# EFFECTIVENESS OF CONTROLLED ATMOSPHERES OF DIFFERENT CARBON DIOXIDE CONCENTRATIONS AND HIGH NITROGEN CONTENT AGAINST THE LESSER GRAIN BORER- *RHIZOPERTHA DOMINICA (F.)*

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***Abstract***

The aim of this study was to investigate the efficacy of controlled atmospheres (CA) of various carbon dioxide concentrations (25, 50, 75 and 100%) against the various stages of *R.dominica* at 20 and 30 ± 1 °C and 65 ± 5% RH. Furthermore, the efficacy of CA of 99.9% $N_2$ against the various stages of *R. dominica* was studied at the two above mentioned temperatures and relative humidity. Experiments were conducted at the laboratory of the plant protection Department of the Faculty of Agriculture, Moshtohor, Benha University. Carbon dioxide and Nitrogen gases were provided as pure gas in pressure cylinders which connected with pressure regulators.

The results of efficiency of Controlled atmosphere (CA) containing various $CO_2$ concentrations (25, 50, 75 and 100%) against the various stages of *Rhizopertha dominica* at 30 and 20 °C showed that the efficiency of $Co_2$ was concentration and exposure period dependent. Increasing the $Co_2$ concentration and exposure period resulted in higher insect mortality. Also at higher temperature of 30 °C the efficacy of the various CA was higher than those at 20 °C. Also the susceptibility of the various insect stages different from one stage to another.

The results indicated clearly that the efficiency of CA of 99.9% $N_2$ was insect stage, exposure time and temperature dependent. Rising the exposure period and the temperature resulted in higher efficiency.

## INTRODUCTION

The lesser grain borer *Rhizopertha dominica* (F.), (Coleoptera: Bostrychidae) is a primary pest of cereal grains and other seeds; also feeds on dried potatoes, tapioca and herbs. Larvae and adults bore into grain eating out the entire starchy interior and the seed coat in places, leaving irregularly-shaped holes. Large quantities of floury dust are produced. Heavily infested wheat has a honey- like odour.

Methyl bromide was used extensively to control stored products pests, it cause about 5-10% of total ozone depletion in the earth's stratosphere. Ozone depletion increases the level of UV radiation which has been linked to skin cancer, eye

cataracts and degradation of immune system. Thus, the Montreal Protocol (1997) declared the phase-out of this fumigant in industrialized countries by the year 2005. The phase-out date for developing countries has been fixed for the year 2015.

Further possible post harvest alternatives of MB includes controlled or modified atmospheres (CA) of various carbon dioxide concentrations or CA of high nitrogen content and other combined methods.

Controlled atmospheres (CA) received considerable attention in recent years as one of the alternative methods to control stored product pests. CA treatments depend for their effectiveness in combating insects on removal of life-supporting oxygen or addition of toxic levels of carbon dioxide or a combination of the two. In practical control treatments, the levels of both oxygen and carbon dioxide are frequently changed so that toxicity may be enhanced by the combined effects of the two.

The aim of this work was to study the efficacy of (CA) of various $CO_2$ concentrations (25, 50, 75 and 100%) against the various stages of *Rhizopertha dominica* (F.) at 30 and 20 $\pm$ 1°C. Also to investigate the efficacy of CA of 99.9% $N_2$ against the various stages of *Rhizopertha dominica* (F.) at 30 and 20 $\pm$ 1 °C.

## MATERIALS AND METHODS

*** Insects:**

Laboratory strain of the lesser grain borer, *Rhizopertha dominica*(F.) (Bostrychidae, Coleoptera) was used during this work. Insects were collected from the stores during 2006 and maintained at the stored product pests', laboratory of the plant protection Dept. Faculty of Agric., Moshtohor Benha University.

*** Insect cultures**

The insects were reared in glass jars of approx. 250 ml., each jar contained about 450g. of wheat kernels for *R. dominica* and covered with muslin cloth and fixed with rubber band. Insect cultures were kept under controlled conditions of 30 ± 1°C and 65$\pm$ 5% R.H. at the rearing room of the laboratory. Wheat grains were treated well by freezing at -18°C for 2 weeks before application to eliminate any possible infestation by any insect species. The moisture content of the grains was about 14%.

**Cultures for supplying the developmental stages of *Rhizopertha dominica* required for the tests:**

For the tests 0-48 hrs-old eggs, 16 days-old larvae, 24 days-old pupae, and 1-2 weeks old adults were taken for the experiments. Glass jars, each containing 450

wheat kernels +50 g. wheat flouer. Wheat kernels were prepared into each jar approx. 1000 adult insects (1-2 weeks-old) "50% ♀ and 50% ♂" were added to the food and left for two days in the media for laying the eggs. After this, the insects were separated using a sieve (2.5 mm.) and the food was thoroughly mixed for uniformity. Then portions were assumed to contain 0-48 hrs-old eggs, which considered the standard age for ovicidal action.

For obtaining the larvae, adult insects were added to the food for laying eggs as mentioned above and then the adults were separated from the media similar after 2 days. Then the culture was kept for two weeks at the rearing conditions after the removal of the adults, to achieve the larvae for conducting the experiments.

To obtain the pupal stages these cultures were maintained for 24 days after the removal of the adult insects, the portions were assumed to contain 24 days old pupae.

***Preparation of the test-insects for controlled atmospheres (CA) treatments:**

Batches of 30 adult insects were placed in wire gauze cages ( 14 mm diam. and 45 mm long ), filled with about 10g wheat grains, and the cages were closed with rubber stoppers. The cages were then introduced into the 0.55-L gastight Dreshel exposure flasks. Insects in these flasks were treated for different exposure periods at 30±1°C and 20±1°C as well as 65±5% R.H. After the desired exposure periods, the flasks were aerated and the insects were transferred into Petri dishes and kept at the above mentioned temperatures prior to mortality assessment.

**Gases used:**

Carbon dioxide ($CO_2$) and nitrogen ($N_2$) were provided as pure gases in pressurized steel cylinders. Each cylinder was connected to a pressure regulator. The dilution method was used to achieve the required $CO_2$ concentration. For the atmosphere of nearly pure $N_2$, the valve of the $N_2$ cylinder was opened for two minutes in order to flush the Dreshel exposure flask with the gas. CAs of 25, 50, 75and 100 % $CO_2$ in air and 99.9% $N_2$ were prepared and concentrations were measured.

**Determination of the concentrations of gases:-**

$CO_2$ was monitored using Gas Analyzer model 200-600 (Gow – Mac – Instrument CO., USA) Nitrogen concentration was determined inside the flaskes using Oxygen Analyzer 572, SERVOMEX, England.

**Bioassay tests:**

Insect samples were exposed to the various treatments for varying length of time. After the desired exposure period mortality assessment was performed. Mortality percentages were corrected by Abbott's formula (1925 ).

Adult mortalities of *R. dominica* were determined after 48 hrs. from aeration of the flaskes. The mortality of the immature stages of *R. dominica* was recorded as reduction rate of the F1 progeny which was inspected after 75 days from treatment.

**The inhibition rate of progeny was calculated as follows:-**

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

**Statistical Analysis:-**

A probit computer program after Noack and Reichmuth, 1978 was used for determining the lethal times for the gases.

## RESULTS AND DISCUSSION

**Efficacy of controlled atmosphere (CA) containing various Carbon dioxide ($CO_2$) concentrations against the various St ges of *Rhizopertha dominica* (F.) at two temperatures ( 30 and 20 ± 1°C)**

The efficacy of CA of 100% $CO_2$ against *Rhizopertha dominica* (F.) at 30 ± 1°C and 65 ± 5% RH is given in table (1). The results revealed that, the time needed to obtain 50% kill were 2.5, 2.9, 1.7, 1.93 days for the adult, larva, pupa and egg, respectively. The time needed to obtain 90% kill were 9.8, 9.4, 9.3, 10.33 days for the adult, larva, pupa and egg, respectively. Accordingly, the time required to achieve 99% mortality were 29.6, 24.4, 37.1, 40.50 days for the adult, larva, pupa and egg, respectively

The efficacy of CA of 100% $CO_2$ against *Rhizoperth dominica* at 20 ± 1°C and 65 ± 5% RH is shown in table (2). The results indicated that, the time needed to obtain 50% mortality were 2.9, 0.48, 2.9, 2.64 days for the adult, larva, pupa and egg, respectively. The time required to obtain 90% mortality were 13.50, 18.2, 17.4, 13.98 days for the adult, larva, pupa and egg, respectively. Also the time required for 99% kill were 43.8, 78.6, 73.3, 54.37 days for the adult, larva, pupa and egg, respectively.

Based on the LT90 CA of 100% $CO_2$ was more effective against the adult and egg stages of *Rhizoperth dominica* than on larva and pupa. This result indicated that

the adults and eggs of *Rhizoperth dominica* at 30 °C were more tolerant to the CA of 100% $CO_2$ than the other stages (larvae and pupae ).

On the other hand at 20 °C and also based on the LT90 values, the larva and pupa of *R. dominica* were more tolerant to the CA of 100% $CO_2$ than the adult and egg stages.

Table 1. Lethal time values and parameters of mortality regression line for *Rhizopertha dominica* (F.) exposed to CA of 100% $CO_2$ at 30 ± 1°C and 65 ± 5% R.H.

| Stage | Lethal time (day) and their 95% confidence limits | | | Slope ± SD | R |
|---|---|---|---|---|---|
| | LT 50 | LT 90 | LT 99 | | |
| Adult | 2.5 (2.1-3.06) | 9.8 (7.3-13.3) | 29.6 (17.4-50.5) | 2.1 ± 0.026 | 0.9965 |
| Larva | 2.9 (2.5-3.4) | 9.4 (7.1-12.4) | 24.4 (15.3-38.6) | 2.5 ± 0.74 | 0.9245 |
| Pupa | 1.7 (1.3 - 2.2) | 9.3 (6.4-14) | 37.1 (18-78) | 1.7 ± 0.12 | 0.9705 |
| Egg | 1.93 (1.5 -2.49) | 10.33 (7.3-14.59) | 40.50 (21.63 -75.8) | 1.76 ± 0.163 | 0.9803 |

CA = Controlled atmosphere.

R = Correlation coefficient of regression line.

SD = Standard deviation of the mortality regression Line.

Table 2. Lethal time values and parameters of mortality regression line for *Rhizopertha dominica (F.)* exposed to CA of 100% $CO_2$ at 20 ± 1°C and 65 ± 5% R.H.

| Stage | Lethal time(day) and their 95% confidence limits | | | Slope ± SD | R |
|---|---|---|---|---|---|
| | LT 50 | LT 90 | LT 99 | | |
| Adult | 2.9 (2.4 -3.5) | 13.05 (9.1-18.6) | 43.8 (23.7-81.13) | 1.9 ± 0.061 | 0.9906 |
| Larva | 0.48 (2.2 -4.1) | 18.2 (9.8-33.9) | 78.6 (24.09- 256.6) | 1.6 ± 0.13 | 0.9476 |
| Pupa | 2.9 (2.4 - 3.7) | 17.4 (12.5-24.2) | 73.3 (40 -135) | 1.7 ± 0.61 | 0.9197 |
| Egg | 2.64 (2.16-3.2) | 13.98 (10.25-19.07) | 54.37 (31.14-94.92) | 1.7 ± 0.087 | 0.9894 |

CA = Controlled atmosphere.

R = Correlation coefficient of regression line.

SD = Standard deviation of the mortality regression Line.

The efficacy of CA of 75% $CO_2$ against *Rhizopertha dominica* at 30 ± 1°C and 65 ± 5% RH is given in table (3). The results revealed that, the time required to

obtain 50% kill were 2.9, 1.3, 2.4, 5.4 days for the adult, larva, pupa and egg, respectively. The time needed to achieve 90% mortality were 9.6, 6.7, 14.9, 15.6 days for the adult, larva, pupa and egg, respectively. The time required to obtain 99% kill were 25.3, 25.3, 66.10, 36.6 days for the adult, larva, pupa and egg, respectively.

The efficacy of CA of 75% $CO_2$ against *Rhizopertha dominica* at 20 ± 1°C and 65 ± 5% RH is tabulated in table (4). The results indicated that, the time needed to obtain 50% mortality were 3.9, 6.4, 1.8, 1.83 days for the adult, larva, pupa and egg, respectively. The time required to obtain 90% kill were 12.08, 31, 19.8, 13.87 days for the adult, larva, pupa and egg, respectively. The time needed to obtain 99% mortality were 29.9, 113, 136.9, 72.07 days for the adult, larva, pupa and egg, respectively.

The obtained results at 30 ± 1°C indicated clearly at the $LT_{90}$ values that the pupae and the eggs of *R. dominica* were more tolerant than the other stages. On the other hand, at 20± 1 °C the larvae and pupae were more tolerant than the other stages.

Table 3. Lethal time values and parameters of mortality regression line for *Rhizopertha dominica (F.)* exposed to CA of 75% $CO_2$ at 30 ± 1° C and 65 ± 5% R.H.

| Stage | Lethal time(day) and their 95% confidence limits | | | Slope ± SD | R |
|---|---|---|---|---|---|
| | LT 50 | LT 90 | LT 99 | | |
| Adult | 2.9 (2.3 -3.6) | 9.6 (6.9-13.4) | 25.3 (13.6-47.1) | 2.5 ± 0.071 | 0.9821 |
| Larva | 1.3 (0.98 - 2) | 6.7 (5 - 9.3) | 25.3 (13.2- 48.4) | 1.8 ± 0.066 | 0.9855 |
| Pupa | 2.4 (1.7 - 3.3) | 14.9 (8.5-26.3) | 66.10 (23.1-194.1) | 1.6 ± 0.066 | 0.9795 |
| Egg | 5.4 (4.7-6.3) | 15.6 (12.5-19.4) | 36.6 (24.8-54.07) | 2.8 ± 0.16 | 0.9784 |

CA = Controlled atmosphere.

R = Correlation coefficient of regression line.

SD = Standard deviation of the mortality regression Line.

Table 4. Lethal time values and parameters of mortality regression line for *Rhizopertha dominica* (F.) exposed to CA of 75 % $CO_2$ at 20 ± 1° C and 65 ± 5% R.H.

| Stage | Lethal time(day) and their 95% confidence limits | | | Slope ± SD | R |
|---|---|---|---|---|---|
| | $LT_{50}$ | $LT_{90}$ | $LT_{99}$ | | |
| Adult | 3.9 (3.3 - 4.7) | 12.08 (8.5 -17.11) | 29.9 (16.3 - 54.9) | 2.6 ± 0.0089 | 0.9979 |
| Larva | 6.4 (5.4 - 7.5) | 31 (22 - 44.1) | 113 (62.03- 204.7) | 1.9 ± 0.044 | 0.9946 |
| Pupa | 1.8 (1.2 - 3) | 19.8 (12 - 34) | 136.9 (47 - 399.3) | 1.2 ± 0.019 | 0.9944 |
| Egg | 1.83 (1.39-2.41) | 13.87 (9.45 – 20.3) | 72.07 (37.25-151.66) | 1.46 ± 0.046 | 0.9917 |

CA = Controlled atmosphere.

R = Correlation coefficient of regression line.

SD = Standard deviation of the mortality regression Line.

The efficacy of CA of 50% $CO_2$ against *Rhizopertha dominica* at 30 ± 1°C and 65 ± 5% RH is given in table (5). The results revealed that, the time needed to obtain 50% kill were 2.9, 2.6, 2.0, 1.94 days for the adult, larva, pupa and egg, respectively. The time needed to obtain 90% kill were 11.3, 12.9, 9.3, 10.06 days for the adult, larva, pupa and egg, respectively. The time needed to achieve 99% mortality were 33.5, 47.9, 32.5, 38.49 days for the adult, larva, pupa and egg, respectively.

The efficacy of CA of 50% $CO_2$ against *Rhizopertha dominica* at 20 ± 1°C and 65 ± 5% RH is shown in table (6). The results indicated that, the time needed to obtain 50% mortality were 8.1, 3.5, 2.3, 5.4 days for adult, larva, pupa and egg, respectively. The time required to obtain 90% mortality were 22.7, 17.3, 19.10, 18.2 days for the adult, larva, pupa, and egg, respectively. The time needed to obtain 99% kill were 52.6, 63.7, 95, 49.02 days for the adult, larva, pupa and egg respectively.

Based on the LT90, at 30 °C the larvae and adults of *R. dominica* were more tolerant than the other stages, while at 20 °C, the pupae and adults were more tolerant than the other stages.

Table 5. Lethal time values and parameters of mortality regression line for *Rhizopertha dominica* (F.) exposed to CA of 50% $CO_2$ at 30 ± 1° C and 65 ± 5% R.H.

| Stage | Lethal time(day) and their 95% confidence limits | | | Slope ± SD | R |
|---|---|---|---|---|---|
| | LT 50 | LT 90 | LT 99 | | |
| Adult | 2.9 (2.5 -3.5) | 11.3 (8.2-15.5) | 33.5 (19.4-57.7) | 2.2 ± 0.14 | 0.9789 |
| Larva | 2.6 (2.1 -3.1) | 12.9 (8.7-19.1) | 47.9 (23.6 - 97.3) | 1.8 ± 0.63 | 0.9864 |
| Pupa | 2.0 (1.6 - 2.5) | 9.3 (6.7-13) | 32.5 (17.4 - 60.6) | 1.9 ± 0.11 | 0.9786 |
| Egg | 1.94 (1.56-2.4) | 10.06 (7.5-13.49) | 38.49 (22.24 -66.6) | 1.79 ± 0.043 | 0.9517 |

CA = Controlled atmosphere.

R = Correlation coefficient of regression line.

SD = Standard deviation of the mortality regression Line.

Table 6. Lethal time values and parameters of mortality regression line for *Rhizopertha dominica* (F.) exposed to CA of 50% $CO_2$ at 20 ± 1° C and 65 ± 5% R.H.

| Stage | Lethal time (day) and their 95% confidence limits | | | Slope ± SD | R |
|---|---|---|---|---|---|
| | LT 50 | LT 90 | LT 99 | | |
| Adult | 8.1 (6.8 -9.5) | 22.7 (16.6 - 31.08) | 52.6 (31.6-87.6) | 2.8 ± 0.27 | 0.9657 |
| Larva | 3.5 (2.7 - 4.5) | 17.3 (10.1-29.6) | 63.7 (23.9- 169.9) | 1.8 ± 0.13 | 0.9582 |
| Pupa | 2.3 (2.4 - 3.8) | 19.10 (14.03 - 28.5) | 95 (49-185) | 1.5 ± 0.12 | 0.9803 |
| Egg | 5.4 (4.5 -6.5) | 18.2 (12.2- 27.3) | 49.02 (23.6-101.5) | 2.4 ± 0.040 | 0.9876 |

CA = Controlled atmosphere.

R = Correlation coefficient of regression line.

SD = Standard deviation of the mortality regression Line.

The efficacy of CA of 25% $CO_2$ against *Rhizopertha dominica* at 30 ± 1°C and 65 ± 5% RH is presented in table (7). The results indicated that, the time needed to obtain 50% mortality were 3.5, 2.8, 3.4, 5.2 days for the adult, larva, pupa and egg respectively. The time required to achieve 90% kill were 20.46, 12.6, 18.4, 22.0 days for the adult, larva, pupa and egg respectively. The time needed to obtain 99% kill were 86.2, 43.2, 73.2, 70.3 days for the adult, Larva, pupa and egg, respectively. The efficacy of CA of 25% $CO_2$ against *Rhizopertha dominica* 20± 1°C and 65 ± 5% RH is tabulated in table (8).

The results revealed that, the time needed to obtain 50% mortality were 7.9, 1.7, 3.5, 1.6 days for the adult, larva, pupa and egg, respectively. The time required to obtain 90% kill were 44.3, 18, 21.2, 19.88 days for the adult, larva, pupa and egg, respectively. The time needed to achieve 99% mortality were 180, 122, 93.2, 156.28 days for the adult, larva, pupa and egg, respectively. Based on the $LT_{90}$ values, the eggs and adults of *R.dominica* at 30°C were more tolerant than the larvae and pupae. Meanwhile, at 20 °C the adults and pupae were more tolerant than the other stages.

Results of CA of various $CO_2$ concentrations (25, 50, 75 and 100% $CO_2$) revealed that, the efficacy of the CA of $CO_2$ was obviously proved at higher $CO_2$ concentration than at lower one. Meanwhile, the efficacy of CA of various $CO_2$ concentrations was achieved at higher temperature than at lower one and increased with increasing the exposure period. This result is in harmony with the results of other investigators: El-Lakwah, *et al.* (1996) investigated the effects of modified atmospheres containing more than 99% $N_2$, or 98% $CO_2$ and also 46% $Co_2$ on adult mortalities of *Sitophilus oryzae*, *Tribolium castaneum* and *Rhizopertha dominica*, seed germination of wheat, maize, broad bean, cowpea and pea; chlorophyll and carotene contents of their seedlings were investigated in the laboratory. Mortality results of the various atmospheres showed 100% kill after 7 and 14 days exposure periods for the insect species under study. Germination of the various crop seeds did not significantly affected at the indicated preceding periods. Also, chlorophyll A and carotene contents of the seedlings did not show significantly any adverse effects at these long exposure periods. Thus, the modified atmosphere of nearly pure nitrogen or enriched with carbon dioxide could be used safely as seed treatment against stored product insects. The obtained results are in harmony with the findings of other investigators (El-lakwah, et al., 1996; El-lakwah et al., 1998 and Locatelli, and Daolio, 1991)

Table 7. Lethal time values and parameters of mortality regression line for *Rhizopertha dominica* (F.) exposed to CA of 25% $CO_2$ at 30 ± 1° C and 65 ± 5% R.H.

| Stage | Lethal time (day) and their 95% confidence limits | | | Slope ± SD | R |
|---|---|---|---|---|---|
| | $LT_{50}$ | $LT_{90}$ | $LT_{99}$ | | |
| Adult | 3.5 (2.6-4.6) | 20.46 (11.6-36.1) | 86.2 (31.8-233.5) | 1.6 ±0.086 | 0.9796 |
| Larva | 2.8 (2.1-3.7) | 12.6 (8.1-19.6) | 43.2 (18.4 -101.1) | 1.10 ± 0.22 | 0.9401 |
| Pupa | 3.4 (2.6 -4.5) | 18.4 (10.2-33.2) | 73.2 (24.4 - 219.5) | 1.7 ± 0.054 | 0.9798 |
| Egg | 5.2 (4.3 -6.4) | 22.0 (15.5-31.2) | 70.3 (36.4 -135.5) | 2.0 ± 0.0080 | 0.9980 |

CA = Controlled atmosphere.

R = Correlation coefficient of regression line.

SD = Standard deviation of the mortality regression Line.

Table 8. Lethal time values and parameters of mortality regression line for *Rhizopertha dominica* (F.) exposed to CA of 25% $CO_2$ at 20 ± 1°C and 65 ± 5% R.H.

| Stage | Lethal time (day) and their 95% confidence limits | | | Slope ± SD | R |
|---|---|---|---|---|---|
| | LT 50 | LT 90 | LT 99 | | |
| Adult | 7.9 (6.6-9.5) | 44.3 (33.7-58.3) | 180 (113.4-286) | 1.7 ± 0.36 | 0.9746 |
| Larva | 1.7 (1.2-2.4) | 18 (11-30) | 122 (43-345.4) | 1.2 ± 0.073 | 0.9770 |
| Pupa | 3.5 (3 -4.2) | 21.2 (14.1-32) | 93.2 (45.4-191.3) | 1.6 ± 0.11 | 0.9793 |
| Egg | 1.6 (7.11-2.25) | 19.88 (12.73-31.07) | 156.28 (61.71-395.8) | 1.76 ± 0.091 | 0.9766 |

CA = Controlled atmosphere.

R = Correlation coefficient of regression line.

SD = Standard deviation of the mortality regression Line.

**Efficacy of controlled atmosphere (CA) of high Nitrogen content (99.9% $N_2$) against *Rhizopertha dominica* (F.) at 30 and 20 ± 1°C**

The efficacy of CA of 99.9% $N_2$ against the various stages of *Rhizopertha dominica* at 30 ± 1°C and 65± 5% R.H. is given in table (9). the results revealed that, the time needed to obtain 50% kill were 1.9, 2.6, 2.6 and 1 days for the adult, larva, pupa and egg, respectively. The time required to obtain 90% kill were 12.9, 7.7, 9.7, 9.76 days for the adult, larva, pupa and egg, respectively. The time needed to achieve 99% kill were 59.5, 18.3, 28.4, 62.40 days for the adult, larva, pupa and egg, respectively.

The efficacy of CA of 99.9% $N_2$ against the various stages of *Rhizoperthe dominica* at 20 ± 1°C and 65 ± 5% R.H. is shown in table (10). The results revealed that, the time needed to obtain 50% mortality were 2.8, 4.6, 5.7, 2.5 days for the adult, larva, pupa and egg, respectively. The time to obtain 90% kill were 12.7, 15.2, 18.7, 30.0 days for the adult, larva, pupa and egg, respectively. The time for 99% mortality were 43.6, 39.7, 49.3, 232.1 days for the adult, larva, pupa, and egg, respectively.

The results showed clearly that the lethal times required for kill various stages of insect were obviously longer at lower temperature (20 °C) than at higher one (30 °C). This result indicated clearly that the efficacy of CA of 99.9% $N_2$ was higher at 30 °C than at 20 °C. Based on the LT90 values, larvae were more sensitive to CA of 99.9% $N_2$ than the other insect stages at 30 °C. While at 20 °C the adults were more sensitive than the other stages.

The obtained results are in harmony with the findings of other investigators : El-lakwah, *et al.* (1998) stated that, to avoid the problem of using methyl bromide and synthetic insecticides for controlling stored product pests, an alternative technique, the application of modified atmospheres, is available. The efficacy was evaluated of using a modified atmosphere of approximately 1% $O_2$ plus 99% $N_2$ against *Sitophiuls oryzae, Rhizopertha dominica* and *Tribolium castaneium.* Experiments were carried out in the laboratory at 26 and 6 degrees C. The time required to achieve certain kill for the various stages of the three insect species was considerably longer at lower temperatures than at higher ones. Marked differences in the susceptibilities of the various stages of the insect species were obtained, whereas the adult stage was the most sensitive one. *T. castaneum* was the most susceptible species. The obtained results are in harmony with the findings of other investigators (El-lakwah, et al., 1998; Mohamed, 2006 and El-Lakwah et al., 1996).

Table 9. Lethal time values and parameters of mortality regression line for *Rhizopertha dominica* (F.) exposed to CA of 99.9 % $N_2$ at 30 ± 1°C and 65 ± 5% R.H.

| Stage | Lethal time(day) and their 95% confidence limits | | | Slope ± SD | R |
|---|---|---|---|---|---|
| | LT 50 | LT 90 | LT 99 | | |
| Adult | 1.9 (1.5 -2.4) | 12.9 (7.7-21.6) | 59.5 (24.5-144.5) | 1.5 ± 0.067 | 0.9857 |
| Larva | 2.6 (2.2 -3.2) | 7.7 (5.9- 9.9) | 18.3 (11.7- 28.6) | 2.77 ± 0.39 | 0.9602 |
| Pupa | 2.6 (2.2 - 3.1) | 9.7 (7.8 -12.13) | 28.4 (19.5 - 41.3) | 2.2 ± 0.31 | 0.9746 |
| Egg | 1 (0.73-1.36) | 9.76 (6.36 -15) | 62.40 (27.3 -143) | 1.7 ± 0.076 | 0.9863 |

CA = Controlled atmosphere.

R = Correlation coefficient of regression line.

SD = Standard deviation of the mortality regression Line.

Table 10. Lethal time values and parameters of mortality regression line for *Rhizopertha dominica* (F.) exposed to CA of 99.9 % $N_2$ at 20 ± 1°C and 65 ± 5% R.H.

| Stage | Lethal time (day) and their 95% confidence limits | | | Slope ± SD | R |
|---|---|---|---|---|---|
| | LT50 | LT90 | LT99 | | |
| Adult | 2.8 (2.3-3.3) | 12.7 (8.7-18.4) | 43.8 (23.7-81.13) | 1.9 ± 0.021 | 0.9957 |
| Larva | 4.6 (4.0 -5.4) | 15.2 (12.3-18.8) | 78.6 (24.09- 256.6) | 2.5 ± 0.18 | 0.9875 |
| Pupa | 5.7 (4.9- 6.5) | 18.7 (14.7-23.7) | 73.3 (40-135) | 2.4 ± 0.36 | 0.9756 |
| Egg | 2.5 (1.7-3.4) | 30.03 (17.6-51.3) | 54.37 (31.14-94.92) | 1.2 ± 0.026 | 0.9922 |

CA = Controlled atmosphere.

R = Correlation coefficient of regression line.

SD = Standard deviation of the mortality regression Line.

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# فاعلية الأجواء المحكمة التى تحتوى على تركيزات مختلفة من غاز ثانى أكسيد الكربون أو تركيز عالى من غاز النيتروجين ضد حشرة ثاقبة الحبوب الصغرى

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تهدف هذه الدراسة إلى تقدير فاعلية استخدام جو محكم يحتوى على تركيزات مختلفة من ثانى أكسيد الكربون وهى (٢٥، ٥٠ ، ٧٥ و ١٠٠%) ضد الأطوار المختلفة لحشرة ثاقبة الحبوب الصغرى وذلك على ٢٠ ° و ٣٠ ° ± ١ درجة مئوية ٦٥ ± ٥% رطوبة نسبية .

علاوة على ذلك تم تقدير فاعلية جو محكم يحتوى على ٩٩,٩% نيتروجين ضد الاطوار المختلفة للحشرة وكذلك على درجتى الحرارة والرطوبة النسبية المذكورة سابقاً.

وقد تم اجراء هذه التجارب فى المعمل بقسم وقاية النبات بكلية الزراعة بمشتهر جامعة بنها . وتم استخدام اسطوانات بها ضغط معين من الغاز الطبيعى (ثانى أكسيد الكربون والنيتروجين) وهذه الاسطوانات مزودة بمنظم للضغط .

أوضحت النتائج تأثير فاعلية جو محكم يحتوى على تركيزات مختلفة من ثانى اكسيد الكربون (٢٥ ، ٥٠ ، ٧٥ و ١٠٠%) وذلك لمكافحة الأطوار المختلفة لحشرة ثاقبة الحبوب الصغرى عند درجات الحرارة ٢٠ ، ٣٠ درجة مئوية.

ويعتمد تأثير غاز ثانى أكسيد الكربون على التركيز وفترة التعريض فنجد أنه عند زيادة تركيز غاز ثانى أكسيد الكربون مع زيادة فترة التعريض يزداد نسب الموت للحشرات. وأيضا نجد عند درجات الحرارة المرتفعة (٣٠ ° م) يزداد تأثير الغاز عنها عند درجات الحرارة المنخفضة (٢٠ ° م) ونلاحظ أن حساسية الأطوار المختلفة للحشرة تختلف من طول لأخر.

أوضحت النتائج أن فاعلية جو محكم من ٩٩,٩% نيتروجين قد توقفت على طور الحشرة و فترة التعريض ودرجة الحرارة.