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Efficacy of Plant Oils and Insecticide for Controlling *Tetranychus urticae* Koch as Influenced by Onion Intercropping with Tomato

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ABSTRACT

The present work was carried out at the experimental farm of Sakha Agricultural Research Station, Kafr El-Sheikh Governorate (31^0 07¯ N Latitude and 30^0 57¯ E longitude with an elevation of about 6 meters above sea level), Egypt in 2020/2021 and 2021/2022 seasons. The aim of the present work was to evaluate some compounds (Ethion, chamomile oil, *Chamomilla recutita* L. and black cumin oil, *Nigella sativa* L.) against *Tetranychaus urticae* Koch (Acarina: Tetranychidae) on tomato (*Lycopersicon esculentum* Mill.) Intercropped with onion. Three intercropping systems (tomato sole, one row, two rows and three rows at the top of the ridge and onion sole). These compounds were tested for toxicity of *T.urticae* under laboratory and field conditions using leaf dipping and spray methods, respectively. Ethion was the most effective (R = 83.3 and 67.6) in the first and second seasons, respectively, while chamomile and black cumin oils were least toxic with R% value of 24.5% and 34.8% respectively during the first and the second seasons, respectively. The laboratory tests took a similar trend. Chamomile and black cumin oils had a less toxic effect on egg deposition, % hatchability and sterility compared to Ethion. The intercropping system (one row of onion) with tomato produced the highest yield and yield attributes except plant height. The highest LER (land equivalent ratio; 1.71 and 1.69) and the highest total income (135530 and 187035 L.E.) were obtained with Ethion treatment when tomato intercropping with one row of onion at the top of tomato ridge of two seasons, which seems to be the appropriate suggestion for farmers in North and Middle Nile Delta region, Egypt.

Keywords: Onion, Tomato, LER. *Tetranychaus urticae*, Ethion, *Chamomilla recutita*, *Nigella sativa*.

1. Introduction

Tomato (*Lycopersicon esculentum* Mill.) is one of the most important vegetable crops grown in large areas in Egypt all the year round for local market, processing and for exportation. To reduce cost, increase land utilization rate and adding marginal income to farmers, intercropping tomato with other field crops is suggested. There are an advantages of the associated cropping system as compared to mono-crop cultures. However, several researchers have conducted trails on the effect of intercropping some field crops to protect tomato plants to unfavorable conditions. Schuerger (1994) showed that mean fruit weight was slightly lower (12%) for intercropped than mono cultured tomato plants. Onion is a valuable crop since ancient times and ranks second after tomatoes crop in the list of the worldwide cultivated vegetables. The unit of both water and area productivity is still low and it is needed to be increased according to the increasing people demands throughout improved agricultural practices such as irrigation management and intercropping system to maximize productivity of water and soil units.
The two-spotted spider mite, *Tetranychaus urticae* (Koch) is a pest of many important vegetables, and causes much damage. Application of the intercropping system in agriculture reduces the population

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density of *T. urticae* compared to sole cultivation. The use of essential oils to combat mite is one of the compounds that reduce the population density of mite and is safe for the environment pollution. Controlling mites by a combination of chemical and essential oil methods has proved a be less costly and more controllable on mites than application only pesticides. Hishop and Prokopy (1981) showed that the controlling phytophagous pests by biological and pesticides methods proved to be more controllable on mite then using pesticides only. Sobhy (2008) found that the combinations of essential oils proved to be more effective against mites and showed that the black cumin had a moderate effect on hatchability and on egg sterility. Many researchers found similar data on spider mite (Nasser et al,, 1995 and Osman 1997). Farag and AbdEL-Rahaman (2021) found that plant oil showed an ovicidal action and negatively affected population density and biological aspects of *T. urticae*. Nasser (1998) indicated that the plant extract (black cumin) had a considerable toxicity against *T. urticae*.

The aim of the present work was to evaluate some compounds (Ethion, chamomile oil, *Chamomilla recutita* L. and black cumin oil, *Nigella sativa* L.) against *Tetranychaus urticae* Koch (Acarina: Tetranychidae) on tomato (*Lycopersicon esculentum* Mill.) intercropped with onion.

2. Materials and Method

2.1. Field trails

This field trial was performed at Sakha Agricultural Research Station during two successive seasons; 2020/2021 and 2021/2022. The station is situated at 31°-07' N latitude, 30°-57' E longitude with an elevation of about 6 metres above the sea level. It represents the conditions and circumstances of the northern part of the Middle Nile Delta region. The aim of the present work was to evaluate three systems of intercropping of onion at three treatments of tomato. The experiment was laid out in a split plot design, in a Randomized Complete Block design, with three replications. The main plots were devoted to the three compounds; Ethion, chamomile oil (*Chamomilla recutita*) and black cumin oil(*Nigella sativa*) . The sub – plots were allocated for the three mixed intercropping treatments of tomato with onion as follows;

1-One row onion at the top of the ridge,
2-Two rows at the top of the ridge
3-Three rows at the top of the ridge.

In addition, each of tomato and onion was sown as sole crops (control treatments). Tomato cv. Super strain-B was transplanted at a distance of 35 cm apart between plants on one side of ridges, on 18 and 20th December, in 2020/ 2021 and 2021/2022, respectively (in both solid and intercropping). The harvest started on 16 and 25th January for solid tomato, but the harvesting started on the 15April and finished at 25 May in intercropping pattern. Onion (*Allium cepa* L.) variety Giza 20 Cv. was used. All agronomic practices and fertilization were performed as recommended for the crops. The area of each plot was 12.6 m^2 (3.5 m length x 3.6 m width), with ridges of 120 cm width, 3.5 m length. The experiment was established on a clayey and well-drained soil. The previous crop was maize during both seasons.

2.2. Data recorded

At harvest time, data of yield and its attributes were recorded on 10 plants, randomly chosen from each crop as follows:

I. Tomato

Plant height, number of branches/plant, fruit diameter, number of fruits / plant, fruit weight, fruit yield / plant, good fruit yield / fed, damage fruit yield / fed, total fruit yield / fed, straw yield / fed and biological yield / fed.

II. Onion

Plant height, number of leaves per plant, bulb diameter, bulb weight, yield (t/ fed).

III. Land equivalent ratio (LER)

The ratio of area needed under sole cropping to that of intercropping at the same management level to produce an equivalent yield, according to Mead and Willey (1980). It is calculated as follows:

$$\textbf{LER} = \frac{yab}{yaa} + \frac{yba}{ybb}$$

Where, $\mathbf{y_{aa}}$ and $\mathbf{y_{bb}}$ are the sole crop yields of crops a and b, respectively, $\mathbf{y_{ab}}$ is the intercrop yield of crop a, and $\mathbf{y_{ba}}$ is the intercrop yield of crop b.

V. Economic evaluation

Farmer's benefit was calculated by determining the total cost and net return of intercropping culture as compared to recommended solid culture of tomato.

Total return of intercropping cultures = Price of tomato yield + price of onion yield (L.E.).

Net return/fed = Total return – (fixed costs of tomato + variable costs of onion according to intercropping pattern).

The market prices of tomato were 5000 and7000 LE/ t and of onion were 3000 and 3500 LE t in 2020/2021 and 2021/2022, respectively.

2.3. Insect pests

2.3.1. Compounds tested

Three compounds were used: All tested compounds were in the formulated form and dosages calculated on the basis of ppm of active ingredient.

- Ethion 50 % EC is an organophosphate insecticide, supplied by El- Help Pesticides and Chemicals Company; Egypt, was applied at a rate of 200ml/fed.
- Chamomile oil, *Chamomilla recutita* (95%), provided by Central Agricultural Pesticides Laboratory-Natural oil, was applied at a rate of 1L/ fed.
- Black cumin, *Nigella sativa* oil (95%), provided by Central Agricultural Pesticides Laboratory-Natural oil, was applied at a rate of 1L/ fed.

2.3.2. Mite colony establishment

Mite colony was established at Mite Unit, Plant Protection Research Institute, Sakha Agricultural Research Station Branch, Kafr El- Shiekh Governorate. To establish a culture of *Tetranychaus urticae* (Koch) (Acarina: Tetranychidae), mites were obtained from unsprayed tomato fields, transferred to the laboratory, reared on tomato plants of one month age, potted maintained under laboratory conditions of 30 ± 2 C° and 65 ± 5 RH. Three days later, the adult females settled on tomato plants and started laying eggs. The newly hatching adults were used in the laboratory experiments, according to Dittrich (1962).

2.3.3. Field experiments

The applied compounds were evaluated against the spider mite on tomato and onion plants. Three replicates were assigned for each treatment. All tested compounds were applied at their half recommended rates using a knapsack sprayer (20 L volume) with one nozzle. The rate of water used for diluting compounds was 200 liter/feddan. Samples of 10 leaves of each of tomato and onion were randomly collected from each plot before and after treatments. The percentage reduction of mite infestation was calculated according to Handerson and Tilton (1955). Duncan (1955**)** multiple range tests at the 5% level was used for comparison of significant differences among statistically differing treatments.

2.3.4. Laboratory experiments

To evaluate the toxic effect of tested compounds against the two-spotted spider mite, *T. urticae*, all treatments were evaluated by the leaf disc dip technique according to Siegler (1947). Four replications were prepared from each treatment using tap water with triton 2% for good mixing of oil with water. Four fresh tomato discs (2 cm diameter) were cut and dipped in the treatment concentrations for 30 seconds and left to dry and dipped in the tap water only as a check (un treatment). The leaf disks were kept fresh by placing on moisturized filter paper on a piece of wet cotton to absorb any water vapor, put in nine cm diameter Petri dish. The treated discs were placed individually in dishes. Ten adults of *T. urticae* were transferred by means of a fine soft brush to each disc. Four replications were made for each treatment and the control. Adult females of *T. urticae* were put inside the disc to tomato plants treatment and stems. Three adult female mites were allowed to oviposit on different compound-treated discs for 4 days. Microscope was used in examination of eggs and the mites and the living and dead lobes. Number of dead mites and the percentage of mortality were calculated 24 h after the treatment, according to the method of Keratum *et al.* (1994) and Sekeroglu, (1997). Thus, the percent of sterility was calculated according to Toppozada *et al.* (1966).

$$\% \text{ Sterility} = 100 \left[\frac{\text{No. of eggs laid/ female in treat} \times \% \text{ hatch in treat}}{\text{No. of eggs laid/ female in control} \times \% \text{ hatch in control}} \times 100 \right]$$

2.6. Statistical analysis

Data were subjected to analysis of variance (ANOVA) and Test (LSD) p=0.01. The mortality data were corrected using the formula of Abbott (1925). Data were plotted on log dosage probit papers (Finney, 1971) to estimate LC50 values (Ldp line), different means were compared (Duncan,s test using the SAS program, SAS Institute, 2010).

3. Results and Discussion

3.1. Tomato

3.1.1. Effect of tested compounds on tomato

Data in Table (1) showed that the tested compounds (Ethion, chamomile oil and black cumin oil) had a significant effect on all studied characters of tomato in both seasons. Black cumin oil treatment gave the tallest plants in the two seasons, while Ethion treatment gave the shortest plants in both seasons.

Table 1: Growth, fruit yield and components of tomato as affected by some compound treatments.

Treatment compounds	Plant height (cm)	Number of branches / plant	Fruit diameter (mm)	Number of fruits / plant	Fruit Weight (g)	fruit yield / plant (kg)
			First Season 2020/2021			
Ethion	76.21	5.75	52.67	35.57	79.97	2.85
Chamomile oil	80.33	5.56	50.43	35.13	76.34	2.68
Black cumin oil	90.65	4.56	47.34	33.78	72.56	2.46
LSD 5%	9.48	1.15	7.75	2.31	9.91	0.05
			Second Season 2021/2022			
Ethion	77.44	4.78	51.66	34.69	75.78	2.64
Chamomile oil	78.67	4.58	49.44	33.34	73.57	2.45
Black cumin oil	81.46	3.57	46.33	32.01	69.44	2.24
LSD 5%	8.97	1.16	7.78	3.62	9.68	0.07

Table 1: Cont.

Treatment compounds	Good fruit yield / fed. (ton)	Damage fruit yield / fed. (ton)	Total fruit yield / fed. (ton)	Straw yield / fed. (ton)	Biological yield / fed. (ton)
		First Season 2020/2021			
Ethion	27.73	2.38	30.11	2.51	32.08
Chamomile oil	24.87	3.23	28.30	2.22	30.19
Black cumin oil	19.63	6.19	25.82	1.58	27.53
LSD 5%	2.59	0.85	3.44	0.13	3.52
		Second Season 2021/2022			
Ethion	25.49	2.21	27.70	1.87	29.59
Chamomile oil	22.57	3.33	25.90	1.68	27.60
Black cumin oil	17.59	5.93	23.50	1.58	25.09
LSD 5%	2.33	0.79	3.12	0.07	3.13

Ethion resulted in best values of tomato yield and yield components, while the lowest values were recorded for black cumin oil treatment in both seasons. Similar results were obtained by Nasser *et al.* (1995) and Osman (1997); Farag and AbdEL-Rahaman, (2021).

3.1.2. Effect of intercropping

Data in Table (2) showed that intercropping systems had a significant effect on all studied characters in two seasons. The intercropping system (one row of onion) produced the shortest plants in the both seasons. While, the intercropping system (three rows of onion) gave the tallest plants in the two seasons. Concerning the yield components, the highest values were found at the intercropping system (one row of onion). This result may be due to more light use efficiency of solar radiation utilized by tomato plants, which in turn enhances the conversion of light energy to chemical energy and consequently encourages dry matter accumulation. Results of fruit yield/fed showed that intercropping in general increases this trait as compared with sole cropping (Table 2). Intercropping system (three rows of onion) produced the lowest yield per feddan. These results are mainly due to the effect of distribution of plants for both crops per unit area, which resulted in low or high intra and inter specific competition among tomato plants, as well as between tomato and onion plants when intercropped at high densities. Similar results were reported by Moshira and Iman (2016), Moshira and Heba (2021).

Table 2: Growth, grain yield and components of tomato as affected by intercropping systems.

Treatment Compounds	Plant height (cm)	Number of branches / plant	Fruit diameter (mm)	Number of fruits / plant	Fruit Weight (g)	fruit yield / plant (kg)
			First Season 2020/2021			
One row of onion	79.93	6.59	56.18	37.43	80.23	2.93
Two rows of onion	82.24	5.42	49.74	34.77	79.57	2.82
Three rows of onion	84.14	3.84	43.19	31.83	67.82	2.16
LSD 5%	8.22	0.94	4.93	1.45	4.87	0.22
Solid tomato	80.93	5.12	50.13	34.54	75.24	2.57
			Second Season 2021/2022			
One row of onion	72.56	5.57	55.19	36.32	77.98	2.73
Two rows of onion	79.90	4.42	48.73	33.15	74.07	2.53
Three rows of onion	85.23	2.81	42.18	30.07	65.57	1.96
LSD 5%	2.56	0.92	5.17	2.46	4.69	0.03
Solid tomato	80.68	4.77	49.21	33.94	74.23	2.54

Table 2: Cont.

Treatment Compounds	Good fruit yield / fed. (ton)	Damage fruit yield / fed.(ton)	Total fruit yield / fed. (ton)	Straw yield / fed. (ton)	Biological yield / fed. (ton)
			First Season 2020/2021		
One row of onion	27.93	2.96	30.89	2.73	33.10
Two row of onion	25.86	3.97	29.83	2.31	31.70
Three row of onion	17.32	5.36	22.68	1.31	24.03
LSD 5%	2.03	0.67	2.70	0.08	2.71
Solid tomato	18.24	4.38	22.62	1.41	23.99
			Second Season 2021/2022		
One row of onion	26.09	2.79	28.88	2.03	30.92
Two row of onion	22.91	3.84	26.75	1.77	28.53
Three row of onion	15.57	5.17	20.74	1.23	21.98
LSD 5%	3.13	0.66	4.19	0.03	4.17
Solid tomato	16.67	4.14	20.81	1.24	22.03

3.1.3. Effect of interaction

Data recorded in Table (3) indicated that the effect of interaction between compounds treatment and intercropping system was significant on all studied traits; plant height, number of branches / plant, good fruit yield /fed (ton), damage fruit yield / fed (ton), total fruit yield / fed (ton) and biological yield / fed (ton). While, Plant height was highest with black cumin oil but, damage fruit yield / fed (ton) attained the height values with chamomile oil treatment when were planted under system (C), as three rows of onion in both seasons 2020/2021, 2021 /2022. Similar results were obtained by Moshira and Iman (2016), Moshira and Heba (2021).

Table 3: Growth, fruit yield and components of tomato as affected by the interaction between compounds treatment and intercropping system.

Treatment compounds	Intercropping system	Plant height (cm)	Number of branches / plant	Fruit diameter (mm)	Number of fruits / plant	Fruit Weight (g)	fruit yield / plant (kg)
				First Season 2020/2021			
Ethion	A	76.01	7.01	58.01	38.01	85.34	3.23
	B	79.34	5.67	50.34	35.34	75.34	2.65
	C	82.61	4.01	43.01	32.01	68.34	2.17
Chamomile oil	A	82.67	6.34	53.01	37.01	81.67	3.01
	B	85.67	5.66	49.67	34.01	75.34	2.55
	C	87.34	3.67	42.34	31.68	67.01	2.11
Black cumin oil	A	87.67	5.67	52.01	36.01	77.34	2.77
	B	90.34	4.67	48.67	34.01	74.34	2.53
	C	91.01	3.34	41.34	31.34	66.01	2.07
LSD 5%		N.S	N.S	0.71	2.80	9.36	4.08
				Second Season 2021/2022			
Ethion	A	71.67	6.01	57.01	37.01	80.34	2.98
	B	80.01	4.67	49.34	33.34	73.34	2.43
	C	84.34	3.01	42.01	29.67	67.01	1.99
Chamomile oil	A	73.67	5.34	52.01	36.01	78.67	2.84
	B	80.01	4.67	48.67	33.01	70.34	2.33
	C	84.67	2.67	41.34	29.34	65.34	1.92
Black cumin oil	A	73.67	4.67	51.01	34.67	78.34	2.72
	B	82.67	3.67	47.67	33.01	68.34	2.26
	C	88.01	2.34	40.34	28.34	61.67	1.73
LSD 5%		N.S	N.S	0.23	14.02	9.02	0.09

A; One row of onion B; Two row of onion C; Three row of onion

Table 3: Cont.

Treatment compounds	Intercropping system	Good fruit yield / fed (ton)	Damage fruit yield / fed (ton)	Total fruit yield / fed (ton)	Straw yield / fed (ton)	Biological yield / fed (ton)
				First Season 2020/2021		
Ethion	A	24.76	2.28	27.04	2.40	29.43
	B	22.15	3.79	25.94	1.87	27.81
	C	18.66	4.27	22.95	1.36	24.31
Chamomile oil	A	20.97	4.26	25.23	2.38	27.61
	B	18.52	6.01	24.53	2.40	26.93
	C	16.45	8.26	24.71	1.87	26.58
Black cumin oil	A	22.08	1.81	23.89	2.37	26.26
	B	20.41	2.30	22.71	1.83	24.56
	C	18.76	3.00	21.76	1.66	23.42
LSD 5%		N.S	N.S	N.S	0.15	N.S
				Second Season 2021/2022		
Ethion	A	24.15	2.05	26.20	2.16	28.36
	B	22.01	3.65	25.66	1.63	27.31
	C	18.54	4.32	22.86	1.24	23.10
Chamomile oil	A	20.53	3.97	24.50	2.12	26.62
	B	17.81	5.87	23.68	1.57	25.23
	C	15.43	7.91	23.34	1.06	24.38
Black cumin oil	A	21.63	1.71	23.34	2.28	25.64
	B	20.01	2.11	22.12	1.78	23.92
	C	17.81	2.86	20.67	1.52	23.17
LSD 5%		N.S	N.S	N.S	4.09	N.S

A; One row of onion B; Two row of onion C; Three row of onion

3.2. Effect of tested compounds on
3.2.1. Onion

Data in table (4) showed that the treatments had a significant effect on all studied characters on onion in both seasons. Planting onion intercropped with tomato under Ethion treatment induced the highest values in plant height, number of leaves, bulb diameter, bulb weight and yield/fed in both seasons; 2020/2021and 2021/2022. Differences in yield may be due to the effect of intra and inter specific competition between onion plants and tomato plants. Similar results were obtained by **Akhtar *et al.*, (2010**).

Table 4: Effect of treatment compounds in plant height, number of leaves, bulb diameter, and bulb weight and yield/fed of onion.

Treatment compounds	Plant height (cm)	Number of leaves	Bulb diameter (cm)	Bulb weight (gm.)	Yield (ton/ fed.)
			First Season 2020/2021		
Ethion	67.21	7.43	3.51	49.81	4.90
Chamomile oil	61.69	7.10	3.37	43.63	4.83
Black cumin oil	59.89	6.60	3.11	38.78	4.19
LSD 5%	0.76	0.15	0.15	1.48	0.12
			Second Season 2021/2022		
Ethion	68.01	9.31	4.56	4.56	4.80
Chamomile oil	66.49	9.06	4.19	4.19	5.35
Black cumin oil	63.77	8.93	3.92	3.92	5.44
LSD 5%	0.63	0.11	0.14	0.14	0.20

3.2.2. Intercropping system

Data in Table (5) showed that intercropping systems had a significant effect on all studied characters in two seasons. Number of leaves, bulb diameter, bulb weight and yield/fed except plant height recorded the highest values in onion grown under intercropping system of one row of onion.

Table 5: Effect of intercropping system in plant height, number of leaves, bulb diameter, and bulb weight and yield/fed of onion.

Intercropping system	Plant height (cm)	Number of leaves/ plant	Bulb diameter (cm)	Bulb weight (g)	Yield/ fed (ton.)
			First Season 2020/2021		
One row of onion	58.30	8.30	3.73	52.88	4.13
Two row of onion	64.34	7.17	3.44	43.11	4.71
Three row of onion	67.07	5.60	2.78	34.43	4.85
LSD 5%	0.81	0.25	0.11	1.50	0.20
Solid onion	82.23	8.83	11.32	64.23	12.65
			Second Season 2021/2022		
One row of onion	63.93	9.31	4.89	60.00	4.59
Two row of onion	66.04	8.83	4.31	55.80	5.34
Three row of onion	68.44	8.95	3.30	43.01	5.51
LSD 5%	0.32	0.14	0.10	1.60	0.28
Solid onion	80.83	10.01	10.31	69.24	13.00

These results are mainly attributed to more light use efficiency of solar radiation utilized by onion plants, which resulted in minimizing competition between onion plants as well as between onion and tomato plants for light, which in turn enhances the conversion of light energy to chemical energy and consequently encourages the dry matter accumulation. These results may be due to the differences of distribution for both crops per unit area under intercropping systems. This pattern of intercropping resulted in maximizing the effect of intra and inter specific competition among onion plants and also between onion and tomato plants, which leads to low light use efficiency of solar radiation utilized by onion, which in turn low in the conversion of light energy to chemical energy and consequently, low dry matter accumulation. Similar results were reported by Moshira *et al.,* (2015) and Moshira and Ghada (2021).

3.2.3. Interaction

Data recorded in Table (6) indicated that the effect of interaction between compounds treatment and intercropping systems was significant for number of leaves/ plant, bulb diameter, and bulb weight but not significant with plant height and yield/fed. The highest was attained when planting onion intercropped with tomato at Ethion treatment under intercropping system (A) one row of onion, while plant height was highest with black cumin oil treatment under intercropping system (c) three rows of onion. Yield/fed was highest with Ethion treatment under intercropping system(c) three rows of onion in two seasons 2020/2021and 2021/2022 respectively. Similar results were obtained by Akhtar *et al.* (2010); Asmae *et al.* (2019) and Nasr (2020).

Table 6: Effect of interaction between compounds treatment and intercropping system on onion yield and yield attributes.

Treatment compound	Intercropping system	Plant height (cm)	Number of leaves/plant	Bulb diameter (cm)	Yield/ fed. (ton)
		First Season 2020/2021			
Ethion	A	54.13	8.50	62.50	5.11
	B	56.77	8.33	53.97	5.16
	C	62.10	8.13	50.07	5.36
Chamomile oil	A	61.03	7.67	45.03	4.54
	B	62.93	7.20	41.57	5.06
	C	68.40	6.67	38.90	5.09
Black cumin oil	A	64.50	6.13	36.87	3.86
	B	65.37	5.77	35.37	4.29
	C	71.13	5.00	32.40	4.38
LSD 5%		**1.10**	**0.26**	**2.56**	**0.21**
		Second Season 2021/2022			
Ethion	A	60.77	9.57	69.60	5.61
	B	64.10	9.37	68.50	5.70
	C	65.87	9.20	61.90	5.81
Chamomile oil	A	63.63	9.10	58.90	5.10
	B	66.67	8.83	57.30	**5.21**
	C	67.80	8.63	52.30	5.50
Black cumin oil	A	66.90	9.27	45.17	4.10
	B	68.70	8.97	45.13	4.84
	C	70.37	8.87	40.33	4.90
LSD 5%		**ns**	**ns**	**ns**	**ns**

A; One row of onion B; Two rows of onion C; Three rows of onion

3.2.4. Competitive relationships and yield advantage

Competitive relationships and total income of intercropping tomato with onion are shown in Table (7).

Ethion produced the highest values of land equivalent ratio (1.71 and 1.69) and total income (135530 and 187035 LE per feddan) in the first and second seasons, respectively, under system (A) one row of onion. Similar results were obtained by Moshira and Iman (2016), Moshira and Heba (2021).

3.2.5. Effect of tested compounds on motile stages of *T. urticae.*

Data presented in table (8) showed that ethion was the most effective compound in reducing the population density of motile stages of mite, *T.urticae.* Chamomile oil was of moderate effect, whereas *Nigella sativa* was the least effective compound in reducing the population density of motile stages of *T.urticae* five days after application (75.6, 41.9 and 45.5 % reduction) compared to control after the first spray ,respectively. On the other hand, five days after second spray, ethion treatment induced the highest reduction (91.0 %) in *T.urticae* infestation compared to check, followed by *Chamomilla recutita* (43.1%) and *Nigella sativa* oil (24.3 %) during 2021.

Table 7: Effects of tested compounds and intercropping system tomato with onion on land equivalent ratio and economic evaluation.

Treatments		Relative yield (RY)		Land equivalent ratio (LER)	Gross return for tomato LE	Gross return for onion LE	Total return LE	Net return LE
Compounds	Intercropping system	tomato	onion					
		First season						
Ethion	**A**	1.20	0.51	1.71	135200	15330	150530	135530
	B	1.15	0.41	1.56	129700	15480	145180	130180
	C	1.02	0.42	1.44	114750	16080	130830	115830
Chamomile oil	**A**	0.96	0.36	1.32	126150	13620	139770	124770
	B	0.96	0.40	1.36	122650	15180	137830	122830
	C	1.08	0.40	1.48	123550	15270	138820	123820
Black cumin oil	**A**	0.98	0.69	1.67	119450	11580	131030	116030
	B	0.96	0.65	1.61	113550	12870	126420	111420
	C	0.93	0.65	1.58	108800	13140	121940	106940
		Second season						
Ethion	**A**	1.26	0.43	1.69	183400	19635	203035	187035
	B	1.23	0.44	1.67	179620	19950	199570	183570
	C	1.10	0.45	1.55	160020	20335	180355	164355
Chamomile oil	**A**	1.18	0.39	1.57	171500	17850	189350	173350
	B	1.14	0.40	1.54	165760	18235	183995	167995
	C	1.12	0.42	1.54	163380	19250	182630	166630
Black cumin oil	**A**	1.12	0.32	1.44	163380	14350	177730	161730
	B	1.06	0.37	1.43	154840	16940	171780	155780
	C	0.99	0.38	1.37	144690	17150	161840	145840

Table 8: Effect of tomato intercropping with onion and chemicals compounds on *Tetranychaus urticae* Koch under field conditions.

Treatment	Number pre- the first spray	Number pre- the second spray	No. of *T. urticae* after spray (5 days)				Mean % R
			First spray		Second spray		
			No.	% R.	No.	% R.	
		Season 2020/2021					
Ethion	155.63	61.83	36.73	75.6	5.34	91.0	83.3
Chamomile oil	158.81	53.63	89.63	41.9	29.26	43.1	42.5
Black cumin oil	148.93	62.64	78.74	45.5	45.48	24.3	34.8
Control intercropping	160.46	68.64	155.52	-	65.75	-	-
Control sole	185.43	256.22	177.46	-	197.87	-	-
		Season 2021/2022					
Ethion	159.52	54.11	45.68	70.4	17.48	64.8	67.6
Chamomile oil	161.71	38.42	101.79	34.9	24.38	30.9	32.9
black cumin oil	158.59	45.37	123.54	19.4	30.25	27.6	23.5
Control intercropping	168.33	58.52	162.58	-	53.64	-	-
Control sole	203.11	266.02	200.87	-	274.69	-	-

*= the second spray after the first spray 20 days
R ; reducation

Data in table (8) indicated that all compounds reduced *T. urticae* infestation compared with control in first and second spray in the second season. Concerning the first spray, ethion gave the best effect (70.4 % reduction) followed by chamomile oil (34.9 %), and then black cumin (19.4 %). In the second spray in 2022, a similar trend was observed. Ethion exhibited the highest efficacy of reduction (64.8 %) followed by chamomile (30.9 %) and black cumin oil (27.6 %). In general, these results indicated that all treatments, ethion, *C. recutita* and *N. sativa* oils may have the ability to don't penetrate the tomato leaf tissue leaf dibbing, resulting in their high effect compared to the control. These results agree with those of Abd EL- Rahman *et al.,* (2021) who reported the similar results of garlic oil and moringa oil against motile stages of *T. urticae* and *T. cucurbitacearum*. Akhtar *et al.* (2010) cited that essential oil has low toxicity to non-target mite. So treatment essential oil may be recommended to reduce numbers mite, *T. urticae*. Asmae *et al.* (2019) and Nasr (2020) found that neem essential oil treatment reduced *T. urticae* infestation and they added that products as essential oil is much effective and safe. Thus, insecticides and essential oils are used to reduce infestations to *T. urticae* 3, 7, 10 and 13 days post spray, the mean percentage of reduction by garlic oil, moringa and jojoba were 53.40, 39.44 and 24.86, respectively (Farag and Abd EL-Rahman 2021) and they added that plant oil can be useful for an integrated pest management programs against *T. urticae*. Habashi (2018) reported the ability and stability of the aqueous garlic extract to control of the tow spotted spider mite, *T. urticae*. Abd EL-Rahman *et al.,* (2022) indicated that abamectin was the highest toxic chemical with the motile stages, whereas neem extract was the least toxic, and they added that all compounds were effective in reducing population densities of *T. urticae*

3.3. Laboratory experiments

3.3.1. Susceptibility of *T. urticae* motile stages to some tested compounds

The results recorded in Table (9) indicated that ethion proved to be the most toxic compound against the motile stages of *T.urticae* with LC_{50} values of 389.8 ppm. Chamomile oil has a moderate toxicity to adult and nymph stages of *T.urticae* with LC_{50} value of 4236 ppm. Black cumin oil was the least toxic to *T.urticae* with LC_{50} value of 5387ppm. Thus, these compounds exhibited insignificant differences among the three compounds. Concerning the toxicity index at LC_{50} level, ethion was the highest toxic compound against motile stages of the mite with a toxicity index of 100, while *C. recutita* and black cumin oils had a moderate toxic effect to adult and nymph stages of *T.urticae* with toxicity indices of 9.20 and 7.23, respectively.

Table 9: Susceptibility of *Tetranychaus urticae* motile stages to some compounds under laboratory condition.

Treatment	LC_{50} 95 % CL	Toxicity index	Slope value	x^2
Ethion	389.8 (299.1- 436.6)	100	1.36 ± 0.65	1.45
Chamomile oil	4236 (4137–4326)	9.20	1.76 ± 0.67	2.53
black cumin oil	5387 (5233 -5476)	7.23	1.82 ± 0.92	3.28

3.3.2. Residual effect of evaluated compounds on egg deposition, hatchability and sterility of *T. urticae*

The effect of sub lethal concentrations of the tested compounds on egg deposition, hatchability and sterility percentage of the adult female mites of *T. urticae* is shown in Table (10). Ethion was the most effective compound on egg deposition with 12.70 eggs, while chamomile oil has a moderate toxic effect to adults, protonymphs and deutonymphs of *T.urticae* with 22.43 eggs. *Nigella sativa* oil has a low effect on similar to chamomile oil, 25.63 eggs. In general, the effect of different compounds can be arranged descendingly as follows: Ethion, chamomile oil and cumin oils. Several studies carried out on the effect of different compounds on mite biology, indicted that these compounds always increased sterility percentage in descending order as follow; chamomile and black cumin oil, had a moderate effect on serial action, they were 75.84 and 57.67 %, increase then control, respectively. On the other hand, results showed difference was observed between ethion, chamomile and black cumin oil; both caused level of reduction (56.32 and 43.27, respectively and significantly differences between them. The obtained data were in agreement with the results obtained by **Sobhy, 2008 and Osman, (1997), w**ho found that plant oil had a moderate effect on egg deposition and percent of sterility.

Table 10: Residual effect of evaluated compounds on egg deposition, hatchability and sterility of *T. urticae*

Treatment	*No. of egg/3 females	Grand mean	No. of eggs hatch	% Hatchability	% Sterility	% R
Ethion	12.70 ± 0.96 d	4.23 ± 0.78 c	3.65 d	28.74	91.58	78.45
Chamomile oil	22.43 ± 0.68 c	7.47 ± 0.45 b	10.47 c	46.67	75.84	56.32
Black cumin oil	25.63 ± 0.43 b	8.54 ± 0.94 b	18.34 b	71.55	57.67	43.27
Control	45,25 ± 0.98 a	15.35 ± 0.56 a	43.32 a	95.73	-	-
LSD 1%	1.76	1.22	1.89			

* 4 days after treatment

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