A recycling tunnel to reduce environmental drift in spraying goblet vineyards

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Abstract
Since about 50 years ago, goblet vineyards were progressively abandoned in favour of espaliers, because they presented some critical points as low vine quality and no adequate mechanisation. Nowadays, experts and oenologists claim that goblet vineyards, cultivated with modern criteria, may provide high crop quality. Moreover, some growers are going to set up cultivation with increased distance between rows (about 1.8 2.0 m), that allows the use of conventional tractors designed for espalier vineyards. In order to fulfil the mechanisation requirements of the crop, the Section of Mechanics and Mechanisation of the DiGeSA of the University of Catania is developing and optimising an innovative multi-functional straddling frame, pulled from a conventional tractor, which is able to carry several tools, as vine-trimmer, sprayer, rotary hoes for soil cultivation, horizontal booms for herbicide treatment under canopies, easily available on the market. This paper reports the results of some trials carried out with the frame equipped with a tunnel sprayer, able to reduce the environmental drift during pesticide treatments. The first results showed that the recovery at fixed point, at varying pressure, distance between shields and number of open nozzles, ranged from 4% up to 83%, with general mean of 44%, whereas that during in field tests, with vineyard Leaf Area Index of 0.73 m^2/m^2, ranged from 37% up to 53%, with general mean of 46%.

Key words: pesticide application, alberello, tunnel sprayer.

Introduction

Goblet vineyards have been progressively abandoned in favour of espaliers, because of low vine quality and lack of mechanisation. However, recent experiences in Sicily and Tuscany (Schillaci *et al*., 2009a) demonstrate that high crop quality may be obtained from goblet vineyards by adopting modern criteria of cultivation. Moreover, this growing form requires only a single stake per trunk, so resulting in less impact on the landscape, less initial outlay, and less waste disposal. In addition, recent plants present distances between rows of about 1.8-2.0 m, that allow the use of operating machines, towed by or mounted on common narrow-track tractors, for soil and canopy management and for pesticide application.

All these factors show a great sustainability of goblet vineyards in confront of espaliers and justify the interest in this growing form, together with the research of solutions able to increase the mechanisation of the crop activities. To this end, a promising solution came from an idea of a wine-grower of the South-East of Sicily that built a handmade frame to which could be applied several tools of easy availability (Schillaci *et al*., 2009b). This pre-prototype consists in a frame supported by two pneumatic tyres, towed by a common "vineyard"

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(narrow track) tractor and designed to operate straddling the rows. Thanks to the financial support of the ENAMA and the scientific direction of the Section of Mechanics and Mechanisation of the DiGeSA Department of Catania and of the CRA-ING of Treviglio (Bergamo), this pre-prototype was redesigned and is now under optimisation.

Presently, the machine consists in a steel-made frame with rectangular lay-out (1.80 m × 1.55 m), maximum height of 2.61 m, ground clearance of 2.40 m, and track of 2.40 m. The frame can carry the tools used for the commonest activities in vineyard, as vertical and horizontal pruning-bars for canopy management, inter-row rotary hoes for soil tillage, and a tunnel sprayer for pesticide application.

The present paper reports the first results of some static and in field tests when the frame was fitted with the tunnel sprayer.

Materials and Methods

The tunnel sprayer

The tunnel sprayer (Figure 1), manufactured by LIPCO (Germany), is specifically designed for pesticide application in espalier vineyards and similar crops. It consists of two shields equipped with a collector at the bottom for the recovery of the mixture, and a recycling unit, based upon a Venturi tube (Figure 2), that, after filtration, returns the recovered mixture to the spray tank.

Figure 1. The frame equipped with the tunnel sprayer.

Figure 2. The recycling unit with the filter.

Each shield has rectangular shape (width = 1.25 m, height = 2.20 m) and is equipped with a spray boom fitted with 5 fan Albuz APE 80 nozzles. The distance between the shields can be adjusted from 0.2 up to 1.1 m by means of a hydraulic piston. The sprayer is completed with a 500 L spray tank, a diaphragm pump, a pressure regulator, and the oil-pressure system. The shields are applied to the frame, while spray tank and pump are placed on a shelf located on the hydraulic lift of the tractor. At this development stage, the machine isn't equipped with auxiliary tanks. Moreover, in order to limit costs and complexity, the shields aren't equipped with fans, even if this could affect negatively the uniformity of the applications on vine canopies (Planas *et al*., 2002; Molari *et al*., 2005).

The research activity

The research activity consisted of both static and in field tests.

Static tests were aimed at assessing the recovery capabilities of the sprayer, in absence of vines, at varying:

- distance between the shields: 0.9 and 1.1 m;
- working pressure: 5 and 6 bar;
- number of open nozzles per side: 2, 3, and 4.

Four replicates we carried out for each test condition, for a total of 36 measurements. The recovery *R* was calculated per each replicate according to (Pergher and Petris, 2009):

$$R,\% = \frac{V_r}{V_s} \times 100,$$

being:

- V_r (L): the amount of water recovered by the recycling system;
- V_s (L): the amount of water sprayed by the nozzles.

V_s and V_r were measured by means of two water meters, the first inserted in the nozzle feed pipe, the second in the Venture tube feed pipe. The amount of water issuing from the recovery unit, equal to that recovered by the shields and that in input to the Venture tube, was collected in an auxiliary tank. Definitively, calculations were performed according to:

$$V_s = WM_n(t + \Delta T) - WM_n(t)$$

$$V_r = WC - (WM_V(t + \Delta T) - WM_V(t)),$$

being:

- t: start of measuring time;
- ΔT : spraying time;
- WM_n: reading of the water meter inserted in the nozzle feed pipe;
- WM_V: reading of the water meter inserted in the Venture tube feed pipe;
- WC: water collected in the auxiliary tank.

The in field tests were conducted in a six years old *Syrah* vineyard with row spacing of 0.9 × 2.0 m, at beginning of fruit setting phenological stage (code 71 of the BBCH scale). Vines were characterised by measuring Leaf Area Index (LAI) and height and width of the canopy.

The average height of the vines, branched at 0.3–0.4 m above the ground, was 1.4 m; the width of the canopy in the bunch zone was 0.5 m and that in the tying zone 0.3 m. Each vine had on average 7 shouts 1.2 m long, each carrying 23 leaves. The LAI of the vineyard (0.73 m^2/m^2) was estimated on the basis of a sample of 115 leaves, whose surface was measured by using a flat scanner to acquire their images and the *ImageJ* software (Abramoff *et al*., 2004) to analyse them.

Spraying tests were carried out by setting the following working parameters:

- boom sprayer fitted with four open nozzles per side;
- working pressure: 6 bar;
- distance between the shields: 1.1 m;
- total flow rate: 8.16 L/min;
- working speed: 1.28 m/s;
- theoretical volume rate: 533 L/ha.

Four rows about 135 m long were sprayed with water only and the recovery for each row was computed as in the static tests. Moreover, four water sensitive papers were also putted on the ground, inside *Petri* dishes, near three sprayed vines. Their analysis, carried out by using again a flat scanner and the *ImageJ* software, allowed the gathering of the first indications on the ground losses.

All data analyses and graphical representations were carried out by using the open source software *R* (R Development Core Team, 2009).

Results and Discussions

Static tests

The recovery, averaging all the test conditions, was 44.5%; it ranged from 4.0% (5 bar, 1.1 m, 2 open nozzles) up to 82.7% (5 bar, 1.1 m, 3 open nozzles) (Figure 3).

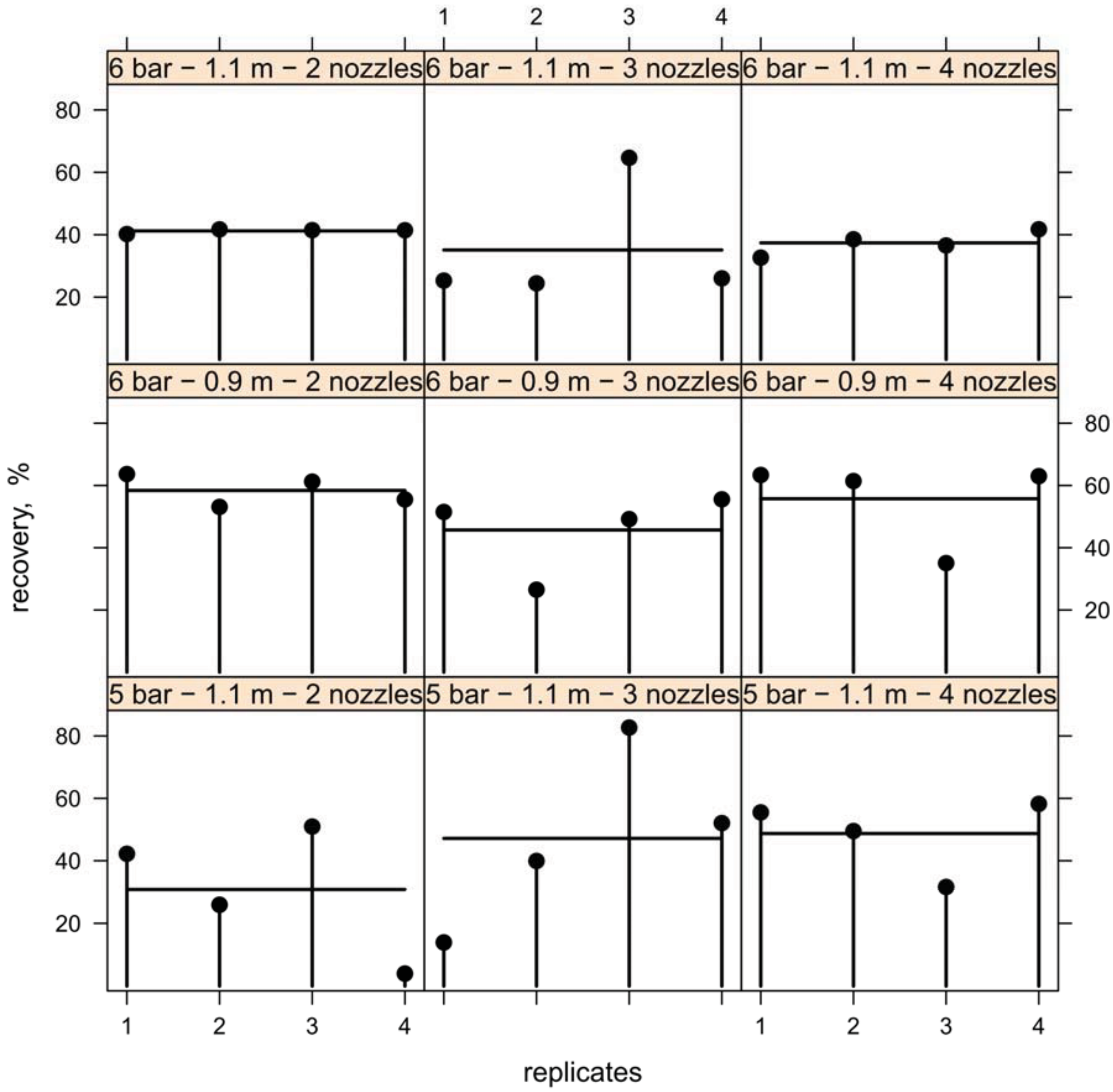

Figure 3. Recovery for each replicate of the static tests (horizontal lines represent mean values).

The analysis of variance applied to the recovery values produced the results reported in Table 1. Mean values for each factor considered in the analysis are reported in Figure 4.

Table 1. Analysis of variance of the recovery values.

Source	df	SS	MS	F	*p*-value
Distance	1	1394.7	1394.7	5.778	0.0234
Pressure	1	111.7	111.7	0.463	0.5022
Nozzles	2	146.1	73.1	0.303	0.7413
Distance × Nozzles	2	424.5	212.3	0.879	0.4266
Pressure × Nozzles	2	653.4	326.7	1.353	0.2753
Residuals	27	6517.7	241.4		

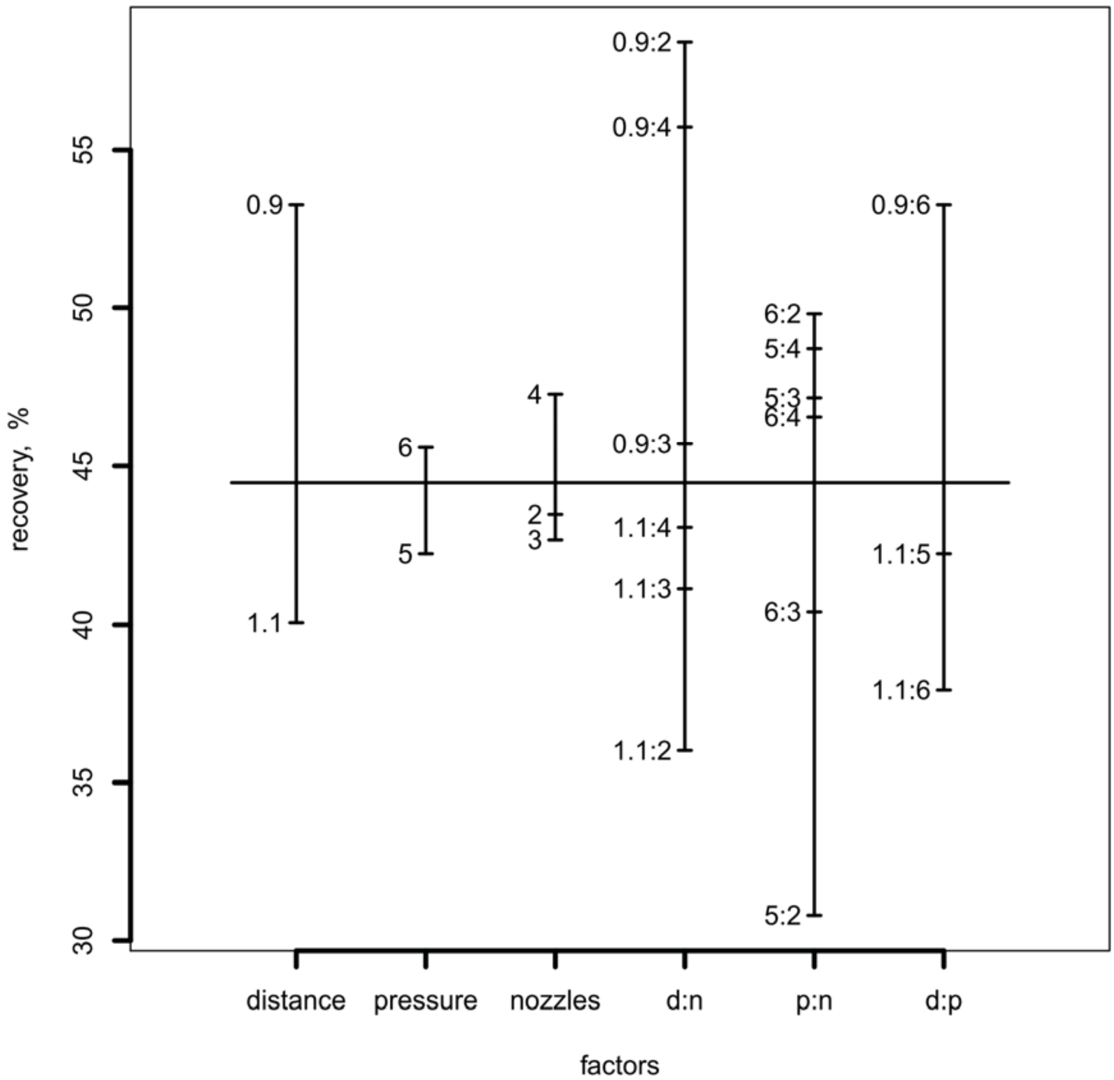

Figure 4. Mean values of the recovery at varying distance between shields (d), pressure (p) and number of open nozzles (n).

The results show that only the distance between the shields had a significant effect on the recovery (*p*-level = 0.023): it was 53.3% when the distance was 0.9 m and 40.1% when it was 1.1 m. This means that the increase in the distance between the shields makes the recovery worse, so the machine should be used in field keeping the shields as much as possible close, compatibly with the vine size. Moreover, the increase in the distance had also effect on the data dispersion (Figure 3), probably because of a greater influence of external factors as wind and temperature. In fact, recovery values ranged from 26.5% up to 63.7% (CV = 22.0%) when the distance was 0.9 m and from 4.0% up to 82.7% (CV = 41.4%) when it was 1.1 m.

The increase in pressure improved the recovery, but not significantly (*p*-level = 0.502). The recovery increased from 42.2% up to 45.6% when the pressure increased from 5 to 6 bar. High pressure values, in fact, help drops to reach the opposite shield, so increasing the recovery. Higher differences in pressure levels could make significant this factor.

Finally, the influence of the number of open nozzles was not statistically significant ($p = 0.741$): the highest value of recovery (47.3%) was measured with 4 open nozzles, the lowest (42.7%) with 3.

The interactions were all not statistically significant: the recovery was always smaller when the distance between the shields was 1.1 m, whatever the number of open nozzles and the pressure level, while no relationship emerged between pressure and number of open nozzles.

In field tests

The in field tests, even if absolutely preliminary, showed a recovery ranging from 36.9% up to 52.5%, with mean value of 45.5%. The analogous static tests (same pressure—6 bar—, same distance between shields—1.1 m—, and same number of open nozzles—4—) provided a recovery of 37.4%. Even if further investigations are necessary, with different foliar development and other working parameters, these first results are encouraging: almost half of the sprayed mixture was recovered, so greatly reducing the environmental losses.

Ground losses near the sprayed rows were quite high: the covered surface on water sensitive papers ranged from 62.9% up to 68.8%, with mean value of 65.6%. May be they could be reduced by properly adjusting the nozzle angle and by reducing the distance between the shields.

Conclusions

The study, even if preliminary, allows for the following conclusions, to be integrated by further investigations:

- The results concerning the spraying system induce to consider the machine an interesting solution to pesticide application in goblet and low espalier vineyards as regards the reduction of drift losses. A recovery of 45.5% at beginning of fruit setting phenological stage states that almost half of the sprayed mixture can be recovered.
- A full evaluation of the machine requires further experimentations, among which a comparison with a conventional sprayer in terms of foliar deposition and its distribution on the canopy. Some Authors report in fact some asymmetry of distribution, which produces different deposits on the two sides of the canopy (Ade and Pezzi, 2001), or lower deposits in the high parts of the canopy when using drift-mitigating air induction cone nozzles (Jamar *et al*., 2010).
- Further experimentations should be carried out in order to identify the optimal working

parameters in terms of pressure, nozzle type and angle, distance between the shields, working speed, all variables that may affect foliar deposition and its distribution on the canopy.

- Finally, further development should regard a re-design of the frame and of the shields, reducing the size of the machine in comparison to the goblet vine size. Moreover, it should be evaluated the advisability of fitting the shields with fans so to improve spray distribution and penetration, even if this increases costs and complexity.
- After all, the frame, equipped with operating tools easily available on the market at low cost, may represent a valid solution to the mechanisation requirements of goblet and low espalier vineyards.

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