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# Thermal initiation of thanatosis to improve the pneumatic removal of the Colorado potato beetle

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<sup>1</sup>Chemical Engineering Department, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada; and <sup>2</sup>Potato Research Centre, Agriculture and Agri-Food Canada, Fredericton, New Brunswick E3B 4Z7, Canada. \*Email: PelletierY@agr.gc.ca

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Couturier, M., Hicks, J.B., Rouison, D. and Pelletier, Y. 2005. **Thermal initiation of thanatosis to improve the pneumatic removal of the Colorado potato beetle.** Canadian Biosystems Engineering/Le génie des biosystèmes au Canada **47**: 2.5 - 2.12. The Colorado potato beetle (*Leptinotarsa decemlineata* (Say)) reacts to disturbance by undergoing a defense mechanism known as thanatosis. The insects release their hold from the plant and fall to the ground. In this work, thanatosis was initiated by blowing hot air on the Colorado potato beetles. The fraction of insects falling to the ground was found to be a function of the air velocity, air temperature, and exposure time. These observations led to the design of a thermal-pneumatic device for the removal and collection of the insects from their host plants. This apparatus was equipped with a collection device to collect the insects transported by the blowing air. Adult removal from the plant was increased from about 50 to about 85% when the air was heated from 25 to 100°C. Removal of fourth instars was much less affected by the heat, with average removals of nearly 74% for both ambient-temperature and hot-air runs at an air speed of 25 m/s. On average, about 65% of the insects removed were captured in the collection device. **Keywords:** Colorado potato beetle, physical control method, thanatosis.

Le doryphore de la pomme de terre (*Leptinotarsa decemlineata* (Say)) réagit aux menaces extérieures par une réaction comportementale connue sous le nom de thanatose. L'insecte se laisse alors tomber au sol. Nos travaux portent sur la possibilité de provoquer la réaction de thanatose chez le doryphore de la pomme de terre avec de l'air chaud. La proportion d'insectes décrochés était fonction de la vitesse de l'air, de la température de l'air ainsi que du temps de contact. Ces observations nous ont permis de mettre au point un appareil thermo-pneumatique permettant de décrocher les doryphores. Cet appareil était muni d'un système de collection des insectes transportés par le courant d'air. Nos résultats démontrent que la proportion d'insectes délogés passe de 50 à 85% lorsque l'air est chauffé à 100°C. Les larves de quatrième stade n'étaient pas aussi susceptibles à l'air chaud car près de 74% furent délogées dans les essais avec l'air chaud et froid à 25 m/s. En moyenne, environ 65% des insectes délogés étaient capturés par le système.

## INTRODUCTION

The Colorado potato beetle, *Leptinotarsa decemlineata* (Say), is the most important defoliator of the potato crop in Eastern North America (Hare 1980). Present control strategies are based primarily on the use of insecticides that are potentially damaging to human health and the environment. This insect pest has also demonstrated the ability to become resistant to insecticides used against it (Boiteau et al. 1987). Alternative

control methods are being developed to overcome these disadvantages (Duchesne and Boiteau 1995). Several physical control methods have been developed and evaluated for potato protection (Ferro 1995). Insect vacuum collectors used for the control of insects affecting strawberry, lettuce, and carrot have been adapted to protect potatoes (Boiteau et al. 1992). Some systems draw air upward through the canopy to dislodge the insects and carry them upward into the vacuum fan. Other systems blow a fast air stream horizontally through the canopy to dislodge the insects and to carry them into a collection apparatus on the other side of the plants (Lacasse et al. 1994; Laguë et al. 1999b; Rifai et al. 1997). The collection apparatus can be replaced by a propane flame to inactivate insects deposited on the ground between rows (Laguë et al. 1999a).

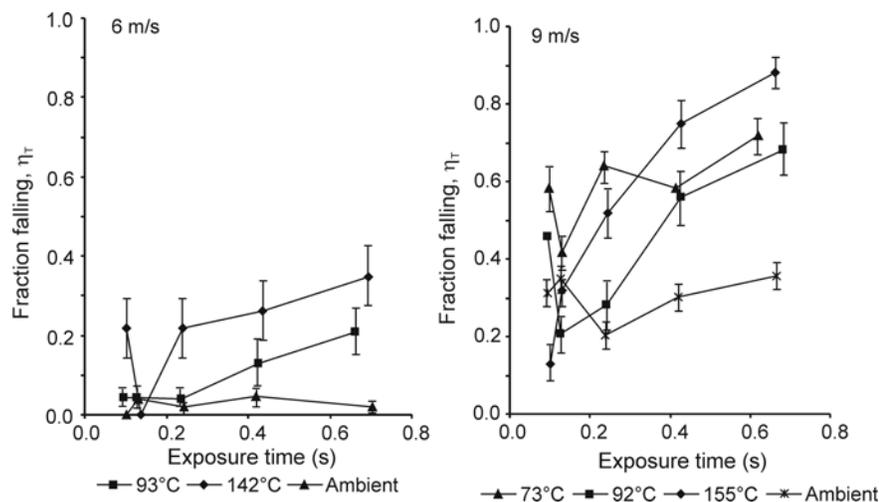
The main factor limiting the efficacy of these pneumatic systems is the ability to dislodge the insects. The adult and the large larvae of the Colorado potato beetle can hold onto the leaf with forces equivalent to more than their own weight (Misener and Boiteau 1993a). As a result, the air velocity required to successfully carry the insects produces a relatively low rate of dislodging (Lacasse et al. 1994; Rifai et al. 1997). While differences exist between hood designs, successful dislodgement of insects requires high airflow speeds (Khelifi et al. 1995b; 1996). This is a drawback because plant damage increases as the speed of the airflow is increased (Khelifi et al. 1995a). Vibrations were evaluated for their effect on thanatosis initiation (Boiteau and Misener 1996). Thanatosis is the behavioral reaction of insects that simulate death and fall off when threatened. Frequency of more than 20 Hz with amplitude of more than 0.6 mm seems to produce thanatosis in adult Colorado potato beetles. These conditions are difficult to engineer in a pneumatic insect control prototype.

The terminal velocity of the adults and larvae of the Colorado potato beetle is around 9 m/s (Misener and Boiteau 1993b). This means that if thanatosis could be effectively initiated, the airflow required to carry them to the capture device would probably be much reduced. It would allow the pneumatic apparatus to be smaller and more effective. In this study, we evaluated the use of hot air as a trigger for thanatosis in adult and fourth instar of the Colorado potato beetle. The dislodging and capture performance of a thermal-pneumatic prototype was evaluated in the laboratory and preliminary results gathered in the field.

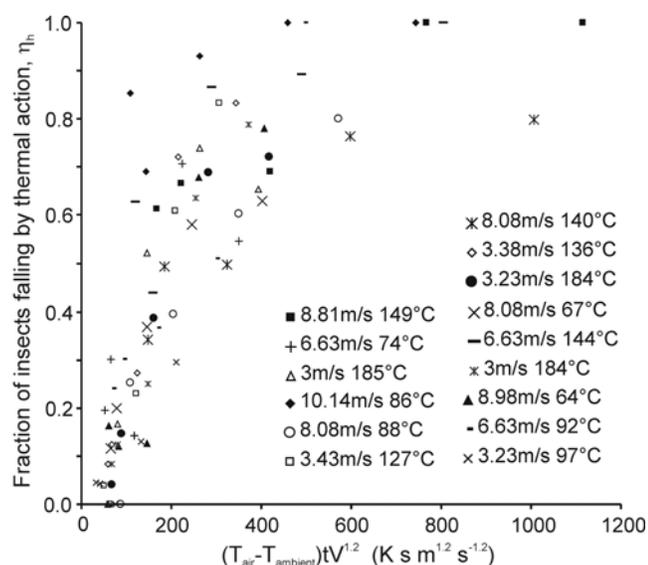








**Fig. 5.** Fraction of fourth instar larvae of the Colorado potato beetle removed by the thermal apparatus at different exposure times, air temperatures, and air speeds.



**Fig. 6.** Fraction of adult Colorado potato beetles removed from a plant by thermal action as a function of a product proportional to the change in temperature of the antennae (see text for more explanation). Data obtained in the laboratory at different air speeds, contact times, and air temperatures.

are two possible reasons for this discrepancy. First, the velocity used in the calculations was measured under cold conditions (i.e., with the propane torch turned off) and likely underestimated the velocity under hot conditions. Second, the velocity term in  $(T_{air} - T_{ambient})tV^{1.2}$  also accounts for the influence of the velocity on the air temperature blown on the insects. The term  $T_{air}$  corresponds to the air temperature at the outlet of the blower. However, when the air reaches the insects on the plant it is already partially mixed with the colder ambient air; hence, the resulting air temperature sensed by the beetles is lower than  $T_{air}$  and depends on the air velocity. The use of the term  $V^{1.2}$  to account for the multiple effects of air velocity is an

oversimplification. In fact, the exponent  $n$  is not constant over the range of velocities tested but increases with velocity. This partly explains the scatter in Fig. 6 and suggests that the term  $V^{1.2}$  will likely underestimate the effect of air velocity at velocities greater than 10 m/s.

#### Evaluation of the capture efficiency

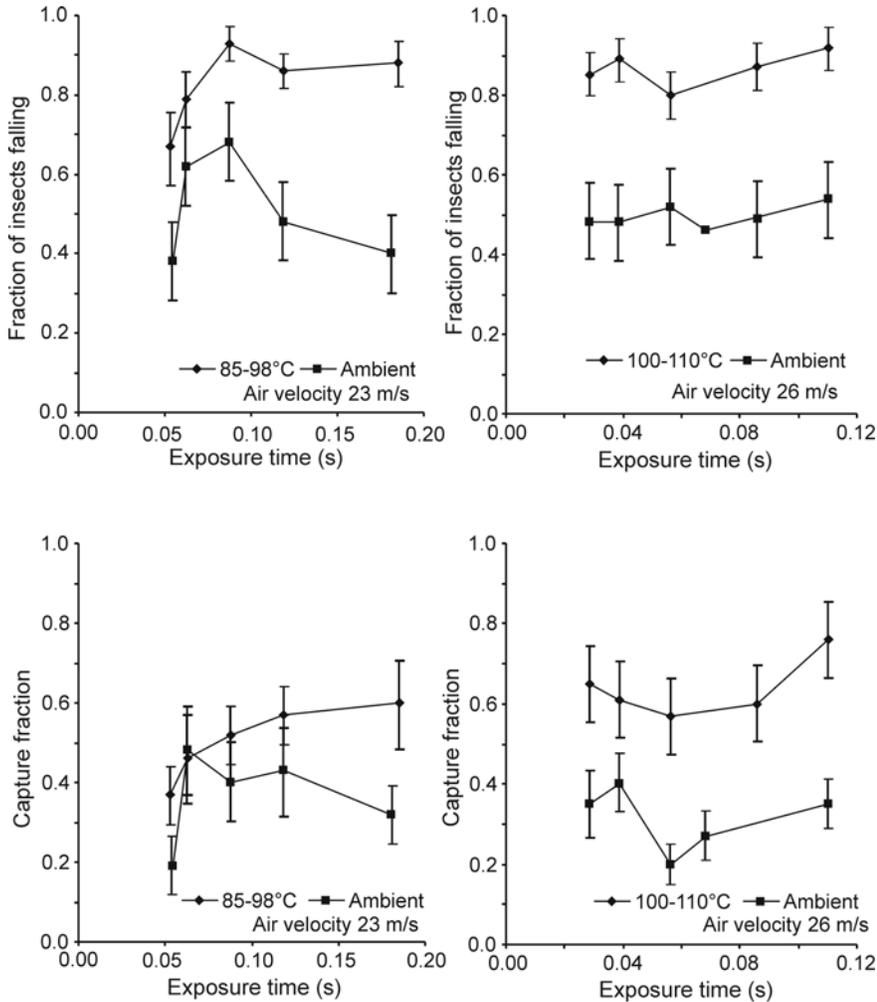
The design of the apparatus for laboratory tests (Fig. 1) required the inclusion of an insect collector (Fig. 2) for evaluation of the capture efficiency (Laguë et al. 1999a). Air temperatures between 90 and 100°C could readily be attained with this system. The purpose of this device was to trigger thanatosis and then blow the insects in the collecting device.

The effects of air temperature, air velocity, and exposure time on the fraction of adults and larvae removed from the plant and captured were evaluated in the laboratory with the apparatus of Fig. 2. Figures 7 and 8 show the results obtained with adults. It should be noted that at exposure times much shorter than the ones tested here, many insects would not detect any thermal variation or moving air and hence would not let go from the plant. However, over the range of exposure times reported in Figs. 7 and 8, the results showed little correlation with the exposure time indicating that  $(T_{air} - T_{ambient})tV^n$  was above the threshold value in all cases. The data also showed little dependence on exit air velocity. This was because the two openings provided about the same air velocity (57 mm wide opening: 26 m/s; 102 mm wide opening: 23 m/s). Hence, the capture fractions, removal fractions, and capture efficiencies were pooled and are summarized in Table 1.

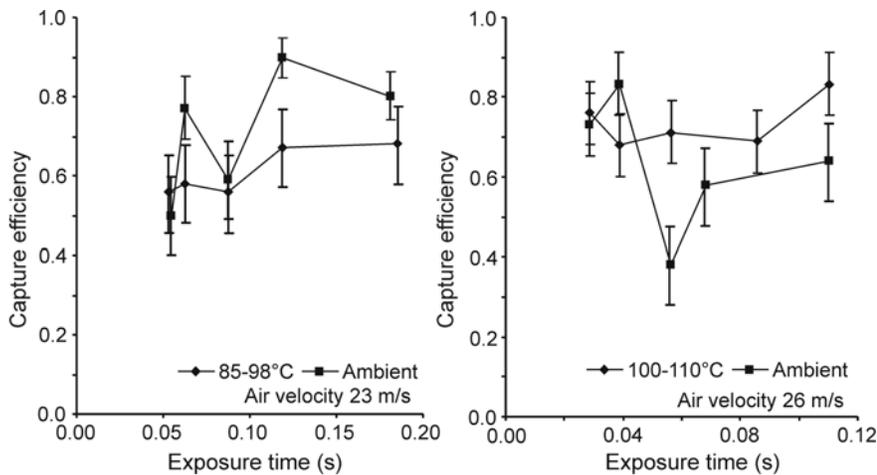
The adult removal fractions for the hot air trials ( $0.85 \pm 0.04$ ) were significantly higher than those with ambient air ( $0.51 \pm 0.05$ ). This confirms that the use of heated air in the pneumatic control of adult Colorado potato beetles significantly increases the fraction of adults dislodged from the plant. Because more insects were removed, more could be captured and hence the capture fraction of total insects initially on the plant also improved by using heated air ( $0.58 \pm 0.05$ ) over ambient air ( $0.34 \pm 0.05$ ). The insect capture efficiency on the other hand was about the same for the ambient-air and hot-air runs ( $0.63 \pm 0.08$  and  $0.67 \pm 0.04$ , respectively). This is not surprising because the insect capture efficiency is a parameter dependent mostly on the design of the capture device and not on the exit air temperature.

Similar findings were obtained when the thermal-pneumatic apparatus was tested under field conditions. The fraction of adults removed from the potato plants increased from 0.55 ( $\pm 0.13$ ) to 0.79 ( $\pm 0.04$ ) when the exhaust air was heated to 130°C. Little difference was observed between the insect capture efficiencies measured without ( $0.58 \pm 0.06$ ) and with ( $0.67 \pm 0.02$ ) heated air. These results corroborate the findings obtained in the laboratory (Table 1) and provide confidence in their applicability to field conditions.

Further tests were performed in the laboratory on fourth instars. The results are presented in Fig. 9. The majority of larvae released their hold from the plant without heat



**Fig. 7. Adult removal fractions and capture fractions obtained in the laboratory with the thermal-pneumatic apparatus.**



**Fig. 8. Adult capture efficiencies obtained in the laboratory with the thermal-pneumatic apparatus.**

application at exposure times greater than 0.092 s. For this reason, only two lower exposure times were examined. No difference between the results obtained with ambient air and hot

air at both 0.052 and 0.062 s was observed. In other words, contrary to the results obtained at air speeds less than 10 m/s (Fig. 5), the use of hot air did not improve the removal of larvae from the plant when the air velocity was about 25 m/s. The results were thus pooled and are included in Table 1.

In comparison to the adult insects, the larvae were less affected by the thermal action of the prototype and more by its mechanical action when using ambient air at 23 m/s. When the thermal-pneumatic prototype passed by the plant, the plant quickly bent in the direction of the moving air and then oscillated back to its normal position. This rapid swaying motion of the plant triggered thanatosis and removed about 50% of the adults and 75% of the larvae. This marked difference in the response of the adults and larvae to mechanical action was not observed in the first section of this work when the air velocities were lower.

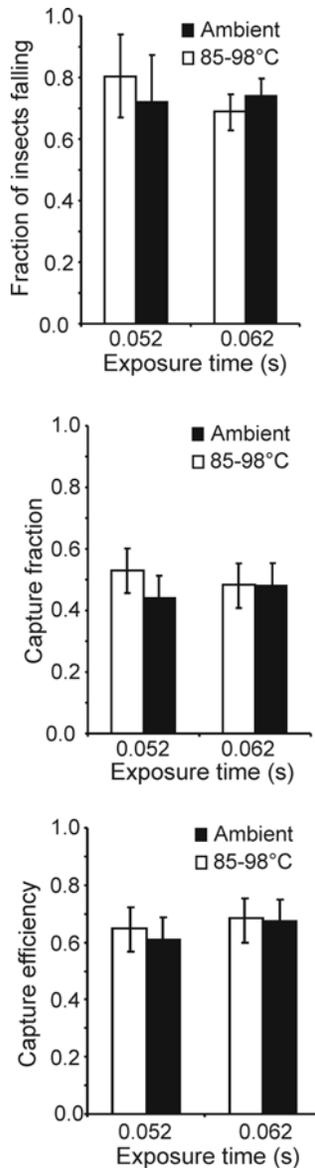
As shown in Table 1, the ratio of collected insects to removed insects (i.e., the capture efficiency) was about 0.65 for the thermal-pneumatic prototype, irrespective of the insect life stage or air temperature. This is not surprising since fourth instar and adult Colorado potato beetles are similar in size and shape and are projected in the same fashion once they let go from the plant.

More information about the capture of the insects was obtained by recording with a video camera the motion of adult Colorado potato beetles during treatment with the thermal-pneumatic prototype. These observations were made in an effort to explain why not all insects were removed or captured. As mentioned earlier, in addition to high temperatures, the insects experienced a rapid swaying motion of the plant as it first bent under the influence of the blowing air and then returned to its original position. This swaying motion of the plant played an important role in determining the trajectory of the insects. During laboratory testing, insects would occasionally let go as the plant was swinging back to its original position and were thereby propelled away from the capture device and ended up on the floor. In other cases, the insects would let go as the plant bent towards the capture device but would bounce off the screen and fall on the floor. Those who got captured would typically let go of the plant as it was bending towards the capture device. They were then

**Table 1. Comparison of performance indices of the thermal-pneumatic prototype with a pneumatic system.**

Performance index	Thermal-pneumatic prototype (laboratory tests at 25 - 35 m/s air)			Pneumatic (field tests* at 35 - 50 m/s ambient air)	
	Adults		Larvae	Adults	Larvae
	Ambient air	Hot air	Ambient and hot air		
Removal fraction	0.51 ± 0.05	0.85 ± 0.04	0.74 ± 0.09	0.61	0.83
Capture fraction	0.34 ± 0.05	0.58 ± 0.05	0.48 ± 0.07	0.54	0.51
Capture efficiency (%)	63 ± 8	67 ± 4	65 ± 10	88	62

\*Lacasse et al. 1994



**Fig. 9. Larvae removal fractions, capture fractions, and capture efficiencies obtained in the laboratory with the thermal-pneumatic apparatus (air velocity of 23 m/s).**

### Comparison with a pneumatic collector

Field tests were performed with a similar pneumatic collector by the Department of Agricultural Engineering at Université de Laval (Lacasse et al. 1994). Their prototype used ambient air only. Furthermore, exit air velocities were significantly higher than the ones examined here (ranging from 35 to 50 m/s). In agreement with our findings, the removal and capture efficiencies of their pneumatic collector showed little dependence on air speed and contact time. Average results from their study are included in Table 1 for comparison purposes. The adult and larvae removal efficiencies obtained by Lacasse et al. (1994) are similar to those obtained with ambient air in this study. The adult capture efficiency of the pneumatic apparatus of Lacasse et al. (1994) is, however higher, suggesting that the design of their capture device is better. Nonetheless, the thermal-pneumatic apparatus of this study was able to achieve much higher adult removal efficiencies at lower air velocities when hot air was used. This result is a consequence of the influence of heat on the initiation of thanatosis, as outlined in the first section of this work. Lower air velocities translate into lower power requirements for the air propulsion system and reduced plant damage.

### CONCLUSION

The use of hot air in the pneumatic control of Colorado potato beetles significantly increased the fraction of adults dislodged from the plant. In laboratory and field tests performed at air speeds of approximately 25 m/s, the fraction of adults removed from the potato plants increased from about 0.50 to about 0.85 when the air was heated from 25 to approximately 100°C. The experimental data suggests that thanatosis was triggered when the temperature of the beetles' antennae or legs exceeds a certain threshold temperature. Contact times required to trigger thanatosis in the adults were too short to result in a significant increase in the insects' body temperature and to cause thermal damage to the plants. Removal of the fourth instar larvae was however more affected by the air speed than by the air temperature. Larvae removal increased from about 30% at 9 m/s to about 74% at 23 m/s when using air at ambient temperature. In all cases, about 65% of the insects removed from the plants were captured in the collection device.

The thermal-pneumatic control method proposed in this study is a promising alternative to conventional methods for controlling the Colorado potato beetle. Its principal advantages over other pneumatic methods include lower air velocities and higher adult removal rates.

## ACKNOWLEDGEMENTS

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