Resistance of adult Colorado potato beetles to removal under different airflow velocities and configurations

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Khelifi, M., Laguë, C. and Lacasse, B. 1995. **Resistance of adult Colorado potato beetles to removal under different airflow velocities and configurations.** Can. Agric. Eng. 37:085-089. The speed and orientation of airstreams required to remove adult Colorado Potato Beetles (CPB), *Leptinotarsa decemlineata* (Say), from potato plants were determined. We found that horizontal airstreams moving across the plants at a mean velocity of 27.5 m/s at the foliage level yielded the best removal rate (100%). Results also show that neither beetle sex nor their degree of previous exposure to airflow has an effect on the removal rate.

Keywords: vacuum, insects, pest control, potato.

Les effets de la vitesse et de la direction d'écoulement des flux d'air au travers de plants de pomme de terre sur le décrochage de doryphores de la pomme de terre, *Leptinotarsa decemlineata* (Say), au stade adulte ont été évalués. Nous avons pu déterminer qu'un écoulement d'air horizontal ayant une vitesse moyenne de 27,5 m/s au niveau du feuillage procurait le meilleur taux de décrochage des insectes (100%). Les résultats montrent également que ni le sexe des insectes, ni leur exposition antérieure à des jets d'air, n'affecte leur taux de décrochage des plants de façon significative.

Mots clefs: aspirateur, insectes, contrôle des insectes nuisibles, pomme de terre.

INTRODUCTION

Because it has developed a resistance to many insecticides, the Colorado Potato Beetle (CPB), *Leptinotarasa decemlineata* (Say), is unquestionably the major pest insect for potato crops (Norman et al. 1981; Boiteau et al. 1987; Harris and Svec 1981, 1976). Non-chemical means of control, such as the use of vacuum machines, are therefore being developed as an alternative measure.

When used against CPBs, vacuuming has only demonstrated limited success (Boiteau et al. 1991) despite its excellent performance in removing small flying insects, especially from strawberry and lettuce crops (Inman 1990). Although CPBs behave more like crawling insects, they can also grasp leaves with remarkable force. This could explain the unsatisfactory results obtained so far with vacuum machines (Bédard 1991).

deVries (1987) indicated that CPB adults can grasp the edge or the lower surface of leaves with a force of 0.041 N as opposed to 0.011 N when placed on the upper face of leaves. Nevertheless, 0.011 N still represents 20 times the weight of an individual adult CPB.

Boiteau et al. (1991) mentioned that following a single pass of a vacuum machine, 10 to 28% of the adults, 43 to 70% of the second and third instar larvae, and 45.5 to 70% of the fourth instar larvae still remained on the potato plant foliage. This suggests that the larvae are more resistant to pneumatic control than the adults. Misener and Boiteau (1991) carried out many laboratory tests to determine the force required to remove CPBs from leaves. Their results revealed that forces up to 0.04 N, 0.03 N, and 0.01 N were necessary to detach from potato plant leaves adults, fourth instar larvae, and second or third instar larvae, respectively. Nevertheless, these results were highly related to the position of the CPBs on the leaves, in particular the adults, and the grasping mode of the larvae whether it was with tarsi or with mandibles.

Morphologically, the CPB male's foot is slightly different from the female's (Pelletier and Smilowitz 1987). This probably helps in securing the male on the female during mating. Indeed, mating is a long-term process and can last for as long as seven minutes on average (Szentesi 1981). During that time, the female can stay motionless, feed on foliage or walk around. This morphological difference may help males resist airflows better than females. On the other hand, it is known that males are more mobile in the field (Szentesi 1981) and this could make them more susceptible to removal by airflows from potato foliage than females.

One other factor that could greatly affect the efficiency of CPB pneumatic control machines is the repeated exposure of insects to airflows. The two following hypotheses may be formulated. The first one suggests that frequent pneumatic interventions in the field could induce fatigue, to some extent, in CPBs. This may cause them to drop from potato plant foliage and consequently result in a high removal rate. The second hypothesis is exactly the opposite of the first one. Repeated exposure to airflows could, on a short term basis, incite CPBs to develop a resistance towards pneumatic control. This could result in low removal rates and reduce the effectiveness of pneumatic control systems.

As mentioned so far, CPBs are able to resist airflows of high velocities. In addition, their reaction to airflows depends upon their growth stage. For this reason, we realize that the problem of successfully controlling CPBs cannot be solved as a whole. It has to be split into small case studies based on the different growth stages of CPBs. This presents the advantage of allowing for a better understanding of the problem. To date, besides the limited studies of deVries (1987), Boiteau et al. (1991), and Misener and Boiteau (1991, 1992), work related to pneumatic removal of CPBs has not been carried out. The study reported herein was therefore designed: a) to optimize the airflow speed and orientation for a better removal of adult CPBs, b) to investigate the response of male and female CPBs to airflows, and c) to study the effect of repeated exposures to airflows on the removal rate of CPBs from potato plant foliage. Such information is very crucial in designing efficient pneumatic control machines that could contribute to reducing the needs for chemical insecticides for CPB control. Pneumatic control of CPB adults that emerge early in the season represents a preventive measure that could result in an efficient protection of the crop throughout the rest of the season.

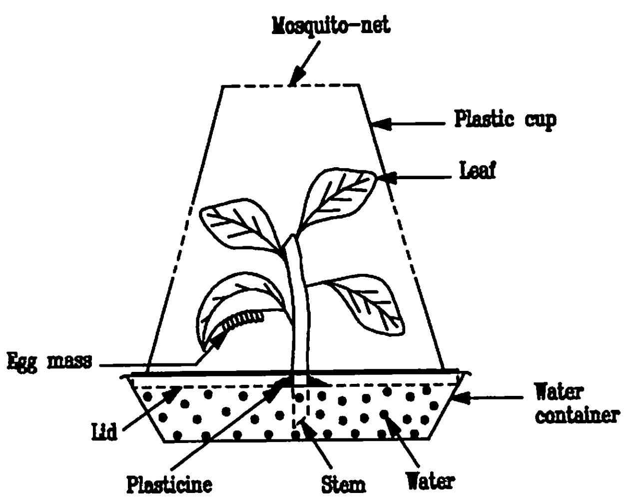
MATERIALS AND METHODS

Potato plants and adult CPBs

The most popular potato variety cultivated in Québec, namely Superior, was used for the experiments. Potato eyes were seeded in 150 mm diameter pots. All plants were watered three times a week. The necessary population of CPBs, evaluated at around 1000 adults, was reared in collaboration with the Department of Biology of Laval University. The rearing technique consisted of collecting eggs from potato plants twice a week, placing them in small plastic cups (Fig. 1), transferring all the cups to a growing chamber (Plant Growth Chamber, Model 16S, Controlled Environments Ltd., Winnipeg, MB) operated at a 25°C temperature and an 18 hour photoperiod per day, feeding the CPB larvae until the end of their second instar, transferring the third instar CPBs to 1 x 0.5 x 0.5 m cages located in a greenhouse under similar conditions, and providing them with fresh whole potato plants until they reached the adult stage.

Airstream speed and orientation combinations

Six airstream orientations were selected: four that only relied on blowing air through the plants foliage (simple horizontal (sh), oblique ascending (oa), oblique descending (od), and two oblique ascending (toa) airstreams blowing across the plant) and two that combined blowing and vacuuming (simultaneous horizontal air suction and blowing on either side of the plant (sab), and a combination of two ascending airstreams blowing and one air suction from the top of the plant (tas)) (Fig. 2).



The three levels of air speed were 20.5, 24, and 27.5 m/s. These speeds were tested in a previous study on the effect of air velocities, cultivar, and growth stage on damage sustained by potato plants (Khelifi et al. 1995) and were considered safe for the crop.

The experiments were conducted on potato plants in their vegetative growth phase having a dozen leaves and a height of 0.25 to 0.30 m. A completely randomized factorial design was selected with two factors: air combination or configuration (C, six levels) and airstream velocity (A, three levels). Each treatment was applied to five adult CPBs and replicated ten times. Removal rate of CPBs dislodged from the plant foliage was the measured response.

The experiments consisted of releasing five adult CPBs at the bottom of each plant and allowing them enough time to settle themselves randomly on the foliage. The plant was then placed on the test bench developed by Khelifi et al. (1992) and exposed to airflow for 20 s. We then counted the CPBs that had been removed from the plant. The air speed was measured at the plant foliage level (0.20 m away from the hoods) using a 2% precision telescopic anemometer (Multi-Purpose Solomat Instrument, Model MPM 500e, Solomat Instrumentation Division, Norwalk, CT). The air temperature and relative humidity in the greenhouse where the experiments took place were 27°C and 55%, respectively.

Effect of CPB sex

Adult CPBs were split into two groups: males and females. The technique used to constitute these groups consisted of either separating each couple that was mating or putting aside every female laying eggs. Potato plants (cv. Superior) in their vegetative growth stage having 12 leaves and a height of 0.32 m, were placed on two distant locations to avoid any possible mixing of the two sexes. Thereafter, groups of 10 CPBs were released at the bottom of a plant. They were allowed enough time (at least half an hour) to randomly settle on the foliage before conducting the experiments. Each plant infested by 10 CPBs was placed on the test bench and exposed to an horizontal airflow during a 20 s period. The air speeds used in the first series of experiments (20.5, 24, and 27.5 m/s) were again tested. Each trial was replicated five times for the measurement of the removal rate of CPBs.

Effect of previous expositions to airflow

Two additional different CPB groups were constituted. The first one contained adult CPBs that had been frequently exposed to airflows during the previous experiments. The second group contained adults that had never been exposed to airflows. The trials were conducted on the two types of CPBs (exposed and never exposed) as described in the second series of experiments.

Statistical analyses

The data were tested for the two most important assumptions required for a valid analysis of variance, the homogeneity of variances and the normality, using Bartlett and Shapiro-Wilk

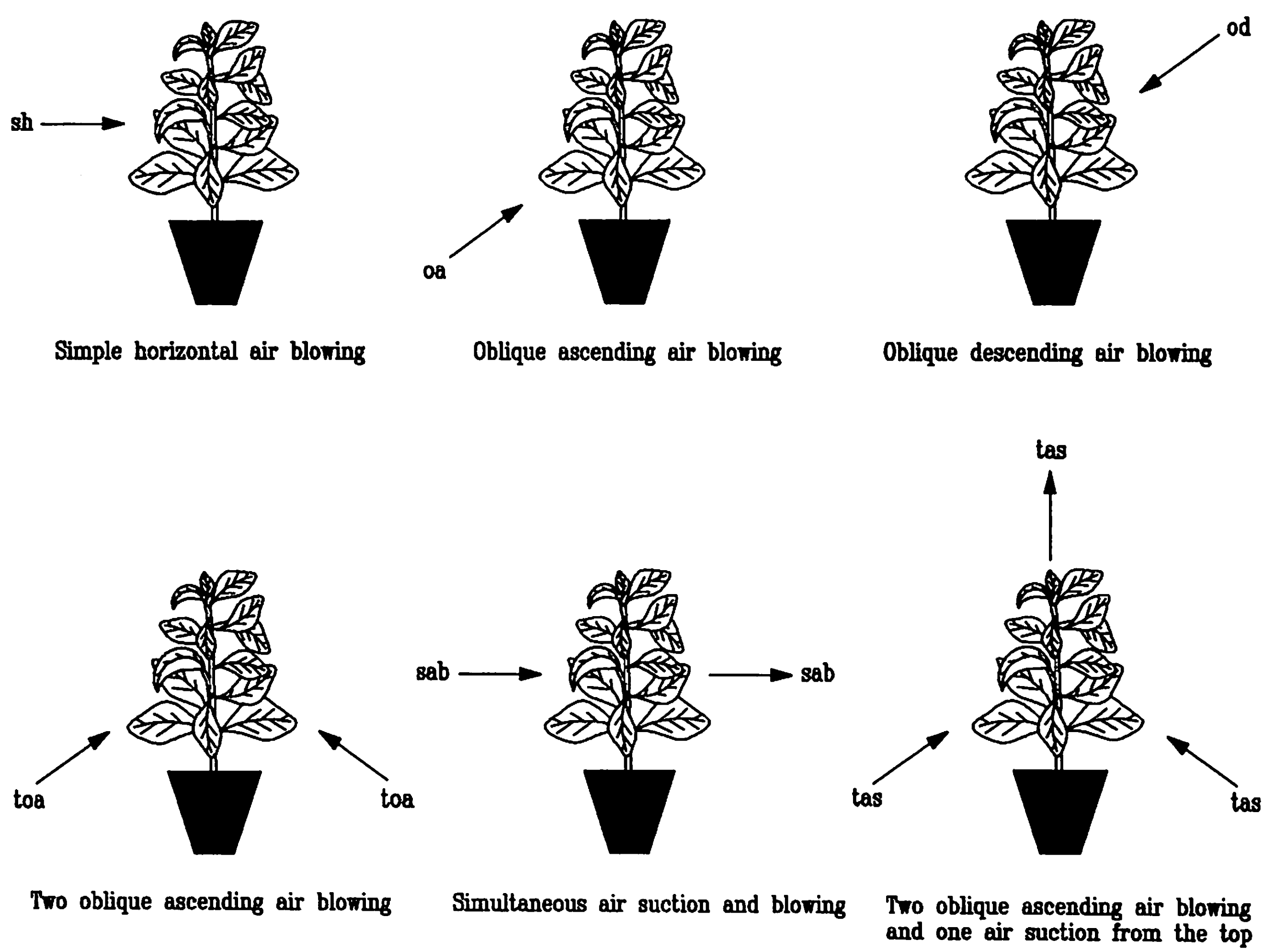


Fig. 2. Schematic representation of the different configurations used during the experiments.

tests, respectively. An angular transformation (arcsin $\sqrt{Y}$) was performed on the first series of experimental data to improve the homogeneity of variances (Steel and Torrie 1980). An analysis of variance was 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

Airstream and orientation effects

Mean CPB removal rates for the 18 treatments are presented in Table I. These results show that the removal rate was the highest under airstreams of 27.5 m/s. The simple horizontal air blowing configuration, in particular, gave a perfect performance. On the other hand, the use of either an oblique ascending airstream, or of a combination of two oblique ascending airstreams and an air suction from the top resulted in the lowest removal rates under the three airstream speeds. This suggests that these two configurations are not adequate for the removal of CPBs.

The effects of air speed and configuration were highly significant as shown in Figs. 3 and 4. On the other hand, the interaction between these two factors was found not to be significant. Consequently, only the main factors, namely configuration and air speed, independently affected the removal rate of CPBs from the plant foliage.

Table I. Mean removal rates and standard deviations (%) of CPBs from plant foliage under the effect of three air speeds

Configuration	Air speed (m/s)		
	20.5	24	27.5
Simple horizontal air blowing	62 ± 31.9	94 ± 9.6	100
Horizontal air suction and blowing	62 ± 19.8	88 ± 16.8	96 ± 8.4
Two oblique ascending air blowing	66 ± 13.5	84 ± 18.4	90 ± 14.1
Oblique descending air blowing	56 ± 22.7	84 ± 22.7	84 ± 15.7
Two oblique ascending air blowing and an air suction from the top	56 ± 22.7	74 ± 21.2	76 ± 20.5
Oblique ascending air blowing	48 ± 19.3	68 ± 26.9	78 ± 11.3

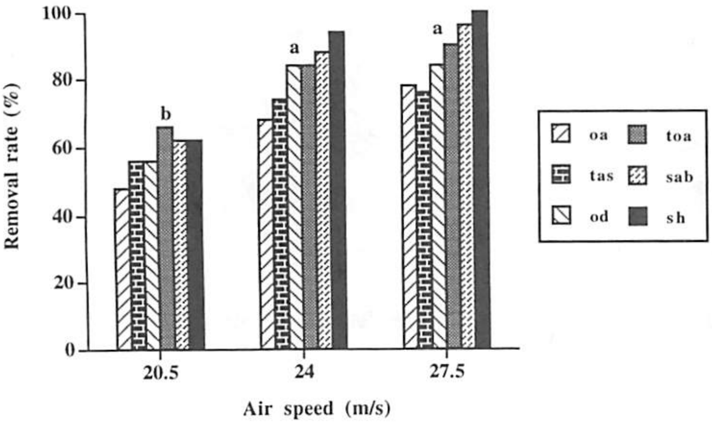


Fig. 3. Effect of airspeeds on the CPBs removal efficiency under six different configurations. Means with the same letter are not significantly different at the 5% level.

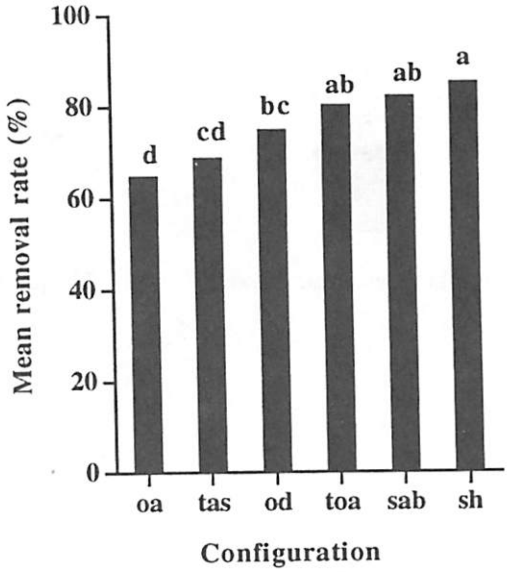


Fig. 4. Effect of the airstream orientations on the CPBs removal efficiency. Means with the same letter are not significantly different at the 5% level.

Air speeds of 24 and 27.5 m/s were not significantly different ($p \leq 0.05$) as opposed to that of 20.5 m/s. In general, the removal efficiency increased considerably from 20.5 to 24 m/s. Beyond this air speed interval, the increase was not significant (Fig. 3).

The use of a simple horizontal airstream blowing (sh) to remove CPBs from the plants was the best configuration. The use of a simultaneous horizontal air suction and blowing on either side of the plant (sab) had a similar efficiency to that of two oblique ascending airstreams (toa). The three remaining configurations, namely, (od), (tas), and (oa) had lower efficiencies.

The mean removal rate with (tas) was lower than that with (toa). This contradictory performance results from the pushing of the leaves together towards the stems of the plants by the (toa) which protects, to some extent, the CPBs against the suction effect. The use of an air suction at the top of the plant could not therefore improve the removal rate of CPBs. Also, the (tas) configuration was not observed as being advantageous because of its tendency to suck up more soil than CPBs.

The best performance was obtained with the (sh) and (sab) configurations. These two configurations do not require a shaking system to further improve the removal efficiency. At this stage, the selection of the more appropriate configuration among these two was not obvious. For this reason, we examined a very important factor which is the collection of CPBs removed from the plant foliage. Practically, a simple horizontal airstream would only throw the CPBs on the ground. Later, CPBs could climb back on potato plants and continue defoliating them. This problem could be eliminated with air suction and blowing on either side of the plant as CPBs removed from the plant foliage would then be collected by the suction hood. While passing through the fan blades, they would be crushed into small pieces. In the worst case, CPBs that escaped from the fan blades would be severely hurt as was observed during the experiments.

Effects of CPB sex and previous expositions to airflow

Results of these two series of experiments are summarized in Tables II and III. They show that the removal rate is comparable for males and females as well as for the two types of CPBs.

The ANOVA of the data presented in Tables II and III reveals a highly significant effect for air speed ($p \leq 0.01$). This confirms the results of the previous series of experiments. However, neither the sex nor the type of CPBs was

Table II. Mean removal rates and standard deviations of male and female CPBs exposed to three air speed levels

Air speed (m/s)	Removal rate (%)	
	Male	Female
20.5	40 ± 20	58 ± 13
24	62 ± 15	68 ± 26
27.5	76 ± 11	82 ± 11

Table III. Mean removal rates and standard deviations of the two adult CPB types exposed to three air speed levels

Air speed (m/s)	Removal rate (%)	
	Never exposed	Exposed
20.5	30 ± 19	34 ± 13
24	46 ± 15	52 ± 18
27.5	82 ± 15	80 ± 14

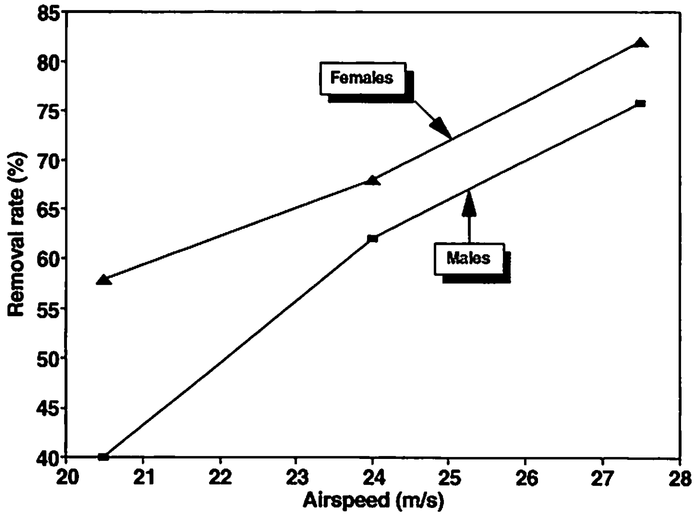


Fig. 5. Effect of the sex on the CPBs removal efficiency under three airspeed levels.

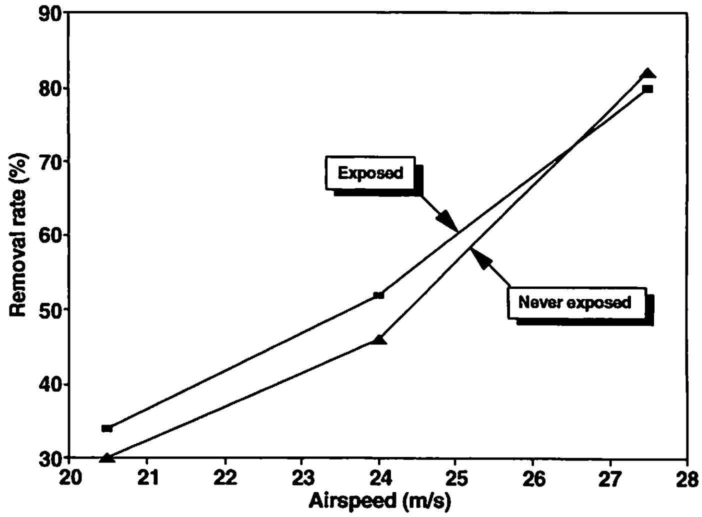


Fig. 6. Effect of the type (exposed to airflow or not) on the CPBs removal efficiency under three airspeed levels.

significant. In addition, the interactions between sex and air speed as well as between the type of CPB and air speed were not significant. Consequently, the removal rate of CPBs is mainly related to the air speed factor. Figures 5 and 6 illustrate these results.

Figure 5 shows that beyond 24 m/s, the removal rate of males is very close to that of females with a slight advantage for females. For air speeds lower than 24 m/s, females are more prone to be blown away than males. Figure 6 shows that the type of CPB does not affect their behavior towards airflows. Indeed, the difference between the two CPB categories on a removal rate basis is very small for the three airflow levels tested.

CONCLUSION

The most appropriate configuration among the six tested consisted of a simple horizontal airstream and suction on either side of the plants (sab). This promising configuration, simple and practical, requires less energy to collect CPBs removed by airstreams. The removal efficiency was very high in particular under the two highest airspeed levels of 24 and 27.5 m/s.

For speeds above 20.5 m/s, the removal rate of CPBs from potato plant foliage was totally independent of the sex of the insect. In addition, the hypotheses of fatigue and possible development of a resistance towards airflows by adult CPBs induced by repeated exposures, were not found to be valid. These two factors should not affect the effectiveness of pneumatic control systems for adult CPBs.

Finally, the results obtained are of great importance for the design of pneumatic control hoods which could be used efficiently at field scale.

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