

## A review of practices in precision application of granular fertilisers

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### Abstract

There is an implicit assumption in cited literature on precision agriculture (PA) that spreading of fertiliser is performed perfectly in the field leading to uniform application, this is not true. Variation can be large and often the actual performance of spreading equipment used has never been measured or verified. In various countries around the world there are quality assurance (QA) systems designed to achieve a prescribed level of performance. Even within these QA schemes limited testing is undertaken and always under perfect or near perfect conditions.

The test methods are designed to establish an acceptable bout width which meets an acceptable evenness of spread if driven accurately. The test does not take into account wind conditions (except for requiring less than 15kmhr<sup>-1</sup> for testing), humidity, slope, terrain or the instrumentation to maintain the desired bout width.

This paper examines the effect of the farm environment and the physical characteristics of fertilisers on the spread patterns of fertilisers in the field. Fertilisers with heterogeneous particle size distributions proved to have more robust spread patterns under field conditions than those with homogeneous particle size distributions.

### Background

There is an assumption in the farming sector that spreading of fertiliser is performed perfectly in the field leading to uniform application. Some countries have (QA) systems designed to achieve a prescribed accuracy based on ISO 5690 (1985). The correct bout width is established either by driving over collection trays whilst spreading, or more recently in a testing hall using a pivot table and trays on weigh cells. The contents are then weighed and a bout width established. There are several international schemes for establishing bout widths for spreaders being driven over trays (Jones et al. 2007). The testing hall pivot table developed at the Laboratory for Agro-machinery and Processing with the assistance of the K.U. Leuven Research Fund (Dintwa et al. 2004); and described by (Piron et al. 2010) uses computer algorithms to model spread patterns in 3 dimensions in one pass, in a few minutes allowing hundreds of tests to be completed in a day. This is much quicker than driving over trays where each test can take around 2 hours.

The level of variation is expressed as a coefficient of variation (CV) used to calculate optimum bout widths; a CV of 15% for nitrogenous products and 25% for those without N is required. In-field performance has been simulated using GIS methodologies and GPS tracking of vehicles, this indicates the level of variation is higher in the field than in QA tests (Lawrence, et al. 2006; Lawrence, et al. 2007; Grafton, et al. 2013). This work was carried out on flat ground and identified the major factors contributing to high in-field CV, which is unrelated to the CV obtained in a QA test.

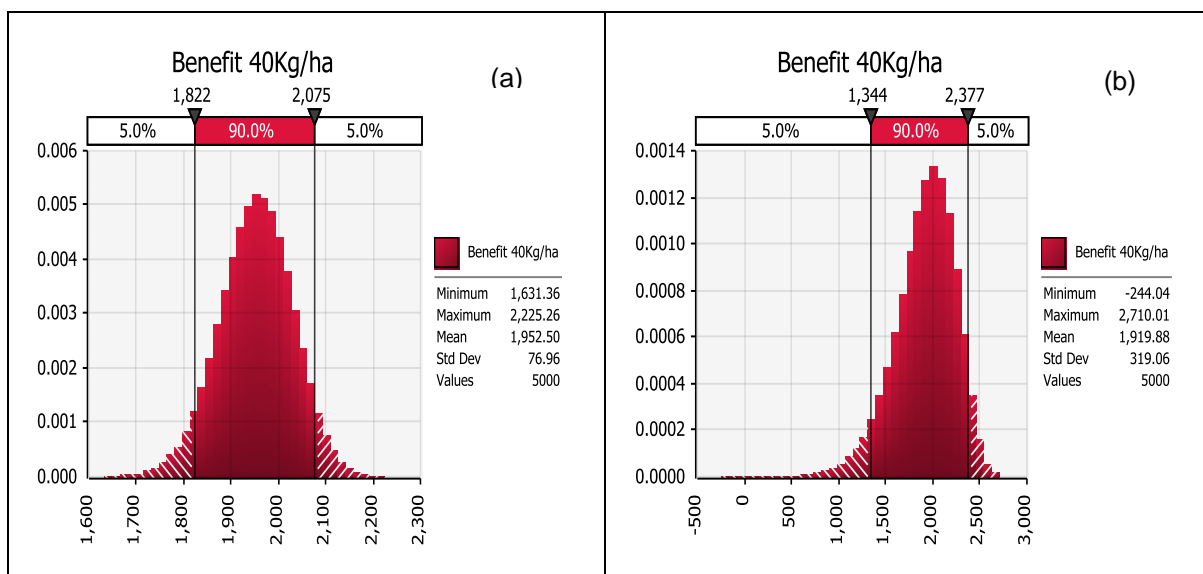
In 2006 Lawrence et al. (2006) presented work which indicated that around that time; on farms where the in-field performance of spreading was measured, the calculated annual losses were between \$52 and \$72 per hectare on dairy pasture in New Zealand conditions. This is production not achieved because the optimum application rate was not applied; costs were modelled from a nitrogen response equation. The average field CV's achieved over the 4 farms in the study ranged from 36 to 43 % individual paddocks were even more variable. This was from a typical annual N use of 185kgha<sup>-1</sup> per annum, completed in 5 split applications. The cost of each application was \$10.24 per ha, therefore the annual loss of production was higher than the actual cost of application.

Prior to Lawrence et al. (2006) little work had been completed where the actual distribution on the field had been accounted for, this was done through using a simulation of spread pattern from a tracked vehicle going over a paddock. A further possible way to take account of the increasingly wide distribution of spot application rates is to simulate the variable distribution as taking a simple average has no real effect as the average doesn't change. Spreading distribution was simulated through applying a statistical package called "@Risk" version 7.5 (Palisade Corporation, NY). The software runs Monte Carlo simulations to produce a distribution of outputs based on either discrete or continuous distributions with a number of iterations based on the user's preference; in this case a continuous output was required with 5,000 iterations. The application rate had a normal distribution fitted which was given a standard deviation based on the coefficient of variation of the spreading performance. That is; an application rate of 140Kg Nha-1 spreading at a CV of 15%, would have a normal distribution fitted, with a mean of 140 and a standard deviation of 21. This was used to estimate the economic loss from spreading.

The spreading benefit was derived by assigning an output which varied with the spreading rate being simulated; using the yield curve for wheat response to nitrogen application an asymptotic function was produced for example from Miller, et al. (2009), where (x) is the N application rate. The simulated financial loss is calculated in table 1, at four levels of field CV, The wheat is valued at \$300 per tonne and urea is 46% nitrogen. The response (y) was multiplied by NZ\$300 to find the targeted benefit and the response curve was used to calculate the response in "@Risk" assuming nitrogen is delivered by urea, see Figures 1(a) and 1(b). Equation (1):

$$-0.00293x \quad (1)$$

This is one of a number of response curves, which have a similar shape by Miller et al. (2009) but response is greatly influenced by the base fertility of the soil the crop is grown in, this curve is used to illustrate the approach taken.



**Figure 1a.** Shows a Monte Carlo simulation of spread response using a Normal distribution at 15% CV when applied to the wheat response curve equation (1) from Miller et al. (2009) at a price of \$300 per tonne and a urea application rate of 40kg/ha-1.

**Figure 1b.** Shows similar simulation using a Normal distribution at 60% CV when applied to the wheat response curve equation (1) at a price of \$300 per tonne and a urea application rate of 40kg/ha-1.

It is obvious that the Monte Carlo distributions in Figures and 1a and 1b appear different and although derived from applying a normal distribution to a response curve, Figure 1b is more skewed and has a much higher kurtosis. Figure 1b has a larger standard deviation, the model shows significant quantities are spread at rates along the asymptote of the response curve. Applications along the asymptote consume fertiliser but provide very little additional benefit; as a consequence significant amounts are also under applied where the sharply descending response curve reduces the benefit achieved.

The variation in fertiliser application which generates visible striping and lodging is an in-field (CV) of around 40%, which results in a yield reduction between 20% and 30% (Søgaard and Kierkegaard, 1994; Miller, et al. 2009; Mersmann, et al. 2013; Grafton, et al. 2013). The effects and the costs of changes in rate and costs of increased (CV) are shown in Table 1.

**Table 1. Shows a range of urea spreading rates, the target application rate and response based on spread CV using equation 1 response curve with four levels of field CV.**

	40 kg urea	60 kg urea	80 kg urea	100 kg urea	120 kg urea	140 kg urea	160 kg urea	180 kg urea	200 kg urea
<b>Target response</b>	1,955	2,188	2,382	2,542	2,675	2,784	2,874	2,948	3,008
<b>Cost of spread inaccuracy</b>									
CV 15%	2.14	4.05	5.99	7.82	9.43	10.74	11.76	12.46	12.89
CV 30%	8.60	16.19	24.17	31.77	38.51	44.17	48.69	52.09	54.47
CV 45%	19.43	28.99	55.15	73.07	89.52	104.07	116.23	126.45	134.74
CV 60%	34.76	55.32	100.22	134.75	167.20	197.35	225.02	251.01	275.06

## Methods

This paper examines the effect of field conditions on spread patterns from spreaders using in-field spread pattern tests, in farm conditions encountered during normal operation. Grafton et al. (2015a) conducted a number of field trials were undertaken with several twin disk spreaders where the effects of slope, border control and wind were measured and compared to performance on the flat using three twin disk spreaders using the Spreadmark test method, a guideline developed from ISO 5690 (NZFQC, 2013), see Figures 2 and 3.



**Figure 2. shows tray layout**

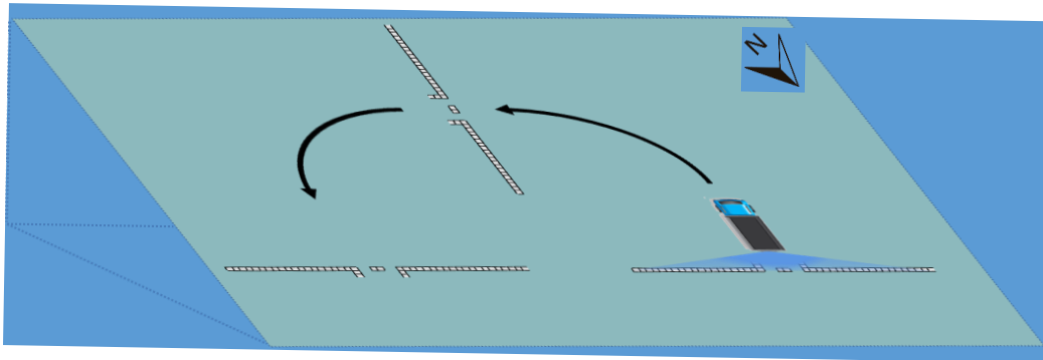


Figure 3. shows tray layout on 12 degree slope

## Results

All 3 spreaders were able to meet their tested bout widths on the flat trials for all 4 products: urea, di-ammonium phosphate (DAP), Nitrophoska TE and single superphosphate (SSP). However, when tested on a 12° slope only the spreaders applying superphosphate were able to meet the certified bout width. Slope then wind had the greatest effect on spread pattern distortion, of the environmental tests undertaken, see Tables 2 and 3. The CV increases markedly on moderate slopes and winds and had a greater effect than the paddock shape and size already known to adversely impact CV. Border control when fitted was effective if each product was calibrated prior to application.

Table 2. Shows recommended tested bout width for spreading urea, the target CV, actual CV achieved on the slope trial and the bout width which would be required to meet the required test CV of 15%. This result was similar for DAP and Nitrophoska TE.

Test	Equipment	Recommended Bout width (BW)	Targeted CV	CV at Recommended	Effective (CV=15%)	BW
1	Scania tr	30	15%	37%	12	
2	Scania tr	30	15%	>40%	9	
3	Scania tr	30	15%	38.5%	9	
4	Transpr. tr	14	15%	>40%	4	
5	Transpr. tr	14	15%	36.5%	5	
6	Transpr. tr	14	15%	>40%	4	
7	Transpr. tr	14	15%	37%	4	
8	Transpr. tr	14	15%	>40%	4	
9	Transpr. tr	14	15%	>40%	4	
10	Transpr. tr	14	15%	34%	4	
11	Transpr. tr	14	15%	>40%	3	

**Table 3. Shows recommended tested bout width for spreading SSP, the target CV, actual CV achieved on the slope trial and the bout width required to meet the required test CV of 25%.**

Test	Equipment	Recommended Bout width (BW)	Accepted CV	CV at Recommended BW	Effective BW (CV=25%)
1	Kuhn-Axis	24	25%	25%	24
2	Kuhn-Axis	24	25%	39%	20
3	Scania tr	30	25%	25%	30
4	Scania tr	30	25%	22%	37
5	Scania tr	30	25%	24.5%	35
6	Scania tr	30	25%	29%	25

Not all machines were available for all the days testing were undertaken as they are commercial machines whose operators donated their time and machinery for the experiments.

### Discussion

Machines are tested to calculate the bout widths that the machinery should be operated at. Performance in the field is significantly impaired compared to those test conditions. SSP with a heterogeneous particle size distribution had the most robust spread pattern in the field conditions encountered. A contributing factor to this is that SSP does not contain nitrogen so is permitted a higher CV. There is also the likelihood that homogeneous particles are all affected in a similar manner so any adverse conditions will impact the entire product delivery (Grafton, et al. 2015b).

### Conclusion

Field conditions encountered in the trials had a significant impact on the accuracy and uniformity of spread. This results in significant financial loss caused by the variability of spread as it impacts fertiliser response. A better understanding is required of the performance of twin disk spreaders over a range of conditions which they are used in. In many situations bout widths need to be significantly reduced.

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