Serum copper levels and supplementation: Seasonal and farm variation

P R Wilson and L J-M Audigé [*]

Abstract

Data from previous reports of copper levels in adult deer was analysed to demonstrate a seasonal pattern with highest serum and liver copper levels in autumn and lowest levels in spring. Data from one study farm enabled further analysis of seasonal differences with a higher percentage of deer in October with low serum levels having low blood levels, demonstrating the expected trend for depletion of liver reserves but maintenance of serum levels. The ability to predict liver levels by measuring serum Cu therefore varies with season.

Serum copper concentrations from an intensive survey of 15 farms over 2 years showed that copper concentrations in adult hinds were lower than in yearling hinds and weaners, respectively. This was particularly evident at the September sampling. The average reductions in blood copper from autumn to spring were 3.0 and 5.2 μmol/L for yearling and adult hinds, respectively. No seasonal pattern was observed for weaners. The pattern of copper supplementation showed that some farmers were using copper appropriately, and preventing deficiency. Others used copper where serum measurements indicated that supplementation was unnecessary. Some failed to re-establish adequate serum copper despite treatment.

These data suggest that monitoring of deer for copper in spring will provide the highest probability of detecting low copper levels, that age differences in copper concentrations are most evident in spring, and that there is a need for greater precision in diagnosis, treatment and prevention regimes and monitoring, to achieve appropriate copper usage and ensure that deer are not at risk of copper deficiency.

1. Introduction

"Low" copper levels are widespread in farmed deer throughout New Zealand (Mackintosh *et al*, 1986; Harrison *et al*, 1989; and Animal Health Laboratory reports in *Surveillance* and *Veterinary Cervus*). Possibly more than 25% of the more than $6 million animal remedy market for copper is targeted for deer. In addition, there is an unknown expenditure on application of copper sulphate with fertilizer by deer farmers. Thus the deer farmer has a vested interest in receiving and acting on the best possible advice from veterinarians in relation to copper status, given that copper deficiency syndromes can have a severe impact on

[*] Institute of Virology and Immunoprophylaxis, Mittelhaüsern, Switzerland

deer health, wellbeing and economic returns on one hand, and given the cost of supplementation on the other.

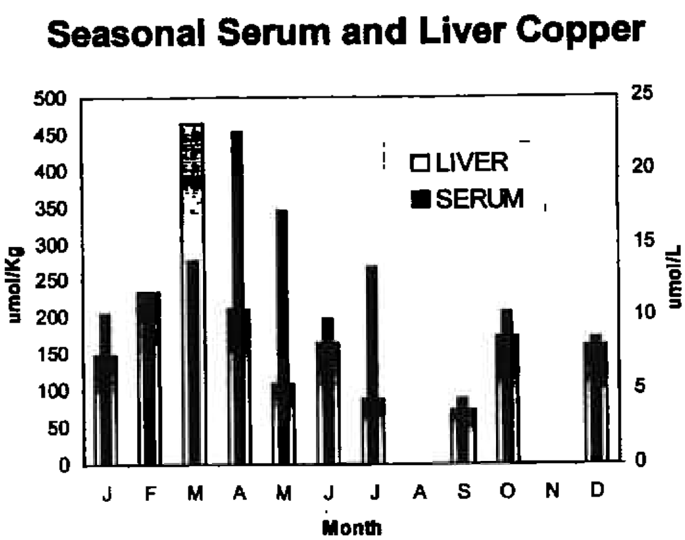
In an ideal world, veterinarians would be able to objectively investigate copper deficiency, identify the cause(s), advise the most cost-effective therapeutic or preventive supplementation regime, predict both tissue and production responses to supplementation and provide cost-benefit analyses for the client. This, of course, is far from the reality of the moment. This paper briefly addresses some of the questions which arise in terms of diagnosis and supplementation. It reviews previous data, and provides further data on seasonal variation in copper concentrations, portrays a summary of current copper supplementation on deer farms, and proposes a risk management approach to decision-making about copper investigations and supplementation.

2. Seasonal patterns

2.1 Published data

The only previous published data from which seasonal patterns can be deduced is that of Mackintosh *et al*, (1986). Those authors describe collection of 426 paired serum and liver samples from deer and at deer slaughterhouses in both the North and South Islands at different times of the year. Summary data of mean liver and serum concentrations by month are presented in Figure 1. Both liver and serum mean copper levels are highest in the autumn and lowest in spring.

Figure 1. Mean seasonal serum and liver copper



One group of data contributing to Figure 1 was from deer sampled from one farm in March and October. That data is presented in Table 1, along with data of all samples combined, and shows considerably different distributions of serum and liver copper concentrations at different seasons on the same property. A lower percentage of deer had both low serum and liver levels in March than in October. In October 71% of deer with low liver Cu concentration had low serum Cu concentration, whereas in March, 40% of deer with low liver Cu concentrations had low serum CU concentration. When data from all seasons and all properties are combined, 47% of deer with low liver Cu concentrations had low serum concentrations. Thus, interpretation of the relationship between serum and liver copper concentrations may vary between season, with the ability to predict low liver copper concentrations from low serum copper concentrations being greater in spring than in autumn. The higher the Cu concentration in serum relative to liver in summer and autumn is probably related to higher seasonal dietary intake

Table 1. Numbers of deer (and (%)) with serum and liver Cu concentrations above and below "normal" on one farm at 2 seasons, and all data combined (calculations based on data points from graphs in Mackintosh *et al*, (1986).

	March		October	
Serum < 8 μmol/l	6	(3 3)	9	(20 4)
Liver < 100 μmol/kg	8	(4 3)	15	(34 1)
Serum < 8 μmol/l and liver < 100 μmol/kg	2	(1 1)	5	(11 4)
Normal serum with normal liver	173	(94.9)	27	(61 4)

2.2 Deer herd health and production profiling data

Descriptions of this research project are to be found in Audigé (1995) and Audigé *et al*, (1993, 1998). Fifteen herds were involved in the survey. Ten serum samples (5 male, 5 female) were collected from weaners March, June and September both years, and in November year 1, and from 5 yearling and 5 adult hinds in March and September. Copper supplementation to all classes of deer, including mineralised anthelmintic, copper needles and injections were recorded.

NOTE: Serum copper measurement was chosen because this is an appropriate indicator of animals at risk of copper deficiency. No attempt is or should be made to infer liver Cu stores from this data.

Discussion of results is based on means of serum copper levels. Examination of the data presented in Tables 2 and 3 reveals that where herd mean levels are above 10.6 μmol/L, no individual animals in the herd were below 4 μmol/L. Data would suggest that mean blood copper levels would need to be below 4 μmol/L before animals in the herd were at risk of clinical copper deficiency disease or growth rate reduction (Killorn and Wilson, 1991, Ellison, 1995). No antler growth rate response was observed in stags with mean serum *ferroxidase levels as low as 10 iu/L (Walker et al, 1997) It is now apparent that the recognised "normal" level of 8 μmol/L provides a significant safety margin between the "adequate" and "dysfunctional" serum copper level.*

Therefore, for purposes of discussion of data presented here a conservative mean figure of 10.6 μmol/L has been chosen to distinguish where an individual or individuals in the herd may be at risk of clinical or subclinical copper deficiency, ie: at which the copper levels in that animal is approaching the "dysfunctional" level Thus, where the herd mean is 10 6 μmol/L or more, there is a low probability that any animal is at risk of copper deficiency The following results and discussion should be read in that context..

2.2.1 Weaners

Table 2 presents the farm mean weaner serum copper concentrations (μmol/l) and the range, together with the number of deer from each sampling with serum Cu ≤ 10.6 μmol/l.

Farm 3 had mean serum levels consistently below 10.6 μmol/l both years despite treatment in year 2. Farm 5 had mean serum levels below 10.6 μmol/l year 1 only. Some other farms had mean levels below 10.6 μmol/l on some occasions, more commonly in autumn and winter. Mean levels on all those farms increased in November, despite lack of treatment on most. Signs of clinical copper deficiency were confirmed only in herd 3, both years (Audigé *et al*, 1994), and suspected in one case with a hip lesion on farm 5.

Careful scrutiny of mean copper concentrations between years shows that on some farms mean copper concentrations were similar at all seasons both years, yet on other farms there were considerable differences between years despite lack of treatment. In some instances this may have been a carry-over from treatment of mothers in the year before the study (eg: Farm 5), although treatment effects may not persist for that period (Booth *et al*, 1989). It is likely that feed management practices such as different residual pasture heights, supplementary feeding, and seasonal effects on pasture composition would have a significant influence on copper levels between seasons on the same farm. This has been observed elsewhere (Walker *et al*, 1997) and would no doubt support the observations of many practitioners.

The range of farm mean copper levels (male and females combined) at each sampling period is presented graphically in Figure 2. In March, June and September mean copper levels were above 12 μmol/l, but there was a wide range in farm means with some below 8 μmol/l. In November the overall average was almost 15 μmol/l, and even those farms with low levels earlier in the year had mean levels well into the adequate range. The higher levels in November were due to a seasonal increase and not supplementation.

Table 2. Mean (n = 10) and range ( ) of serum copper (Cu) concentrations (µmol/l) from weaner deer up to 12 months of age from 15 survey farms number with levels < 8µmol/L [ ], and copper supplementation date and method

Farm	Yr		MONTH											
			J	F	M	A	M	J	J	A	S	O	N	D
1	1	T												
		Cu			18.7 (14-26)			15 1 (12-20)			16 1 11-23)		15 8 (11-22)	
	2	T									6-14			
		Cu			14 3 (7 8-21)[1]			15 7 (12-21)			11 3 (6-14)[1]		NR	
2	1	T												
		Cu			11 5 (4 8-19[2]			10 1 (5 4-12)[1]			11 2 (6 4-11)[1]		13 7 (6 4-20)[2]	
	2	T												
		Cu			12 8 (6 6-18)[1]			13 6 (9 7-16]			10 4 (7 8-13)[1]		NR	
3	1	T											C10	
		Cu			5 1 (2 2-13)[9]			9/0 (5 9-14)[5]			4 2 (2 1-.4)[10]		10 1 (5 5-17)[3]	
	2	T	C5											
		Cu			4 4 (1 4-7.7)[10]			4 7 (2.6-7.1)[10]			11 3 (5 8-17)[4]		NR	
4	1	T		A2	A1	A1	A1	A1						
		Cu			11 7 (5 2-16[2]			10 2 (6 3-14)[3]			11 6 (7 8-16)[1]		14 6 (12-18)	
	2	T	A1	A1	A1	A1	A1	A1	A1	A1				
		Cu			14 8			12 8 (6 8-25)			11 5 (5 8-17)[2]		NR	
5	1	T									2 2			
		Cu			5 8 (2 9-11)[8]			5 7 (2 5-13)[9]			6 5 (2 7-11)[8]		10 3 (1-16)[3]	
	2	T												
		Cu			10 2 (5 5-15[4]			10 7 (2 2-18)[2]			11 4 (8 2-17)		NR	
6	1	T												
		Cu			16 1 (12-25)			13 9 (7 1-14)[1]			13 0 (6 3-18)[1]		15 9 (9 8-20)	
	2	T												
		Cu			14 0 (9 6-18)			11 4 (7 7-14)[1]			9.3 (6.8-10)[3]		NR	
7	1	T								C4				
		Cu			13 3 (10-17)			14 0 (8 6-20)			14 3 (11-18)		16 2 (13-19)	
	2	T					A1	C5		A1		A1		
		Cu			14 9 (11-18)			17.0 (12-22)			14 4 (9 2-19)		NR	
8	1	T			A1	A1		A1						
		Cu			14 5 (11-16)			14.1 (8 8-22)			12 4 (5 6-22)[1]		14.0 (5 7-25)[2]	
	2	T					C10A1	A1	A1					
		Cu			8 2 (3 7-20)[6]			12 6 (5 9-15)[1]			11 3 (6 5-13)[3]		NR	

Farm	Yr		MONTH											
			J	F	M	A	M	J	J	A	S	O	N	D
9	1	T		A1	A1	A1		A1C10	A1					
		Cu			10 8 (4 5-16)[4]			13 5 (5 9-19)[1]			12 0 (6.6-16)[1]		14 0 (9 1-19)	
	2	T	A1			A1		A1C10						
		Cu			12 6 (5 2-17([1]			12.7 (8 5-16)			10 8 (4 5-16)[2]		NR	
10	1	T												
		Cu			NR			11 5 (8 5-14)			16 4 (8 3-27)		15 2 (12-19)	
	2	T												
		Cu			13 6 (4 7-20)[2]			13 0 (9 9-17)			13 7 (10-18)		NR	
11	1	T												
		Cu			14 3 (7 5-21)[1]			15 4 (11-20)			12 5 (5 0-24)[2]		17 1 (6 8-22)[1]	
	2	T												
		Cu			8 4 (4-14)[3]			11 7 (8 2-15)			9 8 (3 4-13)[4]		NR	
13	1	T												
		Cu			8 6 (4 2-15)[1]			9 0 (4 5-11)[3]			10 6 (3 4-13([2]		13 2 (9-15)	
	2	T						C5				C10		
		Cu			10 8 (4 4-17)[3]			8 7 (5 1-11)[4]			10 5 (2 3-16)[1]			
14	1	T												
		Cu			12 7 [11-17]			13 4 (12-17)			15 4* (11-14)		NR	
15	1	T												
		Cu			14 3 (8 2-20)			15 0 (9 7-20)			12 8 (9 7-15)		16 5 (11-24)	
	2	T												
		Cu			11 8 (6 7-19[1]			14 2 (9.3-18)			13 0 (8 8-18)		NR	
16	1	T			A1									
		Cu			NR			18 0 (9 7-34)			15 8 (11-20)		16 7 (11-22)	
	2	T												
		Cu			18 2 (13-29)			13 5 (11-17)			13 6 (11-18)		NR	

T = treatment type:

A1	=	one treatment mineralised anthelmintic
A2	=	Two treatments, mineralised anthelmintic
C4	=	4 gm copper oxide wire particles
C5	=	5 gm " " "
C10	=	10 GM " " "

Nr = NOT RECORDED

* 5 animals only sampled

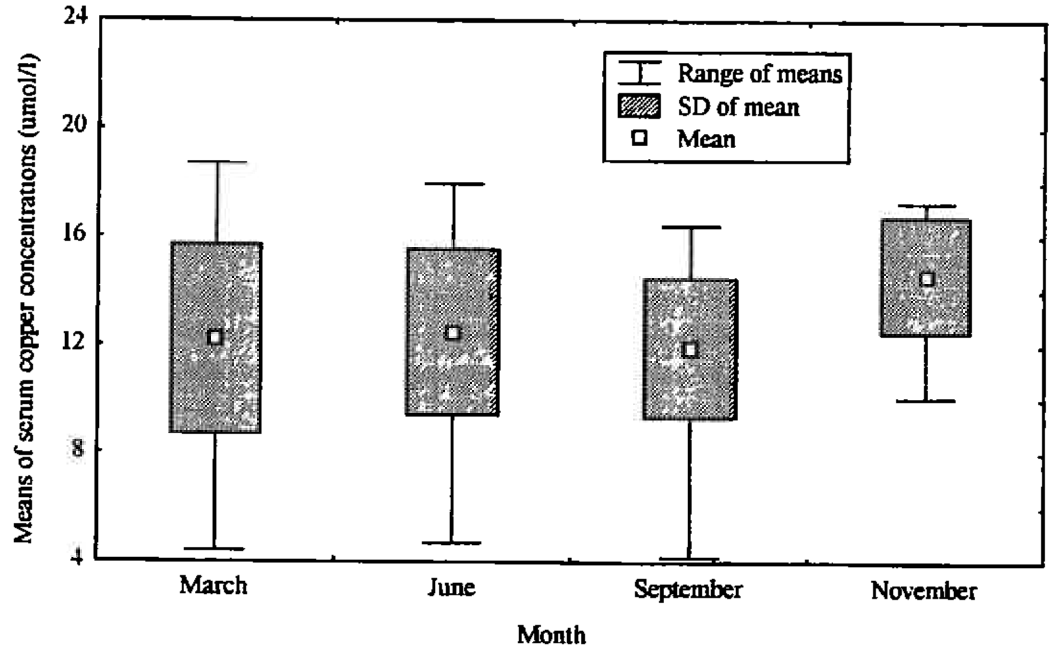


Figure 2. Range of farm mean serum Cu concentrations from weaners by season. Data from males and females, and both years combined.

This data suggests that to get a reasonable picture of the overall status of weaner deer, sampling autumn, winter or spring would provide a good prediction However, sampling in November would not recognise those herds which were previously low in copper Data also confirms that the investigation of the copper status of a deer herd can only be achieved by repeated measurements over the years because of variation between season Evaluation of copper status must be an on-going process

2.2.2 *Yearling and adult hinds*

Farm mean serum Cu concentrations in yearling and adult hinds, and supplementation, along with numbers of deer with serum Cu <10 6 μmol/L are presented in Table 3

With the exception of adult hinds on Farm 3 year 1, none of the deer sampled had received copper supplementation within 4-5 months of sampling Four farms (Nos 5, 8, 9 and 13) had mean serum copper of less than 10 6 μmol/L in March in either yearling or adult hinds

By September, mean serum copper concentrations had fallen below 10 6 μmol/l in yearling and/or adult hinds in one or both years of study on 13 farms In instances where copper supplementation was given during winter, serum Cu in some deer remained below 8 μmol/L in September, and in the case of farm 7, no deer had Cu levels above 8 μmol/L after copper injection in August

Table 3. Mean and range ( ) of serum copper (Cu) concentrations (µmol/l) from yearling (n = 5) and adult hinds (n = 5 from 15 survey farms, number with levels < 8µmol/L [ ], and copper supplementation date and method

Farm	Yr	MONTH J	F	M	A	M	J	J	A	S	O	N	D
1	1 T												
	CuYH			15.4 (12-19)						17.2 (15-20)			
	AH			14.8 (11-23)						14.4 (8-21)			
	2 T												
	CuYH			13.6 (12-16)						14.0 (12-19)			
	AH			13.2 (6.5-17)[2]						11.7 (6-16)[2]			
2	1 T												
	CuYH			18.4 (15-22)						11.7 (8.4-16)			
	AH			15.6 (13-17)						6.7 (4.1-13)[4]			
	2 T												
	CuYH			13.6 (8-16)						8.4 (2.9-11)[1]			
	AH			16.0 (12-21)						6.0 (2.7-8.3)[3]			
3	1 T												
	CuYH			NR									AHC2
	AH			12.0 (7.9-14)[1]						1.5 (1.2-1.7)*			
	2 T						YS/AS C20	YH/AH C20		1.7 (0.8-3.4)[5]			
	CuYH			11.8 (8.2-14)						11.0 (10-13)			
	AH			12.6 (11-15)						10.0 (5.8-13)[1]			
4	1 T											YH/A HD	
	CuYH			15.0 (13-17)						11.8 (4.1-19)[1]			
	AH			16.6 (13-21)						10.2 (4.9-15)[1]			
	2 T						YH/AH C12					YH/A HD	
	CuYH			14.4 (9-18)						11.0 (7-16)[1]			
	AH			12.1 (6-20)[3]						10.0 (4.3-15)[1]			
5	1 T								YH/AH C10			YS/AS C20	
	CuYH			3.7 (1.5-7.3)[1]						17.0 (13-19)			
	AH			13.3 (15-22)						15.8 (14-18)			
	2 T												
	CuYH			7.5 (1-11)[2]						2.0 (0.2-3.2)[5]		YS/AS	

Farm	Yr	MONTH													
		J	F	M		A	M	J	J	A	S		O	N	D
	AH			12 8	(9 9-17)						3 7	(0 2-8 4)[4]		C20	
6	1 T														
	Cu/YH			12 0	(7 2-15)[1]						8 0	(0 9-13)[2]			
	AH			17 2	(15-22)						12 4	(3 4-15)[1]			
	2 T														
	CuYH			17 0	(16-19)						10 2	(5 1-14)[1]			
	AH			14.4	(8 8-23)						9 3	(2 7-16)[2]			
7	1 T									AHI YSC4					
	Cu/YH			11 7	(8.3-14)						4 0	(1.4-7.4)[5]			
	AH			11 2	(6 8-15)[1]						9 2	(2 3-17)[2]			
	2 T							AH/YSC1 0		AS C10					
	CuYH			18 6	(16-22)						15.0	(14-16)			
	AH			16 0	(12-20)						10 2	(7 4-13)[1]			
8	1 T														
	Cu/YH			16 6	(15-18)						17 2	(14-23)			
	AH			17 6	(15-20)						6 3	(3 7-10)[3]			
	2 T							YH/AH C10		AS C20					
	CuYH			11 7	(8-15)						9 3	(5 6-14)[1]			
	AH			8 0	(2 7-18)[3]						10 8	(5 9-13)[1]			
9	1 T							YH/AH C10	YS/AS C10						
	Cu/YH			13 4	(11-16)						11 4	(9 1-13)			
	AH			11 6	(8 1-15)						11 3	(9 4-14)			
	2 T								YS C10 AS C20						
	CuYH			10 5	(7 5-13)[1]						9 5	(4 6-13)[1]			
	AH			8 4	(5 9-12)[3]						11 3	(6 7-13)[1]			
10	1 T														
	Cu/YH			NR							6 9	(2 2-11)[2]			
	AH			NR							9.1	(4 6-20)[3]			

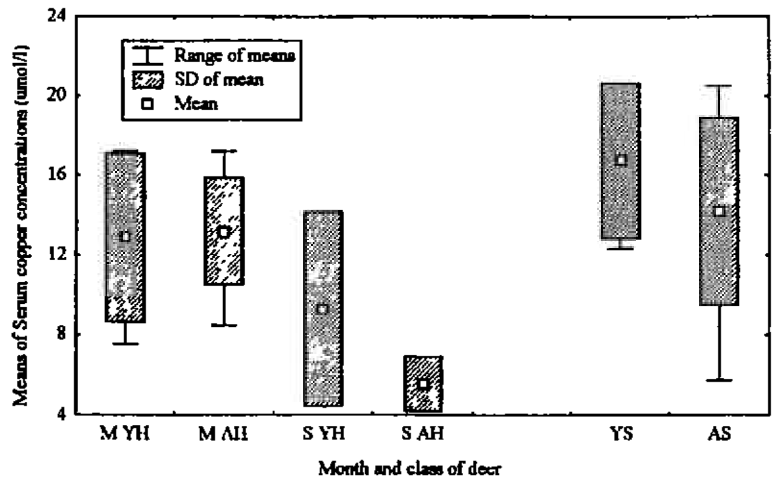
Farm	Yr	MONTH													
		J	F	M		A	M	J	J	A	S		O	N	D
	2 T														
	CuYH			11.9	(6 6-10)[1]						6.0	(3-10)[4]			
	AH			13.2	(12-15)						9.6	(6 5-12)[2]			
11	1 T														
	Cu/YH			11.2	(3 8-19)[1]						NR				
	AH			13.7	(9 4-19)						5.0	(2 2-6 6)[5]			
	2 T														
	CuYH			12.6	(4 1-18)[1]						8.0	(3.3-11)[2]			
	AH			14.8	(11-20)						5.1	(0.7-12)[4]			
13	1 T														
	Cu/YH			17.2	(13-24)						10.3	(5 7-15)[3]			
	AH			10.3	(8 3-13)						8.0	(2 1-14)[3]			
	2 T														
	CuYH			8.1	(4 4-14)[3]						7.8	(3 6-15)[4]			
	AH			7.0	(4 1-11)[4]						4.7	(2 3-6)[5]			
14	1 T														
	Cu/YH			11.4	(8.8-14)						NR				
	AH			12.8	(12-14)						9.5	(7 8-11)[1]			
15	1 T														
	Cu/YH			12.0	(11-15)						9.6	(2 3-14)[1]			
	AH			11.8	(10-15)						4.6	(2 6-5 6)[5]			
	2 T														
	CuYH			14.0	(11-19)						12.0	(6 2-15)[1]			
	AH			13.5	(7 7-18)[1]						11.1	(7 5-15)[1]			
16	1 T														
	Cu/YH			NR							14.4	(12-18)			
	AH			NR							14.8	(10-18)			
	2 T														
	CuYH			17.2	(15-23)						10.0	(8 5-12)			
	AH			16.4	(12-21)						11.9	(8 3-14)			

T = Treatment
AH = Adult hind
YH = Yearling hind
* 2 deer sampled

AS = Adult stag
YS = Yearling stag
C = Copper oxide wire particles (4,10,12,20 = g/dose)

I = Coprin injection
D = Mineralised anthelmintic drench
NR = not recorded

The range of farm mean serum copper concentrations in adults and yearlings are presented in Figure 3. These data show that by September some yearling hind herds had reached low copper concentrations, yet the farm mean of serum copper concentration of the average farm was still in the adequate range. In contrast there is a substantial reduction in the average farm mean serum copper concentration in adult hinds and the range has considerably narrowed. These data suggest that if a single point serum sampling was to be undertaken to determine the copper status of a deer herd, selection of adult hinds in September would be the most appropriate animal class and timing. This conclusion is supported by the seasonal pattern of concentrations shown in Figure 1.



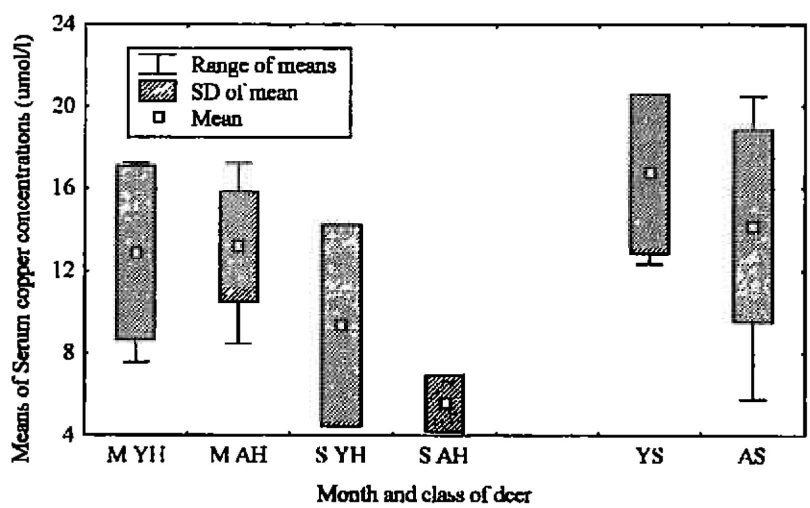


Figure 3. Range of farm mean serum copper concentrations from adult and yearling hinds in March and September. Data from both years combined.

2.2.3 Relationships between autumn and spring copper concentrations in hinds

The change in mean serum copper concentration for yearling and adult hinds for both years on each farm are presented in Table 4.

Table 4. Change in mean serum Cu (μmol/L) from March to September in yearling and adult hinds on farms not using copper supplementation

Farm	Year	Yearling	Adult
1	1	+1 8	-0 4
		+0 4	
	2	-0 4	-1 5
2	1	-6 7	-8 9
	2	-5 2	-10 0
3	1		-10 3
4	1	-3 2	-6 4
5	2	-5-5	-9 1
6	1	-4 0	-4 8
	2	-6 8	-5 1
8	1	+0 8	-10 9
9	2	-1 0	+1 7
11	1	-3 1	-8 7
	2		-9 7
13	1	-6 9	-2 3
	2	-0 3	-2 3
14	1		-3 3
15	1	-2 4	-7 2
	2	-2 0	-2 4
16	2	-7 2	-4.5
Mean		**-3.0**	**-5.2**
Median		**-2.4**	**-5.1**
Range		((+1 8) – (-7 2))	((+1 7) – (-10 9))

Reduction in mean serum copper level from March to September, analysed by the Wilcoxon signed-rank test, averaged 3.0 μmol/l for yearling hinds ($p < 0.01$) and 5.2 μmol/l for adult hinds ($p < 0.001$). The average reduction was less for yearling hinds than adult hinds. This probably reflects a difference in management of those two groups, with adult hinds generally being on a more restricted plane of nutrition than younger hinds, reducing Cu intake and/or increasing soil, and therefore competing element, intake. While there is considerable range about each of these points, these data can be used to suggest that if average serum copper concentration in yearling hinds was below 13 μmol/l in March, there is a probability that 50% will be below 10.6 μmol/l in September suggesting, therefore, that some deer may then be at risk of Cu deficiency. Similarly for adult hinds, if mean serum Cu concentrations in March were 15.7 μmol/l, 50% of those groups would be expected to have mean serum copper concentrations in September below 10.6 μmol/l.

It must be reiterated that serum levels are only an indirect measure of copper status of deer. Similar data between seasons for liver concentrations would be especially useful in helping determine the necessary pre-winter liver stores of copper for maintenance of adequate copper status through to spring/summer.

3. Copper supplementation

Supplementation methods and dates are presented in Tables 2 and 3.

During the two years of this survey, administration of copper oxide wire particles (COWP) was the most common form of supplementation. Four, 5, 10 and 20 gm doses were used. One farm used an injectable copper on one occasion. Four farms used mineralised anthelmintic as a form of supplementation. Three of these also used COWP supplementation. In all, 8 of the 15 farms provided supplementation to weaners during the first 12 months of life, whereas 6 farmers gave copper supplementation to yearling and adult hinds and/or stags.

Note: Serum copper data was not made available to the farmers during the study, with the exception of farm 3 when an outbreak of osteochondrosis was recorded (Audigé *et al*, 1994). Some farmers would have had previous monitoring of copper levels.

3.1 Weaners

The following is a summary of supplementation practices:

- Eight of 15 farmers gave copper supplementation
- One farmer supplemented year 1 only
- Two farmers supplemented year 2 only
- Five farmers supplemented both years
- Three farmers treated where there was little evidence of copper deficiency (treatments 4, 5 or 10 gm COWP)
- Two farmers (Nos. 5 and 11) did not treat but had low copper levels
- One farmer (No 3) treated after the occurrence of clinical disease, but very low Cu levels persisted (dysfunctional range) in many of the treated deer. Some were therefore still at risk
- On six farms it was not possible to differentiate whether normal copper levels were a result of treatment or despite treatment.

The supplementation regimes chosen by various farmers are summarised in Table 5.

Table 5. Number of occasions each supplementation regime was followed on farms supplementing weaners with copper over the two years of study (summarised data from Table 2)

Treatments/Supplementation	Number
Pre-wean and winter	1
Pre-wean, autumn and winter	3
Autumn only	2
Autumn and winter	2
Autumn, winter and spring	1
Winter only	2
Winter and spring	1
Spring only	1

These observations show a considerable range in the use of copper supplementation. Data shows that some farmers are successfully preventing the risk of clinical and/or subclinical copper deficiency. Data also suggests that other farmers supplement when supplementation is not necessary. Others do not supplement when supplementation would be advised. Some farmers supplemented when there was no evidence of risk of copper deficiency. On average, this constituted $1.70/head/year product cost plus time with administration on all these properties.

3.2 Yearling and adult hinds

Copper usage in yearling and adult hinds is summarised in Table 3. Key points are:

- Six farmers supplemented adult and/or yearling hinds and/or stags
- Low copper levels were observed on all farms that supplemented
- In some instances animals had serum Cu < 4 μmol/L even after supplementation, and therefore were still at risk of deficiency
- Six farmers used copper oxide wire particles, one used injectable copper, one used a mineralised drench
- One farmer supplemented only hinds
- Five treated hinds and stags.

Observations of the timing of supplementation presented in Table 3 showed that all farmers using supplement did so in winter, and three also provided supplement in early summer. In one instance of early summer treatment, all deer had adequate copper (> 8 μmol/l) at the September sampling, prior to supplementation.

3.3 Combined weaner, yearling and adult treatments

Combining the data from Tables 2 and 3, it can be seen that:

- Five farmers supplemented both weaner and older deer
- Three farmers supplemented weaners but not adults
- One farmer treated yearlings and adults but not weaners.

The prevalence of low copper levels in adults is higher than the prevalence of low copper in weaners. That more farmers supplemented weaners than adults would suggest that some farmers may not necessarily be targeting the appropriate class of animal for supplementation.

3.4 General comments

This information suggests that there is a lack of objectivity involved in copper supplementation programmes on some deer farms. Many of the products used for copper supplementation are prescription animal remedies. This would suggest that in some situations veterinarians may be prescribing copper without adequate and full knowledge of the copper status. In other situations the farmer may not be receiving appropriate advice as to treatment timing or age group targets. Another possible explanation is that farmers may not be following advice, or that farmers are obtaining product other than on prescription, and are using it with no advice at all.

All of the above possibilities would suggest that there is a significant opportunity for veterinary practices in encouraging deer farmer clients to become more familiar with their copper status, and therefore to develop more rational supplementation and monitoring programmes. Data presented suggests that there is significant financial wastage in this area amongst deer farmers, and the cost of professional advice would be considerably outweighed by the advantages in many situations.

4. A "Risk" approach to decision making on copper supplementation

The investigation, diagnosis and advice for control and supplementation for copper deficiency for a given deer herd is complex.

4.1 Questions to consider

What constitutes deficiency?
What serum levels are appropriate?
What liver levels are appropriate?
What sub-clinical production deficits are present?
Are current "critical levels" the same for all copper-responsive conditions?

What and when is it best to monitor?
Age, sex, season, sample/tissue
Species – red, wapiti, hybrid

What is the underlying cause of the copper deficiency?
Primary feedstuff copper deficiency, interfering factors in or on feedstuff
Environmental/seasonal factors

What is the best treatment/prevention method?

Fertiliser, water additive, oral bolus, oral copper oxide wire particles, injections, salt licks, drench additives, oral copper sulphate

Will an "economic" production response be achieved?

Growth, antler production, improved reproduction, sub-clinical and/or clinical disease prevention, reduction in mortality rates.

4.2 Risk assessment

There are few standard answers to questions about copper in deer: the knowledge required to provide objective answers to many of the questions above simply does not exist. This may be viewed by some as unfortunate, and a failing of science to come up with the answers. This makes it difficult for the practitioner to predict a response to copper supplementation. There is insufficient information to provide many benchmarks. For example, the incidence rate of enzootic ataxia in deer with liver copper levels of less than 60 μmol/kg is not known. All that can be concluded is that the risk appears to be absent in animals with liver copper of more than 60 μmol/kg.

Thus, a logical approach to investigation and management of low copper levels on a deer farm would be to regard each case as a unique clinical challenge. The approach to management should be an individualised risk analysis. Thus, the "answer" to the question lies in the risk analysis of the individual situation. For example:

- What is/are the risk(s) of copper deficiency on this property?
- What is/are the risk(s) of production loss?
- Can potential production losses be quantified?
- What is/are the risk(s) of not treating/preventing?
- What is/are the risk(s) of supplementation?
- What is/are the risk(s) of incorrect diagnosis by the chosen series of analysis?
- What is the financial risk, eg: what is the debt to equity ratio on the property? Can the farm afford a significant outbreak of copper deficiency production-limiting disease? Does cash flow permit a treatment/prevention programme?

A risk analysis approach begins with the premise that there are few, if any, absolutes. The "answer" that arises as a result of a risk analysis is a perceived point in the scale between two absolutes – yes and no.

It recognises that there are a substantial number of interrelated factors on a property which may contribute to the desirability/necessity of supplementation. Risk analysis also begins with the premise that truth is ultimately inescapable, meaning that if incorrect diagnosis and/or recommendations are made, they will eventually be discovered. This is more likely to be less costly if monitoring is done routinely. Risk analyses should not be static or applied on a once-only basis. If a "conservative" or "low" or "no" supplementation programme is implemented, a high level of monitoring should follow (ie: the need for monitoring is inversely proportional to the frequency of supplementation). Conversely, if the supplementation is intensive, monitoring can be less intensive. Paramount among the factors needing consideration in a risk assessment process are the farmer's goals and objectives,

management, stocking policy, grazing methodology, financial situation, disease, health, production, labour, season, other stock etc.
Ultimately it is the client who decides the course of action. The veterinarian's role is to ensure that all factors (risk factors) are known by the client. The best decisions are made when all the information is known.

5. Conclusions

This presentation has highlighted a number of seasonally related differences in animal copper concentrations in different age groups of deer. It presents results of a survey of copper usage in deer, which combined with tissue measurements, suggest that a number of decisions about copper supplementation in deer herds can be improved. There is a need for more monitoring, both of the need or otherwise, for supplementation, and the effectiveness of supplementation programmes on individual farms. There is a greater need for specific advice as to which class of animal to treat, which class of animal to monitor, and when those processes should be undertaken. A risk analysis approach to the diagnosis and management of investigations of copper status and of copper deficiency situations should provide the best outcomes for both the farmer and the animals.

References

Audigé LJM, Wilson PR, Morris RS (1993) Deer herd health and production profiling: The method. Proc. Deer Course for Veterinarians No 10, pp78-95

Audigé LJM, Wilson PR, Morris RS, Davidson GW (1994) Osteochondrosis, skeletal abnormalities and enzootic ataxia associated with copper deficiency in a farmed red deer herd. NZ vet J 43, 70-6.

Audigé LJM (1995) Deer herd health and production profiling. PhD Thesis, Massey University

Audigé LJM, Wilson PR, Morris RS, Davidson GW (1995). Osteochondrosis, skeletal abnormalities and enzootic ataxia associated with copper deficiency in a farmed red deer (*Cervus elaphus*) herd. NZ vet J 43, 70-6.

Audigé LJM, Wilson PR, Morris RS (1998) Deer herd health and production profiling III Concepts and components. NZ vet J. Submitted.

Booth DH, Wilson PR, Alexander AM (1989). Liver copper in farmed deer the effect of oral oxidised copper wire particles. NZ vet J 37, 98-101

Harrison TJ, Sykes AR, Familton AS (1989) Copper levels in livers of red deer in the South Island and their relationship with soil group. Proc Deer Course for Veterinarians No 6. Deer Branch NZVA. Ed. PR Wilson, pp158-62.

Killorn KJ, Wilson PR, Morris RS (1991). Copper and deer growth. Proc. Deer Course for Veterinarians No 8, Deer Branch NZVA. Ed. P R Wilson, pp210-16

Mackintosh CG, Wilson PR, Beatson NS, Turner K, Johnstone P (1986). Preliminary report of the liver:serum copper relationship in red deer. Proc Deer Course for Veterinarians No 3, Deer Branch NZVA. Ed PR Wilson pp156-64.

Walker IH, Wilson PR, Beckett S (1997). Copper and velvet antler production: A clinical trial. Proc. Deer Course for Veterinarians No 14, Deer Branch NZVA. Ed. PR Wilson, pp219-228