Article — Artikel

The application of a selenium fertiliser for the correction of marginal deficiencies in grazing sheep

S W P Cloete[a], F E van Niekerk[b], M Young[c], G D van der Merwe[c] and J Clark[d]

ABSTRACT

A commercial fertiliser, consisting of a poorly soluble barium selenate core with a coating of highly soluble sodium selenite, was evaluated in 2 trials for the provision of selenium (Se) to grazing sheep. The fertiliser was administered at a level of 1 kg per hectare to 3 of 6 kikuyu paddocks during 1995 and 1996 in Trial 1, while the other paddocks were left untreated. The Se status of SA mutton merino ram lambs, as reflected by whole blood, liver and kidney Se concentrations, was elevated ($P < 0.01$) for at least 5 months after application of the fertiliser. Whole blood and liver Se concentrations of animals grazing unfertilised control paddocks were indicative of a subclinical Se deficiency at times (<100 ng Se/mℓ whole blood and <300 μg Se/kg liver dry matter). In Trial 2, 4 of 7 paddocks on which an oat fodder crop was established were treated with the Se fertiliser during 1995 and 1997. The remaining 3 paddocks were left unfertilised as controls. Groups of 10–15 pregnant SA mutton merino ewes were introduced to these paddocks within 2 weeks of parturition. These ewes and their progeny utilised these paddocks for a mean (±SD) period of 41 ± 8 days after parturition. The whole blood Se concentrations of these ewes and their offspring were elevated ($P < 0.01$) relative to their contemporaries utilising control paddocks. No suggestion of a subclinical Se deficiency was discernible in animals grazing control paddocks, although whole blood Se levels approached 100 ng Se/mℓ during 1997. The application of Se fertiliser did not result in improvements in ewe reproduction or lamb growth. There was a suggestion of an improvement ($P = 0.21$) in mean (±SE) lamb survival on paddocks receiving Se fertiliser compared to control paddocks (71.5 ± 4.6 % *vs* 62.2 ± 5.3 % respectively).

Key words: blood, lamb survival, liver, selenium.

Cloete S W P, Van Niekerk F E, Young M, Van der Merwe G D, Clark J **The application of a selenium fertiliser for the correction of marginal deficiencies in grazing sheep**. *Journal of the South African Veterinary Association* (1999) 70(3): 107–111 (En.). Elsenburg Agricultural Centre, Private Bag X1, Elsenburg, 7607 South Africa.

INTRODUCTION

Subclinical selenium (Se) deficiencies in sheep are often unpredictable and transient in nature. Associated subminimal concentrations of Se in forages, resulting in lower production levels, may remain undetected. Subclinical Se deficiencies and production responses to supplementation were reported in the southern Cape coastal area[1] and the Kwa-Zulu Natal midlands[21]. A number of methods can be used for supplementing Se to grazing ruminants. The use of mineral licks to provide Se is limited owing to low and variable intakes[4]. The monthly drenching of sheep with sodium selenite is cumbersome to perform under certain conditions[20]. Intraruminal Se pellets[10,11] or glass boluses[15] serve as a readily available source of Se, but these products are not commercially available in South Africa at present.

An alternative may be to provide Se by topdressing pastures with sodium selenate[8,22]. Because of the cost factor involved under extensive conditions, where a low stocking density is maintained, Se may be applied in strips to cover only 20 % of paddocks[4]. A later concept involved the application of poorly soluble barium selenate as a slow-release source of Se to pastures at a rate of 10 g Se per ha[23,25,26]. This product not only maintained elevated plasma Se levels for up to 3 years in sheep, but it also resulted in improved wool production and an increased live weight in sheep maintained on Se-fertilised paddocks compared to control animals on untreated paddocks[27].

Against this background, we assessed the influence of a commercial Se fertiliser on the Se status of sheep on sites that were known to be marginally Se deficient[1].

MATERIALS AND METHODS

Location and treatments

The trials were conducted at the Outeniqua experimental farm (33° 55′ S, 22° 25′ E) near George in the southern Cape. The site experiences cool summers and mild winters, with a total annual long-term precipitation of 694 mm. The average monthly rainfall varies from 47.1 mm in July to 70.3 mm in October. The fine, sandy loam topsoil overlies structured clay, which is usually derived from granite and Table Mountain sandstone. It is acidic and low in trace minerals. Production responses of sheep as a result of oral or parenteral supplementation with copper (Cu) and selenium (Se) on the site have been reported previously[1,20].

The commercial Se fertiliser used in the experiment was available in granular form. It consisted of a poorly soluble barium selenate core, coated with highly soluble sodium selenite. It has been shown that similar preparations allowed the sustained release of Se over a long period[25,26]. The fertiliser contained *c.* 10 % Se, and was administered at a level of 1 kg/ha in 2 trials.

Trial 1: Se fertiliser was administered to 3 kikuyu (*Pennisetum clandestinum*) paddocks ranging from 0.5 to 2.1 ha during May 1995. Three similar-sized paddocks without Se fertilisation were left as controls. All paddocks received equal quantities of supplemental irrigation. Pastures were grazed by 9-month-old SA mutton merino ram lambs, at an initial stocking density of *c.* 20 sheep per ha. Mature SA mutton merino wethers were used to balance numbers of sheep on different-sized paddocks. The efficiency of Se uptake on fertilised pastures was determined by the analysis of whole blood and organ Se concentrations. Heparinised blood samples (10 mℓ) from 5 designated ram lambs per paddock were obtained monthly (from May to September) by jugular venipuncture, and stored at –20 °C before analysis. During July and September, 5 ram lambs from each paddock were slaughtered to obtain liver and kidney samples. These samples were

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[a] Elsenburg Agricultural Centre, Private Bag X1, Elsenburg, 7607 South Africa.

[b] Department of Human and Animal Physiology, Private Bag X1, Matieland, 7601 South Africa.

[c] Outeniqua Agricultural Development Centre, PO Box 249, George, 6530 South Africa.

[d] Regional Veterinary Laboratory, Private Bag X5020, Stellenbosch, 7600 South Africa.

Received: February 1999. Accepted: July 1999.

stored at –20 °C before analysis. The concentration of Se in whole blood, liver and kidney samples was determined by fluorometric procedures[13].

During 1996, these paddocks were similarly fertilised with Se. Another group of ram lambs utilised the paddocks at a somewhat lower stocking density of *c.* 15 sheep per ha. Sampling was conducted as described above, but monthly blood samples were obtained from June to November. Slaughter of 5 animals for liver and kidney samples took place in July, September and November. Towards the end of the trial, the flocks were disrupted by stock theft, and slaughter animals were available for only 2 of the 3 control paddocks in November 1996.

Trial 2: four of 7 paddocks were fertilised with Se in May 1995, as described previously. The remaining paddocks were left untreated as controls. Six of these paddocks were *c.* 0.7 ha in size, while the 7th was smaller (0.5 ha). An oat fodder crop was cultivated on all paddocks, which were utilised by groups of 9 to 15 pregnant SA mutton merino ewes. The ewes were introduced onto the paddocks at a fixed stocking rate of 20 ewes per ha in mid-June, just before lambing in July. After lambing, the ewes and their progeny grazed on the paddocks until docking at an average (±SD) age of 41 ± 8 days. At this stage, whole blood samples were obtained from individual ewes and lambs by jugular venipuncture. Lambs were weighed and identified with their mothers within 24 hours of birth. Live weight at docking and weaning (at an average age of 125 ± 9 days) were recorded. These data were used to determine lamb survival to weaning of individual lambs and the reproduction (number and weight of lambs weaned) of individual ewes. The blood samples were treated as described previously. The trial was repeated during June/August 1997, using the same paddocks.

Statistical analysis

The treatments were administered to paddocks, and not individual animals. It was thus impossible to treat individual animals as experimental units. Paddocks were therefore replicated and regarded as experimental units. Means were calculated for the respective paddocks, and used in the statistical analyses. The concentrations of Se in whole blood of the ram lambs in Trial 1 were analysed according to factorial designs[18] with treatment (Se fertilised or control) and month (May to September in 1995 and June to November in 1996) as factors. Liver and kidney Se concentrations were analysed according to a 2 (treatments) × 2 (slaughter dates; July and September) experimental design in 1995. The corresponding analysis in 1996 was a 2 (treatments) × 3 (slaughter dates; July, September and November) factorial.

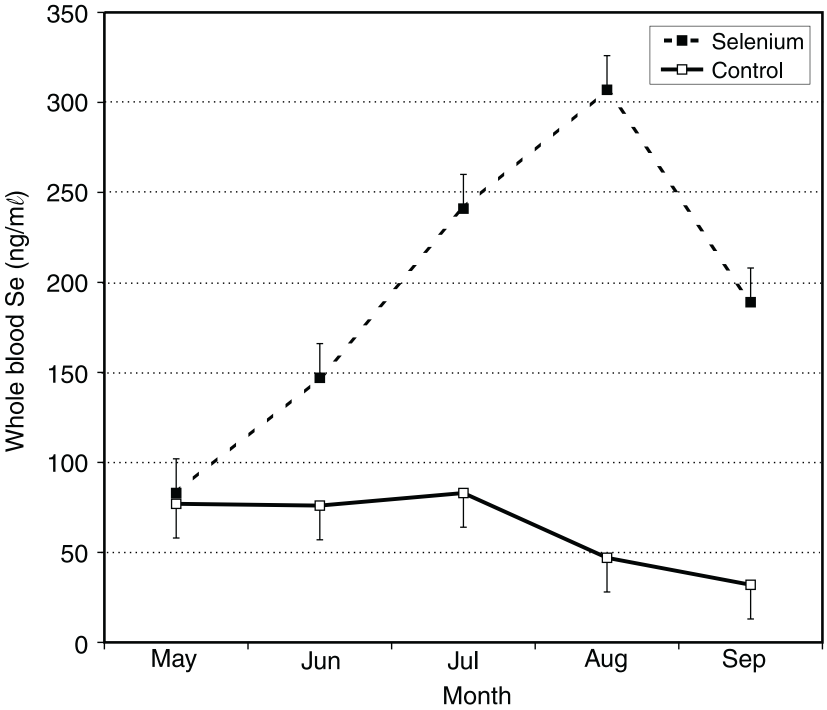

Fig. 1: **Concentrations of whole blood Se in ram lambs grazing paddocks treated with Se fertiliser, or untreated control paddocks during 1995.** Vertical bars denote standard errors.

Whole blood Se concentrations of ewes and lambs in Trial 2 at docking were analysed as 2 (treatments) × 2 (years; 1995 or 1997) factorial designs. The Se treatment was represented by 4 replications per year, whereas 3 replications per year constituted the control treatment. Recordings obtained from individual ewes were used to calculate paddock means for reproductive performance. Ewe reproductive parameters included the mean percentage of lambs weaned and weight of lamb weaned per ewe available. As far as lambs were concerned, survival (lambs weaned expressed as a percentage of lambs born) was calculated on a within paddock basis. Paddock means for the continuous variables (live weight at birth, docking and weaning) were derived from least-squares analyses[6]. The fixed models fitted to the data included the effects of paddock, sex (ram or ewe), birth type (single or multiple) and the 2-factor interactions between these effects. This approach was used to ensure that paddock means were adjusted for unevenness in the distributions of sex and birth type, since individual paddock means were based on relatively small sample sizes within birth type classes. Age at docking and weaning were included as linear covariables, to adjust means for age differences between paddocks. Paddock means for the production traits were analysed according to a multi-factor analysis of variance, including years (1995 and 1997) and treatments (Se-fertilised or control) as factors. The 2-factor interaction was included in preliminary runs. Since it was not significant, only the main effects were retained in the final analysis.

RESULTS

Trial 1

No clinical symptoms of a Se deficiency were found in any of the trials. Whole blood Se concentrations of ram lambs were affected ($P < 0.001$) by treatment, month and their interaction in 1995 and 1996. The models fitted the data well, and accounted for a proportion of ≥ 0.89 of the available variation. During 1995, Se fertilisation of pasture markedly increased ($P < 0.01$) whole blood Se concentrations from approximately 80 ng/mℓ to values exceeding 140 ng/mℓ within a month (Fig. 1). After being introduced to the pasture for 4 months, blood Se concentrations increased to >300 ng/ml, followed by a decline to approximately 190 ng/mℓ in September. Concentrations of whole blood Se of lambs on the control paddocks were maintained at approximately 80 ng/mℓ for 3 months, before declining to <50 ng/mℓ.

During 1996, whole blood Se concentrations of ram lambs on the fertilised paddocks were increased ($P < 0.01$) to >200 ng/mℓ within 1 month of introduction (Fig. 2), with a maximum value of 290 ng Se per mℓ whole blood in October. Whole

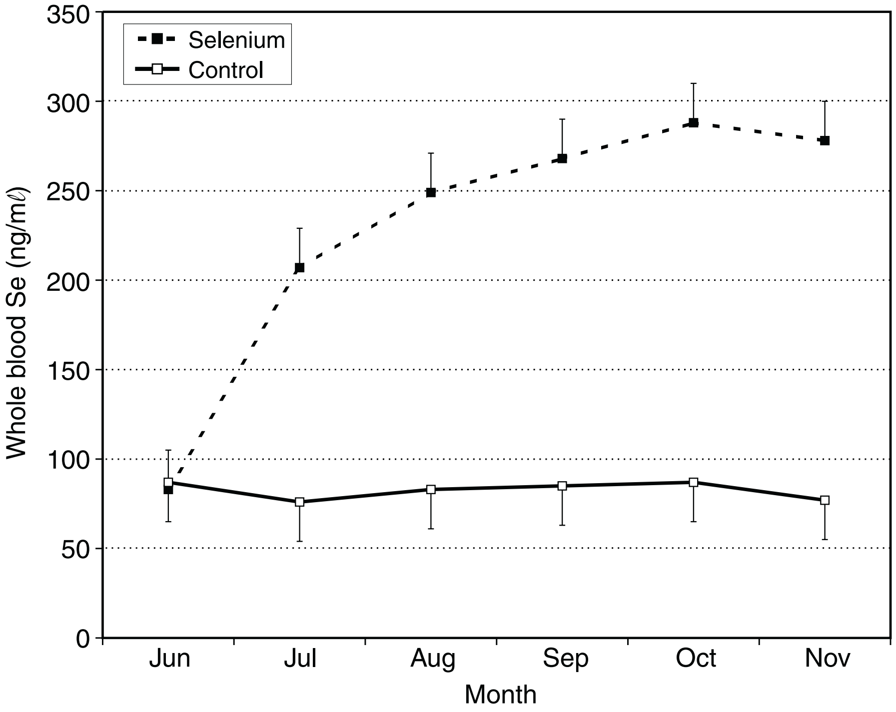

Fig. 2: **Concentrations of whole blood Se in ram lambs grazing paddocks treated wih Se fertiliser, or untreated control paddocks during 1996. Vertical bars denote standard errors.**

blood Se concentrations of lambs on the control paddocks ranged from 76 ng/mℓ to 87 ng/mℓ.

During 1995, no interaction was observed between Se treatment and slaughter date as far as liver Se concentrations were concerned (Table 1). Liver Se concentrations of lambs grazing fertilised paddocks were 3.5 times as high (378 *vs* 1323 μg/kg) as that of lambs utilising the control paddocks in July, and 3.7 times as high (282 *vs* 1038 μg/kg) as that of lambs on control paddocks in September ($P < 0.01$). Time of slaughter and Se treatment interacted ($P = 0.06$) in 1996. Lambs on the fertilised paddocks maintained liver Se concentrations *c.* 4 times as high (477 *vs* 2051 μg/kg) as those on the control pasture in September ($P < 0.01$). The difference between treatments was reduced in October and November, but remained significant ($P < 0.01$).

No interaction between Se treatment and slaughter month was observed for kidney Se concentrations. During 1995, kidney Se concentrations were elevated ($P < 0.07$) on the Se-fertilised paddocks (5900 ± 554 *vs* 3477 ± 554 μg/kg kidney DM). A similar tendency ($P = 0.07$) was observed during 1996 (6944 ± 475 *vs* 5230 ± 505 μg/kg kidney DM, respectively).

Trial 2

The model fitted to whole blood Se concentrations of the ewes and their lambs fitted the data well, accounting for >0.90 of the available variation. Whole blood Se concentrations of ewes and lambs were increased ($P < 0.01$) on the Se-fertilised paddocks relative to the control paddocks during 1995 and 1997 (Table 2). During 1997, the responses in both ewes and lambs were greater than in 1995. This resulted in an interaction ($P < 0.05$) between Se treatment and year.

The model fitted to the ewe reproduction and lamb survival data had a poorer fit than those presented earlier, and accounted for respective proportions of 0.38 and 0.18 of the total variation in lamb survival and lambs weaned per ewe. The proportions of total variation accounted for in live weight traits ranged from 0.56 for birth weight to 0.11 in the case of weaning weight. Year effects were significant ($P < 0.10$) in some instances. No significant ($P < 0.10$) difference in ewe reproduction and lamb weights was observed between paddocks fertilised with Se and control paddocks. Absolute differences favoured the Se-treated paddocks for mean (±SE) lamb survival relative to the control paddocks (71.5 ± 4.6 % *vs* 62.2 ± 5.3 %, respectively; $P = 0.21$).

DISCUSSION

Blood and organ Se concentrations

Whole blood Se concentrations of the ram lambs grazing untreated control paddocks in Trial 1 were generally below 100 ng/mℓ, regarded by some authorities as the threshold of marginal deficiencies[7]. Other workers suggested a threshold as low as 20 ng/mℓ[9]. In subsequent work, a response to supplementation was observed at 76 ng Se/mℓ whole blood in ewes rearing a lamb[12]. The corresponding concentration for non-breeding ewes was 40 ng Se/mℓ whole blood. Hepatic Se of ram lambs in Trial 1 similarly declined to concentrations below 300 μg/kg DM in September 1995. This is generally

Table 1: **Mean** (SE) **liver selenium concentrations** (μg/kg DM) **in ram lambs maintained on selenium-fertilised and control paddocks during 1995 and 1996. Each mean is based on 3 replicates, except for the control treatment in 1996. Only 2 replicates were available in this case, because of stock theft.**

Year and month of slaughter	Treatment	
	Se-fertilised	Control
1995		
July	1323^1 (94)	378^2 (94)
September	1038^1 (94)	282^2 (94)
1996		
September	2051^1 (177)	477^2 (178)
October	1395^1 (177)	616^2 (178)
November	1309^1 (177)	483^2 (222)

^{1,2}Different superscripts in the same row denote significance ($P < 0.01$).

Table 2: **Mean** (SE) **whole blood selenium concentrations** (ng/mℓ) **in ewes and lambs maintained on selenium-fertilised and control paddocks during 1995 and 1997. Based on a 2 × 2 factorial design with 4 replicates in the Se-fertilised treatment and 3 replicates in the control treatment.**

Sheep type and year	Treatment	
	Se-fertilised	Control
Ewes		
1995	355^1 (18)	161^2 (21)
1996	481^1 (18)	130^2 (21)
Lambs		
1995	375^1 (21)	150^2 (25)
1996	526^1 (21)	113^2 (25)

^{1,2}Different superscripts in the same row denote significance ($P < 0.01$).

regarded as indicative of a marginal deficiency[7]. These findings suggest a marginal deficiency in Se on the experimental site, particularly during spring, as reported previously[1]. As far as the productive ewes were concerned, no conclusive evidence of a marginal Se deficiency was obtained, although the Se concentrations in the whole blood of control ewes and lambs approached 100 ng/mℓ during 1997. Since the ewes were not exposed to the experimental paddocks for extended periods, this cannot be regarded as conclusive evidence of the lack of a subclinical deficiency on these paddocks.

The grazing of kikuyu pastures fertilised with Se clearly improved the Se status of ram lambs under these conditions, as reflected by increased whole blood and hepatic Se concentrations in Trial 1. A similar conclusion was evident in the case of the producing ewes in Trial 2. In the case of the ram lambs in Trial 1, this increase persisted for at least 6 months, making the product extremely suitable for rectifying the medium term Se status of grazing sheep. Increased Se concentrations in whole blood[1,11,12,14], serum[12,17,28], plasma[15] and liver[1,12,15,20] were commonly reported after oral or parenteral supplementation of Se under marginal conditions. It is conceded that the period over which the availability of Se was assessed in the present investigation was probably too short. When applied as fertiliser, sodium selenate was effective in increasing plasma Se concentrations of grazing sheep for up to 15 months[26]. In the case of slow-release barium selenate, maximum responses in plasma Se were only achieved during the 2nd and 3rd year following application[26]. This formulation was, in fact, effective in preventing subclinical Se deficiencies for at least 4 years after application[25].

Production of ewes

Overall lamb production (defined as weight of lamb weaned per ewe mated) of ewes grazing pasture marginally deficient in Se was markedly improved by *c.* 50 % after supplementation[1]. The alleviation of a subclinical Se deficiency was found to result in improvements of all the components of overall reproduction rate, namely ewe fertility[5,29], multiple birth rate[1,16], lamb survival[10,14] as well as early growth of lambs and Angora goat kids[2,11,20,28]. The survival of beef calves was similarly improved after Se treatment[19]. Responses in lamb survival were often unpredictable and transient. Langlands *et al.*[10], for instance, found that the administration of Se improved lamb survival relative to the control treatment at a high stocking rate (0.86 *vs* 0.74, respectively), while no effect was discernible at a low stocking rate (0.83 *vs* 0.84). The study of Segerson *et al.*[17] reported more stillbirths in control lambs compared to Se-treated contemporaries. Improvement in lamb survival could not be related to the thermoregulatory ability of lambs in another study[3].

Improvement in ewe fertility and multiple birth rate was not expected in the present study, since supplementation only commenced shortly before lambing. The control ewes were furthermore not subjected to the unfertilised paddocks for extended periods of time. They could thus draw on Se reserves built up on the pastures that were utilised before the present trial. There was a suggestion of a better lamb survival on fertilised paddocks compared to control paddocks. Whether this is related to reported improvements in lamb survival following Se supplementation remains uncertain, and should be investigated in further production-orientated studies.

CONCLUSIONS

The medium-term Se status (6–8 months) of ram lambs grazing marginally deficient kikuyu paddocks was clearly enhanced by the application of a slow-release Se fertiliser. A similar conclusion could be drawn with regard to the short-term Se status of ewes and lambs on an oat fodder crop, over a period of approximately 2 months. It must be conceded that the potential of the fertiliser to improve the long-term Se status (>12 months) of the pastures was not adequately assessed in this study. Viewed against the results of Whelan *et al.*[26] and Whelan and Barrow[25], it is clear that products of a similar nature are able to provide sufficient Se to eliminate deficiencies for up to 4 years following application. Those studies, as well as that of Whelan[24], suggest that fertilisation with $BaSeO_4$ as a slow-release product provides a practical and safe way of Se supplementation to grazing ruminants for periods of up to 3 years after application.

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