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Effect of Temperature and Relative Humidity on Certain Acaricides Toxicity

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Abstract. The lethal effect of five acaricides, on the red spider mite *Tetranychus urticae*, was examined in laboratory under fifteen sequent degrees of temperature (within 2-44 ℃) at a relative humidity of 94% then, under ten sequent percentages of relative humidity (within 67-94%) at a temperature of 35 ℃. Tested acaricides were: fenpyroximate (Ortus® 5% EC), ethion (Endo® 50% EC), abamectin (Vertimec® 1.8% EC), chlorfenapyr (Challenger® 36% SC) and hexythiazox (Maccomite® 10% WP).

LC_{50} values of each acaricide correlated negatively with temperature degrees but correlated positively with relative humidity percentages.

High air temperature effect (reducing LC_{50} values) was stronger than high air relative humidity effect (increasing LC_{50} values) for all the tested acaricides.

Key words: temperature, relative humidity, acaricides, toxicity

1. Introduction

Temperature and air humidity have effects on insecticides toxicity. The toxicity of Pirimiphos-methyl and deltamethrin to *Sitophilus oryzae* showed opposite relationships with temperature [1]. Mortality of the western flower thrips, *Frankliniella occidentalis* (Pergande) subjected to different insecticides was increased with increasing temperature [2]. The resistance of the newly-hatched nymphs of *Laodelphax striatellus*, to imidacloprid, chlorpyrifos and fipronil decreased with the increase of treatment time at 35 ℃ [3]. Temperature had a significant impact on the tolerance of *Callosobruchus maculatus*, *Callosobruchus chinensis* and *Callosobruchus rhodesianus* to insecticides over 4 ℃. [4]. When dimethoate, chlorpyrifos and λ-cyhalothrin were applied to control green bug populations existing on winter wheat in Oklahoma, insecticides control responded similarly to temperature [5]. Storing raw cucumber at 4 ℃ for 48 h. caused organophosphorus pesticide reduction by 60.9–90.2% [6]. The fumigant phosphine activity against *Reticulitermes speratus* was approximately 8 times higher at 15 ℃ than that at 5 ℃ [7].

For air relative humidity, Particular susceptibility to moderately low or high temperature at low humidity is considered as an alternative to chemical treatments [8].

The present study is an attempt to determine the most suitable hygro-thermal conditions wherein each acaricide do efficiently, in other words, to define the most suitable acaricide that performs well in a particular hygro-thermal condition, at small concentrations, to reduce pollution.

2. Materials and Methods

2. 1. Residual film bioassay:

The lethal effect of five acaricides; Ortus 5% EC, Endo 50% EC, Vertimec 1.8% EC, Challenger 36% SC and Maccomite 10% WP, on the phytophagous mite *T. urticae* was examined in laboratory. Distilled water was used to prepare different diluted concentrates of each acaricide. Three fresh leaves of water melon

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plants free from *T. urticae* individuals were dipped in each concentrate then, left for an hour to dry. The basal terminates of the treated leaves petiols were put in very small bottles filled with water to keep the leaves alive for a long time while, the other terminates were surrounded with a mixture of vaseline and camphor oil to forbid escaping the examined mites. Ten live adult mites were transferred kindly from fresh leaves of water melon plants to the treated leaves by using a brush. All the previous steps were repeated at different degrees of temperature (2-44 °C) at 94% relative humidity then, at different percentages of relative humidity (67-94%) at a temperature of 35 °C by using a refrigerated incubator. For control, similar steps were done using leaves of water melon plants previously treated with distilled water only. The number of dead mites were counted and recorded after 72 hours of doing the treatments.

2. 2. Statistical analysis:

About ten concentrations of each acaricide that caused response percentages between 0 % and 100 % were considered to define LC_{50} values (median lethal concentration) and LC_{95} values (lethal concentration for 95 % of the population) by the method described by Finney [9]. LC_{50} values of each acaricide at the minimum, medium and maximum degrees of temperature and percentages of relative humidity under consideration were compared. Simple correlation coefficients between LC_{50} values and temperature degrees at a relative humidity of 94% also, between LC_{50} values and relative humidity percentages at a temperature of 35 ℃ for each tested acaricide were calculated and discussed. The slopes of LC_{50} - temperature line moreover, the slopes of LC_{50} - relative humidity lines were calculated for all the tested acaricides.

3. Results and Discussion

3. 1. Effect of temperature:

It is worthy to mention that *T. urticae* mites could bear temperatures within the range (2–44) ℃.

LC_{50} values and LC_{95} values (p.p.m.) of the tested acaricides under different degrees of temperature, at a relative humidity of 94% and at different percentages of relative humidity at a temperature of 35 ℃ are presented in Table I. LC_{50}values (p.p.m.) are graphically illustrated in Fig.1.

Table I: LC_{95} and LC_{50} values (p.p.m.) of the tested acaricides against the red spider mite *T. urticae*.

		Acaricides									
		Ortus		Endo		Vertimec		Challenger		Maccomite	
		LC_{95}	LC_{50}	LC_{95}	LC_{50}	LC_{95}	LC_{50}	LC_{95}	LC_{50}	LC_{95}	LC_{50}
Temperature (℃)	2	662.00	648.00	8326.41	7770.06	87.31	64.93	53.31	42.00	1777.24	1658.07
	5	653.70	640.08	7270.11	6714.73	57.89	49.13	37.26	29.79	1629.19	1505.16
	8	621.93	611.24	6240.12	6005.81	43.26	36.41	26.32	21.20	1406.52	1278.27
	11	601.63	584.81	5719.35	5401.55	32.38	29.56	15.52	14.14	1237.76	1146.85
	14	578.96	550.44	4997.46	4790.13	28.82	26.55	14.27	12.20	1057.18	959.24
	17	649.00	555.76	4659.67	4399.61	23.42	21.44	10.83	9.41	961.69	807.63
	20	562.78	508.65	4151.94	3746.11	19.39	16.59	8.90	6.10	850.08	698.29
	23	563.61	461.81	3232.63	2908.00	12.81	10.95	4.52	3.34	600.95	574.23
	26	595.18	443.46	2874.56	2378.51	11.13	8.43	3.20	1.66	428.79	397.43
	29	630.00	320.00	2452.34	2038.74	8.61	5.93	0.35	1.13	338.43	269.30
	32	362.38	197.21	1367.65	1081.54	5.22	2.92	0.46	0.26	315.86	240.67
	35	173.08	118.76	1069.81	782.67	2.93	1.33	0.36	0.18	269.77	200.84
	38	140.69	73.70	541.93	377.21	2.29	1.00	0.21	0.14	244.18	181.99
	41	15.65	12.19	405.80	298.16	1.11	0.47	0.21	0.14	180.34	147.33
	44	10.10	9.51	249.54	219.56	0.21	0.14	0.18	0.13	164.69	128.74
Relative humidity (%)	67	124.62	83.90	1025.61	467.38	1.80	0.48	0.14	0.08	191.20	140.67
	70	120.36	83.59	1043.38	601.06	1.28	0.54	0.13	0.08	191.49	151.70
	73	150.36	85.92	842.42	626.64	1.88	0.48	0.11	0.07	209.40	146.39
	76	180.23	94.93	911.53	620.60	2.32	0.67	0.12	0.09	217.26	160.02
	79	170.50	92.15	964.98	642.49	2.72	0.75	0.14	0.08	209.54	164.52
	82	178.79	107.11	913.87	661.25	4.07	0.80	0.22	0.11	235.29	173.30
	85	217.57	110.45	946.75	658.65	3.67	0.93	0.28	0.12	239.37	169.52
	88	206.12	116.66	972.38	721.54	3.02	1.00	0.30	0.15	283.17	191.73
	91	264.38	113.96	1125.87	802.69	3.17	1.24	0.45	0.18	285.18	197.40
	94	173.08	118.76	1069.81	782.67	2.93	1.33	0.36	0.18	269.77	200.84

According to Fig. 1, the more the temperature increases the more the toxicity increases. That matches the results of a previous study wherein the efficacy of dicofol, chlorfenethol, and plictran against *Eriophyes pyri*

(Pagenstecher) was reduced when temperatures were low [10]. In contrast, bifenazate and diazene had high toxicity to all life stages of *T. urticae* and *Panonychus citri* with no temperature dependency [11].

3. 1. 1. Comparison among LC_{50} values of each acaricide at the minimum, medium and maximum degrees of temperature:

Data shown in Table II clear that Vertimec was found to be the most sensitive, among the tested acaricides, to low temperature (LC_{50} at 2 ℃ = 463.79 fold of LC_{50} at 44 ℃) while, Maccomite was found to be the least sensitive one to low temperature (LC_{50} at 2 ℃ = 12.88 fold of LC_{50} at 44 ℃).

Similarly, in a previous study, synthetic pyrethroids; bioallethrin, *d*-phenothrin, and fenvalerate were more toxic to females of the two-spotted spider mites, *T. urticae* Koch, at 30 ℃ than at 20 ℃. LC_{50}. values differed by 1.7, 3.8, and 5.3 fold, respectively. However, two other synthetic pyrethroids; flucythrinate and cyfluthrin, gave similar toxicity values at these two temperatures [12].

3. 1. 2. Simple correlation coefficients between LC_{50} values and temperature degrees:

Data shown in Table III demonstrated strong negative correlation coefficients between LC_{50} values and temperature degrees at a relative humidity of 94% for all the tested acaricides. Moreover, correlations within 2-20 ℃ were slightly stronger than those within 23-44 ℃ for all the acaricides. In addition, slope values of LC_{50}-temperature line within 2-20 ℃ were superior compared with those within 23-44 ℃ except for ortus wherein the opposite was noticed. Hence, temperature degrees within 2-20 ℃ have stronger effect on LC_{50} values than within 23-44 ℃. Likewise, in a previous investigation, bioallethrin, *d*-phenothrin, and fenvalerate exhibited positive temperature coefficients against the mite, *Cenopalpus pulcher* (Canestrini and Fanzago). On the other hand, cypermethrin displayed a neutral temperature coefficient at 25-35 ℃ and negative temperature coefficients at 15-25 ℃ and 15-35 ℃ temperature ranges [13].

In a previous study, toxicity of deltamethrin, bifenthrin, and endosulfan to the fourth-instar larvae of *Chilo suppressalis* (Walker), at 17, 27, and 37 ℃ displayed positive temperature coefficients. However, temperature coefficients of deltamethrin and bifenthrin between 17 and 27 ℃ and between 27 and 37 ℃ varied. Inhibition of the above three insecticides to mitochondrial Na^+–K^+-ATPase and Ca^{2+}–Mg^{2+}-ATPase was affected by temperature [14]. Also, adults of the lesser mealworm, *Alphitobius diaperinus* showed that, above 40 ℃, transpiration flow abruptly increased coincide with the start of vigorous locomotors activity. This critical point corresponds to the opening of the spiracles from which the water is expelled from the tracheal system [15]. Heating to a critical temperature may induce water loss through cuticulin. Mites were subjected to more acaricide dose at active locomotion which is recognized by more oxygen consumption [16]. Recordering oxygen consumption of three oribatid species at six temperatures for three subsequent days showed that acute response to temperature increase is the main metabolic characteristic [17]. Oxygen consumption by the dust mite *Dermatophagoides farinae* varied with temperature [18]. Similarly, a previous study indicated that relatively low or high temperatures are responsible for a variety of physiological stress responses in mites. Induced thermal stress was associated with increased reactive oxygen which caused oxidative damage. Antioxidant enzymes of *Panonychus citri* significantly increased to play an important role in the process of antioxidant response to thermal stress [19]. The parasitic mites *Demodex folliculorum* and *D. brevis* can survive better at low temperatures than at high temperatures. Temperatures above 37 ℃ were harmful to the mites [20]. Exposure to high temperatures negatively affects predators and prey mites of avocado orchards [21]. For most stored-product insects, at temperatures >35 ℃, insects eventually die. The more extreme the temperature the more quickly insects die, with death occurring in a few minutes at 55 ℃. Lethal temperatures depend on species, stage of development, acclimation, and relative humidity [22].

Decreased toxicity at low temperatures may refer to the acaricide decomposition. A previous study affirmed the degradation of the pesticide fenthion on grapes kept in a refrigerator at 0 ± 0.5 ℃ and relative humidity 80% [23]. Cold environments impose several ecological and physiological constraints upon arthropods, including reduction of metabolic rate, locomotory activity, and feeding [24]. No feeding activity was detected on soil mites at −4 ℃, but increased at other temperatures [25].

3. 2. Effect of relative humidity:

LC_{50} values (p.p.m.) and LC_{95} values (p.p.m.) of each tested acaricide under different percentages of relative humidity are presented in Table I. LC_{50} values (p.p.m.) are graphically illustrated in Fig. 1. The more the relative humidity increases the more the toxicity decreases. Comparatively, toxicity of nanostructured alumina against *Sitophilus oryzae* and *Ryzopertha dominica* insects decreased as humidity increased [26].

3. 2. 1. Comparison among LC_{50} values of each acaricide at the minimum, medium and maximum percentages of relative humidity:

Data shown in Table III demonstrate that Vertimec was found to be the most sensitive to high air humidity (LC_{50} at R.H. 94 % = 2.77 fold of LC_{50} at R.H. 67 %) while, Ortus was found to be the least sensitive one (LC_{50} at R.H. 94 % = 1.42 fold of LC_{50} at R.H. 67 %). Likewise, when inert dusts were applied, in a previous study, to control *Dermanyssus gallinae* mites, there was a clear ranking of efficacy particularly at 75% relative humidity. At 85% RH the efficacy was significantly lower for all the tested compounds [27].

3. 2. 2. Simple correlations coefficient between LC_{50} values and relative humidity percentages:

Data shown in Table II demonstrated strong positive correlations coefficient between LC_{50} values and relative humidity percentages, within 67 – 94%, at the temperature of 35 ℃ for all the tested acaricides. Moreover, correlations within 82 – 94% were slightly stronger than those within 67-79% for all the acaricides. In addition, slope values of LC_{50}-relative humidity line within 82-94% were slightly more than those within 67-79 % except for Ortus and Challenger wherein the opposite was noticed. Hence, relative humidity percentages within 82-94% have stronger effect on LC_{50} values than within 67-79 %.

Strong toxicity at low air humidity may refer to increasing the acaricide percentage in relation to the weight of mites as a consequent of water loss. In a previous study at near 0 % R. H., between 20 and 40 ℃, the rate of body water loss of *Alphitobius diaperinus* adults gradually increased; on the other hand, the insects gained weight in an atmosphere close to saturation [15]. However, evaporation times of pesticide droplets increased exponentially as R.H. increased [28]. Oxygen consumption by the dust mite *D. farinae* varied with water vapour activity [18]. Low air humidity itself controls some arthropods. According to previous studies, fed larvae-protonymphs of *Metaseiulus occidentalis* and *Typhlodromus pyri* were more tolerant to low humidity than those of *Neoseiulus fallacis* and *Amblyseius andersoni* (Chant) [29]. Low humidity treatments are not effective to control *Acarus farris,* despite the good results in laboratory [30].

Table II: Comparison among LC_{50} values of each acaricide at the minimum, medium and maximum degrees of temperature and relative humidity percentages of the treatments.

Acaricide	Temperature					Relative humidity				
	2 °C		23 °C		44 °	94 %		79 %		67 %
	LC_{50}	*F. t.	LC_{50}	F. t.	LC_{50}	LC_{50}	*F.r.	LC_{50}	F. r.	LC_{50}
Ortus	648.00	68.14	461.81	48.56	9.51	118.70	1.42	92.15	1.09	83.90
Endo	7770.06	35.39	2908.00	13.24	219.56	782.60	1.67	642.40	1.37	467.38
Vertimec	64.93	463.79	10.95	78.21	0.14	1.33	2.77	0.75	1.56	0.48
Challenger	42.00	323.08	3.34	25.69	0.13	0.18	2.25	0.09	1.12	0.08
Maccomite	1658.07	12.88	574.23	4.46	128.74	200.80	1.43	164.50	1.17	140.67

* F. t.: Fold of LC_{50} value of an acaricide at a temperature in relation to LC_{50} value at 44 ℃.
* F. r.: Fold of LC_{50} value of an acaricide at a relative humidity in relation to LC_{50} value at R. H. 67%.

Table III: Relationship between temperature, or relative humidity, and LC_{50} of the tested acaricides.

	range	Relationship between temperature, or relative humidity, and LC_{50} (Correlation coefficients & Slopes)									
		Ortus 5% EC		Endo 50% EC		Vertimec 1.8% EC		Challenger 36% SC		Maccomite 10% WP	
		#Co.	slope	Co.	slope	Co.	slope	Co.	slope	Co.	slope
T.(℃)	2 - 20 ℃	-0.98 **	-7.71	-0.99 **	-213.31	-0.96 **	-2.50	-0.95 **	-1.87	-0.99 **	-54.68
	23 - 44 ℃	-0.97 **	-24.36	-0.96 **	-136.92	-0.94 **	-0.52	-0.84 **	-0.13	-0.91 **	-18.53
	2-44 ℃	-0.96 **	-17.13	-0.99 **	-184.75	-0.93 **	-1.36	-0.87 **	-0.82	-0.97 **	-37.68
RH (%)	67-79 %	0.86 ns	0.92	0.82 ns	12.33	0.88 *	0.02	0.22 ns	3.33	0.91 *	1.87
	82-94 %	0.90 *	0.89	0.92 *	12.89	0.99 **	0.05	0.97 **	0.01	0.92 *	2.08
	67-94 %	0.96 **	1.49	0.93 **	9.81	0.97 **	0.03	0.92 **	0.01	0.98 **	2.43

\# Co. = Correlation coefficient value. ** = significant at 1 % level. * = significant at 5 % level.
ns = not significant at 5 % level.

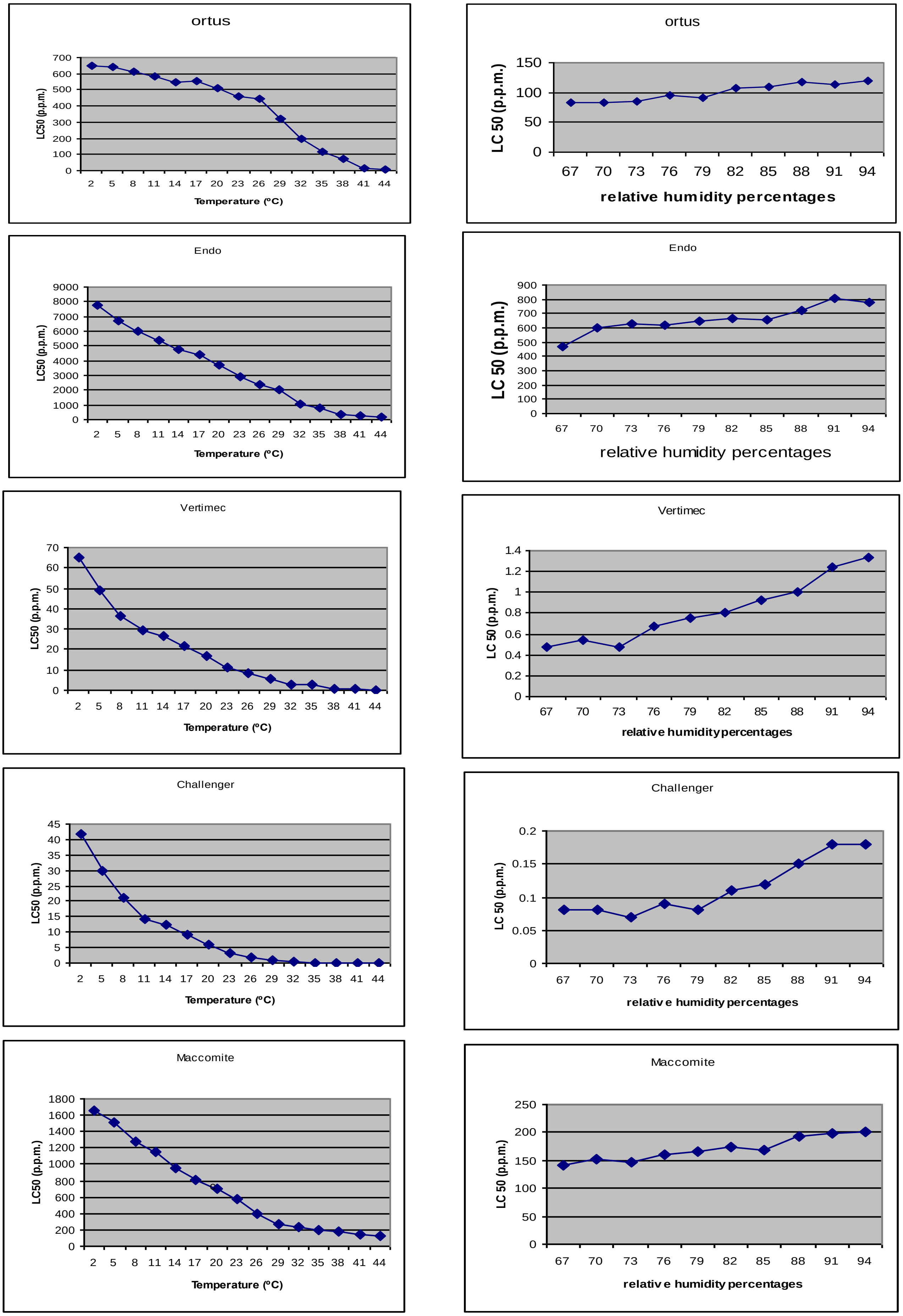

Fig. 1: Toxicity of the acaricides at different degrees of temperature and percentages of relative humidity.

3. 3. Comparison between the effect of temperature and the effect of relative humidity:

Temperature has stronger effect, on LC_{50} values, than relative humidity for the following reasons:

1- Folds expressing the increase of LC_{50} values resulting from temperature decrease (F. t.) exceeded folds expressing the increase of LC_{50} values resulting from relative humidity increase (F. r.), Table II.

2- Correlation coefficient values concerning temperature within 2-23 ℃ were significant at 1 % level, while correlation coefficient values concerning relative humidity within 67-79% are either not significant or just significant at 5% level, Table III.

3- The slope of the LC_{50} - temperature line, within 2-44, is more than the slope of LC_{50} - relative humidity line, within 67-94, Table III

Finally, hygro-thermal conditions have a strong effective on pesticides toxicity. A previous study about the effect of passive water loss and deltamethrin-induced water excretion on the mortality of the epigeal linyphiid spider *Oedothorax apicatus* showed that both onset of mortality and number of dead spiders were satisfactorily predicted at a range of combinations of temperature and relative humidity. So, water loss is an important cause of death for spiders poisoned by deltamethrin. The results of that previous study support the existence of two independent, but simultaneous, toxic effects of pyrethroid insecticides; an effect on behavior causing rapid immobilization or knockdown which is correlated positively with air relative humidity and negatively with temperature, and an effect on active water excretion causing dehydration which is correlated positively with temperature[31].

In conclusion, it is recommended to spray the above mentioned acaricides in hot days or times avoiding the days and times of high relative humidity. Besides, Vertimec is the most recommended acaricide at days, times and regions of low temperature while, Ortus is the most recommended acaricide at days, times and regions of high relative humidity.

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