

MODULE I: PESTICIDES MANAGEMENT – THE SWATH KIT

Objectives:

- Teach the basic elements of analyzing swath patterns of agricultural aircraft.
- Familiarize users with basic theory and principles of aerial deposition.
- Droplet spectrum basics. How to investigate the spectrum with the Swath Kit.
- Familiarization with the Swath Kit for use in the field.

I. HOW AIRCRAFT SPRAY PATTERNS ARE FORMED

A Why perform spray Pattern Analysis?

Establishing lane separation for particular combination of crop/forest and spray material.

Checking spray aircraft prior to projects.

Checking distribution across the swath

Checking droplet spectrum of deposits.

B Wake creation, atomizer positioning and droplet spectrum effects.

Major lesson on airflow around an airfoil will be given in the AGDISP part of the course. Vortices (singular: vortex) are always produced by an airfoil. The heavier the aircraft and the slower it flies, the stronger the vortex.

Consequently, it is a good idea to fly into wind (or better still in no wind) to see the effects of the vortices.

Newton's 3rd law – essentially a mass of air gets moved down so the aircraft can stay up. Phenomenal amount of air, not very quickly.

Avoidance of nozzle placement past 66% of span (sometimes 75%).

Smaller droplets will tend to be affected by the vortices. Adjust placement accordingly.

C Weather effects on spray patterns.

Wind – By far the main influence. Affects cross wind and into wind applications

A 100µm droplet sinks at less than 1 foot/sec.

In forestry heights (typically 50ft) the offset has to be considerable. This means that if you are applying crosswind applications, you should allow for considerable offset, sometimes even flying beyond the cardline. On into wind applications, remember to tell the pilot to keep the spray on until at least 1,000 ft past the cardline before switching off.

Remember that the different sized droplets arrive at the cards from different positions along the spray line (big ones drop from nearby the cardline; smaller ones from further out).

D Droplet spectrum considerations.

Small drops are more difficult to catch on flat targets than fast droplets when moving. The effective area of the card varies with droplet angle.

Targets which allow orientation to the droplet trajectory are much more effective at catching droplets. However, small droplet will still be able to scoot around the targets.

The Forest Service often sprays biological insecticides like Btk. It is useful to remember that small droplets of Bt often have sub-lethal doses and in some cases no active ingredient at all. Therefore it is important to concentrate on the bulk of the material.

Vmd/nmd definitions.

Schick, R.L., (1998) An Engineer's Practical Guide to Drop Size, Spraying Systems Co., Wheaton, IL Available off the web.

Be very careful about Droplet Density as a parameter. The difference between 20 droplets/cm² (the holy grail from a few years ago 5 droplets/cm² may be only 10% in terms of volume. (the 75% small drops which are not caught contain only 10% of the active ingredient).

E Effective use of spray collectors

It is always useful to compare the real (probably biological) target you want to reach with your spray with the flat plate collector. Broad leaf forests are probably quite well simulated by such collectors, but coniferous forests are not.

To limit the number of card lines it is common to run several replicates (3 is a good compromise between quality of results and statistical validity) and average the final results. Statisticians tell us that laying out three card lines is not a true way of obtaining replicates although if the card lines are sufficiently spaced, the results may be acceptable as replicates.

If you lay out 5 lines 100 feet apart and have the aircraft fly over the card line, comparison of the cards will show that there are often quite marked differences between the lines, supposedly taken under almost identical conditions.

The lesson here is to avoid too much dependence on one run. The number of runs to perform depends on what the objective of the patterning exercise is.

II. ANALYSIS OF A SIMULATED AIRCRAFT SPRAY PATTERN

The sprayer will be a Windex-type hand spray bottle. Forty cards will be spaced at 3-inch interval. The pattern will be simulated to look like cross-wind spray application made by an aircraft. A fan with its axis parallel to the spray line will direct spray so that the lighter droplets get moved down the card line whereas larger droplet fall out 'upwind'. We may add some anomalies – like a heavy patch or a light patch in the middle, and see how the Swath Kit displays it.

We can't control the application rate, but we'll make it look like a 0.5–1.0 gal/acre application. We'll fix the card spacing to be 5 feet.

We will run a simulated spray for each group, and compare and average the runs during the last (fourth) run.

B Introduction to the Swath Kit.

A lightweight, field portable image analyzer and weather data recording system (recording wind speed, wind direction, temperature and RH).

Both these units interface with a laptop computer using a powerful program which integrates the data and enables aircraft-focussed analyses to be performed.

I cannot teach you all about the Swath Kit in 90 minutes. We find that people learn to use the Kit by themselves, but the process can be accelerated with a day's training course.

We will already have an aircraft profile (we'll choose a modern agricultural aircraft a turbine Air Tractor). The program helps you select nozzles and calculate the number of nozzles required, but we do not have enough time to demonstrate this aspect.

We will assume that the Air Tractor has been fitted with 10 Micronair AU5000 rotary atomizers and will be spraying an undiluted formulation of Btk. The Forest Service and Btk manufacturers recommend the use of rotary atomizers to assure good distribution.

C Measurement of the spray pattern with the image analyzer

Before analyzing your first set of cards, it is a good idea to review the principles of how the Swath Kit uses image analysis to obtain data about a swath pattern from a set of spray cards.

The deposit stains formed by the droplets have to exhibit a contrast that can be picked up by the TV camera / frame-grabber combination. The image is fed to the SKWin program, which on the basis of calibration values decides what part of the image was actually caused by droplets, and rejects the remainder as background. The program then calculates the area of each stain, transforms its area to a circular form and calculates its diameter. It then applies a spread factor to account for the spreading of a round droplet to form a larger stain, and calculates the volume of the droplet that caused the stain. It proceeds to do that for every stain measured.

The program keeps a running total of the volume of all the droplets it has measured, the number of droplets and surface area covered by the stains. To make calculation of droplet sizes possible, the program distributes the range of droplet sizes into 20 bin classes, which can then be used for statistical analysis. There is a default bin class distribution, but any progressive sequence of numbers can be used to set the upper and lower limits of the size class bins.

Although data are binned, the program keeps a record of every droplet. These data can be used to recalculate the readings of the cardline if, for example a new spread factor is applied, or a new filter setting is applied.

The swath pattern is built up from individual card data based on three parameters – volume (or mass) per unit area, droplet density or proportion of area covered. The program takes the same swath pattern, and repeatedly adds it, staggering successive patterns according to the aircraft's desired lane separation. The graphic display and statistics reflect the choice of swath orientation (racetrack or to-and-from flight) and lane separation.

D Spray Pattern Analysis

1. Some decisions have to be made on how to analyze the spray pattern. Which parameter to use? Volume/area, percentage coverage or droplet density? Volume/area best for LV applications.
2. Spread Factors.
We'll be using Novartis water sensitive paper – select appropriate SF.
3. Pattern shapes.
We know that the application is being applied cross-wind. Therefore we will not use to-and-fro as a modeling option (where the main pattern and a mirror-image of it is sequentially combined based on direction of flight). Wind has a far greater effect on the patterns than aircraft wake effects.
4. Simulated overlapping of patterns.

Definitions:

Lane Separation: the assigned distance between adjacent parallel swaths.

Swath Width: the distance of the physical spread of a swath. Effective SW generally refers to the usable part of the SW and the basis on which a LS is assigned. The two are therefore usually identical in size and used interchangeably.

This option allows us to vary the lane separation to see what a realistic LS setting would be. What is the standard for selecting a LS? Generally evenness of deposit. If we had calibrated the aircraft for, lets say 75 feet and the pattern looks good at 90 feet, we can increase the flow rate of the spray system accordingly and assume it will not have much effect on the swath width.

5. Droplet spectrum analysis.

A distribution table and a simple display graph of the droplets analyzed are available. Available-statistics can be used to investigate whether the selection of nozzles was suitable for the mission.

6. What I can and can't believe.

Active ingredient: You can enter the active ingredient concentration of the spray mix. If you use an aqueous mixture, a certain proportion of it will evaporate during descent. As it loses water, the concentration of the AI will increase in the spray. The Swath Kit has no way of estimating what proportion of the spray was lost and therefore assumes that the original and final concentrations were the same. Even if you catch 100% of the spray, the recovery will indicate a lower AI rate. Generally it is better to use application rates (vol/area); if you catch most of your spray and use an accurate spread factor, the final result will be an accurate indication of what evaporated.

Pattern Shape: Look for broad trends in replicates. Never base operational decisions on one pattern.

Application Rate: The Spread Factor is a linear dimension, but it is used to make volume (3 dimensional) calculations. Therefore any error in the spread factor will be compounded.

7. E.g. A 25% overestimation of the spread factor will give a 95% over-estimation of volume ($1.25 \times 1.25 \times 1.25 = 1.95$).

Droplet Density: Tiny droplet register as a count in the same manner that a large droplet would. Therefore a droplet with 1,000 times the volume of a small droplet would be counted equivalently. As stated above, you may lose 75% of the droplets, which may only account for less than 10% of the spray volume.

III. From Lab to Field: Real world considerations

A How to run a successful field trial

This is a subject for a day-long training course. But briefly here are a few pointers.

Terrain: Find a site that doesn't have structures nearby which would cause air disturbance and would interfere with aircraft approaches. Avoid hilly terrain—the wind fields are unpredictable and aircraft do not fly at the usual spray attitude (the wake pattern greatly changes as aircraft climb and descend).

Planning: Make sure you have all the materials you need before you start.

Set up the card lines so that you can move them easily when the wind changes.

Ensure that you have sufficient labor to carry out the tasks—5 people is a typical number that covers every base.

Communication: Brief the pilot so that he understands what you are planning to do. Ask and listen to any suggestions that he may have. Ensure good radio communications with the pilot throughout the trials.

B Common errors and how to overcome them

Again, this can only be covered very briefly:

Aircraft positioning: The swath goes off to one side.

If spraying from typical forestry altitudes (50 feet above cards) allow for the crosswind element by offsetting the aircraft upwind, when making runs into a wind that has shifted from the perpendicular. Calculate the crosswind wind strength component by taking the sine of the angle of the wind away from the perpendicular to the card line and multiplying it by the wind strength.

E.g. The cardline is 270-90 (i.e. set up for a due north wind – 0°) and the wind is from 30° at 10 mph. The sine of 30° is 0.5, so the strength of the crosswind blowing across the card is 5 mph. Figure out how far small droplets traveling at that speed will move before impacting. (1 mph is 1.5 ft/sec).

Card numbering confusion:

There are two main camps here:

1. Pre-number all cards (e.g. Run 12 – Card 43) which is easy to do with a spreadsheet program. This means that unused cards are trashed (which is wasteful).
2. Label the cards after collecting, leaving untouched ones for later runs, meanwhile labeling the stained cards on the fly. Some people just number the position number and mark the run number later. These methods require good organization and enough labor to collect and label cards.

Insufficient contrast on the cards:

The image analysis stage is difficult because the threshold has to be re-set constantly because the stains are hard to distinguish. If you are using new materials, make sure that you do some preliminary dye tests with the spray mix/collectors to establish how much tracer dye to add.

C Work-arounds

No Spread Factor:

A work-around the problem of not having a spread factor can be made with a bit of guesstimating. You will definitely not win the Nobel prize for this, but your data may make sense. Choose a humid day when you are sure that you can catch most of your deposit – typically that means low wind conditions. Spray a couple of sets of cards and read them using an estimated spread factor. Adjust the spread factor (it is easier to use a linear one, where just the slope, $\beta 1$ coefficient is changed) until you get a 90% recovery. Take the mean of the two runs, and use this spread factor for that specific spray material *under the same spray conditions*. The non-scientific part of this method is the assumption that you have caught 90% of your deposit and that no evaporation has occurred.

D Getting the best of both worlds

Combining Swath Kit data with simulation model results.

The Forest Service is making the swath modeling program AGDISP available to be used by other programs, including the Swath Kit. Scheduling delays have meant that this program is not yet incorporated into the Swath Kit.

The main use of the simulation program will be primarily before spray trials, to do tests of atomizer positions, swath width size etc. However, it will be possible to use the aircraft/spray system information combined with the weather data to see what theoretically could have been obtained. This will be a method of constantly testing the theoretical model with how it compares with the real world.