WEATHER AND SPRAY OPERATIONS

Introduction

At the time of a spray application, it is important to recognize that weather conditions have a direct effect upon spray deposit and hence spray effectiveness. Five conditions to be aware of are:

- ☞Low humidity and high temperatures causing evaporation of volatile components of the spray.
- ☞Insufficient wind or turbulence resulting in a hanging spray cloud.
- ☞Inversion layer resulting in poor settling of smaller drops.
- ☞Thermals caused by the heating of an unstable air mass.
- ☞Rain or wet foliage causing spray runoff.

Low Humidity High Temperatures

If an insecticide formulation contains evaporative components or is diluted in an evaporative carrier such as water, then the size of droplets reaching the target and their behavior will vary with time of flight and be influenced by temperature and humidity. When spraying a forest, evaporation is a problem more so than in agricultural spraying because the aircraft's height above the forest canopy is at least 15 meters. According to calculations reported by Ciba-Geigy, at 29^{o}C. a water-based droplet 100 microns in size can evaporate by 40 percent after falling only 0.6 meters whereas an oil-based droplet of the same size can lose only 28 percent of its weight after 9 meters. Most insecticide formulations contain additives to impede evaporation. However, among insecticide formulations, a variation in evaporation rate can be expected. Sundaram and others, have demonstrated different evaporation rates for three water-based formulations, each sprayed with VMD's less than 100 microns:

Futura XLV (1.65 percent/minute)
Thuricide 48LV (1.75 percent/minute)
Dimilin WP-25 (2.45 percent/minute)

Note the evaporation rate of Dimilin is 40 percent higher compared to the two Bt. products.

For water-based formulations the greatest influence on evaporation rate was initial droplet size (the larger the initial droplet, the less the influence of evaporation) and relative humidity the next most important influence. Oil-based formulations showed a negligible effect from changes in relative humidity. Ironically, for both water- and oil-based formulations, the influence of temperature was considered small in comparison to other factors. One of those other factors is surface tension of the droplet. Surface tension increases the resistance to small droplet formation and it's the small droplets that have the highest evaporation rates. Surface tension is a function of the formulation.

For gypsy moth aerial spray operations in the eastern United States, the temperature/humidity thresholds at which spraying should be stopped are:

- ☞Aqueous formulations--temperatures in excess of 27° C. and/or relative humidity less than 60 percent.

- ☞Oil-based formulations with water added--temperatures in excess of 27° C. and/or relative humidity less than 40 percent.

The 60 percent relative humidity rule for aqueous formulations is based upon the observation that the rate of change of an aqueous formulation is dramatic below 60 percent relative humidity. These thresholds are particularly important when using small droplet sizes (less than 115 microns) and as explained above, relative humidity should be of most concern.

Temperature and humidity should be measured at the spray block or in a geographically similar area close to the block. Measurements should be made at least 2 meters above the ground. Relative humidity is the amount of water vapor in the air relative to the maximum amount the air could hold if it were saturated at the same temperature. It is always expressed as a percent. The psychrometer or sling psychrometer is the most accurate method for determining relative humidity. A sling psychrometer must be spun for 90 seconds to arrive at an accurate reading of depression of the wet bulb. The wet bulb reading is used in conjunction with dry bulb reading to estimate relative humidity.

Insufficient Wind or Turbulence

Wind provides energy to move a spray cloud and should be used to help target spray deposition. For this reason, the best wind conditions are organized in one general direction and steady. Ideal wind conditions range from 5-15 kph, without gusts. Winds less than 5 kph, are usually variable and hence less dependable.

Smaller spray droplet sizes (20-100 microns), because of their lower fall velocities, are greatly affected by wind. Wind distributes droplets over and around the foliage by turbulent diffusion. It is the essential mechanism whereby droplets are spread out after they are out of influence of the aircraft wake. Without wind, turbulent mixing will be negligible and the droplets will stay in a relatively dense cloud falling very slowly and moving with the predominant air flow. Spraying in near-calm conditions is common and successful in agricultural spraying when applying large (>250 micron) droplets. Agricultural aircraft also fly close to the target (1-3 meters), with downwash or wake causing penetration of the spray deposit. Most forest sprays, however, are released too high above the canopy to be effectively distributed by wake effect alone. For this reason, it is advantageous to have some wind energy and turbulent forces to help move the spray cloud along and into the canopy.

When a spray cloud reaches the top of the canopy, its penetration into the canopy is a function of air turbulence and sedimentation of the droplets. Turbulent eddies within the canopy are important because they carry the small droplets into the foliage (Fig. lB). The sedimentation speeds (that is, droplets falling by gravity alone) of 30- and 50-micron drops are about 0.1 and 0.25 kph, respectively. In a forest canopy, windspeeds of 5-16 kph can greatly augment dispersion of droplets.

When spraying in near calm conditions, droplet density is primarily controlled by aircraft wake effect and droplet sedimentation. The aircraft should fly as close to the target as safety permits (usually 15 meters). Downwash decreases with increasing aircraft speed; therefore, the aircraft should also fly somewhat slower. If these calm conditions will predominate during spraying, the aircraft should be recalibrated for the slower air speed.

In general, near calm conditions should be avoided. The basic concept is to cover large amounts of foliage with a maximum amount of insecticide. It is generally recognized that large drops (larger than 100 um) contain over 50 percent of the spray mass. Consequently, an attempt should be made to use smaller droplets released into a 5-16 kph steady wind. The turbulence associated with these winds will aid in distributing the droplets throughout the canopy.

At the other extreme, high winds (over 16 kph) can result in increased drift. Windspeed measurements should be taken only to insure that they fall within the acceptable operational range of 1-16 kph. As with temperature and humidity, windspeeds outside these limits should serve as caution zones. Windspeeds above 16 kph are not necessarily detrimental to effective spray deposit, however, above this threshold spray deposit should be closely monitored for off target movement. Of particular importance at higher windspeeds is the assurance that gusting winds will not cause patchiness in the spray deposit.

Wind direction should also be observed to insure that it will not result in spray drift outside the spray area. Wind direction should be used to help target the spray cloud, with aircraft flying perpendicular to its direction. Spraying perpendicular to the wind direction uses the energy of the wind to help spread the cloud across and into the target, resulting in a more even application as successive swath patterns overlap.

Windspeed and direction estimates should be made as close to the spray area as possible. Cup anemometers provide a reliable method of estimating windspeed. They should be used in an opening at least four to five tree-heights across and at least 2 meters above ground cover. Windspeeds should be estimated using the Beaufort speed categories shown in Table 1. In general, windspeed increases with height above open ground level. For a windspeed measured at 2-3 meters above the ground, add 50 percent (multiply windspeed by 1.5) to more closely reflect windspeeds in the canopy.

The simplified Beaufort wind scale (Table 1) can be used as a guide when an anemometer is not available. These windspeed indications can also be used to estimate windspeeds at the canopy top, which may be different from those observed at ground level.

Inversion Layers

Droplet deposition on the forest canopy occurs mainly by impaction and sedimentation. A common reason for lack of deposition of small droplets is the existence of a temperature inversion. An inversion layer is a band of air which underlies a warmer air mass. In flat

Table 1. Simplified Beaufort Windspeed Scale

Beaufort Number	Wind description	Visible sign	Approximate kph
0	Calm	Smoke rises vertically	0 - 1
1	Light air	Direction is shown by smoke drift; barely moves tree leaves	1.5 - 5
2	Light breeze	Leaves rustle, wind felt on face; small twigs move	6 - 11
3	Gentle breeze	Leaves and small twigs in constant motion; blows up dry leaves from ground	12 - 19
4	Moderate breeze	Small branches move; raises dust and loose paper	20 - 29
5	Fresh breeze	Large branches and small trees in leaf begin to sway	30 - 39

areas, this is usually caused by radiation or radiational cooling of the ground during cloud free nights, and in mountainous areas by drainage of cool air into lower elevations. If small drops are sprayed above this layer, they will hang suspended and tend to move horizontally with the airmass. In the inversion region, turbulence is also lacking as inversions are usually stable calm conditions (Fig. 1A). Large droplets fall easily, and are not moved out of the spray area. Be aware, however, that the small droplets can drift a long way, and will not be substantially dispersed under such conditions.

Maximum temperature inversions usually occur when a high daytime ground temperature is followed by radiation cooling to cloudless sky. The cold-sky radiation cooling produces an inversion which starts in early evening, continues through the night reaching a peak in the early morning and is the usual pattern for inversion establishment in relatively flat areas. Spraying that begins too early (at daylight) may be less likely to distribute small droplets within the canopy simply because of inversion conditions and lack of turbulent eddies. Spraying in a cloudless evening, after a sunny day, may also show poor small droplet distribution in the canopy due to the reestablishment of a temperature inversion. In both cases, the wake of the aircraft is the principal energy source distributing small droplets.

With overcast skies, temperature gradients above and within a forest are too small to influence droplet dispersal within a canopy. Under clear skies, temperature gradients are greater. Generally, temperature inversions above the forest crown disappear by 8:00 a.m., and within the canopy by 9:00 a.m. By 7:00 p.m. on clear days, inversions can again be established in the canopy.

One of the best indications of an inversion is smoke rising a short distance vertically, then hanging, forming a horizontal layer (Fig. lA). Figure 1C represents ideal conditions for spraying. While spraying, another common indication of a hanging spray cloud is droplet deposit on the windshield and fuselage of the aircraft. On the ground, “cool spots” in the low areas along the roadway may be detected. Typically occurring conditions to expect an inversion are:

- ☞ A high pressure area has been centered over the region for at least one day.
- ☞ Warm days followed by clear, cool nights.
- ☞ Visibility shows a marked decrease without the presence of precipitation.

Thermal Updrafts

There are certain unstable air conditions which result in air parcels near the earth warming and rising, then being replaced by cool air from above. These form vertical eddies bringing cool air down from aloft and carrying warm air away from the ground. These eddies provide one of the ways by which the solar energy that is absorbed at the ground is carried aloft. This process becomes very noticeable in spring and summer particularly in dry areas. Pilots know these vertical eddies as thermal updrafts that cause a bumpy ride as the aircraft passes through.

A spray released into these thermal updrafts will be entrapped in a rising bubble of air and will not reach the canopy. The best ways to recognize thermal updrafts is through pilot reports, rising columns of smoke, dust devils, and usually the appearance of fair weather cumulus clouds. Fair weather cumulus clouds are white and have flat bases with rounded tops resembling cauliflower. This is a cloud formation that usually appears in late morning or early afternoon and is produced by upward rising currents of air. The clear areas between the clouds are areas in which the predominant air motion is downward.

Spraying should be stopped whenever thermal updraft conditions appear. Use the appearance of fair weather cumulus clouds as the indication that thermal updrafts are established.

Rainfall and Wet Foliage

The precise effect of rain upon spray deposition has not been well documented for forestry applications. However, rainfall is known to have an adverse effect on spray deposit retention and residual levels of *Bacillus thuringiensis* (Bt.) on foliage. Therefore, a spray sticker is recommended when using diluted Bt. Undiluted applications of some formulations that contain stickers may not require additional sticker to be added. Generally, the Dimilin manufacturer recommends that spraying should not take place when rain is imminent (definite rain is less than 1.6 kilometers away, or there is more than a 75 percent chance) or when foliage is dripping wet After the spray material is dry (several hours), rain will have less of an affect on the deposited material.

For Bt. rainfall is generally considered a problem when it is in excess of 0.2 centimeters and occurs within several hours before or after the spray application. Rain before the application may leave foliage too wet for Bt. to stick to it or it may adversely alter surface tension of the leaf or drop. Foliage conditions should be checked on a walk through the planned treatment area. If the foliage is wet or if water can be shaken from it, spraying should be delayed until conditions are drier.

Weather observers should observe and note rainfall in treatment areas. The easiest and most reliable method of estimating amount of rainfall is to place rain gauges in representative areas within the general spray area.

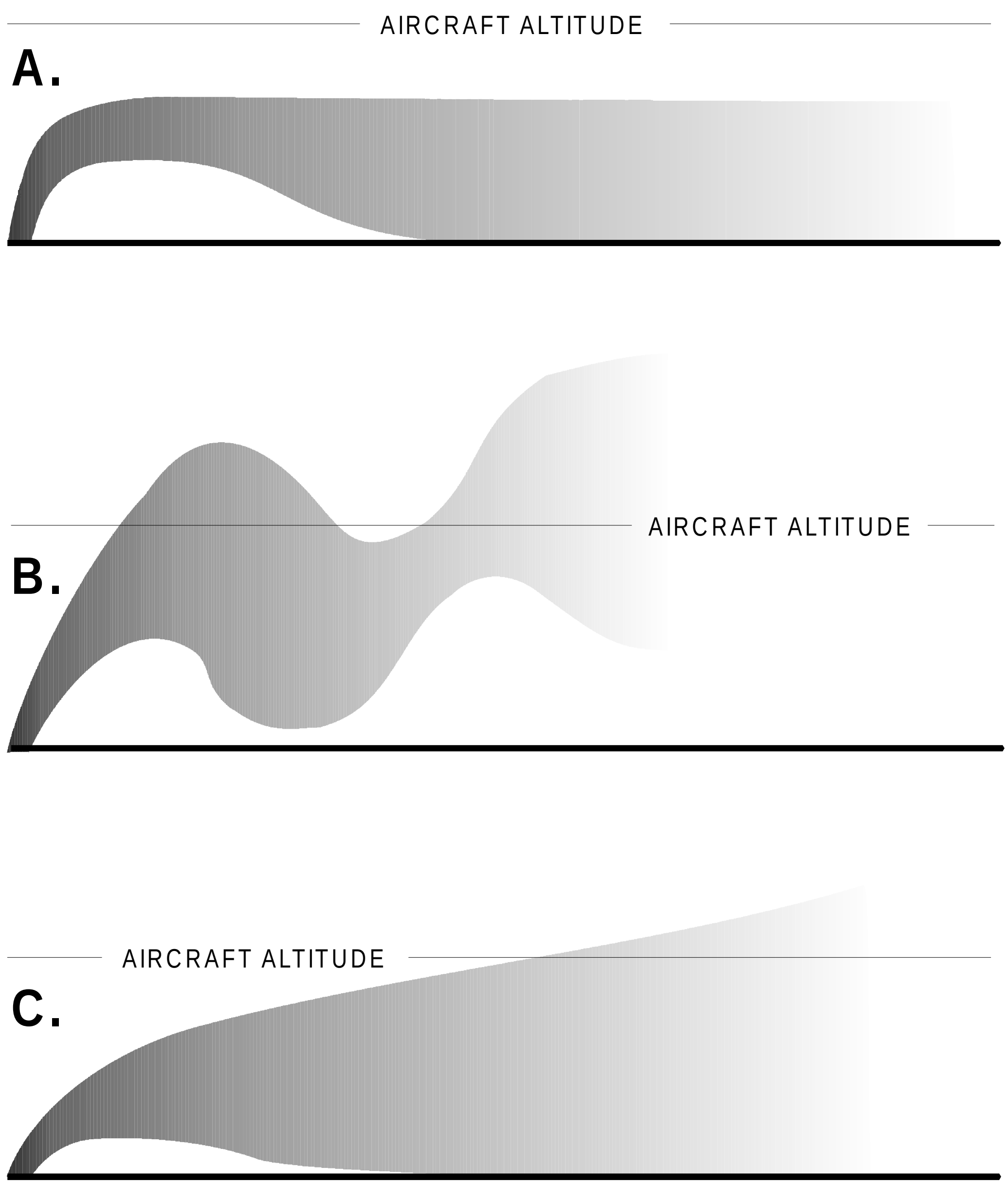

*Figure 1. Schematic diagram showing smoke plume diffusion under (**A.**) stable, calm or inversion condition, (**B.**) unstable condition, and (**C.**) slightly unstable condition.*