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Fennel (*Foeniculum vulgare* Mill.) growth, productivity and essential oil yield under different sowing methods and some stimulant substances

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Abstract

The present work was conducted at the Experimental Farm, Faculty of Agriculture, Al-Azhar University, Assiut, Egypt during the two successive seasons of 2019/2020 and 2020/2021 to study the impact of sowing methods (normal and reciprocal) and foliar spray with some stimulant substances (compost tea, E.M. (effective microorganisms) and vitamin E), as well as, their interactions on the growth traits, fruit yield/plant and per feddan (feddan = 4200m^2), essential oil % and essential oil yield/plant and per fed of fennel (*Foeniculum vulgare* Mill.) plants. The plants were foliar sprayed with stimulant substances namely, control (no sprayed plants), compost tea at 25, 50 and 100 g/l, compost tea at 25 g/l + 5 ml E.M. compost tea at 50 g/l + 5 ml E.M, compost tea at 100 g/l + 5 ml E.M., compost tea at 25 g/l + 50 ppm vitamin E, compost tea at 50 g/l + 50 ppm vitamin E and compost tea at 100 g/l + 50 ppm vitamin E. The obtained results showed that the application of sowing methods positively affected the plant growth traits (plant height, branch number/plant and herb dry weight/plant), fruit yield/plant and per feddan, essential oil %, essential oil yield/plant and per feddan. Clearly, reciprocal sowing method gave better results of these parameters than those detected by normal sowing method. As for stimulant substance treatments, all examined parameters significantly influenced by foliar spray with these substances. Obviously, foliar spray with all stimulant substances at all concentrations, either single or together, resulted a significant augment in all studies aspects, except for compost tea at 25 and 50 g/l, mostly, as compared to no sprayed ones. Foliar spray with the combined treatment (compost tea at 100 g/l + 50 ppm vitamin E) and the combined one (compost tea at 100 g/l + 5 ml E.M.) proved to be more effective in increasing these traits than other treatments and control. The interaction between the two tested factors on all parameters was statistically significant, for the two seasons. Apparently, reciprocal sowing method with foliar spray with compost tea at 100 g/l + 50 ppm vitamin E or with compost tea at 100 g/l + 5 ml E.M. gave the most effective treatments in augmenting these traits.

Keywords: fennel, *Foeniculum vulgare*, normal and reciprocal sowing methods, compost tea, E.M., vitamin E.

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1. Introduction

Fennel (*Foeniculum vulgare* Mill.) is member of the most important medicinal and aromatic plants. It belongs to Apiaceae family; it is an annual, biennial, or perennial aromatic herb, depending on the variety (Farrell, 1988; Wichtl and Bissel, 1994). Fennel has useful in medicinal folklore as sedative, carminative, stimulant and diuretic (Charles *et al*., 1993). The fruits of fennel contain essential oil which plays important roles as carminative, flavouring agents, and laxative preparations (Lawless, 1997). Stary and Jirasck (1975) suggested that the essential oil is 1-3 % in fennel fruits which has been antiflammatory and antispasmodic effect on smooth muscle. Planting method is one of the most important cultural practices which has been affected the growth, yield and chemical composition of different plant species. Sowing arrangement and sowing distance are essential cultivating activity to obtain environmentally efficient natural resources and act a major role in regulating the competition between neighbour plant canopies (Li *et al*., 2020). Proper plant arrangement not only improves the land productivity, but also prevents growing the weeds (Osnigbove *et al*., 2016). Organic agriculture is one of the most agricultural practices in order to enhancing the growth, yield and chemical composition, particularly obtaining high quality of products. Organic manures have been advantages for examples: Safe for human, animals and environment, free of polluters, environmentally friendly. Minimize mineral fertilizers consequently lowering the production costs, improve the fertility of soil and soil properties. Organic manures contain plant growth substances like, indole-3-acetic acid (IAA) and gibberellic acid (GA), macronutrients, necessity micronutrients and beneficial microorganisms (Natarajan, 2007 and Sreenivasa *et al*., 2010). Compost plays important roles whereas, it utilized to enhance soil physical and biological properties namely water retention capacity, pH drainage, better availability of soil microorganisms and lowering the negative effect of chemical-based pesticides and fertilizers in the ecosystems (ZheljazKov and Warman, 2004). Compost tea has a liquid extract which is useful for the soil and plants more quickly than compost. It augments the ability of soil to hold nutrients and retain water (Martin and Brathwaite, 2012; Scheuerell and Mahaffee, 2002). The use of compost tea as foliar spray led to preventing the diseases due to the impact of beneficial organisms (Ingham, 2005; Scheuerell and Mahaffee, 2004; Souleymane *et al*., 2010). The unique role of compost in augmenting the growth, seed yield and essential oil content have been described by Mohamed and Abdou (2004), El-Kouny and Salem (2006), Abdou *et al*. (2012a), Ali *et al*. (2017) and Abo-Kutta (2016) on fennel plants, Ibrahim (2017) on white mustard and Abd El Kader *et al*. (2022)

on peppermint. Concerning compost tea, Ezz-El-Din and Hendawy (2010) on borage, Gharib *et al*. (2008) on margoram and Jasson *et al*. (2017) on *Hypoxis hemerocallidea* and *Siphonochilus aethiopicuscte* plants. Effective microorganisms (E.M.) has been bio stimulant substance and it used as bio fertilizer due to it contains N-fixing bacteria (photosynthetic bacteria + lactic acid bacteria + yeasts). E.M. substance plays an important role in enhancing soil properties and stimulating the fruit yield, as well as, raising the tolerance (Ho and Hwan, 2000). Recently, E.M. technology has to be used in agricultural practices, forestry and this technology is totally natural and environmentally safe (Allahverdiyev *et al*., 2011). The promotion of the growth, seed yield and essential oil content as a result of applying E.M. was exhibited by Abdou *et al*. (2012b) on fennel, Ibrahim (2014) on *Ammi visnaga*, El-Houssini (2009), Fouad (2017) on borage, Ali *et al*. (2016) and Abd El-Rahman (2016) on chamomile, Abdalla (2009) on roselle and Marzok (2011) on basil plants. Alpha-tocopherol (vitamin E) is group of compounds synthesized only by photosynthetic organisms. It has believed to protecting the chloroplast membranes from photo oxidation and helps to provide an optimal environment for the photosynthetic machinery (Munne-Bosch and Algere, 2002). Vitamin E has to be protecting the plants against various environmental stresses (Hess, 1983). The enhancement in the growth, seed yield and essential oil content due to the addition of vitamin E have been explored by Botros (2013) on caraway, Helmy (2016) on cumin, Ayad *et al*. (2009) on geranium, Ismail (2008) on black cumin and Abd El-Salam and Nora (2014), and Marzok (2017) on basil. Therefore, the objective of this research was to investigate the influence of planting methods (normal and reciprocal) and some stimulant substances (compost tea, E.M. and vitamin E), as well as their interactions on the growth, fruit yield, essential oil % and essential oil yield of fennel (*Foeniculum vulgare* Mill.) plants to figure out the most suitable treatment for enhancing these traits.

2. Materials and methods

2.1 Experimental site and treatments description

The present investigation was carried out during the two seasons of 2019/ 2020 and 2020/2021 at the Experimental Farm, Faculty of Agriculture, Al-Azhar University, Assiut, Egypt to determine the influence of sowing methods and some stimulant substances, as well as their interactions on the growth aspects, fruit yield/ plant and per feddan, essential oil % and essential oil yield/plant and per fed of fennel (*Foeniculum vulgare* Mill.) plants. The fruits of fennel (*Foeniculum vulgare* Mill.) were obtained from Department of Medicinal and Aromatic Plants, Horticulture Research Institute, Giza, Egypt. This experiment was set up

in a split plot design with three replicates. The main plots (A) were sowing method including two methods, while stimulant substance treatments occupied the sub-plots (B) included ten treatments, thus the interaction treatments (A×B) were twenty treatments. Fennel seeds were sown on Nov 10th, for both seasons, in the Experimental suit (2×1.8 m) in hills spaced in between 40 cm. containing 3 rows at 60 cm apart. These seeds were sown by the two methods as follows: One side of the row (normal method) and two sides (reciprocal method or paired row). The plants were thinned fourty days later to two plants/hill, therefore, the experimental plot contained 30 plants. The physical and chemical characterizes of the used soil were determined according to Klute (1986) and Yancy *et al*. (1982) and are listed in Table (1).

Table (1): The physical and chemical properties of the used soil for 2019/2020 and 2020/2021 seasons.

Characters	Value		Characters	Value	
	2019/2020	2020/2021		2019/2020	2020/2021
Clay (%)	50.11	49.81	$CaCo_3$ (%)	2.49	2.39
Silt (%)	38.53	37.91	pH (1:2.5)	7.6	7.5
Sand (%)	11.36	12.28	E.C (m/mhos/cm)	1.31	1.34
Texture	Clay loam	Clay loam	Total N (%)	0.16	0.15
Organic matter (%)	2.41	2.59	Available P (%)	2.83	3.03
			Exchange K (mg/100 g soil)	2.27	2.23
			Exchange Ca^{++} (mg/100 g soil)	34.1	35.57
			Exchange Na (mg/100 g soil)	2.19	2.28

The treatments of stimulant substances (B) were as follows: control (no sprayed plants, compost tea at 25 g/l compost tea at 50 g/l, compost tea at 100 g/l, compost tea at 25 g/l + 5 ml E.M., compost tea at 50 g/l + 5 ml E.M., compost tea at 100 g/l + 5 ml E.M., compost tea at 25 g/l + 50 ppm vitamin E, compost tea at 50 g/l + 50 ppm vitamin E. and compost tea at 100 g/l + 50 ppm vitamin E. Compost tea extract was prepared as follows: It is prepared by leave out the used tap water in the open air for 24 h before its uses to be chlorine-free. Fine plant residues compost was weighted according to the used concentrations in this study *i.e*., 25, 50 and 100 g/l water and was added pure molasses at 1 ml/l to the bucket and brewed aerobically for 48h through a continuously running air pump during the fermentation period until completion of the fermentation process, whereas the color of extract becomes light brown, and it was applied immediately (Ingham, 2015; Martin, 2015). E.M. at 5 ml/l was added to the components during the preparation of compost tea extract, in case of preparing the treatments of compost tea extract + E.M at 5 ml/l. The chemical analysis of compost tea extract according to Sakr (2017) is presented in Table (2).

Table (2): The chemical analysis of compost tea extract according to Sakr (2017).

Parameters	Value	Parameters	Value
Humidity (%)	99.44	HCO_3 (meq/L)	40.00
Organic carbon (%)	29.93	Cl (meq/L)	34.00
Total N (mg/l)	73.50	SO_4 (meq/L)	49.20
Total P (mg/l)	11.24	Ca (meq/L)	7.41
Total K (%)	0.22	Mg (meq/L)	5.85
pH	7.87	Na (meq/L)	48.62
EC (d.S/m)	6.93		

E.M. substance was obtained from Ministry of Environment - Egypt (Each of 1 ml E.M. contains 10^7 cells of active bacteria.) and vitamin E (alpha-tocopherol) was obtained from Aljumhuriah Chemicals Company. These examined stimulant substances were foliar sprayed four times at two weeks interval starting December 30th, in the two seasons, the plants were foliar spray till run off. One day period was allowed between spraying these substances. All other agricultural practices were performed as usual. At the end of the experiment (the first week of May), in both seasons, the following data were recorded: Plant height (cm), branch number/plant, herb dry weight (g)/plant, fruit yield (g)/plant and fruit yield (ton)/feddan was calculated. Also, essential oil % in the fruits was extracted and determined according to the method described by Guenther (1961), then essential oil yield (ml)/plant was calculated by multiplying essential oil % in the fruits in fruit yield (g)/plant and essential oil yield (l)/feddan, was calculated. All obtained data were tabulated and statistically analyzed according to MSTAT-C (1986) using the L.S.D. test at 5% to know the differences among all treatments according to Mead *et al*. (1993).

3. Results and discussion

3.1 Plant height (cm)

The presented data in Table (3) revealed that plant height of fennel was significantly affected by the application of cultivation methods (normal and reciprocal), in the two seasons. Clearly such trait was significantly increased due to using reciprocal method by 3.5 and by 3.1 % over than normal one, during the two experimental seasons, respectively. The positive effect of reciprocal method on plant height was also studied by Gadissa and Chemeda (2009) on green pepper (*Capsicum annuum* L.). As for stimulant substance treatments, data in Table (3) pointed out that spraying fennel plants with the three examined stimulant substances, either single or mixed led to a significant augment in plant height, in both seasons, except for the treatment of compost tea at 25 g/l, in the first season, as compared to no sprayed ones. In most cases, the combined treatments gave higher values of such trait than those detected by single ones, during the two growing seasons. Obviously, foliar spray with the combined treatments (compost

tea at 100 g/l + vitamin E at 50 ppm) and the combined one (compost tea at 100 g/l + E.M. at 5 ml) gave the longest plants reached 10.9, 9.9, 10.5 and 8.7 % over the check treatments during the two consecutive seasons, respectively.

Table (3): Effect of sowing methods, compost tea, E.M., alpha-tocopherol and their interactions on plant height (cm) of fennel during 2019/2020 and 2020/2021 seasons.

Biostimulants (B)	Planting method (A)					
	First Season			Second Season		
	One	Two	Mean (B)	One	Two	Mean (B)
Control	149.8	155.9	152.9	155.4	159.8	157.6
Compost tea 25 g/l	153.3	159.0	156.2	160.1	165.1	162.6
Compost tea 50 g/l	156.6	160.1	158.4	162.2	167.7	165.0
Compost tea 100 g/l	161.8	166.5	164.2	169.1	172.4	170.8
Compost tea 25 g/l + 5 ml E.M.	157.4	164.7	161.0	161.9	167.8	164.8
Compost tea 50 g/l + 5 ml E.M.	162.3	169.9	166.1	167.8	173.3	170.5
Compost tea 100 g/l + 5 ml E.M.	165.8	170.5	168.1	168.3	174.2	171.3
Compost tea 25 g/l + 50 ppm vitamin E	156.0	161.5	158.7	164.3	169.8	167.1
Compost tea 50 g/l + 50 ppm vitamin E	161.1	167.2	164.2	166.8	170.8	168.8
Compost tea 100 g/l + 50 ppm vitamin E	167.4	171.7	169.6	170.9	177.4	174.2
Mean (A)	159.2	164.7		164.7	169.8	
L.S.D 0.05 %	A= 1.7	B= 4.6	AB= 6.5	A=2.0	B= 4.3	AB= 6.1

The role of compost in increasing plant height was also demonstrated by Ezz El-Din and Hendawy (2010) on borage, Ibrahim (2014) on *Ammi visnaga*, Abo-Kutta (2016) on fennel plants, Ibrahim (2017) on white mustard and Sakr (2017) on marigold. The enhancement in plant height due to applying E.M. was also concluded by Abdou *et al*. (2012b) on fennel, Fouad (2013) on *Calendula officinalis*, Ibrahim (2014) on *Ammi visnaga* plants, Mohamed (2009) on guar plant and Marzok (2011) on basil plant. Many authors emphasized that vitamin E addition led to an augment plant height like Ramraj *et al.* (1997) on mustard, Ismail (2008) on black cumin and Abdou *et al.* (2013) on caraway. In regard to the interaction, it was statistically significant effect on plant height of fennel, during the two experimental seasons. Apparently, the longest plants were detected from the application of reciprocal cultivation method with spraying compost tea at 100 g/l + vitamin E at 50 ppm followed by the same method with compost tea at 100 g/l + E.M. at 5 ml in comparison with those obtained by other combination treatments, in both seasons, as clearly shown in Table (3).

3.2 Number of branches/plant

The revealed data in Table (4) cleared that cultivation methods positively affected branch number/plant of fennel during both seasons. Obviously, the application of reciprocal method significantly increased branch number/plant by 2.3 and by 2.2 % over the normal method, in the first and second seasons, respectively. The importance of applying reciprocal cultivation method in enhancing branch number have to examined by Gadissa and

Chemeda (2009) on green pepper (*Capsicum annuum*, L.). Concerning stimulant substance treatments, it could be noticed that foliar spray with these materials, either separately or in combinations resulted a significant increase in branch number/plant, except for the treatment of compost tea at 25 g/l + E.M. at 5 ml comparing to no sprayed plants, in the first season. Similarly, such parameter was significantly augmented due to foliar spray with these substances, except for the treatments of compost tea at 25 and 50 g/l, as well as compost tea at 25 g/ l + E. M. at 5 ml, as compared to untreated ones, in the second season. Clearly, higher values of branch number/plant were detected by utilizing the combined treatments, mostly than those given by individual ones, in the two seasons. Moreover, foliar spray with the combined treatment (compost tea at 100 g/l + vitamin E at 50 ppm) and the combined one (compost tea at 100 g/l + E.M. at 5 ml) proved to be more effective in increasing branch number/plant than those observed by other treatments and control. Numerically, the two previous superior treatments augmented such aspect by 15.7, 13.3, and 20.2 and by 15.5 % over control during the two consecutive seasons, respectively, as clearly declared in Table (4). The enhancement in branch number as a result of applying compost was also insured by Abdou *et al.* (2012b) on fennel plants, Sakr (2017) on marigold, Ezz El-Din and Hendawy (2010) on borage, Ibrahim (2014) on *Ammi visnaga*. The beneficial influence of E.M. on augmenting branch number was also stated by Abdou *et al*. (2012b) on fennel Fouad (2013) on *Calendula officinalis*, Ibrahim (2014) on *Ammi visnaga* plants, Mohamed (2009) on guar plant and Marzok (2011) on basil plant.

Table (4): Effect of sowing methods, compost tea, E.M., alpha-tocopherol and their interactions on branch number of fennel during 2019/2020 and 2020/2021 seasons.

Biostimulants (B)	Planting method (A)					
	First Season			Second Season		
	One	Two	Mean (B)	One	Two	Mean (B)
Control	8.1	8.5	8.3	8.5	8.4	8.4
Compost tea 25 g/l	8.7	8.6	8.7	8.6	8.7	8.7
Compost tea 50 g/l	8.9	8.4	8.7	8.6	8.9	8.8
Compost tea 100/l	8.7	8.9	8.8	8.9	9.4	9.1
Compost tea 25 g/l + 5 ml E.M.	8.5	8.7	8.6	8.7	8.6	8.7
Compost tea 50 g/l + 5 ml E.M.	9.2	9.1	9.2	9.0	9.6	9.3
Compost tea 100 g/l + 5 ml E.M.	9.4	9.4	9.4	9.5	9.8	9.7
Compost tea 25 g/l + 50 ppm vitamin E	8.6	8.8	8.7	9.3	9.3	9.3
Compost tea 50 g/l + 50 ppm vitamin E	9.0	9.7	9.3	9.4	9.4	9.4
Compost tea 100 g/l + 50 ppm vitamin E	9.5	9.6	9.6	9.9	10.2	10.1
Mean (A)	8.8	9.0		9.0	9.2	
L.S.D 0.05%	A=0.2	B=0.4	AB=0.6	A=0.2	B=0.5	AB=0.7

The augment in branch number due to the use of vitamin E was also proved by Ismail (2008) on black cumin, and Hendawy and Ezz El-Din (2010) on fennel. With respect to the combined between the two studied factors, the data

in Table (4) pointed out that branch number/ plant of fennel was significantly influenced by the interaction treatments, in both seasons. Apparently, the maximum values of branch number/ plant were noticed from the application of reciprocal planting method plus compost tea at 50 or 100 g/l + vitamin E at 50 ppm fallowed by the same method with compost tea at 100 g/l + E.M. at 5 ml comparing to those revealed by other combination treatments, in the two seasons.

3.3 Herb dry weight/plant

Table (5) illustrated that herb dry weight/ plant of fennel was significantly affected by the utilization of planting methods, during the two growing seasons. It is obvious that the use of reciprocal planting method registered higher values of herb dry weight/ plant than those obtained by normal planting method as ranged 4.0 and 2.3 % in the two seasons, respectively. The role of reciprocal planting method in improving herb weight was also explored by Gadissa and Chemeda (2009) on green pepper (*Capsicum annuum*, L.). It worthy that spraying fennel plants with stimulant substances, either alone or together caused a significant increase in herb dry weight/ plant, in both seasons, except for compost tea at 25 g/l in the first season, comparing to the check treatment. Apparently, supplemented the plants with the combined treatments recorded higher values of herb dry weight/plant, mostly than those given by single ones, during the two seasons. Moreover, the heaviest herb dry weight/plant were obtained from the addition of the combined treatment (compost tea at 100 g/l+ vitamin E at 50 ppm) and also the combined one (compost tea at 100 g/l + E.M. at 5 ml) reached 24.0, 19.3, 25.6 and 21.9 % over no sprayed plants, in the first and second seasons, respectively, as clearly emphasized in Table (5). The stimulating effect of compost on herb weight was also described by Ezz El-Din and Hendawy (2010) on borage, Ibrahim (2014) on *Ammi visnaga*, Abdou *et al*. (2012b), Ali *et al.* (2016) and Abo- Kutta (2016) on fennel. The enhancement of herb weight due to the application of E.M. have to be revealed by Abdou *et al*. (2012b) on fennel, Fouad (2013) on *Calendula officinalis*, Ibrahim (2014) on *Ammi visnaga* plants, Mohamed (2009) on guar plant and Marzok (2011) on basil plant. The positive influence of vitamin E on herb weight was also pointed out by Ismail (2008) on black cumin and Abdou *et al.* (2013) on caraway. In relation to the interaction, it was statistically significant effect on herb dry weight/plant of fennel during the two experimental seasons (Table 5). From the obtained results, it could be concluded that the application of reciprocal method with foliar spray with compost tea at 100 g/l + vitamin E at 50 ppm and the same method plus compost tea at 100 g/l + E.M. at 5 ml registered the most effective treatments on increasing herb dry weight/plant, in comparison with these

noticed by other combination treatments, in the two seasons.

Table (5): Effect of sowing methods, compost tea, E.M, alpha-tocopherol and their interactions on herb dry weight/plant (g) of fennel during 2019/2020 and 2020/2021 seasons.

Biostimulants (B)	Planting method (A)					
	First season			Second season		
	One	Two	Mean (B)	One	Two	Mean (B)
Control	91.1	95.9	93.5	99.8	100.8	100.3
Compost tea 25 g/l	95.9	101.3	98.6	102.9	106.5	104.7
Compost tea 50 g/l	102.4	105.1	103.7	100.8	110.9	105.9
Compost tea 100/ l	103.7	108.9	106.3	118.9	111.4	115.1
Compost tea 25 g/l + 5 ml E.M.	99.8	102.2	101.0	108.2	111.0	109.6
Compost tea 50 g/l + 5 ml E.M.	105.7	110.6	108.2	115.9	120.9	118.4
Compost tea 100 g/l + 5 ml E.M.	110.3	112.7	111.5	119.8	124.8	122.3
Compost tea 25 g/l + 50 ppm vitamin E	100.8	109.9	105.4	111.7	115.7	113.7
Compost tea 50 g/l + 50 ppm vitamin E	107.8	112.2	110.0	116.1	118.8	117.5
Compost tea 100 g/l + 50 ppm vitamin E	116.1	115.7	115.9	124.9	127.0	126.0
Mean (A)	103.4	107.5		111.9	114.8	
L.S.D 0.05%	A=3.0	B=6.3	AB=8.9	A=2.7	B=4.0	AB=5.6

3.4 Fruit yield (g)/plant and (tons) per feddan

Shown data in Tables (6 and 7) indicated that fruit yield/plant and per fed of fennel were positively responded to the application of the two planting methods, during both seasons. Obviously, the application of reciprocal method gave higher fruit yield/plant and per feddan by 7.8 and by 7.0 % over than of the normal sowing method, in the two seasons, respectively. Moreover, reciprocal sowing method produced 1.930 and 2.113 kg/feddan fruits, while the normal one recorded 1.791 and 1.975 kg/feddan fruits, in the first and second seasons, respectively. The beneficial role of reciprocal planting method in augmenting fruit yield was also reported by Aujla *et al*. (2004), Plaut *et al*. (1988) on cotton plant and Antony and Singandhupe (2004) on capsicum. It is evident from the revealed data in Tables (6) that foliar spray with the examined stimulant substances, either separately or in combinations led to a significant increase in fruit yield/plant and per fed, except for the treatment of compost tea at 25 g/l for both seasons, comparing to untreated plants. Clearly higher values of these traits were detected due to the combined treatments, mostly than those observed by individual ones in the two seasons. The highest fruit yield/ plant and per fed were obtained when supplying the plants with the combined treatment (compost tea at 100 g/l + vitamin E at 50 ppm) and, also the combined one (compost tea at 100 g/l + E.M. at 5 ml) as ranged 33.9, 30.9, 30.3 and 27.7 % over the check treatment, during the two growing seasons, respectively. In connection, these above-mentioned superior treatments yielded 2.093, 2.045, 2.277 and 2.228 ton/feddan fruits, in relative to control (1.563 and 1.747) ton/feddan fruits, during both seasons,

respectively. The role of compost in augmenting fruit yield has been explained by Ali *et al.* (2016) on fennel plants, Ezz El-Din and Hendawy (2010) on borage, Helmy (2016) on cumin plants and Ibrahim (2014) on khella plants. The capability of E.M. on enhancing fruit yield was also demonstrated by Abdou *et al.* (2009) on borage, Ibrahim (2014) on *Ammi visnaga*, Ismail (2008) on black cumin and Botros (2013) on caraway.

Table (6): Effect of sowing methods, compost tea, E.M, alpha-tocopherol and their interactions on fruits weight/plant (g) of fennel during 2019/2020 and 2020/2021 seasons.

Biostimulants (B)	Planting method (A)					
	First Season			Second Season		
	One	Two	Mean (B)	One	Two	Mean (B)
Control	44.3	49.5	46.9	49.8	55.0	52.4
Compost tea 25 g/l	48.0	51.1	49.5	53.5	56.6	55.0
Compost tea 50 g/l	50.3	54.9	52.6	55.8	60.4	58.1
Compost tea 100/l	55.8	60.5	58.2	61.3	66.0	63.7
Compost tea 25 g/l + 5 ml E.M.	52.2	56.1	54.1	57.7	61.6	59.6
Compost tea 50 g/l + 5 ml E.M.	55.5	59.8	57.7	61.0	65.3	63.2
Compost tea 100 g/l + 5 ml E.M.	58.7	64.0	61.4	64.2	69.5	66.9
Compost tea 25 g/l + 50 ppm vitamin E	54.4	56.7	55.6	59.9	62.2	61.1
Compost tea 50 g/l + 50 ppm vitamin E	57.1	61.9	59.5	62.6	67.4	65.0
Compost tea 100 g/l + 50 ppm vitamin E	61.0	64.6	62.8	66.5	70.1	68.3
Mean (A)	53.7	57.9		59.2	63.4	
L.S.D 0.05%	A=2.4	B=3.4	AB=4.8	A=3.0	B=3.2	AB=4.5

Table (7): Effect of sowing methods, compost tea, E.M, alpha-tocopherol and their interactions on fruits yield (tons/feddan) of fennel during 2019/2020 and 2020/2021 seasons.

Biostimulants (B)	Planting method (A)					
	First Season			Second Season		
	One	Two	Mean (B)	One	two	Mean (B)
Control	1.478	1.649	1.563	1.661	1.832	1.747
Compost tea 25 g/l	1.599	1.702	1.651	1.782	1.886	1.834
Compost tea 50 g/l	1.678	1.829	1.753	1.861	2.012	1.937
Compost tea 100/l	1.861	2.016	1.938	2.044	2.199	2.122
Compost tea 25 g/l + 5 ml E.M.	1.740	1.869	1.804	1.923	2.052	1.988
Compost tea 50 g/l + 5 ml E.M.	1.851	1.993	1.922	2.034	2.176	2.105
Compost tea 100 g/l + 5 ml E.M.	1.956	2.134	2.045	2.139	2.318	2.228
Compost tea 25 g/l + 50 ppm vitamin E	1.813	1.890	1.852	1.997	2.073	2.035
Compost tea 50 g/l + 50 ppm vitamin E	1.904	2.064	1.984	2.088	2.248	2.168
Compost tea 100 g/l + 50 ppm vitamin E	2.033	2.153	2.093	2.217	2.337	2.277
Mean (A)	1.791	1.930		1.975	2.113	
L.S.D 0.05%	A=0.100	B=0.110	AB=0.157	A=0.111	B=0.105	AB=0.149

The primitive influence of vit. E on fruit yield was also proved by Hendawy and Ezz El-Din (2010) on fennel and Abdou *et al.* (2013) on caraway. Concerning the interaction between the two studied factors, it was statistically significant effect on fruit yield/plant and per fed of fennel, during the two experimental seasons. It appears that the most effective treatments in increasing seed weight/ plant and per fed were obtained from the application of reciprocal sowing method

plus compost tea at 100 g/l + vitamin E at 50 ppm and, also the same method with compost tea at 100 g/l + E.M. at 5ml, in comparison with those detected by other combination treatments in the two seasons. In this concern, the two preneus superior treatment to amounted 2.153, 2.134, 2.337 and 2.318 ton/feddan fruits in contrast with untreated plants gave (1.478 and 1.661) ton/feddan fruits during the two seasons, respectively, as clearly postulated in Table (7).

3.5 Essential oil %

Data in Table (8) emphasized that the application of the planting methods significantly affected essential oil % of fennel fruits, during the two experimental seasons. It is obvious that reciprocal cultivating method gave higher values of essential oil % by 3.9 and by 4.7 % over than the normal method, in both seasons, respectively. In respect to stimulant substance treatments, data in Table (7) cleared that essential oil % in fennel fruits was significantly augmented as a result of foliar spray with the three stimulant substances, either individual or mixed, in both seasons, except for the treatment of compost tea at 25 g/l in the two seasons and also compost tea at 50 g/l in the second one, as compared to untreated plants. Apparently, higher values of such trait were obtained from using the combined treatments, mostly, than these revealed by single ones, during the two growing seasons.

Table (8): Effect of sowing methods, compost tea, E.M, alpha-tocopherol and their interactions on essential oil % of fennel during 2019/2020 and 2020/2021 seasons.

Biostimulants (B)	Planting method (A)					
	First season			Second season		
	One	Two	Mean (B)	One	Two	Mean (B)
Control	1.49	1.58	1.53	1.58	1.69	1.64
Compost tea 25 g/l	1.54	1.63	1.59	1.60	1.74	1.67
Compost tea 50 g/l	1.83	1.88	1.86	1.66	1.78	1.72
Compost tea 100/l	1.85	1.91	1.88	1.95	1.98	1.97
Compost tea 25 g/l + 5 ml E.M.	1.78	1.82	1.80	1.91	2.02	1.97
Compost tea 50 g/l + 5 ml E.M.	1.81	1.88	1.85	2.05	2.07	2.06
Compost tea 100 g/l + 5 ml E.M.	1.99	2.03	2.01	2.18	2.30	2.24
Compost tea 25 g/l + 50 ppm vitamin E	1.82	1.86	1.84	2.01	2.03	2.02
Compost tea 50 g/l + 50 ppm vitamin E	1.90	2.01	1.95	2.13	2.20	2.17
Compost tea 100 g/l + 50 ppm vitamin E	2.03	2.09	2.06	2.27	2.37	2.32
Mean (A)	1.80	1.87		1.93	2.02	
L.S.D 0.05%	A=0.05	B=0.07	AB=0.10	A=0.07	B=0.10	AB=0.14

In connection, the highest values of essential oil % were noticed when foliar spray with the combined treatment (compost tea at 100 g/l+ vitamin E at 50 ppm) and also the combined one (compost tea at 100 g/l + E.M. at 5 ml) which they increased it by 34.6, 31.4, 41.5 and by 36.6 % over no sprayed ones, in the first and second seasons, respectively. The capability of compost on enhancing essential oil % was also exhibited by Sakr (2001), Scavroni *et al.*

(2005), Abdou *et al.* (2012a) and Abd El-Kader *et al*. (2022) on *Mentha piperita* plants, Sukhmal *et al.* (2006) on *Mentha arvensis*, El-Nady (2015) on *Cymbopogon citratus* plants, El-Gendy *et al*. (2001), Carlen *et al*. (2004), Khalid *et al*. (2006) and El-Sanafawy (2007) on *Ocimum basilicum*, Abdou *et al*. (2014) on lavender, Ali *et al*. (2016) on fennel. The stimulation in essential oil % due to the addition of E.M. have to be studied by Kamel (2016) on yarrow. The augment in essential oil % as a result of applying vitamin E was also reported by Refaat and Balbaa (2001) on lemongrass, Hendawy and Ezz El-Din (2010) on fennel. Accordingly, the combined between the two examined factors on essential oil of fennel fruits had a significant effect, during the two consecutive seasons. Obviously, the application of reciprocal sowing method in combination with compost tea at 100 g/l + vitamin E at 50 ppm and the same method plus compost at 100 g/l + E.M. at 5 ml achieved the highest values of essential oil %, in comparison with those detected by other combination treatments, during the two experimental seasons, as clearly declared in Table (8).

3.6 Essential oil yield (ml)/plant and (l)/ feddan

The illustrated data in Tables (9 and 10) revealed that essential oil yield/ plant and per fed of fennel were positively affected by the application of sowing methods, during the two growing seasons. Clearly, reciprocal planting method significantly increased these aspects by 11.3 and by 11.4 % over the normal method, in the two seasons, respectively.

Table (9): Effect of sowing methods, compost tea, E.M, alpha-tocopherol and their interactions on essential oil yield/plant (ml) of fennel during 2019/2020 and 2020/2021 seasons.

Biostimulants (B)	Planting method (A)					
	First Season			Second Season		
	One	Two	Mean (B)	one	Two	Mean (B)
Control	0.66	0.78	0.72	0.79	0.93	0.86
Compost tea 25 g/l	0.74	0.83	0.79	0.86	0.98	0.92
Compost tea 50 g/l	0.92	1.03	0.98	0.93	1.08	1.00
Compost tea 100/l	1.03	1.16	1.09	1.19	1.31	1.25
Compost tea 25 g/l + 5 ml E.M.	0.93	1.02	0.97	1.10	1.25	1.17
Compost tea 50 g/l + 5 ml E.M.	1.01	1.12	1.06	1.26	1.35	1.30
Compost tea 100 g/l + 5 ml E.M.	1.17	1.30	1.23	1.39	1.60	1.50
Compost tea 25 g/l + 50 ppm vitamin E	0.99	1.06	1.02	1.20	1.26	1.23
Compost tea 50 g/l + 50 ppm vitamin E	1.08	1.24	1.16	1.33	1.48	1.41
Compost tea 100 g/l + 50 ppm vitamin E	1.24	1.35	1.29	1.51	1.66	1.59
Mean (A)	0.98	1.09		1.16	1.29	
L.S.D 0.05%	A=0.07	B=0.08	AB=0.12	A=0.04	B=0.14	AB=0.20

Moreover, reciprocal method produced 36.3 and 43.0 l/feddan essential oil, in relative to the normal one gave 32.6 and 38.6 l/feddan essential oil, during both seasons, respectively. Obviously, foliar spray with these stimulant substances, either separately or in combination led to a significant augment in essential oil

yield plant and per fed of fennel, except for the treatment of compost tea at 25 g/l, in the two seasons, as compared to the check treatment. In most cases, higher values of essential oil yield plant and per feddan were obtained by foliar spray with the combined treatments than those given by alone application, in the two seasons. Apparently, the highest essential oil yield/ plant and per fed were detected from supplying the plants with the combined treatment (compost tea at 100 g/l + vitamin E at 50 ppm) and also the combined one (compost tea at 100 g/l + E.M. at 5 ml) than those noticed by other treatments and control, during the two seasons. Numerically, these previous superior treatments augmented these characteristics by 79.6, 71.3, 84.3 and by 73.9 % over no sprayed ones, in the two seasons, respectively. In this connection, these above-mentioned treatments produced 43.1, 41.1, 52.9 and 49.9 l/feddan essential oil, while control plants gave 24.0 and 28.7 l/feddan essential oil, in the first and second seasons, respectively, as clearly proved in Table (10).

Table (10): Effect of sowing methods, compost tea, E.M., alpha-tocopherol and their interactions on essential oil yield (l/feddan) of fennel during 2019/2020 and 2020/2021 seasons.

Biostimulants (B)	Planting method (A)					
	First Season			Second Season		
	One	Two	Mean (B)	one	two	Mean (B)
Control	22.0	26.1	24.0	26.3	31.0	28.7
Compost tea 25 g/l	24.6	27.8	26.2	28.5	32.7	30.6
Compost tea 50 g/l	30.7	34.4	32.6	30.9	35.8	33.4
Compost tea 100/l	34.4	38.5	36.4	39.8	43.6	41.7
Compost tea 25 g/l + 5 ml E.M.	31.0	34.0	32.5	36.8	41.5	39.1
Compost tea 50 g/l + 5 ml E.M.	33.5	37.4	35.5	41.9	45.0	43.4
Compost tea 100 g/l + 5 ml E.M.	39.0	43.2	41.1	46.5	53.4	49.9
Compost tea 25 g/l + 50 ppm vitamin E	33.0	35.2	34.1	40.0	42.1	41.1
Compost tea 50 g/l + 50 ppm vitamin E	36.1	41.5	38.8	44.4	49.5	46.9
Compost tea 100 g/l + 50 ppm vitamin E	41.2	45.1	43.1	50.4	55.4	52.9
Mean (A)	32.6	36.3		38.6	43.0	
L.S.D 0.05%	A=2.0	B= 2.5	AB=3.6	A=1.2	B=4.8	AB=6.8

The capability of compost tea on augmenting essential oil yield has been stated by Abdou *et al*. (2014) on lavender, Ali *et al*. (2016) on fennel. The enhancement of essential oil yield due to applying E.M. was also demonstrated by Kamel (2016) on yarrow. The promoting effect of vitamin E on essential oil yield was also emphasized by Refaat and Balbaa (2001) on lemongrass, Hendawy and Ezz El-Din (2010) on fennel. As for the combined, the listed data in Tables (9 and 10) indicated that essential oil yield/plant and per fed of fennel were significantly influenced by the interaction treatments, during the two growing seasons. Clearly, the application of reciprocal sowing method with spraying the plants with compost tea at 100 g/l + vitamin E at 50 ppm and the same method plus compost tea at 100 g/l + E.M. at 5 ml proved to be more effective

in increasing essential oil yield/plant and per fed than these revealed by other combination treatments, during the two seasons. Moreover, the two previous superior treatments yielded 45.1, 43.2, 55.4 and 53.4 l/feddan essential oil in relative to the check treatment recorded 22.0 and 26.3 l/feddan essential oil, in both seasons, respectively. From the obtained results, it could be discussed as follows: The enhancement of growth, fruit yield and essential oil content due to the application of reciprocal sowing method as proper plant arrangement might be attributed to the beneficial roles of reciprocal method which was explained by some investigators like, Isaac *et al*. (2020) on sesame, Zhou *et al*. (2015) on wheat and soybean, Osnighove *et al*. (2016) and Mansaray *et al*. (2020) on cassava and Hossain *et al*. (2005) on turmeric plants. The augment in the previous aspects resulting from the addition of compost tea reflected the positive, biological and physiological roles of compost as organic manure which was reached by many authors such as, Bohn *et al* (1985) suggested that organic matter is a main source of N, P and S, as well as, high concentrations of both B and Mo, besides to as a source of energy for the growth of Azotobacter. Organic manures are vital role in improving soil structure (Dauda *et al*., 2008) and also augmenting the microbial biomass (Dhull *et al*., 2004). Compost is one of the most widely important organic manures, which plays an essential role in the soil like, water retention capacity, pH, the drainage, better availability of microorganisms in soil and lowering the negative influence of chemical fertilizers and pesticides in the ecosystems (Zheljazkov and Warman, 2004). E.M. (Effective microorganisms) is a bio-fertilizer; it contains N fixing bacteria (photosynthetic bacteria + lactic acid bacteria + yeasts). The application of E.M. to the soil, plant ecosystem led to an enhance in the growth, yield and quality of craps, as well as soil health (Kengo and Hui-lian (2000). Moreover, adding E.M. caused an enhancement in the maturational status, morphological, physical and chemical properties (Correa, 2002). Alpha-tocopherol (vitamin E) is a major antioxidant substance which acts protect the membranes lipids from photo oxidation process particularly those of chloroplast (Havaux *et al*., 2000; Hess, 1983; Zhang *et al*, 2000). Foliar spray with vitamin E positively affected the chemical constituents of medicinal plants (Ayad *et al*., 2009). From the obtained results, it could be recommend led to cultivating fennel (*Foeniculum vulgare* Mill) seeds by reciprocal method and foliar spray with compost tea 100 g/l + vitamin E at 50 ppm or + E.M. at 5 ml to enhancing the growth and augmenting fruit yield and essential oil production under this investigation conditions.

References

Abd El-Kader, E. H. (2022), *Response of peppermint (Mentha piperita) plants to some organic fertilization,*

ascorbic acid and active yeast treatments, M.Sc. Thesis, Faculty of Agriculture, Al-Azhar University, Assiut, Egypt.

Abd El-kader, E. H., Ali, A. F. and Tawfik, O. H. (2022), "Growth and essential oil of peppermint (*Mentha piperita* L.) plants as influenced by compost and some biostimulants", *Archives of Agriculture Sciences Journal*, Vol. 5 No. 1, pp. 53–76.

Abd El-Rahman H. A. (2016), *Possibility of improving the productivity of Matricaria chamomilla plants by using some agricultural treatments*, M.Sc. Thesis, Faculty of Agriculture, Al-Azhar University (Assiut Branch), Assiut, Egypt.

Abd El-Salam and Nora M. K. (2014), *Response of sweet basil plants to some agricultural treatments*, Ph.D. Thesis, Faculty of Agriculture, Minia University, Minia, Egypt.

Abdalla, Alia Sh. (2009), *Effect of E.M. Minia azotein and ascorbic acid on Hibiscus sabdariffa* var. *Sabahia 17 plants*, M.Sc. Thesis, Faculty of Agriculture, Minia University, Minia, Egypt.

Abdou, M. A. H., Aly, M. K, Ahmed, E. T., Taha, R. A. and Abd El Latif, M. T. M. (2014), "Physiological studies on *Lavandula officinalis* plant", *Minia Journal of Agricultural Research and Development*, Vol. 34 No.1, pp. 32–42.

Abdou, M. A. H., Attia, F. A., Ahmed, E. T., El-Sayed, A. A. and Abd-El-Naeem, L. M. (2012a), *Physiological studies on mint plants*, In Proceedings of the Second International Conference of Physiological, Microbiological and Ecological Plant Sciences, Faculty of Science, Minia University, Egypt, pp. 207–228.

Abdou, M. A. H., El-Sayed, A. A., Taha, R. A**.** and Botros, W. S. (2013), *Physiological Studies on caraway plants*, The First Assiut International Conference of Horticulture, Faculty of Science, Assiut University, Egypt.

Abdou, M. A. H., Taha, R. A., Abd El-Raaof, R. M. and Salah El-Deen, R. M. (2012b), *Response of fennel plants to organic, bio and mineral fertilization*, Second International Conference Physiological, Microbiological and Ecological Plant Sciences, Faculty of Science, Minia University, Egypt, pp. 191–205.

Abo-Kutta, W. M. H. (2016), *The role of organic fertilization and some antioxidants in improving the growth, yield and some chemical constituents of fennel (Foeniculum vulgare Mill) plants*, M.Sc. Thesis, Faculty of Agriculture, Al-Azhar University, Assiut, Egypt.

Ali, A. F., Hassan, E. A. Hamad, E. H. and Abo-Quta, W. M. H. (2017), "Effect of compost, ascorbic acid and salicylic acid treatments on growth, yield and oil production of

fennel plant", *Assiut Journal of Agricultural Sciences*, Vol. 48 No. 1, pp. 139–154.

Ali, A. F., Hassan, E. A., Hamad, E. H. and Abd-El-Rahman, A. H. (2016), "Possibility of enhancing growth and productivity of chamomile plant by utilizing effective microorganisms, thiamine and some amino acids", *Journal of Biological Chemistry & Environmental Sciences*, Vol. 11 No.1, pp. 363–388.

Allahverdiyev, S. R., Kirdar, E., Gunduz, G., Kadimaliyev, D., Revin, V., Filonenko, V., Rasulova, D. A., Abbasova, Z. I., Gani-Zade, S. I. and Zeynalova, E. M. (2011), "Effective microorganisms (E.M) technology in plants", *Education*, Vol. 14, pp. 103–106.

Antony, E. and Singandhupe, R. B. (2004), "Impact of drip and surface irrigation on growth, yield and WUE of capsicum (*Capsicum annum* L.)", *Agricultural Water Management*, Vol. 65 No. 2, pp. 121–132.

Aujla, M. S., Thind, H. S. and Buttar, G. S. (2004), "Cotton yield and water use efficiency at various levels of water and N through drip irrigation under two methods of planting", *Agricultural Water Management*, Vol. 71 No. 2, pp. 167–179.

Ayad, H. S., Gamal El-Din, K. M. and Reda, F. (2009), "Efficiency of stigmasterol and α-tocophrerol application on vegetative growth, essential oil pattern, protein and lipid peroxidation of geranium (*Pelargonium graveolens*, L.)", *Journal of Applied Sciences Research*, Vol. 5 No. 7, pp. 887–892.

Bohn, H. L., Meneal, B. L. and Connor, G. A. O. (1985), *Soil Chemistry*, 2ed ed., Wiley Interscience Publication, John Wiley & Sons, New York, USA.

Botros, W. S. E. (2013), *Physiological studies on caraway plants*, M.Sc. Thesis, Faculty of Agriculture, Minia University, Egypt.

Carlen, Ch., Neyroud, J. A., Carron, C. A. and Rey, Ch. (2004), "Effect of different organic fertilizers on yield of aromatic and medicinal plants", *Revue suisse de Viticulture, Arboriculture, Horticulture*, Vol. 36 No. 6, pp. 263–276.

Charles, D. J., Morales, M. R. and Simon, J. E. (1993), *Essential oil content and chemical composition of finocchio fennel*, New Crops, Wiley, New York, USA, pp.570–573.

Correa, M. (2002), *The impact of effective microorganisms (EM) in various farming systems*, In International Workshop on EM Technology Programme, Thailand.

Dauda, S. N., Ajayi, F. A. and Nodor, E. (2008), "Growth and yield of watermelon (*Citrullus lanatus*) as affected by poultry manure application", *Journal of Agriculture*

and Social Sciences, Vol. 4 No. 3, pp. 121–124.

Dhull, S., Goyal, S., Kapoor, K. and Mundra, M. (2004), "Microbial biomass carbon and microbial activities of soils receiving chemical fertilizers and organic amendments", *Archives of Agronomy and Soil Science*, Vol. 50 No. 6, pp. 641–647.

El-Gendy, S. A., Hosni, A. M., Ahmed, S. S., and Sabri, R. M. (2001), "Sweet basil (*Ocimum basilicum* L.) productivity under different organic fertilization and inter-plant spacing levels in a newly reclaimed land in Egypt", *Annals of Agricultural Science*, Vol. 46 No. 1, pp. 319–338.

El-Houssini, Reem, M. (2009), *Response of borage plants to some organic and biofertilization treatments*, Ph.D. Thesis, Faculty of Agriculture, Minia University, Egypt.

El-Kouny, H. M. and Salem, A. S. (2006), "The combined impact of organic manure in different rates and depths in soil on fennel plants and soil properties under flooding and drip irrigation systems", *Alexandria Science Exchange*, Vol. 27 No. 3, pp. 342.

El-Nady, M. K. (2015), *Physiological studies on lemongrass plants*, M.Sc., Thesis, Faculty of Agriculture, Minia University, Minia, Egypt.

El-Sanafawy, S. E. A. (2007), *Effect of some fertilization treatments on Ocimum basilicum and Origanum majoranum*, Ph.D. Thesis, Faculty of Agriculture, Tanta University, Kafr El-Sheikh, Egypt.

Ezz El-Din, A A. and Hendawy, S. F. (2010), "Effect of dry yeast and compost tea on growth and oil content of *Borago officinalis* plant", *Research Journal of Agricultural & Biological Sciences*, Vol. 6 No. 4, pp. 424–430.

Farrell, K. T. (1998), *Spices, condiments and seasonings*, Springer Science & Business Media, Berlin, Germany, pp. 106–109.

Fouad, F.A. (2013), *Effect of organic and biofertilization treatments on pot marigold (Calendula officinalis L) plants*, M.Sc. Thesis, Faculty of Agriculture, Minia University, Egypt.

Gadissa, T. and Chemeda, D. (2009), "Effects of drip irrigation levels and planting methods on yield and yield components of green pepper (*Capsicum annuum*, L.) in Bako, Ethiopia", *Agricultural Water Management*, Vol. 96 No. 11, pp. 1673–1678.

Gharib, F. A., Moussa, L. A. and Massoud, O. N. (2008), "Effect of compost and bio-fertilizers on growth, yield and essential oil of sweet marjoram (*Majorana hortensis*) plant", *International Journal of Agriculture and Biology*, Vol. 10 No. 4, pp. 381–387.

Guenther, E. (1961), *The essential oils*,

V. III, D. Van Nostrand Company, Inc., New Yor, USA.

Havaux, M., Bonfils, J. P., Lutz, C. and Niyogi, K. K. (2000), "Photodamage of the photosynthetic apparatus and its dependence on the leaf developmental stage in the npq1 Arabidopsis mutant deficient in the xanthophyll cycle enzyme violaxanthin de-epoxidase", *Plant Physiology*, Vol. 124 No. 1, pp. 273–284.

Helmy, T. A. (2016), *Influence of agricultural treatments on cumin plant*, Ph.D. Thesis, Faculty of Agriculture, Minia University, Egypt.

Hendawy, S. F. and Ezz El-Din, A. A. (2010), "Growth and yield of *Foeniculum vulgare* var. *azoricum* as influenced by some vitamins and amino acids", *Ozean Jornal of Applied Sciences*, Vol. 3 No. 1, pp. 113–123.

Hess, J. L. (1983), "Vitamin E, a-tocopherol", In: *Antioxidants in Higher Plants*, Alscher R. G. and Hess J. L. (Eds), CRC Press Inc., Boca Raton, Florida, USA, pp. 111–134.

Ho, H. I. and Ji Hwan, K. (2000), *The study on the plant growth hormones in EM-A case study*, In International Conference on EM Technology and Nature Farming, Pyongyang, North Korea.

Hossain, A., Ishimine, Y., Motomura, K. and Akamine, H. (2005), "Effects of planting pattern and planting distance on growth and yield of turmeric (*Curcuma longa* L.)", *Plant Production Science*, Vol. 8 No. 1, pp. 95–105.

Ibrahim, M. F. (2017), *Effect of organic, mineral fertilization and inoculation with some microorganisms on white mustard plants grown in sandy soil*, Ph.D. Thesis, Faculty of Agriculture, Al-Azhar University, Egypt.

Ibrahim, T. I. E. (2014), *Influence of some agricultural treatments on Ammi Visnaga plants*, Ph.D. Thesis, Faculty of Agriculture, Minia University, Minia, Egypt.

Ingham, E. (2005), *The compost tea brewing manual*, Vol. 728, Soil Foodweb, Incorporated Corvallis, OR, USA.

Isaac, A. A., Oyebisi, A. K., Kayode, O. S. and Mojisola, A. S. (2020), "Effects of spatial arrangement and population density on the growth and yield of sesame (*Sesamum indicum* L.) in a sesame/maize intercrop", *Journal of Agricultural Sciences (Belgrade)*, Vol. 65 No. 4, pp. 337–350.

Ismail, S. I. I. (2008*), Anatomical and physiological studies on Nigella Sativa L. plant*, Ph.D. Thesis, Faculty of Agriculture, Mansoura University, Egypt**.**

Jasson, T., Nchu, F. and Laubscher, C. P. (2017), *Effects of compost tea*

extract on growth, nutritional value, soil quality of Hypoxis hemerocallidea and Siphonochilus aethiopicus, Doctoral dissertation, Cape Peninsula University of Technology, Cape Town, South Africa.

Kamel, H. M. (2016), *Response of yarrow plants to some agricultural treatments*, Ph.D. Thesis, Faculty of Agriculture, Minia University, Egypt.

Khalid, K. A. (2006), "Influence of water stress on growth, essential oil, and chemical composition of herbs (*Ocimum sp.*)", *International Agrophysics*, Vol. 20 No. 4., pp. 289–296

Klute, A. (1986), "Water retention: laboratory methods", *Methods of soil analysis: part 1 physical and mineralogical methods*, Vol. 5, pp. 635–662.

Koné, S. B., Dionne, A., Tweddell, R. J., Antoun, H. and Avis, T. J. (2010), Suppressive effect of non-aerated compost teas on foliar fungal pathogens of tomato", *Biological Control*, Vol. 52 No. 2, pp. 167–173.

Lawless, J. (1997), *The illustrated encyclopodia of essential oils*, Element Books Ltd., United Kingdom.

Li, X., Han, Y., Wang, G., Feng, L., Wang, Z., Yang, B. and Li, Y. (2020), "Response of cotton fruit growth, intraspecific competition and yield to plant density", *European Journal of Agronomy*, Vol. 114, Article ID: 125991.

Mansaray, A. pabaturde, K. A. Yormah, T. B. Hy Marie, Y. and Rahman, C. A. (2020), "Effect of spatial arrangement, plant architecture and cropping system on the growth, yield and yield components of cassava (*Manihot esculenta* L)", *Journal of Global Agriculture and Ecology*, Vol. 10 No. 1, pp. 1–7.

Martin, C. C. G. (2015), "Potential of compost tea for suppressing plant diseases", *CABI Reviews*, Vol. 9 No. 1, pp. 1–38.

Martin, C. C. G. and Brathwaite, R. A. I. (2012), "Compost and compost tea: Principles and prospects as substrates and soil-borne disease management strategies in soil-less vegetable production", *Biological Agriculture & Horticulture*, Vol. 28 No. 1, pp. 1–33.

Marzok, Z. S. A. (2017), *Effect of plant spaces, active yeast and some vitamins on basil plant*, Ph.D. Thesis, Faculty of Agriculture, Minia University, Egypt.

Marzok, Z. S. A. (2011), *Physiological studies on basil plant*, M.Sc. Thesis, Faculty of Agriculture, Mansoura University, Egypt.

Mead, R. N., Currow, R. N. and Harted, A. M. (1993), Statistical methods in agricultural and experimental biology, 2nd Ed., Chapman, London,

pp. 10–44.

Mohamed, A. M. (2009), *Physiological studies on guar plants*, M.Sc. Thesis, Faculty of Agriculture, Minia University, Egypt.

Mohamed, M. A. and Abdou, M. A. (2004), "Growth and soil production of fennel (*Foeniculum vulgare* Mill.): Effect of irrigation and organic fertilization", *Biological and Horticulture*, Vol. 22, pp. 31–39.

MSTAT-C (1986), *A Microcomputer program for the design management and analysis of agronomic research experiments*, version 4.0, Michigan State University, USA.

Munné-Bosch, S. and Alegre, L. (2002), "The function of tocopherols and tocotrienols in plants", *Critical Reviews in Plant Sciences*, Vol. 21 No. 1, pp. 31–57.

Natarajan, K. (2007), *Ponclagavga for plant*, Proceedings of National Conference on Glory of Gomatha, Veterinary University, Tirupati., India, pp. 72–75.

Osaigbove, A. U., Remison, S. U., and Law-Ogbomo, K. E. (2016), "Effect of spatial arrangement on growth and yield of cassava (*Manihot esculenta* Crantz) and maize (*Zea mays* L.) intercrop in a forest zone of Edo State", *Nigerian Journal of Agriculture, Food and Environment*, Vol. 12 No. 2, pp. 63–73.

Plaut, Z., Carmi, A., Canbolat, M., Eker, S. and Celikel, G. (1988), "Cotton growth and production under drip irrigation restricted wetting", *Irrigation Sciences*, Vol. 9, pp. 143–156.

Ramraj, V. M., Vyas, B. N., Godrej, N. B., Mistry, K. B., Swami, B. N. and Singh, N. (1997), "Effects of 28-homobrassinolide on yields of wheat, rice, groundnut, mustard, potato and cotton", *The Journal of Agricultural Science*, Vol. 128 No. 4, pp. 405–413.

Refaat, A. M. and Balbaa, L.K. (2001), "Yield and quality of lemon grass plants (*Cymbopogon flexuous*) in relation to foliar application of some vitamins and micro-elements", *Egyptian Journal of Horticulture*, Vol. 28 No. 1, pp. 41–57.

Sakr, W. R. (2017), "Chemical and biological fertilization of *Calendula officinalis* plant grown in sandy soil", *Journal of Horticultural Science & Ornamental Plants*, Vol. 9 No. 1, pp. 17–27.

Sakr, Walaa R. A. S. (2001), *Effect of some organic and inorganic fertilizers on Mentha piperita L.*, M.Sc. Thesis, Faculty of Agriculture, Cairo University, Egypt.

Scarvoni, J., Boaro, C. S. F., Marques, M. O. M. and Ferreira, L. C. (2005), "Yield and composition of the essential oil of *Mentha piperita*, L. (Lamiaceae) *grown with biosolid* ", *Brazilian Journal of Plant*

Physiology, Vol. 4, pp. 130–145.

Scheuerell, S. and Mahaffee, W. (2002), "Compost tea: principles and prospects for plant disease control", *Compost Science & Utilization*, Vol. 10 No. 4, pp. 313–338.

Scheuerell, S. J. and Mahaffee, W. F. (2004), "Compost tea as a container medium drench for suppressing seedling damping-off caused by *Pythium ultimum*", *Phytopathology*, Vol. 94 No. 11, pp. 1156–1163.

Sreenivasa, M. N., Najaraj, M. N. and Bhat, S. N. (2010), "Beejarnruth; A source for beneficial bacteria, Kamataka", *Journal of Agricultural Science*, Vol. 17, pp. 72–77.

Stary, F. and Jirasck, V. (1975), *A concise guide in colour herbs*, Hamlyn, London, United Kingdom.

Sukhmal, C., Anwar, M. and Patra, D. D. (2006), "Influence of long term application of organic and inorganic fertilizer to build up soil fertility and nutrient uptake in mint mustard cropping sequence", *Communications in Soil Science and Plant Analysis*, Vol. 37 No. 112, pp. 63–76.

Wichtl, M. and Bissel, N. G. (1994), *Herbal drugs and phyto-pharmaceuticals*, *Medpharm Scientific Publishers, Stuttgart*, Germany, pp. 107–108.

Wilde. S. A., Covey, R. P., Lyer, J. C. and Voigt. G. K. (1985), *Soil and plant analysis for tree culture*, Oxford & IBH Publishing Co., New Delhi, India.

Yamada, K. and Xu, H. L. (2001), "Properties and applications of an organic fertilizer inoculated with effective microorganisms", *Journal of Crop Production*, Vol. 3 No. 1, pp. 255–268.

Yancey, P. H., Clark, M. E., Hand, S. C., Bowlus, R. D. and Somero, G. N. (1982), "Living with water stress: evolution of osmolyte systems", *Science*, Vol. 217 No. 4566, pp. 1214–1222.

Zheljazkov, V. D. and Warman, P. R. (2004), "Source separated municipal solid waste compost application to Swiss chard and basil", *Journal of environmental quality*, Vol. 33 No. 2, pp. 542–552.

Zhou, X. B., Chen, Y. H. and Ouyang, Z. (2015), "Spacing between rows: effects on water-use efficiency of double-cropped wheat and soybean", *The Journal of Agricultural Science*, Vol. 153 No. 1, pp. 90–101.