

SEASONAL AND YEAR-TO-YEAR VARIATION IN HOURS SUITABLE FOR SPRAYING

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Introduction

Many important agricultural chemicals are applied as sprays of fine droplets. Spray application minimizes mechanical damage to the crop and leads to good coverage of the target foliage by the chemical. During the time that spray droplets are suspended in the air they are susceptible to unintended lateral movement away from the target, a process termed drift. Meteorological variables with significant effect on drift are atmospheric stability and wind speed, and to a lesser extent, humidity. Stability refers to the tendency of adjacent volumes of air to mix together. The ideal atmospheric condition to apply chemicals by spraying is slightly unstable. In this situation most of the applied chemical can settle onto the crop, and the rest will mix vertically and dissipate. Under highly unstable conditions, strong vertical and lateral motions of wind make drift a problem because the chemical is not given an opportunity to settle onto the crop.

Conversely, under stable conditions with strong temperature inversions, applied chemicals may also drift laterally because vertical mixing is suppressed. Normal conditions have warmer air at the surface, with progressively cooler air with height. The buoyancy of warm air helps to mix the atmosphere as a result. During an inversion this pattern is reversed, with colder air under the warmer, effectively trapping the chemicals under the warm layer. These particles then can drift laterally far from the point of application. Inversions are typically associated with winds that are nearly calm early or late during the day.

The chemical industry-funded Spray Drift Task Force found that wind speed was not associated with drift except in cases where droplet diameter was less than 141 microns (http://www.agdrift.com/ground/ground_main.htm). This size range includes most ground spraying operations, in which drops range in diameter from 80 to 150 microns (Wixted et al., 1998). However, this study measured drift only beyond 25 feet downwind of the target deposition site and only conducted trials under wind speeds between 7 and 16 mph (3 to 7 m/s).

Additionally, spray boom height and spray pressure affect drift. The higher a boom is placed, the greater opportunity for drift. For most ground-based agricultural applications, spray boom height is approximately 20 inches (0.5 m) (Spray Drift Task Force, http://www.agdrift.com/ground/ground_main.htm).

Increasing spray nozzle pressure reduces the size of spray drops, thereby increasing the time it takes droplets to settle onto crops (Wixted et al., 1998). A droplet 50 microns in diameter falls at a rate of about 3 in/sec (0.07 m/s) in still air, while a 200 micron-diameter droplet falls at 24 in/sec (0.61 m/s) (Wixted et al., 1998). Droplets of

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these sizes applied at a boom height of 20 inches will take 6.8 and 0.8 seconds to fall to the ground, respectively.

Objectives

Spray applicators can control many of the factors influencing drift, but not wind speed and stability. As a result, there are times when weather makes application of chemicals by spraying potentially damaging. We determined how much of the typical growing season would be unavailable for spraying following prudent wind speed thresholds.

There are no definitive, uniform national guidelines for regulating wind speeds under which chemicals may be applied (C. Boerboom, University of Wisconsin-Extension Agronomist, personal communication). For this study we selected an upper limit of 10 mph (5 m/s) at a height of 33 feet (10 m), the current standard anemometer height at National Weather Service and Federal Aviation Authority weather stations. Analyses were conducted both with and without a lower speed threshold of 2 mph.

The wind speed thresholds selected for this study are equivalent to about 1.3 and 6.6 mph (0.6 and 3.0 m/s) at 20-in. boom height. For these conditions very small droplets (50-micron diameter) could, in principle, drift laterally 10 to 70 feet, while droplets 200 microns in diameter might be displaced laterally 1 to 8 feet.

Methods

Hourly wind speed data were obtained from a CD-ROM produced by EarthInfo (1998) for the National Climatic Data Center (NCDC). Wind speeds in knots were one-minute average values measured at Madison (station identification MSN), Green Bay (GRB), La Crosse (LSE), Eau Claire (EAU), and Milwaukee (MKE) airports.

Anemometer heights differed among stations and in time at a station. Data not at 33 feet (10 meters) were standardized to that height using the following equation:

$$U_2/U_1 = (Z_2/Z_1)^a \quad (1)$$

where U is the wind speed, Z is the height, and a is a constant which varies with temperature and surface roughness (Baker, 1983). The subscript 1 refers to the lower height and 2 to the upper height. For rural and airport sites, Baker (1983) uses a value of 0.14 for a , which is the value we also used.

We defined the spraying season as the months April through September. Only daylight hours were considered. If an observation fell within 0.5 hour of sunset or sunrise, it was included. A “spray hour” is any daylight hour in the spray season with wind speeds 2 to 10 mph at the standardized height.

Three-year running averages of seasonal spray hours were graphed for the five airport sites. This duration running average was chosen to smooth the data to some

extent. Monthly spray hour sums were graphed for Green Bay, Madison, and Milwaukee, the sites with the longest continuous records. Seasonal and monthly sums were also ordered and assigned probabilities so that ogives could be produced.

More detailed analyses were made of the years 1985-95 because we expect no climatological change in such a short time span. Additionally, an averaging period of about 10 years is appropriate for estimating the most likely weather in coming years. Madison, Green Bay, and Eau Claire were analyzed in this way. Sums of spray hours by month and by season were calculated. The average and median number of spray hours for each month and each season were determined as well. The monthly data was later ordered and assigned specific probabilities so that ogives could be produced.

Analyses were conducted using both 0 and 2 mph as lower limits for application. Chemical applicators will often apply during calm and near calm conditions, provided a temperature inversion is not present (J. Doll, University of Wisconsin-Extension Agronomist, personal communication), and we wanted to see how these additions changed the distribution of spray hours. Eau Claire was omitted from the 0-10 mph analysis because uncertainty regarding its anemometer height; its spray hour sums were approximately 6% more than those in Green Bay.

Results and Discussion

Comparing the five airport sites shows the three-year running averages vary between 800 and 1800 spray hours (Fig. 1). The late 1970s and late 1990s both apparently had more spray hours than the late 1980s. Short duration trends can be seen across several sites. For example, a dip in the number of spray hours around 1991 is reflected in the La Crosse, Madison, and Milwaukee curves.

The long-term trends of individual monthly spray hours approximate the shape of the seasonal sums (Fig. 2). That is, no one month appeared to be responsible for the inter-annual variability shown in Fig. 1. As the season progressed, the curves shifted upward toward more spray hours in the mid-summer months, and then back downward to less spray hours near the end of the season. Table 1 shows the monthly average, median, and range of spray hours.

For the period 1985-95, Madison had consistently fewer total seasonal spray hours than the other two cities, while Eau Claire generally had slightly more hours than Green Bay. Over these 11 years, Madison averaged 1062 spray hours per season, Green Bay averaged 1327, and Eau Claire averaged 1398. Some possible explanations for the difference between sites could be latitudinal difference, degree of urbanization around the airport observation stations, placement of the meteorological instruments at the airports, or maintenance of the meteorological instruments.

On a monthly basis, Madison had approximately 20% fewer spray hours than Green Bay and Eau Claire. On a plot of month versus average monthly sum of spray hours, the curves for each site increased from the beginning of the spray season until

Table 1. Median and range of spray hours for period of record.

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Site	Month	Spray Hour Sums				
		Median	Range			
			----- hrs -----			

Eau Claire	April	156	77-231			
	May	220	134-256			
	June	257	147-346			
	July	270	142-323			
	August	254	140-299			
	September	184	123-246			
	Season	1341				
Green Bay	April	144	101-230			
	May	219	165-287			
	June	253	193-363			
	July	305	217-338			
	August	282	214-351			
	September	206	157-243			
	Season	1409				
La Crosse	April	176	126-273			
	May	236	190-336			
	June	290	200-350			
	July	298	227-366			
	August	290	231-357			
	September	215	157-287			
	Season	1505				
Madison	April	132	88-182			
	May	191	148-249			
	June	242	165-308			
	July	284	209-335			
	August	254	173-327			
	September	171	134-271			
	Season	1274				

July, when spray hours then began to decrease (Fig. 3). Analyzing each month separately using ogives also showed Madison had consistently lower spray hours per month, while Green Bay and Eau Claire took turns having more hours available for spraying (Figure 4). For example, in June, 50% of years in Madison had less than 194 spray hours per month, in Green Bay less than 235, and in Eau Claire less than 265.

The probability distribution of spray hours allows planning considering a range of levels of risk of being unable to meet all commitments. For example, a custom applicator in Dane County can learn from Figure 4 that there is a 50% chance of having 194 hours or less of suitable weather for spraying in June. If the applicator is adverse to the risk of being unable to meet commitments, s/he might prefer to plan based on 149 spray hours in June, the minimum amount available 90% of years.

The addition of zero and one mile per hour wind speeds increased Madison's seasonal sum of spray hours by an average of 11% or 119 spray hours per season (Fig. 5). For the 11-year period, increases ranged from 78 to 154 hours per season out of a median total of 1062. In Green Bay, the additional wind speeds increased the seasonal sum by an average of 8% or 113 spray hours per season, with a range of 58 to 159 extra hours. While removing the lower threshold increased the median of the probability distribution of spray hours for each month, the distribution did not change shape (Figure 5).

For individual months of the spraying season, in Madison, 10 to 14% gains in the number of spray hours were observed. This translates into 11 to 23 additional spray hours per month. For Green Bay, between 6 and 10% gains (8 to 23 additional spray hours per month) were observed. The removal of the threshold appears to add only a small number of sprayable hours while it may substantially increase the chances of drift.

In summary, year-to-year variation in the number of daylight hours with wind speeds suitable for spraying agricultural chemicals is considerable. From the probability distributions of seasonal and monthly totals an applicator can learn the likelihood that the coming growing season will have at least a particular number of hours suited for spraying. Probabilities of wind speeds outside of recommended ranges were analyzed for ranges of 0-10 mph and 2-10 mph measured at 33 feet. Reanalysis for additional thresholds and heights is possible.

Sources

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