# Liver copper concentration in cattle and herbage copper, sulphur, iron and molybdenum concentrations on commercial farms in the Wairoa region

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## Abstract

Seasonal changes in herbage elements (Cu, Mo, S, Fe), pasture growth, and soil moisture were measured and their relationships with liver Cu concentration in weaner heifers (n=10–12) and breeding cows (n=10–12) were determined on 7 commercial farms in the Wairoa region. Liver biopsy samples were collected at 2 to 4 monthly intervals and herbage and soil moisture monthly from spring 1996 to spring 1998. Mean Mo concentration of herbage offered to cattle on the 7 farms ranged from 0.7 to 3.2 mg Mo/kgDM and Cu herbage concentrations from 5.7 to 10.5 mg Cu/kgDM. Mean concentrations of Cu in cattle livers ranged from 85 to 204 µmol Cu/kgFW across farms. Herbage Cu, S and Fe concentrations were highly seasonal with low levels in late spring–summer and high levels in autumn and winter. In contrast, herbage Mo was less seasonal. There was a suggestion that variation in liver Cu across seasons was positively affected by increasing herbage Cu concentration and negatively affected by increasing herbage S concentration and unaffected by herbage Mo concentration. Over the two years 46% of non-Cu supplemented cows and 32% of weaners had deficient (<95 µmol Cu/kgFW) liver Cu levels but clinical signs of Cu deficiency were not observed. Weaner liver Cu concentrations were low in summer and autumn (126 µmol/kgFW) but repleted over the winter and spring seasons (195 and 237 µmol/kgFW respectively). Cows had highest levels of liver Cu in summer (147 µmol/kgFW) but these fell steadily over winter to reach low (62 µmol Cu/kgFW) levels in spring before calving. The study supports the conclusion of Korte (1995) that in the Wairoa region herbage Mo may impair absorption of Cu in cattle grazing pasture with Mo levels as low as 0.5 mg/kgDM, but once herbage Mo rises above 2 mg/kgDM then further reduction in Cu absorption is minimal.

**Keywords:** copper, cows, herbage composition, herbage minerals, liver, molybdenum, season, soil moisture, weaners

## Introduction

Copper (Cu) deficiencies are widespread in the New Zealand beef industry, particularly in the Wairoa region where 60–70% of breeding cows and 40% of ewes are routinely supplemented with Cu. Copper deficiencies are not only associated with low Cu intakes, but more frequently are caused by dietary antagonists, such as molybdenum (Mo), sulphur (S) and iron (Fe) which impair the absorption and/or utilisation of Cu (Suttle & McLauchlan 1976). In an earlier survey conducted on 100 farms in the Wairoa region, it was found that herbage Mo concentration was the main predictive factor associated with low liver Cu concentrations in lambs, weaner cattle and breeding cows (Korte *et al.* 1995). Further, this survey suggested that herbage Mo concentrations as low as 0.5 mg Mo/kg DM reduced liver Cu concentrations in cattle. Previously it was thought that Mo only affected liver Cu concentrations at much higher (>3 mg Mo/kgDM) concentrations (Suttle & McLauchlan 1976).

Clinical symptoms of Cu deficiency in cattle are usually manifest during spring. Molybdenum has been widely reported to be one of the more seasonal herbage elements, rising sharply in spring (Cornforth 1984). It was therefore hypothesised that increases in Mo herbage in spring may reduce liver Cu concentrations in cattle and trigger outbreaks of clinical Cu deficiency. It was the objective of this experiment to measure seasonal relationships of herbage elements (Cu, Mo, S, Fe), pasture growth, and soil moisture and to determine their relationships with liver Cu concentration in weaner heifers and breeding cows on commercial farms in the Wairoa region.

## Materials and methods

### Farms and animals

Seven farms in the Wairoa district were selected to encompass both high and low Mo soils. Liver biopsies were collected (Wairoa Veterinary Services), at 2–4 monthly intervals (within constraints of a wet winter in 1997 and a drought in 1998), from weaner heifers (n=10–12) and breeding cows (n=10–12). Individually identified cattle were sampled from spring 1996 to spring

1997 (the average number of samples collected was 2.4 and 3.3 for cows and weaners respectively). A second group was sampled from autumn 1998 to spring 1998 (average number of samples collected was 3.6 for both cows and weaners). The monitor animals were managed with their cohorts under normal farm management practices but without Cu supplementation. Farm A used Cu fertiliser (9 kg/ha $CuSO_4$) on 60 ha of the flat areas of the farm at 8 month intervals.

Liver samples were frozen and Cu concentrations were later determined by inductively coupled plasma (ICP) emission spectrometry (Lee 1983) and for low Cu concentrations by Zeeman flameless atomic absorption.

**Herbage and soil**

Three cages were sited within a permanent 5 $m^2$ monitor site on each farm. At 1 month intervals, herbage from within and outside the cage, and standing herbage offered to the breeding cows and weaner cattle (from the paddocks they were presently grazing), was clipped to 2 cm using electric hand shears. Cages were resited after herbage collection. Herbage was washed and dried (60°C>24 hrs) and herbage mass calculated. Dried washed herbage was sent to a commercial laboratory for measurement of herbage Cu, Mo, S and Fe concentrations. Herbage collected from both within and outside the cage was subsampled every two to three sample collections and separated into grass, legume, weeds and dead components before drying and weighing. Soil cores (75 mm depth) were collected for gravimetric determination of soil moisture.

**Statistics**

Herbage mineral concentrations, soil moisture and pasture growth rates were $\log_e$ transformed before analysis to normalise the data. Least square means and associated 95% confidence limits of $\log_e$-transformed variables were back-transformed for presentation. Analyses were conducted using the GLM procedure of SAS (SAS 1989), with season and farm treated as fixed effects. Three month inclusive periods were used to define seasons; spring (September to November), summer (December to February), autumn (March to May) and winter (June to August). Associations amongst herbage element concentrations, soil moisture, pasture growth rate and herbage composition variables were analysed by calculation of partial correlations after adjusting for farm and season effects. Analysis of the relationship between liver Cu concentrations and herbage mineral concentration was performed by pairing liver measurements with herbage data from pasture on which the cattle had been grazing within the 45 day period preceding the liver biopsy. The MIXED procedure of SAS (SAS 1989) was used to produce a reduced model pooling data from both classes of cattle and all farms. Iron and Mo were dropped from the equation because there was no evidence of a significant effect on liver Cu.

## Results and discussion

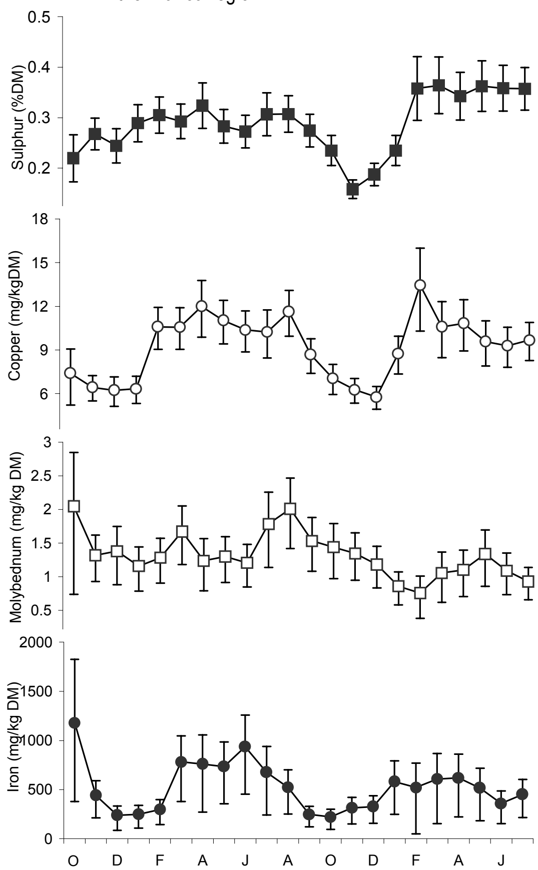
Herbage minerals, herbage growth and soil moisture were all highly seasonal ($P<0.001$) on the fixed herbage sample site. The pattern of seasonal concentrations of herbage Cu and S was very similar (Figure 1). Lower concentrations were found during summer but concentrations increased by 30–50% over autumn and winter (Table 1). Herbage Fe concentration was also low (mean of 260 mg/kgDM for 2 years) in summer but 180% higher in winter presumably due to soil contamination of the herbage. In contrast, mean concentrations of Mo only differed by 18% between seasons with concentrations being lower in autumn largely due to low levels of Mo in herbage in the autumn of 1998 (Table 1). In association with these lower herbage Mo concentrations, liver Cu in cows and weaners were 180 and 237 µmol/kgFW respectively higher in the autumn of 1998 compared to that of 1997 (Table 1). Mean herbage Mo concentration by month across farms did show a seasonal trend but this was smaller than the other elements (Figure 1). Increases in herbage Mo were observed on half of the farms between June and December but the timing of such rises was not consistent across farms and years (data not shown). Herbage Mo concentration increased as soil moisture increased in autumn ($r=0.63$, $P<0.01$) and when the proportion of dead herbage decreased in winter and spring ($P<0.05$). Herbage Mo has been

**Table 1** Effect of season on herbage minerals (S sulphur; Cu copper; Fe iron; Mo molybdenum) from regrowth cages and liver Cu concentrations in cows and weaner cattle on seven Wairoa farms in 1997 and 1998.

| Season | Year | Herbage minerals q(mg/kgDM) S | Cu | Fe | Mo | Liver Copper (µmol Cu/kgFW) Cows | Weaners |
|---|---|---|---|---|---|---|---|
| Aut | 1997 | 3.5 | 11.1 | 383 | 1.3 | 11 | 12 |
| Aut | 1998 | 3.5 | 11.7 | 470 | 1.0 | 49 | 62 |
| Win | 1997 | 3.5 | 12.6 | 571 | 1.4 | 15 | 44 |
| Win | 1998 | 3.9 | 12.1 | 580 | 1.2 | 32 | 38 |
| Spr | 1997 | 3.1 | 10.5 | 280 | 1.6 | 9 | 42 |
| Spr | 1998 | 3.7 | 10.0 | 282 | 1.1 | 18 | 59 |
| Sum | 1997 | 2.9 | 7.2 | 245 | 1.3 | 20 | 20 |
| Sum | 1998 | 2.6 | 7.9 | 275 | 1.2 | 30 | 28 |
| Season | | 0.0001 | 0.0001 | 0.0001 | 0.004 | 0.0001 | 0.0001 |
| Season*Year | | 0.0001 | 0.0001 | 0.0001 | 0.01 | 0.0001 | 0.0001 |
| Month(year) | | 0.0001 | 0.0008 | 0.09 | 0.09 | na | na |

widely reported to be one of the more seasonal herbage elements largely based on studies conducted on peat soils, soils in which herbage Mo was low and where Mo had been applied with fertiliser. This study on soils with high native Mo concentrations suggested that herbage Mo did not show a consistent seasonal trend in the Wairoa environment.

**Figure 1** Effect of month on herbage sulphur, copper, molybdenum and iron on a fixed sampling site on seven farms in the Wairoa region.




Overall, herbage offered to cattle contained 0.7 to 3.2 mgMo/kg DM and 6.6–10.3 mg Cu/kgDM (Table 2). Farms B and C, located on Hangaroa soils, and farms F and G, located on Tuai soils, had concentrations of Cu in the herbage sufficiently low to potentially induce direct Cu deficiencies. Mean farm liver Cu tended to fall with increasing mean herbage Mo and decreasing Cu concentration with the exception of farm A. Six of the seven farms in this study support the findings of Korte (1995) which found that Mo impaired absorption of Cu in cattle grazing Wairoa pastures with Mo levels as low as 0.5 mg/kgDM, but once herbage Mo rose above 2 mg/kgDM, then the reduction in absorption is not further diminished. Seasonal variations in liver Cu within farms was positively affected by increasing herbage Cu concentration and negatively affected by increasing herbage S concentration. However, this equation only explained 5% of the variation in cattle liver Cu concentrations (Korte *et al.* 1999). Herbage Mo was notably absent from this equation because herbage Mo within a farm was largely constant while liver Cu concentrations were variable. In addition, it is probable that once herbage Mo increased above 2 mgMo/kgDM there was enough Mo present in the diet to saturate Cu thiomolybdates within the gut of cattle. It appears therefore that in Wairoa, seasonal fluctuations in herbage Mo do not drive changes in liver Cu concentration.

Over the 2 years, 46% of cows and 32% of weaners had liver concentrations below the critical reference value for potential deficiency (<95 µmol Cu/kgFW). The mean liver Cu concentration was lower (P<0.001) in cows (180 µmol Cu/kgFW) than in weaners (280 µmol/kgFW). Cows, therefore, should be the first priority for Cu supplementation. Weaner liver Cu concentrations were low in summer and autumn (125 µmol Cu/kgFW) but repleted over the winter and spring seasons (195 and 238 µmol Cu/kgFW respectively). This repletion/depletion cycle in weaners largely follows the seasonal changes in herbage Cu concentration. In

**Table 2** Effect of farm on mineral concentrations in herbage offered to cattle and on liver copper concentration (cows and weaners combined) from 1996 to 1998 for seven farms in the Wairoa district.

| Mineral concentrations | E | D | A[1] | G | F | C | B | P< |
|---|---|---|---|---|---|---|---|---|
| Herbage (mg/kgDM) | | | | | | | | |
| Molybdenum | 0.7[e] | 1.2[d] | 1.2[d] | 1.8[c] | 2.2[b] | 2.6[b] | 3.2[a] | 0.0001 |
| Copper | 8.7[c] | 9.8[ab] | 10.3[a] | 6.6[e] | 8.4[c] | 7.6[d] | 7.3[d] | 0.0001 |
| Sulphur | 3.0[a] | 2.8[a] | 2.9[a] | 2.7[a] | 2.4[ab] | 2.2[b] | 2.0[b] | 0.0001 |
| Iron | 380[c] | 600[e] | 580[e] | 280[d] | 230[d] | 400[b] | 580[e] | 0.0001 |
| Liver (µmol/kgFW) | | | | | | | | |
| Copper | 200[e] | 160[ab] | 90[c] | 160[ab] | 120[b] | 110[bc] | 110[bc] | 0.0001 |

[1] Uses Cu fertilisers
[abcde] Different superscripts within the row indicate that the means differ significantly at P<0.05

contrast, cows had the highest concentrations of Cu in their livers in summer (147 µmol Cu/kgFW) but these fell steadily over winter to reach low (62 µmol Cu/kgFW) levels in spring before calving when the cow has a high demand for Cu. By late pregnancy many of the non Cu supplemented cows in this study were classified as being deficient based on their liver Cu concentrations but these cows did not manifest clinical symptoms. There is a gap in our knowledge regarding the factors which trigger the onset of clinical Cu deficiency in cows and weaners with marginal liver Cu reserves.

## Recommendations

It is recommended that on farms where clinical Cu deficiencies have been previously observed, that cows grazing pastures with more than moderate herbage Mo (>0.7 mg Mo/kg DM) in autumn be routinely directly supplemented with Cu in late autumn/winter to ensure adequate liver stores to meet the high demands for Cu in late pregnancy and the subsequent lactation. Treatment of the breeding cow should also increase liver Cu concentrations in calves at birth and possibly in calves at weaning. The effectiveness of the supplementation regimen can be monitored by liver biopsy. Young cattle on farms with a history of Cu deficiency in young cattle and/or herbage with high Mo concentrations (>2 mg/kg DM), should be supplemented with Cu in the spring–summer period based on measured liver Cu levels.

## Conclusions

In Wairoa, herbage Mo concentrations are less seasonal than herbage concentrations of Fe, S or Cu. Seasonal changes in cattle liver Cu concentrations within a farm are more related to physiological demand and herbage Cu and S concentrations than fluctuations in herbage Mo. However liver Cu concentrations fell as herbage Mo concentrations increased from 0.7 to a plateau of over 2 mgMo/kgDM.

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