Donahaye, E.J., Navarro, S. and Leesch J.G. [Eds.] (2001) Proc. Int. Conf. Controlled Atmosphere and Fumigation in Stored Products, Fresno, CA. 29 Oct. - 3 Nov. 2000, Executive Printing Services, Clovis, CA, U.S.A. pp. 657-661

METHODS TO TEST THE EFFICACY OF PHOSPHINE FUMIGATION TO CONTROL HESSIAN FLY, *MAYETIOLA DESTRUCTOR* (SAY), IN LARGE-SIZE, POLYPROPYLENE FABRIC-WRAPPED BALES OF EXPORTED HAY

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ABSTRACT

Hydrogen phosphide fumigation is proposed as a quarantine treatment to control Hessian fly in large-size, polypropylene fabric-wrapped bales of timothy hay for export to Japan. Mean temperatures in the bales (15.5-18.9ºC) over 7 d were found to be acceptable for fumigation with a dose of 2.12 g/m^3 aluminum phosphide. Methods to determine the efficacy of the treatment to control the pest were elucidated for the new hay handling procedure. A test protocol was developed and approved by the Ministry of Agriculture Forestry and Fisheries of Japan in August 2001.

INTRODUCTION

Hessian fly *Mayetiola destructor* (Say), is a pest of regulatory concern in timothy, alfalfa, oat, Sudan grass, and Bermuda grass hays exported to Japan. A multiple quarantine treatment of compression ($\geq$80 kg/cm^2) and hydrogen phosphide (PH_3) fumigation (2.12 g/m^3 (= 60 g/28.3 m^3) aluminum phosphide for 7 d at 22ºC) was developed through basic laboratory tests and large-scale commercial testing of the puparial stage (Yokoyama *et al.,* 1993a,b, 1994a,b, 1996, 1999). The treatment was approved by regulatory agencies to control Hessian fly in compressed hay and film-wrapped, compressed bales (46-61 cm long) fumigated in freight containers (Yokoyama *et al.*, 1999).

Hydrogen phosphide fumigation has been proposed as a quarantine treatment to control Hessian fly in large-size (114 cm long by 114 cm wide by 76 cm high), polypropylene fabric-wrapped bales of timothy hay. The large size of the bales and the unique bale processing procedure excluded this method in the previously developed multiple quarantine treatment for compressed bales exported to Japan. The Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan required the development of a test protocol to confirm the efficacy of PH_3 to control Hessian fly in the large-size, polypropylene fabric-wrapped bales.

PH_3 was shown to diffuse through a fine weave, polypropylene fabric (0.381 mm thick, mean $\pm$ SEM of 2.19 $\pm$ 0.07 mm width of each strand) and a coarse weave,

polypropylene fabric (0.381 mm thick, mean ± SEM of 2.55 ± 0.02 mm width of each strand) in laboratory tests at Degesch America, Weyers Cave, Virginia (Ryman, 1999). Woven polypropylene fabrics are therefore considered suitable materials for packaging fumigated hay.

The objective of this study was to develop methods to infest the bales with Hessian fly and to determine the suitability of bale temperatures for PH_3 fumigation in development of a test protocol for export of large-size, polypropylene fabric-wrapped bales to Japan.

MATERIALS AND METHODS

Placement of test materials in large-size bales

Fabric bags (20 cm wide by 30 cm long) were sewn from a cotton-polyester blend of red voile. The bag was stitched along the length on both sides and across the width in the middle to make two pouches. Openings were made at the top of each pouch. Wheat seedlings (approximately 150 plants) were placed into each pouch to simulate infestations of Hessian fly puparia. Pink flagging tape was attached to the top (122 cm long tape) and bottom (30 cm long tape) of the fabric bag to facilitate placement in each bale and recovery after each test.

The fabric bags containing wheat seedlings and a copper plate, used to determine severity of exposure to PH_3, were lowered by flagging tape into the hopper of a large-size bale compressor (32 kg/cm^2 of pressure) and compressed with timothy hay, *Phleum pratense*, in Ellensburg, Washington. Two bags were placed near each end and in the middle of each bale and the copper plate was placed in the middle of the bale. The final size of the polypropylene wrapped bale was about 114 cm long by 114 cm wide by 76 cm high. Fifteen bales were prepared with test materials.

Large-scale commercial tests

A freight container (12.2 m long by 2.4 m wide by 2.9 m high) was loaded with 9 rows of large-size, polypropylene fabric-wrapped bales with 6 bales per row (2 bales wide by 3 bales high). One bale containing 6 bags of wheat seedlings per bale and a copper plate was placed at random in each of the following 5 positions in the freight container: front (row 1) top and bottom, middle (row 5), back (row 9) top and bottom.

Bale temperature was determined every 6.5 min during the test with temperature loggers (model XTI08, Stowaway, Logan, UT) connected to external thermistors on extension cables (1.8 m long) that were placed in the interior of the bales through polyethylene tubing inserted in drilled channels. Temperatures were recorded in each bale that had test materials in each of the five positions in the freight container and in the middle air space among the bales of the middle row. Temperatures were reported as the mean ± SEM of the three replicate freight containers at 1-3 d and 1-7 d. Gas lines as described by Yokoyama *et al*. (1996) were placed in the same bales

as the temperature thermistors and a copper plate was attached to the back door of the freight container to reveal fumigation conditions.

Each freight container with test materials was considered a replicate and the test was replicated 3 times. The three freight containers were placed in a heated building at about 20ºC for 7 d. Temperatures inside the heated building were monitored with a thermohygrograph and reported as the means $\pm$ SEM of the daily high and low temperatures for 7 d. The freight containers were unloaded and the test materials removed from the bales and evaluated at the end of the 7-d test.

Placement of test materials in large-size bales

Placement of fabric bags containing wheat seedlings and copper plates into the large-size bales in the chamber for compression was hazardous due to moving machinery, and consequently, the use of flagging tape to lower the materials into the chamber greatly reduced the risk of injury. In 3-5 strokes the hydraulic ram, compresses the hay that had been passed through a slicing grid. During the process, only 1 of 90 bags was not compressed inside the bale and was found on the bale surface. All bags containing wheat seedlings and all copper plates were recovered at the end of the test when the freight containers were unloaded and the bales containing test materials were opened. The red color of the fabric bags and the bright pink color of the flagging tape facilitated the location and recovery of the materials.

RESULTS AND DISCUSSION

Large-scale commercial tests

Evaluation of temperature conditions and exposure of the wheat seedlings to compression were done at the USDA, ARS, Fresno, California. Wheat seedlings were removed from the fabric bags and found to be severely damaged by compression and similar in appearance to seedlings exposed to compression (80 kg/cm^2) in standard bales (Yokoyama *et al.,* 1996). The wheat seedlings, if infested with Hessian fly would have been placed over vermiculite in pots and caged to determine emergence of adults (Yokoyama *et al.,* 1993a). Under actual test conditions, about 10 000 Hessian fly puparia would be tested in each replicate for a total of 30 000 insects in 3 replicates.

A fumigant dose of 2.12 g/m^3 (= 60 g/28.3 m^3) was accepted for the multiple quarantine treatment for compressed bales. This fumigant dose of 2.12 g/m^3 (= 60 g/28.3 m^3) aluminum phosphide is proposed to control Hessian fly in large-size bales because aluminum phosphide tablets can be purchased in 33 tablet packages and a dose of 61 g/28.3 m^3 would eliminate the need to subdivide the tablets to achieve a lower dose. A reduction in handling of fumigant tablets would help prevent dosage errors. Yokoyama *et al*. (1994b) reported that Hessian fly response was similar at dosages of >60 g/28.3 m^3 aluminum phoshide for 3 d in laboratory tests.

The initial mean ± SEM bale temperature in all bales with test materials was 15.2 ± 0.5ºC. The mean ± SEM of the lowest and highest daily temperature in the heated building over 7 d was 18.2 ± 0.5ºC. Bale temperatures in different locations in the freight container during the 7-d test are shown in Table 1. Mean temperatures in the bales ranged from 15.5 to 18.9ºC during the 7-d test. Mean temperatures in compressed standard-size bales in a previous large-scale commercial test conducted in a heated building ranged from 14.7 to 20.0ºC during the 7-d exposure period (Yokoyama *et al.,* 1999). The test with large-size bales was conducted during cold weather, and use of the heated building enables fumigation to be carried out at the proposed dose of 2.12 g/m^3 (61 g/28.3m^3) aluminum phosphide for 7 d (Degesch America, 2000) and overnight aeration.

TABLE 1
Temperatures after three and seven days in different locations in three replicate freight containers loaded with large-size polypropylene wrapped bales of timothy hay

Location	Mean ± SEM Temperature ºC	
	3 d	7 d
Front top	17.7 ± 1.3	18.9 ± 1.6
Front bottom	15.5 ± 0.4	16.7 ± 0.6
Middle bale	15.9 ± 0.2	16.7 ± 0.1
Middle air	16.6 ± 0.9[a]	17.2 ± 0.6[a]
Back top	16.3 ± 0.9	18.4 ± 0.6
Back bottom	16.3 ± 0.4[a]	17.9 ± 0.4[a]

[a]Two replicates.

This test protocol was submitted to the Japan MAFF in March 2001 and approved in August 2001. The next phase in this research is to conduct a large-scale commercial test under as described in the protocol to confirm the efficacy of the treatment to control Hessian fly in large-size, propylene fabric-wrapped bales of timothy hay.

ACKNOWLEDGEMENTS

We thank Ron T. Anderson, National Hay Association, for coordinating industry support; and Scott Isherwood and Rick Rommell, Anderson Hay and Grain, Ellensburg, Washington, for field support. This research was supported in part by the National Hay Association and the Kittitas County Timothy Hay Growers and Suppliers.

REFERENCES

Degesch America, (2000) Applicator's manual for Degesch phostoxin tablet prepac. Degesh America, Weyers Cave, Virginia.

Ryman, D.L. (1999) Woven polypropylene porosity study. Degesch America, Weyers Cave, Virgina, Report 29 March 1999.

Yokoyama, V.Y., Hatchett, J.H. and Miller G.T. (1993a) Hessian fly (Diptera: Cecidomyiidae) control by hydrogen phosphide fumigation and compression of hay for export to Japan. *J. Econ. Entomol.,* **86,** 76-85.

Yokoyama, V.Y., Hatchett, J.H. and Miller, G.T. (1993b) Hessian fly (Diptera: Cecidomyiidae) control by compression of hay for export to Japan. *J. Econ. Entomol.,* **86,** 803-808.

Yokoyama, V.Y., Hatchett, J.H. and Miller, G.T. (1994a) Hessian fly (Diptera: Cecidomyiidae) Mortality related to moisture, season, temperature, and harvesting practices for compressed and fumigated hay exported to Japan. *J. Econ. Entomol.,* **87,** 1266-1271.

Yokoyama, V.Y., Hatchett, J.H., Miller, G.T. and Hartsell, P.L. (1994b) Hydrogen phosphide residues and efficacy to control Hessian fly (Diptera: Cecidomyiidae) in compressed hay for export to Japan. *J. Econ. Entomol.,* **87,** 1272-1277.

Yokoyama, V.Y., Miller, G.T., Hartsell, P.L. and Hatchett, J.H. (1996) Complete mortality of Hessian fly (Diptera: Cecidomyiidae) puparia in two large-scale tests to confirm the efficacy of a multiple quarantine treatment for compressed hay exported to Japan. *J. Econ. Entomol.,* **80**, 705-711.

Yokoyama, V.Y., Miller, G.T., Hartsell, P.L. and Ely, T. (1999) On-site confirmatory test, film wrapped bales, and shipping conditions of a multiple quarantine treatment to control Hessian fly (Diptera: Cecidomyiidae) in compressed hay. *J. Econ. Entomol.,* **92,** 1206-1211.

Yokoyama, V.Y., Miller, G.T. (2001) Bale compression and hydrogen phosphide fumigation to control cereal leaf beetle (Coleoptera: Chrysomelidae) in exported rye straw *J. Econ. Entomol.,* (in press).