Instrumentation to Document Environmental Conditions during Pesticide Applications

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Abstract

Proper and accurate assessment of weather conditions before and during an application is necessary to make sound decisions regarding application timing. In addition, good records document proper use in case of a complaint. Simple, relatively inexpensive instruments can be used to measure wind direction and speed as well as other environmental conditions (e.g., temperature and humidity). This article discusses how weather conditions can be measured at a pesticide application site.

Keywords: pesticide, application, timing, weather data, wind, records, drift

Introduction

Accurate timing of pesticide applications is a critical component in obtaining the best results possible from pest control products. Timing decisions may simultaneously incorporate multiple variables. For instance, treatments may be planned to both expose a pest to a pesticide during a vulnerable part of its life cycle and to take advantage of, or avoid, rainfall after an application. Weather conditions play a major factor in affecting timing decisions; these conditions also play a significant role in the occurrence of spray drift. Spray drift is a major concern because it diverts the chemical from the intended target, reduces efficacy, and deposits pesticide where it is not needed or wanted. When a pesticide drifts it may cause both environmental and economic damage through injury to susceptible vegetation, harm to wildlife, deposition of illegal residues on crops, and contamination of water supplies.

Many pest control product labels contain either guidance or specific instructions regarding suitable environmental conditions and application timing. While following the label instructions to the letter may not guarantee applicator's freedom from inadvertent economic or environmental damage, these directions are based on both generic drift studies and specific product tests. Hence, applicators should monitor and make accurate records of weather conditions at application time both to reduce liability and make better decisions regarding timing of the application.

Many factors influence drift. Some (e.g., operating pressure; nozzle, type, orientation, orifice size) are directly under the control of the applicator. Weather conditions during and following an application are uncontrollable. Weather conditions affecting spray drift include wind speed, wind direction, temperature, relative humidity, and atmospheric stability. While an applicator cannot control the weather, he or she can, and should, consider weather conditions and predictions when planning pesticide applications.

The accuracy of weather-related data in application records will depend on the methods used to gather that information. Ramsay and Foss (2004) reported that many applicators usually estimated wind speed and direction using best estimates or distant weather monitoring stations (e.g., radio, television, web site, airport) to support application timing decisions. Some pesticide labels have specific no-spray-zone requirements based on the distance a specific droplet size may move off-target at a given wind speed. Others have specific restrictions regarding wind speed during application. Use of modern, portable instrumentation is critical for gathering precise data. Anything from simple hand-held devices to sophisticated computerized logging devices is available and highly recommended for on site data collection.

This paper will provide information about instrumentation available to measure critical weather data, and instruction on practical methods to measure these data at the time of application. The proper use of a few instruments in addition to precisely recording measurements taken at the application site can improve the accuracy of the data and reduce liability to the applicator.

Documenting Environmental Conditions

Wind direction and speed are critical factors affecting drift. The presence and proximity of downwind sensitive areas (e.g., water, vegetation, wildlife, and people) are often overlooked by applicators. The greater the wind speed, the farther small droplets will travel off-target. Determining the wind direction and speed relative to sensitive areas is important when attempting to minimize damage from spray drift. Leaving a buffer zone or no-spray zone at the downwind edge of a spray area will reduce off-target movement. After the wind has died down or changed direction the buffer zone can be safely sprayed.

Wind direction and speed should be recorded before and during every application. It is important that each factor be measured and recorded accurately. Wind direction should be measured first, followed by wind speed. Depending on the field size and location, multiple recordings over time and location can be essential. It is also critical to understand the importance of collecting data on site or as near to the application site as possible. Weather conditions are highly variable over wide areas. Weather data taken from distant sources are not likely to match the conditions at the application site. Surrounding topography such as trees, hills, valleys, and buildings will influence the speed and direction of the wind. In addition, most remote weather data sources (e.g., National Oceanic and Atmospheric Administration [NOAA], airports, radio, and television) commonly measure wind data at 10 meters (30 feet) above the ground. This does not match the release height of a typical pesticide application. For these reasons weather statistics obtained from off-site sources may not be descriptive of actual conditions during an application.

Measuring Wind Direction

The compass is an essential tool to accurately determine wind direction. The most accurate records report the magnetic direction of the wind, defined as the direction from which the wind comes. A compass reading in degrees (e.g., 90°, 135°) is more specific, therefore preferable, to a directional indication (e.g., E, SE). Figure 1 illustrates a simple compass sufficient to measure wind direction precisely.

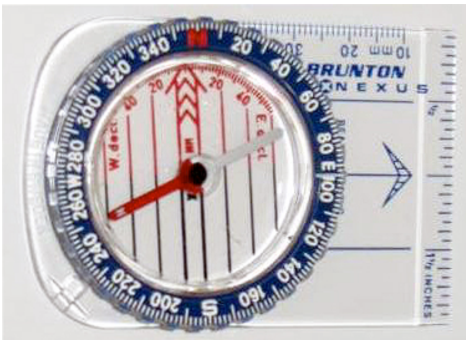

Figure 1. Example of a compass used for determining wind direction.

Basic compass parts include a compass needle, rotating housing, orienting arrow, and direction of travel arrow, all set on a flat base. The red end of the compass needle always points toward the earth's magnetic pole, measured as 360°. The rotating housing contains a 0-360° scale that facilitates calculations.

There are several methods to determine magnetic wind direction. One simple method entails turning yourself to face into the wind. An easy way to facilitate this is to tie a short ribbon or piece of flagging on the end of a 6 to 8-foot pole, then stand directly behind the blowing ribbon end. Hold the compass flat, allowing the needle to swing freely. The red end of the compass needle will point north (360°). Align the orienting arrow on the housing, and the direction of travel arrow inscribed on the base, to exactly match the red end of the compass needle. With one hand holding the housing in place, rotate the base with the other hand until the direction of travel arrow points into the wind. Read the value at the base of the travel arrow and subtract that number from 360° to obtain the wind direction in degrees. Remember to take readings in locations where the wind direction will not be influenced by surrounding hilly terrain, trees, or buildings. Also, remember to keep the compass away from steel objects that may cause magnetic deviation. Table 1 lists selected examples of compasses available for determining wind direction.

Table 1. Examples of hand-held instrumentation used for determining wind direction.[a]

Name	Features	Cost [b]
Brunton 28NL	Micro, traveler	$ 6.00
Brunton 7DNL	Star, Analog, magnified display	$ 8.00
Brunton 10BLNL	Weather eye compass	$ 10.00
Brunton Nomad	Digital	$ 59.00
Brunton 15TDCL	Elite compass with sighting mechanism	$ 59.00
Plastimo Iris 50	Double reading scales, magnified sight	$ 69.00
Brunton SM	Sightmaster compass	$ 77.00
Brunton SUM 360LA	Surveymaster direct sighting compass	$186.00
Brunton MNS	Multinavigator GPS with true-magnetic built in	$359.00
Compaq – iPAC	With Navman is a multifunctional GPS	$700.00

[a] Brand names appearing in this publication are for identification purposes only. No endorsement is intended, nor is criticism implied of similar products not mentioned. Examples chosen based on criteria listed in Appendix A.
[b] Listed in order of price. Cost based on web page reviews as of September 2004.

Measuring Wind Speed

It may be necessary to record wind speeds at several points during the application phase, and at several locations within the area treated. This activity is important because landforms, trees, and buildings will influence wind characteristics; additionally, wind speed and direction will change over time. The interaction of weather conditions with factors such as application duration, size of the area treated, and physical features of the application location determine the number of measurements necessary. At a minimum, applicators should take readings at the beginning, middle, and end of each application. Some professional application contracts require wind speed measurements in two-hour increments. The more often you record wind direction and speed, the better your liability protection.

Wind speed estimation, based on systems like the Beaufort Scale (Heidorn 1998), was common in the past for estimating speed without the use of an instrument. Estimation systems of this type are based on visible effects of the wind on the physical environment. For instance, behavior of smoke, trees, flags, and waves is rated on a scale then assigned a descriptor such as calm, gentle, strong, or gale. This method would prove accurate only for those trained in making such estimates. For most applicators this method would not be practicably defensible in a legal case.

Fixed weather stations containing anemometers capable of monitoring wind conditions at all times are the best type of instrument for measuring wind speed. However, major drawbacks include cost and location; they may not be located close enough to the application site to provide useful data. Table 2 lists several examples of fixed stations that are commercially available.

Table 2. Examples of fixed station instrumentation used for determining wind speed, temperature, and humidity [a]

Name	Features	Cost [b]
Oregon Scientific	(WM-918) Basic station with anemometer (free software and communication cable)	$ 159.95
Davis Weather Monitor II	Anemometer for wind speed, direction, temp, humidity, wind chill (cable)	$ 265.00
Davis Vantage Pro	Console, anemometer, temp, humidity, cable	$ 445.00
Davis Vantage Pro	Same plus solar powered, wireless (400 ft. range)	$ 535.00
Texas Instruments	TI 1-Wire Sensor	$ 629.95
Spectrum Tech.	Watchdog Model 525 (software $ 130.00 extra)	$ 795.00
Davis Vantage Pro+	Additional sensors (UV, solar radiation, etc.) cabled	$ 805.00
Davis Vantage Pro+	Same plus solar powered, wireless (400 ft. range)	$ 895.00
Spectrum Tech.	Watchdog Model 900ET (software extra)	$1495.00

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Systems of this design may be most practical in golf course and research field settings. However, note that any instrument mounted in a permanent location still has limitations due to variability that may occur across the application site. One advantage is these instruments are capable of relaying weather data electronically to a base station computer. Ideal instrumentation would include devices that record both wind direction and speed "on the go". Systems of this type are currently under development and are expensive.

At present, the best approach for obtaining simple and accurate wind speed recordings at application sites is to use a hand-held wind speed device, an example of which is shown in Figure 2 below.

Figure 2. Examples of wind meters used for determining wind speed, temperature, and humidity.

Many of the instruments available also include additional temperature and humidity sensors. Hand-held wind speed instruments are typically pocket-sized and have several operating modes capable of determining average, maximum, and current wind speeds. Most units use high precision impeller/bearing combinations that provide accurate readings and record speeds from less than 1 mph to approximately 90 mph. Other features include easy-to-read liquid crystal displays (LCD) with a variety of display units (miles per hour, feet per minute, knots, kilometers per hour, and meters per second). Appendix A lists useful features to consider in selecting hand-held instrumentation. Table 3 lists several examples of hand-held instruments available for determining wind speed, temperature, and humidity.

Hold the instrument directly into the wind to obtain the most accurate measurements. Be sure to avoid any structural interference, including your body. Take the measurement for several seconds to allow for short-term variances. Averages of longer duration measurements are best. If possible, record the wind speed at the spray release height. Remember that, typically, wind speeds will gain in velocity as you increase altitude.

Table 3. Examples of hand-held instrumentation used for determining wind speed (1-9), temperature (3,5,6,7,9), and humidity (6,7,9) [(a)]

Name		Features	Cost [(b)]
1	Dwyer	Floating ball	$ 15.00
2	Wind Wizard	Mechanical vane	$ 42.46
3	Skymate SM18	Maximum, average, current wind speed, temperature	$ 49.95
4	Kestrel 1000	Maximum, average, current wind speed	$ 64.95
5	Kestrel 2000	Maximum, average, current wind speed, temperature	$ 86.35
6	Kestrel 3000	All wind speed features plus temperature, wind chill, dew point, heat index, relative humidity	$ 129.55
7	Skymate SM19+	Maximum, average, current wind speed, temperature, humidity	$ 139.95
8	Turbo Meter	Wind Speed in knots, ft/min, meters/sec, mph	$ 142.55
9	Kestrel 4000	Measures every major environmental condition. Chart mode allows graphing 250 measurements.	$ 213.95
10	Kestrel 4000+	Same as above plus computer interface bundle	$ 283.90

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Temperature and Humidity

Temperature and humidity also affect the amount of drift occurring through evaporation of spray particles. Although some evaporative loss occurs under all atmospheric conditions, these losses are less pronounced in cool and damp conditions. Higher temperatures and lower humidity increase the evaporation rate and remove water from the spray droplet. Applicators should avoid using volatile products in hot weather as this results in droplets that are smaller and have higher concentrations of pesticides. Product labels often advise against spraying certain products under conditions of high temperature and low humidity. The applicator can increase droplet size, thus reduce drift, by selecting larger orifice nozzles and by decreasing the equipment operating pressure. Large droplets are less prone to evaporate, thus have a greater probability of reaching their target. Temperature also influences atmospheric air turbulence, stability, and inversions. Again, it is advisable to record temperature and humidity data specific to the application location and time. This is best accomplished on site with hand-held instrumentation. Many wind meters are also equipped to measure temperature and humidity and, in combination with wind speed, can also provide data on wind chills, heat indexes, and dew point temperatures.

Temperature Inversions

One of the more difficult conditions for applicators to understand and recognize is atmospheric stability. Stable atmospheres are specific environmental conditions that may lead to higher drift potential. They vary with time and by location, and can be influenced by other meteorological conditions. A major component of atmospheric stability is the relationship between temperature and altitude. If temperature increases with altitude (not the normal phenomenon), an inversion is likely present. Temperature inversions, where cold air is trapped against the ground surface by a warm upper layer, are most prevalent beginning in the late evening (6 p.m.) and continuing into the early morning (6 a.m.), and tend to be present when the air is calm (Fritz 2003). A lack of wind may indicate an inversion; hand-held instruments will record little or no air movement at the surface if an inversion exists. During a temperature inversion, normal mixing of air molecules will not occur. Thus, released smoke plumes will tend to move parallel to the surface of the earth rather than form a rising column. In contrast, if temperature decreases with increasing altitude (considered a normal phenomenon), the atmosphere is considered unstable. A rising and dissipating column of smoke is evidence of vertical air movement. A good indicator of atmospheric instability is measurable wind at or near the surface.

Applying pesticides during stable atmospheric conditions (inversions) is not recommended. In unstable (non-inversion) conditions, the mixing or turbulence of the air will disperse unsettled, lightweight spray particles into the higher levels of the atmosphere much as smoke rises and dissipates. This reduces the potential for lateral off-site drift. However, when a temperature inversion is present those unsettled, lightweight, and often-invisible spray droplets will hover along the ground much like fog, instead of rising, mixing, and dissipating. Later, when the inversion breaks up and the wind starts to blow, usually as a result of the sun rising and heating the ground, these droplets may be transported off-site. This off-site movement may occur several hours after the application and neither it's direction nor the amount of damage it may cause is predictable. This type of drift is a special concern when sensitive areas are located near the application site. To reiterate, stable (inversion) atmospheric conditions promote off-target drift. Spraying during completely calm conditions is no longer recommended because a temperature inversion may be present. It would be advisable to spray when winds are light (2-5 mph) and steady (predictable direction).

A major concern for applicators is detecting the presence of a temperature inversion. Detecting and recording temperature differential with increasing altitude would be useful, however, many applicators are limited on the atmosphere distance over which they can take measurements. Thus, both surface condition instrument readings and common sense are the best ways to assess the likelihood of a temperature inversion. A practice commonly used by aerial applicators is to inject oil into the manifold of the airplane engine to puff smoke into the application area. The presence of an inversion can be detected by observing the movement of the smoke; if it settles into the application area, an inversion is unlikely. The pilot can also determine wind direction by using this practice. Ground-based applicators may use smoke bombs in a similar manner. In addition to calm conditions (no wind), another factor affecting drift potential is the time of day. Inversions usually occur in late evening and early morning. Other clues that indicate an inversion exists include low-hanging fog in layers, smoke trails that run parallel to the surface, and pockets of warm air in low-lying areas of the application site. Cool air is denser than warm air; hence, if mixing can occur, cool air sinks and warm air rises. As a rule, one would expect to find cooler air in valleys and depressions and warmer air at higher locations like ridges and hilltops. This explains why frost may occur in low-lying spots but not in surrounding areas where the elevation is slightly higher. However, a temperature inversion may trap warm air next to the surface. As the morning temperatures warm the earth and winds pick up, most inversions will disperse. Remember, one of the worst times to spray is during a temperature inversion because drift may result.

Summary

Proper and accurate documentation of weather data during a pesticide application is critical. All certified applicators are required to make and maintain application records of federally restricted-use products. Growers who employ farm workers must record and post application information for all pesticides as required by the Worker Protection Standard. In addition, many states have additional recordkeeping requirements. Such requirements are often little more than documentation of what product was applied, by whom, in what quantities, and at which location. Keeping a full set of records that include on-site weather data for each application is essential for several reasons, one of the most critical being applicator liability.

Hand-held instruments provide an easy and reliable method for applicators to obtain weather data needed for sound decision-making regarding application timing. Proper timing will improve efficacy and minimize the incidence of spray drift. A compass enables an applicator to determine wind direction. A wind meter with temperature and humidity sensors is sufficient for documenting wind speed, temperature, and humidity. For a small investment, these two devices can document proper pesticide use and provide valuable support in defense of an application complaint.

For more specific product information, refer to the web pages listed in Appendix B or directly contact manufacturers for details.

References

Fritz, B. 2003. Measurement and analysis of atmospheric stability in two Texas regions. Paper presented at the ASAE/NAAA Technical Session and Natl. Agricultural Aviation Assn. Convention, Reno, NV. [On-Line] http://apmru.usda.gov/Aerial/2003ASAE/AA03-005.htm.

Heidorn, K. 1998. The weather legacy of Admiral Sir Francis Beaufort. Spectrum Educational Enterprises. Victoria, BC, Canada. [On-Line] http://www.islandnet.com/~see/weather/history/beaufort.htm

Ramsay, C. and C. Foss. 2004. Use of a survey as an educational tool for recordkeeping. J. Pesticide Safety Education. [On-Line] 6: 1-14. http://aapse.ext.vt.edu/JPSE/v6.html.

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Appendix A. Guidelines for selecting useful features in hand-held instruments.
Multiple modes on the same instrument (current, average, maximum wind speed, temperature, humidity) that also span useful data ranges
Digital (LCD) readout with large, easy to read digits
Rapid update capability
Multiple measurement units for maximum flexibility (kt, mph, fpm, m/s, km/h, °F, °C)
Small, sealed (water tight and dust proof), and shock resistant
Auto shut-off, user-replaceable battery (watch type) with long life
High quality bearing with user-replaceable impeller

Appendix B. Selected web pages for weather instrumentation devices [a].
www.aventech.com
www.ambientweather.com
www.benmeadows.com
www.brunton.com
www.chesapeaketechnology.com/html/retrieverWD.htm
www.davisnet.com/weather/index.asp
www.gemplers.com
www.onlinemarine.com
www.oregonscientific.com
www.scientificsales.com/constat.htm
www.specmeters.com
www.westmarine.com

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