An assessment of the trace element status of grazing livestock in the Wendon Valley

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Abstract

The Co (Vitamin B_{12}), Se, Cu and I status of livestock on 12 Wendon Valley farms was determined from the trace element concentrations of pasture, blood and liver samples collected in spring and autumn and comparing them to accepted trace element reference ranges established from earlier New Zealand-wide trace element supplementation trials recording animal responses. Both marginal Co and Se deficiencies in lambs were found on two farms while another three farms were marginally Co deficient, one farm was very Co deficient and a further two farms were marginally Se deficient. Iodine deficiency was observed in new-born lambs from ewes wintered on swedes, whereas the Cu status of all sheep was adequate. No Co deficiency was found in cattle but Se deficiency was observed on four farms. A marked depletion of liver Cu stores and Cu deficiency was found in all cattle and deer during the late winter/ early spring. Growth responses to Vitamin B_{12} and Se supplementation in lambs, and the absence of goitre in new-born lambs to I supplementation in ewes were also observed. The established diagnostic protocols based on pasture, blood and liver samples were shown to be effective in determining the trace element status of grazing livestock in the Wendon Valley.

Keywords: blood, cattle, copper, deer, iodine, liver, pasture, selenium, sheep, vitamin B_{12}

Introduction

Trace element deficiencies have been well documented in New Zealand (Andrews *et al.* 1963; Cunningham 1950; Sinclair & Andrew1958). Marginal Co, Se, Cu and I deficiencies result in poor animal performance and a decrease in farm profitability (Grace 1994). While biochemical criteria or tissue reference ranges to assess the trace element status of grazing livestock have been established from trace element supplementation trials animal recording performance responses (Clark *et al.* 1985, 1998; Metherell *et al.* 1997) the use and value of this information is not always appreciated. Once a particular trace element deficiency has been diagnosed, then an effective strategy can be implemented to prevent the problem (Grace 1992). In situations where farmers do not know the trace element status of their livestock, then there are costs in terms of lost production if they do not supplement deficient animals and if they supplement adequate animals then this is also an unnecessary cost. Further, the assessment of the trace element status of livestock should be conducted as part of the overall farm animal health programme. The Wendon Valley study was set up to demonstrate the protocols and procedures used to determine the trace element status of livestock.

Materials and methods

Farms

Twelve farms in the Wendon Valley, near Gore, selected on the basis of farmer interest and commitment, were used for the trace element study. The properties varied in size from 1500 to 11 000 stock units consisting of sheep, cattle and some deer. The farms were made up of river flats and terraces (Recent soils) (Hewitt 1992), rolling downs and hills (Pallic and Brown soils) with larger properties having steeper hill country (Brown soils). On most properties brassica crops were used as a winter feed supplement.

Collection of herbage and animal monitoring

Pasture and brassicas. In the first year in December 1997, and in February and June 1998, three to five sites on each farm were selected depending on soil type, fertiliser history and topography for sampling pasture on a 100 m transect. Likewise kale and swede crops were randomly sampled in June 1998. All herbage samples were analysed for Co, Se, Cu and I.

Monitor Animals. Small paddocks from each farm which had not been topdressed in the last 5–10 years with trace element-amended fertilisers were grazed with 10 weaned lambs from December 1997 to May 1998 and with 10 weaner calves and hinds from March 1998 to

October 1998. These monitor animals and their dams had not been supplemented with trace elements in the previous 8–10 months.

The lambs were bled in December and then again in May when their livers were also collected at slaughter. Calves and weaner hinds were bled in April and then in October when liver biopsies were taken. All blood (serum) and liver samples were analysed for Vitamin B_{12}, Se and Cu.

Trace element supplementation trials

On the basis of the pasture and animal tissue data collected in the first year (1997/1998), farms were selected for Co, Se and I supplementation studies in 1998/1999 to demonstrate the effect of trace element deficiencies on animal performance.

Cobalt supplementation. From 200–300 weaned lambs, on each of six farms (numbers 1, 2, 4, 7, 9 and 11), 60 animals were selected, eartagged and divided into two groups of 30 in December 1998. Group 1 lambs were the untreated control and Group 2 were injected with 6mg Vitamin B_{12} (SMARTShot B_{12}, AgResearch). They were all weighed and 10 monitor animals/group bled at the start of the trial in December. All lambs were grazed as a single group and weighed at about monthly intervals for the next 6 months. Blood samples were collected in March and May together with liver samples at slaughter in May 1999.

Selenium supplementation. From 200–300 weaned lambs, on each of five farms (numbers 1, 3, 4, 5 and 6) in December 1998, 60 lambs were selected, eartagged and divided into two groups of 30. Group 1 lambs were the untreated control and Group 2 were injected with 50 mg Se as $BaSeO_4$ (Deposel, Novartis). They were grazed as a single group, weighed at the start of the trial and at about monthly intervals for 6 months, with blood being collected from 10 monitor animals/group in December, March and May 1999 when livers were collected at slaughter.

Iodine supplementation. On two farms (numbers 3 and 5) in early March 1999, 800 ewes were eartagged and divided into two groups of 400. Group 1 ewes were the control while Group 2 were injected with 1.5 ml (390 mg I) of iodised oil (Flexidine, Bomac). They were grazed as a single group, joined with the ram in late April, scanned in late July and separated into the two treatment groups for lambing in mid September 1999. The ewes on farm 3 were wintered on pasture while the ewes on farm 5 were fed swedes 8 weeks before lambing. All

Table 1 The pasture Co, Se, Cu and I mean concentrations (mg/kgDM) from Wendon Valley Farms in 1997 and 1998. Data presented are from transects with lowest pasture concentrations at each sampling. A range is given for the February 1998 sampling. Bold figures indicate deficiencies.

	Co			Se			Cu			I		
Farm	Dec	Feb	Jul	Dec	Feb	Jul	Dec	Feb	Jul	Dec	Feb	Jul
1	0.15	**0.07** 0.07–0.09	0.11	0.03	0.04 0.04–0.08	0.5	6	8 8–10	10	**0.09**	**0.11** 0.11–0.16	0.16
2	0.14	**0.07** 0.07–0.12	0.1	**0.02**	0.03 0.03–0.05	0.04	6	11 11–12	10	**0.12**	**0.13** 0.13–0.32	0.16
3	0.11	0.14 0.14–0.17	0.18	**0.02**	0.03 0.03–0.03	0.04	5	12 11–14	10	**0.09**	**0.05** 0.05–0.07	0.30
4	0.10	0.07 0.07–0.07	0.18	0.03	0.03 0.03–0.12	0.06	7	9 9–13	11	0.19	**0.05** 0.05–0.08	0.72
5	0.28	0.11 0.11–0.26	0.37	0.03	0.04 0.04–0.07	0.04	6	11 11–15	9	0.19	**0.05** 0.07–0.14	**0.07**
6	**0.09**	**0.08** 0.08–0.11	0.43	0.04	0.04 0.04–0.06	0.05	8	9 9–12	12	0.14	0.07 0.09–0.22	0.3
7	**0.05**	**0.05** 0.05–0.12	0.14	0.06	0.05 0.05–0.15	0.05	6	8 8–11	9	0.16	0.09 0.15–0.20	0.41
8	**0.08**	**0.09** 0.09–0.22	0.17	0.03	0.04 0.04–0.13	0.08	6	6 6–12	12	0.16	0.15 0.15–0.20	0.80
9	**0.09**	**0.09** 0.009–0.13	0.40	0.03	0.05 0.05–0.13	0.06	6	11 11–13	13	0.15	0.13 0.13–0.22	0.95
10	0.13	**0.08** 0.08–0.21	0.11	**0.02**	0.04 0.04–0.11	0.8	8	8 8–10	9	0.20	0.15 0.15–0.68	0.24
11	0.16	0.14 0.14–0.30	0.24	0.03	0.05 0.05–0.24	0.10	6	7 7–11	10	0.21	0.22 0.22–0.26	0.37
12	0.14	0.17 0.17–0.19	0.23	0.04	0.09 0.09–0.12	0.07	6	9 9–10	12	0.51	0.36 0.36–0.57	0.4
Dietary Requirements (mg/kgDM) (Grace 1994)												
Sheep		0.1			0.03			5			0.15	
Cattle		0.06			0.03			10			0.15	

Table 2 Mean kale and swedes Co, Se, Cu and I concentrations (mg/kgDM) from Wendon Valley Farms in June 1998. Bold figures indicate deficiencies.

Farm	Swedes								Kale							
	Leaf				Bulb				Leaf				Stem			
	Co	Se	Cu	I	Co	Se	Cu	I	Co	Se	Cu	I	Co	Se	Cu	I
1	0.13	0.05	**4**	0.22	**0.05**	0.03	**3**	**<0.05**								
3	0.1	0.03	**4**	0.24	**0.02**	**0.02**	**6**	**<0.05**								
4	**0.03**	0.03	**4**	0.24	**0.03**	0.03	**4.5**	**<0.05**								
6	**0.09**	0.03	**5**	0.24	**0.04**	0.03	**2.8**	**<0.05**								
7									**0.04**	0.06	**2**	**0.07**	**0.05**	**0.02**	**3**	0.17
8	**0.08**	0.07	**5**	0.59	**0.06**	**0.02**	**1.5**	**<0.05**								
9	**0.05**	0.09	**4**	0.16	**0.02**	**0.02**	**1.2**	**<0.05**								
10									0.11	0.06	**2**	**0.1**	**0.07**	**0.05**	**4**	0.19
12									**0.04**	0.06	**4**	**0.05**	**0.02**	**0.03**	**2**	0.12

Dietary Requirements (mg/kgDM) (Grace 1994)	Co	Se	Cu	I
Sheep	0.1	0.03	5	0.15
Cattle	0.06	0.03	10	0.15

dead lambs were post mortemed and the numbers of lambs born dead or alive recorded. At docking, the lambing and neonatal mortality percents were calculated. At docking, blood and milk samples were collected from 10 monitor ewes per group for I determinations.

Statistics

Significant differences between treatments were determined by analysis of variance using Minitab (Minitab Corporation, PA, USA).

Results

There was considerable variation between transects within a farm (all data not shown), the time of sampling and between farms (Table 1). Cobalt-deficient pastures (i.e., <0.1 mg Co/kgDM) were observed only on some farms in December and February but not in July. Likewise, Se-deficient pastures (i.e., <0.03 mg Se/kgDM) were found on some farms in December only. Pastures on all farms were adequate in Cu (i.e., >5 mg Cu/kgDM) for sheep but were inadequate (i.e., <10 mg Cu/kgDM) for cattle in December and on some farms in February and July. The concentration of Mo in the pastures was usually less than 1.0 mg/kgDM while a few pastures did contain 1.8 mg Mo/kgDM. Pasture I concentrations were low (i.e., <0.15 mg I/kgDM) on about a third of the farms in February.

With the exception of Se in the leaves of swedes and kale and I in leaves of swedes and stems of kale, the brassica crops did not meet the dietary trace element requirements of sheep and cattle (Table 2).

On the basis of serum and liver Vitamin B_{12} concentrations, lambs on farms 1, 2, 4, 6, 7 and 9 were found to be deficient in Co (Vitamin B_{12}) (Table 3), and on the basis of blood and liver Se concentrations, lambs on farms 1, 3, 4 and 5 were also shown to be deficient in Se. None of the lambs were Cu-deficient.

Table 3 Mean blood and liver Vitamin B_{12}, Se and Cu concentrations in Wendon Valley sheep. Data are from the May 1998 sampling. Bold figures indicate deficiencies.

Farm	Vitamin B_{12} Serum pmol/L	Vitamin B_{12} Liver nmol/kgFW	Se Blood nmol/L	Se Liver nmol/kgFW	Cu Serum µmol/L	Cu Liver µmol/kgFW
1	**209**	**176**	**156**	**328**	17.7	934
2	572	314	540	800	14.7	1516
3	575	444	**119**	**340**	14.1	11532
4	**296**	**211**	**80**	**264**	13.9	1578
5	833	482	**184**	**346**	12.2	1214
6	587	**336**	1125	1818	11.2	2200
7	**145**	**85**	1137	1450	12.2	2202
8	610	396	371	786	13.8	2540
9	**280**	**188**	305	586	15.6	2224
10	1325	586	292	756	11.6	1498
11	706	338	299	623	15.7	1896
12	-	490	1742	7506	14.4	1774
Trace element reference range (MAF 1997)						
Deficient	<336	<280	<130	<250	-	<65
Adequate	>500	>375	>250	>450	>8	>95

None of the cattle were Co deficient but cattle were Se deficient on farms 7, 8 and 11 (Table 4). With the exception of farm 12, all of the cattle had lower serum Cu concentrations and depleted liver Cu stores.

None of the deer were Co or Se deficient but liver Cu stores of deer on both farms were depleted (Table 5).

The treatments increased (30–60%) the mean Vitamin B_{12} tissue concentrations (Table 6) and more than doubled the mean Se concentrations in blood (serum) and liver of all treated lambs when compared to untreated animals at days 120 and 180 as well as their daily liveweight gains to Vitamin B_{12} on farm 7 ($P<0.01$) and to Se supplementation on farms 5 and 6 ($P<0.05$).

The ewes on farm 3 were fed pasture only while ewes on farm 5 were fed swedes for 8 weeks during mid to late lactation. The I supplementation significantly ($P<0.01$) increased plasma and milk I concentrations at 210 days after treatment on both farms and prevented goitre in the lambs born to ewes fed the swedes (Table 7). The I status of the ewes on farm 3 was significantly higher ($P<0.05$) than those on farm 5. No goitre was observed in the lambs born to pasture-fed ewes on farm 3.

Table 4 Mean Blood and liver Vitamin B_{12}, Se and Cu concentrations in Wendon Valley cattle. The Vitamin B_{12} and Se data are from the October 1998 sampling and the Cu is from the April 1998 and October 1998 samplings. Figures in bold indicate deficiencies.

Farm	Vitamin B12 Serum (pmol/L)	Se Blood nmol/L	Se Liver nmol/kgFW	Cu Serum µmol/L		Cu Liver µmol/kgFW
	Oct	Oct	Oct	April	Oct	Oct
2	207	610	1353	9.0	**6.9**	**75**
6	235	700	1110	8.9	**3.6**	**57**
7	214	**190**	**620**	10.8	**3.0**	**28**
8	217	**152**	**418**	9.3	**6.7**	**67**
10	284	893	1618	9.4	**6.9**	**66**
11	480	**215**	**500**	10.0	**7.8**	**52**
12	298	281	886	9.6	8.5	485
Trace element reference range (MAF 1997)						
Deficient	<73	<130	<600	<4.5	<45	
Adequate	-	>250	>850	>8.0	>95	

Table 5 Mean blood and liver Vitamin B_{12}, Se and Cu concentrations in Wendon Valley deer. Data are from the October 1998 sampling. Figures in bold indicate deficiencies.

Farm	Vitamin B12 Serum (pmol/L)	Se Blood nmol/L	Se Liver nmol/kgFW	Cu Serum µmol/L	Cu Liver µmol/kgFW
3	117	794	1278	12.3	**81**
4	90	203	633	**5.2**	**83**
Trace elemen reference range (MAF 1997)					
Deficient	-	-	-	<4	<60
Adequate	>73	>120	-	>8	>100

Discussion

When the intakes of Vitamin B_{12}, Se, Cu and I do not meet the animal's requirements the trace element stores become depleted, blood (serum) Vitamin B_{12}, Se, Cu and I concentrations decrease and the animals become deficient. This then leads to a dysfunction of biochemical processes, clinical signs of the deficiency and impaired animal performance (Underwood & Suttle 1999).

Trace element deficiencies are detected when the performance of supplemented animals is significantly greater than that of untreated animals (Clark *et al.* 1985). The biochemical criteria or pasture and animal tissue reference ranges used to determine the Co

Table 6 The effect of Vitamin B_{12} and Se supplementation on mean tissue Vitamin B_{12} and Se concentrations and mean (± S E) lamb growth rate on Wendon Valley farms. Figures in bold indicate deficiencies.

Farm	Treatment	Serum Vitamin B12 (pmol/L) Day 1	120	180	Liver Vitamin B12 (nmol/kg FW)	Blood Se (pmol/L) Day 1	120	180	Liver Se (nmol/kg FW)	Daily weight gain (g/day)
1	Control	738	1045	680	330	583	631	787	1127	127 ± 4.5
	VitB12	608	1377	1292	448					124 ± 3.7
	Se					804	2083	2371	2781	135 ± 3.9
	VitB12+Se	651	1451	1263	665	695	2466	3031	3421	133±3.5
2	Control	767	521	501	267					144 ±5.1
	VitB12	777	1343	1040	565					156 ±5.8
3	Control					311	134	144	390	97±3.2
	Se					423	1759	1923	2769	87±4.0
4	Control	858	1006	983	396	761	295	140	384	107±6.9
	Vit B12	891	1428	1450	584					114±5.4
	Se					684	2490	2863	3419	117±5.3
	VitB12+Se	880	1181	1267	558	790	2837	2806	3877	118±5.2
5	Control					433	121	66	252	**79±3.9**
	Se					473	808	933	1290	**93±4.1*** [a]
6	Control					354	116	82	279	**145±3.5**
	Se					343	1644	1490	1865	**154±3.3***
7	Control	71	169	266	72					**82±6.6**
	VitB12	75	465	437	186					**191±5.4****
9	Control	733	564	582	283					92±6.4
	VitB12	608	1231	1390	542					90±8.00
11	Control	1269	1257	1130	501					167±4.4
	VitB12	1403	1646	1364	813					177±4.6

[a] Means significantly different * $P<0.05$, ** $P<0.01$

Table 7 Effect of an Iodine premating injection on ewe mean (± S E) plasma and milk I concentrations at docking and new-born lamb thyroid liveweight ratios at post mortem.

		Control	I
Farm	Winter feeding	Plasma I (µg/L)[a]	
3	pasture	43 ± 3.0	65 ± 4.0 **
5	pasture/swedes	29 ± 3.0	51 ± 3.5 **
		Milk I (µg/L)	
3	pasture	72 ± 14.0	197 ± 34.0 **
5	pasture/swedes	26 ± 7.0	132 ± 15.0 **
		Thyroid (g)/Liveweight (kg)[b]	
3	pasture	0.21	0.21
5	pasture/swedes	2.29	0.37 **

[a] Significance ** P<0.01
[b] Thyroid (g)/liveweight (kg) greater than 0.4 reflect a subclinical I deficiency (Clark *et al.* 1998)

(Vitamin B_{12}), Se, Cu and I status of livestock have been established from animal trials where the responses in animal performance or reduced incidence of disease to trace element supplementation were related to changes in pasture, blood (serum) and liver Co, (Vitamin B_{12}), Se, Cu and I concentrations (MAF 1997).

As the pasture trace element concentrations were different between transects within a farm and between seasons, it is important to collect 3–5 samples per farm in order to represent the farm in terms of differences in soil types, pasture composition and topography. The seasonal nature of trace element deficiencies and animal requirements means that the timing of the collection of pasture samples is very important. For example, Co and Se deficiencies occur in young lambs during spring and early summer (Clark *et al.* 1985; Metherell *et al.* 1997) while a high Cu status in cattle in the autumn is necessary to counter the winter decline in liver Cu stores and to ensure an adequate Cu status during the spring mating (West & Sargison 1998). Likewise the premating Se and I status of ewes in the autumn must be adequate to ensure a good lambing percent (Metherell *et al.* 1998; Clark *et al.* 1998). Mixed grass/clover samples of actively growing pasture should therefore be collected during November/December and February/March to assess the trace element concentrations at critical times of sheep, cattle and deer. The impact of the Cu x Mo interaction on Cu requirements can also be determined from pasture Cu, Mo and S (Grace 1994).

Brassica crops provide adequate energy and crude protein as a winter forage but they are low in Co, Cu and I as well as containing goitrogens (Grace *et al.* 2000). Therefore, it is important that the I status of ewes and the Cu status of cattle is adequate to high in the autumn before feeding brassicas to ensure that goitre does not occur in new-born lambs and that the Cu status is adequate for the spring mating of cows.

A comparison of the blood and liver Vitamin B_{12}, and Se concentrations of the monitor lambs, on the 12 farms with the reference ranges, showed that six farms were Co deficient ranging from a very deficient property (farm 7) to properties that were marginally Co deficient. A marked response in lamb growth to Vitamin B_{12} supplementation was observed on farm 7 during 1998/1999. As the severity of Co deficiency varies from season to season, the magnitude of lamb growth responses to Vitamin B_{12}/Co supplementation will also vary (Lee 1951). Four farms, not necessarily the same farms, were marginally Se deficient. These properties also had generally low pasture Co and Se concentrations. All sheep had an adequate Cu status. The monitor calves showed that the cattle had an adequate Vitamin B_{12} status while their Se status on three farms out of seven was deficient . On all farms, except one, the liver Cu stores and bloods Cu concentrations of the young cattle decreased markedly over the winter/early spring. The reasons for this decline in Cu status is not known but it could be related to increased soil ingestion and or increases in pasture Mo concentrations (Grace 1994).

The differences observed in the incidence of trace element deficiencies between sheep and cattle on the Wendon Valley farms support the findings that the dietary Co requirements of sheep are about double those of cattle while the dietary Cu requirements of cattle are about double those of sheep (Grace 1994). The dietary Se requirements of sheep and cattle are similar. In deer, the dietary Co and Se requirements are less or similar to those of sheep while their dietary Cu requirements appear to be similar to those of cattle.

While soils low in Co and Se result in pastures also being low in Co and Se (Hawke *et al.*1994), the use of this soil trace element data is usually not sensitive enough to determine the Co/Vitamin B12 and Se status of grazing livestock. This study has clearly demonstrated that using the recommended pasture and animal tissue sampling protocols, and the established pasture and tissue trace element reference ranges, allows the trace element status of grazing livestock to be determined. Further, the observed between-farm variation means that these diagnostic procedures need to be carried out for each farm as part of their overall animal health programme.

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