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A proposal for a higher tier investigation of pesticide drift exposure to non-target organisms (NTO) in field trials

Ein Methodenvorschlag zur Untersuchung von Effekten driftbedingter Pflanzenschutzmittel-Exposition auf Nicht-Ziel-Organismen im Freiland

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Abstract

A trial methodology is described which would allow the investigation of drift dose effects of herbicides on plants in the field. The deposition process of drifting droplets resulting from spray application differs enormously from the retention process of a spray. The proposed methodological approach would provide a drift dose response of herbicides in field trials and could be an alternative to current laboratory dose response assessments using spray applications of different dose levels. Field drift trials also cover the observation of plant recovery, because a longer observation period is possible. The proposed methodology offers the possibility of higher tier effect investigation in the risk assessment process of pesticide registration.

Key words: Risk assessment, pesticide registration, non-target organisms, drift exposure, field trial

Zusammenfassung

Ein Methodenvorschlag wird vorgestellt, der die Untersuchung realer Driftexposition durch Herbizide im Freiland ermöglicht. Bisher wird die Dosis-Wirkungs-Beziehung von Drift durch Applikation reduzierter Aufwandmengen im Spritzverfahren simuliert. Der Depositionsprozess von verdriftenden Tröpfchen ist allerdings sehr verschieden von der Retention im Spritzbereich. Das vorgeschlagene Verfahren könnte Drift-Dosis-Wirkungs-Beziehungen im Freiland liefern und damit eine Alternative zur derzeit praktizierten Spritzapplikation gestaffelter Aufwandmengen im Labor geben. In den Felduntersuchungen könnten Effekte über einen längeren Zeitraum beobachtet werden, z. B. die Wiedererholung der exponierten Pflanzen. Der vorgeschlagene Ansatz eröffnet Möglichkeiten zu einer höherstufigen Risikobewertung von Abdrift in der Pflanzenschutzmittelprüfung.

Stichwörter: Risikobewertung, Pflanzenschutzmittelzulassung, Nicht-Ziel-Organismen, Driftexposition, Freilanduntersuchung

Introduction

Registration authorities recognise pesticide drift as a major exposure path for non target organisms. This assumption is based on drift sediment measurements which are done by collecting drift sediments on artificial plane collectors. Petri dishes are placed downwind on bare ground or cut meadows (BBA, 1992; GANZELMEIER, 1995).

Different processing and interpretation of such data sets have led to different standard drift values in different countries and discussions concerning their use and applicability do continue.

In the risk assessment of the registration process, TER (Toxicity Exposure Ratio) values are calculated, setting the PEC (Predicted Environmental Concentration) in relation to the toxicity data from standardised laboratory trials (OECD, 2003). These laboratory trials are done by spray application of a range of dose levels, usually with comparably high water volumes. This laboratory test leads to a dose response curve describing the relation between calculated nominal dose rate and observed effects. It simulates a field spray application but **not** the processes that create drift deposits. Especially, it does not create realistic deposits or deposit structures, as the deposits created are atypical for the retention of drifting particles (KOCH et al., 2004).

Today, higher tier studies are done in the field using the same design and application technique as in the laboratory trials (DE SNOO et al., 2001). The major differences are plot size, age of plants and the meteorological conditions. Drift and resulting drift deposits on single plants or individual targets are highly variable due to the almost infinite possibilities of target shape, inclination and position in a canopy. This seems to be in contradiction to the need for reproducible trial results but may be an explanation of elasticity in any biological reaction.

KOCH et al. (2004) conducted trials to visualise drift deposition patterns and showed that drift deposits differ enormously from spray deposits. They also demonstrated the different reaction of young plants typically used in laboratory trials compared to field grown plants. In their investigation, they used Paraquat to visualise drift patterns in undisturbed canopies and described a drift dose response relation in the field.

This paper outlines the approach and discusses the methodology and its possible adaptation for a wider use.

Dose response and spray deposit – dose response and drift deposit

Before describing the trial set up and conduct, some terminology should be clarified. In arable crop spraying, dose rate means the quantity of product delivered to an oversprayed ground area ($kg/10,000\,m^2$) which is termed the **nominal dose rate**. This principle of dosing is an indirect dosing procedure. The dose rate is not related to a target unit (plant, leaf, etc.) but to the oversprayed area independent from individual target units that may cover this area or not (KOCH, 1992). For example, leaf area indices (LAI) or other canopy describing parameters are not taken into account.

Fig. 1. Plot and drift zone with marked sampling positions (yellow sticks in the drift zone).

On the other hand, biological effects (efficacy or toxicity) depend on the quantity of chemical on the target itself, e.g. ng/cm² leaf surface, and also on the contaminated surface area or interface area. The amount of product retained on a target (e.g. leaf, fruit, etc.) is termed as **deposit,** and is usually calculated as the mean of individual values (KOCH, 1993). KOCH and WEISSER (1995, 2001) have emphasised the target specific relationship between nominal dose rate and deposits on targets within this area. Overlapping random processes within the application process itself result in a wide variation of individual deposits for a single application. A clear target specific relation between nominal dose rate and mean deposit is observed from a series of deposit measurements (KOCH and WEISSER, 1995).

The allocation of the dose rate to the oversprayed ground area and the obvious relevance of deposit to the target itself illustrates the indirect character of the way the dose is expressed.

Beyond this basic element of pesticide spray application, there is no clear and principle relation between nominal dose rate and initial **drift** deposits on plant surfaces. Drift deposits occur as a gradient, decreasing with distance from the sprayed area, but they are highly variable within the canopy, i.e. in the horizontal and vertical extension of the canopy structure (KOCH et al., 2003). Drift creates a patchy deposition pattern in a canopy. The most important driver is the fine drop volume. Drifting particles are typically less than 100 μm in size (KOCH, 2003). Canopy roughness (TESKE et al. 1997) and small scale turbulence dominate air movement in the boundary layer (BÖTTCHER, 2000) and thus control the particle transportation as well as the retention process (KOCH et al., 2004).

Drift has been investigated usually by using artificial collectors (GANZELMEIER,1995; STALLINGA et al., 1999; Spray drift task force, 1997; MILLER, 2000; PRAAT et al., 2000). As drift deposits are supposed to be the relevant exposure route for NTOs (non-target organisms), the structure as well as the magnitude of deposition should be examined in relevant undisturbed canopies. From this point of view, the general assumption that relates a percentage of the nominal dose rate to a distance from the field edge may be discussed.

One possibility to describe a dose response relation of drift is to relate exposure effects to initial drift deposits on plants.

Set up of drift deposit measurement and drift effect assessment in field trials

As an example KOCH et al. (2004) have demonstrated the drift dose relationship for Paraquat in wheat. The application was done under conditions that encourage drift in order to achieve an extended drift gradient.

A meteorological pole equipped with sensors for wind direction and wind velocity mounted 2 meters above ground is needed. Additional sensors for air humidity and air temperature are useful to describe and document the application situation. Favourable meteorological parameters are: temperature below 25 °C, humidity above 40 %, and wind velocity between 3 and 7 m/s (Fig. 2).

Using a plot sprayer and nozzles with high drift potential allow a crop/canopy to be treated with respect to the aim of study, i.e. plants, plant age, etc. can be chosen as required. Before performing the application, it is necessary to align the


Fig. 2. Application with a plot sprayer under drift provoking conditions to assure an extended drift gradient (wind velocity = 7 ms; nozzle: XR 110 02, 2.1 bar, fine drop volume ~10 %, 200 l/ha).

Fig. 3. Drift deposition pattern after Paraquat application, visualisation of the patchiness of drift deposits. Bleached spots are resulting from retained drifted droplets.

driving direction of the plot sprayer perpendicular to the actual wind direction. Within the drift zone, all levels of drift exposure are expected but cannot be allocated in advance. Nevertheless, 20 to 30 positions should be marked before application or at the moment of sampling (Fig. 1). The positions may be distributed throughout the drift zone at random. They should cover both the maximum expected deposit close to the sprayed plot and areas of very low exposure, by using positions far enough away from the sprayed plot. As a matter of experience from former described investigations 10 meters are said to be sufficient for accurate drift dose assessment. To relate deposit (dose) and effect, a tracer is added to the spray liquid. KOCH et al. (2003) used sodium-fluorescein (50 g/ha) for the investigation of deposits on plant surfaces because of it's high sensitivity. The tracer is soluble in water and allows to quantify the deposits at the marked positions in the drift zone. The tracer deposit is measured using UV fluorescence spectrophotometry, expressed as ng/cm² leaf surface. Quantity and characteristic of the tracer must ensure adequate quantification within a wide interval of drift deposits and a low limit of detection.
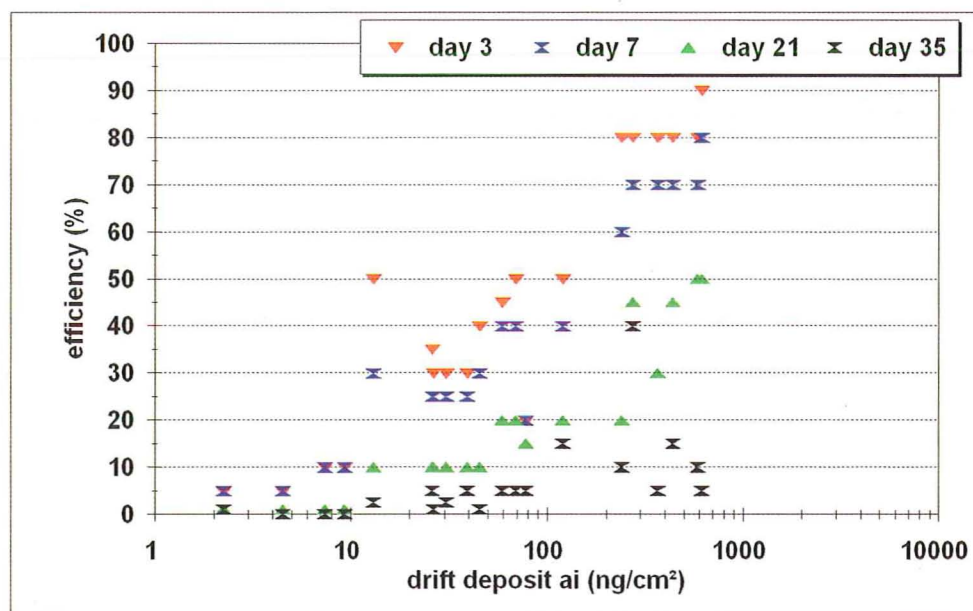
The measured deposits can be recalculated to the active ingredient (i.e., chemical) deposit. The determination of chemical deposits is possible, but requires techniques such as LCMS and is therefore much more expensive.

It is assumed that such tracer deposits at the sampling positions roughly represent the chemical deposits at the effect assessment sites, although we know that drift deposits are scattered and occur in a patchy pattern (KOCH et al., 2004). Depending on the formulation of the compound, the ratio between tracer and chemical in droplets prone to drift (< 100 μm in diameter) and here of particular interest, needs to be investigated in order to allow chemical recalculation from tracer deposit.

Biological effects are assessed separately and subsequent to the quantification of initial drift deposits. This assessment needs a clear decision concerning the appropriate parameter. For Paraquat effects on wheat, KOCH et al. (2004) assessed the affected leaf area (Fig. 3).

For compounds with other modes of action differentiated assessments are necessary. The methodological approach allows any number of sampling sites in the drift zone and repeated assessments of the effects over an adequate time period (i.e., chemical specific). At least for herbicides, the observation of the development of effects over a certain time period allows to observe such subsequent effects as recovery of plants to be assessed in a real field environment (Fig. 4). Recovery from herbicide exposure needs more attention in this branch of risk assessment and the described trial design is a possible approach to deal with this aspect.

Before any investigation is conducted the procedure of deposit quantification must be clarified. This includes tests that verify that the used tracer represents the product under test. If no tracer is appropriate the active itself must be analysed and quantified as the relevant exposure.

Discussion

The investigation of effects related to drift from pesticide application is a major issue of risk assessment in pesticide registration. Today, no practicable method is available to investigate effects of real drift deposits in the field, although it is obvious that the investigation of drift should evaluate real drift deposits and their effects. Unfortunately current test methods

Fig. 4. Dose response of Paraquat drift exposure on wheat over 35 days.

lack realistic trial designs because real drift scenarios seem to be too difficult to be investigated in standard trials. Currently, spray applications with reduced dose levels are favoured to obtain effects of estimated drift exposure because of methodological reasons. The established procedure for herbicide testing is based on laboratory trials as described in the OECD guideline 227 (OECD, 2003). Such trials are relatively fast and cheap but do not consider the different physics of spray retention compared to the transport of drifting droplets, resulting in differences in particle retention and deposition pattern. This difference can be described in terms of the magnitude of chemical deposit (ng/cm²) as well as with coverage (% contaminated plant surface) (KOCH et al., 2004) and patchiness of droplet retention. Spray deposits are intended to be homogeneous and high in number/cm², while drift deposits resulting from modern spraying technology are highly inhomogeneous and decrease rapidly in number/cm² within very short distances due to low drift potential of spraying techniques and the filtering effect of canopies.

The described proposal offers an opportunity for a higher tier approach under more realistic conditions such as application, droplet retention, deposit creation and exposure, plant condition and canopy structure, etc. They include the existing field variability of ecosystems which is a basic element for the stability of populations and their reaction to stressors.

The described trial methodology enables studies in undisturbed canopies with plant communities under field conditions. Further investigation and consideration is needed to decide upon appropriate parameters that are used to assess effects. Effects of a product like Paraquat which creates clearly visible leaf spots is easy to judge, e.g. similar to the assessment of leaf damage due to powdery mildew or other leaf diseases. Other suitable parameters might be e.g. plant growth reduction or any other parameter typical for phytotoxic effects.

The general problem with drift investigations is that they have to be performed under conditions where drift is provoked and enhanced (KÜHNE et al., 2002). Thus extreme situations are described. It is necessary to illustrate the general meaning of such results.

The approach does not provide an answer coping with the relationship between actual drift deposit and distance to a sprayed field because the application technique as well as actual meteorological conditions are the dominant factors controlling drift processes and drift deposition at a defined position or distance. Such information may be derived from data as reported by KOCH et al. (2003) who investigated drift deposits with respect to different application techniques.

The term "dose" here means the magnitude of deposited chemical (ng/cm²). Drifting droplets are retained on any surface they hit and it is difficult or impossible to predict positions of defined drift deposition in a field situation. The drift quantity is dependent on the fine drop volume of the nozzles used, the boom height and the structure and roughness of the canopy over which the drift cloud moves.

Consequently, the same deposit might be observed at very different distances from the edge of the sprayed plot, depending on the above mentioned (influencing) factors.

Recent activities are ongoing to carry out investigations of drift deposits in wind tunnels. Principally it is assumed that the described procedure may also be applicable in the same way for the elaboration of drift dose response in a wind tunnel. In both trial set-ups the link to the drift sediments used for risk assess-

ment must be deduced. Such a calculation could be based on the total surface of the investigated canopy surface described by the Retention Area Index (RAI) (KOCH et al., 2004) The adaptation of the proposed test procedure on the investigation of insecticides requires further research with respect to insect specific features, e.g. mobility of the organism.

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