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Role of hedgerows in intercepting spray drift: Evaluation and modelling of the effects

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Abstract

When a pesticide is applied a proportion of the sprayed solution may become a cause of pollution in the surrounding environment, with ecotoxicological implications and phytotoxicity to other crops. In many countries buffer zones along field edges are recommended to shield surface waters, and hedgerows can play an important role in reducing pesticide risk. This study focuses on droplet drift, with the aim of evaluating the hedgerow efficacy in reducing drift from broadcast air-assisted sprayers and then to construct a simple model for estimating the spray drift level in surrounding fields. Three experiments were conducted in North-East Italy in 2004 and 2005, in winter, summer and autumn to obtain suitable optical porosity values in order to evaluate their effects. Three study situations (no hedgerow, single, double hedgerow) and two sprayer–hedgerow interaction scenarios (sprayer working perpendicular to or parallel with the hedgerow) were considered. Hedgerows were 7–8 m in height, while spray release height ranged from 1 to 2 m. The sampling method proved to be effective, with more than 73% of total amount sprayed being intercepted. Where there was at least one hedgerow, off-site spray reductions ranged from 82.6 (with optical porosity of 74.7%) to 97% (with optical porosity of 10.8%). The presence of a double hedgerow did not produce a higher interception rate. Analysis of the spatial pattern of drift showed that where there is a hedgerow with an optical porosity of 74–75%, the aerial drift caused by common broadcast air-assisted sprayers becomes negligible at a distance of 6–7 m. Hedgerows thus proved to be effective in intercepting spray drift leaving cultivated fields. In particular, low optical porosities provided high interception rates, even with very dense canopies, as no spray bypass was recorded. Spray drift profile was then modelled taking into account the effect of wind and optical porosity of a nearby hedgerow. A negative-exponential model is proposed. The model fits the experimental data quite satisfactorily and may be used to estimate spray drift magnitude in relation to wind speed and optical porosity of any hedgerow crossed by a droplets cloud spray drift.

Keywords: Hedgerow; Spray drift; Pesticide; Modelling

1. Introduction

When a pesticide spray is applied, a proportion may drift off-target and cause pollution in the surrounding environment, with ecotoxicological implications and phytotoxicity to other crops. Spray drift is usually divided into (Vicari et al., 2001; Gauvrit, 1988): thermal drift (lighter droplets transported to high altitude), vapour drift (volatilization from target) and droplets drift (droplets off-target bleed by ambient wind). This study focuses on droplet drift, i.e. the fraction of spray carried off-target by the wind during application, with the aim of evaluating the hedgerow efficacy in reducing spray drift by measuring how much spray drift may be retained by vegetated structures, and then to construct a simple model for estimating the spray drift level in surrounding fields as a function of the distance from spray origin, wind and optical porosity of the hedgerow.

Many solutions have been developed (Matthews and Thomas, 2000) to reduce the magnitude of the phenomenon

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and increase on-target spray amounts, i.e. novel deflectors (Landers, 2002) and anti-drift nozzles, which are a very versatile solution, as they can even be attached, at low cost, to traditional farm sprayers.

According to some authors, anti-drift nozzles can reduce spray drift by up to 90%, increasing droplet size and consequently making them less subject to wind action (Ganzelmeier and Rautmann, 2000; Craig, 2004). However, other surveys report that in many cases these devices are unable to provide sufficient environmental protection (Heijne et al., 2002). Bache (1980) demonstrated that collection efficiency for large size droplets (diameter equal to or above 150 μm) is affected mainly by foliage structure, whereas droplet size and wind speed are less important. High crop Leaf Area Indices are effective in capturing spray and minimizing drift out of an orchard, but measurable drift can escape sprayed blocks. Pesticide soil-deposit and air levels are attenuated by the presence of a barrier and decrease with distance from this shelter. Using well-calibrated broadcast air-assisted sprayers in low-wind conditions (1–5 m s^{-1}), the boundary barrier density is the main factor influencing levels of droplets drift (Holland et al., 1997).

After spraying, droplets tend to travel with their initial trajectory and velocity, and then be carried by the ambient wind until deposition. If vegetation or other structures are in the spray's path, droplets may be intercepted. Studies conducted by the Spray Drift Task Force (SDTF) (EPA, 1999) and others (Holland et al., 1997; Praat et al., 2000) have shown that in orchard spraying, canopy development and sprayer position relative to the canopy can have a major influence on spray drift.

Hedgerows can play an important role in reducing pesticide risk: together with appropriate application technologies they can reduce drift in Integrated Crop Management systems and achieve a satisfactory protection of aquatic habitats (Burn, 2003; Brown et al., 2004). In many countries pesticide buffer zones along field edges (where pesticide spraying is forbidden) are recommended to shield surface waters. In England, according to Local Environmental Risk Assessment for Pesticides (LERAP), the buffer zone width may be reduced by 6 m if there is a proper hedgerow along the field margin (LERAP, 2002). Dutch regulations encourage the use of natural or artificial barriers to reduce drift (Hewitt, 2001).

Many surveys show that a drift reduction of up to 90% can typically be achieved using appropriate vegetative barriers downwind of a spray area (Hewitt, 2001; Ucar and Hall, 2001). Although the results coming from various tests cannot be directly compared, due to different experimental methods, they show a good aptitude of hedgerows in reducing droplets drift: reduction percentages, compared to no hedgerow, range from 50–80% (Richardson et al., 2004) to 70–90% (Van de Zande et al., 2000). Porskamp et al. (1994) observed greater drift reductions in summer and early autumn (at least 90% when a hedge was present) than in April (68–79% with the hedge) and concluded that reductions in drift of 68% to >90% could be obtained using a windbreak around an orchard being sprayed.

Filtering capacity is also influenced by hedgerow texture, such as morphological characteristics and shape of the plants (Ucar et al., 2003), which directly influence optical porosity. Optical porosity is a two-dimensional measure of canopy porosity determined from the plant silhouettes. It has been proved to be a promising alternative to aerodynamic porosity, especially for thin windbreaks (Kenney, 1987; Heisler and DeWalle, 1988). Dorr et al. (1998) reported that, within the context of designing vegetated buffers for spray drift interception, 40–50% porosity appears to be the optimum level for spray interception.

Other authors obtained better results on spray drift reduction using hedgerows at least twice the height of the spraying device. So, hedgerow height has to be considered in relation to the crop grown in the field (Graham, 1987; Van de Zande et al., 2000). Guidelines for planting vegetated buffer zones for drift reduction are provided in Queensland, Australia, and suggest buffer widths of around 20 m. However, these are almost impossible to achieve in many cropping systems in the world (Voller, 1999).

Ideally, spray drift buffers should consist of a variety of plants with different leaf shapes, growth habits and heights, so that the chance of capture within the structure is increased (Robertson, 2002).

The experiments described in this paper were conducted with the aim of evaluating hedgerow efficacy in reducing spray drift by measuring how much spray drift may be retained by vegetated structures and to construct a simple model for estimating the spray drift level in areas surrounding fields as a function of the distance from spray origin, wind and optical porosity of the hedgerow.

Several models have been developed to predict spray drift behaviour: for example a paper published by the Danish Environmental Protection Agency described a model to assess the risk of transport of pesticides to surface water bodies. The model appears very complete, accounting for spray drift, dry deposition, atmospheric transport and mixing and volatilization (Asman and Jørgensen, 2003).

Raupach et al. (2001) developed another model, based on the notion that the fraction of particles in the oncoming flow which pass through the windbreak (or transmittance σ of the windbreak for particles), is related to the optical porosity τ. They found that the very simple approximation $\sigma = \tau$ works well for most applications involving the interception of spray droplets by windbreaks, and the total deposition of particles on a windbreak is determined by a trade-off between particle absorption and throughflow, implying an optimum value of τ for maximum total deposition that occurs when $\tau \cong 0.2$, for particles larger than 30 μm and vegetation elements smaller than 30 mm. Considering that the quality of a model depends on the quality of the assumption made, it has to be taken into account that, as shown by Raupach et al. (2001), the dynamic of flux through a windbreak is very complex. For example, in their model