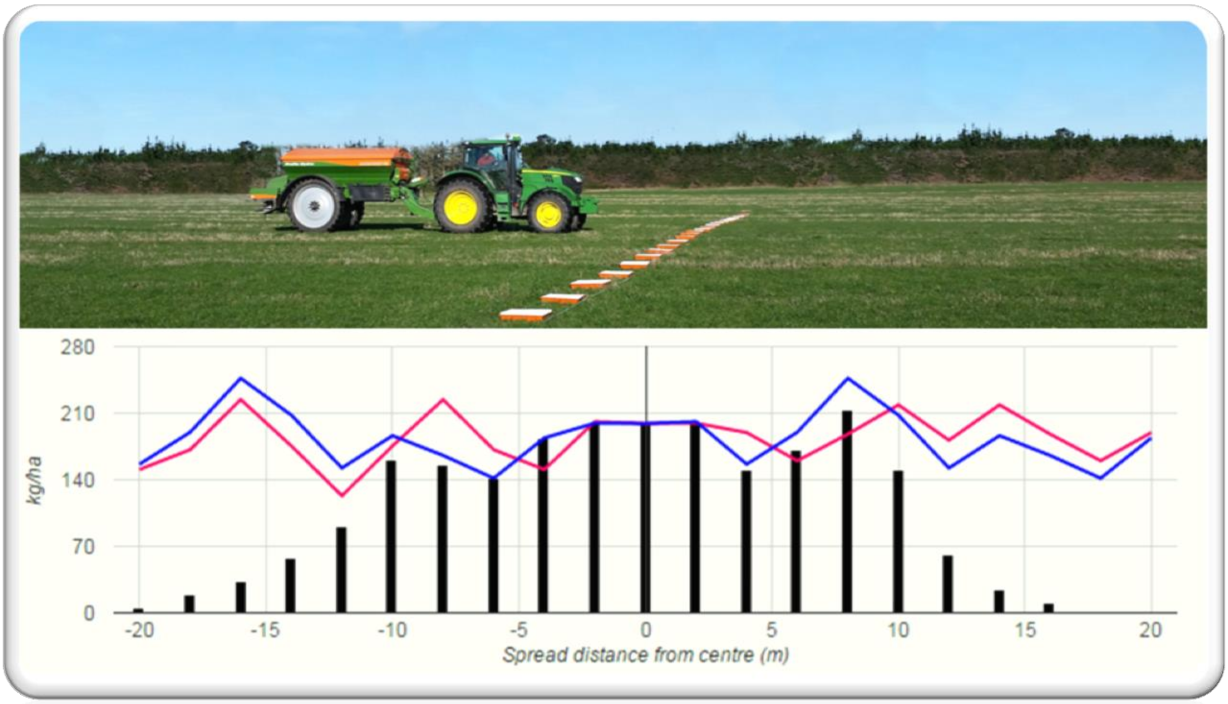
Training Handbook



Broadcast Fertiliser Applicator Performance Assessment

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Introduction

Ground based fertiliser application uses a wide range of application methods to apply a vast array of fertiliser products, requiring careful matching of equipment and technique to the fertiliser and production system.

There are two broad types of ground based spreading equipment:

- Broadcast equipment that spreads fertiliser beyond the width of the machine (including single, twin disc and oscillating spout spreaders)
- Placement equipment where the swath width is equal to or less than the width of the machine (including band spreaders, side-dressers, planters with fertiliser application).

This booklet covers broadcast speading equipment.

Ensure equipment is correctly maintained and serviced and set up according to manufacturer's instructions. If the performance checks show actual application varies from the intended rate or distribution pattern, follow manufacturer's recommendations to make appropriate adjustments. Re-check performance after such adjustments are made.

Why check application equipment performance?

As farming intensification increases, so does the need for greater precision in fertiliser application. Intensification brings a greater risk of negative impacts on farm profits and on the environment through errors and inefficiencies in fertiliser application.

Recommendations and nutrient management plans from fertiliser and agricultural consultants assume the fertiliser material will be spread evenly and accurately over the target area at the target application rate. Poor spreading can negate the best management plans and result in significant production losses and loss of nutrients to water. Knowing what should be done is important. Knowing what is actually done is important too.

Excessive application variation is undesirable as it has a negative impact on crop or pasture performance and can increase leaching losses. If striping can be seen in crops, spreading variation is likely to exceed 40%, and yield loss will be 20% or more.

It is now generally accepted that for nitrogen fertilisers, the spatial coefficient of variation, CV, should not exceed 15%. For other fertilisers types a CV not exceeding 25% is acceptable.

Published Guidelines

All fertiliser spreader testing programs or standards aim to achieve the same goal, uniform distribution of nutrients where they provide the most efficient economic and agronomic use for both the contractor and the farmer.

Internationally recognised standards for testing broadcast spreaders include:

- International Standards Organisation (i and ii)
- American Society of Agricultural Engineers

Quality assurance programs include:

- Spreadmark (New Zealand)
- Accu-Spread (Australia)
- European Standard (ES)

Broadcast Equipment description

Broadcast equipment that spreads fertiliser beyond the width of the machine (including single, twin disc and oscillating spout spreaders)

Single disc spreaders

Smaller or older spreaders may use a single spinning disc to throw fertiliser particles sideways.

The size and rotational speed of the disc determines the speed of pellets or particles as they leave the disc, so contribute to spread distance. By shaping the disc and using different vanes, the application pattern can be adjusted.

Many single disc machines spread unevenly, with a greater amount of fertiliser being applied on one side than the other.

Image 1: Single disc fertiliser spreader ©Equipment Rental

Twin disk spreaders

Many newer machines use twin discs that rotate in opposite directions. This improves uniformity and may increase spread distance.

Some equipment allows the speed or settings of one disc to be adjusted to concentrate fertiliser application in a narrower band for headland application.

Image 2: Double disc spreader with contra-rotating discs for more even application

Oscillating spout spreaders

Oscillating spout machines fling fertiliser from a tube shaking rapidly from side to side. The length, speed and design of the spout control fertiliser placement.

By changing spouts and speeds, even, banded or single side fertiliser applications are possible.

Image 3: Oscillating spout fertiliser spreader ©Vicon

Image 4: Adjusting settings on double disk spreader

Factors affecting spreading performance

There are many factors that affect the rate and uniformity of fertiliser distribution during an application spreading event. Calibration of equipment helps ensure an acceptable application rate and distribution are achieved.

Machine settings

Machine settings that control application rate and spread pattern include:

- Machine travel speed
- Machine alignment
- Discharge door opening
- Discharge height
- Disc rotation speed
- Disc vane settings
- Fertiliser position on disk
- Oscillating spout size & shape
- Spout oscillation rate

Image 5: Adjusting disc vane angle to alter spread pattern

Application conditions

Application conditions also impact spread pattern. Important factors include:

- Humidity and temperature
- Wind speed
- Wind direction
- Slope/Ground contour

Product characteristics

Fertiliser is a highly variable product. Spreading rates and patterns are affected by many factors that influence discharge rate and ballistics, including:

- Fertiliser density
- Particle size
- Particle shape
- Moisture content
- “Flowability”

Impact of striping

The latest generation spreaders may recommend swath spacing up to 30m or more to reduce the number of tram lines and crop damage and makes application much faster.

However, crop striping is a significant issue when very wide throw equipment is used, even if set-up correctly. In many situations the cost saving of increasing bout widths will be less than the reduction in income by reducing yield by increasing the in-field CV of the spread.

Striping is only visible at in-field coefficient of variation (CV) of around 40%. This gives a yield reduction of at least 20%, so has large economic impact[1].

The economic impact of striping increases exponentially as in-field CV increases. If CV doubles, the economic loss increases by four times. If CV increased three times, the economic loss would increase nine times.

Image 6: Crop striping can be a significant issue when spreading blended fertilisers

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[1] Yule, I.J. and Grafton, M.C.E. 2013. New Spreading Technologies for Improved Accuracy and Environmental Compliance

Ballistics

Drag (wind resistance) restricts the distance a particle can travel horizontally. The effect changes with particle shape, size and density. Even using manufacturer recommended settings, problems arise when fertiliser particles are not uniform.

A spread 22.5m in each direction is required to achieve uniform application at a 30m bout width. To propel particles 22.5m from a height of 1.5m above ground, they must be ejected at around $60ms^{-1}$ (216km/h).

Table 1: Distances in metres typical fertiliser particles will travel in a horizontal plane when ejected at various speeds (from Grafton, Yule & Robertson, 2013)

Horizontal velocity	NH_3SO_2	KCl	MAP	DAP	Urea	SSP 1.0mm	SSP 2.9mm	SSP 4.7mm
$60ms^{-1}$	17.0	21.8	18.8	17.9	23.6	17.9	24.0	25.2
$50ms^{-1}$	15.3	18.6	16.6	16.0	19.8	16.0	20.0	20.9
$40ms^{-1}$	13.1	15.1	13.8	13.5	15.8	13.5	16.0	16.5
$30ms^{-1}$	10.2	11.3	10.6	10.4	11.7	10.5	11.7	12.0
$20ms^{-1}$	6.9	7.3	7.0	6.9	7.4	7.0	7.5	7.6
$10ms^{-1}$	3.1	3.2	3.2	3.1	3.2	3.1	3.2	3.3

Fertiliser ballistic differences for common materials with different physical properties start to become significant at particle speeds over 30m/s. This is particularly the case with blended products. Their particle density, size and shape all differ, so the products have different ballistic properties.

Unless mixes have similar properties, blends should not be sown at bout widths much greater than 20m.

At widths greater than 20m, test equipment using the material to be spread. Reducing the number of applications by blending fertilisers may be a false saving.By choice, use homogenous products.

Image 7: Uneven distribution of lime caused by excessive swath spacing (bout width)

Assessing Performance

These guidelines are designed to allow a farmer to rapidly determine performance of a spreader as it is operating on a given day, with a given product in prevailing weather conditions. If any factor changes, the results are likely to be different.

There are two aspects to be assessed; the rate of application (kg/ha) and the evenness of the spread pattern (coefficient of variation, CV).

Safety Considerations

The process of checking performance and calibrating equipment involves a number of potentially hazardous operations. It involves people in close proximity to moving machines with high speed moving parts and potential for crush injuries. Full attention must be given to safe practice.

- Ensure properly trained people operate the equipment
- Follow manufacturer’s operating and safety instructions
- Keep hands clear of moving parts.
- Take care near power take-offs and other shafts
- Avoid risk of crushing by three pointed linkage movement

Equipment Calibration

There is a vast range of fertiliser application equipment types and technologies. Even manufacturers cannot fully guide calibration because the product used, terrain covered and weather conditions all have influence on the final result.

Ensuring equipment is correctly maintained and serviced and set up according to manufacturer’s instructions is part of good practice.

If the performance checks show actual application varies from the intended rate or distribution pattern, follow manufacturer’s recommendations to make appropriate adjustments. Machine settings that influence spread pattern are listed and give a guide to options for calibration to enhance performance.

Re-check performance after such adjustments are made.

Application Rate (kg/ha)

A final check of the application rate can be made by comparing the amount of fertiliser actually applied to a known area. If accurate paddock size is known (many are incorrectly assumed) and the total fertiliser applied is known, then a simple division provides the answer.

A quick check when only part of the paddock is covered is recommended. Area can be calculated from bout width and distance travelled. If a known amount of fertiliser is put into the spreader, the amount applied can be determined by measuring the amount remaining after application.

The fertiliser application rate (kg/ha) is determined by the product bulk density (kg/L), product discharge flow (L/min), bout width (m) and spreader travel speed (km/h). A factor of 600 is needed to adjust for mixed units; kilometres and metres, minutes and hours.

In practice, the product density and discharge flow can be combined as the product discharge rate; the mass of product leaving the hopper each minute (kg/min).

$$\textit{Application Rate} = \frac{\textit{Discharge Rate}}{\textit{Bout Width} \times \textit{Travel Speed}} \times 600 \qquad \text{Equation 1}$$

Machines with electronic equipment to control application rate must still be calibrated to ensure accurate results. Follow manufacturers' instructions.

Check the discharge rate by weighing the amount of product collected in a set time (suggest minimum of 30 seconds) with the spreader operating.

Determine Product Discharge Rate

NOTE: Avoid contact with PTO shafts, spinning discs or other moving parts

Static Test

A static test (not driving) may require particular techniques such as manually turning a drive wheel. Collecting a sample from an operating broadcast spreader may require shrouding the discharge. This may be difficult and care is essential to avoid injury.

- Ensure the hopper is about half full, and in any case contains sufficient product to ensure discharge at the correct rate for the setting.
- Arrange a shroud or containers to collect discharged fertiliser
- Run the applicator for a timed period (at least 30 seconds)
- Weigh the caught fertiliser in the measured time period (e.g.17.24 kg)

e.g. 17.24 kg / 30 seconds x 60 = 34.48 kg/min Equation 2

Moving test

If the machine must be moving to work, a variation is required.

- Load a known weight of product into the spreader (e.g. 40 kg)
- Drive along the paddock and discharging it fertiliser for a measured period of time (ideally a minimum 30 seconds)
- Weigh the fertiliser remaining in the spreader (e.g. 22.76 kg)
- Subtract the amount remaining from the amount loaded to determine the amount discharged in the measured time period (e.g. 40 – 22.76)

e.g. 40.00kg – 22.76kg = 17.24kg; Equation 3

e.g. 17.24 kg / 30 seconds x 60 = 34.48 kg/min Equation 4

Determine Product Bulk Density

Product bulk density is the mass of a known volume of product and is recorded as kg per litre of fertiliser.

Some applicators use the product density to determine correct machine settings. For example, density is a key factor in determining discharge door openings. If manufacturers supply calibrated scales and standard volume sample collectors, follow instructions to determine product density.

If not, collect a known volume sample of product (minimum of 2 Litres) and weigh it as accurately as possible (to the nearest 10g or better). Divide the weight by the volume.

e.g. 1.56kg / 2.0 L = 0.78 kg/L Equation 5

If the fertiliser appears to have variable grain size, take a few samples and compare the density values determined. If product bulk density is very variable, it is likely field application rates will also be variable.

Determine Bout Width or Swath Spacing

The swath spacing or bout width is the working distance between adjacent spreader passes. It is measured in metres (m).

GPS enabled equipment can keep adjacent passes parallel. Manually steered systems without guidance may have considerable variation in the distance between adjacent passes and a severe impact on overall field uniformity.

For the purpose of this test the farm's usual expected swath spacing is used.

e.g. Adjacent runs 16m apart Equation 6

SUGGESTION: Investigate the effect of variable tracking by calculating values using the identified range of swath widths.

Spreader Travel Speed

The speed of the spreader, truck or tractor (m/min)

It may not be safe to rely on tractor speedometers. GPS speeds are reliable, but should be recorded to parts of a km/h. A field check is easily made by recording the time taken to cover a set distance (minimum 50m).

Distance (m) / time (sec) x 3.6 = Speed (km/h) Equation 7

e.g. 50m / 20.81sec x 3.6 = 8.65 km/h Equation 8

Determine Application Rate

Calculate the application rate according to Equation 1

$$e.g.\ \frac{34.48\frac{kg}{min}}{16m\ x\ 8.65km/h}\ x\ 600 = 149.48kg/ha$$ Equation 9

Spread Pattern

The basis of this test is collector trays placed at equal distances across the direction of spreader travel. The trays must extend the full width of the spread pattern, which is usually greater than the bout spacing or swath width.

Tray design

Tray design is critical. Standard fertiliser test trays are recommended. These are typically 500mm x 500mm square (0.25m^2). They will have internal baffles to stop fertiliser pellets or granules bouncing out.

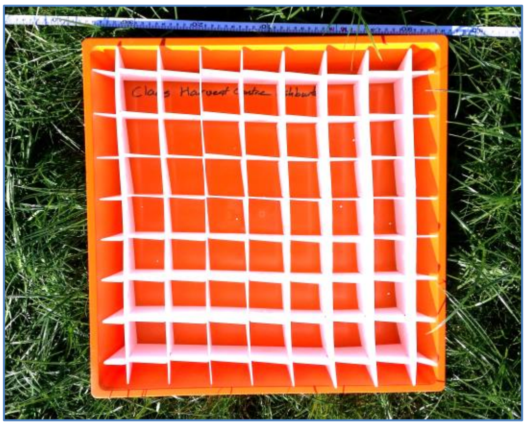

Image 8: Amazone fertiliser collection tray

Image 9: Transpread collection tray

Tray Layout

Place one tray on the centre line of the spreader drive path.

Remaining trays are placed with equal numbers to the left and right to at least the furthest extent of fertiliser spread. The trays are equally spaced ideally with one tray in the centre of each adjacent spreader drive path (See Figure 1).

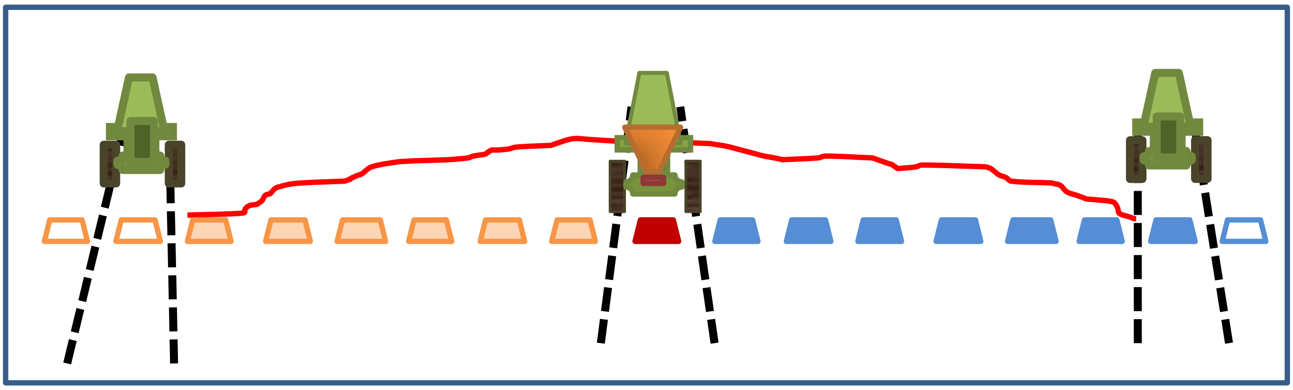

Figure 1 Tray layout relative to spreader drive paths

Image 10: A line of collection trays laid out across the fertiliser spreader travel path

Simple Check: In-Field overlap

Spread trays evenly between three adjacent spreader passes and apply fertiliser, as shown in Figure 2.

Figure 2 shows an up-and-back or to-and-fro application path. In this case area “a” receives overlapped applications from the left side of the spreader and area “b” receives overlapped applications from the right side of the spreader.

It is valuable to compare the two sides individually as well as combined.

Some spreaders, in particular types of single disk spreader, have a tendency to put a greater amount out on one side of the machine. Going round-and-round a paddock may give better results.

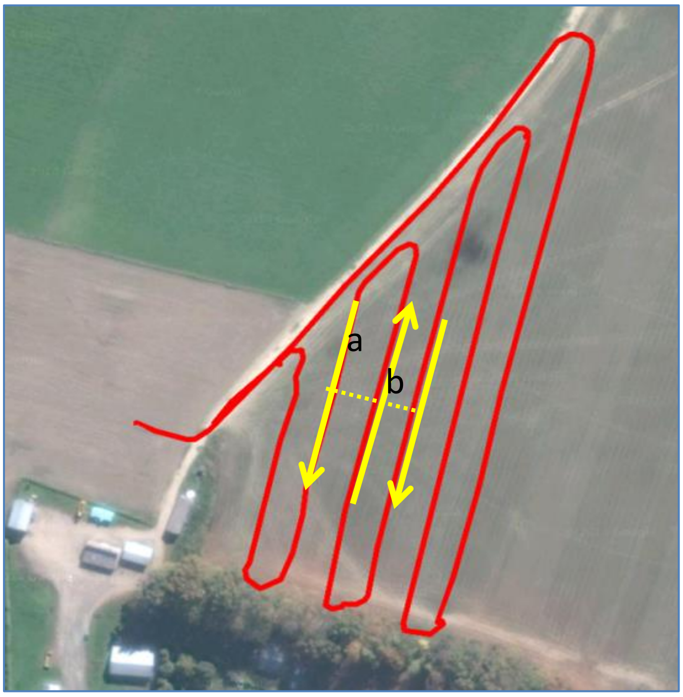

Figure 2 Tray layout and spreader runs for in-field overlap test

FertSpread Mathematical Overlap

Calculating overlap based on measurements from a single pass allows assessment of current practice and alternatives, such as different swath or bout widths, and the effect of running round-and-round or to-and-fro.

FertSpread does the complex calculations.

Ensure the trays are placed out at least as far as the furthest fertiliser particles get spread. This may be further than adjacent passes.

All fertiliser applied must be measured. Data will be used by overlap formulae.

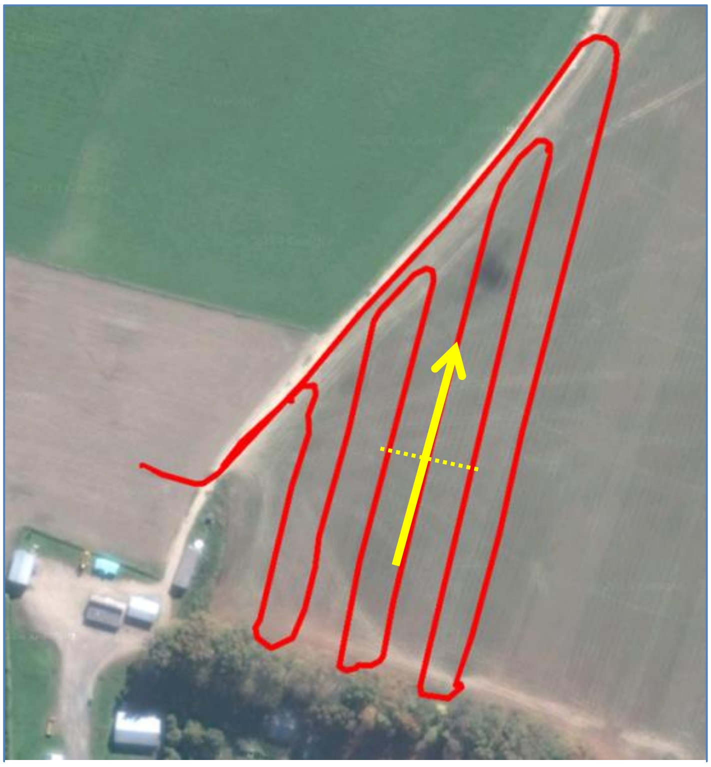

Figure 3 Tray layout and spreader run for a single pass test

Recording application data

Weighing samples

High resolution scales that weigh to 0.01 gram are needed. The amounts caught can be very small – less that a gram and even less than a tenth of a gram.

These scales need to be set on a horizontal surface and are affected by air movement.

Because of the very small quanities involved, it is generally best to collect samples into snaplock/ziplock plastic bags and weigh them inside out of any wind.

Image 11: Collected fertiliser sample being weighed on electronic scales

Measuring volumes

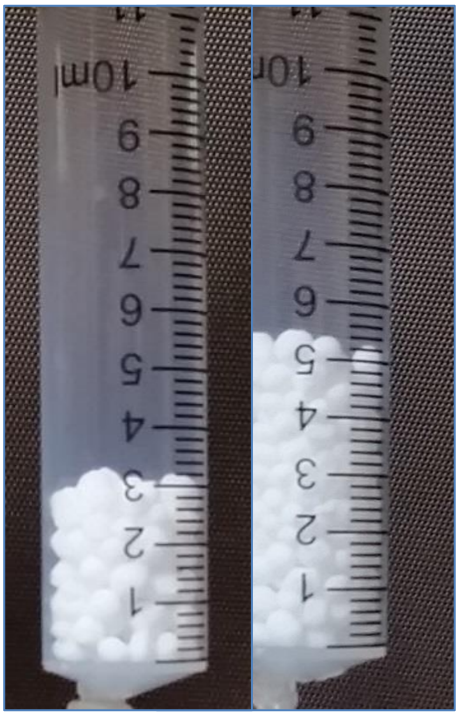

Image 12: Graduated syringes used to measure volume of fertiliser caught in trays

An alternative approach is to measure the volume of fertiliser caught. This can be simple and can be done more easily in the field.

A cheap and easily available method uses small graduated syringe bodies as measuring cylinders (Image 12).

Mounting a number of syringes in a rack provides a simple way to quickly assess the application pattern (Image 13).

While volumes can give a good indication of relative amounts, it is difficult to accurately compare the measured volume to a weight and therefore rate per hectare.

Image 13: A rack of graduated syringes acts as measuring cylinders and simply displays the application pattern

Quantifying spread variability

The variability of application is described statistically. The measurement used is the coefficient of variation (CV) which describes how much the individual measured quantities vary from the average of them all. A low CV means there is little variation. A high CV means there is a lot of variation.

The coefficient of variation is calculated by dividing the standard deviation by the mean of all results.

$$CV = \frac{s}{\bar{x}} \times 100 \qquad \text{Equation 10}$$

The Standard Deviation measures the amount individual measurements vary from the average.

$$s = \sqrt{\frac{\sum(x-\bar{x})^2}{N-1}} \qquad \text{Equation 11}$$

It is generally accepted that for nitrogen fertilisers, the spatial coefficient of variation, CV, should not exceed 15%. For other fertilisers types a CV not exceeding 25% is acceptable.

Accessing *FertSpread*

FertSpread is a free on-line tool to record and calculate spreader performance.

Access *FertSpread* at www.fertspread.nz

Register to use *FertSpread* and have results saved for future reference. Reports can be downloaded for inclusion in industry quality assurance programmes.

Definitions

Term	Definition
Application: Round and Round One-direction	An application method in which successive adjacent swaths are made in the same direction of travel (racetrack or circuitous application). This method produces a right-on-left overlapping of adjacent patterns.
Application: To and Fro Progressive	An application method in which the spreader applies adjacent swaths in alternate directions (back and forth application). This method produces a right-on-right pattern overlap alternately with a left-on-left pattern overlap.
Application: Single-pass	An application method in which the spreader applies one swath over the collection trays.
Application rate	The amount of any material applied per unit treated.
Bout Width (Swath spacing)	The distance between successive passes or runs of an aircraft or ground spread vehicle. See Figure 4
Bulk Density	The weight per unit volume of bulk fertiliser, kg per m^3 or tonnes per m^3 (t/m^3)
Collector efficiency	The percentage of true application rate caught in a collection device; i.e., the weight of material caught in the collection device divided by the area of the collection device and expressed as a percentage of the true application rate at that point in the pattern.
Coefficient of Variation CV%	Coefficient of variation. It is the ratio of the standard deviation to the mean and is used to indicate the evenness of spread. A CV% of zero would mean perfectly even spreading.
Discharge Flow	The volume of product per minute leaving the applicator (L/min)
Discharge Rate	The weight (mass) of product per minute leaving the applicator (kg/min)
Size Guide Number SGN	The mean or average particle size, expressed as mm x 100. e.g., SGN of 350 = 3.50 mm diameter
Standard Deviation	A statistical term which means a measure of the extent of scatter of sample values about their mean value. About two thirds of sample values will be within one standard deviation on either side of the mean. Standard deviation is the square root of the sum of the squares of the differences between each of the sample values and the mean value divided by the number of samples minus one.

Swath spacing (Bout width)	The lateral distance between spreader centrelines for adjacent swaths.
Swath width	The width of a spread pattern from one pass of the aircraft or ground spread vehicle. See Figure 4
Swath width, effective	The swath spacing that will produce acceptable field deposition uniformity for the intended application.
Uniformity Index UI	The ratio of small particles to large particles and indicates the range of particle sizes. A UI of 100 would mean all particles are the same size. For "well granulated" fertilisers (e.g., DAP) the UI is normally about 50. For fertilisers with a wide range of sizes the UI may be less than 10.

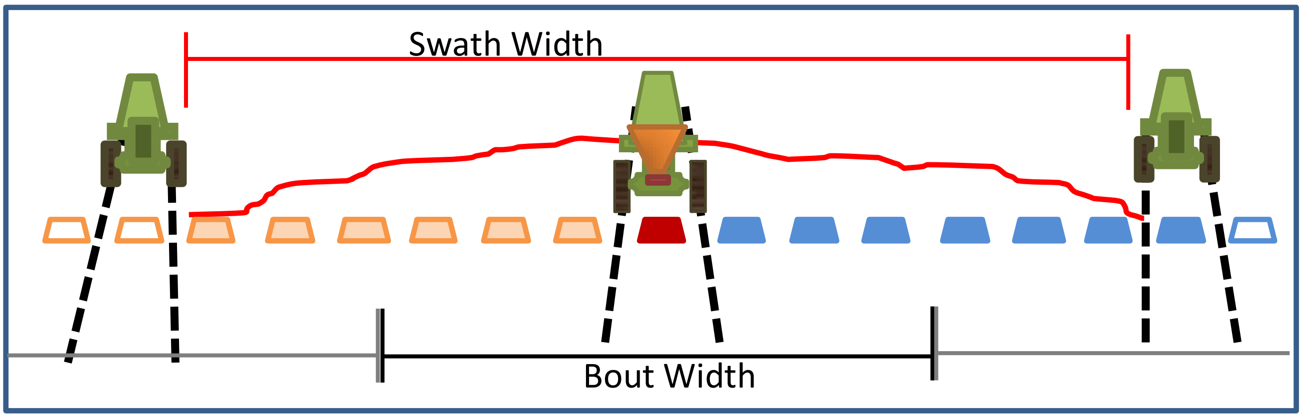

Figure 4 Swath width and spread pattern and Bout width related to successive spreader passes

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