Cooperation Centre for Scientific Research Relative to Tobacco

CORESTA Guide N° 2

Technical Guide for Phosphine Fumigation Parameters for the Control of Cigarette Beetle and Tobacco Moth

August 2019

Pest and Sanitation Management in Stored Tobacco Sub-Group

CORESTA TECHNICAL GUIDE N° 2

Title:

Technical Guide for Phosphine Fumigation Parameters for the Control of Cigarette Beetle and Tobacco Moth

Status: Valid

Note: This document will be periodically reviewed by CORESTA

Document history:

Date of review	**Information**
January 2004	Version 1
June 2009	Version 2
October 2013	Version 3
August 2019	Version 4

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1. Introduction

Two insects, the cigarette beetle, *Lasioderma serricorne,* and the tobacco moth, *Ephestia elutella,* infest cured tobacco. These pests can be controlled by successful fumigation. The tobacco moth is more susceptible to phosphine than the cigarette beetle at high temperatures (TDRI, 1985) and thus the fumigation standards established for control of the cigarette beetle are those that should be used for controlling both insects (Savvidou, 2003).

Following trials with phosphine fumigations in Europe in the late 1950s and subsequent testing in Japan and the USA, phosphine became the fumigant of choice in the tobacco industry by 1975 (reviewed in Ryan, 1995).

In the late 1960s, ineffective fumigations as a result of resistance to phosphine were reported in a wide range of insect species (Champ and Dyte, 1976). However, at that time, there were no tobacco fumigation failures associated with cigarette beetle resistance. Phosphine resistance was not reported for the cigarette beetle until 1994, when the first ineffective field fumigation was recorded in India (Rajendran and Narasimhan, 1994). The incidences of failed fumigations and phosphine resistant beetles are being documented with increasing frequency worldwide.

2. Background

The potential of widespread phosphine resistance of cigarette beetles poses a serious risk to the continued successful use of phosphine as a fumigant for stored tobacco (Zettler and Keever, 1994). Therefore in 1998, the CORESTA Sub-Group on Pest and Sanitation Management in Stored Tobacco commissioned Fera Science Ltd (Fera) (formerly the Food and Environment Research Agency and the Central Science Laboratory) of the UK, as an independent laboratory, to assess the global variability of response by *Lasioderma serricorne* to phosphine (Mills et al., 2000; Savvidou et al., 2003). This work showed a range of responses among the phosphine susceptible cigarette beetle populations, with some able to survive the fumigation treatments used by the industry at that time (Mills et al., 2000; Savvidou and Bell, 2001). In addition a collaborative effort was established with North Carolina State University which focused on the effect of temperature, concentration and exposure-time on fumigation effectiveness (Keever et al., 1997).

Having established the fumigation parameters required to achieve 100 % mortality of susceptible populations of cigarette beetles, attention was turned to resistant beetles. In 2003, 2010 and 2012, Fera was once again commissioned to determine various parameters sufficient to achieve 100 % mortality of all life stages of known resistant beetle strains (Savvidou and Pennington, 2004; Wontner-Smith and Cardwell, 2010, 2012).

In 2005, working independently, Japan Tobacco and Detia Degesch substantiated the correlation between the lethal concentrations necessary to kill cigarette beetles and the knockdown time of adult beetles exposed to high levels of phosphine. This work was the basis for Detia Degesch to develop a discriminating dose test (i.e. a resistance test kit) to distinguish between susceptible and resistant cigarette beetle populations and thus the ability to determine which fumigation standard to use for a given fumigation (Steuerwald et al., 2006).

3. Phosphine Fumigation Parameters for Tobacco Moths and Susceptible Cigarette Beetles

The laboratory and field studies confirmed that three parameters influence fumigation effectiveness:

1) Tobacco temperature
2) Exposure-time
3) Phosphine concentration

These three parameters must be strictly controlled to ensure effective fumigations and prevent the development of resistant populations of cigarette beetles. Based on current knowledge of the effects of temperature, time and phosphine concentration on fumigation effectiveness, the following guidelines for tobacco fumigation will ensure control of all stages of tobacco moths and susceptible cigarette beetles:

- ***Fumigation is only recommended when the tobacco temperature is at or above 16 °C (61 °F).***
- ***The minimum phosphine concentrations must be maintained during the whole exposure-time at the centre of tobacco bales/cases.***
- ***The concentration and exposure-time will vary depending upon the tobacco temperature.***
- ***Strict compliance with the fumigant label and local or national regulations is mandatory.***
- ***Loose tablet fumigant formulations are not preferred by the tobacco industry.***

Table 1. Minimum exposure-time required to achieve 100 % control of all stages of tobacco moth and susceptible cigarette beetle populations at 200 ppm or 300 ppm phosphine at the bale/case centre.

Tobacco Temperature		Phosphine Concentration at the Bale/Case Centre	Minimum Exposure-Time
(°C)	(°F)	(ppm)	(days)
16-20	61-68	300	6
> 20	> 68	200	4

Note: The tobacco temperature must be checked before the start of the fumigation.

Extensive work was performed in the region of 10 °C to 15 °C to provide data indicating concentrations/times that would provide successful fumigations (Savvidou and Bell, 2001). However, within this temperature range the time/concentration parameters needed to achieve 100 % mortality were deemed to not be practical for tobacco fumigations (i.e. the needed concentrations would be too high and the needed time would be too long). **Treatments that do not meet the minimum parameters must be avoided as they will contribute to the further development of phosphine resistance.**

4. Phosphine Fumigation Parameters for Resistant Cigarette Beetles

Two mechanisms of phosphine resistance have been determined in stored product insects: a mechanism of reduced phosphine uptake by active exclusion and an enhanced detoxification of phosphine (Price, 1984; Chaudhry and Price, 1990). Phosphine resistance is controlled by at least two genes, one for controlling active exclusion and one for controlling detoxification of the gas (Mills and Athie, 2000).

For resistant cigarette beetles the same parameters apply and must be strictly controlled to ensure effective fumigations and prevent the development of increased resistance in these populations. Based on the current knowledge of the effects of temperature, time and phosphine concentration on fumigation effectiveness, the following guidelines for tobacco fumigation will ensure effective control of all stages of resistant cigarette beetles:

- ***Fumigation is only recommended when the tobacco temperature is at or above 16 °C (61 °F).***
- ***The minimum phosphine concentrations must be maintained during the whole exposure-time at the centre of tobacco bales/cases.***
- ***The concentration and exposure-time will vary depending upon the tobacco temperature.***
- ***Strict compliance with the fumigant label and local or national regulations is essential.***
- ***Loose tablet fumigant formulations are not preferred by the tobacco industry.***

Table 2. Minimum exposure-time required to achieve 100 % control of all stages of resistant cigarette beetle populations at 300 ppm, 600 ppm or 700 ppm phosphine at the bale/case centre.

Tobacco Temperature (°C)	Tobacco Temperature (°F)	Phosphine Concentration at the Bale/Case Centre (ppm)	Minimum Exposure-Time (days)
16-20	61-68	300	12
20-25	68-77	300 700	12 10
> 25	> 77	300 600	12 6

Note: The tobacco temperature must be checked before the start of the fumigation.

Recognizing that it may have been difficult for some to meet the higher dose fumigation parameters, the Sub-Group investigated with laboratory tests the efficacy of lower doses for longer periods of time (thus the addition of the lower dose parameters in this latest version of the Guide) (Wontner-Smith and Cardwell, 2010, 2012). From the available research, it appears that extended exposures to phosphine are much more effective against insects than higher concentrations alone and that the toxic effects of phosphine accumulate slowly in resistant insects, with the resistance mechanism being overwhelmed during long exposure periods (Chaudhry, 2000).

5. Safety

Strict compliance with the fumigant label and the local or national regulations is mandatory not only for efficacy but also for the health and safety of the fumigators and bystanders. Fumigators must be mindful of the potential dangers to themselves and bystanders associated with using the product. Personal protective equipment and monitoring equipment must be available and used to ensure the safety of anyone in the vicinity of the fumigation.

6. Potential Changes and Impact

High standards of sealing of fumigation structures are required to ensure the minimum phosphine concentrations at the bale/case centre throughout the exposure-times. Changes in logistics may be required and costs associated with fumigation may be impacted.

The minimum tobacco temperature of 16 °C for susceptible and resistant beetles required to fumigate may also require changes in timing and logistics, such as, fumigation after pack-out, fumigation in a fumigation chamber fitted with a heating system, delayed fumigation and/or fumigation conducted in the country of destination instead of the country of origin or vice-versa.

7. Implementation

Fumigation with phosphine is the main tool for post-harvest pest management of infested tobacco and as such, all possible efforts must be made to enforce good fumigation practices to control infestation and minimize the development and spread of phosphine resistance. The CORESTA Sub-Group on Pest and Sanitation Management in Stored Tobacco is conducting worldwide joint training sessions to share the phosphine fumigation parameters for the control of cigarette beetle and tobacco moth populations with the Industry.

The presence of resistant beetles has now been documented in all tobacco growing regions around the world. Identifying these populations within the countries of origin and implementing fumigation practices to deal effectively with these populations are critical steps that are needed to curb the spread of phosphine resistance and to keep phosphine as a viable insecticide for the tobacco industry.

Only having one fumigant available to the Industry makes the preservation of its effectiveness paramount and difficult. Those circumstances that have led to the development of resistance must be avoided. Poor fumigations must not be tolerated. Fumigation enclosures must be inspected or pressure tested to ensure that there are no leaks. Commodity temperature and phosphine concentration readings must be monitored to ensure that the standards set out in this document are achieved. Gas detection equipment and thermometers must to regularly calibrated to ensure that the readings are accurate and comply with the fumigation parameters.

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