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Effect of Compost Tea Application on Disease Incidence and productivity of Intercropping Maize and Soybean

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ABSTRACT

A field experiment was conducted at Sakha Agricultural Researches Station, ARC, Egypt, during seasons of 2023 and 2024 to decide the effect of compost tea application on productivity and some disease incidence in the intercropping system of maize and soybean. The experimental design was randomized complete blocks design in four replicates. The intercropping system was 100% of recommended density of maize and 50% of recommended density of soybean. The six studied compost tea treatments were soil addition of compost tea at 12 liters/ha, foliar spraying of compost tea at 12 liters/ha, soil addition of compost tea at 12 liters/ha plus foliar spraying with compost tea at the rates of 6, 12, 18 and 24 liters/ha compared to without compost tea addition. Soil addition of 12 liters/ha alongside foliar spraying with compost tea at 24 liters/ha significantly increased values of all studied characters of both maize and soybean, also significantly reduce percent of stalk rot disease, northern leaf blight, Southern Leaf Blight of maize and anthracnose of soybean under intercropping system. Also, the highest values of land equivalent ratio (LER), relative crowding coefficient (RCC) and net return were produced by compost tea soil addition at 12 liters/ha and foliar application at 24 liters/ha. So, it can be concluded that the lowest disease incidence and maximum productivity of both crops, LER, and economic return under intercropping system of soybean and maize were obtained from application of compost tea as soil addition with 12 liters/+foliar spraying with 24 liters/ha.

Keywords: Maize, soybean, intercropping, Competitive relationships, compost tea additions, productivity, disease incidence.

1. Introduction

The importance of cereals in humans and animals nutrition is widely recognized by millions of people around the world. Moreover, maize (*Zea mays* L.) is the third most important cereal crop in the world after wheat and rice. In industrialized countries, a greater proportion of grains are used as livestock feed, whether fresh, silage, or grains and as industrial raw materials for food and non-food uses. On the other hand, in developing countries, it is mainly used as human food, with increasing use as animal feed.

Soybean (*Glycine max* (L) Mer.) is an important source of edible vegetable oils and proteins for both humans and animals, with a protein content of more than 40%, 20% edible vegetable oil, 30% carbohydrate, 10% total sugar and 5% ash (IITA, 1993). In addition, the nutritional quality of soybean proteins as shown by the amino acid distribution is almost as good as meat proteins and soybean meal is rich in minerals, especially iron, phosphorus, and calcium. It also contains a good percentage of

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vitamins, thiamine, riboflavin, and niacin (Tiamigu and Idowu, 2001). Soybean oil is rich in essential fatty acids and cholesterol-free, and is also increasingly used in the production of biodiesel (Acikgoz *et al.,* 2009).

Intercropping of legumes such as soybean and cereals similar to maize has been reported to be more productive than mono-cropping (Ghosh *et al.,* 2006). This may be through efficient use of light energy and other growth resources. Moreover, the optimal use of land resources can be achieved when crops are intercropped with increased plant density. Intercropping offers potential advantages in resource use, reduced inputs, and increased sustainability in crop production (Egbe *et al.,* 2010). Recently, it has become necessary to increase the productivity of maize and soybean to face the wide gap between their production and consumption. Maize and soybean agronomists are constantly looking for better ways to help farmers increase yield and net profit, such as proper intercropping and the best fertilizer application methods i.e. most favorable compost tea addition treatment.

Compost tea is an aqueous extract prepared by mixing compost with water in a certain ratio. Compost tea consists of water-extractable components such as mineral supplements, organic acids and active microorganisms especially bacteria, fungi, protozoa and other microbial metabolites (Gomez-Brandon *et al.,* 2015). Moreover, compost tea compounds affect positively on the plant rhizosphere, improve the physical and chemical properties of the soil, and suppress some plant pathogens (Abou-El-Hassan and El-Batran, 2020).

Compost tea has properties that improve soil quality by building a biologically diverse food web in the soil. Compost tea also creates a biofilm on plants when the tea is sprayed on plants via foliar spraying (Morris *et al.,* 1997). This biofilm helps prevent water loss from plants by preventing water evaporation from the leaves. Many plants have the ability to absorb some nutrients through their leaves, making plants able to immediately benefit from a foliar spraying of compost tea. Therefore, compost tea should by used as a foliar spray and also used to water plants near the root zone as a soil additive (Schmidt, 2010).

Various reports have indicated that plant productivity has been significantly enhanced by improving plant nutrient status and reducing disease incidence using compost tea (Carballo *et al.,* 2014). ELmorsy *et al.* (2016) reported that 100% compost tea concentration had the highest effect in reducing pre- and post-emergence wilt incidence, as well as germination rate and disease severity. It also had the highest effect in increasing plot yield, 100-seed weight, and protein and oil content in soybean compared to the control treatment. Hussein *et al.* (2019) showed that combined application of compost tea and/or bio-fertilizer with NPK fertilizer recorded over values of ear parameters, grain mass per ear, seed index, harvest index, and grain yield of maize compared of sole NPK. Abou-El-Hassan and El-Batran (2020) demonstrated the possibility of using algae, azolla and yeast extracts to improve the efficiency of compost tea to produce good yield and quality of sweet corn without mineral fertilizers. Priya *et al.* (2021) described the positive effects of compost tea on growth, quality and nutrient status of soybean. Shrinivas *et al.* (2021) concluded that foliar application of compost tea along with recommended dose of mineral fertilizers increased nutrient content, uptake and yield of soybean crop. Bako *et al.* (2024) illustrated the feasibility of utilizing 1 kg compost per 10 L water compost tea concentration to produce good yield and quality of maize without mineral fertilizers.

It is now recognized that stalk rot complex of maize is a major problem in tropical and subtropical maize growing areas. However, post flowering maize stalk rot is usually more noticeable than pre-flowering maize stalk and results in reduced maize yield. Pre-flowering stalk rots include pythium stalk rot (*Pythium aphanidermatum*) and bacterial stalk rot (*Erwinia chrysanthemi* pv. Zeae), while others, such as Fusarium wilt, late wilt (*Cephalosporium maydis*), black bundle disease and charcoal rot (*Macrophomina phaseolina*), appear at the post-flowering stage. (Subedi, 2015).

Anthracnose is one of the most significant production constraints in all soybean growing regions. The fungus *Colletotrichum truncatum* (Schw.) causes anthracnose with yield losses of 26% and 30% observed by Backman *et al*. (1982) and Mahmood and Sinclair (1992), respectively.

Northern Leaf Blight (NLB) (*Exserohilum turcicum* Pass.; teleomorph: *Setosphaeria turcicum*) is a major plant disease of maize in humid climates wherever it is grown. NLB causes long, oval, gray-green lesions, 3–15 cm long. As the lesions mature, they become tan with distinct, dark zones of fungal sporulation. As the disease progresses further, lesions may coalesce to form large infested areas, and entire leaves may become infested (Pataki *et al.,* 1998).

Southern Corn leaf blight (SCLB) or Maydis Leaf Blight (MLB) caused by *Helminthosporium maydis* (Syn. Bipolaris maydis (Nisik.) Shoemaker), (telomorph: *Cochliobolus heterostrophus*) is a serious fungal disease of maize worldwide where maize is grown under warm, humid conditions (White, 1999). Intercropping between crops to increase crop production has been considered one of the modern methods that used to achieve this goal. Maize seed production has been increased by intercropping soybeans with maize (Singh *et al.,* 1973 and Finlay, 1974). Soybean is affected by many pests and diseases that reduce the productivity of growing areas, and intercropping systems may solve these problems. Planting soybean under maize plants reduce the infection of Stalk rot complex and increasing yield of maize (Samra *et al.,* 1971 and Abd-El-Rahim *et al.,* 1984).

In other studies, intercropping soybean with maize increased the total number of infected plants and stalk rot, but decreased the incidence of downy mildew in soybean (Botros, 1988 and El-Gantiry *et al.,* 1993). The intercropping of maize and soybean reduced kernel and ear rot diseases in maize and pods, seed rot as well as leaf spot in soybean, while achieving optimum production of both crops (Ismail *et al.,* 2000). Therefore, this study aimed to investigate the effects of intercropping soybean with maize and compost tea addition treatments on the growth, yield, and its attributes, as well as the incidence of diseases in both crops. In addition, increase land utilization rate, reduce disease incidence and increase economic return per unit area through intercropping system under the environmental conditions of Kafrelsheikh Governorate, Egypt.

2. Materials and Methods

2.1. Study site and objective:

A field experiment was conducted out at Sakha Agricultural Research Station (latitude of 31.100 N and longitude 30.930 E, at an elevation of 14 m above sea level), Kafr El-Sheikh Governorate, Egypt, during two summer growing seasons of 2023 and 2024. This study aimed to decide the effect of soybean (*Glycine max* L.) intercropped with maize (*Zea mize*) and compost tea addition treatments on productivity and disease incidence maize and soybean crops.

2.2. Soil sampling and analysis

Soil samples were taken from the experimental site from the top of the soil surface at a depth of 30 cm during land preparation in the 2023 and 2024 seasons, and then analyzed in the laboratory, moreover, their physical and chemical properties are shown in Table 1. The mechanical and chemical analyses of the soil were performed following the method described by Page (1982). While the elements N, P and K as well as some micronutrients were determined by applying the procedure documented by Jackson (1967).

2.3. Experimental design and treatments

The field experiment was carried out in a randomized complete blocks design (RCBD) with four replicates. The six studied compost tea treatments were soil addition of compost tea at 12 liters/ha, foliar spraying of compost tea at 12 liters/ha, soil addition of compost tea at 12 liters/ha+foliar spraying with compost tea at the rates of 6, 12, 18 and 24 liters/ha compared to without compost tea addition.

Cultivation solo both of maize and soybean in three replicates to estimate Competitive relationships. Compost was kindly provided by the Agricultural Microbiology Department of the Agricultural Research Centre in Sakha, Kafr El-Sheikh, Egypt, in order to make compost tea. It was made by brewing water and compost in a 1:10 w/v (compost: water) ratio under constant aeration for 48 hours. According to *(Naidu,* et al., *2010),* tap water was introduced to the brewing tank around 48 hours prior to usage to allow for volatilization and remove the presence of chlorine. Initially, during the brewing process, molasses (10mL/L) was added as a carbon supplement to enhance the growth of beneficial microorganisms in the compost tea. The compost tea was then filtered after that. During the growth season, the compost tea characteristics were as follows: Total count of bacteria (7.3 and log cfu mL^{-1}), total count of actinomycetes (4.11 log cfu mL^{-1}), total count of fungi (4.01 log cfu mL^{-1}), pH (7.1), EC (2.40 dS m^{-1}), total N (5100 ppm), available P (3320 ppm), and available K (4156 ppm). Soil addition with compost tea was done with sowing irrigation. The foliar solution volume was 475 Liter/ha and spraying by hand sprayer (for experimental plots). Foliar spraying with aforementioned compost tea levels was carried out two times after 30 and 45 days from sowing.

Each experimental unit included four terraces, each 1.4 m width and 4.0 m length, resulting in an area of 22.4 m^2. Each terrace contain two rows of 4 m length equal 8 rows the distance between hill 25 cm ,number of plants in each row 16 plants so the number of plant for each plot (8 rows x 16 plants = 128 plants after thin the plants). The preceding winter crop was wheat (*Triticum aestivum* L.) in both seasons (2023 and 2024).

Table 1: Soil analyses of experimental sites throughout the 2023 and 2024 growing seasons.

Properties		2023 Season	2024 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		7.85	7.90
EC ds/m^2		1.90	1.85
Organic matter (g kg^{-1})		11.7	10.8
Total N %		0.13	0.12
Total carbonate %		6.24	6.23
CEC meq/100 g soil		41.34	41.52
SP %		78.35	78.48
SAR		4.55	4.64
Available (mg/kg)	N	27.00	26.40
	P	8.85	8.65
	K	245.70	265.00
Soluble cations (meq/L)	Zn	6.30	6.10
	Mn	14.22	13.69
	Ca^{++}	6.36	6.35
	Mg^{++}	6.46	5.81
	Na^{+}	10.20	9.99
	K^{+}	0.45	0.46
Soluble anions (meq/L)	CO_3^{--}	0.00	0.00
	HCO_3^{-}	4.60	4.46
	Cl^{-}	9.55	8.85
	SO_4^{--}	10.20	9.32

2.4. Cultural practices

The experimental field was well prepared through three operations of ploughing, compaction and division and then divided into experimental units with dimensions as mentioned above. Ordinary calcium superphosphate (15.5% P2O5) was added in a single dose to all plots during soil preparation at a rate of 360 kg/ha. In addition to the Without treatment of both crops maize and soybean as recommendations of Ministry of Agriculture and Land Reclamation was done, maize was planted on both sides of Raised bed (140 cm width) at a distance of 25 cm apart and leave one plant/hill (100% of recommended plant density). However, soybean was intercropped with maize by planting in two rows at the back of terraces, 30 cm apart, at a distance of 15 cm between the hills and leaving two plants/hill (50 % of recommended plant density). White maize hybrid (Single Cross 130) at the recommended seeding rate and soybean Giza 111 cultivar at 72 kg seeds/ha were sown on 20th and 23rd May in the first and second seasons. Nitrogen fertilizer (Ammonium nitrate 33.5% N) was applied at a rate of 285 kg N/ha to both maize and soybean in two equal portions, half after thinning (before the first irrigation) and the other half before the second irrigation. Potassium sulfate (48% K_2O) was added at a rate of 120 kg/ha to the experimental units before the second irrigation. Other agricultural practices for both maize and soybean were maintained as usual, in accordance with the recommendations of the Ministry of Agriculture and Land Reclamation, except for the factors under study.

Maize was harvested on September 25 and 30, while soybean was harvested on September 20 and 25 in the first and second seasons, respectively.

2.5. Data recorded

Number of days from sowing to 50 % tasseling and silking for maize plants were determined as the number of days from planting to 50 % tasseling and silking of each sub-plot plants.
At harvest time, random samples of five guarded plants of both maize and soybean were taken from each plot to determine the following characters.

2.6. Maize characters

Plant height (cm), ear height (cm), ear position (%) and stem diameter (cm). Ear leaf area (cm^2) was calculated by the following formula according to Gardner *et al.* (1985); Ear leaf area = Ear leaf length × maximum width of ear leaf × 0.75.

Ear length (cm), ear diameter (cm), number of rows/ear, number of grains/row, ear weight (g), ear grains weight (g), shelling (%) and 100-grain weight (g). Grain yield (ton/ha) was determined by the weight of grains per kilograms adjusted to 15.5 % moisture content of each plot, then converted to ton per hectare.

2.7. Disease characteristics

2.7.1. Stalk rot disease incidence % of maize

Disease incidence % of stalk rot disease of maize was determined using the following equation:

Disease incidence (%) = No. of infected plants/ Total no of plant assessed × 100

2.7.2. Northern leaf blight% of maize:

According to the methods by (Abebe *et al.,* 2008) Disease severity was rated by CIMMYT methods using 1-5 scoring scale. Northern leaf blight disease severity % rating was done as follow;

1.0 = very slightly infected, one or two restricted lesion on lower leaves or trace.
2.0 = slightly to moderate infection on lower leaves, a few scatter lesions on lower leaves.
3.0 = abundant lesions on lower leaves, a few on middle leaves.
4.0 = abundant lesions on lower and middle leaves extending to upper leaves.
5.0 = abundant lesions on all leaves, plant may be prematurely killed by blight

2.7.3. Southern leaf blight% of maize:

Disease severity% of Southern leaf Blight was rated on a row basis using a 0–10 scale with 0.5 increments, corresponding to the percentage of infected leaf area of the entire plant (0 = no disease, 1 = 10%, 10 = 100%) Pataky *et al.,* (1998).

2.7.4. Anthracnose% of Soybean:

The anthracnose severity was recorded by following 0 – 9 scale of Mayee and Datar (1986).

0= no of lesions/ discoloration
1= 1% area covered with lesions/spot/ discoloration
3= 1.1-10% area covered with lesions/spot/ discoloration
5= 10.1–25% area covered with lesions/spot/ discoloration
7= 25.1–50% area covered with lesions/spot/ discoloration
9= > 50% area covered with lesions/spot/ discoloration

2.8. Soybean characters:

Plant height (cm), number of branches/plant, number of pods/plant, number of seeds/pod and 100 – seed weight (g). Seed yield (ton/ha) was determined by harvesting whole plants in each plot were and left to dry on air, then they were threshed and the seeds (which were at 13 % moisture) were weighted (kg), then converted to ton per hectare. Disease characteristic of soybean was Anthracnose.

2.9. Competitive relationships

The following competitive relationships were calculated:

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

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

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

Relative crowding coefficient (RCC) or K: It was calculated according to De-Wit (1960) as follows: K = Kab x Kba

$$Kab = \frac{Yab \ x \ Zba}{(Yaa - Yab)Zab} \qquad Kba = \frac{Yba \ x \ Zab}{(Ybb - Yba)Zba}$$

Where: a is maize and b is soybean, respectively. Zab is percentage of the area occupied by maize and Zba is percentage of the area occupied by soybean.

2.10. Economic evaluations

In 2023 season, gross return from each treatments was calculated in American dollars ($) according to the exchange rate of the Central Bank of Egypt, September 2023 (one Dollar = 30.85 Egyptian pounds), where market price of maize was 406 $/ton and soybean seed was 648 $/ton, the costs maize from planting to harvest = 1813 $/ha and the costs soybean from planting to harvest = 1157 $/ha. While in 2024 season, gross return from each treatments was calculated also in American dollars ($) according to the exchange rate of the Central Bank of Egypt, September 2024 (one Dollar = 48.73 Egyptian pounds), where market price of maize was 308 $/ton and soybean seed was 616 $/ton, the costs maize from planting to harvest = 1221 $/ha and the costs soybean from planting to harvest = 830 $/ha.

2.11. Statistical analysis

The obtained data were statistically analyzed according to the technique of analysis of variance (ANOVA) for the randomized complete blocks design (RCBD) as published by Gomez and Gomez (1984) using "MSTAT-C" computer software package. Means of the treatments were compared using Duncan's multiple range tests at 5 % level of probability as described by Duncan (1955).

3. Results and Discussion

3.1. Maize growth, yield and its attributes:

Data recorded in Table 2 showed that the effect of compost tea addition treatments on growth attributes (number of days from sowing to 50 % tasseling and silking, plant height, ear height, ear position and stem diameter, of maize intercropped with soybean was significant in both growing seasons. It can be stated that adding compost tea to the soil at the rate of 12 L/ha in addition foliar spraying of maize plants intercropped with soybean with compost tea also at the rate of 24 L/ha resulted in a significant increase in all studied maize intercropped with soybean growth and produced the highest values of number of days from sowing to 50 % tasseling and silking, plant height, ear height, ear position, stem diameter, in both seasons. While, compost tea soil addition at 12 liters/ha and spraying plants with compost tea at 18 liters/ha came in the second rank after aforementioned compost tea addition treatments and followed by compost tea soil addition at 12 liters/ha and spraying plants with compost tea at 12 liters/ha, compost tea soil addition at 12 liters/ha and spraying plants with compost tea at 6 liters/ha, spraying plants with compost tea only at 12 liters/ha and then compost tea soil addition only at 12 liters/ha with respect to its effect on growth in both seasons. These results may be attributed to the fact that compost tea has soil-enhancing properties by building a biologically diverse food web. Compost tea also creates a biofilm on plants when sprayed on plants via foliar spraying (Morris *et al.,* 1997). This biofilm helps prevent water loss of plants by preventing water from evaporation from leaves.

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Table 2: Number of days from sowing to 50 % tasseling and silking, plant height, ear height, ear position and stem diameter of maize intercropped with soybean as affected by compost tea addition treatments during 2023 and 2024 seasons.

Characters / Treatments	Number of days to 50 % tasseling		Number of days to 50 % silking		Plant height (cm)		Ear height (cm)		Ear position (%)		Stem diameter (cm)	
	2023	2024	2023	2024	2023	2024	2023	2024	2023	2024	2023	2024
	Compost tea addition treatments											
T1	56.7 e	57.7 c	60.0 c	61.0 c	214.0 e	217.0 e	120.0d	122.5 e	56.08cd	56.45cd	1.885f	1.902f
T2	57.0 de	58.0 c	60.2 c	61.2 c	216.7de	219.7de	121.0cd	123.2 e	55.82d	56.08d	2.082e	2.102e
T3	57.5cde	58.2 bc	60.5 c	61.5 c	217.2cd	220.2cd	123.7 c	125.5d	56.96 c	56.98 c	2.120d	2.140d
T4	58.0bcd	59.0abc	61.0bc	62.0bc	219.2cd	222.2cd	128.2b	130.0 c	58.50b	58.49b	2.160c	2.185c
T5	58.5abc	59.5ab	62.0ab	63.0ab	220.0bc	223.0bc	130.2b	131.7bc	59.20ab	58.80ab	2.170c	2.190c
T6	58.7ab	59.7 a	62.0ab	63.0ab	222.7ab	225.7ab	133.2 a	132.7ab	59.55 a	58.99ab	2.195b	2.215b
T7	59.5 a	60.2 a	63.2 a	64.2 a	225.0 a	228.0 a	134.0 a	134.5 a	59.82 a	59.08 a	2.277a	2.297a

T1: Without **T2:** Compost tea soil addition at 12 L/ha **T3:** Spraying with compost tea at 12 liters/ha **T4:** Compost tea soil addition at 12 L/ha + Spraying with compost tea at 6 liters/ha **T5:** Compost tea soil addition at 12 L/ha + Spraying with compost tea at 12 liters/ha **T6:** Compost tea soil addition at 12 L/ha + Spraying with compost tea at 18 liters/ha **T7:** Compost tea soil addition at 12 L/ha + Spraying with compost tea at 24 liters/ha

Many plants have the ability to absorb some nutrients through their leaves making plants able to immediately benefit from the foliar application of compost tea. Therefore, it is recommended to use compost tea as a foliar spray, as well as to water plants near the root zone as a soil additive (Schmidt, 2010). Various reports have illustrated that the use of compost tea significantly enhanced plant productivity by improving plant nutrient status and reducing disease incidence (Carballo *et al.,* 2014). Compost tea is rich in nutrients, organic compounds and beneficial microbes that positively effect on the plant rhizosphere, in addition to improve the physical and chemical properties of the soil and suppressing some plant pathogens. These results are consistent with (Abou-El-Hassan and El-Batran, 2020). On the other hand, the lowest growth attribute values of maize intercropped with soybean were the result of control treatment (without adding compost tea as a soil additive or foliar spraying) in both seasons.

Data in Table 3 showed that the effect of compost tea addition treatments on growth attributes ear leaf area, ear length, ear diameter, number of rows/ear and number of grains/row of maize intercropped with soybean was significant in the two growing seasons. It can be stated that compost tea soil addition at 12 liters/ha in addition foliar spraying plants of maize intercropped with soybean with compost tea also at 24 liters/ha significantly increased all studied growth, While, compost tea soil addition at 12 liters/ha and spraying plants with compost tea at 18 liters/ha came in the second rank after aforementioned compost tea addition treatments and followed by compost tea soil addition at 12 liters/ha and spraying plants with compost tea at 12 liters/ha, compost tea soil addition at 12 liters/ha and spraying plants with compost tea at 6 liters/ha, spraying plants with compost tea only at 12 liters/ha and then compost tea soil addition only at 12 liters/ha with respect to its effect on growth, yield and its attributes of maize intercropped with soybean in both seasons. These results are in agreement with (Abou-El-Hassan and El-Batran, 2020). He reported that Compost tea is rich in nutrients, organic compounds and beneficial microbes that positively effect on the plant rhizosphere, in addition to improve the physical and chemical properties of the soil and suppressing some plant pathogens. On the other hand, the lowest growth attribute values of maize intercropped with soybean were the result of control treatment (without adding compost tea as a soil additive or foliar spraying) in both seasons.

The data revealed in Table 4 showed that the effect of compost tea addition treatments on yield and its attributes (ear weight, ear grains weight, shelling %, 100-grain weight and grain yield/ha) in both seasons maize intercropped with soybean was significant in the two growing seasons. It can be stated that compost tea soil addition at 12 liters/ha in addition foliar spraying plants of maize intercropped with soybean with compost tea also at 24 liters/ha significantly increased all studied growth, While, compost tea soil addition at 12 liters/ha and spraying plants with compost tea at 18 liters/ha came in the second rank after aforementioned compost tea addition treatments and followed by compost tea soil addition at 12 liters/ha and spraying plants with compost tea at 12 liters/ha, compost tea soil addition at 12 liters/ha and spraying plants with compost tea at 6 liters/ha, spraying plants with compost tea only at 12 liters/ha and then compost tea soil addition only at 12 liters/ha with respect to its effect on yield and its attributes of maize intercropped with soybean in both seasons .

Grain yield/ha of maize intercropped with soybean resulted from compost tea soil addition at 12 liters/ha and spraying plants with compost tea also at 24 liters/ha markedly increased by. 16.20, 21.26, 23.25, 24.30, 25.63 and 28.34 % in the first season as well as increased by 14.57, 20.63, 22.57, 23.79, 25.10 and 27.93 % in the second seasons as compared with without treatment.

Compost tea soil addition at 12 liters/ha and spraying plants with compost tea at 18 liters/ha, compost tea soil addition at 12 liters/ha and spraying plants with compost tea at 12 liters/ha, compost tea soil addition at 12 liters/ha and spraying plants with compost tea at 6 liters/ha, spraying plants with compost tea only at 12 liters/ha, compost tea soil addition only at 12 liters/ha and control treatment, respectively. The increases in growth, yield and its attributes of maize intercropped with soybean as a result of compost tea soil addition and foliar spraying plants with compost tea also may be due to the fact that compost tea is rich of nutrients, organic compounds and beneficial microbes that positively effect on the plant rhizosphere, besides improves soil physical and chemical properties as well as suppress disease incidence (Abou-El-Hassan and El-Batran, 2020). These results are in partial compatible with those recorded by Hussein *et al.* (2019), and Bako *et al.* (2024).

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Table 3: Ear leaf area, ear length, ear diameter, number of rows/ear and number of grains/row of maize intercropped with soybean as affected by compost tea addition treatments during 2023 and 2024 seasons.

Characters / Treatments	Ear leaf area (cm^2)		Ear length (cm)		Ear diameter (cm)		Number of rows /ear		Number of grains /row	
	2023	2024	2023	2024	2023	2024	2023	2024	2023	2024
	Compost tea addition treatments									
T1	577.7 g	584.2 g	16.22 f	16.42f	4.38 g	4.50 f	17.15g	17.35f	34.35f	36.40g
T2	624.4 f	629.4 f	16.47e	16.67e	4.47 f	4.57 e	17.42f	17.65e	36.07e	38.05f
T3	652.1 e	657.1 e	16.62d	16.82d	4.49 e	4.59 e	17.72e	17.92d	36.55e	39.00e
T4	660.7d	665.7d	16.72d	16.92d	4.54 d	4.64 d	18.00d	18.20c	37.45d	39.82d
T5	685.5 c	690.7 c	16.97c	17.17c	4.59 c	4.69 c	18.17c	18.37bc	38.30c	40.65c
T6	694.9b	699.9b	17.12b	17.32b	4.63 b	4.73 b	18.32b	18.52b	38.95b	41.45b
T7	713.2 a	718.2 a	17.47a	17.67a	4.69 a	4.79 a	18.57a	18.77a	39.52a	42.57a

T1: Without **T2:** Compost tea soil addition at 12 L/ha **T3:** Spraying with compost tea at 12 liters/ha **T4:** Compost tea soil addition at 12 L/ha + Spraying with compost tea at 6 liters/ha **T5:** Compost tea soil addition at 12 L/ha + Spraying with compost tea at 12 liters/ha **T6:** Compost tea soil addition at 12 L/ha + Spraying with compost tea at 18 liters/ha **T7:** Compost tea soil addition at 12 L/ha + Spraying with compost tea at 24 liters/ha

Table 4: Ear weight, ear grains weight, shelling percentage, 100-grain weight and grain yield/ha of maize intercropped with soybean as affected by compost tea addition treatments during 2023 and 2024 seasons.

Characters / Treatments	Ear weight (g)		Ear grains weight (g)		Shelling (%)		100-grain weight (g)		Grain yield (ton/ha)	
	2023	2024	2023	2024	2023	2024	2023	2024	2023	2024
	Compost tea addition treatments									
T1	125.1f	128.1f	101.90	104.8g	80.61 c	80.78 d	21.21g	21.75f	5.820g	5.988g
T2	146.1e	149.1e	121.6f	122.7f	80.85 c	81.13 cd	22.31f	22.75e	6.945f	7.009f
T3	160.5d	163.4d	129.4e	132.0e	81.53 b	81.58bcd	23.33e	23.25d	7.391e	7.544e
T4	162.8c	165.8c	132.7d	135.3d	81.55 b	81.82abc	24.23d	24.25c	7.583d	7.733d
T5	166.5b	169.5b	134.6c	137.5c	81.70 b	81.98abc	24.84c	24.67b	7.688c	7.857c
T6	167.7b	170.7b	137.0b	139.9b	82.10 b	82.30 ab	25.31b	24.82b	7.826b	7.995b
T7	173.2a	176.3a	142.2a	145.4a	83.22 a	82.51 a	25.79a	25.27a	8.122a	8.309a

T1: Without **T2:** Compost tea soil addition at 12 L/ha **T3:** Spraying with compost tea at 12 liters/ha **T4:** Compost tea soil addition at 12 L/ha + Spraying with compost tea at 6 liters/ha **T5:** Compost tea soil addition at 12 L/ha + Spraying with compost tea at 12 liters/ha **T6:** Compost tea soil addition at 12 L/ha + Spraying with compost tea at 18 liters/ha **T7:** Compost tea soil addition at 12 L/ha + Spraying with compost tea at 24 liters/ha

3.2. Soybean growth, yield and its attributes

Compost tea addition treatments *i.e.* without compost tea addition, compost tea soil addition at 12 liters/ha, foliar spraying plants with compost tea at 12 liters/ha, compost tea soil addition at 12 liters/ha + foliar spraying plants with compost tea at the rates of 6, 12, 18 and liters/ha significantly affected soybean growth, yield and its attributes (plant height, number of branches/plant, number of pods/plant, 100-seed weight and seed yield/ha) under intercropping system of maize and soybean in the two growing seasons as data exposed in Table 5. Application of compost tea as soil addition at 12 liters/ha besides foliar spraying soybean plants intercropped with maize by compost tea also at 24 liters/ha significantly increased all studied growth, yield and its attributes and resulted in the highest values of plant height, number of branches/plant, number of pods/plant, 100-seed weight and seed yield/ha of soybean intercropped with maize in both seasons. The second best compost tea addition treatment was compost tea soil addition at 12 liters/ha and spraying plants with compost tea at 18 liters/ha that followed by compost tea soil addition at 12 liters/ha and spraying plants with compost tea at the rates of 12 and 6 liters/ha, then spraying plants with compost tea only at 12 liters/ha and then compost tea soil addition only at 12 liters/ha with respect to its effect on growth, yield and its attributes of soybean intercropped with maize in both seasons. On the contrary, control treatment (without addition of compost tea as soil addition or foliar spraying) resulted in the lowest values of growth, yield and its attributes of soybean under intercropping system with maize in both seasons.

Seed yield/ha of soybean intercropped maize with resulted from compost tea soil addition at 12 liters/ha and spraying plants with compost tea also at 24 liters/ha markedly increased by 5.64, 10.37, 17.30, 18.92, 20.90 and 24.42 % in the first season in addition to increase by 5.14, 8.80, 15.36, 16.95, 18.78 and 22.10 % in the second seasons as compared with Without treatment, compost tea soil addition at 12 liters/ha and spraying plants with compost tea at 18 liters/ha, compost tea soil addition at 12 liters/ha and spraying plants with compost tea at 12 liters/ha, compost tea soil addition at 12 liters/ha and spraying plants with compost tea at 6 liters/ha, spraying plants with compost tea only at 12 liters/ha, compost tea soil addition only at 12 liters/ha and control treatment, respectively. These increases in growth, yield and its attributes of soybean intercropped with maize because of compost tea soil addition foliar spraying on the plants possibly owing to compost tea has the properties of being a soil conditioner through building biologically varied nutrients in the soil. Also, compost tea creates a biofilm on the plants when given to the plants as a foliar spraying that facilitates prevent water loss of the plants by preventing water from evaporating out of the leaves (Morris *et al.,* 1997), which caused increases in plant growth characters, yield and its attributes of soybean. These results are in partial compatible with those recorded by El-Morsy *et al.* (2016); Priya *et al.* (2021) and Shrinivas *et al.* (2021).

3.3. Disease incidence

The data revealed in Table 6 revealed that, the effect of compost tea addition treatments (without, compost tea soil addition at 12 liters/ha, foliar spraying plants with compost tea at 12 liters/ha, compost tea soil addition at 12 liters/ha + foliar spraying plants with compost tea at the rates of 6, 12, 18 and liters/ha) on disease incidence of maize and soybean (stalk rot disease, northern leaf blight, Southern Leaf Blight disease of maize and anthracnose disease of soybean under natural infection) were significant in the two growing seasons. Application of compost tea as soil addition at 12 liters/ha in addition foliar spraying plants with compost tea also at 24 liters/ha produced the lowest values of stalk rot disease, Northern leaf blight, Southern Leaf Blight diseases of maize and anthracnose disease of soybean under natural infection in both seasons. Whereas, compost tea soil addition at 12 liters/ha and spraying plants with compost tea at 18 liters/ha ranked secondly and followed by compost tea soil addition at 12 liters/ha and spraying plants with compost tea at the rates of 12 and 6 liters/ha, spraying plants with compost tea only at 12 liters/ha, then compost tea soil addition only at 12 liters/ha and control treatment with respect to its favourable effects on disease incidence of maize and soybean under natural infection in both seasons. On the other side, the highest values of stalk rot disease, north leaf blight and swath leaf blight of maize and anthracnose of soybean under natural infection were resulted from Without treatment in both seasons.

Several authors have shown the *stimulatory* and suppressive effect of different compost applications in *several* cropping systems against several pathogens such as Rhizoctonia solani, Fusarium oxysporum and Verticillium dahlia (Marin *et al.,* 2013 *and* Markakis *et al.,* 2016). *Also*, Ilangumaran and Smith (2017) noted that among the most abundant microorganisms in these extracts were plant-growth

Table 5: Plant height, number of branches/plant, number of pods/plant, 100 – seed weight and seed yield/ha of soybean intercropped with maize as affected by compost tea addition treatments during 2023 and 2024 seasons.

Characters	Plant height (cm)		Number of branches /plant		Number of pods /plant		100 – seed weight (g)		Seed yield (ton/ha)	
Treatments	**2023**	**2024**	**2023**	**2024**	**2023**	**2024**	**2023**	**2024**	**2023**	**2024**
	Compost tea addition treatments									
T1	90.25 e	92.25 e	2.25 d	2.50 d	22.00 e	25.00 e	13.19 g	13.29 g	1.037 g	1.181 g
T2	93.25 d	95.25 d	3.00 c	3.25 c	26.00 d	29.00 d	13.61 f	13.71 f	1.099 f	1.240 f
T3	95.25 c	97.25 c	3.00 c	3.31 c	28.25 d	31.25 d	13.88 e	13.98 e	1.157 e	1.295 e
T4	96.75 b	99.25 b	3.25 bc	3.50 bc	32.00 c	35.00 c	14.14 d	14.24 d	1.254 d	1.393 d
T5	98.00 b	100.25b	3.75 ab	4.00 ab	35.25 b	38.25 b	14.17 c	14.27 c	1.279 c	1.422 c
T6	99.75 a	101.50a	3.75 ab	4.00 ab	38.75 a	41.75 a	14.36 b	14.45 b	1.311 b	1.454 b
T7	101.00a	102.50 a	4.25 a	4.50 a	40.25 a	43.25 a	14.51 a	14.61 a	1.372 a	1.516 a

T1: Without **T2:** Compost tea soil addition at 12 L/ha **T3:** Spraying with compost tea at 12 liters/ha **T4:** Compost tea soil addition at 12 L/ha + Spraying with compost tea at 6 liters/ha **T5:** Compost tea soil addition at 12 L/ha + Spraying with compost tea at 12 liters/ha **T6:** Compost tea soil addition at 12 L/ha + Spraying with compost tea at 18 liters/ha **T7:** Compost tea soil addition at 12 L/ha + Spraying with compost tea at 24 liters/ha

Table 6: Stalk rot disease, north leaf blight and swath leaf blight of maize and anthracnose of soybean under natural infection as affected by compost tea addition treatments during 2023 and 2024 seasons.

Characters	Stalk rot disease (%)		Northern leaf blight (%)		Southern leaf Blight (%)		Anthracnose (%)	
Treatments	**2023**	**2024**	**2023**	**2024**	**2023**	**2024**	**2023**	**2024**
	Compost tea addition treatments							
T1	10.33a	9.28 a	3.07 a	2.75 a	8.12 a	7.46 a	5.43 a	5.03 a
T2	9.12ab	8.35 b	2.67 b	2.37 b	7.06 b	6.48 b	4.93 b	4.51 b
T3	8.06bc	7.31 c	2.24 c	1.96 c	6.37 c	5.72 c	4.62 c	4.25 c
T4	6.90cd	5.93 d	1.97 d	1.67 d	5.37 d	4.73 d	4.12 d	3.71 d
T5	6.62cd	5.57 e	1.75 e	1.47 e	4.12 e	3.47 e	3.41 e	2.98 e
T6	6.07d	5.05 f	1.50 f	1.20 f	3.37 f	2.70 f	2.62 f	2.22 f
T7	5.86 d	3.78 g	1.25 g	0.95 g	2.06 g	1.36 g	1.43 g	1.03 g

T1: Without **T2:** Compost tea soil addition at 12 L/ha T3: Spraying with compost tea at 12 liters/ha **T4:** Compost tea soil addition at 12 L/ha + Spraying with compost tea at 6 liters/ha **T5:** Compost tea soil addition at 12 L/ha + Spraying with compost tea at 12 liters/ha **T6:** Compost tea soil addition at 12 L/ha + Spraying with compost tea at 18 liters/ha **T7:** Compost tea soil addition at 12 L/ha + Spraying with compost tea at 24 liters/ha promoting rhizobacteria (PGPR), which influence plant growth through *various* mechanisms (e.g., nitrogen fixation, nutrient solubilization, release of growth hormones, and enzymes) that *result in improved nutrient availability.* These mechanisms *appear* to be involved in plant-induced resistance, making plants able to cope with subsequent stresses (Hamid *et al.,* 2021). Compost tea extracted from green waste appears to exhibit the best suppressive effects against a wide range of different plant pathogens (Martin *et al.,* 2012). Therefore, the use of these extracts as a potential eco-friendly alternative to fertilizers and synthetic fungicides has been increased in recent years due to their beneficial effects on crops (Pane *et al.,* 2013). The microbiotas in compost tea also play a fundamental role in these extracts ability to suppress plant diseases or promote growth (De Corato, 2020)

In addition, compost tea contains various species of the genera Trichoderma, Penicillium, Aspergillus, Bacillus, Enterobacter, Rhizobacteria or Pseudomonas spp., among others, which may have the ability to control pathogens and stimulate plant growth (Ingham *et al.,* 2005). As such, there is a scarcity of information regarding the effect of compost tea on plant diseases under field conditions, especially soil-borne diseases. Compost tea and its extract suppress plant pathogens and soil-borne diseases under controlled environments. Most studies have shown that compost tea suppresses soil-borne pathogens and diseases in recent *in vitro* studies, (Tian and Zheng 2013). Pioneering works by Stindt (1990) and Samerski and Weltzien (1988) suggested that the theoretical basis for effectiveness of compost tea in controlling aerial plant diseases is its ability to alter the microbiota of the phyllosphere and to induce resistance in plant hosts.

3.4. Competitive relationships

The effect of compost tea treatments on competitive relationships *viz.* land equivalent ratio (LER) and relative crowding coefficient (RCC) are presented in Tables 7.

3.5. Land equivalent ratio

Results indicate that the averaged values of LER ratios of all treatments of compost tea application were greater than 1.0 indicating that intercropping gave advantages in LER, which means the productivity of intercropping system was higher than sole system. Data also show the relative yield of maize (Lm) was greater than the relative yield of soybean (Ls) at all compost tea application treatments. Where in the intercropping system, plant density of maize was 100% of its sole planting, whereas the plant density of soybean was 50%. The highest LER values (1.47 and 1.45) were produced by intercropping soybean with maize that received compost tea as soil addition at 12 liters / ha along with 24 liters/ha as foliar spraying in 2023 and 2024 season, respectively. Meanwhile, the lowest LER values (1.07) were achieved by control treatment in both seasons. This result could be attributed to soil addition at 12 L / ha beside the high rate of compost tea (24 L / ha) as foliar spraying application provides a sufficient supply of nutrients to plants. These results are in harmony with those obtained by (Priya *et al.,* 2021 and Bako *et al.,* 2024).

3.6. Crowding coefficient:

It is obvious from the same table yield advantage obtains when the multiply of K maize and K soybean is larger than one, and the system has a disadvantage if K is less than one (De-Wit, 1960). The highest values of RCC (41.80 and 21.72) were obtained from application of compost tea as soil addition at 12 liters/ha additionally foliar spraying at 24 liters/ha of soybean intercropped with maize in both seasons. While, the lowest values of RCC (1.37 and 1.38) were recorded from control treatment (without addition of compost tea) within together seasons. This indicates yield advantage due sufficient nutrients, owing to high application of compost tea. Results also indicated that relative crowding coefficient values of maize (K maize) exceeded those of soybean (K soybean) indicating that maize was higher competitor than soybean and was the dominant component. Results herein were in accordance with those obtained by (Adeola *et al.,* 2023) found that maize has a higher competitive ability for above and below-ground resources than soybean in the intercrop.

3.7. Economic evaluation

Concerning the economic evaluation of compost tea addition treatments (without, compost tea soil addition at 12 liters/ha, foliar spraying plants with compost tea at 12 liters/ha, compost tea soil addition at 12 liters/ha + foliar spraying plants with compost tea at the rates of 6, 12, 18 and 24 liters/ha) during the two summer seasons 2023 and 2024, the data accessible in Table 8 apparent showed that the highest

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Table 7: Land equivalent ratio, aggressivity and relative crowding coefficient of intercropping soybean with maize as affected by compost tea addition treatments during 2023 and 2024 seasons.

Character	Land equivalent ratio			Relative crowding coefficient			Land equivalent ratio			Relative crowding coefficient		
	Lm	Ls	LER	Km	Ks	K	Lm	Ls	LER	Km	Ks	K
Treatment	2023 season						2024 season					
	Compost tea addition treatments											
T1	0.70	0.37	1.07	1.17	1.17	1.37	0.69	0.38	1.07	1.11	1.24	1.38
T2	0.84	0.39	1.23	2.55	1.28	3.27	0.81	0.40	1.21	2.10	1.34	2.81
T3	0.89	0.41	1.30	4.03	1.40	5.64	0.87	0.42	1.29	3.33	1.44	4.80
T4	0.91	0.45	1.36	5.24	1.61	8.42	0.89	0.45	1.34	4.10	1.64	6.72
T5	0.93	0.45	1.38	6.21	1.67	10.36	0.91	0.46	1.37	4.79	1.70	8.16
T6	0.94	0.47	1.41	8.14	1.75	14.20	0.92	0.47	1.39	5.86	1.78	10.41
T7	0.98	0.49	1.47	21.98	1.90	41.80	0.96	0.49	1.45	11.31	1.92	21.72

M = Maize ; S = Soybean
T1: Without **T2:** Compost tea soil addition at 12 L/ha **T3:** Spraying with compost tea at 12 liters/ha **T4:** Compost tea soil addition at 12 L/ha + Spraying with compost tea at 6 liters/ha **T5:** Compost tea soil addition at 12 L/ha + Spraying with compost tea at 12 liters/ha **T6:** Compost tea soil addition at 12 L/ha + Spraying with compost tea at 18 liters/ha **T7:** Compost tea soil addition at 12 L/ha + Spraying with compost tea at 24 liters/ha

Table 8: Effect of compost tea addition treatments of soybean intercropped with maize on economic evaluation during the two summer seasons 2023 and 2024.

Treatments	Economic evaluation									
	2023					2024				
	Actual Maize yield ($)	Actual soybean yield ($)	Total income ($)	Total cost ($)	Economic return ($)	Actual Maize yield ($)	Actual soybean yield ($)	Total income ($)	Total cost ($)	Economic return ($)
	Compost tea addition treatments									
T1	2362.9	672.0	3034.9	2213.0	821.9	1844.3	727.5	2571.8	1571.0	1000.8
T2	2819.7	712.2	3531.8	2223.0	1308.8	2158.8	763.8	2922.6	1581.0	1341.6
T3	3000.7	749.7	3750.5	2233.0	1517.5	2323.6	797.7	3121.3	1591.0	1530.0
T4	3078.7	812.6	3891.3	2243.0	1648.3	2381.8	858.1	3239.9	1601.0	1638.9
T5	3121.3	828.8	3950.1	2253.0	1697.1	2420.0	876.0	3295.9	1611.0	1684.9
T6	3177.4	849.5	4026.9	2263.0	1763.9	2462.5	895.7	3358.1	1621.0	1737.1
T7	3297.5	889.1	4186.6	2273.0	1913.6	2559.2	933.9	3493.0	1631.0	1862.0

T1: Without **T2:** Compost tea soil addition at 12 L/ha **T3:** Spraying with compost tea at 12 liters/ha **T4:** Compost tea soil addition at 12 L/ha + Spraying with compost tea at 6 liters/ha **T5:** Compost tea soil addition at 12 L/ha + Spraying with compost tea at 12 liters/ha **T6:** Compost tea soil addition at 12 L/ha + Spraying with compost tea at 18 liters/ha **T7:** Compost tea soil addition at 12 L/ha + Spraying with compost tea at 24 liters/ha

values of actual yield ($), total income ($) and economic return (%) of both maize and soybean crops were obtained from application of compost tea as soil addition at 12 liters/ha in addition foliar spraying plants with compost tea also at 24 liters/ha in both seasons. However, the second best compost tea addition treatments for economic evaluation was compost tea soil addition at 12 liters/ha and spraying plants with compost tea at 18 liters/ha that followed by compost tea soil addition at 12 liters/ha and spraying plants with compost tea at the rates of 12 and 6 liters/ha, spraying plants with compost tea only at 12 liters/ha, and then compost tea soil addition only at 12 liters/ha under intercropping system of maize and soybean in both seasons. While, the lowest values of actual yield ($), total income ($) and economic return (%) of both maize and soybean crops were recorded by control treatment (without addition of compost tea as soil addition or foliar spraying) under Intercropping system of maize and soybean in both seasons.

4. Conclusion

It could be concluded that the maximum values of growth, yield and its attributes, minimum disease incidence as well as highest actual yield, total income and economic return of both soybean and maize under intercropping system were obtained from application of compost tea as soil addition at 12 liters/ha additionally foliar spraying plants with compost tea also at 24 liters/ha under environmental conditions of Kafr El-Sheikh Governorate, Egypt.

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