MORTALITY RESPONSES OF *NYSIUS HUTTONI* TO A DRY-HEAT DISINFESTATION TREATMENT FOR APPLES

D.B. BIRTLES, B.C. WADDELL and J.H. MAINDONALD

DSIR Plant Protection, Private Bag, Auckland
DSIR Physical Sciences, Private Bag, Auckland

SUMMARY

Wheatbug (*Nysius huttoni* White) has been intercepted on apple exports. The time-mortality responses of adult wheatbug were compared both on and off fruit at a range of temperatures. Complementary log-log analyses of time-mortality data showed no significant differences in the susceptibility between the insects on and off fruit. The estimated time for 99% mortality of wheatbug on and off fruit at a temperature of 47.3°C was in excess of 11 days. When wheatbug were treated off fruit at a temperature of 50°C, the estimated time for 99% mortality was significantly reduced to 16.4 h.

Keywords: Wheatbug, dry-heat, apples, disinfestation, quarantine, *Nysius huttoni*

INTRODUCTION

Previous research on the use of heat as a disinfestation treatment for controlling insect pests potentially infesting export apples predicted that all life stages tested of lightbrown apple moth (LBAM, *Epiphyas postvittana* (Walker)) infested onto 'Granny Smith' apples would be killed by approximately 28 h exposure to 40°C from an initial fruit pulp temperature of 0.0 or 20°C (Dentener *et al* 1990). Further research on greenheaded leafroller (*Planotortrix octo* (Dugdale)), brownheaded leafroller (*Ctenopseustis obliquana* (Walker)) and LBAM showed LBAM eggs were the most tolerant species and life stage of leafroller (Waddell *et al* 1992).

Wheatbug (*Nysius huttoni* White) does not feed directly on apples but may be found on the fruit at harvest and therefore is referred to as a 'hitchhiker' species. Preliminary studies suggested that wheatbug was more tolerant to heat than LBAM. The aims of this research were to determine the time-mortality responses of adult wheatbug to dry-heat, and to predict the conditions required for complete mortality.

METHODS

'Granny Smith' apples were obtained from the DSIR Research Orchard, Kumeu, Auckland. The fruit were kept free of insecticidal sprays for at least 8 weeks prior to harvest to ensure no residual pesticide toxicity to insects.

Heat treatments were applied in controlled temperature chambers constructed by DSIR Technical Services, Mt Albert Research Centre. Each chamber had internal dimensions 900 mm long by 330 mm high by 315 mm wide, and contained a centrifugal fan with air volume of 290 m³/h (G2E 120-CA 07-03, Ziel-Ebm). Compressed air entering the chamber was forced by the fan across a heating element and down through a tapering perforated plastic wind sock which had 2 rows of holes (15 mm diameter) along its length. The air moved vertically downwards and through a perforated (20 mm diameter) metal plate mounted 20 mm from the base of the chamber and was then recirculated by the fan. Each chamber was sealed by a perspex door (1030 mm long by 440 mm high and 10 mm thick) with small openings (40 mm diameter) for temperature and humidity probes, and for removing insect samples from the chamber with minimal disruption to the air flow and temperature. Four plastic pots containing a total of 1.6 litres of water maintained humidity in the chamber. The temperatures in each chamber were independently controlled by pulsing heating elements for

Proc. 45th N.Z. Plant Protection Conf. 1992: 269-273

different lengths of time depending on the differential between the target and current temperatures. The parameters for the initial and target temperatures, and the temperature ramp time duration, were set on a lap-top computer (Toshiba, Model T1200HB) connected to the chambers.

Wheatbugs were reared in the laboratory by DSIR Plant Protection Rearing Section. A rearing method was developed using a natural host plant, twin cress, *Coronopus didymus* (Singh, pers. comm. 1992). The temperature was maintained at 25°C, and the insects were exposed to a light cycle of L:D 18:6.

Adults less than 2 weeks old were collected and placed in plastic containers (520 ml) with fine wire mesh at each end. Approximately 100 wheatbug were collected in each container with a 1:1 sex ratio. 'Granny Smith' apples provided a substrate for the trials on fruit. The lids of the containers had three small holes into which were inserted three 15 cm cotton dental wicks. The wicks protruded about 9 cm from the outside of the lid. The container was inverted to immerse the wicks in a reservoir to prevent the wheatbug dehydrating. Prior to heat treatment the wheatbug were held overnight at 20°C. Eight containers with wheatbug were placed in each chamber and sub-sampled at different exposure times to achieve a range of insect mortalities.

Ten trials (six on fruit and four off fruit) were conducted at nominated target temperatures in the range 45-52°C with a 2 h ramp-up time. The air temperature inside the containers were recorded using probes connected to Grant Squirrel® data loggers (Model SQ32-8U/8U and Model 1206-14U/2L). Humidity was recorded after the first 2 h of each trial using a Vaisala probe (Model HMP 32 UT) connected to a Grant Squirrel® data logger (Model SQ8-2U/1L). Temperature and humidity data were transferred from the data loggers using the Grant® Instruments Squirrel Analysis Program.

After exposure, the insects were held for at least 24 h at 20°C, then assessed as live or dead by the presence or absence of movement when touched. Control insects were not exposed to heated air, but were kept at 20°C and assessed under the same conditions as the treated insects.

A complementary log-log transformation was applied to the data to model the response of mortality versus the temperature profile (Maindonald 1988; Preisler & Robertson 1989). Control mortality was excluded when fitting the model to the data, but included in the subsequent determination of the LT_{50} and LT_{99} (i.e. estimated times for 50% and 99% mortality respectively) using MLP (Ross 1980). The mortality observed for each sub-sample was therefore related to the actual air temperature recorded in each sample container, regardless of the temperature variations within the chamber.

The treatment temperature was calculated as a weighted average, ignoring most of the ramp-up time, specifically;

$$\text{indicative temperature} = \log (\sum e^{hT} \Delta t / (\text{Time}))$$

where 'T' is the temperature (°C), time is calculated from reaching a temperature 1.0°C lower than the 50th percentile of the recorded temperatures; 'Δt' is an element of time. The time to reach a given level of mortality reduces by a factor e-h for each °C increase in temperature. The value for 'h' was derived from an iterative search for the optimum value as defined by the minimum residual sums of squares relating log(-log (1-mortality)) to average temperature. The major effect of heat results from temperatures close to or above the indicative temperature.

RESULTS AND DISCUSSION

The indicative temperatures for the six trials on fruit were, 42.4, 44.8, 45.3, 47.6, 47.8 and 48.4°C. These temperatures were lower than the nominated temperatures due to the apples absorbing the heat. The overall mean of the indicative temperatures was 46.1°C and the estimated value for h was 0.5. Mean relative humidities in these trials ranged from 63.3-78.2%.

The indicative temperatures for the four off fruit trials were 45.1, 47.7, 50.5 and

51.1°C. Calculations of the indicative temperatures in trials 1, 2 and 4 were limited to the first five sample points because of incomplete temperature recordings. The overall mean indicative temperature for trials off fruit was 48.6°C, and h was 1.05. Mean relative humidities ranged between 73.0-79.9%.

To be able to compare the response of wheatbug on and off fruit times were adjusted to a temperature of 47.3°C. This temperature was midway between the overall mean indicative temperatures of the 'on' and 'off' fruit trials and therefore minimised the effects of extrapolating. The equation for the time-mortality response curve for wheatbug on fruit at 47.3°C was:

$$\log(-\log(1-p)) = -2.242 + 0.593 \log(x).$$

Because the range of x -values was narrow, errors in ' x ' (resulting from the measured air temperatures not precisely reflecting the exposure temperature of the insects on fruit) led to a reduced slope and much increased LT_{99} estimate (Figure 1). For the trials on fruit it would have been more accurate to measure fruit surface temperatures.

Fig. 1: The estimated time-mortality response of adult wheatbug on apples to heated air at a temperature of 47.3°C,

The LT_{99} for wheatbug on fruit at 47.3°C was 597.9 h (Table 1). Control mortalities ranged from 2.8-13.1% in the on fruit trials.

TABLE 1: The estimated time (95% fiducial limits) in hours for 50% ($L = LT_{50}$) and 99% (LT_{99}) wheatbug mortality after exposure to heated air.

Temperature °C	On/Off fruit	LT_{50}	LT_{99}
47.3	on	28.9 (19.1-57.5)	597.9 (212.9-4074)
	off	25.5 (16-36)	279.0 (165-618)
50.0	off	1.5 (0.9-2.1)	16.4 (9.7-36.3)

Insects are sensitive to quite small differences in temperature, particularly in the high mortality region of the time-mortality curve (Jang 1986), but as the mortality level in this set of experiments was quite low (less than 65% in four of the trials), the sensitivity of the insects response to temperature could not be estimated accurately. Results cannot be reliably extrapolated to higher temperatures.

The equation for the time-mortality response curve (Figure 2) for wheatbug off fruit at 47.3°C was:

$$\log(-\log(1-p)) = -2.806 + 0.771 \log(x).$$

Fig. 2: The estimated time-mortality response of adult wheatbug off apples to heated air at a temperature of 47.3°C.

The LT_{99} for wheatbug off fruit at 47.3°C was 279 h (Table 1). Control mortalities ranged from 0.5-8.1% in the off fruit trials. The extent of the overlap of confidence limits at this temperature indicates there were no significant differences between the LT_{50} and LT_{99} values for wheatbug on and off fruit.

At 50°C, the LT_{99} for wheatbug off fruit was reduced to 16.4 h (Table 1). The time-mortality response at 50°C was used to estimate the response of wheatbug off fruit to a range of temperatures (Figure 3). At higher temperatures very short periods of time will achieve high levels of kill. Wheatbug is clearly more tolerant of heat than LBAM (Birtles *et al* 1991; Dentener *et al* 1990).

Fig. 3: The estimated time-mortality response of adult wheatbug off apples to heated air based on the LT_{50} and LT_{99} responses at 50°C.

The temperatures used in these trials were higher than that identified as acceptable for use with 'Gala' apples (Lay-Yee and Rose 1991). The results from trials on fruit indicated wheatbug were relatively unaffected by a temperature of 47.3°C and therefore lower temperatures would not achieve 100% mortality of wheatbug. Extrapolation of the results suggests (Figure 3) that a temperature of 52°C measured at the surface of the fruit for approximately 3 h may control wheatbug. Fruit quality evaluations to determine if the fruit were able to tolerate exposures of around 3 h to temperatures in this region may allow dry-heat to be used for wheatbug disinfestation.

Recently, commercial packhouses have adopted control measures to reduce the risk of wheatbug contaminations occurring, especially during night packing (Anon. 1991). These measures include keeping doors closed during night packing and insect-proofing openings and windows, installing insect electrocution devices near access

doors to the packing area, and installing high pressure sodium vapour lights with a colour temperature not exceeding 2,500°K. If wheatbug interceptions are reduced as a result of introducing these measures, further research on a disinfestation method for this quarantine pest needs to be evaluated.

ACKNOWLEDGEMENTS

We gratefully acknowledge the New Zealand Apple and Pear Marketing Board and the Foundation for Science and Technology for funding this research and Drs T.A. Batchelor, N.P. Markwick and D.M. Suckling for comments on the manuscript.

REFERENCES

- Anonymous, 1991. NZAPMB Code of Practise: *NZAPMB Tech. Bulletin. No. 12*; 15 pp.
- Birtles, D.B., Waddell, B.C. and Maindonald, J.H., 1991. High temperature disinfestation of nectarines: Lightbrown apple moth larvae. *Proc. 44th N.Z. Weed and Pest Control Conf.*: 61-65.
- Dentener, P.R., Peetz, S.M., Birtles, D.B. and Maindonald, J.H., 1990. Heat Treatment of New Zealand Apples. Disinfestation of lightbrown apple moth. *Report Number 1. Technical report prepared for the New Zealand Apple and Pear Marketing Board*. 39pp.
- Jang, E.B., 1986. Kinetics of thermal death in egg and first instars of three species of fruit flies (Diptera: Tephritidae). *J. Econ. Entomol.* 79: 700-705.
- Lay-Yee, M. and Rose, K.J., 1991. The effect of high temperature CA and heat treatments on the quality of Royal Gala and Granny Smith apples. *Technical report prepared for the New Zealand Apple and Pear Marketing Board*. 37 pp.
- Maindonald, J.H., 1988. Fitting complementary log-log response lines. *Report prepared for the Ministry of Agriculture, Forestry and Fisheries, Japan*. 11 pp.
- Preisler, H.K. and Robertson, J.L., 1989. Analysis of time-dose mortality data. *J. Econ. Entomol.* 82: 1534-1542.
- Ross, G.J.S., 1980. MLP 3.06. Maximum Likelihood Program. Lawes Agricultural Trust, Rothamsted Experiment Station, England.
- Waddell, B.C., Birtles, D.B. and Maindonald, J.H., 1991. Heat treatment of New Zealand apples. Disinfestation of lightbrown apple moth, Green-headed leafroller and Brown-headed leafroller. *Report number 4. Technical report prepared for the New Zealand Apple and Pear Marketing Board*.