Perfformances evaluation of different vertical patternators

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Summary

Assessment of vertical spray profile is one of the main steps to adjust sprayers for bush and tree crops, as it allows to verify that the spray plume matches the target canopy profile.

The equipment used for assessing the vertical spray profile is typically a vertical test bench or patternator.

Even if the sprayer adjustment is recommended in EU Directive 128/2009/EC, the use of vertical test benches is only optional in the procedures for the inspection of air-assisted sprayers in use currently adopted in the EU Member States, that mainly refer to EN 13790-2 and to new ENISO FDIS 16122-3.

At present, in the International Standards, there is not any indication of the minimum requirements that the vertical test benches have to fulfill, neither in terms of constructive characteristics or of functional parameters.

For this reason, the types of vertical test benches used in the test stations, even if are based on the same principle of functioning (presence of a vertical surface to collect the whole liquid sprayed and of graduated tubes for measuring it), present some differences in terms of structure, mainly related to collectors types and their disposal along the test bench.

Two main categories of vertical test benches can be identified: 1) equipped with a continuous collecting wall; 2) equipped with a discrete number of separated collectors. In each category it is then possible to have different models, depending on the size, materials, number and position of the collectors.

With the main purpose to define methodology and criteria for the vertical patternator evaluation, specific performance tests were carried out in laboratory using four different types of vertical test benches and a horizontal test bench complying with ISO 5682-1 requirements. Spray recovery capacity and reproducibility of results, both in terms of recovery and of spray profile were assessed using different droplet sizes, air speeds and air directions.

Results of these first experimental trials pointed out that the criteria applied to assess the performance of the vertical test benches seemed able to discriminate the differences between the models tested. Amount of spray recovery was mostly affected by droplets size rather than by air velocity. Spray profile detected on the different vertical patternator types examined resulted generally similar. These first experimental results could constitute a basis for the development of a SPISE advice about test methodology and requirements for vertical test benches.

Introduction

Proper adjustment of vertical spray profile is a key aspect to optimize pesticide application with air-assisted sprayers for orchards and vineyards. The spray profile, in fact, shall be adequate to the target canopy profile in order to address the spray plume only in correspondence of the target and to minimize off-target losses. A useful tool enabling to assess the vertical spray profile produced by an air-assisted sprayer is a vertical test bench that enables to collect the liquid sprayed at the different heights and therefore allows to verify the overall vertical spray profile (Pergher *et al.*, 2002).

As there are different types of such vertical test benches available on the market but, at present, there is not any specific Standard that indicates the minimum technical features and requirements that these devices should match, experimental tests at Crop Protection Technology DISAFA laboratory were carried out in order to evaluate the performances of some different models of vertical test benches. The aim was to pave the way to a SPISE advice about test methodology and requirements that in future could be applied to such devices.

Materials and methods

Tests were carried out comparing 5 different types of test benches (4 vertical and 1 horizontal), featured by different shapes and sizes of the spray collecting surfaces.

Three vertical test benches were constituted by discrete plates disposed along the vertical frame of the bench having the following technical features:

Test bench equipped with stainless steel plates 300 x 100 mm size (collecting surface of each single plate equals to 300 cm^2) and spacing between consecutive plates along the vertical axis (vertical resolution) of 100 mm. Plates are disposed in three vertical arrays. First plate is positioned at 455 mm height from the ground. Maximum height of the test bench is 4500 mm, total width is 1000 mm (Fig. 1A).

Test bench equipped with stainless steel plates 200 x 200 mm size (collecting surface of each single plate equals to 368 cm^2) and vertical resolution of 200 mm. Plates are disposed in two vertical arrays. First plate is positioned at 465 mm height from the ground. Maximum height of the test bench is 4500 mm, total width is 640 mm (Fig. 1B).

Test bench equipped with plastic plates 200 x 220 mm size (collecting surface of each single plate equals to 437 cm^2) and vertical resolution of 200 mm. Plates are disposed in two vertical arrays. First plate is positioned at 500 mm height from the ground. Maximum total height of the test bench is 4500 mm, total width is 640 mm (Fig. 1C).

In all the three models the liquid collected by the plates is conveyed to graduated tubes by means of small pipes.

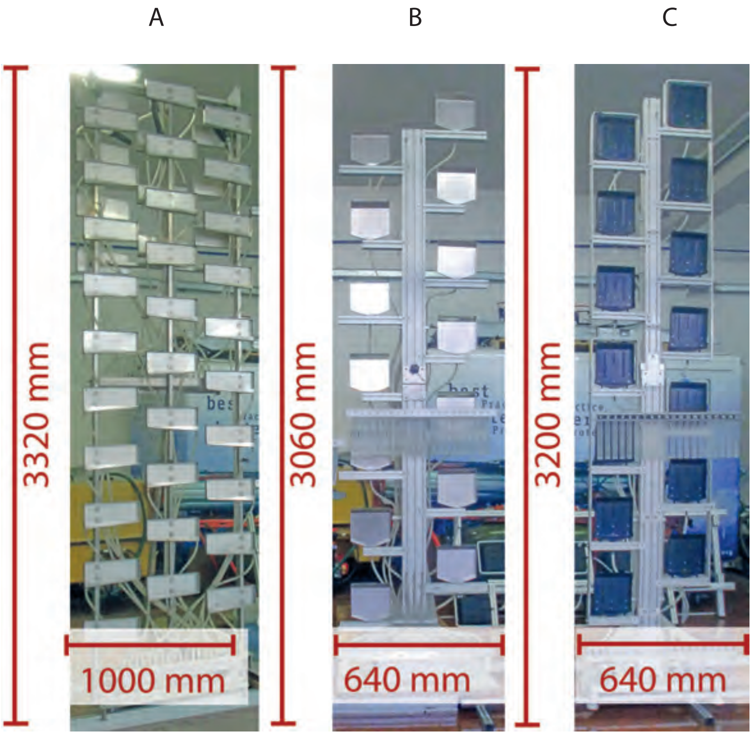

Fig. 1. The three types of vertical test benches fitted with discrete spray collectors used in the tests with relative heights.

The fourth model of vertical test bench examined was a patternator equipped with 96 horizontal lamellae made of plastic inserted in a stainless steel frame. Vertical resolution of this test bench is 100 mm, corresponding to the collecting surface of three lamellae (the liquid captured by three consecutive lamellae is conveyed to a graduated tube). First lamella is positioned at 310 mm height from the ground. Total height of the test bench is 3500 mm, total width is 1800 mm (Fig. 2).

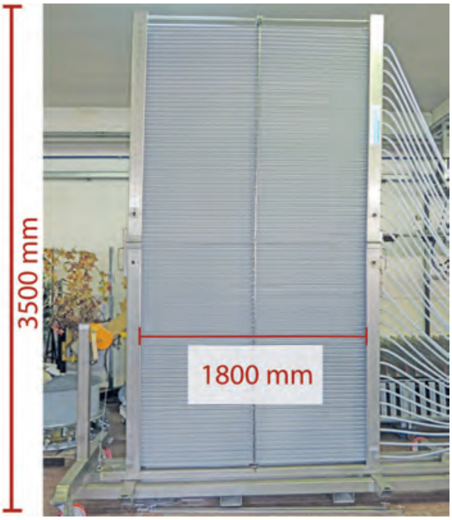

Fig. 2. Lamellae vertical patternator examined in the trials.

A fifth test bench used for comparison was constituted by a stainless steel horizontal test bench complying with ISO 5682-1 standard (Fig. 3). The test bench, 6 m wide, is equipped with 60 grooves, each 100 mm wide, 200 mm deep and 2000 mm long. The liquid recovered in each groove is collected in a graduated tube 500 ml capacity.

The choice to use also this standardized horizontal test bench was made in order to get some reference data to compare with the results obtained using the vertical test benches.

Fig. 3. Horizontal test bench complying with ISO 5682-1 standard used in the tests.

All tests were carried out at Crop protection Technology DiSAFA laboratory using a spraying unit electrically driven consisting in a tangential fan 1440 mm high and with a fan diameter of 150 mm, combined with five hydraulic nozzles mounted on a vertical spray boom at 300 mm spacing. In all tests, the spraying unit was positioned at a distance of 800 mm from the test benches and just one nozzle – the one positioned in the middle of the spraying unit - was activated.

Spraying parameters considered during the tests were droplets size, air velocity and air direction.

Three different conventional hollow cone nozzles and three different air induction hollow cone nozzles, always operated at 0.10 MPa pressure, were used in the tests in order to assess the effect of droplet size (VMD) ranging from 70 to 460 µm (Tab. 1).

Tab. 1. Nozzle types with related droplet size employed in the tests.

Nozzle model	Type	Flow rate (l/min) at 0.10 MPa	VMD (µm)
Teejet TXB 8001VK	Conventional hollow cone	0.68	70
Teejet TXB 8002VK	Conventional hollow cone	1.44	80
Teejet TXB 8004VK	Conventional hollow cone	2.75	105
Teejet AITXB 8001VK	Air induction hollow cone	0.70	245
Teejet AITXB 8002VK	Air induction hollow cone	1.45	380
Teejet AITXB 8004VK	Air induction hollow cone	2.75	460

Three different air velocities, measured in correspondence of the test benches, therefore at 80 cm distance from the spraying unit, were applied in the tests: 5.0 m/s; 8.2 m/s; 12.5 m/s. For each air velocity value, all the nozzles were tested, therefore 18 spraying unit configurations were tested keeping the spraying unit vertical (spray jet and air flow perpendicular vs. the test bench, Fig. 4A) and 18 configurations were tested positioning the spraying unit inclined 30° with respect to the vertical axis (spray jet and air flow inclined vs. the test bench, Fig. 4B).

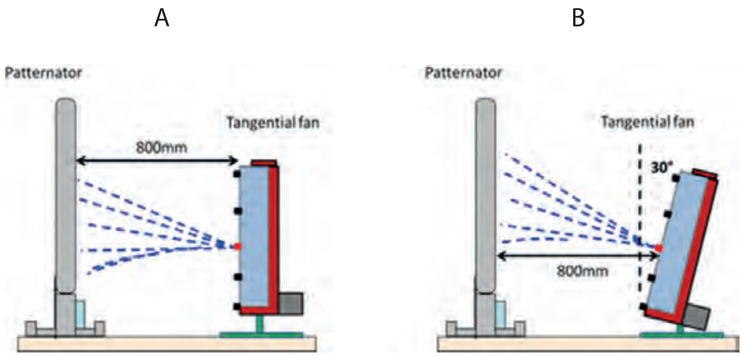

Fig. 4. Positions of the spraying unit with respect to the test bench examined in the tests.

For each test bench and for each spraying unit configuration three test replicates were carried out.

Trials made using the vertical test benches equipped with plates were made keeping them static and moving the spraying unit in front of them at 60 mm/s forward speed along a motorized rail track. Tests made with the lamellae patternator and with the horizontal test bench were carried out keeping both the spraying unit and the test bench in static position. When the standardized horizontal test bench was employed, the spraying unit was suspended over it at a distance of 800 mm (Fig. 5) so that the spray jet and the air flow were addressed perpendicular to the spray collecting surface. In this latter case it was not possible to carry out the tests with the spraying unit inclined with respect to the test bench.

Fig. 5. Position of the spraying unit with respect to the horizontal test bench.

Three criteria for assessing the performance of the test benches according to the different spraying unit configurations examined were applied:

Spray recovery capacity;

Reproducibility of the recovery capacity results;

Spray profile reproducibility.

Spray recovery capacity was determined measured the amount of liquid collected by each test bench with respect to the total amount of liquid sprayed during the test.

Concerning the three test benches equipped with plates (discrete collecting elements), taking in account that the spraying unit moved in front of them during the trials, the recovery capacity (RC) was calculated according to the following formula:

$$RC = \left(\sum_{i=1}^{n} a_i/s\right)/(Q * t)$$

where:

a_i is the amount of liquid collected by each single plate (ml)

s is the number of passes made by the spraying unit in front of the test bench

Q is the spraying unit flow rate, expressed in ml/s

t is the time (s) spent by the spraying unit in front of the test bench during one pass (function of forward speed and collector width)

For the lamellae vertical patternator and for the horizontal test bench, considering that the spraying unit was operated in static position, the spray recovery capacity (RC) was calculated through the formula:

$$RC = \sum_{i=1}^{n} a_i / Q$$

where:

a_i is the amount of liquid (ml/min) collected in each graduated tube of the test bench;

Q is the spraying unit flow rate, expressed in ml/min

In both the formulas, the amount of liquid collected was considered as the mean value of the three test replicates.

To evaluate the reproducibility of the spray recovery capacity, for each sprayer configuration examined and for each test bench, the coefficient of variation calculated between the values obtained in three test replicates was considered.

Finally, to assess the reproducibility of the spray profile on the same test bench, a specific Spray Profile Index (SPI) was calculated as the total sum of the differences between maximum and minimum values of the spray liquid amount collected at each sampling height along the test bench, obtained in the three test replicates. All the amounts of spray liquid collected at the different sampling heights were expressed as percentage of the total recovery on the test bench.

The lower is SPI value, the more similar the spray profiles are.

$$SPI = \sum^{n} (max - min)$$

Results

Spray recovery capacity

Results obtained using the different test benches pointed out that, keeping the air velocity constant, the spray recovery capacity increases according to the droplets size (VMD). When very fine droplets were applied (VMD around 100 µm), generally only 50% of the sprayed liquid was collected by the test benches (Fig. 6); the recovery capacity increased up to 90% when the medium-coarse droplets, featured by a VMD ranging from 245 to 460 µm, were sprayed. Highest values of spray recovery were registered using the vertical test bench equipped with the plastic plates. This trend was confirmed also when the spray unit was inclined 30° with respect to the vertical test benches (Fig. 7).

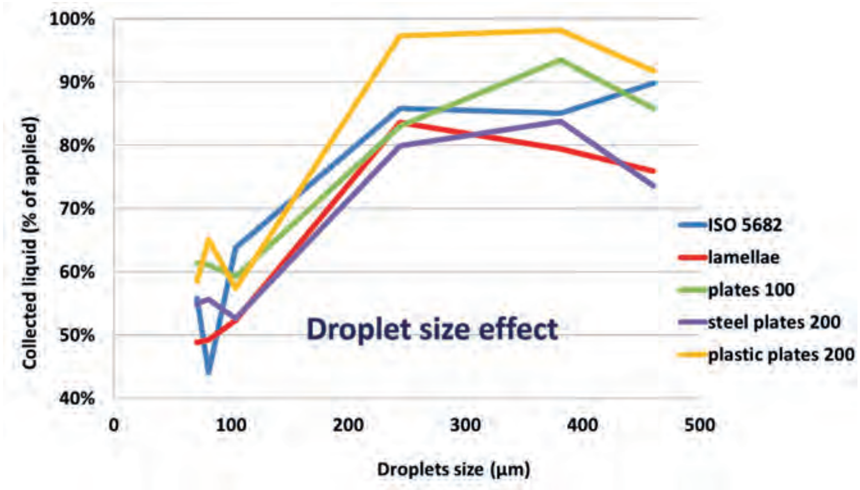

Fig. 6. Spray recovery registered for the different test benches examined according to the droplets size (VMD, µm). Data referred to tests carried out employing an air velocity of 8.2 m/s and addressing the spray jet and air flow perpendicular to the test bench.

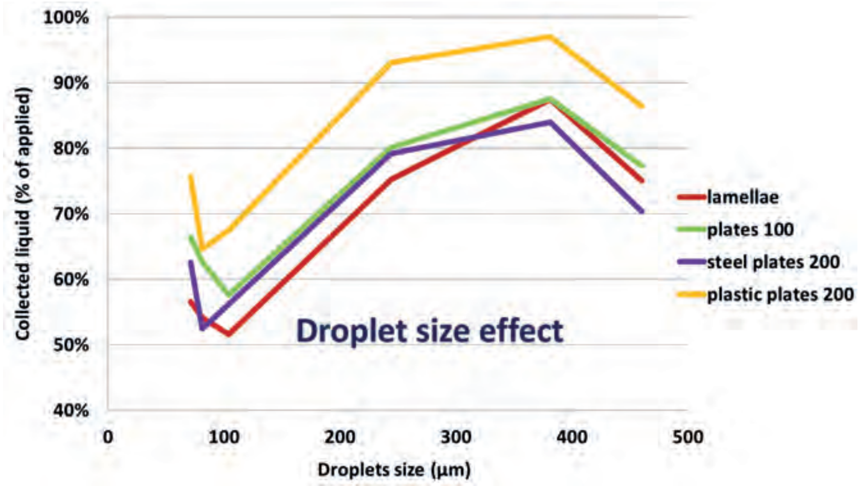

Fig. 7. Spray recovery registered for the different test benches examined according to the droplets size (VMD, µm). Data referred to tests carried out employing an air velocity of 8.2 m/s and operating the spray unit inclined 30° with respect to the vertical test benches.

Effect of the air velocity on spray recovery was very limited when the fine droplets (VMD = 105 µm) were sprayed, except than for the horizontal test bench ISO 5682, where the increment of the air velocity probably enhanced rebounds of droplets from the bench and therefore reduced the spray recovery capacity (Fig. 8).

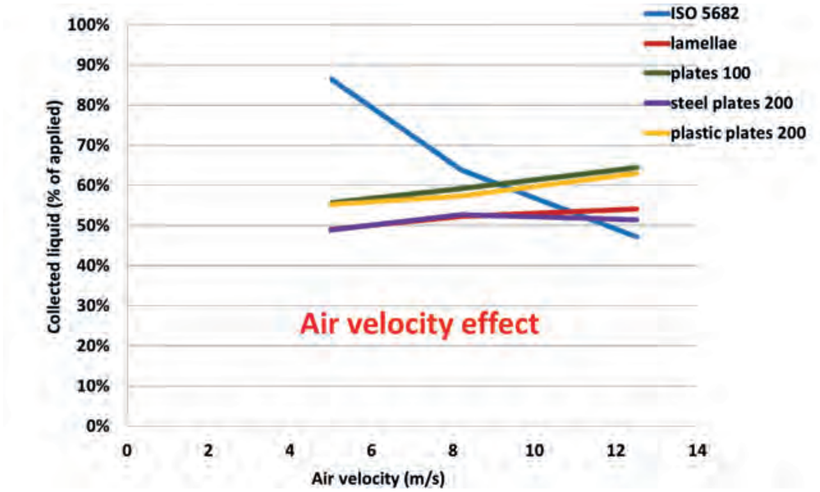

Fig. 8. Spray recovery registered for the different test benches examined according to the air velocity employed, when fine droplets were applied (VMD = 105 µm). Data referred to tests carried out employing TXB 8004 VK nozzle and addressing the spray jet and air flow perpendicular to the test bench.

On the other hand, when the coarse droplets (VMD = 460 µm) were applied, at high air velocity (12.5 m/s) a decrease of spray recovery capacity of the test benches was generally observed (Fig. 9). This trend was noticed for most of the test benches (in particular for the horizontal test bench ISO 5682), except than for the lamellae test bench. For this latter patternator, in fact, a higher spray recovery was registered employing the maximum air velocity.

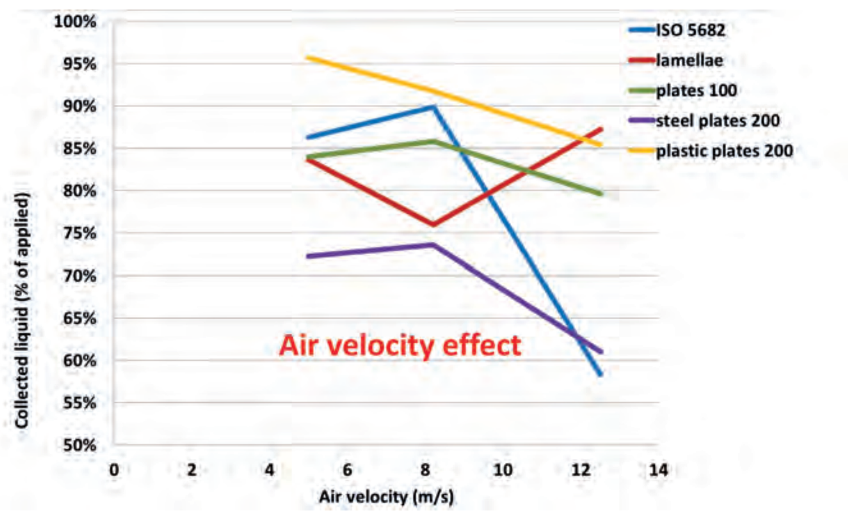

Fig. 9. Spray recovery registered for the different test benches examined according to the air velocity employed, when coarse droplets were applied (VMD = 460 µm). Data referred to tests carried out employing AITXB 8004 VK nozzle and addressing the spray jet and air flow perpendicular to the test bench.

Reproducibility of the recovery capacity results

The analysis of the coefficient of variation calculated on the three replicates of each test (combination of nozzle type and air velocity) pointed out that, when the spray jet was addressed perpendicular to the test bench - independent of the test bench model -, the reproducibility of the spray recovery results was pretty good (CV < 10 %), especially when the medium/coarse droplets were applied (Fig. 10). Higher CV values, around 20% between the three test replicates, were found spraying the very fine droplets on the vertical test benches equipped with plates (Fig. 10).

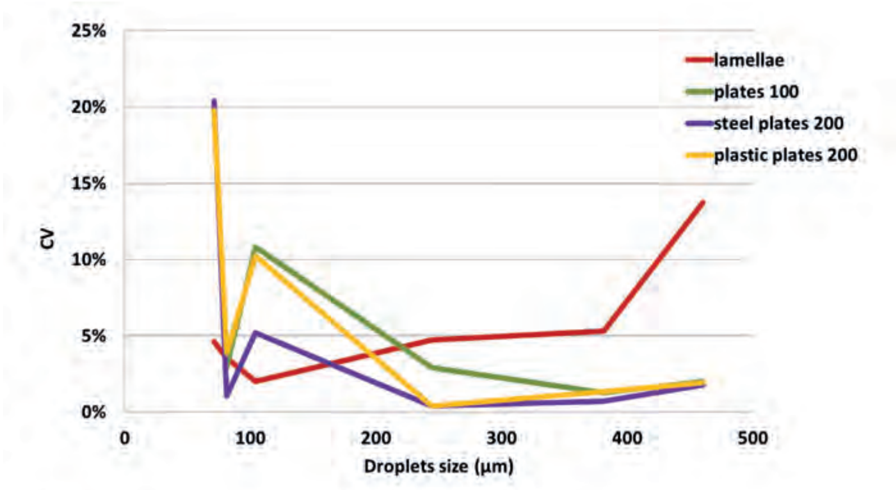

Fig. 10. Reproducibility of the spray recovery results (CV) registered for the different test benches examined according to the droplets size. Data referred to tests carried out employing the air velocity of 8.2 m/s and addressing the spray jet and air flow perpendicular to the test bench.

When the spray unit was rotated 30° with respect to the vertical test benches (see Fig. 4B) the reproducibility of spray recovery results was even better (CV below 5%) when the test benches equipped with plates were used, while it was poorer when the lamellae patternator was employed. In this latter case the CV resulted often over 10%, except when coarse droplets were sprayed (Fig. 11).

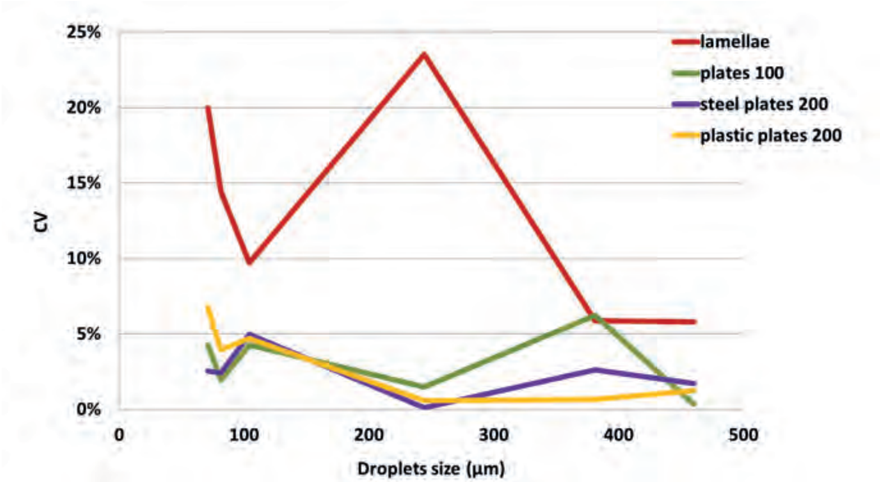

Fig. 11. Reproducibility of the spray recovery results (CV) registered for the different test benches examined according to the droplets size. Data referred to tests carried out employing the air velocity of 8.2 m/s and operating the spray unit inclined 30° with respect to the vertical test benches.

Spray profile reproducibility

Assessment of spray profile reproducibility carried out through the calculation of the Spray Profile Index (SPI) pointed out that, when the spray jet was addressed perpendicular to the test bench and the medium/coarse droplets were sprayed, a high reproducibility of the profiles, with SPI values below 0.1, was found using the vertical test benches equipped with plates (Fig. 12); more differences between the spray profiles obtained during the test replicates were noticed when the very fine droplets were applied, with SPI values up to 0.4. Concerning the lamellae patternator, a different trend of the reproducibility of the spray profile was noticed, as SPI resulted very low even when the fine droplets were used, but it grew over 0.2 when the coarse droplets were sprayed (Fig. 12).

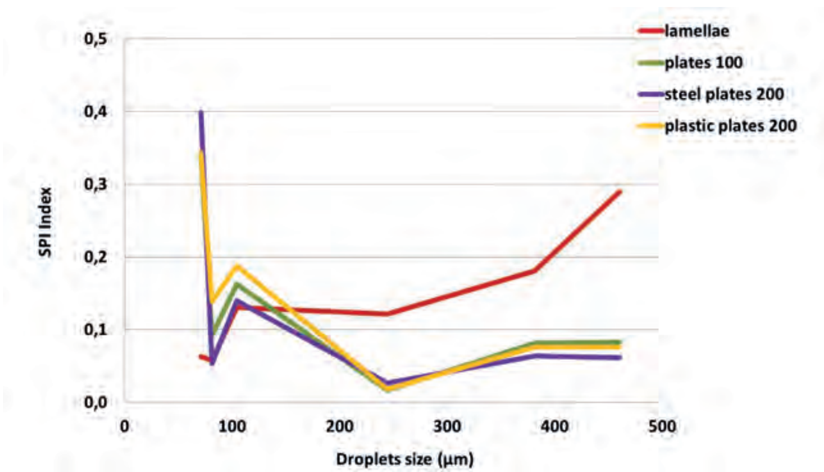

Fig. 12. Trend of Spray Profile Index (SPI) registered for the different test benches examined according to the droplets size. Data referred to tests carried out employing the air velocity of 8.2 m/s and addressing the spray jet and air flow perpendicular to the test bench.

When the spray unit was rotated 30° with respect to the vertical test benches, the reproducibility of the spray profiles generally resulted better, especially employing the vertical test benches equipped with plates, with SPI values always below 0.15 (Fig. 13).

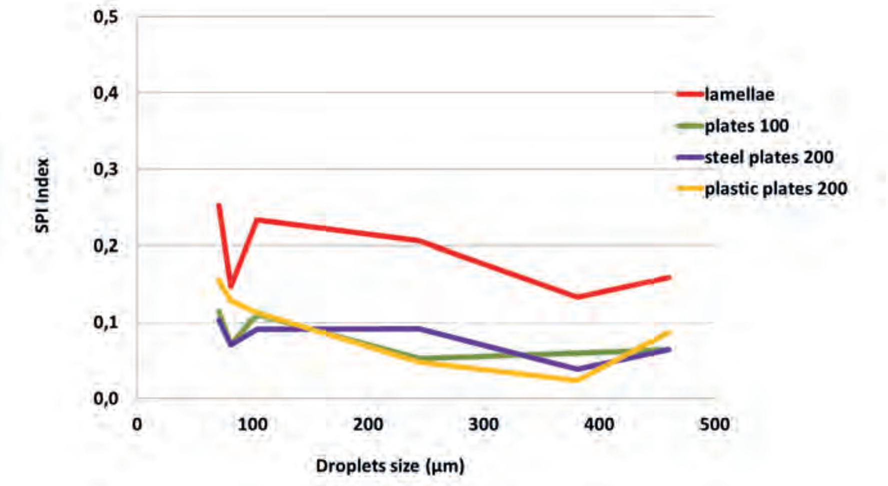

Fig. 13. Trend of Spray Profile Index (SPI) registered for the different test benches examined according to the droplets size. Data referred to tests carried out employing the air velocity of 8.2 m/s and operating the spray unit inclined 30° with respect to the vertical test benches.

Conclusions

The criteria applied for the evaluation of the vertical patternator performance seemed able to discriminate the differences between the five types tested. Spray quality influenced spray recovery, with higher collection efficiency of the test benches observed when medium/coarse droplets were sprayed. The effect on spray recovery of air velocity, in the range considered during the experiments (5.0 ÷ 12.5 m/s), resulted very low. The reproducibility of spray recovery was pretty good with all the test bench models assessed, as the coefficient of variation between three test replicates resulted within 20%. For each combination of nozzle and air velocity examined, the spray profiles detected on the different models of vertical test benches generally resulted similar (Fig. 14).

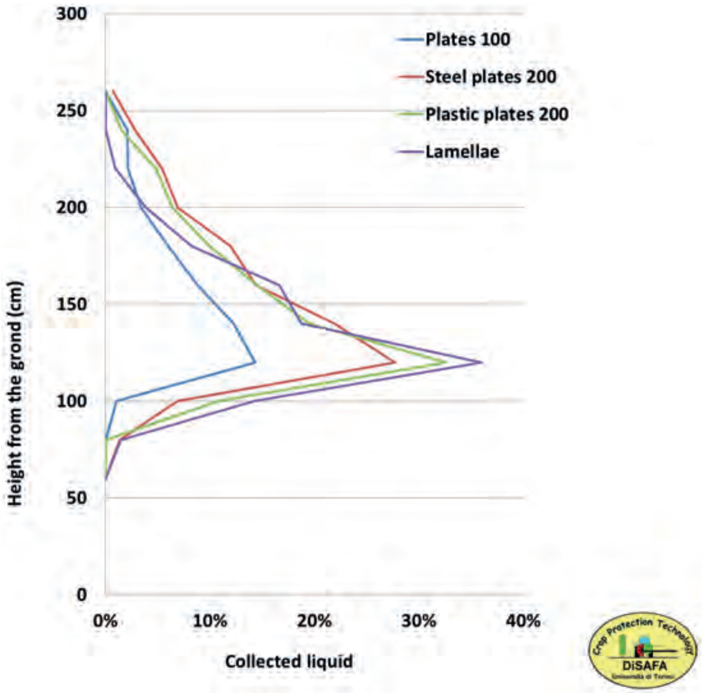

Fig. 14. Vertical spray profiles detected with the different vertical test benches examined when the conventional hollow cone nozzle TXB8004 combined with the air velocity of 8.2 m/s was employed and the spray unit was inclined 30° with respect to the vertical test benches.

The tests carried out enabled to acquire first experimental data about the performances of different vertical test benches, it is needed to carry out further investigations (e.g. using axial fans and nozzles positioned on semi-circular booms) in order to get more information about the behavior of vertical test benches in conditions closer to their use for air-assisted sprayer calibration.

Nevertheless these first experimental data could be useful for starting the development of a SPISE advice about "test methodology and requirements for vertical patternators".

References

EN 13790-2 (2003) - Agricultural machinery - Sprayers - Inspection of sprayers in use - Part 2: Air-assisted sprayers for bush and tree crops.

EN ISO FDIS 16122-3 (2014) - Agricultural and forestry machinery — Inspection of sprayers in use — Part 3: Sprayers for bush and tree crops.

ISO 5682-1 (1996) - Equipment for crop protection – Spraying equipment - Part 1: Test methods for sprayer nozzles.

Pergher G., Balsari P., Cerruto E., Vieri M. (2002). The relationship between vertical spray patterns from air-assisted sprayers and foliar deposits in vine canopies. Aspects of Applied Biology 66, International advances in pesticide application, 323-330.

Acknowledgments

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