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Mitigation of the impact of water deficiency on intercropped sesame and peanut systems through foliar application of potassium-silicate and triacontanol

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ABSTRACT

Climate changes are increasing over time, adversely affecting water availability and crop productivity. Potassium silicate (K-Si) or Triacontanol (TRIA) reportedly plays an important role in mitigating water stress conditions. A two-year field experiment was carried out during the 2021 and 2022 growing seasons to assess the effect of three irrigation treatments as 120, 100 and 80% of reference evapotranspiration (ETo) and foliar spraying with K-Si and TRIA, compared to control (no spraying) on the yield, water and land equivalent ratio as well as farmer's benefits of sesame intercropped with peanut system (33% S: 100% P). The average values of applied irrigation water were 9654, 8045 and 6436 m^3/ha for irrigation with 120, 100 and 80% ETo, respectively. The results indicated that the highest yield of both crops was obtained under irrigation with 120% ETo and spraying with K-Si. Foliar spraying with K-Si or TRIA mitigates the adverse effects of low irrigation water application and its adverse effects on yield and its components in both crops under study. Irrigation with 100% ETo (saved 17% of the applied water under 120% ETo) and spraying with K-Si produced a higher yield of both crops than the obtained under irrigation with 120% ETo and no spraying. Furthermore, the highest value of water equivalent ratio (WER), land equivalent ratio (LER), total income (TI) and monetary advantage index (MAI) of sesame intercropped with peanut system were found under irrigation with 120% ETo and spraying with K-Si. However, irrigation with 100% ETo and spraying with K-Si produced higher values of these indices than the obtained under irrigation with 120% ETo and no spraying. Thus, it could be concluded that, to increase the productivity of unit land and water (LER and WER), as well as TI and MAI of sesame intercropped with peanut, irrigation with 120% ETo and spraying with K-Si should be utilized. Furthermore, to save 17% of the applied irrigation water, irrigation with 100% ETo and spraying with K-Si can be used and that obtained higher values of LER, WER, TI and MAI, than the obtained under irrigation with 120% ETo and no spraying.

Keywords: Drought stress, land equivalent ratio, water equivalent ratio, total income

INTRODUCTION

Water scarcity is predicted to become more frequent and severe in many parts of the world owing to climatic changes (Singh *et al.,* 2014), where lower amounts of irrigation water will be available for agriculture. Intercropping is one of the efficient crop production management that can be used to conserve irrigation water with minimum adverse effects on the environment, as well as a useful approach to achieve sustainable agriculture and increase resource use efficiency (Saad et al., 2022). Sesame (*sesamum indicum* L.) and peanut (*Arachis hypogaea* L.) are important oilseed crops in many regions of the world, serving as industrial and food crops (Özkan, 2018; Sezen *et al.,* 2019). There is a gap between sesame production and consumption in Egypt, estimated by 38%, whereas there is a surplus in peanut production of 46% (CAPMAS, 2018). Intercropping sesame with peanut can partially contribute to reducing the sesame food gap. To our knowledge, although studies have been conducted on intercropping sesame with peanut to increase productivity in Egypt, no studies have been done on assessing the applied irrigation amount to this intercropping system.

The application of deficit irrigation is another approach to attain the sustainable use of water resources. Chai *et al.* (2016) defined deficit irrigation as the "application of irrigation water below the full required amounts for optimal growth and yield, as well as improving crop's water use efficiency". Because any shortage and/or poor management of irrigation water has negative impacts on crop yield (Magombeyi *et al.,* 2018), planned deficit irrigation can minimize yield losses. The reduction in yield due to water shortage is primarily attributed to the disruption of physiobiochemical processes, inhibition of photosynthesis, and stunted plant growth and development (Yuan *et al.,* 2016). Drought stress alters the pathway availability of water and nutrients to become out of equilibrium, hence, reductions in plant growth and yield of peanut (Saudy and El-Metwally 2019). Growth, yield and nutrient uptakes of peanut plants grown under field capacity were higher than those plants grown under low water application (Arruda *et al.,* 2015). A significant reduction in final peanut pods yield, pod yield per plant, seed weight per plant, number of pods per plant, number of seeds per pod and 100-seed weight were found under low water application (Aydinsakir *et al.,* 2016; Gomaa *et al.,* 2021). Rathore *et al.* (2021) found that irrigation peanut with amounts of 60 and 50% of ETc significantly reduced yield, economic benefit, water productivity and kernel oil content, but 80% of ETc increased WP with only a marginal reduction in economic benefit and yield.

Sesame is a resilient crop with a strong adaptation to drought-prone environments (Dossa *et al.,* 2019). Although sesame is a drought-resistant crop, water stress affects sesame growth, capsule development, and final yield (Wang *et al.,* 2016). Özhan (2018) indicated that exposing sesame plants to water stress had unfavorable effects on plant height, number of capsules per plant, seed yield as well as oil yield. Drought decreased the growth period and also accelerated flowering, which caused a reduction in the number of capsules per plant (Farokhian *et al.,* 2021). Pandey *et al.* (2021) reported that water stress had been shown to reduce sesame yield by 28% and negatively affected yield attributes.

Potassium silicate (K-Si) is a source of highly soluble potassium (K) and silicon (Si). K+ is a major plant nutrient and plays an essential role in a variety of physiological processes, i.e. photosynthesis, protein synthesis and maintenance of water status in plant tissues (Marschner, 2012; Al-Huqail *et al.,* 2019). Whereas Si could enhance plant growth and yield under normal and stress conditions (Thakral *et al.,* 2021). The application of Si improves water use efficiency by increasing the relative water content in plants under drought stress (Maghsoudi *et al.,* 2016). Gomaa *et al.* (2021) indicated that spraying with K-silicate increased the water use efficiency of peanut, as compared to no spraying treatment. Foliar application of potassium silicate not only increased seed yield, yield components, and oil content under fully irrigated but also alleviated the harmful effects of drought stress on sesame plants (Yasin and Abdelsalam, 2022). Whereas, Abd-Allah *et al.,* (2021) reported that spraying with 200 ppm K-silicate to faba bean intercropped with sugar beet increased the water equivalent ratio to 1.37, compared to 1.25 under no spraying. Application of plant growth regulators, such as triacontanol (TRIA) in very small amounts, can effectively increase the growth and yield of plants (Pang *et al.,* 2020). TRIA has been well documented for its essential roles in plant response to abiotic stresses such as drought (Alharbi *et al.,* 2021; El-Beltagi *et al.,* 2022). Its exogenous application ameliorates the stress effect in plants by increasing plant biomass, chlorophyll pigments, mineral nutrients acquisition, compatible solutes accumulation and enzymatic and non-enzymatic antioxidant defence systems (Perveen *et al.,* 2016). Foliar application of TRIA increased plant height, leaf area, and biomass of hot pepper plants (Sarwar *et al.,* 2022). It has been reported that foliar application of TRIA reduced the harmful effects of abiotic stresses on wheat (Perveen *et al.,* 2014), maize (Perveen *et al.,* 2016), and rice (Alharbi *et al.,* 2021). However, there was no research implemented on spraying sesame/peanut intercropping systems with TRIA under deficient water application.

Under the current conditions of water scarcity in Egypt, foliar application of K-silicate or TRIA could mitigate the adverse effects of low irrigation water application and its adverse effects on crop yield and its components. In addition, foliar application of these two compounds on an intercropping system, such as sesame intercropped with a peanut system, can even contribute more to saving irrigation water and produce more sesame yield without using extra land, which could solve part of the sesame food gap in Egypt. Thus, the objective of this investigation was to compare the capability of K-Si and TRIA in reducing yield losses and increasing farmers' income under low irrigation water application to sesame intercropped with peanut system, as well as increase land and water productivity.

MATERIALS AND METHODS

A field experiment was carried out during the two growing seasons of 2021 and 2022, at Ismailia Agricultural Research Station, Agricultural Research Center, Ismailia Governorate (Lat. 30° 35' 30" N, Long. 32° 14' 50" E, 10 m elevation above sea level), Egypt, to compare between the capability of K-silicate and TRIA in reducing yield losses and increasing farmers' income under low irrigation water application to sesame intercropped with peanut system, as well as increase land and water productivities. The average monthly weather data at the experimental site during both growing seasons were obtained from the following website: https://power.larc.nasa.gov/data-access-viewer/site (Table 1). Data of monthly weather were used to calculate monthly averages of reference evapotranspiration (ETo) values using the Basic Irrigation Scheduling model (BISm) according to Snyder *et al.* (2004). The model uses Penman-Monteith equation presented in the United Nations FAO Irrigation and Drainage Paper (Allen *et al.,* 1998) to calculate ETo values.

Table 1. Average monthly weather data at the experimental site in 2021 and 2022 seasons.

Month	2021 season					2022 season				
	SR ($MJ/m^2/day$)	T_{max} (°C)	T_{min} (°C)	WS (m/s)	ETo (mm/day)	SR ($MJ/m^2/day$)	T_{max} (°C)	T_{min} (°C)	WS (m/s)	ETo (mm/day)
May	29.2	34.9	17.9	2.9	8.2	27.7	32.2	16.8	3.5	7.9
Jun	29.9	34.6	19.3	3.0	8.2	29.9	36.2	20.9	3.1	8.6
Jul	29.0	38.0	22.4	2.8	8.6	29.1	37.0	21.9	2.8	8.5
Aug	27.1	38.3	23.6	2.6	8.1	26.5	37.0	23.5	3.1	8.1
Sep	23.6	34.6	21.3	3.0	7.0	23.2	34.7	21.7	3.1	7.0
Oct	18.8	30.1	18.6	2.9	5.2	18.02	29.88	18.85	2.67	4.9

SR=solar radiation, T_{max}= maximum temperature, T_{min}= minimum temperature, wind speed= WS, = reference evapotranspiration.

Soil samples were collected from the experimental site at 60 cm depth for assaying some physical, hydro-physical and chemical properties according to Tan's (1996) standard method, as shown in Tables 2 and 3.

Table 2. Soil texture and hydro-physical properties of the experimental soil.

Soil depth (cm)	Particle size distribution			Texture class	Soil water status			Bulk density ($mg\ m^{-3}$)
	Fine sand %	Silt %	Clay %		Field capacity %	Permanent wilting point %	Available water %	
0-20	93.80	3.90	2.30	Sandy	12.75	3.55	9.20	1.66
20-40	95.55	3.10	1.35		9.05	2.50	6.55	1.74
40-60	96.20	2.95	0.85		7.75	2.05	5.70	1.70

Table 3. Soil chemical properties of the experimental soil.

Soil depth (cm)	pH	EC ($dS\ m^{-1}$)	Soluble cations ($meq\ L^{-1}$)				Soluble anions ($meq\ L^{-1}$)			
			Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}	Cl^{-}	SO_4^{2-}
0-20	7.18	0.34	1.24	0.55	1.55	0.16	-	1.08	1.72	0.70
20-40	7.37	0.33	1.24	0.50	1.60	0.14	-	1.06	1.73	0.69
40-60	7.39	0.27	1.26	0.48	1.62	0.16	-	1.08	1.75	0.69

Experimental design and treatment:

The experiment was implemented in a strip-plot design based on a randomized complete block arrangement with three replicates. Irrigation treatments, as the first factor, were assigned to the vertical strip, while foliar spraying treatments, as the second factor, were allocated to the horizontal ones. The area of the experimental plot was 14.4 m^2 and consisted of four raised beds (3.0 m long and 1.2 m wide). Wheat was the preceding crop in both growing seasons. Experimental treatments were as follows:

I- Irrigation treatments

- Irr_{120}: Irrigation with water equivalent to 120% ETo, it is equal 9654 m^3/ha.
- Irr_{100}: Irrigation with water equivalent to 100% ETo, it is equal 8045 m^3/ha.
- Irr_{80}: Irrigation with water equivalent to 80% ETo, it is equal 6436 m^3/ha.

II- Foliar spraying

- F1: Control (no spraying).
- F2: Spraying with 200 ppm potassium silicate (K-Si).
- F3: Spraying with 1.0 ml/L with Triacontanol (TRIA).

K-silicate fertilizer (K_2SiO_3, 500 g K/L and 114 g Si/L) was produced by Technogene Company, China. The foliar fertilizer solution (200 ppm Si) was prepared through mixed K-Si equal 0.952 L with 476 L water /ha. The EC value of the spray solution was from 400 to 450 ppm. Meanwhile, TRIA 0.1 EC ($C_{30}H_{62}O$) was produced by Maxah Bio-Tech Company, India. It was prepared by mixing 0.476 L TRIA with an amount of water equal to 467 L/ha. Three foliar spraying doses were applied 30, 45 and 60 days after sowing, either for K-Si or TRIA.

Agricultural practices

Peanut (cv. Giza 6) and sesame (cv. Shandaweel 3) seeds were cultivated on May 16th and 15th for peanut and on June 6th and 2nd for sesame in 2021 and 2022 seasons, respectively, in sole and intercropping systems. The sesame crop was harvested on September 9th and 5th in both seasons 2021 and 2022, consecutively. Furthermore, the peanut crop was harvested on September 27th and 25th of both seasons 2021 and 2022, respectively. The additive intercropping system was used, where peanut seeds were sowed on all raised beds, one plant /hill at 10 cm spaced, on both sides of the raised bed (120 cm width). Meanwhile, sesame seeds were intercropped in the middle of the raised bed, in one peanut-raised bed and leaving the other one, with left two plants/hill spaced 15 cm apart (100 % peanut: 33.3% sesame). In sole culture, peanut and sesame were planted on a ridge 60 cm apart, and plants were thinned to one plant/hill at 10 cm apart for peanut and two plants/hill at 20 cm for sesame. The recommended sole culture of both crops was used to calculate competitive relationships. Peanut seeds were inoculated by *Rhizobium* before seeding, and Arabic gum was used as a sticking agent in solid and intercropping cultures.

Fertilization program: Mono calcium super phosphate (15.5% P_2O_5) at the rate of 476 kg/ha was applied during soil preparation for sole and intercropping systems. At sowing, all experimental units received 47.6 kg N/ad as booster dose as ammonium sulfate (20.6% N) and 119 kg/ha of potassium sulphate (50% K_2O) for peanut in both cropping systems. In the sole and intercropping culture of sesame, N as ammonium sulfate was applied at the rate of 142.8 and 47.6 kg /ha in three equal doses at 20, 35 and 50 days of sowing, while one dose of K was used at sowing of sesame at the rate of 119 and 39.7 kg /ha as potassium sulphate, respectively. Both N and K fertilizers were applied via irrigation water. Other agricultural practices were done as recommended by the Egyptian Ministry of Agriculture and Land Reclamation.

Irrigation system

The experiment was irrigated using a sprinkler system. The crops were irrigated using a solid-set sprinkler irrigation system with rotary RC 160 sprinklers of 0.40 to 1.12 and an average discharge rate of 0.58 m3/hour at 2.80 bars nozzle pressure. The main PVC pipeline for the sprinkler system has a diameter of 160 mm. Sub-main PVC pipelines have a diameter of 110 mm and PVC lateral lines (50 mm diameter). The distance between the laterals was 10 x 10 meters.

Water relations

1- Applied Irrigation Water (AIW)

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

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

Where: AIW= depth of applied irrigation water (mm), ETo= reference evapotranspiration (mm/day), I= irrigation intervals (days), Ea= application efficiency of the irrigation system (85%), LR= leaching requirements. The LR was not considered because the ECe of the soil profile is low. The values of ETo and water consumptive use (WCU) were calculated using BISm model (Snyder *et al.,* 2004).

2- Water Equivalent Ratio (WER)

The WER was used to quantify the efficiency of water use by an intercropping system (Mao *et al.,* 2012). The WER is defined as the total water needed in sole crops to produce the equivalent amount of the species yields on a unit area of intercrop as follows:

$$\mathrm{WER} = \frac{\left(\frac{Y_{int,p}}{WU_{int,p}}\right)}{\left(\frac{Y_{mono,p}}{WU_{mono,p}}\right)} + \frac{\left(\frac{Y_{int,s}}{WU_{int,s}}\right)}{\left(\frac{Y_{mono,s}}{WU_{mono,s}}\right)}$$

Where: Yint,p and Yint,s are the yields of intercropped peanut and sesame, respectively. WUint,p and WUint,s are water consumptive used by the intercropped peanut and sesame, respectively. Ymono,p and Ymono,s are the yields of mono cultivation of peanut and sesame, respectively. WUmono,p and WUmono,s are water consumptive use by mono peanut and sesame, respectively.

The collected data

At harvest, ten guarded plants were taken randomly from the middle of each experimental plot to estimate growth and yield component characters, while the seed yield of both crops was estimated in kg from the whole plot and converted to seed yield/ha. For peanut crop, plant height (cm), no. of branches/plant, no. of pods/plant, pods weight/plant (g), seeds weight/plant (g), 100-pods weight (g), 100-seed weight (g) and pod yield (ton /ha). For sesame, plant height (cm), no. of capsules /plant, 1000-seed weight (g), seed yield/plant (g) and seed yield (ton /ha). The seed oil content of both crops was determined using Soxhlet apparatus and Hexane ether according to A.O.A.C. (1995).

Competitive Relationships

Land Equivalent Ratio (LER)

The LER is the ratio of area needed under sole cropping to produce the same product under intercropping at the same management level to produce an equivalent yield LER was calculated according to Willey (1979) as follows:

$$LER = \frac{Yab}{Yaa} + \frac{Yba}{Ybb}$$

Where: Yaa and Ybb are the sole crop yields of crops a (peanut) and b (sesame), respectively, while Yab is the intercropped yield of crop a, and Yba is the intercropped yield of crop b.

Competitive Ratio (CR)

The CR, as proposed by Willey and Rao (1980), gives the exact degree of competition by indicating the times in which one crop is more competitive than the other. It is calculated according to the following equation:

$$CRa = \frac{LERa}{LERb} \times \frac{Zba}{Zab}, \quad CRb = \frac{LERb}{LERa} \times \frac{Zab}{Zba}$$

Where LERa and LERb are the relative yields of intercrop peanut and sesame, respectively. Zab and Zba are the area ratio of crop a (peanut) and b (sesame) when intercropping, respectively.

Economic performance

Farmers' benefit was calculated by determining each of the total return, total cost and net return of intercropping cultures, as well as sole planting, according to the following equation:

Total return (LE/ha.) = (yield A x price A + yield B x price B).

The prices used in the analysis were farm prices for peanut seeds 958.5 and 1137.5 U$/ton, and the price of sesame was 1278 and 1551.2 U$/ton in the first and second season, consecutively.

Monetary Advantage Index (MAI):

The MAI values were calculated based on gross returns, as suggested by Willey (1979). MAI= [Value of combined intercrops x (LER – 1)] /LER

Statistical analysis:

The collected data were subjected to the statistical analysis of variance (ANOVA) using the MSTAT-C package (Freed, 1991). The treatment means were compared using the least significant differences (L.S.D.) at 0.05 level of probability as outlined by Gomez and Gomez (1984).

RESULTS

Peanut yield and its components:

Effect of irrigation treatments:

The studied irrigation treatments had a significant effect on peanut yield components, as well as pod yield per hectare in both growing seasons (Tables 4 & 5), where the highest values were obtained under irrigation with 120% ETo, except the percentage of seed oil content. At the same time, the lowest values were obtained under irrigation with 80% ETo. Decreasing irrigation amounts to 100 and 80% ETo reduced pod yield per plant considerably by 6.33 and 13.39 %, respectively, compared to the application of 120% ETo in the first season, and the reduction was 6.71 and 14.27 %, respectively, in the second season. Likewise, the reduction in pod yield per hectare under irrigation with 100 and 80% ETo, was 6.39 and 12.78 % in the first season, and by 6.28 and 13.66%, in the second season, respectively, compared to irrigation with 120% ETo. However, the percentage of seed oil content had the highest value under irrigation with 100% ETo, while the lowest percentage was obtained by irrigation with 120% ETo.

Table 4. Effect of irrigation treatments, foliar spraying and their interaction on peanut yield components in both seasons.

Irrigation treatments	Foliar spray (FS)	Plant height (cm)		Branches number/plant		Pods number/plant		Pods weight /plant (g)		Seed weight/plant (g)	
		2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Irr_{120}	Control	59.96	67.83	5.63	6.36	19.96	21.26	40.56	44.53	36.33	38.26
	K-Si	72.10	73.90	7.13	7.13	22.03	24.03	43.20	50.86	38.36	43.53
	TRIA	73.96	72.30	7.16	7.06	23.06	23.96	43.73	50.73	40.96	43.43
Mean		**68.67**	**71.34**	**6.64**	**6.85**	**21.68**	**23.08**	**42.50**	**48.71**	**38.55**	**41.74**
Irr_{100}	Control	54.53	56.60	5.16	5.50	19.23	20.30	37.83	42.30	34.80	36.20
	K-Si	70.13	66.56	6.56	6.50	22.00	22.63	41.00	48.06	41.10	42.63
	TRIA	67.30	65.06	6.40	6.46	21.06	22.43	40.59	45.96	37.86	40.00
Mean		**63.99**	**62.74**	**6.04**	**6.15**	**20.76**	**21.78**	**39.81**	**45.44**	**37.91**	**39.61**
Irr_{80}	Control	47.00	46.33	4.56	5.06	17.43	19.40	34.16	39.06	31.60	32.13
	K-Si	65.76	60.60	6.16	6.06	20.46	22.53	39.66	44.80	39.03	40.73
	TRIA	60.96	58.33	6.03	6.10	19.43	21.00	36.60	41.43	34.00	37.13
Mean		**57.91**	**55.09**	**5.58**	**5.74**	**19.11**	**20.97**	**36.81**	**41.76**	**34.88**	**36.66**
Mean of	Control	53.83	56.92	5.12	5.64	18.87	20.32	37.52	41.96	34.24	35.53
	K-Si	69.95	67.02	6.62	6.56	21.50	23.06	41.29	47.91	39.50	42.30
	TRIA	66.79	65.23	6.53	6.54	21.18	22.45	40.31	46.04	37.61	40.19
$LSD_{0.05}$ (Irr)		1.27	0.63	0.16	0.16	1.70	0.19	1.00	0.49	0.29	0.30
$LSD_{0.05}$ (FS)		1.71	0.77	0.28	0.08	1.15	0.31	0.58	0.55	0.56	0.31
$LSD_{0.05}$ (Irr x FS)		2.96	1.33	N.S	0.15	1.98	N.S	N.S	0.95	0.97	0.54
Solid peanut		**54.56**	**60.70**	**7.05**	**7.20**	**25.3**	**26.20**	**54.60**	**59.70**	**45.80**	**50.20**

Effect of foliar spraying:

The results in Tables (4 & 5) showed that the spraying with either K-silicate or triacontanol (TRIA) positively and significantly affected peanut yield and its components in both growing seasons, where the foliar application of K-Si or TRIA mitigated the effect of deficit irrigation application of 100 and 80% ETo, compared to no spraying and resulted in increasing peanut yield and its components in both growing seasons. The results also indicated that spraying of K-Si produced the highest values of the studied characters of peanut, followed by TRIA application, without significant differences between them in most of the studied characters. Pod yield per hectare was higher under spraying with K-Si, compared to no spraying by 11.08 and 9.05% in the first and second season, respectively. In comparison, TRIA increase pod yield/ha by 8.65 and 7.30% in the 2021 and 2022 season, respectively. The results also showed that the oil percentage was higher under spraying with K-silicate, followed by TRIA, compared to no spraying treatments.

Table 5. Effect of irrigation treatments, foliar spraying and their interaction on peanut yield and its components in both seasons.

Irrigation treatment	Foliar spray	100-pods weight (g)		100-seeds weight (g)		Pod yield (ton/ha)		Seed oil content (%)	
		2021	2022	2021	2022	2021	2022	2021	2022
Irr_{120}	Control	195.66	204.66	85.33	86.66	3.44	3.56	40.10	41.85
	K-Si	200.33	210.66	87.66	89.00	3.70	3.72	44.45	43.38
	TRIA	201.66	212.00	88.00	90.00	3.65	3.71	45.38	44.65
Mean		**199.22**	**209.11**	**87.00**	**88.55**	**3.59**	**3.67**	**43.31**	**43.29**
Irr_{100}	Control	188.33	190.66	82.00	84.66	3.17	3.21	45.65	46.03
	K-Si	195.66	201.00	88.33	87.66	3.50	3.58	51.00	49.55
	TRIA	193.33	199.33	86.33	86.33	3.43	3.49	49.50	48.69
Mean		**192.44**	**197.00**	**85.55**	**86.22**	**3.37**	**3.43**	**48.72**	**48.09**
Irr_{80}	Control	179.33	177.66	79.33	80.33	2.87	2.95	45.50	44.00
	K-Si	193.33	193.66	86.00	85.33	3.33	3.30	48.11	48.89
	TRIA	190.66	188.33	83.00	84.00	3.22	3.23	47.98	46.03
Mean		**187.77**	**186.55**	**82.78**	**83.22**	**3.14**	**3.16**	**47.20**	**46.31**
Mean of	Control	187.77	190.99	82.22	83.88	3.16	3.24	43.75	43.96
	K-Si	196.44	201.77	87.33	87.33	3.51	3.53	47.85	47.27
	TRIA	195.22	199.89	85.78	86.78	3.43	3.48	47.62	46.46
$LSD_{0.05}$ (Irr)		3.57	4.52	1.74	2.60	0.14	0.12	1.11	1.15
$LSD_{0.05}$ (FS)		1.78	2.06	0.70	1.28	0.06	0.07	0.38	0.85
$LSD_{0.05}$ (Irr x FS)		3.08	3.57	N.S	N.S	0.10	0.09	N.S	N.S
Solid peanut		**215.00**	**227.00**	**91.00**	**93.00**	**3.856**	**3.963**	**45.83**	**46.12**

Interaction effect between irrigation treatments and foliar spraying:

A significant effect was observed for the interaction between irrigation treatments and foliar application by K-Si or TRIA on studied characters of peanut in the two seasons, except the number of branches/plant, was found significant only in the second season. While the number of pods per plant, 100-seed weight and percentage of oil content were found to be insignificantly affected by the interaction in both growing seasons. The lowest values of all the studied characters of peanut were obtained with no spraying under the lowest amount of applied irrigation water, namely 80% ETo, in both seasons. On the contrary, the highest values of peanut yield and its components were obtained when irrigation was applied with 120% ETo and spraying peanut plants with TRIA, followed K-Si. Likewise, decreasing irrigation levels from 120% ETo to 80% ETo and spraying peanut plants with K-Si reduced pod yield losses compared to the no spraying treatment by16.03 and 11.86 % in 1st and 2nd season, consecutively (Table 5).

Furthermore, reducing the applied irrigation water to 100% ETo and 80% ETo along with spraying peanut with K-silicate or TRIA produced higher values of all studied characters, compared to no spraying and irrigation with 120% ETo treatments. This result implied that the application of K-silicate or TRIA could mitigate the effect of deficient water application to peanut and contributes in increasing the yield and its components. These results held true for both growing seasons (Table 5).

Sesame yield and its components:

Effect of irrigation treatments:

The results in Table (6) revealed that there were significant effects of irrigation treatments on the studied characteristics of sesame in both growing seasons. The highest values of all studied characters were obtained under irrigating sesame plants with 120% ETo. On the contrary, the lowest values of studied characters were found under irrigation with 80% ETo. Concomitant with the decrease in capsules number per plant under irrigation with 80% ETo, seed yield per plant and seed yield per hectare was decreased by 18.1% for both characters in the first season and by 18.0 and 19.4% for both characters in the second season. Whereas lower reductions in seed yield per plant (7.0 and 7.5%) and seed yield per hectare (7.9 and 7.6%) in the first and second season, respectively were found under irrigation with 100% ETo. However, irrigation with 100% ETo increased oil percentage, compared to irrigation with 120% ETo, by 10.9 and 7.1% in the first and second season, respectively.

Effect of foliar spraying:

The results in Table (6) indicated that there were significant effects of foliar application of K-Si or TRIA on all the studied characters of sesame in both growing seasons. The highest values of growth and yield components were obtained under spraying K-silicate, compared to TRIA and no spraying. However, the difference between the K-Si and TRIA failed to reach level of significance, in the two growing seasons, except for the number of capsules/plant. Similarly, seed yield per hectare was increased with spraying with K- silicate and TRIA, compared to no spraying by 38.0 and 32.7% in the first season and by 36.4 and 32.9 % in the second ones, respectively. Application of K-Si and TRIA not only increased seed yield but also enhanced the percentage of seed oil content by 11.9 and 9.9 % in the first season and by 7.5 and 6.7% in the second growing season, respectively.

Interaction effect between irrigation treatments and foliar spraying:

The interaction between irrigation treatments and foliar spraying was found significant for plant height only in the first season, seed yield/ha and seed oil content in the two growing seasons (Table 6). The results showed that spraying sesame plants with K-Si or TRIA increased the performance of all studied characters under the different irrigation levels compared with the control (no spray) treatment. Where spraying sesame plants with TRIA under irrigation level, 120 % ETo (Irr_{120}) recorded the highest value of plant height 164.73cm. Meanwhile, applied K-Si under irrigation treatment 120% ETo produced the highest yield components and seed yield/ha. On the other hand, no foliar spraying under irrigation with 80% ETo recorded the minimum values of above mention traits in the two growing seasons. However, spraying sesame plants with K-Si that received water amount equal to 100% ETo produced the highest percentage of seed oil content, which was 56.93 and 53.30 % in the first and second season, respectively. This result emphasizes the role of K-silicate in enhancing sesame growth, which positively reflected the final yield and increased it by 38 and 36.4% in the first and second season, respectively. Moreover, sesame yield losses were reduced by spraying with K-silicate or TRIA when the applied irrigation water was reduced from 120% ETo to 80% ETo, compared to no spraying. It can also be noticed from the table that irrigation with 100 or 80% ETo produced higher sesame yield than its counterpart value under irrigation with 120% ETo and no spraying.

Table 6. Effect of irrigation treatments, foliar spraying and their interaction on sesame yield and its components in both seasons.

Irr. treat.	Foliar Spray.	Plant height (cm)		Capsules number/plant		1000-seed weight (g)		Seed yield/plant (g)		Seed yield (ton/ha)		Seed oil content (%)	
		2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Irr_{120}	Control	151.4	151.1	148.3	150.7	3.20	3.30	9.76	8.40	0.533	0.531	46.50	45.36
	K-Si	164.5	162.7	159.8	162.3	3.50	3.40	12.56	12.96	0.699	0.703	51.00	49.15
	TRIA	164.7	158.4	151.6	157.8	3.43	3.40	12.26	12.33	0.680	0.687	49.23	50.20
Mean		**160.2**	**157.4**	**153.2**	**156.9**	**3.37**	**3.36**	**11.53**	**11.23**	**0.637**	**0.640**	**48.91**	**48.24**
Irr_{100}	Control	142.3	141.4	144.0	147.0	3.23	3.33	9.16	8.40	0.472	0.480	50.72	49.10
	K-Si	155.1	157.1	157.4	161.1	3.56	3.50	11.66	11.56	0.657	0.662	56.93	53.30
	TRIA	154.3	154.3	151.2	155.5	3.33	3.50	11.33	11.20	0.633	0.633	55.14	52.67
Mean		**150.6**	**150.9**	**150.9**	**154.5**	**3.37**	**3.44**	**10.72**	**10.39**	**0.587**	**0.592**	**54.26**	**51.69**
Irr_{80}	Control	127.1	136.2	125.8	131.6	3.07	3.11	7.25	7.12	0.408	0.409	48.60	49.33
	K-Si	144.7	145.6	143.4	147.3	3.33	3.30	10.73	10.40	0.595	0.571	55.30	52.10
	TRIA	147.6	146.9	139.5	144.6	3.20	3.26	10.33	10.10	0.563	0.568	55.85	50.50
Mean		**139.8**	**142.9**	**136.2**	**141.2**	**3.20**	**3.22**	**9.44**	**9.21**	**0.522**	**0.516**	**53.25**	**50.64**
Mean of	Control	140.3	142.9	139.4	143.1	3.16	3.24	8.72	7.97	0.471	0.473	48.61	47.93
	K-Si	154.8	155.1	153.5	156.9	3.46	3.40	11.65	11.64	0.650	0.645	54.41	51.51
	TRIA	155.5	153.2	147.4	152.6	3.32	3.38	11.31	11.21	0.625	0.629	53.41	51.12
LSD0.05 (Irr)		4.40	6.88	5.91	4.94	0.06	0.05	0.23	0.42	0.004	0.008	1.08	0.98
LSD0.05 (F)		2.96	3.84	3.58	3.84	0.18	0.03	0.49	0.57	0.002	0.007	0.55	0.28
LSD0.05 (Irr x F)		5.13	N.S	N.S	N.S	N.S	N.S	N.S	N.S	0.004	0.012	0.92	0.64
Solid sesame		**166.8**	**164.8**	**140.7**	**144.1**	**3.28**	**3.30**	**11.64**	**11.39**	**1.546**	**1.539**	**52.0**	**53.10**

Applied irrigation water, water consumptive use and yield reduction of peanut and sesame under intercropping:

The results in Table (7) showed that the amounts of applied irrigation water in the first growing season for sesame intercropped with peanut were 9636, 8030, and 6442 m^3/ha, whereas in the second season, the values were 9672, 8060, and 6448 m^3/ha under application of 120, 100, and 80% ETo, respectively. The values of water consumptive use recorded 8580, 7090 and 5790 m^3/ha in the first season and were 6811, 7115 and 5810 m^3/ha in the second season under application of 120, 100, and 80% ETo, respectively. The results also showed that, irrigation water saving was 17% under irrigation with 100% ETo compared to 120 % ETo in both growing seasons. These amounts of saved water resulted in a reduction by 9 and 11% in peanut and sesame yield, respectively, averaged over the two growing seasons under no spraying. The reductions in the yield of peanut and sesame were the lowest under K-silicate spraying, namely 5 and 6%, respectively, averaged over the two growing seasons. Whereas irrigation with 80% ETo saved 33% of the applied irrigation water under 120% ETo and resulted in yield loss in both peanut and sesame by 17 and 23%, respectively, averaged over the two growing seasons under no spraying. However, spraying K-silicate resulted in the lowest yield losses by 11 and 17%, respectively, averaged over the two growing seasons (Table 7).

Table 7. Applied irrigation water to sesame intercropped with peanut system, its water consumptive use and yield reduction as a result of irrigation and foliar spray treatments.

Irrigation treatment	Foliar spraying	Applied irrigation water (m^3/ha)		Water consumptive use (m^3/ha)		Peanut yield reduction (%)		Sesame yield reduction (%)	
		2021	2022	2021	2022	2021	2022	2021	2022
Irr_{120}	Control	9636	9672	8580	8611	--	--	--	--
	K-Si	9636	9672	8580	8611	--	--	--	--
	TRIA	9636	9672	8580	8611	--	--	--	--
Irr_{100}	Control	8030	8060	7090	7115	8	10	11	10
	K-Si	8030	8060	7090	7115	5	4	6	6
	TRIA	8030	8060	7090	7115	6	6	7	8
Irr_{80}	Control	6424	6448	5790	5810	17	17	23	23
	K-Si	6424	6448	5790	5810	10	11	15	19
	TRIA	6424	6448	5790	5810	12	13	17	17

Water Equivalent Ratio (WER)

The results in Table (8) revealed that the value of partial WER peanut was higher than its counterpart value for sesame as a result of differences in planting density (100% peanut: 33.3% sesame) in both growing seasons. The highest values of total WER were found under irrigation with 120% ETo and application of K-silicate, namely 1.62 and 1.61 in the first and second season, respectively. This result revealed the role of K-silicate in enhancing peanut and sesame growth under their intercropping system, which positively reflected on their final yields and increased the value of WER. Furthermore, it also indicated that the water utilization of this intercropping system, represented by total WER was increased by 62 and 61% as a result of spraying with K-silicate. Lower values of total WER were found under irrigation with 100% ETo and application of K-silicate, namely 1.54 in both seasons. Whereas the lowest values of partial and total WER were obtained under irrigation with 80% ETo and no spraying, namely 1.14 and 1.13 in the first and second season, respectively. The results in the table also showed that spraying with K-silicate under irrigation with 100% ETo attained higher values of total WER, compared to no spraying and irrigation with 120% ETo, namely 1.54 versus 1.40, respectively, in both seasons.

Table (8): Effect of irrigation treatments and foliar spraying on partial and total water equivalent ratio (WER) for sesame intercropped with peanut in both seasons.

Irrigation Treatment	Foliar spraying	2021			2022		
		WER_{sesame}	WER_{peanut}	WER_{total}	WER_{sesame}	WER_{peanut}	WER_{total}
Irr_{120}	Control	0.51	0.89	1.40	0.51	0.89	1.40
	K-Si	0.67	0.95	1.62	0.68	0.93	1.61
	TRIA	0.65	0.96	1.61	0.67	0.93	1.60
Irr_{100}	Control	0.45	0.82	1.28	0.47	0.80	1.27
	K-Si	0.63	0.91	1.54	0.64	0.90	1.54
	TRIA	0.61	0.89	1.50	0.61	0.87	1.49
Irr_{80}	Control	0.39	0.74	1.14	0.40	0.74	1.13
	K-Si	0.57	0.86	1.44	0.55	0.83	1.38
	TRIA	0.54	0.83	1.38	0.55	0.81	1.36

Competitive relationships

Land Equivalent Ratio (LER)

The results in Table (9) pointed out a considerable yield advantage as a result of intercropping sesame with peanut in both growing seasons, where LER exceeded unity in all treatments, as compared to solid cultures of both crops. Increasing the applied water irrigation was accompanied by an increase in the relative yield of peanut (LERa), relative yield of sesame (LERs), and total LER. Moreover, spraying with K-silicate or TRIA increased LER, compared to no spraying, irrespective of irrigation treatment. The highest value of LER, namely 1.40 was achieved by irrigation with 120 % ETo and spraying with K-silicate in both growing seasons, followed by 1.40 and 1.39 obtained from spraying with TRIA under the same irrigation treatment in the first and second season, respectively. This result showed the role of K-silicate in enhancing peanut and sesame growth under their intercropping system, which positively reflected their final yields and increased the value of LER. Moreover, this result confirm that intercropping sesame with peanut, irrigation with 120% ETo and spraying with K- silicate can enhance the unit of land productivity by 40%, compared to sole peanut cultivation in both growing seasons. The lowest values of LER, namely 1.01 were obtained under irrigation with 80% ETo and no spraying in both growing seasons. However, the value of LER under irrigation with 100 % ETo and spraying K-silicate was higher than its counterpart under irrigation with 120% and no spraying in both growing seasons, which showed the role of K-silicate in mitigating water deficiency.

Table 9: Effect of irrigation treatments, foliar spraying and their interaction on the land equivalent ratio (LER) in both seasons.

Irrigation treatment	Foliar appl.	Land equivalent ratio (LER)			Competitive ratio (CR)		Land equivalent ratio (LER)			Competitive ratio (CR)	
		LERa	LERb	LER	CRa	CRb	LERa	LERb	LER	CRa	CRb
		2021 season					2022 season				
Irr_{120}	Control	0.89	0.34	1.24	0.87	1.16	0.90	0.35	1.25	0.87	1.15
	K-Si	0.96	0.45	1.40	0.69	1.43	0.94	0.46	1.40	0.68	1.46
	TRIA	0.95	0.44	1.40	0.72	1.38	0.94	0.45	1.39	0.70	1.43
Mean		**0.93**	**0.41**	**1.34**	**0.76**	**1.32**	**0.93**	**0.42**	**1.35**	**0.75**	**1.35**
Irr_{100}	Control	0.82	0.30	1.13	0.90	1.11	0.81	0.32	1.13	0.86	1.15
	K-Si	0.91	0.42	1.33	0.71	1.40	0.90	0.43	1.33	0.70	1.43
	TRIA	0.89	0.41	1.30	0.72	1.38	0.88	0.41	1.29	0.72	1.40
Mean		**0.87**	**0.38**	**1.25**	**0.78**	**1.30**	**0.86**	**0.39**	**1.25**	**0.76**	**1.33**
Irr_{80}	Control	0.75	0.26	1.01	0.94	1.07	0.74	0.27	1.01	0.93	1.08
	K-Si	0.87	0.38	1.25	0.75	1.34	0.83	0.37	1.20	0.75	1.34
	TRIA	0.83	0.36	1.20	0.76	1.31	0.82	0.37	1.19	0.73	1.36
Mean		**0.82**	**0.33**	**1.15**	**0.82**	**1.24**	**0.80**	**0.33**	**1.13**	**0.80**	**1.26**
LSD0.05 (Irr)				0.01	0.01	0.02			0.01	0.02	0.02
LSD0.05 (F)				0.02	0.02	0.02			0.01	0.02	0.03
LSD0.05 (Irr x F)				0.03	N.S	N.S			0.02	N.S	N.S

a= peanut; b= sesame

Competitive Ratio (CR)

The results in Table (9) showed that the competitive ratio values were also influenced by the interaction between irrigation and foliar spraying treatments, where the highest values of CR for sesame were found under Irr_{120} and spraying plants by K-Si, whereas CR for peanut behaved the opposite trend. These results were true in both growing seasons. Furthermore, The CR values for sesame were generally greater than those of peanut, irrespective of irrigation or foliar spraying treatments. This indicated that peanut were dominated component, while sesame was the dominant component under all the studied treatments. Also, it can be assumed that sesame grown in association with peanut utilizes natural resources more aggressively than peanut, which appeared to be dominant.

6. Total income and Monetary Advantage Index (MAI):

The economic evaluation of the effect of interaction between irrigation and foliar spraying treatments on the studied intercropping system of sesame and peanut was performed for the total income and monetary advantage index of the two components and compared the counterpart values of sole peanut (Table 10). The economic performance was done to determine if intercropping sesame with peanut was profitable for farmers to adopt this system. Spraying with K-Si and irrigation with 120% ETo had the highest total income and MAI than the other treatments, followed by spraying with TRIA. Whereas the lowest values of both estimates were found under irrigation with 80% ETo and no spraying in both seasons. Furthermore, spraying with K-Si and irrigation with 100% ETo attained a higher value of total income and MAI than the value obtained under irrigation of 120% ETo and no spraying in both seasons.

Table 10. Effect of irrigation treatments, foliar spraying and their interaction on total income and MAI in both seasons.

Irrigation level	Foliar appl.	Peanut income (U$/ha)		Sesame income (U$/ha)		Total income (U$/ha)		MAI	
		2021 season	2022 season	2021 season	2022 season	2021 season	2022 season	2021 season	2022 season
Irr_{120}	Control	3308	681	3268	664	3989	3932	763	778
	K-Si	3542	893	3410	879	4410	4284	1252	1217
	TRIA	3496	869	3405	858	4389	4269	1239	1198
Mean		**3448**	**814**	**3361**	**800**	**4263**	**4161**	**1085**	**1064**
Irr_{100}	Control	3040	604	2946	600	3643	3546	410	398
	K-Si	3353	839	3279	828	4192	4107	1040	1019
	TRIA	3291	809	3203	791	4099	3993	954	906
Mean		**3228**	**750**	**3143**	**740**	**3978**	**3882**	**801**	**775**
Irr_{80}	Control	2749	522	2701	512	3271	3212	32	43
	K-Si	3194	760	3028	713	3954	3741	791	632
	TRIA	3085	719	2957	710	3804	3667	425	577
Mean		**3009**	**667**	**2895**	**645**	**3676**	**3540**	**416**	**417**
LSD0.05 (Irr)						40.42	18.47	132.80	20.11
LSD0.05 (F)						56.86	32.60	123.45	35.01
LSD0.05 (Irr x F)						98.49	56.46	N.S	60.63
Solid peanut		**3696**	**3634**	-	-	**3696**	**3634**	-	-

DISCUSSION

Water is essential for successful crop production, therefore, any shortage and poor management have negative impacts on crop yield (Magombeyi *et al.,* 2018). The yield reduction due to water stress is primarily attributed to the disruption of physiobiochemical processes, inhibition of photosynthesis, and stunted plant growth and development (Yuan *et al.,* 2016). In addition, drought stress alters the pathway availability of water and nutrients to become out of equilibrium, hence, reductions in plant growth and yield of peanut (Saudy and El-Metwally, 2019). These results are in line with those reported by Aydinsakir *et al.* (2016), who pointed out that seed yield reduction for I0, I25, I50, I75, and I125 were 81.0, 68.5, 28.5, 12.0, and 4.5%, respectively, compared to irrigation at 100% based on cumulative evaporation (I100 %). Water stress caused a significant decrease in pod yield/ha, pod yield/plant, seed weight/plant, no. of pod/plant, no. of seed/pod and 100 seed (Gomaa *et al.,* 2021). However, moderate water deficiency produce the highest oil percentage. These results are in line with the findings of Gomaa et al. (2021) who mentioned the that oil percentage recorded the highest values with irrigation after depletion of 40% of available soil water. Ouda *et al*. (2018a) stated that the oil percentage in peanut seeds was increased under irrigation with 100% ETo, compared to the application of 120% ETo. Although sesame is a drought-resistant crop, water stress affects sesame growth, capsule development, and final yield (Wang *et al.,* 2016).. These results are in agreement with the finding of Özhan *et al.* (2018) indicated that exposing sesame plants to water stress had unfavorable effects on plant height, number of capsules per plant, seed yield as well as oil yield. Dossa *et al.* (2019) reported that limited water supply adversely affects seed yield and other growth parameters of sesame. Furthermore, Pandey *et al.* (2021) reported that exposing sesame plants to drought has been shown to reduce yield by 28% and negatively affect yield-attributing traits. Farokhian *et al.* (2021) found that drought reduced the number of capsules per plant by decreasing the growth period and also accelerating flowering. El-Mehy *et al.* (2018) stated that the oil % was decreased as a high water deficiency was detected, while moderate irrigation increased the oil % in sunflower plants.

The application of K-Si or TRIA increase yield, yield component, and quality of both crops, compared to no spraying, could be due to numerous reasons, K^+ plays an essential role in a variety of physiological processes, and maintenance of water status in plant tissues under normal and stress conditions (Marschner, 2012; Al-Huqail *et al.,* 2019). Whereas Si could improves water use efficiency by increasing the relative water content in plants (Maghsoudi *et al.,* 2016), and enhance plant growth and yield under normal and stress conditions (Thakral *et al.,* 2021). Divito and Sadras (2014) reported that K-silicate, as a source of potassium, is an activator for many enzymes involved in N-fixation and in protein synthesis. Furthermore, Alaloosy (2002) indicated that K^+ is an important element in increasing lipids synthesis in oil crops, which explains the increase in peanut seed oil content. Similar results were obtained by Gomaa *et al.,* (2021), who stated that foliar application of potassium silicate recorded the maximum 100- pods weight, no. of pods/plant, pods yield/fed, and percentages of oil. Triacontanol (TRIA) in very small amounts, can effectively increase the growth and yield of plants (Pang *et al.,* 2020). TRIA has been well documented for its essential roles in plant response to abiotic stresses such as drought (Alharbi *et al.,* 2021; El-Beltagi *et al.,* 2022). Its exogenous application ameliorates the stress effect in plants by increasing plant biomass, chlorophyll pigments, mineral nutrients acquisition, compatible solutes accumulation and enzymatic and non-enzymatic antioxidant defence systems (Perveen *et al.,* 2016). Application of K-Si and TRIA not only increased seed yield but also enhanced the percentage of seed oil content by 11.9 and 9.9 % in the first season and by 7.5 and 6.7% in the second growing season, respectively. These results are in agreement with Yasin and Abdelsalam (2022), who found that plant height, the number of capsules per plant, weight of seeds per capsule, the weight of seeds per plant, 1000-seed weight, and seed yield per hectare, as well as percentage of seed oil were increased due to application of higher potassium fertilizer level, compared to no application.

The increase of growth, yield, quality, WER and LER as well as total income (TI) and monetary advantage index (MAI) under water deficiency may be due to the vital role of K-silicate in reducing water-deficit stress on plant growth and yield. A similar trend was observed by Abdeen and Mancy (2018) where K-silicate spraying significantly increased the macronutrients uptake and then increased the growth and productivity of sorghum. Gomaa *et al.* (2021), who noted that the greatest values of 100-pod weight, number of pods/plant and pod yield/fed were recorded when peanut crop were irrigated after depletion of 55% available soil water under foliar application of potassium silicate, compared to depletion of 70 and 85% available soil water and tap water application. Foliar application of K-silicate not only increased seed yield, yield components, and oil content under fully irrigated but also alleviated the harmful effects of drought stress on rapeseed plants (Shirani Rad *et al.,* 2022). Furthermore, results clearly indicated that spraying sesame intercropped with peanut with K-silicate could mitigate the reduction in the applied irrigation. Similar results were obtained by Noreldin and Abd-Allah (2022) when they irrigated faba bean intercropped with a sugar beet system with 100% ETo and sprayed K-silicate. They attained 10 and 3% reductions in the yield of both crops, respectively, compared to the application of 120% ETo. Moreover, Abd-Allah *et al.,* (2021) reported that spraying with 200 ppm K-silicate to faba bean intercropped with sugar beet increased the water equivalent ratio to 1.37, compared to 1.25 under no spraying. Rathore *et al.* (2021) found that irrigation peanut with amounts of 80% of ETc increased water productivity with only a marginal reduction in economic benefit and yield. Noreldin and Abd-Allah (2022), where the values of total WER were 1.42 for faba bean intercropped with sugar beet under irrigation with 100% ETo and application of K-silicate. The application of K-Si under water deficiency not only increase WER but also improved LER. These results are in agreement with the findings of Ouda *et al.* (2018a), who found that the application K_2O fertilizer at the highest level (114 kg/ha) under moderate water stress (1.0 ETo) increased LER values as compared to the lowest level of K_2O fertilizer (50 kg/ha) under full irrigation (1.2 ETo) in peanut /sunflower intercropping system. Abd-Allah *et al.* (2021), who found that the value of LER under the application of 200 ppm potassium silicate and irrigation treatment 100% ETo was higher than its counterpart value under irrigation with 120% ETo and no spraying in both growing seasons. Also, it can be assumed that sesame grown in association with peanut utilizes natural resources more aggressively than peanut, which appeared to be dominant. Similar results were obtained by Ouda *et al.* (2018b) for sunflower intercropped with peanut system, where CR value for peanut was lower than the value of CR for sunflower. El-Mehy *et al.* (2018) stated that peanut was the dominated crop in the studied intercropping system under irrigation with 120% ETo. Sesame intercropped with peanut. All intercropping treatment under deficit irrigation (100 and 80 % ETo) with spraying plants by K-silicate or TRIA had highest total income compared to sole peanut, in both seasons. These results are in accordance with Abd Alla *et al.* (2021) who reported that spraying faba bean intercropping with sugar beet with potassium silicate under water stress increased total and net income compared to unsprayed treatment.

CONCLUSION

The current situation of water scarcity requires the use of innovation to conserve irrigation water. One of these innovations is implementing intercropping systems. Furthermore, foliar spraying with K-Si or TRIA is another approach to attain irrigation water saving. Our results showed that foliar spraying with K-Si or TRIA has a more positive effect than no spray and enhanced the yield and its components of both crops under the three irrigation treatments (120,100 and 80% ETo), with the highest values obtained under 120% ETo. However, irrigation with 100% ETo (saved 17% of the applied water under 120% ETo) and spraying with K-Si produced a higher yield of both crops than the obtained under irrigation with 120% ETo and no spraying. A similar trend was obtained for the water equivalent ratio (WER), land equivalent ratio (LER), total income (TI) and monetary advantage index (MAI) of sesame intercropped with peanut system. Therefore, it is recommended to intercrop sesame with peanut (33.3% sesame + 100% peanut of planting densities), irrigation with 120% ETo and spraying with K-Si to increase the productivity of unit land and water (LER and WER), as well as TI and MAI. Furthermore, to save 17% of the applied irrigation water, irrigation with 100% ETo and spraying with K-Si can be used and that obtained higher values of the yield of both crops, LER, WER, TI and MAI, than the obtained values under irrigation with 120% ETo and no spraying.

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التخفيف من تأثير نقص الماء على نظام تحميل السمسم مع الفول السوداني بالرش الورقي لسيليكات البوتاسيوم والتراى اكتينول

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أجريت تجربة حقلية خلال موسمي 2021 و 2022 لتقييم تأثير ثلاث معاملات للري بكمية مياه تعادل (120 ، 100 و 80٪ من البخر نتح ETo) والرش باستخدام سيليكات البوتاسيوم و التراى اكتينول ، مقارنة بالكنترول (عدم الرش) للتخفيف من تأثير نقص الماء على المحصول والعلاقات المائية والعائد الإقتصادى للمزارع لنظام تحميل السمسم مع الفول السوداني (33% سمسم: 100% ول سودانى). كان متوسط كمية مياه الري المضافة 9654 و 8045 و 6436 م 3 / هكتار للري بمعدل 120 و 100 و 80٪ على التوالي. أشارت النتائج إلى أن أعلى محصول لكلا المحصولين تم الحصول عليه عند الري بكمية مياه تعادل 120٪ من البخرنتح (ETo) والرش بسيليكات البوتاسيوم . أدى الرش الورقى بكلا من سليكات البوتاسيوم او التراى اكتينول إلى تخفيف التأثير السلبى للرى بكمية مياه منخفضة وآثارها على المحصول ومكوناته لكلا المحصولين. أدى الري بمعدل 100٪ من البخرنتح ETo (والتى فرت 17٪ من كمية المياه المضافة باستخدام الرى بـــ 120٪من البخرنتح ETo) والرش بسيليكات البوتاسيوم إلى تحقيق أعلى محصول لكلا من الفول السوداني والسمسم مقارنة بالري بمعدل120٪ ETo وبدون رش. علاوة على ذلك ، تحققت أعلى قيمة لمعدل المكافئ المائى (WER) المكافئ الأرضى (LER) وإجمالي الدخل (TI) والميزة النقدية (MAI) للسمسم المحمل مع الفول السوداني تحت الري بمعدل 120٪ ETo والرش بالسيليكات. ومع ذلك ، فإن الري باستخدام 100٪ ETo والرش بسيليكات البوتاسيوم حققت قيمًا أعلى لهذه الصفات من تلك التي تم الحصول عليها تحت الري باستخدام 120٪ ETo وبدون رش.

لذلك يمكن إستنتاج الأتي: لزيادة إنتاجية وحدة الأرض والمياه (LER و WER) ، وكذلك إجمالى الدخل للمزارع و الميزة النقدية للسمسم المحمل مع الفول السوداني ، يجب استخدام الري بنسبة 120 ٪ ETo والرش باستخدام السيليكات. علاوة على ذلك ، لتوفير 17٪ من كمية مياه الري المضافة ، يمكن استخدام الري بـ 100٪ ETo والرش بسيليكات البوتاسيوم والذي حقق قيم LER و WER و TI و MAI أعلى من تلك التي تم الحصول عليها تحت الري باستخدام الرى بـ 120٪ ETo وعدم الرش.

الكلمات المفتاحية: الإجهاد المائى، المكافئ الأرضى، المكافئ المائى، إجمالى الدخل