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Study the effect of two organic fertilizers, methods of fertilization on productivity, pests and predatory insects associated with eggplant under modified climatic condition

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Abstract

This study investigated the effects of two organic fertilizer (compost tea and humic acid) compared to chemical fertilizer on plant growth, productivity, pests and predatory insects associated with eggplant *Solanum melongena* var. Black beauty under net house in 1st of April at 2019 and 2020 seasons. Application of fertilizers through fertigation enhanced significantly number of leaves, stem fresh weight, average fruit weight and total fruit yield. Moreover, stem diameter, nitrogen content in leaves (%), phosphorus content in leaves (%), potassium content in leaves (%), number of fruits and total yield were enhanced significantly due to using compost tea. However, using the humic acid cause a significant enhancement in number of shoots, number of leaves, stem diameter and leaves fresh weight. In addition, application of compost tea through the fertigation cause a significant superiority in number of shoots, nitrogen content in leaves (%), phosphorus content in leaves (%), potassium content in leaves (%), number of fruits, average fruit weight and total yield. The highest significant values of leaves fresh weight and stem dry weight were mainly due using humic acid through foliar application. Three main pest species and seven different predators' species were recorded associated with pests on eggplant. The application of foliar and fertigation compost tea increased pest populations significantly compared with humic acid and control. But also, increase the predators' population.

Keywords: Eggplant; Compost tea; Humic acid; Method of fertilization; Pests; predatory insects

1. Introduction

Eggplant (*Solanum melongena* L.) is one of the important vegetable crops of tropical and temperate parts of the world. It is a member of the Solanaceae family. It has been widely grown in southern Europe, the Middle East, Africa and Asia for hundreds of years [1]. The varieties of eggplant show a wide range of oval shaped to long club-shaped and colors are white, yellow, green, purple pigmentation to almost black [2]. Eggplant fruits are known for its low in calories and having a mineral composition beneficial for human health and it is rich source of potassium, magnesium, calcium and iron [3].

Fertilizers are a major input for increased agricultural productivity. The form of these inputs can influence pest populations in various ways in agroecosystems, depending on the kind of fertilizer used, the crop grown and the insect

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species present [4]. There is some evidence that synthetic fertilizers reduce plant resistance to insect pests [5], tend to enhance insect pest populations and can increase the need for insecticide applications [6]. Conversely, there are reports in the literature demonstrating that field applications of a range of types of organic matter and traditional thermophilic composts suppress attacks by insect pests [7, 8 and 9].

Organic fertilizers were be used by human since the dawn of history as an available natural resource for nitration of different cultivated crops. Under stress of increasing the population, demands for food are increased. It became a stressful condition for farmers, lands and agricultural production system. This forced farmers to use chemicals (fertilizers & pesticides) to accelerate the crop production and increase crop productivity. But, recently organic fertilizers and organic farming strongly raisin after all gained side effects of using chemicals in agriculture.

Accordingly, organic farmers are working for a balanced environment with high biodiversity, reduced loss of nutrients and natural buffering potential against diseases and pests [10].

In commercial production of vegetable crops, to replace chemical fertilizers with organic fertilizers is urgently needed. At the same time, another urgent need for integrated application of alternate fertilizers sources for sustaining the desired crop productivity [11].

The most famous organic fertilizer is compost, which is a mixture of the remnants of degraded plant material and the by-products of the degrading organisms. It provides incentive for communities to recover locked nutrients in the peel, eliminate the problem of waste disposal and increases values of the materials. A safe image of compost and easier to use is compost tea (CT). They are gaining a lot of interest in improving conventional and/or product productivity organic cultivated vegetables [12]. So, compost tea could be used as an agent for promoting plant growth in organic cultivation of crops [13].

Moreover, from plant protection point of view, it is especially true for the control of foliar diseases where teas are a desirable alternative to synthetic pesticides in order to prevent chemical residues on treated parts of plants intended for fresh use [14]. On the other hand, foliar application seems best suited to maximizing the dual nutrition and phytopathogenic effects of compost tea [15].

Another considered natural organic substance is humic acids; which consider as an important role in creating positive effect on morphological and physiological status of higher plants. Such effect translated to stimulation or inhibition of crop growth and development on bases of its concentration [16, 17].

Method of fertilizing crops by organic fertilizers is discussed in some studies. The first group of authors studies the method of foliar application; however the second group investigates the effect of soil feeding. Comparing foliar application to soil feeding, foliar application is better than soil feeding by 8 to 10 times and faster to reach the smallest root after 60 minutes from application [18]. In addition, they indicated that foliar sprays of fertilizers can induce systemic protection against foliar insect pests in various crops.

Recently, some attention has been paid to the use of organic compost extracts such as compost tea in agriculture primarily as a natural fungicide. Koné [19] demonstrated the action of tea on foliar pathogens in tomato. The use of compost tea in disease control and foliar attack is an alternative to the use of chemical pesticides in agriculture.

The main goals of this investigation are to compare between the effectiveness of both tested images of organic fertilizers, foliar application and fertigation (soil feeding) of fertilizing Eggplants organically as well as them interactions on eggplant growth, yield and pests and their associated predators' populations on eggplant.

2. Material and methods

2.1. Experimental site

To evaluate the superiority of two images of organic fertilizers as well as to compare between foliar application and soil feeding of fertilizing eggplants organically, current investigation was performed at Dokki protected cultivation experimental site, Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center (ARC), Dokki, Giza, Egypt. The altitude and longitude N 30º.00'.00" and E 31º.140 '.00 ", respectively.

2.2. Greenhouse preparation

The experiment was conducted under unheated net house, 60 m long, nine meters width and 4.25 m height. Total area of greenhouse was 540 m^2. The greenhouse was covered with white screen insect proof net. It was divided into five ridges separated by pathway 0.60 m wide. Each ridge was 1 m width and 60 m long were prepared and recommended doses of nutrients were applied before transplanting (extension bulletin no. 1294/2013). The soil set was irrigated using drip irrigation system in which the dripping line was placed about 10 cm from the center of the seed hole.

2.3. Plant material and culture circumstances

Eggplant seedlings (*Solanum melongena* L. cv. Black beauty) were transplanted in 1^{st} of April of 2019 and 2020 seasons, at a spacing of 0.5m between plants inside the same raw and 0.5m between each two rows.

2.4. Treatments

Two factors were tested within the current investigation as follow: Two sources of organic fertilizers that were (1) compost tea and (2) humic acid and two applications of fertilizing the eggplants organically; (1) fertigation (soil feed) and (2) foliar application.

Compost tea was prepared by soaking 150 g of compost (plant compost) in 30 letters of tap water for 24 hours. Second step to prepare the compost tea was by adding 150 ml of beneficial bacteria as follow: A mix of nitrogen and phosphorus fixing bacteria *"Azotobacter chroococcum* and *Bacillus megaterium*". The application of two bacterial mix was starting from second weeks to the end of the sixth week after transplanting. Furthermore, from the seventh week after transplanting to the end of the growing season a potassium fixing bacteria (*Bacillus circulans*) was add to last mentioned bacterial mix.

Bacterial mix was prepared on nutrient broth medium and incubated on shaker incubator for 48 hrs. at 120 rpm and 30°C. It was made in Central Laboratory of Organic Agriculture. *Azotobacter chroococcum* for fixed nitrogen and *Bacillus megaterium* for absorbed phosphor and *Bacillus circulans* for facilitated potassium.

The chemical analysis of compost (Nile compost), humic acid and characteristics of compost tea shown in Table (1).

Table 1 Chemical analysis of used Nile compost, humic acid and extract compost tea

Items	pH	EC	Org. matter %	Org. carbon %	Humate %	C/N ratio	N %	P %	K %	Mg %	Ca %	S %	Fe ppm	Cu ppm	Mn ppm	Zn ppm
Nile compost	8.2	5.5	44	25.5	-	16.5:1	1.6	0.60	1.6	-	-	-	1750	200	125	60
Humic acid	-	-	-	67.5	92%	-	0.3	0.12	13	0.2	0.12	0.3	-	-	-	-
Compost tea	6.7	0.96	-	-	5.8	-	2.2	0.12	2.8	-	-	-	-	-	-	-

2.5. Pests and their predators sampling

Population density of insect pests and their predators were estimated weekly in the 5 experimental sectors (compost tea fertigation, compost tea foliar, humic fertigation, humic foliar and control foliar "chemical fertilizers") from the second week after planting to harvest time in 2019 and 2020. In twenty random plants; three leaves represented (upper, middle and bottom level)/plant were selected directly inspected/sector/sampling date. The populations of the pests and their predators were recorded directly on the inspected plant using the aid of (10x) hand lens.

2.6. Temperature profile

To represent a clear vision about temperature circumstances during the growing seasons of the current investigation, maximum and minimum soil temperature for each treatment were daily recorded. All values were collected and averaged every 10 days. Data was collected using meteorological station located inside the shade house.

2.7. Recorded data

Data regarding growth, yield and its components were recorded after 90 days from transplanting as follow: plant height (cm), number of shoots, number of leaves, stem diameter, stem and leaves fresh and dry weights (The dry weight was measured after drying the samples at 70°C for 24 hrs. in forced air oven).

Fruits from each treatment were harvested twice a week to determine: (1) total fruit yield "Kg/m^2" (the weight of all pickings), (2) average fruit weight "g" (ten fruits were randomly taken from each treatment to determine average fruit weight, and (3) number of fruits/m^2

Moreover, percentage of nitrogen, phosphorus and potassium concentrations in eggplant leaves were determined at 60 days after transplanting. Nitrogen content was determined by the modified macro Kjeldahl method [20]. Phosphorus was determined calorimetrically as described by King [20]. While, potassium was determined according to method of Jackson [21].

Weekly count for number of pests per $inch^2$ of eggplant leaf was done for all treatments. Aphid, Whitefly, mite and Jassid were the targeted pests to count. In addition, a weekly count for number of predators per $inch^2$ of eggplant leaf was done for all treatments.

2.8. Experimental design and data analysis

Tested treatments were arranged in split plot design with three replications. Methods of fertilization were arranged in the main plot. However, sources of organic fertilizers were arranged in the sub-main plot. Population density of insect pests and their predators were statistically analyzed using two ways ANOVA.

The analysis of variance approach was used to statistically assess the data obtained. Duncan's multiple range tests were used to compare mean values at a 5% level of probability [22].

3. Results

3.1. Temperature profile

3.1.1. Soil temperature

Its noticeable from data in Figure (1) that, soil temperature recorded increment as a response to the studied treatments during both studied seasons of 2019 and 2020. It's clear also from data in Figure (1) that, injection of fertilizers through the drip irrigation system cause increase in soil temperature compared to adding fertilizers using foliar application.

The soil temperature increment was observed after 15 days from transplanting. Adding compost tea through fertigation recorded the highest soil temperature during both studied seasons of 2019 and 2020 compared to other studied treatments. Moreover, injection of humic acid through the drip irrigation system cause the second recorded highest soil temperature. Contrary, using foliar application did not caused any change in the recorded soil temperature throughout both studied seasons of 2019 and 2020.

Soil temperature changes daily and seasonally. Soil temperature controls processes of soil chemical and biological activities. Different organic materials rate of decomposition and mineralization mainly controlled by soil temperature [23]. In addition, soil acts as heat storage during the day and warm season. Contrary, it works as a source of heat during night and cold season. Soil temperature represents summation of absorbed heat and released heat from organic matter decomposition to that lost from the soil [24].

A number of studies pointed to increase in soil temperature as a direct result for using compost [25]. Mentioned soil temperature increment, reflected on promoting the available nutrients in soil, this resulted in enhanced the plant growth [26].

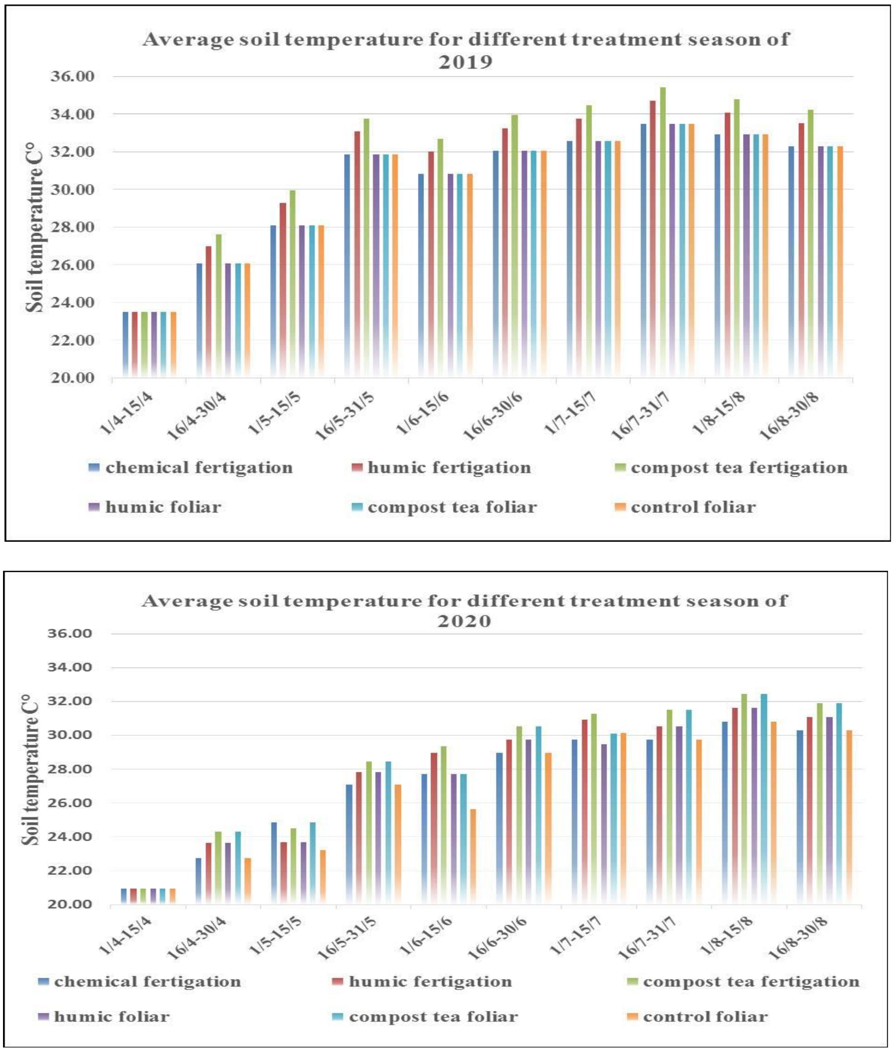

Figure 1 Average soil temperature for different treatment during seasons 2019 and 2020

3.2. Response vegetative growth characteristics

3.2.1. Plant height

It's concluded from data in Table (2) that, methods of fertilizers application was not affected significantly on studied eggplant plant height however during season of 2019 or 2020. Contrary, tested images of organic fertilizers addition to control (chemical fertilizers) significantly affected obtained values of plant height during both studied seasons of 2019 and 2020. Highest significant value was found in plants treated with compost tea followed by those fertilized by humic acid. Concerning effect of the interaction between method of application and images of fertilizers, no significant effect was found on eggplant plant height. Same trend of results were repeated during both studied seasons of 2019 and 2020.

3.2.2. Number of shoots

Illustrated data in Table (2) showed a significant superiority in eggplant number of shoots under fertigation condition compared to foliar application in seasons of 2019 and 2020. Focusing on effect of tested images of fertilization, compost tea significantly increase number of shoots followed by chemical fertilizers without significant different between them. Regarding effect of the interaction between method of application and images of fertilizers on number of shoots. Interaction between fertigation and compost tea recorded the highest significant value of number of shoots. Second highest value was obtained under conditions of interaction between fertigation and chemical fertilizers. No significant different was found between first and second highest values of number of shoots. The obtained trend of result was confirmed in the both studied seasons.

3.2.3. Number of leaves

From data in Table (2) it's confirmed that using fertigation to applied fertilizers caused a significant increment in number of leaves compared to using foliar application in seasons of 2019 and 2020. In addition, number of leaves enhanced significantly by using chemical fertilizer followed by compost tea. However lowest significant number of leaves was found in plants fertilized with humic acid. On the other hand, applied chemical fertilizers through fertigation (interaction between fertigation and chemical fertilizers) represent the highest significant value of eggplant number of leaves. However, interaction between fertigation and humic acid recorded second highest obtained value of eggplants number of leaves. The same trend of result was found during the second season.

Table 2 Response of eggplants plant height (cm), number of shoots, number of leaves and stem diameter (cm) to two methods of fertilizing (foliar spray and fertigation) and two images of organic fertilizers (humic acid and compost tea) compared to chemical fertilizer and them interaction during seasons of 2019 and 2020

Treatments	**Methods of application (A)**		
	Plant height (2019)		
Images of fertilizer (B)	**Foliar application**	**Fertigation**	**Mean**
Humic acid	120.00^{a}	121.67^{a}	120.84^{B}
Compost tea	137.00^{a}	137.00^{a}	137.00^{A}
Chemical (control)	117.00^{a}	112.62^{a}	114.81^{C}
Mean	124.67^{A}	123.77^{A}	
	Plant height (2020)		
Humic acid	125.45^{a}	126.52^{a}	126.00^{B}
Compost tea	150.24^{a}	141.35^{a}	145.79^{A}
Chemical (control)	121.44^{a}	116.39^{a}	118.91^{C}
Mean	132.38^{A}	128.08^{A}	
	Number of shoots (2019)		
Humic acid	8.34^{d}	15.67^{bc}	12.00^{B}
Compost tea	11.00^{cd}	23.00^{a}	17.00^{A}
Chemical (control)	13.51^{cd}	19.83^{ab}	16.67^{A}
Mean	10.95^{B}	19.50^{A}	
	Number of shoots (2020)		
Humic acid	9.10^{e}	16.80^{bc}	12.95^{B}
Compost tea	12.09^{de}	24.80^{a}	18.45^{A}
Chemical (control)	14.77^{cd}	20.47^{ab}	17.62^{A}
Mean	11.98^{B}	20.61^{A}	
	Number of leaves (2019)		
Humic acid	125.53^{e}	256.53^{b}	191.03^{C}
Compost tea	188.66^{d}	222.83^{c}	205.75^{B}
Chemical (control)	152.10^{e}	296.70^{a}	224.40^{A}
Mean	155.43^{B}	258.58^{A}	
	Number of leaves (2020)		
Humic acid	131.20^{f}	264.19^{b}	197.70^{C}
Compost tea	191.83^{d}	229.40^{c}	210.62^{B}
Chemical (control)	157.54^{e}	301.33^{a}	229.44^{A}
Mean	160.19^{B}	264.97^{A}	
	Stem diameter (2019)		
Humic acid	1.28^{a}	1.63^{a}	1.46^{B}
Compost tea	1.53^{a}	1.77^{a}	1.65^{A}
Chemical (control)	1.10^{a}	1.50^{a}	1.30^{C}
Mean	1.30^{A}	1.63^{A}	
	Stem diameter (2020)		
Humic acid	1.37^{a}	1.70^{a}	1.54^{B}
Compost tea	1.60^{a}	1.84^{a}	1.72^{A}
Chemical (control)	1.15^{a}	1.55^{a}	1.35^{C}
Mean	1.37^{A}	1.70^{A}	

* Alphabetic inside the table refers to analysis of variance of statistically assess the data.

3.2.4. Stem diameter

Discussing data of stem diameter that illustrated in Table (2), its noticeable the tested method of fertilizers application was not affected significantly on eggplant stem diameter during both studied seasons of 2019 and 2020. Whenever, using compost tea to fertilize eggplant causes a significant enhancement in eggplant's stem diameter followed by humic acid. Hence, interaction between method of fertilizer application and images of fertilization was not affected significantly on the current discussed character (stem diameter). The discussed trend of results was similar in seasons of 2019 and 2020.

Table 3 Response of eggplants stem fresh weight (g), leaves fresh weight (g), stem dry weight (g) and leaves dry weight (g) to two methods of fertilizing (foliar spray and fertigation) and two images of organic fertilizers (humic acid and compost tea) compared to chemical fertilizer and them interaction during seasons of 2019 and 2020

Treatments	**Methods of application (A)**		
	Stem fresh weight (2019)		
Images of fertilizer (B)	**Foliar application**	**Fertigation**	**Mean**
Humic acid	200.00^{d}	310.00^{b}	255.00^{B}
Compost tea	306.70^{b}	290.00^{c}	298.35^{A}
Chemical (control)	141.70^{e}	357.30^{a}	249.50^{C}
Mean	216.13^{B}	319.10^{A}	
	Stem fresh weight (2020)		
Humic acid	205.40^{d}	318.50^{b}	261.95^{B}
Compost tea	314.60^{b}	297.10^{c}	305.85^{A}
Chemical (control)	144.30^{e}	363.30^{a}	253.80^{C}
Mean	221.43^{B}	326.30^{A}	
	Leaves fresh weight (2019)		
Humic acid	245.00^{b}	216.60^{c}	230.80^{A}
Compost tea	190.20^{a}	115.00^{d}	152.60^{C}
Chemical (control)	126.70^{d}	197.10^{a}	161.90^{B}
Mean	187.30^{A}	176.23^{B}	
	Leaves fresh weight (2020)		
Humic acid	250.80^{b}	223.10^{c}	236.95^{A}
Compost tea	194.60^{a}	118.50^{e}	156.55^{C}
Chemical (control)	129.20^{d}	197.40^{a}	163.30^{B}
Mean	191.53^{A}	179.67^{B}	
	Stem dry weight (2019)		
Humic acid	22.74^{a}	12.85^{d}	17.80^{A}
Compost tea	19.00^{abc}	14.52^{cd}	16.76^{A}
Chemical (control)	15.71^{bcd}	20.18^{ab}	17.95^{A}
Mean	19.15^{A}	15.85^{B}	
	Stem dry weight (2020)		
Humic acid	23.79^{a}	14.40^{b}	19.10^{A}
Compost tea	20.71^{ab}	16.41^{ab}	18.56^{A}
Chemical (control)	17.92^{ab}	22.39^{a}	20.16^{A}
Mean	20.81^{A}	17.73^{B}	
	Leaves dry weight (2019)		
Humic acid	13.19^{a}	14.38^{a}	13.79^{B}
Compost tea	16.30^{a}	15.73^{a}	16.02^{A}
Chemical (control)	15.22^{a}	17.35^{a}	16.29^{A}
Mean	14.90^{B}	15.82^{A}	
	Leaves dry weight (2020)		
Humic acid	13.70^{a}	15.80^{a}	14.75^{B}
Compost tea	17.50^{a}	17.57^{a}	17.54^{A}
Chemical (control)	17.60^{a}	17.60^{a}	17.60^{A}
Mean	16.27^{B}	16.99^{A}	

* Alphabetic inside the table refers to analysis of variance of statistically assess the data.

3.2.5. Stem fresh weight

Results concerning effect of method of application on eggplant's stem fresh weight are shown in Table (3). Fertigation method compared to foliar application was significantly the cause to increase stem fresh weight in both seasons of 2019 and 2020. Moreover, fertilizing eggplant using compost tea increase the stem fresh weight significantly followed by humic acid. Where, interaction between fertigation and chemical fertilizer followed by interaction between fertigation and humic acid enhanced obtained values of stem diameter significantly. The illustrated result was true in 2019 and 2020 seasons.

Table 4 Response of eggplants nitrogen phosphorus and potassium contents (%) in leaves to two methods of fertilizing (foliar spray and fertigation) and two images of organic fertilizers (humic acid and compost tea) compared to chemical fertilizer and them interaction during seasons of 2019 and 2020

Treatments	**Methods of application (A)**		
	Nitrogen content in leaves (2019)		
Images of fertilizer (B)	Foliar application	Fertigation	Mean
Humic acid	2.73^{c}	3.97^{b}	3.35^{C}
Compost tea	4.97^{a}	4.90^{a}	4.94^{A}
Chemical (control)	3.93^{b}	3.43^{bc}	3.68^{B}
Mean	3.88^{A}	4.10^{A}	
	Nitrogen content in leaves (2020)		
Humic acid	3.43^{c}	4.27^{b}	4.85^{C}
Compost tea	5.70^{a}	5.79^{a}	5.89^{A}
Chemical (control)	4.70^{b}	3.97^{bc}	4.34^{B}
Mean	4.61^{A}	4.68^{A}	
	Phosphorus content in leaves (2019)		
Humic acid	0.55^{b}	0.57^{b}	0.56^{B}
Compost tea	0.84^{ab}	0.91^{a}	0.88^{A}
Chemical (control)	0.59^{ab}	0.55^{b}	0.57^{B}
Mean	0.66^{A}	0.68^{A}	
	Phosphorus content in leaves (2020)		
Humic acid	0.55^{a}	0.63^{a}	0.59^{B}
Compost tea	0.89^{a}	1.06^{a}	0.98^{A}
Chemical (control)	0.88^{a}	0.57^{a}	0.73^{B}
Mean	0.77^{A}	0.75^{A}	
	Potassium content in leaves (2019)		
Humic acid	3.47^{d}	4.03b^{c}	3.75^{C}
Compost tea	4.50^{ab}	4.73^{a}	4.62^{A}
Chemical (control)	4.27^{abc}	3.80^{cd}	4.04^{B}
Mean	4.08^{A}	4.19^{A}	
	Potassium content in leaves (2020)		
Humic acid	3.70^{d}	4.13^{cd}	3.92^{C}
Compost tea	4.76^{ab}	5.06^{a}	4.91^{A}
Chemical (control)	4.33^{bc}	3.83^{cd}	4.08^{B}
Mean	4.26^{A}	4.34^{A}	

* Alphabetic inside the table refers to analysis of variance of statistically assess the data.

3.2.6. Leaves fresh weight

Foliar application significantly increased eggplant's leaves fresh weight compared to add fertilizers through fertigation method in seasons of 2019 and 2020 (Table 3). Additionally, eggplant's leaves fresh weight affected significantly by different tested images of fertilizers. Humic acid recorded the highest significant leaves fresh weight followed by chemical fertilizers with significant different between them. Regarding interaction between method of fertilizers application and images of fertilizers, Table (3) showed that interaction between (fertigation method and chemical) and (foliar application and compost tea) recorded the highest significant leaves fresh weight without any significant difference between them. Whenever, interaction between foliar application and humic acid recorded the second highest value of leaves fresh weight in respect to a significant different between the two interactions. Obtained result was true in 2019 and 2020.

3.2.7. Stem dry weight

Foliar application increased obtained values of stem dry weight during two studied seasons of 2019 and 2020 compared to used fertigation as a technique for applied fertilizers (Table 3). However, different studied images of fertilizers were not affected significantly on stem dry weight during season of 2019 and 2020 (Table 3). Moreover, interaction between foliar application and humic acid recorded the highest significant stem dry weight followed by interaction between fertigation and chemical fertilizers with significant different between them. Last mentioned trend of interaction superiority confirmed during two studied seasons 2019 and 2020.

3.2.8. Leaves dry weight

Leaves dry weight affected significantly by studied methods of fertilizers application as showed in Table (3). Applied fertilizers through drip irrigation system (fertigation) significantly increased the leaves dry weight compared to foliar application in the two seasons of 2019 and 2020. While, another significant effect was obtained when using different images of fertilizers. Using chemical fertilizers followed by compost tea increased significantly leaves dry weight with significant different between them in 2019 and 2020 seasons. In addition, interaction between method of fertilizers application and images of fertilizers was not affect significant on leaves dry weight in seasons of 2019 and 2020.

3.3. Response nitrogen, phosphorus and potassium content (%)

3.3.1. Nitrogen content in leaves (%)

Method of fertilizers application was not significantly affected the percentage of nitrogen content in leaves during two studied seasons of 2019 and 2020 (Table 4). Hence, compost tea compared to other tested images of fertilizers enhanced significantly the percentage of nitrogen content in leaves in seasons of 2019 and 2020.

In addition, the chemical fertilizers ranked second after compost tea (with significant different between them) in enhanced the percentage of nitrogen content in leaves during first and second season. Concerning effect of interaction between method of application and images of fertilizers, interaction between fertigation and compost tea followed by interaction between foliar application and compost tea increased significantly the percentage of nitrogen content in leaves (without any significant different between them). This result was true in both tested seasons.

3.3.2. Phosphorus content in leaves (%)

No significant effect was found in percentage of phosphorus in leaves because of using different method of fertilizers application (fertigation or foliar application) in both seasons of 2019 and 2020 (Table 4). In addition, compost tea compared to other tested images of fertilizers increased significantly the percentage of phosphorus content in leaves in seasons of 2019 and 2020. Additionally, the chemical fertilizers ranked second after compost tea (without significant different between them) in enhanced the percentage of phosphorus content in leaves during the studied seasons of 2019 and 2020. Moreover, interaction between method of fertilizers application and images of fertilizers was not affect significant on percentage of phosphorus content in leaves at seasons of 2019 and 2020.

3.3.3. Potassium content in leaves (%)

Method of fertilizers application was not significantly affected the percentage of potassium content in leaves during the two studied seasons of 2019 and 2020 (Table 4). In another hand, compost tea compared to other tested images of fertilizers enhanced significantly the percentage of potassium content in leaves at seasons of 2019 and 2020. Addition, the chemical fertilizers ranked second after compost tea (with significant different between them) in enhanced the percentage of potassium content in leaves during first and second season (Table 4). Concerning effect of interaction between method of application and images of fertilizers, interaction between fertigation and compost tea followed by interaction between foliar application and compost tea increased significantly the percentage of potassium content in leaves in both studied seasons of 2019 and 2020 (without any significant different between them).

3.4. Response yield and its component

3.4.1. Number of fruits/m^2

Number of eggplants fruits affected significantly by method of fertilizers application. During two studied seasons of 2019 and 2020, number of fruits increased significantly by using foliar technique compared to fertigation application which is ranked second after foliar (Table 5). Moreover, a significant effect on eggplant number of fruit was detected because of using different images of fertilizers (Table 5). Plants that fertilized with compost tea recorded the highest significant number of fruits followed by those treated with chemical fertilizers in studied seasons of 2019 and 2020.

Regarding to effect of interaction between method of application and images of fertilizers, interaction between fertigation and compost tea followed by interaction between foliar application and compost tea increased significantly number of fruits in both studied seasons of 2019 and 2020.

3.4.2. Average fruit weight (g)

Average fruit weight of eggplants affected significantly by method of fertilizers application. During two studied seasons of 2019 and 2020, average fruit weight increased significantly by using fertigation technique compared to foliar application which is ranked second after fertigation (Table 5). Moreover, a significant effect on eggplant average fruit weight was detected because of using different images of fertilizers (Table 5). Plants that fertilized with chemical fertilizers recorded the highest significant average fruit weight followed by those treated with humic acid in studied seasons of 2019 and 2020 (Table 5). Regarding to effect of interaction between method of application and images of fertilizers, interaction between fertigation and chemical fertilizers followed by interaction between fertigation and humic acid increased significantly number of fruits in both studied seasons of 2019 and 2020 (without any significant different between them).

Table 5 Response of eggplants number of fruits/m^2, average fruit weight (g) and total yield (kg/ m^2) to two methods of fertilizing (foliar spray and fertigation) and two images of organic fertilizers (humic acid and compost tea) compared to chemical fertilizer and them interaction during season of 2019 and 2020

Treatments	**Methods of application (A)**		
	Number of fruits/m^2 (2019)		
Images of fertilizer (B)	**Foliar application**	**Fertigation**	**Mean**
Humic acid	227.00^{f}	253.00^{d}	240.00^{C}
Compost tea	411.00^{b}	422.00^{a}	416.50^{A}
Chemical (control)	290.00^{c}	244.00^{e}	267.00^{B}
Mean	309.33^{A}	306.33^{B}	
	Number of fruits/m^2 (2020)		
Humic acid	233.00^{f}	261.00^{d}	247.00^{C}
Compost tea	417.00^{b}	427.00^{a}	422.00^{A}
Chemical (control)	297.00^{c}	252.00^{e}	274.00^{B}
Mean	315.66^{A}	313.33^{B}	
	Average fruit weight g (2019)		
Humic acid	73.00^{c}	80.00^{ab}	76.50^{B}
Compost tea	75.00^{c}	75.50^{bc}	75.25^{C}
Chemical (control)	76.00^{bc}	82.03^{a}	79.02^{A}
Mean	74.66^{B}	79.18^{A}	
	Average fruit weight g (2020)		
Humic acid	76.50^{b}	84.00^{a}	80.25^{B}
Compost tea	78.13^{b}	79.00^{b}	78.57^{C}
Chemical (control)	77.00^{b}	85.00^{a}	81.00^{A}
Mean	77.21^{B}	82.67^{A}	
	Total yield Kg/m^2 (2019)		
Humic acid	16.58^{c}	20.25^{b}	18.41^{C}
Compost tea	30.83^{a}	31.78^{a}	31.31^{A}
Chemical (control)	22.12^{b}	20.02^{b}	21.07^{B}
Mean	23.18^{B}	24.02^{A}	
	Total yield Kg/m^2 (2020)		
Humic acid	17.83^{e}	21.93^{d}	19.87^{C}
Compost tea	32.59^{b}	33.74^{a}	33.16^{A}
Chemical (control)	22.88^{c}	21.43^{d}	22.15^{B}
Mean	24.43^{B}	25.69^{A}	

* Alphabetic inside the table refers to analysis of variance of statistically assess the data.

3.4.3. Total fruit yield (kg/m²)

Eggplants total fruits yield affected significantly by method of fertilizers application. During two studied seasons of 2019 and 2020, the total yield increased significantly by using fertigation technique compared to foliar application which is ranked second after fertigation (Table 5). Moreover, a significant effect on eggplant total yield was detected because of using different images of fertilizers (Table 5). Plants that fertilized with compost tea recorded the highest significant total yield followed by those treated with chemical fertilizers in studied seasons of 2019 and 2020. Regarding to effect of interaction between method of application and images of fertilizers, interaction between fertigation and compost tea increased significantly total fruits yield in both studied seasons of 2019 and 2020.

3.5. Pest species

Three main pest species were recorded on eggplant in all treatments under the greenhouses in 2019 and 2020. They belong to two orders and three families; cotton aphid (*Aphis gossypii* Glover) (Hemiptera: Aphididae), the tobacco whitefly (*Bemisia tabaci* Genn.) (Hemip.: Aleyrodidae) and the two spotted spider mite *Tetranychus urticae* Koch. (Acari: Tetranychidae).

It has been found that, the highest presence of pests was in the application of fertigation compost tea followed by foliar compost tea (29.02, 22.56% in 2019 and 23.3, 23.2% in 2020, respectively). While the lowest presence of pests was in the application of fertigation humic followed by foliar humic (8.68, 8.22% in 2019 and 9.52, 9.3% in 2020, respectively). These results compared with control (31, 34% in 2019 and 2020, respectively) (Fig. 2).

The results show that, the tobacco whitefly, *B. tabaci* was the most dominant pest species in all treatments in the two seasons (Fig.3). Its dominance percentage among the other pests was 67.61, 72.97, 48.79 and 54.25% in 2019 and 65.61, 58.51, 49.37 and 44.79% in 2020 in the application of fertigation compost tea, foliar compost tea, fertigation humic and humic foliar, respectively, compared with control (chemical fertilizers) (71.21, 70.39% in 2019 and 2020, respectively).

As shown in fig. 3, the highest population number of *B. tabaci* was on fertigation then foliar application of compost tea while the lowest population was on fertigation then foliar application of humic application. Population of *B. tabaci* varied significantly both between two years of study ($F= 5.71$, $df =160$, $P <0.05$) and among the treatments ($F= 5.36$, $df =80$, $P <0.05$) in 2019, ($F= 2.49$, $df =80$, $P <0.05$).

The population number of the cotton aphid, *A. gossypii* and two spotted spider mite *T. urticae* were similar to *B. tabaci* in that the highest populations were on fertigation then foliar application of compost tea while the lowest populations were on fertigation then foliar application of humic application (Fig.3). The population number of aphid on eggplants differed significantly between two years ($F= 4.41$, $df =160$, $P <0.05$) and among the treatments ($F= 4.98$, $df =80$, $P <0.05$) in 2020, ($F= 4.96$, $df =80$, $P <0.05$).

Among all pests the *T. urticae* was the less population number in all treatments in the two seasons (fig.3). Also, the population of mites did not differ on the different treatments on eggplant plant in 2019 and 2020. No significant interaction occurred between two years ($F= .083$, $df =160$, $P <0.05$) and treatments ($F= 0.93$, $df =80$, $P <0.05$) in 2019, ($F= 0.74$, $df =80$, $P <0.05$).

3.6. Predator species

Seven different predators' species were recorded associated with pests on eggplant in 2019 and 2020. *Scolothrips sexmaculatus* (Thysanoptera: Thripidae) and *Stethorus punctillum* Weise (Coleoptera: Coccinellidae) were recorded associated with mites. *Chrysoperla carnea* (Steph.) (Neuroptera: Chrysopidae) and *Aphidoletes aphidimyza* (Diptera: Cecidomyiidae) were recorded associated with aphid. *Macrolophus pygmaeus*, *Orius* spp. and also *C. carnea* are polyphagous predators were recorded associated with whitefly and aphid. Praying mantis, *Miomantis paykullii* Stal. (Mantodea: Mantidae) is a general predator. It's appeared with few population numbers in all experiment treatments in the two years.

The results showed that the highest presence of predators was in the fertigation application of compost tea followed by foliar application of compost tea (33, 30% in 2019 and 36, 31% in 2020, respectively). While the lowest presence of predators was in the fertigation application of humic acid followed by foliar application of humic acid (12, 10 % in 2019 and 13, 10% in 2020, respectively). These results compared with control (chemical fertilizers) (12, 11% in 2019 and 2020, respectively) (Fig.4).

M. pygmaeus was the most dominant insect predators' in all treatments in the two seasons. Its dominance percentage among the other insect predators was 66.87, 52.19, 52.5 and 64.52% in 2019) and (70.01, 51.29, 56.92 and 69.85% in 2020) in fertigation application of compost tea, foliar application of compost tea, fertigation application of humic and foliar application of humic, respectively. These results compared with control (chemical fertilizers) (52.86, 63.05% in 2019 and 2020, respectively). There was significant difference among the treatments with *M. pygmaeus* populations (F= 6.12, df =80, P <0.05) in 2019, (F= 5.4, df =80, P <0.05) 2020. *S. punctillum* was the most dominant mite predators' in all treatments in the two seasons. Its dominance percentage among the other insect predators' was 62.16, 60.61, 79.9 and 52.63% in 2019) and (57.14, 61.73, 73.47 and 71.43% in 2020) in fertigation application of compost tea, foliar application of compost tea, fertigation application of humic and foliar application of humic acid, respectively. These results compared with control (chemical fertilizers) (54.07, 60.39% in 2019 and 2020, respectively). There was no significant difference among the treatments with *S. punctillum* populations (F= 0.03, df =80, P <0.05) in 2019, (F= 0.023, df =80, P <0.05) 2020.

The application of compost tea as an organic fertilizer in eggplants increased pest populations significantly compared with humic acid and control (chemical fertilizer). But also, increase the predators' population. The increase of the population numbers of pests followed by an increase in the population number of the predators.

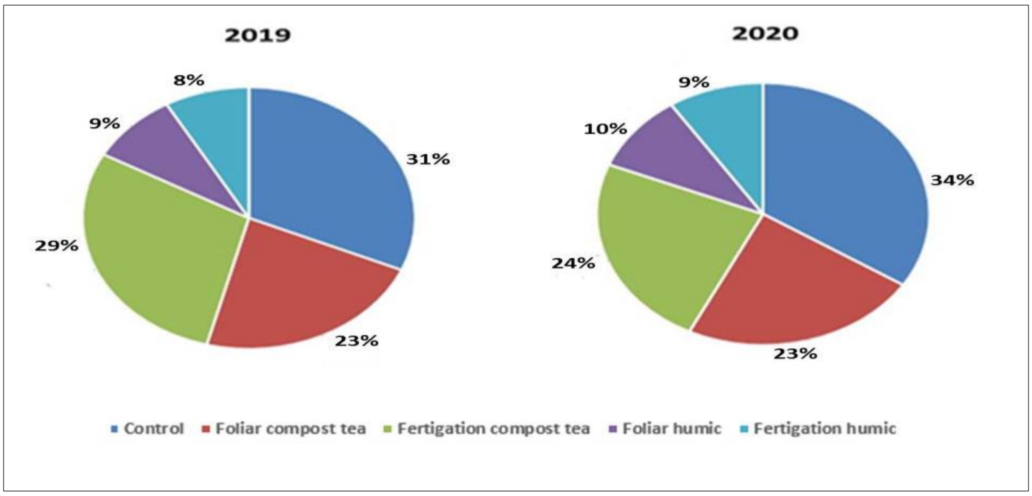

Figure 2 Comparison total number of pests among all treatments on eggplant under greenhouse in 2019-2020

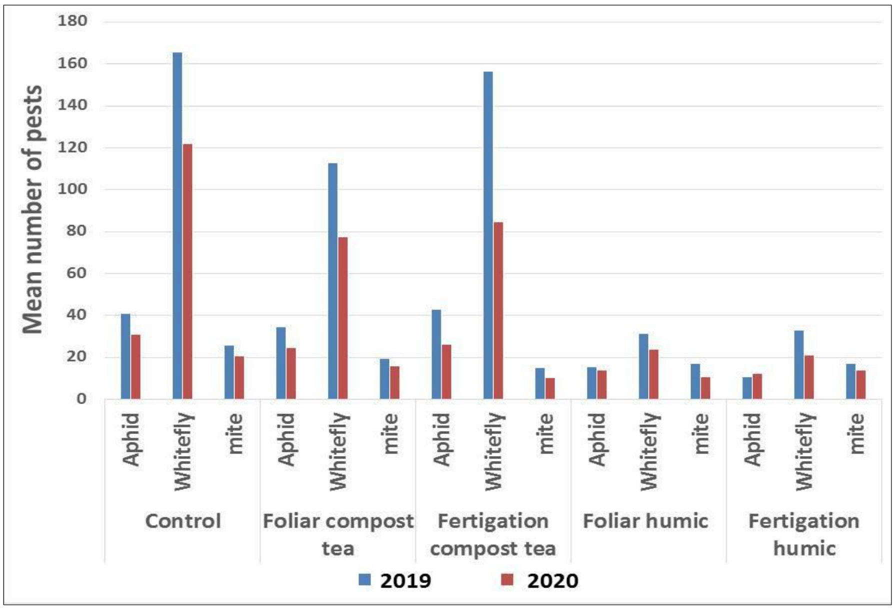

Figure 3 Mean number of pests/inch^2 of leaf (aphid, whitefly and mite in all treatments of eggplant under greenhouses, 2019-2020

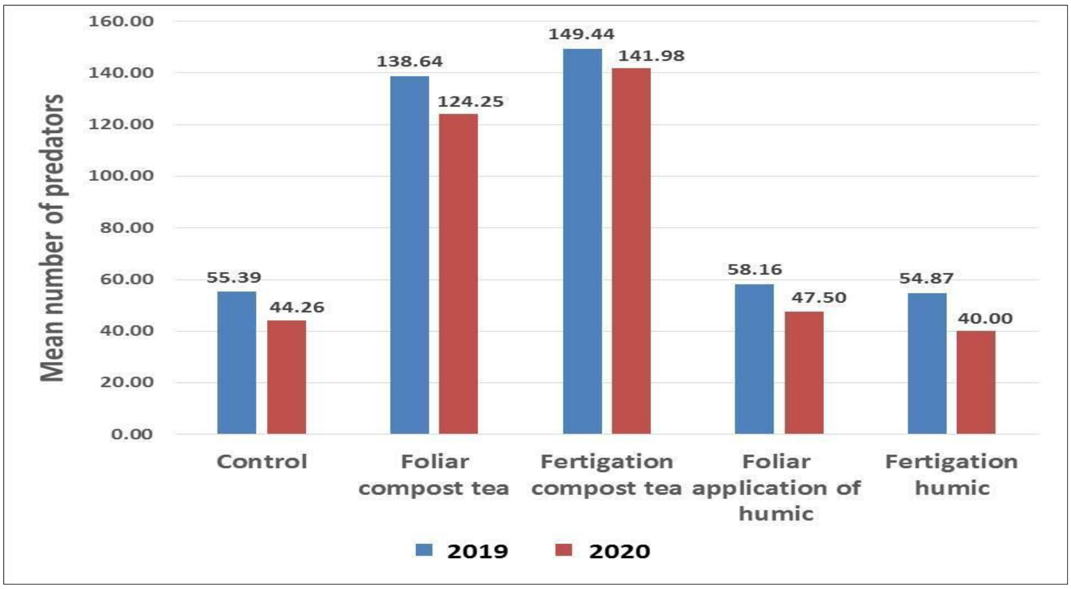

Figure 4 Mean number of predators on eggplant under greenhouses, 2019-2020

4. Discussion

In the current investigation obtained results confirmed the superiority of fertigation as a method for fertilizers application in many characteristics i.e. number of shoots, number of leaves, stem fresh weight, leaves dry weight, average fruit weight and total yield. Similar result was reported by Ram [27], author clear up superiority of fertigation because of the direct supplies of phosphorus to active roots zone and directly uptake without undergoes transformations in the soil. Focusing on yield and its components, the author reported that add total recommended fertilizers using fertigation enhanced tomato yield by 21.95 % as well as, enhanced the productivity of chilly crop because of fertigation.

Results related to performance of leaves fresh weight, stem dry weight and number of fruits were in harmony with Abad [28], they mentioned that addition of nutrients to plant through foliar application considered as an effective method for feeding plants and recovery of the inability of soil to transfer nutrients to plant. Authors explained different crops and varieties are not similar in its ability of absorb nutrients and convert them into plant biomass. So, crops or varieties with less ability to absorb nutrients show high response to foliar application of fertilization. In addition, Haytova [29] presented explanation to effectiveness of foliar application on basis of the ability to facilitate mineral rapid absorption, addition to avoidance of soil role that limit root uptake.

Regarding to efficiency of compost tea in increasing yield and its component as obtained in this study, Zaccardelli [12], reported the significant effect of compost tea application on behavior of yield of vegetable crops under greenhouse cultivated organically. Yields increment explained on basis of increase of the number of fruits per plant, whereas the average fruit weight was not affected by treatment. In harmony, average fruit weight in our study responded significantly to chemical fertilization (control).

In addition, results that showed the superiority of compost tea was in agreements with Kim [13], who recommended using compost tea as a plant growth promoter in organic cultivation of crops. Additionally, Zaccardelli [12], explained superiority of compost tea on basis of being a product of compost containing valuable molecules and micro-organisms in a liquids image. The molecules and micro-organisms in compost tea stimulate plant growth.

Related to humic acid obtained results related to leaves fresh weight (ranked first significantly), number of shoots (ranked second), stem diameter (ranked second), stem fresh weight (ranked second), leaves fresh weight (ranked second) and average fruit weight; it appears to be similar to those obtained by Osman and Rady [30]. They mentioned that eggplant plants characters of number of branches and fresh weight of leaves per plant were improved by using humic acid as a bio stimulator compared to non-treated plants (control). Humic acids increase growth and yields of various crops including vegetables [31]. Several mechanisms was suggested, one of which was their positive effects on nutrient uptake of vegetable crops [32]. Another hypotheses was presented by Nardi [16] on basis of promote plant growth and increase stress tolerance, improve soil physical properties and complex metal ions. Another studies demonstrate impact of humic acid depending on increasing enzyme catalysis, enhancing respiration and photosynthesis, and stimulating nucleic acid metabolism [16].

Meanwhile, humic acid stimulated plant growth and consequently yield by acting on mechanisms involved in: cell respiration, photosynthesis, protein synthesis, water and nutrient uptake, enzyme activities [33]. Additionally, several studies elucidated that humic acid increase root length, root number and root branching [34].

Obtained results concern interaction between fertigation and compost tea were in agreement with discussed results by [35]. Authors indicated that add organic fertilization such as compost to the plants through soil feeding (fertigation) reflected positively on every vegetative growth parameter as well as enhancement of chemical content, total chlorophyll and total fruit yield [35].

However, obtained results regard to interaction between foliar application and humic acid were in harmony with [32]. They obtained a significant increment in vegetables crop as a direct results of using humic acid as foliar application.

Rather than, the cotton aphid *A. gossypii*, the tobacco whitefly *B. tabaci* and the two spotted spider mite *T. urticae* are the most serious pests that infesting the vegetable crops in different areas in the world. The most dominant predators recorded associated with pests on vegetables were *C. carnea*, *O. albidipennis*, *O. laevigatus*, *Coccinella undecimpunctata*, *Scymnus interruptus* Mars, *S. punctillum* Weise, *Cydonia vicina* Muls. *M. pygmaeus* [36, 37, 38, 39, 40 and 41].

It was the main purpose of the paper to study the effect of foliar application and fertigation feeding of bio-fertilizer (compost tea and humic acid) on pests and their associated predators' population on eggplant. The application of foliar and fertigation compost tea increased pest populations significantly compared with humic acid and control. But also, increase the predators' population. In fact, the increase of the population numbers of pests followed by an increase in the population number of the predators.

Edwards and Stinner [6] indicated that organic fertilizers could contribute to decreased pest attacks by increasing pest and predator species diversity and enhancing the activity of pest microbial antagonists.

5. Conclusion

It's concluded from obtained results that using fertigation as a method for fertilizers application increased many characteristics related to plant growth and total yield. In addition, to use compost tea in fertigation give increment in the nutritional status which is translated to significant increase in both of number of fruits and total yield. In addition, the application of compost tea (both fertigation and foliar application) as an organic fertilizer in eggplants increased pest populations significantly compared with humic acid and control (chemical fertilizer). But also, increase the predators' population. The increase of the population numbers of pests followed by an increase in the population number of the predators.

Also, authors recommended mixing between both methods of fertilizers application (fertigation and foliar application). Such mix between the two methods guarantee to obtained all the best of each of the used method of fertilization. Moreover, it recommended to mix between all types of fertilizers (chemical, compost and humic) cause every type of fertilizer enhance some of the growth or yield characteristics.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest.

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