SOME FACTORS AFFECTING THE EFFICIENCY OF CONTROLLED ATMOSPHERES AGAINST *CALLOSOBRUCHUS MACULATUS* (FAB.) AND *TROGODERMA GRANARIUM* (EVERTS).

Salama, A. E., A. H. Hosny, A. A. Ismail, R. Abo-Arb* and S. I. A. Ibrahim
Pesticides Department, Fac. Of Agric. Kafr El-Sheikh, Univ., Egypt.
**Plant protection Research institute, Agric. Res. Center Dokki, Giza, Egypt.*

ABSTRACT

The effects of some factors (gas composition, time of treatment and the role of oxygen concentration) affecting the efficiency of controlled atmospheres (CAs) against both *C. maculatus* and *T. granarium* were studied. The data confirmed that both CO_2 and N_2 are quite safe and potent and could be used easily and successfully for controlling stored grain insects particularly in the presence of low concentration of oxygen. Pure CO_2 is highly effective for controlling adults of *C. maculatus* with LT_{50} value of 19.85 hours, while *T. granarium* was relatively somewhat tolerant towards pure CO_2 with LT_{50} value of 46.81 hours. On the other hand, pure N2 was relatively fair toxic against *C. maculatus* with LT_{50} value of 23.38 hours. Based on LT_{50} values, it is quite clear to conclude that adults of *C. maculatus* are somewhat susceptible than adults of *T. granarium* to the toxic action of CA whether contained high level of CO_2 or N_2. The efficiency of using CA as protectant against *C. maculatus* is in general, much more potent than using it as grain-treatment. The data also showed that oxygen played a very important and critical role as it acted as a synergist for increasing the efficiency of both CO_2 and N_2 against stored-grain insects.

Concerning the effect of CA on insect-fertility and fecundity, the data quite revealed that there are highly significant reductions in the number of deposited eggs, the percent of egg-hatchability as well as the percentages of adult emergence.

INTRODUCTION

The four-spotted bean weevil; *C. maculatus* (Fab.) and the Khapra beetle; *T. granarium* (Everts) are among the most economic insects that caused deleterious effects and significant loss of the yield-quality and quantity all over the world particularly in the developing countries. **Amirault (1995)** reported that, *C. maculatus* (Fab.) caused loss in the cowpea yield ranged between 13-24%. Moreover, **Adedire** and **Akinneye (2004)** reported that, dry weight loss of cowpea seed due to *C. maculatus* exceeds 2900 tones each year.

C. maculatus was increased generally as the concentration of CO_2 was increased.

With respect to the effect of pure CO_2 against *T. granarium*, the data presented in Table (1) show that the adult stage is relatively somewhat tolerant towareds pure CO_2 with LT_{50} value of 46.81 hours, which is almost more than two times the LT_{50} value of CO_2 against adults of C., *maculatus*. This result agreed with the trend of the previous findings of **Le-Torc'h (1983)** who reported that *T. granarium* was less susceptible to pure CO_2 than five of tested insect species.

As for the efficiency of pure nitrogen against *C. maculatus*, the data presented in Table (1) revealed that, pure nitrogen has relatively fair toxic potential against *C. maculatus* with respect to the efficacy of CO_2 on the same insect. In other words, the percent mortalities of pure nitrogen are: 30, 48, 73, 76, 78 and 80% after exposure time of 10, 24, 48, 72, 96 and 120 hours, respectively.

The LT_{50} value was also determined and found to be 23.38 hours. Based on LT_{50} values, CO_2 is considered somewhat faster in its action than pure nitrogen in spite of the significant different between their molecular weights which are equal to 44 and 28 for CO_2 and nitrogen, respectively.

Concerning the effect of pure nitrogen against *T. granarium*, the results in Table (1) showed that, pure nitrogen has almost the same toxic effect of pure CO_2 but with a relatively slow action. Based on LT_{50} values (37.07 hours), *T. granarium* is considered somewhat more tolerant to the toxic action of pure nitrogen with respect to the LT_{50} value of *C. maculatus* (23.38 hours).

With respect to the available literatures, our results agreed with **Zakladnoi** (1976) who pointed out that pure CO_2 is more rapidly toxic than puree nitrogen to the adults of *S. granaries, S. oryzae, R. dominica and T. castaneum*. In addition, **Mbata and Reichmuth (1993)** showed that adults of *C. subinnotatus* exposed to 100% Co_2 or 100% N_2, the times required to obtain 100% mortality were 16 and 24 hours for Co_2 and N_2, respectively.

(half or complete opened) with a glass stopper and serve as outlet of the different gases.

4. Method of applying the controlled atmosphere (CA):

This was done according to the method advised by **Ibrahim (2007).**

5- Statistical analysis and equations:

Statistical analysis of all data was carried out according to Duncan's multiple range test (Duncan, 1955).

- % reduction of egg, larvae, pupae or adult with respect to control =

$$\left[1 - \frac{\textbf{Treatment}}{\textbf{Control}}\right] \text{x } 100$$

- $\% \text{ adult emerged} = \frac{\text{Mean No. of adult emerged}}{\text{Mean No. of ggs laid}} \text{x } 100$

- % reduction of emerged adults was calculated according to the equation of **El-Lakwah et al. (1992):**

$$\% \text{ reduction} = \frac{\text{Mean No. of emerged in control - Mean No. of emerged in treatment}}{\text{Mean No. of emerged in control}}$$

$$\text{x } 100$$

RESULTS AND DISCUSSION

1. Efficacy of pure gases (CO2 and N2) each applied separately against adults of both insects:

Data presented in Table (1) clearly indicate that pure CO_2 (100% CO_2) is highly effective for controlling adult of *C. maculatus* with LT_{50} value of 19.85 hours. This value considered a good indicator for the rapid action of CO_2. However, the relative rapid response of *C. maculatus* to CO_2 might be due to anoxia and the toxic action of CO_2 particularly in case of complete absence of oxygen. This result agreed with the previous findings of **prozell and Richmath (1992)** who found that a mixture of 99% CO_2 and 1% air resulted in 100% kill off all life stage of *S. granaries* within 3 hours. Moreover, **El-Lakwah et al., (1992)** reported that the mortality of adult of

C. maculatus was increased generally as the concentration of CO_2 was increased.

With respect to the effect of pure CO_2 against *T. granarium*, the data presented in Table (1) show that the adult stage is relatively somewhat tolerant towareds pure CO_2 with LT_{50} value of 46.81 hours, which is almost more than two times the LT_{50} value of CO_2 against adults of C., *maculatus*. This result agreed with the trend of the previous findings of **Le-Torc'h (1983)** who reported that *T. granarium* was less susceptible to pure CO_2 than five of tested insect species.

As for the efficiency of pure nitrogen against *C. maculatus*, the data presented in Table (1) revealed that, pure nitrogen has relatively fair toxic potential against *C. maculatus* with respect to the efficacy of CO_2 on the same insect. In other words, the percent mortalities of pure nitrogen are; 30, 48, 73, 76, 78 and 80% after exposure time of 10, 24, 48, 72, 96 and 120 hours, respectively.

The LT_{50} value was also determined and found to be 23.38 hours. Based on LT_{50} values, CO_2 is considered somewhat faster in its action than pure nitrogen in spite of the significant different between their molecular weights which are equal to 44 and 28 for CO_2 and nitrogen, respectively.

Concerning the effect of pure nitrogen against *T. granarium*, the results in Table (1) showed that, pure nitrogen has almost the same toxic effect of pure CO_2 but with a relatively slow action. Based on LT_{50} values (37.07 hours), *T. granarium* is considered somewhat more tolerant to the toxic action of pure nitrogen with respect to the LT_{50} value of *C. maculatus* (23.38 hours).

With respect to the available literatures, our results agreed with **Zakladnoi** (1976) who pointed out that pure CO_2 is more rapidly toxic than puree nitrogen to the adults of *S. granaries*, *S. oryzae, R. dominica and T. castaneum*. In addition, **Mbata and Reichmuth (1993)** showed that adults of *C. subinnotatus* exposed to 100% Co_2 or 100% N_2, the times required to obtain 100% mortality were 16 and 24 hours for Co_2 and N_2, respectively.

Table (1): Effect of pure CO_2 and pure nitrogen applied separately on adults of both *C. aculates* and *T. granarium.*

Pure gas applied singly	Insect	% mortality of adults after:						LT_{50} values hours	Confidence limits	Slope values
		10 hr	24 hr	48 hr	72 hr	96 hr	120 hr			
Pure CO_2	*C. maculatus*	25	50	90	92	95	100	19.85	17.17-22.50	0.1959
	T. granarium	0.0	20	53	67	83	97	46.81	42.68-50.98	0.2455
Pure N_2	*C. maculatus*	30	48	73	76	78	80	23.38	17.95-28.68	0.1485
	T. granarium	15	36	55	68	81	86	37.07	32.03-42.33	0.1630
Control	*C. maculatus*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	T. granarium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

II- The role of oxygen concentrations on the efficiency of controlled atmosphere containing 80% CO2 or N2 against both stored grain insects:

The data presented in Tables (2 and 3) reflected the response of adult *C. maculatus* (%mortality) to controlled atmosphere (contained 100 CO_2 or N_2) occurred very rapidly as 48-50% of the population under test died within the first 24 hours (Tables 2 and 3), while the corresponding %mortality in case of *T. granarium* ranged between 36-38%. This result re-confirmed that *T. granarium* has relatively some tolerant potential towards the toxic action of CO_2. The data also showed that, replacement of 20% CO_2 with 20% nitrogen resulted in decreasing the percent mortality of both insects. In term of figures, the percent mortalities dropped from 50 to 41% and from 38 to 32% in cases of *C. maculatus* and *T. granarium* respectively (Table 2). On the other hand, replacement of 20% nitrogen with 20% CO_2 resulted in increasing the mortalities from 48 to 55% and from 36 to 46% in cases of *C. maculatus* and *T. granarium* respectively. This might be due to the differences in their modes of action and/or the difference in population susceptibility to CO_2 and nitrogen.

It is of great interest to notice that, the presence of a very low concentration of oxygen (0.6%) significantly increased the efficiency of controlled atmosphere (either contained 80% CO_2 or 80% N_2) against both insects (Tables 2 and 3). It other words, the initial percent mortalities of adults *C. maculatus* for instance, recorded after 24 hours increased significantly from 41 to 60% in case of controlled atmosphere contained

80% CO_2 + 0.6 O_2 (Table 2), and from 55 to 65% (Table 3) in case of controlled contained 80% N_2 + 0.6 O_2. The same trend of results was observed in case of *T. granarium* as the initial percent mortality increased significantly from 32 to 65% in case of controlled atmosphere contained 80% CO_2 + 0.6 O_2 (Table 2)and from 46 to 60% in case of CA contained 80% N_2 + 0.6 O_2 (Table 3).

Table (2): Efficiency of controlled atmospheres contained 80% CO_2 mixed with different concentration of oxygen on adults of *C. maculatus* and *T. granarium* and the balance is nitrogen.

Series of gas Conc.	Gas ratio			% mortality of adults after:						LT_{50} values hours	Confidence limits	Slope values
	CO_2 V	N_2 V	O_2 V		24 hr	48 hr	72 hr	96 hr	120 hr			
S*	100	0.0	0.0	M1	50	90	92	95	100	20.00	18.55-26.76	0.336
	100	0.0	0.0	M2	38	53	67	83	97	37.91	9.88-57.11	0.559
1	80.0	20.0	0.0	M1	41	60	80	90	95	32.42	27.09-37.26	0.266
	80.0	20.0	0.0	M2	32	45	64	78	90	44.75	38.51-50.59	0.252
2	80.0	19.4	0.6	M1	60	85	90	95	100	19.44	14.196-23.95	0.313
	80.0	19.4	0.6	M2	65	78	85	91	96	15.47	8.47-21.56	0.273
3	80.0	15.0	5.0	M1	40	53	80	80	88	36.03	28.98-42.18	0.247
	80.0	15.0	5.0	M2	50	69	76	80	88	24.00	15.27-31.21	0.296
4	80.0	10.0	10.0	M1	25	48	81	81	85	46.47	40.64-52.02	0.256
	80.0	10.0	10.0	M2	20	46	70	76	80	50.68	44.66-56.57	0.257
5	80.0	7.0	13.0	M1	20	45	76	76	80	52.80	46.62-58.95	0.256
	80.0	7.0	13.0	M2	16	25	45	62	70	76.31	67.97-86.76	0.265
6	80.0	5.0	15.0	M1	19	40	69	69	80	58.15	51.58-65.00	0.257
	80.0	5.0	15.0	M2	13	20	42	58	60	89.25	78.79-104.22	0.272
Control	-	-	-	M1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	-	-	-	M2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

S*=Standard = 100%CO_2 in complete absence of oxygen and nitrogen
M1 = % mortality of *C. maculatus* (adults)
M2 = % mortality of *T. granarium* (adults)

Our results coincided with the results of **Calderon and Navarro (1979)** who mentioned that the role of the presence of low concentration of oxygen might have a synergistic effect on CO_2 atmospheres, which ultimately affect on insect mortality. On the other hand, all treatments in which adults of both insects were subjected to CA containing a concentration of oxygen exceed 5%, the initial percent mortalities recorded 24 up to 72 hours are very low (19 – 25%) mortality in case of *C. maculatus* and (13 -20% mortality) in case of *T. granarium* (Table 2), then increased gradually to reach 60 -80% mortality after 120 hours of exposure. These results could be explained by the fact that the insects can survived well in the presence of high level of oxygen concentration, but by time and during the first 5 days of storage in a sealed place, the survived insects consumed most of the oxygen contents and minimize its concentration to a very low level quite enough to cause anoxia. Accordingly it is quite fair to conclude that, oxygen played a very important and critical role as it acted as a synergist for increasing the efficiency of both CO_2 and N_2 against stored grain insect.

Table (3): Efficiency of controlled atmospheres contained 80% nitrogen mixed with different concentrations of oxygen on adults of *C. maculatus* and *T. granarium* and the balance is CO_2.

Series of gas Conc.	Gas ratio CO_2 V	N_2 V	O_2 V	% mortality of adults after:	24 hr	48 hr	72 hr	96 hr	120 hr	LT_{50} values hours	Confidence limits	Slope values
S*	0.0	100	0.0	M1	48	73	76	78	80	21.87	11.46-30.34	0.241
	0.0	100	0.0	M2	36	55	68	81	86	38.50	31.55-44.66	0.247
1	20.0	80.0	0.0	M1	55	75	80	90	92	20.80	13.59-26.93	0.260
	20.0	80.0	0.0	M2	46	62	77	83	88	29.85	21.91-36.52	0.245
2	19.4	80.0	0.6	M1	65	75	85	93	96	16.59	9.78-22.51	0.274
	19.4	80.0	0.6	M2	60	68	75	86	90	18.39	9.50-25.92	0.249
3	15.0	80.0	5.0	M1	45	50	73	80	88	34.02	26.36-40.57	0.245
	15.0	80.0	5.0	M2	40	48	70	75	85	38.71	30.81-45.62	0.242
4	10.0	80.0	10.0	M1	20	48	68	81	85	48.83	43.35-54.12	0.263
	10.0	80.0	10.0	M2	23	43	65	77	82	50.89	44.75-56.90	0.255
5	7.0	80.0	13.0	M1	10	45	63	76	80	57.45	51.94-63.00	0.283
	7.0	80.0	13.0	M2	20	42	60	71	77	56.60	49.83-63.58	0.253
6	5.0	80.0	15.0	M1	16	40	58	69	75	60.96	54.23-68.16	0.258
	5.0	80.0	15.0	M2	15	39	52	63	72	67.06	59.47-75.78	0.257
Control	-	-	-	M1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	-	-	-	M2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

S*=Standard = 100%CO_2 in complete absence of oxygen and nitrogen
M1 = % mortality of *C. maculates* (adults)
M2 = % mortality of *T. granarium* (adults)

In general, the current results agreed with the previous findings of many investigators i.e. **Reichmurth (1986)** and **Krishnamurthy et al., (1986)** who indicated that the effectiveness of CO_2 was appreciably increased with reduced oxygen concentration, at least down to 1%. In addition, **El-Sayed (1998)** stated that CA containing higher level of CO_2

plus lower O_2 contents were more effective against the active and diapausing larvae of *T. granarium* than atmospheres with lower CO_2 content plus higher O_2 concentrations.

Based on LT_{50} values presented in Tables (2 and 3), it is quite clear that adults of *C. maculatus* are somewhat susceptible than adults of *T. granarium* to the toxic action of CA whether contained high level of CO_2 or N_2. In other words, the LT_{50} values of pure CO_2 against *C. maculatus* is 19.85 hours, while the corresponding value of *T. granarium* is 46.81 hours (Table 1). Moreover, the LT50 values of *C. maculatus* and *T. granarium* against pure nitrogen are 23.38 and 37.07 hours, respectively.

The data also showed that, there is some significant differences between the response of each insect towards both tested gases. In term of figures the LT_{50} values of *C. maculatus* are 19.85 and 23.38 hours for its response to CO_2 and N_2, respectively. The same trend of results was observed in case of *T. granarium* as its LT_{50} values are 46.81 and 37.03 hours for the response of insect to CO_2 or N_2 respectively. These results matched with the findings of many investigators **(Navarro and Diase, 1987; Hashem and Reichmuth, 1994; El-Lakwah and Halawa, 1997 and El-Sayed, 1998).**

The current results also confirmed that both CO2 and nitrogen are quite safe and could be used easily and successfully in CA particularly in the presence of low concentration of oxygen, but which gas considered more preferable to be used in CA strategy to control stored grain insects. However, this will depend on the availability of the gas, gas impurities, cost of application, sensitivity of the pest to the gas and type of products under storage.

III- Efficacy of the time of CA-treatment against *C. maculatus*:

In the following experiments, the different concentrations of CA were used either as grain-protectant (when the CAs were applied before the occurrence of insect-infestation) or as grain-treatments (when CAs were applied after the occurrence of insect-infestation). Taken in our consideration that both tested insects differed in their life-cycle i.e. *C. maculatus* deposited its eggs on the outer-surfaces of cowpea seeds, and the newly hatched larvae entered directly into the seeds and spend all her life cycle inside the seeds. On the other hand, *T. granarium* deposited its eggs in the wheat-grain and spend her life-cycle outside the grains. Thus, under these circumstances, it is not fair to compare between the biological response (fecundity and fertility) of both insects to the action of CAs, since *C. maculatus* spend her life-cycle inside the seeds under restricted movement and less exposure to CAs while *T. granarium* spend its life-cycle in continuous exposure to CAs. According, for precise evaluation between the efficiency of CAs as grain-protectant and grain treatment, we will focused our comparison on *C. maculatus* as an example.

The efficiency of time of CA-treatment against *C. maculatus*:

The results presented in Table (4) revealed significant differences in the mortality percentages among all treatments and control. Moreover, the response of adults to the toxic action of CA is dosage-dependent and positively correlated with the increase of CO_2 concentration. However, the reduction in oxygen concentration produced hypoxia or anoxia while an increase in CO_2 concentration produced hypercarbia. In addition, **Wigglesworth (1965)** suggested that high concentration of carbon dioxide might cause the muscle of spiracles to relax and the spiracles to be opened leading to more fumigant uptake. These might be behind the toxic action of CA.

The data also showed that oxygen concentration affect considerably the efficiency of CA. In other words, the increase of oxygen concentration resulted in decreasing the efficiency of CA and vice versa. This result confirmed our previous results that oxygen play an important role in synergistic the toxic action of carbon dioxide. Moreover, many investigators showed that insect mortality was generally increased as the concentration of CO_2 increased (**Spratt et al., 1985; Krishnamurthy et al., 1986; Hashem and Reichmuth, 1994; El-Lakwah et al., 1992, 1994 and El-Lakwah and Halawa, 1997**).

Concerning the effect of CA concentrations on the number of deposited eggs, the results in Table (4) showed that, there are highly significant reductions in the number of laid eggs with respect to untreated control treatment. However, these reductions are also concentration dependent and positively correlated with the concentration of CO_2. Their values are: 57.6, 45.5, 33.3, 15.2 and 3.0% for CA containing concentrations of CO_2 of 95, 80, 65, 45 and 25%, respectively.

The effects of CA on insect-fertility and fecundity have been studied by many investigatores. The use of CO_2 to anaesthetise freshly emerged adults of *C. maculatus* was shown to affect the fecundity. Increasing the time of exposure (from 30 seconds to 32 minutes) to an atmosphere of 100%

CO_2 caused significant decrease of the fecundity compared to untreated control. Life-time fecundity was also significantly reduced after exposure to 100% CO_2 **(Dawson, 1995)**. Our results also confirmed the previous finding of **Ofuya and Reichmuth (2002);** they found that emerged adult bruchids laid fewer eggs after 12 hours of exposure to CA (70% CO_2 in air and 1% O_2 in nitrogen). In case of *L. bostrychophila*, **Jin Jun et al. (2001)** revealed that the development, survivorship and reproduction were all inhibited by hypoxia and hypercarbia compared with the control.

It is of great interest to mention that the use of CA concentrations before insect infestation affected also the percent of egg-hatchability. This effect was very pronounced and accounted 50% hatchability in the first and second concentrations of CA, which contained high level of CO2, coincided with very low concentration of oxygen (0.4, 0.8%, respectively). It is rather interest to report that although all tested treatments caused remarkable effects on the fecundity and fertility of *C. maculatus* but non of these treatments caused complete inhibition of egg-hatching and/or complete cessation of egg-laying.

The current results also revealed that CAs affected significantly the percentages of adult emergence. In term of figures, the percentages reductions of adult emergence with respect to control are 92.7, 82.7, 72.4, 51.7 and 33.4%, respectively (Table 4). This effect is also dosage dependent and correlated positively with the increase of CO_2 concentration.

Concerning the efficiency of using CAs on cowpea seeds after being infested with *C. maculatus*, the data presented in Table (4) revealed that there was no significant difference in the number of deposited eggs /10 females either between treatments and control or within treatments. This result was expected since the eggs are already deposited before being exposed to the specific concentration of CA.

Concerning the effects of CAs on egg-mortality the data presented in Table (4) revealed that this effect is dosage-dependent and positively correlated with the concentration of carbon dioxide. In other words, the percentages of egg-mortality are 43.3, 40, 37.6, 26.4 and 20.3% for the 1^{st}, 2^{nd}, 3^{rd}, 4^{th}, 5^{th} concentrations of CA, respectively. This result agreed with the trend of results of **Calderon and Navarro (1980)** who found that eggs of *T. castaneum* and *R. dominica* exposed to atmospheres containing 2-8% oxygen supplemented 5-30% CO_2 were more susceptible than their adult stage. Moreover, **Tunc (1983)** indicated that 0-24 hour old eggs of *Plodia* *interpunctella* (Hubner) were completely killed in high CO_2 and low oxygen atmospheres. **Spratt et al. (1985)** showed that the eggs and pupae of *T. granarium* exposed to 60% CO_2 in air died within 6 days; however, mortality increased with increasing CO_2 concentration. **Soderstrom et al. (1991)** indicated that the mortality of *C. pomonella* eggs treated with oxygen deficient or CO_2 enriched atmospheres is exposure time-dependent. **Ofuya and Reichmuth (1992)** found that complete kill of eggs of the bruchid *A. obtectus* occurred in one or more days of exposure to pure CO_2.

With regareds to the effects of the different concentrations of CA on percent egg-hatchability, the results in Table (4) quite indicate that significant differences were observed either among all treatments and control or within treatments. Moreover, the effect was also dependent on CO_2 level in the different concentrations of CA. In other words, the most pronounced concentration is the first concentration, which contained the higher level of CO2 (95%), coincided with the lower concentration of oxygen (0.4%). However, the percentages reductions of egg-hatchability with respect to the control treatment could be arranged descendingly according to the continuous decrease in CO_2 contents as follows: 42.9, 40.8, 35.4, 23.8 and 18.8% for the different concentrations of CA containing 95, 80, 65, 45 and 25% CO_2, respectively. The data also showed that the concentration of oxygen in the CA is very critical for the efficiency of the toxic action of CO_2.

In conclusion, to compare between the efficiency of CA against *C. maculatus*, either in case of using CA before or after insect infestation, the data presented in Table (4) quite indicate, in general that, the efficiency of using CA as protectant against *C. maculatus*, is much more potent than using it as grain-treatment. However, one can fairly recommended the use of CA as protectant for controlling stored grain pests including both stored grain insects; *C. maculatus*, and *T. granarium*.

Table (4): Efficiency of different CA-concentrations applied directly before or after the infestation with *C. maculatus*.

Series	Different Conc. CA			% adult mortality after 24h		A		B		C		D	
	CO_2	N_2	O_2	b*	a*	b*	a*	b*	a*	b*	a*	b*	a*
1	95	6.4	0.4	80	**	140	321	57.6	3.3	50	43.3	70	182
2	80	19.2	0.8	77.5	**	180	315	45.5	5.1	50	40.0	90	189
3	65	33.5	1.5	30.0	**	220	330	33.3	0.6	40.9	37.6	130	206
4	45	48.5	6.5	27.5	**	280	330	15.2	0.6	28.9	26.4	199	243
5	25	65.0	10.0	25.0	**	320	325	3.0	2.1	21.9	20.3	250	259
Control	normal air			0.0	**	330	332	0.0	0.0	4.5	3.9	315	319

Table (4): Continued

Series	Different Conc. CA			% adult mortality after 24h		E		F		G		H	
	CO_2	N_2	O_2	b*	a*	b*	a*	b*	a*	b*	a*	b*	a*
1	95	6.4	0.4	80	**	50	56.7	77.8	42.9	21	72	92.7	76.5
2	80	19.2	0.8	77.5	**	50	60.0	71.4	40.8	50	87	82.7	71.6
3	65	33.5	1.5	30.0	**	59	62.4	58.7	35.4	80	121	72.4	60.5
4	45	48.5	6.5	27.5	**	71	72.4	36.8	23.8	140	172	51.7	43.8
5	25	65.0	10.0	25.0	**	78	79.7	20.6	18.8	193	206	33.4	32.7
Control	normal air			0.0	**	95	96.1	0.0	0.0	290	306	0.0	0.0

Notice that no adults were present at the beginning of the experiment to be evaluated. **b*= before being infested with *C. maculatus*. **a***=after being infested with *C. maculatus*. **A**=No. of deposited egg/10females. **B**= % reduction of deposited eggs with respect to control. **C**= % of egg mortality. **D**=No. of eggs hatched. **E**= % of egg-hatchability. **F**= % reduction of egg-hatchability withrespect to control. **G**=No. of emerged adults. **H**= % reduction of adult emergence with respect to control.

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الملخص العربي

كفاءة الأجواء الهوائية المعدلة ضد حشرتى خنفساء اللوبيا وخنفساء الصعيد

أحمد السيد سلامه ، عبد العزيز حسن حسنى ،أحمد عبد الحميد أبو زيد إسماعيل ، رافت ابو عرب* ،سحر ابراهيم احمد
قسم المبيدات ـــ كلية الزراعة ـــ بكفر الشيخ ـــ جامعة كفر الشيخ
*معهد بحوث وقاية النبات – الدقى – الجيزة – القاهرة

تم دراسة تأثيرات بعض العوامل (تركيب الغاز وقت المعالجة ودور تركيز الأوكسجين) على كفاءة الأجواء الهوائية ضد حشرتى خنفساء اللوبيا وخنفساء الصعيد. أكّدت البيانات بأنّ كلا من غاز ثاني اكسيد الكربون والنيتروجين من الغازات الامنه والفعالة جدا يمكن أن استخدامها بسهولة وبنجاح للسيطرة على حشرات الحبوب المخزونة خاصتا في حالة استخدام التركيز المنخفضه من الاوكسجين. كذلك اكدت النتائج ان غاز ثانى اكسيد الكربون النقى فعّال جدا للسيطرة على الحشرة الكاملة لخنفساء اللوبيا ، حيث بلغ الزمن اللازم لقتل ٥٠% من الحشرات حوالى ١٩,٨٥ ساعة، بينما كانت خنفساء الصعيد اكثر تحملا حيث بلغ الزمن اللازم لقتل ٥٠% من الحشرات حوالى ٤٦,٨١ ساعة.

ومن ناحية اخرى اثبت الدراسة ان النيتروجين النقى يعتبر سام نسبيا ضد خنفساء اللوبيا حيث بلغ الزمن اللازم لقتل ٥٠% من العشيرة حوالى ٢٣,٣٨ ساعة. واعتمادا على استخدام معيار الزمن اللازم لقتل ٥٠% من الحشرات كمقياس سرعة فعل الغاز حيث اوضحت النتائج ان حشرة خنفساء اللوبيا اسرع تاثرا من خنفساء الصعيد وخاصة عند استخدام تركيزات مرتفعة من غاز ثانى اكسيد الكربون او النيتروجين. وعموما فان كفاءة إستعمال الاجواء المعدلة قبل حدوث الاصابة كاسلوب وقائى ضد خنفساء اللوبيا يعتبر اكثر فعالية من استخدامها كاسلوب لمكافحة الافة بعد حدوث الاصابة.

كذلك اوضحت النتائج ان الأوكسجين يلعب دور مهم جدا وحاسم لزيادة كفاءة وفعل كلا من غازى ثانى اكسيد الكربون والنيتروجين ضدّ حشرات الحبوب المخزونة. كذلك اكدت النتائج حدوث انخفاض معنوى فى خصوبة الحشرات (معدل وضع البيض وكذلك نسبة الفقس) بالإضافة إلى حدوث انخفاض معنوى فى نسبة انبثاق الحشرات البالغه.