Holmes, A.; Ekanayake, D.; Nguyen, P. & Werner, A. 2024. The Uniformity of Ground Spreading Common New Zealand Blended Fertilisers. In: Opportunities for Improved Farm and Catchment Outcomes. (Eds. C.L. Christensen, D.J. Horne and R. Singh). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 36. Farmed Landscapes Research Centre, Massey University, Palmerston North, New Zealand. 2 pages.

THE UNIFORMITY OF GROUND SPREADING COMMON NEW ZEALAND BLENDED FERTILISERS

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Abstract

Farmers increasingly ask spreading contractors to apply fertiliser blends. Most fertiliser in NZ is spread using twin-disc fertiliser spreaders mounted on trucks or tractors. These spreaders aim to achieve a uniform spread by overlapping passes in the field. Fertiliser spread testing in NZ uses the Spreadmark® scheme as a fertiliser placement quality assurance programme.

This study assessed the Field Coefficient of Variation (Field CV) achieved when spreading commonly blended compound fertilisers in NZ, including measuring the Field CV of the individual components of the fertiliser blend. Fertiliser blends were tested using commercially available, Spreadmark® accredited, twin-disc spreaders on flat fields in the Waikato and South Canterbury with a standard pan test method.

Across the four blended fertilisers tested in the Waikato, there were significant differences in the Field CV achieved when spreading the fertiliser component alone, versus its spread as a component of the fertiliser blend, in 80% of comparisons. For the two blends tested in South Canterbury, there were significant differences in the Field CV achieved when spreading the fertiliser component alone, versus its spread as a component of the fertiliser blend, in only 40% of the six comparisons. The average deviance between spreading a fertiliser component alone, versus its spread as a component of a fertiliser blend between the two spreaders in Waikato, and the two spreaders in South Canterbury, was 11.8%. The average deviance between spreading a fertiliser component alone, versus its spread as a component of a fertiliser blend between the Waikato, and South Canterbury, was 16.8%.

The differences between the spreading variability of components lead to differences in the maximal Bout (working) Width of spreading such fertiliser mixes. The tested non-nitrogen fertilisers can only be spread at a 22 m working width to stay within maximal variability (25%), whereas the tested N-fertiliser can be spread at a 27 m working width to stay within maximal variability (15%).

Introduction

Fertiliser is an important input in crop and animal production systems in New Zealand (NZ), with more than 1 million tonnes of fertiliser applied in 2021 (FANZ, 2023). To achieve the most profitable and environmentally responsible use of fertiliser, there are two key factors to achieving an optimal fertiliser programme: (i) advising the correct type and rate of fertiliser to apply, and (ii) spreading this fertiliser evenly across the field (van Meirvenne et al., 1990). Currently, many NZ farmers order fertiliser blends containing several plant nutrients to be applied to their fields by their own spreaders or by groundspread contractors. This paper focuses on the spreading of fertiliser blends. The type and operation of a fertiliser spreader, the type of fertiliser, and the weather conditions during spreading are key factors contributing to the uniform spreading of fertilisers.

Differences in particle sizes and physical properties (e.g. angle of repose, friction coefficient, particle resilience) of components in fertiliser blends can cause separation during handling, transportation, and application, resulting in uneven distribution of nutrients and yield loss (Maharjan et al., 2022; Villette et al., 2017). Striping of crops and pastures can occur with increasing working and spreading width, especially when fertiliser blends of products with different ballistic properties are used. Striping is only visually noticeable when the Field CV is above about 40%. Such high variability can cause yield losses of more than 20% (Grafton et al., 2015). Economic losses resulting from the uneven distribution of fertilisers in NZ have been estimated by Horrell, 1999, and Grafton et al., 2013, with the latter estimating that high variability for spreading N fertiliser results in annual losses of around $170 million nationally from urea use on dairy pasture.

Most fertiliser in New Zealand is spread using twin-disc fertiliser spreaders mounted on trucks or tractors. These spreaders achieve a uniform spread only by overlapping passes in the field, as shown in Figure 1.

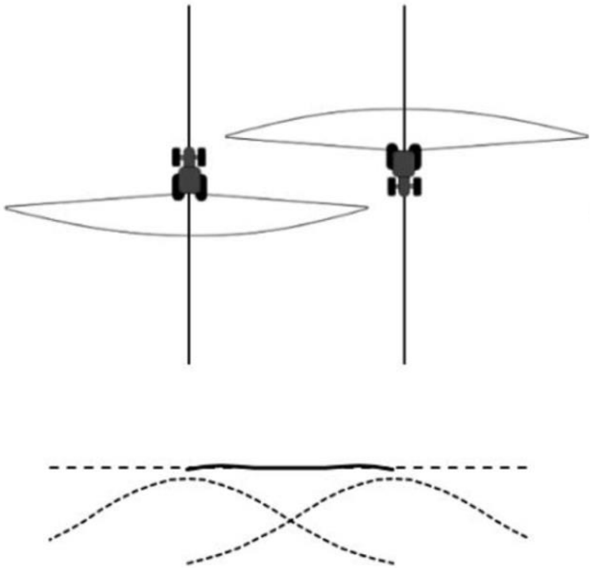

Figure 1: Optimally spaced parallel tracks – if the spreader is correctly calibrated, this should result in the best possible fertiliser distribution for a given spreader. The dashed curves illustrate the application rate of each pass of the spreader corresponding to the driving situations above. The full line shows the accumulated (total) application rate compared to the target (horizontal dashed lines) (Gyldengren et al., 2020).

Fertiliser spread testing is undertaken to ensure that the required rate of fertiliser is applied consistently across the paddock for achieving economically and environmentally optimal ground spreading on farms. Spreading uniformity is measured using transverse tray tests under various standards over the world such as: ISO Standard 5690/1 (ISO, 1985a), ASABE Standards S341.2 (ASABE, 2022); EN 13739-2 (2003); Spreadmark code of practice (FQC, 2022) or Accu-Spread® (AFSA, 2023). The transverse distribution data is then used to calculate the coefficient of variation (CV) following overlapping spreading passes. This CV measurement is used to evaluate the spreading quality, determine the suitable swath spacing based on the fertiliser and spreader configurations, and ultimately certify the spreader working width (Grafton et al., 2013; Villette et al., 2017). In NZ, the Spreadmark® programme was established by the NZ Groundspread Fertilisers Association in 1994. The Spreadmark® scheme is a fertiliser placement quality assurance programme with the objective of placing fertilisers where they can be of the most agricultural benefit and the least environmental harm. Overall systems are subject to a regular independent audit to ensure that both farmers/growers and Regional Councils can have confidence in the programme (FQC, 2022).

The NZ Spreadmark® standard specifies a Transverse CV of 15% for nitrogenous fertilisers and 25% for other fertilisers and lime. These values were chosen by Spreadmark® as they are considered the trigger point where the spreading accuracy is seen as being economically significant (ISO, 1985b).

A considerable amount of work studying fertiliser spreading has been undertaken by Ian Yule and Miles Grafton, with Grafton et al., 2013, claiming that NZ spreader operators have a narrow range of test results generated from spread pattern tests, as spread testing is time-consuming. However, despite 25 - 35% of the fertiliser applied in NZ comprising blended fertilisers, there has been no testing of the uniformity of spreading blended fertilisers and comparing this to the uniformity of spreading the individual components that make up the blend.

It has traditionally been assumed that all components of a fertiliser blend are spread at a uniform rate across the spread pattern, however Virk et al., 2013, showed in a US-study how individual compounds all have different spread characteristics. They applied N, P and K in a blended fertiliser across a field, and when the spread uniformity was evaluated using overlapped pattern data analysis, the lowest Field CV was recorded for N (24.6%) while the Field CV was higher for P (30.3%) and K (35.3%). The blended fertilizer was applied at a mean rate of 401 kg ha^{-1} with a calculated Field CV of 23.3% (Virk et al., 2013). The resulting uneven spread patterns apply bands of higher and lower fertiliser rates than required across the spreading width.

Terminology

Many terms are used in the agricultural industry to describe fertilisers and fertiliser spreading performance. In this paper, the technical terms used are based on the European Standard (EU, 2019) definitions as follows:

- *Straight Fertilisers* are products with a single macronutrient of nitrogen, phosphate, or potassium, and also possibly one or more micronutrients.
- *Compound Fertilisers* contain at least two of nitrogen, phosphorus, and potassium. Compound fertilisers can be made physically by blending other fertiliser products, creating Compound Blends. Compound blended fertilisers make up approximately 25-35% of the 720,000 tonnes of fertilisers applied annually (2018/19) to NZ pastoral and arable farms.
- *Complex Fertilisers* have a declared content of at least two of the nutrient's nitrogen, phosphorus, and potassium. These fertilisers are created by chemical reaction, thus are not physical blends. Complex fertilisers are not assessed in this work.

Grafton et al., 2013, outlined two commonly used terms when discussing fertiliser CV. Spreadmark® measures the Transverse CV from a transverse tray test, which is used to calculate the appropriate working or swath width for a spreading vehicle or aircraft to produce an acceptable overlapping spread pattern. The Field CV is the actual CV achieved in the field and is of economic importance and reflects the additional effects of inaccurate driving, incorrect starting and stopping positions and the effect of field shape. For this study, we are interested in the Field CV as these measures the actual variation in spread achieved over the field.

This study wanted to show measure the difference in Field CV achieved when spreading common blended compound fertilisers in NZ compared to the Field CV of the individual components of the fertiliser blend.

Materials and Methods

Spread testing was conducted on flat fields on a dairy farm near Te Aroha, in the Waikato, and on an arable farm near Timaru, in South Canterbury. Commercially available, Spreadmark® accredited, twin-disc spreaders were used in both locations. In the Waikato, truck mounted fertiliser bins from Ace Engineering and Paul Hoyle; while in South Canterbury tractor mounted Kverneland Exacta TL GEOSPREAD and Bogballe M2W spreaders were used. Full details of machinery settings and fertiliser characteristics are given in Holmes et al., 2023.

The physical characteristics of the fertiliser used for this work were analysed from samples of the fertilisers tested using the sieve box method defined in the Spreadmark Code of Practice (FQC, 2022). Samples were collected from the spreader prior to testing. Some of the fertilisers exhibited large differences between the two regions in the percentage of particles in each sieve size class. This was very noticeable with there being significantly more dust trailing from the spreaders in the Waikato than South Canterbury.

For tray testing, five rows spaced fifteen metres apart, comprising 35 trays each uniformly spaced at 1 m, with pans on either side of the centre pan removed to allow the tractor and spreader to pass unobstructed was used for calibration and during the standard pan tests.

Collection pan dimensions measured 50 cm wide x 50 cm long x 10 cm tall with a gridded divider used to prevent material loss due to bouncing out of the tray. The blended fertilisers were premixed at the local Ballance and Ravensdown service centres. For the Waikato tests, the groundspread truck collected the blend directly from the service centre. For the South Canterbury tests, the blends were packaged into one-tonne bags and transported to the testing site and loaded into the fertiliser spreader on-site.

Prior to passing over the catch trays, the fertiliser was spread for approximately fifty metres to ensure an even flow was achieved. After each pass the contents of each tray was collected, weighed, and in the case of blended fertilisers, collected for later analysis.

Each tray sample of blended fertiliser was separated manually based on particle colour to obtain sub-samples for each blend component. This data was then used to calculate spread patterns for each blend component.

Statistical analysis was carried out using GenStat® 22nd Edition by David Baird, VSN (NZ) Limited. A generalized linear model with a log-link and Poisson distribution was used to model the data, as the variance of the measurements was proportional to the mean. The dispersion was estimated making it a quasi-maximum likelihood model. Significance of effects used the deviance ratio with an Approximate F test.

Results & Discussion

For each combination of spreader and fertiliser, a fertiliser distribution graph was calculated similar to the Spreadmark® Test Report. The bar graph in Figure 2 shows the breakdown of the spread pattern by each individual component of the fertiliser blend, calculated following hand separation of the samples collected in each tray.

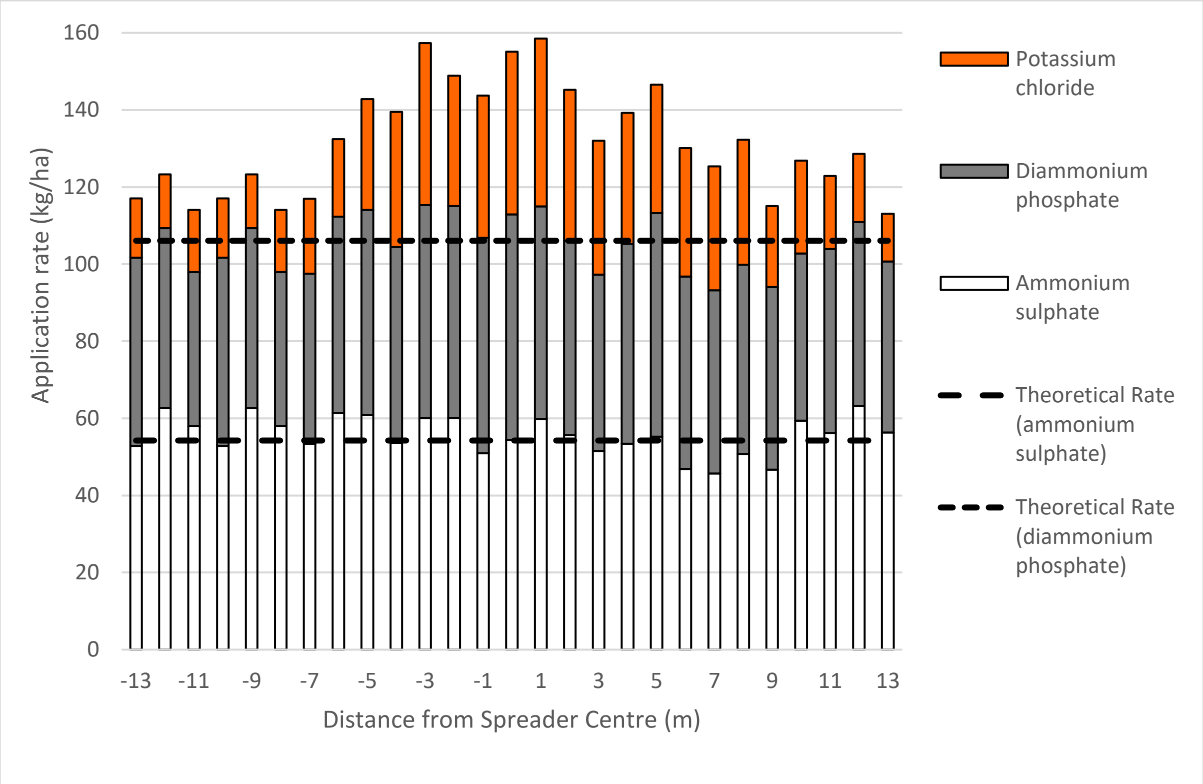

Figure 2: Application rate of individual fertiliser components in Cropzeal 16N blend at 200 kg/ha in South Canterbury by Bogballe M2W spreader spreading overlapping passes at 24 metre working width.

It can be seen from Figure 2 that there are large differences in the spread of the different fertiliser components across the spread pattern. To assess the effect of this, it is then necessary to create a Bout (working) Width report for each of the individual components in the fertiliser blend to assess the Field CV for each component. When Cropzeal 16N was spread at a 24 m working width it achieved a Field CV of approximately 11% for round and round spreading. When the Field CV of the three components is measured individually the Field CV for ammonium sulphate and diammonium phosphate is 9%, but the CV for potassium chloride is approximately 35% (Figure 3). This finding supports anecdotal beliefs in the industry that the CV of spreading potassium chloride would be higher than those of ammonium sulphate and diammonium phosphate. A study was undertaken in the USA that applied N, P and K in a blended fertiliser across a field. When the spread uniformity was evaluated using overlapped pattern data analysis, the lowest Field CV was recorded for N (24.6%) while the Field CV was higher for P (30.3%) and K (35.3%), similar to this study. The blended fertilizer was applied at a mean rate of 401.3 kg ha^{-1} with a calculated CV of 23.3% (Virk et al., 2013).

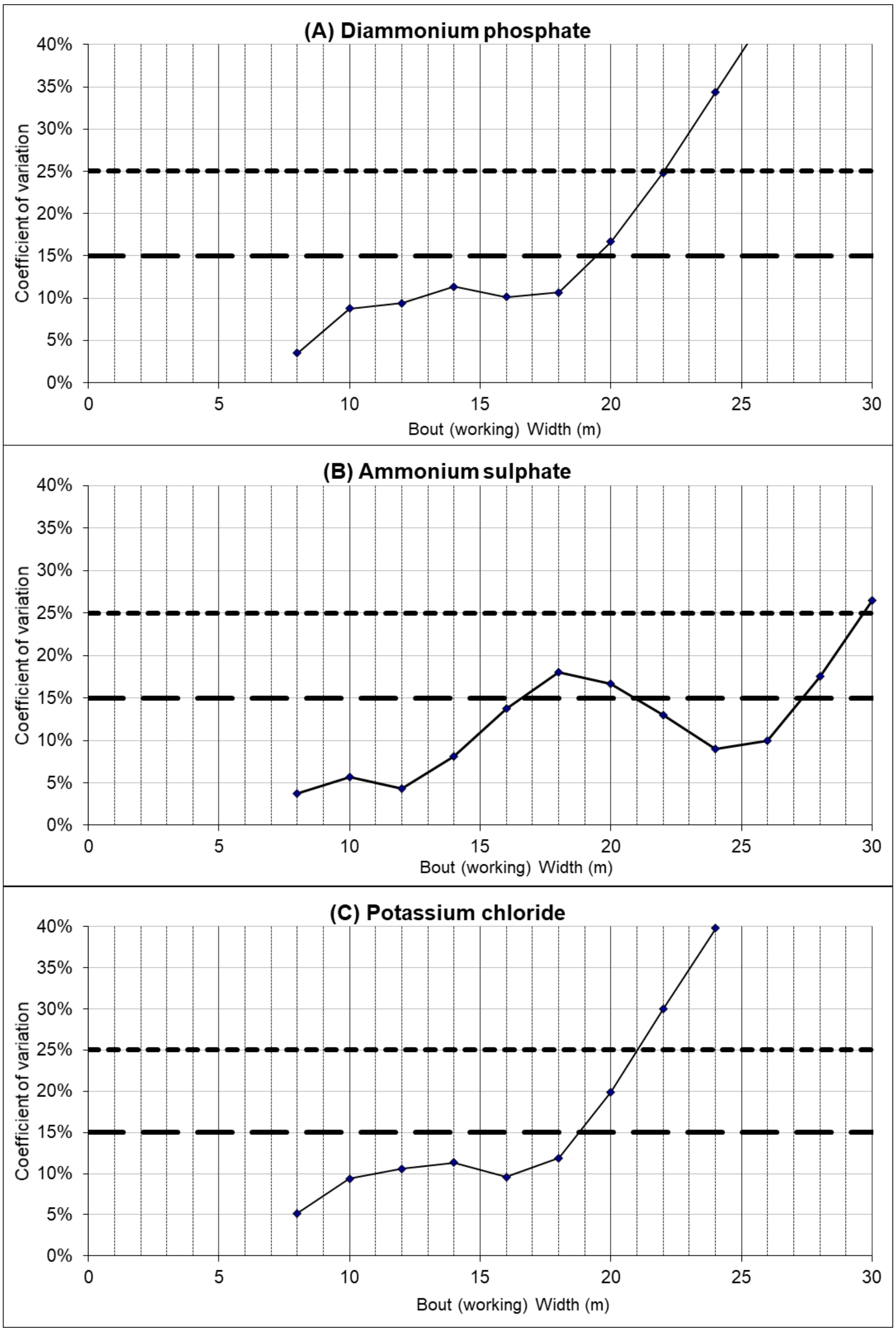

Figure 3: Bout (working) Width calculation from Spreadmark Test Report. South Canterbury Bogballe spreader, spreading individual components in Cropzeal 16N blend at 200 kg/ha, round and round the field. ■■■■■■■ minimum acceptable Transverse CV of 25% for fertilisers not containing nitrogen; ▬ ▬ ▬ ▬ minimum acceptable Transverse CV of 15% for fertilisers containing nitrogen (FQC, 2022).

Difference between spreading components individually or as part of a blend.

Ideally, there would be no significant difference between the spreading of each fertiliser component regardless of if it spread alone, or as part of a blend. We compared the Field CV of 1,120 combinations of spreaders, working widths and fertilisers, and found that the Field CV of the spread of an individual component of a fertiliser blend was lower than that of that component spread alone for only seven combinations. The greatest variation was for one ammonium sulphate spread in the Waikato by one truck at a 20-metre working width, with the Field CV for it being 43% greater when spread as part of a blend than by itself. Interestingly, one diammonium phosphate was spread more uniformly as part of a blend, than alone, from both trucks in the Waikato at spreading widths greater than 20 metres.

Some specific findings of note are that there was low variation in the Field CV (<15%) obtained when spreading ammonium sulphate at 26 m in both Cropzeal 16N and Cropmaster 15 blends in South Canterbury, but in the Waikato the Field CV values had significant differences (17.0% - 67.5%) when spread as ammonium sulphate alone or in the blends. 26 metres was chosen because the average certified bout width of products and machines across the national Spreadmark® certified fleet is 26 - 28 meters (Groundspread NZ, pers. comm., 2023). There was no consistency in Field CV of diammonium phosphate spread alone or as part of Cropzeal 16N and Cropmaster 15 blends. The Field CV of spreading diammonium phosphate alone or as part of Cropzeal 16N and Cropmaster 15 blends tended to be lower in South Canterbury (18.7% - 40.7%) compared with Waikato (21.7% - 48.0%). Similar to ammonium sulphate, there was an insignificant difference in Field CV at 26 m working width of potassium chloride spread alone or as part of Cropzeal 16N in South Canterbury, while there was high variation in the Waikato. There were significant differences in Field CV (21.4 – 62.8%) at 26 m working width between fertiliser components applied alone or as part of SustaiN / SOA and 30% Potash super blends in the Waikato.

Table 1 shows the difference in Field CV achieved when spreading the fertiliser component alone, versus its spread as a component of a fertiliser blend. Results are averaged between the two spreaders in each region.

Table 1: Difference in Field Coefficient of Variation at 26 m working width between spreading individual components alone and as part of a blended fertiliser.

Region	Blend	Component	Blend	Pure	Deviance	Probability
South Canterbury	Ravensdown Cropmaster 15	Ammonium sulphate	10.8	12.8	0.80	0.785
		Diammonium phosphate	13.7	25.3	2.60	0.000
		Potassium chloride	12.9	23.0	1.23	0.176
	Ballance Cropzeal 16N	Ammonium sulphate	8.5	9.0	1.31	0.116
		Diammonium phosphate	8.3	14.4	1.52	0.032
		Potassium chloride	19.6	16.2	0.86	0.695
Waikato	Ravensdown Cropmaster 15	Ammonium sulphate	42.0	12.8	4.60	0.000
		Diammonium phosphate	29.9	23.1	2.48	0.000
		Potassium chloride	35.0	23.9	1.31	0.114
	Ballance Cropzeal 16N	Ammonium sulphate	33.6	12.6	4.45	0.000
		Diammonium phosphate	31.0	37.0	2.22	0.000
		Potassium chloride	38.4	40.1	4.75	0.000
	Ballance SustaiN / ammonium sulphate	SustaiN	26.2	22.4	4.71	0.000
		Ammonium sulphate	42.3	12.6	5.70	0.000
	Ravensdown 30% Potash super	Superphosphate	43.6	34.2	1.10	0.323
		Potassium chloride	35.9	23.9	4.08	0.000

Across the four blended fertilisers tested in the Waikato, there were significant differences in the Field CV achieved when spreading the fertiliser component alone, versus its spread as a component of the fertiliser blend, in 80% of comparisons. For the two blends tested in South Canterbury, there were significant differences in the Field CV achieved when spreading the fertiliser component alone, versus its spread as a component of the fertiliser blend, in only 40% of the six comparisons.

The average deviance between spreading a fertiliser component alone, versus its spread as a component of a fertiliser blend between the two spreaders in Waikato, and the two spreaders in South Canterbury, was 11.8%. The average deviance between spreading a fertiliser component alone, versus its spread as a component of a fertiliser blend between the Waikato, and South Canterbury, was 16.8%. We are unable to directly compare the difference resulting from the different fertiliser characteristics in each region as different spreaders were used in region.

When we compared the Transverse CV of all fertilisers tested versus the Field CV, we found the average Transverse CV at 24 metres working width was 5.3% less than the average Field CV. This shows that while the typical Spreadmark® testing regime is a good basis for establishing machine settings, it does not accurately measure the variation in fertiliser spreading across the field. However, Transverse CV can only provide a general clue on spread pattern since it is a result of many parameters. Therefore, transverse tests have limited ability to show how mechanical parameters or fertiliser characteristics affect field spread pattern deposition. In practice, it is extremely difficult to carry out adapted experiments of this regard with enough replications. Knowledge on the ballistic segregation of blended fertilisers is limited due this difficulty. In addition, knowledge on some aspects such as the effect on the Field CV of increasing the number of runs or reducing the speed of travel of some standard tests and the effect of the application rate on the measurement of the Field CV value are rare (Villette et al., 2017).

Acknowledgments

This work was undertaken thanks to funding obtained from the Sustainable Food and Fibre Futures fund from the Ministry of Primary Industries for project S3F-21125 "Reducing off-target fertiliser application".

We acknowledge the cash and in-kind co-funding of the other project partners the Fertiliser Quality Council (FQC); Groundspread NZ (New Zealand Groundspread Fertilisers Association); and Environment Canterbury (ECan).

Thanks also to the owners and operators of the fertiliser spreaders; Travis and Julie Churchill of Spread Test NZ for undertaking the spread tests; and David Baird of VSN NZ for statistical analysis.

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