Insect scorcher for the control of the Colorado potato beetle

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Hicks, J., Coututier, M. and Pelletier, Y. 1999. **Insect scorcher for the control of the Colorado potato beetle**. Can. Agric. Eng. **41**:227-231. A single-row insect scorcher for the control of the Colorado potato beetle has been developed and tested under controlled laboratory and field conditions. In contrast with the existing propane flamer, this device cools the combustion gases by dilution with air to about 500°C. By controlling the temperature of the gases and the contact time, it is possible to irreversibly damage the adult potato beetles without damaging the plants. During single field treatments with the prototype mounted at the front of the tractor, projected mortalities in excess of 60% were obtained with negligible plant damage at travel speeds between 2 and 3 km/h. Slightly lower projected mortality rates were obtained in late summer when the prototype was located at the rear of the tractor. It is estimated that the use of this new thermal treatment device will require less than 27 kg of propane per hectare.

Un appareil pouvant appliquer un traitement thermique pour le contrôle du doryphore de la pomme de terre a été développé et évalué au laboratoire et au champ. Contrairement au brûleur au propane sur le marché, cet appareil refroidit les gaz de combustions jusqu'à une température de 500°C en y mélangeant de l'air. Il devient alors possible d'endommager les doryphores adultes sans endommager les plantes en contrôlant la température du mélange. Lors d'essais au champ avec cet appareil monté à l'avant d'un tracteur voyageant à des vitesses entre 2 et 3 km/h, nous avons observé une mortalité projetée de 60% et un dommage négligeable des plantes. Des résultats légèrement inférieurs furent observés plus tard en saison avec l'appareil situé à l'arrière du tracteur. Nous avons calculé que l'appareil utilise 27 kg de propane par hectare.

INTRODUCTION

The Colorado potato beetle, *Leptinotarsa decemlineata* (Say) is the most important defoliator of potato plant crops in Eastern North America (Hare 1980). Present control strategies are based on the use of insecticides which are potentially damaging to human health and the environment. Furthermore, through genetic adaptations, the Colorado potato beetle can become resistant to insecticides used against it (Boiteau et al. 1987). Alternative control technologies are being developed to overcome these disadvantages.

Propane flamers for the control of Colorado potato beetles have been in use since 1989 and have been tested for effects on all stages of the insect life cycle (Moyer et al. 1992; Duchesne et al. 1992). The current technique involves passing a propane flame over the potato plants to kill or disable the adult potato beetles on the leaves. This method is limited to plants shorter than 150 mm and can damage plants at low travel speeds if more than one application per season is required (Ferro 1995). As a result, the technique can only be used once early in the growing season if reductions in crop yield are to be avoided.

These disadvantages have motivated further research into the use of lower gas temperatures to thermally damage the insects without damaging the plants. Insect legs and antennae are relatively small and thus can heat up to damaging levels faster than plant leaves via convection from the surrounding gases. Once insect legs reach 65°C, they are permanently damaged and the beetles are unable to recover from these injuries (Pelletier et al.1995).

A prototype based on this principle was built and underwent lab trials before being tested in a field situation. The objective of this study was to evaluate the control capability of this new thermal treatment device by examining insect damage after treatment. From the insect damage results, a projected mortality value was calculated based on insect survival rates following treatments. Tests were performed at different passing speeds and exhaust air temperatures.

MATERIALS and METHODS

Flamer prototype

A Tundra Toaster™ (Model CH1, Venturi Manufacturing Ltd., Moncton, NB), originally designed as a temporary space heater, was transformed into the apparatus used in this study (Fig. 1). The device burns gaseous propane from a standard 8 kg tank and was modified to provide a maximum thermal output of 65 kW (which corresponds to a propane consumption rate of about 5 kg/h). The propane tank was placed in a plastic container filled with warm water to prevent ice formation around the tank. Combustion and dilution air was provided by a blower unit powered by a 0.2 kW electric motor. A hemispherical bluff body made of porous fire brick and having a diameter of 100 mm was located downstream of the combustion tube to stabilize the flame. The velocity of the gases inside the 178 mm I.D. duct leading to the hood was about 19 m/s when the air flow was adjusted to give an exit gas temperature of 500°C. The hood was 610 mm long, 300 mm wide, and 300 mm high and was used during field tests to reduce mixing between the hot exit gases and surrounding air.

Laboratory tests were performed with the apparatus mounted on a trolley which travelled along a track six meters in length. A chain driven by a variable speed DC motor pulled the trolley along the track at a uniform velocity. In this manner, the prototype could be passed at various speeds over potted

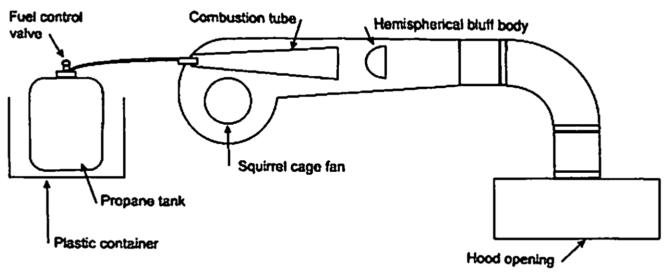

Fig. 1. Schematic of the prototype.

plants located along the track. The apparatus was later mounted onto a Kubota L245H tractor for field testing with both front and rear mounting configurations. An equivalent DC motor replaced the blower's AC motor that was used in the lab tests to accommodate the tractor's electrical system.

Plants and insects

All potato plants used in this study were of the Russet Burbank variety. Initial laboratory tests were performed with greenhouse grown potato stems trimmed down to two leaflets and placed individually in pots containing moist vermiculite. Plant damage evaluation in the lab was performed using whole plants from the greenhouse and with potted plants grown outdoors. Potatoes were also planted in the field periodically throughout the summer so that plants between 100 and 200 mm in height were available throughout the summer for field testing. Larger plants were not used because colonization of potato fields by adult Colorado potato beetles occurs in spring when potato plants are usually less than 200 mm in height.

Initial laboratory tests were performed using adult beetles grown in a greenhouse. These were transported in buckets to the lab where they were manually placed on stems kept in a screened cage. Insects from the field were used once available. Beetles were set on the stems for approximately thirty minutes before testing. Insects used for field tests were manually placed on field plants and left to acclimatize for 20 to 30 minutes before the tests.

Testing

Plants and insect specimens were placed in the path of the oncoming apparatus. The apparatus was then passed over the plant at a noted speed (1 to 5 km/h) and exit gas temperature. The distance between the top of the plant and the gas exit was typically 130 to 250 mm depending on the height of the plant.

Each laboratory trial at a set temperature and passing speed was performed using three to five potted potato plants, each holding five to seven adult insects. Exit gas temperatures were varied between 500 and 700°C in the laboratory and were maintained at approximately 500°C in all field trials. Attempts at using higher temperatures in the field led to combustion instabilities because of ice formation on the propane tank. Field treatments for a given passing speed were performed on plant rows approximately 10 m long. Each row contained five, 1-m sections marked off by white stakes. Each section contained 15 adult beetles distributed on 2 to 4 plants. Treated insects were collected and rated for damage immediately after each test.

Insect damage was qualitatively assessed by observing the mobility of the beetles and was noted on a scale ranging from 0 to 6. A score of 0 was assigned when there were no apparent signs of injury; 1 when one or more tarsal joints had been damaged; 2 when the beetle could not climb a vertical surface because of injuries to tarsal and tibia-femur joints; 3 when the beetle was dragging one or more legs as a result of injuries to the tarsal and tibia-femur joints; 4 when the beetle was unable to walk as a result of injuries to tarsal and tibia-femur joints; 5 when the beetle was unable to move one or more legs as a result of injuries to tarsal, tibia-femur and coxa-femur joints; and 6 when the beetle was found dead. The percentages of insects in each damage class were compared using Kruskal-Wallis One Way Analysis of Variance on Ranks for multiple groups and using Mann-Whitney Rank Sum Tests for two groups. The significance level used was 0.1.

Plant damage was assessed 24 h after thermal treatment. Damaged portions of the plant leaf or stem could be identified by wilting and a brown coloration. For each treated plant the percentage of the total leaf area that was damaged was evaluated visually by estimating the proportion of the leaf surface which was wilted or discolored.

Insect survival

Insect survival tests were performed to determine insect mortality for each damage class. Thirty to fifty beetles of each of the 0 to 5 damage classes were placed in the field inside screened cages containing one or more potato plants. The number of live and dead beetles was recorded after five days. Missing beetles were assumed to be alive and to have escaped.

RESULTS

The survival rate of the insects after exposure to the hot gases of the insect scorcher was a function of the severity of the inflicted injuries (Table I). The survival rate after five days decreased with increasing value of the damage index and was nil for insects which incurred a damage level of 5 or 6 during treatment. The projected mortality was estimated from the five-day survival results for each damage class by adding the percentage of beetles found dead and the percentage of beetles found alive but unable to climb on the plants. It was assumed that beetles unable to climb on the potato plants would eventually die from starvation. The mortality results of Table I were subsequently combined with the insect damage distribution obtained after each treatment to estimate the percentage of insects exterminated by the insect scorcher. The

Table I. Insect damage rating categories with corresponding survival rates after 5 days and projected mortality.

Damage rating	Description	5 day survival (%)	projected mortality (%)
0	normal	100	0
1	some tarsal damage	85	15
2	unable to climb	79	44
3	dragging legs	70	75
4	unable to walk	60	100
5	unable to move legs	0	100
6	dead	0	100

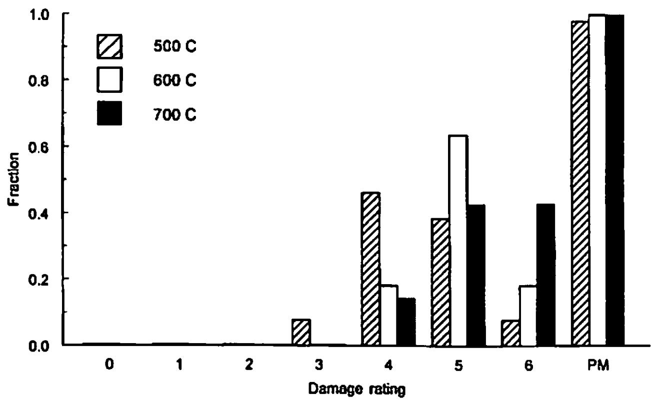

Fig. 2. Insect damage rating distribution and projected mortalities (PM) in the laboratory at a passing speed of 1.1 km/h and various exit gas temperatures.

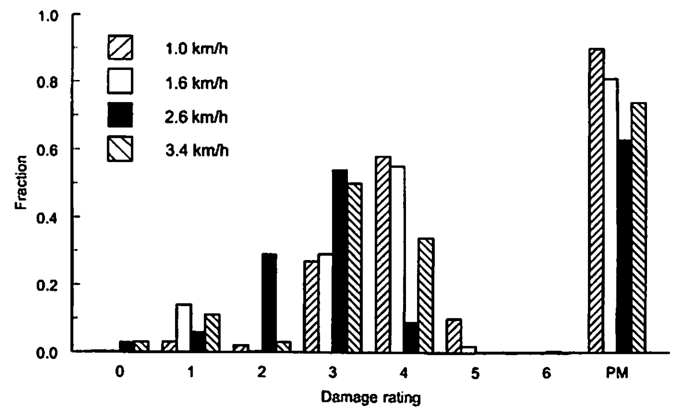

Fig. 3. Insect damage rating distribution and projected mortalities (PM) in the laboratory at an exit air temperature of 600°C and various passing speeds.

projected overall mortality for each treatment was calculated by multiplying the percentage of beetles in each damage category with the corresponding projected mortality from Table I and by summing the resulting six products.

Laboratory tests were performed at a passing speed of 1.1 km/h to determine the effect of temperature on insect damage (Fig. 2). An increase in temperature from 500 to 700°C resulted in insects incurring higher degrees of damage, but projected mortalities remained approximately at 100% in all cases. Tests performed at 600°C and varying speeds showed that the overall extent of damage declines with increasing passing speed (Fig. 3). The variation in beetle damage within a single plant can be explained in terms of their individual position on the plant. Beetles in direct contact with the heated gas on top of the plant incur higher thermal damage than those shielded on the underside of leaves.

Table II. Median insect damage rating resulting from field tests at an exit gas temperature of 500°C and various speeds.

Speed (km/h)	Mounting configuration	Date[1] (1996)	Number of insects	Median[2] damage rating
1.6	front	July 22	56	3a
	front	July 29	49	3b
	rear	August 20	62	2.5bc
	rear	August 21	68	3abc
2.0	front	July 22	58	3dg
	front	July 25	69	3d
	front	July 29	53	3de
	rear	August 20	75	2ef
	rear	August 21	71	2efg
2.9	front	July 22	71	3h
	front	July 23	70	3h
	front	July 25	71	3h
	front	July 25	75	3h
	front	July 29	64	3h
	rear	August 20	55	1i
	rear	August 21	75	2i
3.5	front	July 25	75	2j
	front	July 29	58	1k
	rear	August 21	72	1k
5.0	front	July 23	63	2m
	front	July 23	75	1m
	front	July 29	57	1n
	rear	August 21	59	1n

[1] Weather conditions noted for each date: July 22, sunny; July 23, hazy and windy; July 25, cloudy; July 29, very hot and sunny; August 20, sunny; August 21, cloudy.
[2] Medians followed by the same letter are not significantly different ($P<0.05$, Dunn's Method).

The temperature of the exhaust gases during the field tests was relatively constant at approximately 500°C with passing speeds between 1.6 and 5.0 km/h. Tests were carried out on various days using front and rear tractor mountings to determine the effects of environmental conditions and mounting location on damage results (Table II). In each speed trial, the median insect damage did not vary significantly from section to section of the same row, and the results were pooled. As can be seen in Table II, the trials performed on different days at the same speed and with the same mounting configuration generally gave similar results.

As in the laboratory tests, the damage level decreased with increasing speed and to clearly demonstrate the importance of this variable, the data have been grouped into categories. These categories are for speeds less than or greater than 3.0 km/h for the months of July and August (Fig. 4). When the field results are classified in this manner, there are significant differences between results from the months of July and August as well as between speeds above and below 3 km/h ($P \leq 0.001$). Results from July at speeds below 3 km/h gave the highest projected mortalities. The lowest projected mortalities occurred during the month of August at speeds greater than 3 km/h.

During the laboratory and field trials, the percent plant damage was found to be at most 6% for a passing speed of 1.6 km/h and decreased to

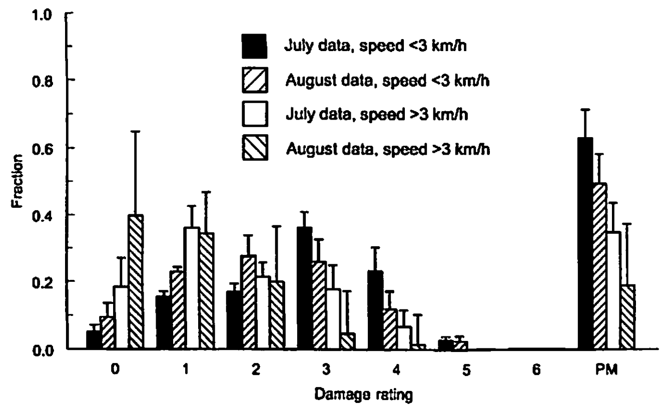

Fig. 4. Insect damage rating distribution and projected mortalities (PM) in the field for the months of July and August at speeds below and above 3 km/h. Error bars are 90% confidence intervals for the mean.

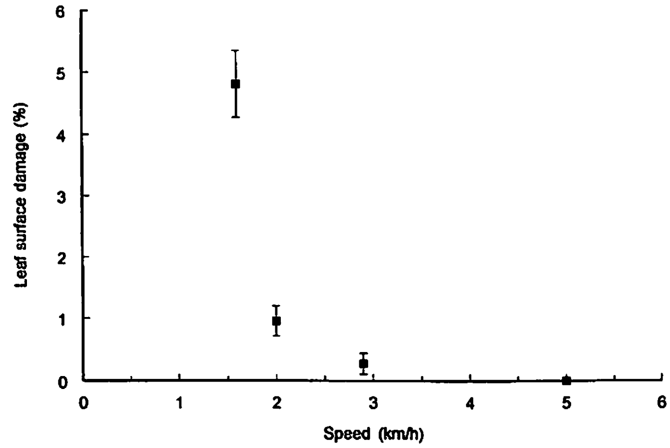

Fig. 5. Average plant damage in the field as a function of passing speed. Error bars are 90% confidence intervals for the mean.

0% at speeds greater than 3 km/h (Fig. 5). Hence, to minimize plant damage and maximize projected insect mortalities, the optimum speed is somewhere between 2 and 3 km/h when using hot gases at 500°C. At these speeds, the propane requirements for one field treatment are expected to be approximately 18 to 27 kg per hectare at a propane consumption rate of 5 kg/h and a row spacing of 914 mm.

DISCUSSION

A significant proportion of insects escape lethal damage from the propane scorcher at speeds above 3 km/h. This can be explained in terms of the contact time required to heat the legs to damaging levels via convection from the hot gases. As the speed increases, the insects are in contact with the hot gases for a shorter period of time and thus less heat is transferred to them.

The injury level of the insects can be increased by decreasing the passing speed of the apparatus or by increasing the temperature of the exit gases. Either approach will lead to a greater quantity of heat being absorbed by the legs, which must be heated above 65°C for permanent damage to occur (Pelletier et al. 1995). Extreme insect damage is however not required to control this pest, as the beetles only need to be disabled such that they are unable to climb back up onto the plant where they feed.

Different mounting configurations were used in this study to determine whether the position of the thermal treatment device on the tractor affects insect damage levels. It was hypothesized that the presence of the tractor ahead of the propane scorcher in the rear mounting configuration may disturb the insects and have a negative impact on the results. It was however observed that the lateral motion of the tractor above the plants has no apparent effect on the behavior of the beetles located on the plants. For this reason, the rear mounting configuration is not believed to be the cause of the lower damage levels observed in August. The significant difference between the results obtained in July and August is instead attributed to the fact that the insects used in these tests were from different generations. The new adults that emerge from the ground in late summer feed briefly before entering an overwintering diapause. Their behavior is different than that of the early summer adults which have overwintered in the soil and are primarily concerned with eating and mating. This difference in beetle behavior may have resulted in different vertical distributions of the insects within the plants.

The distribution of the insects within the plant canopy at the time of treatment has a significant effect on insect damage results. Insects located on top of the plants are highly vulnerable to thermal treatment whereas those hiding behind leaves are partially shielded from the hot gases. This explains why insects are not all damaged to the same extent during a given treatment.

Plant damage after one treatment was in all cases much lower than the threshold level of 10% (Hare 1980) above which crop yield is expected to decrease. For this reason, the insect scorcher could probably be used several times throughout the early growing season without risk to the crop. Plants ranging from 100 mm to 200 mm in height were treated with equal success. The prototype was able to provide up to 63% insect mortality with one pass at an exit gas temperature of 500°C and at speeds less than 3 km/h. Unfortunately, larvae were not found to be significantly affected by the prototype. The insect scorcher could probably be used on plants taller than 200 mm but the penetration depth of the treatment will depend on the density of the foliage. For this reason, it is preferable to use the scorcher when the insects are feeding on the top portion of the potato plants. Further work should be undertaken to develop a multi-row unit that operates at higher temperatures (600-700°C) so that faster travel speeds and shorter treatment times may be achieved in the field. A liquid-propane feeding system with vaporization at the burner should also be used to avoid ice formation on the propane tank.

SUMMARY

The insect scorcher developed in this study is a promising alternative to existing techniques for controlling the Colorado potato beetle. Unlike the propane flamer, the insect scorcher can irreversibly damage the adult potato beetles without damaging the plants. This is achieved by controlling the temperature of the hot gases and the exposure time of the plants. Colorado potato beetles are also unlikely to become resistant to this method of control via genetic adaptations as they can with insecticides.

Negligible plant damage and projected insect mortalities in excess of 60% were repeatedly obtained during field trials with the prototype mounted on the front of a tractor traveling at speeds between 2 and 3 km/h. Plants ranging from 100 to 200 mm in height were treated with equal success. All field trials were performed with an exit gas temperature of 500°C whereas tests in the laboratory were performed at temperatures between 500 and 700°C. Insect damage increased with increasing temperature and decreasing speed. Plant damage also increased with decreasing speed but was negligible at speeds greater than 2 km/h. Use of the insect scorcher at a speed of 2.5 km/h is expected to require about 22 kg of propane per hectare.

ACKNOWLEDGMENTS

Thanks are extended to Cathy Clark and the summer students at Agriculture and Agri Food Canada for their help on this project. Thanks are also extended to the technicians of the Chemical Engineering Department at the University of New Brunswick for their assistance in the construction of the prototype.

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