EVALUATION OF CIGARETTE BEETLE CONTROL USING A COMPUTER-CONTROLLED CARBON DIOXIDE FUMIGATION SYSTEM

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The toxicity of carbon dioxide (CO_2) to the cigarette beetle was evaluated in laboratory and field studies. A computer controlled system (CCS) was designed to monitor and control CO_2 concentration and temperature during fumigations. This CCS achieved stable CO_2 concentrations ($\pm 0.2\%$) and temperatures ($\pm 0.25^{\circ}C$). Exposure combinations of CO_2 concentration (35%, 45%, and 60%) and durations of exposure (3, 4, and 5 days) were evaluated. Results showed that CO_2 demonstrates a selective toxicity to different insect stages (adult, egg, larva, and pupa). The pupa was the most sensitive stage with 100% killed at the lowest CO_2 concentration (35%) in 3 days. All eggs and adults were killed at 60% CO_2 concentration after a 3-day exposure. The larva was the most resistant stage. The second instar larva required a minimum of 60% CO_2 concentration and a 4-day exposure for 100% mortality. There was only 85% mortality in the fourth instar larva at the highest exposure rate (60% CO_2 concentration for 5 days). In the field, a 60% concentration of CO_2 was evaluated during a 4 day fumigation. Mortality rates were similar to those observed in laboratory studies. CO_2 is reported to have fewer risk factors to mammalian species than the most commonly used fumigant (phosphine). However, the use of CO_2 to control cigarette beetles is less effective than phosphine and is more costly. A combination of phosphine at 10 ppm and CO_2 at 35% concentration killed all stages of the cigarette beetle in 3 days. This alternative will reduce the amount of phosphine used, give complete control of all cigarette beetle stages, and decrease costs.

INTRODUCTION

The most destructive insect associated with stored tobacco and tobacco products is the cigarette beetle. Costs, due to damage to the finished product by this insect, can be extremely high due to lost sales. The most effective method of disinfesting product is by fumigation. Phosphine is currently the primary fumigant used by the tobacco industry for control of cigarette beetles on tobacco and tobacco products. It has several disadvantages and other methods are being examined. Some of these disadvantages include: acute toxicity, environmental concerns, long aeration times, flammable, corrosive and waste disposal.

One of the alternatives to phosphine fumigation is carbon dioxide fumigation. The advantages include: low acute toxicity, no residue, non-corrosive, non-flammable, and no waste disposal. Although there are concerns over rising carbon dioxide levels in the environment, the amount of carbon dioxide added by fumigation would be minute. Carbon dioxide has been reported to be an effective method for killing the cigarette beetle in the laboratory by Childs and Overby in 1983. Keever and Ryan, in separate 1988 reports, documented successful large scale fumigation of stored tobacco with carbon dioxide. A large scale fumigation described by Keever & Ryan can cost 10X the amount of a comparable phosphine fumigation. Our project employed a computer controlled exposure system which could first be evaluated under controlled laboratory conditions, then be incorporated into a large chamber fumigation system.

MATERIALS AND METHODS

Previous methods for regulating carbon dioxide levels were primitive, typically consisting of discrete measurement of carbon dioxide using Dreger tubes. Large fluctuations in carbon dioxide concentration were not uncommon. Gas concentrations would fluctuate throughout the effective range of toxicity from 35% to 60%.

A computer controlled monitoring and regulating system was developed which continuously monitored carbon dioxide levels and regulated the concentration at 10 minute intervals. In addition, the system monitors and regulates air temperature during laboratory studies. Figure 1 is a

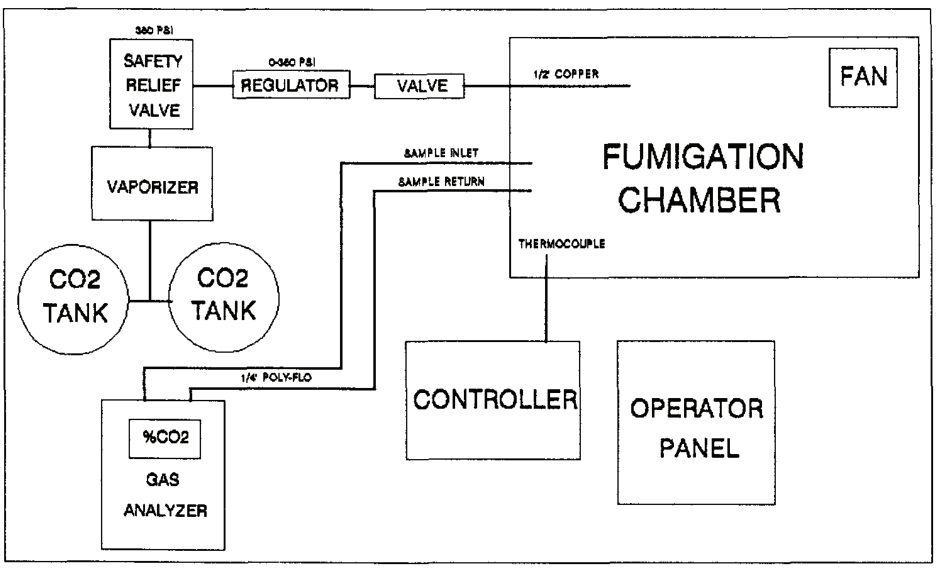

Figure 1. Schematic of chamber, carbon dioxide computer, and delivery system.

schematic showing the general configuration of the system. All facets of the system are under control of software developed at R.J. Reynolds using an IBM PC computer. During operation, the carbon dioxide concentration in the chamber reached 60% in 4 hours. Slightly longer times were required to reach the target temperature of 32°C. Carbon dioxide concentration fluctuated 0.2% and temperature fluctuated 0.25°C after equilibration (Figure 2). Temperatures in the

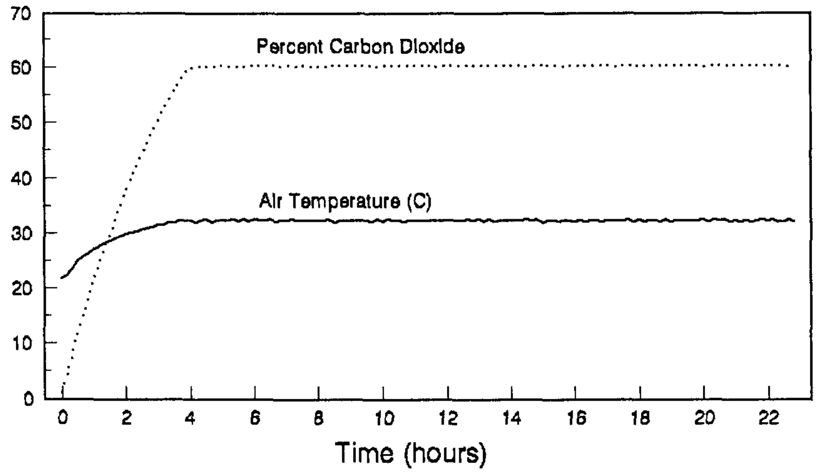

Figure 2. Carbon dioxide and temperature control data from laboratory chamber fumigation.

product however, took as long as 3 days to reach equilibrium (Figure 3). Relative humidity in the chamber dropped very

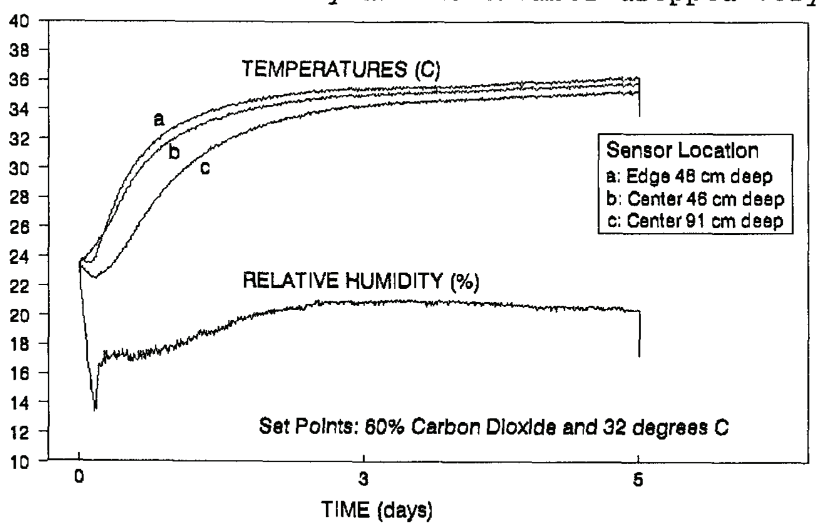

Figure 3. Temperature and humidity conditions in product containers during a 5-day carbon dioxide fumigation.

rapidly during introduction of the dry carbon dioxide, then increased to 20-50% RH throughout the fumigation.

Two types of chambers were used in these studies: Laboratory studies - 946 cubic feet and large chamber studies - 2,660 cubic feet. The following stages of the cigarette beetle were tested during all or part of the treatments: eggs, adults, 2nd and 4th instar larvae and pupae. Adults, larvae, and pupae were exposed in groups of 50 in tubes capped with stainless screens. The tubes were placed in plastic probes. Larval and pupal tubes contained cornmeal/yeast rearing medium. Eggs were exposed in chambers on glass slides. Probes containing the test insects were imbedded to a depth of 3.5 feet in a bulk can filled with cigarette packs used during our standard processing. Adult mortality was evaluated 4 hours after the probes were removed from the fumigation chamber. Mortality in all other stages was judged by the number of emerging adults or larvae compared to unexposed controls.

Carbon dioxide was controlled and monitored by the CCES. Phosphine was introduced into chambers in the form of aluminum phosphide pellets (weight 0.6 grams, release 0.2 grams hydrogen phosphide). Phosphine was monitored with Drager tubes or the Sentex portable GLC with an AID detector for quantifying hydrogen phosphide.

Results

Laboratory Carbon Dioxide

Exposure to carbon dioxide for 3 days killed 100% of pupae at all concentrations (Figure 4). The most effective

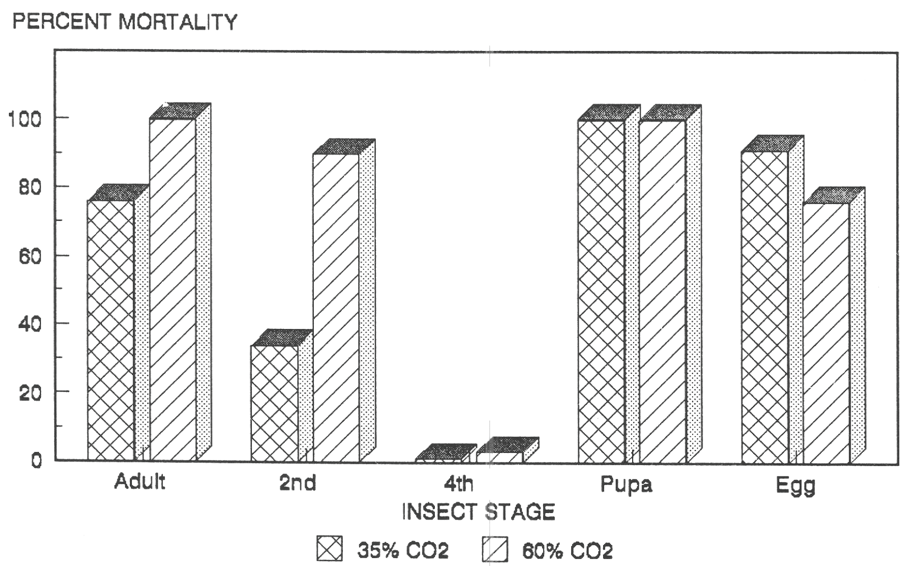

Figure 4. Cigarette beetle mortality due to fumigation at various carbon dioxide concentrations during a 3-day exposure.

exposure condition for all stages of the cigarette beetle was 60% carbon dioxide concentration for 4 days (Figure 5).

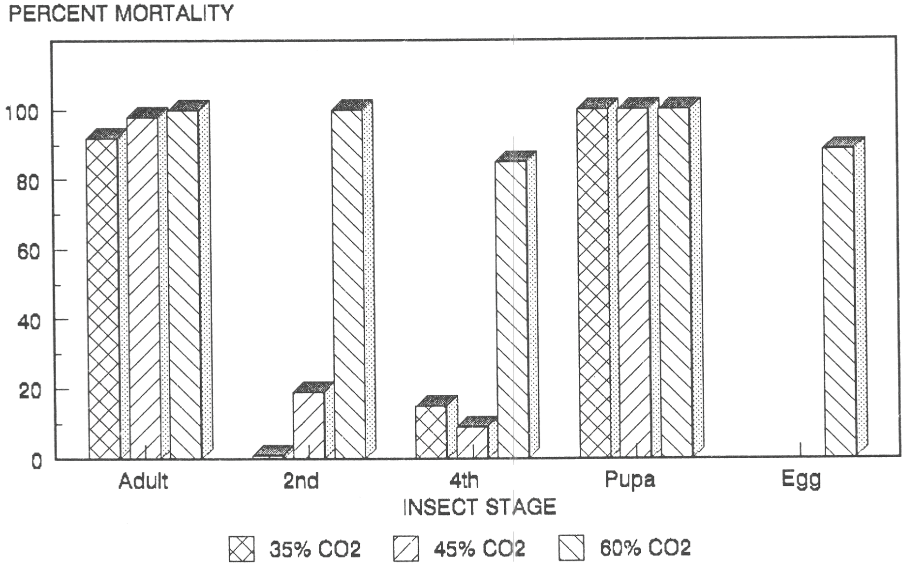

Figure 5. Cigarette beetle mortality due to fumigation at various carbon dioxide concentrations during a 4-day exposure

Under these conditions 100% of the eggs, adults, second instar larvae, and pupae were killed while 15% of the fourth instar larvae survived. Effectiveness was not increased by prolonging exposure time to 5 days (Figure 6).

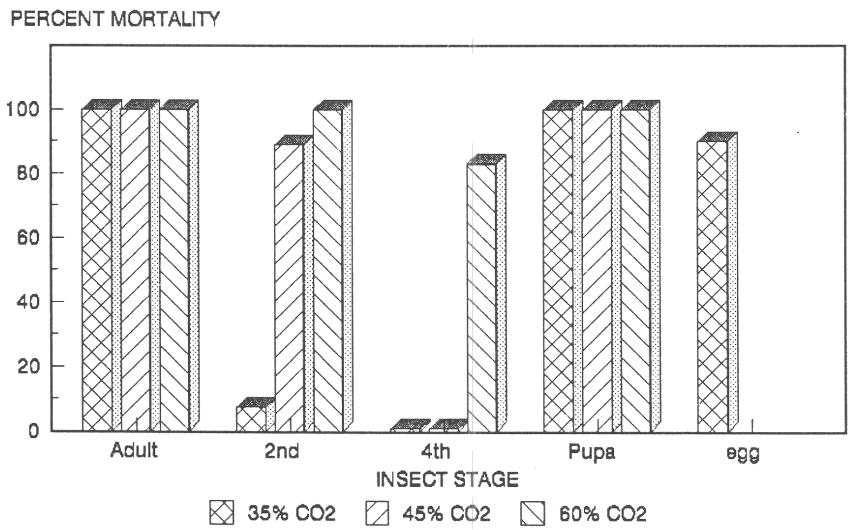

Figure 6. Cigarette beetle mortality due to fumigation at various carbon dioxide concentrations during a 5-day exposure.

Large Chamber Carbon Dioxide

The most effective exposure condition, determined in laboratory studies, was used in field experiments. Two stages were evaluated: adults - for immediate results and 4th instar larvae - the stage most resistant to carbon dioxide. In the field all insects were killed (Figure 7). Higher

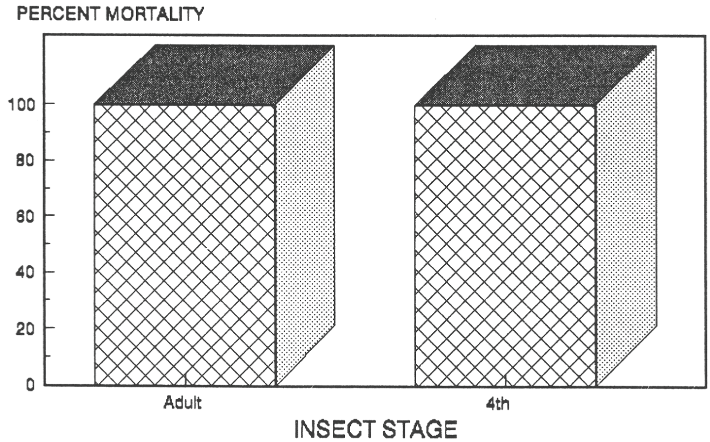

Figure 7. Cigarette beetle mortality due to fumigation in a large chamber at 60% carbon dioxide for 4 days.

mortality in the large chamber may be due to longer exposure to gas because of higher rate of entry and a temperature of 34°C.

Laboratory Mix Phosphine - Carbon Dioxide

Aluminum phosphide at reduced doses released low levels of phosphine gas (Figure 8 & 9). At these reduced levels

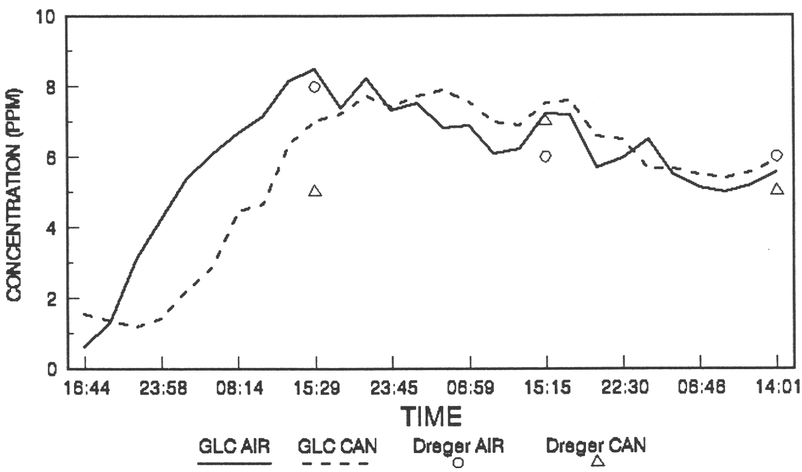

Figure 8. Phosphine levels during a 2-pellet 3-day fumigation measured hourly by GLC and daily by Drager tube.

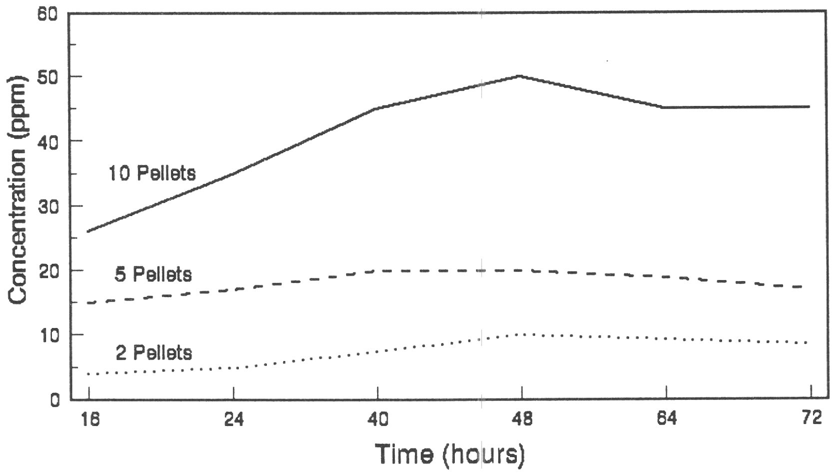

Figure 9. Aluminum phosphide dose correlated to phosphine concentration during a 3-day fumigation.

only pupae of the cigarette beetle survived after 3 days exposure (Figure 10). Combining carbon dioxide and phosphine

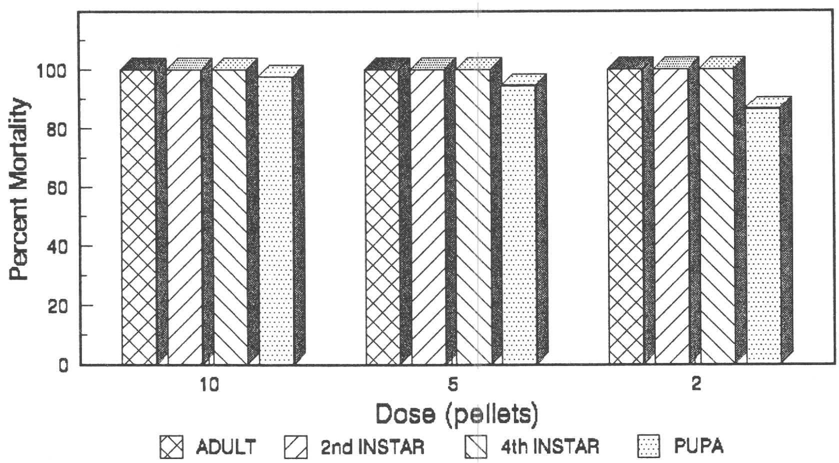

Figure 10. Mortality of cigarette beetle stages exposed to different doses of aluminum phosphide for 3 days.

at reduced rates should kill all stages after 3 days exposure. Studies are in progress to confirm this hypothosis.

CONCLUSIONS

Cost of fumigating with carbon dioxide can be relatively high when carbon dioxide is purchased in small allotments. However, purchasing carbon dioxide in bulk can reduce the cost of the gas about 80%. The cost of the computer control system is small when amortized over the life of the system.

Costs of fumigating at different levels of carbon dioxide are compared to the cost of a standard phosphine fumigation in Figure 11. In the laboratory at 60% concentration of carbon

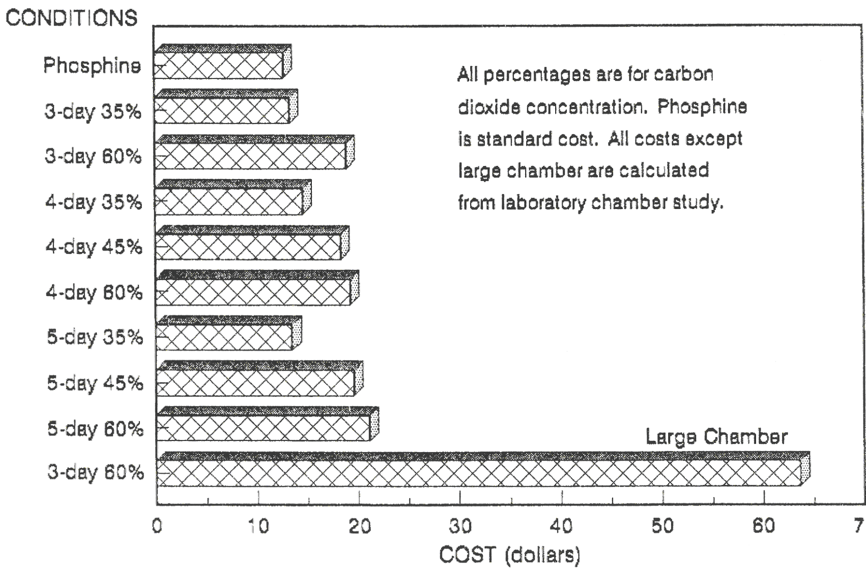

Figure 11. Cost of uusing phosphine and carbon dioxide in a large fumigation chamber (2,660 cubic foot).

dioxide for 4-days cost of control was 51% higher than a phosphine fumigation. In the large chamber study, at this same exposure rate, cost was 5 times this amount. This was due to gas lose around the doors in the field chamber.

Different stages of the cigarette beetle are sensitive to the toxic effects of phosphine and carbon dioxide. Employing them at reduced levels but in combination may provide complete control of the cigarette beetle. This would reduce both cost and negative environmental effects. Experiments are underway to confirm this hypothesis.

REFERENCES

1. Childs, D.P., and J.E. Overby. (1983) Mortality of the cigarette beetle in high-carbon dioxide atmospheres. J. Econ. Ent. 76(3):544-546.

2. Keever, D.W. (1989) Use of carbon dioxide to disinfest a tobacco warehouse of the cigarette beetle. J. Agric. Ent. 6(1),43-51.

3. Ryan, L. (1988) Low oxygen fumigation for beetle control. University of Kentucky Fumigation Short Course. Lexington, KT.

LUTTE CONTRE LE LASIODERME DU TABAC PAR L'EMPLOI D'UN SYSTEME DE GAZAGE AU DIOXYDE DE CARBONE PILOTE PAR ORDINATEUR

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RESUME

La toxicité du dioxyde de carbone (CO_2) envers le lasioderme du tabac a été étudiée en laboratoire et lors d'études sur le terrain. Un système piloté par ordinateur (SPO) a été conçu pour mesurer et surveiller les concentrations de CO_2 ainsi que les températures pendant les opérations de fumigation. Ce SPO a permis d'obtenir des concentrations en CO_2 stables (± 0,2 %) et des températures stables (± 0,25° C). L'exposition de combinaisons de concentrations en CO_2 (35 %, 45 % et 60 %) et de durées d'exposition (3, 4 et 5 jours) ont été expérimentées. Les résultats ont montré que le CO_2 développe une toxicité différente selon les stades de l'insecte (adulte, oeuf, larve et nymphe). La nymphe s'est avérée représenter le stade le plus sensible avec 100 % de mortalité aux concentrations en CO_2 les plus basses (35 %) en trois jours. La totalité des oeufs et des adultes a été tuée à une concentration en CO_2 de 60 % après une exposition de trois jours. La larve a représenté le stade le plus résistant. Il a fallu une concentration de 60 % en CO_2 et 4 jours d'exposition pour obtenir une mortalité du second stade larvaire de 100 %. Au quatrième stade larvaire, il n'y avait qu'une mortalité de 85 % au niveau le plus élevé d'exposition (60 % de CO_2 pendant 5 jours). Sur le terrain, on a mesuré une concentration en CO_2 de 60 % pendant 4 jours de fumigation. Les taux de mortalité ont été les mêmes que ceux observés lors des études en laboratoire. On rapporte que le CO_2 présente moins de risques pour les mammifères que le fumigant le plus employé, la phosphine. Cependant, l'emploi du CO_2 dans la lutte contre le lasioderme du tabac est moins efficace et plus chère que la phosphine. Une combinaison de phosphine à 10 ppm et de CO_2 à la concentration de 35 % a tué tous les stades de développement du lasioderme du tabac en 3 jours. Cette solution alternative réduit la quantité de phosphine utilisée, tue tous les stades de développement du coléoptère et diminue les coûts.