COMBINED EFFECT OF SOME PLANT EXTRACTS UNDER MODIFIED ATMOSPHERE OF CARBON DIOXIDE AGAINST STORED GRAIN INSECTS

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Abstract

Where, tests were conducted inside fiberglass bins during summer time, the temperature of grain was 32 ± 2°C.The plant extracts tested were the acetone and petroleum ether extracts of Poinciana seeds *(Delonix regia);* Cloves flowering buds *(Syzgium aromaticum);* Cinnamon *(Cinnamonum zeylancicum);* Radish seeds *(Raphanus sativus);* and Mustard seeds *(Brassica alba).* Test insects were *Sitophilus orzae(L); Rhizopertha dominica (F.) and Tribolium Castaneum.*

The various plant extracts were tested alone at 0.4% and 0.8% (w/w) concentrations and under modified atmosphere (MA) of 20 ± 5% Co_2. Results concerning Co-toxicity values resulted from addition of 20 ± 5% Co_2 to the acetone and petroleum ether extracts of various plants revealed that the extracts at 0.4% and 0.8% produced additive effects for all tested insect species at all exposure periods. Comparing the toxicity of these materials to the insect species, the rice weevil *Sitophilus oryzae (L.)* was the most sensitive, followed by the lesser grain borer *Rhizopertha dominica (F)* and the red flour beetle *Tribolium castaneum* (Herbst) adults. Meanwhile, treatment of various insect species with the plant extracts under modified atmosphere of Co_2 produced obviously higher mortality values than each treatment alone and proved to be effective against the three insect species under study.

INTRODUCTION

Today, attention has been focused to control stored product pests with other alternative pest control agents such as extracts of plant leaves, flowers and seeds as powders (Ivbijaro, 1984; Su, 1985; Halawa, 2003 and 2004; 2005 and Halawa *et al.,* 2009).

Controlled or modified atmospheres (MA) received considerable attention in recent years as one of the alternative methods to control stored product insects.
The effectiveness of Co_2 to some stored products insects is increased with reduced oxygen concentrations at least down to 7% level. But *Sitophilus spp.* had shown a reversal response at very low oxygen concentrations (Krishnamurthy *et al.,* 1986 and Reichmuth, 1986).

The exposure of insects to carbon dioxide and its effect on insect mortality were studied by some investigators (Harein and Press, 1968; Aliniazee, 1971; Jay and Pearman, 1971 and Tunc, 1983).

The aim of this study was to investigate the combined effect of the plant extracts and the MA of 20 ± 5% Co_2 against certain insects infesting stored grains.

MATERIALS AND METHODS

Insects:

Laboratory strains of three stored products insects namely the rice weevil *Sitophilus oryzae* (L.) (Curculionidae, Coleopetera); the lesser grain borer *Rhizopertha dominica* (F.) (Bostrychidae) and the red flour beetle *Tribolium castaneum* (Herbst) were used during this study.

Insects were maintained at the stored products pests laboratory of the plant protection Dept., Faculty of Agric., Moshtohor, Zagazig University.

Plant extracts:

Seeds of Poinciana (Delonix regia), cloves flowering buds (*Syzygium aromaticum*), cinnamon (*Cinnamonum zeylanicum*), radish seeds (*Raphanus sativus*) and mustard seeds (*Brassica alba*) were either bought from the local market or from the farm of the faculty. The active ingredient present in the preceding plant species are:

1- Poinciana: L-Azetidine-2-carboxylic acid (Cromwell, 1979).
2- Cloves: Casuarictin and Eugeniin (Tellimagrandin II) (Okuda, 1983).
3- Cinnamon: Carpacin (Isosafrole methyl ether) (Mohandas, 1969).
4- Radish seeds: Brassinin (Shimizu, 1986) and (Methyl Mercaptan 9 Methane thiol: Methyl thioalcohol) (Keethaas, 1931).
5- Mustard seeds: S-Methyl-L-Cysteine S-oxide (3-"Methyl sulfonyl" alanine) (Bansley, 1968).

These plants were ground using a high speed mill into a fine powder and then extracted with acetone at 50°C under reduced pressure to a small volume as described by Su (1985). The crude gum of the extract was weighed and dissolved by the solvent to get 10% (w/v) stock solution. Concentrations were prepared by diluting the stock solution using the same solvent. Five ml of the stock solution was added to fifty grams of maize grains to obtain a concentration of 1% w/w Grain was mixed well with and left for two hours for air dryness. Thirty adult insects were confined with the treated maize grains in the tests.

Three replicates were used for each concentration. Jars were covered with muslin and rubber band. Untreated grains were mixed only with 5 ml solvent for complete

coverage. Mortality was assessed after 1, 2, 3, 5, 7 and 14 days from treatment, jars were kept at 26 ± 2°C and 65 ± 5% R.H.

Reduction in F1-progeny was calculated after 60 days from treatment according to the following equation:

$$\% \text{ Reduction} = \frac{\text{No. of emerged adults in control} - \text{No. of emerged adults in treatment}}{\text{No. of emerged adults in control}} \times 100$$

Modified atmosphere (MA) tests:

Tests of modified atmosphere (MA) of carbon dioxide were achieved inside closed fiberglass bins, each of Ca 0.2m^3 volume.

Each Fiberglass bin was provided with one inlet tube near its top and one outlet near the bottom for insersion of carbon dioxide as well as for monitoring of Co_2 concentration inside the bin. The sealing of the bins was improved by constructing a well closed covers. The bins were kept under storage conditions inside a store-room during the whole period of the experiment.

Technique:

Bags, each containing 50 g of maize grains and 30 adults of the test insect were inserted inside the bins. The cover of each bin was closed well. Modified atmosphere of 25% Co_2 was established inside the bins.

After the desired exposure period, each glass bin was aerated and insects, were transferred to the laboratory for mortality assessment. Mortality data were corrected using Abbot's formula (1925). Grains temperature and the relative humidity inside the metal drum were recorded during the tests.

Determination of Co_2 concentration:

Carbon dioxide (Co_2) concentration was monitored using carbon dioxide gas analyzer model 200-600 Gow-Mac-Instruments company U.S.A. inside the metal drums.

Calculation of joint action of the plant extract and CO_2:

For the evaluation of the combined action of the plant extract and MA of Co_2 the following equation adopted by Mansor *et al.* (1966) was used.

$$\text{Co-toxicity factor} = \frac{\text{Observed mortality (\%)} - \text{Expected mortality}}{\text{Expected mortality (\%)}} \times 100$$

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

Statistical analysis:

Dosage mortality response was determined by probit analysis (Finney 1971 using a computer program of Noack and Reichmuth(1978).)

RESULTS AND DISCUSSION

Effect of the plant extracts under modified atmosphere (MA) of 20 ± 5% Co_2 and their combined action with the tested insect species.

The effectiveness of acetone and petroleum ether extracts of certain plants, i.e. Poinciana seeds (*Delonix regia*), Cinnamon strip bark (*Cinnamomum zeylanicum*), Cloves flowering buds (*Syzygium aromaticum*), Mustard seeds (*Brassica alba*) and Radish seeds (*Raphanus sativus*), was tested against the adults of *Sitophilus oryzae* (L.), *Rhizopertha dominica* (F.) and *Tribolium castaneum* (Herbst). Tests were carried out in the laboratory at 26 ± 2°C and 60 ± 5% R.H.

The various plant extracts were tested alone and under MA of 20 ± 5% CO_2 at 0.4% and 0.8% (w/w) concentrations only. Tests were conducted inside fiberglass bins during summer time (grain temp. = 32 ± 2°C).

The obtained results are shown in Tables (1-20). Results concerning Co-toxicity values results from addition of 20 ± 5% CO_2 to Poinciana seeds (D. regia) extracts are given in Tables (1 & 2) results revealed that the 0.4 & 0.8% acetone extracts under 20 ± 5% CO_2 produced additive effect for the three insect species at all exposure periods. Also results revealed that the 0.4 and 0.8% (w/w) petroleum ether extracts of Poinciana seeds under 20 ± 5% Co_2 produced also additive effects for all three insect species at the various exposure periods (Tables 3 & 4).

Effect of MA Co_2, acetone and petroleum ether extracts of Cinnamom strip bark *C. zeylanicum* alone and in combinations on the percent mortality and their Co-toxicity factors are listed in (Tables 5, 6, 7 and 8) Co-toxicity values presented in these Tables, clearly showed at 1, 2, 3 and 5 days exposure periods additive effects for the two tested concentrations with the three insect species.

Joint action effect of 20 ± 5% Co_2 plus acetone and petroleum ether extracts of cloves flowering buds (*S. aromaticum*) to the adults of the three insects infesting stored maize grains inside the fiberglass bins is summarized in Tables (9-12). The results revealed additive effects for the three insect species at all tested exposure periods.

That is to say, carbon dioxide potentiated the toxicity of the extracts against *S. oryzae, R. dominica* and *T. castaneum* by using various mixtures of the plant extracts adding Co_2 at various exposure periods.

Joint action effect of 20 ± 5% Co_2 and the extracts of white mustard seeds (*Brassica alba*) for the adults of the three insect species infesting stored maize grains is given in Tables (13-16).

Results showed additive effects for *S. oryzae, R. dominica* and *T. castaneum* after 1, 2, 3 and 5 days exposure periods.

On the other hand, Co-toxicity factors resulting from addition of Co_2 to *B. alba* seeds extracts at (0.4 and 0.8%) concentrations of acetone and petroleum ether was greater for *S. oryzae* than in case of *R. dominica* and *T. castaneum* after all exposure periods.

Results concerning co-toxicity factor resulting from adding 20 ± 5% CO_2 to 0.4 and 0.8 concentrations of the acetone and petroleum ether extract of radish seeds (*R. sativus*) are listed (Tables 17, 18, 19 and 20). The results indicated additive effects at all exposure time for *S. oryzae, R. dominica* and *T. castaneum* adults.

From the above data it could be shown that the joint action of the extracts of the five tested plants under MA of 20 ± 5% Co_2 produced additive effects for all three insect species at all exposure periods.

Also, the various plant extracts were more toxic against *S. oryzae* adults than other insect species at both concentrations and all exposure periods. Meanwhile, petroleum ether extract was more toxic than the acetone extract. The results obtained for the joint action are in harmony with the findings of other investigators evaluating the combined action of other plant extracts and various modified atmospheres against stored products insects (El-Lakwah *et al.*, 1996; Halawa *et al.*, 1998; Mohamed, 1999; El-Lakwah *et al.*, 2000 and Abd El-Aziz, 2002).

The toxicity effect of these plant extracts is due to the fact that these plants contain L-Azetidi-2-carboxylic acid, Casuarictin, Eugeniln II; Tellimagrandin, Carpacin, Brassinin and S-Methyl-L-Cysteine- S-oxide or substances, which posses antifeedant, repellent or other lead to a moulting disturbance which is often lethal (Cronwell, 1979; Okuda, 1983; Mohandas, 1969; Shimizu, 1986 and Keethaas, 1931). Furthermore, treatment of the various insects with the plant extracts under modified atmosphere of CO_2 produced higher mortality values than each treatment alone and proved to be effective against the three insect species.

Table 1. Joint action effect of 20 ± 5% CO_2 and 0.4% (w/w) acetone extract of Poinciana seeds (*Delonix regia*) to the adults of some insects infesting stored maize grains inside the fiberglass bins at 32 ± 2°C and 60 ± 5% RH.

Insect species	Exposure period (days)	% adult mortality			CO-toxicity factor	Type of joint action
		MA of 20±5% CO_2 alone	Extract at 0.4% (w/w) alone	Extract + CO_2		
Sitophilus oryzae	1	6.7±0.0	42.5±1.9	51.2±3.3	4.1	d
	2	33.1±5.0	83.8±5.0	100±0.0	0.0	d
	3	46.7±6.9	100±0.0	100±0.0	0.0	d
	5	52.7±3.3	100±0.0	100±0.0	0.0	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Rhizopertha dominica	1	3.3±0.0	5.9±1.9	8.0±0.0	-13.5	d
	2	6.1±1.9	10.7±0.0	13.7±1.9	-18.5	d
	3	14.7±3.3	18.7±1.9	38.6±1.9	15.6	d
	5	19.6±3.0	33.1±1.9	44±1.9	-16.5	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Tribolium castaneum	1	3.3±0.0	0.0±0.0	3.3±0.0	0.0	d
	2	7.2±0.0	10±1.9	14±3.3	-18.6	d
	3	16.8±1.9	19.9±2.0	33.2±1.9	-9.5	d
	5	27.6±3.3	29.3±3.3	50±1.9	-12.1	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--

d = additive effect.

Table 2. Joint action effect of 20 ± 5% CO_2 and 0.8% (w/w) acetone extract of Poinciana seeds (*Delonix regia*) to the adults of some insects infesting stored maize grains inside the fiberglass bins at 32 ± 2°C and 60 ± 5% RH.

Insect species	Exposure period (days)	% adult mortality			CO-toxicity factor	Type of joint action
		MA of 20±5% CO_2 alone	Extract at 0.8% (w/w) alone	Extract + CO_2		
Sitophilus oryzae	1	6.7±0.0	57.4±1.9	70±3.3	9.2	d
	2	33.1±5.0	100±0.0	100±0.0	0.0	d
	3	46.7±6.9	100±0.0	100±0.0	0.0	d
	5	52.7±3.3	100±0.0	100±0.0	0.0	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Rhizopertha dominica	1	3.3±0.0	60±1.9	67.8±3.3	7.1	d
	2	6.1±1.9	68.2±1.9	73.7±1.9	-8.0	d
	3	14.7±3.3	75±1.9	78.5±3.3	-12.5	d
	5	19.6±3.0	77.3±1.9	83.2±1.9	-14.1	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Tribolium castaneum	1	3.3±0.0	3.3±0.0	5.7±0.0	-13.6	d
	2	7.2±0.0	11.7±1.9	22.2±1.9	17.5	d
	3	16.8±1.9	24.4±2.0	39.6±3.3	-3.9	d
	5	27.6±3.3	36.4±3.3	54±3.3	-15.6	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--

d = additive effect.

Table 3. Joint action effect of 20 ± 5% CO_2 and 0.4% (w/w) petroleum ether extract of Poinciana seeds (*Delonix regia*) to the adults of some insects infesting stored maize grains inside the fiberglass bins at 32 ± 2°C and 60 ± 5% RH.

Insect species	Exposure period (days)	% adult mortality			CO-toxicity factor	Type of joint action
		MA of 20±5% CO_2 alone	Extract at 0.4% (w/w) alone	Extract + CO_2		
Sitophilus oryzae	1	6.7±0.0	35.1±1.9	66.7±3.3	11.5	d
	2	33.1±5.0	90±1.9	100±0.0	0.0	d
	3	46.7±6.9	100±0.0	100±0.0	0.0	d
	5	52.7±3.3	100±0.0	100±0.0	0.0	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Rhizopertha dominica	1	3.3±0.0	3.3±0.0	6.7±0.0	1.5	d
	2	6.1±1.9	13.8±1.9	16.8±1.9	-15.6	d
	3	14±3.3	25.3±1.9	32.3±1.9	-17.8	d
	5	19.6±3.0	58.6±1.9	66.2±1.9	-15.3	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Tribolium castaneum	1	3.3±0.0	3.3±0.0	6.7±0.0	1.5	d
	2	7.2±0.0	10.7±1.9	15.5±1.9	-13.4	d
	3	16.8±1.9	17.7±1.9	28.3±3.3	-18.0	d
	5	27.6±3.3	29.6±3.3	45.8±3.3	-19.9	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--

d = additive effect.

Table 4. Joint action effect of 20 ± 5% CO_2 and 0.8% (w/w) petroleum ether extract of Poinciana seeds (*Delonix regia*) to the adults of some insects infesting stored maize grains inside the fiberglass bins at 32 ± 2°C and 60 ± 5% RH.

Insect species	Exposure period (days)	% adult mortality			CO-toxicity factor	Type of joint action
		MA of 20±5% CO_2 alone	Extract at 0.8% (w/w) alone	Extract + CO_2		
Sitophilus oryzae	1	6.7±0.0	71.5±1.9	86.7±8.4	10.9	d
	2	33.1±5.0	100±0.0	100±0.0	0.0	d
	3	46.7±6.9	100±0.0	100±0.0	0.0	d
	5	52.7±3.3	100±0.0	100±0.0	0.0	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Rhizopertha dominica	1	3.3±0.0	58.6±3.3	66.7±3.3	7.8	d
	2	6.1±1.9	36.1±1.9	71.5±1.9	3.3	d
	3	14±3.3	70.1±1.9	79.0±1.9	-6.1	d
	5	19.6±3.0	78.1±1.9	92.5±1.9	-5.3	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Tribolium castaneum	1	3.3±0.0	6.7±0.0	9.4±1.9	-6.0	d
	2	7.2±0.0	13.3±1.9	18.8±1.9	-8.3	d
	3	16.8±1.9	20.1±1.9	30.7±3.8	-16.8	d
	5	27.6±3.3	39.2±3.3	53.7±3.3	-19.6	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--

d = additive effect.

Table 5. Joint action effect of 20 ± 5% CO_2 and 0.4% (w/w) acetone extract of Cinnamom strip bark (*Cinnamomum zeylanicum*) to the adults of some insects infesting stored maize grains inside the fiberglass bins at 32 ± 2°C and 60 ± 5% RH.

Insect species	Exposure period (days)	% adult mortality			CO-toxicity factor	Type of joint action
		MA of 20±5% CO_2 alone	Extract at 0.4% (w/w) alone	Extract + CO_2		
Sitophilus oryzae	1	6.7±0.0	16.7±3.3	28.0±1.9	19.6	d
	2	33.1±5.0	52.5±1.9	100±0.0	16.8	d
	3	46.7±6.9	89.9±3.8	100±0.0	0.0	d
	5	52.7±3.3	95.0±1.9	100±0.0	0.0	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Rhizopertha dominica	1	3.3±0.0	3.6±0.0	6.7±0.0	-2.9	d
	2	6.1±1.9	10.7±1.9	14.0±3.3	-16.7	d
	3	14.0±3.3	20.1±1.9	27.2±1.9	-20.0	d
	5	19.6±3.0	32.1±1.9	41.7±1.9	-19.3	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Tribolium castaneum	1	3.3±0.0	0.0±0.0	3.9±0.0	9.1	d
	2	7.2±0.0	8.3±1.9	14±1.9	-9.7	d
	3	16.8±1.9	18.0±1.9	28±1.9	-19.5	d
	5	27.6±3.3	31.1±1.9	47±1.9	-20	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--

d = additive effect.

Table 6. Joint action effect of 20 ± 5% CO_2 and 0.8% (w/w) acetone extract of Cinnamom strip bark (*Cinnamomum zeylanicum*) to the adults of some insects infesting stored maize grains inside the fiberglass bins at 32 ± 2°C and 60 ± 5% RH.

Insect species	Exposure period (days)	% adult mortality			CO-toxicity factor	Type of joint action
		MA of 20±5% CO_2 alone	Extract at 0.8% (w/w) alone	Extract + CO_2		
Sitophilus oryzae	1	6.7±0.0	37.4±1.9	52.9±1.9	19.9	d
	2	33.1±5.0	76.2±1.9	100±0.0	0.0	d
	3	46.7±6.9	95±5.0	100±0.0	0.0	d
	5	52.7±3.3	96.2±0.0	100±0.0	0.0	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Rhizopertha dominica	1	3.3±0.0	5.6±0.0	8.9±0.0	0.0	d
	2	6.1±1.9	13.6±1.9	18.5±1.9	-6.0	d
	3	14.0±3.3	23.7±1.9	31.0±3.3	-17.8	d
	5	19.6±3.0	35.6±1.9	50.0±3.3	-9.4	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Tribolium castaneum	1	3.3±0.0	5.5±0.0	8.4±1.9	-4.5	d
	2	7.2±0.0	10±1.9	16.8±0.0	-2.3	d
	3	16.8±1.9	20.4±3.3	30±1.9	-19.3	d
	5	27.6±3.3	36.6±1.9	77±5.6	19.9	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--

d = additive effect.

Table 7. Joint action effect of 20 ± 5% CO_2 and 0.4% (w/w) petroleum ether extract of Cinnamom strip bark (*Cinnamomum zeylanicum*) to the adults of some insects infesting stored maize grains inside the fiberglass bins at 32 ± 2°C and 60 ± 5% RH.

Insect species	Exposure period (days)	% adult mortality			CO-toxicity factor	Type of joint action
		MA of 20±5% CO_2 alone	Extract at 0.4% (w/w) alone	Extract + CO_2		
Sitophilus oryzae	1	6.7±0.0	51.2±3.3	28.0±1.9	-6.9	d
	2	33.1±5.0	88.7±3.3	100±0.0	0.0	d
	3	46.7±6.9	91.2±1.9	100±0.0	0.0	d
	5	52.7±3.3	100±0.0	100±0.0	0.0	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Rhizopertha dominica	1	3.3±0.0	64.2±1.9	75.0±1.9	11.1	d
	2	6.1±1.9	65.4±1.9	76.2±1.9	6.6	d
	3	14.0±3.3	71.5±1.9	79.9±1.9	-6.5	d
	5	19.6±3.0	75.3±1.9	79.9±1.9	-15.8	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Tribolium castaneum	1	3.3±0.0	0.0±0.0	3.9±3.3	18.1	d
	2	7.2±0.0	14±1.9	23.3±1.9	9.9	d
	3	16.8±1.9	24.6±1.9	33±1.9	-20.0	d
	5	27.6±3.3	42.2±5.0	61±3.3	-12.6	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--

d = additive effect.

Table 8. Joint action effect of 20 ± 5% CO_2 and 0.8% (w/w) petroleum ether extract of Cinnamom strip bark (*Cinnamomum zeylanicum*) to the adults of some insects infesting stored maize grains inside the fiberglass bins at 32 ± 2°C and 60 ± 5% RH.

Insect species	Exposure period (days)	% adult mortality			CO-toxicity factor	Type of joint action
		MA of 20±5% CO_2 alone	Extract at 0.8% (w/w) alone	Extract + CO_2		
Sitophilus oryzae	1	6.7±0.0	71.3±3.8	77.5±3.3	-0.6	d
	2	33.1±5.0	91.2±1.9	100±0.0	0.0	d
	3	46.7±6.9	98.7±1.9	100±0.0	0.0	d
	5	52.7±3.3	100±0.0	100±0.0	0.0	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Rhizopertha dominica	1	3.3±0.0	75.3±1.9	86.2±1.9	9.4	d
	2	6.1±1.9	77.7±3.3	91.2±3.3	8.8	d
	3	14.0±3.3	70.1±1.9	91.2±3.3	-1.9	d
	5	19.6±3.0	82±1.9	91.2±3.3	-8.8	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Tribolium castaneum	1	3.3±0.0	6.6±0.0	11.6±1.9	17.1	d
	2	7.2±0.0	16.7±0.0	24.6±1.9	2.9	d
	3	16.8±1.9	25.8±3.3	36.3±3.3	-14.8	d
	5	27.6±3.3	61.1±1.9	78.6±6.7	-11.4	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--

d = additive effect.

Table 9. Joint action effect of 20 ± 5% CO_2 and 0.4% (w/w) acetone extract of Cloves flowering bud (*Syzygium aromaticum*) to the adults of some insects infesting stored maize grains inside the fiberglass bins at 32 ± 2°C and 60 ± 5% RH.

Insect species	Exposure period (days)	% adult mortality			CO-toxicity factor	Type of joint action
		MA of 20±5% CO2 alone	Extract at 0.4% (w/w) alone	Extract + CO2		
Sitophilus oryzae	1	6.7±0.0	53.1±1.9	61.7±1.9	3.2	d
	2	33.1±5.0	87.6±1.9	100±0.0	0.0	d
	3	46.7±6.9	100±0.0	100±0.0	0.0	d
	5	52.7±3.3	100±0.0	100±0.0	0.0	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Rhizopertha dominica	1	3.3±0.0	14.0±1.9	16.7±3.3	-3.5	d
	2	6.1±1.9	65.8±1.9	74.7±1.9	3.9	d
	3	14.0±3.3	76.4±2.0	89.8±2.0	-0.7	d
	5	19.6±3.0	84.6±1.9	96.7±1.9	-3.3	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Tribolium castaneum	1	3.3±0.0	0.0±0.0	3.6±0.0	9.1	d
	2	7.2±0.0	13.0±1.9	24.0±1.9	18.8	d
	3	16.8±1.9	21.4±3.3	33.3±1.9	-12.8	d
	5	27.6±3.3	60.6±3.3	71.0±3.3	-19.5	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--

d = additive effect.

Table 10. Joint action effect of 20 ± 5% CO_2 and 0.8% (w/w) acetone extract of Cloves flowering bud (*Syzygium aromaticum*) to the adults of some insects infesting stored maize grains inside the fiberglass bins at 32 ± 2°C and 60 ± 5% RH.

Insect species	Exposure period (days)	% adult mortality			CO-toxicity factor	Type of joint action
		MA of 20±5% CO_2 alone	Extract at 0.8% (w/w) alone	Extract + CO_2		
Sitophilus oryzae	1	6.7±0.0	62.8±1.9	67.8±5.0	-2.4	d
	2	33.1±5.0	100±0.0	100±0.0	0.0	d
	3	46.7±6.9	100±0.0	100±0.0	0.0	d
	5	52.7±3.3	100±0.0	100±0.0	0.0	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Rhizopertha dominica	1	3.3±0.0	20.0±1.9	21.5±1.9	-7.7	d
	2	6.1±1.9	69.3±1.9	78.4±1.9	4.0	d
	3	14.0±3.3	82.3±3.3	93.3±3.3	-3.1	d
	5	19.6±3.0	88.2±1.9	98.6±2.0	-1.4	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Tribolium castaneum	1	3.3±0.0	5.0±0.0	9.8±1.9	18.0	d
	2	7.2±0.0	22.8±1.9	36.0±5.0	20	d
	3	16.8±1.9	57.1±1.9	64.3±5.0	-13.0	d
	5	27.6±3.3	78.5±6.7	89.2±3.3	-10.8	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--

d = additive effect.

Table 11. Joint action effect of 20 ± 5% CO_2 and 0.4% (w/w) petroleum ether extract of Cloves flowering bud (*Syzygium aromaticum*) to the adults of some insects infesting stored maize grains inside the fiberglass bins at 32 ± 2°C and 60 ± 5% RH.

Insect species	Exposure period (days)	% adult mortality			CO-toxicity factor	Type of joint action
		MA of 20±5% CO_2 alone	Extract at 0.4% (w/w) alone	Extract + CO_2		
Sitophilus oryzae	1	6.7±0.0	37.4±1.9	43.7±3.8	-0.9	d
	2	33.1±5.0	98.7±1.9	100±0.0	0.0	d
	3	46.7±6.9	100±0.0	100±0.0	0.0	d
	5	52.7±3.3	100±0.0	100±0.0	0.0	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Rhizopertha dominica	1	3.3±0.0	73.8±1.9	83.8±1.9	8.7	d
	2	6.1±1.9	85.7±0.0	97.5±2.0	6.2	d
	3	14.0±3.3	85.7±0.0	100±0.0	-0.3	d
	5	19.6±3.0	85.7±0.0	100±0.0	0.0	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Tribolium castaneum	1	3.3±0.0	5.0±0.0	8.3±1.9	0.0	d
	2	7.2±0.0	8.3±1.9	18.1±5.0	16.7	d
	3	16.8±1.9	32.5±1.9	42.1±3.3	-8.5	d
	5	27.6±3.3	51.7±2.0	64.9±5.0	-18.2	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--

d = additive effect.

Table 12. Joint action effect of 20 ± 5% CO_2 and 0.8% (w/w) petroleum ether extract of Cloves flowering bud (*Syzygium aromaticum*) to the adults of some insects infesting stored maize grains inside the fiberglass bins at 32 ± 2°C and 60 ± 5% RH.

Insect species	Exposure period (days)	% adult mortality			CO-toxicity factor	Type of joint action
		MA of 20±5% CO_2 alone	Extract at 0.8% (w/w) alone	Extract + CO_2		
Sitophilus oryzae	1	6.7±0.0	62.5±3.3	73.7±3.3	6.5	d
	2	33.1±5.0	100±0.0	100±0.0	0.0	d
	3	46.7±6.9	100±0.0	100±0.0	0.0	d
	5	52.7±3.3	100±0.0	100±0.0	0.0	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Rhizopertha dominica	1	3.3±0.0	86.9±1.9	97.5±2.0	8.1	d
	2	6.1±1.9	86.9±1.9	97.5±3.8	4.8	d
	3	14.0±3.3	88.1±3.3	100±0.0	0.0	d
	5	19.6±3.0	89.2±2.0	100±0.0	0.0	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Tribolium castaneum	1	3.3±0.0	30.0±1.9	34.9±3.3	4.8	d
	2	7.2±0.0	36.1±5.0	50.0±3.3	15.5	d
	3	16.8±1.9	53.0±3.3	63.8±3.8	-8.6	d
	5	27.6±3.3	81.8±3.3	89.1±3.3	-10.9	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--

d = additive effect.

Table 13. Joint action effect of 20 ± 5% CO_2 and 0.4% (w/w) acetone extract of White Mustard seeds (*Brassica alba*) to the adults of some insects infesting stored maize grains inside the fiberglass bins at 32 ± 2°C and 60 ± 5% RH.

Insect species	Exposure period (days)	% adult mortality			CO-toxicity factor	Type of joint action
		MA of 20±5% CO_2 alone	Extract at 0.4% (w/w) alone	Extract + CO_2		
Sitophilus oryzae	1	6.7±0.0	44.9±5.0	57.4±1.9	11.2	d
	2	33.1±5.0	96.2±3.3	100±0.0	0.0	d
	3	46.7±6.9	97.4±3.8	100±0.0	0.0	d
	5	52.7±3.3	100±0.0	100±0.0	0.0	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Rhizopertha dominica	1	3.3±0.0	7.4±0.0	9.2±1.9	-14.0	d
	2	6.1±1.9	14.9±1.9	17.0±3.3	-19.0	d
	3	14.0±3.3	23.3±1.9	30.0±3.3	-19.6	d
	5	19.6±3.0	34.5±1.9	34.5±2.0	-19.6	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Tribolium castaneum	1	3.3±0.0	3.3±0.0	6.9±1.9	4.5	d
	2	7.2±0.0	10.4±1.9	14.0±1.9	-19.5	d
	3	16.8±1.9	14.0±1.9	28.1±1.9	-8.8	d
	5	27.6±3.3	32.9±2.0	48.9±3.3	-19.2	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--

d = additive effect.

Table 14. Joint action effect of 20 ± 5% CO_2 and 0.8% (w/w) acetone extract of White Mustard seeds (*Brassica alba*) to the adults of some insects infesting stored maize grains inside the fiberglass bins at 32 ± 2°C and 60 ± 5% RH.

Insect species	Exposure period (days)	% adult mortality			CO-toxicity factor	Type of joint action
		MA of 20±5% CO_2 alone	Extract at 0.8% (w/w) alone	Extract + CO_2		
Sitophilus oryzae	1	6.7±0.0	73.7±3.3	75.0±1.9	-6.7	d
	2	33.1±5.0	100±0.0	100±0.0	0.0	d
	3	46.7±6.9	100±0.0	100±0.0	0.0	d
	5	52.7±3.3	100±0.0	100±0.0	0.0	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Rhizopertha dominica	1	3.3±0.0	13.0±2.0	13.5±1.9	-17.2	d
	2	6.1±1.9	21.8±1.9	24.6±1.9	-11.8	d
	3	14.0±3.3	54.0±2.0	61.6±1.9	-9.4	d
	5	19.6±3.0	70.1±1.9	79.0±1.9	-11.9	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Tribolium castaneum	1	3.3±0.0	6.7±0.0	12.0±1.9	20.0	d
	2	7.2±0.0	16.7±1.9	22.2±1.9	-7.1	d
	3	16.8±1.9	20.1±3.3	44.0±5.0	19.2	d
	5	27.6±3.3	57.6±3.3	75.2±3.3	-11.7	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--

d = additive effect.

Table 15. Joint action effect of 20 ± 5% CO_2 and 0.4% (w/w) petroleum ether extract of White Mustard seeds (*Brassica alba*) to the adults of some insects infesting stored maize grains inside the fiberglass bins at 32 ± 2°C and 60 ± 5% RH.

Insect species	Exposure period (days)	% adult mortality			CO-toxicity factor	Type of joint action
		MA of 20±5% CO_2 alone	Extract at 0.4% (w/w) alone	Extract + CO_2		
Sitophilus oryzae	1	6.7±0.0	51.8±3.3	63.0±1.9	7.7	d
	2	33.1±5.0	98.7±1.9	100±0.0	0.0	d
	3	46.7±6.9	100±0.0	100±0.0	0.0	d
	5	52.7±3.3	100±0.0	100±0.0	0.0	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Rhizopertha dominica	1	3.3±0.0	3.3±0.0	6.0±0.0	-9.1	d
	2	6.1±1.9	13.0±1.9	15.5±1.9	-18.8	d
	3	14.0±3.3	34.5±1.9	42.5±1.9	-12.4	d
	5	19.6±3.0	59.4±1.9	63.7±1.9	-19.4	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Tribolium castaneum	1	3.3±0.0	3.3±0.0	6.0±0.0	-9.1	d
	2	7.2±0.0	9.4±1.9	15.0±1.9	-9.6	d
	3	16.8±1.9	21.4±2.0	32.1±3.3	-16.0	d
	5	27.6±3.3	32.0±3.3	47.7±5.0	-20.0	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--

d = additive effect.

Table 16. Joint action effect of 20 ± 5% CO_2 and 0.8% (w/w) petroleum ether extract of White Mustard seeds (*Brassica alba*) to the adults of some insects infesting stored maize grains inside the fiberglass bins at 32 ± 2°C and 60 ± 5% RH.

Insect species	Exposure period (days)	% adult mortality			CO-toxicity factor	Type of joint action
		MA of 20±5% CO_2 alone	Extract at 0.8% (w/w) alone	Extract + CO_2		
Sitophilus oryzae	1	6.7±0.0	100±0.0	96.7±0.0	-9.4	d
	2	33.1±5.0	100±0.0	100±0.0	0.0	d
	3	46.7±6.9	100±0.0	100±0.0	0.0	d
	5	52.7±3.3	100±0.0	100±0.0	0.0	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Rhizopertha dominica	1	3.3±0.0	65.4±1.9	71.2±2.0	3.6	d
	2	6.1±1.9	65.4±1.9	75.0±1.9	4.9	d
	3	14.0±3.3	79.7±1.9	91.2±2.0	-2.7	d
	5	19.6±3.0	84.4±3.3	91.2±2.0	-8.8	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Tribolium castaneum	1	3.3±0.0	6.7±0.0	8.0±1.9	-20.0	d
	2	7.2±0.0	15.5±2.0	21.4±1.9	-5.7	d
	3	16.8±1.9	26.7±3.3	43.9±3.8	0.9	d
	5	27.6±3.3	46.4±2.0	60.6±3.8	-18.1	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--

d = additive effect.

Table 17. Joint action effect of 20 ± 5% CO_2 and 0.4% (w/w) acetone extract of Radish seeds (*Raphanus sativus*) to the adults of some insects infesting stored maize grains inside the fiberglass bins at 32 ± 2°C and 60 ± 5% RH.

Insect species	Exposure period (days)	% adult mortality			CO-toxicity factor	Type of joint action
		MA of 20±5% CO_2 alone	Extract at 0.4% (w/w) alone	Extract + CO_2		
Sitophilus oryzae	1	6.7±0.0	53.9±1.9	56.2±5.0	-7.3	d
	2	33.1±5.0	91.2±2.0	100±0.0	0.0	d
	3	46.7±6.9	100±0.0	100±0.0	0.0	d
	5	52.7±3.3	100±0.0	100±0.0	0.0	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Rhizopertha dominica	1	3.3±0.0	3.3±0.0	6.0±0.0	-9.1	d
	2	6.1±1.9	10.1±1.9	13.0±0.0	-19.7	d
	3	14.0±3.3	57.6±3.3	67.0±1.9	-6.4	d
	5	19.6±3.0	82.2±1.9	89.4±0.0	-10.6	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Tribolium castaneum	1	3.3±0.0	0.0±0.0	3.3±0.0	0.0	d
	2	7.2±0.0	10.0±0.0	14.0±0.0	-18.6	d
	3	16.8±1.9	21.4±3.3	31.0±1.9	-18.8	d
	5	27.6±3.3	23.0±2.0	41.0±1.9	-19.0	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--

d = additive effect.

Table 18. Joint action effect of 20 ± 5% CO_2 and 0.8% (w/w) acetone extract of Radish seeds (*Raphanus sativus*) to the adults of some insects infesting stored maize grains inside the fiberglass bins at 32 ± 2°C and 60 ± 5% RH.

Insect species	Exposure period (days)	% adult mortality			CO-toxicity factor	Type of joint action
		MA of 20±5% CO_2 alone	Extract at 0.8% (w/w) alone	Extract + CO_2		
Sitophilus oryzae	1	6.7±0.0	86.2±3.3	89.9±5.0	-3.2	d
	2	33.1±5.0	100±0.0	100±0.0	0.0	d
	3	46.7±6.9	100±0.0	100±0.0	0.0	d
	5	52.7±3.3	100±0.0	100±0.0	0.0	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Rhizopertha dominica	1	3.3±0.0	55.1±5.0	62.0±6.6	6.2	d
	2	6.1±1.9	78.8±3.3	88.6±3.3	4.4	d
	3	14.0±3.3	88.2±1.9	91.1±1.9	-8.9	d
	5	19.6±3.0	91.1±1.9	94.0±1.9	-6.0	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Tribolium castaneum	1	3.3±0.0	5.6±0.0	10.5±1.9	18.0	d
	2	7.2±0.0	13.0±1.9	18.0±1.9	-10.9	d
	3	16.8±1.9	24.9±3.3	34.0±3.8	-18.5	d
	5	27.6±3.3	30.0±3.3	47.0±1.9	-18.4	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--

d = additive effect.

Table 19. Joint action effect of 20 ± 5% CO_2 and 0.4% (w/w) Petroleum ether extract of Radish seeds (*Raphanus sativus*) to the adults of some insects infesting stored maize grains inside the fiberglass bins at 32 ± 2°C and 60 ± 5% RH.

Insect species	Exposure period (days)	% adult mortality			CO-toxicity factor	Type of joint action
		MA of 20±5% CO_2 alone	Extract at 0.4% (w/w) alone	Extract + CO_2		
Sitophilus oryzae	1	6.7±0.0	44.9±1.9	60.0±1.9	16.3	d
	2	33.1±5.0	100±0.0	100±0.0	0.0	d
	3	46.7±6.9	100±0.0	100±0.0	0.0	d
	5	52.7±3.3	100±0.0	100±0.0	0.0	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Rhizopertha dominica	1	3.3±0.0	29.6±1.9	29.6±3.3	-10.0	d
	2	6.1±1.9	32.1±0.0	33.3±3.3	-12.8	d
	3	14.0±3.3	35.6±3.3	44.4±0.0	-10.5	d
	5	19.6±3.0	54.6±5.0	63.0±3.3	-15.1	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Tribolium castaneum	1	3.3±0.0	3.3±0.0	6.0±0.0	-9.0	d
	2	7.2±0.0	8.3±0.0	18.0±0.0	16.1	d
	3	16.8±1.9	10.0±1.9	29.2±3.3	9.0	d
	5	27.6±3.3	27.6±1.9	45.0±3.3	-18.5	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--

d = additive effect.

Table 20. Joint action effect of 20 ± 5% CO_2 and 0.8% (w/w) Petroleum ether extract of Radish seeds (*Raphanus sativus*) to the adults of some insects infesting stored maize grains inside the fiberglass bins at 32 ± 2°C and 60 ± 5% RH.

Insect species	Exposure period (days)	% adult mortality			CO-toxicity factor	Type of joint action
		MA of 20±5% CO_2 alone	Extract at 0.8% (w/w) alone	Extract + CO_2		
Sitophilus oryzae	1	6.7±0.0	72.5±1.9	95.0±1.9	19.9	d
	2	33.1±5.0	100±0.0	100±0.0	0.0	d
	3	46.7±6.9	100±0.0	100±0.0	0.0	d
	5	52.7±3.3	100±0.0	100±0.0	0.0	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Rhizopertha dominica	1	3.3±0.0	78.5±3.3	88.8±3.3	8.6	d
	2	6.1±1.9	85.7±0.0	96.7±0.0	5.3	d
	3	14.0±3.3	88.1±1.9	96.7±0.0	-3.3	d
	5	19.6±3.0	95.1±1.9	96.7±0.0	-3.3	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--
Tribolium castaneum	1	3.3±0.0	12.0±1.9	16.7±1.9	9.2	d
	2	7.2±0.0	20.4±3.3	26.7±3.3	-3.3	d
	3	16.8±1.9	27.8±1.9	37.5±1.9	-15.9	d
	5	27.6±3.3	53.0±6.6	82.2±5.0	2.0	d
Control	--	0.0±0.0	0.0±0.0	0.0±0.0	--	--

d = additive effect.

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التأثير المشترك لبعض مخاليط المستخلصات النباتية مع جو معدل من ثانى أكسيد الكربون ضد حشرات المواد المخزونة

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أجريت هذه التجارب داخل الصوامع الفيبرجلاس أثناء فصل الصيف وكانت درجة حرارة الحبوب ٣٢ ± ٢°م.المستخلصات النباتية المختبره هى المستخلص الأسيتونى والأثير البترولى لبذور البوانسيانا ، وبراعم أزهار القرنفل ، والقرفة، وبذور الفجل ، وبذور المسترده

تم اختبار المستخلصات النباتية تحت الدراسة بتركيزين هى ٠,٤ ، ٠,٨% (وزن/وزن) بمفردها وتحت جو معدل يحتوى على ٢٠ ± ٥% ثانى أكسيد الكربون ضد الحشرات الكاملة لكل من سوسة الأرز ، وثاقبة الحبوب الصغرى ، وخنفساء الدقيق الكستنائية.

وقد أظهرت نتائج التأثير المشترك لإضافة ثانى أكسيد الكربون بتركيز ٢٠ ± ٥% مع مستخلصات الأسيتون ومستخلصات الأثير البترولى للنباتات المختلفة بتركيز ٠,٤% ، ٠,٨% تأثيراً إضافياً مع الحشرات المختبرة ومع كل فترات التعريض. وعند مقارنة التأثير السام للنباتات تحت الدراسة ضد الثلاثة أنواع الحشرية المختبرة وجد أن سوسة الأرز أكثرها حساسية يليها ثاقبة الحبوب الصغرى ثم خنفساء الدقيق الكستنائية ومعاملة الأنواع الحشرية المختبرة بالمستخلصات النباتية تحت جو معدل يحتوى على ثانى أكسيد الكربون أظهر بوضوح نسب موت عالية من المعاملة المنفردة ، مما يحمى الحبوب من الإصابة بالأنواع الحشرية المختلفة تحت الدراسة.