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Competitive interactions and economic assessment of different intercropping systems of peanut and sesame with foliar application of humic acid

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ABSTRACT

A two-year field experiment was carried out at the Demo Experimental Farm of the Faculty of Agriculture, Fayoum University, Fayoum Governorate, Egypt, during two summer growing seasons (2018 and 2019) to evaluate the optimal humic acid (HA) rate with appropriate intercropping of sesame with peanut to achieve higher land usage and profitability for farmers. Eighteen treatments were the combinations between three foliar application of HA treatments (0, 4, and 8 g HA l^{-1} abbreviated as HA_0 (without treatment), HA_1, and HA_2, respectively, and six cropping systems (100% peanut + 100% sesame, 100% peanut + 75% sesame, 100% peanut + 50% sesame, 100% peanut + 25% sesame, 100% peanut, and 100% sesame) as well as their soild patterns for peanut and sesame. The experiment was conducted using a split-plot design with three replicates. Main plots were assigned for HA foliar applications, while cropping systems were randomly distributed in the sub-plots. The results indicated that HA_2 had the highest land equivalent ratio (LER) compared to the HA foliar application treatments. The 100% peanut and 100% sesame intercropping system produced the highest LER when compared to the other intercropping systems, with peanut plants as the dominated component and sesame as the dominant component. Intercropping system 100% peanut + 100% sesame with application of HA_2 had the highest LER, total, and net returns, alongside the lowest aggressive compared to other treatments. Intercropping system 100% peanut + 100% sesame with application of HA_2 had the highest land usage (1.82 and 1.90 in 2018 and 2019 season, respectively) and profitability (54711 EGP $feddan^{-1}$) compared to solid planting of peanut (6905 EGP $feddan^{-1}$).

Keywords: Intercropping, Peanut, Sesame, Aggressiveness, Competitive relationships, Economic evaluation.

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1. INTRODUCTION

Sesame (*Sesamum indicum* L.) and peanut (*Arachis hypogaea* L.) are different species of plants. Whereas sesame belonging to the *Pedaliaceae* family and peanut to the *Fabaceae* family. Both are commonly used in cooking and have distinct flavors and nutritional profiles. When two different crops are grown together, inter-specific competition may arise **(Vandermeer, 1989)**. Due to the possibility of intercrop competition for resources like sunlight and nutrients, intercropping may have a disadvantage when compared to sole crops **(West and Griffith, 1992)**. Accordingly, evaluating the appropriate spatial arrangement for an intercropping system can have a positive impact on the interaction between the component crops, influencing their utilization of environmental resources and ultimately the success of intercropping compared to sole cropping systems. Intercropping systems are typically designed to optimize interspecies interactions for both above-and belowground competition **(Li *et al*., 2006)**. The benefits of intercropping are typically realized when there is a strong complementarity between species for nutrient and light resources, outweighing any competition effects. To optimize the advantages of a sustainable agricultural strategy, it is crucial to select the appropriate intercropping system based on agricultural objectives, environmental conditions, and resource availability **(Yang *et al*., 2021)**. Thus, various measures were used to assess the efficiency of intercropping systems compared to sole cropping **(Hiebsch and McCollum, 1987)**.

The land equivalent ratio (LER) indicates that intercropping systems result in more efficient land usage. **Mead and Willey (1990)** reveal hat LER compares the yield of species cultivated in intercropping to that of the same species grown in solid planting on the same plot of land. In this respect, **Vandermeer (1989)** stated that a value of one indicates no difference; a value above one indicates that intercropping outperforms solid planting, and a value below one suggests that yields have reduced due to competition. In the combined data from both seasons, intercropping peanut and sesame at the ratios of 2:1 and 1:1 systems resulted in greater LER **(Toaima *et al.*, 2004)**. In another study, **El-Mehy *et al*. (2023)** observed a significant yield gain over solid cultures of both crops, with LER above unity in all treatments of intercropping sesame and peanuts. Furthermore, they stated that foliar spraying with potassium silicate ($KSiO_3$) or triacontanol enhanced LER when intercropping sesame with peanuts as opposed to the control. Additionally, the relative crowding coefficient (K) and aggressivity (A) are terms used to describe the

competitive interactions between

species in intercropping systems. The (indicates whether a species produces less, equal, or more yield than predicted **(Hall, 1974)**. A species with an K less than one produces less yield, equal to one produces the predicted yield, and greater than one produces more yield. In this respect, **Panda *et al*. (2022)** found that treatments of sesame + groundnut in 1:1, 1:2, 1:3, 2:2, 2:3, and 3:3 ratios, respectively, showed yield advantages. This was determined by the K product. A measures how much one species's yield increase is higher than another's (**McGilchrist, 1965)**. An A value of 0 indicates equal competition between the two species. In this respect, sesame was the dominant component across all investigated treatments, whereas peanut plants were the dominanted component regardless of foliar spraying treatments **(El-Mehy *et al.*, 2023)**

Intercropping systems offer economic benefits by increasing crop yield and profitability through optimal land use efficiency. Growing peanuts as a solid crop yielded a lower net return than intercropping 100% peanut + 50% sesame **(Toaima *et al*., 2004)**. Also, **Khan *et al*. (2017)** showed that intercropping sesame with peanut Produce higher monetary advantages over solid planting of both crops. Moreover, **Panda *et al*. (2022)** demonstrated that there was a positive monetary advantage when the groundnut population was 50% or higher in peanut-sesame intercropping. Therefore, this study aims to achieve higher land usage and profitability for farmers.

2. MATERIALS AND METHODS

The present investigation was carried out at the Demo Experimental Farm of the Faculty of Agriculture, Fayoum University, Fayoum Governorate, Egypt, during two successive summer growing seasons, 2018 and 2019 to achieve higher land usage and profitability for farmers. Physical and chemical properties of the experimental soil **(Table 1)** were analyzed according to **Page *et al.* (1982)** and **Klute and Dirksen (1986).** **Table 2** shows main components of HA applied in this experiment on a dry weight basis.

The experiment was conducted using a split-plot design with three replicates. Main plots were assigned for HA foliar applications, while cropping systems were randomly distributed in the sub-plots. Eighteen treatments were the combinations between three HA treatments and six cropping systems as follows:

2.1. Humic acid treatment

1. Control (without treatment; H_0)
2. Foliar application with humic acid at rate 4 g l^{-1} (HA_1)
3. Foliar application with humic acid at rate 8 g l^{-1} (HA_2)

Table 1. Physical and chemical properties of the experimental soil in the first and second seasons

Soil properties	**2018**	**2019**
Physical properties		
Sand (%)	75.64	76.46
Silt (%)	12.43	11.87
Clay (%)	11.93	11.67
Texture class	Loamy sand	Loamy sand
Chemical properties		
$CaCO_3$ (%)	10.11	8.64
Electrical conductivity (dS m^{-1})	3.56	3.64
pH	7.34	7.52
Organic matter (%)	0.83	0.76
Total N (%)	0.078	0.071
Available P (ppm)	6.54	5.86
Available K (ppm)	146	143
Fe (ppm)	10.51	9.47
Mn (ppm)	2.11	1.76
Cu (ppm)	0.52	0.24
Zn (ppm)	0.54	0.38

Table 2. Main components of humic acid (HA) applied in this experiment on a dry weight basis

Component	Concentration (%)	Component	Concentration (%)
Pure HA content	90.30	S	0.48
N	0.95	Fe	0.61
P	1.04	Mn	0.09
K	1.46	Zn	0.32
Ca	2.81	Cu	0.55
Mg	0.92	Na	0.04

2.2. Intercropping and solid systems

Six different systems of intercropping peanut and sesame used in this study were as follows:

1. I1: 100% peanut +100%sesame (100P : 100S) (growing sesame on the other side of all peanut ridge)
2. I2: 100% peanut +75% sesame (100P: 75S) (each 4 ridges, growing sesame on the other side of three peanut ridge and leaving one ridge of peanut without intercropping).
3. I3: 100% peanut +50% sesame (100P: 50S) (each 4 ridges, growing sesame on the other side of two peanut ridge and leaving two ridges of peanut without intercropping.
4. I4: 100% peanut +25% sesame (100P:25S) (each 4 ridges, growing sesame on the other side of one peanut ridge and leaving three ridges of peanut without intercropping.
5. Pure stand of peanut was grown on all ridges at 20 cm as a distance between hills.
6. Pure stand of sesame was grown on all ridges at 10 cm as a distance between hills.
7. Solid planting of peanut: it was grown on all ridges distanced at 20 cm between hills with foliar application of water treatment as control (HA_0), HA at rate 4 g l^{-1} (HA_1), and HA at rate 8 g l^{-1} (HA_2).
8. Solid planting of sesame: it was grown on all ridges distanced at 10 cm between hills with foliar application of water treatment as control (HA_0), HA at rate 4 g l^{-1} (HA_1), and HA at rate 8 g l^{-1} (HA_2).

The peanut variety was used Giza 6 while sesame variety was used Shandweel-3. Each plot area was 14.4 m^2 (8 ridges × 0.6 m wide × 3 m long). Sesame and peanut crops were sown at the same time in the two seasons, i.e. 26 April. Sesame and peanut plants were thinned out three weeks after planting. Sesame plants were thinned, to secure one Plant $hill^{-1}$ while peanut plants were thinned, to secure two Plants $hill^{-1}$. The foliar spray was done with humic acid twice in two equal doses, the first time after 40 days from sowing the second after 15 days of the first application. All other cultural practices of peanut and sesame were done as a recommended.

Land equivalent ratio (LER) defined as the ratio of area needed under sole cropping to one of intercropping at the same management level to produce an equivalent yield **(Mead and Willey, 1980)**. It is calculated as follows: LER = (Yab/Yaa) + (Yba/Ybb).

Relative crowding coefficient (K), which estimates the relative dominance of one species over the other in the intercropping system **(Banik *et al*., 2006)** was calculated as follows: $K = K_a \times K_b$, $K_a = Y_{ab} \times Z_{ba}/[(Y_{aa} - Y_{ab}) \times Z_{ab}]$; $K_b = Y_{ba} \times Z_{ab}/[(Y_{bb} - Y_{ba}) \times Z_{ba}]$.

Aggressivity (A), which represents a simple measure of how much the relative yield increase in one crop is greater than the other in an intercropping system **(Willey,**

1979) was calculated as follows: Aab = [Yab / (Y_{aa} × Z_{ab})] – [Y_{ba} / (Y_{bb} × Z_{ba})]; A_{ba} = [Y_{ba}/(Y_{bb} × Z_{ba})] – [Y_{ab} / (Y_{aa} × Z_{ab})], Where, Y_{aa} = pure stand yield of crop a (peanut); Y_{bb} = pure stand yield of crop b (sesame); Y_{ab} = intercrop yield of crop a (peanut); Y_{ba} = intercrop yield of crop b (sesame); Z_{ab} = the respective proportion of crop a in the intercropping system (peanut); Z_{ba} = the respective proportion of crop b in the intercropping system (sesame). Economic evaluation (EGP feddan^{-1}) was calculated by determining each of total returns, costs and net returns of intercropping and solid plantings. Total returns feddan^{-1} (EGP) = peanut seed yield x price of peanut seeds + sesame seed yield × price of sesame seeds. Net returns feddan^{-1} (EGP) = total returns - variable costs for the crops in intercropping and solid planting. Prices and financial costs calculated by market price. Analysis of variance of the obtained results of each season was performed. The measured variables were analyzed by ANOVA using MSTAT-C statistical package. Mean comparisons were performed using the least significant differences (LSD) test with a significance level of 5% **(Gomez and Gomez, 1984)**.

3. RESULTS AND DISCUSSION

3.1. Competitive relationships

3.1.1. Land equivalent ratio (LER)

3.1.1.1. Effect of HA foliar spraying

The HA treatments had a significant effect on LER in both seasons, with yield advantage ranging from 36 to 66%, and from 48 to 69% of land usage in the first and second seasons, respectively. This suggests that HA application can improve crop productivity and yield.

3.1.1.2. Effect of cropping systems

Cropping systems were affected significantly LER in both seasons **(Table 3)**. Intercropping system 100% peanut and 100% sesame had the highest LER (1.72 in the first season and 1.81 in the second, respectively compared to the other intercropping systems in both seasons. The converse was true for the intercropping system 100% peanut and 25% sesame (1.39 in the first season and 1.35 in the second, respectively. These results are likely attributed to the unique characteristics of individual peanut and sesame plants in the intercropping system. Planting 100%peanut alongside 100%sesam e effectively reduced interspecific competition for agricultural resources. The findings align with the outcomes acquired by **Toaima *et al.* (2004) and El-Mehy *et al*. (2023)**.

Table 3. Effect of Humic acid (HA) foliar spraying, cropping systems, and their interactions on relative yields and land equivalent ratio (LER) of peanut and sesame in both seasons

Foliar HA	Cropping system (CS)	Peanut yield (t/feddan)		Sesame yield (t/ feddan)		LER peanut		LER sesame		LER	
		2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
HA_0	100% P + 100% S	0.656	0.712	0.638	0.653	0.93^{B}	0.91^{C}	0.76^{D}	0.85^{C}	1.70^{C}	1.75^{C}
	100% P + 75% S	0.706	0.722	0.611	0.407	1.01^{A}	0.92^{C}	0.73^{F}	0.53^{H}	1.74^{B}	1.45^{F}
	100% P + 50% S	0.710	0.718	0.551	0.380	1.01^{A}	0.92^{C}	0.66^{H}	0.49^{I}	1.67^{C}	1.41^{G}
	100% P + 25% S	0.707	0.737	0.333	0.279	1.01^{A}	0.94^{BC}	0.40^{K}	0.36^{K}	1.41^{F}	1.30^{H}
	Mean	**0.694**	**0.722**	**0.533**	**0.429**	$\mathbf{0.99^{a}}$	$\mathbf{0.92^{b}}$	$\mathbf{0.64^{c}}$	$\mathbf{0.56^{c}}$	$\mathbf{1.63^{a}}$	$\mathbf{1.48^{c}}$
HA_1	100% P + 100% S	0.706	0.799	0.703	0.722	0.81^{D}	0.92^{C}	0.83^{B}	0.86^{B}	1.63^{D}	$1.78B^{C}$
	100% P + 75% S	0.722	0.791	0.682	0.606	0.82^{D}	0.92^{C}	0.80^{C}	0.72^{E}	1.63^{D}	1.64^{D}
	100% P + 50% S	0.776	0.866	0.563	0.448	0.89^{C}	1.00^{A}	0.66^{H}	0.53^{G}	1.55^{E}	1.54^{E}
	100% P + 25% S	0.790	0.853	0.357	0.292	0.90^{BC}	0.99^{A}	0.42^{J}	0.35^{L}	1.32^{G}	1.33^{H}
	Mean	**0.748**	**0.827**	**0.576**	**0.517**	$\mathbf{0.86^{b}}$	$\mathbf{0.96^{ab}}$	$\mathbf{0.68^{b}}$	$\mathbf{0.61^{b}}$	$\mathbf{1.53^{b}}$	$\mathbf{1.57^{b}}$
HA_2	100% P + 100% S	0.774	0.821	0.837	0.769	0.92^{BC}	0.97^{AB}	0.91^{A}	0.94^{A}	1.82^{A}	1.90^{A}
	100% P + 75% S	0.789	0.850	0.698	0.666	0.94^{B}	1.00^{A}	0.76^{E}	0.81^{D}	1.69^{C}	1.81^{B}
	100% P + 50% S	0.851	0.855	0.624	0.503	1.01^{A}	1.01^{A}	0.68^{G}	0.61^{F}	1.69^{C}	1.62^{D}
	100% P + 25% S	0.830	0.856	0.418	0.325	0.98^{A}	1.01^{A}	0.45^{I}	0.40^{J}	1.44^{F}	1.40^{G}
	Mean	**0.811**	**0.845**	**0.644**	**0.565**	$\mathbf{0.96^{a}}$	$\mathbf{1.00^{a}}$	$\mathbf{0.70^{a}}$	$\mathbf{0.69^{a}}$	$\mathbf{1.66^{a}}$	$\mathbf{1.69^{a}}$
Mean of CS	100% P + 100% S	0.712	0.777	0.726	0.714	0.97^{A}	0.93^{B}	0.83^{A}	0.88^{A}	1.72^{A}	1.81^{A}
	100% P + 75% S	0.739	0.787	0.663	0.559	0.92^{B}	0.95^{B}	0.76^{B}	0.69^{B}	1.68^{B}	1.63^{B}
	100% P + 50% S	0.779	0.813	0.579	0.443	0.89^{C}	0.98^{A}	0.67^{C}	0.55^{C}	1.63^{C}	1.52^{C}
	100% P + 25% S	0.775	0.815	0.369	0.298	0.96^{A}	0.98^{A}	0.42^{D}	0.37^{D}	1.39^{D}	1.35^{D}

Means followed by the same letter in each column for each factor are not significantly different according to Duncan test ($p \leq 0.05$).
Solid planting of peanut (P) was 0.703 t $feddan^{-1}$ in the first season and 0.784 t $feddan^{-1}$ in the second season.
Solid planting of sesame (S) was 0.836 t $feddan^{-1}$ in the first season and 0.773 t $feddan^{-1}$ in the second season.

3.1.1.3. Effect the interaction between Humic acid (HA) treatments and cropping systems

The interaction between HA treatments and cropping systems affected significantly Land equivalent ratio (LER) in both seasons **(Table 3)**. Intercropping system 100% peanut + 100% sesame with application of HA_2 had the highest LER (1.82 in the first season and 1.90 in the second season) compared to Control in both seasons. This indicates that the combination of peanut and sesame with HA_2 application resulted in the most efficient use of resources and land, leading to higher overall productivity. Additionally, the success of this intercropping system suggests potential benefits for farmers looking to maximize yields and sustainability in their fields. These outcomes are consistent with the findings of **El-Mehy *et al*. (2023)**.

3.1.2. Relative crowding coefficient (K)

3.1.2.1. Effect of Humic acid (HA) foliar spraying

The HA treatments did not affect significantly Relative crowding coefficient in both seasons **(Table 4)**, indicating that the application of HA did not have a noticeable impact on competition within the study area.

3.1.2.2. Effect of cropping systems

Cropping systems did not affect significantly Relative crowding coefficient in both seasons **(Table 4)**. The cropping systems did not have a noticeable impact on Relative crowding coefficient in either of the two seasons. This indicates that the choice of cropping system had minimal influence on the competitive interactions between peanut and sesame in intercropping systems.

3.1.2.3. Effect the interaction between Humic acid (HA) treatments and cropping systems

The interaction between HA treatments and cropping systems did not affect significantly relative crowding coefficient in both seasons **(Table 4)**. The cropping systems did not ingrate with HA and had a noticeable impact on the relative crowding coefficient in either of the two seasons. This suggests that the application of HA may not be compatible with certain cropping systems, leading to changes in plant spacing and competition levels among crops. Further research is needed to determine the specific mechanisms behind this phenomenon and how it can be addressed for optimal crop growth and yield.

3.1.3. Aggressivity (A)

3.1.3.1. Effect of Humic acid (HA) foliar spraying

The HA treatments had a significant effect on A in both seasons **(Table 4)**. The HA_1 had the highest A peanut (-0.37) and A sesame (0.37) in the first season, meanwhile HA_2 had the highest A peanut (-0.21) and A sesame (0.21) in the second season. Generally, this suggests that HA may be a more effective treatment for increasing A in both peanut and sesame crops.

3.1.3.2. Effect of cropping systems

Cropping systems were affected significantly aggressivity (A) in both seasons **(Table 4)**. Intercropping system 100% peanut + 100% sesame had the lowest A peanut (0.05 in both seasons) and A sesame (-0.05 in both season) compared to the other intercropping systems. The converse was true for the intercropping system 100% peanut (-0.73 in the first season and -0.49 in the second season) and 25% sesame (0.73 in the first season and 0.49 in the second season). This indicates that, although peanut plants were the dominated component, sesame was the dominant component by increasing its plant density up to 100% of sole planting. These results may be due to a reduction in sesame plant density from 100 to 25% when intercropped with peanuts, which increases inter specific competition between the intercrops for essential growth resources. The findings suggest that the competitive abilities of intercropping systems varied in their aggressiveness and impact on overall crop yield. Further research is needed to explore the optimal plant density ratios for different intercropping combinations to maximize productivity while minimizing competition.

3.1.3.3. Effect the interaction between Humic acid (HA) treatments and cropping systems

The interaction between HA treatments and cropping systems affected significantly A in both seasons **(Table 4)**.

Table 4. Effect of humic acid (HA) foliar spraying, cropping systems, and their interactions on relative crowding coefficient (K) and aggressivity (A) of peanut and sesame in both seasons

Foliar HA	Cropping system (CS)	K peanut		K sesame		K		A peanut		A sesame	
		2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
HA_0	100% P + 100% S	14.58^{A}	10.08^{A}	3.22^{G}	5.47^{C}	46.98^{A}	55.14^{A}	0.17^{A}	0.06^{B}	-0.17^{A}	-0.06^{B}
	100% P + 75% S	-11.43^{A}	9.41^{A}	3.62^{F}	1.49^{I}	-41.49^{A}	13.98^{A}	0.03^{B}	0.22^{A}	-0.03^{B}	-0.22^{A}
	100% P + 50% S	-6.06^{A}	6.95^{A}	3.88^{E}	1.93^{H}	-23.32^{A}	13.46^{A}	-0.31^{F}	-0.07^{C}	0.31^{F}	0.07^{C}
	100% P + 25% S	78.91^{A}	4.67^{A}	2.65^{I}	2.26^{G}	209.95A	10.55^{A}	-0.59^{I}	-0.50^{F}	0.59^{I}	0.50^{F}
Mean		**19.00^{a}**	**7.78^{a}**	**3.34^{c}**	**2.79^{c}**	**48.03a**	**23.28^{a}**	**-0.17^{a}**	**-0.07^{a}**	**0.17^{a}**	**0.07^{a}**
HA_1	100% P + 100% S	4.26^{A}	12.63^{A}	4.72^{C}	6.07^{B}	20.12^{A}	76.72^{A}	-0.02^{C}	0.07^{B}	0.02^{C}	-0.07^{B}
	100% P + 75% S	3.55^{A}	10.46^{A}	5.39^{B}	3.45^{D}	19.12^{A}	36.07^{A}	-0.24^{E}	-0.05^{C}	0.24^{E}	0.05^{C}
	100% P + 50% S	4.21^{A}	13.04^{A}	3.91^{E}	2.28^{G}	16.45^{A}	29.75^{A}	-0.44^{H}	-0.06^{C}	0.44^{H}	0.06^{C}
	100% P + 25% S	2.46^{A}	1.96^{A}	2.89^{H}	2.13^{GH}	7.11^{A}	4.22^{A}	-0.77^{J}	-0.40^{E}	0.77^{J}	0.40^{E}
Mean		**3.62^{a}**	**9.52^{a}**	**4.23^{b}**	**3.48^{b}**	**15.70a**	**36.69^{a}**	**-0.37^{c}**	**-0.11^{a}**	**0.37^{c}**	**0.11^{a}**
HA_2	100% P + 100% S	11.11^{A}	35.73^{A}	9.86^{A}	14.67^{A}	109.41^{A}	520.58^{A}	0.01^{BC}	0.03^{B}	-0.01^{BC}	-0.03^{B}
	100% P + 75% S	13.96^{A}	-96.81^{A}	4.16^{D}	5.68^{C}	58.13^{A}	-548.06^{A}	-0.07^{D}	-0.08^{C}	0.07^{D}	0.08^{C}
	100% P + 50% S	17.50^{A}	34.86^{A}	4.20^{D}	3.15^{E}	73.15^{A}	109.24^{A}	-0.35^{G}	-0.21^{D}	0.35^{G}	0.21^{D}
	100% P + 25% S	1.34^{A}	10.60^{A}	3.32^{G}	2.61^{F}	4.50^{A}	27.66^{A}	-0.83^{K}	-0.57^{G}	0.83^{K}	0.57^{G}
Mean		**10.98^{a}**	**-3.91^{A}**	**5.38^{a}**	**6.53^{a}**	**61.30^{a}**	**27.35^{a}**	**-0.31^{b}**	**-0.21^{b}**	**0.31^{b}**	**0.21^{b}**
Mean of CS	100% P + 100% S	9.98^{A}	19.48^{A}	5.93^{A}	8.74^{A}	58.84^{A}	217.48^{A}	0.05^{A}	0.05^{A}	-0.05^{A}	-0.05^{A}
	100% P + 75% S	2.03^{A}	-25.65^{A}	4.39^{B}	3.54^{B}	11.92^{A}	-166.01^{A}	-0.10^{B}	0.03^{A}	0.10^{B}	-0.03^{A}
	100% P + 50% S	5.22^{A}	18.28^{A}	3.99^{C}	2.45^{C}	22.09^{A}	50.82^{A}	-0.36^{C}	-0.11^{B}	0.36^{C}	0.11^{B}
	100% P + 25% S	27.57^{A}	5.74^{A}	2.95^{D}	2.33^{C}	73.85^{A}	14.14^{A}	-0.73^{D}	-0.49^{C}	0.73^{D}	0.49^{C}

Means followed by the same letter in each column for each factor are not significantly different according to Duncan test ($p \leq 0.05$).
Solid planting of peanut (P) was 0.703 t $feddan^{-1}$ in the first season and 0.784 t $feddan^{-1}$ in the second season.
Solid planting of sesame (S) was 0.836 t $feddan^{-1}$ in the first season and 0.773 t $feddan^{-1}$ in the second season.

Intercropping system 100% peanut + 100% sesame with application of HA_2 had the lowest A peanut (0.01 in the first season and 0.03 in the second season) and A sesame (-0.01 in the first season and 0.03 in the second season) compared to Control in both seasons. Intercropping system 100% peanut + 25% sesame with application of HA_2 had the highest A peanut (-0.83 in the first season and -0.57 in the second season) and A sesame (0.83 in the first season and 0.57 in the second season) compared to other treatments in both seasons. The number of peanut and sesame plants (which make up 100% of the solid planting for each crop) decreased inter- and intra-species competition for the limited growth resources by foliar application of HA_2.

3.1.4. Economic evaluation

The total return of intercropping sesame with peanut varied between treatments from 73711 EGP feddan^{-1} by intercropping 100% peanut + 100% sesame with application of HA_2 to 40632 EGP feddan^{-1} by intercropping 100% peanut + 25% sesame with application of HA_0 as compared with solid planting of peanut with application of HA_0 (22305 EGP feddan^{-1}) **(Table 5)**. Meanwhile, the net return of intercropping sesame with peanut varied between treatments from 54711 EGP feddan^{-1} by intercropping 100% peanut + 100% sesame with application of HA_2 to 24332 EGP feddan^{-1} by intercropping 100% peanut + 25% sesame with application of HA_0 as compared with solid planting of peanut with application of HA_0 (6905 EGP feddan^{-1}) **(Table 5)**. These results indicated that intercropping system 100% peanut + 100% sesame with application of HA_2 achieved the highest economic return feddan^{-1}. These results are consistent with those obtained by **Toaima *et al*. (2004) and Khan *et al*. (2017)**.

Table 5. Economic evaluation of humic acid (HA) foliar spraying**,** cropping systems, and their interactions, average of the two seasons (2018 and 2019)

Foliar HA	Cropping system	Crop income (EGP feddan^{-1})		Total income (EGP feddan^{-1})
		Peanut	Sesame	
HA_0	100% P + 100% S	20520	40021	60541
	100% P + 75% S	21420	31558	52978
	100% P + 50% S	21420	28861	50281
	100% P + 25% S	21660	18972	40632
	Solid planting of peanut	22305	—	22305
	Solid planting of sesame	—	49879	49879
HA_1	100% P + 100% S	22575	47740	70315
	100% P + 75% S	22695	42780	65475
	100% P + 50% S	24630	36797	61427
	100% P + 25% S	24645	24025	48670
	Solid planting of peanut	26100	—	26100
	Solid planting of sesame	—	54963	54963
HA_2	100% P + 100% S	23925	49786	73711
	100% P + 75% S	24585	42284	66869
	100% P + 50% S	25590	34937	60527
	100% P + 25% S	25290	23033	48323
	Solid planting of peanut	25395	—	25395
	Solid planting of sesame	—	54064	54064

Solid planting of peanut (P) was 0.703 t feddan^{-1} in the first season and 0.784 t feddan^{-1} in the second season.
Solid planting of sesame (S) was 0.836 t feddan^{-1} in the first season and 0.773 t feddan^{-1} in the second season.

Table 5. Contined

Foliar HA	Cropping system	Total cost (EGP $feddan^{-1}$)	Net return (EGP $feddan^{-1}$)	Increase in net return (%)
HA_0	100% P + 100% S	19000	41541	501.61
	100% P + 75% S	18100	34878	405.11
	100% P + 50% S	17200	33081	379.09
	100% P + 25% S	16300	24332	252.38
	Solid planting of peanut	15400	6905	---
	Solid planting of sesame	9800	40079	---
HA_1	100% P + 100% S	19000	51315	379.58
	100% P + 75% S	18100	47375	342.76
	100% P + 50% S	17200	44227	313.34
	100% P + 25% S	16300	32370	202.52
	Solid planting of peanut	15400	10700	---
	Solid planting of sesame	9800	45163	---
HA_2	100% P + 100% S	19000	54711	447.38
	100% P + 75% S	18100	48769	387.93
	100% P + 50% S	17200	43327	333.49
	100% P + 25% S	16300	32023	220.39
	Solid planting of peanut	15400	9995	---
	Solid planting of sesame	9800	44264	---

Solid planting of peanut (P) was 0.703 t $feddan^{-1}$ in the first season and 0.784 t $feddan^{-1}$ in the second season.
Solid planting of sesame (S) was 0.836 t $feddan^{-1}$ in the first season and 0.773 t $feddan^{-1}$ in the second season.

4. Conclusion

It can be concluded that foliar application of Humic Acid at rate 8 g l^{-1} in intercropping of 100% peanut and 100% sesame is more profitable and efficient use of land for farmers, rather than planting each crop separately.

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