EFFECT OF METEOROLOGICAL CONDITIONS ON THE DEPOSIT PATTERN OF INSECTICIDES[1]

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ABSTRACT. The deposit pattern of a spray cloud is affected by the micrometeorological conditions at the time of application. With the development of new application technology, new insecticides requiring lower dosages or volumes of application and the need to prevent damage to the environment as a result of drift or double swathing, it is essential that all pesticide applicators make use of available knowledge pertaining to meteorological factors affecting spray drift and deposit. Basic equipment requirements for determining suitability of weather conditions for spraying are described.

The aerial application of pesticides has evolved from a small operation based on single engined aircraft with a payload not much more than the weight of the pilot to large operations covering acreages up in the hundreds of thousands using multi-engined aircraft with payloads of about 30,000 lbs. Regardless of the type of aircraft used, the basic principles of aerial application of insecticides have not changed in the past 25 years. Once the insecticide is released, it forms a cloud of material which disperses as it descends from the aircraft. The droplets are deposited, and in their lifetime from emission to deposition they are affected by atmospheric conditions. A starting reference for studies on the drift and deposition of spray droplets is the work done at Porton by Gunn (1948). In this study, Gunn described the HU factor and its use in determining the swath width for aerial spraying. This swath width is governed by the height of the aircraft above the ground (H) and the cross wind speed (U) As the droplets fall through the vertical distance 'H', the cross wind displaces them laterally to give the resultant swath width across the target area. The net swath width is determined by the wind speed and the direction of the wind relative to the line of flight of the aircraft. With the variation in drop sizes there is a "sifting out" of the droplets with the larger, heavier drops falling more rapidly and closer to the line of flight, and the smaller lighter drops, with their slower rate of fall, being deposited at greater distances from the line of flight. At the extreme limit are the very small droplets (in size range 5–10 μm) which will remain airborne for hours. This drift of insecticide is used by the operator to provide effective, economical coverage of the target area. Operational swath widths range from 100 ft (small aircraft such as Ag-Cat, Pawnee, Agtruck) to the 3000 ft swaths achieved in Canada, with the DC-6 and Super Constellation aircraft. Irrespective of the type of aircraft, the deposit pattern under the effects of the cross wind will exhibit a peak with a "tail" extending down wind.

The extent of the tail of the deposit is governed by the number of small droplets in the spray cloud. With a fine spray (many small droplets), the deposit will, when graphed, indicate a long tail. The aircraft flight lines are adjusted to give an overlap of the swaths which helps to smooth out irregularities in deposit on the spray block.

It is this effect that is aimed for and made possible by the use of more efficient spray atomizing devices and with good control of the aircraft guidance (Joyce et al. 1969). This pattern of deposit is theoretically possible over smooth terrain where the pilot, by maintaining a constant altitude, can keep the 'H' value constant and where the wind speed and direction

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are constant. In effect, the HU factor is constant during the whole of the spray application. In reality this seldom happens; in most areas the terrain is, at the least, rolling, and more frequently hilly, with deep valleys and high hills. The pilot cannot maintain a constant altitude above ground and as a result the 'H' value is changing all the time. With a fixed emission rate, this means that as the swath width changes, the amount of the material on the target area varies. With the overlap of several swaths, some of the unevenness of the spray deposit can be smoothed out.

The effect of terrain on spray deposit is further complicated by the meteorological conditions that exist in these areas. With variations in ground features and tree cover, there are variations in wind speed, direction, turbulence, and temperature regimes. In hilly areas, under the effects of the rising or setting sun, there are different temperature systems depending on whether the slope is in shade or in direct sun. The warming or cooling results in a change in the thermal stability of the air mass in that particular region. Akesson and Yates (1964) have reported the relationship between the stability of the air mass with the spray deposit. This team (Yates et al. 1974) showed that in the field of agricultural spraying a simple stability ratio could be used to measure the suitability of weather conditions for spraying. Extension of this work to the forest scene (Armstrong 1973, 1975) demonstrated that the relationship still holds if the stability ratio is measured in the region between tree-top height and the height of spray emission. Thermally stable conditions with a minimum cross wind of about 2 mph appear to be the best conditions for aerial applications. Sprays can be applied at higher wind speeds (up to 10–15 mph); however, at these speeds there is the problem of determining the required offset of the aircraft to allow for drift of the spray cloud if the 'H' factor cannot be reduced to a safe altitude. In regions with valleys, air mass movement tends to follow a pattern of moving up or down the length of the valley during the day with associated movements up or down the sides of the valleys (Geiger 1961). Winds over hilltops can produce wave effects which will result in no deposit of material on the hill crown and concentrations in other areas. The results of all these factors can be a patchiness in deposit which is seen as uneven insect kill with the associated lack of protection.

When an aerial spray program is aimed at mosquitoes breeding in forested areas the micrometeorological conditions in the interface layer at treetop height can become complex and affect pesticide deposition patterns. Frictional turbulence is an advantage in that it helps to mix the insecticide cloud through the tree canopy. Open tree-free patches in a forest stand not only result in variations in thermal stability but cause a deep penetration of the air to the ground level of that particular area (Geiger 1961). This brings the cloud of insecticide down, but the pattern of air movement is such that there can be concentrations of insecticide at ground level.

The size of the clearing and movement of the insecticide cloud down to ground level create problems in assessing spray deposit. There can be a concentrating effect of the insecticide in different portions of the clearing according to the size of the clearing, the height of adjacent trees, and the wind speed. In studies correlating spray deposit with meteorological conditions, this pattern of deposit has been recorded (Armstrong 1975). A series of repeat applications were made in which the only variable was the weather. As part of the sample unit layout, a circular arrangement of cards was placed in a clearing in a white spruce plantation. Spray deposit was measured in terms of volume of material, number of drops/cm^2 and drop size characteristics of the deposit. A pattern of deposit was observed in which there was generally more insecticide in terms of volume of material and number of drops/^{2} on the down-wind side of the opening. On occasion there was a reversal of this trend which is attributed to variations in wind movement patterns.

Reference has been made to the use of cards for collection of spray droplets. This is a standard procedure used by most spray researchers where information on drop-size distribution and number of droplets per unit area is required. Criticism of this sampling technique can be made, and it is acknowledged that the flat collecting surfaces are not the best for collecting small droplets (Joyce et al. 1969, Himel 1969). These problems are acknowledged but as long as the faults of the system are recognized, and the deposit is correlated with insect mortality, this method, along with units such as a rotorod collector, is one of the few practical methods available for measuring spray deposits.

The amount of spray deposited will vary according to the weather conditons at the time of spray application. Repeat applications of waterbase sprays and oil sprays under measured meteorological conditions showed the correlation between amount of spray deposited and the stability of the air mass at the time of application (Armstrong 1975). This relationship holds true for experimentally applied sprays and operational sprays. The data indicate that under most conditions a deposit of 50% of the emitted spray is a good spray. Studies, on the aerial application of acephate (Armstrong and Nigam 1975), showed the variations in percentage spray deposited that can be found in a well controlled experimental aerial spray. Not only was there this variation in average deposit on the block but as a result of factors previously mentioned (position of sample unit, micrometeorological effects, etc.), there were wide variations in deposits across the spray block. The variations and causes for variations in spray deposit are found in all spray operations.

With these weather associated problems interfering with and preventing the achievement of the desired uniform deposit it is obvious that the spray applicator must take every precaution to ensure that the spray is applied under suitable weather conditions. Yates et al. (1974) and Armstrong (1975) have demonstrated that the stability ratio[2] when determined in the correct microclimatic zone will give an objective assessment of the suitability of weather conditions for spray application. The only equipment required is an anemometer plus 2 temperature sensors to determine temperature differential, mounted on a mast of the appropriate height. Many applicators have fitted vehicles with a mast and strobe light to provide swath guidance to the pilot; this would provide an excellent mast for the anemometer and sensor set and as such would provide weather data where required (in the spray area) at the time of spraying. With such a set-up the applicator is saved from having to make a subjective assessment of weather for start and stop times, and in fact this duty, with a set of guidelines indicating upper and lower limits of weather, can be given to the field crew. If the applicator wishes, a record of weather conditions at the time of application can be retained in case there are any questions about lack of effective application as a result of weather or any concern with drift off the target area.

If the spray operation is to be done in an area where it is necessary to take weather readings to heights higher than about 20 ft (i.e. forested areas) either a portable extendable tower, or a tethered balloon can be used to carry the sensors. A tower capable of being extended to about 60 ft can be easily and quickly moved and erected; it cannot be used as a guide for the spray aircraft. Taller towers are available but, with their increased weight and need for an extensive guy-wire system, they require a lot of time and

[2] Stability ratio defined as

$$S.R. = \frac{T_2 - T_1}{\bar{\mu}^2} \times 10^5$$

where $T_2 - T_1$ is the temperature differential in °C between two heights with T_2 the upper position and T_1 the lower position $\bar{\mu}$ is the wind speed in cm/se.

space for setting up. Tethered balloons, carrying a sensor package to several hundred feet have also been used successfully. Information on towers, balloons and sensor equipment is available in catalogues and publications in the field of meteorology and weather equipment. The basic requirements for the sensors are that the wind speed indicator should have a starting threshold of about 0.5 mph and need not go higher than about 20 mph, and the temperature sensors should be accurate enough to indicate a temperature difference of about 0.5°F.

The meteorological records collected can be used to correlate weather conditions at the time of application and from the particular spray area with spray efficacy. In this way the accuracy of the guidelines for determining suitability of spray weather can be improved and, with a better understanding of the micrometeorological peculiarities in the particular spray area (flat open terrain, coastal or inland areas, hilly country, wooded areas), the operator can ensure better, more effective spray applications.

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