Statistical analyses combining data from LessN trials

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Report prepared by Dave Saville, Biometrician,
Saville Statistical Consulting Limited, Box 69192, Lincoln 7640
(Email: savillestat@gmail.com; phone: 03-345 5799)

based upon data and other information supplied by Tim Jenkins,
Centre for Sustainable Agricultural Technologies Ltd
P.O. Box 29683, Fendalton, Christchurch 8540
(Email: tim@csat.co.nz; cell-phone: 027 4378950)

METHOD

Treatments

The treatments of current interest are as follows:

> Control
> LessN40: 40 kg urea dissolved and 3 L LessN in total volume of 200 L
>   sprayed on per hectare basis
> LiqU40: 40 kg urea dissolved in total volume of 200 L sprayed on per hectare basis
> LiqU80: 80 kg urea dissolved in total volume of 200 L sprayed on per hectare basis
> SolU40: 40 kg urea solid, per hectare basis
> SolU80: 80 kg urea solid, per hectare basis

The first three treatments were included in all trials, while the LiqU80 treatment was included in about 80% of the trials, and the last two treatments in only a quarter of the trials.

Trials

There were 52 trials in which nitrogen responses were observed; these were used in the analyses reported herein. In addition, there were a small number of trials where no nitrogen response was observed, which have been excluded from the combined analyses reported below.

All trials included either 4, 5 or 8 replicate plots for each treatment.

The 52 trials were a mixture of Donaghys and Independent trials. Combined analyses were therefore carried out for both "All trials" and just the Independent trials.

Combined analyses

For each variable of interest and each comparison of interest, such as the comparison of LessN40 with LiqU40, the difference between the two treatment means (D) was calculated for each of the trials for which it could be calculated.

These D values were then regarded as constituting a random sample of all possible D values which could have been observed. For this to be valid, we must be able to think of these N-responsive trials as a random sample of all possible N-responsive trials in a well-defined study population. That is, we must try to think of a large study population that these trials represent. For example, is this population all pastoral farms in New Zealand, or is it a more restricted population?

Assuming such a population can be imagined, the statistical analysis is then simple. The available D values (e.g., 52 for some comparisons, or as low as 5 for others) are then used to calculate a mean, standard deviation and hence a 95% confidence interval for the "true average for D, averaged over the study population" (as described in Saville, 1980).

If this 95% confidence interval does *not* include zero, then the true average for D is "significantly different from zero (p<0.05)".

Comparisons of interest

There were four comparisons of interest, consisting of LessN40 versus each of the other four nitrogen treatments.

These comparisons were carried out for both DM production based upon the difference between pre-grazing and post-grazing **probe** measurements, and, for a small number of trials, based upon post-grazing DM **mower** cuts.

Variables of interest

Variables of interest (referred to as D above) were as follows:

- Difference in DM production (kg/ha) between the LessN40 and the specified other N treatment.

- Difference in DM production *on a daily basis* (kg/ha/day) between the LessN40 and the specified other N treatment. This adjusted for varying lengths of the growth periods.

- Ratio of the DM production nitrogen response (N treatment *minus* Control) *per kg of nitrogen applied,* between the LessN40 and the specified other N treatment.

- Ratio of the DM production *percentage* nitrogen response (N treatment *minus* Control, as a percentage of Control), between the LessN40 and the specified other N treatment.

For the last two variables, it was necessary to logarithm transform the D values prior to the derivation of the 95% confidence interval. The best estimate and lower and upper limits of the 95% confidence interval (95% CI) were then "back-transformed" to ordinary units for presentation in this report.

The last two variables (ratios) were also multiplied by 100 for ease of interpretation (values larger than 100 mean that LessN40 was superior to the other nitrogen treatment, while values smaller than 100 mean that LessN40 was inferior to the other nitrogen treatment).

Omission of "unusual values" and "unusual trials"

This report differs from the 16 October, 2012 report in that three unusual treatment means are excluded from all analyses reported herein. These are all means from Donaghys' trials. For the "probe" data, the first was a LiqU40 treatment mean which was inexplicably lower than Control, and the second was a LiqU80 treatment mean for which leaf scorching was observed on the plots (Table M(a)); if not removed, both of these unusual values make LessN40 look "better" than if they are removed. For the "mower" data, the only unusual value (excluded) was a LiqU80 treatment mean which was inexplicably lower than Control (Table M(b)); again, if not removed, this unusual value makes LessN40 look "better" than if it is removed. Thus Table 1 of this report differs slightly from Table 1 of the 16 October, 2012 report in rows 1, 2, 5, 6, 10 and 14 of the left-hand half of the table (Probe data), and in rows 2 and 6 of the right-hand half of the table (Mower data). Table 2 is unchanged between the two reports, since no Independent trials were involved.

Secondly, three trials were identified in which the soil temperature was less than the minimum of 10°C recommended for LessN application (Tables M(c and d)). Tables 1 and 2 of this report were therefore redone with these three trials omitted, and results are presented in Tables 3 and 4. These three trials were all Independent trials, with both Probe and Mower data. Therefore all values in rows 1, 2, 5, 6, 9, 10, 13 and 14 change between Tables 1-2 and Tables 3-4 in this report (the LiqU40 and LiqU80 rows only), with no changes in the other rows (since SolU40 and SolU80 were not included in any of these three trials).

Lastly, one trial was set up soon after 200mm of rain fell, causing flooding of the trial site, and it was thought this may have affected the trial results (Tables M(e and f)). Tables 3 and 4 of this report were therefore redone with this fourth trial also omitted, and results are presented in Tables 5 and 6. This fourth trial was also an Independent trial, with both Probe and Mower data. Therefore all values change between Tables 3-4 and Tables 5-6 in this report *except* for the values in rows 2, 6, 10 and 14 which remain unchanged (the LiqU80 rows, since LiqU80 was not included in this trial).

Table M: Details of one "unusual treatment mean" (*bold and italicised*) in each of three Donaghys trials, two in (a) Probe and one in (b) Mower data sets. These three values have been omitted from all analyses reported in all tables in this report. In (c) and (d) respectively, Probe and Mower treatment means are reported for three Independent trials where temperatures were below the recommended level; these values have been omitted from all analyses reported in Tables 3 - 6 in this report. In (e) and (f) respectively, Probe and Mower treatment means are reported for one Independent trial where flooding occurred just prior to the trial being set up; these values have been omitted from all analyses reported in Tables 5 - 6 in this report. NA means treatment was not included in the trial.

Trial	Control	LessN40	LiqU40	LiqU80	SolidU40	SolidU80
(a) "Probe" treatment means omitted from analyses in all Tables 1 - 6						
Culverden2	553	907	***517***	1012	NA	NA
SpreadSpray1	605	1150	966	***875***	738	1024
(b) "Mower" treatment mean omitted from analyses in all Tables 1 - 6						
NewPlymouth	3484	4058	3500	***3409***	NA	NA
(c) "Probe" trial data omitted from analyses in Tables 3 - 6 (low temp)						
Canterbury07	1092	1316	1372	1232	NA	NA
ManawatuDairy	1520	2091	1947	2229	NA	NA
ManawatuSheep	745	1048	952	1277	NA	NA
(d) "Mower" trial data omitted from analyses in Tables 3 - 6 (low temp)						
Canterbury07	1400	1624	1652	1736	NA	NA
ManawatuDairy	1556	1915	1702	2071	NA	NA
ManawatuSheep	621	1088	1003	1251	NA	NA
(e) "Probe" trial data omitted from analyses in Tables 5 - 6 (flooding)						
Reporoa	637	1004	1056	NA	1100	1208
(f) "Mower" trial data omitted from analyses in Tables 5 - 6 (flooding)						
Reporoa	643	909	810	NA	1003	1063

RESULTS

Results *including* the three low temperature, and previously flooded, trials

Results are given in Tables 1 and 2 for "all trials" and "independent trials only", for both probe and mower data. In the text, we now discuss these data for each comparison separately.

The results are discussed here for the trials *including* the three low temperature, and previously flooded, trials. At the very end of the Results section (following Table 6), we rewrite this summary of results based upon Tables 5 and 6 (*excluding* the three low temperature, and the one previously flooded, trials).

LessN40 compared to LiqU40

These two treatments differ only in that LessN was added to one of the two treatments. Here the results with the greatest precision would be expected to be those in the left half of Table 1, for "**all trials**" assessed using the **probe** method (since these are based upon 51 trials, as compared to 20 with the mower, or 13-14 "independent trials").

In the first row in the left half of Table 1(a), we see that the LessN40 treatment out-yielded the LiqU40 treatment by an average of 250 kg DM/ha [95% CI: 208 - 291] (p<0.001). When adjusted for the number of days of growth, a similar result was obtained (left half of Table 1b), with the average difference being 10.2 kg DM /day /ha [95% CI: 8.4 - 12.0] (p<0.001).

When the nitrogen (N) response of each treatment (versus control) was calculated, expressed *per kg of N applied*, and the ratio of the two N responses calculated, it was found that on average, LessN40 yielded 2.51 times the DM response per kg of N as did the LiqU40 treatment [95% CI: 2.11 - 2.98] (p<0.001), as seen in the left half of Table 1(c).

When the N response of each treatment (versus control) was calculated and expressed as a *percentage of the control* DM yield, and the ratio of the two percentage N responses calculated, it was found that on average, the LessN40 yielded 2.51 times the percentage DM response to N as did the LiqU40 treatment [95% CI: 2.11 - 2.98] (p<0.001), as seen in the left half of Table 1(d).   That is, this variable was identical to the one calculated in the last paragraph, due to both treatments having the same rate of applied N.

For "**all trials**" assessed using the **mower** method, results are based on 20 trials and are given in the right half of Table 1. These results generally followed the same pattern described above, with all differences being statistically significant, though "less significant" than with the probe data, and with DM responses being roughly 10 - 25% lower than with the probe method.

For the "**independent trials only**" assessed using the **probe** and **mower** methods, results are based on 13 - 14 trials and are given in Table 2. These results again followed the same general pattern described above, with all differences being statistically significant. Again, the mower results were "less significant" than with the probe data, and DM responses were lower with the mower method than with the probe method. In addition, the differences between the LessN40 and LiqU40 treatments were *always lower* than in the "all trials" results (by about 55% in the very worst case).

LessN40 compared to SolU40

These two treatments differ in two ways, in the presence or absence of LessN, and in liquid versus solid forms of N. Here there are relatively few trials reported in the left half of Table 1 (as compared to the LessN40 versus LiqU40 comparison) for "**all trials**" assessed using the **probe** method (12 trials, as compared to 10 with the mower, or 8-9 "independent trials").

In the third row in the left half of Table 1(a), we see that the LessN40 treatment out-yielded the SolU40 treatment by an average of 201 kg DM/ha [95% CI: 101 - 301] (p<0.01). When adjusted for the number of days of growth, a similar result was obtained (left half of Table 1b), with the average difference being 7.4 kg DM /day /ha [95% CI: 3.5 - 11.3] (p<0.01).

When the nitrogen (N) response of each treatment (versus control) was calculated, expressed *per kg of N applied*, and the ratio of the two N responses calculated, it was found that on average, the LessN40 yielded 2.05 times the DM response per kg of N as did the SolU40 treatment [95% CI: 1.33 - 3.16] (p<0.01), as seen in the left half of Table 1(c).

When the nitrogen (N) response of each treatment (versus control) was calculated and expressed as a *percentage of the control* DM yield, and the ratio of the two percentage N responses calculated, it was found that on average, the LessN40 yielded 2.05 times the percentage DM response to N as did the SolU40 treatment [95% CI: 1.33 - 3.16] (p<0.01), as seen in the left half of Table 1(d). That is, this variable was identical to the one calculated in the last paragraph, due to both treatments having the same rate of applied N.

For "**all trials**" assessed using the **mower** method, results are based on 10 trials and are given in the right half of Table 1. These results generally followed the same pattern described above, with all differences being statistically significant.

For the "**independent trials only**" assessed using the **probe** and **mower** methods, results are based on 8 - 9 of the above trials and are given in Table 2. These results again followed the same general pattern described above, with all differences being statistically significant, although less significant than with "all trials". In addition, the differences between the LessN40 and SolU40 treatments were always lower than in the "all trials" results.

LessN40 compared to LiqU80

These two treatments differ both in that LessN was added to one of the two treatments and in rate of applied urea (40 versus 80). Here the results with the greatest precision would again be expected to be those in the left half of Table 1, for "**all trials**" assessed using the **probe** method (since these are based upon 42 trials, as compared to 10 with the mower, or 5 "independent trials").

In the second row in the left half of Table 1(a), we see that the LessN40 treatment was not significantly different in yield from the LiqU80 treatment. When adjusted for the number of days of growth, a similar result was obtained (left half of Table 1b).

When the nitrogen (N) response of each treatment (versus control) was calculated, expressed *per kg of N applied*, and the ratio of the two N responses calculated, it was found that on average, the LessN40 yielded 1.98 times the DM response per kg of N as did the LiqU80 treatment [95% CI: 1.85 - 2.12] (p<0.001), as seen in the left half of Table 1(c).

When the nitrogen (N) response of each treatment (versus control) was calculated and expressed as a *percentage of the control* DM yield, and the ratio of the two percentage N responses calculated, it was found that on average, the LessN40 gave a similar percentage response to N as did the LiqU80 treatment, as seen in the left half of Table 1(d), in spite of the fact that the latter treatment had twice the rate of applied N.

For "**all trials**" assessed using the **mower** method, results are based on 10 trials and are given in the right half of Table 1. These results followed the same pattern described above, but with considerably wider 95% confidence intervals due to the lower number of trials.

For the "**independent trials only**" assessed using the **probe** and **mower** methods, results are based on only 5 trials and are given in Table 2. For the **probe** data, results followed the same pattern as described above. However, with the **mower** data, results differed in that the LiqU80 treatment was significantly better (p<0.01) than the LessN40 treatment for DM response, DM response on a daily basis, and percentage DM response to N; conversely, in terms of N response per kg of N applied, LessN40 was significantly better than LiqU80 (p<0.01).

LessN40 compared to SolU80

These two treatments differ in three ways, in that LessN was added to one of the two treatments, in rate of applied urea (40 versus 80), and in form (liquid versus solid). Here there are relatively few trials reported in the left half of Table 1 (as compared to the LessN40 versus LiqU40 comparison) for "**all trials**" assessed using the **probe** method (12 trials, as compared to 10 with the mower, or 8-9 "independent trials").

In the fourth row in the left half of Table 1(a), we see that the LessN40 treatment was not significantly different in yield from the SolU80 treatment. When adjusted for the number of days of growth, a similar result was obtained (left half of Table 1b).

When the nitrogen (N) response of each treatment (versus control) was calculated, expressed *per kg of N applied*, and the ratio of the two N responses calculated, it was found that on average, the LessN40 yielded 2.04 times the DM response per kg of N as did the SolU80 treatment [95% CI: 1.73- 2.40] (p<0.001), as seen in the left half of Table 1(c).

When the nitrogen (N) response of each treatment (versus control) was calculated and expressed as a *percentage of the control* DM yield, and the ratio of the two percentage N responses calculated, it was found that on average, the LessN40 gave a similar percentage response to N as did the SolU80 treatment, as seen in the left half of Table 1(d), in spite of the fact that the latter treatment had twice the rate of applied N.

For "**all trials**" assessed using the **mower** method, results are based on 10 trials and are given in the right half of Table 1. These results followed the same pattern described above, but with wider 95% confidence intervals due to the lower number of trials.

For the "**independent trials only**" assessed using the **probe** and **mower** methods, results are based on 8-9 of the above trials and are given in Table 2. In all cases, results followed the same pattern as described above.

Table 1: Combined analyses for ALL trials (omitting three values, as detailed in Table M(a and b)). 95% confidence intervals for the comparison of the LessN40 treatment with each other nitrogen treatment. In (a) and (b), the difference between the two treatments is not statistically significant (p<0.05) if the 95% confidence interval includes zero. In (c) and (d), the ratio (difference) of the two treatments is not statistically significant (p<0.05) if the 95% confidence interval includes a ratio of 100%. Also, (c) and (d) are equivalent variables if they have a common rate of applied nitrogen (40). The significance of each difference is also shown in the "best estimate" columns of the table; *=5% sig.; **=1% sig.; *=0.1% sig. (and no asterisks means "not significant").**

	Probe data				Mower data			
		95% confidence interval for true mean				95% confidence interval for true mean		
	Number of trials	Lower confid limit	Best estimate	Upper confid limit	Number of trials	Lower confid limit	Best estimate	Upper confid limit
(a) Difference in DM production (kg/ha) between LessN40 and the following treatment:								
LiqU40	51	208	250***	291	20	51	213*	375
LiqU80	42	-42	-13	16	10	-159	31	221
SolU40	12	101	201**	301	10	65	167**	269
SolU80	12	-65	6	76	10	-104	-11	82
(b) Difference in DM production *on a daily basis* (kg/ha/day) between LessN40 and:								
LiqU40	51	8.4	10.2***	12.0	20	2.3	8.9*	15.4
LiqU80	42	-1.5	-0.4	0.7	10	-6.0	1.5	8.9
SolU40	12	3.5	7.4**	11.3	10	2.6	6.6**	10.6
SolU80	12	-3.1	0.0	3.1	10	-4.9	-0.6	3.7
(c) 100-ised ratio of the DM production nitrogen response (N treatment *minus* Control) *per kg of nitrogen applied,* between LessN40 and:								
LiqU40	51	211	251***	298	20	130	190**	278
LiqU80	42	185	198***	212	10	130	207**	328
SolU40	12	133	205**	316	10	136	223**	365
SolU80	12	173	204***	240	10	138	200**	289
(d) 100-ised ratio of the DM production *percentage* nitrogen response (N treatment *minus* Control, as a percentage of Control), between LessN40 and:								
LiqU40	51	211	251***	298	20	130	190**	278
LiqU80	42	93	99	106	10	65	103	164
SolU40	12	133	205**	316	10	136	223**	365
SolU80	12	87	102	120	10	69	100	145

Table 2: Combined analyses for the Independent trials only (no values omitted). 95% confidence intervals for the comparison of the LessN40 treatment with each other nitrogen treatment. In (a) and (b), the difference between the two treatments is not statistically significant (p<0.05) if the 95% confidence interval includes zero. In (c) and (d), the ratio (difference) of the two treatments is not statistically significant (p<0.05) if the 95% confidence interval includes a ratio of 100%. Also, (c) and (d) are equivalent variables if they have a common rate of applied nitrogen (40). The significance of each difference is also shown in the "best estimate" columns of the table; *=5% sig.; **=1% sig.; ***=0.1% sig. (and no asterisks means "not significant").

| | | Probe data | | | | Mower data | | |
| | | 95% confidence interval for true mean | | | | 95% confidence interval for true mean | | |
	Number of trials	Lower confid limit	Best estimate	Upper confid limit	Number of trials	Lower confid limit	Best estimate	Upper confid limit
(a) Difference in DM production (kg/ha) between LessN40 and the following treatment:								
LiqU40	14	87	156***	225	13	42	103**	163
LiqU80	5	-209	-42	125	5	-221	-142**	-63
SolU40	9	43	168*	292	8	21	147*	272
SolU80	9	-109	-21	67	8	-126	-22	82
(b) Difference in DM production *on a daily basis* (kg/ha/day) between LessN40 and:								
LiqU40	14	3.5	6.4***	9.3	13	1.8	4.0**	6.2
LiqU80	5	-7.5	-1.3	4.9	5	-7.7	-5.3**	-2.9
SolU40	9	1.3	6.8*	12.2	8	0.8	5.6*	10.5
SolU80	9	-5.0	-0.9	3.3	8	-6.0	-1.0	3.9
(c) 100-ised ratio of the DM production nitrogen response (N treatment *minus* Control) *per kg of nitrogen applied,* between LessN40 and:								
LiqU40	14	129	164***	209	13	116	153**	202
LiqU80	5	121	196*	318	5	122	139**	159
SolU40	9	107	191*	340	8	114	205*	367
SolU80	9	157	193***	238	8	123	191*	298
(d) 100-ised ratio of the DM production *percentage* nitrogen response (N treatment *minus* Control, as a percentage of Control), between LessN40 and:								
LiqU40	14	129	164***	209	13	116	153**	202
LiqU80	5	60	98	159	5	61	70**	80
SolU40	9	107	191*	340	8	114	205*	367
SolU80	9	78	97	119	8	61	96	149

Table 3: Combined analyses for ALL trials (omitting 3 values and 3 low temperature trials). 95% confidence intervals for the comparison of the LessN40 treatment with each other nitrogen treatment. In (a) and (b), the difference between the two treatments is not statistically significant (p<0.05) if the 95% confidence interval includes zero. In (c) and (d), the ratio (difference) of the two treatments is not statistically significant (p<0.05) if the 95% confidence interval includes a ratio of 100%. Also, (c) and (d) are equivalent variables if they have a common rate of applied nitrogen (40). The significance of each difference is also shown in the "best estimate" columns of the table; *=5% sig.; **=1% sig.; *=0.1% sig. (and no asterisks means "not significant").**

| | Probe data | | | | Mower data | | | |
| | 95% confidence interval for true mean | | | | 95% confidence interval for true mean | | | |
	Number of trials	Lower confid limit	Best estimate	Upper confid limit	Number of trials	Lower confid limit	Best estimate	Upper confid limit
(a) Difference in DM production (kg/ha) between LessN40 and the following treatment:								
LiqU40	48	220	261***	303	17	44	234*	425
LiqU80	39	-35	-7	21	7	-162	106	373
SolU40	12	101	201**	301	10	65	167**	269
SolU80	12	-65	6	76	10	-104	-11	82
(b) Difference in DM production *on a daily basis* (kg/ha/day) between LessN40 and:								
LiqU40	48	9.0	10.7***	12.5	17	2.2	9.9*	17.5
LiqU80	39	-1.2	-0.1	0.9	7	-6.3	4.3	14.9
SolU40	12	3.5	7.4**	11.3	10	2.6	6.6**	10.6
SolU80	12	-3.1	0.0	3.1	10	-4.9	-0.6	3.7
(c) 100-ised ratio of the DM production nitrogen response (N treatment *minus* Control) *per kg of nitrogen applied,* between LessN40 and:								
LiqU40	48	222	263***	313	17	129	201**	312
LiqU80	39	188	200***	213	7	125	244*	475
SolU40	12	133	205**	316	10	136	223**	365
SolU80	12	173	204***	240	10	138	200**	289
(d) 100-ised ratio of the DM production *percentage* nitrogen response (N treatment *minus* Control, as a percentage of Control), between LessN40 and:								
LiqU40	48	222	263***	313	17	129	201**	312
LiqU80	39	94	100	106	7	63	122	238
SolU40	12	133	205**	316	10	136	223**	365
SolU80	12	87	102	120	10	69	100	145

Table 4: Combined analyses for the Independent trials only (omitting 3 low temperature trials). 95% confidence intervals for the comparison of the LessN40 treatment with each other nitrogen treatment. In (a) and (b), the difference between the two treatments is not statistically significant (p<0.05) if the 95% confidence interval includes zero. In (c) and (d), the ratio (difference) of the two treatments is not statistically significant (p<0.05) if the 95% confidence interval includes a ratio of 100%. Also, (c) and (d) are equivalent variables if they have a common rate of applied nitrogen (40). The significance of each difference is also shown in the "best estimate" columns of the table; *=5% sig.; **=1% sig.; *=0.1% sig. (and no asterisks means "not significant").**

	Probe data				Mower data			
		95% confidence interval for true mean				95% confidence interval for true mean		
	Number of trials	Lower confid limit	Best estimate	Upper confid limit	Number of trials	Lower confid limit	Best estimate	Upper confid limit
(a) Difference in DM production (kg/ha) between LessN40 and the following treatment:								
LiqU40	11	105	182***	259	10	35	107**	179
LiqU80	2	-74	37	148	2	-1226	-138	949
SolU40	9	43	168*	292	8	21	147*	272
SolU80	9	-109	-21	67	8	-126	-22	82
(b) Difference in DM production *on a daily basis* (kg/ha/day) between LessN40 and:								
LiqU40	11	4.2	7.5***	10.9	10	1.6	4.2**	6.9
LiqU80	2	-7.9	1.8	11.5	2	-37.6	-5.5	26.7
SolU40	9	1.3	6.8*	12.2	8	0.8	5.6*	10.5
SolU80	9	-5.0	-0.9	3.3	8	-6.0	-1.0	3.9
(c) 100-ised ratio of the DM production nitrogen response (N treatment *minus* Control) *per kg of nitrogen applied,* between LessN40 and:								
LiqU40	11	137	180***	236	10	113	158*	220
LiqU80	2	103	221*	474	2	23	138	823
SolU40	9	107	191*	340	8	114	205*	367
SolU80	9	157	193***	238	8	123	191*	298
(d) 100-ised ratio of the DM production *percentage* nitrogen response (N treatment *minus* Control, as a percentage of Control), between LessN40 and:								
LiqU40	11	137	180***	236	10	113	158*	220
LiqU80	2	52	111	237	2	12	69	412
SolU40	9	107	191*	340	8	114	205*	367
SolU80	9	78	97	119	8	61	96	149

Table 5: Combined analyses for ALL trials (omitting 3 values, 3 low temperature trials and one trial set up after flooding). 95% confidence intervals for the comparison of the LessN40 treatment with each other nitrogen treatment. In (a) and (b), the difference between the two treatments is not statistically significant (p<0.05) if the 95% confidence interval includes zero. In (c) and (d), the ratio (difference) of the two treatments is not statistically significant (p<0.05) if the 95% confidence interval includes a ratio of 100%. Also, (c) and (d) are equivalent variables if they have a common rate of applied nitrogen (40). The significance of each difference is also shown in the "best estimate" columns of the table; *=5% sig.; **=1% sig.; *=0.1% sig. (and no asterisks means "not significant").**

| | Probe data | | | | Mower data | | | |
| | 95% confidence interval for true mean | | | | 95% confidence interval for true mean | | | |
	Number of trials	Lower confid limit	Best estimate	Upper confid limit	Number of trials	Lower confid limit	Best estimate	Upper confid limit
(a) Difference in DM production (kg/ha) between LessN40 and the following treatment:								
LiqU40	47	228	268***	308	16	40	243*	446
LiqU80	39	-35	-7	21	7	-162	106	373
SolU40	11	139	228***	317	9	107	196***	285
SolU80	11	-39	25	88	9	-93	5	103
(b) Difference in DM production *on a daily basis* (kg/ha/day) between LessN40 and:								
LiqU40	47	9.3	11.0***	12.7	16	2.0	10.2*	18.3
LiqU80	39	-1.2	-0.1	0.9	7	-6.3	4.3	14.9
SolU40	11	5.2	8.6***	11.9	9	4.7	7.9***	11.0
SolU80	11	-1.5	1.0	3.5	9	-4.1	0.2	4.6
(c) 100-ised ratio of the DM production nitrogen response (N treatment *minus* Control) *per kg of nitrogen applied,* between LessN40 and:								
LiqU40	47	228	270***	319	16	127	204**	326
LiqU80	39	188	200***	213	7	125	244*	475
SolU40	11	146	224**	344	9	158	252**	401
SolU80	11	183	212***	247	9	141	211**	314
(d) 100-ised ratio of the DM production *percentage* nitrogen response (N treatment *minus* Control, as a percentage of Control), between LessN40 and:								
LiqU40	47	228	270***	319	16	127	204**	326
LiqU80	39	94	100	106	7	63	122	238
SolU40	11	146	224**	344	9	158	252**	401
SolU80	11	92	106	123	9	71	105	157

Table 6: Combined analyses for the Independent trials only (omitting 3 low temperature trials and one trial set up after flooding). 95% confidence intervals for the comparison of the LessN40 treatment with each other nitrogen treatment. In (a) and (b), the difference between the two treatments is not statistically significant (p<0.05) if the 95% confidence interval includes zero. In (c) and (d), the ratio (difference) of the two treatments is not statistically significant (p<0.05) if the 95% confidence interval includes a ratio of 100%. Also, (c) and (d) are equivalent variables if they have a common rate of applied nitrogen (40). The significance of each difference is also shown in the "best estimate" columns of the table; *=5% sig.; **=1% sig.; *=0.1% sig. (and no asterisks means "not significant").**

	Probe data				Mower data			
		95% confidence interval for true mean				95% confidence interval for true mean		
	Number of trials	Lower confid limit	Best estimate	Upper confid limit	Number of trials	Lower confid limit	Best estimate	Upper confid limit
(a) Difference in DM production (kg/ha) between LessN40 and the following treatment:								
LiqU40	10	142	205***	269	9	26	108*	189
LiqU80	2	-74	37	148	2	-1226	-138	949
SolU40	8	86	200**	315	7	67	181**	295
SolU80	8	-79	2	83	7	-116	-3	109
(b) Difference in DM production *on a daily basis* (kg/ha/day) between LessN40 and:								
LiqU40	10	5.9	8.6***	11.3	9	1.1	4.1*	7.2
LiqU80	2	-7.9	1.8	11.5	2	-37.6	-5.5	26.7
SolU40	8	3.3	8.2**	13.1	7	3.2	7.1**	11.1
SolU80	8	-3.1	0.4	3.8	7	-5.2	0	5.2
(c) 100-ised ratio of the DM production nitrogen response (N treatment *minus* Control) *per kg of nitrogen applied,* between LessN40 and:								
LiqU40	10	151	194***	247	9	107	157*	231
LiqU80	2	103	221*	474	2	23	138	823
SolU40	8	116	213*	389	7	135	237**	416
SolU80	8	166	203***	248	7	123	203*	336
(d) 100-ised ratio of the DM production *percentage* nitrogen response (N treatment *minus* Control, as a percentage of Control), between LessN40 and:								
LiqU40	10	151	194***	247	9	107	157*	231
LiqU80	2	52	111	237	2	12	69	412
SolU40	8	116	213*	389	7	135	237**	416
SolU80	8	83	102	124	7	61	101	168

Results *excluding* the three low temperature, and previously flooded, trials

Results are given in Tables 5 and 6 for "all trials" and "independent trials only", *excluding* the three low temperature, and the one previously flooded, trials, for both probe and mower data. In the text, we again now discuss these data for each comparison separately.

LessN40 compared to LiqU40

These two treatments differ only in that LessN was added to one of the two treatments. Here the results with the greatest precision would be expected to be those in the left half of Table 5, for "**all trials**" assessed using the **probe** method (since these are based upon 47 trials, as compared to 16 with the mower, or 9-10 "independent trials").

In the first row in the left half of Table 5(a), we see that the LessN40 treatment out-yielded the LiqU40 treatment by an average of 268 kg DM/ha [95% CI: 228 - 308] (p<0.001). When adjusted for the number of days of growth, a similar result was obtained (left half of Table 5b), with the average difference being 11.0 kg DM /day /ha [95% CI: 9.3 - 12.7] (p<0.001).

When the nitrogen (N) response of each treatment (versus control) was calculated, expressed *per kg of N applied*, and the ratio of the two N responses calculated, it was found that on average, LessN40 yielded 2.70 times the DM response per kg of N as did the LiqU40 treatment [95% CI: 2.28 - 3.19] (p<0.001), as seen in the left half of Table 5(c).

When the N response of each treatment (versus control) was calculated and expressed as a *percentage of the control* DM yield, and the ratio of the two percentage N responses calculated, it was found that on average, the LessN40 yielded 2.70 times the percentage DM response to N as did the LiqU40 treatment [95% CI: 2.28 - 3.19] (p<0.001), as seen in the left half of Table 5(d). That is, this variable was identical to the one calculated in the last paragraph, due to both treatments having the same rate of applied N.

For "**all trials**" assessed using the **mower** method, results are based on 16 trials and are given in the right half of Table 5. These results generally followed the same pattern described above, with all differences being statistically significant, though "less significant" than with the probe data, and with DM responses being roughly 10 - 25% lower than with the probe method.

For the "**independent trials only**" assessed using the **probe** and **mower** methods, results are based on 9 - 10 trials and are given in Table 6. These results again followed the same general pattern described above, with all differences being statistically significant. Again, the mower results were "less significant" than with the probe data, and DM responses were lower with the mower method than with the probe method. In addition, the differences between the LessN40 and LiqU40 treatments were *always lower* than in the "all trials" results (by about 60% in the very worst case).

LessN40 compared to SolU40

These two treatments differ in two ways, in the presence or absence of LessN, and in liquid versus solid forms of N. Here there are relatively few trials reported in the left half of Table 5 (as compared to the LessN40 versus LiqU40 comparison) for "**all trials**" assessed using the **probe** method (11 trials, as compared to 9 with the mower, or 7-8 "independent trials").

In the third row in the left half of Table 5(a), we see that the LessN40 treatment out-yielded the SolU40 treatment by an average of 228 kg DM/ha [95% CI: 139 - 317] (p<0.001). When adjusted for the number of days of growth, a similar result was obtained (left half of Table 5b), with the average difference being 8.6 kg DM /day /ha [95% CI: 5.2 - 11.9] (p<0.001).

When the nitrogen (N) response of each treatment (versus control) was calculated, expressed *per kg of N applied*, and the ratio of the two N responses calculated, it was found that on average, the LessN40 yielded 2.24 times the DM response per kg of N as did the SolU40 treatment [95% CI: 1.46 - 3.44] (p<0.01), as seen in the left half of Table 5(c).

When the nitrogen (N) response of each treatment (versus control) was calculated and expressed as a *percentage of the control* DM yield, and the ratio of the two percentage N responses calculated, it was found that on average, the LessN40 yielded 2.24 times the percentage DM response to N as did the SolU40 treatment [95% CI: 1.46 - 3.44] (p<0.01), as seen in the left half of Table 5(d). That is, this variable was identical to the one calculated in the last paragraph, due to both treatments having the same rate of applied N.

For "**all trials**" assessed using the **mower** method, results are based on 9 trials and are given in the right half of Table 5. These results generally followed the same pattern described above, with all differences being statistically significant.

For the "**independent trials only**" assessed using the **probe** and **mower** methods, results are based on 7 - 8 of the above trials and are given in Table 6. These results again followed the same general pattern described above, with all differences being statistically significant, although less significant than with "all trials". In addition, the differences between the LessN40 and SolU40 treatments were always lower than in the "all trials" results.

LessN40 compared to LiqU80

These two treatments differ both in that LessN was added to one of the two treatments and in rate of applied urea (40 versus 80). Here the results with the greatest precision would again be expected to be those in the left half of Table 5, for "**all trials**" assessed using the **probe** method (since these are based upon 39 trials, as compared to 7 with the mower, or just 2 "independent trials").

In the second row in the left half of Table 5(a), we see that the LessN40 treatment was not significantly different in yield from the LiqU80 treatment. When adjusted for the number of days of growth, a similar result was obtained (left half of Table 5b).

When the nitrogen (N) response of each treatment (versus control) was calculated, expressed *per kg of N applied*, and the ratio of the two N responses calculated, it was found that on average, the LessN40 yielded 2.00 times the DM response per kg of N as did the LiqU80 treatment [95% CI: 1.88 - 2.13] (p<0.001), as seen in the left half of Table 5(c).

When the nitrogen (N) response of each treatment (versus control) was calculated and expressed as a *percentage of the control* DM yield, and the ratio of the two percentage N responses calculated, it was found that on average, the LessN40 gave a similar percentage response to N as did the LiqU80 treatment, as seen in the left half of Table 5(d), in spite of the fact that the latter treatment had twice the rate of applied N.

For "**all trials**" assessed using the **mower** method, results are based on 7 trials and are given in the right half of Table 5. These results followed the same pattern described above, but with considerably wider 95% confidence intervals due to the lower number of trials.

For the "**independent trials only**" assessed using the **probe** and **mower** methods, results are based on only 2 trials and are given in Table 6. For the **probe** data, results followed the same pattern as described above. With the **mower** data, results were roughly similar but the confidence intervals were very wide due to the extremely low sample size of 2.

LessN40 compared to SolU80

These two treatments differ in three ways, in that LessN was added to one of the two treatments, in rate of applied urea (40 versus 80), and in form (liquid versus solid). Here there are relatively few trials reported in the left half of Table 5 (as compared to the LessN40 versus LiqU40 comparison) for "**all trials**" assessed using the **probe** method (11 trials, as compared to 9 with the mower, or 7-8 "independent trials").

In the fourth row in the left half of Table 5(a), we see that the LessN40 treatment was not significantly different in yield from the SolU80 treatment. When adjusted for the number of days of growth, a similar result was obtained (left half of Table 5b).

When the nitrogen (N) response of each treatment (versus control) was calculated, expressed *per kg of N applied*, and the ratio of the two N responses calculated, it was found that on average, the LessN40 yielded 2.12 times the DM response per kg of N as did the SolU80 treatment [95% CI: 1.83- 2.47] (p<0.001), as seen in the left half of Table 5(c).

When the nitrogen (N) response of each treatment (versus control) was calculated and expressed as a *percentage of the control* DM yield, and the ratio of the two percentage N responses calculated, it was found that on average, the LessN40 gave a similar percentage response to N as did the SolU80 treatment, as seen in the left half of Table 5(d), in spite of the fact that the latter treatment had twice the rate of applied N.

For "**all trials**" assessed using the **mower** method, results are based on 9 trials and are given in the right half of Table 5. These results followed the same pattern described above, but with wider 95% confidence intervals due to the lower number of trials.

For the "**independent trials only**" assessed using the **probe** and **mower** methods, results are based on 7-8 of the above trials and are given in Table 6. In all cases, results followed the same pattern as described above.

CONCLUSIONS

Results were similar between the solid and liquid forms of urea as long as they were applied at the same rate of nitrogen.

In general terms, the LessN40 treatment yielded twice the DM response per kg of applied nitrogen as did the two treatments with the same rate of applied nitrogen (40 kg urea/ha), and was equivalent to the two treatments with twice the rate of applied urea (80 kg/ha).

This last statement is approximate in that results varied somewhat between mower and probe methods of assessment, between "all trials" and "independent trials only", and also with which trials were included in the analyses.

REFERENCE

Saville, D. J. (1980). Replication of field trials in space and time. *Proc. Agronomy Society of N.Z. 10*, 97-99.

Statistical analyses combining data from LessN trials

Table prepared by Dave Saville, Biometrician
Saville Statistical Consulting Limited, Box 69192, Lincoln 7640
(Email: savillestat@gmail.com; phone: 03-345 5799)

	Probe data				Mower data			
		95% confidence interval for true mean				95% confidence interval for true mean		
	Number of trials	Lower confid limit	Best estimate	Upper confid limit	Number of trials	Lower confid limit	Best estimate	Upper confid limit
(a) Difference in DM production (kg/ha) between LessN40 and the following treatment:								
LiqU40	51	208	250	291	20	51	213	375
LiqU80	42	-42	-13	16	11	-123	87	298
SolU40	12	101	201	301	10	65	167	269
SolU80	12	-65	6	76	10	-104	-11	82
(b) Difference in DM production *on a daily basis* (kg/ha/day) between LessN40 and:								
LiqU40	51	8.4	10.2	12.0	20	2.3	8.9	15.4
LiqU80	42	-1.5	-0.4	0.7	11	-4.7	4.0	12.8
SolU40	12	3.5	7.4	11.3	10	2.6	6.6	10.6
SolU80	12	-3.1	0.0	3.1	10	-4.9	-0.6	3.7
(c) 100-ised ratio of the DM production nitrogen response (N treatment *minus* Control) *per kg of nitrogen applied,* between LessN40 and:								
LiqU40	51	211	251	298	19	134	198	293
LiqU80	42	185	198	212	9	130	217	362
SolU40	12	133	205	316	10	136	223	365
SolU80	12	173	204	240	10	138	200	289
(d) 100-ised ratio of the DM production *percentage* nitrogen response (N treatment *minus* Control, as a percentage of Control), between LessN40 and:								
LiqU40	51	211	251	298	19	134	198	293
LiqU80	42	93	99	106	9	65	108	181
SolU40	12	133	205	316	10	136	223	365
SolU80	12	87	102	120	10	69	100	145

NOTE: Excluded Trials/Treatments are:
Non-Nitrogen Responsive Trials
Trials with Experimental Design that did not include Urea only at 40 kg urea/ha
'Canterbury07'trial mower ratio calculations since the ratio was negative and unable to be log transformed.
'NewPlymouth' trial LiqU80 mower ratio calculation since the treatment performed below control and thus gave a negative value unable to be incorporated.
'SpreadSpray1' trial LiqU80 treatment for probe and mowing since the treatment performed poorly and had leaf scorch
'Culverden2' trial LiqU40 treatment since the treatment performed below control.