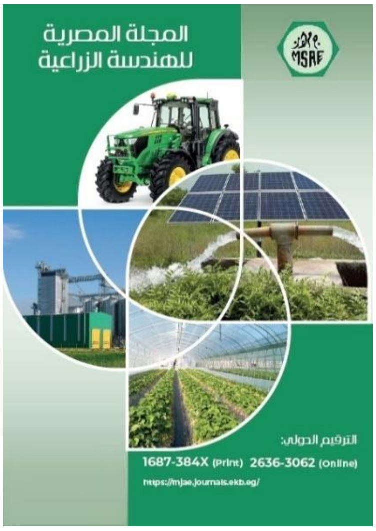
مستويات الري الناقص وتأثيرها على ثمار الطماطم باستخدام نظام الري السطحي بالخطوط مع ثلاث مصادر سماديه

أحمد محمد المؤيد[١]

[١] أستاذ الري والصرف الحقلي المساعد – القسم الزراعي – كلية الزراعة – جامعة ذمار – اليمن



الملخص العربي

أجريت التجربة في ربيع العام ٢٠٢٤ م في محافظة ذمار. وكانت معاملات التجربة تشمل ٣ معاملات للري الناقص (١٠٠ % و٨٠ % و٦٠ % من ETc الاحتياجات المائية لمحصول الطماطم) و٤ معاملات سماديه (سماد حيوانات المزرعة العاشبة وسماد الدواجن وسماد كيميائي وبدون سماد معاملة الكونترول). وأظهرت النتائج أن أعلى قيمة لصفة طول ثمار الطماطم أعطيت من معاملة ١٠٠ % مستوى ري بمتوسط ٢١,٩٤٩ mm، وأقل قيمة لصفة طول ثمار الطماطم أعطيت لمعاملة ٦٠ % مستوى ري ناقص بمتوسط ١٩,٨٣٦ mm. وكانت أعلى قيم لقطر ثمار الطماطم بمعاملة ١٠٠ % مستوى ري بمتوسط ٣٧,٩٢٦ mm، وأقل قيم لقطر ثمار الطماطم بمعاملة ٦٠ % مستوى ري ناقص بمتوسط ٣٠,٨٩٣ mm.

كما أن أعلى إنتاجية لطماطم كانت لمعاملة ١٠٠ % مستوى ري بمتوسط ٢٩,٣٧٩ طن/هكتار، بينما كانت أقل إنتاجية ل ٦٠ % مستوى ري ناقص بمتوسط ٢٤,٣٢٢ طن/هكتار.

وكانت النتائج أن ٦٠ % معاملة الري الناقص أعطت أعلى قيم لكفاءة استخدام مياه الري بمتوسط ٣٢٩٥,١٦٧ كجم/متر^{٣}. وأقل قيمة لكفاءة استخدام مياه الري أعطيت بمعاملة ١٠٠ % مستوى ري ٢٥,٠٥٨ كجم/متر^{٣}. وكانت هناك فروق معنوية بين معاملات مستويات الري المختلفة في كفاءة استخدام مياه الري ١٠,٣٠٠٥ عند مستوى معنوية ٠,٠٥.

وأظهرت النتائج أن أعلى قيم إنتاجية لكفاءة استخدام السماد مع معاملة ١٠٠ % مستوى ري بمتوسط إنتاجية ٣٥,٢٤٨ كجم/ ١ كجم سماد، بينما كانت أقل قيم إنتاجية لكفاءة استخدام السماد لمعاملة ٦٠ % مستوى ري ناقص بمتوسط إنتاجية ٥,١٩٣ كجم/ ١ كجم سماد. وكانت هناك فروق معنوية بين مستويات الري المختلفة وكفاءة استخدام السماد ١,٠٧٩٨ عند مستوى معنوية ٠,٠٥.

الكلمات المفتاحية:
مستويات الري الناقص، نوع السماد; كفاءة استخدام المياه، محصول الطماطم.