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Controlling of Artichoke powdery mildew and improving Vegetative growth and yield productivity by using Dl- β-aminobutyric acid (BABA) with some natural essential oils

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ABSTRACT

Artichoke can be affected by many diseases that reduce quality and yield especially powdery mildew caused by *Leveillula taurica*. In recent years, there has been an increased interest to use essential oil combinations to improve their natural antimicrobial and antifungal activities. The present work was conducted to study the efficacy of the controlling artichoke powdery mildew with some compounds eco-friendly environment because of their efficacy as plant resistance inducers and their effects on improving the growth, productivity and quality of artichoke plants. Results indicated that percentage of disease incidence and disease severity of powdery mildew was significantly decreased by spraying some essential oils: garlic, camphor, black seed and clove each at 0.5% three times with 15 days interval in combination with DL- β-aminobutyric acid (BABA). A reduction of the disease incidence by DL- β-aminobutyric acid (BABA) was occurred in addition to an increase of vegetative characters when used with essential oils. Spraying artichoke plants with essential oils exhibited a significant increase in the activity of peroxidase, polyphenoloxidase and chitinase in artichoke leaves infected by *Leveillula taurica* compared with a control. Thus, spraying any of the tested oils alone does not have a significant effect on growth, yield and quality unless it is associated with the addition of BABA compared with the fungicide only one 40%EC. Also, the spraying of garlic oil + BABA has achieved the highest rates of increase in the early and total yield.

Keywords: Artichoke, powdery mildew, essential oil, controlling, DL- β-aminobutyric acid (BABA), peroxidase, polyphenoloxidase, Chitinase, growth, productivity and flower head weight

Introduction

Globe artichoke (*Cynara scolymus* L) is an important vegetable crop in Egypt and the world because of its nutritive and medical values. The immature flower bud (head) is the edible part of the crop which includes the fleshy receptacle and fleshy tender basis of bracts. It is a good source of inulin, fibers and minerals (Ryder *et al*, 1983). The edible flower buds and other artichoke plant extracts are rich in polyphenols and have high levels of antioxidant activity (Liorach*et et al*, 2002). Moreover, it gained a highly exportable importance to the European markets. The globe artichoke harvested area in the world is about 125,000 hectares, of which about 75% are in the Mediterranean area and in Italy (50,321 ha), Spain (13,200 ha), Egypt (8,909 ha), France (8,690 ha) and Morocco (3,710 ha). In the last years, globe artichoke cultivation has been also extended to China (9,500 ha), to USA (2,910 ha), as well as to some countries of South America such as Peru (6,848 ha), Chile (4,651 ha), Argentina (3,700 ha) (FAOSTAT, 2010).

Artichoke can be affected by many diseases that reduce quality and yield. Damage can be caused by a wide range of biological agents, including fungi, bacteria and viruses. The most important disease caused by fungi is powdery mildew caused by *Leveillula taurica* (Walker *et al.,* 2001). The pathogen is associated with more than 1000 plant species, including peppers, artichoke and tomato, and is spreading quickly around the world (Souza and Filho, 2003).

Powdery mildew control using synthetic fungicides currently maintains a prominent role in plant protection, but these chemicals can cause development of the pathogen resistance towards chemical agents (McGrath, 2001; Pérez-García *et al.,* 2009) and risks for the environment.

In recent years, there has been an increased interest in the use of essential oil combinations to improve their natural antimicrobial and antifungal activities. Fu *et al.* (2007) observed an increase of the antifungal effects caused by combinations of essential oils. Previous studies of Annesi *et al.* (2011),

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carried out to evaluate the efficacy of a strengthener and an essential oil used alternately with a synthetic fungicide for control of powdery mildew.

The essential oils are complex mixtures of several chemical compounds including terpenes, alcohols, aldehydes and phenols, and these materials exhibit potential herbicidal and fungicidal properties (Tworkoski *et al.,* 2002).

Hegazi and El-Kot, (2010) evaluated biocontrol agents by using some essential oils (clove, cinnamon, garlic, ginger and fennel oils) against powdery mildew at concentration 0.05 mg/L as foliar spray.

Derbalah *et al.* (2012) studied the effect of some non-traditional methods as clove oil extracts against powdery mildew of tomato caused by *Leveillula taurica* under greenhouse conditions. They found that the tested treatments were effective against the powdery mildew disease relative to control.

DL-β-aminobutyric acid (BABA) is a non-protein amino acid that is an effective inducer of resistance against a variety of plant pathogens without possessing any direct antimicrobial activity. Which sprayed onto the leaf surface induces resistance against various foliar pathogens (Jakab *et al.* 2001; Cohen 2002). It has shown a capacity to enhance defenses in a range of plant species, including tomato (*Lycopersicon esculentum* L.), pepper (*Capsicum annuum* L.) and cauliflower (*Brassica oleracea)* (Cohen *et al.,* 1994; Hwang *et al.,* 1997 and Silue *et al.,* 2002).

Dang *et al.* (1997) studied the efficacy of a flusilazole compound in comprising with other recommended fungicides (calixin, karathane and sulfex) for the control of powdery mildew on ber, mango and Indian mustard in India. Under a prophylactic spray schedule, all the fungicide gave good control of powdery mildew. In ber, karathane (0.1%) gave the highest disease control (92.2%).

Fiume (1997) reported that sweet pepper (*Capsicum annuum*) plants cultivated in greenhouses, sprayed with tetraconazole fungicide alone or combined with neem oil was the most effective reduction in disease incidence and disease severity of powdery mildew caused by *Leveillula taurica.*

Early control of powdery mildew is the most effective strategy for effective control and maintenance of yield and quality of cucurbits (Davis *et al.* 2001; McGrath, 1997)

The present work was conducted to study the efficacy of the controlling powdery mildew caused by *Leveillula taurica* with some compounds eco-friendly environment by investigating the efficacy of foliar spray with some plant resistance inducers treatments and their effects on improving the growth, productivity and quality of artichoke plants.

Materials and Methods

Experimental design and treatments:

This experiment was carried out during two successive seasons of 2015/2016 and 2016/2017 at the Experimental Farm, Faculty of Agriculture, Moshtohor, Benha University. Some safety compounds, *i.e,* Garlic oil (*Allium sativum*), clove oil (*Syzygium aromaticum*), Camphor oil (*Cinnamomum camphora*), Black seed (*Nigella sativa*) only or in combination with DL-β-aminobutyric acid (BABA) comparing with the fungicide Only One 40%EC were used to study the effect of spraying them on disease severity of artichoke powdery mildew, earliness and productivity of globe artichoke cv. Concerto. The plant materials of the cultivar used were obtained from the Horticulture Research Institute, Agricultural Research Center, Ministry of Agriculture.

The soil type of the experimental site was heavy clay with a pH of 7.6 and Ec.1.3 dSm^{-1} as average of both seasons. The experimental design was conducted in Randomized Complete Block Design (RCBD) with four replicates. The experiment included eleven treatments as foliar spraying three times started after 60 days from planting date and repeated every 15 days through the growing season.

The planting dates were end of August and first of September in both seasons respectively. The propagation materials were treated pre-planting with fungicide Topsin M-70 for 30 minutes and hand planted at 1m apart between each two plants on the ride and 1m between the ridges, plot area was 20 m^2 (4 lines × 5 m long × 1 m width). Other agricultural practices were applied as commonly recommended for commercial globe artichoke production by the ministry of agriculture.

The usual cultural practices of the globe artichoke were followed i.e. NPK were added at rates of 600 kg ammonium sulphate (20.6 % N), 150 kg P_2O_5 (calcium superphosphate) and 240 kg potassium sulphate (48 % K_2O) per hectare added at three equal doses after 2, 3 and 4 months after planting.

The plants were left to natural infection in the open field and no artificial infestation was practiced. Spraying of plants with the different treatments began when the powdery mildew was detected on the undersurface of the leaves during our weekly disease monitoring observations. Six treatments were used for controlling powdery mildew [4 plant oils, BABA and the fungicide]. Control treatment was sprayed using distilled water only.

Tested treatments:

1. Plant oils:

Three different oils i.e. Camphor oil, Garlic oil and Clove oil were extracted according to the method of Amelia, *et al.* 2017 and Black seed oil was extracted with the method of Khairullah, *et al*. 2016. Oils were stored in the dark at 4^{o}C for no more than a week, until we complete. The oils were emulsified with 0.05% Tween 20 (Reuveni, *et al.,* 1996; Terzi, *et al.,* 2007) before application.

2-Fungicide and DL-3-aminobutyric acid (BABA):

The fungicide used, i.e. only One EC (Flusilazole 40%; 6 cm/100L water) was prepared at a recommended dose at a rate of 0.6 cm/10L depending on their active ingredient. Abiotic compound DL-3-aminobutyric acid (BABA) have been used at a concentration 0.5 mg/L.

Foliar application treatments:

The plants were sprayed with a hand atomizer as soon as the first signs of the symptoms were observed. Percentage of disease incidence and disease severity were determined after 7 days from the last spray (95 days after planting) according to the scale reported by Horsfall and Barrett (1945) and Bari (2004).

The treatments were conducted as follows:

1- Spraying plant oils i.e. Camphor oil, Garlic oil, Clove oil and Black seed oil at concentration 0.5% as individual treatments.
2- Spraying BABA at a concentration (0.5 mg/L) as individual treatment.
3- Combination each plant oils + BABA at the same concentration that mentioned before.
4- Spraying Only One 40% EC at a rate of 0.6 cm/10L as individual treatment.
5- Control treatment was treated with distilled water.
6-

Assessment of Powdery mildew disease:

Powdery mildew, scale from 0 to 4, where a rating of 0 indicated no powdery mildew lesions and 4 indicated more than 75% of the leaf area covered with lesions according to Bari, (2004) with slight modification was used for assessing the disease, where 0 = healthy; 1.0 = 1-25% leaf area covered with lesions; 2.0 = 26-50%; 3.0 = 51-75%; and 4.0 = 76-100%.

$$\textbf{Disease Severity}\ \% = \left(\frac{1A + 2B + 3C + 4D}{4T}\right) X\ 100$$

Where A, B, C and D are the number of plants corresponding to the infection numerical grade; 1, 2, 3 and 4 respectively and 4T is the total number of investigated plants, (T) multiplied by the maximum discoloration grade 4, where T = A+B+C+D.

The percentage of treatment efficiency in the reduction of powdery mildew severity was calculated using the following equation:

$$\textbf{Efficiency} = \left(\frac{\text{Treatment} - \text{Control}}{\text{Control}}\right) X\ 100$$

Biochemical Associated with the Infection by *Leveillula taurica*

1- Determination of Peroxidase:

Peroxidase activity was determined according to the method described by (Allam and Hollis, 1972). The cuvette contained 0.5 mL 0.1 M potassium phosphate buffer at pH 7.0 + 0.3 mL of enzyme extract + 0.3 mL 0.05 M pyrogallol + 0.1 mL 1.0% H_2O_2 and distilled water to bring cuvette contents to 3.0 mL. The reaction mixture incubated at 25°C for 15 minutes, then the reaction was inactivated by adding 0.5 mL. of 5.0% (v/v) H_2SO_4 (Kar and Mishra, 1976). Peroxidase activity was expressed as the increase in absorbance at 430nm/gram fresh weight/15 minutes.

2- Determination of Polyphenoloxidase:

Polyphenoloxidase activity was determined according to a modification of Ishaaya, (I971), in a reaction mixture consisting of 0.5 mL phosphate buffer (0.1 M, PH 7), 200 µL enzyme solution and 200 µL catechol solution (2%). Prior to the initiation of the reaction, the substrate and other ingredients of the reaction mixture were separately incubated at the optimum temperature of the reaction (25ºC). The enzyme reaction was initiated by adding catechol solution. Then after exactly 1 min, the optical density was determined. Zero adjustment was against the sample blank. The phenol oxidase activity was determined as O.D. units ×103 at an absorbency of 405 nm.

3- Determination of Chitinase Activity:

a. Substrate preparation

Colloidal chitin was prepared according to Bade and Stinson, (1981) as follows: 4.0 g of purified chitin powder (Sigma) was suspended in 100 mL water at 4°C and stirred in cold concentrated H_2SO_4 (30 mL) at 4°C was added drop wise to the suspension. The cold viscous chitin solution was filtered through glass wool into 1800 mL ice-cold 50% ethanol with rapid stirring. The precipitated colloidal chitin was washed with distilled water to pH 5. It was buffered with phosphate buffer (pH 6.5, 0.2 M) before use as a substrate.

b. Enzyme assay:

The reaction mixture according to Ishaaya and Casida, (1974) with some modifications consisted of: 1 mL phosphate buffer (0.2 M, pH 6.5), 200 mL 0.5 % colloidal chitin and 200 mL enzyme solution. After 1.5-hour incubation at 37 ºC, enzyme activity was terminated by boiling test tube. Undigested chitin was sediment by centrifugation for 15 min at 8.000 r.p.m. The supernatant was taken for determination of N-acetylglucoseamine that produced because of chitin digestion by Chitinase.

3- Vegetative Measurements:

Data recorded:

1-Vegetative growth characteristics:

Five plants were randomly selected from each plot and marked to evaluate plant height, leaves number per plant and the offshoots number per plant in the beginning of a research during the two seasons.

2 –Flower head yield and its components: early, late and total flower head yields based on weight of heads per plant were recorded as follows:

a. **The early yield:** it was expressed as weight of heads produced from the first of March till the middle of April (45 days).
b. **The late yield:** expressed as weight of heads produced from the middle of April till the end of June {end of the production season of globe artichoke (75 days)}.
c. **Total yield:** expressed as the weight of all heads produced throughout the entire harvesting season (120 days).

3- Head characteristics:

Average head weight and the edible part weight were recorded in monthly yield throughout the harvesting season in a representative sample of 20 flower heads.

4- Head chemical composition:

For chemical determination, a representative sample of 100 g. from the edible part of each experimental treatment was taken, oven dried at 70° C till constant weight, then the dry matter percentage was recorded, Inulin percentage and total phenolic contents as well as crud fibers were determined. Inulin was assayed according to the method of Winton and Winton (1958). Also, crude fiber content of the edible part was estimated according to the method of A.O.A.C. (2000).

Statistical analysis:

All obtained data were subjected to the proper analysis according to SAS (1996) and the means were compared using the least significant differences test (L.S.D.) at 5% (Snedecor and Cochran, 1991).

Results

Effect of safety compounds on artichoke powdery mildew disease *in vivo*:

Data in Table 1 reveal that all tested essential oils, DL-3-aminobutyric acid (BABA) and the fungicide Only one 40% had a greater significant effect in decreasing the powdery mildew disease severity percentage caused by *Leveillula taurica* on artichokes plants during the two growing seasons 2015/16 and 2016/17 in comparing with control treatment under open field conditions. In this respect, only one fungicide treatment followed by clove oil with BABA scored highest significant decrease in disease severity percentage (15 and 18%, respectively). Meanwhile, black seed oil was the lowest efficient treatment, being 48% in comparing with control. In general, the tested fungicide was more efficient in this regard than the other treatments (Efficacy %).

Table 1. Effect of safety compounds on disease severity of artichoke powdery mildew during 2015/16 and 2016/17 seasons.

Treatment	Disease severity percentage			
	2015/2016	**2016/2017**	**Mean**	**Efficacy %**
Garlic oil	23.0	23.0	23.0	72.95
Garlic oil + BABA	32.0	34.0	33.0	61.17
Clove oil	29.0	27.0	28.0	67.05
Clove oil + BABA	18.0	18.0	18.0	78.82
Camphor oil	18.0	20.0	19.0	77.64
Camphor oil + BABA	42.0	44.0	43.0	49.41
Black seed oil	47.0	49.0	48.0	43.52
Black seed oil + BABA	30.0	32.0	31.0	63.52
BABA only	20.0	22.0	21.0	75.29
Only one 40%EC	16.0	14.0	15.0	82.35
Control (Distilled water)	85.0	85.0	85.0	00.00
L.S.D at 5%	**1.57**	**1.67**	**1.55**	**0.002**

Efficacy% calculated based on the mean of disease incidence and disease severity percentage in two seasons for comparison all tested treatments with a control.
BABA=DL-3-aminobutyric acid.

Effect on activity of peroxidase, Polyphenoloxidase and Chitinase:

Data presented in Table 2 show that spraying artichoke plants with essential oils exhibited significant increase in the activity of peroxidase, polyphenoloxidase and chitinase in artichoke leaves infected by *Leveillula taurica* compared with a control. The higher activity of peroxidase was observed in case of spraying garlic oil with BABA which recorded 58.50 µg fw/min/g, followed by the treatment with BABA only at 0.5 mg/mL where recorded 55.50 µg fresh weight /min/g compared with 20.30µg fresh weight /min/g for a control.

As for Polyphenoloxidase activity, data presented in Table 2 reveal that, all tested oils, BABA and Only one 40% increased Polyphenoloxidase activity over control. The highest values for Polyphenoloxidase activity were recorded in case of spraying with black seed oil which it recorded 86.85 µg fresh weight /min/g, followed by the treatment with black seed oil incompination with BABA which gave 66.78 85 µg fresh weight /min/g compared with 18.76µg fresh weight /min/g in case of control.

Also, foliar application of BABA either individually or in combinations with garlic, Clove or black seed oils increased chitinase activity. In this respect, BABA only followed by treatment of black seed oil gave 30.90 05µg NAGA x 10^3/min/g fresh weight compared with control treatment that recorded 17.26 µg NAGA x 10^3/min/g fresh weight.

Table 2: Effect some safety compounds on activity of peroxidase, Polyphenoloxidase and Chitinase in artichoke leaves.

Treatment	Peroxidase	Polyphenoloxidase	Chitinase
	O.D 430 /g FW	O.D 405 /g FW	µg NAGA X 10^3/g FW
Garlic oil	40.50	30.33	20.82
Garlic oil + BABA	58.50	50.58	29.40
Clove oil	31.65	20.99	24.36
Clove oil+ BABA	25.80	77.85	24.75
Camphor oil	32.40	48.96	26.10
Camphor oil + BABA	21.54	20.79	22.26
Black seed oil	52.20	86.85	30.90
Black seed oil+ BABA	35.10	66.78	25.35
BABA only	55.50	48.24	31.05
Only one 40%EC	41.40	36.90	26.40
Control (Distilled water)	20.30	18.76	17.26
L.S.D at 5%	**0.0017**	**0.0018**	**0.0019**

O.D = optical density **FW** = fresh weight **BABA**=DL-3-aminobutyric acid

Vegetative growth characteristics:

Data in Table 3 illustrate that foliar application of BABA either individually or in combination with garlic, clove or black seed oils increased significantly the number of artichoke leaves, the plant height and the offshoot number per plants as compared with the control (plants sprayed with distilled water only). Such treatments recorded no significant difference in the investigated growth parameters with the reference treatment that received the fungicides i.e. only one 40%EC during the two seasons of study.

Table 3: Effect of foliar application with safety compounds on growth characteristics of globe artichoke during 2015/2016 and 2016/2017 seasons.

Treatment	Leaves number / plant		Plant height (cm)		Offshoots number /plant	
	2015/16	2016/17	2015/16	2016/17	2015/16	2016/17
Garlic oil	29.71	35.31	83.89	90.80	1.11	2.00
Garlic oil + BABA	36.88	39.36	89.38	94.84	1.31	2.22
Clove oil	28.66	36.93	78.39	86.75	1.27	1.95
Clove oil+ BABA	32.98	35.10	92.45	93.11	1.65	2.27
Camphor oil	34.57	29.28	86.32	85.17	1.31	1.63
Camphor oil + BABA	26.34	29.95	87.91	90.29	1.66	2.07
Black seed oil	24.13	28.45	77.74	69.14	0.98	1.70
Black seed oil+ BABA	32.53	36.14	94.18	80.64	1.78	2.01
BABA only	37.84	30.28	95.05	90.09	1.91	1.96
Only one 40%EC	38.48	39.37	83.89	83.74	1.11	1.83
Control (Distilled water)	26.09	28.32	70.12	68.18	0.97	1.64
L.S.D. at 0.05	**6.121**	**6.821**	**7.70**	**9.48**	**0.60**	**0.39**

On the other hand, sole applications of garlic, clove or black seed oils seemed to have no significant effect on the investigated parameters as compared with the control treatment. The highest increases in plant heights during the first growing season were detected in plants sprayed by either BABA solely or the fungicide treatment with no significant difference with those sprayed with either garlic oil+ BABA, clove+ BABA, camphor oil + BABA or black seed oil+ BABA. On the other hand, the highest increases that occurred in the second growing season were detected for plants sprayed with garlic oil, only with no significant difference with those sprayed with either BABA, clove oil, garlic oil+ BABA, clove oil+ BABA or black seed oil+ BABA. The highest increase that occurred in offshoots were detected for plants sprayed with garlic oil + BABA with no significant difference with fungicide sprayed (Only one 40%EC).

The results illustrate a decrease in the values of characteristics of vegetable growth (leaves number, plant height and offshoots) compared with all other treatments when spraying with distilled water (control) and showed a significant difference in the plant height in both seasons. It is clear from the results that spraying any of the oils used alone does not have a significant effect on growth unless it is associated with the addition of BABA spray on the plant and this was evident in the characteristics of the number of leaves and plant height in both seasons.

Head yield and its components:

Mixed type sprays foliar sprays increased significantly the early, late and total yields as compared with the control treatment (Table 4). Spraying plants with either clove, camphor or black seed oil seemed to have no further significant effect on the studied parameters as compared with the control during the two seasons of study. It is worthy to mention that the foliar application of either garlic + BABA or Camphor oil + BABA recorded significant superiority over the reference fungicide treatment in the early and total yields during both seasons of study. The highest increases in the early yield was attained due to the foliar application of garlic + BABA (75.91 – 96.47%) or garlic solely (58.23-80.96%) or camphor + BABA (56.45 – 95.46%) followed by the foliar application of clove oil+ BABA (50.04-55.49%), the fungicide treatment (27.33 – 41.24%) or BABA solely (30.58 – 39.85%).

Table 4: Effect of foliar application with safety compounds on flower head weight per plant (kg) of globe artichoke during 2015/2016 and 2016/2017 seasons

Treatment	Early yield		Late yield		Total yield	
	2015/16	2016/17	2015/16	2016/17	2015/16	2016/17
Garlic oil	1.435	1.951	3.952	3.807	5.387	5.258
Garlic oil + BABA	1.558	2.169	5.074	5.024	6.632	6.693
Clove oil	0.886	1.530	3.238	2.541	4.124	3.571
Clove oil+ BABA	1.233	1.850	4.902	4.452	6.135	5.802
Camphor oil	0.972	1.541	3.685	2.689	4.657	3.730
Camphor oil + BABA	1.550	1.929	4.987	4.711	6.537	6.140
Black seed oil	0.860	1.208	2.917	2.813	3.777	3.521
Black seed oil+ BABA	1.226	1.692	4.744	4.568	5.970	5.760
BABA only	1.109	1.610	4.449	3.200	5.569	4.270
Only one 40%EC	1.120	1.570	3.661	4.191	4.770	5.301
Control (Distilled water)	0.793	1.233	3.037	2.617	3.830	3.350
L.S.D. at 0.05	**0.120**	**0.309**	**0.706**	**0.88**	**0.642**	**0.756**

Head characteristics:

Foliar application with either BABA or garlic solely as well as the fungicide treatment increased significantly the average head weight as compared with the control (Table 5). Moreover, the foliar application with the mixed types recorded further significant increases in the average head weight during both seasons of study except “black seed oil+ BABA” that recorded insignificant increases in the head weight as compared with the fungicide during the second season only. The highest increases in the average head weight of the early and late yield were achieved by the foliar application of garlic either solely or in combination with BABA beside of the “camphor+ BABA” during both seasons of study, however, such increases seemed to be insignificant with the foliar spray of “clove+ BABA” in the late yield during the two studied seasons. The treatment “black seed oil+ BABA” came second while the foliar application of either BABA solely or the fungicide treatment came third. Generally, the highest edible part weight was attained by the foliar application of either garlic oil or BABA solely, “garlic oil + BABA” or the fungicide treatment as compared with the control during the two studied seasons.

Head chemical composition:

Results shown in Table 6 reveal that the fiber content in the early yield of globe artichoke decreased significantly owing to the application of either “Garlic oil”, “Clove oil + BABA “, black seed + BABA, or “Camphor oil + BABA”. On the other hand, all investigated treatments seemed to have no significant effect on the fibers content in the late yield of the globe artichoke. Generally, fibers content in heads of the late yield were higher than those found in the early yield. Concerning the inulin percentage in globe artichoke, the only treatments that recorded significant increases in this percentage were “Clove oil+ BABA” and garlic oil” in the early yield, and “Clove oil+ BABA” and “Camphor oil” in the late yield. It is worthy to mention that the inulin content in the late yield was lower than that detected in the early yield.

Table 5: Effect of foliar application with safety compounds on flower head physical quality (average head weight and edible part weight) of globe artichoke during 2015/2016 and 2016/2017 seasons

Treatment	Average head weight (g)				Edible part weight (g)			
	Early yield		Late yield		Early yield		Late yield	
	2015/16	2016/17	2015/16	2016/17	2015/16	2016/17	2015/16	2016/17
Garlic oil	282.1	286.1	246.9	252.0	77.71	81.79	66.65	73.23
Garlic oil + BABA	281.3	291.7	250.7	259.1	81.81	90.78	69.58	77.79
Clove oil	267.4	275.9	216.8	231.2	65.13	72.48	53.04	68.20
Clove oil+ BABA	276.1	284.6	240.3	248.9	67.20	75.94	61.62	70.31
Camphor oil	267.6	277.2	226.2	233.2	66.84	74.13	59.63	64.09
Camphor oil + BABA	280.8	288.7	249.6	255.6	83.57	85.90	68.16	74.91
Black seed oil	264.7	272.1	214.8	220.2	63.44	72.60	52.71	60.32
Black seed oil+ BABA	275.2	279.9	238.6	243.2	69.04	78.96	61.96	70.21
BABA only	270.7	277.9	235.0	240.0	70.98	79.70	62.85	73.21
Only one 40%EC	271.5	278.8	233.8	234.6	70.94	79.30	64.29	65.92
Control (Distilled water)	262.5	271.6	198.6	218.6	64.27	72.51	50.55	59.22
L.S.D. at 0.05	**2.4**	**7.0**	**12.3**	**13.8**	**4.53**	**9.62**	**3.23**	**6.87**

Table 6: Effect of foliar application with safety compounds on fibers content and inulin percentage of globe artichoke during 2015/2016 and 2016/2017 seasons

Treatment	Fibers content (mg/g D.W.)				Inulin (%)			
	Early yield		Late yield		Early yield		Late yield	
	2015/16	2016/17	2015/16	2016/17	2015/16	2016/17	2015/16	2016/17
Garlic oil	1.89	1.82	2.21	2.24	0.320	0.334	0.243	0.246
Garlic oil + BABA	2.05	2.10	2.25	2.21	0.427	0.432	0.266	0.263
Clove oil	2.16	2.19	2.29	2.27	0.303	0.334	0.233	0.235
Clove oil+ BABA	1.87	1.79	2.13	2.15	0.537	0.543	0.267	0.264
Camphor oil	2.20	2.26	2.32	2.29	0.320	0.332	0.253	0.255
Camphor oil + BABA	1.95	2.01	2.25	2.23	0.433	0.442	0.257	0.259
Black seed oil	2.17	2.22	2.25	2.27	0.300	0.311	0.220	0.222
Black seed oil+ BABA	1.85	1.81	2.24	2.23	0.303	0.314	0.227	0.229
BABA only	2.21	2.30	2.12	2.16	0.317	0.323	0.243	0.246
Only one 40%EC	1.94	1.98	2.20	2.22	0.433	0.421	0.250	0.257
Control (Distilled water)	2.19	2.23	2.21	2.24	0.300	0.311	0.220	0.224
L.S.D. at 0.05	**0.13**	**0.16**	**ns**	**ns**	**0.023**	**0.012**	**0.008**	**0.011**

Discussion

In this study, results illustrated that disease percentage of infection and disease severity of powdery mildew on globe artichoke (*Cynara scolymus*, L) was significantly decreased by spraying some essential oils: garlic, camphor, black seed and clove each at 0.5% three times with 15 days interval in combination with DL-3-aminobutyric acid (BABA). The results showed that these 6 treatments significantly surpassed others in most cases and the essential oils treatments gave the most effective or similar results with those obtained when using the fungicide Only One 40%.

It has been shown that the *Nigella sativa* oil exhibited strong antifungal activity against phytopathogenic fungi (Rathee *et al*. 1982). Furthermore, the antifungal activity of black seed oil against different fungi was investigated by Rahhal, (1997). He found that the essential oil of *N. sativa* was effective against all tested fungi except *Botrytis fabae*. Farid *et al*., (2000) have demonstrated that black seed oil can control powdery mildew disease caused by *Erysiphe cichoracearum.*

Several plant extracts and plant oils were found to be effective in controlling obligate diseases including powdery mildew all over the world (Haroun, 2002 and Nada, 2002). Raj-Kishore *et al.,* (1996) reported that eugenol was effective compound in controlling powdery mildew (*E. polygoni*) which gave 100% inhibition at the lowest concentration (250 mg/L).

A formulation of clove oil, whose major constituent is eugenol, is used for weeds control, electively inhibiting plant germination, suggesting its potential use as a bio herbicide (Dudai *et al.,* 1999). Eugenol has also been demonstrated to be active against plant pathogenic nematodes (Sangwan *et al.,* 1990) and to have antifungal activity (De Oliveira Pereira *et al.* 2013). This product has been approved for use in organic food production (Mohan *et al.,* 2011).

Spraying artichoke plants with essential oils exhibited significant increase in the activity of peroxidase, polyphenoloxidase and chitinase in artichoke leaves infected by *Leveillula taurica*. The higher activity of peroxidase was observed in case of spraying garlic oil with BABA followed by the treatment with BABA only. As for polyphenoloxidase activity, results revealed that, all tested oils, BABA and the fungicide only one 40% increased Polyphenoloxidase activity over control. The highest values for Polyphenoloxidase activity were recorded in case of spraying with black seed oil followed by the treatment with black seed oil in combination with BABA. Also, foliar application of BABA either individually or in combination with garlic, clove or black seed oils increased chitinase activity.

The present results concerning the increase in peroxidase, polyphenol-oxidase and chitinase enzymes activity agree with those reported by Abd-El-Kareem (1998) and El-Habbak (2003). Similar results were obtained by Yurina *et al.,* (1993); who found that peroxidase activity was related to resistance and tolerance against powdery and downy mildew. Resistance or tolerant varieties of cucurbits had higher activity of the enzyme than susceptible ones. El-Mougy, *et al.,* 2013 revealed that the plants applied with resistance inducers treatments gave the best increase in the activity of Peroxidase, Polyphenol oxidase and Chitinase enzymes, which escalating defense response for diseases resistance in sprayed cucumber, pepper and tomato plants.

In this study, may be due to reduction of the disease incidence by DL- β-aminobutyric acid (BABA) addition to an increase of vegetative characters when used BABA with essential oil. BABA is a non-protein amino acid known to induce resistance against a wide spectrum of pathogens (Jakab *et al*. 2001; Cohen, 2002 and Cohen *et al.,* 2011). This was combined with studies of activity of enzymes related to plant defense, i.e., polyphenol oxidase and catalase. BABA treatment significantly reduced the population of *R. solanacearum* in stems of tomato plants and additionally also significantly increased both fresh and dry weight of roots and shoots of tomato plants compared with the inoculated control.

It is clear from the results that spraying any of the oils used alone does not have a significant effect on growth, yield and quality unless it is associated with the addition of BABA spray on artichoke plants as compared with fungicide (Only one 40%EC). This may be due to a reduction of the disease incidence in plants in addition to an increase of vegetative characters in artichoke plants. BABA applied as a foliar spray causes the plant hormone salicylic acid (SA) to accumulate, which is a key hormone in controlling systemic acquired resistance (Jakab *et al.* 2001, Cohen 2002 and Silue *et al.,* 2002). BABA is known to induce resistance against pathogens in various systems, including tomato, potato, grapevine, and pea (Cohen *et al.*, 1999; Jakab *et al*., 2001). In field experiments, Cohen (2002) found that BABA provided significant control of late blight of potato, while Liljeroth *et al.* (2010) showed that BABA used together with a reduced fungicide dose gave the same level of late blight control as a full dose of the standard fungicide treatment. Zimmerli *et al*., (2000) reported that BABA protected *Arabidopsis* against the oomycete pathogen *Peronospora parasitica* through activation of natural defense mechanisms of the plant such as callose deposition, the hypersensitive response, and the formation of trailing necroses. BABA was still fully protective against *P. parasitica* in transgenic plants or mutants impaired in the salicylic acid, jasmonic acid, and ethylene signaling pathways. Treatment with BABA did not induce the accumulation of mRNA of the systemic acquired resistance (SAR)-associated PR-1 and the ethylene- and jasmonic acid-dependent PDF1.2 genes. However, BABA potentiated the accumulation of PR-1 mRNA after attack by virulent pathogenic bacteria. As a result, BABA-treated *Arabidopsis* plants were less diseased compared with the untreated control.

In this respect, the individual oil spraying has achieved significant differences compared with the control treatment (distilled water) in the characteristics of vegetable growth and quality, which is likely to play a role in disease resistance and stimulate growth. This is consistent with the results of Huang and Lakshman (2010) when used clove oil and Mostafa *et al.* (2015) when used garlic and camphor oils.

Also, the spraying of garlic oil + BABA has achieved the highest rates of increase in the early and total yield and significantly higher than the spray fungicide interpreted by the role of garlic in the improvement of growth, and this is confirmed by Zaki *et al.* (2008) on sweet pepper and El-Saadony *et al.* (2017) on pea.

Conclusion

Based on obtained data it could be concluded that, the highest growth and productivity of globe artichoke (*Cynara scolymus* L.) cv. Concerto were obtained using combination of garlic oil + BABA (DL- β-aminobutyric acid) as foliar application and controlling powdery mildew *Leveillula taurica* in open field and heavy clay soil of Egypt.

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