THE VARIABILITY IN NEW ZEALAND SINGLE SUPERPHOSPHATE GRANULE STRENGTH AND SIZE, AND IMPLICATIONS FOR ACCURATE FERTILISER APPLICATION

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Abstract

Tension exists between single superphosphate (SSP) manufacturers and ground spreaders on the physical quality of SSP in New Zealand. Spreaders have criticised that, for the past several years, SSP has increased in variability and contains a high percentage of fine SSP particulates. This may cause uneven spreading, because small particles are influenced by wind drift and have poor ballistic properties, which can lead to striping. The purpose of this study was to determine the level of variability in SSP particle size distribution and what effect this variability has on spreading.

Nineteen SSP samples were taken from Ravensdown Fertiliser Co-operative and Ballance Agri-Nutrient sites throughout the North Island. They were sieve tested and strength tested to determine the variability in their particle distribution and granule strength. Single superphosphate was found to have a high degree of variability in particle distribution that was independent of manufacturer and location. Percentage of fines ranged from 0.3% to 44%, with an average of 19%.

An explanation for the increase in small particles is the exclusion of Christmas Island rock phosphate from SSP. Christmas Island rock phosphate (CIRP) is known to have a high level of iron oxide, which acts as a binding agent, increasing granule strength. However, CIRP has not been included in SSP since 2011, due to diminishing supply. A decrease in strength was observed in SSP without CIRP, which increases the probability of particle attrition, during transportation and storage. Improvements could be made to the manufacturing process to increase SSP granule quality. However, the investment required to do this would increase the price of SSP making it uneconomical for farmers.

Analysis of historical Spreadmark test patterns was done to determine if there was any difference in test patterns before and after 2011. No significant difference in bout widths was observed, which indicates variability in SSP particle size distribution does not impact even spreading. Bulk truck spreading trials of a SSP sample with high fines and low fines content was done to confirm the relationship found in the Spreadmark test patterns.

Introduction

Tension exists between single superphosphate (SSP) manufacturers and bulk truck fertiliser spreaders on the quality of SSP manufactured in New Zealand. The issue under debate is that the quality of SSP has decreased in the last several years, which has decreased the accuracy of bulk truck spreading. The main concern is that SSP has a high level of fine particulates, which creates dust when it is applied, has poor ballistic properties and is influenced by wind drift. This causes a loss of productivity for the farmer, due to uneven spreading (Horrell et al., 1999).

Though manufacturers have product specifications, it is difficult to produce SSP with consistent physical characteristics because of a number of factors, including variability in manufacturing procedures and raw materials. Spreaders have indicated that there is significant variation in the SSP supplied, which affects their ability to give farmers a high quality of service. This project sought to determine the level of variability in SSP particle size distribution and what effect this variability has on spreading.

Single superphosphate particle distributions across different companies and locations were investigated. There was a focus on granule strength as it is an important physical characteristic that could explain any variation observed in the results. The effect of any variability on bulk truck spreading was determined using ballistics modelling and Spreadmark test patterns. A high fines and low fines sample was compared in a large scale spread test, using a truck spreader, to determine the change in the recommended bout widths. Historical Spreadmark test patterns, from the last seven years, were also analysed for differences in the recommended bout widths. Bout widths for SSP were expected to decrease for increasing fines content, as shown in a study by the Australian Fertiliser Services Association (AFSA, 2012).

Methodology

Single superphosphate samples were collected from 19 sites in the North Island. The sites were a combination of Ravensdown and Ballance service centres, the Ravensdown manufacturing plant at Awatoto and the Ballance manufacturing plant at Mount Maunganui. Two samples were taken from some locations, such as Feilding and Te Puke, because both companies have a store there.

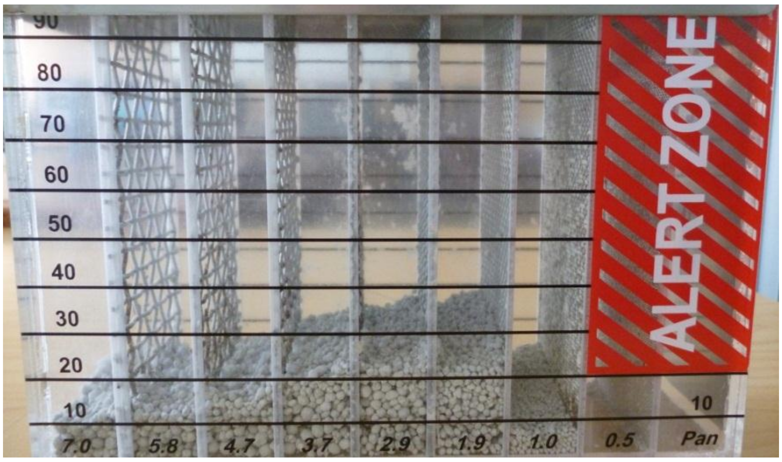

Figure 1: Fertmark approved size box with ideal sample.

A sieve test was carried out on site using Fertmark's approved sieve box. It is used by spreaders to determine the fertiliser's size distribution so that appropriate adjustments to their bout widths can be made to achieve accurate spreading. Results were compared to an ideal sample, as supplied in a sieve box by Ravensdown. The Fertmark sieve box has a warning for spreaders for particles less than 1 mm, as seen in figure 1. These small granules are prone to fall behind the spreader, since they have poor ballistic properties and are influenced by wind drift, due to their buoyancy in air. This causes uneven spreading.

The sieve box was used to find the size guide number (SGN) and uniformity index (UI) of the fertiliser sample. This was used to ascertain the level of variation between SSP samples and the ideal sample. The size guide number is the average particle size multiplied by 100, which should be between 250 and 350 for even spreading. The uniformity index is the ratio corresponding to the 95% and 10% level in the cumulative distribution curve multiplied by 100, and should be between 20 and 60 (Ballance Agri-Nutrients). They were found using version 16 of the Spreadmark test pattern, which relies on a field sieve calculator box. Values determined by this method are prone to error, as they require user interpolation. However, it provides a general indication, which is easy to use in the field by the applicator.

Ballance Agri-Nutrients have set strict guidelines on how to attain a well distributed sample from a fertiliser bin. A sample should be acquired one third of the distance up the pile and from within the pile. Samples should not be taken from the surface, since results will trend towards larger particles, or from the bottom of the pile, since over time smaller particles percolate down the pile. It was found that bins varied over sites; therefore it was difficult to eliminate some sampling error.

Particle size distribution, granule strength and specific density were determined to find the level of variation between samples. Approximately 15 kilogram of SSP was taken from each site and sieve tested at Massey University's Particle Laboratory. The sieve sizes used were 4.75 mm, 3.55 mm, 2.36 mm, 1.70 mm, 1.18 mm and pan. Using an Electrolab electromagnetic sieve shaker, approximately 0.5 kg of material was sieved. A riffle box was used to get a sample with a representative particle distribution for sieving, since percolation would have occurred after collection. Two replicates were measured from each site. The shaker was set at a power level of 10 and the material was sieved for 10 minutes.

Particle strength was tested using a Bogballe force indicator. It measures the amount of force (in kilograms) required to break a granule. Particle strength was measured for granules ≥ 4.75 mm, $3.55 < x < 4.75$ and $2.36 < x < 3.55$. Five replicates of each size range were done. Specific density was measured using the immersion method where a known mass of SSP was immersed in a volume of liquid. The change in volume was used to determine the density. Kerosene was used as the liquid, since SSP is water soluble.

Sampling results were compared with manufacturers' specifications. Table 1 show the specifications set by Ballance. Crushing strength is the amount of force required to break a particle.

Table 1: Ballance single superphosphate specifications.

Bulk density	1.1 – 1.2 kg/L
Particle size range	1-4 mm – at least 60 percent <0.5 mm - <5 percent
Crushing strength	2 kg
Moisture level	7 percent
Fluorine content	<270 g/kg-P
Cadmium content	<280 mg/kg-P

Results of initial sampling were used to determine a high physical and low physical quality sample, in terms of particle size, of SSP for a spread pattern test. Half a tonne of these samples were spread with a Rural Bulk Spreading (RBS) truck on flat pasture land, located at 297 Fitzherbert East Road. Testing was done in accordance with the guidelines set under Spreadmark to find the recommended bout width. The SGN, UI and bulk density were determined for the two samples as they are required inputs for version 16 of the Spreadmark test report.

Discussion

Site Sampling

Results of the sieve box and laboratory sieve test indicated that there was high variability in superphosphate supplies. Particle size distributions ranged between locations and companies. Most of the samples taken were within the specifications set by their respective manufacturers. However, there was a high level of variation and some samples had large fines content. The level of fines ranged from 0.3% to 44% with an average of 19% (table 2).

Samples taken from Whanganui and Carterton were taken from the outer rim of a 15 m tall pile. It was difficult to get a representative sample for safety reasons, as the pile could slide due to the steep angle of repose. The majority of particles were large, which is unusual. It was decided that a sample from Whanganui would represent a high quality product for the spread pattern tests because the sample is uniform and has low fines content (approximately 0.3%).

Table 2: SGN, UI and fines content for Ballance (B) and Ravensdown (R) sample sites.

Location	SGN	UI	Fines Content (%)
R-Taratahi	434	51	2.4
B-Waipukurau	402	33	10.0
R-Te Puke	364	8	11.5
B-Feilding	342	34	22.3
R-Whanganui	323	39	0.3
R-Taupo	311	19	26.3
B-Dannevirke	295	28	10.1
R-Awatoto	289	29	8.7
R-Dannevirke	260	12	15.3
B-Irirangi	259	16	26.7
B-Edgecumbe	256	14	26.8
B-Greatford	252	23	25.0
B-Shannon	241	17	29.7
B-Mt. Maunganui	237	11	9.5
B-Rotorua	232	4	29.3
R-Mangatainoka	229	30	18.3
R-Feilding	206	32	17.5
B-Reporoa	206	16	27.9
B-Te Puke	169	6	43.8

The sieve box test showed that most of the samples had particles that passed through the 1 mm sieve, in to the alert zone. All site samples differed from the ideally distributed sample. A majority of the site samples had less than 10% of particles greater than 7.0 mm. Most of the particles were found to be 1 mm < x < 2.9 mm. The ideal sample was obtained from Ravensdown in 2011 (figure 1). It included Christmas Island rock phosphate (CIRP), which is no longer used in superphosphate due low supply. This has resulted in the closure of the phosphate mines and the area has been turned in to a World Heritage site.

Size guide numbers and uniformity index values also showed variability with SGN ranging from 169 to 434 and UI from 6 to 51 (table 2). The average SGN was 279. Forty-seven percent of SGN are within 250 – 350, which indicates that almost half of the samples were considered suitable for even spreading by Fertmark's standards.

A high fines content can be explained by low granule quality, in particular granule strength. The average particle strength for each company is shown in table 3. Particles above 3.55 mm meet or exceed their manufacturer's specifications. However as the granule becomes smaller, their strength decreases. The probability that the granule will break will increase, creating smaller granules. Transportation and storage of SSP contribute to create fines.

Table 3: Average particle strength for Ravensdown and Ballance.

Particle Size (mm)	Ballance (kg)	Ravensdown (kg)
> 4.75	4.09	4.13
3.55 < x < 4.75	2.38	2.54
2.36 < x < 3.55	1.35	1.26

Superphosphate Delivery

Samples taken from manufacturing sites showed the fines content being less than or around 10% (figure 2). However, in some cases, when SSP leaves the service centres, their quality has decreased.

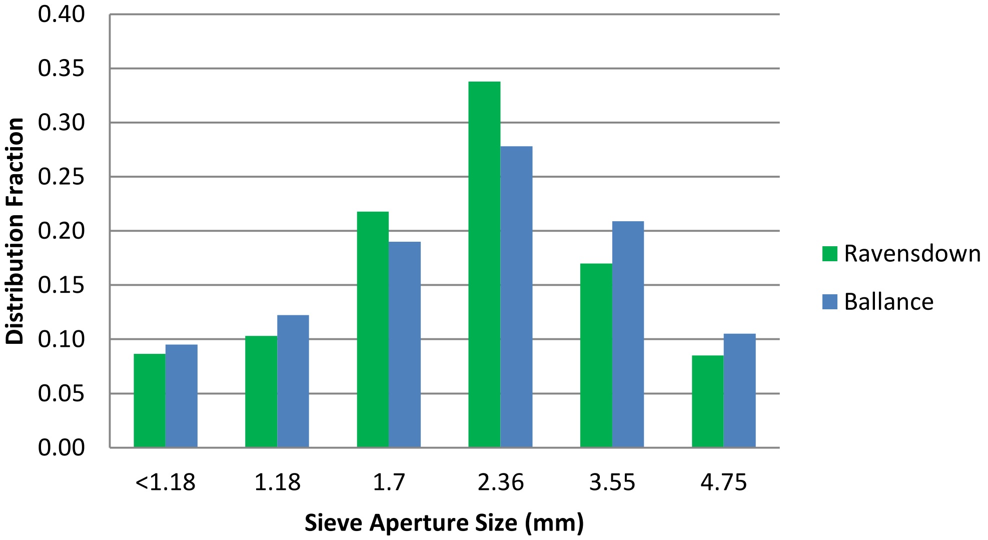

Figure 2: SSP particle distribution fraction from Ravensdown and Ballance manufacturing sites in the North Island.

Single superphosphate is exposed to damaging forces between the manufacturer and farmer. Low frequency vibrations, during transportation, are one reason. Single superphosphate is manufactured at Napier or Tauranga before it is transported around the North Island. Transportation is done by bulk trucks or, in some locations, rail. Particles will rub against each other and the sides of the truck, causing particle attrition. Despite this, no link between the distance travelled from the manufacturing plant and store, and the level of fines in the SSP was observed. Storage will also create fines. Fertiliser is stored in bins, which can hold between 100 and 9,000 tonnes of SSP at any time. Small granules percolate to the bottom of the pile during storage. These granules have several tonnes of force acting upon them, which can cause internal bonding forces to break.

Single superphosphate's high hygroscopicity means that storage piles will naturally harden over time. The humidity found in a coastal country, such as New Zealand, aids this occurrence. Single superphosphate is broken apart using a hammer-mill and screen to get the required distribution before it is applied to land. This prevents large particles and contaminants from entering the final product, but does not prevent fines. Single superphosphate is also blended with other fertilisers to reduce application costs. As it runs over machinery, particles can break due to rough handling. Spreading has a similar effect. As the granules enter the spinning discs or the hopper, it is exposed to high velocities, which could break the particles, creating fines. This is more prevalent at high application rates, as particles accumulate on the spreading discs faster than they are ejected. Low particle strength increases the probability of particle attrition.

Superphosphate Manufacture

Manufacturers have to consider a multitude of factors when producing SSP, such as cost, and the percentage of cadmium, phosphorus, aluminium and iron. The right balance is needed to produce SSP of an acceptable quality, which may result in a decrease in granule strength. Iron oxide (Fe_2O_3) concentration is an important factor in granule strength, since it acts as a binding agent. Barrett (1989) defines iron and aluminium oxide as R_2O_3, where R represents the metal. Christmas Island rock has high levels of R_2O_3, approximately 5.6 – 6.0% (Barrett, 1989). However, CIRP has not been included in New Zealand SSP since 2011, which has resulted in a decrease in the iron oxide content. This has caused a decline in SSP particle strength. Single superphosphate with CIRP (table 4) required more force to break apart for all particle sizes, compared to SSP without CIRP (table 3). Exclusion of CIRP from SSP has, therefore, decreased granule strength. The data from table 4 was found using the sample shown in figure 1.

Table 4: Force required fracture SSP granules when CIRP is included.

Particle Size (mm)	Force (kg)
> 4.7	7.24
3.7 < x < 4.7	3.82
2.9 < x < 3.7	2.50

A suitable replacement for CIRP, in terms of R_2O_3 content, has not been sourced as it is difficult to get rock with the appropriate characteristics. Bou Craa Moroccan phosphate rock, for example, is used in New Zealand SSP but has a low iron oxide content (0.14 – 0.31%) (Munoz Cabezon, 2005). However, if Al_2O_3 and Fe_2O_3 content are above 5% – 7.5% there is a decrease in phosphorus (P) solubility, which reduces phosphate availability for plant growth (Marshall and Hill, 1952).

Christmas Island phosphate rock also had a high P percentage, approximately 36% (Barrett, 1989) and a low cadmium concentration, between 7 and 43 mg/kg-P (Mar and Okazaki, 2012). Bou Craa rock has a similar P content, but it has higher cadmium levels and price. Concentrations up to 507 mg Cd/kg-P have been found (Mar and Okazaki, 2012). It is, therefore, blended with other rocks, which results in SSP with lower phosphorus content. An example is rock phosphate from Vietnam, which is cheaper because the phosphorus content of their rock is approximately 23% (Noltholt, Sheldon, and Davidson, 1989). This has led to a decrease in the phosphorus level of New Zealand SSP, from 11% to 9%, in the past few years. China, Russia and Senegal are other countries that New Zealand sources from.

Granule quality can be increased by improving the manufacturing process. Granulation has a major impact on particle strength. Currently, both manufacturers use a drum granulator to produce SSP with the required physical characteristics. Tumbling granulators are the most common form of granulation used in the fertiliser industry. Feed enters the top of a sloped rotating drum. Single superphosphate will collide, as it travels along the drum, and agglomerate to create larger granules. Granules exiting the drum are dried to remove excess moisture, which hardens the granule. A classifier is able to recycle any over/under-sized granules. The advantage of drum granulation is its high capacity at a low operating cost (Walker, 2007). However, other granulation methods may further improve particle strength.

Compression granulation is a method where a fine powder is packed together to form granules, such as pelletising or screw extrusion (Sochon and Salman, 2005). Compression is able to form particles of high strength because it reduces porosity (less air pockets therefore higher density). Such a process will form a constant particle size, which is not suitable if a particle size distribution is required. A disadvantage of pelletisation is that SSP granules may not be easily deformed due to their hardness, which makes it difficult to recycle flawed pellets (Walker, 2007). Fluidised granulation is another method that produces high strength particles when utilising a liquid feed. Size distribution is easily controlled. However, this method is capital intensive, and has high operating costs due to air requirements and dust control (Litster and Ennis, 2004).

Other processes could be included to improve SSP granule strength. If green SSP is left to mature for a longer period, there could be an improvement in granule strength. Some parts of the world, such as China, leave green SSP to mature for up to six weeks before it is granulated (Smith, 2013). This is called the run-of-pile technique. Extra driers and screens can also be included, which would produce SSP with fewer fines. However, the inclusion of more equipment and extra storage areas would increase the price of SSP in New Zealand.

Cost Analysis

Cost is the largest limitation to carrying out manufacturing improvements. Currently, the price of SSP in New Zealand is NZ$ 328.93 (Ravensdown Co-operative, 2013) and NZ$ 388 (Ballance Agri-Nutrients, 2013). When applying fertiliser, a nitrogen source, such as urea, may be required. An analysis was done to compare the cost margin of using SSP and urea against di-ammonium phosphate 13s (DAP 13s). DAP 13s is composed of phosphorus (10.8%), sulphur (14.8%) and nitrogen (12.5%). The combination of all the required nutrients is convenient for farmers since less spreading is done. However, DAP 13s is almost twice the price of SSP.

A cost analysis was completed using pricing from Ravensdowns (2013). It was based on an application rate of 300 kg/ha of SSP and 80 kg/ha of urea. The cost of spreading was assumed to be NZ$ 12.50 per hectare. Results show a saving could be made when using SSP and urea, except when an equivalent phosphorus content is needed (table 5). Initial estimates suggest that the cost of upgrading a manufacturing plant, to improve granule quality, would increase the price of SSP by at least NZ$ 60, which would make it uneconomical (Smith, 2013).

Table 5: Cost analysis for superphosphate and urea against DAP 13s.

Product	**Super**	**Urea**	**DAP 13s**	**N-Equal DAP 13s**	**P-Equal DAP 13s**	**S-Equal DAP 13s**
Price per tonne (NZ$)	328.93	619.29	635.94			
N content (%)	0	46	10.8			
P content (%)	9	0	14.8			
S content (%)	11	0	12.6			
Application rate (kg/ha)	300	80	**300**	**341**	**183**	**262**
Spreading cost ($/ha)	12.5	12.5	12.5	12.5	12.5	12.5
Price per kg (NZ$)	0.3289	0.6193	0.6359	0.6359	0.6359	0.6359
N content (kg N/ha)	0.0	36.8	32.4	36.8	19.8	28.3
P content (kg P/ha)	27.0	0.0	44.4	50.5	27.1	38.8
S content (kg S/ha)	33.0	0.0	37.8	43.0	23.1	33.0
Fertiliser cost ($/ha)	98.68	49.54	190.78	216.86	116.38	166.62
Application cost ($/ha)	111.18	62.04	203.28	229.36	128.88	179.12
Total cost ($/ha)	173.22		203.28	229.36	128.88	179.12
Savings using Super instead of DAP 13s ($/ha)			**30.06**	**56.13**	**-44.35**	**5.89**

Historical Spreadmark Test Patterns

Spreadmark test patterns were analysed to determine whether there were any significant changes in the recommended bout widths of spreaders between SSP with and without CIRP. There were 39 spread tests for 2007-10 (with CIRP) and 18 tests for 2011-13 (without CIRP). The recommended bout width was determined for a coefficient of variation (CV) at 25%, since SSP does not contain nitrogen. Data in table 6 and 7 represents a variety of spreaders.

The average bout width from 2007 to 2010 was 23.91 m with a standard deviation of 4.93 m. Standard deviation shows the dispersion of the data from the average. Larger standard deviations indicate higher levels of variation. A bout width of 22.61 m with a standard deviation of 7.45 m was found for 2011-13, which is not a significant difference. Tests from 2011-13 showed that the lowest SGN was 203 and four values were missing. The average SGN and bulk density was 285 and 1184 kg/m^3, respectively. Size guide numbers ranged from 122 to 392 for 2007-10 with an average of 224. Average bulk density was 1133 kg/m^3. This indicates that the mean particle size has increased in the past seven years. The small increase in bulk density may indicate that there are more small particles present, which will fill more gaps than larger particles.

Table 6: Spreadmark test patterns for 2011-13.

Test	**Year**	**Application Rate (kg/ha)**	**Recommended Bout Width (m)**	**SGN**	**UI**	**Bulk Density (kg/m^3)**
1	2013	193	32	258	29	1200
2	2013	235	26.5	205	12	1120
3	2013	177	24	-	-	-
4	2013	258	26.5	-	-	-
5	2013	171	32.5	-	-	-
6	2013	204	38.5	-	-	-
7	2012	239	20	385	30	1100
			25			1100
			31			1100
8	2012	248	17	385	30	1100
			23			1100
			31			1100
9	2013	189	15	233	-	1250
			24			1250
10	2013	160	24	299	51	1200
11	2013	159	24	299	-	1200
12	2011	55	12	203	9	1150
13	2011	119	7	203	9	1260
14	2011	52	18	256	9	1260
15	2011	52	17	227	5	1240
16	2011	55	15	203	9	1200
17	2011	38	19	240	8	1285
18	2011	48	18	247	8	1285

Table 7: Spreadmark test patterns for the period 2007-10.

Test	Year	Application Rate (kg/ha)	Recommended Bout Width (m)	SGN	UI	Bulk Density (kg/m^3)
1	2008	377	26	237	5.61	1050
2	2008	345	29	237	5.61	1065
3	2008	428	25.5	237	5.61	1050
4	2008	354	27	237	5.61	1050
5	2008	300	26	275	26	1060
6	2008	300	27.6	234	10	1080
7	2008	300	28	275	26	1160
8	2007	278	21	119	-	1200
9	2007	341	21.5	119	-	1046
10	2007	267	18.5	130	11.21	1368
11	2007	322	12	130	11.21	1368
12	2007	322	20.5	130	11.21	1368
13	2007	237	16	130	11.21	1368
14	2007	345	28.5	122	-	1065
15	2007	369	26	122	-	1065
16	2007	398	24	122	-	1065
17	2007	187	26.5	122	-	1065
18	2008	193	23	307	7.11	1080
19	2008	147	26	307	7.11	1060
20	2008	267	24.5	195	9.73	1150
21	2008	155	17 21 29.5	143	-	1120
22	2008	229	22	191	7	1120
23	2008	187	23	191	7	1120
24	2008	219	20	392	25	1120
25	2009	186	32	260	11	1050
26	2010	350	18	266	8	1170
27	2010	88	18	276	11	1170
28	2010	240	32	269	30	1045
29	2010	110	31	313	22	1075
30	2010	303	13.5 18 25	232	9	1180
31	2010	245	27.5	232	9	1180
32	2010	280	23.5	232	9	1180
33	2010	292	27	256	25	1150
34	2010	325	25	226	14	1150
35	2010	291	28	226	14	1150
36	2010	353	16 21 29	226	16	1150
37	2010	277	28	386	1	1050
38	2010	311	30	386	1	1090
39	2010	398	24	386	1	1050

The perception by ground spreaders that decreases in physical quality has affected spread patterns and, therefore, evenness may not be the case, since an increase in the SGN has not changed the bout width. This is unexpected because increases in fine particulates were thought to decrease the bout width, as more small particles fall behind the spreader (Australian Fertiliser Services Association, 2012). However, bout widths are affected by numerous factors, such as spreader design and operation. There has been significant development in spread truck technology, in the last several years, which could improve bout widths independent of SSP variation. Also, Fertmark trials are repeated until maximum bout widths are achieved. These tests represent the best results.

Spreadmark Test

A Spreadmark test of samples with high (Feilding) and low fines (Whanganui) was done to clarify the results found by historical test patterns. Both samples were acquired from Ravensdown. Table 8 shows a summary of physical characteristics of both samples. The size guide numbers of the sample originally obtained (table 2) and the sample spread tested (table 8) are different even though they are from the same location. This can be explained by the high demand of SSP during the sampling period, therefore a different batch may have been used in the pattern test. Variation in the rock phosphate blends, since this is a batch process, and other factors could have contributed to the difference, including how the SSP is treated during transportation and storage, and the weather.

Table 8: Physical characteristics of SSP samples.

Characteristic	Whanganui	Feilding
SGN	354	291
UI	35	35
Bulk Density (kg/m^3)	1040	1140
Fines Content (%)	0.3	17.5

Two hundred and forty trays (0.5 m x 0.5 m) were positioned in three rows of 80. A RBS truck did a single pass over the trays spreading 500 kg of SSP. The operator used the same truck and set the same parameters for both trials so that any variation observed will be independent of the equipment and operator (table 9). The height of the spinners to the ground was 970 mm. There was no or limited (< 15 km/hr) wind throughout the test period.

Table 9: Parameters set by operator.

Parameter	Value
Set bout width (m)	26
Set application rate (kg/ha)	350
Spinner revolutions	1050

Results of the two spread patterns are shown in figure 3 and 4. There was a difference in the spread pattern. However, this did not affect the recommended bout width of the spreader, which was greater than 32 m for both SSP samples. The result is more robust in its prediction of no statistical difference at a CV of 25%. This similarity suggests that variability in SSP particle size distribution will not have a significant effect on the accuracy of the spread pattern. Though the application was dusty and many of the small particles did fall behind the spreader, many of the larger particles made it to the outer boundary of trays.

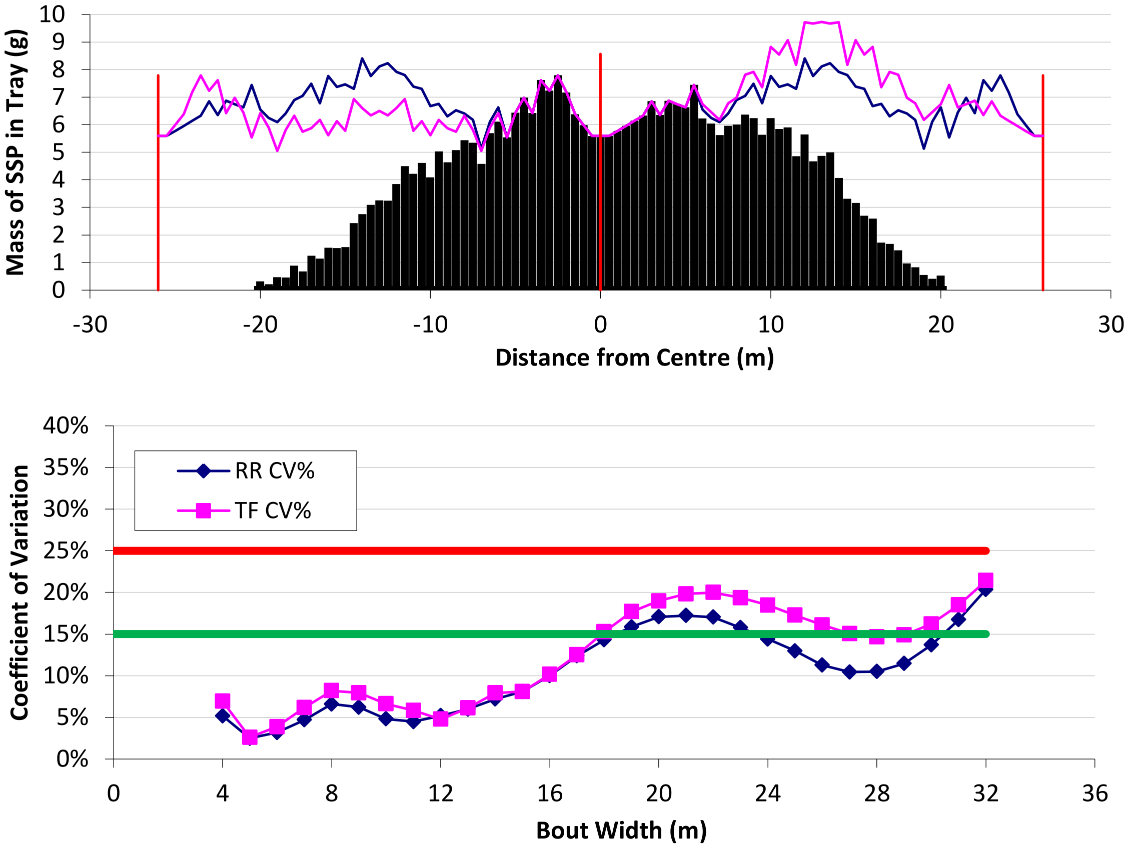

Figure 3: Spread pattern test of Feilding SSP.

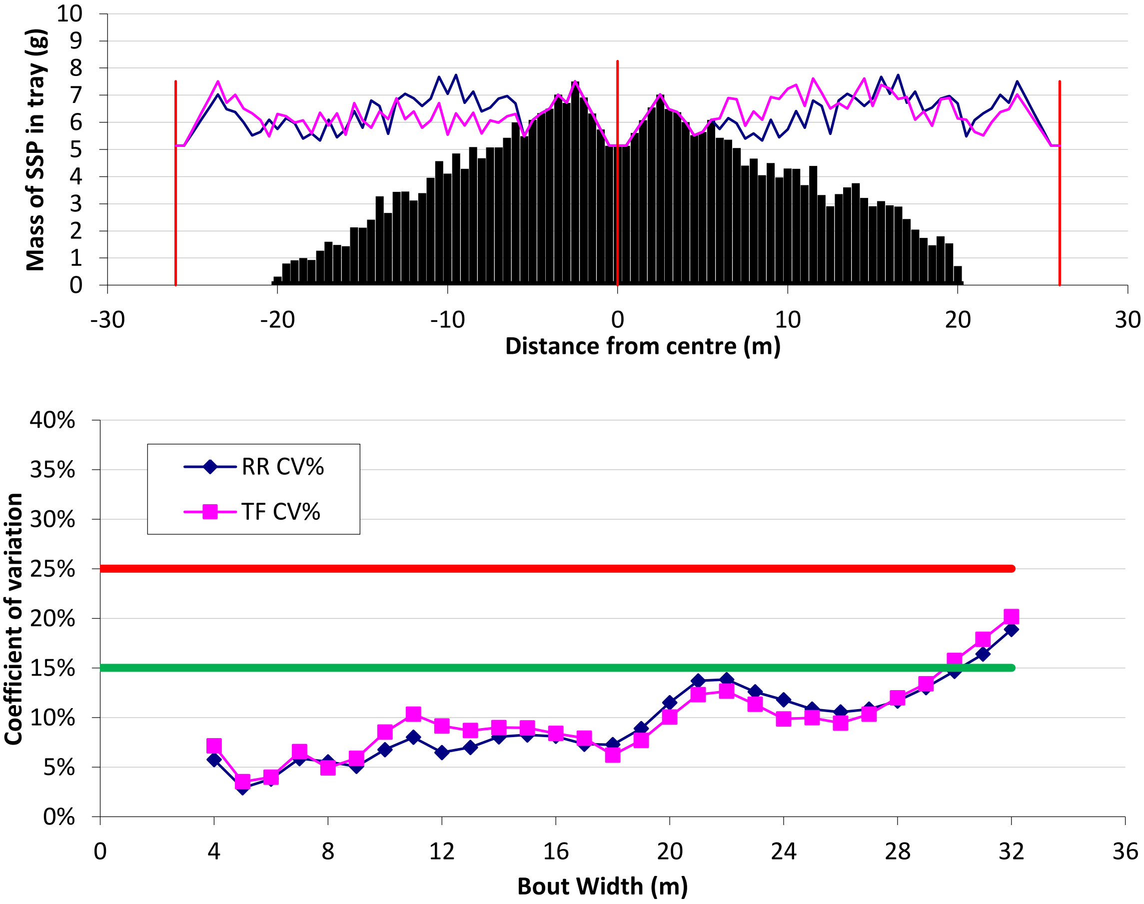

Figure 4: Spread pattern test of Whanganui SSP.

Conclusions

New Zealand single superphosphate has a high level of variability in particle size distribution that is independent of manufacturer and location. This can be explained by the decrease in granule strength because CIRP has been excluded from SSP blend, due to diminishing supply. Improvements could be made to the manufacturing process to increase granule strength. However the financial cost of these would increase SSP price, making it uneconomical for farmers.

Historical Fertmark test patterns have indicated that there has been no change in the recommended bout widths for truck spreaders before and after 2011. This shows that a change in the physical quality of SSP has no effect on accurate spreading. The bulk spread test of a SSP sample with high fines and low fines content confirmed this result, since both had a recommended bout width of greater than 32 m.

Future work should be done on a spread test of a single superphosphate sample with a size guide number below 250 (higher fines content). The SGN of the high fines content sample done in this study was 291, which according to the Fertmark sieve box would result in an even spread. A higher fines content will reduce the percentage of large particles in the sample which may reduce the bout width. Further research could be done on the impact of different spreaders on recommended bout widths. This could include investigation on spreaders of different age, technology and cleanliness. Currently a wide variety of machinery is used in truck spreading. It is likely that these factors would have more effect on the particle distribution leaving the spreader. This could help in determining what operational conditions will optimise spreading.

Acknowledgements

The authors wish to acknowledge Ravensdown and Ballance for providing single superphosphate samples, time and expertise. Rural Bulk Spreading for supplying a spreader and Tony Greer for operating the spreader. Dr. Russell Wilson for his assistance, and farm land on which the spread test was carried out. Dr. Ina Draganova, Dr. Jeya Jeyakumar, Mr. Michael Tuohy, Amrita Kokatnur and Briar Robertson for assisting in the spread test. The Fertiliser Quality Council for supplying the scholarship so that this study could be undertaken.

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