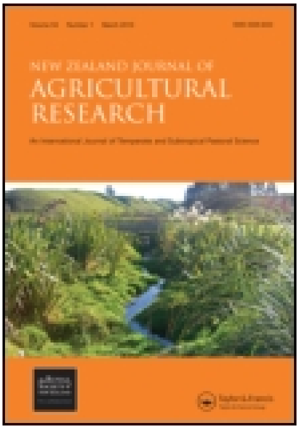

New Zealand Journal of Agricultural Research

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tnza20

A field comparison of pasture selenium uptake from different forms of selenium fertiliser

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Version of record first published: 17 Mar 2010.

To cite this article: R. G. McLaren & L. M. Clucas (2006): A field comparison of pasture selenium uptake from different forms of selenium fertiliser, New Zealand Journal of Agricultural Research, 49:3, 227-232

To link to this article: http://dx.doi.org/10.1080/00288233.2006.9513713

New Zealand Journal of Agricultural Research, 2006, Vol. 49: 227–232
0028–8233/06/4903–0227

A field comparison of pasture selenium uptake from different forms of selenium fertiliser

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Abstract The uptake of selenium (Se) by pasture herbage from four different Se fertiliser materials was determined in a field experiment throughout the course of a whole year. The products tested were: the commercially available Selenium Chip™; Selcote® Ultra; and two new formulations (Ravensdown A and B), manufactured in a way to slow the release of Se in the form of sodium selenate. All four Se fertilisers increased pasture herbage Se concentrations above the level required to meet the nutritional requirements of grazing livestock; however, the size and duration of the responses varied between products. The Ravensdown A product was as effective as Selcote Ultra at maintaining pasture Se concentrations above the critical animal health level for the whole year of the trial. The effects of the other two products, particularly the Selenium Chip, were not so long-lasting. Recoveries of Se in the pasture herbage throughout the year ranged between c. 15 and 17% of the Se originally applied in the fertilisers.

Keywords fertiliser trial; pasture selenium uptake; selenium fertilisers; water-soluble selenium

A05075; Online publication date 4 July 2006
Received 19 December 2005; accepted 4 April 2006

INTRODUCTION

Selenium (Se)-responsive diseases in farm animals are of considerable economic importance in New Zealand, and responses in grazing ruminants occur over large areas in both North and South Islands (Watkinson 1983). Since 1982, topdressing of pastures with Se as selenate has been permitted, usually in the form of pellets or prills mixed with other fertilisers, usually superphosphate. To date there has been a somewhat restricted number of Se fertiliser products available on the New Zealand market, in the main consisting of either products based solely on sodium selenate or on mixtures of sodium and barium selenate. Products based on sodium selenate are often regarded as quick-release, and those based on barium selenate as slow-release selenium fertilisers (e.g., Whelan & Barrow 1994; Morton et al. 1999). However, there is little information available, either in New Zealand or overseas, on the relative effectiveness of different Se fertilisers in maintaining pasture herbage Se concentration above the requirements for grazing livestock. One study, undertaken in a Mediterranean environment in Western Australia (Whelan & Barrow 1994), indicated that a slow-release Se fertiliser based on barium selenate could be effective for up to 4 years, whereas an application of sodium selenate at the same rate (10 g Se/ha) was effective for only 15 months. However, the relevance of this study to the generally wetter environment in New Zealand is debatable.

The recent development of a new slow-release Se fertiliser based solely on sodium selenate (A. H. C. Roberts pers. comm.) has provided opportunities to compare the effectiveness of this new material with existing Se fertiliser products currently available to farmers in New Zealand. Loganathan & Hedley (2006) have recently reported the results of a comparative study including the new Se fertiliser materials undertaken under glasshouse conditions. This paper reports the results of a field trial that compared the selenium uptake by pasture from four Se fertiliser materials, including two formulations of the new product and two existing and commonly used Se fertilisers.

MATERIALS AND METHODS

Selenium fertilisers

Four different Se fertiliser materials were compared in this experiment. They were:

(i) Selenium Chip™ (Wrightsons). This product contains 1% Se as sodium selenate in a granule which encapsulates Se until soil moisture is present. (www.wrightson.net.au)

(ii) Selcote® Ultra. This product is described as a 1% selenium granule. The formulation contains both fast (sodium selenate) and slow (barium selenate) release forms of Se (slow-release Se).

(iii) A Se prill supplied by Ravensdown Fertiliser Cooperative Ltd containing 1% Se as sodium selenate, granulated with certain additives to slow the release of Se. This product contained 60% water soluble Se (Ravensdown Se prill A).

(iv) A Se prill supplied by Ravensdown Fertiliser Cooperative Ltd as for (iii) but containing 2% Se, of which 76% was water soluble (Ravensdown Se prill B).

Experimental details

The field experiment was conducted on the Lincoln University dairy farm in Canterbury, New Zealand on a free-draining Templeton fine sandy loam soil (Immature Pallic Soil: Hewitt 1993). Properties of the soil at the experimental site were as follows: soil pH 6.0; organic carbon 2.71%; Olsen P 31; cation exchange capacity 12.0 cmol(+)/kg; base saturation 66%. The pasture consisted of ryegrass (var. 'Bronsyn' and 'Impact') and white clover (var. 'Aran' and 'Sustain'). The area for the experiment was mown in early October 2003 and the following basal nutrients applied: 21 kg P/ha and 64 kg S/ha applied as S superphosphate (19% S); 30 kg K/ha applied as KCl; 26 kg N/ha applied as an ammonium sulphate (70%)/urea (30%) blend.

The experiment consisted of 28 plots (2 × 5 m) in a completely randomised design and was conducted under centre pivot irrigation, with grazing animals excluded. During the period of the experiment there was 504 mm rainfall, and between October 2003 and April 2004 c. 1240 mm of irrigation was applied. The Se fertiliser treatments were applied to the plots 2 weeks after the basal fertiliser application and consisted of: 1. control (no Se fertiliser), 2. Se Chip at 1.0 kg/ha, 3. Selcote Ultra at 1.0 kg/ha, 4. Ravensdown A Se prill at 1.0 kg/ha, 5. Ravensdown B Se prill at 0.5 kg/ha. There were six replicates for each of the fertiliser treatments and four replicates for the control.

Fertiliser application

As received, the four Se fertiliser materials varied greatly in both their average granule size, and range of granule sizes present. Also, it was known that with some products, there could be considerable variation in Se content with granule size (Loganathan & Hedley 2006). This presented a problem in terms of how best to apply the materials to the plots.

Therefore, in order to compare the materials under as uniform conditions as possible (in terms of granule size and distribution pattern on the plots), and using information available at the time, each fertiliser was sieved to collect granules between 1 and 2.8 mm diameter for use in the trial. The granules were placed on the plots in a grid pattern (between 65–95 granules per plot). Subsequent analysis of the 1–2.8 mm granule fractions revealed some differences between materials in Se concentration as compared with their nominal concentrations, and hence in the rates of selenium applied (Table 1). The original intention was to apply Se at a rate of 10 g/ha.

Sampling and analysis

The experimental plots were sampled throughout one entire year following the treatment applications. Throughout the active growing season, pasture was harvested every 20–30 days (Table 2), in accordance

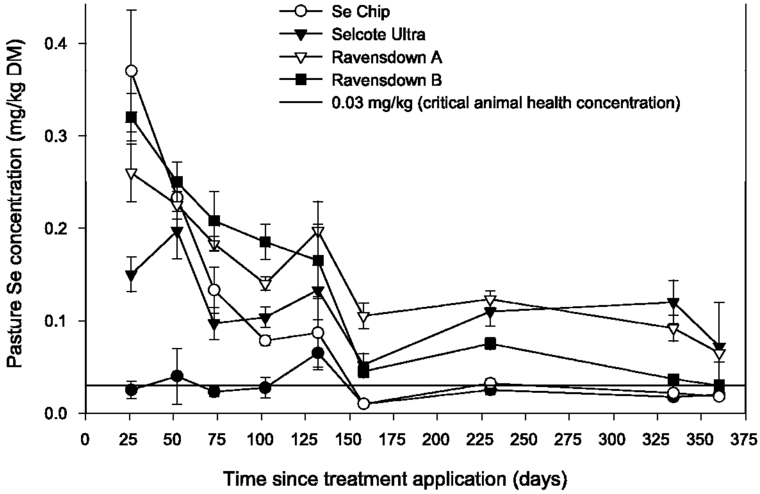
Table 1 Selenium concentrations in the 1–2.8 mm granule fraction of the fertiliser products and rates of Se applied.

Product	Selenium (% w/w)	Selenium applied (g/ha)
Se Chip™	0.67	6.7
Selcote® Ultra	0.67	6.7
Ravensdown A	0.94	9.4
Ravensdown B	1.73	8.7

Table 2 Harvest dates.

Harvest no.	Date	Time since treatments applied (days)
1	19 Nov 2003	26
2	15 Dec 2003	52
3	5 Jan 2004	73
4	3 Feb 2004	102
5	4 Mar 2004	132
6	31 Mar 2004	158
7	10 Jun 2004	230
8	22 Sep 2004	334
9	22 Oct 2004	364

Fig. 1 Effect of Se fertiliser treatments on pasture Se concentrations. Bars indicate ± SE.



with the farm grazing rotation periods. During the winter, there were longer periods between harvests. A mower with a cutting bar width of 1.2 m was used to mow down the entire length of the plot and the herbage fresh weight recorded in the field. The samples were mixed thoroughly before taking composite grab subsamples for dry matter determination. Following sampling, all remaining herbage was removed from the experimental plots.

The grab subsamples were dried at 60°C in an oven, weighed, and then finely ground and analysed for Se by Analytical Research Laboratories Ltd, Napier. The finely ground samples were digested in a mixture of 70% $HClO_4$ and 69% HNO_3 at a volume ratio of 4:10, and Se concentrations in the digests determined by inductively coupled plasma (ICP) or hydride generation atomic absorption spectrometry (limit of detection for Se was 0.01 mg/kg DM). Selenium concentrations in the fertiliser materials were determined using the same procedure.

Table 3 Total dry matter yield of experimental treatments.

Treatment	Total pasture yield (t DM/ha ± SE)
Control	12.1 ± 0.29
Se Chip™	12.1 ± 0.31
Selcote® Ultra	11.7 ± 0.26
Ravensdown A	11.1 ± 0.25
Ravensdown B	12.0 ± 0.39

Statistical analysis

Calculation of standard errors and tests of statistical difference (*t*-tests) were carried out using Minitab® Release 14 statistical software.

RESULTS AND DISCUSSION

Pasture dry matter yield

Cumulative pasture yields for the period of the trial are shown in Table 3. Differences in yield between treatments were small, although the mean yield for the Ravensdown A plots was significantly lower ($P < 0.05$) than those for the control and Se Chip plots. The overall mean cumulative pasture dry matter (DM) yield was 11.8 t DM/ha (SE ± 0.15).

Pasture herbage Se concentrations

The mean Se herbage concentrations for the different treatments are shown in Fig. 1. Selenium concentrations for the control plots were generally at or below the critical animal health concentration of 0.03 mg/kg (Miller 1983) throughout the experimental period. All four of the Se fertiliser materials tested in this trial increased pasture herbage Se concentrations, although the size and duration of the responses varied considerably. Responses to all products were quick and, with the exception of Selcote Ultra, the highest pasture Se concentrations were observed at the first harvest. The Se Chip produced the highest initial Se concentrations, but concentrations tailed

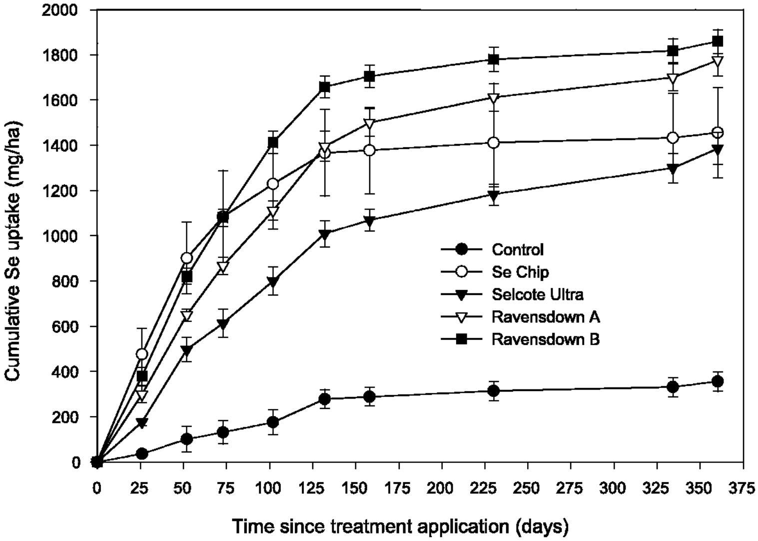


Fig. 2 Effect of Se fertiliser treatments on cumulative pasture Se uptake. Bars indicate ± SE.

off relatively quickly, and were significantly higher than concentrations in the control pasture for the first four harvests only. After the fifth harvest, pasture Se concentrations in the Se Chip-treated plots remained at or below the critical 0.03 mg/kg concentration. The response pattern of Se concentrations observed to Se Chip is very similar to that observed previously for sodium selenate based fertilisers (e.g., Grant 1965; Watkinson 1983).

In contrast, treatment with Selcote Ultra increased and maintained pasture Se concentrations well above 0.03 mg/kg throughout the trial. The difference in response between the Se Chip and Selcote Ultra products can be related to their different compositions. The source of Se in Se Chip is sodium selenate, a highly soluble compound, whereas Selcote Ultra contains both fast and slow releasing forms of Se. The difference between the two types of product is similar to that observed by Whelan & Barrow (1994) in Western Australia, except that under their conditions (Mediterranean climate) the effects of both quick and slow acting fertilisers were much more long-lasting than in the present study.

Both the Ravensdown A and B formulations maintained pasture Se concentrations at significantly higher concentrations than in the control herbage throughout the trial. In the case of the Ravensdown A product, pasture Se concentrations were maintained well above the 0.03 mg/kg level at all harvests. With the Ravensdown B product, pasture Se concentrations at the final two harvests just reached the 0.03 mg/kg level. The difference between the two Ravensdown products is most likely related to differences in the percentage Se solubility between the two products. The Ravensdown A product has a lower proportion of water-soluble Se compared with the Ravensdown B formulation. The Ravensdown A product gave a very similar response pattern to the currently available Selcote Ultra, a product that is designed specifically to give a longer-term response. Clearly, restricting the proportion of water-soluble Se in the product appears to be a significant factor in obtaining a longer-lasting effect.

At no time during the experiment, even with the initial Se concentrations obtained with the Se Chip, did herbage concentrations approach the concentrations (5–40 mg/kg, Judson & Reuter 1999) that might result in chronic toxicosis in livestock.

Cumulative Se uptake

The cumulative Se uptakes (mg Se/ha) during the trial for each of the treatments are shown in Fig. 2. Uptakes are calculated from the Se concentrations and dry matter yields from the plots. All four Se fertiliser treatments show substantially increased cumulative Se uptake by pasture compared to the control.

For the Se Chip and the Ravensdown B product, the bulk of the Se uptake (over 90%) occurred over the first six harvests (158 days), with very little further uptake during the final three harvests. In contrast, with the Selcote Ultra and Ravensdown A products, c. 20% of the total Se uptake occurred over the last three harvests. The highest cumulative Se uptakes were obtained with the two Ravensdown products. Cumulative uptakes from the Se Chip and Selcote

Fig. 3 Estimated pasture Se concentrations based on an application rate of 10 g Se/ha.

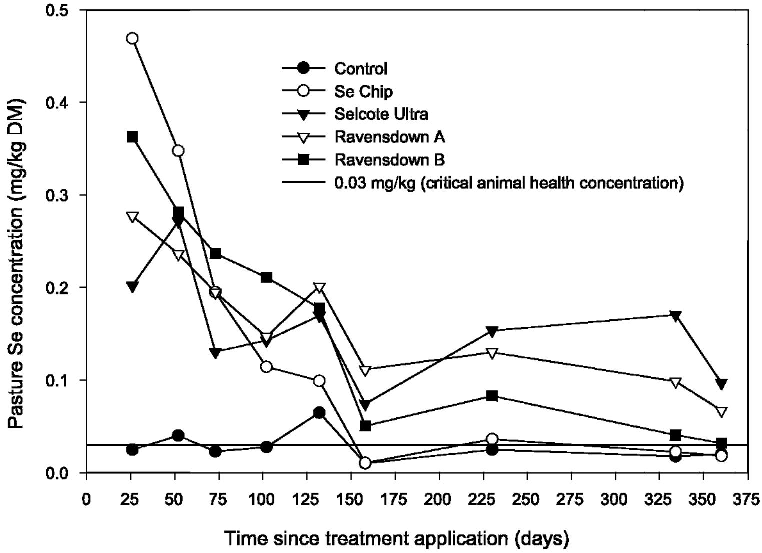


Table 4 Cumulative recovery of applied Selenium.

Treatment	Se applied (mg/ha)	Se recovered[1] (mg/ha)	% recovery
Se Chip™	6700	1088	16.4
Selcote® Ultra	6700	731	15.4
Ravensdown A	9400	1112	15.1
Ravensdown B	8650	1379	17.4

[1]Se uptake in control herbage subtracted.

Ultra products were similar to each other, and lower than uptakes from the Ravensdown products.

Recovery of applied Se

To compare the uptake of Se by pasture in relation to the amounts of Se applied, the recovery of Se in the pasture was calculated as a percentage of that applied in the fertiliser (Table 4). Over the period of the experiment, in spite of the different response patterns, the recoveries of applied Se in the pasture herbage from all four products were similar, ranging from 15.1 to 17.4%. Similar pasture recoveries of applied Se were obtained for sodium selenate by Watkinson & Dixon (1979), although over a much shorter period than in the current study. These recoveries are much lower than the 48–63% Se recovered in the glasshouse study reported by Loganathan & Hedley (2006). However, in the glasshouse environment, plant roots generally tend to be restricted to smaller volumes of soil than in the field and, in the study by Loganathan & Hedley (2006), there would have been no Se losses by leaching. In our field study, the experimental plots received c. 1750 mm water during the year in a combination of rainfall and irrigation. Since the soil is not strongly retentive for anions, this may well have resulted in some loss of Se as selenate in drainage water. Other explanations for the low recoveries of Se in pasture herbage could be volatilisation of Se or transformations (including reduction) to less bioavailable forms of Se. However, we have no evidence for the occurrence of such processes.

Some of the differences in the amounts of Se recovered between products (Table 4) were probably related to the differences in the amounts of Se initially applied (see Table 1). However, since pasture Se concentration appears to be linearly related to Se application rate (Watkinson 1983), using the percentage Se recovery figures at each harvest it is possible to estimate herbage Se concentrations assuming an addition of 10 g Se/ha for each product. The results are shown in Fig. 3. The trends of decreasing Se concentration with time are obviously the same as those shown for the actual data (Fig. 1), although the estimated pasture Se concentrations are of course higher. The response to the Se Chip product is predicted to have still essentially disappeared after the fifth harvest. Similarly, the pasture Se concentration for the Ravensdown B product is predicted to be minimal for the last two harvests.

Particle size may also have an important influence on the release of Se. Although a relatively narrow particle size range was used for all four products (1–2.8 mm), there were clearly still some differences in average particle size between products. The smaller the granule, the quicker the Se is likely to be dissolved. Unfortunately, none of the products tested had uniform granule size, thus making comparisons difficult. If Se concentration varies with granule size, as indicated for some products (P. Loganathan pers. comm.), exact comparisons become difficult.

The effects of granule size are likely to be particularly important for small plot experiments when relatively small weights of material are required for application. For example, in this study, the weights of products applied were only 1.0 or 0.50 g per plot. We think that production of prills with both uniform size and composition (readily versus slowly soluble Se) could be of considerable importance for the consistent effectiveness of the final product.

CONCLUSIONS

All four Se fertilisers tested increased pasture herbage Se concentrations above the level required to meet the nutritional requirements of grazing livestock, however, the size and duration of the responses varied between products. The Ravensdown A prill was equally as effective as Selcote Ultra at maintaining pasture Se concentrations above the critical animal health level for the whole year of the trial. The Se Chip, although producing higher initial pasture Se concentrations, had a substantially shorter effect than the other materials tested. Alteration of the percentage of water-soluble Se in the Ravensdown product clearly has the potential to control the rate of release of Se from these fertiliser prills.

ACKNOWLEDGMENTS

This work was funded by Ravensdown Fertiliser Cooperative Ltd. The authors acknowledge the help of Jim Moir in setting up the field experiment and Carole Barlow, Hamish Masters, Sam Smith and Laure Verneyre for assistance with the sampling.

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