SUMMARY

This study was conducted at the laboratory of stored products pests of the Plant Protection Department, Faculty of Agriculture at Moshtohor, Tukh, Qualubia, Zagazig University and supported by the National project of integrated pest management for post-harvest pests financed by EEC-counterpart funds, Ministry of Agriculture and land Reclamation, Egypt.

The objective of this study was to investigate the effectiveness of certain methyl bromide alternatives i. e. controlled atmospheres (CA) of various carbon dioxide concentrations; CA of very high nitrogen content, phosphine gas produced from metal phosphide (aluminium or magnesium) and combinations of phosphine and carbon dioxide against some stored product-insects inside three closed storage facilities i. e. steel bins, fiberglass bins and metal drums.

Insects tested were the adults and immature stages of the rice weevil ***Sitophilus oryzae*** (L.); lesser grain borer ***Rhizopertha dominica*** (F.) and the red flour beetle ***Tribolium castaneum*** (Herbst.) as well as active and diapausing larvae of Khapra beetle ***Trogoderma granarium*** Everts.

The chosen treatments as methyl bromide alternatives were tested inside gastight steel bins each of 0.5 m^3 volume and was filled with ca. 450 kg wheat grains, closed fiberglass bins each of around 0.6 m^3 volume and was filled with about 450 kg wheat grains and closed metal drums (Barrels) each of ca. 0.2 m^3 volume. Trials were conducted also in closed metal drums (Barrels), each drum was filled with about 50 kg wheat grain.

The closed steel bins and fiberglass bins were situated on the roof of the building of the Plant Protection Department of the Faculty of Agriculture at Moshtohor but the drums were kept under storage condition in a stored-room during the whole periods of the tests.

The obtained results could be summarized as follows: -

1-Efficacy of controlled atmospheres (CA) of certain carbon dioxide concentrations against the tested insect species at various grain temperatures inside the three storage facilities:

The results of the efficacy of controlled atmospheres containing around 30 and 60 % CO_2 at grain temperatures of 18 ± 2°C and 28 ± 2°C against the adults and immature stages of ***S. oryzae, R. dominica*** and ***T. castaneum*** as well as the active and diapausing larvae of ***T. granarium*** showed that insect mortality was concentration, tightness of the bin and exposure period-dependent. Mortality values increased with the rise of concentration, in the CA and period of exposure. The efficacy of the tested CA of CO_2 against the various insects was also, greater at higher grain temperature than at lower one. The higher the tightness of the storage enclosure, the higher the effectiveness of the treatment.

In general, the diapausing larvae of ***T. granarium***, the pupae and eggs of ***S. oryzae, R. dominica*** were highly tolerant to the CA of CO_2 than the other insect stages and immature stages of ***T. castaneum***. Meanwhile, the diapausing larvae of ***T. granarium*** were less susceptible to the CA of CO_2 than active one. The susceptibility of the tested insects to the CA of CO_2 varied according to insect species and stage of development.

For example, the time to population extinction for the tested stages of various insect species when exposed to CA of 30 ± 5% CO_2 at grain temperature of 28 ± 2°C inside the closed fiberglass bins were 2; 6; 5 and 7 weeks for the adults, eggs, larvae and pupae of ***S. oryzae***, respectively. The corresponding values for ***R. dominica*** were 2 weeks for the adults, and 7 weeks for the eggs, larvae and pupae. In case of ***T. castaneum,*** these values were 2; 4; 3 and 4 weeks for adults, eggs, larvae and pupae, respectively. As for ***T. granarium,*** the time to population extinction at the above mentioned temperature and CA of CO_2 was 6 and 7 weeks for the active and diapausing larvae, respectively.

The time to population extinction for the tested stages of various insect species when exposed to CA of 60 ± 5% CO_2 at grain temperature of 28 ± 2°C inside closed metal drums were 3; 28; 21 and 35 days for the adults, eggs, larvae and pupae of ***S. oryzae***, respectively. The corresponding values for ***R. dominica*** were 5; 28; 28 and 35 days for the adults, eggs, larvae and pupae, respectively. In case of ***T. castaneum,*** these values were 5; 10; 7 and 7 days for their different stages, respectively. As for ***T. granarium,*** the time to population extinction at the above mentioned temperature and CA of CO_2 was 28 and 35 days for the active and diapause larvae, respectively.

2-Efficacy of CA of 99% N_2 against the tested insect species at various grain temperatures inside the closed steel bins:-

The results of the efficacy of CA of 99 % N_2 at grain temperatures of 18 ± 2°C and 28 ± 2°C against the adults and immature stages of ***S. oryzae, R. dominica*** and ***T. castaneum*** as

well as the active and diapausing larvae of ***T. granarium*** inside the closed steel bins indicated that the efficacy of the CA of 99 % N_2 was temperature and exposure period-dependent. Insect mortality increased with the increase of the period of exposure and it was also, greater at the higher grain temperature than at lower one.

Susceptibility of the insects to the CA of 99 % N_2 varied according to insect species and stage of development. For example, the lethal times required to achieve population extinction for the different stages of insect species at 28 + 2°C were 7; 28; 21 and 28 days for the adults, eggs, larvae and pupae of ***S. oryzae***, respectively. The corresponding figures for ***R. dominica*** were 10; 28; 21 and 28 days for the adults, eggs, larvae and pupae, respectively. For ***T. castaneum,*** these values were 10; 14; 7 and 10 days for the adults, eggs, larvae and pupae, respectively. As for the active and diapause larvae of ***T. granarium,*** these values were 28 days for both stages.

In general, these results revealed that the pupae and eggs of the various tested insects were more tolerant to the CA of 99 % N_2 than the other stages. Also the diapausing larvae of ***T. granarium*** were highly tolerant to this CA of N_2.

3-Efficacy of phosphine against the tested insect species inside the various storage facilities:

The results of the efficacy of 100 ppm phosphine against the various insects at 28 ± 2°C revealed that insect mortalities increased with extending the exposure time. Susceptibility of the insects varied according to insect species and stage of development. For example, the time required to achieve population extinction inside closed steel bins for the various

stages of the insects were 2; 3; 3 and 5 days for the adults, eggs, larvae and pupae of ***S. oryzae***, respectively. The corresponding values for ***R. dominica*** were 2 days for the adults, and 5 days for the eggs, larvae and pupae. For ***T. castaneum,*** these values were 2; 3; 2 and 2 days for the adults, eggs, larvae and pupae, respectively. As for ***T. granarium,*** these figures were 3 and 5 days for the active and diapausing larvae, respectively.

These data showed clearly that the pupae of ***S. oryzae*** and ***R. dominica*** were highly tolerant to phosphine at 28 ± 2°C than their other stages inside the closed steel bins. While in case of ***T. castaneum*** larvae were less susceptible to phosphine than the adult and egg stages. Also, the diapausing larvae of ***T. granarium*** were highly tolerant to phosphine than active one.

4-Efficacy and combined action of phosphine with carbon dioxide against the tested insect species at various grain temperatures inside the various storage facilities:-

The results of the efficacy and combined action of phosphine (100 ppm) with CO_2-concentrations (30 and 60%) at a wide range of grain temperatures (18 - 28°C) against the various stages of ***S. oryzae, R. dominica*** and ***T. castaneum*** as well as the active and diapausing larvae of ***T. granarium*** inside the various storage facilities showed clearly that the efficacy of phosphine alone increased with rising the grain temperature, tightness of the storage facility and the period of exposure. Meanwhile, insect mortalities resulted from the combinations of phosphine and carbon dioxide were generally greater than those obtained from each gas alone and were also exposure period-dependent.

Co-toxicity values resulted from the mixtures of phosphine plus carbon dioxide showed in most cases additive and/or

potentiation effects with the various insects at various exposure periods inside all storage facilities.

Thus, combinations of phosphine and carbon dioxide could be used as an effective alternative to replace methyl bromide in grain fumigation against stored product insects inside closed storage facilities. This method has the advantages of enhancing the efficacy of each gas alone and reducing the exposure period required for complete kill especially for the most tolerant insect stages such as pupae and larvae found inside the grains and the diapausing larvae of ***T. granarium.***

The obtained data clearly revealed that, the closed steel bins posses the highest gastightness compared to the other tested storage facilities, while the fiberglass bins showed the lowest gastightness during conducting the various experiments, and the tightness of the fiberglass bins was not sufficient for application of CA of 99% N_2 to achieve complete extinction of the populations of the tested stored product insect species under study.

Meanwhile, the tightness of the closed fiberglass bins was much lower than that of the closed steel bins and metal drums during conducting the experiments, also gas loss inside the storage facilities increased by increasing the exposure period.