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Dienstleistungszentrum Ländlicher Raum Rheinhessen-Nahe-Hunsrück, Bad Kreuznach

Methodology and sampling technique of spray deposit and distribution measurement in orchards

Überlegungen zur Methodik der Untersuchung von Belagsmassen und deren Verteilung bei der Applikation von Pflanzenschutzmitteln in Obstanlagen

Heribert Koch and Horst Knewitz

Abstract

The investigation of spray deposits in orchards is carried out to describe the application quality in terms of deposit level and variability, sprayer function and adjustment. Very different sampling techniques are used, making the comparison of data difficult or impossible. Differences are observed concerning the sampling unit, being artificial or natural. Sampling procedures are random samples or differ in stratification. Deposit measurement is done by analysing individual units or bulk samples. Another aspect of confusion is different understanding of deposit which can be coverage, number of particles/cm² or initial deposit (ng/cm² or ng/g freshweight). A sampling technique is proposed which enables to assess the magnitude and variation of deposits on single leaves as well as the spatial deposit distribution in a tree row.

Key words: Sampling technique, spray deposit measurement, orchard, sprayer adjustment, plant protection products

Zusammenfassung

Untersuchungen der Belagsmassen in Obstanlagen werden mit dem Ziel durchgeführt, die Applikationsqualität zu beschreiben. Dabei geht es um das Niveau der Belagsmassen und um deren Variabilität mit Blick auf die Gerätefunktion und Geräteeinstellung. In der Literatur werden sehr unterschiedliche Stichprobenverfahren beschrieben, was den Ergebnisvergleich schwierig macht. Unterschiede bestehen insbesondere hinsichtlich der Stichprobeneinheit, die ein natürlicher oder künstlicher Kollektor sein kann, aber auch ein einzelnes Blatt oder eine Sammelprobe umfassen kann. Die Stichprobenverfahren können Zufallsstichproben sein oder unterschiedliche Stratifizierungen aufweisen. Weiterhin werden zur Belagsbeschreibung der Bedeckungsgrad, die Anzahl Tropfen je cm² oder der Initialbelag (ng/cm² Blattoberfläche oder ng/g Frischgewicht) verwendet. Für Obstanlagen wird ein Stichprobenverfahren vorgeschlagen, das es ermöglicht, die Belagsmasse auf einzelnen Blättern zu erfassen sowie deren Variabilität zu schätzen und darüber hinaus ein Abbild der spatialen Verteilung im Baum zu liefern.

Stichwörter: Stichprobenverfahren, Belagsmessung, Obstanlage, Sprühgeräteeinstellung, Pflanzenschutzmittel

Introduction

The general interest for understanding pesticide spray deposition on a crop is recognised in the almost stereotype and permanent repeated request of uniform distribution on the canopy surface. Uniform distribution promises to minimise the delivered chemical dose.

It is assumed that uniform distribution or low variability of deposits allows to reduce the delivered chemical rate and achieve deposits that result in acceptable biological efficacy. This postulate includes:

- a minimum deposit on targets is needed in order to achieve the intended biological efficacy,
- the minimum required deposit depends on the delivered chemical rate,
- in principal it is technically possible to achieve a uniform distribution on targets in a crop.

Deposit measurements reported in literature are carried out according to very different methods. Sampling technique, sampling unit (type, size and number), sample size and as well the measuring technique vary. Some examples may give an impression of the situation.

KÜMMEL et al. (1991) placed artificial collectors (filter papers) on a permanent wire construction in a tree row, allowing repeated measurements at the same row position or tree structure in an orchard. MURRAY et al. (2000) report a technique to perform multiple applications using metal chelate tracers.

Many other authors stratify the tree crown into blocks or sampling zones were artificial collectors, e.g. filter papers (SOLANELLES et al., 2001), ribbon targets (SALYANI and FAROOQ, 2003; 2005) or water sensitive papers are placed in the tree crown (De Moor et al., 2000; NIEDERHOLZER, 2004). Leaves (KOCH et al., 1992) or shoots (WHITNEY and SALYANI, 1991) were also used as sampling unit out of block shaped target zones. Other data are based on random or stratified samples where the deposit is investigated on the natural targets, e.g. leaves, buds, shoots or fruits (SCHMIDT and KOCH, 1995; CROSS et al., 1997; JAEKEN et al., 2001; JAEKEN, 2002). GANZELMEIER and SCHMIDT (2003) have argued for harmonisation of the sampling procedure and referred to the method described by SCHMIDT and KOCH (1995).

An additional aspect of confusion is the fact that deposition is often understood as quantity of chemical (ng/cm² or ng/g freshweight), as coverage (% covered surface area on target) or as number of particles/cm², investigated on artificial collectors or natural targets as well. More detailed analysis of upper and lower leaf side (HOLOWNICKI et al., 2004) focus on other effects and the results describe the deposition again in a specific way.

Such different procedures of data generation and interpreting parameters and the variation in sampling and measuring units makes a clear comparison and interpretation quite complicated or almost impossible. Statistical parameters like mean or coefficient of variation depend on sampling unit and sampling procedure as well as on sample size. However, it is important to understand sampling and measuring procedures in order to compare and interpret results and limitations of comparability. Apart from statistical aspects like frequency distribution or mean and variation of deposits it is much more important to understand the spatial distribution in the trees which results from the geometrical relation between nozzle position/orientation and air flow direction of the sprayer and tree geometry itself. The spatial distribution pattern of deposits allows to detect low deposit zones in the canopy and subsequent adjustment of the sprayer configuration.

The investigation of the variability of spray deposits requires to sample and analyse units that are biologically relevant. Such a unit is an individual unit, e.g. a leaf, a bud or a fruit. A possible parameter is the coefficient of variation (CV %) calculated from the deposit (ng/cm²) of individually analysed units and the portion of units with low deposits. Such data are available for a series of plant species (KOCH and WEISSER, 1994; 2001) and show that the deposits on leaves as achieved from spray application are typically characterised by a CV (%) between 40 and 80 %. This can be interpreted as uniform, because it describes the "natural and system inherent variability" which cannot be reduced due to the indirect dosing process, consisting of overlapping random processes (KOCH, 2005). For apple leaves but also for other targets the range between lowest and highest deposit, expressed as ng/cm² is roughly a factor between 12 and 15 (KOCH and WEISSER, 1994).

What is deposit and what parameter should be focused on?

Coverage

Coverage means the percentage of plant surface that is covered or contaminated with chemical. It is a matter of fact that coverage is almost solely depending on delivered water volume. In former days growers applied "to run off" which guaranteed maximum coverage (the canopy was "washed") although losses were not considered. It is concluded that if coverage is of major interest the water volume should be optimised. Investigating the coverage by using water sensitive paper (WSP) is very common but WSP hardly represents different plant surfaces in terms of their retention characteristics (HOLOWNICKI et al., 2002). Small droplets may not result in a visible or detectable dot. Coverage does not provide information about the magnitude of chemical on the target.

Number of particles/cm²

It is not clear what importance the number of droplets per cm² has. On the other hand it is very clear that the number of particles per unit leaf surface depends on the droplet spectrum and if a high number is preferred, a fine droplet spectrum is required or the water volume has to be increased.

It can be stated that over the past 20 years and as the drift issue became more relevant, many efforts were made to increase droplet size and to reduce the fine drop volume. Political and ecological pressure to reduce drift has forced a trend to "coarse droplet application" which may be interpreted in a sense that the number of droplets per unit plant surface is not as relevant as sometimes considered.

Initial deposit

It is absolutely clear that the initial deposit, expressed as ng/cm² on targets (leaf, bud, fruit, upper or lower side of a leaf etc.) in a sprayed canopy is the effective dose on a single target and thus is a key parameter of efficacy and of all other processes following retention and deposit formation. Consequently deposit measurements should reflect the variability of deposits on individual target units. Leaves with a low a.i. deposit will probably show disease infection earlier than leaves with sufficient or high deposit. On the other hand and from the perspective of the spraying technique, it is essential to get information about the spatial or geometrical distribution of deposits. In other words, it is necessary to understand what kinds of individual deposits are achieved. In the same way it is important to understand in which sector of the canopy higher or lower deposits occur. This aspect of geometrical distribution is of major importance when sprayer adjustment, nozzle orientation and air stream homogeneity are considered and shall be optimised.

Artificial or natural collectors

Artificial collectors like filter papers have been used in many investigations as outlined above. The advantage clearly is the standardised collector size and the possibility to conduct subsequent measurements at the same site, in the same tree. On the other hand artificial collectors show different deposition characteristics in comparison to leaves or fruits. This in turn affects the retention process and the formation of the initial deposit. Placement of such collectors is very labour intensive. Deposition measurements are mostly done with tracers. Depending on available analytical equipment researchers use fluorescent dyes or e.g. metal compounds which can be detected by atomic absorption spectrometry. Here, the sensitivity of the system is relevant as well as appropriate stability of tracers on the investigated surface in sunlight at the trial location and time.

Sampling unit

Deposit measurements are intended to describe the result of the work of a sprayer which is the initial deposit on the canopy as a whole and more detailed on the individual targets. The second main purpose is to investigate processes of deposit formation with respect to biological efficacy, residues or side effects (KOCH and WEISSER, 1995). From this perspective it seems to be necessary to investigate the deposit on individual target units, like leaf, upper or lower leaf side, bud, fruit or berry. This sampling unit should be the measuring unit in order to provide full information about the variability of deposits. Bulk samples may be easier to handle and useful to assess the mean deposit but information about deposit variability is lost.

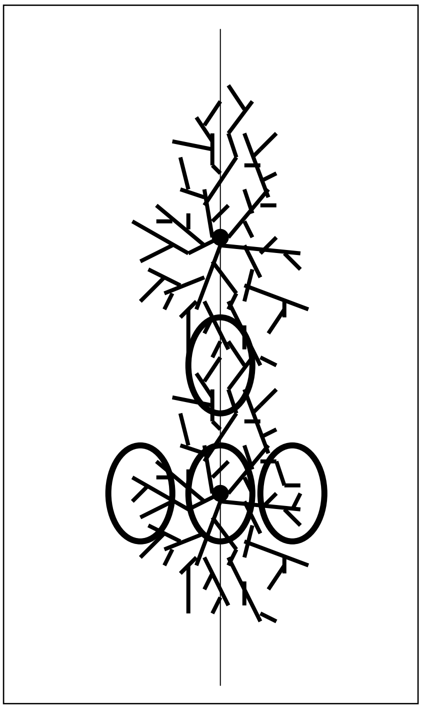
Proposed stratified sampling procedure

The appropriate sampling procedure shall consider what questions have to be answered and what structure is expected in the investigated population.

In our case initial deposits on leaves are investigated in order to provide information about average deposit, deposit variability and the spatial distribution of deposits in the canopy. Thus the position of sampled leaves must be recorded to be able to reconstruct the geometrical situation.

Investigations done by SCHMIDT and KOCH (1995) were aimed to compare sprayer adjustment at a static vertical patternator with the distribution pattern created in the dynamic application situation in trees. The sampling procedure should ensure a vertical profile over crown height and include the whole variability of deposits. The stratification of the fruit wall into vertical sampling zones and the documentation of the height position of each sampled leaf allows to describe a vertical deposition pattern. This in turn enables to understand the relation between nozzle orientation and deposit formation. It was decided to take 30 individual

Fig. 1: Schematic top view of 2 trees indication sampling zones: left, trunk, right and crown overlap in fruit trees (in driving direction). Leaves are taken from 5 trees.



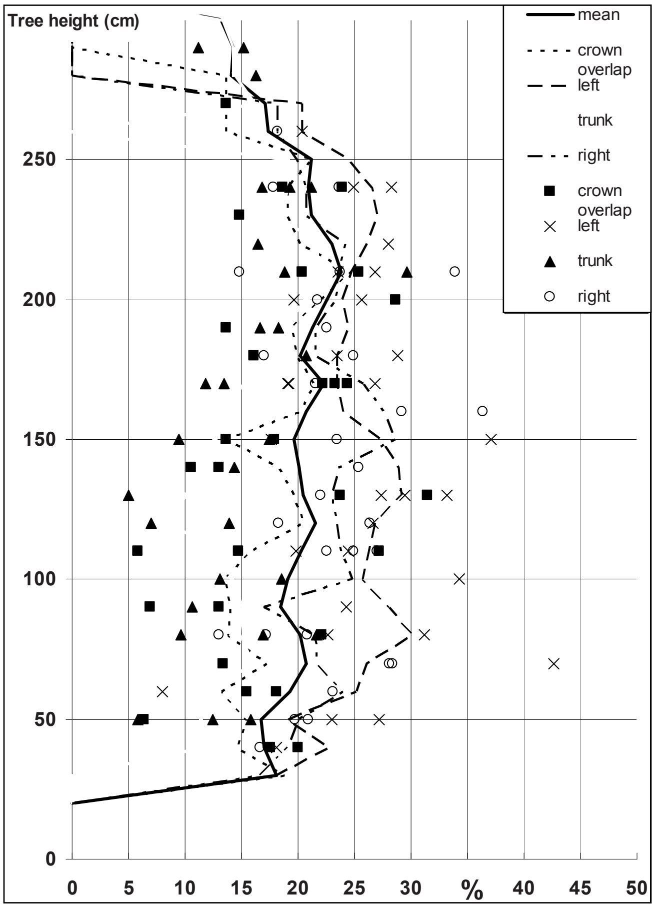


Fig. 2: Example of the vertical distribution pattern in 4 sampling zones in apple, including the average profile. Relative initial deposits (%) on individual apple leaves in relation to delivered quantity per 10 000 m² fruit wall (ng/cm² leaf surface per g/10 000 m² fruitwall). Sprayer: Lochmann RA 15-80 axial fan, ID 90 02, 10 bar, variety Golden Delicious.
Single dots indicate deposits of individual leaves. Sampling heights are recorded at in 10 cm steps. Curves are running means for the 4 sampling zones over height. The total mean results in an almost vertical line which indicates a most uniform distribution.

leaves out of 4 sampling zones over canopy height and record the height above ground in 10 cm steps. Sampling should be done out of 5 trees.

The sampling zones (fig. 1) are:
A) canopy zone where trees of adjacent trees overlap,
B) outer canopy zone at the right side of the row,
C) inner canopy zone close to the stem,
D) outer canopy zone at the left side of the row.

Deposits are expressed as percentage of the nominal dose rate, expressed as g tracer/10 000 m² fruitwall.

In total 120 values are transferred into an Excel-datasheet. Data are used to calculate mean, standard deviation and coefficient of variation (%) for the 4 zones as well as overall.

The second analysis describes the vertical distribution profile by calculating the running mean over the height (fig. 2). Ideally this running mean should be a vertical line which indicates the most uniform distribution pattern. Curved profiles show inhomogeneous distribution and require adjustment of nozzle orientation or air flow direction towards the allocated canopy zone.

Discussion

In literature a wide spectrum of sampling and measuring techniques is recognised, making a comparison of results difficult or even impossible. Facing the widely accepted understanding that the distribution of chemicals on canopies must be uniform in order to achieve acceptable biological efficacy with minimum dose it is necessary to investigate deposits and their distribution pattern on treated plants and in real canopies. Beside all technical and personal limitations a minimum consensus should be achieved in order to allow clear understanding and interpretation of data in the ongoing discussion about dose expression and dose determination, sprayer calibration and adjustment, water volume, nozzle configuration and sprayer design.

For various reasons natural targets should be preferred as collectors because they are positioned and aligned in their crop typical habit. In addition they also summarise all surface characteristics as they are expressed due to crop, variety, growth stage, actual weather conditions, retention capacity, region, meteorological history, etc. Any artificial collector will exclude such effects. The advantage of artificial collectors is standardisation, the disadvantage is the loss of information about the variability of crop specific deposit formation.

The most informative sampling unit is a part of the crop that is relevant in the sense of biological efficacy. This is e.g. the individual leaf, bud or fruit. It might be part of it or upper side and lower side if appropriate and technically possible.

If the application quality of sprayers, their adjustment and other technical issues are investigated in fruit crops the single leaf might be the best applicable sampling unit. Leaves fill the orchard geometry in terms of canopy size. The leaf is the “target unit” for important diseases like scab, meaning the chemical quantity on a single leaf is the “efficacy relevant dose”. In this sense it is necessary to investigate and describe the total variability of deposits in the sample rather than to exclude it. Only if the total variability is known and it is possible to relate low deposits to sprayer function or nozzle orientation respectively, options are open for appropriate adjustment and improvement in the sense of reduction of deposit variability.

Many researchers take a random sample of leaves out of the tree. This intends that each of the leaves has the same chance to be sampled which in practice is more theoretical than realistic. A random sample in it's original sense would mean with respect to deposit measurements that not leaves are sampled but leaves with deposit, according to their frequency as they occur in the population (which is unknown but generally skew). Beside this theoretical and practical problem random samples only provide limited information. Data compiled from random samples only allow statistical interpretation, e.g. to calculate mean and standard deviation or coefficient of variation (%). It is impossible to derive information about the spatial deposit distribution and the allocation to e.g. a zone that is covered by a single nozzle.

A random sample as well as the stratification in sampling zones or blocks ignores the relation or geometry between sprayer and tree row. On the other hand investigations of the distribution pattern in trees, achieved by single nozzles (KOCH et al., 1998) show the need to describe and understand the spatial distribution pattern over height and depth of the tree crown. Such information is essential if effects of sprayer configuration, nozzle settings, etc. are investigated.

From this point of view it is much more informative to apply a sampling procedure which allows interpretation of the spatial distribution of deposits in relation to the application equipment (SCHMIDT and KOCH, 1995). Because the spray is delivered by a set of nozzles with overlapping spray fans and obvious effects of nozzle orientation, as well as flow rate, deposits in different zones of a tree are affected when nozzle orientation or air flow change. To investigate effects as nozzle position, nozzle orientation, air volume and air flow direction, etc. it is important to document the position of sampled leaves in the canopy and to use this information for the improvement of sprayer adjustment. It has been proved to be appropriate to document the height position of sampled leaves in fruit trees. Deposit values then can be transformed into a vertical deposition profile which corresponds to nozzle orientation and air flow characteristics. It is recommended to divide fruit trees into sampling zones. Typically samples are collected from the front and back side of treated tree rows and in the centre zone around the stem which is assumed to be the most difficult sector. Our proposal is a 4th zone where branches of neighbouring trees meet and overlap. (SCHMIDT and KOCH, 1995), 30 leaves out of each of the 4 zones in modern trained fruit trees are sampled over tree height. Leaf height position is documented in 10 cm intervals. An Excel data sheet is used to assemble and document the data and to calculate the running mean over tree height which illustrates the vertical distribution profile in the four sampling zones and in total. This profile can be related to the nozzle and air flow configuration of the sprayer and in turn can be optimised in order to achieve an almost vertical line, representing the mean deposit over tree height. This sampling procedure allowed KOCH et al. (1998) to investigate the single nozzle distribution profile and to identify the centre of the spray swath of each single nozzle and to allocate the scan position of the sensor.

An important aspect of deposition measurements is the work load of such investigations. Calibration, adjustment and configuration of the sprayer, application, sampling of leaves (or placement and sampling of artificial collectors) and analysis is time consuming and requires a sophisticated logistic which depends on available measuring techniques. Apparently artificial collectors are standardised in size and need no measurement of the collecting surface. Their clear disadvantage is that they do not represent the retention characteristics of leaves or fruits.

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Contact address: Dr. Heribert Koch, Dienstleistungszentrum Ländlicher Raum Rheinhessen-Nahe-Hunsrück, Rüdesheimer Str. 66-68, 55545 Bad Kreuznach, Deutschland, E-Mail: heribert.koch@dlr.rlp.de