Effect of irrigation with fish farm effluent on two legume crops interplanted with orange trees in a sandy soil

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Abstract

This research was conducted to study the effect of applying three irrigation water quality treatments (Full irrigation using Nile water and 100% NPK fertilizer (Irr I, control); full irrigation using 50% fish farm effluent + 50% Nile water + 50% NPK fertilizer (Irr II); full irrigation using fish farm effluent (Irr III) to two legume crops (faba bean and lupine) interplanted under young orange trees, in addition to the solid planting of all crops in a two-year experiment. The highest yield of the two legume crops under interplanting systems with orange and its solid planting was obtained using only fish farm effluent (Irr III). The highest values of orange yield and water equivalent ratio were obtained when lupine was interplanted under orange trees using Irr III. Similarly, the highest values of land equivalent ratio were obtained for lupine interplanted under orange trees using Irrigation III in the first growing season and faba bean in the second growing in the same treatment. Thus, to reduce pressure on Nile water, we recommend the use of fish farm effluent in irrigation, in general, and use it particularly to irrigate lupine interplanted under orange trees, which increase land and water equivalent ratios.

Keywords: Faba bean, lupine, fish farm effluent, water equivalent ratio, land equivalent ratio

INTRODUCTION

Using water of low quality for irrigation could negatively affect crop yield. Although fish farm effluent is considered as low quality water, it could be a source of irrigation water and a source of organic materials as well, that could be used for fertilization of crops. Isitekhale and Adamu (2016) reported that only 25% of N and 20% of P of fish feed is recovered in harvested fish and the rest is accumulated in farm effluent. Incorporating these organic wastes into the soil helps to build up soil organic matter layers needed for steady supply of nutrients to the growing plants (Zieman *et al.*, 2007). Ojobor and Tobih (2015) reported that fish farm effluent increased the yield of cultivated crops and improved soil chemical properties, such as available phosphorus, water soluble potassium, calcium and magnesium. FAO (2014) reported that a combination of fish farming and crop cultivation is a well-developed practice in China where the nutrient-rich residues that settled in fish farms proved to be a high-quality manure when applied to crops. Thus, using fish farm effluent for irrigation, after testing it for harmful contents, could have a significant role in conserving Nile water resources and reduce contamination of the environment.

Legumes are a major source of proteins not only for human but also for livestock (Hubbell and Gerald, 2003). Legume crops are good candidates to be used in a crop rotation because of its role in increasing soil fertility (Sheha *et al.*, 2014), raising the organic content and increasing available nitrogen contents in the soil (Singh *et al.*, 2003), which positively affects the following crops (Kumpawat and Rathore, 2003). Faba bean is considered one of the most important winter legume crops in Egypt and has a high nutritive value (Eldardiry *et al.*, 2017). It has become one of the strategic crops due to income it provides to farmers (Sharaan *et al.*, 2004). Lupine is another winter legume crop, which is cultivated for its edible seeds (Prusinski, 2017). It is a source of protein for animal and human nutrition in various parts of the world and is well adapted to marginal soils and various climates (Abd El Wahed *et al.*, 2015).

As a result of being a crop with high economic value, orange high production is important for local consumption and for exportation. Interplanting orange trees with crops of economic importance for the Egyptian population could increase their production, as well as increase orange production. Several authors in Egypt showed that interplanting legume crops under orange trees increased orange yield. Abdel-Aziz *et al.*, (2008) showed that fruit yield of orange was enhanced and fruit drop was reduced under interplanting with legume cover crops. El-Mehy and El-Badawy (2017) indicated that interplanting soybean under orange trees could substitute for 25% of the recommended NPK, resulted in an increase in the yield of both crops. Selim *et al.*, (2020) interplanted two soybean plant distributions (wide and narrow distribution) with the same planting density under orange trees. They found that wide soybean plant distribution increased orange fruit yield per hectare by 10%, in addition to increased land equivalent ratio and total return, compared to solid planting of orange trees. However, very few studies tested the effect of interplanting winter legumes under orange trees. Thus, the objective of this investigation was to study the effect of applying different water quality treatments to two legume crops interplanted under orange trees cultivated in a sandy soil to maximize water and land productivity.

MATERIALS AND METHODS

Experimental site

A field experiment was conducted in El-Kassaseen Agricultural Experiments Research Station (Lat. 30° 35' 30" N, Long. 32° 14' 50" E, 10 m a.s.l.), Agricultural Research Center, Ismailia Governorate, Egypt during 2018/19 and 2019/20 growing seasons. The aim of the experiment was to study the effect of three water qualities and NPK fertilizer treatments on interplanting faba bean, or lupine under 3-year old orange trees in two separate experiments.

The monthly averages of meteorological data of the experimental site from 2017 to 2019 are presented in Table 1.

Strip plot experimental design with three replicates was used, where water qualities and fertilizer treatments were randomly assigned to the vertical strips and cropping systems were allocated to the horizontal strips. Each strip plot area was 48 m^2 (6 m x 8 m).

Some mechanical and chemical properties of the soil averaged on 60 cm in depth were determined by the standard methods as described by Tan (1996) and presented in Table 2.

Table 1: Average of meteorological data from in the studied growing seasons

Month	2019					2020				
	SR	TX	TN	WS	ETo	SR	TX	TN	WS	ETo
Jan	13.3	18.7	7.5	3.31	2.0	12.9	17.8	8.6	3.3	1.8
Feb	15.9	20.4	8.6	2.84	2.6	15.1	20.0	9.1	2.6	2.7
Mar	19.1	22.3	10.2	3.16	3.5	19.8	23.6	11.0	3.2	3.7
Apr	23.6	26.3	13.1	3.15	4.7	23.8	25.8	13.2	2.9	4.7
May	27.7	33.7	17.8	3.29	6.6	27.7	30.7	16.6	3.0	6.7
Jun	29.6	35.8	22.0	3.10	6.7	30.0	34.3	19.5	3.0	6.7
Jul	29.1	37.2	23.1	2.84	6.8	29.0	36.9	22.3	2.8	6.9
Aug	26.9	37.3	23.7	2.68	6.3	23.0	37.2	23.0	2.7	6.4
Sep	19.4	33.8	22.0	2.78	4.9	23.1	36.0	23.2	2.8	5.2
Oct	18.3	30.9	19.8	2.65	3.6	18.6	31.9	21.0	2.7	3.7
Nov	15.2	27.6	16.5	2.62	2.7	14.2	25.1	15.7	2.4	2.7
Dec	12.0	20.9	11.2	3.16	1.9	12.1	20.9	10.9	3.1	1.9

SR = solar radiation (MJ/m^2/day), TX and TN = maximum and minimum temperature, respectively (°C), WS = wind speed (m/s), ETo = reference evapotranspiration (mm/day).

Table 2: Some physical and chemical properties of the soil at the experimental site

Soil properties	Soil depth (cm)			
Particle size distribution	0-15	15-30	30-45	45- 60
Coarse sand, %	68.5	73.5	74.1	77.1
Fine sand, %	25.8	22.1	22.2	18.9
Silt, %	3.67	2.90	2.80	3.10
Clay, %	2.00	1.40	0.90	0.80
Texture class	Sandy	sandy	Sandy	sandy
Bulk density, Mg m^{-3}	1.64	1.76	1.74	1.70
Field capacity, % w/w	12.7	11.1	6.90	7.85
Permanent wilting point, % w/w	3.65	2.90	2.15	2.10
Available water, %	9.05	8.25	4.75	5.75
pH (1:2.5)	7.61	7.58	7.56	7.40
ECe, soil past extract, dS m^{-1}	0.56	0.54	0.50	0.48
Soluble cations, meq L^{-1}				
Ca^{2+}	1.24	1.20	1.24	1.26
Mg^{2+}	0.55	0.53	0.50	0.48
Na^{+}	1.55	1.57	1.60	1.62
K^{+}	0.16	0.18	0.14	0.16
Soluble anions, meq L^{-1}				
CO_3^{2-}	-	-	-	-
HCO_3^{-}	1.05	1.15	1.06	1.08
Cl^{-}	1.72	1.74	1.73	1.75
SO_4^{2-}	0.66	0.68	0.68	0.70

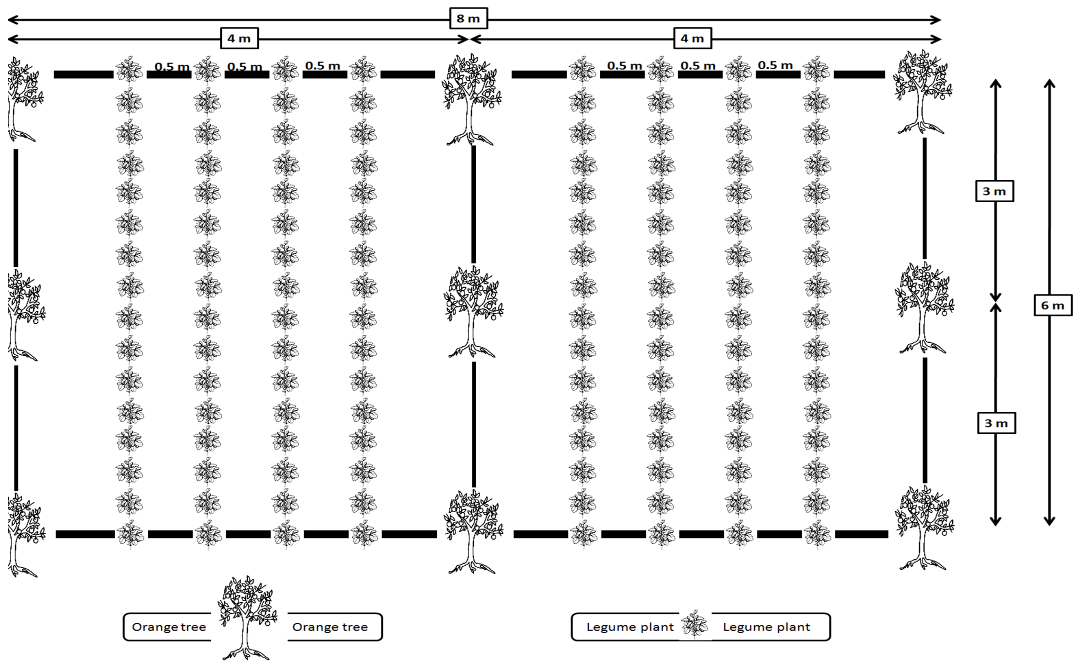

Figure 1: Interplanted one of the studied legume crop under orange trees

Experimental treatments

The treatments could be stated as follows:

Water qualities and NPK treatments

- **Irrigation I:** Full irrigation (120 ETo) using Nile water and 100% NPK fertilizer (control)
- **Irrigation II:** Full irrigation (120 ETo) using 50% fish farm effluent and 50% Nile water, in addition to 50% NPK fertilizer
- **Irrigation III:** Full irrigation (120 ETo) using fish farm effluent only.

Cropping systems

- Interplanting faba bean and lupine under orange trees
- Solid cultivation of legume crops
- Solid orange cultivation

Figure 1 showed the arrangement of one of the studied legume crops between oranges trees. Four ridges were implemented between orange trees distributed as two plants per hill distanced at 25 cm between hills in both sides of ridges, 50 cm width (161280 plants per ha). The solid cultivation of each legume crop were planted on ridges (60 cm width) by growing two plants per hill spaced at 20 cm between hills in both sides (336000 plants per ha). The ridges were distanced at 1.25 m from the orange trees to avoid orange canopy shading.

The studied crops

Orange trees

Orange trees, either interplanted or solid, were planted on distance 3 × 4 m between trees (833 orange trees per ha). The trees were three-year old. Farmyard manure at the rate of 47.6 m^3/ha, as well as calcium super phosphate (15.5% P_2O_5) at the rate of 36.9 kg P_2O_5/ha were added in the beginning of November as a common fertilizer practice done every year. Phosphoric acid applied at the rate of 4 liter/ha was applied every 15 days. Nitrogen fertilizer as ammonium nitrate (33.5% N) was added in the rate of 288 kg N/ha as 12 kg/ha every week. Potassium fertilizer in the form of potassium sulfate (48% K_2O) was added at the rate of 57.6 kg K_2O/ha during land preparation. The studied cultivar was *Valencia* (summer) orange and it was harvested on 15/4/2019 and 20/4/2020 in the first and second season, respectively.

For either interplanted or solid faba bean or lupine, sowing was done on 1st and 11th of November 2018 and 2019 growing seasons, respectively for both crops. The sowing of interplanted crops was done on four ridges between orange trees distributed as two plants per hill distanced at 25 cm between hills in both sides of ridges, 50 cm width (161280 plants per ha). These legume plants were distanced at 1.25 m from the orange trees to avoid shading by the trees canopy. There were no preceded summer crops for either faba bean or lupine interplanted under orange trees.

The solid cultivation of each legume crop were planted on ridges (60 cm width) by growing two plants per hill spaced at 20 cm between hills in both sides (336000 plants per ha).

The studied cultivars were *Giza 843* and *Giza 1* for faba bean and lupine, respectively. Faba bean harvest was done on 18th and 26th of April 2019 and 2020 growing seasons, respectively. For lupine, harvest was done on 2nd and 10th of May 2019 and 2020 growing seasons, respectively. Water qualities and NPK treatments were applied for either faba bean or lupine as follows:

Irrigation I: Full irrigation using regular Nile water and 100% recommended NPK fertilizer (control), where the required irrigation water was applied using the regular Nile water. In both growing seasons, faba bean seeds were inoculated by *Rhizobium leguminosarum*, and lupine seeds were inoculated by *Rhizobium lupine* before sowing and Arabic gum was used as a sticking agent. Calcium super phosphate (15.5% P_2O_5) was applied at a rate of 238 and 476 kg/ha for interplanted and solid cultivation, respectively in the two winter seasons. Nitrogen fertilizer was added in the form of ammonium nitrate (33.5% N), with the rate of 35.7 and 71.4 kg N/ha for interplanted and solid planting of faba bean and lupine via irrigation water in two doses, 15 and 45 days after sowing, respectively. Potassium was applied as potassium sulphate (48% K_2O) in the rate of 120 and 240 kg K_2O/ha for interplanted and solid legumes, respectively in two doses, 25 and 45 days after sowing.

Irrigation II: Full irrigation using 50% fish farm effluent and 50% Nile water, in addition to 50% NPK fertilizer, where the required irrigation water was divided into 50% added as fish farm effluent and the other 50% was completed with regular Nile water with 50% of the required NPK.

Irrigation III: Full irrigation using fish farm effluent only.

At harvest, the studied traits for both winter crops were plant height (cm), number of branches per plant, number of pods per plant, and 100-seed weight (g).

Irrigation system

The used irrigation system was drip and was established on both sides of the tree trunk at a distance of one meter. Each tree is provided with two drippers (discharge 4 Liter per hour) and the time of operation was 4 hours/day (32 L/tree/day) throughout the period of study. The studied legume crops have a separate irrigation network other than the one used for orange trees to prevent fertilizers mixing. Irrigation was done every 3 days and all fertilizer was added via irrigation water.

Dissolved oxygen (DO) and pH of fish farm effluent treatments at different dates was measured by Central Laboratory for Aquaculture Research at Abbasa, El-Sharkia Governorate.

The amounts of applied irrigation water were calculated according to the equation given by Vermeiren and Jopling (1984) as follows:

$$AIW = \frac{ETo \times I}{Ea\,(1 - LR)}$$

where:

AIW= depth of applied irrigation water (mm)

ETo = reference evapotranspiration (mm d^{-1}).
I = irrigation intervals (days)
Ea= irrigation application efficiency of the irrigation system.
LR= leaching requirements (equal 1.0)

The values of ETo and water consumptive use were calculated using BISm model (Snyder *et al.*, 2004).

Water equivalent ratio (WER)

WER was used to quantify the efficiency of water use by an intercropping system of each legume crop under orange trees. It is defined as the total water needed in sole crops to produce the equivalent amount of the species yields on a unit area of intercrop (Mao *et al.*, 2012). WER was calculated for each legume crop intercropped under orange trees as follows:

$$WER = \frac{\left(\frac{Y_{int,L}}{WU_{int,L}}\right)}{\left(\frac{Y_{mono,L}}{WU_{mono,L}}\right)} + \frac{\left(\frac{Y_{int,O}}{WU_{int,O}}\right)}{\left(\frac{Y_{mono,O}}{WU_{mono,O}}\right)}$$

Where: $Y_{int,L}$ and $Y_{int,O}$ are the yield of intercropped of each legume crop and orange, respectively. $WU_{int,L}$ and $WU_{int,O}$ are water consumptive use by the intercropped legume crops and intercropped orange. $Y_{mono,L}$ and $Y_{mono,O}$ are the yield of each mono legume crop and orange, respectively. $WU_{mono,L}$ and $WU_{mono,O}$ are water consumptive use by each mono legume crop and orange, respectively. If the WER > 1, it suggests that the water utilization of intercropping is higher than that of monoculture and that imply advantage in implemented intercropping system. If WER < 1, it shows that water utilization of intercropping is lower than that of monoculture and that imply disadvantage.

Land equivalent ratio (LER)

LER is the ratio of the area under sole cropping to the area under intercropping needed to give equal amounts of yield at the same management level. It is the sum of the fractions of the intercropped yields divided by the sole-crop yields. LER is calculated for each of the legume crops intercropped under orange trees as follows:

$$\mathbf{LER = (Y_{LO}/Y_{LL}) + (Y_{OL}/Y_{OO})}$$

Where: Y_{LO}= Intercropped yield of one of the studied legume crops, Y_{LL}= Pure stand yield of one of the studied legume crops, Y_{OL}= intercropped yield of orange, and Y_{OO}= Pure stand yield of orange. If the LER > 1, it suggests that the land utilization of intercropping is higher than that of monoculture. If LER < 1, it shows that land utilization of intercropping is lower than that of monoculture.

Statistical Analysis

Analysis of variance of the obtained results of each season was performed. The measured variables were analyzed by ANOVA using MSTATC statistical package (Freed, 1991). Mean comparisons were performed using the least significant differences (LSD) test with a significance level of 5% (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Quality of fish farm effluent

Analysis of the quality of fish farm effluent is presented in Table 3. The results showed that both the pH and dissolved oxygen (DO) were suitable for crops irrigation without causing stress to the studied interplanting systems. Soil pH plays an important role in the availably of soil nutrients for the growing plants (Neina, 2019). Furthermore, oxygen supplies to the root zone is essential for healthy plant growth, thus dissolved oxygen helps the roots absorb nutrients at a faster rate, and can increase a plant's growth rate (Bagatur, 2014).

Effect of irrigation treatments and cropping systems on faba bean

The results in Table 4 indicated that all the studied faba bean traits were significantly affected by the application of water qualities treatments and cropping systems in both growing seasons, except seed yield per hectare in the first season. Furthermore, the interaction between irrigation treatments and cropping systems was found insignificant for all the studied traits in the first growing season. In the second growing season, the interaction between irrigation treatments and cropping systems was found insignificant for all the studied traits, except 100-seed weight (Table 4).

The same table also showed that faba bean yield was higher in the second growing season, compared to the first growing season. This could be a result of decomposition of faba bean roots after its harvest in the first season, which could increase organic matter in the rhizosphere (Li *et al.*, 2003). Furthermore, the table also showed that the yield of interplanted faba been was almost half of the solid cultivation under the three irrigation treatments in both growing seasons as a result of lower planting density under the interplanting system. The highest faba bean yield of both interplanted and solid planting was obtained when Irrigation III was applied, compared to irrigation I (Table 4). This result could be attributed to high amount of N and P in fish farm effluent as stated by Isitekhale and Adamu (2016), which improves soil quality, facilitate root uptake of nutrient, which increases crops productivity as stated by Udoh *et al.*, (2016). The lowest faba bean yield was obtained when Irrigation I was applied for both interplanted and solid planting. This result was true for both growing seasons (Table 4). It is attributed to the application of 100% NPK in the control treatment could depress nodulation in faba bean, compared to Treatment III. Dean and Clark (1980) indicated that application of N fertilizer in large amounts inhibits root infection and nodulation development in faba bean. It is worth noting that there was no preceding crop for faba bean.

Effect of irrigation treatments and cropping systems on lupine

In the first growing season, all the lupine traits were significantly affected by the application of water qualities treatments, except number of pods per plant. With

Table 3: Quality of fish farm effluent at different dates during the two growing seasons

Date	Season	pH	Dissolved oxygen	Date	Season	pH	Dissolved oxygen
14-Nov	1st season	7.0	6.2	**18-Jan**	1st season	7.2	4.1
	2nd season	7.8	7.4		2nd season	8.0	6.4
21-Nov	1st season	7.1	5.6	**25-Jan**	1st season	7.1	4.1
	2nd season	7.8	6.5		2nd season	7.9	8.7
28-Nov	1st season	7.2	5.2	**16-Feb**	1st season	6.8	3.1
	2nd season	7.7	8.7		2nd season	7.9	5.5
11-Dec	1st season	7.1	3.5	**23-Feb**	1st season	7.0	9.0
	2nd season	7.8	3.8		2nd season	7.5	10.5
19-Dec	1st season	7.2	3.9	**03-Mar**	1st season	7.2	8.9
	2nd season	7.8	4.2		2nd season	7.4	7.5
27-Dec	1st season	6.9	7.8	**13-Mar**	1st season	7.1	6.7
	2nd season	7.8	7.1		2nd season	7.4	7.6
09-Jan	1st season	7.1	7.6	**20-Mar**	1st season	7.2	5.2

Table 4: Effect of water qualities and NPK treatments, cropping systems and their interactions on faba bean yield and its attributes in 2018/19 and 2019/20 seasons

Irrigation treatment	Cropping system	Plant height (cm)	Number of branches/ plant	Number of pods/ plant	100-seed weigh (g)	Seed yield (ton/ha)
		First season				
Irrigation I	Intercrop	119.6	2.48	5.93	68.6	1.12
	Solid	117.6	2.56	9.71	76.9	2.90
	Mean	118.6	2.52	7.82	72.7	2.01
Irrigation II	Intercrop	125.3	2.32	7.06	75.1	1.20
	Solid	122.4	2.45	11.73	85.4	3.03
	Mean	123.8	2.38	9.40	80.2	2.11
Irrigation III	Intercrop	120.7	2.45	6.65	70.7	1.22
	Solid	118.4	2.51	11.00	82.4	3.08
	Mean	119.5	2.48	8.82	76.5	2.15
Average of cropping systems	Intercrop	121.8	2.41	6.55	71.4	1.18
	Solid	119.4	2.51	10.81	81.6	3.00
L.S.D. 0.05 water qualities (I)		1.22	0.01	0.34	0.87	N.S.
F-test 0.05 Cropping systems		*	**	**	**	**
L.S.D. 0.05 Interaction		N.S.	N.S.	N.S.	N.S.	N.S.
		Second season				
Irrigation I	Intercrop	121.8	2.45	5.91	71.1	1.14
	Solid	120.2	2.53	10.91	81.8	2.98
	Mean	121.0	2.49	8.41	76.5	2.06
Irrigation II	Intercrop	125.3	2.26	6.73	76.3	1.29
	Solid	122.0	2.39	11.71	87.0	3.19
	Mean	123.6	2.32	9.22	81.7	2.25
Irrigation III	Intercrop	121.9	2.44	6.96	70.2	1.31
	Solid	118.4	2.47	12.21	83.5	3.22
	Mean	121.0	2.49	8.41	76.5	2.06
Average of cropping systems	Intercrop	123.0	2.38	6.53	72.6	1.25
	Solid	120.2	2.46	11.61	84.1	3.13
L.S.D. 0.05 water qualities (I)		2.72	0.09	0.45	1.04	0.13
F-test 0.05 Cropping systems		**	*	**	**	**
L.S.D. 0.05 Interaction		N.S.	N.S.	N.S.	1.25	N.S.

Irrigation I: Full irrigation using Nile water and 100% NPK fertilizer (control), Irrigation II: Full irrigation using 50% fish farm effluent and 50% Nile water, in addition to 50% NPK fertilizer, Irrigation III: Full irrigation using fish farm effluent.

respect to cropping systems, all the lupine traits were significantly affected by it. Furthermore, all the traits were insignificantly affected by the interaction between water qualities treatments and cropping systems (Table 5). Moreover, in the second growing season, all the lupine traits were significantly affected by the application of water qualities treatments and cropping systems. All the traits were found insignificantly affected by the interaction between application of water qualities treatments and the cropping systems, except number of pods per plant and seed yield per hectare (Table 5).

Table 5 also showed that lower lupine yield was observed under interplanted lupine with orange trees, compared to solid planting as a result of lower planting density. Moreover, lupine yield in the second season was higher than the first season under the three water qualities treatments a result of the residual effect left in the soil after the cultivation of legume crops in the first season. Li *et al.*, (2003) reported that legumes, when interplanted, fix more atmospheric N_2 than in monoculture; as a result of competition between the interplanted crops in the use of N_2 and that has positive effects on the organic matter in the rhizosphere and this could be the reason for the higher yield in the second season. The lowest lupine yield was observed under Irrigation I, where 100% of Nile water and NPK were applied, compared to the other treatments where fish farm effluent was included (Table 5).

Effect of irrigation treatments and cropping systems on orange yield

The results in Table 6 indicated that both orange fruit yield per tree and orange fruit yield per hectare were significantly affected by the application of irrigation treatments, cropping systems and the interaction between them in both season. Orange fruit yield per tree in the second season was insignificantly affected by the interaction between irrigation treatments and cropping systems in both growing seasons. Furthermore, Hauggaard-Nielsen *et al.*, (2009) and Rose *et al.,* (2015) indicated that faba bean is less susceptible to suppression of biological nitrogen fixation to the added nitrogen fertilizer to trees under interplanting conditions. Therefore, it is better suited as interplanted legume crop under trees, which explain the superiority of faba bean in increasing orange yield, compared to the other studied legume crops.

Table 5: Effect of water qualities and NPK treatments, cropping systems and their interactions on lupine yield and its attributes in 2016/17 and 2017/18 seasons

Irrigation treatment	Cropping system	Plant height (cm)	Number of branches/ plant	Number of pods/ plant	100-seed weigh (g)	Seed yield (ton/ha)
		First season				
Irrigation I	Intercrop	121.1	1.54	10.92	21.0	2.85
	Solid	118.3	1.94	18.58	28.0	6.79
	Mean	119.7	1.74	14.75	24.5	4.82
Irrigation II	Intercrop	122.3	1.46	10.08	21.9	2.94
	Solid	119.0	1.87	16.98	29.0	6.91
	Mean	120.6	1.66	13.53	25.4	4.92
Irrigation III	Intercrop	127.1	1.72	11.70	24.1	2.98
	Solid	123.9	2.25	18.08	29.4	7.01
	Mean	125.5	1.98	14.89	26.8	4.99
Average of cropping systems	Intercrop	123.5	1.57	10.90	22.3	2.92
	Solid	120.4	2.02	17.88	28.8	6.90
L.S.D. 0.05 water qualities (I)		1.63	0.11	N.S.	0.58	0.14
F-test 0.05 Cropping systems		**	**	**	**	**
L.S.D. 0.05 Interaction		N.S.	N.S.	N.S.	N.S.	N.S.
		Second season				
Irrigation I	Intercrop	127.2	1.69	15.30	22.8	2.79
	Solid	122.8	2.13	18.70	28.2	7.09
	Mean	125.0	1.91	17.00	25.5	4.94
Irrigation II	Intercrop	125.6	1.76	13.23	23.4	2.97
	Solid	122.3	2.28	17.42	28.5	7.45
	Mean	123.9	2.02	15.32	25.9	5.21
Irrigation III	Intercrop	130.0	1.79	16.28	25.1	3.25
	Solid	125.6	2.35	19.30	31.2	7.80
	Mean	127.8	2.07	17.79	28.1	5.52
Average of cropping systems	Intercrop	127.6	1.74	14.93	23.8	3.01
	Solid	123.5	2.25	18.47	29.3	7.44
L.S.D. 0.05 water qualities (I)		0.99	0.06	0.84	1.23	0.08
F-test 0.05 Cropping systems		**	**	**	**	**
L.S.D. 0.05 Interaction		N.S.	N.S.	0.85	N.S.	0.09

Irrigation I: 100% Nile water + 100% NPK fertilizer (control), Irrigation II: 50% fish farm effluent + 50% Nile water + 50% NPK fertilizer and Irrigation III: 100% fish farm effluent only.

It can be also noticed from the table that orange yield was higher in the second growing season, compared to the first season. Ferguson *et al.*, (2013) indicated that legume crops have the ability to remove calcium and magnesium in the soil more than cereals and replace it with hydrogen, which results in removing OH^- ions and increases H^+, thus lowering soil pH and increase available soil nutrients for the growing plants (Neina, 2019).

The interplanted orange yield was found to be higher than its yield resulted from solid cultivation, which can be attributed to the effect of legume crop interplanting under orange trees (Table 6).

Water consumptive use and applied irrigation water

Table 7 showed that the value of the applied irrigation amounts to faba bean was higher than the amounts applied to lupine, namely 539 and 541 mm for faba bean versus 518 and 532 mm for lupine in the first and second seasons, respectively. It can also noticed from the table that both the values of the applied irrigation water and water consumptive use of the three studied crops were higher in the second growing season, compared to the first growing season. This could be attributed to higher values of ETo in the second growing season, compared to the first growing season.

Table 6: Effect of irrigation water treatments, cropping systems and their interactions on lentil yield and its attributes in both seasons

Irrigation treatments	Cropping systems	Fruit yield/tree (kg)	Fruit yield/ha (ton)
First season			
Irrigation I	**Intercropped**	5.43	2.83
	Solid	5.15	2.43
	Mean	5.29	2.63
Irrigation II	**Intercropped**	5.60	2.90
	Solid	5.16	2.77
	Mean	5.38	2.83
Irrigation III	**Intercropped**	6.11	3.26
	Solid	6.00	3.10
	Mean	6.05	3.18
Average of cropping systems	**Intercropped**	5.71	2.99
	Solid	5.43	2.77
L.S.D. 0.05 Irrigation treatments		0.23	0.04
L.S.D. 0.05 Cropping systems		0.19	0.14
L.S.D. 0.05 Interaction		N.S.	N.S.
Second season			
Irrigation I	**Intercropped**	6.43	3.21
	Solid	6.09	2.67
	Mean	6.26	2.94
Irrigation II	**Intercropped**	6.45	2.91
	Solid	6.17	2.84
	Mean	6.31	2.87
Irrigation III	**Intercropped**	6.66	3.52
	Solid	6.60	3.30
	Mean	6.63	3.41
Average of cropping systems	**Intercropped**	6.51	3.21
	Solid	6.28	2.93
L.S.D. 0.05 Irrigation treatments		0.26	0.42
L.S.D. 0.05 Cropping systems		0.14	N.S.
L.S.D. 0.05 Interaction		N.S.	N.S.

Irrigation I: 100% Nile water + 100% NPK fertilizer (control), Irrigation II: 50% fish farm effluent + 50% Nile water + 50% NPK fertilizer and Irrigation III: 100% fish farm effluent only.

Table 7: Applied irrigation water and water consumptive use for legume crops and orange in both growing seasons

Crop	Applied irrigation water (mm)		Water consumptive use (mm)	
	First season	Second season	First season	Second season
Faba bean	539	541	469	471
Lupine	518	532	451	463
Orange	1493	1540	1299	1340

Water equivalent ratio (WER)

The results in Table 8 indicated that WER for orange was higher when each legume crop was interplanted under it using the three irrigation treatments in both growing seasons, compared to solid planting. The total WER was higher than 1.0 in both growing seasons for all interplanting systems under the three irrigation treatments, with the highest values obtained for lupine under Irrigation III. This result implied that the water utilization of lupine interplanted under orange trees was higher than the value of the faba bean, as well as that of solid orange cultivation as explained by Feng *et al.,* (2017). In this case, the value of WER_{total} for lupine interplanted under orange trees were increased by 65 and 69% in the first and second growing seasons, respectively when Irrigation III was applied. Similar results were obtained by Zohry *et al.,* (2020).

Land equivalent ratio (LER)

The results in Table 9 revealed that the legumes interplanting systems with orange have lower values of relative yield (RY_{legume}) than its counterpart value of orange (RY_{orange}). The highest values of total land equivalent ratio (LER_{total}) were obtained for lupine interplanted under orange trees using Irrigation III in the first growing season and in the second growing season it was found when faba bean interplanted under orange trees using Irrigation III, where it were increased by 64 and 60%, respectively. El-Mehy and El-Badawy (2017) found that soybean interplanted under orange trees is a successful technology to increase land equivalent ratio. Similar results were obtained by Zohry *et al*., (2020).

CONCLUSION

In the present research, we compared between three irrigation treatments on the basis of their capability to increase land and water equivalent ratios through using land and water resources more efficiently. Between the three studied irrigation treatments, we found that irrigation with fish farm effluent could attain the highest yield of the two studied legume crops interplanted under orange trees. Furthermore, between the two legume crops, we found that lupine interplanted under orange trees could attain the highest yield of orange trees, land equivalent ratio and water equivalent ratio. Thus, to reduce pressure on Nile water resources and increase food availability, we recommend the use of fish farm effluent in irrigation, in general, and use it particularly to irrigate lupine interplanted under orange trees, which increase land and water equivalent ratios.

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Table 8: Water equivalent ratios for legume crops interplanted under orange under the studied irrigation treatments in both growing seasons

Irrigation treatments	Crop	First season			Second season		
		WER_{legume}	WER_{orange}	WER_{total}	WER_{legume}	WER_{orange}	WER_{total}
Irrigation I	Faba bean	0.39	1.03	1.41	0.42	1.17	1.59
	Lupine	0.42	1.03	1.45	0.39	1.22	1.61
Irrigation II	Faba bean	0.39	1.04	1.43	0.44	1.23	1.67
	Lupine	0.43	1.14	1.57	0.42	1.25	1.67
Irrigation III	Faba bean	0.40	1.05	1.45	0.44	1.24	1.68
	Lupine	0.43	1.22	1.65	0.42	1.27	1.69

Irrigation I: 100% Nile water + 100% NPK fertilizer (control), Irrigation II: 50% fish farm effluent + 50% Nile water + 50% NPK fertilizer and Irrigation III: 100% fish farm effluent only.

Table 9: Land equivalent ratios for legume crops interplanted under orange under the studied irrigation treatments in both growing seasons

Irrigation treatments	Crop	First season			Second season		
		RY_{leg}	RY_{ora}	LER_{total}	RY_{leg}	RY_{ora}	LER_{total}
Irrigation I	Faba bean	0.38	1.03	1.41	0.38	1.12	1.50
	Lupine	0.40	1.11	1.51	0.39	1.09	1.48
Irrigation II	Faba bean	0.39	1.16	1.55	0.40	1.12	1.52
	Lupine	0.41	1.19	1.60	0.39	1.10	1.49
Irrigation III	Faba bean	0.39	1.18	1.57	0.41	1.19	1.60
	Lupine	0.42	1.22	1.64	0.41	1.16	1.57

Irrigation I: 100% Nile water + 100% NPK fertilizer (control), Irrigation II: 50% fish farm effluent + 50% Nile water + 50% NPK fertilizer and Irrigation III: 100% fish farm effluent only.

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