Comparison of dose response of pesticide spray deposits versus drift deposits

Dosis-Wirkungs-Beziehungen bei realen Drift-Belägen und bei Spritzbelägen

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Abstract

Drift deposits on wheat plants were quantified and corresponding effects of Paraquat assessed in order to describe drift dose response relations. Paraquat interrupts the photosynthetic process and chlorotic spots appear. The dose response of spray deposits was investigated in parallel on young wheat and alfalfa plants and on alfalfa plants grown from root stocks. There was a marked difference in deposition pattern as well as herbicidal effect. Plants in the field reacted quite differently to drift exposure compared with sown plants to spray application. Alfalfa plants grown from root stocks sprayed in the laboratory showed a distinct difference to plants grown from seed and recovered. Sown and tray grown wheat and alfalfa did not recover from spray deposits, even at low dose levels. The results illustrate the capacity of plants to recover as a relevant factor of risk assessment.

Key words: Drift, pesticide dose response, pesticide exposure, non target organisms, drift exposure, risk assessment

Zusammenfassung


Stichwörter: Abdrift, Dosis-Wirkungs-Beziehung, Pflanzenschutzmittelexposition, Nicht-Ziel-Organismen, Driftexposition, Risikobewertung

Introduction

Pesticide drift from spray application in agriculture is subject to intensive discussion and is judged by regulatory authorities to be a major exposure path for non target organisms in water courses and field boundaries. In Germany, basic drift values have been established (GANZELMEIER, 1995) for pesticide application risk assessment and for the classification and registration of drift reducing techniques (BBA, 2000). Within the pesticide registration process, companies are obliged to submit data showing dose response effects on non target organisms. These tests are carried out primarily in the laboratory. For investigating dose related herbicidal effects, glass house grown young plants are used. The application of the test plants is done by spray application with water volumes used typically by farmers (OECD, 2000). This type of application is intended to achieve a “good coverage” on the plants, meaning a large portion of the plant surface comes into contact with an active ingredient. The atomisation is characterised by a spectrum of droplet sizes which may bounce or run off at impact on leaves. The resulting data set describes the dose response of a spray application on glasshouse grown young plants. This situation is quite different to that of plant communities under field conditions exposed to drift. In laboratory tests, only young and sensitive plants are used for methodological reasons.

On the other hand, the process of drift deposition is quite different from the process of spray retention (KOCH et al., 2003). The various differences between the field and laboratory situations has lead to investigations to compare both procedures of “application”.

In this investigation, dose means the deposit on plant surfaces (ng/cm² leaf surface) and does not refer to the dose rate delivered per ha, unless mentioned explicitly.

Material and methods

Investigation of drift deposits on wheat under field conditions

A plot sprayer was used to apply 4 l of Gramoxone Extra per ha (100 g/l Paraquat) in a water volume of 200 l/ha. Paraquat is not systemic. It interrupts the photosynthetic process rapidly, destroys chlorophyll and creates chlorotic spots. This Paraquat specific effect makes the deposition pattern of retained drifting droplets perceptible. Drifting droplets are supposed to form a scattered deposition pattern. Their retention site should be identified by the Paraquat induced effect. To quantify the deposits on the leaf samples collected from the drift zone, 50 g/ha sodium-fluorescein were added to the spray fluid as a fluorescent tracer. The pressurised plot sprayer was equipped with 5 nozzles (TeeJet XR 110 02) at 2.1 bar.
Nozzle spacing was 50 cm at a height of 50 cm above the canopy. The application was carried out in wheat (BBCH growth stage 21, beginning to tiller) wind velocity approx. 7 m/s, i.e. out of the range of Good Agricultural Practice (ANON., 1998). The direction of spraying was aligned to be almost perpendicular to the wind direction. Under these conditions, an extended drift gradient was expected. In advance of the application, 16 positions in the drift zone were marked. After application and when the deposits were dry, leaf samples were taken at the marked sites. These leaf samples were used to quantify the drift deposit by measuring the fluorescence of the resolved sodium-fluorescein at a wavelength of 484 nm (excitation) and 512 nm (emission). The Paraquat affected leaf area was assessed throughout the period of the following 7 weeks at the marked sites where the drift deposit had been measured.

Fig. 1. Application with plot sprayer, wind velocity: 7 m/s.

Fig. 2. Spray and drift zone 10 days after Gramoxone Extra (Paraquat) was applied.

A second application was done in a set-aside meadow with single alfalfa plants scattered over the trial area. This application was carried out late in the season when the alfalfa plants were flowering and were not in the vegetative phase but in the generative phase. Alfalfa was found to develop very clear symptoms and was chosen as a second test species beside wheat.

**Investigation of spray deposits on wheat and alfalfa plants in the laboratory**

In a subsequent set of trials, glass house grown wheat plants (BBCH 21) were sprayed using a laboratory track sprayer, applying dose rates 1%, 5%, 10%, 20%, 30%, 40%, 50% and 100% of the registered dose rate (4 l/ha Gramoxone Extra) in a...
Results

Drift dose response on wheat in the field

Paraquat induced chlorotic spots with dark dots indicating the original drift particle deposit in the centre. Leaf section size: ca. 1.5 x 3.0 cm.

Fig. 8. Paraquat induced chlorotic spots with dark dots indicating the original drift particle deposit in the centre. Leaf section size: ca. 1.5 x 3.0 cm.
leaf damage resulted from a drift deposit of about 100 ng/cm². More than 80% damage was not observed at the marked positions. In the following weeks, we assessed reduced effects as shown in fig. 4. In practice, the size of the affected leaf area was not reduced but the portion decreased due to the development of subsequent leaves. Within the following 35 days, wheat did not show growth interruption or delay. The plants continued to grow and developed much as unaffected plants. No difference in grain yield was observed between drift affected and unaffected plants (unpublished data from STRUB, 2002).

Spray dose response on glass house grown wheat in the laboratory

Paraquat induced chlorosis from spray application in the lab was assessed and deposits were measured in the same way. Figure 5 shows the spray dose response of the tested dose levels and repeated assessments over 7 weeks in glass house/tray grown wheat. Deposits ranged from 13 ng/cm² to approximately 1000 ng/cm² and were the result of defined dose rates per ha delivered in a water volume of 200 l/ha. Leaf damage and the affected area increased until day 14. 50% leaf damage was achieved by a drift deposit of about 110 ng/cm². No recovery or plant growth was observed in the following two weeks.

Alfalfa laboratory, sown plants and root stock grown in the glass house

Alfalfa sown in trays was treated 8 weeks after sowing with a set of dose rates using the laboratory track sprayer. Deposit measurement and damage assessment were done as described above. Figure 6 shows the affected leaf area in relation to spray deposits over a period of 35 days. The maximum effect was observed on day 7 and remained at the same level at all investigated dose levels. No recovery was observed, surprisingly not even at the lowest tested dose (1%). Dose response relations were approximately: 10% damage at 70 ng/cm²; 50% damage at 200 ng/cm²; 90% damage at 1000 ng/cm².

From a set aside meadow, alfalfa root stocks were dug out and grown for some weeks in trays under glass house conditions. The plants emerging from these rootstocks were sprayed and investigated in the same way as described above. The maximum affected leaf area was observed on day 7. The results in fig. 7 demonstrate the recovery as reported from the field grown wheat plants, indicating again that the individual condition of the plants, their growth capacity and their nutritional reserves are major elements of recovery. 10% affected leaf area was related to a deposit of approx. 100 ng/cm², 50% to 600 ng/cm², 90% was not observed, even at full dose.

Discussion

The quantification of drift deposits on plant surfaces and associated effects is a new approach to demonstrate the dose response of chemicals caused by drift exposure, and Paraquat is an appropriate active ingredient to demonstrate the principles. Drift is itself a complex process and drift deposition is further influenced by the canopy structure itself (KOCH et al., 2003). Our approach is appropriate to investigate both parameters in real field situations including both the application as well as habitat characteristics such as plant age, plant community, climatic conditions, etc.

Ecotoxicological risk assessment is part of the registration of pesticides and is based on the comparison of data generated in laboratory trials. Effects of chemicals on non-target plants have to be investigated according to OECD draft guideline 208 B (OECD, 2000) and plants should be grown from seeds to the 2-4 leaf stage. The dosing procedure is done by spray application of a set of dose rates (g/ha), simulating defined levels of drift exposure. This kind of tests assumes that spray and drift deposition should result in the same effects, and that spray application in the lab represents drift contamination in the field.

In the context of spray application theory, machine operated spray application is related to the oversprayed area (KOCH, 1992) which in arable crops is equivalent to the ground area (ha). Spray application cannot be related to a single target unit, e.g., a leaf or a plant. Deposits of machine operated applications always result in a wide variation but are clearly target specific (KOCH and WEISSER, 2001). In contrast to the deposit formation from a spray, there is currently no practicable method available for routine application and testing of defined and predictable drift deposits. Thus, other standardised methods might be still needed to fill this gap in order to assess effects of drift deposits because drift deposits are not the result of a defined delivered dose rate (kg/ha). Under field conditions the formation of drift deposits on a single plant is unpredictable. Figure 4 shows the dose response independent from the distance to the sprayed plot. It is assumed that different levels of drift deposition may occur at different distances depending on the drift potential of the application technique, wind, and other canopy related factors (density, height).

KOCH et al. (2003) have demonstrated that the droplet retention process of a spray application is quite different from the retention of drifting particles which tend to be less than 100 μm in diameter.

Spraying arable crops with a boom sprayer directs the atomised spray volume towards the target, i.e. the canopy, where the droplets impact, aided by gravity. On impact, droplets are either retained, reflected, or run off so that finally only a certain portion of the delivered volume will be retained on plant surfaces. In contrast to this overlapping sequence of random processes, drifting particles are moving more or less horizontally, transported by moving air. They are retained on impact at any surface. A single drifting particle will create an interfacial area of less than 100 μm in diameter, meaning, the coverage of such a drift deposit is very small. The deposition pattern has been demonstrated by KOCH et al. (2004). The most important feature in a canopy is the patchiness of drift deposits.

This investigation was intended to show the difference between drift deposition and spray retention. Beside the difference in the retention process, plants grown in the field under natural conditions may react different due to different sensitivity or because of different capacity to recover. The sensitivity of individual plants in the field in general is depending on various factors like plant age, plant size and other individual factors (e.g., water and nutrition supply, differences in cuticular waxes, etc.). This in consequence leads to the observed variation of effects at similar drift deposition levels. It is well known from efficacy trials that the sensitivity of plant species against herbicides is dependent on their growth stage. With respect to maximum efficacy it is essential for any herbicide to know the optimum moment of application, usually defined by a growth stage. This aspect may need more attention in the risk assessment because most individuals or populations exposed to drift are probably not in the most sensitive stage. It should also be considered that the Paraquat affected leaf area is much larger than the plant surface contaminated from retained particles (KOCH et al., 2004). While particles of 100 μm in diameter create a deposit area of approx. 0.00785 mm², the final induced chlorotic spot can be several mm in diameter (fig. 8).

Although the presented results are based only on one test each with one active ingredient (Paraquat), i.e., a non systemic compound, there are several notable aspects:
Drift dose response and spray dose response trigger different effects.

On-crop spray deposits (ng/cm²) can be related to a defined and delivered dose rate (kg/ha).

Off-crop drift deposits (ng/cm²) cannot be related to a defined delivered dose rate (kg/ha). They depend primarily on the technique specific fine drop volume and on actual meteorological conditions.

Lab grown young plants as exposed by spray application in laboratory tests react differently to drift contaminated plants grown in the field.

The population of field grown plants/species especially in off-crop habitats reacts with greater variability and expresses a much higher capacity to recover, compared to sown and lab grown plants.

Even highly affected plants exposed to high drift deposits recover or simply keep growing.

There is therefore a need to consider the difference of drift retention in comparison to spray retention in risk assessment and the reduction of effects due to recovery.

References


OECD, 2000: OECD Guideline for the testing of Chemicals, proposal for Updating guideline 208, Terrestrial (Non-Target) Plant Test; 208 B: Vegetative Vigour Test.


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