# Organic Plant Protection Treatments in Greenhouse and Open Field by an Electrical Prototype

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## Abstract

**Two different versions of the patented device designed and built by Section of Mechanics and Mechanization of DiGeSA have been used in distribution tests of natural enemies (*Phytoseiulus persimilis* and *Orius laevigatus*) on greenhouse vegetable and flower crops (bell pepper and chrysanthemum) and on open field strawberry crops. For both the enemies, manual and mechanized releases were compared.**
**The results of the preliminary laboratory tests prove that the dosage and distribution mechanism are suited to biological pest control strategies, both on greenhouse and on open field. These results encourage the diffusion of organic plant protection on vegetables in accordance with the recent European Directive 2009/128/CE.**
**With the version used on bell pepper the average time to turn the machine has been relatively high because of scanty manoeuvrability. With the version used on strawberry crops, set on a handle directly carried by the operator or mounted on a bar carried by a tractor, the device performance is improved both in distribution uniformity and in manoeuvrability. Also the version used on chrysanthemum, with three prototypes carried by a tool-bar applied on a trolley, has allowed to obtain a good uniformity distribution with rewarding work capacity. Thanks to the better results in terms of work capacity, costs would be contained when compared with those of manual distribution practiced so far.**

**Keywords:** plant protection machines, sustainable pest management, horticulture

## Introduction

Since the report of 2008 written by IFOAM (International Federation of Organic Agriculture Movements) and by FIBL - International Association of Organic Agriculture Research Institutes, it appears that Europe is in second place with 8.2 million hectares of organic crops, preceded from Oceania with 12.1 million hectares. In particular, in Europe, in the last years, there has been a steady increase of areas planted with organic crops. This is confirmed by the last report elaborated by Eurostat - Statistics in Focus, 10/2010 - that indicates an increase of 7.4% of the total area dedicated to organic crops between 2007 and 2008, with a total area of 7,6 million hectares, that is 4,3% of the agricultural area of the 27 EU countries.
In this context, Italy has an important role in the organic production sector, with over one million hectares cultivated by about 50.000 farms. In Italy, Sicily (218.647 ha) is the first region by number of hectares cultivated organically (vegetables, cereals and arable crops, olive groves, citrus, vineyards, meadows and pastures, uncultivated lands) (SINAB, 2009).
European Directive 2009/128/EC, imposing great changes on the use of pesticides. In fact, from January 2014 will be required to adopt integrated pest management strategies and to encourage low-input pest management pesticides.

The pest controls, which provide of manual auxiliary release on infested plants, however, involve a considerable employment of time and also do not ensure a uniform distribution. Several researches have been carried out to encourage the diffusion of organic and integrated production systems. For example in the eighties were made the first attempts with the use of small aircraft (Bouse and Morrison, 1985; Drukker et al., 1993; Maini et al., 1988; Pickett et al., 1987) or by air flow distributors drawn by tractors Gardner and Giles, 1997, Giles et al., 1995, Giles and Wunderlich, 1998). More recently have been implemented small portable machines, which perform the release due to a current of air generated by a small fan (Baraldi et al., 2006; Opit et al., 2005; Pezzi et al., 2002; Van Driesche et al., 2002). Also on the rose buds has been studied the effectiveness of treatments with Phytoseiulus persimilis released mechanically by means of a special dispenser (Casey and Parrella, 2005).
However, if in the greenhouses are well-established the biological and integrated pest control techniques on many vegetable crops such as tomato (Celli, 1998; Maranzoli and Benuzzi, 1995, Shipp and Wang, 2003), cucurbits (Conte and Dalla Monta, 2001; Ferrari et al., 1996, Lopes et al., 2010; Orlandini and Martellucci, 1997), bell pepper and aubergine (Benuzzi, 1996, Bosco et al., 2008; Santonicola and Milone, 1998), strawberry (Tommasini et al., 2001; Trumble and Morse, 1993), and also, after adjustment to agro-environmental situation, on flower crops (Buitenhuis et al., 2009, Chow et al., 2008; Opit et al., 2004), in open fields not yet found extensive applications.
In this context, at the Section of Mechanics and Mechanisation of the DiGeSA (University of Catania – Italy), have been built two versions and realized four applications of a prototype for the mechanical distribution of natural enemies, commonly used for biological control of horticultural and floricultural crops, in greenhouse and open field (Blandini et al., 2006; Blandini et al., 2007a, b, c; Blandini et al., 2010; Tropea Garzia et al., 2006).

**Materials and Methods**

*The prototypes*

Two different versions and four different applications of the prototype were used during the experimental tests in greenhouse and in open field.
<u>The first version</u> of the prototype (Figure 1) measures 36 cm long by 46 cm high with a mass of 4.17 kg excluding batteries. It is made by a steel frame with a "C" shape. On the upper arm of this frame a disc supporting a hopper is bolted. This, with conical shape and made of polypropylene, holds 2 $dm^3$ and is fixed along a loop of the supporting disc by means of a bushing which is screwed to the exit hole of the hopper. The top has affixed an electric motor which governs the rotation (30 rpm) of a helical distributor (doser), fixed along the vertical axis of the hopper. The product, thanks to the doser, falls onto distributor disc, that is mounted on the lower arm of the frame and turns (600 rpm) around its vertical axis by means of a direct-drive electric motor attached below the prototype. The distributor disc, made of PVC, has 20 cm diameter and 8 radial 7 mm high fins. The two electric motors are powered by continuous 6 V current (Blandini et al., 2006; Blandini et al., 2007c).
To vary the jet direction of the natural enemies onto the crops from the distributor disc, the supporting disc can rotate with respect to the frame around the same rotation axis of the distributor disc and the point of anchorage of the hopper can be changed along the loop of the supporting disc. Changing the diameter of the bushings, it is possible to regulate the amount of the product to be distributed.
In order to improve the uniformity of the product flow rate, the work width and its versatility a most recent version of the prototype was built (Figure 2) without changes in the functioning principle, but only in some of its components. The new version of the prototype is 42 cm long

and 43 cm high with a mass of 4.10 kg. The hopper is smaller (about 1.5 $dm^3$) than the previous version and is made of aluminium to permit better centring of the doser with respect to the exit hole for the product. The doser, rotating inside the hopper, is obtained from the tip of a drill for concrete, with the cutting elements at the end removed. The finned distributor disc has a diameter of 30 cm instead of the 20 cm of the previous version and it is made of aluminium (Blandini et al. 2008).

**Figure 1. The first version of the prototype.**

**Figure 2. The most recent version of the prototype.**

Four different applications of these versions were used for experimental tests: two on greenhouse vegetable and flower crops (bell pepper and chrysanthemum) and other two on open field strawberry crops.
The first version of the prototype was mounted on a two wheeled frame to manoeuvre it within a **bell pepper** greenhouse during experimentation tests. With this application the working height relative to crop height can be adjust and hold its position. The switchs to operate the electric motors are near the right handle (Figure 3).
To carry out the tests of distribution on **chrysanthemum** greenhouse, three prototypes were applied to a carrying bar. This is mounted on top of a frame with 4 wheels, driven manually, being 100 cm high and 100 cm long. The rut of the frame can vary between 85 and 150 cm and the distance separating each prototype can be regulated in function of the crop lay-out. The prototypes were connected electrically to one another in parallel, powered by a single 12 Ah rechargeable battery and commanded by a single switch (Figure 4).
Open field tests on two different **strawberry** fields were carried out. In the first field three prototypes mounted on a 3.2 m carrying bar and connected to three point linkage to a 2 WD tractor were used (Figure 5). As in chrysanthemum tests, the prototypes were connected electrically to one another and commanded by a single switch, positioned near the tractor driver. In the second strawberry field, the tests were carried out with the prototype applied to the bar carried directly by an operator with a shoulder strap and lateral handle (Figure 6).

*The greenhouse tests*
The tests were run in the Ragusa province (south-eastern of Sicily) in greenhouses cultivated with organic farming system. Manual and mechanised lot distribution were compared using the same rate. While running the both tests, the work times of distribution were recorded as indicated by CIOSTA (Comité International d'Organisation Scientifique du Travail en Agricolture) in order to calculate the work capacity (ha/h) of the prototype. Other results on biological control efficacy were produced by entomologist and reported on in printing papers.

**Figure 3.The first version of the prototype applied to the wheeled frame.**

**Figure 4. The new prototypes applied to the wheeled frame.**

**Figure 5. The distribution with three new prototypes carried by a tractor.**

**Figure 6. The distribution with the new prototype carried by an operator.**

Three releases were performed in **bell pepper** greenhouse of 1000 $m^2$. Only one distribution of *Phytoseiulus persimilis* was carried out whereas for *Orius laevigatus* a single distribution (normal) and a double distribution at six days interval was compared. In the case of manual distribution, the product was left on 4 – 6 plants in the same row, randomly chosen and equidistant. In the case of mechanical distribution, product was left on the whole lane or alternate lane. On every lane there were two rows of plants 0.7 m apart; the inter-row distance of two lane was about 1.20 m, and the plant density was 5 plants/$m^2$. The work width was 1 m in the first release and 2 m (single rate) and 1 m (double rate) in the second release. The prototypes were regulated at an average height of 0.9 m from the ground in *P. persimilis* release and 1.20 m in *O. laevigatus* release.

The releases of natural enemies on **chrysanthemum** greenhouse (1500 $m^2$) were carried out on two plots: one for mechanical release and the other one for manual release. On every plot there were 7 rows of plants 0.11 m apart; the distance of plants on the row was 0.10 m and the plant density was 90 plants/$m^2$. The work width was 4.8 m and the area considered for the experiments was about 160 $m^2$ and included a total of 21 ridges. Two releases were performed at seven days interval. On each of the two release dates, the two natural enemies (*P. persimilis* and *O. laevigatus)* were distributed separately.

*The open field tests*

The tests were carried out on two different strawberry fields (without and with cover tunnel in plastic film) located in the Syracuse province (eastern of Sicily) with two different applications of the prototype. The cultivation takes place on 0.8 m large ridges covered with black plastic film and the distance between two ridges was about 0.6 m.

The first tests were performed on *Camarosa* cultivar without cover tunnel (Tests 1). On every ridge there were two rows of plants 0.3 m apart; the inter-row distance of two plants was 0.25 m, so the plant density was 8 plants/m$^2$. The prototypes were regulated at an average height of 50 cm from the ground and at an inter-row distance of 1.4 m, so that each one was also positioned in correspondence of the centre line of each ridge. Consequently, the work width was 4.2 m. The area considered for the experiments was about 600 m$^2$ and included a total of 6 ridges. In this case only one treatment with both natural enemies was carried out.

The other tests were performed on *Carmela* cultivar with cover tunnel (Tests 2). In this case the inter-row distance was 0.2 m and consequently the plant density was 12 plants/m$^2$. The tests were carried out on a surface of 150 m$^2$ including 3 ridges and the prototype applied to the bar carried directly by an operator was used. In this case two treatments with both natural enemies a fortnight apart were carried out.

**Results**

*The greenhouse tests*

The greenhouse tests on **bell pepper** show the mean mechanised work capacities are always greater compared to the manual one, notwithstanding that treatment times strictly depend on dosages (Table 1). To carry out the distribution of the natural enemies at the fixed rates with the prototype on the wheeled frame it has been necessary to maintain the average advancement speed of about 1 m/s for *O. laevigatus* and of about 2 m/s for *P. persimilis*. The average time to turn the machine has been of about 9 s because of scanty manoeuvrability. In these conditions the work capacities were about 0.6 ha/h for *O. laevigatus* single rate and about 0.3 ha/h for *O. laevigatus* double rate; actual work capacity of about 0.7 ha/h has been recorded for *P. persimilis*.

In order to comply with the working conditions in **chrysanthemum** tests, it has been necessary to maintain the average advancement speed of about 0.10 m/s for *O. laevigatus* and of 0.14 m/s for *P. persimilis*. Therefore, it has been possible to obtain actual work capacities of about 0.18 and 0.24 ha/h, compared with a 0.14 ha/h capacity performed in manual distribution. Under this working conditions, the quantity of dispersal material correspond to 19 phytoseiids/m$^2$ and 9 anthocorid bugs/m$^2$: more than the rate recommended. This is because, in order to ensure a better pest control and avoid production losses, the whole content of packages employed during the test has been distributed.

**Table 1. Performances of the distribution in the greenhouse tests: mean values**

| Tests | Forward speed (m/s) | Mechanical Work Capacities (ha/h) | Manual Work Capacities (ha/h) | Product distributed (g/m$^2$) | |
|---|---|---|---|---|---|
| | | | | *O. laevigatus* | *P. persimilis* |
| Bell pepper | 1 - 2 | 0.4 - 0.7 | 0.3 | 0.3 | 0.3 |
| Chrysanthemum | 0.10 - 0.14 | 0.18 - 0.24 | 0.1 | 0.4 | 0.6 |

A certain uniformity in the prototypes functioning is highlighted by the limited changes in the average flow in the two releases (0.17 and 0.18 g/s for *O. laevigatus*; 0.42 and 0.37 g/s for *P. persimilis*). The only noteworthy difference can be found in the rotational speed of the distributor disc, probably due to the level of battery power which was higher in the second release (Table 2).

**Table 2. Distribution parameters in the chrysanthemum tests where three prototypes in parallel were used.**

| | **Prototypes** | **Distributor disk velocity** (rpm) | **Doser velocity** (rpm) | **Flow** (g/s) | |
|---|---|---|---|---|---|
| | | | | *O. laevigatus* | *P. persimilis* |
| First release | 1 | 534 | 30 | 0.20 | 0.47 |
| | 2 | 510 | 29 | 0.16 | 0.37 |
| | 3 | 501 | 29 | 0.16 | 0.41 |
| | *mean* | *515* | *29* | *0.17* | *0.42* |
| Second release | 1 | 552 | 30 | 0.20 | 0.31 |
| | 2 | 542 | 29 | 0.18 | 0.47 |
| | 3 | 524 | 29 | 0.17 | 0.41 |
| | *mean* | *539* | *29* | *0.18* | *0.37* |

*The open field tests*
The tests carried out with the three prototypes applied to the 2 WD tractor (Tests 1) permitted to obtain an effective work capacity of about 0.6 ha/h in the case of *O. laevigatus* and about 1 ha/h in the case of *P. persimilis*. The average forward speeds were 0.4 m/s and 0.6 m/s respectively (Table 3).
In the second strawberry field (Tests 2), using only one prototype applied to the bar carried by an operator, the work capacity were significantly lower (about 0.2 ha/h) than those obtained with the tractor carried prototypes. This result was due both to the effective work width of 1.4 m instead of 4.2 m with the tractor and to the lower forward speed, only 0.12 m/s, that was needed to keep the distribution of the packages on the established surface (Table 3).

**Table 3. Performances of the distribution in the strawberry open field tests**

| **Tests** | **Forward speed** (m/s) | **Mechanical Work Capacities** (ha/h) | **Distributed product** ($g/m^2$) | |
|---|---|---|---|---|
| | | | *O. laevigatus* | *P. persimilis* |
| 1 | 0.4 - 0.6 | 0.6 - 1 | 0.2 | 0.4 |
| 2 | 0.4 | 0.2 | 0.2 | 0.4 |

With respect to distribution parameters shown in Table 4, an increase in quantity was observed, particularly for *P. persimilis*, due to the spillage from the doser during turning manoeuvres caused by the vibrations transmitted by the tractor. In fact, the headlands were not large enough to allow the fast turning of the tractor equipped with the carrying bar.
The same increase in quantity was not recorded with the *O. leavigatus* because of greater dimensions of its dispersal material (buckwheat husks mixed with vermiculites).

**Table 4. Distribution parameters in the first strawberry field where three prototypes in parallel were used.**

| Prototypes | Distributor disk velocity (rpm) | Doser velocity (rpm) | Flow (g/s) | |
|---|---|---|---|---|
| | | | *O. laevigatus* | *P. persimilis* |
| 1 | 530 | 29 | 0.13 | 0.55 |
| 2 | 453 | 27 | 0.10 | 0.54 |
| 3 | 448 | 26 | 0.19 | 0.42 |
| *mean* | *477* | *27* | *0.14* | *0.50* |

## Conclusions

As already shown in previous paper the distribution mechanism of the prototype is well suited to biological pest control strategies also in the open field in accordance with the recent European Directive 2009/128/CE. With the three applications of the new version of prototype, the manoeuvrability has been much improved and consequently better results can be obtained in terms of both work capacity and uniformity. In particular the prototype mounted on the carrying bar connected to three point linkage to a tractor could represent an suitable solution for the distribution of natural enemies in strawberry crops.

Also the work capacities show the advantage using the machine tested as opposed to the manual distribution generally adopted for biological and integrated crops.

From these experiences, mechanised distribution has clearly proved advantageous in terms of time and work especially when the time wasted in lane turnarounds, improving the limited manoeuvrability of the machine, were reduced.

Moreover, to increase the work capacity the headlands would be large enough to allow the fast turning of the tractor and the reduction of the stopping times of the prototypes, so to limit the product lost because of the not inconsiderable vibrations transmitted by the tractor.

At last, if there were no problems with turning, it would be possible to increase the work capacity by increasing the work width and consequently the bar length and thus the number of prototypes used.

It's important pointing out that on the basis of the information provided by the farmers hosting the tests, it would seem that the productive yield obtained with biological treatments and those with chemical treatments were comparable.

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