CARBON DIOXIDE FUMIGATION OF *THRIPS TABACI* IN EXPORT ONIONS

B.B.C. PAGE, M.J. BENDALL, A. CARPENTER[†] and
C.W. VAN EPNHUIJSEN

*New Zealand Institute for Crop & Food Research Limited, Private Bag 11600,
Palmerston North, New Zealand*

[†]Deceased February 2002

Corresponding author: pageb@crop.cri.nz

ABSTRACT

As an alternative to chemical pesticides, elevated carbon dioxide atmospheres were examined as a method for controlling thrips on export onions. A replicated gas delivery system was used to deliver a constant supply of various concentrations of carbon dioxide (CO₂) to thrips-infested onions within sealable bags. Six CO₂ treatments – an air control and 15, 30, 45, 60 and 100% CO₂, (all in balance air) – were applied for 6, 12, 24, 48 and 72 h. Mortality was 100% at CO₂ concentrations of 30% or more after at least 24 h. However, the control treatments also had a high level of mortality and although there were significant differences between the control treatment and the CO₂ treatments, these differences were not large.

Keywords: thrips, *Thrips tabaci*, elevated carbon dioxide, onions.

INTRODUCTION

Onion thrips (*Thrips tabaci* Lind.) pose a major threat to the export of New Zealand onions. There is resistance from customers to the use of pesticides by growers and a limited number of fumigants are available for post-harvest disinfestation. Quarantine regulations for horticultural exports require produce to be free from all living insects. Therefore, novel methods of pest control are being sought, such as the use of elevated CO₂ atmospheres.

The use of carbon dioxide as a fumigant is accepted by biodynamic and organic markets as it is not considered to be a chemical treatment. High concentrations of CO₂ have been shown to be effective in controlling various insect pests, such as codling moth (Soderstrom & Brandl 1989), adult flower beetles (Banks & Fields 1995; Seaton & Joyce 1993), black field crickets (Stevenson & Hurst 1995), green peach aphids (Carpenter 1997; van Epenhuijsen et al. 2002) and two spotted spider mites (Mitcham et al. 1997b). High concentrations (50-90%) of CO₂ have also been used with success to control Western flower thrips, *Frankliniella occidentalis* (Pergrande), on strawberries (Aharoni et al. 1981). New Zealand flower thrips (*Thrips obscuratus*) showed high mortality when exposed to 60% CO₂ (Carpenter et al. 1996). Mitcham et al. (1997a) reported that although previous research indicated high mortality rates of Western flower thrips were achieved with relatively short exposure (16 – 24 h) to a concentration of 80% CO₂ at 5°C, their more recent work failed to substantiate these results. Mortality occurred slowly at a concentration of 65% CO₂; total mortality was only achieved when concentrations of 90-95% CO₂ were applied for 2-3 days at 0°C. To the best knowledge of the authors, there are no previous reports of the use of CO₂ to fumigate onions infested with onion thrips.

Potter et al. (1994) researched the relationship between temperatures and elevated CO₂ levels on thrips (*Thrips obscuratus* Crawford) and found that the effect of temperature on mortality depended on the concentration of CO₂ and the duration of exposure. An

New Zealand Plant Protection 55:303-307 (2002)

exposure of 6 days at a CO₂ concentration of 18% was sufficiently toxic to cause 100% mortality, regardless of the temperature. In a New Zealand commercial situation, onions are stored and exported at ambient temperatures and the temperature of 20°C used in our trial was chosen to reflect this. The temperature was kept constant because the period of the trial was not long enough to accurately reflect the ambient temperature range expected in a commercial situation.

METHODS

Export grade Pukekohe Long Keeper onions (cv. Dominator, Pukekohe grown) that were naturally infested with onion thrips were used in the trial.

Experimental design

Twenty-four plastic bags, each containing 60 randomly selected onions, were constantly supplied with gas via pressurised cylinders (BOC Gases, Palmerston North). The bags were stored at 20°C. Six different CO₂ concentrations, 15, 30, 45, 60 and 100% CO₂, were applied to the onion-filled bags and each treatment was replicated four times. A control treatment consisted of the supply of air only. The concentrations of CO₂ were regularly measured throughout the experiment using a CO₂ gas sampler (Analytical Development Co., England). From each treatment, randomly selected onions were removed and assessed for thrips at intervals of 6, 12, 24, 48 and 72 h after the bags were filled with gas. The bags were then resealed.

Thrips assessment

The onions were cut in half (latitudinally) and the first two layers of skin were removed. If any thrips were present, one or two layers of the white fleshy bulb scales were removed. The area near the roots was also peeled and checked, and if thrips were present the bulb and scales were separated as well. To accurately assess mortality, the insects were allowed a 24 h recovery period at 15°C before mortality rates were assessed. Counts were recorded of both live and dead thrips in each bulb.

Statistical analysis

The variability in mortality within bags was significantly less than that between bags. Therefore, a generalised linear mixed model was used to analyse the data (Schall 1991). This has a binomial error distribution and logit link function. Confidence intervals for mortality (95%) are given for each combination of CO₂ concentration and duration of exposure. Treatments with confidence intervals that do not overlap are significantly different. Confidence intervals cannot be calculated for treatments with 100% mortality.

There was a consistent difference between the control and the higher CO₂ concentrations at each treatment duration, but it was not always statistically significant. To show this overall trend, exponential curves were fitted to the control treatment and the treatments with a concentration of 15 and 30% CO₂. Other concentrations were not included as this would result in too many bags with 100% mortality. The curves were fitted to the averages for the treatments. All analysis was done using the statistical package Genstat 5.

RESULTS

A higher level of thrips mortality occurred in the CO₂ treatments than in the controls (Table 1; Fig. 1). All of the thrips were killed at CO₂ concentrations of 30% or more after at least 24 h. However, the control treatments had a high level of mortality, which increased over time ($P < 0.05$), and the differences between the control treatment and the CO₂ treatments were not large. The high level of mortality in the control treatment could be due to handling of the onions; onions measured later in the trial experienced the most handling. The effect of CO₂ treatment on thrips mortality was most apparent at short exposure times.

TABLE 1: Generalised linear mixed model (GLMM) showing predicted percentages of thrips killed (95% confidence intervals shown in brackets).

CO ₂ concentration	6	12	Time (h) 24	48	72
Control	61 (51, 70)	77 (66, 86)	74 (64, 82)	89 (8, 94)	86 (76, 92)
15%	79 (67, 88)	- ¹	91 (8, 96)	97 (89, 0.99)	100 (85, 100)
30%	85 (70, 93)	97 (84, 99)	100	100	100
45%	77 (65, 85)	85 (66, 94)	100	100	- ²
60%	74 (60, 84)	- ¹	100	100	- ²
100%	95 (87, 98)	94 (78, 99)	100	100	- ²

¹Because of leaky gas cylinders, data for the two treatments with 15 and 60% CO₂ at 12 h were not recorded.

²No data recorded, due to empty gas cylinders.

There was a statistically significant difference between the control and the 100% CO₂ treatment after 6 h. There was also evidence of a difference between the control and treatments with more than 15% CO₂ after 24 h. Although there was not always a statistically significant difference between the control and the CO₂ treatments at each duration, the mortality in the controls was consistently lower than in the CO₂ treatments at each duration of exposure. Over time, mortality rose towards a maximum (Fig. 1). The asymptote (or maximum) for the control is significantly lower than the asymptote for the 15% and 30% CO₂ treatments ($P < 0.001$).

FIGURE 1: Percentage of dead thrips at different CO₂ concentrations with time.

DISCUSSION

Results show that high CO₂ concentrations and long exposure increased thrips mortality. Our system ensured that the thrips-infested onions were continuously exposed to the CO₂ concentrations being delivered, in part due to the small containers used and ease of containment of the gas within the plastic bags. In commercial situations where much greater volumes of produce need to be disinfested, the system used must ensure that all onions are fully exposed to the CO₂. The use of high pressure CO₂ has been examined to this end (Fleurat-Lessard et al. 1996). The use of CO₂ at atmospheric pressure under tarpaulins or in fumigation chambers is a well-known control method, and there are numerous applications of this technique to control stored product insects (Banks & Fields 1995). CO₂ has been used to fumigate large buildings in Europe under tarpaulins to control wood-boring pests (Fleurat-Lessard et al. 1996). Containerised treatments of produce may be possible and this approach needs to be tested for onions.

To be effective, elevated CO₂ atmospheres must be maintained until all insects die. The required exposure time is dependent on the concentration of CO₂ and the treatment temperature. The successful use of CO₂ as a fumigant depends on the initial concentration achieved and a leak-proof system. Effective purging of CO₂ is also essential after the treatment has been completed. As these factors vary between facilities, a set dosage per tonne of produce can only be a rough guide to the required treatment time. Using high rates and long exposure times may be the only reliable approach to the effective use of CO₂ for disinfestation.

In this experiment, a temperature of 20°C was chosen to mimic the conditions that would be expected when onions are fumigated in commercial operations, i.e. at ambient store temperatures. Changes in temperature often have variable effects on the toxicity of modified atmospheres. Temperatures lower or higher than those we tested may influence thrips mortality. Additional research is needed to ensure that the toxicity of the control atmosphere meets quarantine requirements. Gas absorption, as seen in grains and canola (Cofie-Agblor 1998), could occur so absorption rates of CO₂ by various onion types needs to be determined.

ACKNOWLEDGEMENTS

Our thanks to Don Brash for his advice in the course of this work.

REFERENCES

- Aharoni, Y.; Stewart, J.K.; Guadagni, D.G. 1981: Modified atmospheres to control western flower thrips on harvested strawberries. *J. Econ. Entomol.* 74: 338-340.
- Banks, J.; Fields, P. 1995: Physical methods for insect control in stored-grain ecosystems. In: Jayas, D.S.; White, N.D.G.; Muir, W.E. ed. *Stored grain ecosystems*. Marcel Dekker Inc., New York. Pp. 353-409.
- Carpenter, A. 1997: A comparison of the responses of aphids and thrips to controlled atmospheres. *Proc. Seventh Int. Controlled Atmosphere Res. Conf.* 1: 91-95.
- Carpenter, A.; Wright, S.; Lash, P. 1996: Response of adult New Zealand flower thrips, *Thrips obscuratus*, to high carbon dioxide and low oxygen atmospheres at various temperatures. *Bull. Entomol. Res.* 86: 217-221.
- Cofie-Agblor, R.; Muir, W. E.; Jayas, D.S.; White, N.D.G. 1998: Carbon dioxide sorbtion by grains and canola at two CO₂ concentrations. *Stored Prod. Res.* 34: 159-170
- Fleurat-Lessard, F.; Fields, P.; Le Tourc'h, J. 1996: Methyl bromide alternatives. A European perspective. Workshop on Alternatives to Methyl Bromide, Toronto Canada. Pp. 83-90.
- Mitcham, E.J.; Shelton, M.; Cantwell, M. 1997a: California Department of Pesticide Regulation; Pest Management Grants: final report, year 1. www.cdpr.ca.gov/docs/dprdocs/methbrom/95-0252.pdf (20/03/01).
- Mitcham, E.J.; Zhou, S.J.; Bikoba, V. 1997b: Controlled atmospheres for the quarantine control of three pests of table grapes. *J. Econ. Entomol.* 90:1360-1370.

- Potter, M.A.; Carpenter, A.; Stocker, A.; Wright, S. 1994: Controlled atmospheres for the post harvest disinfestations of *Thrips obscuratus* (Thysanoptera: Thripidae). *J. Econ. Entomol.* 87:1251-1255.
- Schall, R. 1991: Estimation in generalized linear models with random effects. *Biometrika* 78: 719-72.
- Seaton, K.A.; Joyce, D.C. 1993: Effects of low temperature and elevated CO₂ treatments and of heat treatments for insect disinfestations of some native Australia cut flowers. *Sci. Hort.* 56: 119-133.
- Soderstrom, E. L.; Brandl, D. G. 1989: Codling moth response to controlled atmospheres. *Proc. Fifth Int. Controlled Atmosphere Res. Conf. 1*: 215-219.
- Stevenson, D.G.; Hurst, P.L. 1995: Mortality of black field crickets (*Teleogryllus commodus*) in carbon dioxide atmospheres. *N.Z. J. Zool.* 22: 381-385.
- van Epenhuijsen, C.W.; Carpenter, A.; Butler, R. 2002: Controlled atmospheres for the post-harvest control of *Myzus persicae* (Sulzer) (Homoptera: Aphididae): Effects of carbon dioxide concentration. *J. Stored Prod. Res.* 38: 281-291.