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# Enhancing Water Use Efficiency and Yield of Pomegranate Crop by Using Fish Drainage Water with Bio-Fertilizer under Drip Irrigation System

**M. A. M. Moursy [1,2], Amro Negm [3,*], H. G. Ghanem [4] and Kamal I. Wasfy [5,6]**

1 Water Management Research Institute, National Water Research Center, El-Qanater El-Khairiya 13621, Egypt
2 Saudi Irrigation Organization (SIO), Al-Hassa 31982, Saudi Arabia
3 Department of Agricultural and Environmental-Sciences Production, Landscape, Agroenergy, University of Milan, 20133 Milan, Italy
4 Water and Irrigation System Engineering Department, Faculty of Agriculture Engineering, Al-Azhar University, Nasr City 4450113, Egypt
5 Agricultural Engineering Department, Faculty of Agriculture, Zagazig University, Zagazig 44519, Egypt
6 Faculty of Organic Agriculture, Heliopolis University for Sustainable Development, Al Salam City 11785, Egypt
* Correspondence: amro_negm@hotmail.com; Tel.: +1-403-8740-030

**Abstract:** Fish drainage water is a non-conventional water resource that can be exploited for irrigation due to its constituents of beneficial nutrients, signifying it as environment-friendly bio-fertilizers. Limited water resources, the elevated cost of mineral fertilizers hazards as well as attaining healthy food are of paramount significance in the agriculture sector in Egypt. The utilization of bio-fertilizers is an avenue to fulfil agricultural sustainability, production of clean crops and preservation of the soil from the accumulation of heavy metals and chemicals. Hence, this study aims to find non-conventional alternative water resources to be used for irrigation of pomegranate fruit yield. Two resources of water were utilized, and three types of bio-fertilizers were applied. Results showed that, fish drainage water increased the total yield (kg/fed) by 25.2% as compared to freshwater. Chicken manure increased the total yield (kg/fed) by 22.37 and 11.89% in comparison with cattle and compost organic fertilizer under fish drainage water, respectively. The use of chicken manure yielded the highest net return (2420.79US $/fed), while compost and cattle dung were found to be (2123.52US $/fed) and (1721.66US $/fed), respectively, under using fish drainage water. The study showed that the use of fish drainage water as an organic resource would be an alternative to commercial fertilizers, which could reduce the total cost and thus increase the net profit and yield. Less dependency of commercial fertilizer would have an impact on reducing the emissions of $CO_2$ mitigating global warming.

**Keywords:** water resource; chicken manure; cattle dung; compost; fruit quality; fruit yield; net return



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## 1. Introduction

Water shortage is expected to be one of the biggest problems facing the world [1,2]. The management of water resources for irrigation and determination of crop water requirements are on the top of the priority to achieve sustainability of agro-ecosystem productivity [3,4]. Traditionally, irrigation, techniques were intensively investigated in waster-scarce environments, e.g., the Mediterranean region aiming to manage water resources [5,6] and enhancing irrigation methods [7]. Among these investigated techniques is drip irrigation, which is considered a valuable avenue for improving water-use efficiency in high-density planting systems for orchards, achieving significant water savings, and maintaining sustainable production levels [8]. Moreover, drip irrigation led to a23.5% increase in yield and 48.6% water saving whereas drip with fertigation resulted in a 40 to 61% increase in pomegranate yield as compared to the conventional method [9]. To evaluate the performance of drip irrigation among different irrigation methods, water use efficiency (WUE) is typically utilized as an indicator. The WUE is defined as the ratio between the amount of water that is used for an intended purpose and the total amount of water input within a spatial domain of interest. To increase the efficiency of this domain of interest, it is vital to identify losses and minimize them. The WUE, also known as water productivity, was determined as the ratio of crop yield per unit area, in terms of grain, to crop evapotranspiration (mm) where it is usually expressed either in kg/ha mm or in kg/m$^3$ (kg of grain or biomass per unit).

In this research study, an experimental field of Pomegranate (*Punica granatum* L.) irrigated using drip irrigation was set up. The pomegranate culture in Egypt is limited and, in most areas, it is considered a minor crop. Presently, the pomegranate area is quickly increasing for exportation goals, especially in newly reclaimed soils [10]. The total cultivated area of pomegranate in Egypt reached 24,308.91Ha with a total production of 219,663 ton [11], while the global production of pomegranate was higher than 3,000,000 ton [12]. The pomegranate tree needs a certain amount of nitrogen for growing as nitrogen supports the growth of foliage and the production of flowers that eventually set fruit.

Currently, the modern irrigation techniques which use the production of aquatic organisms, including fish drainage water, plants, and shellfish drainage water is aquaculture [13]. One of the advantages of this technique is reducing the impact of the increasing global demand for fish drainage water products on wild fish drainage water populations if appropriate steps are taken to prevent negative environmental impacts [14]. The fish drainage water stools were enriched with fertilizer; accordingly, integrating farms with a fish drainage water culture component would diminish the amount of chemical fertilizer for the trees and crops [15]. Recent studies have found that agri-aquaculture effluent had the highest value of 94.06% germination ratio, 42.48 cm root length,14.28 cm root diameter, 20.08% sucrose percentage 8.69 ton/Ha root yield and 8.24 kg/m$^3$ root water use efficiency if compared with treatments of freshwater [16]. Moreover, another study found that irrigated onion crop with aquaculture drainage gives the maximum yield of (7.99 and 7.1 ton/Ha) for surface and subsurface drip irrigation, respectively, compared to the same crop if irrigated using groundwater resource, which gives 7.32 and 5.92 ton/Ha, respectively, for surface and subsurface drip irrigation [17]. Irrigation with fish farm effluent significantly increased the fresh and dry weight of shoot and root, leaf number, and stem height in both basil and purslane plants. In the fish farm treatment, the fresh weight of shoots increased by 203 and 250% compared to freshwater irrigation in basil and purslane plants, respectively [18].

Organic fertilizers are naturally available mineral sources that contain a moderate amount of plant essential nutrients. These types of fertilizers are capable of mitigating problems associated with synthetic fertilizers and are able to reduce the necessity of repeated application of synthetic fertilizers to maintain soil fertility. Moreover, it helps to have a gradual release of nutrients into the soil solution and maintain nutrient balance for the healthy growth of crop plants and finally improve the soil microbe's structure. The improper use of organic fertilizers leads to over-fertilization or nutrient deficiency in the soil [19]. Hence, the controlled release of organic fertilizers is an effective and advanced way to overcome these impacts and maintain sustainable agriculture yield [20]. The application of organic manure at the rate of 132.7 kg/ha in the greenhouse increased root, shoot and fruit dry weights of chili pepper by 21.4, 52.4, and 79.7%, respectively, compared to the controlled values [21]. Furthermore, the compost usage reduced bulk density, enhanced infiltration and hydraulic conductivity, added to increase water content and plant available water [22,23]. Chicken compost increased plant height, stem diameter, and fruit fresh weight by 1.98 and 3.21, 15.45 and 9.31 and 22.81 and 15.4% compared to the cow and goat compost [24]. Chicken manure may be added to compost to increase grapevine yield, fruit quality, and nutrient status as well as reduce pollution [25]. The use of bio-fertilizers alone had no significant positive effects on fruit characteristics; nonetheless the combination with other organic fertilizers such as cow manure, vermicompost, and humic improved the yield of pomegranate and reduced some pomegranate disorders [26]. For example, biochar, compost and chicken manure increased wheat and barley grain yield by 6.36 and 16.59, 14.92 and 28.43 and 21.21 and 31.17%, respectively, compared to 0.0 organic additions. Chicken manure recorded the maximum wheat and barley straw yield of 1668.35 and 1046.78 kg/Ha, respectively [27]. This study applied an innovative approach of bio-fertilization compared to the previous studies. As the previous ones considered either the application of water resources or organic fertilizer separately to examine its effect on several orchards (not including the pomegranate crop). However, this study combined both the application of water resources and organic fertilizer and their interaction on the yield and WUE of pomegranate cultivation in Egypt. Moreover, this is the first study in Egypt to be applied to this kind of orchard (pomegranate). This study covered the possibility of benefiting from fish drainage water as a non-conventional source of irrigation, especially under scares water resources and the change in the climate.

In the framework of this research, the aim is to maximize the use of non-conventional methods as a source of water and nitrogen with the use of bio-fertilizers in order to get a healthy yield of pomegranate fruit crops. As a result, the outputs of this research will be able to evaluate the effect of using fish drainage water in irrigation as an alternate source compared to freshwater on pomegranate fruit yield. Moreover, it will also help to enhance the water and fertilizer use efficiency by using different types of biofertilizers under drip irrigation. Finally, the study includes the impact of different resources on the quality and yield of the fruits from an economic point of view.

## 2. Materials and Methods

The present study was conducted during agricultural seasons 2018/2019 and 2019/2020 from January to December at Abu Hamad (longitude 30°28′5″ E and latitude 31°44′ N), Sharkia Governorate, Egypt, to study the effect of nontraditional resources on the quality and yield of pomegranate fruits, as shown in Figure 1.

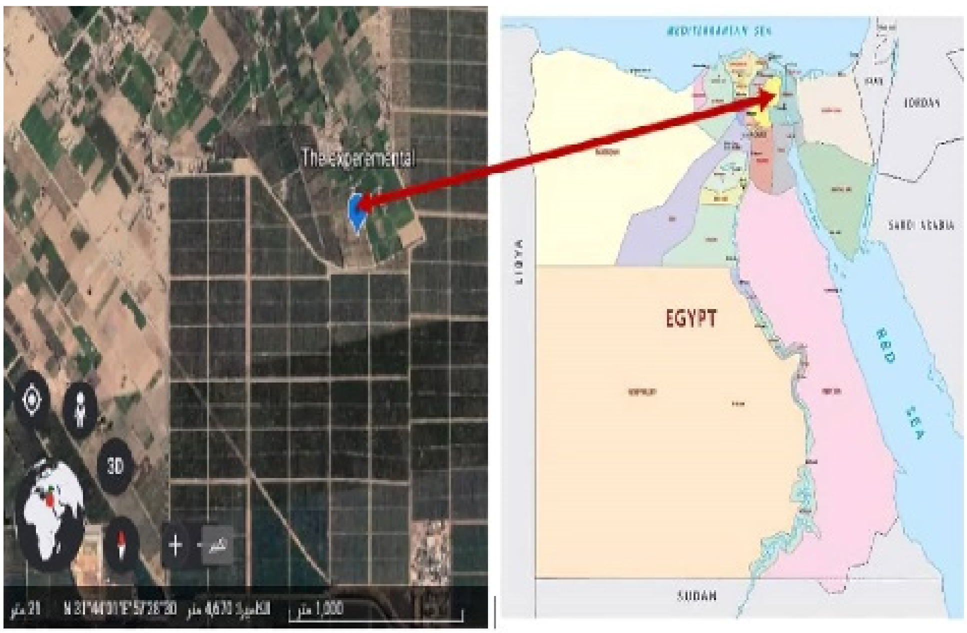


**Figure 1.** GPS location of the experiment.

### 2.1. Experimental Setup

#### 2.1.1. Soil Analysis

Soil samples were taken and determined according to the method proposed by [28,29]. The physical and chemical properties of the soil are presented in Table 1.

**Table 1.** Physical and chemical properties of the used loamy soil.

| Physical Properties, % | | | | | | | |
|---|---|---|---|---|---|---|---|
| Soil Depth, cm | Sand | Silt | Clay | Texture | Field Capacity | Permit Wetting Point | Available Water |
| 0–30 | 38.66 | 33.47 | 27.87 | Loamy soil | 23.83 | 13.81 | 10.02 |
| 30–60 | 35.19 | 37.71 | 27.10 | | 26.39 | 14.56 | 11.83 |
| 60–90 | 33.54 | 38.05 | 28.41 | | 28.09 | 14.91 | 13.18 |

| Chemical Properties, meq/1 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Soil Depth, cm | EC * (ds/m) | Anions | | | Cations | | | | SAR ** |
| | | $HCO^{-3}$ | $CL^{-1}$ | $SO^{-4}$ | $Ca^{++}$ | $Mg^{++}$ | $Na^{+}$ | $K^{+}$ | |
| 0–30 | 0.77 | 1.98 | 1.13 | 4.89 | 1.33 | 0.66 | 5.59 | 0.42 | 5.39 |
| 30–60 | 0.63 | 1 | 2.38 | 2.62 | 2.29 | 1.26 | 2.1 | 0.35 | 1.34 |
| 60–90 | 0.60 | 0.93 | 3.37 | 4.5 | 2.05 | 1.98 | 4.33 | 0.44 | 3.01 |

* EC: Electrical conductivity, ds/m, ** SAR: Sodium Absorption ratio.

#### 2.1.2. Cultivar Type

Pomegranate cultivars "Manfalouty cv." (*Punica granatum* L.) were planted at a spacing of 3 × 4 m with 350 trees/fed and their age is 5 years old.

#### 2.1.3. Water Resources

Two types of irrigation water resources (freshwater and fish drainage water) were used in the present study. The amount of water changed every day was about 25% of the total amount of water in the fish farm [30]. The chemical specifications are shown in Table 2.

**Table 2.** Chemical analysis of freshwater and fish drainage water.

| Water Resource | PH | EC, ($ds \cdot m^{-1}$) | DO, ($mg \cdot L^{-1}$) | TSS, ($mg \cdot L^{-1}$) | $NO_3$, ($mg \cdot L^{-1}$) | $NO_2$, ($mg \cdot L^{-1}$) | $NH_3$, ($mg \cdot L^{-1}$) |
|---|---|---|---|---|---|---|---|
| Freshwater | 7.24 | 1.03 | 2.23 | 103 | 0.87 | 0.031 | 0.019 |
| Fish drainage water | 7.71 | 1.19 | 3.87 | 184 | 198 | 0.28 | 0.27 |

#### 2.1.4. Fertilizer Types

Different cultural practices such as fertilization, pruning, and pest control were conducted according to the recommendations of the Egyptian Ministry of Agriculture. The fertilizer requirements of the pomegranate crop were 80 N—36 P—77 K—15 Mg—9 Ca—2 B units/fed under freshwater, while under fish drainage water 40 N—36 P—77 K—15 Mg—9 Ca—2 B units/fed [31]. Fertilizing doses were added through the irrigation process. Three types of organic manure (compost, chicken manure, and cattle dung) were added at a rate of 40 kg N/fed and each tree got 95.5 g N/season [32]. Some characteristics of the organic fertilization used were identified as shown in Table 3.

**Table 3.** Characteristics of the used organic fertilizers.

| Measurements | Types of Organic Fertilizer | | |
|---|---|---|---|
| | Compost | Chicken Manure | Cattle Dung |
| Mass of 1 $m^3$, kg | 683 | 451 | 911.8 |
| Moisture Content, % | 17.6 | 23.65 | 23.4 |
| PH | 7.96 | 7.87 | 8.5 |
| EC, dS/m | 4.45 | 5.21 | 4.2 |
| C/N ratio | 13.45 | 11.92 | 4.1 |
| Organic Matter, % | 31 | 65.12 | 9.2 |
| Total Nitrogen, % | 1.23 | 2.91 | 1.11 |
| Total Phosphoric, % | 1.25 | 0.97 | 0.7 |
| Total Potassium, % | 1.34 | 1.44 | 0.45 |

### 2.1.5. Irrigation System

The layout of the drip irrigation system of the study is shown in Figure 2. It consisted of an electrical engine (50 hp) that operated a centrifugal pump with a flow rate of 80 $m^3/h$. The fertigation unit consisted of a small pump (1 hp) and tank (200 L), sand filter for freshwater, sand and screen combined filters for fish drainage water, control valves, and pressure gauges. In this experiment, we used the combined filter for this issue. This filter was tested in the previous study [17,33] which found that this filter helped to improve the irrigation efficiency, reduced dripper clogging, and increased the life of drip irrigation.

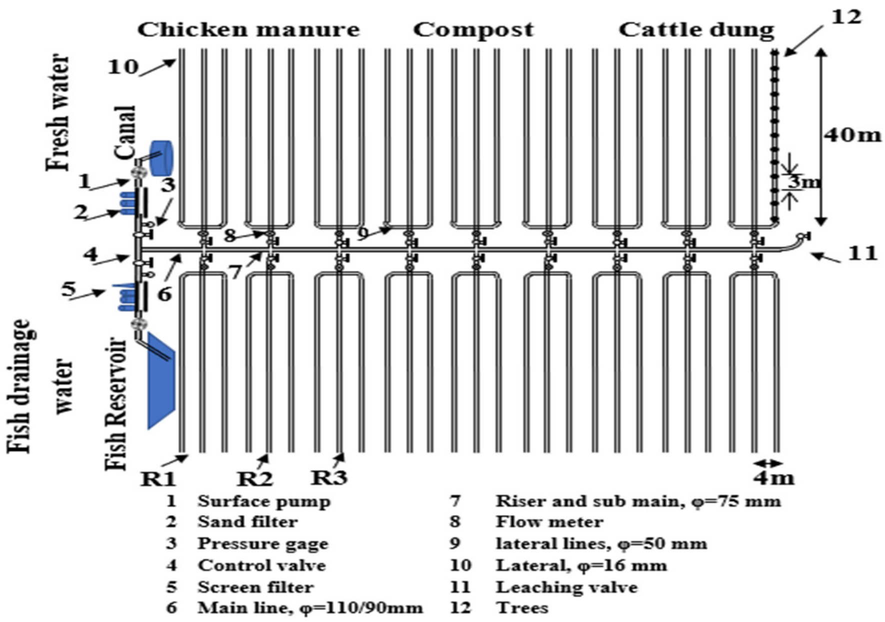


**Figure 2.** The layout of the drip irrigation system.

The main, sub-main, and secondary lines were made from PVC with diameters of 100, 75, and 50 mm, respectively. Lateral lines were made from polyethylene with 16 mm diameter, 40 m length, and 4 m spacing. The distance between the emitters along the lateral lines was 3 m. Four emitters with compensating type were used for each tree with a total discharge of 8 L/h.

### 2.2. Experimental Procedure

The experiments were carried out at about 2 feddans, with dimensions of 108 m × 80 m. The main plot was the water resource, while the sub-main plot was fertilizer types.

#### 2.2.1. Experimental Conditions

Experiments were conducted as follows:

- Two types of water resources (Freshwater and Fish drainage water).
- Three types of organic fertilizers (Compost, Chicken manure and Cattle dung).

#### 2.2.2. Measurements and Determinations

To study the effects of the previous parameters on the yield and quality of fruits, the following indicators were taken into consideration as follows:

- *Irrigation water requirement*

The irrigation water requirement ($IR$ L/day/tree) has been calculated according to [34] as:

$$IR = [(ET_c + LR) \times sl \times sm]/E_a \quad (1)$$

where $ET_c$: Crop evapotranspiration (mm/day), $LR$: Leaching requirement (%), $sl$: Distance between the rows (4 m), $sm$: Distance between the trees at the same row (3 m) and $E_a$: Irrigation system efficiency (85%).

Crop evapotranspiration ($ET_c$) was calculated according to [35]:

$$ET_c = ET_O \times K_c \times K_r \quad (2)$$

where $ET_o$: Reference evapotranspiration (mm/day) using Crop Wat program version 8, $K_c$: Crop coefficient (0.4–0.8) depended on the stage of the tree [12] and $K_r$: Reduction factor (-), which is calculated by the following equation:

$$K_r = G_C/85 \quad (3)$$

where $G_C$: Ground cover, equal the percentage of tree cover to planting spacing. Leaching requirement was calculated according to [36] as follows:

$$LR = EC_{iw}/(5EC_{th} - EC_{iw}) \quad (4)$$

where $EC_{iw}$: Electrical conductivity of the irrigation water (ds/m), $EC_{th}$: Soil salinity

Therefore, Irrigation was applied from 1st February and continued until mid-October. During December and January (only), each tree was irrigated by 10 L per week at one time [29].

Based on the above-mentioned equations, the highest irrigation requirements of freshwater and fish drainage water were 1225.5 and 1284.4 L/month in July, while the lowest values were 40 and 40 L/month in December and January, respectively. This result is in agreement with previous study [13]. Irrigation requirements were calculated through agricultural seasons as illustrated in Table 4.

**Table 4.** Irrigation water requirements of pomegranate trees during the growing season.

| Month | $ET_o$, (mm/day) | $K_c$ (–) | $K_r$ (–) | $ET_c$, (mm/day) | $LR_{Fresh}$ | $LR_{Fish}$ | $IR_{Fresh}$, (L/month) | $IR_{Fish}$, (L/month) |
|---|---|---|---|---|---|---|---|---|
| January | 2.60 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 40.00 | 40.00 |
| February | 3.00 | 0.40 | 0.44 | 0.53 | 0.52 | 0.66 | 415.40 | 468.60 |
| March | 3.70 | 0.50 | 0.44 | 0.81 | 0.52 | 0.66 | 585.10 | 644.00 |
| April | 4.90 | 0.60 | 0.44 | 1.29 | 0.52 | 0.66 | 769.30 | 826.30 |
| May | 5.94 | 0.70 | 0.44 | 1.83 | 0.52 | 0.66 | 1029.50 | 1088.40 |
| June | 6.16 | 0.80 | 0.44 | 2.17 | 0.52 | 0.66 | 1177.80 | 1236.70 |
| July | 6.47 | 0.80 | 0.44 | 2.28 | 0.52 | 0.66 | 1225.50 | 1284.40 |
| August | 6.38 | 0.80 | 0.44 | 2.25 | 0.52 | 0.66 | 1211.70 | 1270.60 |
| September | 6.02 | 0.80 | 0.44 | 2.12 | 0.52 | 0.66 | 1118.90 | 1175.90 |
| October | 5.90 | 0.80 | 0.44 | 2.08 | 0.52 | 0.66 | 1101.00 | 1158.00 |
| November | 3.40 | 0.80 | 0.44 | 1.20 | 0.52 | 0.66 | 728.30 | 785.30 |
| December | 2.30 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 40.00 | 40.00 |
| Total | | | | | | | 9442.50 | 10,018.40 |

- *Water use efficiency*

Water use efficiency ($WUE$, kg/m$^3$) was calculated as given below by following Pene and Edi 1996 [37]:

$$WUE = Crop\ yield / Irrigation\ water\ requirement \quad (5)$$

- *Nitrogen use efficiency*

The nitrogen use efficiency ($NUE$, kg/kg$_N$) was determined according to Vites 1965 [38] as given below:

$$NUE = Crop\ yield / Applied\ Nitrogen \quad (6)$$

- *Fruit quality*

The fruit physical properties and fruit juice chemical composition were determined as fruit quality. Fruit physical properties were recorded as fruit length and width. For sugars determination, the flesh of each fruit sample was cut into small pieces with a clean knife and mixed well. Five grams of the cut flesh were used for water extraction by distilled water [39]. Total sugars were determined calorimetrically using phenol and sulfuric acid [40]. TSS % was measured using an Atago N-20 refractometer (Made In Japan) at 20 °C.

- *Yield an its components*

Pomegranate fruits of the experimental trees were harvested in mid-September. The total fruit yield (kg/tree) and for each fed (kg/fed) was calculated using the following methods:

$$Total\ yield\ per\ tree = Number\ of\ fruits \times average\ of\ fruit\ weight \quad (7)$$

$$Total\ yield\ per\ fed = Total\ yield\ per\ tree \times Number\ of\ tree/fed \quad (8)$$

- *Total cost, return and net return*

Total production costs ($PC$, US $/fed) were calculated with the following equation:

$$PC = Fish\ farm\ costs + Irrigation\ system\ costs + Agricultural\ operation\ cost \quad (9)$$

Total return ($TR$), (US$/fed): was calculated with the following equation:

$$TR = Total\ return\ of\ tree + Total\ return\ of\ fish \quad (10)$$

$$Total\ return\ of\ tree = Tree\ price \times Fruit\ yield \quad (11)$$

$$Total\ return\ of\ fish = Fish\ price \times Fish\ yield \quad (12)$$

Net return (*NR*, (US$/fed) was calculated by:

$$NR = TR - PC \quad (13)$$

- *Statistical Analysis*

The experiments were conducted using the split-plot design. The obtained data were subjected to analysis of variance (ANOVA) according to Snedecor and Cochran et al., 1980 [41]. The least significant difference (LSD) at the 5% significance level was used to compare the means of various treatments Steel, and Torries [42].

## 3. Results and Discussion

The results were taken under the influence of various factors within the framework of the current study during the agricultural seasons as an average of the obtained values, which will be discussed under the following headings:

### 3.1. Water Use Efficiency (WUE)

The highest value of WUE was 5.43 kg/m$^3$ obtained by using fish drainage water with chicken manure fertilizer, while the lowest value was 3.85 kg/m$^3$ under freshwater and cattle dung as illustrated in Figure 3. The values of WUE of fish drainage water were more than the freshwater due to the increase in crop yield, which means the fish drainage water is considered a good alternative water resource for irrigation of crops. These results agree with the findings of Moursy, 2018, Elmetwalli and Amer 2019, and Azza et al., 2020 [16,17,43]. Research results indicated that the highest values of WUE were obtained under chicken manure followed by compost. The values were 3.85, 4.00, and 4.52 kg/m$^3$ for cattle dung, compost and chicken manure, respectively, using freshwater. The use of chicken manure as a bio-fertilizer enhanced the fruit yield and, therefore, the WUE was increased. The effect of using different types of fertilizers gave significant differences in WUE, while interaction between fertilizers and water resources was not significant on WUE.

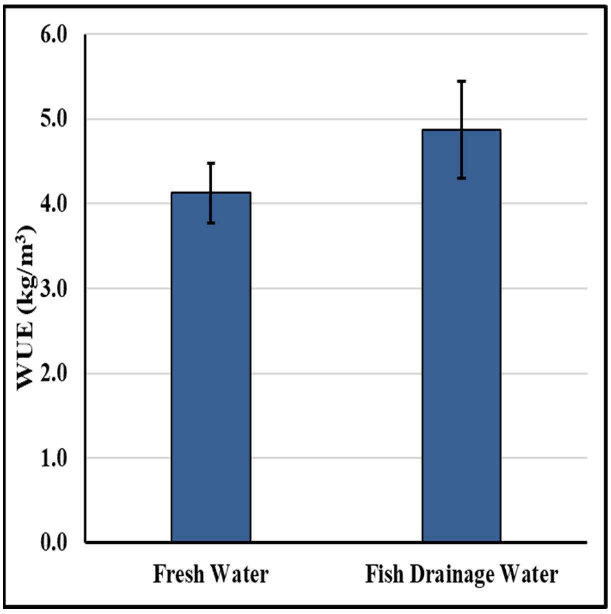


**Figure 3.** Effect of fresh and fish drainage water in combination with organic fertilizers on water use efficiency (WUE).

### 3.2. Nitrogen Use Efficiency (NUE)

Figure 4 shows that the fish drainage water gave the highest results compared to the freshwater resource. Due to the high content of nitrogen existing in fish drainage water compared to the freshwater, the NUE values were 93.9 for cattle dung, 107.1 for compost, and 119.0 kg/kgN for fish drainage water. While the NUE were 39.8, 41.3 and 46.7 kg/kgN for chicken manure under the application of freshwater. These results are in agreement with those obtained by Azza et al., 2020 [17]. In general, the fertilization by three different resources of bio-fertilizers gave different significant differences for NUE and the highest values were obtained under chicken manure followed by compost.

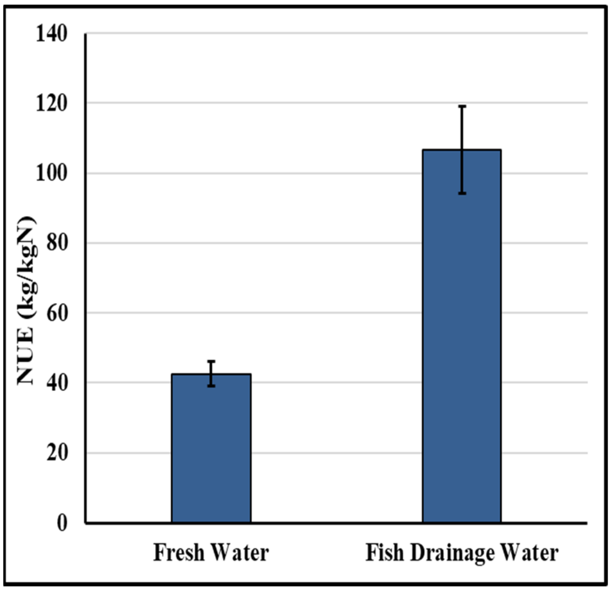


**Figure 4.** Effect of fresh and fish drainage water in combination with different organic fertilizers on NUE.).

### 3.3. Fruit Quality

#### 3.3.1. Fruit Physical Properties

- Fruit length

Table 5 shows that the highest value of fruit length was obtained using fish drainage water. The statistical analysis indicates that fish drainage water increased the fruit length by 4.6% compared to freshwater. As to the effect of fertilizer types, chicken manure increased fruit length by 3.1 and 5.8% compared to compost and cattle dung, respectively. These findings coincide with those stated by Mohamed et al., 2018 [31]. Moreover, the statistical analysis showed that there were no significant differences in fruit length values between fertilizer and water resources and, the interaction between them. The highest value of fruit length of 11.40 cm was obtained using fish drainage water combined with chicken manure as a bio-fertilizer type. On the contrary, a fruit length of 10.23 cm was observed using freshwater combined with cattle dung.

**Table 5.** Physical properties of pomegranate Fruits under different water resources and fertilizer types.

| Treatments | Fruit Length, (cm) | Fruit Width, (cm) |
|---|---|---|
| Water resource (W) | | |
| Freshwater ($W_1$) | 10.45 | 9.62 |
| Fish drainage water ($W_2$) | 10.93 | 10.32 |
| F test | NS | NS |
| LSD | - | - |
| Fertilizer type (F) | | |
| Cattle dung ($F_1$) | 10.40 | 9.61 |
| Compost ($F_2$) | 10.67 | 10.08 |
| Chicken manure ($F_3$) | 11.00 | 10.22 |
| F test | NS | NS |
| LSD | - | - |
| Interaction effects | | |
| $W_1 + F_1$ | 10.23 | 9.25 |
| $W_1 + F_2$ | 10.51 | 9.79 |
| $W_1 + F_3$ | 10.61 | 9.82 |
| $W_2 + F_1$ | 10.57 | 9.96 |
| $W_2 + F_2$ | 10.82 | 10.37 |
| $W_2 + F_3$ | 11.40 | 10.62 |
| F test | NS | NS |
| LSD | - | - |

- Fruit width

Table 5 shows that the fruit width was decreased by 4.4% using freshwater compared to fish drainage water. The highest value of fruit width of 10.32 cm was obtained under fish drainage water. Regarding the effect of fertilizer type, chicken manure gave the highest values of fruit width compared to both compost and cattle dung. Mohamed et al., 2018 [31] reported similar results for pomegranate trees. The statistical analysis of the effects of water resources, fertilizer resources, and interaction between both of them on fruit width showed that there were no significant differences.

### 3.3.2. Fruit Juice Chemical Composition

- Total sugar

Total sugar under different treatments is presented in Figure 5. The highest value of total sugar content of 8.26% was obtained using fish drainage water combined with chicken manure, on the other hand, the lowest value of 7.30% was observed using freshwater combined with cattle dung. Overall, the fish drainage water increased the total sugar by approximately 5.1, 7.8, and 7.2% compared to freshwater using organic fertilizer types of cattle dug, compost, and chicken manure, respectively.

- Total soluble solids content (TSS)

The total soluble solids content (TSS) data is presented in Figure 6 showing that freshwater decreased TSS by 3.06, 3.21, and 3.61% compared to fish drainage water under cattle dug, compost, and chicken manure, respectively. The application of chicken manure increased TSS compared to cattle dung and compost by 4.45 and 2.96% under freshwater, while under fish drainage water were 5.05 and 3.4%, respectively. This increase is attributed to the elevated levels of macronutrients and micronutrients in manures resulting in better growth of plant which positively reflected on quality of fruits. Similar results were obtained by Elissa, 2016, Moreno-Reséndez et al. 2016 [44,45], who found that using 100% chicken manure increased TSS.

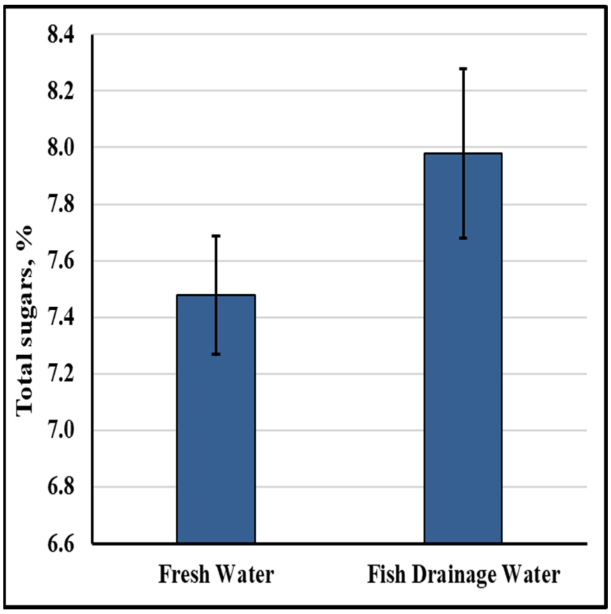


**Figure 5.** Effect of freshwater and fish drainage water in combination with different organic fertilizer types on total sugar content of the fruit juice.

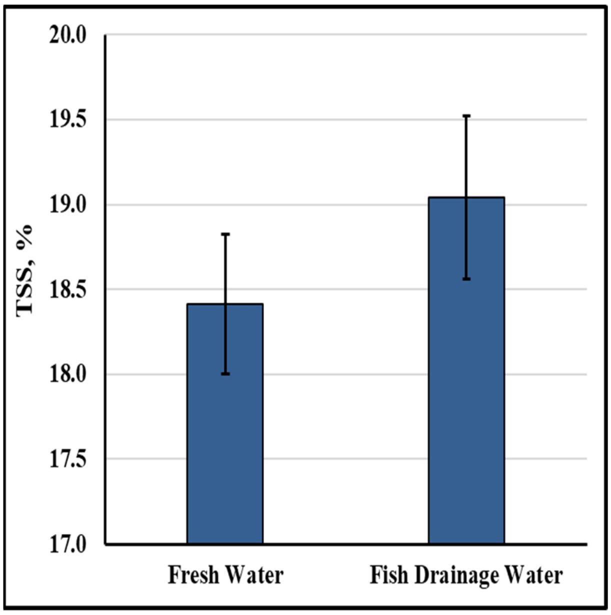


**Figure 6.** Effect of freshwater and fish drainage water in combination with different organic fertilizer types on Total soluble solids content (TSS) of the fruit juice.

*3.4. Fruit Yield and Its Components*

For fruit weights, it was found that there were highly significant differences between different water resources. Moreover, for the fertilizer types there were significant differences among them (Table 6). This return that there is a high difference in the N content between water resources, while in the types of fertilizers, the differences are not high as shown in Tables 2 and 3. The interaction between irrigation resources and fertilizer type didn't give any significant effect. With regards to the water resource types, it was found that the fish drainage water resource gave the highest significant values. While for fertilizer types, the chicken manure gave the highest values followed by compost. The maximum value of average fruit weight, total yield per tree, and total yield per fed were 597.88 g, 54.39 kg/tree, and 19,036.67 kg/fed, in that order under the application of fish drainage water combined with chicken manure. The reduction of fruit weight was 28.2% under freshwater compared to fish drainage water. Hence, the yield was greatly decreased under freshwater compared to fish drainage water. Fish drainage water increased the total yield (kg/fed) by 25.2% compared to freshwater. This increase is attributed to several reasons. Firstly, due to the increase in the concentration of dissolved nitrogen and other nutrients in fish drainage water which contains more dissolved nitrogen than freshwater nitrogen (more than 20 kg/ha). Not only that but the fish water contains other elements as well such as phosphorous and potassium, which are two elements of macronutrients for crops. Secondly, it returns to the fact that the plant finds it easier to absorb nitrogen because of the complete dissolution of nitrogen in fish water, while in freshwater the dissolution is incomplete. Moreover, nitrogen is a major component of chlorophyll, the basis of plant photosynthesis, which increases vegetative growth and the plant's ability to produce and transport food and helps crops to grow better and faster. As a result, it helps to increase the crop yield. These results are comparable with the findings of [16,17,46]. Chicken manure increased the average total yield (kg/fed) by 22.37 and 11.89% compared to cattle and compost organic fertilizer under fish drainage water, respectively, this agrees with a similar study [32]. This return to the fact that organic fertilizers such as chicken manure with a high content of micronutrients increase plant uptake of micronutrients and nutrients, as a result, it leads to improving plant growth and photosynthesis. Some previous research studies explained the commercial effects of using fish drainage water for irrigating many crops such as sugar beet, sesame [17,30], and potato [46]. They indicated the usage of fish drainage in irrigation is more effective than fresh water from the economic and commercial points of view. Moreover, in the current study, the research finding supports these results, especially under the increase in the cultivation area of pomegranate [11].

**Table 6.** Fruit yield and its components of pomegranate trees under different water resource and fertilizer types.

| Treatments | Average Fruit Weight, (g) | Total Yield, (kg/tree) | Total Yield, (kg/fed) |
|---|---|---|---|
| Water resource (W) | | | |
| Freshwater ($W_1$) | 433.95 | 38.95 | 13,631.67 |
| Fish drainage water ($W_2$) | 556.32 | 48.75 | 17,064.22 |
| F test | * | * | * |
| LSD | 7.6 | 5.45 | 11.4 |
| Fertilizer type (F) | | | |
| Cattle dung ($F_1$) | 469.39 | 39.66 | 13,880.00 |
| Compost ($F_2$) | 496.55 | 43.37 | 15,179.17 |
| Chicken manure ($F_3$) | 519.48 | 48.53 | 16,984.67 |
| F test | * | NS | NS |
| LSD | 4.28 | - | - |
| Interaction effects | | | |
| $W_1 + F_1$ | 422.36 | 36.40 | 12,739.00 |
| $W_1 + F_2$ | 438.53 | 37.78 | 13,223.33 |
| $W_1 + F_3$ | 440.97 | 42.66 | 14,932.67 |
| $W_2 + F_1$ | 516.42 | 42.92 | 15,021.00 |
| $W_2 + F_2$ | 554.57 | 48.96 | 17,135.00 |
| $W_2 + F_3$ | 597.98 | 54.39 | 19,036.67 |
| F test | NS | NS | NS |
| LSD | - | - | - |

* Significant level of 5%. - Nonsignificant.

### *3.5. Total Cost, Return and Net Return*

Results indicated that the highest total cost obtained value was 1824.89US $/fed using freshwater combined with chicken manure, while the lowest value was 1512.17 US $/fed using fish drainage water combined with cattle dung (Table 7). The irrigation cost of fish water was higher than the fresh water, as pumping from a fishpond requires adding the lifting cost of water from the fishpond to the total irrigation cost. The highest total return was 4219.55 US $/fed using the fish drainage water combined with chicken manure. The use of chicken manure as a source of bio-fertilizer gave the highest net return (2420.79 US $/fed) compared to compost (2123.52 US $/fed) and cattle dung (1721.66 US $/fed) using fish drainage water. Approximately 62% of the small tree farms in Egypt range between 0 to 10 feddans [47]. Therefore, the result of this experiment which has an area of 2 feddans is considered representative of most of the Egyptian tree farms which small farmers mostly occupy. Based on the above-mentioned results, it was clarified that using fish drainage water for irrigation with chicken manure is considered the best bio-fertilizer source for pomegranate crops followed by compost.

**Table 7.** Total cost, return and net return of pomegranate trees under different water resource and fertilizer types.

| Measurements | Water Resources | | | | | |
|---|---|---|---|---|---|---|
| | Fresh Water | | | Fish Drainage Water | | |
| | Cattle Dung | Compost | Chicken Manure | Cattle Dung | Compost | Chicken Manure |
| Total Irrigation cost, US $/fed | 261.19 | 261.19 | 261.19 | 273.29 | 273.29 | 273.29 |
| Fertilization cost (chemical + organic), US $/fed | 429.94 | 515.92 | 716.56 | 391.72 | 477.71 | 678.34 |
| Weed cost, US $/fed | 95.54 | 95.54 | 95.54 | 95.54 | 95.54 | 95.54 |
| Cultivation cost, US $/fed | 751.59 | 751.59 | 751.59 | 751.59 | 751.59 | 751.59 |
| Total cost, US $/fed | 1538.26 | 1624.25 | 1824.89 | 1512.17 | 1598.13 | 1798.76 |
| Total return, US $/fed | 2604.57 | 2737.25 | 3166.68 | 3233.76 | 3721.64 | 4219.55 |
| Net return, US $/fed | 1066.31 | 1113.00 | 1341.80 | 1721.66 | 2123.52 | 2420.79 |

## 4. Conclusions

Fish drainage water was utilized as water resources and fertilizers for irrigation. The results showed that using freshwater yielded a value of 13,631.7 kg/fed which was significantly lower than the value obtained when fish drainage water was utilized. Two types of water resources were tested in this study, in which the yield gets reduced by 25.2% using fresh water and increased by 50% using fish water. For the fertilizer types, the chicken manure resulted in the highest WUE compared to other types of fertilizers. Chicken manure increased the average fruit weight, yield per tree and total yield per fed as compared to the other types of using cattle and compost organic fertilizer under freshwater and fish drainage water resources. There are highly significant differences between the values of yield at different water resources, but among the fertilizer types, there are only significant differences in fruit weights. The use of chicken manure gave the highest net return (2420.79 US $/fed) than compost (2123.52 US $/fed) and cattle dung (1721.66 US $/fed) under using fish drainage water. Using fish drainage water could pave the way for reducing the commercial fertilizers as well as reducing the overall cost. Moreover, such a water resource could be deemed as environmentally friendly bio-fertilizers, which could preserve the environment from being contaminated.

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