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Efficacy of Some Essential Oils in Productivity and Management of some Insect Pests Pre and Post - Harvest of Coriander B- Post- Harvest Study

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Abstract: Coriander is an aromatic and annual herbaceous. Some insects damage coriander dried fruits during storage, but drugstore beetle is an important one. The conventional pesticides are being used as the major way for stored grains and herbs creating many problems like toxic residues in the products and health hazards. From this point, this study was planned to study the ability of some essential oils as bioinsecticides (fumigant) for drugstore beetle in coriander fruits during storage and reducing storage harmful effects on fruits quality. A preliminary experiment (fumigant) was conducted to determine the most effective essential oils of dill, citronella grass, local basil and French basil as bioinsecticides. The most effective oil fumigants were dill and citronella grass essential oils. So another laboratory experiment was created to study their insecticidal activity against drugstore beetle during six months storage as well as following up their effects on coriander fruits quality characters. The results showed that drugstore beetle caused a significant decrease in coriander fruits quality parameters (seed index, volatile oil percentage and Linalool content) during storage of coriander fruits which were maximum in control fruits. While all dill and citronella grass essential oils treatments significantly reduced the harmful effects of drugstore beetle and storage on those quality characters of coriander fruits. As well as reducing losses in dry mass, volatile oil % and Linalool % with the superiority of dill oil. On the other hand, complete reduction of drugstore beetle was obtained by dill and citronella grass essential oils treatments. In other words, they were effective enough to protect coriander fruits up to 6 months storage and maintained quality characters of coriander fruits and no toxic to humans and environment.

Key words: Coriander · Storage · Essential oils fumigant toxicity · Drugstore beetle · Quality characters · Linalool content

INTRODUCTION

Recently, medicinal and aromatic plants occupy a prominent economic position because of the continuous increasing demands for their ingredients as a natural source for safe drugs as a result of concerns about the harmful side of allopathic drugs. The world demand for seed spices is about 150, 000 tonnes, of which India contributes 70, 125 tonnes annually that meeting 47% of the global demand [1].

Coriander (*Coriandrum sativum* L.) is widely distributed and mainly cultivated for its fruits which are popular spice. Besides being used as spice coriander has several medicinal values and recently gaining momentum as an important value added export item in the global market. The fruits are mainly responsible for the medical uses of coriander and have been used as a drug for indigestion, against worms, rheumatism and pain in the joints [2].It has been reported that, coriander exhibit antioxidant, antibacterial, antifungal, antithrombotic and hepatoprotective activities. Moreover, it possess many pharmacological activities like anti-diabetic, anti-mutagenic, anti-lipidemic and antispasmodic. Fruits are reputed as diuretic, refrigerant, tonic, aphrodisiac and treating respiratory and gastrointestinal disorders. They contain an essential oil (up to1%) and the monoterpenoid, linalool, is the main component [3-5].

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The drugstore beetle (*Stegobium paniceum* L.), (Coleoptera: Anobiidae), is a pest of the stored medicinal and aromatic plants and one of the most common insects found in the botanical warehouses [6]. The stored product pests cause economic losses and tremendous damage to post-harvest and the stored grains and seeds, packaged food products and the animal and plant derived items and products. Besides causing direct damage by feeding, they elicit disgust, annoyance and anger in many of those who find them infesting these products [7].

Several insect damage occurs in coriander dried fruits during storage. Among the insects, the drugstore beetle *(Stegobium paniceum)* is the important one [8].

Drugstore beetles have a worldwide distribution, but are more abundant in warmer regions or in heated structures in more temperate climates. It gets its name from its habit of feeding on prescription drugs. It is also found in flour mills, bakeries, pet food, breakfast cereal manufacturing and snack food plants, chocolate factories, confectioneries, whole sale distribution centers and sometimes retail stores. Integrated pest management (IPM) programs are often implemented to control infestations at processing, distribution and storage facilities [9].

Controlling of the stored grain insect populations around the world primarily depends upon applications of organphosphorus, pyrethroides insecticides and the fumigants (i.e. Ecofume and Phosphine). These still the most effective treatments for the stored food, feedstuffs and other agricultural commodities protection from insects infestation. Although effective, their repeated use for decades has led to outbreaks of other insects species and sometimes resulted in the development of resistance. That way of controlling has had undesirable effects on non-target organisms, human health concerns and fostered environmental [10].

The widespread usage of the pesticides has significant drawbacks including concern about pesticide residues on food, handling hazards, increased cost and threat to the human health and environment. These problems associated with using the synthetic insecticides have driven legislative changes that aimed to reduce the consumption of pesticides to a necessary minimum and at replacing risky products with alternative modes of protection against insects [11, 12].

Plant essential oils (EOs) in general have been recognized as an important natural source for pesticides. They represent a market estimated at about US $700.00 million and a total world production of about 45, 000 tons [13] .The growth in botanicals may perhaps be even higher, going from1–2% of the market share to somewhere possibly around 7% of the total market share by 2025 [14].

Essential oils (EOs) materials may be applied to the food crops shortly before harvesting without leaving excessive residues. EOs contain natural flavors and fragrances constituents like monoterpenes, sesquiterpenes and aliphatic compounds which provide characteristic odors. Among these components terpenes especially monoterpenoids and sesquiterpenes have been shown to be toxic to a variety of insects. For these reasons, much effort has been focused on plant essential oils or their constituents as potential sources of insects control agents to replace the chemicals with these alternatives natural constituents which are less toxic to human and environment [15-17].

From the standpoint of pest control, one of the most valued properties of EOs is their fumigant activity against insects, since it may also involve their successful use to control pests in storage showing a broad spectrum of activity against insects, low mammalian toxicity, degrading rapidly in the environment and local availability [13]. In addition, essential oils as natural insecticidal act very rapidly, not only upon contact, but also through fumigation which has been used for the production of stored products against storage pests [18]. In other words, EOs have potential for applications in IPM programs for stored-grain pests because of its high volatility and fumigant activity [19].

Thus, this experiment was planned to investigate the impact of dill and citronella essential oils as fumigant in controlling the drugstore beetles (*Stegobium paniceum* L.) in stored fruits of coriander. As well as, studying their effects on the different quality characters of coriander fruits.

MATERIALS AND METHODS

Sowing and Harvesting: Coriander seeds were sown at El-Baramoon Research Farm, Mansoura Horticulture Res. Station, HRI, ARC, Egypt.

Plots were harvested at the recommended stage of fruit maturity [20]. The harvesting started at 7 am and comprised cutting the stems at ground level and storing the cut material in jute bags to prevent fruit loss.

The harvested fruits were stored and the treatments and data recording during six months storage (three periods) were done at Medicinal and Aromatic Plants Research, (HRI, ARC) and Stored Cereals and Products Research, (PPRI, ARC) Laboratories, Mansoura (31°02’05.7’’N31°23’44.0’’E), Dakahlia, Egypt.

Table 1: Citronella and Dill Essential Oils active constituents (as the strongest fumigant from four tested essential oils).

Essential Oil			Essential Oil Components %					
			Citronella oil (Pale yellow color with lemony odor)					
Myrcene	Limonene	Linalool	Citronellol	Geraniol	Citronellal	Geranyl acetate	Eugenol	Unknown
3.17	2.03	6.14	2.59	31.37	41.22	4.92	7.52	1.03
			Dill Oil (Colorless with sweet odor)					
β - phellandrene			Carvone					Apiol
36.46			44.26					19.28

Table 2: Means of coriander fruits quality characters values after harvesting 2019 season (after statistical analysis except Linalool) and before storage experiment beginning

Types of fruits from field treatments	Seed index	Germination%	Volatile oil%	Linalool
Control	10.02	72.33	0.65	61.08
Citronella application	11.70	81.67	0.82	64.00
Dill application	12.29	82.67	0.87	68.57

Tested Insects: Adults of the drugstore beetle, *Stegobium paniceum* (L.) (Coleoptera: Anobiidae) reared on coriander seeds in a glass jars (each of approximately 500 ml) and kept in an incubator at 30±2°C and 65±5 % R.H. for egg laying.

Plant Materials: Dill seeds (*Anethum graveolens*) (Apiaceae), citronella leaves (*Cymbopogon nardus*) (Poaceae), local variety of basil leaves (*Ocimum basilicum*) (Lamiaceae) and French basil leaves (*Ocimum basilicum*) (Lamiaceae) essential oils were obtained through hydro distillation for 3 hours of plant materials using the Clevenger apparatus according to Egyptian Pharmacopoeia [21]. The extracted pure form essential oils (dill, citronella, local basil and French basil) were stored at 4°C in clean amber glass bottles until using.

The Experiment Design: The experiment was designed as factorial in complete randomized blocks design and arranged in three different groups with three replicates. The first factor was assigned for the different three storage periods while the second factor was assigned for different five essential oils treatments.

The Details of Treatments Were as Follows

Storage Periods:

- Storage period 1: fruits were stored for two months (SP1).
- Storage period 2: fruits were stored for four months (SP2).
- Storage period 3: fruits were stored for six months (SP3).

Essential Oils Treatments: Each period of the 3 Storage periods was dived to five sub group corresponding to the five essential oils fumigation treatments.

- T1: control: Fruits from plants which did not sprayed with any essential oils in field or fumigated during storage (control).
- T2: Fruits from plants which did not sprayed with any essential oils in field but fumigated with citronella essential oil during storage in laboratory.
- T3: Fruits from plants which did not sprayed with any essential oils in field but fumigated with dill essential oil during storage in laboratory.
- T4: Fruits from plants which sprayed with citronella essential oil in field and fumigated with citronella essential oil during storage laboratory.
- T5: Fruits from plants which sprayed with dill essential oil in field and fumigated with dill essential oil during storage laboratory.

Fumigation Experiment (After 2018 Season Harvesting): To investigate the fumigant toxicity of tested volatile oils against adults of *S. paniceum*, a laboratory experiment was carried out using an investigated technique in 1st season 2018 of culturing coriander fruits. The experiment designed according to Sameeh *et al.* [22] a number of fumigant chambers which are wooden boxes, each of approximately 6 L (Fig. 1) were performed. A small electric device with 7 cm^2 disc was fixed in one of the box sides. A glass slab was used to cover the box from the upper side. Each of the electric devices connected to electricity from outside source. Different concentrations of: Dill oil (5, 10, 15, 20 &30%); citronella oil (5, 10, 15, 20, 25, 30 & 40%); French basil oil (5, 15, 20, 30, 40 & 50%); basil oil (15, 20, 40, 60, 80 & 100%), respectively, were used for each oil. Each concentration was replicated 3 times. 10 individuals of tested adults were put into separate 150 ml plastic jars covered with fine small bores muslin then the jars were put into the fumigant chambers. 0.5 ml of each concentration was impregnated on to the disc.

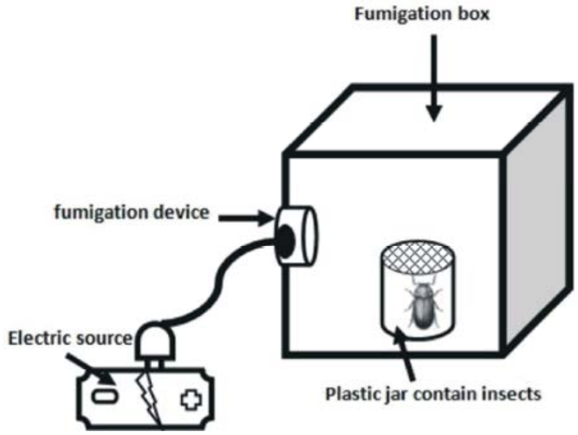


Fig. 1: Plastic jars covered with fine small bores muslin introduced into the fumigant chamber of approximately 6 L with fumigant electric device

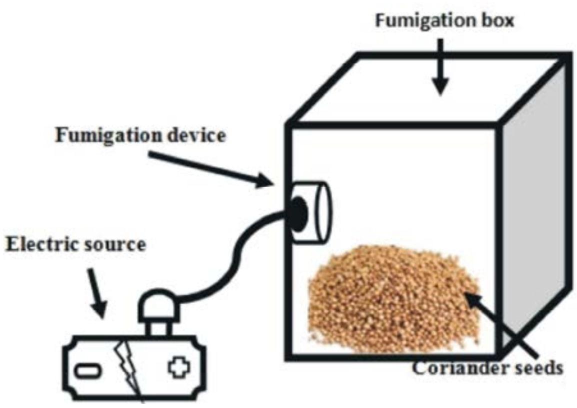


Fig. 2: Treated coriander fruits in field fumigated with oil in laboratory

After evaporation of the solvent, the device was connected to electricity (220v) to help fumigation of oil. The duration of fumigation period used extend up to 24h. A control replicate with solvent only was used for comparing. (%) mortality was then computed at the end of the experiment

Storage Experiment (After 2019 Season Harvesting): Storage experiment was conducted after 2nd season 2019 of coriander fruits culturing to study the ability of citronella and dill (the most effective from the tested essential oils against *S. paniceum* in the preliminary experiment*)* essential oils fumigant at LC_{90} conc. to protect untreated and treated coriander fruits in field for 6 months. The fumigation test was performed in the same wooden boxes as the previous experiment. The first insect infestation was recorded.

Five groups were used for this experiment. 1st group for control (T1), 2nd group untreated field fruits which fumigated with citronella essential oil in laboratory (T2), 3rd group untreated field fruits which fumigated with dill essential oil in laboratory (T3), 4th group fruits which sprayed with citronella oil in field and fumigated with citronella oil in laboratory (T4) and 5th group fruits which sprayed with dill essential oil in field and fumigated with dill essential oil in laboratory (T5). Each group contains 1.5 kg of seeds. Each group fumigated for 3 days respectively (fig. 2)

The Recorded Data of Storage Experiment: The following data were recorded in each storage period:

- Germination percentage: was determined by ISTA [23].
- Volatile oil percentage: was determined using a modified Clevenger apparatus [21].
- Essential Oil Constituents (Stored coriander, Dill and Citronella): The GC analysis of the second season volatile oil samples were done using Gas chromatography instrument, Laboratory of Medicinal and Aromatic Plants Dept., HRI., with the following specifications: DsChrom 6200 Gas Chromatograph equipped with a flame ionization detector, Column: BPX-5, 5% phenyl (equiv.) polysillphenylene-siloxane 30m x 0.25mm ID x 0.25μm film., Sample size: 1ìl. The temperature program ramp increase with a rate of 10° C / min from 70° to 200° C, Detector temperature (FID): 280 °C, Carrier gas: nitrogen, Flow rate: N2 30 ml/min; H2 30 ml/min; air 300 ml/min. The main compounds of the essential oils were identified by matching their retention times with those of the authentic samples injected under the same conditions. The relative percentage of every compound was calculated from the area of the peak corresponding to every compound.

Statistical Analysis: The collected data were statistically analyzed by statistical analysis of variance using COSTAT (version 6.3.0.3.) Statistical software and the significant differences among treatment means were determined by Duncans' multiple range test at P<5% as published by Duncan [24].

The estimated values of LC50, LC90 and mortality (%) were analyzed using a computer program named Ldp-line according to Finney [25]. Slope values and toxicity index were also estimated.

RESULTS AND DISCUSSION

Fumigation Experiment: The mortality percentage of *S.paniceum* adults after exposure to different concentration of 4 essential oils fumigant for 24 h are shown in Table 3. According to recorded data, mortality % increased with increasing of conc. The most effective oil fumigants were dill and citronella.

All tested oils were highly significant toxic ($p<0.05$) in which mortality reached 100% with highest conc. (30, 40, 50 and 100%) of dill, citronella, French basil and basil oil respectively.

Mortality was 23.3, 40, 63.3, 83.3 and 100 % with 5, 10, 15, 20 and 30% conc. of dill oil respectively and was 26.6, 40, 53.3, 70, 83.3, 93.3 and 100% with 5, 10, 15, 20, 25, 30 and 40% conc. of citronella oil respectively and was 26.6, 46.6, 66.6, 86.6, 90 and 100% with conc. 5, 15, 20, 30, 40 and 50% French basil oil respectively and was 20, 33.3, 50, 73.3, 86.6 and 100% with conc. 15, 20, 40, 60, 80 and 100% local basil oil respectively.

Fumigation studies showed that the essential oils had a 'knock down effect' on the test insect. Based on the present results both dill and citronella essential oil exhibit a strong insecticidal efficiency as fumigants against stored grain insects resulted in higher mortality rates of insects. Citronella oil is believed to be an effective repellent for many insects [26, 27]. Rare studies were documented the fumigant toxicity of citronella and dill such as results obtained by Farman *et al.* [28] claimed that fumigation of citronella oil has insecticidal toxicity causing 99% mortality of *S. oryzae* after exposure for 3 h. El-Gizawy *et al.* [29] Studied the contact and fumigant effect of dill oil against *S. oryzae*, *R.dominica* and *T.castaneum* and found that the toxicity against the tested insects was much higher in the fumigant bioassay tests than in the contact method.

Many previous researchers tested the fumigant toxicity of plant oils against stored grain insects according to the traditional method described by Prates *et al.* [30] using filter paper. However, in this research, the toxicity of plant oils was tested using a new fumigant technique. This technique was designed and used in a previous research by Sameeh *et al.* [22] in which fumigant toxicity of fixed and volatile oils of clove, cinnamon and moringa were tested against adults of *S.oryzae* and *T.castaneum* and the results showed that, this method was promising and give a good mortality % against both tested insects after 24 h from exposure also using the same technique Doaa [31] reported that clove and spearmint fixed oil exhibited strong fumigant toxicity against *S. paniceum* which cause 100% mortality at 10 % conc. after 24 h from exposure.

The presence of volatile compounds having strong odour would have blocked the tracheal respiration of the insects leading to their death. Similar observation was made by Brown [32] pointed out that the amount of fumigant absorbed depends on whether the insect's initial contact with the fumigant resulted in supplication or stimulation of the tracheal opening. Moreover, the ability of the insect to exclude vapour from its cuticle and prevent dehydration of body fluid plays a vital role in susceptibility or tolerance to fumigants of various life stages of insects particularly beetles and weevils infesting stored products [33] .The presence of volatile compounds is responsible for strong odour that could block the tracheal respiration of the insects leading to their death [34].The mode of action of oils was partially attributed to interference in normal respiration, resulting in suffocation [35].

In 1996 the EPA established that certain ingredients that pose minimum risk to users and be marketed as insecticides. A number of these ingredients are essential oils, including citronella oil and several others.

Storage Experiment: A laboratory experiment was conducted to study the efficiency of dill and citronella essential oils fumigant at LC_{90} in protection of untreated and treated coriander fruits with dill and citronella oil in field from insect infestation during 6 months storage. Untreated seeds in field and laboratory used as control.

According to observed results in Table 4, citronella and dill essential oils treatments in both field and laboratory were very effective in protecting stored coriander fruits from insect infestation up to 5 and 6 months, respectively comparing with control fruits (T1) which infested after 45 days from storage. Dill oil fumigant in laboratory (T3) only protect coriander fruits from insect infestation up to 75 days while insect infestation appear in fumigated coriander with citronella oil in laboratory (T2) after 45 days.

These results indicated that, citronella and dill essential oils could be used in integrated pest management program as represented a safe powerful alternative in protecting stored coriander fruits during storage.

Table 3: The mortality percentage (mean ± SE) of dill, citronella, local basil and French basil oil fumigants against *Stegobium paniceum* after 24 h

Dill		Citronella		Local basil		French basil	
Conc.%	(%) mortality (mean ± SE)	Conc. %	(%) mortality (mean ± SE)	Conc.%	(%) mortality (mean ± SE)	Conc. %	(%) mortality (mean ± SE)
30	100 ± 0^{a}	40	100 ± 0^{a}	100	100 ± 0^{a}	50	100 ± 0^{a}
20	83.3 ± 6.6^{b}	30	93.3 ± 3.3^{ab}	80	86.6 ± 3.3^{ab}	40	90 ± 5.7^{ab}
15	63.3 ± 6.6^{c}	25	83.3 ± 3.3^{bc}	60	73.3 ± 8.7^{b}	30	86.6 ± 3.3^{b}
10	40 ± 5.7^{d}	20	70 ± 3.3^{c}	40	50 ± 10^{c}	20	66.6 ± 3.3^{c}
5	23.3 ± 3.3^{e}	15	53.3 ± 3.3^{d}	20	33.3 ± 8.8^{cd}	15	46.6 ± 3.3^{d}
---	---	10	40 ± 5.7^{de}	15	20 ± 5.7^{d}	5	26.6 ± 3.3^{e}
---	---	5	26.6 ± 6.6^{e}	---	---	---	---

*Means within a column followed by the same lower case letter are not significantly different (P<0.05)

Table 4: 1st infestation record during 6 months storage of treated coriander fruits in both field and laboratory & laboratory only

Oil	1st infestation record
T1	45 days
T2	45 days
T3	75 days
T4	5 months
T5	6 months

T1: Control, T2: Citronella in laboratory, T3: Dill in laboratory, T4: Citronella in field and laboratory, T5: Dill in field and laboratory

Coriander Fruits Quality Characters During Different Storage Periods with Fumigation Treatments

Germination Percentage, Seed Index and Volatile Oil Percentage: Data in Tables 5 and 6 revealed that the germination percentage, seed index and coriander volatile oil percentage were significantly affected by the different storage periods (from mid May till mid November 2019) and essential oils (citronella and dill) treatments. It was observed that germination percentage was increased during storage periods to reach the highest value (89.67%) at the end of the third storage period (SP3), followed by (85.33%) at the end of the second storage period (SP2). On contrast, seed index and coriander volatile oil were reduced during the three storage periods to reach their lowest values (9.88 g/1000 seed and 0.65% volatile oil) at the end of the third storage period (SP3: mid September – mid November).

Table 5 showed also that citronella and dill essential oils treatments significantly affected on the germination when compared with the control treatment with the superiority of citronella essential oil. The germination percentage reached the highest value when the fruits treated with citronella essential oil (89.56%) in field and laboratory (T4), followed by treatment with dill essential oil (88.00%) in field and laboratory (T5). Also it could be noticed that, the different treatments of citronella and dill essential oils significantly reduced the harmful effect of long storage on the seed index and essential oil percentages. The highest values of seed index (11.69 g) and volatile oil (0.84%) were of fruits treated with dill essential oil in field and laboratory (T5), followed by (11.16 g for seed index) and (0.79% for volatile oil) of fruits treated with citronella essential oil in field and laboratory (T4).While the lowest values (9.06 g for seed index and 0.58% for volatile oil) were of control fruits.

Concerning the effect of interaction between essential oils treatments and storage periods on germination percentage, seed index and volatile oil % of coriander (Table 6), it could be observed that all interaction treatments were significantly affected on the previous fruits quality characters. The best interaction treatment for fruits germination (93.67%) was of fruits treated with citronella essential oil in field and laboratory and stored for 6 months (T4 x SP3) followed by (92.33% germination) of fruits treated with dill essential oil in field and laboratory and stored for 6 months (T5 x SP3). On the other hand, the best interaction treatment for seed index (12.15 g) and volatile oil (0.86%) of coriander was of fruits treated with dill essential oil in field and laboratory and stored for 2 months (T5 x SP1). The interaction of dill essential oil treatment in field and laboratory and 4 months storage (T5 x SP2) gave recorded means closely near to those of the previous best interaction treatment. It is important to mention that, the lowest records for the pervious fruits quality characters were of control fruits which stored for 6 months (T1 x SP3).

Rolania [36] Worked on coriander, dill, cumin and fennel and they concluded that, all the plant oils (neem oil, karanj oil, lemongrass oil, mustard oil, citronella oil and groundnut oil) which used as fruits protectants from cigarette beetle, found to be significantly more superior in reducing fruits damage and loss in weight in comparison to the control.

The results are in the same trend with Sharma [37] who worked on fennel and reported that, during storage the dry mass and volatile oils decreased significantly. Although the germination did not affected during 120 days of storage. While germination studies at up to

Table 5: Effect of different storage periods and essential oils (dill and citronella) treatments on coriander seed index, germination and Volatile oil percentages during storage (mid May till mid November 2019)

Treatments	Germination%	Seed index	Volatile oil%
		Storage periods	
SP1 (Two months)	82.27 c	10.65 a	0.71 a
SP2 (Four months)	85.33 b	10.10 b	0.70 b
Sp3 (Six months)	89.67 a	9.88 c	0.65 c
		Essential oils treatments	
T1	81.22 d	9.06 e	0.58 d
T2	85.56 c	9.58 d	0.61 c
T3	84.44 c	9.55 c	0.62 c
T4	89.56 a	11.16 b	0.79 b
T5	88.00 b	11.69 a	0.84 a

- Means having the same letter (s) in a column are not significant at 5% level.

T1: Control, T2: Citronella in laboratory, T3: Dill in laboratory, T4: Citronella in field and laboratory, T5: Dill in field and laboratory

Table 6: Effect of interaction between different storage periods and essential oils treatments (dill and citronella) on coriander seed index, germination and Volatile oil percentages during storage (mid May-mid Nov. 2019)

Treatments				
Storage periods	EOs treatments	Germination%	Seed index	Volatile oil%
SP1 (Two months)	T1	78.00 h	9.68 h	0.62 f
	T2	82.00 fg	9.91 g	0.63 de
	T3	80.33 g	9.90 g	0.64 d
	T4	86.00 de	11.59 b	0.81 b
	T5	85.00 de	12.15 a	0.86 a
SP2 (Four months)	T1	81.67 g	8.92 l	0.58 g
	T2	85.00 de	9.51 i	0.62 ef
	T3	84.33 e	9.48 i	0.63 def
	T4	89.00 b	11.02 e	0.80 b
	T5	86.67 cd	11.56 c	0.85 a
SP3 (Six months)	T1	84.00 ef	8.58 m	0.53 h
	T2	89.67 b	9.32 j	0.58 g
	T3	88.67 bc	9.26 k	0.59 g
	T4	93.67 a	10.86 f	0.76 c
	T5	92.33 a	11.37 d	0.81 b

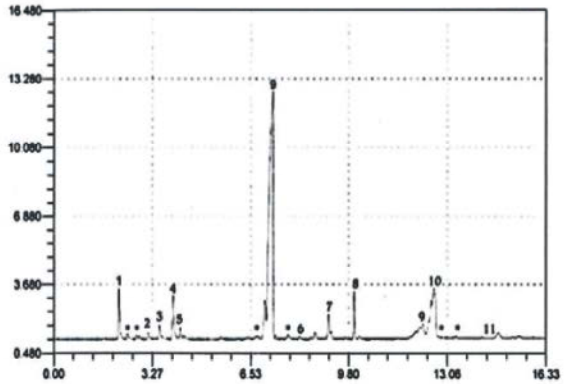
- Means having the same letter (s) in a column are not significant at 5% level.

T1: Control, T2: Citronella in laboratory, T3: Dill in laboratory, T4: Citronella in field and laboratory, T5: Dill in field and laboratory

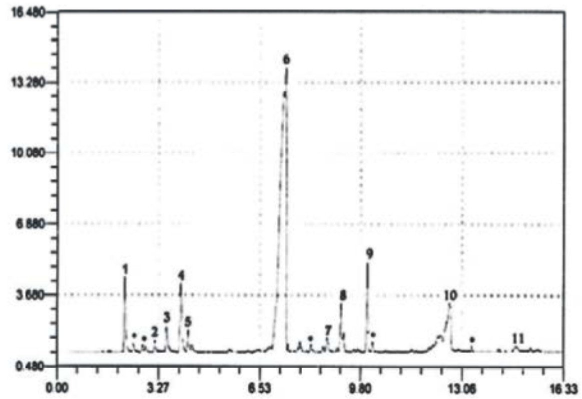
Table 7: Effect of interaction between different storage periods and essential oils (dill and citronella) treatments on coriander volatile oil GC during storage (from mid May till mid November 2019)

Treatments		Essential Oil Constitutes															
S. period	EO Treat.	α–pinene	Sabinene	Myrcene	β-pinene	ρ-Cymene	Linalool	Geraniol	Borneol	Linalyl acetate	Geranyl acetate	β-caryophy -llene	Uniden-tified 1	Uniden-tified 2	Uniden-tified 3	Uniden-tified 4	Uniden-tified 5	Uniden-tified 6
SP1	T1	3.65	1.67	4.21	1.58	1.00	56.01	4.40	4.33	5.42	13.65	1.07	0.62	0.58	0.61	0.44	0.61	0.14
(Two months)	T2	3.75	1.69	4.95	1.74	1.79	60.09	1.41	3.94	4.35	13.22	1.60	0.65	0.73	0.69	0.54	0.57	---
	T3	4.41	2.56	5.58	2.18	2.14	61.03	1.64	4.47	4.06	7.62	1.53	0.79	0.57	0.43	0.90	---	---
	T4	4.74	0.78	5.94	1.99	2.04	62.87	2.03	2.06	7.75	6.21	1.16	0.87	0.84	0.05	0.56	0.09	---
	T5	4.92	1.81	5.67	1.70	1.76	65.65	1.28	4.00	4.09	4.45	2.29	0.75	0.50	0.31	0.38	0.63	0.23
SP2	T1	4.30	1.05	2.82	5.39	2.70	44.61	5.32	5.34	5.19	10.54	2.23	0.86	0.98	0.92	0.89	0.68	0.87
(Four months)	T2	4.57	3.18	2.31	5.88	6.15	52.46	1.88	8.86	2.67	4.20	3.27	0.62	1.00	0.95	0.81	0.77	0.40
	T3	5.03	2.50	2.07	5.69	3.90	53.95	3.42	5.28	3.95	6.58	3.92	0.83	0.57	0.04	0.55	0.61	0.55
	T4	4.76	2.11	2.11	5.70	2.37	54.44	3.61	3.73	3.32	7.47	3.80	0.79	0.86	0.84	0.56	1.00	0.78
	T5	5.07	2.58	2.21	5.45	2.04	60.85	3.17	3.79	3.46	6.92	3.00	0.31	0.17	0.16	0.28	030	0.22
SP3	T1	9.04	1.49	1.72	3.59	11.87	43.33	1.45	8.11	3.54	13.55	1.45	0.28	0.82	0.33	0.86	---	---
(Six months)	T2	8.55	1.05	1.40	3.63	11.14	50.61	1.29	1.57	5.75	10.22	4.79	---	---	---	---	---	---
	T3	9.18	1.07	1.36	3.44	11.29	52.20	1.44	4.26	4.33	10.11	1.50	---	---	---	---	---	---
	T4	9.26	1.31	1.27	3.10	9.06	54.07	0.98	4.10	3.85	12.00	0.99	---	---	---	---	---	---
	T5	9.56	2.17	1.35	3.86	9.87	55.95	0.96	5.03	3.01	7.53	0.70	---	---	---	---	---	---

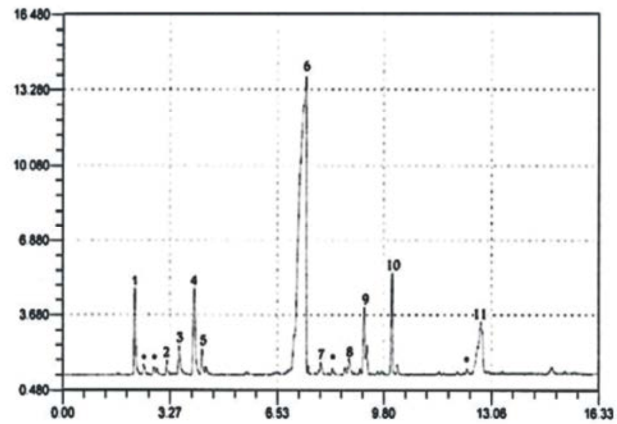
SP1 x T1



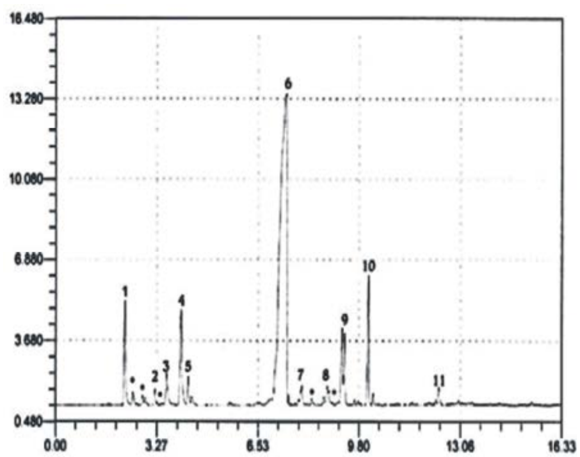
SP1 x T2



SP1 x T3



SP1 x T4



SP1 x T5

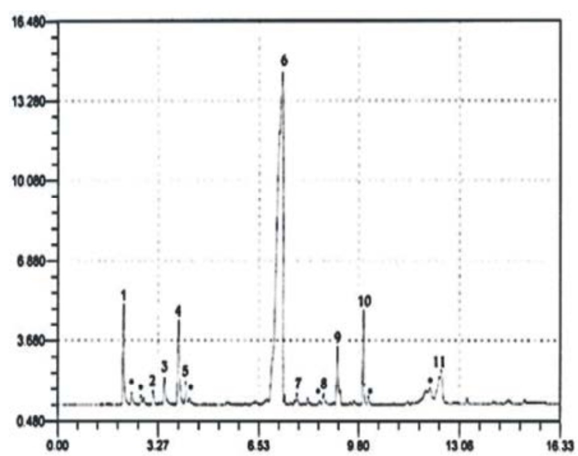


Fig. 3: Effect of interactions between first storage period and essential oil treatments on the coriander volatile oil components (%) during mid May – Mid July 2019 storage

1-α-pinene 2-Sabinene 3-Myrcene 4-β-pinene 5-ρ-Cymene 6-Linalool
7-Geraniol 8-Borneol 9-Linalyl acetate 10-Geranyl acetate 11-β-Caryophyllene *Unidentified compounds

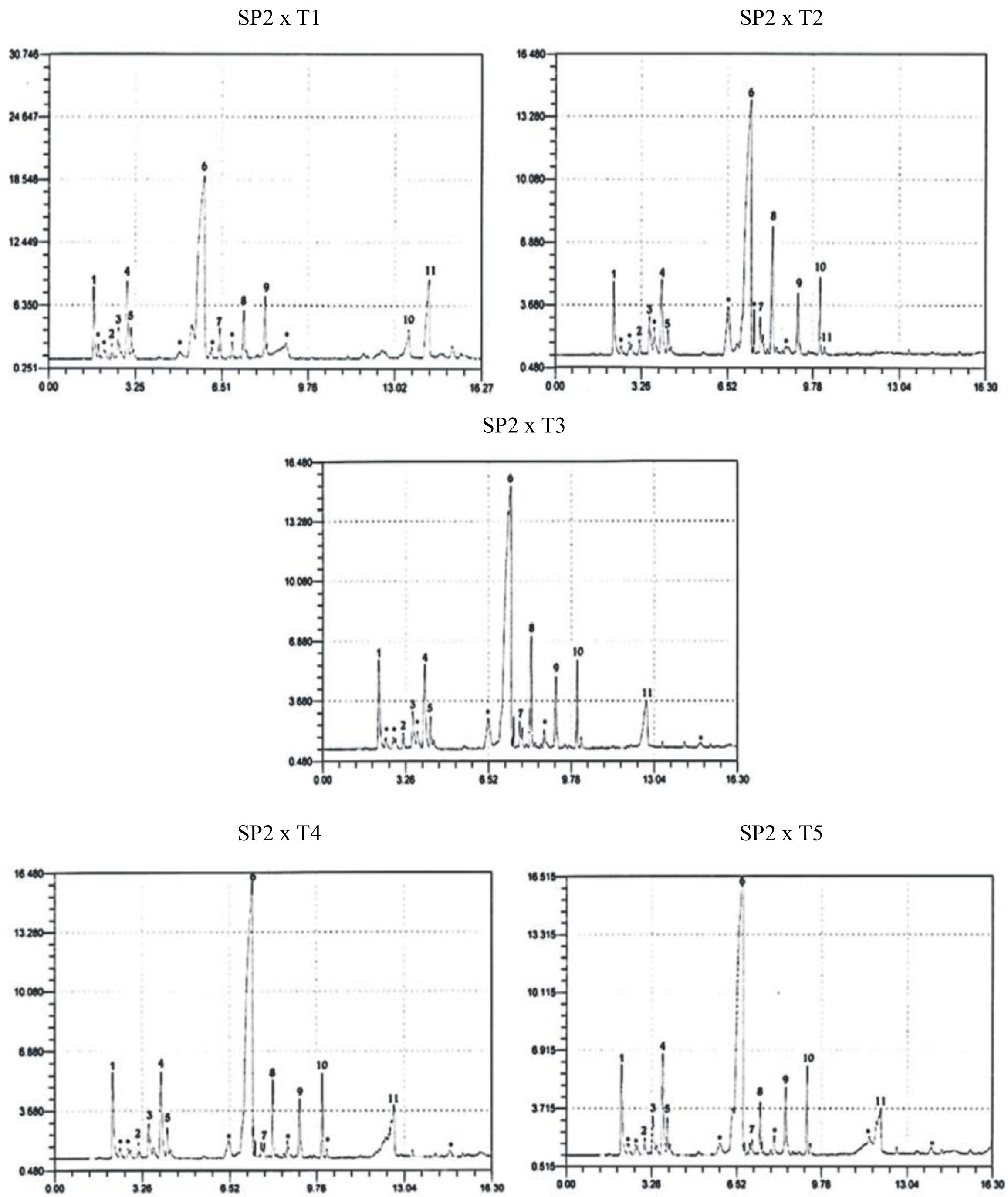


Fig. 4: Effect of interactions between second storage period and essential oil treatments on the coriander volatile oil components (%) during mid July – Mid September 2019 storage

1-α -pinene 2- Sabinene 3- Myrcene 4- β - pinene 5- ρ- Cymene 6- Linalool
7- Geraniol 8- Borneol 9- Linalyl acetate 10- Geranyl acetate 11- β-Caryophyllene *Unidentified compounds

120 days after the treatments with different concentrations of the plant products and essential oils used as protectant, revealed that those treatments did not hamper the viability of fruits. In other words, three was no significant variation in the germination was recorded that varied from 53.53 to 59.25 % with different treatments.

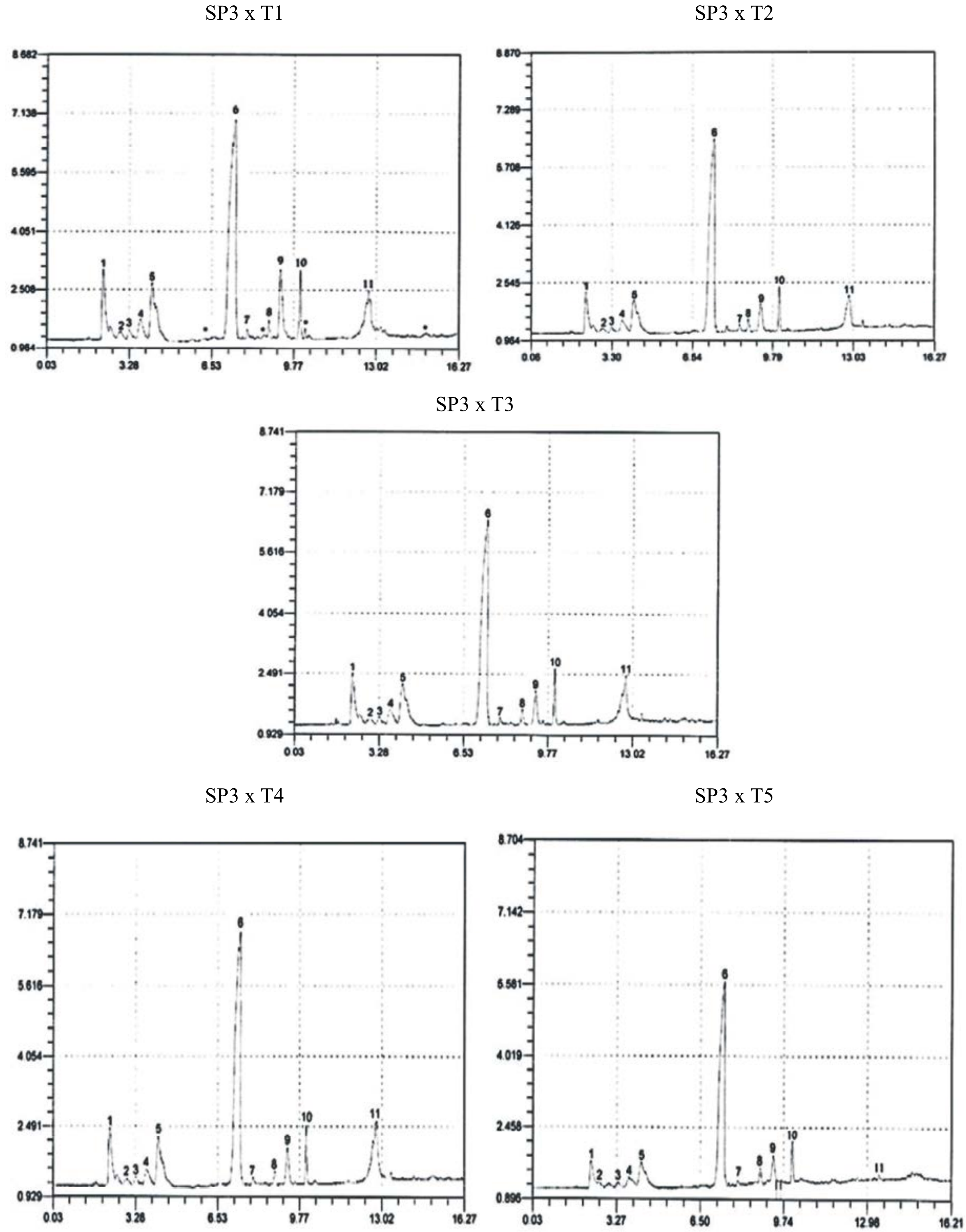


Fig. 5: Effect of interactions between third storage period and essential oil treatments on the coriander volatile oil components (%) during mid September – Mid November 2019 storage

1-α -pinene	2- Sabinene	3- Myrcene	4- β - pinene	5- ρ- Cymene	6- Linalool
7- Geraniol	8- Borneol	9- Linalyl acetate	10- Geranyl acetate	11- β-Caryophyllene	* Unidentified compounds

Supporting our results also the findings of Sharma [37] on cumin, he found that there was a significant reduction in weight dry loss by neem and karanj seed extracts, caster, mustard and eucalyptus oils.

No much work is available on the effect of other plant oils on Apiaceae fruits quality characters as affected by essential oils treatments and storage periods or insects.

Essential Oil G.C Analysis: Analysis of essential oil samples for the samples from the different storage periods and essential oils treatments was illustrated in Table 7 and Figures (3-5). Eleven components of coriander volatile oil were identified: α –pinene, Sabinene, Myrcene, β– pinene, ρ- Cymene, Linalool, Geraniol, Borneol, Linalyl acetate, Geranyl acetate and β-caryophyllene. The main components were Linalool, Geranyl acetate, Linalyl acetate, Borneol, Geraniol, Myrcene and α –pinene.

The principal component Linalool ranged from 43.33 to 65.65% was decreased during the different storage periods to reach the lowest value (43.33%) of control fruits (T1) which stored for six months (SP3: mid September – mid November). On the other hand, the highest percentage of Linalool (65.65%) was recorded from fruits stored from mid May-mid July (SP1) and treated with dill essential oil in field and Laboratory (T5), followed by fruits treated with citronella essential oil in field and laboratory (T4) in the same storage period SP1 (62.87%). In other words as the storage time is short as volatile oil of fruits had a high Linalool percentage. The main component Myrcene (ranged from 1.27 to 5.94%) took the same trend of Linalool during the three storage periods. On contrast, the main component α –pinene (ranged from 3.65 to 9.56%) was increased during the three storage periods and treated with dill and citronell essential oils. The highest percentage of α–pinene (9.56%) was of fruits treated with dill essential oil in field and laboratory (T5) at the end of the third storage period (SP3: mid September – mid November), followed by (9.26%) of the fruits treated with citronella essential oil in field and laboratory in the same storage period SP3. While, the lowest value of α–pinene (3.65%) was of control fruits (T1) in the first storage period (SP1: mid may - mid July). However, Geranyl acetate component (ranged from 4.20 to 13.65%) was increased during the first and third storage periods (SP1 and SP3) while, it was decreased during the second storage period (SP2) with the different essential oils treatments. The Linalyl acetate component (ranged from 2.67 to 7.75%) had the same trend of Geranyl acetate. The Borneol and Geraniol components were decreased during the three storage periods to reach their lowest values at the end of the third storage period (SP3) with the different essential oils treatments.

In General, it was observed that, unidentified components were appeared during the second storage period (SP2: mid July – mid September) with all interaction treatments, even though the value of each compound did not exceed 1%, while these component disappeared at the end of the third storage period (SP3: mid September – mid November) for all interaction treatments except for the control.

Singh *et al.* [38] worked on coriander and reported that, the quality losses of treated sample were found more in control samples and the linalool percentage reduction was 41.73% after storage of 105 days with ozone treatment.

Coriander Fruits Germination Increase%, Dry Mass Loss%, Essential Oil Loss% and Linalool Loss % During Different Storage Periods: Dealing with the effect of different storage periods (from mid May till mid November 2019), citronella and dill essential oils treatments and their interactions on coriander fruits germination increase%, dry mass loss%, volatile oil loss% and Linalool loss % the coriander fruits, Figures (6 -10) revealed that, there was a significant effect on all characters.

From Figure (6 -10), the highest increasing in germination percentages were of fruits stored for six months (17.81% in SP3), fumigated with citronella essential oil laboratory (18.29 % increasing) followed by fruits that fumigated with dill essential oil laboratory (16.75% increasing). The best interaction treatment for germination increasing % (23.97% increasing) was of fruits fumigated with citronella essential oil in laboratory and stored for six months (T2 x SP3).

On contrast, the highest reduction in dry mass %, volatile oil % and Linalool % was of control fruits in all treatments of storage periods (from mid May till mid November 2019).

Magd El-Din [39] worked on coriander and reported that coriander fruits were most appropriate diet and damaged by the cigarette beetle during the period of May till October.

In the same line of our results Olle and Bender [40] reported that, the content of coriander volatile oil decreases with increasing the period of storage.

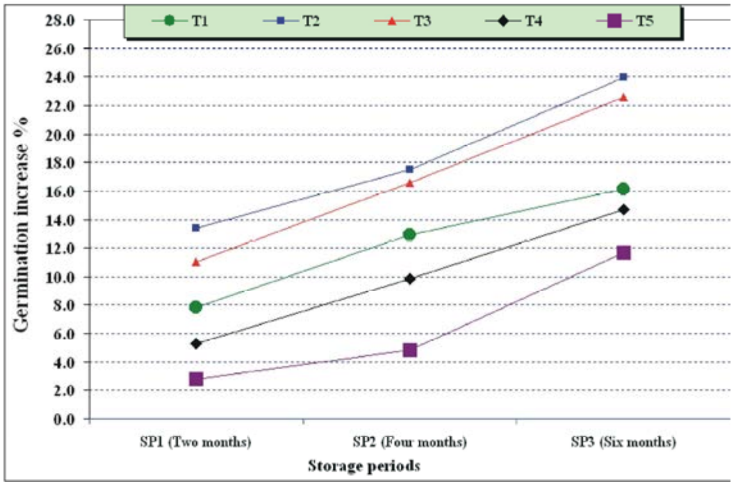


Fig. 6: Germination increase % of coriander fruits as affected by the interaction between different storage periods and essential oils treatments

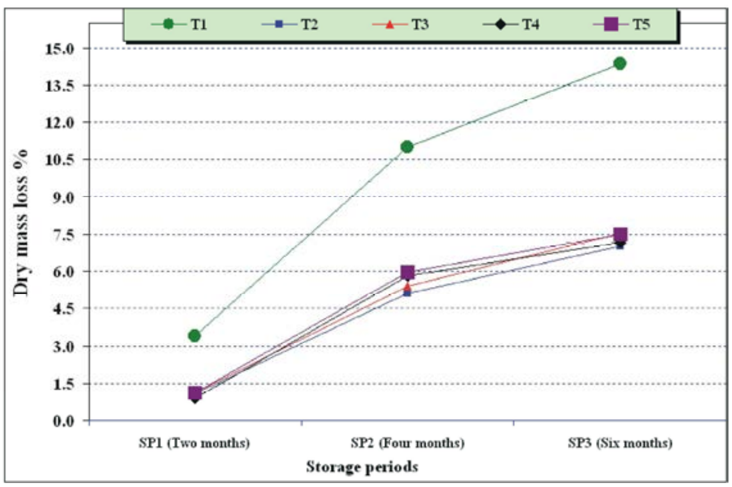


Fig. 7: Dry mass loss % of coriander fruits as affected by the interaction between different storage periods and essential oils treatments

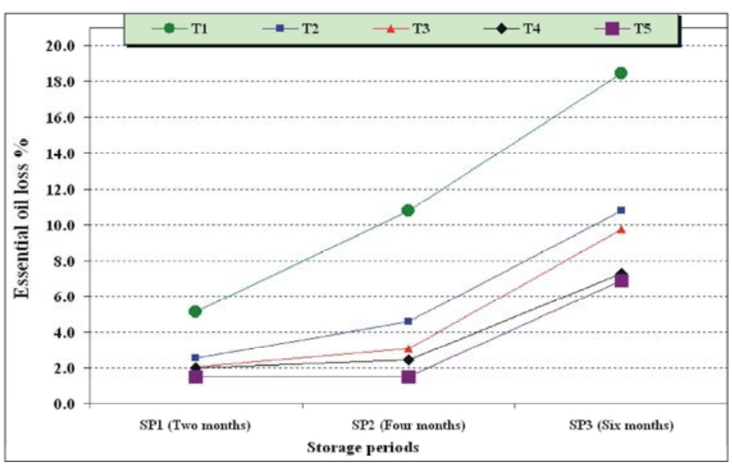


Fig. 8: Essential oil loss % of coriander fruits as affected by the interaction between different storage periods and essential oils treatments

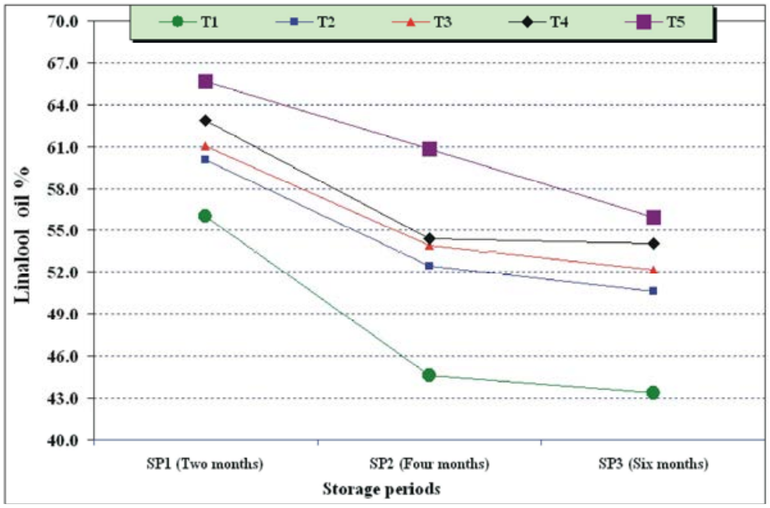


Fig. 9: Linalool % (the principal component of volatile oil) of coriander as affected by the interaction between different storage periods and essential oils treatments

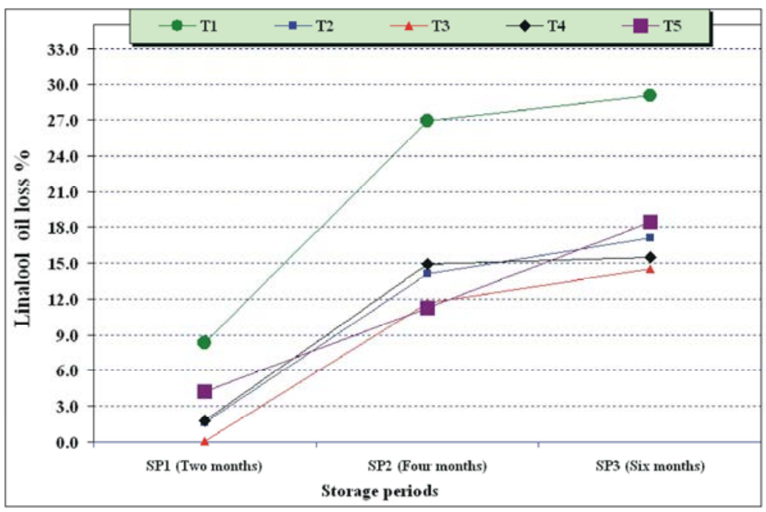


Fig. 10: Linalool loss % of coriander as affected by the interaction between different storage periods and essential oils treatments

The results are in the same trend also with Kant *et al.* [41] they showed that, the maximum reduction in dry mass was during July till August in all tested fruits except dill fallowed by October till December and the least to April till June. The maximum damage or loss and reproduction of coriander fruits was 40 to 50% was noticed in July till September.

Correlation Studies on Quality Characters of Coriander Fruits During Storage Periods: Data in Table 8 revealed that, the various quality characters of coriander fruits (seed index, volatile oil percentage, germination decreasing percentage, dry mass loss percentage, volatile oil loss percentage) were correlated with each other to know the relationship between them during the three storage periods (from mid May till mid November). The relationship of seed index with volatile oil percentage was significant having strong positive correlation (R= 0.982), while the relationship of seed index with dry mass loss (R= - 0.520), volatile oil loss (R= - 0.647) and germination reduction percentages (R= - 0.726) was significant having negative correlation. Thus it could be said that, the increase in seed index decreased dry mass loss percentage, volatile oil loss percentage and the germination decreasing percentage and vice-versa.

Table 8: Correlation coefficients for the relationships between the different fruits quality characters of coriander at the different storage periods

	Correlations (Pearson)				Partial Correlations	
	S_index	V_Oil	D_M_Loss	VO_Loss	D_M_Loss	0.139
S_index	1				VO_Loss	- 0.051
V_Oil	0.982**	1				
D_M_Loss	- 0.520	- 0.410	1		V_oil	0.931
VO_Loss	- 0.647*	- 0.631*	0.854**	1	S_index	0.883
Ger	- 0.726*	- 0.717*	0.463	0.584*		

The relationship of volatile oil with dry mass loss percentage (R= - 0.410), volatile oil loss percentage (R= - 0.631) and the germination decreasing percentage (R= - 0.717) was significant having negative correlation.

The relation of dry mass loss percentage with volatile oil loss (R= 0.854) and germination reduction percentages (R= 0.463) was significant having positive correlation. The relation of volatile oil loss percentage with germination reduction percentages was significant having positive correlation.

Overall, performance of coriander fruits which had heaviest seed index, higher volatile oil content and high germination percentage, showed the minimum dry mass loss, volatile oil loss and germination decreasing.

Finally, we could notice the growing of demand for traditional medicines, because of the fewer side effects of them and they could be considered as healthier, the storage process is an important tool, which if done properly, that can overcome the seasonality of the production, offer safe products to the consumers and maintain the quality and the active ingredients for a long period.

CONCLUSIONS

Dill and Citronella essential oils reduced the harmful effect of storage periods on coriander fruits quality characters (fruits weight, volatile oil content and germination) with the superiority of dill essential oil. As well as these essential oils had fumigant toxicity and repellent activity against drugstore beetle, so they could be utilized as new fumigants for herbs products storage pest management as ecofriendly way.

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