Calibration of orchard sprayers – the parameters and methods

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Summary
According to the new EU directive on sustainable use of pesticides (EC 2009/128) calibration of sprayers has to be implemented in the EU Member States. It is also required in the environmental and operators' safety context of different documents and guidelines determining the implementation of good practices or the compliance with standards of certified crop production. The most recent guidelines underline the up-to-date opinion that calibration of sprayer should optimise the on-crop product deposition, and reduce the off-target loss of pesticides. Therefore calibration for orchard sprayers should in particular include aspects regarding spray volume determination, airflow adjustment and selection of the type, number and configuration of nozzles, aiming at high spray application quality and its environmental impact. Spray volume adapted to specific orchard may be calculated based on Tree Row Volume concept. The air flow setting includes adjustment of air volume/velocity, air flow range and air- flow direction/deflection. The type, number and configuration of nozzles are selected aiming at enhanced deposition and distribution of spray in the crop canopy, and reduced spray drift. The practical methods of calibration considering these aspects are proposed in this paper.

Introduction
According to the directive on sustainable use of pesticides (EC/128, 2009) "Professional users shall conduct regular calibrations and technical checks of the pesticide application equipment in accordance with the appropriate training". This requirement has been put in the directive's Art. 8 regarding inspection of equipment in use. It reflects the opinion of legislators that though the calibration does not belong to the inspection of sprayers it is an important complementary procedure making the sprayer apply pesticides in a sustainable manner, i.e. accurately and safely both for the operator and the environment. Furthermore, the calibration conducted by the pesticide user himself raises his awareness on the economic and environmental impact of the technical efficiency and adjustment of spraying equipment.

The requirement about calibration is to be implemented in the Member States. It means the issue will need to be widely communicated among the pesticide users and they will have to be appropriately trained how to perform the calibration procedure. The full advantage of this educative campaign should be taken to present a new approach to the present-day objectives and modern procedure of the calibration, and most of all to convince the pesticide users on the benefits they can get out of it.

Nowadays the calibration is required also in the environmental and operators' safety context of different documents and guidelines determining the implementation of good practices or the compliance with standards of certified crop production. The examples are: Standards of Good Plant Protection Practice (GPPP) (**www.eppo.int**), Guidelines of Integrated Production (IP) (**www.iobc-wprs.org**), Guidelines of Best Management Practice on avoiding point and diffuse sources (TOPPS-BMP) (**www.topps-life.org**), GLOBALG.A.P Control Points and Compliance Criteria (**www.globalgap.org**).

According to the above mentioned documents the main objective of calibration is ensuring that the correct dose of pesticide is applied. However, the most recent guidelines underline the up-to-date opinion that calibration of sprayer should also optimise the on-crop product deposition, and reduce the off-target loss of pesticides, and by that minimise the residue of chemicals in products (GLOBALG.A.P. standards), and mitigate risk of environmental pollution (TOPPS-BMPs). This progressive approach is clearly reflected in the safe use directive and should be transferred to the activities planned in the Member States. Therefore both the trainings on calibration and the procedure of calibration for orchard sprayers should in particular include aspects regarding spray volume determination, airflow adjustment and selection of the type, number and configuration of nozzles, aiming at enhanced deposition and distribution of spray in the crop canopy, and reduced spray drift. The practical methods of calibration considering these aspects are proposed in this paper.

Getting the sprayer operator motivated and committed

Though the sprayer calibration should be a routine job of the fruit growing practice the growers often ignore it for they are not fully aware of its advantages and are afraid of complicated procedure. Therefore the awareness rising and simplicity of calibration are the key conditions that need to be met in order to achieve universality of calibration. Only the large scale of calibration performance can lead to a permanent and firm progress in sustainable use of pesticides.

The calibration of sprayer consists in adequate selection of nozzles and proper setting of application parameters that best suit the specific circumstances, namely: type of sprayer, weather conditions, and most of all the crop characteristics. To say nothing of application technique the adjustment of application parameters can help a lot to optimise the spraying effect. The results of numerous research studies give evidence that the key parameters such as droplet size, airflow direction and velocity/volume, as well as driving velocity influence both on-target deposition and off-target loss of spray. On the other hand this may influence the efficacy and costs of treatments as well as chemical residue level in fruit, which affect the quality of products and finally the profitability of fruit production. What's more precise calibration allows optimising, which often means reduction, of chemical input, and hence further decrease of crop protection costs. After all with a calibrated sprayer the risk of breakdown is much less which gives an advantage of higher work capacity and lower operating costs. Making the growers aware of economic impact of calibration is the best way to motivate them and get them committed to perform calibrations on a regular basis. The financial benefits resulting from lower costs of pesticides, fuel and labour are complemented by environmental ones such as: less drift (less diffuse source contamination), as well as less spray liquid residue in tank and less deposition on the sprayer after treatment (less point source contamination). For the fruit grower it means lower operator exposure to pesticides, enhanced safety and better image of his products and the fruit growing practice.

In order to encourage the growers to calibrate the sprayers the procedure should be "user-friendly", i.e. as simple as possible and yet effective, not costly and verifiable by simple means. Keeping this in mind we will not avoid, however, making basic calculations of spray volume, driving velocity and required nozzle flow rate, which can be made by anyone familiar with a calculator. A simple set of tools including graduated beaker, measuring tape, watch, calculator, rubber hoses, note-pad and pencil, as well as visual assessment of the results will allow the calibration to be performable by the grower himself, at the growers site (in orchard).

The assumed, measured, calculated or determined calibration data should be recorded. The Table 1 comprising all data arranged in a logic order may be used for the record keeping and serve as a calibration guideline and documentation file for the farm audit purposes.

Tab. 1. Table to record the assumed, measured, calculated and determined calibration data

ORCHARD			Spray Volume [l/ha]	AIR FLOW			TRACTOR		NOZZLES		DRIVING		Driving Velocity [km/h]	Nozzle Flow Rate [l/min]	Pressure [bar]
Tree Height [m]	Tree Width [m]	Interrow [m]		Gear / Blade Angle	Output [m³/h]	Range / Direction	Gear	Obroty [obr/min]	Number [pcs]	Size [ISO]	Driving Distance [m]	Driving Time [s]			

Spray volume determination

In the regions with more or less uniform fruit crop structures i.e. uniform training system of slim trees (leaf-wall) and standard interrow distance of 4,0 or 3,5 m the spray volume may be determined based on the tree height, the parameter which may vary between orchards. However in most countries the diversity of orchard types and crop canopy volumes is very big, thus the interrow distance and canopy width also have to be taken into account. In this case the tree-row-volume (TRV) concept seems to be the best way to determine the spray volume (Fig. 1).

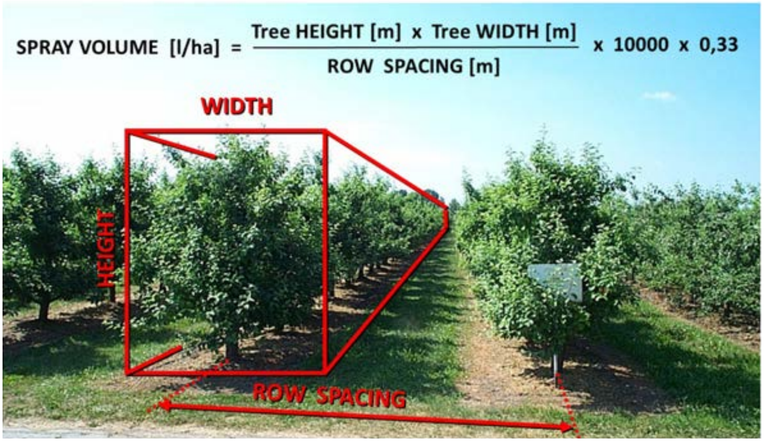

Fig. 1. Tree Row Volume concept to determine spray volume adapted to specific orchard.

For calculation the formula (1) can be used:

$$Q = \frac{H * W}{R} * 10000 * k \qquad (1)$$

where:
Q – spray volume (l/ha)
H – tree height (m)
W – tree width (m)
R – interrow distance (m)
k – unit volume (l/m^3)
The unit volume k expresses a volume of spray liquid per 1 m^3 of canopy volume, which is assumed to produce biologically efficacious spray coverage on the target (canopy foliage). For the orchards in Poland the unit volume k takes value 0,033 l/m^3 which has been tested during the efficacy trials performed in different orchards and with different application methods (Doruchowski et al., 2003). Having used this value in eq. (1) it takes a simple form as below (2):

$$Q = \frac{H * W}{R} * 330 \qquad (2)$$

Thus, in order to calculate the spray volume adapted to the specific orchard the operator needs to measure the basic dimensions of trees and know the tree row spacing.

Air flow adjustment

Three parameters of the air flow should be adjusted: air volume/velocity; air flow range; air- flow direction/deflection (where adjustable). The air flow volume should be big enough to penetrate the crop canopies, but not too big to avoid blowing the spray through the trees (Fig. 2A) and hence reduce on-target deposition and increase the spray loss. Results of field tests show that especially in dwarf and semi-dwarf orchards excessive air flow volume decreases the spray deposition on the tree foliage due to loss of spray being blown through the canopies (Hołownicki et al., 2002). This loss may be reduced by deflecting the air jet backwards up to 30° in sprayers that have individually adjusted air spouts or deflectors with adjustable air slot. (Hołownicki et al., 2000) (Fig. 3).

Fig. 2. Air flow adjustment: A – to big air flow volume resulting in spectacular spray loss;
B – correctly adjusted air flow volume with minimum spray loss.

Thus, the setting of the air flow aims at minimum spray loss because at the same time it is also likely to enhance on-target spray deposition. Since the loss of spray to the air (drift) is spectacular the correct air setting may be assessed visually by the grower himself when spraying on trees with clean water. The air-flow volume and deflection should be adjusted and correlated with the driving velocity of the sprayer so that a complete penetration i.e. full displacement of air in canopy volume is obtained. This is achieved when the crop canopy is filled with spray, and yet no or little spray cloud is observed on the other side of the crop row (Fig. 2B). The lower air-flow velocities should be used at early growth stages as well as narrow and open canopies. Higher air-flow velocities are used for bigger and denser crop canopies, at higher sprayer velocities, and at stronger winds. Finally the range of air flow is adjusted by vane often mounted at the top of the fan or deflector (Fig. 3). In the directed air-jet sprayer the range is adjusted by setting the position and direction of individual air spouts according to the tree size. Having obtained a desired effect during this visual assessment the setting of the fan (transmission gear, fan blade angle) as well as tractor engine RPM and gear box should be recorded in the Tab. 1.

Fig. 3. Cross-flow sprayer with an adjustable air deflector: top vane to adjust air flow range and adjustable air slot to deflect the air flow backwards.

Nozzles

When in orchard, with a sprayer filled with clean water, the number, configuration and type of nozzles are adjusted. The nozzles that spray over or under the tree canopies should be shut-off. The number of nozzles that remain open (n) is to be taken into consideration as the calibration proceeds. If the nozzle position can be adjusted on the sprayer they should be spaced closer where the crop canopy is wider and denser, usually at the bottom.
On modern sprayers multi-nozzle holders are mounted and they should be equipped at least with one set of fine spray nozzles and another one with coarse spray nozzles. Such arrangement allows quick adapting of spray quality to the circumstances, namely kind of chemical, controlled organism and weather conditions. During the wind the coarse spray nozzles should be used to reduce drift and ensure more spray being deposited on the target.

Completing the procedure - driving velocity and nozzle flow rate

For the tractor settings as identified during the air flow adjustment the driving test is performed at a defined distance (e.g. 100 m), and time of driving is measured to calculate the driving velocity according to eq. (3):

$$v = \frac{s}{t} * 3,6 \qquad (3)$$

where:
v – driving velocity (km/h)
s – driving distance (m)
t – driving time (s)
Having all needed data recorded in the Table 1 we may calculate the nozzle flow rate (4):

$$q = \frac{Q * R * v}{600 * n} \qquad (1)$$

where:
n – number of open nozzles (pcs)
The last parameter to determine is a pressure for the nozzles assembled on the sprayer to discharge the requested (calculated) flow rate. It is found in the nozzle table.
The last but very important thing to do is setting the determined pressure, checking the actual flow rate of a few nozzles and making corrections in case of deviations from the requested flow rate.
The described calibration procedure including three basic calculations, visual intuitive assessment of air-flow adjustment and simple measurement of nozzle flow rate makes it very simple to be performed by the grower himself and yet effective enough to bring economic and environmental advantages as described above.

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