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EFFICIENCY OF CERTAIN INSECTICIDES UNDER MODIFIED ATMOSPHERES AGAINST SOME STORED PRODUCT INSECTS BY

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ABSTRACT

The experiments were conducted inside gastight steel bins, each of about 0.5 m^3 volume and filled with approximately 450 kg wheat grains. The bins were situated on the ground of the agricultural experimental farm of the Faculty of Agric., Moshtohor, Tukh, Qualyubia. Grain temperature was 26±2 °C. Modified atmospheres (MAs) tested were 99% N_2 and 30±5% CO_2. Insecticides used were malathion, pirimiphos-methyl and agrothrin. Test insects were the adults of *Sitophilus oryzae*, *Rhizopertha dominica*, active and diapausing larvae of *Trogoderma granarium*. The results showed that pirimiphos-methyl and agrothrin each separately were the most and malathion the least toxic to all 3 test insects. The sensitivity of the tested insects to the insecticides or MAs varied according to insect species. Diapausing larvae of *T. granarium* were the least sensitive species to all the test insecticides and MAs. The efficacy of the tested MA of CO_2 against the various insects was greater than the MA of N_2. The mortality of the insects was concentration and exposure period-dependent.

Combinations of the previously mentioned insecticides with N_2 or CO_2 gave pronounced potentiation, additive and antagonistic effects according to tested concentration, exposure period and insect species.

INTRODUCTION

The loss caused by insect infestation is the most serious problem in grain storage (Sighamony *et al*,. 1986 and Jilani and Saxena, 1990). For more than 30 years, small dosages of synthetic insecticides have been used to protect stored grain from insect infestation, but many stored-grain insects have developed resistance to these insecticides (Parkin, 1965; Zattler, 1974; Champ and Dyte, 1976 and Redlinger *et al.*, 1988).

Modified atmospheres received considerable attention in recent years as one of the alternative methods to control stored product pests. The use of modified atmospheres, containing various levels of carbon dioxide, or high nitrogen content, against stored product pests were evaluated by several investigators (Lindgren and Vincent, 1970; Bell *et al.*, 1984; Navarro *et al.*, 1985; Navarro and Jay, 1987; El-Lakwah *et al.*, 1992; Ofuya and Reichmuth, 1993; Hashem and Reichmuth, 1994; El-Lakwah *et al.*, 1997; Mohamed, 1999 and El-Lakwah *et al.*, 2004).

Malathion, chlorpyrifos-methyl and pirimiphos-methyl are the currently registered organophosphate grain protectants against a variety of stored product insects (Subramanyam *et al.*, 2003). El-Lakwah *et al.*, 1993, stated that the organophosphorus compounds such as malathion and pirimiphos-methyl in addition to pyrethroids are used extensively for control of stored product insects this may be due to the high toxicity against insect pests and low mammalian toxicity.

The objective of this work was to evaluate the effectiveness of the combinations between modified atmospheres (CO_2 or N_2) and insecticides (malathion, pirimiphos-methyl and agrothrin) against *Sitophilus oryzae* (L.), *Rhizopertha dominica* (F.) and *Trogoderma granarium* (Everts.).

MATERIALS AND METHODS

Insects:

Laboratory strains of the rice weevil (*Sitophilus oryzae* L.) and the lesser grain borer (*Rhizopertha dominica* F.) were used as adult stage in these experiments, in addition to active and diapausing larvae of Khapra beetle (*Trogoderma granarium* Everts).

Insect cultures:

These insects were reared in glass jars of approx. 250 ml, each jar contained about 200 g. of wheat kernels for *S. oryzae*, *R. dominica* and *T. granarium* and covered with muslin cloth and fixed with rubber band. Insect cultures were kept under controlled conditions of 26±2 °C and 55±5% RH at the rearing room of the laboratory.

Active and diapausing larvae of 0.8±0.2 mg/larva and 2.7±0.2 mg/larva, respectively were used for the bioassay tests. The used active larvae were those of 3rd and 4th instars. Diapausing larvae were collected from a roll paper which had been placed on the top of the culture media. Diapausing larvae are known to be more tolerant to fumigants, inert gases and insecticides than active larvae taken from culture media (Bell *et al.*, 1984).

Wheat grains were treated by freezing at −18 °C for two weeks before application to eliminate any possible infestation by any other species. The moisture content of the grains was about 14%.

Gases used:

- Carbon dioxide was provided as a pure gas in a pressure cylinder and monitored using a CO_2 Gas-Analyzer model 200-600 (Gow-Mac Instrument Co., USA).
- Nitrogen was provided as a pure gas of more than 99% gas in a pressure cylinder and monitored using an Oxygen Analyzer 572, Servomex, England.

Insecticides:

- Malathion (1% dust), produced by Kafer El-Zayat Chemical and Pesticide Co., Egypt.
- Pirimiphos-methyl (40% dust), produced by ICI Agrochemical Co., England.
- Agrothrin (0.11% natural pyrethum) produced by Agropharm Co., U.K..

Bioassay tests:

The appropriate amount of the above mentioned dusts was mixed thoroughly with wheat grains to give the required concentrations (two concentrations for each insecticide; 2.5 and 5 ppm for both pirimiphos-methyl / 2 and 4 ppm for malathion and agrothrin). Batches of 30 adult insects (1-2 week-old) or 30 active and diapausing larvae of *T. granarium* were confined in the cloth bags (10x16 cm) each containing 50 g. treated or untreated wheat kernels for *S. oryzae*, *R. dominica* and *T. granarium*. Each bag was closed well by a rubber band and placed into the steel bins. All tests were triplicated.

Purging of the gases inside the bin:

After introducing the insect samples inside the bin, and to obtain 30% CO_2 concentration, the cylinder of CO_2 was connected with the upper valve of the bin through a polyethylene tube. The valve of the cylinder was opened for one and half minute, while the bottom valve of the bin was opened and closed after one minute from the initial purging of gas.

For achieving modified atmosphere of high nitrogen content (99% N_2), the upper valve of the bin was opened for 5 minutes after the connection of N_2-cylinder with bin, while the bottom bin valve was opened for two minutes, after which it was closed tightly (El-Lakwah *et al.*, 2003).

Treatment procedure:

Insect samples were exposed to different treatments for various exposure periods (2, 3, 5, 7 and 14 days) inside gastight steel bins during summer time at grain temperature of around 26±2°C and 55±5% RH.

Post- treatment procedure:

Aeration was carried out after exposure periods, the mortality of the insect adults was determined after 48 hrs.

Calculation of Joint Action:

For the evaluation of the joint action of malathion, pirimiphos-methyl and agrothrin under modified atmospheres, the following equation was adopted as reported by Mansour *et al.* (1966):

$$\text{Co-toxicity Factor} = \frac{\text{\%Observed Mortality} - \text{\%Expected Mortality}}{\text{\%Expected Mortality}} \times 100$$

This factor was used to classify the results into three categories. A positive factor of +20 or more meant potentiation effect, a negative factor of –20 or more meant antagonism, and any intermediate value, i.e. between +20 and –20 was considered an additive effect.

RESULTS AND DISCUSSION

The obtained results are given in Tables (1 to 6), the data revealed that pirimiphos-methyl and agrothrin each separately, and at their lower concentrations 2.5 and 2 ppm, respectively, were more toxic than the higher concentration of malathion 4 ppm to all 3 test insects. The present results coincided with those of Hasan *et al*, (1983) in their experiments on the toxicity of bromophos (Nexion), 5 other organophosphorus and 2 organochlorine insecticides against *S. oryzae*, *T. castaneum*, *R. dominica* and *C. chinensis*, malathion was the least toxic to all 4 test insects.

Mortality percentages indicated also that the efficacy of insecticides and CO_2 or N_2 when each of them was used separately or in mixtures (the insecticide under MA of CO_2 or N_2) was increased with extending the time of exposure with all the insect species.

A- The Efficacy and Combined Action of Tested Insecticides Under MA of 30±5% CO_2 to Various Insect Species at Grain Temperature of 26± 2 °C.

Table (1) presents the results of the efficacy and combined action of malathion dust under MA of 30±5% CO_2 to the adults of *S. oryzae* and *R. dominica* as well as active and diapausing larvae of *T. granarium* at grain temperature of 26± 2 °C and 55± 5% RH.

Mortality values resulting from the mixtures of malathion and CO_2 were in general greater than those obtained from each treatment alone, malathion dust at 2 ppm and 7days- exposure gave 42 and 26% mortality with the adults of *S. oryzae* and *R. dominica*, respectivly. These values increased to 68 and 33% at 4 ppm for the tow mentioned insects, respectively. Meanwhile, they were 78 and 84 as well as 30 and 34% after 14 days post – treatment at the low and high malathion concentration for the active and diapausing larvae of *T. granarium*, respectively. However, mortalities resulted from CO_2 alone were 30 and 6% at 2 days-exposure and these values increased to 97 and 99% after 7 days-exposure for the adults of *S. oryzae* and *R. dominica*, respectivly. While these values were 25 and 16% at 5 days-exposure and increased to 77 and 66% after 14 days-exposure for the active and diapausing larvae of *T. granarium*, respectively. Treatment of malathion at 4 ppm under MA of 30±5% CO_2 resulted in complete kill after one week exposure time for *S. oryzae* and *R. dominica* adults, while these combined treatment resulted in 91% and 83% mortality after two weeks exposure period with the active and diapausing larvae of *T. granarium*, respectively. It was quite clear that using MA of CO_2 alone, or in combination with the grain dust followed a time-dependent phenomenon. Co-toxicity values presented in Table (1) which resulting from the mixtures of malathion at 2 and 4 ppm plus 30±5% CO_2 indicated potentiation or additive effect at the two mentioned malathion concentrations and various periods of exposure with *S. oryzae*. While in case of *R. dominica*, a negative effect was observed at short exposure, but these effect turned to an additive effect at longer period as a function of exposure time. In case of the active and diapausing larvae of *T. granarium*, using malathion dust at lower concentration under MA of 30±5% CO_2 at 26± 2 °C resulted in antagonistic effects at the various tested exposure periods of 5 – 14 days. Contrarily, combination of CO_2 and malathion at the higher application rate of 4 ppm exhibited additive effects at the all periods of exposure.

Results of the efficacy and combined action of pirimiphos-methyl dust at 2.5 and 5 ppm under MA of 30±5% CO_2 to the tested insects at grain temperature of 26± 2 °C, 55± 5% RH. are recorded in Table (2).

Table (1): The Combined Action of Malathion Dust Under MA of 30±5% CO_2 to Various Insect Species at Grain Temperature of 26± 2°C and 55± 5% RH.

Exposure Period (days)	*% Mortality at Various Treatments*					*Co-toxicity Factor*		*Type of Joint Action*	
	Malathion (ppm)		*MA of 30± 5% CO_2*	*Malathion + CO_2*					
	2 (a)	*4 (b)*		*(a)*	*(b)*	*(a)*	*(b)*	*(a)*	*(b)*
***S. oryzae*-adults**									
2	1	3	30	62	78	100	136	s	s
3	3	4	90	78	84	-16	-11	d	d
5	22	36	94	90	91	-10	-9	d	d
7	42	68	97	98	100	-2	0	d	d
***R. dominica*-adults**									
2	5	6	6	5	7	-55	-42	a	a
3	14	24	50	50	53	-22	-28	a	a
5	21	28	98	96	98	-4	-2	d	d
7	26	33	99	100	100	0	0	d	d
***T. granarium* active larvae**									
5	20	28	25	29	48	-36	-9	a	d
7	41	48	31	45	71	-38	-10	a	d
10	60	67	54	60	81	-40	-19	a	d
14	78	84	77	75	91	-25	-9	a	d
***T. granarium* diapause larvae**									
5	8	14	16	19	32	-21	7	a	d
7	20	24	26	33	49	-25	-2	a	d
10	18	30	46	47	66	-27	-13	a	d
14	30	34	66	59	83	-39	-17	a	d

a = antagonistic effect / d = additive effect / s = potentiation effect

The obtained mortality percentages showed clearly that the efficacy of pirimiphos-methyl to the different tested insect species was concentration-dependent. The diapause larvae of Khapra beetle were slightly tolerant to pirimiphos-methyl compared with the active larvae and the adults of the tested species. Generally, the results revealed that the combined treatment of pirimiphos-methyl under MA of CO_2 enhanced the resulted mortalities of all the tested insects at all exposure periods. Co-toxicity values resulting from addition of CO_2 at 30±5% concentration to pirimiphos-methyl at its two application rates 2.5 and 5 ppm induced mostly additive effects or sometimes potentiation actions with all the insects at various periods of exposure.

Table (3) shows the results of efficacy and combined action of agrothrin dust at 2 and 4 ppm under MA of 30±5% CO_2 to the tested insects at grain temperature of 26± 2 °C and 55± 5% RH.

Percentage mortalities apparently indicated that the efficacy of agrothrin was concentration-dependent. Treatment of the adults of *S. oryzae* and *R. dominica* with agrothrin at the two applied concentration under the above mentioned MA of CO_2 gave considerably higher mortality values than those of each component alone at various exposure periods. Co-toxicity values of the mixtures showed also additive or potentiation effects with the three insect species at the different periods of exposure.

Table (2): The Combined Action of Pirimiphos-methyl Dust Under MA of 30±5% CO_2 to Various Insect Species at Grain Temperature of 26±2 °C and 55±5% RH.

Exposure Period (days)	*% Mortality at Various Treatments*					*Co-toxicity Factor*		*Type of Joint Action*	
	Pirimiphos-methyl (ppm)		*MA* of 30± 5% CO_2	*Pirimiphos-methyl + CO_2*					
	2.5 (a)	*5 (b)*		*(a)*	*(b)*	*(a)*	*(b)*	*(a)*	*(b)*
***S. oryzae*-adults**									
2	71	80	30	100	100	0	0	d	d
3	86	95	90	100	100	0	0	d	d
5	93	100	94	100	100	0	n	d	n
7	100	100	97	100	100	n	n	n	n
***R. dominica*-adults**									
2	15	36	6	46	96	119	129	s	s
3	35	56	50	71	98	-17	-2	d	d
5	51	74	98	95	100	-5	0	d	d
7	66	97	99	100	100	0	0	d	d
***T. granarium* active larvae**									
5	34	57	25	48	82	-19	0	d	d
7	49	89	31	93	100	16	0	d	d
10	74	94	54	96	100	-4	0	d	d
14	100	100	77	100	100	n	n	n	n
***T. granarium* diapause larvae**									
5	20	23	16	43	52	19	33	d	s
7	30	40	26	65	84	16	27	d	s
10	33	43	46	80	96	1	8	d	d
14	54	66	66	88	98	-12	-2	d	d

d = additive effect / s = potentiation effect / n = co-toxicity factor was not calculated, where the insect mortality of pirimiphos-methyl alone was 100%.

On the other hand, co-toxicity values of applying agrothrin at the concentrations of 2 and 4 ppm under the above mentioned MA of CO_2 at 26± 2 °C indicated antagonistic effects with the active and diapausing larvae of Khapra beetle at all the tested exposure periods of 5 – 14 days.

B- The Efficacy and Combined Action of Tested Insecticides Under MA of 99% N_2 to Various Insect Species at Grain Temperature of 26± 2 °C.

Data of the efficacy and combined action of malathion dust at 2 and 4 ppm under MA of 99% N_2 to the tested insects at grain temperature of 26± 2 °C and 55± 5% RH. are given in Table (4).

Mortality percentages resulting from applying malathion under MA of 99% N_2 at 26± 2 °C gave apparently higher mortality values than when malathion or N_2 was used separately. Co-toxicity values resulting from the mixtures indicated potentiation or additive effect with all the tested insects at various exposure periods.

The results of the efficacy and combined action of pirimiphos-methyl dust at 2.5 and 5 ppm under MA of N_2 to the tested insects at grain temperature of 26± 2 °C and 55± 5% RH.are shown in Table (5).

Table (3): The Combined Action of Agrothrin Dust Under MA of 30±5% CO_2 to Various Insect Species at Grain Temperature of 26±2 °C and 55±5% RH.

Exposure Period (days)	*% Mortality at Various Treatments*					*Co-toxicity Factor*		*Type of Joint Action*	
	Agrothrin (ppm)		*MA of 30± 5% CO_2*	Agrothrin + CO_2					
	2 (a)	*4 (b)*		*(a)*	*(b)*	*(a)*	*(b)*	*(a)*	*(b)*
				***S. oryzae*-adults**					
2	28	54	30	98	100	69	19	s	d
3	44	66	90	99	100	-1	0	d	d
5	70	82	94	100	100	0	0	d	d
7	96	98	97	100	100	0	0	d	d
				***R. dominica*-adults**					
2	78	78	6	100	100	19	19	d	d
3	84	85	50	100	100	0	0	d	d
5	91	94	98	100	100	0	0	d	d
7	100	100	99	100	100	n	n	n	n
				***T. granarium* active larvae**					
5	42	53	25	31	51	-54	-35	a	a
7	59	78	31	38	68	-58	-32	a	a
10	77	88	54	40	73	-60	-27	a	a
14	89	93	77	43	79	-57	-21	a	a
				***T. granarium* diapause larvae**					
5	11	31	16	19	31	-30	-34	a	a
7	25	45	26	35	53	-31	-25	a	a
10	42	56	46	38	62	-57	-38	a	a
14	58	67	66	42	71	-58	-29	a	a

a = antagonistic effect / d = additive effect / s = potentiation effect / n = co-toxicity factor was not calculated, where the insect mortality of agrothrin alone was 100%.

Results of the combinations of pirimiphos-methyl and 99% N_2 indicated generally improved mortalities with all the tested insects at various periods of exposure. Co-toxicity values of the mixtures produced in all cases potentiation or additive effect.

Table (6) shows the results of the efficacy and combined action of agrothrion dust at 2 and 4 ppm under MA of 99% N_2 to the tested insects at grain temperature of 26± 2 °C and 55± 5% RH.

Mortality values resulted from applying agrothrin under MA of 99% N_2 gave generally greater mortalities than each treatment alone for various insects at the different periods of exposure. Co-toxicity values resulting from the mixtures of agrothrin and 99% N_2 revealed in all cases additive or potentiation effect.

The present results agreed with Darwish, (1997); Mohamed, (1999) and El-Lakwah *et al.* (1998, 2000a and 2000b) in their experiments on the combined action of plant extracts in presence of various atmospheres of either CO_2 or N_2. Also El-Lakwah *et al.* (2002) mentioned that the combined action of Dill and Cumin seed extracts under MAs of various carbon dioxide concentrations or MA of very high nitrogen content resulted in either synergistic or additive effects with both larvae active and diapausing of *T. granarium*. at the different periods of exposure.

Table (4): The Combined Action of Malathion Dust Under MA of 99% N_2 to Various Insect Species at Grain Temperature of 26±2 °C and 55±5% RH.

Exposure Period (days)	% Mortality at Various Treatments					Co-toxicity Factor		Type of Joint Action	
	Malathion (ppm)		MA of 99 % N_2	Malathion + N_2					
	2 (a)	4 (b)		(a)	(b)	(a)	(b)	(a)	(b)
S. oryzae-adults									
2	1	3	25	78	96	200	243	s	s
3	3	4	58	95	98	56	58	s	s
5	22	36	94	98	99	-2	-1	d	d
7	42	68	100	100	100	n	n	n	n
R. dominica-adults									
2	5	6	8	48	48	269	243	s	s
3	14	24	11	51	52	104	49	s	s
5	21	28	15	55	59	53	37	s	s
7	26	33	48	61	66	-18	-19	d	d
T. granarium active larvae									
5	20	28	3	80	83	248	168	s	s
7	41	48	8	86	86	76	54	s	s
10	60	67	45	98	100	-2	0	d	d
14	78	84	94	100	100	0	0	d	d
T. granarium diapause larvae									
5	8	14	5	70	78	439	311	s	s
7	20	24	6	78	81	200	170	s	s
10	18	30	15	85	83	158	84	s	s
14	30	34	66	88	100	-8	0	d	d

d = additive effect / s = potentiation effect / n = co-toxicity factor was not calculated, where the insect mortality of 99% N_2 alone was 100%.

Table (5): The Combined Action of Pirimiphos-methyl Dust Under MA of 99% N_2 to Various Insect Species at Grain Temperature of 26±2 °C and 55±5% RH.

Exposure Period (days)	% Mortality at Various Treatments					Co-toxicity Factor		Type of Joint Action	
	Pirimiphos-methyl (ppm)		MA of 99 % N_2	Pirimiphos-methyl + N_2					
	2.5 (a)	5 (b)		(a)	(b)	(a)	(b)	(a)	(b)
S. oryzae-adults									
2	71	80	25	100	100	4	0	d	d
3	86	95	58	100	100	0	0	d	d
5	93	100	94	100	100	0	n	d	n
7	100	100	100	100	100	n	n	n	n
R. dominica-adults									
2	15	36	8	50	73	117	66	s	s
3	35	56	11	53	75	15	12	d	d
5	51	74	15	71	85	8	-5	d	d
7	66	97	48	90	100	-10	0	d	d
T. granarium active larvae									
5	34	57	3	83	98	124	63	s	s
7	49	89	8	88	100	54	4	s	d
10	74	94	45	98	100	-2	0	d	d
14	100	100	94	100	100	n	n	n	n
T. granarium diapause larvae									
5	20	23	5	81	85	224	204	s	s
7	30	40	6	86	86	139	87	s	s
10	33	43	15	91	90	90	55	s	s
14	54	66	66	95	100	-5	0	d	d

d = additive effect / s = potentiation effect / n = co-toxicity factor was not calculated, where the insect mortality of 99% N_2 or pirimiphos-methyl each alone or together was 100%.

Table (6): The Combined Action of Agrothrin Dust Under MA of 99% N_2 to Various Insect Species at Grain Temperature of 26±2 °C and 55±5% RH.

Exposure Period (days)	*% Mortality at Various Treatments* Agrothrin *(ppm)* 2 (a)	4 (b)	*MA of* 99 % N_2	Agrothrin + N_2 *(a)*	*(b)*	*Co-toxicity Factor* *(a)*	*(b)*	*Type of Joint Action* *(a)*	*(b)*
				***S. oryzae*-adults**					
2	28	54	25	96	100	81	27	s	s
3	44	66	58	98	100	-2	0	d	d
5	70	82	94	100	100	0	0	d	d
7	96	98	100	100	100	n	n	n	n
				***R. dominica*-adults**					
2	78	78	8	95	95	11	11	d	d
3	84	85	11	98	100	3	4	d	d
5	91	94	15	100	100	0	0	d	d
7	100	100	48	100	100	n	n	n	n
				***T. granarium* active larvae**					
5	42	53	3	65	80	44	43	s	s
7	59	78	8	73	91	9	6	d	d
10	77	88	45	85	96	-15	-4	d	d
14	89	93	94	94	98	-6	-2	d	d
				***T. granarium* diapause larvae**					
5	11	31	5	51	60	219	67	s	s
7	25	45	6	71	61	129	20	s	d
10	42	56	15	80	65	40	-9	s	d
14	58	67	66	86	95	-14	-5	d	d

d = additive effect / s = potentiation effect / n = co-toxicity factor was not calculated, where the insect mortality of 99% N_2 or Agrothrin each alone was 100%.

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فاعلية بعض المبيدات تحت الأجواء المعدلة ضد بعض حشرات الحبوب المخزونة

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أجرى هذا البحث بغرض دراسة فاعلية تأثير ثلاثة مساحيق من المبيدات هى الملاثيون والبيريميفوس- ميثيل والأجروثرين تحت الأجواء المعدلة من غاز النتروجين ٩٩% و ثانى أكسيد الكربون ٣٠±٥ % على درجة حرارة الحبوب ٢٦±٢م°.

أجريت التجارب داخل الصوامع محكمة الغلق حجم كلا منها ١/٢ م٣ وكانت مملوءة بحوالى ٤٥٠ كيلو جرام من حبوب القمح ووضعت الصوامع داخل مزرعة

الكلية بمشتهر. أجريت هذه الأختبارات على الحشرات الكاملة لكلا من سوسة الأرز ، ثاقبة الحبوب الصغرى وكذلك ضد اليرقات النشطة والساكنة لخنفساء الصعيد.

أوضحت النتائج أن مبيدى البيريميفوس- ميثيل والأجروثرين كانا الأشد سمية بينما مبيد الملاثيون كان الأقل سمية للحشرات تحت الدراسة كما إختلفت حساسية الحشرات المختبرة للمبيدات الثلاثة أو الأجواء المعدلة حسب نوع الحشرة.

وقد أشارت النتائج كذلك أن اليرقات الساكنة لخنفساء الصعيد كانت الأقل حساسية لكل المبيدات المختبرة أو الأجواء المعدلة من النتروجين أو ثانى أكسيد الكربون عند إستخدام كلاً منها منفرداً.

وأظهرت النتائج أيضاً أن فاعلية غاز ثانى أكسيد الكربون كانت أكبر من فاعلية غاز النتروجين كما بينت النتائج أن نسبة الموت للحشرات تتوقف على التركيز المستخدم من المبيد وفترة التعريض.

وقد أعطى التأثير المشترك للمبيدات المختبرة تحت الأجواء المعدلة من غاز النتروجين أوثانى أكسيد الكربون إما تأثير أضافة أو تقوية أو تضاد وكان ذلك متوقفاً على نوع الحشرة ، التركيز المستخدم وكذلك فترة التعرض