Intercropping Systems of Sunflower and Peanut under Different Irrigation Regimes and Potassium Fertilizer Levels

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TWO FIELD experiments were conducted at the research farm of Ismailia Governorate, Egypt during 2016 and 2017 summer seasons. This study was used to determine the suitable spatial arrangement of sunflower and peanut in an intercropping system under three irrigation water levels and three fertilizer (K) levels on yield, the land and water equivalent ratios and farmer's net income.

The three irrigation treatments (0.7, 1.0 and 1.2ETo), the three K fertilizer levels (57, 86 and 114K_2O kg/ha) and the four intercropping systems of sunflower and peanut (different spatial arrangements) were arranged in a strip split plot with three replications.

The results indicated that application of 1.0 and 1.2ETo had similar effect on most of yield traits of the intercrops. Application of 114K_2O kg/ha had the highest values of most yield traits of the intercrops. Intercropping sunflower with peanut (S1), where peanut seeds were sown on both sides of all the raised beds, sunflower seeds were sown on one row above the raised beds and the following bed was left without intercropping gave the highest values of peanut and sunflower yield and its attributes.

In conclusion, the highest yield, land and water equivalent ratios, as well as farmer's net income can be obtained under 1.2ETo, 114K_2O kg/ha and S1 intercropping system.

Keywords: Drip irrigation, Intercropping sunflower with peanut, K fertilizer, Land equivalent ratio and water equivalent ratio, Farmer's net return.

Introduction

Edible oils ranked second after wheat with respect to importation in Egypt. According to the Ministry of Agriculture and Land Reclamation in Egypt, the current edible oil production-consumption gap is estimated by 97%. Due to limited arable areas in the Nile Delta and Valley, emphasis should be given towards cultivation oil seed crops in new reclaimed areas to decrease oil production gap. Sunflower (*Helianthus annuus* L.) oil is one of the most popular edible oil in Egypt. However, its cultivated area is declining due to competition with other profitable crops. To solve this problem, sunflower can be intercropped with peanut (*Arachis hypogaea* L.) (two important crops in Egypt). Peanut is one of the most important suitable crops to be cultivated under sandy soil conditions. According to El-Sawy et al. (2006), intercropping sunflower in peanut cultivated area could be a solution to increase the production of oil seed per unit area. Only three studies were done locally to study the effect of intercropping sunflower as a companion crop with peanut as a main crop. Abd El-Zaher et al. (2009) reported that highest value for yield of peanut were obtained with 100% of peanut planting density and 33% of sunflower planting density. A reduced sunflower planting density, namely 25% was found to result in the highest peanut yield in sunflower intercropped with peanut system (El-Mehy et al., 2018).

Water resources in Egypt are becoming limited and scarce. To overcome this problem,

introduction of irrigation system with high application efficiency, namely drip system is essential. To obtain highest yield value, increasing application of irrigation according to crop needs is required (Taha, 2012). In addition, increasing water use efficiency is another important aspect in facing water scarcity. Drip irrigation has the potential to provide high yields, conserve soil, water, and energy in the meantime. The major benefits of drip irrigation include accurate placement of water and chemicals, reduction of labor requirement, and reduction of water runoff, as well as erosion (Sorensen & Butts, 2014).

In peanut production, irrigation in the appropriate times is important to guarantee stabilize production with high quality (Zhu et al., 2004). Because biomass productivity per unit of consumed water is known as water use efficiency (Krishnamurthy et al., 2007), increasing water use efficiency has an important role under water scarcity condition (Ouda & Zohry, 2018).

To maximize crop yields, the amount of irrigation water and its timing are important aspects to attain the efficient use of this valuable resource (Sezen et al., 2011). It is known that availability of water can limit crop production (Genc et al., 2013). However, improving water use efficiency is necessary for securing sustainability of food production many parts of the world, particularly in semiarid areas (Medrano et al., 2015). Because of the limited water resources, changing production objectives from attaining potential yield per unit of land to attaining potential yield per unit of water is essential (Kadasiddappa et al., 2017).

Potassium contributes in various metabolic functions in plants including activation of some enzymes, photosynthesis, and protein synthesis (Hawkesford et al., 2012). It also have an important role in the development, and production (Raza et al., 2013). Potassium is one of the most important nutrients needed for peanut (Veeramani & Subrahmaniyan, 2012). Potassim can help in mitigating water stress in peanut and its adverse effects (Umar, 2006). In soils with low potassium contents, it is peanut plants usually are highly responsive to potassium application (Almeida et al., 2015). Furthermore, Asadi (2010) indicated that application of potassium fertilizer increased sunflower yield.

Few researches were done on sunflower intercropping with peanut. However, appropriate sunflower and peanut intercropping system under application of required irrigation amounts using drip system and K fertilization and its role in maximize land and water use efficiency have not been studied before. Thus, the objective of this investigation was to determine the suitable spatial arrangement for sunflower and peanut in an intercropping system under different irrigation water amounts and K fertilizer levels on yield, the land and water equivalent ratios and farmer's net income.

Materials and Methods

Two field experiments were conducted at the research farm of Ismailia governorate (Latitude 30° 35' 30" N, Longitude 32° 14' 50" E and elevation for sunflower and peanut in an intercropping system under different of 10m above the sea level), Agricultural Research Center, Egypt during 2016 and 2017 summer seasons. The objective of this investigation was to determine the suitable spatial arrangement irrigation water amounts and potassium (K) fertilizer levels effect on yield production, the land and water equivalent ratios, and farmer's net income. The treatments were the combinations of three irrigation water levels (I_1= 0.7, I_2= 1.0 and I_3= 1.2ETo), three K fertilizer rates (K_1= 57, K_2= 86 and K_3= 114K_2O kg/ha) and four sunflower and peanut intercropping systems in a strip split plot design with three replications.

The studied intercropping systems were implemented either on raised beds (1.2m width) or on ridges (0.6m width). In case of raised beds, peanut seeds were sown in holes on both sides of all the raised beds using two seeds in each hole and the distance between holes were 20cm. Whereas, in case of cultivation on ridges, peanut seeds were sown on one side only with the above distance.

Sunflower seeds were sown in holes using one seed with 20 or 40cm distance depending on the studied system. The studied intercropping systems are presented in Fig. 1 as follows:

S_1= Peanut seeds were sown on all the raised beds. Sunflower seeds were sown above one of the raised beds and the following raised bed was left without intercropping sunflower seeds. The distance between seeds was 20cm.
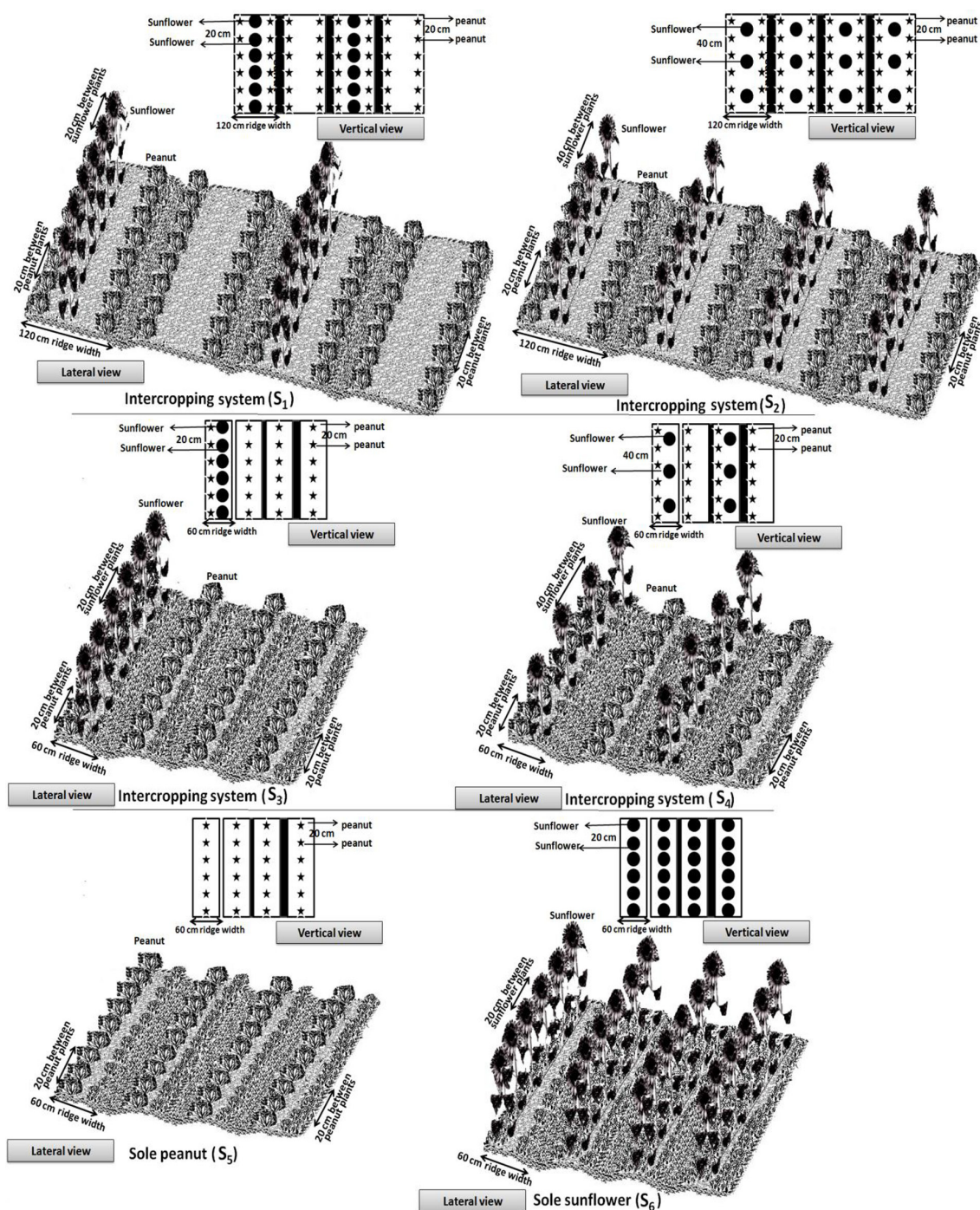
Fig. 1. Intercropping systems of sunflower with peanut and sole cultures of both crops.

S_2= Peanut seeds were sown on all the raised beds. Sunflower seeds were sown above all the raised beds, with 40cm distance.

S_3= Peanut seeds were sown on all ridges on one side and sunflower seeds were sown on the other side, with 20cm distance. The following three

ridges were left without intercropping sunflower seeds.

S_4= Peanut seeds were sown on all ridges on one side and sunflower seeds were sown on the other side with 40cm distance. The following ridge was left without intercropping sunflower seeds.

S_5= Sole peanut was sown with 100% of its recommended planting density on ridges with 20cm planting spacing.

S_6= Sole sunflower was sown with 100% of its recommended planting density on ridges with 20cm planting spacing.

Sole peanut and sole sunflower plants were irrigated with 1.2ETo and received K_2 (86K_2O kg/ha).

The yield and its components for each crop were only used to estimate comparative relationships and did not include in the statistical analysis. The studied sunflower and peanut intercropping patterns were planted with 166,600 and 20,825 plants per hectare, represented 100% and 25% of peanut and sunflower recommended planting densities. Irrigation water treatments were randomly assigned to the horizontal plots, K fertilizer levels were allocated in vertical plots and intercropping systems were distributed in sub plots. Plot area was 21.6m². Each sub plot consisted of 12 ridges, 3.0m long and 0.6m wide or 6 raised beds 3.0m long and 1.2m wide. The soil of the experimental area is sandy texture with an average bulk density of 1.67g/cm³ and is alkaline in reaction with pH value of 8.20.

Average soil electrical conductivity in the saturated paste extract, over 0-60cm depth, was about 0.33dS/m. The electrical conductivity of irrigation water was 0.50dS/m and pH value was 7.55. Chemical and physical soil analyses were conducted by the standard methods described by Tan (1996). The analysis reveals that available NPK was 10.4, 16.9 and 64.4ppm in the experimental site. Wheat was the preceding winter crop in both seasons. Calcium super phosphate (15.5% P_2O_5) at rate of 476kg/ha was applied during soil preparation in the two summer seasons. Peanut cultivar Ismailia1 (semi-erect) and sunflower variety Sakha 53 were used and sown on May 26th and May 30th at 2016 and 2017 summer seasons, respectively. In the two seasons, peanut seeds were inoculated by *Bradyrhizobium* before seeding it. Nitrogen fertilizer was added for sole peanut at a rate of 83.3kg N/ha as ammonium nitrate (33.5% N). Furthermore, nitrogen fertilizer was added for sole sunflower at a rate of 142.8kg N/ha as ammonium nitrate. With respect to sunflower intercropped with peanut, nitrogen fertilizer was added at a rate of 120.9kg N/ha as ammonium

nitrate. Calcium sulfate at the rate of 1190kg/ha was applied for peanut after 35 days from peanut sowing. Recommended cultural practices for growing each crop were implemented as provided by the Egyptian Ministry of Agriculture.

The studied traits
Peanut studied traits
At harvest, the following traits were measured on represented ten guarded plants from each sub plot: plant height (cm), pod weight per plant (g) and shelling percentage. Pod yield of peanut per hectare (ton) was recorded on the basis of experimental plot area by harvesting all plants of each sub plot. Seed samples of fifty grams were grinded into fine powder and stored in brown glass bottles for oil seed content according to the method described by A.O.A.C. (1995). Oil yield per hectare (kg) was calculated by multiplying seed oil content (%) by seed yield per hectare (kg).

Sunflower studied traits
At harvest, the following traits were measured on represented ten guarded plants from each sub plot: Plant height (cm), 1000 seed weight (g) and seed yield per head (g). Seed yield per hectare (kg) was recorded on the basis of experimental sub plot area by harvesting all plants of each plot. Seed samples of fifty grams were grinded into fine powder and stored in brown glass bottles for oil seed content determination according to the method described by A.O.A.C. (1995). Oil yield per hectare (kg) was calculated by multiplying seed oil content (%) by seed yield per hectare (kg).

Land equivalent ratio (LER)
Feng et al. (2016) indicated that "LER refers to the ratio between the benefit from the mixed-cropping of two or more than two crops in the same field and the benefit from the monoculture of every crop".

$$LER = (Y_{ab}/Y_{aa}) + (Y_{ba}/Y_{bb}) \qquad [1]$$

where: Y_{aa}= Pure stand yield of crop a (peanut), Y_{bb}= Pure stand yield of crop b (sunflower), Y_{ab}= Intercrop yield of crop a (peanut) and Y_{ba}= Intercrop yield of crop b (sunflower).

Water relation measurements
Irrigation water was applied every three days using the drip lateral lines connected to the sub-main line. Each lateral line is 20m long and spaced at 0.7m on the sub-main and is equipped

with build-in emitters of 2L/h discharge rate spaced at 0.3m on the lateral lines. A differential pressure tank was connected to the drip irrigation system to inject fertilizer via irrigation water. Evapotranspiration values (ETo) were calculated using BISm model (Snyder et al., 2004). The amounts of applied irrigation water were calculated according to the equation given by Vermeiren & Jopling (1984) as follows:

$$AIW = \frac{ETo \times I}{Ea\,(1-LR)} \quad [2]$$

where: AIW = depth of applied irrigation water (mm), ETo= reference evapotranspiration (mm/day). I= irrigation intervals (days), Ea= irrigation application efficiency of drip system (Ea = 90% in the first seasons and 93% in the second season). LR= leaching requirements (10%). Crop water use was estimated by the method of soil moisture depletion according to Majumdar (2002) as follows:

$$WCU = \sum_{i=1}^{i-4} \frac{\theta 2 - \theta 1}{100} \times Bd \times d \quad [3]$$

where: WCU= Water consumptive use or actual evapotranspiration, ETo (mm), i= Number of soil layer, $\theta 2$= Soil moisture content after irrigation, (%, by mass), $\theta 1$= Soil moisture contents just before irrigation, (%, by mass), Bd= Soil bulk density (g/cm^3) and d= Depth of soil layer (mm).

Water equivalent ratio was also calculated. As stated by Mao et al. (2012), "water equivalent ratio quantify 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" as follows:

$$WER = WER_A + WER_B = [(Yint,_A/WU_{int})/ (Y_{mono'A}/WU_{mono'A})] + [(Y_{int'B}/WU_{int})/(Y_{mono'B}/ WU_{mono'B})] \quad [4]$$

where: WU_{int}, $WU_{mono'A}$ and $WU_{mono'B}$= Water use efficiency of whole intercropping system, A and B in monocultures, respectively, Y_{int}, $Y_{mono'A}$ and $Y_{int'B}$= Yield of whole intercropping system, A and B in monocultures, respectively.

If the WER>1, it suggests that water utilization of intercropping is higher than that of monoculture. If WER<1, it shows that water utilization of intercropping is lower than that of monoculture (Mao et al., 2012).

Farmer net returns

Farmer's benefit (US$) was calculated as a difference between total net returns from intercropping and sole crops. Sunflower and peanut seeds prices presented by Bulletin of Statistical Cost Production and Net Return (2017) were used. Net returns were calculated by subtraction the sum of fixed cost of peanut plus variable costs of both crops according to irrigation water treatments and K fertilizer levels and intercropping systems.

Statistical analysis

Analysis of variance of the obtained results of each season was performed. The homogeneity test was conducted of error mean squares and accordingly, the combined analysis of the two experimental seasons was carried out. The measured variables were analyzed by ANOVA. Mean comparisons were performed using the least significant differences (L.S.D) test with a significance level of 5% (Gomez & Gomez, 1984). The presented results are combined results of yield and its components, as well as, LER, water relations and farmer net returns of the two growing seasons.

Results

Effect of irrigation water amounts, potassium fertilizer, intercropping systems and their interactions on peanut

The results in Table 1 indicate that pods weight per plant, shelling percentage, and seed oil content were significantly affected by irrigation water treatments, potassium fertilizer levels (K) and the interaction between irrigation water treatments and potassium fertilizer levels. Whereas, pod and oil yields per hectare were significantly affected by irrigation water treatments and potassium fertilizer levels only. Application of 1.0ETo and K$_3$ fertilizer recorded the highest shelling percentage. However, the highest pods weight per plant and seed oil content were obtained by the interaction of 1.2ETo and K$_3$ fertilizer. Plant height was not significantly affected by the studied treatments. Pod yield and its attributes were not significantly affected by intercropping systems. Furthermore, these attributed were not significantly affected by the interaction between irrigation water treatments, potassium fertilizer levels, and intercropping systems. In addition, there were no significant differences between application of 1.0 and the 1.2ETo for all the studied peanut traits.

TABLE 1. Effect of irrigation water treatments, potassium fertilizer levels, intercropping systems and their interactioN.S on peanut pod yield and its attributes averaged on the two growing seasons.

Treatments		Plant height (cm)					Pods weight per plant (g)					Pod yield per hectare (ton)				
		S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
I_1	K_1	49.7	49.6	49.8	49.7	49.7	35.6	35.7	35.7	35.7	35.7	2.52	2.41	2.43	2.38	2.43
	K_2	49.9	49.9	50.0	49.9	49.9	36.3	36.3	36.2	36.2	36.3	2.63	2.51	2.55	2.45	2.53
	K_3	50.0	49.9	50.0	49.9	49.9	38.1	38.1	38.2	38.1	38.1	2.70	2.61	2.64	2.53	2.62
Mean		49.9	49.8	49.9	49.9	49.9	36.7	36.7	36.7	36.7	36.7	2.62	2.51	2.54	2.45	2.53
I_2	K_1	50.1	50.1	50.1	50.1	50.1	39.4	39.3	39.4	39.3	39.3	3.19	3.09	3.08	3.07	3.10
	K_2	50.0	49.9	50.1	50.0	50.0	40.7	40.7	40.8	40.7	40.7	3.29	3.15	3.19	3.13	3.19
	K_3	50.1	50.0	50.0	50.0	50.0	41.3	41.7	41.8	42.1	41.7	3.35	3.22	3.28	3.16	3.25
Mean		50.1	50.0	50.1	50.1	50.0	40.4	40.6	40.6	40.7	40.6	3.27	3.15	3.18	3.12	3.18
I_3	K_1	50.1	50.0	49.9	50.0	50.0	39.6	39.7	39.5	39.4	39.5	3.22	3.09	3.09	3.04	3.11
	K_2	49.9	50.0	50.0	50.2	50.0	40.8	40.7	40.8	40.8	40.8	3.30	3.17	3.26	3.13	3.21
	K_3	50.4	50.2	50.0	50.5	50.3	41.9	41.8	41.9	42.2	41.9	3.34	3.22	3.29	3.19	3.26
Mean		50.1	50.1	50.0	50.2	50.1	40.8	40.7	40.7	40.8	40.7	3.28	3.16	3.21	3.12	3.19
Average K_1		50.0	49.9	49.9	49.9	49.9	38.2	38.2	38.2	38.1	38.2	2.97	2.86	2.86	2.83	2.88
Average K_2		49.9	49.9	50.0	50.1	50.0	39.2	39.2	39.3	39.3	39.3	3.07	2.94	3.00	2.90	2.98
Average K_3		50.1	50.1	50.0	50.1	50.1	40.4	40.5	40.6	40.8	40.6	3.13	3.01	3.07	2.96	3.04
Average S		50.0	50.0	50.0	50.0	50.0	39.3	39.3	39.4	39.4	39.3	3.06	2.94	2.98	2.89	2.97
$LSD_{0.05}$ Irrigation (I)						N.S					0.24					0.45
$LSD_{0.05}$ K fertilizer (K)						N.S					0.24					0.15
$LSD_{0.05}$ Intercropping system (S)						N.S					N.S					N.S
$LSD_{0.05}$ I x K						N.S					0.37					N.S
$LSD_{0.05}$ I x S						N.S					N.S					N.S
$LSD_{0.05}$ K x S						N.S					N.S					N.S
$LSD_{0.05}$ I x K x S						N.S					N.S					N.S
Sole peanut						49.33					44.96					3.43

TABLE 1. Cont.

Treatments		Shelling (%)					Seed oil content (%)					Oil yield per hectare (ton)				
		S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
I_1	K_1	66.2	66.4	66.6	66.6	66.5	45.3	45.4	45.2	45.4	45.3	0.75	0.72	0.73	0.71	0.73
	K_2	66.3	66.7	66.8	66.7	66.6	46.3	46.5	46.8	46.8	46.6	0.80	0.77	0.79	0.75	0.78
	K_3	67.4	67.1	66.7	66.6	66.9	46.2	46.2	46.2	46.2	46.2	0.84	0.80	0.81	0.77	0.80
Mean		66.6	66.7	66.7	66.6	66.7	46.0	46.0	46.1	46.1	46.1	0.80	0.76	0.77	0.74	0.77
I_2	K_1	68.2	68.5	68.5	68.4	68.4	49.6	49.7	49.5	49.7	49.6	1.07	1.05	1.04	1.04	1.05
	K_2	69.6	69.6	69.1	69.2	69.4	49.6	49.3	49.3	49.7	49.5	1.13	1.08	1.08	1.07	1.09
	K_3	69.6	69.6	69.8	69.2	69.6	49.6	49.3	49.8	49.8	49.6	1.15	1.10	1.13	1.08	1.11
Mean		69.2	69.2	69.1	68.9	69.1	49.6	49.4	49.5	49.8	49.6	1.12	1.07	1.08	1.06	1.08
I_3	K_1	68.2	68.2	68.2	68.4	68.2	49.3	49.9	49.4	49.3	49.5	1.07	1.04	1.03	1.02	1.04
	K_2	69.9	69.7	69.8	69.6	69.7	49.3	49.2	49.3	49.5	49.3	1.13	1.08	1.11	1.07	1.10
	K_3	69.6	69.2	69.3	69.4	69.4	49.7	49.9	50.0	49.6	49.8	1.14	1.10	1.14	1.09	1.12
Mean		69.2	69.0	69.1	69.1	69.1	49.4	49.7	49.5	49.5	49.5	1.11	1.07	1.09	1.06	1.08
Average K_1		67.5	67.7	67.8	67.8	67.7	48.1	48.3	48.0	48.2	48.1	0.96	0.94	0.93	0.92	0.94
Average K_2		68.6	68.6	68.6	68.5	68.6	48.4	48.3	48.5	48.7	48.5	1.02	0.97	0.99	0.96	0.99
Average K_3		68.9	68.6	68.6	68.4	68.6	48.5	48.5	48.7	48.6	48.5	1.04	1.00	1.02	0.98	1.01
Average S		68.3	68.3	68.3	68.2	68.3	48.3	48.4	48.4	48.5	48.4	1.01	0.97	0.98	0.95	0.98
$LSD_{0.05}$ Irrigation (I)						0.34					0.36					0.15
$LSD_{0.05}$ K fertilizer (K)						0.25					0.30					0.05
$LSD_{0.05}$ Intercropping system (S)						N.S					N.S					N.S
$LSD_{0.05}$ I x K						0.42					0.49					N.S
$LSD_{0.05}$ I x S						N.S					N.S					N.S
$LSD_{0.05}$ K x S						N.S					N.S					N.S
$LSD_{0.05}$ I x K x S						N.S					N.S					N.S
Sole peanut						71.66					51.24					1.25

With respect to application of 0.7ETo, pods weight per plant, pod yield per hectare, shelling percentage, oil content in the seed and oil yield per hectare were significantly reduced by 10.89, 26.08, 3.59, 7.37 and 40.25%, respectively, compared to the values obtained from application of 1.2ETo. With respect to the K_2 fertilizer, pods weight per plant, pod yield per hectare and oil yield per hectare were significantly decreased by 3.30, 2.01 and 2.02%, respectively, in comparison with those of K_3 fertilizer. Comparison between sole and intercropped peanut reveal that pod yield and its attributes were reduced by intercropping system, except for plant height. The reduction in intercropped peanut yield was found to be 13%, compared to sole peanut.

Effect of irrigation water treatments, potassium fertilizer levels, intercropping system and their interactions on sunflower

The results in Table 2 indicate that plant height was significantly affected by the irrigation treatments, potassium levels, intercropping systems, the interaction between irrigation and potassium levels, and the interaction between irrigation treatments and intercropping systems. Furthermore, 1000 seed weight had similar trend as plant height, except for the interaction between irrigation treatments and intercropping systems. Similarly, head seed weight was significantly affected by irrigation treatments, potassium levels, the interaction between irrigation treatments and potassium levels, the interaction between irrigation treatments and intercropping systems, as well as the interaction between irrigation treatments, potassium levels and intercropping systems. In addition, seed and oil yields per hectare were significantly affected by irrigation water treatments, potassium fertilizer levels and intercropping systems. Finally, seed oil content was significantly affected by irrigation treatments, potassium levels and the interaction between both of them. Increasing the amount of applied water from 0.7 to 1.2ETo caused significant increase in all the studied sunflower traits. The results also show that there were no significant differences between the application of 100 and 1.2ETo on plant height, seed yield per hectare, seed oil content and oil yield per hectare in the data of both growing seasons. With respect to 0.7ETo, 1000 seed weight, head seed weight, seed yield per hectare, seed oil content and oil yield per hectare were significantly decreased by 13.14, 7.14, 50.00, 3.52 and 55.10%, respectively, compared

with the values obtained under 1.0ETo (Table 2). Moreover, there were no significant differences between K_2 and K_3 fertilizer on plant height, seed and oil yields per hectare. S_1 Intercropping system had the highest plant height, 1000 seed weight, and head seed weight, seed yield, and oil yield per hectare, compared to S_2 and S_3. The interaction between 1.0ETo and K_3 fertilizer resulted in the highest plant height and seed oil content, compared to the other interaction. However, the highest 1000 seed weight and head seed weight were obtained by the interaction between 1.2ETo and K_3 fertilizer. The interaction between application of 1.2 ETo and S_1 intercropping system recorded the highest head seed weight, compared to the others. In addition, the interaction between 1.2ETo, K_3 fertilizer and S_1 intercropping system recorded the highest 1000-seed weight and head seed weight compared to the others.

Relative yield and land equivalent ratio (LER)

The results in Table 3 indicate that the relative yield of peanut was significantly affected by irrigation water treatments, and potassium levels, whereas relative yield of sunflower was significantly affected by irrigation water treatments, potassium levels and intercropping systems. LER was significantly affected by irrigation water treatments, potassium fertilizer, intercropping systems and the interaction between irrigation water treatments and potassium. fertilizer levels. The value of LER was 0.87 for S_4 intercropping system that received irrigation amount of 0.7ETo and K_1 fertilizer. It was 1.36 for S_1 intercropping system that received irrigation amount of 1.2ETo and K_3 fertilizer, thus, land productivity was increased by 36% (Table 3).

Water relations of peanut and sunflower systems

Water consumptive use and water equivalent ratio were significantly affected by irrigation treatments, potassium levels and by the interaction between irrigation treatments and potassium levels. An increase in water consumptive use of peanut and sunflower intercropping system occurred when the applied irrigation water was increased from 0.7 to 1.2ETo (Table 4).

In all the studied intercropping systems, the values of water equivalent ratio were higher than 1. Under the application of 0.7ETo, K_1 fertilizer and S_4 intercropping systems, the lowest values of water equivalent ratio were obtained. Whereas, the highest values of water equivalent ratio were

obtained under the application of 1.2ETo, K_3 fertilizer and S_1 intercropping system. Thus, an increase in the value of the productivity of the unit of water between 52-56% can be obtained under 1.2ETo, K_3 fertilizer and S_1 intercropping system (Table 4).

Farmer revenue

The total and net incomes of intercropping sunflower with peanut as compared to sole peanut is shown in Table 5. The income of peanut was significantly affected by irrigation treatments only, whereas the income of sunflower, total income and net income were significantly affected by irrigation treatments, potassium levels and intercropping systems. The interaction between irrigation treatments and potassium levels were significantly affect the total income. Total income of intercropped sunflower with peanut varied between treatments from US$ 1195 to 1767 per hectare as compared with sole peanut (US$ 1557 per hectare). Furthermore, net income of intercropped sunflower with peanut varied between treatments from US$ 608 per hectare (0.7 ETo, K_1 fertilizer and S_4 intercropping system) to US$1142 per hectare (1.2ETo, K_3 fertilizer and S_1 intercropping system) as compared to sole peanut (US$ 943 per hectare), which is more profitable than sole peanut cultivation for Egyptian farmers.

Discussion

The few previous studies on intercropping sunflower with peanut in Egypt dealt with either the appropriate sunflower planting density (Abd El-Zaher et al., 2009 and El-Mehy et al., 2018) and/or appropriate irrigation amounts (El-Mehy et al., 2018). Thus, this investigation was done with the aim to determine the suitable arrangement for sunflower and peanut in an intercropping system, the required irrigation water amounts, and the required potassium fertilizer. For peanut, application of 0.7ETo resulted in reduction pods weight per plant, pod yield per hectare, shelling percentage, seed oil content and oil yield per hectare. This result could be attributed to water stress reduced vegetative and reproductive growth through its effects on reducing number and size of leaves, as well as pollination and seed growth. In this concern, Junjittakarn et al. (2014) reported that photosynthesis and plant growth were reduced as a result of water deficits, which negatively affected seed formation and development, total seed yield, pods per plant and seeds per pod (Arruda

et al., 2015). Our results show that there was no significant difference between the application of 1.0 and 1.2ETo on plant height, pod weight per plant, pod yield per ha, shelling, seed oil content and oil yield per ha, which offer an opportunity to save on the applied irrigation water under weather and soil condition of our experiment. The above peanut traits were increased by increasing irrigation water and K fertilizer, which may be attributed to increase of K^+ availability in the soil under non water stress conditions. Raza et al. (2013) indicated that transporting of much of the K^+ through the diffusion process to the root surface is highly dependent on water in the soil. Reddy et al. (2011) also stated that it is directly affecting crop development. In addition, K^+ plays an important role in hormonal balance, especially increasing auxin level, which an important hormone for plant growth (Rubio et al., 2009). Furthermore, Alaloosy (2002) indicated that K^+ is an important element in increasing lipids synthesis in oil crops, which explain the increase in seed oil content and oil yield under K_3 fertilizer.

Our results also indicate that application of 1.0ETo and K_3 fertilizer recorded the highest seed yield per plant and shelling percentage. However, the highest values of pods weight per plant, and seed oil content were obtained by the interaction of 1.2ETo and K_3 fertilizer. This could be attributed to availability of water in rhizosphere area, which increase of K^+ availability. Nájera et al. (2015) indicated that there is a coupling mechanism between irrigation and fertilizer, where irrigation changes soil moisture contents, thus influences the transformation of fertilizer. The evidenced beneficial effect of K^+ fertilization on peanut crop in our experiment was due to the low levels of exchangeable K^+ in the sandy soil the experimental plots. Therefore, increased peanut seed production under K_3 fertilizer could be related to the known role of K^+ in many physiological and metabolic processes, including photosynthesis, osmoregulation, transport of nutrients, transport and storage of carbohydrates, nitrogen absorption and synthesis of proteins (Raza et al., 2014).

The results also show that application of K_3 fertilizer did not help peanut plants to withstand the imposed water stress, where yield and its attributes were highly deceased, compared to the application of more water and K fertilizer.

TABLE 2. Effect of irrigation water treatments, potassium fertilizer levels, intercropping systems and their interactioN.S on sunflower seed yield and its attributes averaged on the two growing seasons.

Treatments		Plant height (cm)					1000 seed weight (g)					Seed weight per head (g)				
		S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
I_1	K_1	123.5	122.3	121.4	120.4	121.9	46.3	48.9	46.3	45.8	46.1	57.9	57.2	57.8	57.1	57.5
	K_2	128.5	126.7	127.7	126.7	127.4	49.5	49.2	49.5	49.1	49.3	59.2	58.8	59.1	58.7	58.9
	K_3	129.7	127.7	128.4	126.7	128.1	50.6	50.7	50.4	50.6	50.6	60.7	59.3	60.6	59.4	60.0
Mean		127.3	125.6	125.8	124.6	125.8	48.8	48.6	48.7	48.5	48.7	59.2	58.4	59.2	58.4	58.8
I_2	K_1	139.2	138.8	140.6	139.6	139.5	52.9	52.5	52.9	52.5	52.7	61.2	60.9	61.2	60.8	61.0
	K_2	143.6	141.8	144.9	143.1	143.4	56.1	55.7	56.0	55.7	55.9	63.6	63.2	63.5	63.2	63.4
	K_3	144.5	143.4	145.4	144.7	144.5	57.0	56.3	57.2	56.6	56.8	64.3	64.6	64.3	64.7	64.5
Mean		142.4	141.4	143.6	142.5	142.5	55.3	54.8	55.4	55.0	55.1	63.0	62.9	63.0	62.9	63.0
I_3	K_1	139.3	138.7	140.9	139.6	139.6	56.0	55.3	56.6	56.4	56.1	61.7	61.4	61.6	61.7	61.6
	K_2	143.6	142.7	145.3	144.6	144.0	58.2	57.8	58.1	57.7	58.0	65.1	65.6	65.5	65.5	65.4
	K_3	143.0	141.8	143.7	142.8	142.8	59.4	58.6	59.2	58.6	59.0	66.5	66.4	66.3	66.4	66.4
Mean		141.9	141.0	143.3	142.3	142.1	57.9	57.3	58.0	57.6	57.7	64.4	64.4	64.5	64.5	64.5
Average K_1		134.0	133.2	134.3	133.2	133.7	51.7	51.2	51.9	51.6	51.6	60.3	59.8	60.2	59.9	60.0
Average K_2		138.6	137.1	139.3	138.1	138.3	54.6	54.2	54.6	54.2	54.4	62.6	62.5	62.7	62.5	62.6
Average K_3		139.1	137.6	139.1	138.1	138.5	55.7	55.2	55.6	55.3	55.4	63.8	63.4	63.7	63.5	63.6
Average S		137.2	136.0	137.6	136.5	136.8	54.0	53.6	54.0	53.7	53.8	62.2	61.9	62.2	61.9	62.1
$LSD_{0.05}$ Irrigation (I)						0.77					0.22					0.06
$LSD_{0.05}$ K fertilizer (K)						0.52					0.11					0.11
$LSD_{0.05}$ Intercropping system (S)						0.62					0.18					0.14
$LSD_{0.05}$ I x K						0.91					0.23					0.16
$LSD_{0.05}$ I x S						1.01					N.S					0.20
$LSD_{0.05}$ K x S						N.S					N.S					N.S
$LSD_{0.05}$ I x K x S						N.S					0.65					0.44
Sole sunflower						168.66					54.26					61.43

TABLE 2. Cont.

Treatments		Seed yield per hectare (kg)					Seed oil content (%)					Oil yield per hectare (kg)				
		S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
I_1	K_1	740.3	649.3	700.3	610.0	675.0	33.8	33.7	33.8	33.8	33.8	249.8	219.0	236.4	206.2	227.9
	K_2	876.7	753.3	824.0	734.0	797.0	34.0	34.1	34.0	34.1	34.0	298.2	256.6	280.2	250.2	271.3
	K_3	869.0	768.7	859.0	796.7	823.3	34.3	34.3	34.3	34.2	34.3	297.9	263.3	294.2	272.6	282.0
	Mean	828.7	723.8	794.4	713.6	765.1	34.0	34.0	34.0	34.0	34.0	282.0	246.3	270.3	243.0	260.4
I_2	K_1	1113.3	980.0	1045.3	926.7	1016.3	35.0	35.0	35.0	34.9	35.0	389.1	342.6	365.6	323.6	355.2
	K_2	1302.0	1132.3	1279.3	1111.7	1206.3	35.1	35.2	35.1	35.2	35.1	457.2	398.0	449.4	391.1	423.9
	K_3	1301.0	1129.0	1276.0	1175.3	1220.3	35.5	35.4	35.4	35.5	35.4	461.3	400.0	452.0	416.6	432.5
	Mean	1238.8	1080.4	1200.2	1071.2	1147.7	35.2	35.2	35.2	35.2	35.2	435.9	380.2	422.3	377.1	403.9
I_3	K_1	1121.7	997.7	1105.0	949.7	1043.5	35.1	34.7	34.8	34.8	34.8	394.0	346.4	384.0	330.1	363.6
	K_2	1319.3	1151.0	1309.7	1122.3	1225.6	35.4	35.5	35.5	35.6	35.5	466.9	408.5	465.3	399.6	435.1
	K_3	1334.7	1176.3	1305.7	1203.0	1254.9	35.3	35.5	35.4	35.3	35.4	471.1	417.8	462.1	425.0	444.0
	Mean	1258.6	1108.3	1240.1	1091.7	1174.7	35.3	35.2	35.2	35.2	35.2	444.0	390.9	437.1	384.9	414.2
Average K_1		991.8	875.7	950.2	828.8	911.6	34.6	34.5	34.5	34.5	34.5	344.3	302.7	328.7	286.6	315.6
Average K_2		1166.0	1012.2	1137.7	989.3	1076.3	34.8	34.9	34.9	35.0	34.9	407.4	354.3	398.3	347.0	376.8
Average K_3		1168.2	1024.7	1146.9	1058.3	1099.5	35.0	35.1	35.0	35.0	35.0	410.1	360.3	402.8	371.4	386.2
Average S		1108.7	970.9	1078.3	958.8	1029.1	34.8	34.8	34.8	34.8	34.8	387.3	339.1	376.6	335.0	359.5
$LSD_{0.05}$ Irrigation (I)						35.18					0.19					12.22
$LSD_{0.05}$ K fertilizer (K)						42.21					0.12					13.37
$LSD_{0.05}$ Intercropping system (S)						30.49					N.S					10.71
$LSD_{0.05}$ I x K						N.S					0.22					N.S
$LSD_{0.05}$ I x S						N.S					N.S					N.S
$LSD_{0.05}$ K x S						N.S					N.S					N.S
$LSD_{0.05}$ I x K x S						N.S					N.S					N.S
Sole sunflower						3442.66					34.91					1201.82

TABLE 3. Relative yields of peanut and sunflower and LER under irrigation water treatments, potassium fertilizer levels and intercropping systems averaged on the two growing seasons.

Treatments		Relative yield of peanut					Relative yield of sunflower					LER				
		S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
I_1	K_1	0.73	0.70	0.70	0.69	0.70	0.21	0.18	0.20	0.17	0.19	0.94	0.89	0.91	0.87	0.90
	K_2	0.76	0.73	0.74	0.71	0.73	0.25	0.21	0.23	0.21	0.22	1.02	0.95	0.98	0.92	0.97
	K_3	0.78	0.76	0.76	0.73	0.75	0.25	0.22	0.24	0.23	0.23	1.03	0.98	1.01	0.96	1.00
	Mean	0.76	0.73	0.74	0.71	0.73	0.24	0.21	0.23	0.20	0.22	1.00	0.94	0.97	0.92	0.95
I_2	K_1	0.93	0.90	0.89	0.89	0.90	0.32	0.28	0.30	0.26	0.29	1.25	1.18	1.20	1.16	1.19
	K_2	0.95	0.91	0.93	0.91	0.92	0.37	0.32	0.37	0.32	0.34	1.33	1.24	1.30	1.23	1.26
	K_3	0.97	0.93	0.95	0.92	0.94	0.38	0.32	0.37	0.34	0.35	1.35	1.26	1.32	1.26	1.29
	Mean	0.95	0.91	0.92	0.90	0.92	0.35	0.31	0.34	0.31	0.32	1.31	1.23	1.27	1.22	1.25
I_3	K_1	0.93	0.90	0.90	0.88	0.90	0.32	0.28	0.32	0.27	0.29	1.26	1.19	1.22	1.16	1.19
	K_2	0.96	0.92	0.95	0.91	0.93	0.38	0.33	0.38	0.32	0.34	1.34	1.25	1.33	1.23	1.27
	K_3	0.97	0.93	0.95	0.93	0.94	0.38	0.34	0.37	0.34	0.35	1.36	1.28	1.33	1.27	1.29
	Mean	0.95	0.92	0.93	0.90	0.92	0.36	0.32	0.36	0.31	0.32	1.32	1.24	1.29	1.22	1.25
Average K_1		0.86	0.83	0.83	0.82	0.83	0.28	0.24	0.27	0.23	0.25	1.15	1.08	1.11	1.06	1.10
Average K_2		0.89	0.85	0.87	0.84	0.86	0.33	0.28	0.32	0.28	0.30	1.23	1.14	1.20	1.12	1.17
Average K_3		0.90	0.87	0.88	0.86	0.87	0.33	0.29	0.32	0.30	0.31	1.24	1.17	1.22	1.16	1.19
Average S		0.88	0.85	0.86	0.83	0.85	0.31	0.28	0.31	0.27	0.29	1.21	1.13	1.17	1.12	1.15
$LSD_{0.05}$ Irrigation (I)		0.07					0.09					0.12				
$LSD_{0.05}$ K fertilizer (K)		0.02					0.05					0.08				
$LSD_{0.05}$ Intercropping system (S)		N.S					0.03					0.06				
$LSD_{0.05}$ I x K		N.S					N.S					0.15				
$LSD_{0.05}$ I x S		N.S					N.S					N.S				
$LSD_{0.05}$ K x S		N.S					N.S					N.S				
$LSD_{0.05}$ I x K x S		N.S					N.S					N.S				

TABLE 4. Applied irrigation water (AIW), water use efficiency (WUE) and water equivalent ratio (WER) for peanut and sunflower intercropping systems under irrigation water treatments and potassium fertilizer levels averaged over the two growing seasons.

Treatments		AIW (m³/ha)					WCU (m³/ha)					WER				
		S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
I_1	K_1	3170	3170	3170	3170	3170	2821	2758	2790	2726	2774	1.05	1.03	1.04	1.02	1.03
	K_2	3170	3170	3170	3170	3170	2878	2805	2825	2786	2824	1.07	1.05	1.05	1.04	1.05
	K_3	3170	3170	3170	3170	3170	2886	2829	2853	2790	2839	1.08	1.05	1.06	1.04	1.06
Mean		3170	3170	3170	3170	3170	2862	2797	2823	2767	2812	1.07	1.04	1.05	1.03	1.05
I_2	K_1	3900	3900	3900	3900	3900	3471	3393	3432	3354	3413	1.29	1.26	1.28	1.25	1.27
	K_2	3900	3900	3900	3900	3900	3510	3452	3476	3315	3438	1.31	1.29	1.29	1.23	1.28
	K_3	3900	3900	3900	3900	3900	3549	3480	3510	3276	3454	1.32	1.30	1.31	1.22	1.29
Mean		3900	3900	3900	3900	3900	3510	3441	3473	3315	3435	1.31	1.28	1.29	1.23	1.28
I_3	K_1	4590	4590	4590	4590	4590	4085	3993	4039	3947	4016	1.52	1.49	1.50	1.47	1.50
	K_2	4590	4590	4590	4590	4590	4131	4062	4091	3902	4046	1.54	1.51	1.52	1.45	1.51
	K_3	4590	4590	4590	4590	4590	4177	4096	4131	3856	4065	1.56	1.53	1.54	1.44	1.51
Mean		4590	4590	4590	4590	4590	4131	4050	4087	3902	4042	1.54	1.51	1.52	1.45	1.51
Average K_1		3886	3886	3886	3886	3886	3459	3381	3420	3342	3400	1.28	1.26	1.27	1.24	1.26
Average K_2		3886	3886	3886	3886	3886	3506	3439	3464	3334	3435	1.30	1.28	1.28	1.24	1.27
Average K_3		3886	3886	3886	3886	3886	3537	3468	3498	3307	3452	1.32	1.29	1.30	1.23	1.28
Average S		3886	3886	3886	3886	3886	3501	3429	3461	3328	3429	1.30	1.27	1.28	1.23	1.27
$LSD_{0.05}$ Irrigation (I)											74.19					0.06
$LSD_{0.05}$ K fertilizer (K)											48.96					0.02
$LSD_{0.05}$ Intercropping system (S)											N.S					N.S
$LSD_{0.05}$ I x K											102.63					0.09
$LSD_{0.05}$ I x S											N.S					N.S
$LSD_{0.05}$ K x S											N.S					N.S
$LSD_{0.05}$ I x K x S											N.S					N.S
Sole peanut				4560					4104					1.00		
Sole sunflower				4679					4211					1.00		

TABLE 5. Farmer's revenue resulted from intercropping sunflower with peanut under irrigation water treatments and potassium fertilizer levels averaged over the two growing seasons.

Treatments		Income for peanut (US$/ha)					Income for sunflower (US$/ha)				
		S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
I_1	K_1	1144	1094	1103	1080	1105	139	122	131	114	126
	K_2	1194	1139	1157	1112	1150	164	141	154	137	149
	K_3	1225	1184	1198	1148	1189	163	144	161	149	154
Mean		1189	1139	1153	1112	1148	155	136	149	134	143
I_2	K_1	1448	1402	1398	1393	1410	209	184	196	174	191
	K_2	1493	1430	1448	1421	1448	244	212	240	208	226
	K_3	1516	1461	1489	1434	1475	244	212	239	220	229
Mean		1484	1430	1443	1416	1443	232	203	225	201	215
I_3	K_1	1461	1402	1402	1380	1411	210	187	207	178	196
	K_2	1498	1439	1480	1421	1459	248	216	246	210	230
	K_3	1520	1461	1493	1448	1481	250	221	245	226	235
Mean		1489	1434	1457	1416	1449	236	208	233	205	220
Average K_1		1351	1299	1301	1284	1308	186	164	178	155	170
Average K_2		1395	1336	1361	1318	1352	218	189	213	185	201
Average K_3		1420	1368	1393	1343	1381	219	192	215	198	206
Average S		1387	1334	1351	1314	1346	207	182	202	180	192
$LSD_{0.05}$ Irrigation (I)						288.21					42.13
$LSD_{0.05}$ K fertilizer (K)						N.S					22.67
$LSD_{0.05}$ Intercropping system (S)						N.S					15.35
$LSD_{0.05}$ I x K						N.S					N.S
$LSD_{0.05}$ I x S						N.S					N.S
$LSD_{0.05}$ K x S						N.S					N.S
$LSD_{0.05}$ I x K x S						N.S					N.S
Sole peanut		1557				1557					---

* Prices of peanut: US$ 454 per ton and sunflower: US$ 188 per ton.

TABLE 5. Cont.

Treatments		Total income (US$/ha)					Net income (US$/ha)				
		S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
I_1	K_1	1283	1216	1234	1195	1232	696	629	647	608	645
	K_2	1358	1281	1312	1250	1300	761	684	715	653	703
	K_3	1389	1329	1360	1298	1344	782	722	753	691	737
Mean		1345	1275	1302	1246	1292	746	678	705	650	694
I_2	K_1	1657	1587	1594	1567	1601	1053	983	990	963	997
	K_2	1738	1642	1688	1630	1675	1125	1029	1075	1017	1061
	K_3	1760	1674	1729	1655	1705	1127	1051	1106	1032	1104
Mean		1717	1633	1669	1617	1659	1106	1021	1057	1004	1047
I_3	K_1	1672	1590	1610	1558	1608	1052	970	990	938	987
	K_2	1746	1655	1726	1632	1690	1116	1025	1096	1002	1059
	K_3	1770	1683	1739	1674	1717	1142	1043	1099	1034	1079
Mean		1725	1643	1690	1621	1670	1098	1012	1061	991	1040
Average K_1		1537	1464	1479	1440	1480	933	860	875	836	876
Average K_2		1614	1526	1575	1504	1554	1000	912	962	890	941
Average K_3		1639	1562	1609	1542	1588	1017	938	986	919	965
Average S		1595	1517	1553	1494	1539	983	903	941	881	927
$LSD_{0.05}$ Irrigation (I)						221.56					110.62
$LSD_{0.05}$ K fertilizer (K)						103.45					82.04
$LSD_{0.05}$ Intercropping system (S)						74.51					69.18
$LSD_{0.05}$ I x K						294.91					N.S
$LSD_{0.05}$ I x S						N.S					N.S
$LSD_{0.05}$ K x S						N.S					N.S
$LSD_{0.05}$ I x K x S						N.S					N.S
Sole peanut						1557			943		943

* Prices of peanut: US$ 454 per ton and sunflower: US$ 188 per ton.

Our results indicate that there is an increase in peanut plant height under intercropping system, compared to peanut sole planting. This result could be attributed to application of K_3 fertilizer, whereas the sole peanut plants received K_2 fertilizer. Pradyut et al. (2006) and Almeida et al. (2015) observed a beneficial effect of K^+ on peanut plant height. Also, our results reveal that reductions in intercropped peanut yield and its attributes were found in all intercropping systems, except for plant height, compared to sole peanut. Competition between sunflower and peanut for light, as sunflower has taller and erect plants, compare to peanut might negatively affected photosynthesis process for intercropped peanut, compared to sole peanut plants.

Application of 0.7ETo reduced the yield and its attributes of sunflower. Similar results were obtained by Alahdadi et al. (2011) and Buriro et al. (2015) who reported that 1000 seed weight, seed oil content and seed yield per hectare was reduced with reducing the applied irrigation amounts. Abdel-Mawgoud et al. (2009) indicated that small root system were observed in sunflower plants grown under water deficit, which resulted in weak shoot growth and this, in turn, reduce both the vegetative growth and the final yield. Increasing applied irrigation water from 0.7 to 1.2ETo caused significant increases in plant height, 1000 seed weight, head seed weight, seed yield per hectare, seed oil content and oil yield per hectare. Taha & Abbass (2008) reported that the response of plant height, head seed weight and seed yield per hectare was found to be linearly related to the amount of irrigation.

Our results also show that there were no significant differences between the application of 100 and 1.2ETo on plant height, seed yield per hectare, seed oil content and oil yield per hectare. Therefore, under the weather and soil condition of our experiments, water saving can be attain through application of 1.0ETo instead of 1.2ETo. The results indicate that sunflower yield and its attributes significantly increased by increasing K fertilizer. These results are supported by Faisal et al. (2013) and Ertiftik & Zengin (2016) for 1000 seed weight, head seed weight, seed yield per hectare, see oil content and oil yield per hectare. Furthermore, Soleimanzadeh et al. (2010) showed that increasing K^+ fertilizer increased oil content in sunflower seeds.

The interaction between irrigation water treatments and potassium fertilizer levels was found significant for sunflower seed yield and its attributes. Application of K_3 fertilizer did not relief water stress caused by application of 0.7ETo in sunflower, which resulted in reduction in seed yield and its attributes compared to the other studied irrigation water treatments. Moreover, there were no significant differences between K_2 and K_3 fertilizer on sunflower seed and oil yields per hectare. This finding can be useful in reducing production cost. Similar results were obtained by Taha & Abbass (2008).

The results also reveal that the spatial arrangements of sunflower plants in the studied intercropping systems affected both peanut and sunflower yield, even though sunflower planting density was similar in all intercropping systems (25% of its recommended planting density). The yield of both peanut and sunflower were reduced in S_2 followed by S_4 compared to S_1 followed by S_3. Regarding to peanut, it seems that the shading effects of sunflower plants were lower under S_1 followed by S_3.

Nevertheless, sunflower seed yield was high under S_1 and S_3, which can be attributed to closeness of sunflower plants to each other and thereby facilitated pollination process more than in S_2 and S_4. Furthermore, Yadav et al. (2002) indicated that because sunflower pollen is heavy and sticky it cannot be carried by wind. Yang et al. (2015) stated that appropriate distance between two component crops in an intercropping system had an effect on the yield of both crops. Moreover, Zhang et al. (2011) stated that when inter-specific competition is lower than intra-specific, high yields are achieved with intercropping. In addition, sunflower spatial arrangements in S_1 intercropping system had the highest values of plant height, 1000 seed weight and head seed weight, seed and oil yields per hectare, compared to the others intercropping systems. Similar results were obtained by El-Mehy et al. (2018), where they intercropped 25, 33 and 50% of recommended sunflower planting density with peanut. They found that intercropping sunflower with peanut with 25% of its planting density reduce competition between peanut and sunflower plants on resources, thus achieved the highest yield of both crops.

Our results indicate that the highest values

of relative yields, land equivalent ratio, water equivalent ratio, farmer's total and net income were obtained from using 1.2ETo, K_3 fertilizer level under S_1 intercropping system, followed by 1.0ETo, K_3 fertilizer under S_1 intercropping system. Similar results were obtained by El-Mehy et al. (2018).

Conclusion

Our results revealed that to obtain the highest peanut yield under intercropping it with sunflower, peanut seeds should be sown on both sides of all the raised beds (1.2 m width) with 20 cm planting spacing (two plants together) in its recommended planting density. In addition, sunflower seeds should be sown on one row above the raised beds, with 20 cm planting spacing (one plant) and the following bed should be left without intercropping sunflower seeds (S_1 intercropping system). This intercropping system can reduce competition between sunflower and peanut plants. Likewise, this intercropping system should be irrigated with 1.2ETo and received 114 K_2O fertilizer to obtain the highest value of land equivalent ratio, water equivalent ratio and farmer's net income. Application of 1.0ETo with 114 K_2O fertilizer under S_1 intercropping system produced slightly lower value of peanut and sunflower yield, LER, WER and farmer's net income, compared to its counterpart values of 1.2 ETo.

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نظم تحميل دوار الشمس على الفول السودانى تحت كميات رى ومستويات مختلفة من التسميد البوتاسى

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أقيمت تجربتان حقليتان بمحطة البحوث والتجارب – مركز البحوث الزراعية بالإسماعيلية – مصر خلال موسمى 2016 و 2017م لتحديد التوزيع النباتى المناسب لدوار الشمس مع الفول السودانى فى الزراعة المحملة تحت كميات مختلفة من مياه الرى بالتنقيط ومستويات من التسميد البوتاسى وتأثير ذلك على الإنتاجية ومعدلات كفاءة إستغلال الأرض والمياه والعائد النقدى للمزارع. تضمنت التجربة ثلاث كميات رى (0.7 ، 1.0 و 1.2 بخرنتح) وثلاث مستويات من التسميد البوتاسى (57، 86 و 114 كجم بو$_2$أ للهكتار) وأربعة نظم تحميل لدوار الشمس مع الفول السودانى (توزيعات كثافيه مختلفة). تم إستخدام التصميم الشرائحى المنشق فى ثلاث مكررات.

أشارت النتائج إلى عدم وجود إختلافات معنوية بين معاملة 1.0 و 1.2 بخرنتح على معظم صفات المحصولين المحملين. أعطى نظام زراعة الفول السودانى على جانبى جميع المصاطب وزراعة سطر واحد من دوار الشمس بمنتصف المصطبة مع ترك المصطبة التى تليها (S_1) أعلى محصول بذور لكل من الفول السودانى ودوار الشمس.

توصى الدراسة بإستخدام 1.2 بخرنتح والتسميد بمعدل 114 كجم بو$_2$أ للهكتار عند زراعة الفول السودانى على جانبى جميع المصاطب وزراعة سطر واحد من دوار الشمس بمنتصف المصطبة مع ترك المصطبة التى تليها بدون تحميل للحصول على أعلى إنتاجية وأعلى معدل لكفاءة إستخدام الأرض والمياه وكذلك أعلى عائد نقدى للمزارع.