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EFFECT OF INTERCROPPING DIFFERENT PLANT DENSITIES OF SESAME WITH MAIZE AND FOLIAR FERTILIZATION ON THE PRODUCTIVITY OF BOTH CROPS

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ABSTRACT: A field experiment was conducted over two consecutive summer growing seasons, 2021 and 2022, to assess the efficacy of foliar treatments (control, Nofatrein, Citreen, and Nofatrein + Citreen) and intercropping of varying plant densities of sesame (25.0%, 33.33%, and 50.0% of recommended density, RD) with maize. The trial employed a split-plot design with three biological replicates. The main plots were designated for different foliar treatment regimes, while the sub-plots were allocated for evaluating three sesame plant densities in the intercropping system with maize.

The results demonstrated that the synergistic foliar application of Nofatrein and Citreen resulted in superior agronomic parameters (plant height (cm) and leaf area (cm^2), including enhanced crop yield and yield components (number of rows per ear, number of grains per row, ear weight (g), ear grain weight (g), (%), and 100-grain weight. for maize and number of capsules/plant (cm), number of seeds/capsule, seeds weight/plant (g), 1000- seed weight (g) for sesame in the intercropping system. Intercropping maize at 25.0% RD of sesame yielded optimal agronomic performance in terms of crop yield and yield attributes for maize. Conversely, such density (25.0%) was associated with the lowest seed and oil yields per hectare for intercropped sesame in comparison to the other tested densities.

The study further identified that the maximal Land Equivalent Ratio (LER), Relative Crowding Coefficient (R.C.C.), and net economic return were realized when employing an alternative ridge sowing technique: maize was sown on one side of each ridge while sesame was sown on the opposite side, with this configuration repeating every three ridges producing 33.33% RD of sesame. This optimal planting configuration was notably effective when accompanied by bi-modal foliar application of Nofatrein and Citreen, under the climatic conditions prevalent in the Kafr El-Sheikh Governorate, Egypt.

Keywords: Maize, sesame, foliar spraying, intercropping systems, plant density, productivity, competitive relationships.

INTRODUCTION

Maize (*Zea mays* L.) is regarded as a cornerstone cereal crop of strategic importance in Egypt and globally. Utilized as cattle feed in many forms fresh, ensilaged, or grain it also acts as a raw material in essential sectors such as maize oil extraction, starch manufacture, and fructose sugar making. Additionally, maize starch is a feedstock for synthesizing various industrial products such as bio plastics, textiles, adhesives, and numerous specialized chemicals. In the 2020 growing season, the arable land allocated to maize cultivation in Egypt included roughly 1.458 million hectares, giving an output of 7.500 million metric tons. (FAO, 2022).

Sesamum indicum L., commonly known as sesame, is among the earliest crops to be domesticated and serves many purposes, from providing seeds for confections to being a source of edible oil. It is also used to make Tahini paste, oilcake, and flour. The seed is particularly rich in oil, constituting between 52% and 60% of its makeup, and protein, accounting for approximately 15% to 25% (Shyu and Hwang, 2002). In Egypt's agro-industrial sector, sesame is important as a food and industrial crop. According to the most recent statistics from 2022, the land area dedicated to sesame farming in Egypt is around 28,988.5 hectares, producing a total seed yield of nearly 38,000 metric tons (FAO, 2022).

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Owing to a shortfall exceeding 50% in locally produced sesame seeds, which are vital for several domestic sectors, including Tahini and sweetener manufacturing, there is an urgent requirement for research to widen the scope of sesame cultivation and enhance its yield. This is particularly relevant in the context of maize-sesame intercropping approaches. Such intercropping offers benefits beyond simply reducing the risks associated with sesame monoculture; it also positively influences labor and land-use efficiency, notably constrained resources. Furthermore, maize and sesame serve as harmonious intercrops, aiding in soil fertility improvement and effective weed control, as substantiated by the study conducted by El-Karamity *et al*. (2020).

With clear advantages in nutrient bioavailability over conventional soil amendments, applying foliar nutrients has become a crucial technique in contemporary agronomy to correct plant nutritional imbalances (Silberbush, 2002). Commercial foliar fertilizer Nofatrein is a composite formulation with macronutrients and micronutrients crucial for plant growth, such as nitrogen, phosphorus, potassium, iron, zinc, manganese, boron, and molybdenum. According to Nirere *et al.* (2021), foliar application of N.P.K. increases protein concentration and nutrient uptake in maize crops. Similarly, Usman *et al.* (2020) showed that treating sesame with N.P.K. foliar sprays improved growth indicators and yield outcomes. In the past, studies on flax (El-Shimy *et al.*, 2006 and Nofal *et al.*, 2020), cotton (Mesbah *et al.*, 2020), and maize

The Citreen fertilizer is composed of 15% citric acid, 2% Fe (Iron), 2% Mn (Manganese), and 2% Zn (Zinc). Citric acid is an intermediate in the Tricarboxylic Acid (T.C.A.) cycle, functioning as both a carbon framework and an energy reservoir for respiratory and other metabolic pathways (da Silva, 2003). Additionally, the citrate complex is one of the bioavailable forms of iron participating in intra plant iron translocation (Hell and Stephan, 2003).

In agronomic research, Rekani (2019) observed that the foliar application of iron and manganese significantly enhanced sesame crops' growth and yield parameters. Similarly, a study by Yasin and Abdelsalam (2020) reported that the foliar application of a micronutrient blend containing zinc, iron, and manganese led to a marked elevation in key yield attributes and seed and oil yields. Moreover, the application of Citreen in a foliar manner has been found to influence maize growth positively (El-Yazal, 2019) and pea development (Amer and El-Assiouty, 2004), highlighting its broad-spectrum efficacy in crop management.

Existing agronomic studies have established the significant influence of population density on sesame growth metrics and yield components. For example, of Sevgi *et al.* (2004) verified a direct relationship between population density and growth and yield attributes. Likewise, Ijoyah *et al.* (2016) observed that co-planting sesame at a density of 66,666 plants per hectare resulted in optimal performance in terms of individual and total crop yields, Relative crowding coefficient (R.C.C.), and land equivalent ratio (L.E.R.). This particular density also exhibited the minimum values for competitive ratio and Aggressivity metrics over the two-year study period. In a related context, Tamaru *et al.* (2019) concluded that population density and spatial arrangement were critical variables that markedly influenced sesame yield when intercropped with maize. Isaac *et al.* (2020) showed that specific yield determinants in sesame, such as the number of pods per plant, length of the fruiting zone, and overall yield, were profoundly impacted by the interrelated population densities of maize and sesame. Importantly, the yield variables for sesame improved when maize population density was reduced. Population density also notably affected key metrics related to maize growth and yield. When considering competitive dynamics, the Aggressivity index (A) displayed positive values for sesame and negative ones for maize, indicating differing competitive advantages for each species.

Moreover, the relative crowding coefficient (R.C.C) values showed that sesame was relatively more competitive than maize. Finally, the land equivalent ratio (L.E.R.), a crucial gauge for assessing the efficiency of intercropping systems, was most favorable when a full population of sesame was intercropped with a half-population of maize. The study aimed to determine the productivity, competitive dynamics, and economic evaluation of sesame intercropped with maize under the environmental circumstances of Kafr El-Sheikh Governorate, Egypt

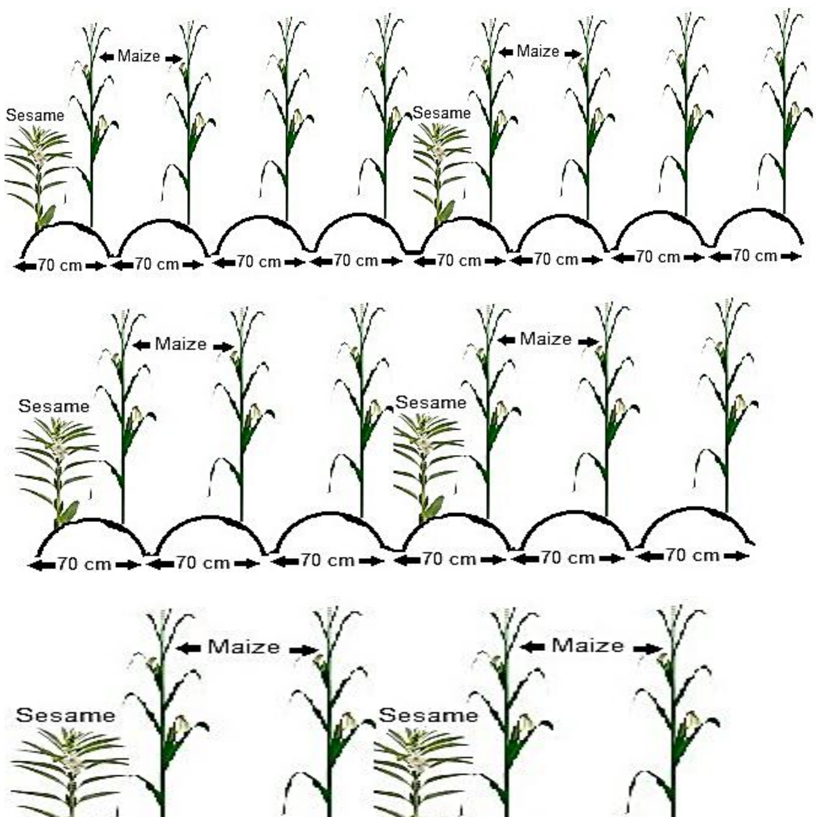
MATERIALS AND METHODS

During the two summer growing seasons of 2021 and 2022, a field trial was carried out at Sakha Agricultural Research Station Farm, Agricultural Research Center, Egypt. Sesame intercropped with maize was investigated to determine how foliar fertilization treatments and plant density affect productivity, rivalry sesame and economic evaluation.

This study used the yellow maize single cross 176 and sesame Shandwell 3 cultivars obtained from the Maize and Oil Crops Research Sections of the Field Crops Research Institute at the Agricultural Research Center in Giza, Egypt.

The experimental design was a split-plot arrangement with four foliar applications as main plots: Control (no foliar application), Nofatrein (2.5 L/ha), Citreen (2.5 L/ha) and Nofatrein + Citreen (2.5 L/ha each). The sub-plots were allocated to three plant densities of sesame intercropped with maize:25.0%, 33.33% and 50.0% RD of sesame was sown manually in hills, 14 cm apart, with 3-4 seeds per hill using the dry sowing method (Afir)

Maize was sown on one side of each ridge and sesame was sown on the other side of 4th , 3th and 2rd ridges, respectively (as shown in Figure 1).



25% for sesame means planting sesame on the same fourth ridge with corn

33.3% for sesame means planting sesame on the same third ridge with corn

50% for sesame means planting sesame on the same seconed ridge with corn

Figure 1: plant distribution of sesame intercropped with maize

Nofatrein and Citreen were intercropped as commercial foliar fertilizers. Nofatrein contains 8% nitrogen, 5% phosphorus, 5% potassium, 4% chelated iron, 3% chelated zinc, 3% manganese, 0.05% boron, and 0.02% molybdenum. Citreen contains 15% citric acid, 2% chelated iron, 2% chelated zinc, and 2% chelated manganese.

In this experiment, the foliar spraying was done with a hand sprayer until the leaves were saturated. The spraying was done twice, at 30 and 51 days after sowing.

Each experimental unit (sub-plot) included 12 ridges of 0.7 m width and 3.0 m long, resulting in 25.2 m^2. The preceding winter crop was sugar beet (*Beta vulgaris* var. saccharifera L.) in the first season and wheat (Triticum aestivum L.) in the second. In the two growing seasons, the soil samples throughout soil preparation were randomly taken from (0 - 30 cm) from the soil surface, particle size distribution and chemical analyses were conceded by the method described by Page *et al.* (1982), and its results are exposed in Table 1. The experimental field was well prepared by previously mentioned plowing experiments, leveling, compaction, and ridging (70 cm between ridges) and then divided into the experimental units (25.2 m^2).

Table 1. The experimental site's particle size distribution and chemical soil properties during the 2021 and 2022 growing seasons.

Properties		2021 season	2022 season
A: Particle size distribution:			
Sand %		9.72	9.73
Silt %		30.24	29.99
Clay %		60.04	60.28
Texture		Clayey	Clayey
B: Chemical analysis:			
pH		7.75	7.82
EC ds/m^2		1.92	1.45
Organic matter (g kg^{-1})		11.40	10.50
Total N %		0.14	0.13
Total carbonate %		6.20	6.21
CEC meq/100 g soil		41.38	41.60
SP %		78.40	78.52
SAR		4.58	4.67
Available (mg/kg)	N	26.20	27.10
	P	8.70	8.55
	K	250.60	260.40
	Zn	6.15	6.00
	Mn	14.10	13.75
Soluble cations (meq/L)	Ca^{++}	8.70	8.62
	Mg^{++}	2.04	2.35
	Na^{+}	8.00	8.57
	K^{+}	0.59	0.31
Soluble anions (meq/L)	CO_3^{--}	0.00	0.00
	HCO_3^{-}	6.84	6.81
	CL^{-}	10.54	10.51
	SO_4^{--}	7.18	7.10

Maize was intercropped with sesame using the previously mentioned plant densities and intercropping systems (Figure 1). Maize was sown manually in hills, 25 cm apart, with 2-3 seeds per hill using a dry sowing method (Afir) on May 24th and 27th in the first and second seasons, respectively. Sesame was sown manually in hills, 14 cm apart, with 3-4 seeds per hill using the dry sowing method (Afir). Sesame was planted on the other side of the fourth, third, or second ridge with corn, respectively (25.0%, 33.33%, and 50.0% of the recommended plant density of sesame) at the same planting date as maize (Figure 1).

Thirty days after sowing, the maize plants were thinned to one plant per hill and the sesame plants to two plants per hill. The solo cultivation of maize and sesame was done according to the recommendation of Nitrogen fertilizer in the form of ammonium nitrate (33.5%) at 285 kg N/ha was added to each sub-plot in two equal doses just before the first and second irrigations. Nitrogen is an essential nutrient for plant growth, and ammonium nitrate is a common form of nitrogen fertilizer. The fertilizer was applied in two doses to ensure that the plants had a steady supply of nitrogen throughout the growing season.

Potassium sulfate (48 % K_2O) at the 120 kg/ha rate was applied to each sub-plot with the first dose of nitrogen fertilizer. Phosphorus fertilizer in form of calcium super phosphate [15.5/P_2O_5] at the rate of 100 kg/fed were applied during the soil preparation.

According to the recommendations, the other agricultural practices for maize and sesame were done as normal practices. This includes practices such as weeding, pest control, and irrigation.

Maize was harvested on September 23rd and 18th , while sesame was harvested on September 28th and 24th in the first and second seasons, respectively.

Recorded data

1. Maize traits

Ninety days after sowing, five guarded plants from the inter-maize ridges were randomly taken from the pure stand and intercropped subplots to measure plant height (cm) and ear leaf area (cm2). At harvest, five guarded plants from the maize ridges were randomly taken from the pure stand and intercropped subplots to measure yield and yield attributes, i.e. ear length (cm), number of rows per ear, number of grains per row, ear weight (g), ear grain weight (g), shelling percentage (%), and 100-grain weight. The total number of plants in each subplot was harvested, and grain yield in tons per hectare was calculated based on the weight of grains at 15.5% moisture content.

2. Sesame traits

At harvest time, five guarded plants from the inter sesame ridges were taken at random from the pure stand and intercropped sub-plots to estimate; plant height, number of capsules/plant (cm), number of seeds/capsule, seeds weight/plant (g), 1000- seed weight (g) and seed yield (kg/ha), where the whole plants in each sub-plot were harvested and left to dry in the air, then they were threshed, and the seeds (which were at 13 % moisture) were weighted (kg/ha). Seed oil percentage (%) in sesame seeds was determined using the Soxhlet apparatus according to A.O.A.C (2007). The oil yield of sesame (kg/ha) was calculated by multiplying seed yield/ha by oil percentage.

3. Competitive relationships

A- Land equivalent ratio (LER) was determined according to the following formula described by Willey and Rao (1980):

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

b- Aggressivity (Ag) was calculated according to Mc-Gilchrist (1965) as the following formula:

For crop (a), $Aab = \frac{Yab}{Yaa\ x\ Zab} - \frac{Yba}{Ybb\ x\ Zba}$

and for the crop (b),

$$Aba = \frac{Yba}{Ybb\ x\ Zba} - \frac{Yab}{Yaa\ x\ Zab}$$

c- Relative crowding coefficient (R.C.C.) or K was calculated according to De-Wit (1960) as follows: $\text{K} = Kab\ x\ Kba$

$$\text{Kab} = \frac{Yab \ x \ Zba}{(Yaa - Yab)Zab}$$

$$\text{Kba} = \frac{Yba \ x \ Zab}{(Ybb - Yba)Zba}$$

Where:

Yaa and Ybb were a pure stand of the crop, a (maize) and b(sesame), respectively. Yab is the mixture yield of a crop, and Yba is the mixture yield of b crop.

Aab= Aggressivity value for the component a (maize).

Aba = Aggressivity value for component b (sesame).

Zab is the percentage of the area occupied by maize, and zba is the percentage of the area occupied by sesame.

4. Economic evaluations

Gross return from each treatment was calculated in Egyptian Pound (L.E.) and then converted to U.S. Dollar (USD), Where market prices of maize grains were 317.66 and 276.00 USD/ton, sesame seed were 2.54 and 2.32 USD/kg in 2021 and 2022 seasons, respectively.

Net return. (USD) = Gross return – Total costs

The obtained data were statistically analyzed according to the technique of analysis of variance (ANOVA) for the split-plot design as published by Gomez and Gomez (1984) using the "MSTAT-C" software package. In addition, treatment means were compared using the least significant difference (L.S.D.) method at a 5 % probability level, as described by Snedecor and Cochran (1980).

RESULTS AD DISCUSSIONS

A- Maize

I-Growth characters

1- Effect of foliar fertilization treatments

Foliar spraying with Nofatrein and Citreen significantly increased plant height, ear leaf area, and ear length of maize in both seasons (Table 2). The highest values for these traits were obtained from the combination of Nofatrein and Citreen, while the lowest values were obtained from the control treatment. Nofatrein is a commercial fertilizer that contains mineral elements such as potassium, nitrogen, phosphorus, iron, calcium, magnesium, boron, and molybdenum. These elements are essential for plant growth and development. The positive effect of Nofatrein on maize growth is consistent with, Amer and El-Assiouty (2004) who found that foliar spraying with Nofatrein increased the growth of pea plants. Additionally, EI-Shimy *et al.* (2006) and Nofal *et al.* (2020) found that Nofatrein improved the growth of flax plants. The authors of the current study suggest that the combination of Nofatrein and Citreen may be particularly effective in promoting maize growth because Citreen may help to improve the uptake of nutrients from the soil.

in addition to mineral elements, Citreen fertilizer also contains citric acid. Citric acid can promote plant growth and biomass by increasing nutrient uptake and enhancing photosynthesis and the synthesis of phytochelatins of castor bean (Mallhi *et al.,* 2019). Microelements in Citreen are also essential for plant growth. El-Yazal *et al.* (2019) reported that Citreen had a positive effect on plant height, dry matter, and ear length of maize.

2- Effect of sesame plant densities

The data delineated in (Table 2) demonstrates that varying plant densities of sesame intercropped with maize exert a significant impact on agronomic character studied (plant height, ear leaf area, and ear length). Specifically, suboptimal plant density of sesame at 25 % of RD was observed to enhance these parameters, yielding the highest recorded values for maize. Conversely, when maize was co-planted with sesame at 50% of RD there was a discernible decline in these agronomic traits across both growing seasons.

This observed diminution in maize's agronomic tseits, when it was intercropped with sesame at 50% of RD can be attributed to the heightened inter-specific competition from the sesame crop. The increased competition significantly undermines the maize's agronomic performance, manifesting as reductions in plant height, ear leaf area, and ear length.

The findings outlined are congruent with existing literature on the subject, as evidenced by multiple scholarly contributions such as those from Badran (2009), Ijoyah *et al.* (2016), Tamiru *et al.* (2019), Isaac *et al.* (2020), Ram (2020), and El-Mehy and Awad (2022). These previous studies have collectively asserted that both population density and spatial configuration exert a substantial influence on key agronomic indices namely leaf area, dry biomass, and ear length in maize when it was intercropped with sesame.

Table 2. Growth character of maize intercropped with different plant densities of sesame as affected by foliar spraying treatments and their interaction throughout the 2021 and 2022 seasons.

Treatments \ Characters		Plant height (cm)		Ear leaf area (cm^2)		Ear length (cm)	
		2021	**2022**	**2021**	**2022**	**2021**	**2022**
Foliar spraying treatments:							
Control (C)		207.1	199.8	591.0	561.5	20.19	19.28
Nofatrein (NF)		224.0	215.9	611.9	605.9	21.48	20.74
Citreen (CT)		236.4	224.0	650.6	638.7	22.87	21.61
NF + CT		256.9	256.8	708.0	697.7	23.24	21.99
LSD at 5 %		4.6	8.93	18.18	20.21	0.25	0.28
Plant densities of sesame (ratio from recommended plant density):							
25.0 % (D_1)		242.8	237.0	659.9	648.6	22.55	21.61
33.33 % (D_2)		230.3	221.2	635.6	624.7	21.90	20.89
50.0 % (D_3)		220.9	214.2	625.6	604.6	21.39	20.22
LSD at 5 %		7.85	6.08	13.80	15.39	0.16	0.19
Interaction:							
C	D_1	213.8	209.5	595.0	588.3	21.24	20.15
	D_2	205.6	197.3	587.5	576.1	20.11	19.15
	D_3	201.8	192.7	590.3	520.3	19.22	18.53
NF	D_1	243.6	234.9	640.3	640.2	21.99	21.43
	D_2	219.4	209.9	605.2	592.0	21.52	20.81
	D_3	211.6	202.9	590.3	585.6	20.93	19.99
CT	D_1	255.2	226.7	655.1	640.2	23.14	22.11
	D_2	228.6	226.8	654.7	644.3	22.86	21.70
	D_3	225.4	218.6	641.9	631.3	22.61	21.03
NF + CT	D_1	278.8	276.9	749.4	725.8	23.82	22.75
	D_2	267.4	250.9	695.0	686.2	23.11	21.90
	D_3	244.6	242.5	679.6	681.2	22.80	21.34
LSD at 5 %		15.71	12.15	27.61	30.78	0.32	0.35
Solo Maize		282.1	280.3	725.6	716.5	23.90	23.00

3- Effect of interaction of foliar fertilization with sesame plant densities

The combined effects of foliar spraying treatments and sesame plant density had a significant impact on maize plant height, ear leaf area and ear length (Table 2). Maize plants intercropped with 25% RD of sesame and sprayed with a combination of Nofatrein and Citreen foliar sprays had the highest plant height, ear leaf area ear lengths in both seasons. Conversely, maize plants intercropped with 50% RD of plant density of sesame without any foliar spraying had the lowest plant height and ear lengths in both seasons.

II- yield and its components

1- Effect of foliar fertilization

Foliar spraying with a combination of Nofatrein and Citreen had a significant positive impact on the number of rows per ear, number of grains per row, ear weight, and weight of ear grains of maize in both seasons (Table 3). The control treatment (without spraying) had the lowest significant values of these maize characteristics in both seasons.

The foliar treatments utilizing Nofatrein and Citreen were efficacious in augmenting several yield components of maize, (number of rows per ear, grains per row, ear weight, and the grain weight per year). These enhancements are attributable to an upsurge in vital growth parameters, such as leaf area in cm^2 which consequently amplified photosynthetic productivity and culminated in increased dry matter accumulation. The efficacy of these treatments is corroborated by previous studies. Amer and El-Assiouty (2004) demonstrated the beneficial impact of Nofatrein when applied as a foliar spray on pea crops, and similar growth enhancements in flax were reported by El-Shimy *et al.* (2006) and Nofal *et al.* (2020). Moreover, the positive influence of Citreen on maize yield parameters—specifically, the number of rows per ear, grains per row, ear weight, and grain weight per ear—has been previously documented by El-Yazal *et al.* (2019).

The influence of foliar application treatments on maize's grain yield per hectare and 100-grain weight is evident from the data presented in (Table 3), spanning both agricultural seasons. Specifically, the application of a foliar fertilization combining Nofatrein and Citreen resulted in the highest observed values for both grain yield per hectare and 100-grain weight in maize. Conversely, the control plots, which were not subjected to any foliar treatments, consistently exhibited the lowest performance metrics for these particular yield components in both seasons.

Furthermore, the foliar treatments of Nofatrein and Citreen were notably efficacious in augmenting maize yield, as evidenced by enhancements in key agronomic factors such as leaf area, ear length, the number of grains per row, and weight of ear grains. These findings are in consonance with previous scholarly work. For instance, El-Yazal *et al.* (2019) documented a beneficial impact of Citreen on maize yield. Similarly, Amer and El-Assiouty (2004) reported favorable outcomes using Nofatrein as a foliar spray in pea cultivation. Additional studies, such as those by El-Shimy *et al.* (2006) and Nofal *et al.* (2020), have also corroborated the growth-promoting effects of Nofatrein in flax crop.

2- Effect of plant densities

The data presented in (Table 3) elucidates a significant relationship between key yield components in maize namely, the number of rows per ear, grains per row, ear weight, and grain weight per ear when it was co-planted with sesame at varying densities (25.0, 33.33, and 50.0% of RD). Notably, the lowest sesame plant density (25.0% of optimal levels) was associated with the maximal yield metrics for these parameters. Conversely, suboptimal yield outcomes, encompassing the lowest values for rows per ear, grains per row, ear weight, and grain weight per ear, were consistently observed when maize was intercropped with sesame at 50% of RD across both agricultural cycles. The enhanced yield components at the 25% sesame density can likely be attributed to elevated leaf area and increased dry matter accumulation, resulting from diminished interspecific competition. This observation is in alignment with extant literature, including studies by Badran (2009), Ijoyah *et al.* (2016), Tamiru *et al.* (2019), Isaac *et al.* (2020), Ram (2020), and El-Mehy and Awad (2022). These researchers have collectively substantiated that both population density and spatial configuration are pivotal factors affecting maize yield components, specifically the number of rows per ear, grains per row, ear weight, and grain weight per ear, when co-planted with sesame.

Data in Table (3) shows that the yield of maize intercropped with sesame at 25%, 33.33%, and 50% of RD was significantly affected.

Table 3. Yield and compnents of maize intercropped with different plant densities of sesame as affected by foliar fertilization treatments and their interaction throughout the 2021 and 2022 seasons.

Characters / Treatments		Number of rows/ear		Number of grains/row		Ear weight (g)		Ear grains weight (g)	
		2021	2022	2021	2022	2021	2022	2021	2022
Foliar spraying treatments:									
Control (C)		14.22	13.57	35.44	34.59	256.88	246.2	195.0	187.4
Nofatrein (NF)		14.31	13.70	40.09	39.14	266.91	257.7	205.6	198.0
Citreen (CT)		14.76	14.10	41.64	40.56	279.57	267.6	218.0	208.8
NF + CT		15.83	14.88	42.48	41.52	288.53	275.2	225.6	216.8
LSD at 5 %		0.06	0.10	0.73	0.70	5.6	6.0	7.5	7.8
Plant densities of sesame (ratio from recommended plant density):									
25.0 % (D_1)		14.97	14.39	42.94	41.94	280.4	270.2	218.8	210.3
33.33 % (D_2)		14.76	14.07	38.98	38.04	272.3	261.2	210.4	202.2
50.0 % (D_3)		14.61	13.72	37.82	36.87	266.2	253.7	204.0	195.7
LSD at 5 %		0.04	0.06	0.54	0.60	1.9	2.1	1.9	2.1
Interaction:									
C	D_1	14.40	13.84	39.04	38.35	265.1	257.4	204.1	197.4
	D_2	14.26	13.51	34.51	33.49	255.1	243.9	193.6	184.9
	D_3	14.00	13.38	32.77	31.93	250.3	237.4	187.4	179.8
NF	D_1	14.50	14.06	42.16	41.06	273.0	265.0	213.4	204.7
	D_2	14.30	13.73	39.54	38.71	265.8	257.6	204.6	198.6
	D_3	14.15	13.30	38.57	37.66	261.8	250.5	198.8	190.9
CT	D_1	15.00	14.56	44.79	43.48	288.1	276.7	226.0	216.7
	D_2	14.68	14.19	40.68	39.72	280.8	268.1	217.4	208.1
	D_3	14.60	13.55	39.46	38.49	269.8	258.2	210.5	201.5
NF + CT	D_1	16.00	15.10	45.77	44.88	295.3	281.6	231.6	222.6
	D_2	15.80	14.87	41.17	40.25	287.5	275.1	226.1	217.1
	D_3	15.70	14.67	40.49	39.42	282.8	268.8	219.2	210.8
LSD at 5 %		0.09	0.15	1.09	1.12	3.2	3.5	3.0	3.3
Solo sesame		16.14	16.00	45.30	46.00	300.0	290.3	249.3	240.3

Table 3: continued

Characters / Treatments		Shelling percentage (%)		100-grain weight (g)		Grain yield (t/ha)	
		2021	2022	2021	2022	2021	2022
Foliar spraying treatments:							
Control (C)		75.89	76.06	32.39	31.94	8.082	7.995
Nofatrein (NF)		77.40	76.84	33.94	33.32	8.502	8.322
Citreen (CT)		77.98	78.00	36.55	35.25	8.770	8.648
NF + CT		78.21	78.79	38.20	37.69	9.164	8.929
LSD at 5 %		NS	1.09	0.67	0.62	0.085	0.151
Plant densities of sesame (ratio from recommended plant density):							
25.0 % (D_1)		78.00	77.82	36.77	35.91	8.969	8.864
33.33 % (D_2)		77.53	77.36	35.18	34.36	8.627	8.437
50.0 % (D_3)		76.58	77.09	33.86	33.38	8.293	8.119
LSD at 5 %		0.72	NS	0.40	0.38	0.104	0.130
Interaction:							
C	D_1	76.95	76.67	34.63	33.80	8.498	8.587
	D_2	75.86	75.80	32.39	31.96	8.064	7.889
	D_3	74.87	75.70	30.14	30.06	7.683	7.510
NF	D_1	78.16	77.24	35.64	34.70	8.951	8.698
	D_2	78.12	77.10	33.45	32.94	8.355	8.264
	D_3	75.93	76.18	32.75	32.33	8.200	8.003
CT	D_1	78.45	78.31	37.68	36.36	9.092	9.047
	D_2	77.45	77.62	36.56	35.03	8.851	8.668
	D_3	78.04	78.07	35.41	34.36	8.368	8.230
NF + CT	D_1	78.45	79.04	39.13	38.76	9.334	9.127
	D_2	78.68	78.92	38.32	37.53	9.237	8.929
	D_3	77.50	78.42	37.16	36.79	8.922	8.731
LSD at 5 %		NS	NS	0.83	0.77	0.209	0.260
Solo Maize		83.11	82.79	39.90	38.72	9.907	9.730

Maize intercropped with the lowest sesame plant density (25%) had the highest grain yield per hectare and 100-grain weight, while maize intercropped with the highest sesame plant density (50%) had the lowest grain yield per hectare and 100-grain weight. This is likely because the lower sesame plant density allowed the maize plants to have more resources (water, light, and nutrients) to grow and produce more grain.

The superior maize yield outcomes in the 25% sesame intercropping regimen could likely be attributed to reduced plant competition, thereby enhancing the maize's agronomic characteristics. These findings align well with Badran (2009), Ijoyah *et al.* (2016), Tamiru *et al.* (2019), Isaac *et al.* (2020), Ram (2020), and El-Mehy and Awad (2022) who affirm at the critical role of plant density and spatial arrangement in determining the yield performance of maize in sesame-maize intercropping systems.

3- Effect of the interaction between foliar fertilization and sesame plant density

The interaction between foliar fertilization treatments and sesame plant density significantly affect the number of rows/ear, number of grains/row, ear weight, and weight of ear grains of maize (Table 3). The highest values of the number of rows/ear, number of grains/row, ear weight, and ear grains weight of maize at 25.0% of the ideal plant density of sesame were produced by foliar spraying with Nofatrein and Citreen in both seasons. The least amount of rows/ear, grains/row, ear weight, and ear grains weight were obtained from maize that was sown with sesame density (50 percent of RD) without foliar spraying plants in both seasons.

The interaction between sesame plant density and foliar fertilization treatments had a significant impact on grain yield per hectare and 100-grain weight of maize (Table 3).

Maize intercropped with 25% RD of sesame of plant density and sprayed with a mixture of Nofatrein and Citreen foliar fertilizers had the highest grain yield per hectare and 100-grain weight, while maize intercropped with 50% of RPD and without foliar spraying had the lowest grain yield per hectare and 100-grain weight.

B- sesame

I -Growth, yield and its components

1- Effect of foliar fertilization treatments

Concerning the effects of foliar fertilization treatments, the data presented in (Table 4) highlights their substantial influence on key sesame yield components, including plant height, number of capsules per plant, number of seeds per capsule, and seed weight per plant, across both agricultural cycles. Utilizing a foliar spray combination of Nofatrein and Citreen led to the highest recorded values for these agronomic traits in sesame during both seasons. In stark contrast, the control plots, which were devoid of any foliar treatments, consistently exhibited the lowest metrics for these particular yield components throughout both growing cycles.

The foliar application of Nofatrein and Citreen notably enhanced several key agronomic traits of sesame, including plant height, capsule count per plant, seed count per capsule, and overall seed weight per plant. The effectiveness of Nofatrein is attributed to its rich mineral content, which includes some essential elements while are crucial for plant growth and development. These observations are congruent with the findings from previous studies. For instance, Amer and El-Assiouty (2004) found similar improvements in pea plants when they were treated with Nofatrein. Additionally, the growth-enhancing effects of Nofatrein on flax plants have been reported in studies conducted by EI-Shimy *et al.* (2006) and Nofal *et al.* (2020).

In addition, Citreen fertilizer is formulated with some essential elements. Citric acid serves as a catalyst for plant growth and biomass accumulation, potentially through its role in enhancing nutrient uptake mechanisms within plants. This is further supported by its positive impact on photosynthesis and the synthesis of phytochelatins, as indicated in the study by Mallhi *et al.* (2019). The microelements present in Citreen also play a pivotal role in facilitating optimal plant development. These observations are corroborated by research conducted by El-Yazal *et al.* (2019), who reported favorable growth outcomes in maize when it was treated with Citreen.

The influence of foliar applications on sesame production is substantial, as seen in (Table 4), affecting metrics like weight per thousand seeds, overall seed yield per hectare, the percentage of oil in the seeds, and the total oil yield per hectare across multiple seasons. The combination of Nofatrein and Citreen as foliar sprays led to peak performance in these categories. In contrast, plots that did not receive any foliar treatments had the poorest outcomes for these critical yield indicators, during both growing periods.

Additionally, the use of Nofatrein and Citreen sprays substantially bolstered sesame yields, particularly enhancing metrics such as the quantity of seeds per capsule, the number of capsules for each plant, and the overall weight of seeds per plant. These outcomes are in alignment with the findings of El-Yazal *et al.* (2019), who documented favorable effects of Citreen on maize yields. Nofatrein has also been applied as a foliar treatment in peas, as repeated by Amer and El-Assiouty, (2004) and has been found to boost the growth of flax, according to research by EI-Shimy *et al.* (2006) and Nofal *et al.* (2020).

2. Effect of plant densities of sesame

The data from (Table 4) indicate that varying the plant density of sesame at 25, 33.33, and 50% RD of sesame had a significant impact on several agronomic parameters of the crop. Specifically, the lowest plant density of sesame (25.0% of RD) yielded the highest results in terms of plant height, number of capsules per plant, number of seeds per capsule, and overall seed weight per plant. Conversely, the lowest values for these agronomic traits were observed when sesame was intercropped at 50% of RD, as recorded across both growing seasons.

In the context of an intercropping system featuring maize and sesame at a 25% plant density of the latter, the sesame demonstrated enhanced agronomic characteristics such as plant height, number of capsules per plant, number of seeds per capsule, and seed weight per plant. These improvements are likely attributed to minimized shading and reduced inter-specific competition for vital growth resources.

This empirical observation aligns with the findings of several previous studies including Badran (2009), Ijoyah *et al.* (2016), Tamiru *et al.* (2019), Isaac *et al.* (2020), Ram (2020), and El-Mehy and Awad (2022). These researchers have also reported a significant influence of plant population density and spatial configuration on agronomic traits like plant height, number of capsules per plant, and seed weight per plant in sesame when co-cultivated with maize.

The data in (Table 4) revealed that varying the planting density of sesame 25%, 33.33%, and 50% of the advised density had a notable impact on the crop. The optimal 1000-seed weight and oil content were observed at the 25% plant density, whereas the peak yield for sesame seeds and oil, measured in kg per hectare, was recorded when the density was set at 50% in both growing seasons.

When sesame was intercropped with maize at a 25% density, the yield was most favorable. This is likely attributed to a reduction in competition between the species, which seems to positively influence the agronomic characteristics of sesame.

The findings of this study are consistent with prior research conducted by Badran (2009), Ijoyah and colleagues (2016), Tamiru and team (2019), Isaac and *et al* (2020), Ram (2020) and El-Mehy and Awad (2022). These earlier works demonstrated that plant density and spatial configuration have a meaningful impact on maize yields when co-planted with sesame.

3- Effect of interaction of foliar fertilization with sesame plant densities

The interaction between foliar fertilization and plant density exerted a significant influence on various agronomic traits of sesame, as documented in (Table 4) Utilizing a foliar spray regimen of Nofatrein and Citreen yielded the most favorable results for sesame plant height, number of seeds per capsule, number of capsules per plant, and seed weight per plant. This was particularly true when applied in tandem with a reduced plant density of 25% of the optimal density for sesame. In contrast, the least favorable outcomes for these agronomic variables were observed in cases where no foliar spraying was conducted, and the sesame plant density was elevated to 50% of the optimal level.

(Table 4) reveals that several factors including foliar fertilization and plant densities had a marked effect on sesame seed metrics like weight per 1000 seeds, yield per hectare, oil concentration, and overall oil yield. The application of foliar sprays consisting of

Nofatrein and Citreen across both growing seasons resulted in the most favorable outcomes for 1000-seed weight and oil concentration, especially at the lowest plant density of 25%. On the effect side, the most substantial yields for seed and oil per hectare were recorded at the maximum plant density of 50%. The least impressive metrics for 1000-seed weight and oil concentration were observed in the absence of any foliar treatment at a plant density of 50%.

Table 4. Growth character and yield and its components of sesame intercropped of different plant densities with maize as affected by foliar fertilization treatments as well as their interaction throughout 2021 and 2022 seasons.

Treatments \ Characters		Plant height (cm)		Number of seeds/capsule		Number of capsules/plant		Seeds weight/plant (g)	
		2021	2022	2021	2022	2021	2022	2021	2022
Foliar spraying treatments:									
Control (C)		159.6	151.6	57.38	56.26	39.36	38.39	8.20	7.66
Nofatrein (NF)		172.5	163.9	59.74	58.83	42.24	41.13	9.01	8.29
Citreen (CT)		183.4	174.2	62.73	61.57	45.77	44.70	9.68	9.21
NF + CT		192.7	183.1	64.64	63.88	49.27	48.49	10.21	9.72
LSD at 5 %		5.5	5.3	0.81	0.75	2.50	2.43	0.40	0.37
Plant densities of sesame (ratio from recommended plant density):									
25.0 % (D_1)		185.9	176.5	63.73	62.74	48.34	47.46	9.93	9.34
33.33 % (D_2)		178.1	169.4	60.60	59.63	43.46	42.34	9.31	8.70
50.0 % (D_3)		167.1	158.8	59.04	58.04	40.69	39.74	8.60	8.11
LSD at 5 %		2.9	3.0	0.58	0.61	2.08	2.10	0.20	0.18
Interaction:									
C	D_1	173.8	164.5	58.55	57.47	40.49	39.74	8.90	8.43
	D_2	164.7	157.0	57.09	56.10	39.69	38.80	7.91	7.63
	D_3	140.4	133.4	56.48	55.22	37.89	36.64	7.80	6.93
NF	D_1	181.4	172.4	63.50	62.82	45.30	44.59	9.55	8.76
	D_2	172.7	164.1	58.22	57.35	42.72	41.04	9.15	8.14
	D_3	163.4	155.2	57.51	56.32	38.71	37.77	8.35	7.96
CT	D_1	188.5	179.0	65.47	64.37	51.97	50.43	10.32	9.90
	D_2	182.7	173.5	62.63	61.33	44.31	43.70	9.86	9.15
	D_3	179.1	170.2	60.11	59.01	41.04	39.99	8.81	8.51
NF + CT	D_1	200.0	190.0	67.41	66.32	55.61	55.08	10.87	10.20
	D_2	192.4	182.8	64.45	63.74	47.10	45.83	10.39	9.97
	D_3	185.7	176.4	62.06	61.60	45.10	44.56	9.46	9.06
LSD at 5 %		5.8	5.9	1.09	1.13	4.17	4.25	0.40	0.37
Solo sesame		201.0	190.6	63.00	60.33	56.90	56.00	10.99	10.50

Table 4. Continued

Characters / Treatments		1000- seed weight (g)		Seed yield (kg/ha)		Oil percentage (%)		Oil yield (kg/ha)	
		2021	2022	2021	2022	2021	2022	2021	2022
Foliar spraying treatments:									
Control (C)		3.40	3.23	545.85	533.22	46.64	45.74	253.70	242.85
Nofatrein (NF)		3.85	3.66	569.56	557.02	50.85	50.07	288.36	277.58
Citreen (CT)		4.07	3.77	590.99	570.65	54.64	54.0	321.59	306.89
NF + CT		4.60	4.35	625.17	610.24	58.34	57.55	363.72	350.21
LSD at 5 %		0.10	0.15	10.67	10.62	0.19	0.21	4.76	5.10
Plant densities of sesame (ratio from recommended plant density):									
25.0 % (D_1)		4.20	3.98	432.88	419.13	54.09	53.38	235.58	225.13
33.33 % (D_2)		3.95	3.73	644.39	626.78	52.37	51.52	338.61	323.95
50.0 % (D_3)		3.79	3.55	671.40	657.44	51.39	50.62	346.34	334.07
LSD at 5 %		0.07	0.08	7.16	5.67	0.31	0.34	3.59	3.01
Interaction:									
C	D_1	3.79	3.61	391.15	378.23	47.74	47.04	186.67	177.83
	D_2	3.36	3.18	607.60	596.25	46.62	45.65	283.29	272.25
	D_3	3.05	2.90	638.80	625.17	45.58	44.54	291.16	278.48
NF	D_1	3.97	3.77	417.33	404.42	52.44	51.79	218.85	209.47
	D_2	3.89	3.70	633.39	619.97	50.72	49.58	321.27	307.43
	D_3	3.71	3.52	657.95	646.67	49.39	48.84	324.96	315.84
CT	D_1	4.19	3.92	444.69	429.13	56.49	55.81	251.20	239.49
	D_2	4.04	3.75	658.66	627.93	54.32	53.82	357.82	337.99
	D_3	3.99	3.66	669.61	654.88	53.12	52.40	355.74	343.17
NF + CT	D_1	4.86	4.62	478.33	464.72	59.70	58.90	285.59	273.72
	D_2	4.53	4.30	677.93	662.95	57.83	57.03	392.06	378.13
	50.0 %	4.42	4.13	719.25	703.05	57.49	56.72	413.50	398.79
LSD at 5 %		0.14	0.15	11.96	11.34	0.62	0.65	7.19	6.02
Solo sesame		4.95	4.70	1619.05	1536.43	59.88	59.30	1112.06	1073.51

C : Competitive relationships

1- Land equivalent ratio

As revealed in (Table 5) all interactive regimes that incorporate both foliar sprays and variable sesame plant densities in an intercropped setting with maize showed an improvement in land productivity. This is in comparison to the results derived from planting either maize or sesame as standalone crops in both examined agricultural seasons. Remarkably, the most efficacious treatment for amplifying land utility entailed intercropping maize with sesame at 33.33% of the plant's recommended density, and concurrently applying foliar sprays of Nofatrein and Citreen. This strategic modality led to an elevation in land use efficiency by 35% and 36% in the 1^{th} and 2^{nd} seasons, respectively. In stark contrast, the least productive scenario involved interpolating maize and sesame at a suboptimal 25% of the suggested density for sesame, while abstaining from any foliar treatments. Such a regimen resulted in a diminution of land productivity by 10% in the initial season and a more substantial reduction of 13% in the latter. In synthesizing these observations, it becomes unequivocal that maize consistently played a significant role in enhancing land use efficiency and the values of the Land Equivalent Ratio (LER) across all treatment combinations more than sole cropping in both seasons.

Table 5. Equivalent Land ratio (LER), Aggressivity (Ag), and relative crowding coefficient (R.C.C.) of intercropping maize with sesame as affected by the interaction between foliar spraying treatments and plant density of sesame throughout 2021 and 2022 seasons.

Treatments	Character	Land equivalent ratio (LER)			Aggressivity (Ag)		Relative crowding Coefficient (R.C.C.)		
		Lm	Ls	LER	Ag m	Ag s	Km	Ks	K
2021 season									
C	D_1	0.86	0.24	1.10	-0.11	+0.11	1.81	1.27	2.29
	D_2	0.81	0.38	1.19	-0.19	+0.19	1.64	1.60	2.63
	D_3	0.78	0.39	1.17	-0.01	+0.01	1.73	1.30	2.25
NF	D_1	0.90	0.26	1.16	-0.13	+0.13	2.34	1.39	3.25
	D_2	0.84	0.39	1.23	-0.20	+0.20	2.02	1.71	3.46
	D_3	0.83	0.41	1.23	+0.01	-0.01	2.40	1.37	3.29
CT	D_1	0.92	0.27	1.19	-0.18	+0.18	2.79	1.51	4.22
	D_2	0.89	0.41	1.30	-0.19	+0.19	3.14	1.83	5.75
	D_3	0.84	0.41	1.26	+0.02	-0.02	2.72	1.41	3.83
NF + CT	D_1	0.94	0.30	1.24	-0.24	+0.24	4.07	1.68	6.83
	D_2	0.93	0.42	1.35	-0.18	+0.18	5.17	1.92	9.93
	D_3	0.90	0.44	1.34	+0.01	-0.01	4.53	1.60	7.24
2022 season									
C	D_1	0.88	0.25	1.13	-0.10	+0.10	1.88	1.31	2.45
	D_2	0.81	0.39	1.20	-0.22	+0.22	1.61	1.69	2.72
	D_3	0.77	0.41	1.18	-0.04	+0.04	1.69	1.37	2.32
NF	D_1	0.89	0.26	1.16	-0.16	+0.16	2.11	1.43	3.01
	D_2	0.85	0.40	1.25	-0.23	+0.23	2.11	1.80	3.81
	D_3	0.82	0.42	1.24	-0.02	+0.02	2.32	1.45	3.37
CT	D_1	0.93	0.28	1.21	-0.19	+0.19	3.31	1.55	5.13
	D_2	0.89	0.41	1.30	-0.20	+0.20	3.06	1.84	5.64
	D_3	0.85	0.43	1.27	-0.01	+0.01	2.74	1.49	4.08
NF + CT	D_1	0.94	0.30	1.24	-0.27	+0.27	3.78	1.73	6.56
	D_2	0.92	0.43	1.36	-0.23	+0.23	4.18	2.02	8.46
	D_3	0.90	0.46	1.35	-0.02	+0.02	4.37	1.69	7.37

m = maize, s = sesame

2- Aggressivity (A)

According to (Table 5), the interaction between foliar spraying treatments and sesame plant density resulted in maize being the dominated crop at most intercropping treatments in the 1st season, and at all treatments the second season. Sesame was also the dominant crop in eight of the 12 treatments in the first season and in all 12 treatments in the second season. These results could be due to competition degree among maize and sesame on nutrients, carbon dioxide, solar radiation and water, which indicate that maize and sesame are partially complementary in resource acquisition. Isaac *et al.* (2020) found that A values were negative for maize and positive for sesame regardless of the spatial arrangement. Contrary to the finding of Kolawole *et al.* (2015) who reported that maize has (+) sign and more competitive than sesame in a sesame/maize system.

3- Relative crowding coefficient (R.C.C.)

The interaction between foliar spraying strategies and the intercrop sesame with maize yield attained in all strategies in both seasons is shown in (Table 5). The maximum value RCC and yield advantage was observed by intercropping 33.33% RD of sesame intercropped with maize, and with foliar application of Nofatrein and Citreen (9.93 and 8.46) in the first and second seasons, respectively. On the other hand, the lowest yield benefit was obtained with an intercrop of 50% RD of sesame with maize of control foliar treatment (2.25 and 2.32) in the first and second seasons, respectively.

Results were in accordance with those obtained by El-Mehy and Awad (2022) who reported that The R.C.C. values of sesame exceeded those R.C.C. of maize with the early sowing date of sesame 3 weeks before maize, indicating that sesame was a dominant component, whereas maize was the dominated. In contrast, maize was the dominant crop with simultaneous planting and delaying sesame sowing date 3 weeks after maize. Ajibola and Kolawole, 2019 indicated that maize had R.C.C. values higher than sesame, thus indicating its dominance in the intercropping system, where sesame was planted two weeks after maize.

D : Economic evaluation

Data given in (Table 6) demonstrated that most treatments of the interaction between foliar spray treatments and plant density of sesame intercropped with maize exceeded total income and net return compared to the cultivation of maize or sesame alone in both seasons. The highest values of total income (4661.08 and 4040.87 USD) were attained when intercropping 50% RD of sesame plant density with maize and) foliar treatment Nofatrein and Citreen in the first and second seasons, respectively. However, the highest values of net economic return (3977.22 and 3416.75 USD) were reached when seeded sesame.

However, the intercropping of 25% of the required sesame plant density with maize and the control foliar treatment in the first and second seasons, produced the lowest values of total income (3693.01 and 3247.54 USD) and net economic return (3049.75 and 2693.99 USD, respectively. These results was accordance with El-Mehy and Awad (2022) and Ram (2020).

Table 6. Effect of the interaction between foliar spraying treatments and plant density of sesame on economic evaluation of intercropping maize with sesame throughout the two summer seasons of 2021 and 2022.

Treatments		Economic evaluation				
		2021				
Foliar spraying treatments	Plant densities of sesame	Actual maize grain yield (USD)	Actual sesame seed yield (USD)	Total income (USD)	Total cost (USD)	Net return (USD)
2021 season						
C	D_1	2699.49	993.52	3693.01	643.27	3049.75
	D_2	2561.63	1543.30	4104.93	678.97	3425.96
	D_3	2440.60	1622.55	4063.15	714.74	3348.41
NF	D_1	2843.39	1060.02	3903.41	643.27	3260.15
	D_2	2654.07	1608.81	4262.88	678.97	3583.91
	D_3	2604.83	1671.19	4276.02	714.74	3561.28
CT	D_1	2888.18	1129.51	4017.70	643.27	3374.43
	D_2	2811.63	1673.00	4484.62	678.97	3805.65
	D_3	2658.20	1700.81	4359.01	714.74	3644.27
NF + CT	D_1	2965.06	1214.96	4180.02	643.27	3536.75
	D_2	2934.24	1721.94	4656.19	678.97	3977.22
	D_3	2834.18	1826.90	4661.08	714.74	3946.34
Solo Maize		3147.08	0.0	3147.08	571.79	2575.29
Solo sesame		0.0	4112.39	4112.39	285.90	3826.49
2022 season						
C	D_1	2370.05	877.49	3247.54	553.55	2693.99
	D_2	2177.40	1383.30	3560.70	585.74	2974.96
	D_3	2072.79	1450.39	3523.19	627.92	2895.27
NF	D_1	2400.68	938.25	3338.94	553.55	2785.39
	D_2	2280.90	1438.33	3719.23	585.74	3133.49
	D_3	2208.86	1500.27	3709.14	627.92	3081.22
CT	D_1	2497.01	995.58	3492.59	553.55	2939.04
	D_2	2392.40	1456.80	3849.20	585.74	3263.46
	D_3	2271.51	1519.32	3790.84	627.92	3162.92
NF + CT	D_1	2519.09	1078.15	3597.24	553.55	3043.69
	D_2	2464.44	1538.04	4002.48	585.74	3416.75
	D_3	2409.79	1631.08	4040.87	627.92	3412.95
Solo Maize		2685.52	0.0	2685.52	499.19	2186.33
Solo sesame		0.0	3564.52	3564.52	257.47	3307.05

CONCLUSION

It could be concluded that intercropping maize with sesame at 33.33% of the recommended sesame plant density and foliar fertilization with (Nofatrein and Citreen) gave the maximum land equivalent ratio (LER), relative crowding coefficient (R.C.C.) and net economic return under the environmental conditions of Kafr El-Sheikh Governorate, Egypt.

REFERENCES

A.O.A.C. (2007). Official Methods of Analysis. 18th Ed. Association of Official Analytical Chemists, Inc., Gaithersburg, MD, Method 04.

Ajibola A. T. and Kolawole G. O. (2019). Agronomic evaluation of performance of sesame varieties in maize-based intercropping system in the Southern Guinean Savanna of Nigeria. J. Exper. Agric. Inter., 37: 1-10.

Al-Dulaimi, O.I.; Al-Ani, M.H.; Al-Rawim, O.H.; Al-Rawi, A.R. and Seadh, S.E. (2021). Response of some maize hybrids to foliar spraying treatments 2- Yield and components. I.O.P. Conf. Series: Earth and Environ. Sci., 761 (2021) 012071, doi:10.1088/1755-1315/761/1/012071.

Amer, S. and El-Assiouty, F. M. M. (2004). Pea seeds production as affected by foliar application with Citreen and Nofatrein. J. Plant Prod., 29(6): 3531-3544.

El-Mehy, A. A. and Awad, M. M. (2022). Response of sesame to intercropping with maize under different sowing dates and plant distributions of sesame. Mor. J. Agri. Sci. 3 (1): 39-48.

Badran, M.S.S. (2009). Effect of intercropping systems and sowing dates on productivity conditions of sesame crop intercropped with maize under newly planted sandy soil. Alex. J. Agric. Res., 54: 9-17.

da Silva, J.A.T. (2003). The cut flower: postharvest considerations. J. Biol. Sci. 3: 406–442.

De-Wit, C.T. (1960). Intercropping its importance and research needs. Part 1.Competition and yield advantages. Verslag Land bov Wkundige Onderz., 66: 1-82 [C.A. Willey, R. W., 1979 (Field Crop Abst., 32: 1-10)].

EI-Shimy, G.; Hussein, M. M. and EI-Refaie, A. M. (2006). Effect of nofatrin (n-biofertilizer) application times on yield and yield components of someflax varieties. J. Plant Prod., 31(6): 3295-3307.

El-Karamity, A.E.; Nagwa, R. Ahmed and Aya, N. Mohamed (2020). Effect of intercropping of some oil summer crops with maize under levels of mineral n and nano n fertilizers. Sci. J. of Agric. Sci., 2(2): 90-103, DOI: 10.21608/sjas.2020.42913.1038 90.

El-Yazal, M. A. S. (2019). The application of citric acid in combination with some micronutrients increases the growth, productivity and a few chemical constituents of Maize (*Zea Mays*) plants. Int. Lett. Nat. Sci., (76): 86-96.

FAO (2022). Food and Agriculture Organization. Faostat, FAO Statistics Division, April, 2022. http://www.fao.org/faostat/en/#data /Q.C.

Gomez, K.N. and Gomez, A.A. (1984). Statistical procedures for agricultural research. John Wiley and Sons, New York, USA.2nd ed., 68 p.

Hell, R. and Stephan, U. W. (2003). Iron uptake, trafficking and homeostasis in plants. Planta, 216(4): 541–551. https://doi.org/10.1007/s00425-002-0920-4

Ijoyah, M.O.; Anyogo, J.O. and Ugese, F.D. (2016). Yield response of Maize (Z*ea mays* L.) and sesame (*Sesamum indicum* L.) intercrop as influenced by planting densities and varieties of sesame at Makurdi, Nigeria. World Sci. News, 37: 25-49.

Isaac, A.A.; Oyebisi, A.K.; Kayode, O.S. and Mojisola, A.S. (2020). Effects of spatial arrangement and population density on the growth and yield of sesame (*Sesamum indicum* L.) in a sesame/maize intercrop. J. of Agric. Sci. 65(4): 337-350.

Kolawole, G.; Babalola, A.B.; Akinola, E.O.; Fadahunsi, T.F. and Ajibola, A.T. (2015). Evaluation of temporal variations for intercropping maize and sesame in the sourthern guinea savannah of Nigeria. American J. Exper.Agric., 9: 1-8.

Mallhi, Z.I.; Rizwan, M.; Mansha, A.; Ali, Q.; Ali, X. S.; Ali, S.; Hussain, A.; Alrokayan, S.H.; Khan, H.A.; Alam, P. and Ahmad, P. (2019). Citric Acid Enhances Plant Growth, Photosynthesis, and Phytoextraction of Lead by Alleviating the Oxidative Stress in Castor Beans. Plants. 8(11): 525.

Mc-Gillchrist, C.A. (1965). Analysis of competition experiments. Biometrics, 21: 975-985.

Mesbah, H. A.; El-Naggar, A. Z.; Abdel-Mageed, A. A. and Abouzaid, M. A. (2020). New approaches for controlling pink and spiny bollworms through pattern of bio control agents and chemicals on cotton properties. J. Advances in Agric. Res., 25(2): 228-246.

Nirere, D.; Mbaraka, S. R.; Rucamumihigo, F. X.; Murorunkwere, F.; Musana, F. R. and Rukangantambara, H. (2021). Effect of foliar application of nitrogen-phosphorus-potassium fertilizers on nutrient uptake and protein content of maize. African J. Biotechnology, 20(12): 465-469.

Nofal, O. A.; Rezk, A. I. and Abbas, M. M. (2020). The role of different fertilization strategies on the yield and quality of different flax varieties in the new lands. Sci. Archives, 1(3): 84-88.

Page, A. L.; Miller, R. H. and Keeney, D. R. (1982). Methods of soil analysis. Part 2. Chemical and Microbiological Properties. 2nd Ed. Am. Soc. Agron. Inc. Publisher Madison, Wisconsin, U.S.A.

Ram M. (2020). Effect of intercropping on productivity and profitability of sesame under dryland arid conditions. Curr. Agri. Res., 8: 152-156.

Rekani, S. I. (2019). Effect of high concentration of Fe and Mn as foliar application on growth and yield of sesame grown in calcareous soil. Int. J. Sci. Res., 8(11): 943-946.

Sevgi, C.; Mehmet, A.; Aalis, H. and Mecmi, I. (2004). Effect of planting method and plant population on growth and yield of sesame (*Sesamum indicum* L.) in a Mediterranean type of environment. Asian J. of Plant Sci., 3: 610-613.

Shyu, Y.S. and Hwang, L.S. (2002). Antioxidative activity of the crude extract of lignan glycosides from unroasted Burma black sesame meal. Food Res. Inter., 35: 357-365.

Silberbush, M. (2002). Simulation of ion uptake from the soil. In Plant Roots Marcel, Dekker: New York, pp : 651-661.

Snedecor, G. W. and Cochran, W. G. (1980). Statistical Methods, 7th Ed., Ames, IA: The Iowa State University Press.

Tamiru, D.; Brehanu, W.; Tikeremariam, F. and Getnet, A. (2019). Determination of optimum spatial arrangement and plant population in sesame sorghum intercropping. Intern. J. of Dev. Res., 9(8): 192-196.

Usman, A.; Gbanguba, U. A.; Ismaila, A. and Umar, A. (2020). Evaluation of Maxicrop foliar fertilizer on the performance of Sesame (*Sesamum indicum* L.) in Badeggi North Central, Nigeria. J. Underutilized Legumes, 2(1): 1-6.

Willey, R.W. and Rao, M.R. (1980). A competitive ratio for quantifying competition between intercrops. Exp. Agric., 17: 257-264.

Yasin, M. A. and Abdelsalam, A. (2022). Impact of micronutrients foliar application and potassium fertilizer levels on productivity and quality of sesame under sandy soil conditions. Zagazig J. Agric. Res., 49(5): 625-635.

تأثير تحميل كثافات مختلفة من السمسم مع الذرة الشامية والتسميد الورقي علي انتاجية المحصولين

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الملخص العربي

أجريت تجربة حقلية في مزرعة محطة البحوث الزراعية بسخا ، مركز البحوث الزراعية ، مصر خلال موسمي 2021 و 2022 لدراسة تأثير التسميد الورقي (بدون رش والرش مرتين بالنوفاترين، السيترين وخليط من كل منهما) وتحميل كثافات نباتية للسمسم 25.0، 33.33 و50.0 % من الكثافة النباتية المثلى للسمسم مع الذرة الشامية على الإنتاجية والعلاقات التنافسية والتقييم الاقتصادي للمحصولين. وقد استخدم تصميم القطع المنشقة في ثلاث مكررات لتوزيع المعاملات التجريبية. تم تخصيص القطع الرئيسية التسميد الورقي بالمحاليل المغذية. كما تم تخصيص القطع الشقية لتحميل لثلاثة كثافات نباتية للسمسم مع الذرة الشامية.

يمكن تلخيص اهم النتائج فيما يلي :

1- أدى التسميد الورقي لنباتات الذرة الشامية والسمسم مرتين بخليط من النوفاترين والسيترين إلى إنتاج أعلى القيم لصفات النمو وصفات المحصول ومكوناته لمحصولي الذرة الشامية والسمسم.

2- ادي تحميل الذرة الشامية على جانب واحد من كل الخطوط (الريشة العمالة) مع السمسم على الجانب الآخر من الخط (الريشة البطالة) علي الخط الرابع 25% من الكثافة النباتية الموصي بها للسمسم) الي اعطاء أعلى القيم لصفات النمو والمحصول ومكوناته لمحصولي الذرة الشامية والسمسم وأدنى القيم من محصول البذور والزيت / هكتار من السمسم المحمل مع الذرة مقارنة الكثافات الأخرى المدروسة

3- بالمقارنة بالزراعة المنفردة لكل من السمسم والذرة الشامية تم الحصول اعلي القيم لكل من معامل استغلال الأرض (LER) ، ومعامل الازدحام النسبي (RCC) و العدوانية (AG) وصافي العائد الاقتصادي من وذلك زراعة الذرة الشامية على جانب واحد من الخط وزراعة السمسم على الجانب الآخر من الخط الثالث (33.33% من الكثافة النباتية الموصي بها للسمسم) بجانب التسميد الورقي مرتين بخليط من الأسمدة التجارية النوفاترين والسيترين وذلك تحت الظروف البيئية لمحافظة كفر الشيخ ، مصر.