The Movement of Spray Drift near a Live Shelterbelt

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Abstract

There has been recent interest in the use of shelterbelts to mitigate spray drift and protect downwind areas. Previous research has investigated the interaction of spray drift and shelterbelts using model shelterbelts, wind tunnel experiments, and numerical modeling; however, there is limited knowledge on the movement of spray drift near a live shelterbelt in field conditions. These experiments measured the ground deposition and airborne concentration of drift near a live carragana/chokecherry mix shelterbelt. It was found that when compared to open field experiments where there was no shelterbelt, the mass of ground deposit was less in the lee of the shelterbelt for a distance of 0-10H downwind of the shelterbelt (where H is the height of the shelterbelt). Further than 10H downwind of the shelterbelt, the mass of ground deposit was similar to the open field. There was an 88% reduction in airborne drift exiting the shelterbelt as compared to the drift entering the shelterbelt, which likely caused the reduction in deposition in the shelterbelt's lee. It was shown that there was a larger proportion of drift diverted over the top of the shelterbelt as compared to the drift exiting the shelterbelt. Although not apparent in these experiments, this suggested that there may be increased deposition further downwind from the shelterbelt as compared to the open field.

Introduction

Pesticide use is an important component of the agricultural industry because it allows the producer control over pests that may otherwise infest their crops. Pesticides are commonly applied to a crop as a spray where the droplet sizes typically range from 10 to 1000 μm in diameter (Bache and Johnstone, 1992). Droplets smaller than 150 μm in diameter are susceptible to off-target movement due to crosswinds (Miller 1993), which is called "spray drift". Spray drift has the potential to harm downwind crops and native plants and pollute waterbodies. While the effects of spray drift may not be lethal to plants or animals, they could delay the growth of vegetation and disrupt the balance of the ecosystem (Marrs et al., 1992). The movement of spray drift is dependent on meteorological conditions including wind speed, wind turbulence, temperature, humidity, and atmospheric stability (Bache and Johnstone, 1992); and operator settings including pressure, nozzle type, fan angle, and fluid properties of the spray mixture (Lefebvre, 1993).

There has been recent interest in the use of shelterbelts to mitigate the movement of spray drift. A shelterbelt, or windbreak, consists of a single or a series of long, narrow rows of trees. Shelterbelts have traditionally been used to combat wind-induced soil erosion, trap snow to improve soil moisture in the spring, shelter livestock, protect roadways and yard sites from wind, and to improve biodiversity (Jones and Sudmeyer, 2002).

The flow around a shelterbelt is complex and consists of six distinct regions (Judd et al., 1996), and is shown in Figure 1. The approach flow upwind of the shelterbelt begins to slow at a distance of approximately 5H, where H is the height of the shelterbelt. The flow is then split into bleed flow, which passes through the shelterbelt, and displaced flow, which passes over the top of the shelterbelt. The quiet zone begins immediately downwind of the shelterbelt and extends to a distance of approximately 5H. Above the quiet zone is the mixing zone, which extends downwind to a distance of approximately 25H. This is where the re-equilibration zone begins which is where the flow begins to return to its upwind velocity profile.

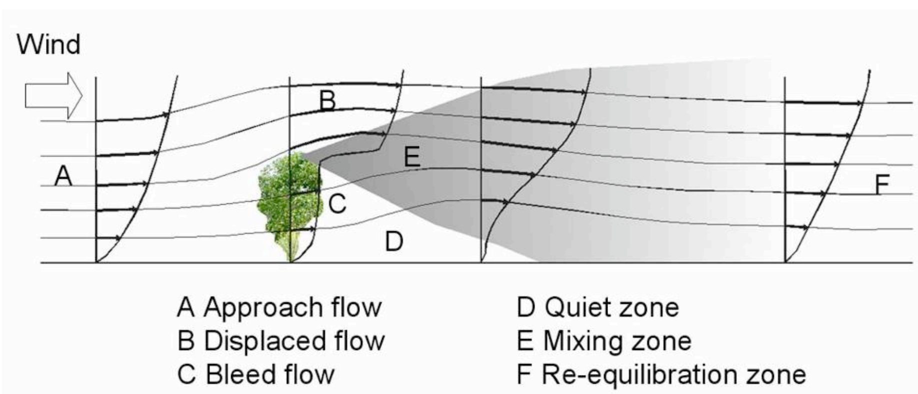

Figure 1. Wind profile around a shelterbelt
Adapted from Judd et al. (1996)

When spray drift passes through a shelterbelt, the airborne concentration of drift is reduced through two mechanisms: (1) a reduction in wind speed that allows droplets to settle out, and; (2) a scrubbing of the droplet-laden flow by the canopy of the shelterbelt (Raupach et al., 2001). This is supported by previous studies that examined the movement of spray drift past natural grass strips (Miller and Lane, 1999), vinyl snow fence (Brown et al., 2004), and riparian areas (Wolf et al., 2004). However, there is limited research on the movement of spray drift past a live shelterbelt. The objective of this research was to collect field data in order to describe the movement and deposition of spray drift past a live shelterbelt in field conditions.

Methodology

The experiments were conducted around a carragana/chokecherry mix shelterbelt located in an alfalfa field near Hanley, Saskatchewan (Figure 2). The shelterbelt was approximately 5 m in height with branches extending 2.5 m on either side; the carragana and chokecherry trees were approximately the same height. The shelterbelt was approximately 400 m long with no significant gaps.

Figure 2. Carragana/chokecherry mix shelterbelt

The deposit of spray drift was measured using a tracer dye, as described in the International Standard 22866:2005 (ISO, 2005). Rhodamine WT, a fluorescent dye, was added to the tank mixture and the spray was applied using a Melroe Spra-Coupe 220. The sprayer was equipped with a 14.5 m wide boom and XR8003 nozzles, which produced a Medium spray quality. The sprayer traveled along a path approximately 250 m in length that was parallel to the shelterbelt at an upwind distance of 15 m (3H). The sprayer traversed three times on the same path while spraying in order to adequately dose the farthest downwind collectors with a quantifiable mass of dye.

Collectors were placed up- and downwind of the shelterbelt to sample both the deposition and airborne concentration of spray drift. The collectors used were Petri-plates, rotorods, and polyethylene string. Petri-plates were used to sample the ground deposition of drift. The plates were placed at the same height as the crop and at perpendicular distances at 5 m intervals upwind of the shelterbelt and at 15 m intervals downwind of the shelterbelt to a distance, x, of 150 m. Rotorods, which are square brass rods bent in a U-shape that rotate at 2400 rpm, were placed at a height, z, of 1, 2, 3, and 4 m immediately up- and downwind of the shelterbelt. The rotorods were used to sample the airborne concentration of drift entering and exiting the shelterbelt. Polyethylene string, which was suspended by a helium blimp at a height of 30 m, was placed immediately downwind of the shelterbelt. The string was used to sample the airborne concentration of drift traveling over the top of the shelterbelt. Each sampling distance had three samplers except for the string, which was limited to one sampler.

After spraying was completed, five minutes were allowed to pass to ensure the drift cloud had traveled past the furthest collector. The samplers were then collected and stored in the dark until subsequent dye extraction in the laboratory. The collectors were washed with ethanol and the fluorescent intensity of the wash (FI) was measured using spectrofluoremetry. The fluorescent intensity was converted to dye concentration (C) using standard solutions, and then normalized by the concentration of dye emitted by the sprayer (% of Applied).

A total of 30 experiments were conducted through 2005 and 2006 under a variety of meteorological conditions. Open field experiments, where the experimental site was clear of obstacles, were conducted in 2006 in an immature barley field. The open field trials had the same experimental setup as the shelterbelt site. A subset of three trials from the shelterbelt experiments was identified where the wind speed and direction were comparable to the open field experiments. A complete analysis of the shelterbelt experiments is provided by Peterson (2008).

Results and Discussion

The experimental data for a subset of the open field and shelterbelt trials are shown below in Table 1. The open field conditions are an average of three trials that were conducted on the same day. An exponential line of best fit (r^2 = 0.99) was used to identify the relationship between ground deposition of drift and downwind distance. Although there is some variation in the meteorological conditions between the open field and its comparative shelterbelt trial, it was assumed that the effect of the difference in conditions was small and that the trials could be reasonably compared.

Table 1. Meteorological Conditions for the Shelterbelt and Open Field Experiments

Trial #	Wind Speed (km/h)	Wind direction[1] (°)	Temperature (°C)	RH (%)
Open Field	11.7	17.3	26.9	35.0
I	10.3	14.4	17.7	33.5
II	15.8	25.7	13.2	42.6
III	9.9	15.5	15.3	40.8

1. Wind direction from perpendicular to the spray swath (90º is parallel to the spray swath)

The ground deposition of spray drift for Trial I and the open field trial is shown below (Figure 3). On the upwind side of the shelterbelt, the deposition was greater for Trial I compared to the open field. The wind speed would have decreased starting at a distance of 5H upwind of the shelterbelt, which could have led to increased droplet settling and deposition. The deposition immediately downwind of the shelterbelt was reduced by 72% compared to immediately upwind of the shelterbelt. This reduction was 27% for the same locations in the open field setting. Downwind of the shelterbelt to a distance of 10H, the deposition was less in the shelterbelt setting compared to the open field. The decreased deposition could have occurred because the drift cloud exiting the shelterbelt would have been “scrubbed” by the shelterbelt’s canopy, which would have decreased the airborne concentration of drift. Further than 10H downwind of the shelterbelt, the rate of deposition was increased for the shelterbelt trial and the concentration of ground deposit was similar for both the shelterbelt and open field trials. This may have been where the proportion of the drift cloud that was diverted over the top of the shelterbelt began to return to ground level.

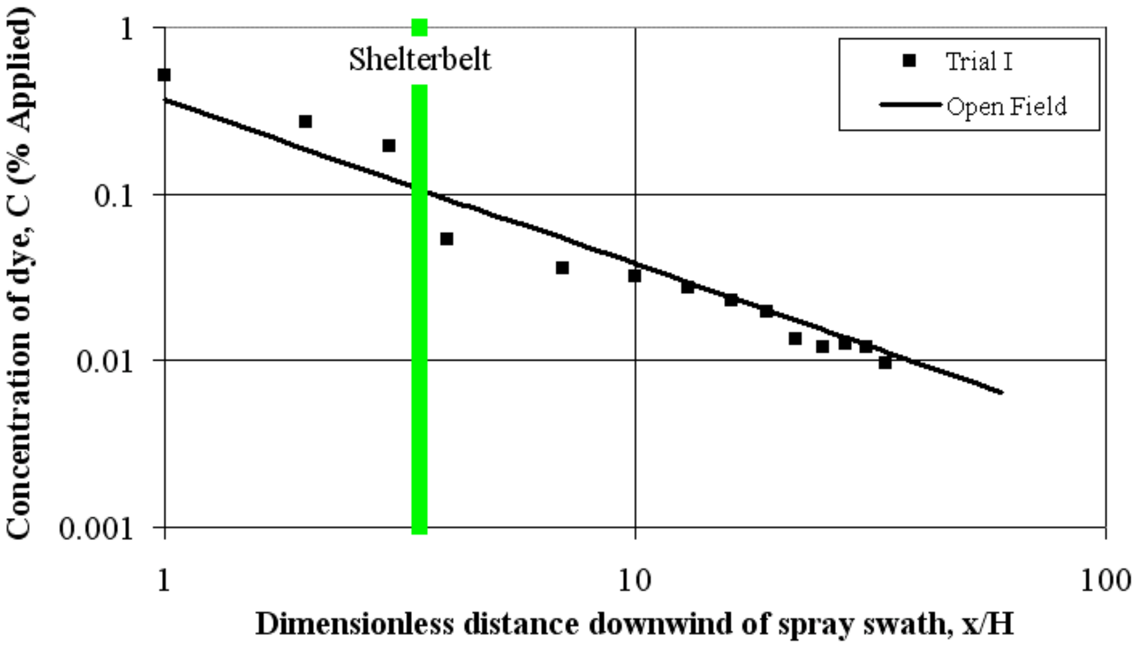

Figure 3. Ground deposition of drift near the shelterbelt compared to the open field

On the upwind side of the shelterbelt, the airborne concentration profiles were similar for both the shelterbelt experiment (Trial II) and open field setting (Figure 4), with the peak concentration occurring at a height of 0.4H for both cases. Downwind of the shelterbelt, the profile was nearly constant to a height of 0.6H for the shelterbelt setting, while in the open field setting, the shape of the profile was comparable to upwind of the shelterbelt. The nearly vertical shape of the concentration profile indicated an attenuation of the drift cloud by the shelterbelt, which could have been caused by a large proportion of the drift cloud being captured within the shelterbelt. The mass of drift exiting the shelterbelt was reduced by 88% compared to the mass of drift entering. In the shelterbelt trial, the airborne concentration of drift downwind of the shelterbelt increased at a height of 0.8H, which may indicate the portion of the drift cloud that was diverted over the top of the shelterbelt.

The increase in airborne concentration at 0.8H is also seen in Figure 5, which shows the concentration profile of drift above the shelterbelt. The airborne concentration of drift was measured to a height of 5H (30 m); however there was no measurable drift beyond a height of 2H. The peak concentration occurred at heights of 0.4H and 1H for the open field setting and shelterbelt trial, respectively. The peak concentration was 31% greater

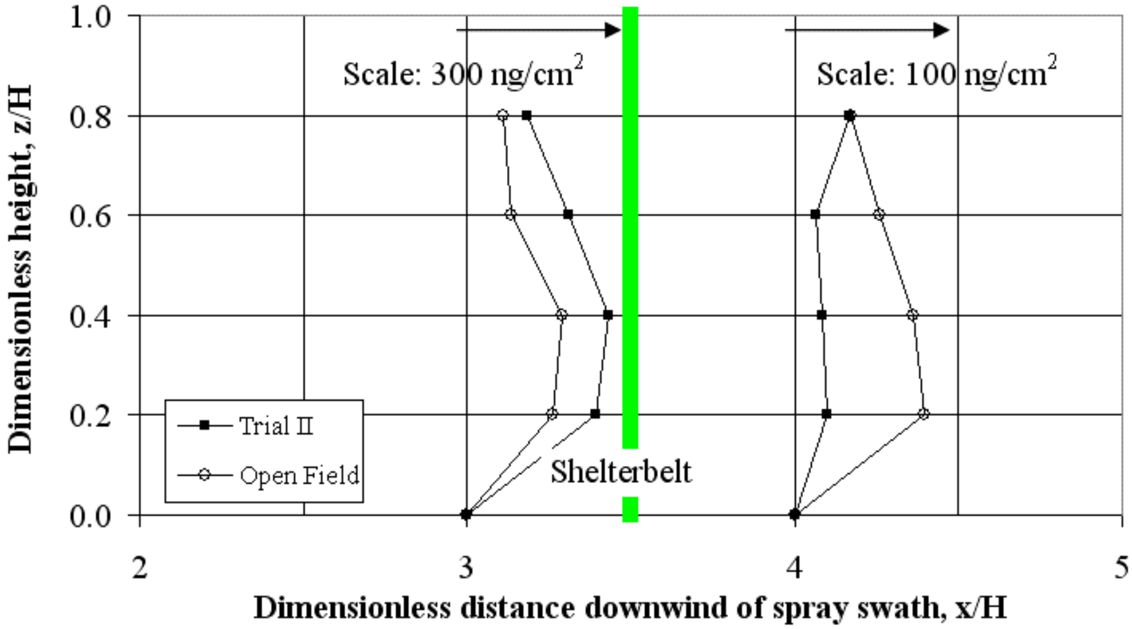

Figure 4. Airborne concentration entering and exiting the shelterbelt compared to the open field

for the shelterbelt trial compared to the open field setting. This is comparable to findings by Miller et al. (2000), who sampled the movement of airborne drift over a relatively wide grass strip and determined that the majority of airborne drift travels over the top of the grass canopy rather than through it. The drift concentration profile for the shelterbelt trial indicated that the proportion of airborne drift that exited the shelterbelt was less than the proportion that was diverted over the top of the shelterbelt.

Both the ground deposition of drift and airborne concentration profiles of drift indicated that there was a greater proportion of drift diverted over the top of the shelterbelt. This was shown in Figure 3 where the rate of deposition increased at a distance of 10H downwind of the shelterbelt. Figure 4 showed an increase in airborne concentration near the top of the shelterbelt, and Figure 5 showed there was a greater proportion of drift passing over the top of shelterbelt compared to the drift exiting the shelterbelt.

Although it was not indicated in these experiments, the increased airborne drift diverted over the top of the shelterbelt has the potential to cause increased ground deposition further downwind of the shelterbelt, compared to the open field. This increase in deposition would likely occur at a distance of approximately 10H downwind of the shelterbelt, which was where the rate of deposition increased (Figure 3). This is comparable to research by Davis et al. (1994) and Wolf et al. (2004), who both found an increase in deposition at distances of 6-10H and 8.7H downwind of a hedge and willow shrubs, respectively. Through numerical modeling, Bouvet et al. (2006) determined that the maximum deposition behind a shelterbelt occurred at a distance of 3-6H downwind of the shelterbelt.

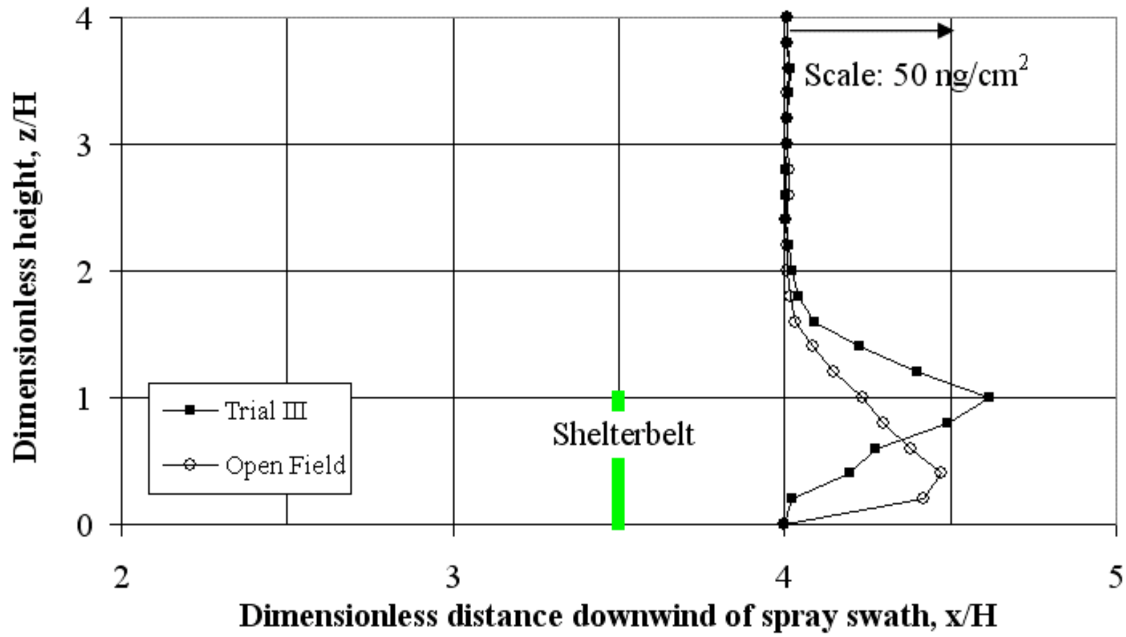

Figure 5. Airborne concentration profile of drift over the top of the shelterbelt compared to the open field

The mass of spray drift captured within the shelterbelt was not expressly measured; however, the airborne drift exiting the shelterbelt was reduced by 88% compared to the drift entering. Some proportion of this reduction may have been due to drift entering the shelterbelt then deflecting above the top of the highest collector. Further research should determine the mass of spray drift that actually deposits within a shelterbelt, and whether this may cause harmful effects to the shelterbelt or the habitat within the shelterbelt margin.

The movement of spray drift is highly dependent on a number of meteorological, crop, site, and operator variables. Although the sprayer settings and experimental setup were the same and the meteorological conditions were similar between the open field and shelterbelt experiments, there was variability that was inherently introduced as the shelterbelt and open field experiments were conducted at different locations under different crop conditions. Davis et al. (1994) attempted to address this variability by cutting a wide opening in their experimental windbreak and placing a sampling line in this opening to characterize the open field setting. Care would need to be taken to ensure the gap was sufficiently wide to minimize the end effects of the windbreak. Without resorting to this destructive approach, the reader should bear in mind the natural variability of field experiments, and that the preceding results are reported to describe the relative movement of spray drift near a shelterbelt compared to the open field, rather than the absolute mass of spray drift at any given location.

Conclusion

This research investigated the movement of spray drift around a live shelterbelt in field conditions. It was determined that, compared to the open field setting, the ground deposit was reduced in the lee of the shelterbelt (0H to 10H downwind of the shelterbelt). For a distance of 10H to 30H downwind of the shelterbelt, the deposit was close to the same for the open field and shelterbelt settings. The airborne drift concentration profiles showed that there was a large reduction in drift exiting the shelterbelt; in this case, there was an 88% reduction in drift exiting the shelterbelt, compared to the drift entering the shelterbelt. There was a greater proportion of drift that was diverted over the top of the shelterbelt, which has the potential to increase ground deposition downwind of the shelterbelt where the diverted flow re-attaches to ground level (between 5H and 25H downwind of the shelterbelt). This increase in ground deposition downwind of the shelterbelt was not found in these experiments, but has been reported in previous research.

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