New Zealand Institute for Crop & Food Research Limited
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CROP & FOOD RESEARCH
Mana Kai Rangahau

Crop & Food Research Confidential Report No. 437

Using carbon dioxide for onion disinfestation

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June 2001

A report prepared for
New Zealand Onion Exporters Association and Vegfed onion sector

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1 Executive summary

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 the limited numbers of fumigants available for postharvest disinfestation. Alternatives such as elevated carbon dioxide controlled atmospheres are being tested.

Controlled atmospheres that employ high carbon dioxide have shown promise for the control of various insects and mites. Treatment efficacy is determined by the concentrations of the carbon dioxide, temperature of the treatment and the length of exposure. From previous work we hypothesed that we might achieve full thrips mortality with 35% carbon dioxide concentration in 24-48 hours.

We evaluated the mortality of onion thrips when exposed to elevated carbon dioxide levels at 20°C. Five carbon dioxide treatments were tested (15, 30, 45, 60 and 100%). Total thrips mortality was achieved at a 30% level of carbon dioxide level for 24 hours.

2 Introduction

Quarantine regulations for horticultural exports demand that produce is free from all live insects. This, along with increasing consumer resistance to pesticide use, is ensuring that new novel alternatives to pest control are being sought.

Carbon dioxide (CO_2) is a fumigant that is accepted by the biodynamic and organic markets as it is not considered to be a chemical treatment. High concentrations of CO_2 have shown some effectiveness 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) and, more recently, green peach aphids (Carpenter 1997) and two spotted spider mites (Mitcham et al. 1997).

Elevated CO_2 has also been used with success to control western flower thrips Frankliniella occidentalis (Pergrande). Aharoni et al. (1981) demonstrated that high levels of CO_2 (50-90%) or low levels of oxygen (<1%) successfully killed western flower thrips on strawberries. For 100% control, hypercarbic conditions (90%) were required for 48 hours. Potter et al. (1994) researched the relationship between temperatures and elevated CO2 levels on thrips. Regardless of temperature, a total mortality of thrips was predicted to occur after six days' of exposure to an 18% CO_2 atmosphere. New Zealand flower thrips showed high mortality when exposed to 60% CO_2 (Carpenter, et al). More recent research done at the University of California (Marita Cantwell and Elizabeth Mitcham pers. comm.) showed that while previous research indicated the high mortality rates of western flower thrips had been achieved at relatively short exposure times (16 – 24 hours) using 80% CO_2 at 5°C, more recent work had failed to substantiate these results. Mortality occurred slowly at 65% CO_2 and total mortality was only achieved when 90-95% CO_2 had been applied for two to three days at 0°C.

Elevated CO_2 concentrations may be an alternative natural disinfesting method for thrips-infested onions. This report summarises the effect of elevated CO_2 concentrations on onion thrip mortality when they were exposed for various durations at 20°C.

3 Methods and materials

During March 2001 a trial was conducted at Crop & Food Research, Palmerston North, looking at differing CO_2 concentrations and their effect on the mortality of both larvae and adult onion thrips (*Thrips tabaci*). Harvested Pukekohe Long Keeper onions (cv. Dominator, Pukekohe grown and export grade) which were naturally infested with onion thrips. A replicated gas delivery system using certified gas via pressurised gas cylinders (BOC Gases; Palmerston North) was designed to deliver various CO_2 concentrations in a constant supply to thrips-infested onions.

Figure 1: The gas delivery system.

Six CO_2 treatments were applied: 0% (air control), 15%, 30%, 45%, 60% and 100%. The balance of each was air. Duration of tests were (6, 12, 24, 48, and

72 hours). Each treatment was replicated four times. Each plot consisted of independent plastic bags containing 60 thrips-infested onions, selected at random. At each sampling time 10 onions from each treatment were randomly selected and removed from the bags before they were resealed. Probability tests were conducted to ensure that enough onions were taken per replicate to contain sufficient live thrips. For accurate mortality assessments, the insects were allowed a 24 hour recovery period at 15 °C. Counts were recorded of both live and dead thrips.

3.1 Thrips assessment

Onions were cut into two pieces. The first and second brown membranous skins were removed as well as one of two layers of the white fleshy bulb scales, depending on the presence or absence of live thrips under the brown skins. On the lower part, any membranous skin was removed and the area peeled near the roots and checked. If thrips were present the flesh scales were separated as well.

Figure 2: Infested onions being gassed in resealable plastic bags with gas inlet.

Gas rates delivered to each treatment were in the range of 70-200 ml/min. Store room temperature was 20°C. Regular CO_2 concentrations were measured and recorded throughout the experiment (Fig. 3). A CO_2 gas analyser (Analytical Development Co., England) was used to test gas concentrations.

Figure 3: Taking gas samples to be analysed.

4 Results

This experiment shows that complete mortality of onion thrips can be achieved using evaluated CO_2 levels. However, this was not achieved until CO_2 concentrations were above 30% (Fig. 4) and only after thrips had been exposed at this level for 24 hours (Fig. 5). Due to a leaking gas cylinder, data for both 15 and 60% CO_2 concentrations at 12 hours thrips mortality data were not recorded. Total thrips mortality was not achieved at 100% CO_2 concentration until after 12 hours so 15 and 60% CO_2 concentration level was considered too low to be effective (Table 1).

Results show that some onion thrips survive very high CO_2 concentrations of up to 100% for at least 12 hours, and of lower levels of CO_2 concentration (15%) for time periods of up to 72 hours (Table 1).

Thrip mortality was often high (62-89%) in the control (0%) treatments. This is thought to be due to increased handling of the onions over the duration of the trial.

Table 1: Mortality of onion thrips following treatments with carbon dioxide at 20°C.

% Carbon dioxide/time (hours)	N	Mean mortality (%)	SD
0/6	337	62.1	7.5
15/6	202	77.6	1.9
30/6	134	84.2	1.2
45/6	218	78.4	1.9
60/6	167	74.3	1.5
100/6	217	92.0	0.7
0/12	288	76.3	2.3
15/12	ND	ND	ND
30/12	144	97.0	0.4
45/12	88	84.2	1.0
60/12	ND	ND	ND
100/12	102	93.0	.05
0/24	300	74.4	3.3
15/24	180	90.9	1.2
30/24	208	100	-
45/24	282	100	-
60/24	450	100	-
100/24	174	100	-
0/48	282	89.2	1.3
15/48	230	97.1	0.4
30/48	317	100	-
45/48	172	100	-
60/48	385	100	-
100/48	233	100	-
0/72	248	87.3	1.4
15/72	204	99.0	0.2
30/72	380	100	-
45/72	ND	ND	ND
60/72	ND	ND	ND
100/72	ND	ND	ND

ND= no data recorded

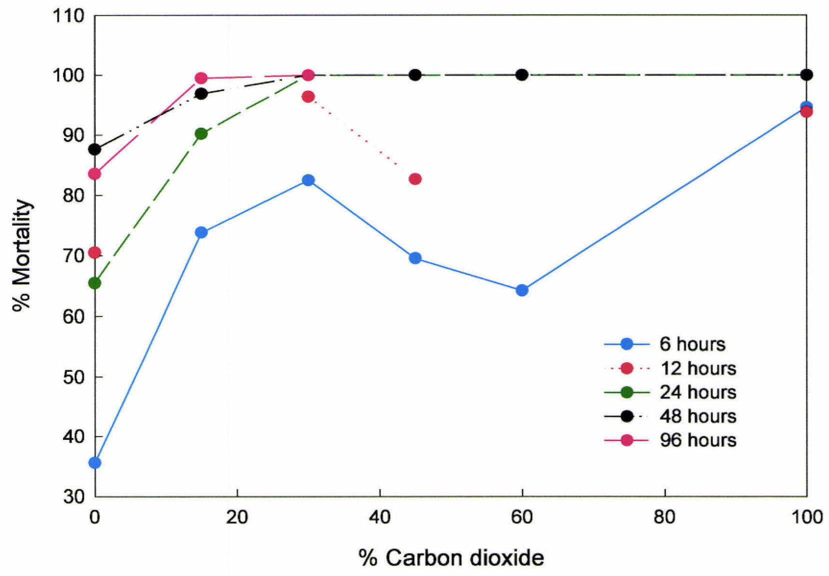

Figure 4: Percentage of dead thrips with increased carbon dioxide levels. Each point represents the percentage of dead to total thrips counts from 40 onions per treatment stored at 20°C.

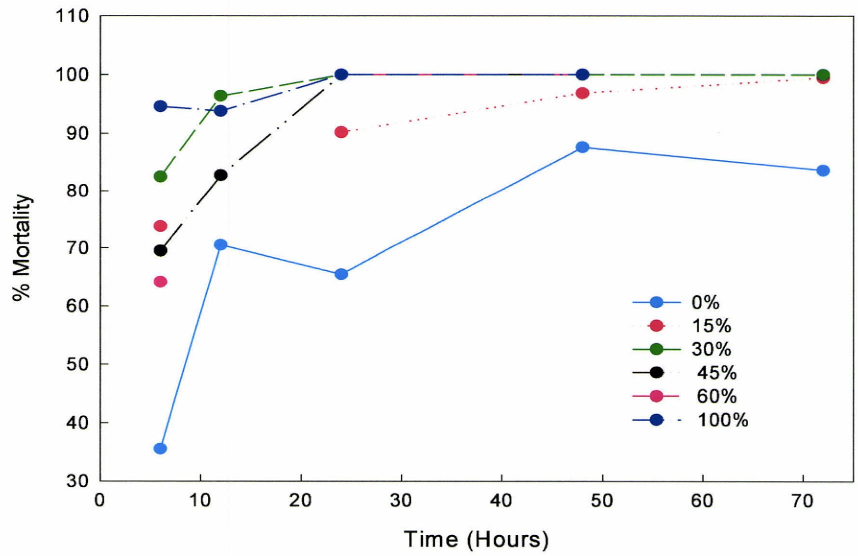

Figure 5: Percentage of dead thrips with increased exposure time. Each point represents the percentage of dead to total thrips counts from 40 onions stored at 20°C.

5 Discussion

The objective of this work was to evaluate the effect under the experimental conditions described of CO_2 for controlling onion thrips. The results show that 100% thrips mortality can be achieved after being exposed for 24 hours using high levels (<30%) of CO_2

Our system ensured that the thrips-infested onions were continuously exposed to the CO_2 concentration being delivered, in part due to the small design and ease of containment of the gas within the plastic bags. In a commercial situation where much greater volumes of produce need to be disinfested a system is required that ensures all onions are fully exposed to the CO_2. The use of high pressure CO_2 has been developed in France (Fleurat-Lessard 1996). Delivering CO_2 at atmospheric pressure under tarpaulins or in fumigation chambers is well known, and there are numerous applications of this technique to control stored product insects (see Banks & Fields 1995). This gas has been used to fumigate entire churches in Europe under tarpaulins to control wood boring pests (Fleurat-lessard et al. 1996). Alternatively, containerised treatments may be possible and need to be tested.

To be effective, the elevated CO_2 atmosphere must be maintained until all of the insects die. The required exposure time is dependent on the percentage of CO_2 and the temperature. Ultimately successful use of CO_2 as a fumigant will depend on the initial concentration being achieved, and maintaining a system that avoids leakage of the fumigant, displaces air volume and allows for CO_2 absorbed by the onions. It must also effectively purge the system once the treatment has been completed. As these factors will vary between facilities, a set dosage per tonne of produce may only be a rough guide to the required treatment time. Longer exposure times may be required to be effective, as seen with the results of this trial.

Different fruits and vegetables have different levels of tolerance to CO_2. We don't know how tolerant onions are to high CO_2 exposure and, therefore, controlled atmospheres must be designed carefully to protect both taste and quality. Using very high CO_2 ensures that the onions are not exposed for long. The levels of CO_2 that would affect onion quality are not known.

In this experiment, 20°C was chosen. It is expected to be close to the temperature used to fumigate onions by industry, i.e. ambient store temperature. Lower or higher temperatures may influence thrip mortality. Additional research would be need to ensure that the toxicity of the control atmosphere meets any quarantine requirement (e.g. Probit 9).

6 Recommendations

These results give a good indication that CO2 fumigation can be used as an effective method for thrips control. Care is need to interpret these results before applying them in a commercial-scale operation. Higher rates and longer durations may well be needed than the 30% concentration, 24 hour time duration used here. Absorption rates of CO_2 by various onion types need to be determined if this method is to be used commercially. Where large volumes of onions need to be disinfested much will depend on designing a system that exposes to the CO_2 fumigant. Pressurised CO_2 applications may be applicable in this situation. Temperatures other than 20°C should be evaluated.

7 *Acknowledgement*

Our thanks to Don Brash for his help and advice.

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