Maximizing Land and Water Productivity by Intercropping Sunflower with Peanut under Sprinkler Irrigation

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ABSTRACT

Effective intercropping pattern, use of highly efficient irrigation system and proper irrigation scheduling are one of the current challenges in agriculture sector for saving water, maximizing crop production and economic benefits. Thus, a two-year field experiment was conducted at Ismailia Research Station (30o 35' N latitude, 30o 26' E longitude, 20.0m above MSL), Egypt during the two growing seasons of 2016 and 2017 to study the effect of three irrigation treatments (1.2, 1.0 and 0.8 ETo calculated by the BIS model) and five peanut/sunflower intercropping patterns ((P1 = 100% peanut + 25 % sunflower), (P2 = 100% peanut + 33% sunflower), (P3 = 100% peanut + 50% sunflower), (P4 = sole peanut), and (P5 = sole sunflower)) on yield and its components of both crops, applied irrigation water, consumptive use, land and water productivity and net income. The experimental layout was designed in strip plot with three replicates. The results indicated that light intensity percentage significantly decreased with the 1.2 ETo treatment. The highest values of growth and yield of pod, seed and oil of peanut and sunflower were detected with the application of 1.2 ETo. Intercropping sunflower with peanut significantly reduced the yield of both crops in both seasons. However, intercropping sunflower at low density (P1) recorded the maximum values for yield and yield components of peanut, compared to the P2 and P3 treatments. The highest values of applied water (451 and 439mm) and consumptive use (403 and 415mm) were obtained in the first and second growing seasons, respectively when P3 (100% P + 50% S) was irrigated with 1.2 of ETo. Intercropping sunflower with peanut increased water use efficiency (kg/mm or cereal unit/mm) compared with sole crop. The average of water equivalent ratio was highest (1.255) produced with P3 under 1.0 ETo treatment, as average of both growing seasons. The maximum value of land equivalent ratio (1.569) and net income (L.E. 22589/ha) were recorded with P3 intercropping pattern irrigated with 1.2 of ETo treatment, on average basis of both growing seasons. Sunflower was the dominant component for the all intercropping systems, while peanut was the dominated crop. Thus, we recommend the implementation of P3 intercropping system, namely 100% peanut + 50% sunflower irrigated with 1.2 of ETo to increase land productivity in sandy soil under sprinkler irrigation or with 1.0 of ETo to save on the applied irrigation water, with yield lose were low. Under severe drought conditions, we recommended application of 0.8 ETo.

Keywords: Sprinkler irrigation, BIS model, Water productivity, Intercropping patterns, Peanut, Sunflower.

INTRODUCTION

The agricultural production and development of arid and semi-arid regions rely mainly on irrigation. Egypt depends on irrigated agriculture in more than 95% of its agricultural area (Abou Zeid, 2002). Egypt water policy mainly depends on the expansion of modern irrigation techniques in the newly reclaimed desert lands and improvement irrigation practices in the old lands of Delta and Valley. The application of modern irrigation techniques, such as drip, bubbler and sprinkler to increase irrigation efficiency is one of the measures utilized for competent use of water (NWRP, 2002).

The current challenge in agriculture is to produce more yields by utilizing less water, especially in regions with limited land and water resources (Fereres and Soriano, 2007 and Zhang *et al.,* 2012). Efficient irrigation systems require the selection of an appropriate method for the crop growth, adequate monitoring of the irrigation system and of water delivery and appropriate application rates depending on the growth stage of the crop. Irrigation requirements differ depending on the locations, soil types and cultural practices (Bilalis *et. al.,* 2009; Abd El-halim *et. al.*,2016).

Severe drought stress has direct impact on photosynthetically active radiation, yield and its components compared to the optimum irrigation condition. Maximum crop production requires complete capture of incident solar radiation and can only be achieved with supporting sufficient levels of water and nutrients (Loomis and Connor, 2002). Plants irrigated at low water depletion of the total available soil water produced greater leaf area than plants irrigated at high levels of water depletion and therefore had greater intercepted photosynthetically active radiation (Langeroodi *et al.,* 2014; Adeboye *et al.,* 2016). Water stress and shading contribute to reduce legume component yield under intercropping (Lesoing and Francis, 1999). Seed yield and seed yield components (pod number per m^2, seed number per m^2 and individual seed weight) were significant declined by water stress (Haro *et al.,* 2008). Rowland *et al.* (2012) indicated

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that, yields of peanut were reduced by 26% and 10% in 2005 and 2006 season, respectively, in the lowest irrigation treatment (50% applied irrigation) compared with full irrigation (100% applied irrigation). Drought significantly changed total oil, linoleic and behenic fatty acids content, plant fresh weight, dry weight, pod yield per plant, number of seed per plant, number of pod per plant, 100 sun dried seed weight, and 100 sun dried pod weight (Asik and Yildiz, 2015). A significant reduction in growth characters, yield and its attributes of sunflower under deficit irrigation was recorded compared with full irrigation (Nezami *et al.*, 2008; Gholinezhad *et al.*, 2009; Langeroodi *et al.*, 2014; El-Dakrourry, 2015).

The proper intercropping pattern increase light use efficiency (Awal *et al.*, 2006; Jiao *et al.*, 2008), achieve water saving (Gaballah and Ouda, 2008; Zhang *et al.*, 2012; Feng *et al.*, 2016; Metwally *et al.*, 2017), with the advantage of high and stable yield than sole crop. Yield is taken as primary consideration in the assessment of the potential of intercropping practices. Sunflower and finger millet as intercrop reduced the pod yield of peanut (Sankaran and Kuppuswamy, 1992). Kandel *et al.* (1996) showed that sunflower oil content was not influenced by intercropped legumes. Intercropping sunflower with peanut significantly reduced pod and seed yield of the two crops compared to sole pattern. Peanut/sunflower intercropping pattern at low density of sunflower gave the highest values of yield and yield components of peanut. However, raising sunflower plant density recorded the highest value of sunflower seed yield/fed and produced higher land equivalent ratio (LER) and net income compared to peanut as sole crop. Sunflower was the dominant component for the all intercropping systems, while peanut was the dominated crop (El-Sawy *et al.*, 2006; Nassar *et al.*, 2008; and Abd El-Zaher *et al.*, 2009).

Similarly, intercropping sunflower at high population density with soybean achieved the highest seed and oil yields per ha of sunflower compared to low population and vice versa true for head diameter, 100-seed weight, and yield per plant (Abdel-Wahab and El Manzlawy, 2016).

Peanut (*Arachis hypogaea* L.) and Sunflower (*Helianthus annus* L.) are two of the most important summer oil in the world. Peanut seeds contain high oil (45%), 26-28 % protein, 20% carbohydrates and 5 % fiber (Fageria *et al.*, 1997). Sunflower has high content of unsaturated fatty acids and lack of cholesterol (Casadebaig *et al.*, 2008). Intercropping sunflower is a trail to introduce oil crops in peanut area to increase oil production (El-Sawy *et al.*, 2006). This study was initiated to assess the effect of irrigation treatments under different peanut/sunflower intercropping patterns on yield and yield components of peanut and sunflower, land equivalent ratio, water use efficiency and net return.

MATERIALS AND METHODS

Experimental site description:

A field experiment was conducted at Ismailia Experimental Research station (30^o 35' N latitude, 30^o 26' E longitude, 20.0m above mean sea level), Ismailia Governorate, Egypt, during 2016 and 2017 summer growing seasons. The experimental site represents the newly reclaimed sandy soil of East of Nile Delta. The climate is cool in winter with a mean air temperature of about 13.0°C. Summer is hot with no rain, and with mean air temperatures that varies from 28.0 to 30.55°C during June, July, and August, as well as mean wind speed of 2.93 m/hr during the daytime for these months. Average monthly weather data at the experimental site during the growing seasons for the period from 2011 to 2015 are presented in (Table 1). These data were used to calculate monthly reference evapotranspiration (ETo) values in the experimental site according to the Basic Irrigation Scheduling model (BISm) as described by Snyder *et al.* (2004).

Samples from the upper 60 cm soil surface were collected at 15 cm interval to determine the main soil physical, chemical properties, and soil-moisture constants. The obtained values are presented in (Table 2). The available macronutrient values of N, P, and K were 16.50, 5.20, and 62.20 mg kg^{-1}, respectively.

Table 1. Mean monthly values of solar radiation (Srad), maximum temperature (Tmax), minimum temperature (Tmin), wind speed (Ws), dew point (Td), and reference evapotranspiration (ETo) at the experimental site from 2011 to 2015

Month	Srad (MJ m^{-2} day^{-1})	Tmax (°C)	Tmin (°C)	Ws (m s^{-1})	Td (°C)	ETo (mm day^{-1})
May	27.73	33.50	17.84	3.06	20.53	6.48
June	28.05	36.31	20.19	3.08	21.91	7.15
July	28.89	38.03	21.90	2.89	22.92	7.29
August	25.10	38.14	22.95	2.79	22.25	6.67
September	23.03	34.84	21.17	2.82	20.47	5.25

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, %	68.55	73.55	74.10	77.15
Fine sand, %	25.78	22.15	22.20	18.95
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	12.70	11.15	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)	7.64	7.58	7.60	7.41
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

Accordingly, the soil was characterized by low fertility and insufficient available water for plant growth. The electrical conductivity (EC) of irrigation water was 0.52 dS m^{-1}, and pH value was 7.55. Chemical and physical soil analyses were conducted by the standard methods as described by Tan (1996).

Experimental design and tested treatments.

A strip plot design with three replicates was used to conduct the field experiment. The horizontal plots (main plot) were devoted to the irrigation treatments (plot size was 576 m^2). The vertical plots (sub-plot) were assigned to the intercropping pattern treatments. Intercropping plot size was 38.4m^2 (8 ridges x 0.60m x 8m). The tested treatments were as follows:

Irrigation treatments (I).

I_1: Irrigation with amounts of water equal to 1.2 ETo.

I_2: Irrigation with amounts of water equal to 1.0 ETo.

I_3: Irrigation with amounts of water equal to 0.8 ETo.

Intercropping pattern treatments (P)

P_1: 100% peanut + 25 % sunflower (one row of peanut intercropped with sunflower at 20 cm apart alternated with three row of peanut left free).

P_2: 100% peanut + 33% sunflower (two row of peanut intercropped with sunflower at 30 cm apart alternated with two row of peanut left free).

P_3: 100% peanut + 50% sunflower (one row of peanut intercropped with sunflower at 20 cm apart alternated with one row of peanut left free).

P_4: 100% peanut (sole peanut, P).

P_5: 100% sunflower (sole sunflower, S).

Cultural practices.

Peanut (Giza 6 var.) and sunflower (Sakha 53 var.) seeds were cultivated on the 8th and 23rd of May 2016 and 2017. Sunflower crop was harvested on the 10th of August of both 2016 and 2017 seasons. Furthermore, peanut crop was harvested on the 24th of September of both 2016 and 2017 seasons. In all intercropping patterns and sole planting, peanut and sunflower were planting on ridges 60 cm apart, plants were thinned to one plant/hill. Nitrogen fertilizer (ammonium nitrate, 33.5% N) was added at the rate of 142.8 kg N/ha, potassium sulfate was added at the rate of 119 kg K_2O/ha, and 122 kg P_2O_5/ha of phosphoric acid (60%) were added.

Peanut and sunflower crops were cultivated under a sprinkler system in a total area (horizontal plot) of 576 m^2 (48 × 12 m) and an irrigation interval of three days. A solid-set sprinkler irrigation system with rotary RC 160 sprinklers of 0.94 to 1.30 m^3/hr discharge rate at 2.80 bars nozzle pressure was used to irrigate the crops. The sprinkler system consists of main PVC pipe line (160 mm diameter), sub main PVC pipe lines (110 mm diameter), and PVC lateral lines (50 mm diameter). The laterals were spaced at 12 X 12 meters apart. Application of the irrigation water treatments started from the fifth irrigation. All fertilizers were added through irrigation water (fertigation) using the differential pressure tank. Fertigation was done in 80% of irrigation time. Fertilizer doses were applied through after 11, 21, and 42 days from planting peanut and sunflower.

Plant measurements.

At 60 days from planting: Light intensity at the middle and bottom of the plant on five plants from each sub-plots of peanut and sunflower were measured by lux meter apparatus at mid–day and expressed as percentage from light intensity (100%) measured above the plants according to Pearce *et al.* (1996).

At harvest: Ten guarded plants were taken randomly from the middle of each sub-plot to measure growth characters and yield components, while yield of both crops were estimated from each sub-plot and then converted to yield/ha.

Peanut traits: plant height, number and weight of pods/plant, seed weight/plant, 100-pod weight, 100-seed weight, pod and oil yields/ha and oil %.

Sunflower traits: plant height, number of leaves/plant, head diameter and weight, weight of seeds/plant, 100-seed weight, seed and oil yields/ha and oil %.

To determine oil percentage (%): Dried mature of seeds were grounded into very fine powder and oil% was determined using Soxhelt apparatus and Hexane ether according to A.O.A.C. (1995).

Irrigation-water measurements and crop-water relations.

Distribution uniformity (DU).

The water distribution uniformity (DU) of the sprinkler system was measured in the field. The DU values were calculated by the equation developed by Merrim and Keller (1978) as follows:

$$DU = (Diq / D) \times 100$$

where:

DU = distribution uniformity (%).

Diq = average depth of water collected by cans from sprinklers at the low quarter of the field (cm).

D = average depth of water collected by cans from all sprinklers (cm).

Water consumptive use (WCU).

Crop water use was estimated by the method of soil moisture depletion according to Majumdar (2002) as follows:

$$WCU = \sum_{i=1}^{i-4} \frac{\theta 2 - \theta 1}{100} \times Bd \times d$$

where:

WCU = water consumptive use or actual evapotranspiration, ETa (mm).

i = number of soil layer.

θ2 = soil moisture content after irrigation, (%, by mass).

θ1 = soil moisture content just before irrigation, (%, by mass).

Bd = soil bulk density, (g/cm^3)

d = depth of soil layer, (mm).

Applied irrigation water:

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

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

where:

AIW = depth of applied irrigation water (mm)

ETo = reference evapotranspiration (mm d^{-1}). ETo values calculated using BISm.

I = irrigation intervals (days)

Ea = irrigation application efficiency of the sprinkler irrigation system (Ea = 78% first seasons and 80% second season for sprinkler system).

LR = leaching requirements (was not considered in this experiment due to its indirect effect on the amount of water applied for water stress treatment, 0.8 ETo)

Water equivalent ratio (WER):

The WER quantifies the amount of water that would be needed in single crops to achieve the same yield as produced with one unit of water in intercrop and it is calculated according the formula of (Mao *et al.*, 2012):

$WER = WER_P + WER_S = WUE_{intP}/WUE_{monoP} + WUE_{intS}/WUE_{monoS}$

Where: $WUE_{intP} = (Y_{intP} / WU_{int})$, $WUE_{monoP} = (Y_{monoP} / WU_{monoP})$, $WUE_{intS} = (Y_{intS} / WU_{int})$ and $WUE_{monoS} = (Y_{monoS} / WU_{monoS})$

Where: WUE_{monoP} and WUE_{monoS} are the water use efficiencies of monocultures of species peanut and sunflower. $WUE_{int,P}$ and $WUE_{int,S}$ are water use efficiencies of species peanut and sunflower in the intercrop. These WUEs are calculated as the yield of crop peanut or sunflower per unit of total water used in the intercrop. Y is yield, WU_{int} is the actual evapotranspiration of whole intercropping system,

$WU_{mono,P}$ and $WU_{mono,S}$ are the actual evapotranspiration of crops peanut and sunflower in monocultures.

Cereal units:

The cereal units (CUs) for peanut and sunflower crops were calculated by Brockaus (1962) as Each 100 kg of seeds of both crops equals 2 units**.**

Water use efficiency (WUE):

Water use efficiency (WUE, kg yield or cereal unit mm^{-1}) reported here as the ratio of crop yield (Y) in kg or cereal unit to water consumptive use (mm) according to (Stanhill, 1986):

$$WUE = Y (kg \text{ or cereal unit } ha^{-1}) / CU (mm\ ha^{-1})$$

where:

Y = Crop yield in kg or cereal unit per ha^{-1}.

CU= Water consumed during the growing season (mm ha^{-1}).

Crop water productivity (WP):

The WP is defined as crop yield expressed in kg or cereal units per unit applied irrigation water (Zhang, 2003) that is given as follow:

WP = crop yield (kg or cereal unit ha^{-1}) / Applied irrigation water (mm ha^{-1})

Competitive relationships and yield advantages:

Land equivalent ratio: LER is the relative land area under sole crops that is required to produce the yields achieved in intercropping. This was determined according to Willey (1979):

$$LER = Yab/Yaa + Yba/Ybb$$

where: Yaa = Pure stand yield of crop (peanut), Ybb = Pure stand yield of crop (sunflower).Yab = Mixture yield of peanut (when combined with sunflower), Yba = Mixture yield of sunflower (when combined with peanut).

Aggressivity (A): is another index represents a simple measure of how much the relative yield increase in crop a is greater than that of crop b in an intercropping system. Aggressivity values were determined according to Mc-Gilchrist (1965):

$$Aab= [Yab/(YaaxZab)] – [Yba/(YbbxZba)]$$

$$Aba= [Yba/(YbbxZba)] – [Yab/(YaaxZab)]$$

where: Aab and Aba =Aggressivity value for peanut and sunflower, respectively.
zab=Sown proportion of peanut (in mixture with sunflower).
zba=Sown proportion of sunflower (in mixture with peanut).

If Aab = 0, both crops are equally competitive, if Aab is positive, a is dominant, if Aab is negative a is dominated crop.

Total and net income:

Total return from each treatment was calculated in Egyptian pound (L.E. 9040 and 4765/ton) for peanut and sunflower, respectively, as an average for the two seasons (Bulletin of Statistical Cost Production and Net Return, 2016).

Net income = Total income – (fixed cost of peanut + variable cost of sunflower).

Statistical analysis:

Data were statistically analyzed according to the technique of analysis of variance (ANOVA) as published by Gomez and Gomez (1984). Means of the treatments were compared using Least Significant Difference (LSD) at 5% level of significance as developed by Waller and Duncan (1969).

RESULTS AND DISCUSSION

Water distribution uniformity

The distribution uniformity values of irrigation water for the both growing seasons were 78 and 80 % for the two tests conducted at the beginning of each growing season, respectively. The obtained results showed a little increase in DU values in the second season as compared to the first season. This trend of results was similar to that obtained by Taha (2012 and 2013).

Effect of irrigation treatments, intercropping patterns and their interaction on light intensity % at middle and bottom of peanut and sunflower plants:

Light intensity % at the middle and bottom of the peanut and sunflower plants were influenced ($p<0.05$) by the irrigation treatments and intercropping patterns, with some exceptions. This observation hold true in both seasons (Table 3). Deficit irrigation at 0.8 of ETo significantly increased light transmission at the middle and bottom of two crops compared to other irrigation treatments. Meanwhile, increasing water irrigation to 1.2 of ETo significantly intercepted the most light and transmitted the least. These results may be due to plants irrigated with 1.2 or 1.0 of ETo produced greater canopy therefore had greater light intercepted and low light intensity%. These results here were accordance with those obtained by Loomis and Connor (2002), Langeroodi *et al.* (2014) and Adeboye *et al.* (2016).

Light intensity % at the middle and bottom of the plants were influenced ($p<0.05$) by the intercropping patterns in both seasons, except light intensity at the bottom of peanut plants in second season only. For peanut, light transmission in sole peanut at middle and bottom of the plants was significantly higher compared to other patterns. the presence of sunflower with peanut plants at high density P3 patterns markedly reduced light transmission by 19.47 and18.80% at the middle and by

Table 3. Effect of irrigation treatments, intercropping patterns and their interaction on light intensity % of peanut and sunflower plants in 2016 and 2017 seasons

Treatment	Trait	Light intensity % of peanut at				Light intensity % of sunflower at			
		middle of the plant		bottom of the plant		middle of the plant		bottom of the plant	
		2016	2017	2016	2017	2016	2017	2016	2017
Irrigation treatment									
I1 1.2 of ETo		9.97	10.12	5.43	5.24	32.55	30.81	12.55	9.11
I2 1.0 of ETo		10.83	10.80	5.96	5.95	36.90	35.89	13.87	12.84
I3 0.8 of ETo		12.11	12.77	6.08	6.68	40.72	39.56	15.18	16.21
LSD at 5% A		**2.07**	**1.99**	**0.60**	**0.33**	**1.99**	**0.24**	**2.15**	**0.33**
Intercropping pattern									
P1 (100%P+25% S)		11.35	11.69	6.04	6.13	39.92	37.78	15.49	15.94
P2 (100%P+33% S)		10.92	11.17	5.64	5.86	38.43	35.83	14.46	10.17
P3 (100%P+50% S)		9.64	9.89	5.05	5.27	35.72	35.45	9.52	9.17
Sole crop		11.97	12.18	6.56	6.57	32.82	32.63	15.99	15.59
LSD at 5% B		**0.57**	**0.22**	**0.29**	**N.S**	**0.29**	**0.18**	**0.19**	**0.31**
Interaction									
I1 1.2 of ETo	P1	10.33	10.58	5.64	5.20	35.74	33.17	14.17	12.33
	P2	9.94	10.06	5.25	5.35	34.26	31.22	13.14	6.56
	P3	8.74	8.78	4.66	4.55	31.55	30.84	8.20	5.56
	Sole crop	10.87	11.07	6.16	5.85	28.65	28.02	14.67	11.98
I2 1.0 of ETo	P1	11.23	11.26	6.18	6.34	40.10	38.25	15.70	16.06
	P2	10.76	10.74	5.77	5.45	38.60	36.30	14.56	10.29
	P3	9.40	9.46	5.19	5.24	35.90	35.92	9.33	9.30
	Sole crop	11.93	11.75	6.70	6.77	33.00	33.10	15.89	15.71
I3 0.8 of ETo	P1	12.49	13.23	6.30	6.85	43.92	41.92	16.60	19.44
	P2	12.06	12.71	5.90	6.78	42.43	39.97	15.68	13.67
	P3	10.78	11.43	5.30	6.00	39.71	39.59	11.04	12.66
	Sole crop	13.11	13.72	6.82	7.09	36.81	36.77	17.41	19.08
LSD at 5% A x B		**0.99**	**0.55**	**0.50**	**N.S**	**N.S**	**0.31**	**N.S**	**N.S**

23.02 and 19.79% at bottom of the plant, respectively, in the two seasons relative to sole peanut. These data indicate that intercepted solar radiation by peanut plant was affected negatively by shading effect of sunflower.

On the other hand, light transmittance at the middle of solid sunflower plants was significantly reduction by 17.79, 14.60 and 8.12% and 13.63, 8.93 and 7.95% compared to P1, P2 and P3 intercropping patterns, respectively, in 2016 and 2017 seasons. Meanwhile, the light intensity % at the bottom of the sunflower plants in P2 and P3 intercropping pattern was the lowest compared with sole sunflower. Differences in their vertical arrangement of foliage and canopy architecture among inter crops indicate differ in light transmission compared to sole crops. As concluded by Awal *et al.* (2006) and Jiao *et al.* (2008).

Interaction effect between irrigation treatments and intercropping had significantly affected on light intensity % at middle of peanut plants in two seasons, bottom of peanut plants in first season and at the middle of sunflower plants in second season (Table 3). Intercropping 25% of sunflower under deficit irrigation had the highest values of light intensity %. Intercepted photosynthetically active radiation corresponds to the size of plant canopy. These results here were accordance with those obtained by Loomis and Connor (2002), Langeroodi *et al.* (2014) and Adeboye *et al.* (2016).

Effect of irrigation treatments, intercropping patterns and their interaction on growth, yield and its attributes of peanut and sunflower:

Peanut:

Plant height, number and weight of pods/plant, seeds weight/plant:

As seen in Table 4, all studied characters of peanut influenced ($P< 0.05$) by irrigation treatments, intercropping patterns and their interaction in the two seasons.

Plant height, number and weight of pods/plant, seeds weight/plant significantly decreased by deficit irrigation (0.8 of ETo) compared to other irrigation treatments. While the greatest values of the previous traits were related with 1.2 of ETo. This is to be expected since water plays an important role in plants and deficit irrigation can have a deleterious effect on most physical processes (Haro *et al.* 2008, Asik and Yildiz 2015, Feng *et al.,* 2016). It is worth to noting that, No.of pods/plant value was higher in the second growing season as compared with the first season, this attributed to distribution uniformity increased in the second growing season as compared to the first under sprinkler irrigation system (Taha, 2012).

Data in Table 4 revealed that intercropping patterns had a significant effect on these traits in both seasons. All traits were decreased by the intercropping compared with sole peanut, except plant height in both seasons. Intercropping sunflower at the high density P3 was produced the maximal plant height, contrary, number of pods and weight/plant, seeds weight/plant were reached their minimal. The shading effect of peanut by the sunflower plant (taller) may also have contributed to reduction in the yield components of peanut and increasing internode length by reducing the light intensity % of the lower growing plant (as shown in Table 3). Similar results were reported by (El-Sawy *et al*., 2006 and Nassar *et al.*, 2008).

Interaction between irrigation treatments and intercropping patterns had a significant effect on plant height, number of pods/plant in both seasons, and seeds weight/plant in 2016 season. Increasing sunflower plant density from 25 up to 50% under irrigation treatment 1.2 of ETo achieved the tallest plants. While the shortest plants of peanut were detected under deficit irrigation (0.8 of ETo) with sole peanut. The highest values of No.of pods/plant and seed weight/plant were detected with irrigation treatment 1.2 of ETo and sole peanut, while irrigated P3 pattern with 0.8 of ETo achieved the lowest values for these traits.

100-pod weight, 100-seed weight, pod and oil yields and oil %.

100-pod weight, 100- seed weight and pod and oil yields/ha were increased ($P < 0.05$) by increasing water irrigation from 0.8 up to 1.2 of ETo, whereas the highest oil % was detected with irrigation treatment 1.0 of ETo in both seasons as shown in Table (5). The lowest values of the above mentioned characters were obtained from irrigation treatment at 0.8 of ETo.

Table 4. Effect of irrigation treatments, intercropping patterns and their interaction on plant height and yield components of peanut in 2016 and 2017 seasons

Trait		Plant height (Cm)		No.of pods /plant		Pods weight /Plant (g)		Seeds weight /plant (g)	
Treatment		2016	2017	2016	2017	2016	2017	2016	2017
Irrigation treatment									
I1 1.2 of ETo		51.25	44.25	15.18	16.34	22.21	23.01	13.81	14.44
I2 1.0 of ETo		50.50	42.25	14.90	15.17	21.94	22.29	13.22	13.42
I3 0.8 of ETo		43.96	32.33	13.63	13.94	19.24	20.24	11.01	11.64
LSD at 5% A		**1.55**	**2.34**	**1.09**	**0.98**	**1.06**	**0.39**	**0.94**	**0.70**
Intercropping pattern									
P1(100% P+25% S)		48.11	38.34	15.03	15.93	21.73	22.05	13.48	13.74
P2(100% P+33% S)		50.39	40.00	13.85	14.17	20.45	21.55	11.87	12.61
P3(100% P+50% S)		55.06	43.56	12.72	13.13	18.55	19.45	10.24	10.94
P4 (sole peanut)		40.72	36.55	16.68	17.36	23.78	24.32	15.13	15.38
LSD at 5% B		**1.80**	**2.10**	**0.86**	**1.15**	**1.41**	**0.76**	**0.92**	**0.58**
Interaction									
I1 1.2 ETo	P1	49.17	43.67	15.92	17.19	22.94	23.25	14.79	15.03
	P2	51.83	43.67	14.36	15.23	21.96	22.58	13.18	13.77
	P3	58.83	47.67	12.51	14.60	19.70	21.18	11.03	12.28
	P4	45.17	42.00	17.92	18.33	24.22	25.01	16.25	16.68
I2 1.0 ETo	P1	51.00	39.67	15.60	16.00	22.52	22.61	14.01	14.15
	P2	54.67	43.67	14.03	14.07	21.28	21.81	12.44	12.81
	P3	56.67	47.33	13.33	13.33	18.54	18.94	10.46	10.59
	P4	39.67	38.33	16.65	17.28	25.41	25.79	15.96	16.12
I3 0.8 ETo	P1	44.17	31.67	13.56	14.60	19.72	20.30	11.63	12.03
	P2	44.67	32.67	13.15	13.20	18.11	20.26	10.00	11.26
	P3	49.67	35.67	12.33	11.47	17.41	18.22	9.22	9.94
	P4	37.33	**29.33**	15.47	16.48	21.72	22.17	13.19	13.34
LSD at 5% A xB		**3.11**	**3.63**	**1.49**	**1.98**	**N.S**	**N.S**	**1.60**	**N.S**

The reducing in pod yield ($P < 0.05$) due to irrigation peanut with 0.8 of ETo compared to high water irrigation treatments 1.2 of ETo were 13.62 % and 12.19%, respectively, in first and second seasons. Oil yield reduction was 15.01% and 12.79% with irrigating peanut with 0.8 ETo compared to 1.2 of ETo, respectively, in both seasons. This trend reflects the effect of more available soil moisture in root zone under 1.2 of ETo throughout the growing season. Since increasing water irrigation accelerated the vegetative growth of peanut and therefore encouraged cell division and meristematic activity by good absorption of nutrients with high levels of available moisture (Hsiao 1973). These results confirmed results of Haro *et al.* (2008), Rowland *et al.* (2012) and Asik and Yildiz (2015).

Solid peanut recorded the highest values of 100-pod weight, 100- seed weight and pod yield and oil yield/ha compared with all intercropping patterns and differences were significantly ($p<0.05$) in the two seasons. The reduction in pod yield for P1, P2 and P3 were 8.17, 12.74 and 16.50% and 9.83, 12.77 and 16.55%, respectively, in first and second season compared to solid peanut. The highest reduction in oil yield/ha were detected when intercropping sunflower at high density (50%) P3. Since oil yield/h were decreased by 8.78, 11.30 and 15.03% (in 2016 season) and 8.11, 10.28 and 14.15 % (in 2017 season) under P1, P2 and P3 intercropping patterns compared to sole peanut, respectively. This reduction in peanut yield under intercropping could be due to inter-specific competition between the intercrop components for water, light, air and nutrients. Contrary, the highest values of oil % were detected with P3 compared to sole and the other intercropping patterns. These observations hold true in two seasons and are in accordance with those obtained by Sankaran and Kuppuswamy, (1992), El-sawy *et al.* (2006) and Abd El-Zaher *et al.* (2009).

The interaction revealed that maximum values of yield and its components were obtained when irrigated sole peanut plants with high amount of water irrigation 1.2 of ETo. Whereas, the minimum values of these traits were gained with P3 (100% peanut + 50% sunflower) under deficit irrigation 0.8 of ETo.

Table 5. Effect of irrigation treatments, intercropping patterns and their interaction on yield and its components of peanut in 2016 and 2017 seasons

Trait		100-pod weight (g)		100-seed weight (g)		Pod yield (ton/ ha)		Oil yield (ton /ha)		Oil %	
Treatment		**2016**	**2017**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
Irrigation											
I1 1.2 of ETo		140.06	137.72	88.62	91.10	3.179	3.184	1.039	1.024	49.05	48.15
I2 1.0 of ETo		137.11	134.03	86.33	87.09	3.083	3.130	1.008	1.004	49.08	48.30
I3 0.8 of ETo		131.72	132.89	77.93	83.64	2.746	2.796	0.883	0.893	48.26	47.93
LSD at 5% A		**3.73**	**2.46**	**1.88**	**0.92**	**0.020**	**0.040**	**0.018**	**0.022**	**0.32**	**0.36**
Intercropping pattern											
P1(100% P+25% S)		139.14	136.66	85.90	91.32	3.003	3.035	0.977	0.974	48.76	48.12
P2(100% P+33% S)		134.44	133.06	82.65	86.16	2.903	2.936	0.950	0.951	49.06	48.57
P3(100% P+50% S)		128.22	124.61	77.34	78.63	2.778	2.809	0.910	0.910	49.08	48.59
P4 (sole peanut)		143.39	137.24	91.29	92.99	3.327	3.366	1.071	1.060	48.27	47.22
LSD at 5% B		**2.90**	**5.69**	**2.75**	**0.85**	**0.028**	**0.158**	**0.004**	**0.017**	**0.12**	**0.18**
Interaction											
I1 1.2 %	P1	144.33	139.50	92.06	94.78	3.192	3.204	1.045	1.027	48.79	48.13
	P2	138.32	137.62	87.04	90.28	3.115	3.128	1.023	1.020	49.19	48.60
	P3	130.62	133.31	81.81	84.52	2.967	2.937	0.988	0.961	49.25	48.60
	P4	146.97	140.46	93.57	94.81	3.443	3.465	1.103	1.090	48.95	47.27
I2 1.0 %	P1	139.44	137.36	89.20	91.26	3.135	3.167	1.020	1.016	49.10	48.07
	P2	135.21	134.03	84.37	85.71	3.000	3.035	0.984	0.983	49.25	48.90
	P3	129.36	126.59	77.99	78.42	2.833	2.892	0.930	0.937	49.93	49.07
	P4	144.43	138.15	93.78	92.97	3.361	3.425	1.097	1.079	48.04	47.17
I3 0.8 %	P1	133.65	136.66	76.45	87.91	2.681	2.735	0.865	0.878	48.40	48.17
	P2	129.79	133.06	76.54	82.50	2.592	2.645	0.842	0.850	48.75	48.20
	P3	124.67	124.61	72.22	72.96	2.533	2.597	0.812	0.833	48.07	48.10
	P4	138.77	137.24	86.51	91.18	3.176	3.208	1.012	1.010	47.81	47.23
LSD at 5% A xB		**9.53**	**N.S**	**4.74**	**3.71**	**0.052**	**0.286**	**0.050**	**0.029**	**0.25**	**0.32**

This was true since increasing water irrigation accelerated the vegetative growth of peanut and decreasing sunflower plant density associated with peanut, which resulting in low competitions on growth resources between peanut and sunflower plants. These results are harmony with those obtained by Lesoing and Francis (1999), Abd El-Zaher *et al.* (2009), Rowland *et al.* (2012) and Asik and Yildiz (2015).

Sunflower:

Plant height, No.of leaves and head diameter and head weight:

The results in Table 6 showed that the studied traits of sunflower were affected (P< 0.05) by irrigation treatments, intercropping patterns and interaction in both seasons.

Plant height, number of leaves/plant, head diameter and head weight significantly increased with increasing water irrigation to 1.2 of ETo without significant differences between 1.2 and 1.0 of ETo for plant height in the two seasons. The lowest values of these traits were obtained from irrigating sunflower with 0.8 of ETo in two successive seasons, these results attributed to increasing water stress under irrigation treatment 0.80 of ETo. Since the increase of a mount irrigation water increased number and length of internodes as well as number of leaves/plant due to the promoting role of enough watering for cell division, expansion and enlargement (Nezami *et al.*, 2008). These results confirmed results of Gholinezhad *et al.* (2009) and El-Dakrourry (2015).

The previous mentioned traits were affected (P ≤ 0.05) by intercropping patterns in both seasons (Table 6). The data indicated that there was relevance between sunflower density and plant height. The more sunflower plants in the area the taller stalks and more No.of leaves/plant were. Thus, sunflower in pure stand resulted in tallest plants and more leaves/plant compared to the other intercropping patterns. While head diameter and head weight behaved opposite trend. Maximum values of these traits were obtained by intercropping pattern P1 (100% P+ 25% S). This result might be due to increased intra-specific competition between sunflower plants for basic growth resources especially solar radiation, which resulted in marked elongation of the internodes of plants searching for more light and higher diminished in diameter and weight of head, under sole sunflower than intercropping patterns. These results are in agreement with those obtained by El-sawy *et al*. (2006), Nassar *et al*. (2008) and Abd El-Zaher *et al.* (2009).

Data listed in Table 6 clearly indicated that plant height, head diameter, head weight were influenced (P ≤ 0.05) by interaction between irrigation treatments and intercropping patterns in both seasons. Solid sunflower gained the tallest plant heights under irrigation treatments 1.2 of ETo. While the highest head diameter and weight produced with intercropping pattern P1 under the same irrigation treatment. Whereas, intercropping pattern P1had the shortest plants compared with other treatments when irrigated with 0.8 of ETo. The lowest head diameter and weight were achieved by solid sunflower under deficit irrigation treatments 0.8 of ETo.

Seed weight/head, 100-seed weight, seed and oil yield/ha and oil%:

Seed weight/head, 100-seed weight, seed and oil yield/ha and oil% of sunflower affected (P< 0.05) by irrigation treatments in both seasons as shown in (Table 7). Irrigation with amounts of water equals to 1.2 of ETo significantly increased seed weight/head, 100-seed weight, seed and oil yields/ha as compared to irrigation with amounts of water equals to 1.0 and 0.8 of ETo. Meanwhile, the lowest values were achieved when irrigated sunflower plants with 0.8 of ETo in both seasons. However, the highest oil content was achieved with 1.0 ETo followed by 1.2 then 0.8 of ETo in a descending order. The increase in seed and oil yield at 1.2 of ETo compared with 0.8 of ETo irrigation treatments were 25.02 % and 22.69% for seed yield and 30.41 and 35.51 % in first and second seasons, respectively. This result reflects the effect of distribution uniformity (DU) in increased applied irrigation water under 1.2 and 1.0 of ETo treatments compared of 0.8 of ETo and more available soil moisture in root zone. That is led to an increase in various physiological processes, higher rates of photosynthesis, number of leaves and flowers which in turn led to better seed development and higher seed and oil yields. These results are in harmony with those obtained by Gholinezhad *et al.* (2009) and Langeroodi *et al.* (2014) and El-Dakrourry (2015).

Intercropping patterns had significantly affected yield and its components in both seasons, except 100-seed weight was not affected in the first season attributed to distribution uniformity increased irrigation water in second season (Table 7). Maximum values of seed weight/head and 100-seed weight were obtained by intercropping pattern P1 (25% S), whereas, minimum values of these traits resulted from pure stand (P5). The improvement of light intensity % in intercropping plots (Table 3) give rise to the raise of the photosynthetic rate of sunflower, which could be resulted the improvement of the yield components of sunflower compared with solid pattern (Nassar *et al*., 2006). Sunflower plant density per unit area is one of the major factors that determining seed and oil yield per unit area. Where intercropping sunflower with peanut in P1, P2 and P3 decreased ($P \leq 0.05$) seed yield per ha by 59.70, 46.83 and 32.59 %, while reduction in oil yield per ha were 60.89, 47.82 and 32.67% respectively, as compared with sole sunflower as average in the both seasons. However, intercropping sunflower with peanut increased seed oil content compared to sole sunflower. These results are in agreement with those obtained by El-sawy *et al.* (2006), Abd El-Zahr *et al.* (2009) and Abdel-Wahab and El Manzlawy (2016) Whereas, Kandel *et al.* (1996) showed that sunflower oil content was not influenced by intercropped legumes.

The previous mentioned traits significantly affected by interaction in both seasons as shown in Table (7). The heaviest seed weight /head and 100- seed weight were obtained from intercropping pattern P1 (25% sunflower) under full irrigation 1.2 of ETo, while the lowest weight of these traits were achieved when irrigated solid sunflower with 0.8 of ETo. On the other hand, solid planting produced the highest seed an oil yield/ha under different irrigation treatments compared with intercropping patterns. This result might be due to adequate moisture availability in the soil which might have led to increase various physiological processes, higher rates of photosynthesis, which in turn led to better seed development and higher seed and oil yields as well as seed and oil yields related to number of plants per unit area El-Dakrourry (2015) and Abd El-Zahr *et al.* (2009).

Effect of the tested treatments on applied irrigation water (AIW) and water consumptive use (WCU):

The depth of applied irrigation water in the 2016 and 2017 seasons under the 1.2, 1.0 and 0.8 ETo irrigation treatments were 451 and 439 mm (4510 and 4390 m^3/ha), 376 and 366 mm (3760 and 3660 m^3/ha) and 303 and 293 mm (3030 and 2930 m^3/ha), respectively (Table 8). The difference between depths of applied irrigation water in the two seasons is due to changes in the efficiencies.

Table 6. Effect of irrigation treatments, intercropping patterns and their interaction on plant height, No.of leaves, head diameter and weight of sunflower in 2016 and 2017 seasons

Trait		Plant height Cm		No. of leaves /Plant		Head diameter (cm)		Head weight (g)	
Treatment		**2016**	**2017**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
Irrigation treatment									
I1 1.2 of ETo		136.17	136.59	15.96	16.16	17.47	18.43	77.05	115.53
I2 1.0 of ETo		134.67	135.50	14.72	15.63	17.45	17.97	69.49	83.70
I3 0.8 of ETo		126.58	129.25	14.00	14.18	16.28	16.91	53.66	52.02
LSD at 5% A		**1.71**	**2.65**	**0.38**	**0.21**	**0.35**	**0.57**	**2.22**	**2.71**
Intercropping pattern									
P1(100% P+25% S)		123.22	125.78	13.80	13.91	19.04	20.89	72.68	96.91
P2 (100% P+33% S)		128.56	130.78	14.54	15.06	17.80	18.68	68.85	88.60
P3 (100% P+50% S)		135.67	136.56	15.13	15.80	16.22	16.15	64.56	81.67
P5 sole sunflower		142.44	142.00	16.09	16.52	15.20	15.35	60.84	67.82
LSD at 5% B		**2.36**	**2.11**	**0.65**	**0.47**	**0.48**	**0.61**	**1.65**	**2.07**
Interaction									
I1 1.2 of ETo	P1	123.67	126.00	14.88	14.75	19.07	21.73	87.87	123.53
	P2	132.33	134.67	15.61	15.9	18.40	19.27	78.46	122.27
	P3	142.33	139.67	16.2	16.63	16.40	16.93	72.87	120.33
	P5	146.33	146.00	17.15	17.36	16.00	15.80	69.00	96.00
I2 1.0 of ETo	P1	127.67	130.33	13.63	14.22	19.93	20.93	73.84	108.93
	P2	130.33	132.00	14.37	15.36	18.20	19.27	72.72	87.87
	P3	136.00	138.67	14.95	16.11	16.67	16.33	67.04	72.87
	P5	144.67	141.00	15.92	16.83	15.00	15.33	64.36	65.13
I3 0.8 of ETo	P1	118.33	121.00	12.91	12.76	18.13	20.00	56.33	58.27
	P2	123.00	125.67	13.65	13.92	16.80	17.50	55.37	55.67
	P3	128.67	131.33	14.24	14.66	15.60	15.20	53.77	51.80
	P5	136.33	139.00	15.2	15.38	14.60	14.93	49.17	42.33
LSD at 5% A x B		**4.09**	**3.66**	**N.S**	**N.S**	**0.49**	**0.53**	**2.69**	**3.58**

Table 7. Effect of irrigation treatments, intercropping patterns and their interaction on seed weight/head, 100-seed weight, seed and oil yields/ha and oil% of sunflower in 2016 and 2017 seasons

Trait		Seed weight /head (g)		100-seed weight (g)		Seed yield (ton/ha)		Oil Yield (ton/ha)		Oil %	
Treatment		2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Irrigation treatment											
I1 1.2 of ETo		42.39	47.66	5.55	6.11	1.529	1.590	0.639	0.664	41.47	40.91
I2 1.0 of ETo		38.29	41.75	5.58	5.88	1.478	1.574	0.622	0.660	41.78	41.76
I3 0.8 of ETo		30.11	32.33	4.37	5.12	1.223	1.296	0.490	0.516	40.19	40.04
LSD at 5% A		**1.67**	**0.64**	**0.94**	**0.21**	**0.072**	**0.042**	**0.004**	**0.010**	**0.16**	**0.30**
Intercropping pattern											
P1(100% P+25% S)		44.44	51.00	5.73	6.35	0.865	0.925	0.350	0.374	40.47	40.56
P2(100% P+33% S)		42.67	45.49	5.28	6.09	1.155	1.206	0.469	0.497	40.55	41.11
P3(100% P+50% S)		34.30	38.16	5.00	5.83	1.454	1.540	0.613	0.633	41.96	41.02
P5 sole sunflower		27.30	27.66	4.66	4.54	2.166	2.275	0.902	0.949	41.61	40.92
LSD at 5% B		**1.10**	**1.00**	**N.S**	**1.20**	**0.064**	**0.057**	**0.005**	**0.011**	**0.11**	**0.20**
Interaction											
I1 1.2 of ETo	P1	52.25	61.06	6.24	6.72	0.990	1.037	0.399	0.418	40.30	40.30
	P2	47.37	53.99	5.22	6.58	1.180	1.222	0.479	0.498	40.57	40.77
	P3	38.33	44.71	5.66	6.12	1.648	1.703	0.703	0.706	42.68	41.47
	P5	31.62	30.87	5.07	5.01	2.298	2.396	0.973	1.033	42.34	43.10
I2 1.0 of ETo	P1	44.48	50.10	6.22	6.80	0.938	1.019	0.378	0.411	40.32	40.37
	P2	44.42	46.97	6.10	6.32	1.249	1.313	0.510	0.554	40.87	42.20
	P3	35.83	39.82	5.76	6.30	1.516	1.615	0.657	0.681	43.33	42.17
	P5	28.41	30.12	4.25	4.09	2.210	2.349	0.941	0.994	42.60	42.30
I3 0.8 of ETo	P1	36.60	41.85	4.72	5.52	0.668	0.719	0.272	0.293	40.79	41.00
	P2	33.22	35.51	4.52	5.37	1.037	1.084	0.417	0.438	40.20	40.37
	P3	28.74	29.96	4.17	5.07	1.199	1.301	0.478	0.512	39.88	39.37
	P5	21.88	21.99	4.07	4.52	1.989	2.080	0.793	0.820	39.88	39.43
LSD at 5% A x B		**1.91**	**1.73**	**1.20**	**2.07**	**0.111**	**0.099**	**0.008**	**0.019**	**0.32**	**0.35**

Table 8. Applied irrigation water and water consumptive use as affected by irrigation treatments and intercropping pattern in the two growing seasons

Irrigation & Intercropping treat.		Applied irrigation water (mm)		Water consumptive use (mm)	
		2016	2017	2016	2017
1.2 ETo	P1	451	439	395	395
	P2	451	439	392	401
	P3	451	439	403	415
	P4	451	439	343	350
	P5	451	439	271	278
1.0 ETo	P1	376	366	322	329
	P2	376	366	327	334
	P3	376	366	336	344
	P4	376	366	293	301
	P5	376	366	251	258
0.8 ETo	P1	303	293	259	263
	P2	303	293	263	267
	P3	303	293	270	278
	P4	303	293	236	240
	P5	303	293	203	206

P1= 100% peanut + 25% sunflower, P2= 100% peanut + 33% sunflower, P3= 100% peanut + 50% sunflower, P4= sole peanut, P5= sole sunflower

Regarding to the water consumptive use, results indicated that increasing plant density and amounts of irrigation water increased water consumption. Also, WCU values tended to increase in the second growing season compared to the first growing season as a result of increasing water distribution uniformity. Data in Table (8) indicated that the highest values of seasonal water consumptive use were 403 and 415mm obtained under irrigation 1.2 ETo and intercropping pattern P3 (100% P + 50% S) in the first and second seasons, respectively. The increase in water consumptive use was due to increasing plant density and root distributions in surface soil for the P3 pattern compared to the other patterns. Similar results were obtained by Abd El- Hafez *et al*. (2002).

Water use efficiency (WUE) and Water Equivalent Ratio (WER):

The results in Table (9) showed that, under all irrigation treatments, total WUE (kg/mm) values of intercropping patterns were higher than sole peanut (P4) or sunflower (P5). The WUE values of peanut were higher than those of sunflower due to plant density of peanut. Increasing sunflower ratio in intercropping were increased water use efficiency for sunflower (WUE_s) and total WUE, but reduced water use efficiency of peanut crop (WUE_p). This reduction could be due to the competition between the intercrop components for water with direct effect on the produced yield (Metwally *et al.*, 2017). The highest values of total WUE (13.82 and 14.02 kg/mm) were detected with P3 (100 %P + 50% S) under irrigation treatment I3 (0.8 ETo) in 2016 and 2017 seasons, respectively. Similarly, all values of water equivalent ratio (WER) of intercropping patterns were greater than 1, which indicated that the water utilization efficiency of the intercropping was higher than that of sole pattern. The highest WER values (1.25 and 1.26) were recorded with P3 (100% P + 50% S) under the 1.0 ETo irrigation treatment. While, the lowest values (1.03 and 1.05) were detected with P1 (100% P + 25% S) when irrigated with 0.8 ETo, in both seasons, respectively. The above results indicated that the intercropping can utilize irrigation water more efficiently than monoculture by about 25 and 26%. These results were confirmed with what was found by Feng *et al.* (2016).

Water use efficiency (WUE) calculated using the cereal units as affected by irrigation treatments and intercropping patterns:

Data in Table (10) showed that the highest water use efficiency values (0.214 and 0.218 CUs/mm of applied water) were obtained for the irrigation treatments 0.8 ETo with P3 (100% peanut + 50 % sunflower) in the first and second seasons, respectively. The lowest water use efficiency values (0.134 and 0.132 CUs /mm of applied water) were obtained for the irrigation treatments 1.2 ETo with sole peanut in the two seasons. It is worth to noting that, irrigation treatment I3 (0.8 of ETo) achieved the highest WUE but caused higher reduction in peanut and sunflower yields by 12.90% (in pod yield) and 19.25% (in seed yield), while irrigation treatment I2 (1.0 of ETo) reduced yield by 2.36% for peanut and 2.17 % for sunflower, respectively, as average of both seasons compared to high water irrigation treatments 1.2 ETo. Therefore, it is recommended to irrigate peanut/sunflower intercropping pattern grown in sandy soil with an amount of 1.0 of ETo with 100% peanut + 50 % sunflower under sprinkler irrigation to increase water use efficiency. Similar results were obtained by Gaballah and Ouda (2008) and Metwally et al. (2017).

Water productivity under irrigation treatments.

The results in Table (11) showed that water productivity tended to increase with the decreasing in the irrigation water applied from 1.2 to 0.8 ETo. The highest values of water productivity (0.183 and 0.194 CUs/mm) were obtained for the irrigation treatments 0.8 ETo with P3 (100% P + 50 % S), followed by the same pattern P3 under I2 irrigation treatment (0.181 and 0.194 CUs/mm) of in first and second seasons, respectively (Table11). While, the lowest values were achieved by sole pattern of both crops under 1.2 ETo irrigation treatment. These results indicate that, the increase in water productivity under intercropping pattern is higher than sole pattern. This trend of results was obtained by Taha (2012).

Land Equivalent Ratio (LER) and Aggressivity.

The total LERs of all the intercropping treatments surpassed the unit indicating yield advantage, as compared to sole pattern of peanut or sunflower crops (Table 12). Relative yield of peanut were higher than those of sunflower in all patterns. The land use was increased by 56.9 % followed by 53.0 and 41.8 % for P3 pattern (50% sunflower) under I1, I2 and I3, respectively, as average of two seasons.

Maximum LER (1.569) was obtained when peanut plants were associated with 50% of sunflower plants (P3) and irrigated with higher irrigation water (1.2 of ETo) as average of two seasons. While the lowest LER (1.189) was achieved with irrigate P1 (100% P+ 25%S) under 0.8 of ETo treatment. The sufficient amount of irrigation water increased LER due to enhancement yield and its components. The results of Feng *et al.*, 2016 and Metwally *et al.* (2017) are coincided with these results.

Table 9. Effect of irrigation treatments, intercropping patterns and their interaction on water use efficiency (kg/mm) and water equivalent ratio in both seasons

I x P		2016 season						2017 season					
		WUE_P kg/mm	WUE_S kg/mm	Total WUE kg/mm	WER Peanut	WER Sunflower	WER	WUE_P kg/mm	WUE_S kg/mm	Total WUE kg/mm	WER Peanut	WER Sunflower	WER
I1 1.2 of ETo	P_1	8.08	2.51	10.59	0.80	0.30	1.10	8.11	2.63	10.74	0.82	0.30	1.12
	P_2	7.95	3.01	10.96	0.79	0.35	1.14	7.80	3.15	10.85	0.79	0.36	1.15
	P_3	7.36	4.09	11.45	0.73	0.48	1.21	7.08	4.10	11.18	0.72	0.48	1.20
	P_4	10.04	-	10.04	-	-	-	9.90	-	9.90	-	-	-
	P_5	-	8.48	8.48	-	-	-	-	8.62	9.34	-	-	-
I2 1.0 of ETo	P_1	9.74	2.91	12.65	0.85	0.33	1.18	9.63	3.10	12.72	0.85	0.34	1.19
	P_2	9.17	3.82	12.99	0.80	0.43	1.23	9.09	3.93	13.02	0.80	0.43	1.23
	P_3	8.44	4.51	12.94	0.73	0.51	1.25	8.41	4.69	13.10	0.74	0.52	1.26
	P_4	11.47	-	11.47	-	-	-	11.38	-	11.38	-	-	-
	P_5	-	8.80	8.80	-	-	-	-	9.10	9.88	-	-	-
I3 0.8 of ETo	P_1	10.35	2.58	12.93	0.77	0.26	1.03	10.40	2.73	13.13	0.78	0.27	1.05
	P_2	9.86	3.94	13.80	0.72	0.40	1.13	9.91	4.06	13.97	0.74	0.40	1.14
	P_3	9.38	4.44	13.82	0.70	0.45	1.15	9.32	4.68	14.02	0.70	0.46	1.16
	P_4	13.46	-	13.46	-	-	-	13.37	-	13.37	-	-	-
	P_5	-	9.80	9.80	-	-	-	-	10.10	10.10	-	-	-

P1= 100% peanut + 25% sunflower, P2= 100% peanut + 33% sunflower, P3= 100% peanut + 50% sunflower, P4= sole peanut, P5= sole sunflower

Table 10. Water use efficiency for peanut/sunflower intercropping pattern under different irrigation treatments in both growing season

Irrigation Treat. & Inter. pattern		Consumed irrigation water, Cu (mm/ha)		Total Cereal units (CUs/ha)		Water use efficiency (CUs /mm)	
		2016	2017	2016	2017	2016	2017
I1 1.2 ETo	P1	395	395	62.36	63.46	0.158	0.161
	P2	392	401	65.14	66.15	0.166	0.165
	P3	403	415	72.52	73.22	0.180	0.176
	P4	343	350	45.91	46.20	0.134	0.132
	P5	271	278	45.96	47.92	0.170	0.172
I2 1.0 ETo.	P1	322	329	60.56	62.61	0.188	0.190
	P2	327	334	65.00	66.73	0.199	0.200
	P3	336	344	68.10	70.86	0.203	0.206
	P4	293	301	44.82	45.67	0.153	0.152
	P5	251	258	44.20	46.98	0.176	0.182
I3 0.80 ET.	P1	259	263	49.11	52.85	0.190	0.201
	P2	263	267	55.30	56.95	0.210	0.213
	P3	270	278	57.76	60.65	0.214	0.218
	P4	236	240	42.35	42.78	0.179	0.178
	P5	203	206	39.78	41.60	0.196	0.202

Also, results indicated that in all intercropping combination, sunflower was the dominant intercrop component whereas peanut was the dominated in both seasons. This is indicated that sunflower had higher competitive ability compared with peanut. Similar results were obtained by El-Sawy *et al.* (2006), Nassar *et al.* (2008) and Abd El-Zaher *et al.* (2009).

Total and net income (L.E./ha)

Results in Table (12) indicated that increasing irrigation water applied increased total and net income, also intercropping patterns under irrigation treatments 1.2 and 1.0 of ETo gained the highest total and net income compared with sole peanut. The highest total and net income (L.E.34670 and 22589/ha) were obtained when irrigated P3 (100%P + 50%S) with sufficient water irrigation 1.2 of ETo. While the lowest total and net income under intercropping patterns (L.E. 28023 and 16463/ha) were achieve when irrigated P1 (100% P + 25%S) with 0.8 ETo treatment, as average in both seasons. These results are in harmony with El-Sawy *et al.* (2006), Nassar *et al.* (2008) and Abd El-Zaher *et al.* (2009).

Table 11. Water productivity for peanut/sunflower intercropping pattern under different irrigation treatments in both growing season

Irrigation Treat. x Inter. pattern		Applied irrigation water (mm/ha)		Total Cereal units (CUs/ ha)		Water productivity (CUs/mm)	
		2016	2017	2016	2017	2016	2017
I 1 1.2 of ETo	P1	451	439	62.36	63.46	0.138	0.145
	P2	451	439	65.14	66.15	0.144	0.151
	P3	451	439	72.52	73.22	0.161	0.167
	P4	451	439	45.91	46.20	0.102	0.105
	P5	451	439	45.96	47.92	0.102	0.109
I2 1.0 of ETo	P1	376	366	60.56	62.61	0.161	0.171
	P2	376	366	65.00	66.73	0.173	0.182
	P3	376	366	68.10	70.86	0.181	0.193
	P4	376	366	44.82	45.67	0.119	0.125
	P5	376	366	44.20	46.98	0.118	0.128
I3 0.8 of ETo	P1	303	293	49.11	52.85	0.162	0.180
	P2	303	293	55.30	56.95	0.183	0.194
	P3	303	293	57.76	60.65	0.191	0.207
	P4	303	293	42.35	42.78	0.140	0.146
	P5	303	293	39.78	41.60	0.131	0.142

Table 12. Effect of irrigation treatments, intercropping patterns and their interaction on land equivalent ratio (LER), aggressivity (A) and total and net income in both seasons

I x P		L peanut	L sunflower	LER	Ap	As	Total income/L. E./ha	Net income L.E./ha
I1 1.2 of ETo	P1	0.926	0.432	1.358	-1.002	1.002	33739	22180
	P2	0.904	0.512	1.415	-0.842	0.842	33941	22208
	P3	0.855	0.714	1.569	-0.888	0.888	34670	22589
	P4	1	-	1			31224	20186
	P5	-	1	1			11183	4579
I2 1.0 of ETo	P1	0.929	0.429	1.358	-0.985	0.985	33148	21588
	P2	0.890	0.562	1.452	-1.062	1.062	33387	21653
	P3	0.844	0.687	1.530	-0.822	0.822	33337	21256
	P4	1	-	1			30673	19634
	P5	-	1	1			10862	4257
I3 0.8 ETo	P1	0.848	0.341	1.189	-0.900	0.900	27785	16225
	P2	0.820	0.521	1.341	-1.144	1.144	28725	16991
	P3	0.804	0.614	1.418	-0.798	0.798	29144	17063
	P4	1	-	1			28856	17817
	P5	-	1	1			9694	3090

P1= 100% peanut + 25% sunflower, P2= 100% peanut + 33% sunflower, P3= 100% peanut + 50% sunflower, P4= sole peanut, P5= sole sunflower

CONCLUSION

Water equivalent ratios and land equivalent ratios of all intercropping patterns were greater than unity, which implied that higher water and land productivity can be attained under intercropping systems. Values of water use efficiency among irrigation treatments showed the superiority of intercropping because of its higher yield than that of sole crops. The highest value of water equivalent ratio (1.255) was produced with P3 under 1.0 ETo treatment, on average basis of both growing seasons. The maximum value of land equivalent ratio (1.569) and net income (L.E. 22589/ha) were recorded with P3 intercropping patterns irrigated with 1.2 of ETo treatment, as average of both seasons. Thus, we recommend the implementation of P3 intercropping system, namely 100% peanut + 50% sunflower irrigated with 1.2 of ETo to increase land productivity in sandy soil under sprinkler irrigation or with 1.0 of ETo under water security where yield lose were low. Under severe drought conditions, we recommended application of 0.8 ETo.

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الملخص العربي

تعظيم إنتاجية الأرض والمياه بتحميل دوار الشمس مع الفول السودانى تحت الرى بالرش

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يعتبر نمط التحميل الملائم واستخدام نظام الري عالي الكفاءة وجدولة الري من التحديات الحالية في قطاع الزراعة لتوفير المياه وزيادة إنتاج المحاصيل والعائد الأقتصادى . لذلك أجريت تجربة حقلية تحت نظام الرى بالرش بالأراضى الرمليه بمحطة بحوث الأسماعلية– مصر، خلال موسمى ٢٠١٦ و٢٠١٧. لدراسة تاثيرثلاث معاملات للرى على المحصول والمكافئ المائى والأرضى لأنماط الزراعة النقيه والمحمله لمحصولى الفول السودانى ودوار الشمس. كان التصمييم الأحصائى المستخدم شرائحى فى ثلاث مكررات. كانت معاملات الرى على النحو التالى بكميات مياه تعادل ١,٢ و١,٠ و٠,٨ من البخر نتح المرجعى مع أنماط التحميل: (١) ١٠٠% فول سودانى + ٢٥% دوار الشمس، (٢) ١٠٠% فول سودانى + ٣٣% دوار الشمس، (٣) ١٠٠% فول سودانى +٥٠% دوار الشمس، (٤) الزراعه النقية للفول السودانى ، (٥) الزراعة النقية لدوار الشمس. وكانت أهم النتائج المتحصل عليها: أثرت معاملات الرى معنويا على جميع الصفات المدروسه للفول السودانى ودوار الشمس. أدى الرى بكميه مياه تعادل ١,٢ من البخر نتح المرجعى إلى تسجيل أعلى القيم لصفات النمو الخضرى والمحصول و مكوناتة بالإضافة إلى محصول الزيت/هكتار لكلا المحصولين، مع إنخفاض النسبة المئوية لشدة الأضاءة. أدى تحميل دوار الشمس مع الفول السودانى إلى إنخفاض إنتاجية كلا المحصولين مقارنة بالزراعة النقية. تحميل دوار الشمس بأقل كثافة نباتية (P1) مع الفول السودانى حقق أعلى محصول من القرون والزيت للهكتار مقارنة بأنماط التحميل الأخرى P2 وP3. سجلت معاملة الرى I 1 (١,٢ من البخر نتح) أعلى كمية مياه مضافة (٤٥١ و٤٣٩ مم) وكميه مياه مستهلكة (٤٠٣ و ٤١٥) مع نمط التحميل P3 (١٠٠% فول + ٥٠% دوار)، فى الموسمين على التوالى. أدى تحميل دوار الشمس مع الفول السودانى تحت جميع معاملات الرى المختلفة إلى زيادة كفاءة إستخدام مياه الرى (كجم / مم أو وحدة حبوب/مم) مقارنة بالزراعة النقية.

حيث سجلت أعلى قيمة لمكافئ إستغلال المياه WER (١,٢٥٥) برى نظام التحميل P3 بكمية مياه تعادل (١,٠ من البخر نتح المرجعى) كمتوسط للموسمين. حقق نمط التحميل ١٠٠% فول سودانى + ٥٠% دوار شمس عند الرى بأعلى كمية مياه رى I 1 (١,٢ من البخر نتح المرجعى) أعلى مكافى لأستغلال الأرض (١,٥٦٩) وأعلى صافى دخل (٢٢٥٨٩جنية/هكتار)، متوسط لكلا الموسمين. كان محصول دوار الشمس هو السائد بينما الفول السودانى هو المحصول المسود. وعلى ذلك نوصى بتنفيذ نظام التحميل P3 (١٠٠% فول سودانى + ٥٠% دوار شمس) والمروى بكمية مياه تعادل ١,٢ من البخر نتح المرجعى (I1) لزيادة إنتاجية وحدة الأرض فى الأراضى الرملية تحت نظام الرى بالرش، بينما نوصى بتنفيذ نظام التحميل P3 والرى بكمية مياه تعادل ١,٠ من البخر نتح المرجعى (I2) لتوفيرمياه الرى (مع إنخفاض قليل فى المحصول) ، وفى حالة ظروف الجفاف الشديدة (ندرة المياه) نوصى بالرى بكمية مياه تعادل ٠,٨ من البخرنتح مرجعى.