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Succinimide solo and mixed with benzoic acid formulations as novel substitutes for pesticides against sucking pests on Cucumis sativus L. in greenhouses

Magdi A. Eskander

magdi.eskander25@gmail.com

Pesticides, Formulation Department, Central Agricultural Pesticide Laboratory (CAPL) Agricultural Research Center, 12618-Dokki-Giza, Egypt.

Raghda, M. Hassan

Bioassay Department, Central Agricultural Pesticide Laboratory (CAPL) Agricultural Research Center, 12618-Dokki-Giza, Egypt.

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Abstract

Insecticides present several challenges, including negative impacts on human health, environmental pollution and the appearance of pesticide-resistant strains of the pests. Therefore, there is an increasing need to explore alternative pest control strategies. Succinimide an organic compound used in pharmaceutical drugs, benzoic acid and its salts are used as microbiological preservatives in a variety of processed foods and drinks. The aim of this work was to formulate succinimide, benzoic acid and its mixture in a suitable formulation form and determine their toxicity against spider mite *Tetranychus urticae* and whitefly *Bemisia tabaci.* The desirable compounds were formulated and passed to specified tests. The toxicity of them assessed against individuals of mites *T. urticae* and adults of *B. tabaci* under laboratory conditions. Two separated experiments were conducted in greenhouse to determine the insecticidal efficacy on eggs and individuals of *T. urticae* and *B. tabaci* nymphs and adults infested cucumber plants. The results revealed that all tested formulated organic compounds showed excellent ovicidal effect against *T. urticae* eggs and nymphs of *B. tabaci* at 4000 ppm. However, they showed good insecticidal effect against individuals of *T. urticae* and adults of *B. tabaci*. Additionally, all studied insect stages showed that succinimide with benzoic acid mixture (EW) was as effective as succinimide (SP) or marginally more effective than benzoic acid (EC). From these results, such formulations could be used as safety alternatives for controlling two- spotted spider mite (eggs and individuals) and whitefly (nymphs and adults) on cucumber plants in greenhouse after completing the other needed trials in future.

1. Introduction

Cucumber (*Cucumis sativus*) is one of the most significant vegetable crops grown worldwide. In Egypt, it holds a prominent place among vegetable crops Abdelatef, et al., 2022. Numerous significant insect pests infest cucumber plants Awadalla, et al., 2020. The two-spotted spider mite, *Tetranychus urticae* is one of important pests on cucumber; it causes several damages to growth plant, resulting reduction in the quality and quantity of the production Clark, et al., 1994. Also, whitefly, *Bemisia tabaci* (Genn) (Hemiptera): Aleyrodidae is considered a harmful insect that causes severe damage to cucumber plants Basu, 1995. It damages plants by feeding directly on them and by serving as a vector for the spread of numerous plant viruses that drastically reduce yields Yadav, et al., 2022. By sucking on the leaves, white flies deplete the plant's nutrients and cause physiological problems. Insect honey dew excretions on leaf lamina encourage the establishment of black sooty mold, which obstructs photosynthetic processes and thus reduces yield. The harm that is directly obvious is the fading and distortion of the leaves **Janssen, 1989.**

Food security, ecological safety, and the environment are all negatively impacted by the use of chemical pesticides Philippe, et al., 2021. Additionally, the over and persistent use of insecticides has caused whiteflies to become resistant Wang, et al., 2020. Nevertheless, whiteflies have become highly resistant to the neonicotinoids thiamethoxam and imidacloprid Naveen, et al., 2017, because due to worries about their potential impacts on pollinators. The European Union banned the outdoor use of three neonicotinoids in 2018: clothianidin, imidacloprid, and thiamethoxam **EU, 2018a; EU, 2018b and EU, 2018c.** Succinimides have been found to be important components of treatment plans Liu, et al., 2021. The fundamental nucleus of succinimides is pyrrolidine-2, 5-dione, and a five-member heterocyclic ring with two carbonyl groups attached as functional groups and nitrogen as the heteroatom. Potential therapeutic compounds can be created by modifying this fundamental skeleton to create derivatives with different aryl or alkyl groups that are substituted with carbon or nitrogen Sarfraz, et al., 2017. This study's primary objective was to develop and assess the toxicity of two synthetic organic compounds as safe substitutes for chemical pesticides in the management of sucking pests (whiteflies and mites) on cucumber plants grown in greenhouses.

2. Materials and Methods

2.1. Tested chemical

Succinimide as organic compound with the formula: $(CH_2)_2$ $(CO)_2$ NH, benzoic acid: ($C_7H_6O_2$) as a white crystalline solid. Surfactants: Span 80, Tween 80, Sodium lauryl sulphate (SLS), polyethylene glycol dioleate (PEG 600 DO), and triton 100X. Solvents: acetone, xylene, ethanol, and dimethyl formamide (DMF) were provided by EL-Gomhoria Co., Cairo, Egypt.

2.2. Physicochemical characteristics of the tested materials.

2.2.1. Solubility: It was determined according to method of Nelson and Fiero 1954.

2.2.2. Free acidity or alkalinity: it was measured by the methods outlined in the **WHO recommendation 1979**.

2.3. Locally prepared succinimide as 90% soluble powder (SP) formulation:

Succinimide was prepared as soluble powder formulations due to its physicochemical characteristics. Many trials were carried using different weights of the active ingredient (a.i) and different weights of surfactants, and all specific physicochemical characteristics were measured to determine which formulas passed the reported tests and were suitable for application and production.

2.4. Locally prepared benzoic acid as emulsifiable concentrate (EC) formulation:

According to the measured physicochemical characteristics of benzoic acid, it prepared as emulsifiable concentrate. Several trials conducted using different weights of benzoic acid dissolving in different weights of solvent or mixture of solvents then adding the different weights of surface active agent and mixing well until stable formulation was achieved. The prepared formulations were subjected to an emulsion stability test according to method of CIPAC 2002. To define the successful prepared formulation that will be suitable for using in pest control under field conditions and production.

2.5. Preparation of succinimide and benzoic acid mixture as oil in water emulsion (EW) formulation:

Due to the physicochemical properties of succinimide and benzoic acid, they could be prepared in one formulation as oil/water (o/w) emulsion. Several trials conducted using different ratios from liquid phase and oil phase, using the method reported by Salvica, et al., 2012. The emulsion stability and other physicochemical properties were measured according the methods reported by CIPAC 2002. for each prepared formulation, before and after accelerated storage at 54 ± 2 $^{\circ}$C for 14 days to define the best one for using in pest control and production.

2.6. Physico-chemical properties of locally prepared benzoic acid as emulsifiable concentrate (EC) formulation and succinimide, benzoic acid mixture as oil in water emulsion (EW) formulation:

2.6.1. Viscosity: Using a Brookfield viscometer model DVII + Pro, the measurement was made using centipoises according to **ASTM 2005.**

2.6.2. Surface tension: independent in method of **ASTM 2001**, it was ascertained by employing a Du-Nouy tensiometer for solutions containing 0.5% (W/V) surfactant.

2.6.3. Emulsion stability test was conducted by using the method described by **FAO/WH**PH: it measured by Cole-Parmer PH conductivity meter 1484-44 using the method reported by Dobrat and Martijn 1995.

2.6.4. Foam: It was measured using the method that outlined by CIPAC 2002.
2.6.5. Free acidity or alkalinity: It was performed as mentioned earlier.
2.7. Physico-chemical characteristics of locally prepared succinimide as 90% soluble powder (SP) formulation:

Solubility, Foam, PH, and free acidity/ alkalinity were determined as mentioned before.
2.7. Physico-chemical properties of newly prepared formulations spray solution at (0.5%):

2.7.1. Surface tension, Viscosity, and pH were determined as mentioned before.

2.7.2. Electrical Conductivity and Salinity: The Cole-Parmer PH/Conductivity meter 1484-44 was utilized to determine it, with µmhos serving as the unit of measurement for electrical conductivity Dobrat and Martijn 1995.

2.8. Bioassay:

2.8.1.Tested insects: Two- spotted spider mite, *T. urticae*, and whitefly *B. tabaci* were reared in Bioassay Department, Central Agricultural Pesticide Laboratory (CAPL) Agricultural Research Center (ARC), Dokki-Giza, Egypt, for many generations on Acalypha marginata at 26 ± 2 ºC, 55 ± 5% R.H., and with a photoperiod of 14:10 hr (light:dark) to keep the culture.

2.8.2. Determination of the toxicity against:

Spider mite T. urticae:

Toxicity of the formulated organic materials, succinimide, benzoic acid, and their mixture were conducted by using the leaf-dip technique according to method of Mead, 2012. with some modifications against adults of *T. urticae* as follow: leaf disks (2.5 cm in diameter) of *A. marginata* plants dipped in five concentrations (3000, 1500, 750, 375, and 187.5 ppm) for each tested formulation for 10 seconds, and then dried on filter paper, after that put into a tiny plastic vial that measured 40 mm in diameter by 37 mm in height. Twenty individuals of mite were transferred to treated leaf disks, each concentration and control have three replicates. The mortality was estimated after 48 hr of treatment.

Whitefly B. tabaci:

Toxicity of the formulated organic materials, succinimide, benzoic acid, and their mixture were determined by using the leaf-dip technique with some modifications against adults of *B. tabaci* under laboratory conditions. Cotton plant leaves were washed, dried and cut into discs (35 mm in diameter), these leaves discs separately dipped in spray solutions for 10 sec in serial concentrations: 2400, 1200, 600, 300, and 150 ppm of each prepared formulation. The leaf discs were put in the base of a tiny, suitable-sized plastic vial with their ataxia surface facing down on agar. As a control, additional leaf discs were immersed in distilled water. Using a mouth aspirator, twenty adults of *B. tabaci* (mixed sex) were added and put into a tiny plastic vial that measured 40 mm in diameter by 37 mm in height. Each treatment had three replicates, and there were additional three replicates for control group **Houndete, et al., 2010a.**

After 24 hr of incubation, mortality was measured. When an insect showed symptoms of movement, it was deemed alive. Abbott's algorithm was used to adjust the mortality statistics Abbot, 1925.

$$\text{Corrected percentage mortality} = \frac{T - C}{100 - C} \times 100$$

Where, T is No. of dead insects adult in treated replicates, and is No. of dead insects adult in control replicates.

The LDP-Line statistical computer program was used to estimate the regression lines' slopes, LC_{50} and LC_{90} values, and 95% confidence limits **Houndete, et al., 2010b., Shadmany and Muhamad 2015.**

2.8.3. Greenhouse Experiments:

Insecticidal potency on B. tabaci.

The insecticidal efficacy of the prepared formulations against nymph and adults of whitefly *B. tabaci* under greenhouse conditions on cucumber plants growing in pots was conducted in greenhouse of the Institute according to **EL-Sisi, et al., 2019.** Five pots every one planted with two cucumber seedlings used with each concentration and five pots as control, sprayed with the prepared formulations at 1000, 2000, and 4000 ppm using a hand sprayer has one nozzle. Whitefly stages population were counting before and after 1, 3, 5, and 7 days of application by direct counting for adults and by collecting 10 leaves from each treatment and transferred in paper bags to laboratory and inspect them under binocular. Reductions percentages were calculated according to Henderson and Tilton 1955.

Insecticidal potency on T. urticae.

Efficacy of prepared formulations on egg hatchability and individuals of the two- spotted spider mite *T. urticae* was determined. In separate trials on cucumber plants growing in pot and infested artificially after 15 days of transplanting using some infested egg plants leaves and permit to the population of mite to adaptation and production nearly 15 days to reach the appropriate scale. The above concentrations were used for each prepared formulation. Five pots were served for treatment and others were served as a control. Before and after spraying 1, 3, 5 and 7 days, ten leaves of each concentration collected and transferred in paper bags to laboratory and inspection the population of eggs and individuals. Reductions percentages were calculated as described above Henderson and Tilton 1955.

2.8.4. Phytotoxicity:

The adverse impacts on plants were determined by recording any burning, curl, and yellowish occurred in leaves of treated plants up to 7 days after treatment.

3. Results and Discussion

3.1. Characteristics:

To formulate any ingredient a.i, must measure the physicochemical characteristics to determine the suitable formulation type. Table (1) illustrates the physicochemical properties of both tested materials. The obtained results revealed that succinimide and benzoic acid displayed acidic property and its acidity values were: 28.43 and 47.90 respectively, also both of them showed solubility in acetone, ethanol, and DMF, while they were insoluble in xylene. Succinimide displayed good solubility in water. So, it could be formulated as soluble powder (SP) formulation, but benzoic acid was insoluble in water and soluble in organic solvent, so it will be prepared as emulsifiable concentrate (EC).

Table 1
Physico- chemical characteristics of the tested materials.

Compound	Solubility % (w/v)					Free acidity as % H_2SO_4
	Water	Xylene	Acetone	Ethanol	DMF	
Succinimide	Sol	N.S*	Sol	Sol	Sol	28.43
Benzoic acid	N.S*	N.S*	Sol	Sol	Sol	47.90
N.S*: non- soluble						

From the finding data, succinimide formulated as SP and data illustrated in table (2) revealed the physicochemical properties for the prepared (SP) formulation before and after accelerated storage at 52 ± 2^0C for 14 days. The obtained results indicated that, the prepared formulation displayed clear solubility in water before and after storage, however no foam formed with soft water but slightly foam formed with hard water 2 ml before storage and 3 ml after storage. It displayed acidic property with values: 0.44 and 0.45 before and after storage, respectively. Slightly decrease in pH value, was noted (4.51) before storage decreased to 4.48 after storage.

Table 2
Physico-chemical properties of the prepared (SP) formulations before and after accelerated storage

Formulation	Before storage						After storage					
	Solubility		Foam		pH	Free acidity as H_2SO_4	Solubility		Foam		pH	Free acidity as H_2SO_4
	S.W	H.W	S.W	H.W			S.W	H.W	S.W	H.W		
Succinimide (SP)	Sol	Sol	0	2	4.51	0.44	Sol	Sol	0	3	4.48	0.45
S.W.: Soft water, H.W.: Hard water												

Due to the physicochemical characteristics of benzoic acid (Table 1), it prepared as EC formulation using organic solvents and blends of emulsifying agents. On the other hand, the mixture of benzoic acid and succinimide were prepared as oil in water emulsion (EW) by mixing the aqueous phase with oil phase and stirring to get homogenous emulsion. Due to data illustrated in Table (3), the physicochemical properties of the prepared EC and EW formulations displayed excellent emulsion stability which no oily or cream separation formed before and after accelerated storage, however both formulations revealed acidic property and their values were: 10.53 and 2.53 for benzoic acid (EC) and the mixture of succinimide with benzoic acid decreased after storage to values:10.33 and 2.43, respectively. In contrarily, the pH values showed increased after storage from 3.3 and 3.51 to 3.4 and 3.55 for EC and EW formulations, respectively. While, their viscosity values showed slightly increase from 1.49 and 3.1 before storage to 1.51 and 3.3 centipoise after storage. On the other hand, their surface tension values revealed slightly decrease after storage from 27.45 and 25.56 before storage to 27.22 and 25.32 dyne/cm after storage, respectively.

Table 3
Physico- chemical properties of the prepared (EC and EW) formulations before and after accelerated storage

Formulation	Before storage						After storage					
	Emulsion stability (ml cream sep.)		Surface tension	viscosity	pH	Free acidity as H_2SO_4	Emulsion stability (ml cream sep.)		Surface tension	viscosity	pH	Free acidity as H_2SO_4
	S.W	H.W					S.W	H.W				
Benzoic acid (EC)	0	0	27.45	1.49	3.3	10.53	0	0	27.22	1.51	3.4	10.33
Succinimide + benzoic acid (EW)	0	0	25.56	3.1	3.51	2.53	0	0	25.32	3.3	3.55	2.43
S.W.: Soft water, H.W.: Hard water												

Data in Table (4) indicated the physicochemical properties of the prepared formulations (SP), (EC), and (EW) at the field dilution rate 0.5%. All prepared formulations (spray solution) revealed good viscosity comparing with water viscosity, where benzoic acid (EC) displayed the highest value 1.36 centipoise, followed by succinimide (SP) 1.27 centipoise and mixture of succinimide with benzoic acid (EW) (1.14 centipoise). These formulations caused lowering the droplet size of spray solution. This finding is in accordance with that obtained by Dorr, et al., 2015 who stated that the physicochemical properties of the spray solution, as well as the size of the droplets, are influenced by the formulation type. Variations in these variables may have an impact on droplet bounce, active component adhesion to leaves, and target coverage, among other things. Spray drift is also influenced by the droplet size spectra, which result from the interaction between the spray

nozzle and the spray solution; the likelihood of drift rises with decreasing droplet size Hilz and Vermeer 2013. However, succinimide (SP) displayed the highest conductivity value (342 µmhos) and salinity (0.2%), followed by benzoic acid (177.9 µmhos) and salinity (0.1%), and the mixture of succinimide with benzoic acid (EW) (151.4 µmhos) and salinity (0.1%). These results increased the biological efficacy for the tested formulations against the target, that are in agreement with that obtained by Molin and Hirase 2004, who stated that lowering pH with raising electrical conductivity is an essential extra feature since the former would make the treated plant more attractive to the spray solution, which would increase penetration and deposition on the tested surface and, eventually, effectiveness. Benzoic acid (EC) displayed the highest surface tension (31.12 dyne/cm), followed by mixture of succinimide with benzoic acid (EW) (30.16 dyne/cm) and succinimide (SP) (26.32 dyne/cm). All prepared formulations displayed lower pH values: 3.3, 3.51, and 4.52 for EC, EW, and SP formulations, respectively.

Table 4
Physico-chemical characteristics of spray solution of the prepared formulations at (0.5%).

Formulation	Viscosity (centipoises)	pH	Surface tension (Dyne/cm)	Conductivity (µ mhos)	Salinity %
Succinimide (SP)	1.27	4.52	26.32	342	0.2
Benzoic acid (EC)	1.36	3.3	31.12	177.9	0.1
Succinimide + benzoic acid (EW)	1.14	3.51	30.16	151.4	0.1

3.2. Bioassay studies:

3.2.1. Toxicity of prepared formulation against *T. urticae*

Laboratory experiment carried out to determine the toxicity of the prepared formulations: Succinimide (SP), benzoic acid (EC) and succinimide with benzoic acid mixture (EW) against two spotted spider mite *T. urticae* individuals and results illustrated in table (5) and figure (1) revealed that, succinimide (SP) formulation displayed the greatest toxicity effect against tested mite followed by the succinimide with benzoic acid mixture (EW) formulation and benzoic acid (EC) where the LC_{50} values were: 1086.47, 1206.21 and 1584.05ppm respectively.

Table 5
LC_{50}, LC_{90}, Toxicity index and slope for the prepared formulations against individuals of *T. urticae* under laboratory conditions.

Material	Parameters				
	LC_{50} (mg/l)	Confidence limit 95% (mg/l)	LC_{90} (mg/l)	Toxicity index	Slope ± S.E.
Succinimide (SP)	1086.47	921.324- 1302.52	6142.0288	100	1.7036 ± 0.1574
Benzoic acid (EC)	1584.05	1293.755- 2036.91	11638.4461	68.588	1.4797 ± 0.1562
Succinimide + benzoic acid (EW)	1206.21	1017.852- 1461.876	7025.9942	90.072	1.6747 ± 0.1580

1 = Succinimide (SP), 2 = benzoic acid (EC), 3 = succinimide + benzoic acid (EW)

Figure 1. **Toxicity lines for tested prepared formulations against T. urticae.**

3.2.2. Toxicity of the prepared formulations against adults of B. tabaci.

Separate laboratory experiment conducted to determine the toxicity of locally prepared formulations. Succinimide (SP), benzoic acid (EC), and mixture of succinimide with benzoic acid (EW) after prepared and passed successfully of all specified tests. Their toxicity against adults of whitefly *B. tabaci* determined and the results obtained in table (6) and figure (2) revealed that, succinimide (SP) displayed the highest toxicity against adults of *B. tabaci* with lowest LC_{50}value 744.267 ppm, followed by succinimide with benzoic acid mixture (EW) displayed with LC_{50} value 815.308 ppm, while benzoic acid displayed the lowest toxicity with highest LC_{50} value 1114.58 ppm that means decreasing the LC_{50} value for any product increasing in toxicity against the treated target.

On the other hand, Figure (2) shows the slopes of toxicity lines for tested formulations where, there are positive relation between the toxicity and the slope value, that's indicating clearly with succinimide (SP) was displayed the highest toxicity and the highest slope value, while there is negative relation between the LC_{50} values and slope values (Table 6).

These findings are in agreement with that obtained with Al- Shehri, et al., 2022, where they stated that the succinimide compounds MSJ2 and MSJ10 shown exceptional activity against butyrylcholinesterase (BuChE) and acetyl cholinesterase (AChE), with respective inhibition values of 91.90 and 93.20% against acetylcholinesterase (AChE), the corresponding inhibitory potentials against butyrylcholinesterase (BChE) were 97.30 and 91.36%. With respective IC_{50} values of 32 and 28.04 µM, the compounds MSJ9 and MSJ10 demonstrated strong α-glucosidase inhibitory potentials of 87.63 and 89.37%.

Table 6
LC_{50}, LC_{90}, Toxicity index and slope for the prepared formulations against adults of *B. tabaci* under laboratory conditions.

Material	Parameters				
	LC_{50} (mg/l)	Confidence limit 95% (mg/l)	LC_{90} (mg/l)	Toxicity index	Slope ± S.E.
Succinimide (SP)	744.27	643.84- 866.05	3311.82	100	1.98 ± 0.17
Benzoic acid (EC)	1114.58	703.97–953.55	5796.30	66.775	1.79 ± 0.16
Succinimide + benzoic acid (EW)	815.31	944.37–1350.61	3690.39	91.287	1.95 ± 0.16

1 (S) = Succinimide (SP), 2(B) = benzoic acid (EC), 3(SB) = succinimide + benzoic acid (EW)

Figure 2. **Toxicity lines for tested prepared formulations against B. tabaci**.

3.3. Greenhouse experiments:

3.3.1. Insecticidal effect of formulated organic compound against mite individuals:

Synthesized organic compounds: succinimide, benzoic acid and succinimide with benzoic acid mixture formulated in appropriate were conducted for the insecticidal potency against individual of *T. urticae* infested cucumber plants in greenhouse. The results obtained in Table (7) revealed that, succinimide with benzoic acid mixture (EW) showed the highest reduction percentage in mite individuals (numbers/leaf of cucumber treated plants) in comparison with untreated cucumber plants after 1, 3, 5, and 7 days. Treatments of succinimide (SP) and benzoic acid indicated % reductions values: 93.02, 91.86 and 86.80% after 7days of spraying for concentration, 4000 ppm. While, % reduction was 56.62, 55.9 and 50.77% after 1st day of spraying for same concentration.

Table 7
The insecticidal potency of formulated organic compounds against individuals of T. urticae infested Cucumis sativus plants in greenhouse.

Materials	Conc. (ppm)	% of Reduction			
		1st day	3rd day	5th day	7th day
Succinimide (SP)	4000	55.9	82.56	87.55	91.86
	2000	47.04	69.90	75.44	81.86
	1000	37.33	56.53	62.69	66.72
Benzoic acid (EC)	4000	50.77	77.60	81.72	86.80
	2000	43.71	62.22	66.59	73.43
	1000	32.23	50.10	58.05	63.13
Succinimide + benzoic acid (EW)	4000	56.62	86.64	90.13	93.02
	2000	49.32	69.64	73.75	80.30
	1000	40.81	51.87	62.21	67.36

3.3.2. Ovicidal effect of prepared formulations against *T. urticae*:

The ovicidal effect of formulated synthetized organic compound against two spotted spider mite *T. urticae* eggs on cucumber plants in greenhouse was determined and results are illustrated in Table (8). All tested compounds displayed excellent ovicidal potency against mite eggs. Succinimide with benzoic acid mixture (EW) displayed the highest ovicidal action with the highest concentration, 4000 ppm after 1st day of spraying, followed by succinimide (SP) and benzoic acid (EC) and their reduction percentages of eggs/leaf were: 60.91, 58.24 and 56.11%, respectively. However, their reduction percentages were: 99.37, 98.52 and 95.83% respectively, after 7th day of spraying.

Table 8
The ovicidal potency of formulated organic compound against T. urticae eggs on Cucumis sativus plants in greenhouse.

Materials	Conc. (ppm)	% of Reduction (eggs stage)			
		1st day	3rd day	5th day	7th day
Succinimide (SP)	4000	58.24	93.33	97.48	98.52
	2000	50.51	79.81	81.86	90.67
	1000	40.22	58.09	67.04	76.11
Benzoic acid (EC)	4000	56.11	88.67	92.72	95.83
	2000	45.32	76.71	80.11	85.04
	1000	38.52	54.18	62.88	73.84
Succinimide + benzoic acid (EW)	4000	60.91	95.67	97.44	99.37
	2000	48.25	79.89	82.82	91.89
	1000	43.64	57.08	67.2	76.06

3.3.3. Insecticidal potency of formulated organic compound against adults of *B. tabaci*

Table 9

The insecticidal effect of formulated compounds against nymphs of B. tabaci infested cucumber plants in greenhouse.

Treatments	Conc. (ppm)	Pre-treat. Count No./leaf	Initial effect		Residual effect				
					No./ leaf after			Mean	% R
			No./ leaf	% R	3 days	5 days	7 days		
Succinimide	4000	198	40	77.85	15	8	5	9.3	94.59
(SP)	2000	196	48	73.15	38	34	31	34.3	79.88
	1000	203	64	65.43	51	49	44	48.0	72.83
Benzoic acid (EC)	4000	213	54	72.20	35	28	26	29.7	84.00
	2000	189	66	61.71	56	46	45	49.0	70.21
	1000	205	78	58.28	68	66	72	68.7	61.52
Succinimide+	4000	194	41	76.68	16	9	7	10.7	93.67
Benzoic acid (EW)	2000	209	57	70.09	47	39	36	40.7	77.65
	1000	211	69	64.14	61	57	62	60.0	67.33
Control	-	216	197		188	184	192	188	

Insecticidal action of formulated synthesized organic compound against nymphs of whitefly *B. tabaci* infested cucumber plants in greenhouse was evaluated by spraying cucumber plants infested with *B. tabaci*. The results are illustrated in Table (9), where they revealed that, all tested formulations displayed good initial and residual effect against nymph stage of *B. tabaci*. Succinimide (SP) revealed the highest initial and residual effect comparing with other tested formulations and its values were: 77.85 and 94.59% of reduction in population of nymphs/leaf with the highest tested concentration (4000 ppm), followed by mixture of succinimide and benzoic acid (EW) which displayed 72.20 and 84.0% reduction in nymph number/leaf. Benzoic acid (EC) gave 76.68 and 93.67% at the same concentration. On the other hand, the lowest tested concentration (1000ppm) revealed good insecticidal activity with all the tested formulations with initial and residual effect as a reduction in infestation, where succinimide (SP) was the best formulation followed by mixture of succinimide with benzoic acid (EW) and benzoic acid (EC

3.3.4. Insecticidal effect of formulated synthesized organic compounds against adults of *B. tabaci*

Data illustrated in Table (10) obtained clearly that all prepared formulations displayed excellent insecticidal potency against adults of whitefly *B. tabaci* after 24 hr (initial effect) or after 7th day of treatment. Succinimide (SP) at 4000 ppm displayed the highest initial effect 79.66% reduction in number of adults/leafs, also revealed the highest residual effect 92.09%, followed by the mixture of succinimide with benzoic acid (EW) which display initial effect 78.23% and residual effect 90.29%. Benzoic acid (EC) gave moderate initial effect, 67.41and 84.95% residual effect at the same concentration. Furthermore, the lowest concentration used (1000 ppm) showed good efficacy against adults of whitefly, where succinimide (SP) displayed the best reduction in adults' number/leaf with initial and residual effect followed by mixture of succinimide with benzoic acid (EW) and benzoic acid (EC) alone.

3.4. Phytotoxicity:

Benzoic acid formulated as EC when sprayed at 4000 ppm on cucumber plants caused severe phytotoxic effect in form of burning on cucumber plants leaves. While, the other tested concentrations of this formulation did not cause any phytotoxic effect on the treated plants. On the other hand, no any phytotoxic symptoms obtained on the treated cucumber plants with succinimide (SP) and succinimide + benzoic acid mixture (EW).

Table 10
Insecticidal potency of formulated synthesized organic compounds against adults of *B. tabaci* infested cucumber plants in greenhouse.

Treatments	Conc. (ppm)	Pre-treat. Count No./leaf	Initial effect		Residual effect				
					No./ leaf after			Mean	% R
			No./ leaf	% R	3 days	5 days	7 days		
Succinimide	4000	98	19	79.66	10	6	5	7.00	92.09
(SP)	2000	104	26	73.77	15	11	10	12.00	87.23
	1000	101	31	67.80	24	19	17	20.00	78.08
Benzoic acid (EC)	4000	103	32	67.41	15	14	13	14.00	84.95
	2000	99	43	54.44	25	23	22	23.33	73.91
	1000	102	57	41.38	32	29	28	29.66	67.81
Succinimide+	4000	106	22	78.23	11	9	8	9.30	90.29
Benzoic acid (EW)	2000	112	31	70.96	18	17	16	17.00	83.20
	1000	105	36	64.03	24	23	19	22.00	76.81
Control	-	107	102		97	95	98	96.66	-

3.5. Mode of action of the tested organic compounds:

Benzoic acid can only cross the cell membrane when it is undissociated. The uncharged acid enters the cell with a comparatively low pH, and the molecules stay inside the cell. The cell's internal pH drops, and metabolic processes are slowed down. Additional impacts were reduced membrane permeability for phosphates, organic acids, and amino acids causing the electron transport system to decouple oxidative phosphorylation and substrate transport. Also, the citric acid cycle is seen to be inhibited **EU 2012.** Derivatives of succinimide show superior inhibition of α-glucosidase, butyrylcholinesterase (BChE), and acetylcholinesterase (AChE) Al- Shehri, et al., 2022.

4. Conclusion

Synthesized organic compounds: succinimide, benzoic acid and their mixture used as a.i to control sucking pests (two spotted spider mite *T. urticae* and whitefly *B. tabaci*) on cucumber plants in greenhouse. Their physicochemical properties were measured, and then prepared in suitable formulation form independent on such characteristics. The prepared formulations passed successfully from the specified tests that confirm their suitability for application and production. Toxicity of the prepared formulations was evaluated against adults of whitefly and individuals of mites under laboratory conditions. The results showed that all the prepared formulations displayed high toxicity against adults of whitefly and individuals of mites. Greenhouse experiments were conducted to evaluate and confirm the insecticidal potency of formulated compounds against two-spotted spider mites (individuals and eggs) and whitefly (adults and nymphs). The obtained results reported that the mixture formulation (EW) showed insecticidal effect on tested insect stages compared with succinimide (SP), that due to the two mode of action of succinimide and benzoic acid in its formula, followed by benzoic acid (EC). Also, all prepared formulations showed toxic effect on eggs of mites *T. urticae* better than individuals and toxicity against nymphs of whitefly *B. tabaci* better than adults.

Declarations

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Data availability:

Data will be made available on request.

Conflicts of interes

Declaration of competing interest:

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Credit authorship contribution statement.

M. A. Eskander: Formulate the tested materials, characteristics, investigations, and writing- review & editing writing - original draft. **Raghda, M. Hassan**: Methodology, investigation, formal analysis and writing- original draft.

References

1. Abbot WSA (1925) A method of computing the effectiveness of an insecticide. J Econ Ent 18(2):265–267. https://doi.org/10.1093/jee/18.2.265a
2. Abdelatef GM, Selim NMM, Abd-El-Wanis MM (2022) Thiamethoxam efficiency applied with two spray techniques against *Bemisia tabaci* (Genn.) on cucumber plants production under greenhouse conditions and it is residues in soil, leaves and fruits. J Plant Prot Pathol Mansoura Univ 11(11):559–556
3. Al- shehri MO, Mahnasshi HM, Sadiq A, Zafar R (2022) Succinimides derivatives as antioxidant, anticholinesterases, anti-α-amylase, and anti- α -glucosidase: in vitro and in silico- approaches. Evidence-Based Complementary and Alternative Medicine, Volume 2022, Article ID 6726438, 12 pages https://doi.org/10.1155/2022/6726438
4. American Society of Testing Materials ASTM (2001) Standard Test Method for Surface and Interfacial Tension Solution D-1331
5. American Society of Testing Materials ASTM (2005) Standard Test Method for Rheological Properties of Non – Newtonian Materials by Rotational (Brookfield type) Viscometer, D-2196 copyright ASTM, Bar Harbor Drive, West Conshohocken, PA 19248 – 2959, United States
6. Awadalla SS, El-Serfi HAK, El-Hariry MA, Wahsh AM (2020) Influence of different cucumber varieties on the occurrence of the piercing-sucking insect pests in Fayoum Governorate, J. of Plant Protection and Pathology, Mansoura Univ. 11(11):559–561
7. Basu AN (1995) *Bemisia tabaci* (Gennadius) Crop pest and principal whitefly vector of plant viruses'. Westview, Boulder
8. CIPAC (2002) Collaborative International Pesticides Analytical Council Limits Hand book. F. Physico- chemical Methods for technical and formulated pesticides
9. Clark ND, Shipp JL, Jarvis WR, Padopoutos AP, Jewett TJ (1994) Integrated management of greenhouse crops a conceptual and potentially practical model. Hortic Sci 29:846–849
10. Dobrat W, Martijn A (1995) Collaborative International Pesticides Analytical Council CIPAC hand book. F, Physicochemical Methods for Technical and Formulated Pesticides
11. Dorr GJ, Wang S, Mayo LC, McCue SW, Forster WA, Hanan J, He X (2015) Impaction of spray droplets on leaves: influence of formulation and leaf character on shatter, bounce and adhesion. Exp Fluids 56(7):143–160
12. El- sisi AG, Hayam M, Saad, Abdel-Aziz MF (2019) Pesticidal efficacy of local save materials: Mineral oils and surfactant against broccoli pests. Egypt J Plant Prot Inst 2(1):16–21

13. European Commission (2018) Commission Implementing Regulation (EU) 2018/783 of 29 May 2018 amending Implementing Regulation (EU) 540/2011 as regards the conditions of approval of the active substance imidacloprid. Off J Eur Union 132:31–34
14. European Commission (2018) Commission Implementing Regulation (EU) 2018/784 of 29 May 2018 amending Implementing Regulation (EU) 540/2011 as regards the conditions of approval of the active substance clothianidin. Off J Eur Union 132:35–39
15. European Commission (2018) Commission Implementing Regulation (EU) 2018/785 of 29 May 2018 amending Implementing Regulation (EU) 540/2011 as regards the conditions of approval of the active substance thiamethoxam. Off J Eur Union 132:40–44
16. FAO/ WHO (2010) Manual on Development and Use of FAO and WHO Specifications for Pesticides, 1st Ed. 3rd Rev. FAO Plant Production and Protection, FAO, Rome, MT 36.3
17. Henderson CF, Tilton EW (1955) Tests with acaricides against the brown wheat mite. J Econ Entomol 48:157–161
18. Hilz E, Vermeer AWP (2013) Spray drifts review: The extent to which a formulation can contribute to spray drift reduction. Crop Prot 44:75–83
19. Houndété TA, Fournier D, Ketoh GK, Glitho IA, Nauen R, Martin T (2010a) Biochemical determination of acetylcholinesterase genotypes conferring resistance to the organophosphate insecticide chlorpyriphos in field populations of *Bemisia tabaci* from Benin, West Africa. Pestic Biochem Physiol 98(1):115–120
20. Houndeté TA, Kétoh GK, Hema OS, Brévault T, Glitho IA, Martin T (2010b) Insecticide resistance in field populations of Bemisiatabaci (Hemiptera: aleyrodidae) in West Africa. Pest Manag Sci 66:1181–1185
21. Janssen JAM, Tjallingii WF, Van Lenteren JC (1989) Electrical recording and ultrastructure of stylet penetration by the greenhouse whitefly. Entomol Exp Appl 52:69–81. https://doi.org/10.1111/j.1570-7458.1989.tb01250.x
22. Liu M, Gao M, Pei L, Environmental (2021) 284, Article ID 119710.
23. Mead MIH (2012) Acaricidal activity of essential oil of lemongrass Chymbopogon citratus
24. (DC) STAPF against Tetranychus urtcae Koch. J. plant prot. And path. Mansoura Univ. 3 (1) 43–51
25. Molin WT, Hirase K (2004) Comparison of Commercial Glyphosate Formulations for Control of Prickly Side, Purple Nutsedge, Morning Glory and Sicklepood. Weed Biology Manage 4(3):136–141. 10.1111/j.1445-6664.200400130.x
26. Naveen NC, Chaubey R, Kumar D, Rebijith KB, Rajagopal R, Subrahmanyam B, Subramanian S (2017) Insecticide resistance status in the whitefly, *Bemisia tabaci* genetic groups Asia-I, Asia-II-1 and Asia-II-7 on the Indian subcontinent. Sci Rep 7:40634
27. Nelson FC, Fiero GW (1954) Pesticide formulations, a selected aromatic fraction naturally occurring in petroleum as a pesticide solvent. J Agric Food Chem 2(14):735–737. https://doi.org/10.1021/jf60034a005
28. Philippe V, Neveen A, Marwa A, Ahmad Basel AY (2021) Occurrence of pesticide residues in fruits and vegetables for the Eastern Mediterranean Region and potential impact on public health. Food Control 119:107457
29. Regulation (EU) n°528/2012 concerning the making available on the market and use of biocidal products. Evaluation of active substances, assessment report benzoic acid Product-type 04 (Food and feed area) 11/2013 Germany
30. Salvica G, Dragica B, Ljiljana R, Andelka T (2012) Development of water-based pesticides system. J Pesticides Phytomedicine (Belgrade) 27(1):77–81. 10.2298/PIF1201077G
31. Sarfraz M, Sultana N, Rashid U, Akram MS, Sadiq A, Tariq MI (2017) Synthesis, biological evaluation and docking studies of 2, 3-dihydroquinazolin-4 (1H)-one derivatives as inhibitors of cholinesterase. 70:237–244Bioorganic Chemistry
32. Shadmany M, Omar D, Muhamad R (2015) Biotype and insecticide resistance status of *Bemisia tabaci* populations from Peninsular Malaysia. J Appl Entomol 139(1–2):67–75
33. Wang Q, Wang M, Jia Z, Ahmat T, Xie L, Jiang W (2020) Resistance to neonicotinoid insecticides and expression changes of eighteen cytochrome P450 genes in field populations of *Bemisia tabaci* from Xinjiang, China. Entomol Res

50:205–211

34. World Health Organization, WHO (1979) Specification of Pesticides Used in Public Health, 5th Ed. Geneva
35. Yadav RK, Kamala J, Saravan K, Manish K (2022) Evaluation of chilli genotypes and understanding biochemical basis of whitefly *Bemisia tabaci* (Genn.) resistance. South Afr J Bot 151:433–444

Figures

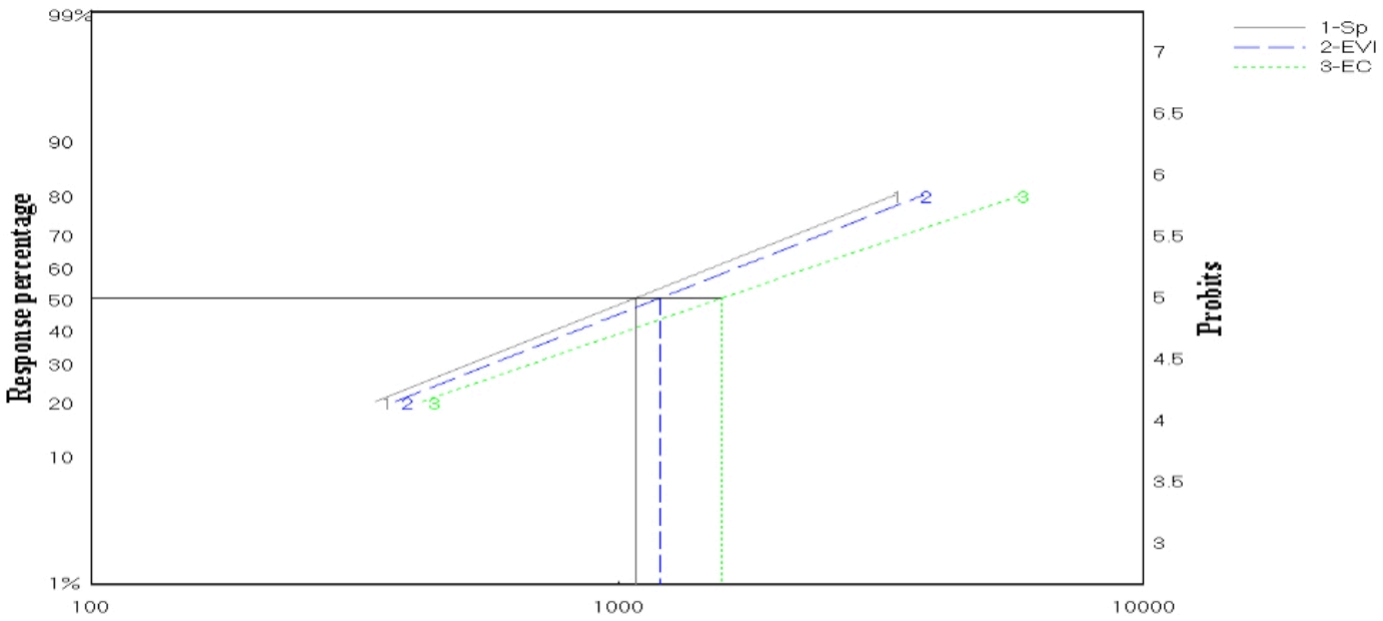


Figure 1

Toxicity lines for tested prepared formulations against *T. urticae.*

1 = Succinimide (SP), 2 = benzoic acid (EC), 3 = succinimide + benzoic acid (EW)

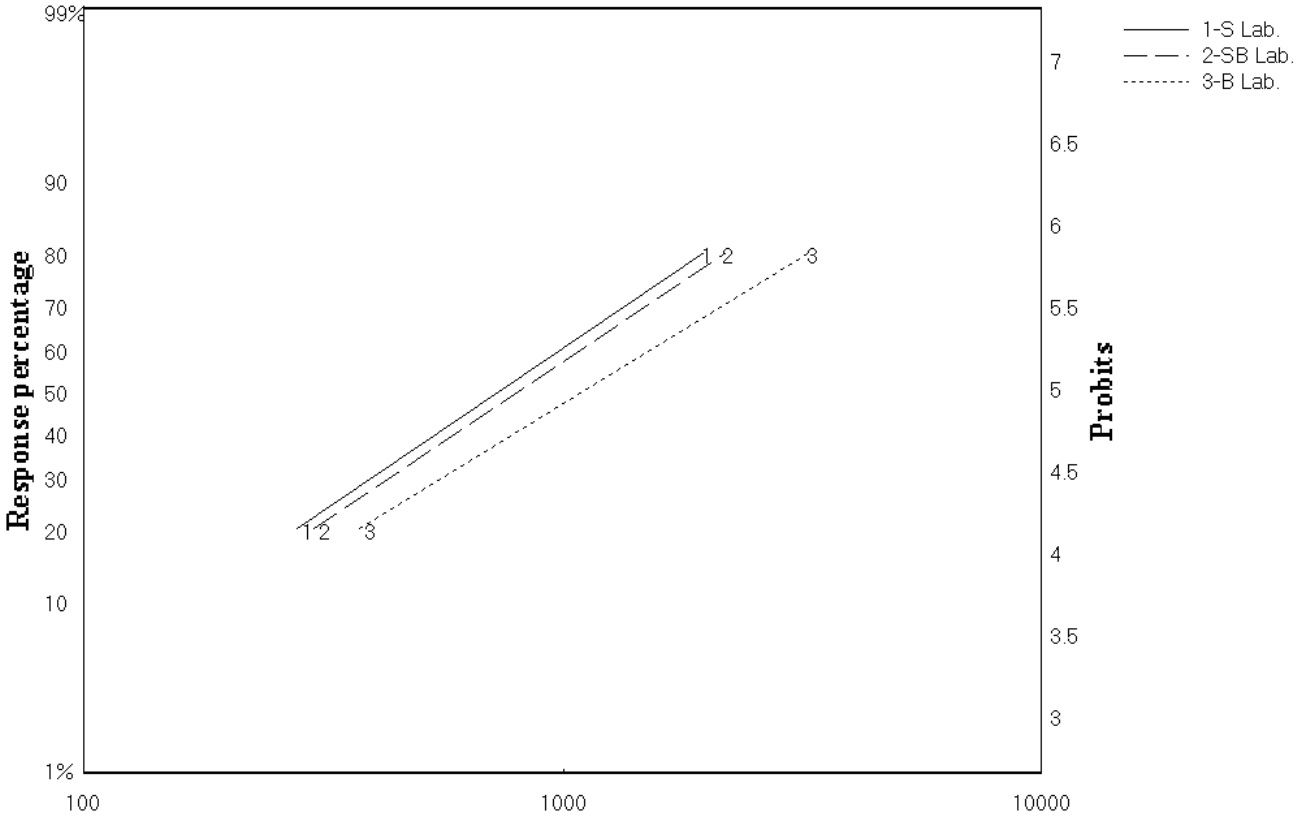


Figure 2

Toxicity lines for tested prepared formulations against *B. tabaci*.

1 (S) = Succinimide (SP), 2(B) = benzoic acid (EC), 3(SB) = succinimide + benzoic acid (EW)