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Enhance productivity and net economic return by intercropping sunflower (*Helianthus annus* L.) with common beans (*Phaseolus vulgaris* L.) under drip irrigation

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ABSTRACT: Intercropping represents ways of maximizing water use efficiency (WUE) for higher yields per unit of irrigation water applied. The field experiments were carried out at the Experimental Farm of Arab El-Awammer Research, Station, Assiut during the two successive growing summer seasons of 2017 and 2018, to study the effect of different irrigation regimes (120, 100 and 80% ETo) and intercropping systems (sole sunflower, sole common bean and intercropping sunflower and common bean) for enhanced productivity and net economic return under drip irrigation. Irrigation with 120% ETo treatment gave higher yield and its compounds and oil % compared to 100 and 80% ETo treatments for sunflower and common bean. The highest stem, head diameters and 100-seed weight and seed and oil yield produced with sole sunflower as compared with intercropping of sunflower with common bean which had the lowest values in both growing seasons. The highest values of IWUE (0.723 and 0.704 kg/m^3) were obtained at intercropping under irrigation with 100% ETo. Values of land equivalent ratio of various intercropping systems were larger than one in the intercropping systems. Sunflower + common bean cropping system produced higher values of net return than sole sunflower and sole common bean. The highest net return (2709 US$/ha) were obtained when irrigated sunflower + common bean intercropping system with 120% ETo in the second season while the lowest net return (234 US$/ha) were obtained when irrigated sole sunflower with 80% ETo treatment in the first season.

Keywords: Sole; Intercropping; Drip irrigation; Water use efficiency.

1. INTRODUCTION

Water is the main element for sustainable and expansion in Egypt. Horizontal extension in agriculture is connected to the country's ability to supply, the water required for that expansion. Imbalance between high water demands and low sources symbolize, high water resources management problem in Egypt. The request on agricultural products and water resources were increased steeply everywhere. The application of fertilizers and water follows standardized exercise with little consideration of spatial, temporal, climatic, and crop-load variability, resulting in lost income and negative environmental impact. Drip irrigation technique was a currently hot research topic in water-saving irrigation technology, which could reduce the amount of irrigation water, improve yields and production efficiency comparing with the conventional irrigation pattern [1]. El-Koliey et al. [2] determination water requirements for sunflower crop in Assiut Governorate, Egypt under surface, sprinkler and drip irrigation systems. They were 1091.9, 727.2, and 642.4 mm, respectively and Hefzy et al. [3] found that, water requirements for sunflower crop were 679.9 mm under sprinkler irrigation systems, which gave the higher yield on newly reclaimed soils of Assiut Governorate, Egypt.

The transitional interval can be benefited between the summer season and the winter season in cultivation short-age crops such as planting of sunflower and common bean which could assist in planting four crops per year in the maize-wheat zone. Intercropping growing two crops (sunflower + common bean) simultaneously where two crops are cultivated in a row. Intercropping can assist in increasing crop productivity especially at smallholders of Egypt. However, there is an urgent need to research the pattern of sunflower sowing that can give high yield with mono-crops and the benefits of the cropping systems. The potential advantage of intercropping of sunflower with vegetable legumes just not used as a portion of human food and also, soil corrosion control, improving soil fertility by nitrogen fixation, organic matter content and increase net income with sunflower production [4-6].

Sunflower (*Helianthus annus* L.) is one of the most significant summer oils in the world. Sunflower has a great maximum of unsaturated fatty acids and low cholesterol [7]. Sunflower oil is the premium oil for its light color, moderate flavor, little saturated fat grade and the ability to resist high cooking heat [8, 9].

Common bean is one of the most important legume crops in the world. It could be sowing as for fresh pods or for dry seed. It is a significant source of vitamins, dietary fibers, proteins and minerals and calories for a lot of people in the world [10]. Water use efficiency was reacted significantly to the irrigation treatments of common bean [11]. In Egypt, seasonal water used of common bean diverse from 382 and 390 mm in 2008 and 2009, respectively. In the two seasons, the water use rate decreased with an increasing number of legumes per day [12].

The compatible intercropping systems boost light use efficiency, water-saving with the benefits of high yield than mono-crop [13]. Muhammad et al. [14] demonstrated that the sunflower + mung bean intercropping system gave the maximum net returns and grain yield per unit area comparison with mono-crop for sunflower and mung bean. Cropping system sunflower + peanut increased water use efficiency (kg/mm or cereal unit/mm) as compared to mono-crop [15]. The average was irrigation water applied of intercropping systems (peanut + sunflower) 4450, 3710 and 2980 m^3/ha under the irrigation treatments (120, 100 and 80%) in the two seasons, respectively [15]. Thence, the current research was concerned: To exploiting the transitional interval can be benefited between the summer season and the winter season in cultivation short-age crops such as planting of sunflower and common bean which could assist in planting four crops per year in the maize-wheat zone. To evaluate the influence of irrigation regimes under sole sunflower and intercropped with common bean on yield and its components, water use efficiency, intercropping indices and net economic return with strengthening the crop area through the intercropping systems.

2. MATERIALS AND METHODS

2.1. Site description

The field experiments were conducted at the Experimental Farm of Arab El-Awammer Research Station (latitude 27°03′ N, longitude 31°01′ E and 71 m above sea level), Agricultural Research Center

(ARC), Assiut, Egypt. The climatic data of the experimental area during the two growing seasons (2017 and 2018) are presented in Table 1.

The experiments were conducted in sandy calcareous soil consisting of sandy 89.9%, silt 7.1% and clay 3%. The main chemical characteristics of soil are summarized as follows: pH 8.37, $CaCO_3$ (%) 35.18, EC 0.35 dSm^{-1}, total nitrogen (%) 0.003, available phosphorus 8.31 ppm and organic matter 0.19%. The preceding crop was maize in both seasons.

Table 1. Average monthly meteorological data of Assiut weather station during the two growth.

Parameter / Month	Temperature (C°)		Relative humidity %	Wind speed km/h	Sunshine hours	ET_o mm/day
	Max	Min				
			Season 2017			
August	37.8	24.6	38.8	17.6	11.9	10.50
September	35.3	20.9	44.6	20.7	10.8	9.50
October	30.3	16.5	47	17.2	10.0	6.94
November	25.1	10.9	54.6	15.2	9.4	4.75
			Season 2018			
August	37.6	24.3	40.7	19.8	11.9	10.81
September	35.5	22	46.2	20.5	10.8	9.43
October	32.6	18.9	46.5	18.1	10.0	7.58
November	26.5	13.1	53.8	14.7	9.4	4.93

2.2. Experimental design and treatments

The experimental layout was a split-plot in a randomized complete block design (RCBD) with three replications. Irrigation regimes were arranged in the main plots, intercropping systems treatments were assigned to sub-plots.

Irrigation regimes (IR):

1: Irrigation with amounts of water equal to 120% ETo.

2: Irrigation with amounts of water equal to 100% ETo.

3: Irrigation with amounts of water equal to 80% ETo.

Intercropping systems (IS):

1: Sole sunflower (S).

2: Sole common bean (C).

3: Sunflower + common bean.

2.3. Crop production

Sole sunflowers seeds were drilled in one side of ridge (60 cm width), with one plants/hill and 20 cm between hills. Sole common bean seeds were drilled in one side of ridge (60 cm width) spaced at 10cm between hills. Sunflower (100%) + common bean (100%) intercrop: sunflower was sown in one side of ridge, while common bean was sown in another side of the same ridge. The plot size was 15 m^2. Each plot consisted of ten rows of 3 m length, and 0.5 m width. sunflower (*Helianthus annus* L.) Giza 102 cultivar and common bean (*Phaseolus vulgaris* L.) Nebraska cultivar. Sunflower and common bean were sown on 25th and 26th of August 2017 and 2018. Sunflower crop was harvested on 15th and 17th of November 2017 and 2018 seasons. Common bean crop was harvested on 25th and 27th of November 2017 and 2018 seasons. Calcium super phosphate (15.5% P_2O_5) at rate of 360 kg ha and potassium sulfate (48.0% K_2O) at rate of 119 kg per ha were applied during soil preparation in the two seasons for all crops. Mineral nitrogen fertilizer for sole sunflower and intercropped at rate of 108 kg N/ha (100% recommended), of ammonium nitrate, 33.5% N". Mineral N fertilizer of common bean was added at rate of 47.6 kg N/ha as ammonium nitrate, 33.5% N" under sole and intercropping.

2.4. Data collection and processing

Sunflower and common bean traits:

At harvest, ten guarded plants of sunflower from each experimental unit were taken randomly to determine i.e. plant height (cm), and the following traits were measured i.e. stem diameter (cm), head diameter (cm), and 100-seed weight (g). Seed, biological yields (ton/ha) were measured as all harvested plants from each experimental unit were weighted then threshed to assess seed yield. In addition, oil %, and oil yield/ha of sunflower. Finally, all plants from each experimental unit were harvested to determine the seed yield of common bean (ton/ha).

Oil percentage: To determine oil percentage (%): Dried mature of seeds were grounded into a very fine powder and oil% was determined using Soxhlet apparatus and Hexane ether according to A.O.A.C. [16].

2.5. Irrigation-water measurements and crop-water relations

Crop evapotranspiration (ETc): - [17]

$$ET_c = ET_0 \times Kc$$

Where:

ETc = Crop evapotranspiration.

ET_0 = Reference evapotranspiration. CROPWAT model (version 8)

Kc = Crop coefficient for mean crop (sunflower), from FAO paper 56.

2.6. Applied irrigation water

The amounts of actual irrigation water applied under each irrigation treatment were determined using the following equation [18]:

$$I.Ra = \frac{ETc + Lf}{Er}$$

Where:

I.Ra = total actual irrigation water applied mm/ interval.

ETc = Crop evapotranspiration

Lf = leaching factor 10 %.

Er = irrigation system efficiency.

2.7. Intercropping indices

2.7.1. Land equivalent ratio (LER)

Land equivalent ratio (LER) which verifies the effective ability of intercropping for using the resources of the environment compared to sole cropping as indicated by Willey and Osiru [19]. The LER values were calculated as: LER = (LER_s + LER_c), where $LER_s = YI_s/Y_s$ and $LER_c = YI_c/Y_c$, where Y_S and Y_C are the yields of sunflower and common bean as sole while YI_s and YI_c are the yields of sunflower and common bean as intercrops, respectively.

$$Yield \quad proportion \quad of \quad sunflower \quad = \frac{LER \;\; Sunflower}{LER}$$

2.7.2. Yield proportion [20]

$$Yield \quad proportion \; of \;\; common \, bean \; = \frac{LER \; Common \; bean}{LER}$$

2.7.3. Relative crowding coefficient (RCC or k)

The relative crowding coefficient (RCC or k) is the measure of the relative dominance of one crop/types over the other in an intercropping or mixed culture [21]. The association of 'a' and 'b' and vice versa, the coefficient is given as:

$$K_{sc} \;\; = \frac{Y_{sc}}{Y_{ss} - Y_{sc}} \times \frac{Z_{cs}}{Z_{sc}}$$

$$K_{cs} \;\; = \frac{Y_{cs}}{Y_{cc} - Y_{cs}} \times \frac{Z_{sc}}{Z_{cs}}$$

Where, K_{sc} and K_{cs} are the relative crowding coefficient of crop 's' and 'c' intercropped with crop 'c'and 's', Y_{ab} and Y_{ba} are the yield per unit area of crop 's' and 'c' intercropped with crop 'c' and 's' (expressed over the area occupied by both crops), Y_{ss} and Y_{cc} are the yield per unit area of the sole crop 's' and 'c', Z_{ab} and Z_{ba} are the proportion of intercropped area initially allocated to crop 's' and 'c', respectively. It has further been suggested that K_{sc} X K_{cs} = K. If the product of the coefficients of component crops (K) is greater than, equal to or less than unity, it indicates there is 'yield advantage', 'no effect' or 'yield disadvantage' for intercropping, respectively.

2.7.4. Aggressivity

Aggressivity (A) was used to determine the competitive relationship between two crops in a mixture as indicated by [22]. The aggressivity was calculated as: $A_s = (YI_s/Y_s \text{ x } ZI_s) – (YI_c/Y_c \text{ x } ZI_c)$, and $A_c = (YI_c/Y_c \text{ x } ZI_c) – (YI_s/Y_s \text{ x } ZI_s)$.

2.7.5. Competitive ratio

Competitive ratio (CR) gives more desirable competitiveness for the crops. The CR represents simply the ratio of individual LERs of the two component crops and considers the proportion of the crops on which they are initially sown as indicated by Willey and Rao [23]. The CR index was calculated using the following formula:

CRs = (LERs / LERc) (Zlc / ZI_s) while $CR_c = (LER_c / LER_s) (ZI_s / ZI_c)$.

2.7.6. Actual yield loss

Actual yield loss (AYL) which gave more accurate information about the competition than the other indices between components of intercropping system. The AYL is the proportionate yield loss of intercrops compared to sole crop as indicated by Banik [24]. The AYL was calculated as: $AYL= AYL_s + AYL_c$, where

$AYL_s = \{(YI_s/XI_s) / (Y_s /X_s)\} - 1$ and $AYL_c = \{(YI_c/XI_c) / (Y_c/X_c)\} -1$, where X is the sown proportion of intercrop sunflower and common bean.

2.7.7. Intercropping advantage (IA)

Intercropping advantage (IA) was calculated using the following formula[25]:

$IA= IA_S+ IA_c$

$IA_s= AYL_s \times P_s$

$IA_c= AYL_c \times P_c$

Where, P_s and P_c are the commercial (price) value of crop ‘s’ and ‘c’, respectively.

2.8. Irrigation water use efficiency (IWUE)

The irrigation water use efficiency (IWUE) values were calculated as follows [26]:

$$IWUE = \frac{Grain\ \ or\ Seed\ \ yield\ \ (Kg\ /\ ha.)}{Irrigation\ \ water\ \ applied\ \ (m^3\ /\ ha.)}$$

2.9. Economic evaluation:

Gross and net returns. Total return from each treatment was calculated in (US$) were used: 311and 1577 US$/ton for sunflower and common bean, respectively, as an average for the two seasons [27].

Net returns = Gross returns – Total variable costs

2.10. Statistical analysis:

Data were analyzed by SAS program version 9.2 [28] software package. Means were compared by Least Significant Difference (LSD) at 5% level of significant [29].

3. RESULTS

3.1. Effect of irrigation regimes on plant height, stem, head diameters and 100-seed weight of sunflower

The data presented in Table 2 show the effect of irrigation regimes on plant height (cm), stem diameter (cm), head diameter (cm) and 100 seeds weight (g). The results show that the effect of irrigation regime on plant height (cm) was no significant in both seasons, but stem diameter (cm), head diameter (cm) and 100 seeds weight (g) were significant in both seasons.

3.2. Effect of irrigation regimes on seed and biological yields of sunflower and seed yield of common yield

The results in Table 2 show that, the effect of irrigation regimes on seed and biological yield of sunflower were significant on both seasons. Irrigation at 120% ETo give the highest seed (3.34 and 3.38 ton/ha) and biological yield (8.4 and 8.7 ton/ha) of sunflower crop, compared to 100 and 80% ETo in the first and second seasons, respectively. Irrigated plants with 120% ETo gave significant higher (1.97 and 2.04 ton/ha) seed yield of common bean in first and second seasons, respectively compared to irrigated with 100 and 80% ETo (1.72 and 1.33 ton/ha respectively).

3.3. Effect of irrigation regimes on oil % and oil yield of sunflower

The data in Table 2 show the oil percentage and oil yield of sunflower. The results show that the effects of irrigation regimes on percentage and oil yield were significant in first and second seasons. The oil yield was significantly increased at 120% ETo compared to the 100% and 80% ETo.

3.4. Effect of intercropping systems on plant height,stem, head diameters and 100-seed weight of sunflower

The result presented in Table 3 the effect of intercropping on plant height and it was showed to be non-significant. sole sunflower had the tallest plants (171.57 cm and 153.19) in the first and second seasons, respectively. The minimum height of 167.13 and 149.23 cm in case of intercropping of sunflower with common bean in the first and second seasons, respectively. However, these differences could not reach the level of significance. Intercropping systems had a significant influence, on the head and stem diameter in the two seasons.The highest stem, head diameters and 100-seed weight produced with sole sunflower as compared with intercropping of sunflower + common bean which had the lowest values of stem, head diameters and 100-seed weight in both growing seasons.

3.5. Effect of intercropping systems on seed and biological yields of sunflower and seed yield of common yield

The results demonstrated in Table 3 clearly revealed that, the intercropping systems affected significantly the seed and biological yields of sunflower and seed yield of common yield in both seasons. The data demonstrated that the average yields obtained were 3.15and 3.18 ton/ha in 2017and 2018 seasons for the sole sunflower, respectively. The corresponding means in 2017 and 2018 were 2.82 and 2.88 ton/ha in the same order. Sole sunflower produced the heavier weight of biological yield as compared with intercropping sunflower and common bean in both seasons. The maximum seed yield 1.97 and 2.01 ton ha^{-1} was found in sole common bean in 2017 and 2018 season, respectively while the minimum seed yield 1.37 and 1.39 ton ha^{-1} was obtained in case of intercropping sunflower with common bean in 2017 and 2018 season, respectively.

3.6. Effect of intercropping systems on oil % and oil yield of sunflower

Data in Table 3 show that, oil % of sunflower was not responded significantly to intercropping sunflower with common bean either in both seasons. However, the results revealed that the intercropping system increased seed oil content as compared with sole planting. Oil yield was reacted significantly to intercropping sunflower with common bean in both seasons. Intercropping sunflower with common bean decreased oil yield compared with sole sunflower as average in both seasons.

3.7. Effect of interaction between irrigation regimes and intercropping systems of sunflower and common bean plants

The results prove in Figure 1 showed that, the effect of interaction between irrigation regimes and intercropping systems (sunflower and common bean) was not significant for all studied characters except seed yield of sunflower in the second season and seed yield of common bean in both seasons. The highest seed yield of sunflower (3.54 ton/ha) in the second season was obtained with sole sunflower plants with irrigation with 120% ETo. Whereas, the highest mean value of seed yield of common bean (Figure 2) was obtained with sole common bean under 120% ETo (2.30 and 2.42 ton/ha) in the first and second seasons, respectively.

Table 2. Effect of irrigation regimes on seed yield and yield components, oil %, oil yield of sunflower and yield common bean.

Irrigation regimes	Plant height (cm)	Stem diameter (cm)	Head diameter (cm)	100-seed weight (g)	Seed yield (ton/ha)	Biological yield (ton/ha)	Oil %	Oil yield	Yield of common bean (ton/ha)
				Season 2017					
120% ETo	180.00	1.11	14.79	52.02	3.33	8.4159	41.45	1.38	1.961
100% ETo	166.67	1.06	13.47	48.17	3.07	7.17421	41.93	1.29	1.716
80% ETo	161.39	0.91	10.28	41.02	2.56	5.23414	39.86	1.02	1.334
LSD 0.05	NS	0.10	0.55	5.42	0.06	0.17	0.62	0.04	0.06
				Season 2018					
120% ETo	160.71	1.32	14.51	51.43	3.38	8.71	41.81	1.41	2.04
100% ETo	148.81	1.06	13.74	46.53	3.11	7.21	41.99	1.31	1.73
80% ETo	144.10	0.77	10.18	40.65	2.59	5.14	40.11	1.04	1.33
LSD 0.05 (IR)	NS	0.10	0.23	3.14	0.09	0.22	0.88	0.06	0.05

NS means not significant.

Table 3. Effect of intercropping systems on seed yield and yield components, oil %, oil yield of sunflower and yield common bean.

Intercropping system	Plant height (cm)	Stem diameter (cm)	Head diameter (cm)	100-seed weight (g)	Seed yield (ton/ha)	Biological yield (ton/ha)	Oil %	Oil yield	Yield of common bean (ton/ha)
				Season 2017					
Sole	171.57	1.08	13.37	49.62	3.15	7.33	41.16	1.30	1.97
Intercrop	167.13	0.98	12.32	44.51	2.82	6.55	41.00	1.16	1.37
F test	NS	*	**	**	**	**	NS	**	**
IR× IS	NS	NS	NS	NS	NS	NS	NS	NS	0.31
				Season 2018					
Sole	153.19	1.08	13.07	47.77	3.18	7.41	41.32	1.31	2.01
Intercrop	149.23	1.02	12.54	44.63	2.88	6.63	41.88	1.19	1.39
F test (IS)	NS	*	**	*	**	**	NS	**	**
IR× IS	NS	NS	NS	NS	0.56	NS	NS	NS	0.58

NS, * and ** means not significant, significant at 0.05 and 0.01 probability, respectively.

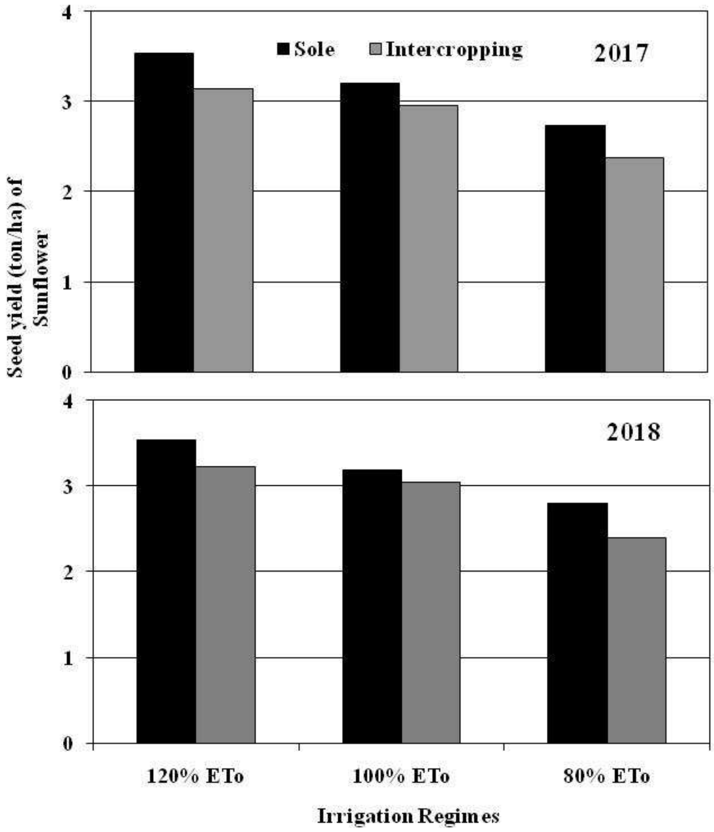

Figure 1. Effect of irrigation regimes, intercropping systems and their interaction on sunflower yield, 2017 and 2018 seasons.

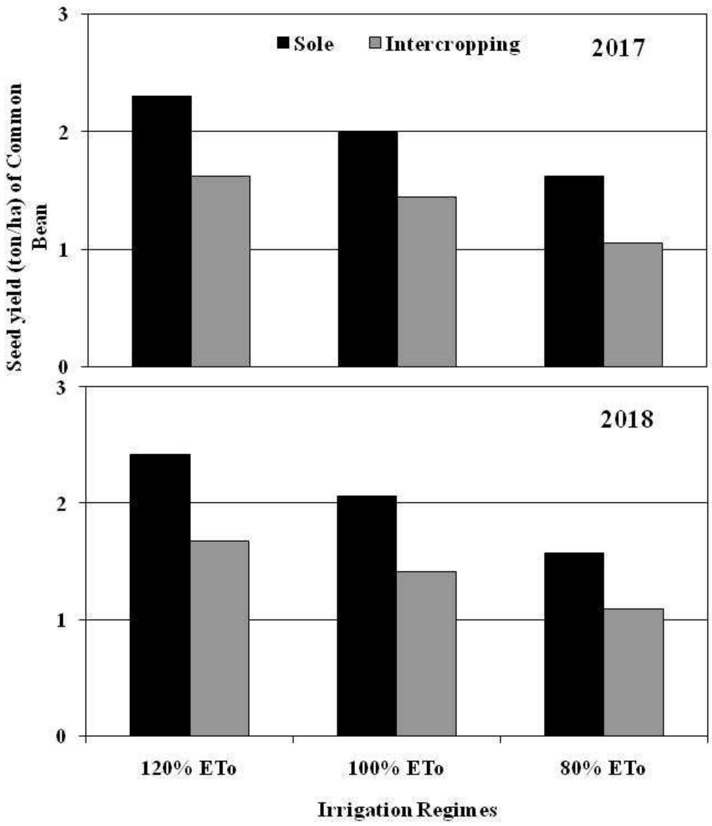

Figure 2. Effect of irrigation regimes, intercropping systems and their interaction on common bean yield, 2017 and 2018 seasons.

3.8. Intercropping indices

3.8.1. Land equivalent ratio (LER)

Presented data in Table 4 detect that values of land equivalent ratio of various intercropping systems were larger than one in the intercropping systems. The partial land equivalent rati values of sunflower were upper than the partial LER of common bean in both seasons. The partial land equivalent ratio of sunflower and common bean in 80% ETo was lower compared to the other treatments in both seasons.

3.8.2. Yield proportion

The data exhibited in Table 4 show that, the yield proportion of sunflower was higher in 80% ETo as compared to 100 and 120% ETo in the 1st season while it was higher in 100% ETo as compared to 80 and 120% ETo in the 2nd season. The yield proportion of common bean was higher in 100% and 120% ETo as compared to 80% ETo in the 1st season while it was higher in 80% ETo as compared to 100 and 120% ETo in the 2nd season. The yield proportion of sunflower was higher than the yield proportion of common bean.

3.8.3. Relative crowding coefficient (k)

The relative crowding coefficient exhibited in Table 4. The relative crowding coefficient in 100% ETo revealed that yield benefit was higher as compared to the other treatments in sunflower and common bean in both seasons. The relative crowding coefficient of sunflower and cropping systems was greater than one in the first and second seasons. The relative crowding coefficient of sunflower was dominant while the common bean was dominated.

3.8.4. Aggressivity (A)

The presented data in Table 4 show that, the aggressivity value was higher in sunflower compare with the common bean in 2017 and 2018. The sunflower was the predominant species and a positive value in the cropping system while the common bean was a negative value in both seasons.

3.8.5. Competitive ratio (CR)

The competitive ratio is else a trend to know the extent of competition between the sole cropping and intercropped cropping. The obtained data in Table 4 show that, the competitive ratio value of sunflower was higher compare with the common bean in both seasons.

3.8.6. Actual yield loss (AYL)

Data in Table 4 illustrate that, the values of actual yield loss sunflower and common bean were less in 100% ETo as compared to 120% and 80% ETo except in the 2nd season of common bean. The partial actual yield loss index for common bean it was higher than the sunflower.

3.8.7. Intercropping advantage (IA)

Illustrated data in Table 4 show that the intercropping advantage values were higher in the sunflower than the common bean in both seasons (2017 and 2018). The intercropping advantage of sunflower + common bean was higher in 100% ETo than 120% and 80% ETo except in the 2nd season of common bean.

Table 4. Effect of irrigation regimes and intercropping systems on land equivalent ratio, yield proportion, relative crowding, aggressivity, competitive ratio, actual yield loss index and intercropping advantage of sunflower based common bean.

Characters / Intercropping systems / Irrigation regimes	Relative yield		LER-Total	Yield proportion (YP)		Relative crowding (k)		K	Aggressivity (A)	
	Sunflower	Common bean		Sunflower	Common bean	Sunflower	Common bean		Sunflower	Common bean
Season 2017										
120% ETo	0.89	0.70	1.59	0.56	0.44	8.00	2.38	19.03	0.18	-0.18
100% ETo	0.92	0.72	1.65	0.56	0.44	12.14	2.61	31.63	0.20	-0.20
80% ETo	0.87	0.65	1.52	0.57	0.43	6.88	1.87	12.84	0.22	-0.22
Season 2018										
120% ETo	0.91	0.69	1.60	1.73	0.44	9.97	2.23	22.21	0.22	-0.22
100% ETo	0.95	0.68	1.64	1.95	0.37	20.10	2.15	43.25	0.27	-0.27
80% ETo	0.85	0.69	1.55	1.52	0.54	5.84	2.26	13.19	0.16	-0.16

Table 4. Continued.

Characters / Intercropping systems / Irrigation regimes	Competitive ratio (CR)		Actual yield loss index (AYL)		AYL	Intercropping advantage (IA)		IA
	Sunflower	Common bean	Sunflower	Common bean		Sunflower	Common bean	
Season 2017								
120% ETo	1.26	0.79	-0.11	-0.30	-0.41	-33.35	-466.57	-499.92
100% ETo	1.28	0.78	-0.08	-0.28	-0.35	-22.84	-437.29	-460.12
80% ETo	1.34	0.75	-0.13	-0.35	-0.48	-38.06	-550.25	-588.31
Season 2018								
120% ETo	1.32	0.76	-0.09	-0.31	-0.40	-27.36	-488.54	-515.89
100% ETo	1.40	0.72	-0.05	-0.32	-0.36	-14.22	-500.29	-514.50
80% ETo	1.23	0.81	-0.15	-0.31	-0.45	-43.88	-483.72	-527.60

3.9. Irrigation water use efficiency (IWUE) kg/m^3

The results of IWUE (kg/m^3) as affected by irrigation regimes and intercropping for sunflower with common bean plants were in Figure 3.

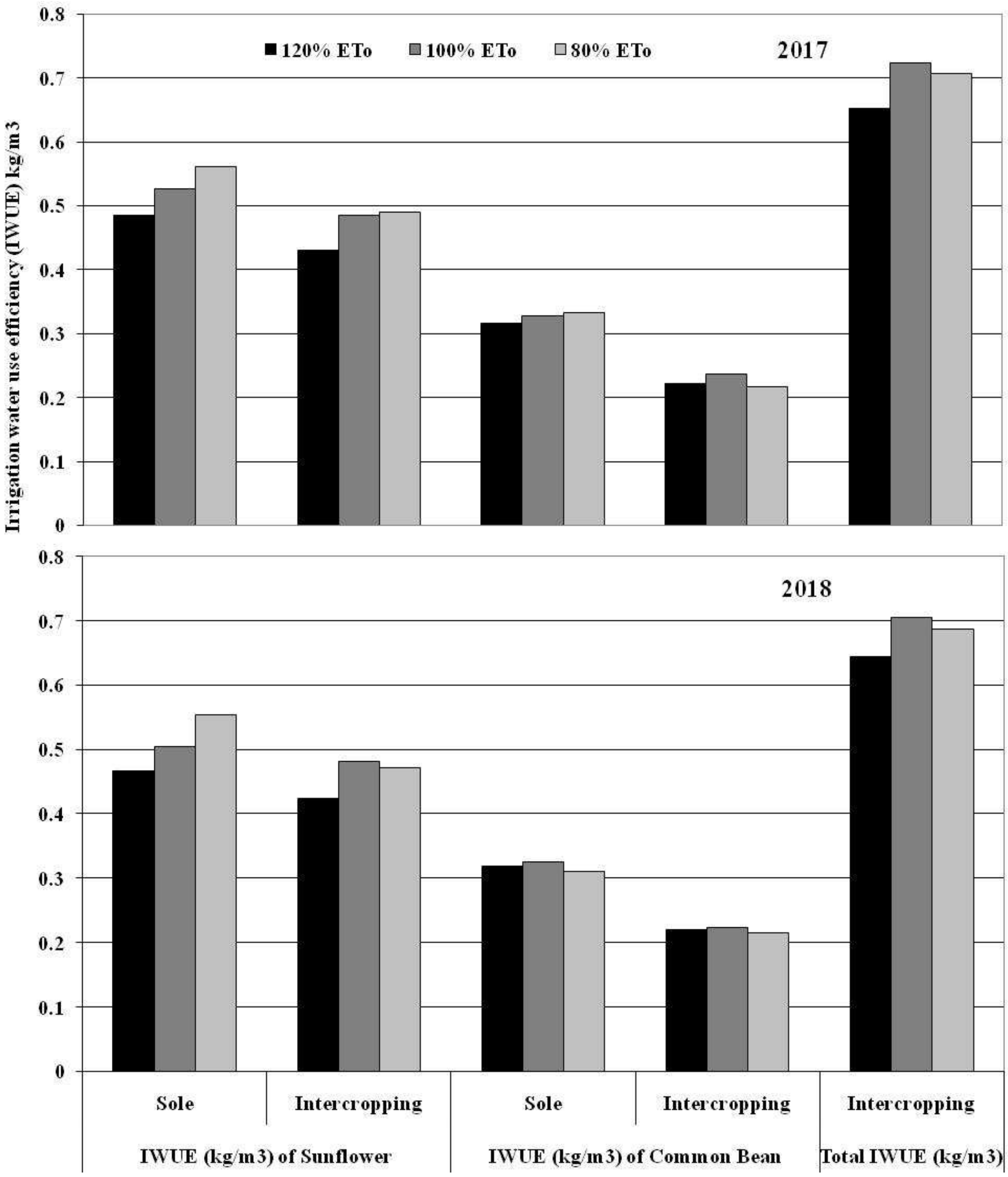

Figure 3. Effect of irrigation regimes, intercropping systems and their interaction on IWUE (kg/m^3), 2017 and 2018 seasons.

The irrigation water applied for sunflower and common bean plants in season 2017 were 7285.7, 6071.4 and 4857.1 m^3/ha under 120%, 100% and 80% ETo, respectively and were 7582.3, 6318.6 and 5054.8 m^3/ha in season 2018, respectively. IWUE were insignificant decreased when plants were irrigated with 120% and 100% ETo compared to 80% ETo in the first season but significant in the second season. The result shows that IWUE rates were increase significant for sunflower sole (0.526 and 0.508kg/m^3) compared to sunflower intercropped with common bean (0.469 and 0.459 kg/m^3) in the first and second seasons, also the rates of IWUE for common bean sole (0.326 and 0.318 kg/m^3) were increase significant compared to sunflower intercropped with sunflower (0.225 and 0.219 kg/m^3) in the first and second seasons. The highest values of

IWUE (0.723 and 0.704 kg/m^3) were obtained at intercropping under irrigation with 100 % ETo, in the first and second seasons, respectively.

3.10. Economic evaluation

Gross and net returns (US$/ha)

Exhibited data in Table 5 sunflower + common bean cropping system produced higher values of net return than sole sunflower and sole common bean. The highest net return (2709 US$/ha) were obtained when irrigated Sunflower + common bean intercropping system with 120% ETo in the second season while the lowest net return (234 US$/ha) were obtained when irrigated sole sunflower with 80% ETo treatment in the first season.

Table 5. Effect of irrigation regimes, intercropping systems and their interaction on gross and net returns US$/ha.

Characters	Gross returns			Net returns		
Intercropping systems / Irrigation regimes	Sole Sunflower	Sole Common bean	System (S+IC)	Sole Sunflower	Sole Common bean	System (S+IC)
Season 2017						
120% ETo	1098	3630	3532	483	2330	2612
100% ETo	994	3141	3189	379	1841	2269
80% ETo	849	2548	2400	234	1248	1480
Season 2018						
120% ETo	1100	3810	3629	485	2510	2709
100% ETo	992	3250	3164	377	1950	2244
80% ETo	870	2472	2457	255	1172	1537

4. DISCUSSION

Improving the efficiency of irrigation water use is a primary goal in agricultural management under the conditions of limited water sources in Egypt and the use of intercropping system is one of the ways to raise the efficiency of irrigation water use. Therefore, the experiments were done to study the effect of intercropping system and irrigation regimes on the productivity of sunflower and common bean crops under drip irrigation system. Irrigation with 120% ETo gave higher plant height (cm), stem diameter (cm), head diameter (cm), 100 seeds weight (g), seed yield and biological yield compared 100% and 80 ETo treatments. These results may be indicate to the effect of increasing available soil moisture in the root zone that support plants to absorb more water and increasing the activity of photosynthesis , excess cells division and cells magnification causing cularization and cortex development [30]. However, plants that faced from water deficit in the root zone have low roots system and weak narrow growth, which in turn reduced both vegetative growth and yield. Similar results were obtained by many researchers [3, 11-15, 31, 33-36]. Maybe the equal plant height in each treatment is all plants have a similar chance for light in intercropping. The results are in general accordance with those obtained by Ahmad [37], Sultana [38], Muhammad et al. [14] and El-Mehy et al. [15]. This result may be due to resources competition of (nutrients, water and area) in the canopy on the land area. The result is in line with Khan and Akmal [39]. The result is in contrast with Abd El-Zaher et al. [40]. Increasing in oil yield was due to an increase in seeds yield. The observed increase in seed oil content under wet level (120% ETo) may be referred to the accumulation of fat during the development of storage organs (seeds) which resulted from transformation of high sugar contents to the fatty acids [30]. These findings cope with Kramer [41] who reported that water stress caused a considerable decrease in organic compounds translocation in the plants. Intercropping sunflower with common bean decreased oil yield compared with sole sunflower as average in both seasons. These results are in agreement with those obtained by others [15, 40, 42, 43]. Whereas, Kandel et al. [44] exhibited that sunflower oil content was not affected by intercropped pulses. The Land equivalent ratio showed the yield advantage over sole cropping due to the best exploitation of ecological resources for growth in the two growing seasons. Here too, it can be deduced that the actual output was higher than the expected output. This could be ascribed to the low competitiveness of common bean compared with sunflower. It seems that sunflower was dominant for has higher values of the relative crowding coefficient than the common bean in both seasons indicating the most competitive impact of sunflower on common bean. There is higher variability in the competitiveness of sunflower compare with the common bean. The major the numeral value, the higher was the variation in competitiveness and the higher the variations among the actual return and the expected return. The values of the competitive ratio of sunflower showed that it was most competitive with the common bean in both seasons. Therefore, the yield benefit was more and the predominant type for sunflower. Maybe sunflower was more competitive than the common bean. The intercropping advantage is an index of the economic viability of cropping systems.as reported by other studies [45-54].The highest values of irrigation water use efficiency (IWUE) kg/m^3 were obtained at intercropping system under irrigation with 100 % ETo, this mean we can be increasing IWUE when used intercropping system compared with sole crop at same water quantity. These obtained trends are in general agreement [12-15, 55]. Increasing applied irrigation water led to increase gross and net returns. These results are in harmony with other studies [15, 39, 41].

5. CONCLUSION

Irrigation water applied for intercropping sunflower and common bean were 7434 m^3/ha under drip irrigation in the arid ecosystem in sandy calcuras soil that gaves the highest yield. Intercropping systems increasing soil and water used efficiency. Values of land equivalent ratio of various intercropping systems were larger than one in the intercropping systems. Sunflower + common bean cropping system produced higher values of net return than sole sunflower and sole common bean. The highest net return (2709 US$/ha) were obtained when irrigated sunflower + common bean intercropping system with 120% ETo in the second season while the lowest net return (234 US$/ha) were obtained when irrigated sole sunflower with 80% ETo treatment in the first season.

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