An Innovative System for Air-Assisted Distribution of Beneficial Organisms on Protected Crops

Ade G.[1], Caprara C.[1], Lanzoni A.[2], Martelli R.[1], Pezzi F.[1]

[1]*Department of Agricultural Economics and Engineering, University of Bologna*
Viale Fanin, 50 – 40127 Bologna, ITALY.
[2]*Department of Agroenvironmental Sciences and Technologies, University of Bologna*
Viale Fanin, 44 – 40127 Bologna, ITALY.
Tel 0039 051 2096192, Fax 051 2096178 claudio.caprara@unibo.it

Abstract

The distribution of chemicals on protected crops is often a critical moment for the operators who are forced to make frequent treatments in an enclosed environment and in the presence of high pesticide concentrations.

The introduction of organic farming techniques improves these aspects but generally requires a substantial commitment of manpower and forces the operator to stay for a long time in environments characterized by temperature and humidity that cause discomfort and fatigue. Increasing the level of mechanization improves the effectiveness of the treatments and ~~it~~ also permits a quicker approach with relevant improvement on workers' health and safety, particularly in greenhouse crops. We therefore developed a prototype for the distribution of beneficial organisms that can increase the labour productivity and distribution quality on protected crops.

Experiments were conducted to assess the efficiency of this prototype, the reduction of working time and the possible effect on the viability of organisms distributed.

The effectiveness of the distribution has been verified through laboratory and field tests to evaluate the effects of the releasing on viability and fertility of beneficial organisms.

The prototype has been demonstrated to properly perform the releasing of arthropods without compromising the viability and fertility of two species of phytoseiids (*Phytoseiulus persimilis* and *Amblyseius swirskii*), whereas in the case of nymphs of the anthocorid *Orius laevigatus*, the survival immediately after the distribution and the post-release survival (reaching of the adult stage) are influenced by the action of the mechanical device.

Keywords: mechanical distribution, protected crops, safety, beneficial organisms

Introduction

Biological pest control is a fundamental tool for crop health, worker safety and environmental protection. Although based on techniques consolidated by decades of experience, biological interventions have so far had little support from mechanization. In the different intervention strategies the few types of mechanization mainly involve weed control, such as flame-weeding, mulching with biodegradable materials and the use of new hoeing techniques. The only concrete example in pest control is the distribution of *Bacillus thuringiensis* in a liquid solution by normal sprayers. Instead, the mechanical distribution of beneficial organisms for biological pest control is still limited to a few examples of an experimental nature (Pezzi *et al.*, 2002; Opit *et al.*, 2005; Baraldi *et al.*, 2006; Blandini *et al.*, 2006).

Various technical and operative conditions restrict mechanical intervention. For example, the necessity to mix the beneficial organisms with inert substrates makes it difficult to handle and above all, to dose the mixtures, because the substrates must almost always be used moist and present a high friction coefficient.

The main limitation to mechanical distribution is due to the possibility of the beneficial organisms being damaged by the machine parts.

Within the ambits of the national project "Mechanization of phytophage control in organic farming", a prototype was developed for the distribution of beneficial organisms that could increase work productivity and distribution quality (Caprara et al., 2007). Tests were conducted to evaluate the efficiency level of this prototype and any effect on the viability of the distributed organisms.

Materials and methods

The prototype was designed to take the following aspects into account:

- direct use of the containers in which antagonists are marketed, to avoid unnecessary and harmful handling;
- controlled extraction of the substrate, to guarantee a wide choice and precision of the dosages;
- pneumatic distribution, to adapt the operation to different working conditions;
- apparatus of small dimensions that can be used as an accessory for pneumatic equipment already available on the farms (backpack sprayers, blowers, etc.).

A system was therefore designed that involves the phial, in which the beneficial organisms are marketed, being inserted directly onto the releasing system of the machine. The extraction of the organisms dispersed in the substrate is facilitated by the presence of a push rod with reciprocal movement generated by an electromagnet. Regulation of the movement (frequency and stopping position) controls the amount of material that emerges and falls into the pneumatic diffuser of the device.

The distributor was installed on an electric-powered blower commonly used for cleaning parks and gardens. The machine was equipped with a 1.6 kW motor, regulation of the air flow on two levels (256 and 360 m^3/h) and output section of flow of 2374 mm^2.

To define the best working conditions the air flow was measured with a fan anemometer (Höntzsch Instruments µP–ASDI) positioned at different distances and heights from the delivery section.

The moisture content, bulk density, texture and friction coefficient of the substrates used (vermiculite and buckwheat chaff) were also measured.

The effect of the mechanical distribution was evaluated on *Phytoseiulus persimilis* Athias-Henriot, *Amblyseius swirskii* Athias-Henriot (Acari Phytoseiidae) and *Orius laevigatus* Fieber (Rhynchota Anthocoridae).

The viability test was conducted with a mechanical release of the beneficial organisms, setting the machine at the slower air flow, and collecting the product dispersed on a test bench composed by containers (0.5 x 0.5 m) lined up in front of the dispenser. The released individuals were collected manually and placed in test tubes for the viability tests. The manual distribution simulated that used traditionally on crops, distributing the organisms on the test bench and using the same amount of mixture as that used in the mechanical distribution

After the release, 20 females of each species of phytoseiid were isolated from both treatments (mechanical and manual) and placed individually to lay eggs in Plexiglas cylinders of Ø 40 x 40 mm (or Petri dishes Ø 90 mm for *A. swirskii*) containing a thin layer of agar and a bean leaf infested with *Tetranychus urticae* Koch (with frozen eggs of *Ephestia kuehniella* Zeller for *A. swirskii*). The specimens were maintained in a climatic chamber at 26 °C, UR 75%, photoperiod 16L:8B. The checks for egg laying and mortality were made after 72 and 120 hours for *P. persimilis* and after 72 and 192 hours for *A. swirskii*. The data relating to the number of eggs and larvae were elaborated by one-way ANOVA. When the assumption of homogeneity of the variances could not be satisfied the Mann-Whitney non parametric test was used. The data on the mortality were elaborated with the chi-squared test. The effect of the mechanical release on population growth was measured using the *instantaneous growth rate* (r_i) calculated on the basis of equation 1:

$$r_i(t) = \frac{1}{t}\ln\left(\frac{N_{(t)}}{N_{(0)}}\right) \qquad (1)$$

where $N_{(0)}$ represents the initial number of individuals (20 females), $N_{(t)}$ the number of individuals present on day t, and t the number of days since the start of the experiment. Positive values of r_i indicate an increasing population, negative values a population in decline and $r_i = 0$ a stable population.

The laboratory trials with *O. laevigatus* were conducted to verify the effects of mechanical release on the mortality of neanids and nymphs of the anthocorid. In particular, the survival of individuals immediately after being released with the machine was evaluated and compared with the manual release. A sample of distributed specimens was reared f for 10 days in Plexiglas cylinders (Ø 50 x 70 mm) on green bean to check for any deaths until the adulthood. The Mann-Whitney non parametric test was used to compare mortality during and after the release.

Results

The physical characteristics of the two substrates (vermiculite for *P. persimilis* and *A. swirskii* and buckwheat chaff for *O. laevigatus*) are reported in Table 1.

Neither of the materials showed a great aptitude for mechanical distribution. The vermiculite, very plastic because of the high moisture content used to guarantee the survival of the phytoseiids, had high values of friction coefficient and bulk density. The average particle size was 1.74 mm in diameter, with a rather high variability of the texture.

The buckwheat chaff, which is drier and lighter than the vermiculite, showed a lower friction coefficient, with a more homogeneous and larger average particle size (maximum diameter 2.06 mm). Despite these apparently better characteristics, difficulties emerged in the emptying of the phials during the mechanical distribution, probably due to the shape of the individual particles.

In the trials of distribution and viability of the arthropods, the machine, positioned at a height of 1 metre, was used with the lowest air flow (256 m^3/h) that was considered more suitable for the distribution. At this setting the air emerged at 30 m/s and generated a fairly regular flow that reached a distance of approximately 9 m (Fig. 1).

Table 1. Physical and texture characteristics of the substrates used for the conservation and distribution of the arthropods

SUBSTRATE	VERMICULITE	BUCKWHEAT CHAFF
Apparent bulk density (kg/m3)	346	140
Friction coefficient	0.62	0.40
Moisture content (%)	35.9	20.1
Average diameter (mm)	1.74	3.06
Distribution by diameter class (mm)	(%)	(%)
>4.0	0	2.3
>3.15-4	2.6	32.7
>2.5-3.15	14.7	61.7
>2.0-2.5	13.2	1.8
>1.6-2.0	23.9	0.8
>1.25-1.6	22.1	0
>0.5-1.25	21	0
<0.5	2.5	0.7

The movement of the push rod was set at the frequency of 2.25 Hz., which emptied the phial in 2 and 4 minutes, for the vermiculite and buckwheat chaff respectively, corresponding to flows of 7.5 and 3 dm^3/h.

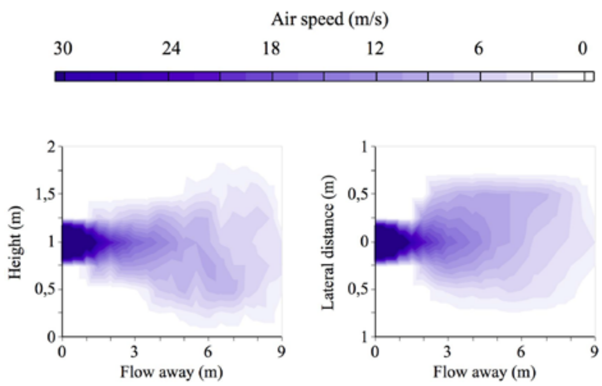

Figure 1. Air speed measured at different heights and distances from the delivery point of the blower.

With these settings and positioning the machine at a height of 1 m provided the distribution diagrams of the two substrates shown in figure 2. The vermiculite reaches a range of up to 7 m, with most of the product falling between 3 and 4 m. The lighter buckwheat chaff reduces the range to less than 5 m, with a peak at 3 m.

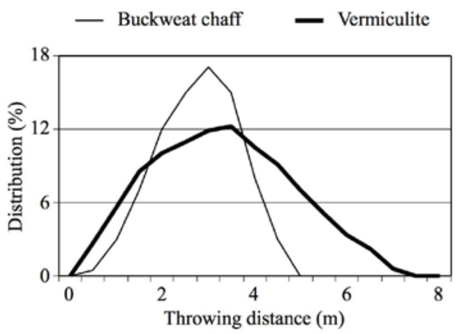

Figure 2. Diagrams of distribution with the two substrates

The laboratory trials demonstrated that the prototype guarantees a correct execution of the release of arthropods without compromising the viability and fertility of the two species of phytoseiid used. In particular, as regards *P. persimilis*, the best performances were recorded for the mechanically released individuals 72 hours after release (figure 3), mainly due to the larger number of larvae ($p<0.01$) present in this treatment. This is also pointed out by the higher value of r_i after 72 hours in the mechanical release treatment compared to the manual (table 2). However, at five days after the release these differences had been annulled for all the parameters analyzed (figure 3 and table 2). Instead, in both periods, mortality presented no significant differences between the two treatments (table 2).

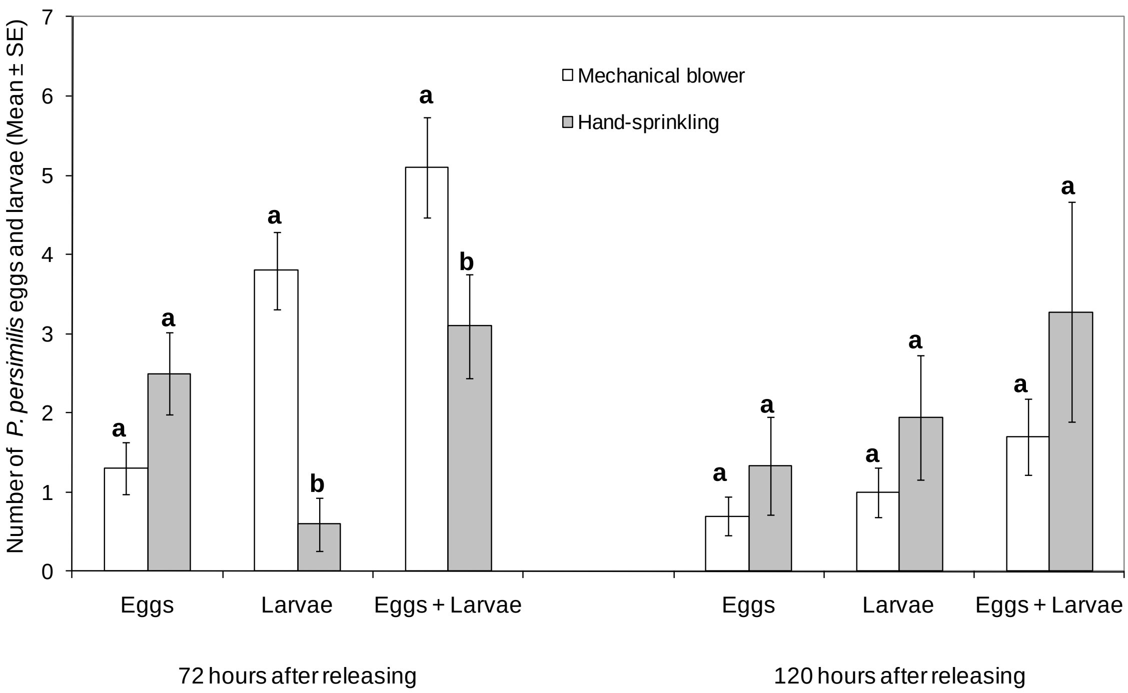

Figure 3. Fertility of *P. persimilis* females after mechanical or manual release in the two periods considered. Different letters indicate significant differences (p<0.05)

Table 2. Instantaneous growth rate (r_i) and survival of *P. persimilis* after mechanical or manual release in the two periods considered. Different letters indicate significant differences (p<0.05)

Treatment	72 hours		120 hours	
	r_i	Survival (%)	r_i	Survival (%)
Mechanical blower	0.543	100a	0.383	60a
Hand-sprinkling	0.377	90a	0.360	66,7a

With *A. swirskii*, neither fertility nor survival were influenced by the mechanical release, as there were no significant differences in these parameters between the two treatments at either 72 or 192 hours after the start of the experiment (figure 4 and table 3). However, the value of r_i in the mechanical treatment was slightly lower than the manual control (table 3). This indicates a tendency that might be worth further investigation.

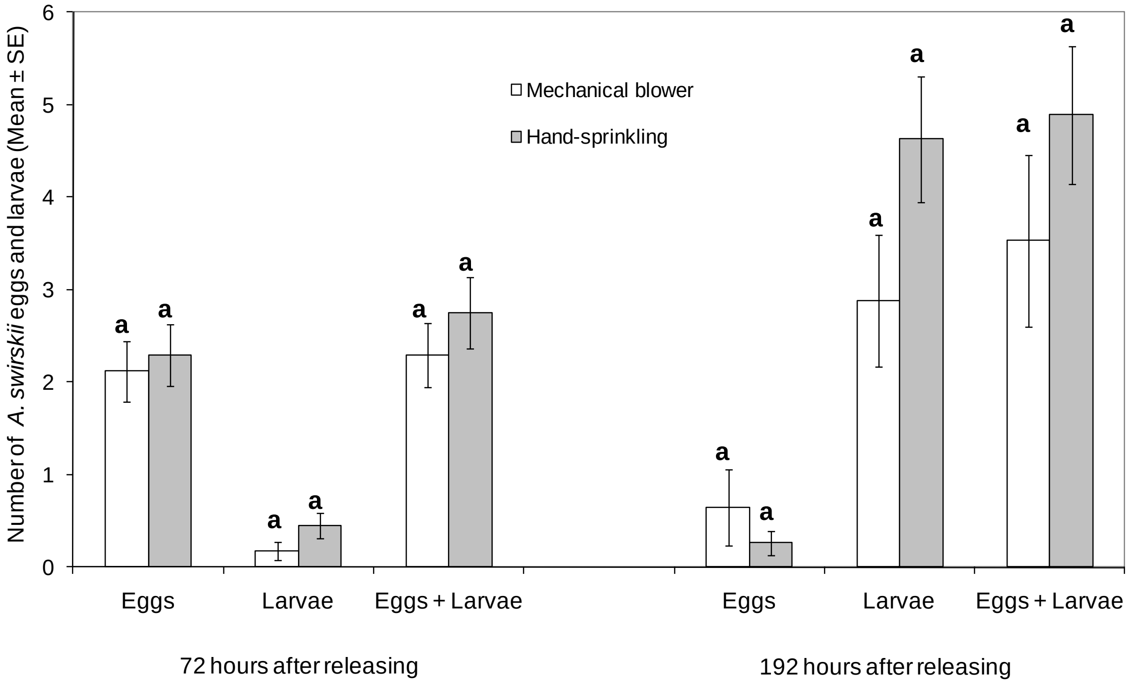

Figure 4. Fertility of *A. swirskii* females after mechanical or manual release in the two periods considered. Different letters indicate significant differences (p<0.05)

Table 3. Instantaneous growth rate (r_i) and survival of *A. swirskii* after mechanical or manual release in the two periods considered. Different letters indicate significant differences (p<0.05)

Treatment	72 hours		192 hours	
	r_i	Survival (%)	r_i	Survival (%)
Mechanical blower	0.277	100a	0.158	76,5a
Hand-sprinkling	0.337	95a	0.192	73,7a

Unlike the findings for the two phytoseiids, for the juvenile stages of *O. laevigatus*, both the survival immediately after the release and the post-release survival (reaching the adult stage) are significantly reduced by the action of the mechanical device (p<0.01) (figure 5). However, the higher mortality in the individuals distributed mechanically is not particularly negative as *O. laevigatus* is generally used in strategies that involve seasonal inoculative releases (Nicoli and Tommasini, 2000) in which it is the progeny of the released individuals that are important for the success of the control. This higher mortality can be managed, in terms of cost, by means of an increase of the dose released or by repeated releases. This latter practice is advised for a better efficacy of the action of *O. laevigatus* (Nicoli and Tommasini, 2000), and may also be considered preferable in terms of the reduction in the working times guaranteed by the mechanical distribution of the organism (Lanzoni *et al.*, 2007).

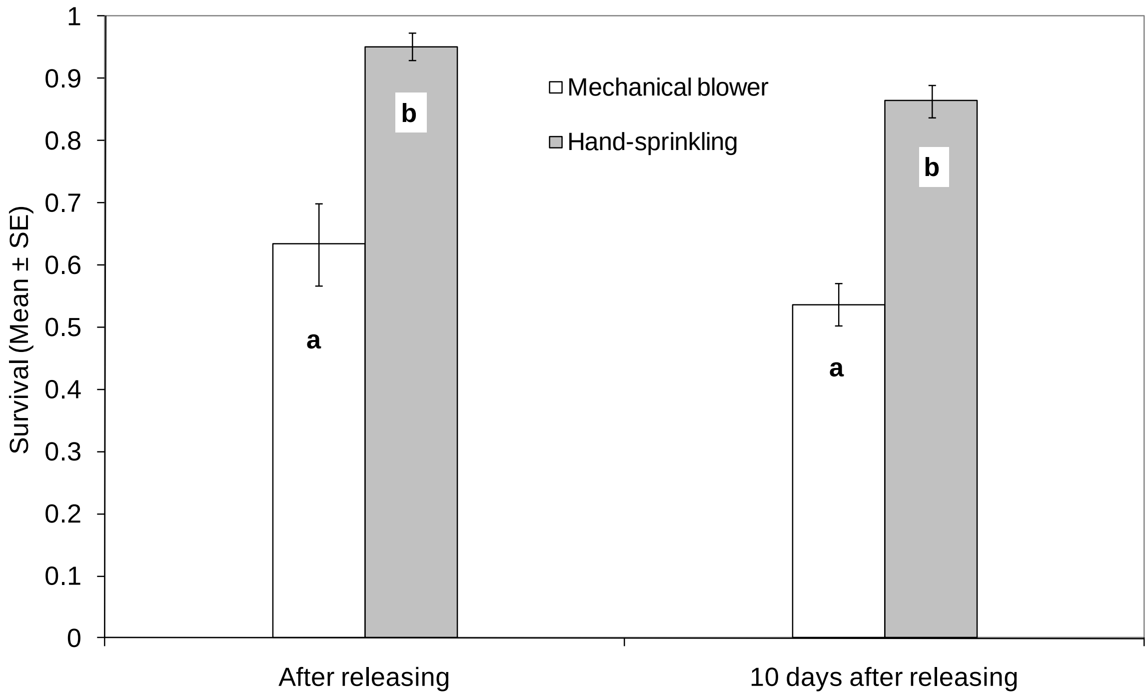

Figure 5. Comparison between survival of the juvenile stages of *O. laevigatus* depending on the type of release. Different letters indicate significant differences (p<0.01)

Conclusions

The functional check of the prototype built for the mechanical distribution of beneficial organisms in biological pest control has provided satisfactory results from both the operational and biological point of view. The practicality of the device designed for the extraction and dosing of the product directly from the phial in which it is marketed has resulted as satisfactory, despite the unfavourable physical characteristics of the substrates (vermiculite or buckwheat chaff) in which the arthropods are dispersed. The distribution and flow of the air generated by the blower guarantees a particularly suitable range (3-4 m) for working in the rather confined spaces of the greenhouses where biological control is widely used.

The trials have demonstrated that the use of the prototype does not reduce the viability and fertility of the two studied phytoseiid species. The efficacy of the mechanical release of *P. persimilis* has already been confirmed in greenhouse experiments (Baraldi *et al.*, 2006), but further work is needed on *A. swirskii*. The use of the prototype for the release of *O. laevigatus* has instead entailed a marked reduction in the viability of the anthocorid, but this can be managed at the time of release.

The results obtained demonstrate that the prototype built for the mechanical distribution of entomophages may be a solution that is simple, economical and adaptable to many types of beneficial organisms.

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