Evaluation of a four-row prototype machine for pneumatic control of Colorado potato beetle

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Laguë, C., Khelifi, M. and Lacasse, B. 1999. **Evaluation of a four-row prototype machine for pneumatic control of Colorado potato beetle**. Can. Agric. Eng. **41**:047-052. Previous research work related to pneumatic control of Colorado potato beetle (CPB) showed that this alternate control means is technically feasible and that it may represent an interesting alternative to chemical means. A four-row prototype machine was designed and built to implement pneumatic control at the field scale. Extensive testing of this machine in the field was completed during a full growing season. The effects of pneumatic control of CPB on the growth of potato plants and on the yields were investigated. Also, the efficiency of a specific pneumatic strategy in controlling CPB was evaluated. Field experiments consisted of: control (no treatment), pneumatic control (once and twice per week), chemical control, and combined chemical and pneumatic control (once and twice per week). Results showed that the use of the pneumatic machine to control the CPB did not have any negative effect on the crop development. The plots treated twice per week with the pneumatic machine gave a comparable yield to the plots chemically treated. However, the use of the pneumatic machine once per week resulted in very low yields. In general, variable CPB control in the plots treated twice per week was achieved by the prototype machine. Nevertheless, the plots treated once per week were rapidly defoliated with the appearance of the large larvae (L3-L4). These results prove that the pneumatic machine could be used to control CPB without affecting the plant growth or yield. However, further improvements of the machine, like the shape of the blowing units, have to be considered in order to better control CPB populations. **Keywords**: Colorado potato beetle, insect control, pneumatic, air flows, potato, prototype.

Des travaux antérieurs portant sur le contrôle pneumatique du doryphore de la pomme de terre (DPT) ont révélé que cette méthode de lutte est techniquement faisable et qu'elle peut représenter une alternative intéressante aux moyens chimiques. Un prototype a été conçu et construit afin d'évaluer cette technologie à échelle réelle et des essais au champ ont été effectués durant une saison complète de croissance. Les effets du contrôle pneumatique de DPT sur la croissance des plants et sur les rendements ont été examinés. De plus, l'efficacité d'une stratégie de contrôle pneumatique du DPT a été évaluée. Les expériences au champ étaient: contrôle (aucun traitement), contrôle pneumatique (une et deux fois par semaine), contrôle chimique, contrôle combiné chimique et pneumatique (une et deux fois par semaine). Les résultats ont montré que l'utilisation du prototype pour contrôler les DPT n'a eu aucun effet négatif sur la croissance des plants. Les parcelles traitées deux fois par semaine avec le système pneumatique ont donné un rendement comparable à celui des parcelles traitées chimiquement. Toutefois, l'utilisation du système pneumatique une fois par semaine a résulté en de très faibles rendements. En général, un certain contrôle des DPT dans les parcelles traitées deux fois par semaine a été accompli avec le système pneumatique. Par ailleurs, les parcelles traitées une fois par semaine ont été rapidement défoliées suite à l'apparition des grosses larves (L3-L4). Les résultats obtenus démontrent que le système pneumatique pourrait être utilisé pour contrôler les DPT sans affecter la croissance des plants ou leur rendement. Toutefois, quelques améliorations, en particulier au niveau de la forme des unités de soufflerie, doivent être apportées au prototype afin de mieux contrôler les populations de DPT. **Mots clés**: Doryphore de la pomme de terre, contrôle des insectes, pneumatique, écoulements de l'air, pomme de terre, prototype.

INTRODUCTION

The Colorado potato beetle (CPB) is the major insect pest of potato crops in North America and Europe (Hare 1980; Boiteau et al. 1992). Over the years, this insect has developed resistance to most of the registered chemical insecticides used to control it (Forgash 1985; Whalon et al. 1993). For this reason, it has become very costly to control this insect pest (Ferro 1995). In addition, heavy reliance on chemicals can often lead to serious health and environmental problems.

In general, most of the plant defoliation is caused by CPB larval feeding, especially the third and fourth instars. However, the density of these larvae is closely related to that of colonizing CPB adults. Ferro et al. (1991) indicated that before entering diapause in the fall, CPB females mate and overwinter enough sperm to produce about 80% of their egg capacity without mating in the spring. A limited population of colonizing CPB females can thus cause substantial economic losses to potato growers during the following season (Ferro 1995). It is therefore imperative to well control the CPB early in the season in order to avoid unrecoverable damages later.

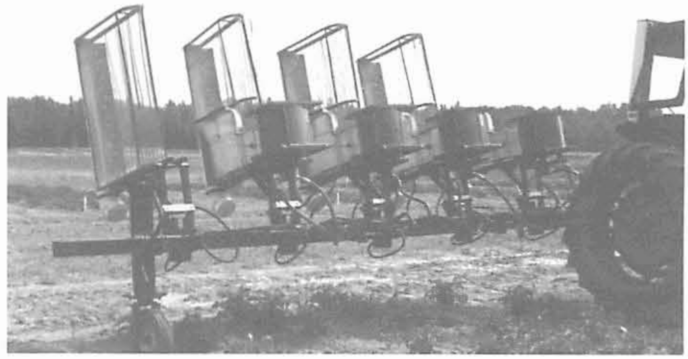
Because of public concern about chemical residues on food, the off-target deposition of chemical insecticides into the environment, and the resistance of CPB to most registered insecticides, many alternative means have been developed in the last few years, in particular the use of pneumatic control machines.

The idea of using vacuum machines to control insect pests is not new. It was used in the 1950's in the cotton fields of the United States (deVries 1987). However, the availability of efficient and economic chemical insecticides on the market rapidly made this technique less attractive to growers. By the early 1980's, CPB had become resistant to all registered insecticides (Ferro 1995). In addition, the use of the systemic insecticide aldicarb (Temik™) that was effective against CPB was prohibited. For these reasons, a potato grower from Massachusetts modified an industrial vacuum to remove CPB from potato plants (Ferro 1995) and since that time, the idea of

(a) General view

(b) Operating mode: (1) collecting unit; (2) fan

(c) Close-up view of the blowing and collecting units: (1) blowing nozzle; (2) grating; (3) collecting pan



(d) Transport mode (also used to empty collecting units)

Fig. 1. Four-row experimental prototype to control CPB.

controlling CPB using pneumatic systems has regained more and more interest.

By the early 1990's, at least eight companies around the world were trying to market pneumatic machines to control CPB (Khelifi 1996). However, the use of these machines in potato fields has only been partially successful and has often resulted in significant damage to the foliage of potato plants (Duchesne and Boiteau 1992; Boiteau et al. 1992). This is mostly attributed to the inadequate design of the operating units as no relevant scientific data were available in the literature (Khelifi et al. 1992).

Over the last few years, several studies related to the pneumatic control of CPB have been carried out at the Department of Soil Science and Agri-Food Engineering of Université Laval, Québec, Canada. Many parameters such as the effects of air speed on potato plants (Khelifi et al. 1995a), the speed and orientation of airstreams required to remove adult CPB from potato plants (Khelifi et al. 1995b), and the airflow inside and around hoods used for pneumatic control of insect pests (Khelifi et al. 1994, 1996a, 1996b) were investigated. In addition, extensive field tests were carried out to determine the effects of different combinations of airflow velocities, airflow widths, and travel speeds on the dislodging and collection of CPB (Lacasse 1996; Lacasse et al. 1998a, 1998b). Based on the results of these studies, a prototype field-scale machine was designed and built. This machine could remove CPB from four rows of potato plants in a single pass in the field.

The general objective of this study was therefore to evaluate, during a full growing season, the efficiency of a four-row prototype machine specifically designed to pneumatically control CPB in potato crops. The specific objectives were:

1. To evaluate the effects of the pneumatic control of CPB on the growth of potato plants and on the yields; and
2. To evaluate the efficiency of a specific pneumatic control strategy in controlling CPB.

MATERIALS and METHODS

Experimental site

All field experiments were conducted in 1995 at the Joseph-Rhéaume Research Farm of Université Laval located in Sainte-Croix on the south shore of the St.-Lawrence River, 50 km upstream from Quebec City. Thirty two four-row plots, each 12 m long, were seeded on May 28 with potato tubers ('Kennebec') placed at 250 mm intervals along rows spaced 910 mm apart. All plots were chemically treated to control weeds and mildew. Hilling of the young plants was completed on July 7 and harvest finished by September 25.

Experimental prototype

Based on previous experimental results obtained by Khelifi et al. (1995a, 1995b) and Lacasse et al. (1998a, 1998b), a simple horizontal airstream blowing configuration was selected. This simplified the design of the machine and significantly reduced the power requirements. Figure 1 shows different views of the prototype machine developed at the Department of Soil Science and Agri-Food Engineering of Université Laval during the winter of 1995. This prototype had four centrifugal fans connected to metal sheet ducts that horizontally directed airstreams across the plants. All airstreams were directed in the same direction with a slight backward angle. On the opposite side of the row, a horizontal grating of iron bars was mounted in front of a collection device inlet to prevent the potato plants from entering the collection unit and also to prevent them from bending too much under the effect of airstreams. A mosquito net was mounted on the collecting device to prevent the dislodged CPB from flowing through it. Dislodged CPB carried by airstreams were stopped by the net and fell into the collecting device. As shown in Figs. 1c and 1d, each device caught the insects dislodged by the adjacent blowing unit. This allows addition of the desired number of units according to the support system used. On each side of the machine, either blowing or catching units were mounted. The adjustment of the height of the blowing slot was achieved with a valve located at the outlet of the fan. It allowed to direct all the airflow to the bottom section (254 mm) at the beginning of the season or to spread it over the whole height of the blowing slot (508 mm) when the size of the plants had increased in order to fully expose the potato plants to the airstream. Airstream width was set at 25.4 mm to reduce the required power.

To prevent compaction, the prototype was completely offset to the right side of the tractor (Fig. 1a). This also allowed for the evaluation of the ease of deployment and off-field travel of an eventual twelve-row system mounted behind a tractor (four-row units on each side and one at the rear). The units covering the rows located on both sides of the tractor could be folded back in the transport mode or when traveling outside the field.

Each unit was allowed to independently slide over the ground surface in order to follow the irregularities of the field. The prototype machine was equipped with hydraulic cylinders that lifted and tilted each unit in the transport mode or for emptying the collecting devices (Fig. 1d).

The use of centrifugal fans having forward curved blades allowed to significantly reduce the noise level compared to previous axial flow fans. Offsetting of the prototype led to a reduction of the travel speed from 5 to 3.8 km/h in order to allow the collecting device to better follow the rows.

Experimental design and procedure

Field treatments consisted of: (1) control (no treatment), (2) pneumatic control (once per week), (3) pneumatic control (twice per week), (4) chemical control, (5) combined chemical and pneumatic control (once per week), and (6) combined chemical and pneumatic control (twice per week).

The first three treatments were aimed at measuring the prototype impact on CPB populations during the entire growing season whereas the last three treatments were carried out to investigate the possible negative effect on the plant growth resulting from pneumatic control. All treatments were randomly arranged in six plots located in four complete blocks. Two buffer plots located on each side of the control plot were treated with chemical insecticides and used to limit the migration of CPB to other plots. Also, plastic-lined trenches surrounding the plots pneumatically treated once per week were used as physical barriers to prevent walking CPB adults from moving into the plots.

Airflow velocity calibration was made with a 2% precision telescopic anemometer (Solomat Instrumentation Division, Norwalk, CT). The power required by the whole hydraulic system was estimated from the pressure drop (pressure gauges) and the oil flowrate (displacement and rotational speed of the pump). For the airspeed used (50 m/s), the power required by each blowing unit was 4.1 kW. Travel speed was set at 3.8 km/h.

To monitor the plant growth, one representative plant per plot was cut each week to measure its height, foliage surface, and dry and fresh weights. Yields were measured at harvesting over a 10 m length section located in the two central rows of each plot. To monitor the populations of CPB in the plots that were chemically untreated, counts were taken at the beginning of each week over 14 plants per plot according to the following classes: adults, small larvae (L1-L2), large larvae (L3-L4), and egg masses.

Statistical analysis procedure

The data were tested for homogeneity of variances and normality. A square root transformation [$(Y + 1/2)^{1/2}$] was performed on the series of experimental data related to the height, foliage surface, and dry weight of the potato plants and to the monitoring of CPB populations whereas a logarithmic transformation [log (Y + 1)] was performed on the series of experimental data related to the yield (Steel and Torrie 1980). These transformations were necessary to improve the homogeneity of variances. An analysis of variance was then performed for each data set using the General Linear Models (GLM) procedure (SAS 1988). Variables with significant F values were further analyzed using an LSD (Least Significant Difference) test at the 5% level of significance.

RESULTS and DISCUSSION

Potato growth and yield

The use of the pneumatic system to control CPB did not have any significant negative effect on the crop development as the growth of potato plants (height, foliage surface, and dry weight) and the yields were similar for all plots chemically treated (Figs. 2 and 3). Also, the use of the pneumatic system (once or twice per week) in addition to the chemical treatments appeared

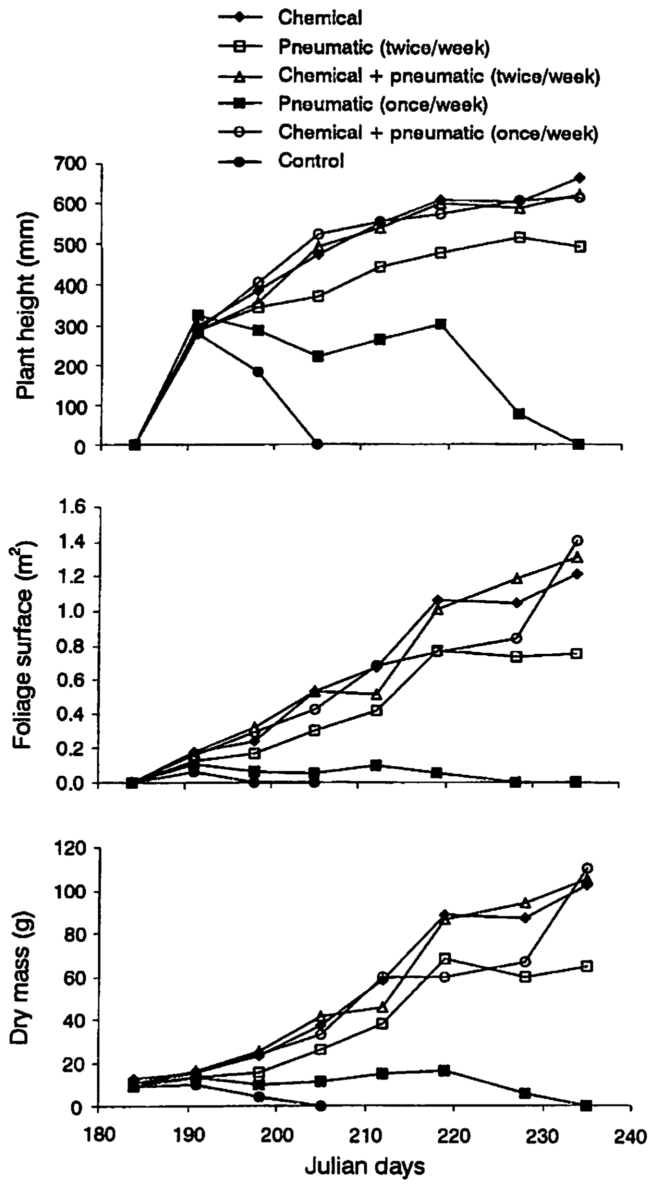


Fig. 2. Evolution of the potato plant height, foliage surface, and dry mass under the effects of the different treatments during a full growing season.

to be unnecessary. The plots treated twice per week with the pneumatic machine gave a comparable yield to the plots chemically treated ($P \leq 0.05$). However, the use of the pneumatic machine once per week resulted in a significantly lower yield compared to the use of pesticides. In addition, the yield of the control plots was zero. These results show that the pneumatic machine could be used to control CPB without affecting crop development or yield.

Control of CPB

Early in the season, the number of egg masses and small larvae (L1-L2) per plant was high because the use of the pneumatic system had little or no effect on them (Fig. 4). During the field trials, control plots were rapidly devastated by the colonizing spring generation of CPB adults that emerged from the ground. This was not surprising as this field had been cropped with potato for four consecutive years and control of CPB had been neglected in the previous years. The plots treated once per week by the pneumatic machine were also rapidly defoliated by the large larvae (L3-L4).

Overall, some control of CPB in the plots treated twice per week was achieved by the prototype machine (Fig. 4). However, the low control of the adult CPB early in the season led to a large number of egg masses and consequently to more small larvae (L1-L2) later. The efficiency of the prototype machine was poor before hilling mainly because many CPB dislodged from the potato plant foliage fell on the ground before reaching the collection units and thereafter climbed back on the plants. Also, small size plants could not correctly lean against the grating of the collection units which reduced the collection efficacy of the machine. Appropriate positioning of the collection units relative to the plant rows was very important, especially for young plants. The reduction of the airstream width to 25.4 mm may also have adversly affected the results.

CONCLUSIONS

1. The use of the pneumatic system to control the CPB did not have any negative effect on the crop development.
2. Additional treatments using the the pneumatic system on the plots chemically treated did not result in significant yield increases.
3. The use of the pneumatic machine twice per week resulted in a comparable yield to that of the plots chemically treated.
4. The use of the pneumatic machine once per week resulted in very low yields compared to the use of pesticides or to pneumatic treatments completed twice per week.
5. Overall, variable control of CPB in the plots treated twice per week was achieved by the prototype machine.

RECOMMENDATIONS

Although no diseases or viruses were observed during this project, it is highly recommended to further investigate possible spread of such diseases or viruses caused by pneumatic control machines.

Further improvements of the prototype machine should be considered to better control CPB populations.

1. A new shape of the blowing units will be designed and tested. One of the two duct bends will be removed to reduce the cost of manufacturing and to double the airstream width while maintaining similar air speeds and power.
2. A new system for eliminating CPB will also be considered. Rather than collecting the dislodged CPB and having to frequently empty the collecting units, the dislodged insects from the potato plants will be allowed to directly fall on the ground in the alleys. Propane burners immediately located behind the blowing units will continuously destroy the dropped CPB. It is well known that the legs and the antenna of the CPB are particularly fragile. Hopefully, the new modifications will improve the efficiency of the pneumatic control because a large number of CPB, including those who used to escape from the collecting units will be destroyed. The flamer adjustments required to adequately destroy CPB are already known. This modification could

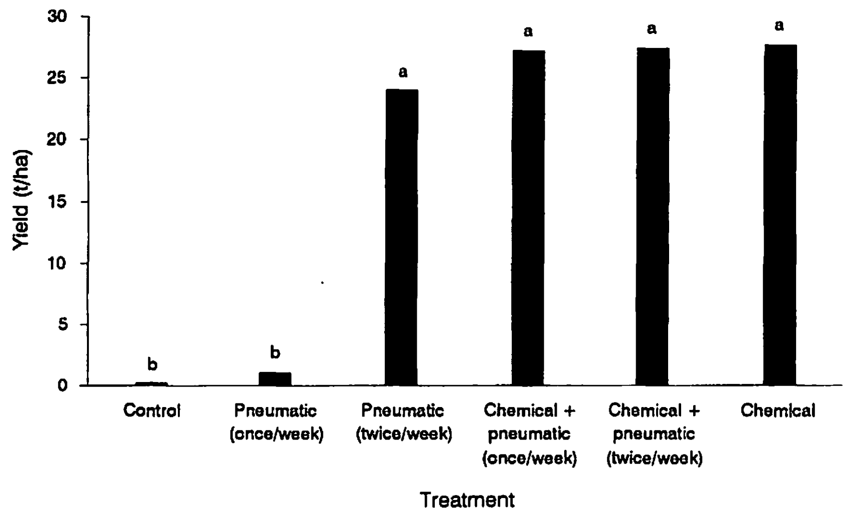


Fig. 3. Potato plant yields for the different treatments.

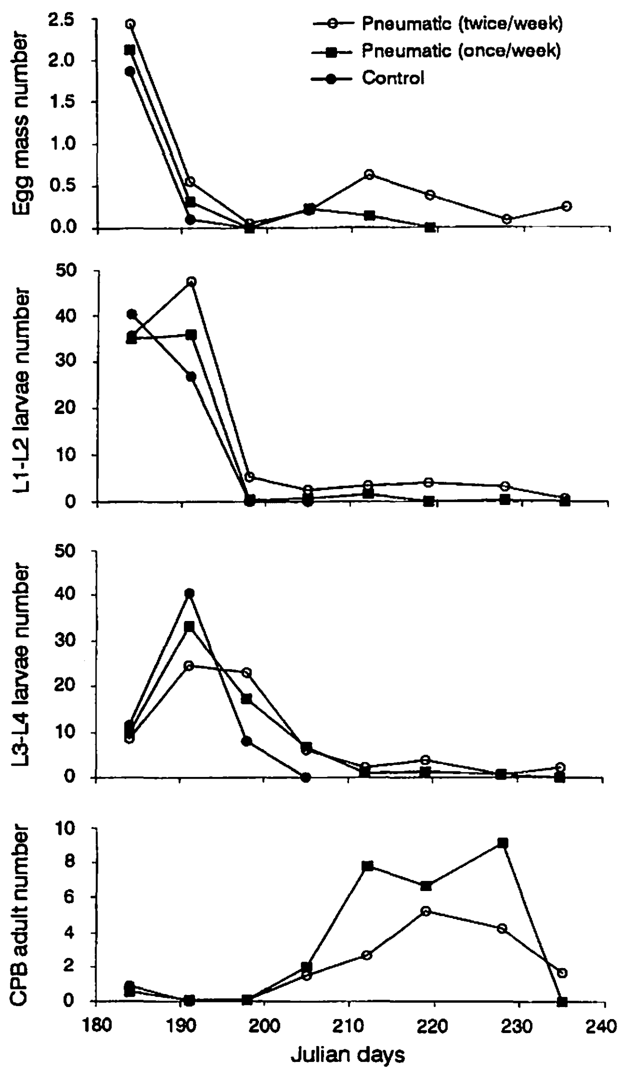


Fig. 4. Evolution of the egg mass number and the populations of CPB under the effects of the pneumatic treatments.

also contribute to increase the travel speed of the prototype machine as the positionning of the blowing units relative to the plants is less critical than the use of the collecting units.

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