Journal of Applied Horticulture, 12(1): 75-80, January-June, 2010

Efficacy of some essential oils on controlling powdery mildew on zinnia (*Zinnia elegans* L.)

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Abstract

A field experiment was carried out during two successive seasons at the Experimental Farm of the Faculty of Agriculture, Kafr El- Sheikh University to evaluate some essential oils as biocontrol agents for powdery mildew on *Zinnia elegans*, L. Marjoram, clove, cinnamon, garlic, ginger and fennel oil were used as a foliar spray at 2 levels (250 and 500 ppm) beside Kema zein 75% and distilled water as a control. The plants were sprayed four times beginning from June 15th with one week interval by a hand atomizer as soon as the first sign of powdery mildew detected on plants. Disease incidence and severity as well as vegetative parameters such as plant height, number of branches per plant, leaf area, fresh and dry weights of shoots, root length and fresh and dry weights of roots were determined in the two seasons. Peroxidase and polyphenol oxidase activities were determined after 24 hour from the last spray in leaves samples. The highest significant decrease in disease incidence and severity and the best results for most of the studied growth and flowering parameters and total green colour were recorded when plants were sprayed with ginger, cinnamon and clove oils, respectively each at 500 ppm compared to the other treatments in both seasons. In addition, the activities of peroxidase (POX) and polyphenol oxidase (PPO) enzymes increased as a result of oil spray on plants. In conclusion, these findings provide a rational basis for possible utilization of these essential oils as a safe and alternative method to fungicides for controlling powdery mildew in zinnia plants.

Key words: *Zinnia elegans,* essential oils, powdery mildew, biocontrol agents.

Introduction

Zinnias are one of the easy to grow herbaceous summer annual flower, blooming from mid-summer all the way until frost. About 10 species of zinnia are garden flowers but only the *Zinnia elegans* is the most popular. *Z. elegans* belongs to family Asteraceae and native to the Southwest United States, Mexico and Central America and therefore, likes an warm-hot climate. Zinnia plant's leaves are lance-shaped, sandpaper like in texture, stalkless, and have erect stems that bear opposite leaves and terminal flower heads. Zinnias come as yellow, orange, white, red, rose, pink, purple, lilac and multi-colored blooms. Zinnia varieties include both miniatures and giants that range from about a foot to over three feet tall. However**,** zinnia plants are subjected to many pathogens, which cause various diseases, *Erysiphe cichoracearum* is one of the important pathogens since it causes one of the most serious disease of zinnia plants namely powdery mildew. This pathogen attacks all plant parts destroying most leaves and flowers, finally the remaining flowers become unmarketable.

The present work aimed to study the efficacy of certain essential oils in controlling powdery mildew on zinnia caused by *E. cichoracearum*.

Material and methods

A field experiment was carried out during the two successive seasons of 2006 and 2007 at the Experimental Farm of the Faculty of Agriculture, Kafr El- Sheikh University to evaluate some essential oils as biocontrol agents for powdery mildew on *Z. elegans* L. Seeds were sown in nursery beds on March 15th in both years and seedlings were transplanted in May 1st to a clay soil in plots 1 x 1.5m^2 at 50 cm apart as a twins in the hill, and each bed was divided into two parts (1 x 0.75 m^2). Each part contained 12 plants (6 hills) and was considered as a replicate. Therefore, every treatment consisted of 36 plants (18 hills) in the three replicates. The experiment was arranged in a completely randomized block design. The plants including control were fertilized with the recommended dose of N, P and K (100, 200 and 100 kg/ application, respectively), beginning from May 15th and repeated three times with two weeks interval. The used fertilizers were ammonium sulphate "20% N", calcium super phosphate "15.5% P_2O_5" and potassium sulphate "48% K_2O". The common agricultural practices *i.e.,* watering, weed control, etc. were done whenever plants needed.

Marjoram, clove, cinnamon, garlic, ginger and fennel oils were added as a foliar spray at 2 levels of 250 and 500 ppm. Tween-20 was used as a surfactant at the rate of 0.1% v/v. Kemah zein 75% was used at recommended dose (2 g/L). The plants were sprayed four times beginning from June 15th with one week interval by a hand atomizer as soon as the first sign of the symptoms were observed. For control treatments, plants were sprayed with distilled water only. Percentage of disease incidence and severity were determined after 7 days from the last spray according to the scale reported by Horsfall and Barrett (1945) and Biswas *et al.* (1992).

Enzymes extraction and assay: Leaf samples of each treatment, healthy and infected, were collected after 24h of the treatment for peroxidase and polyphenol oxidase enzymes activity assay. In addition, untreated healthy and infected leaves were used as control. Enzyme extract was obtained by grinding leaf tissue in 0.1 M sodium phosphate buffer at pH 7.1 (2g leaf tissues) in a

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porcelain mortar. The extracted tissues were strained through four layers of cheesecloth. Filtrates were centrifuged at 3000 rpm for 20 min at 6°C. The clear supernatants were collected and considered as crude enzyme extract. Peroxidase (POX) activity was determined according to the method of Allam and Hollis (1972) by measuring the oxidation of pyrogallol to pyrogalline in the presence of hydrogen peroxide. Peroxidase activity was measured following the changes in absorbance at 425 nm every 1 min up to 4 min. Polyphenol oxidase (PPO) was determined according to Maxwell and Batman (1976). The changes in absorbance were measured spectrophotometrically at 495 nm, and recorded every 1 min up to 4 min. All measurements were assayed using Beckman Spectrophotometer Du®7400. The details of essential oils used as treatments are given in Table 1.

At the end of the experiment, plant height (cm), branch number/ plant, leaf area (cm^2), shoots fresh and dry weights /plant (g), root length (cm), roots fresh and dry weights /plant (g), flower number /plant, flower diameter (cm), flower fresh and dry weights (g), total green colour (SAPD) were recorded. Means between treatments were compared with Duncan's Multiple Range Test according to Snedecor and Cochran (1982).

Results

Effect on disease incidence and severity: In this investigation, the essential oil of marjoram, clove, cinnamon, garlic, ginger and fennel plants were used to control powdery mildew disease of zinnia plants under field conditions**.** Data presented in Table 1 show that all essential oils and Kemah zein 75% treatments significantly decreased disease incidence (average number of powdery mildew spots/leaf) and disease severity (percent surface infected area) on zinnia plants more than distilled water treatment in both seasons. Results indicated that, the best control of the studied disease was obtained when the essential oils were used at 500 ppm compared to 250 ppm in most cases. The oil of ginger at 500 ppm was the most efficient treatment than others on disease incidence and severity in both seasons. It significantly decreased disease incidence and severity from 30.78 to 1.2% and 87.2 to 6.0%, respectively in the first season and from 35.69 to 1.6% and 91.5 to 6.5%, respectively in the second one. This was followed by cinnamon oil treatments.

The treatment of oil of Marjoram was the least effective treatment used at either 25 or 50% in both seasons. In general, all used treatments gave better or similar results with those obtained when the fungicide Kema zein 75% was used.

Effect on peroxidase and polyphenol oxidase activity: Data presented in Table 2 show that peroxidase activity significantly increased as a results of these treatments. The higher activity of peroxidase was observed with ginger oil at 500 ppm followed by fennel oil at 500 ppm.

Polyphenol oxidase activity presented in Table 3 reveal that all used oils and Kemah zein 75% increased polyphenol oxidase activity over control. It also indicates that high concentration of all used essential oils caused higher activity of peroxidase and polyphenol oxidase than lower one in both seasons. The highest values for polyphenol oxidase activity were recorded with cinnamon oil at 500 ppm followed by ginger oil at 500 ppm. The lowest values in both seasons resulted from the treatment of marjoram oil at both concentrations.

Table 1. Effect of some essential oils and Kemah zein 75% treatments on incidence and severity of powdery mildew disease of *Zinnia elegans* L. during 2006 and 2007 seasons

Treatment	Concentration	Average number of spots/leaf (Disease incidence)		Percent of surface infected area (Disease severity)	
		2006	2007	2006	2007
Distilled water	-	30.78a	35.69a	87.2a	91.5a
Kemah zein 75%	2g /L	2.7e	2.3g	8.9e	10.2f
Marjoram oil	250 ppm	9.6c	11.9b	23.5b	24.5b
	500 ppm	9.7b	10.8c	19.2c	20.4c
Clove oil	250 ppm	1.9j	2.1h	7.4i	7.8k
	500 ppm	1.6l	1.8j	7.0l	7.5n
Cinnamon oil	250 ppm	1.8k	1.9i	7.3j	7.6m
	500 ppm	1.4m	1.7k	6.7m	6.8o
Garlic oil	250 ppm	2.3h	2.4f	8.5f	10.4e
	500 ppm	2.6f	2.5e	8.2g	8.7j
Ginger oil	250 ppm	2.0i	1.9i	7.2k	7.7l
	500 ppm	1.2n	1.6l	6.0n	6.5p
Fennel oil	250 ppm	3.2de	3.4d	9.1d	11.5d
	500 ppm	2.4g	2.1h	7.5h	9.5i

Means within a column having the same letters are not significantly different in Duncan's Multiple Range Test.

Table 2. Activity of peroxidase in leaves of *Zinnia elegans* L. after 24 hours from the last treatment with essential oils 75%

Treatments	Concentration	Peroxidase activity/minute after 24 h			
		1	2	3	4
Distilled water	-	0.403g	0.405m	0.409k	0.413e
Kemah zein 75%	2g /L	1.112cde	1.115j	1.121h	1.125cd
Marjoram oil	250 ppm	0.677fg	0.701l	0.713j	0.723e
	500 ppm	0.723efg	0.748k	0.759i	0.766de
Clove oil	250 ppm	1.461bcd	1.575f	1.606e	1.629bc
	500 ppm	1.556def	1.672e	1.687d	1.692cd
Cinnamon oil	250 ppm	1.411bcd	1.506h	1.533f	1.572bc
	500 ppm	1.767ab	1.892d	1.907c	1.914ab
Garlic oil	250 ppm	1.235cd	1.250i	1.357g	1.369c
	500 ppm	1.464bcd	1.561f	1.600e	1.626bc
Ginger oil	250 ppm	1.531bc	1.544g	1.549f	1.555bc
	500 ppm	2.115a	2.146a	2.149a	2.155a
Fennel oil	250 ppm	1.771ab	1.943c	1.981b	1.991ab
	500 ppm	1.961a	1.980b	1.981b	1.988ab

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Plant height: Data presented in Table 4 revealed that all oils and Kemah zein 75% treatments significantly increased plant height over control in both the seasons. The tallest plants in both seasons resulted from the treatment of ginger oil (500 ppm), Kemah zein 75% recorded 196.00, 177.58, and 194.50, and 177.51 cm followed by clove oil (500 ppm) than cinnamon oil (500 ppm) in the first season. The second rank was of clove oil (250 ppm) and (500 ppm) in the second season which produced188.00 and 175.36 cm plant height, respectively. The shortest plants were obtained from the treatment of marjoram oil (250 ppm) and (500 ppm) and recorded 160.33 and 158.44 cm, respectively against 116.00 and 125.71 cm for control in both seasons.

Branch number: All essential oils and Kemah zein75% treatments significantly increased number of branches over control in the two seasons (Table 4). Both cinnamon oil concentrations (250 and 500 ppm) and Kemah zein75% gave the highest number of

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Table 3. Activity of polyphenol oxidase in leaves of *Z. elegans* L. after 24 hours from the last treatment with essential oils and Kemah zein 75%

Treatments	Concentration	Polyphenol oxidase activity/minute			
		1	2	3	4
Distilled water	-	0.043d	0.071h	0.073f	0.077h
Kemah zein 75%	2g /L	0.113a	0.117b	0.119b	0.082gh
Marjoram oil	250 ppm	0.072bc	0.073gh	0.076ef	0.078h
	500 ppm	0.050d	0.097cde	0.100bc	0.102cdef
Clove oil	250 ppm	0.058cd	0.090efg	0.092cde	0.095efgh
	500 ppm	0.087b	0.102bcde	0.104bc	0.105bcde
Cinnamon oil	250 ppm	0.111a	0.112bcd	0.114b	0.116bc
	500 ppm	0.115a	0.145a	0.154a	0.157a
Garlic oil	250 ppm	0.074bc	0.111bcd	0.114b	0.115bcd
	500 ppm	0.088b	0.115bc	0.119b	0.123b
Ginger oil	250 ppm	0.082b	0.094def	0.095cd	0.097defg
	500 ppm	0.114a	0.143a	0.152a	0.155a
Fennel oil	250 ppm	0.050d	0.077fgh	0.081def	0.085fgh
	500 ppm	0.111a	0.112bcd	0.114b	0.115bcd

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branches as 10.67, 10.33 and 10.30, respectively in the first season while in the second one, the treatments of cinnamon oil at 500 ppm and Kemah zein 75% gave 8.55 and 8.49, respectively. In the second rank were the oils of cinnamon (250 ppm) and clove (500 ppm) in the first and second seasons which gave 10.33 and 8.12 branches, respectively. The lowest branch number resulted from the treatments of marjoram oil (250 and 500 ppm) and fennel oil (250 ppm) in the first season and marjoram oil (250 ppm) in the second one as recorded 6.00, 6.33 and 6.00 and 5.85, respectively.

Leaf area: It is obvious from Table 4 that all the oils at both concentrations and Kemah zein 75% produced the wide leaves than control in both the seasons. The widest leaves resulted from plants sprayed with cinnamon oil at 500 ppm in both seasons and Kemah zein75% in the second one. This was followed by ginger oil at 500 ppm and Kemah zein75% in the first season and ginger oil at 250 ppm and Kemah zein75% in the second one. The smallest leaves resulted from the treatments of garlic oil 250 ppm in the first season and marjoram oil at 250 ppm in the second one which gave 29.33 and 31.79 cm^2 leaf area, respectively against 21.58 and 27.25 cm^2 for control in both seasons.

Shoot's fresh and dry weights: It is clear from Table 5 that all oils and Kemah zein75% treated plants had significantly high values for both fresh and dry weight of shoots than control in both seasons. The heaviest fresh and dry shoots /plant in the first season resulted from the treatments of ginger oil at 500 ppm and Kemah zein 75%. Whereas in the second one were the treatments of clove oil at 500 ppm as recorded 286.08 and 41.17 g, respectively. This was followed by the treatments of cinnamon oil at 500 ppm for fresh weight and ginger oil at 250 ppm for dry weight in the first season. The lightest fresh and dry shoots /plant in both seasons were obtained in the treatment of marjoram oil at 250 ppm.

Root length: Data in Table 5 reveal that all used treatments gave significantly longer roots than control in both the seasons. The long roots in the first season were recoreded with clove oil at 500 ppm, ginger oil at 500 ppm and cinnamon oil at 500 ppm and recorded 17.67, 17.62 and 17.00 cm, respectively against 11.67 cm for control without significant differences among themselves in most cases. Whereas in the second season root length was more in clove oil at 500 ppm.

Root's fresh and dry weights: Data presented in Table 6 show that essential oils and Kemah zein75% treatments significantly increased both root fresh and dry weights over control in both seasons. The heaviest fresh roots resulted from ginger oil at 500 ppm and Kemah zein75% in the first season and clove oil at 500 ppm in the second season. The lightest fresh roots resulted from the treatment of cinnamon oil at 250 ppm in the first season and fennel oil at 250 ppm in the second season (15.16 and 9.10 g, respectively) against 11.40 and 8.58 g for control in both the seasons.

Heavy roots were produced under the treatments of clove oil at 250 ppm, clove oil at 500 ppm and ginger oil at 500 ppm in the first season. There were no significant differences among most treatments in the second season.

Flower number: Data in Table 6 indicated that all used treatments significantly increased the flower number over control in both seasons. In the first season, there were non-significant differences among most treatments. The highest flower number resulted from the treatments of clove oil at 500 ppm, Kemah zein75%, cinnamon oil at 500 ppm, ginger oil at 500 ppm, cinnamon oil at 250 ppm, ginger oil at 250 ppm and clove oil at 250 ppm against control. In contrast to this, the significantly higher flower number in the second season resulted from the treatment of ginger oil at 500 ppm. The lowest flower number resulted from the treatments of marjoram oil at 250 ppm and fennel oil at 250 ppm in the first

Table 4. Effect of essential oils and Kemah zein 75% on plant height, branches number and leaf area of *Zinnia elegans* L.

Treatments	Concentration	Plant height (cm)		Branch number / plant		Leaf area (cm^2)	
		2006	2007	2006	2007	2006	2007
Distilled water	-	116.00j	125.71l	3.67f	4.05l	21.58m	27.25l
Kemah zein 75%	2g /L	194.50a	177.51a	10.30ab	8.49a	48.95b	48.55ab
Marjoram oil	250 ppm	160.33i	164.31i	6.00e	5.85k	30.60j	31.79k
	500 ppm	164.00h	158.44k	6.33e	6.10i	31.80i	34.27i
Clove oil	250 ppm	188.00c	171.48e	7.33d	7.54e	35.50f	37.22g
	500 ppm	190.00b	175.36c	8.00c	8.12b	37.63e	46.55d
Cinnamon oil	250 ppm	165.00gh	170.64g	10.33ab	7.90c	44.23c	47.84c
	500 ppm	175.00e	176.98b	10.67a	8.55a	52.20a	48.66a
Garlic oil	250 ppm	165.30g	165.48h	7.00d	6.56g	29.33l	39.12f
	500 ppm	170.00f	170.71f	8.00c	7.13f	34.67g	41.59e
Ginger oil	250 ppm	183.00d	175.23d	8.00c	7.66d	42.37d	48.50b
	500 ppm	196.00a	177.58a	10.00b	8.17b	49.57b	47.88c
Fennel oil	250 ppm	166.00g	162.70j	6.00e	5.94j	30.23k	32.45j
	500 ppm	170.00f	164.31i	7.00d	6.27h	33.52h	35.20h

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Table 5. Effect of some essential oils and Kemah zein 75% on shoots fresh and dry weights (g) /plant and root length (cm) of *Zinnia elegans*, L. during 2006 and 2007 seasons

Treatments	Concentration	Shoots fresh weight / plant (g)		Shoots dry weight plant (g)		Root length (cm)	
		2006	2007	2006	2007	2006	2007
Distilled water	-	99.25m	112.52l	9.04m	11.42l	11.67d	7.52m
Kemah zein 75%	2gm/L	326.09a	280.55b	40.12a	36.88b	16.58b	12.95bc
Marjoram oil	250 ppm	178.04l	244.48k	20.27l	25.15k	16.00c	10.45k
	500 ppm	187.63j	259.80h	21.50k	30.28f	16.33bc	11.60f
Clove oil	250 ppm	289.05f	277.62c	30.77h	36.92b	16.60bc	12.88c
	500 ppm	305.77d	286.08a	33.74e	41.17a	17.67a	13.15a
Cinnamon oil	250 ppm	295.64e	268.53g	32.75f	26.85i	16.33bc	12.47e
	500 ppm	315.62b	277.32d	37.22c	35.49c	17.00ab	13.02b
Garlic oil	250 ppm	242.51h	245.83j	31.53g	28.61g	16.03c	11.26h
	500 ppm	268.06g	268.97f	34.33d	26.52j	16.08c	10.67j
Ginger oil	250 ppm	312.78c	275.24e	38.27b	32.62e	16.67bc	11.45g
	500 ppm	336.08a	283.78b	42.23a	35.22d	17.62a	12.74d
Fennel oil	250 ppm	182.06k	258.81i	22.63i	26.83i	16.00c	10.26l
	500 ppm	188.45i	269.13f	21.77j	27.75h	16.01c	11.08i

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season and marjoram oil at 250 ppm in the second season.

Flower diameter: Table 7 showed that all used treatments increased flower diameter over control in both seasons. The biggest flower in the first season resulted from plants treated with ginger oil at 250 ppm, ginger oil at 500 ppm, fennel oil at 500 ppm and cinnamon oil at 500 ppm without significant differences among themselves in most cases against control. Whereas, in the second year plants treated with ginger oil at 250 ppm, followed by cinnamon oil at 250 ppm recoreded increased diameter.

Fresh and dry weights of flower: Table 7 indicate that all the used essential oils at both concentrations and Kemah zein75% gave the heavier fresh and dry weights of flower than control in both seasons. The heaviest fresh and dry weights in the first season resulted from the plants treated with ginger oil at 500 ppm. Whereas in the second year, the plants treated with both cinnamon oil at 250 ppm and ginger oil at 250 ppm recorded higher fresh weight. The lightest fresh and dry weights in the first season resulted from plants treated with garlic oil at 250 ppm. However, in the second year this resulted from the plants treated with fennel oil at 500 ppm.

Effect on total green colour: Table 8 revealed that all treated plants were greener than untreated ones in both seasons. The greenest plants were those treated with ginger oil at 500 ppm and Kemah zein75% in the first season (33.85 and 3380 SAPD value, respectively). Cinnamon oil at 500 ppm gave 38.72 SAPD value in second season. The palest plants were those treated with marjoram oil at 250 ppm in the first season and marjoram oil at 500 ppm in the second season.

Discussion

In this study, results indicated that disease incidence and severity of powdery mildew on *Z. elegans* L. was significantly decreased by spraying some essential oils as ginger, cinnamon and clove each at 500 ppm, four times beginning from June 15th with 7 days interval. These three treatments significantly surpassed others in most cases and the essential oils treatments gave better or similar results with those obtained when the fungicide Kemazein 75% was sprayed.

These findings could be explained as per previous workers who revealed that essential oils have important ecological functions. One of these functions is to protect the plant against infection by pathogens (Taiz and Zeiger, 1991; El-Kazzaz *et al.*, 2003). The mycelia growth of *Aspergillus flavus* Link was completely inhibited and the hyphal diameter decreased and hyphal wall appeared as precipitates and disappeared in some regions when oil of *Cymbopogon citratus* L. was used. In addition, oil treatment

Table 6. Effect of some essential oils and Kemah zein 75% on roots fresh and dry weights (g)/ plant and flower number of *Zinnia elegans*, L. during 2006 and 2007 seasons

Treatments	Concentration	Roots fresh weight / plant (g)		Roots dry weight / plant (g)		Flower number / plant	
		2006	2007	2006	2007	2006	2007
Distilled water	-	11.40i	8.58l	1.55g	1.18f	10.01f	11.21k
Kemah zein 75%	2gm/L	16.20a	10.88b	2.26b	1.50a	26.95a	17.85b
Marjoram oil	250 ppm	15.38g	9.66j	2.27b	1.35cd	18.00de	15.19j
	500 ppm	15.46f	10.24f	2.20d	1.45b	19.00cd	15.61i
Clove oil	250 ppm	15.83d	10.83c	2.30a	1.48ab	25.67ab	16.21h
	500 ppm	16.01b	11.13a	2.31a	1.53a	27.00a	17.81b
Cinnamon oil	250 ppm	15.16h	10.34e	2.10f	1.48ab	26.33a	16.81g
	500 ppm	15.58e	10.91b	2.24c	1.51a	27.00a	17.75c
Garlic oil	250 ppm	15.38g	9.75i	2.17e	1.32d	20.67c	16.88f
	500 ppm	15.46f	10.14g	2.10f	1.38c	24.33b	17.20e
Ginger oil	250 ppm	15.90c	10.00h	2.20d	1.36cd	26.00ab	17.52d
	500 ppm	16.24a	10.55d	2.30a	1.45b	26.67a	18.11a
Fennel oil	250 ppm	15.33g	9.10k	2.10f	1.27e	17.00e	15.58i
	500 ppm	15.35g	9.77i	2.20d	1.34cd	17.37de	16.92f

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Table 7. Effect of some essential oils and Kemah zein 75% on flower diameter (cm) and flower fresh and dry weights (g) of *Zinnia elegans*, L. during 2006 and 2007 seasons

Treatments	Concentration	Flower diameter (cm)		Flower fresh weight (g)		Flower dry weight (g)	
		2006	2007	2006	2007	2006	2007
Distilled water	-	4.00e	3.21l	1.95j	2.52i	0.32i	0.51h
Kemah zein 75%	2gm/ L	6.62b	4.85c	2.90b	4.86bc	0.65b	0.83c
Marjoram oil	250 ppm	5.50d	4.66f	2.65h	4.71de	0.55gh	0.80c
	500 ppm	6.40b	4.82cd	2.71ef	4.80c	0.57e	0.78cd
Clove oil	250 ppm	5.67d	4.31h	2.65h	4.68e	0.55fgh	0.71ef
	500 ppm	5.83cd	4.08i	2.70g	4.37g	0.56efg	0.68ef
Cinnamon oil	250 ppm	6.33bc	5.87b	2.89c	5.13a	0.63c	0.96b
	500 ppm	6.73ab	4.50g	2.93b	4.80c	0.65b	0.73de
Garlic oil	250 ppm	5.50d	4.01j	2.50i	4.40g	0.54h	0.66fg
	500 ppm	6.33bc	4.87c	2.74e	4.75cd	0.57ef	0.83c
Ginger oil	250 ppm	7.17a	6.01a	2.77d	5.18a	0.66b	1.03a
	500 ppm	6.97a	4.81d	3.03a	4.92b	0.71a	0.81c
Fennel oil	250 ppm	6.33bc	4.72e	2.72f	4.52f	0.59d	0.51h
	500 ppm	6.83ab	3.95k	2.76d	4.28h	0.61c	0.83c

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caused plasma membrane disruption and mitochondrial structure disorganization (Helal *et al.*, 2007). Scarito *et al.* (2007) studied the effect of essential oils of oregano and clove at 0.125 and 0.5 mL L^{-1} concentration on roses. Other investigators reported that the essential oils contained antifungal compounds and fungitoxic agents that can inhibit the growth of certain microorganisms (Farag *et al.*, 1989; Zambonelli, 1996; El-Shoraky, 1998; Chao *et al.*, 2000; El-Shazly, 2000; Abd El-Kader *et al.*, 2003; Voda *et al.*, 2003; Moleyar and Narasimham, 2004; Sheng *et al.*, 2005; Krishna Kishore and Pande, 2007).

Results also showed that spraying zinnia plants with these essential oils induced higher activity of peroxidase and polyphenol oxidase enzymes. The higher activity of enzymes was associated with decreased infection of powdery mildew disease. This means that spraying plants with essential oils gave a defense to plants from invasion with pathogen. Many investigators explained these results since they reported that peroxidase is known to be involved in the oxidation and polymerization of hydroxycinnamyl alcohols to yield lignin and cross-linking isodityrosine bridges in cell wall. It also produces free radicals and hydrogen peroxide which are toxic to many microorganisms (Vance *et al.*, 1980; Fry, 1982; Pena and Kuc,1992). Also, Ride (1983) and Tarred (1983) stated that the increase in peroxidase activity enhances lignifications in response to infection with pathogens which may restrict fungal penetration.

Table 8. Effect of essential oils and Kemah zein 75% on total green colour (SAPD) of *Zinnia elegans* L.

Treatments	Concentration	Total green colour (SAPD)	
		2006	2007
Distilled water	-	23.85k	28.84m
Kemah zein 75%	2g /L	33.80a	37.49b
Marjoram oil	250 ppm	25.44j	34.71j
	500 ppm	25.94i	33.65l
Clove oil	250 ppm	28.98g	35.88g
	500 ppm	31.61c	37.55b
Cinnamon oil	250 ppm	30.46e	36.81d
	500 ppm	31.45d	38.72a
Garlic oil	250 ppm	30.06f	35.34i
	500 ppm	31.69c	37.21c
Ginger oil	250 ppm	33.39b	35.44h
	500 ppm	33.85a	36.75e
Fennel oil	250 ppm	25.95i	34.66k
	500 ppm	26.48h	36.40f

Means within a column having the same letters are not significantly different in Duncan's Multiple Range Test.

The study revealed that spray of ginger, cinnamon and clove oil at 500 ppm reduced disease incidence. In addition, the activities of peroxidase and polyphenol oxidase increased as a result of oil spray on plants. These findings provide a basis for possible utilization of these essential oils as a safe and alternative method to fungicides for controlling powdery mildew in zinnia plants.

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