

Studies on development of resistance to carbon dioxide and combination of phosphine plus carbon dioxide in the red flour beetle (*Tribolium castaneum* Herbst)

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The main objective of the present work was to study the development of resistance in the red flour beetle (*Tribolium castaneum* Herbst) to phosphine, carbon dioxide and their mixture. Also to investigate some biological characteristics of the resistant strain to a combination of phosphine plus carbon dioxide in comparison to the parental stock. This work was conducted at the Plant Protection Dept., Faculty of Agriculture at Moshtohor, Zagazig University. Data obtained could be summarized as follows:

- 1- Development of resistance in *T. castaneum* - adults to phosphine, carbon dioxide and a combination of the two gases: Adult populations of *T. castaneum* were exposed in the laboratory for 16 generations to a fixed concentration of 40 vpm phosphine (56.52 / .lgil) a controlled atmosphere containing 46% carbon dioxide and a combination of 40 vpm PH₃ + 46% CO₂ at varying exposure periods, 26 ± 1°C and 6 ± 1°C, in order to select strains resistant to phosphine, carbon dioxide and their mixture. Selection pressure was carried out at the median lethal dose/time inducing mortalities ranged from 50-70%.
 - 1.1- Development of resistance in *T. castaneum* adults to phosphine, Results indicated, that the lethal time values (LT₅₀, LT₉₀, LT₉₉) were significantly higher at the lower temperature 6 ± 1°C than at the higher one (26 ± 1°C) and at the 16th generation, the lethal times needed for a certain kill were markedly longer for the phosphine resistant strain than the laboratory strain. Results of selection indicated that *T. castaneum* adults have the genetic potential to develop resistance to phosphine and the treatment of the successive generations of this insect with the median lethal dosages of phosphine produced insects with increased tolerance to the fumigant at the two test temperatures. The adults of the 16th generations showed 15.4-fold resistance to phosphine at 26 ± 1°C and 10.2 - fold resistance at 6 ± 1°C when compared with the laboratory stock at the LT₅₀ - level.
 - 1.2 - Development of resistance in *T. castaneum* to carbon dioxide : Results indicated that at the 16th generation. the lethal time values achieved for certain mortality were significantly higher at the two test temperatures, when compared with the laboratory strain. The adults of the 16th generation showed at 26 ± 1°C 1.8 and 1.9 fold at LT₅₀ and LT₉₀ - level. respectively. At 6 ± 1°C the 16th generation revealed 1.7 and 1.8 fold at LT₅₀ and LT₉₀ -level, respectively. This result indicated that *T. castaneum* adults was capable to develop low resistance to an atmosphere contained 46% CO₂.
 - 1.3- Development of resistance in *T. castaneum* to a combination of phosphine + carbon dioxide : Results showed that the lethal time values recorded to obtain certain kill were significantly higher for the 16th generation at the two test temperatures than for the laboratory strain (Parent). At the 16th generation, the adults of *T. castaneum* showed 19.4 - fold resistance to a combination of phosphine plus carbon dioxide at 26 ± 1°C and 18.5 - fold resistance at 6 ± 1°C when compared with the laboratory stock at the LT₅₀ - level. This result indicated clearly that *T. castaneum* adults have the genetic potential to develop resistance to an atmosphere containing a combination of 40 vpm PH₃ + 46% carbon dioxide.
- 2.1. The biological characteristics of the resistant strain of *T. castaneum* to a combination of P₃ + CO₂ in comparison to the parental stock. Results showed that, the resistant strain of *T. castaneum* (F₁₂) selected to a mixture of 40 vpm phosphine + 46%

carbon dioxide laid significantly higher number of eggs than the laboratory strain. But no significant differences were found between the laboratory and PH3 CO₂ resistant strain (F 12) of *T. castaneum* in the average pre-oviposition period and sex ratio. The total developmental period was significantly longer for the laboratory strain than the PH₃ + CO₂ - resistant strain. The average incubation period was significantly longer in the laboratory strains than the PH₃ + CO₂ resistant strain. The larval mortality was considerably higher for the PH₃ + CO₂ resistant strain. The average hatching rate of the eggs significantly increased for the PH₃ + CO₂ resistant strain. The mortality rate of the larval instars was significantly higher for the PH₃ + CO₂ - resistant strain than for the laboratory strain. It was also observed that the emergence rate of the adults was unaffected and amounted to 100% for the two strains.

2.2. The population dynamics of *Tribolium castaneum* resistant strains (PH₃ - RS, PH₃ + CO₂ - RS) in comparison to the parental stock (laboratory strain). Results revealed that the mean adult mortalities were 2.23%, 4.44% and 13.63% for the laboratory, PH₃ - RS, and PH₃ + CO₂ - RS, respectively. These values were obviously higher in case of the PH₃ + CO₂ - RS than the other strains. The population growth rates were 0.054, 0.053, and 0.053 for the laboratory, PH₃ - RS and PH₃ + CO₂ - RS respectively. It is evident that this value was slightly greater for the laboratory strain than the other strains. The maximum number of the alive adults recorded in the food during an observation period of six months was 1090, 805, 664 for the parental stock, phosphine resistant strain, and PH₃ + CO₂ - RS resistant strain, respectively. These values were reached after 120 days in all tested strains. Although the resistant strains to phosphine and the strain resistant to a combination of PH₃ + CO₂ laid significantly higher numbers of eggs in comparison to the laboratory strain, the adult populations recorded during the observation period of six months were in contrast lower for the two resistant strains than the laboratory strain. This could be due to the lower hatchability of egg in the phosphine resistant strain and higher mortalities during the various developmental stages of the two resistant strains in comparison with the parental stock.