THE ASSOCIATION OF SOIL COBALT WITH THE INCIDENCE OF THE 'STAGGERS' FORM OF *PHALARIS AQUATICA* POISONING IN LIVESTOCK.

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Abstract

The total amount, or the availability, of soil cobalt may explain the variability in the prevalence of phalaris staggers in sheep and cattle. The cobalt status of a soil is a reflection of the cobalt status of the parent rock from which it was derived. Soils derived from limestone or sandstone will be very low in cobalt. High soil manganese, high soil pH, or the microbially controlled effects of cold wet soil conditions in winter, will result in low soil cobalt availability. Thirty seven outbreaks of phalaris staggers were investigated within a 50 km radius of Orange over 15 years. A significant soil cobalt association trend was demonstrable for these outbreaks. A winter comparison of plant cobalt values for phalaris samples from 25 staggers free sites and 25 staggers prone sites failed to demonstrate any difference. All phalaris samples had very low cobalt values (<0.04 mg/kg). Livestock probably supplement their cobalt intake by ingesting soil. Pasture plant cobalt levels are very low from June to September. This period coincides with the occurrence of phalaris staggers on farms.

Key words: Phalaris, staggers, poisoning, livestock, alkaloid, cobalt, soil, rock.

Phalaris staggers is a nervous disorder that sometimes affects sheep and cattle when they graze *Phalaris aquatica* dominant pastures. Phalaris staggers is caused by the ingestion of tryptamine and beta-carboline alkaloids and can occur with any of the phalaris cultivars currently in use (2, 3). Although these alkaloids are always present in the plant, staggers only occurs on some phalaris paddocks and only in some seasons. Since 1953, it has been know that the regular ingestion of moderate amounts of cobalt by livestock, will prevent intoxication by the alkaloids that cause 'staggers' (6, 7, 8). In ruminants, dietary cobalt is essential for the rumen based synthesis of vitamin B12. This is one of a mixture of nine cobalt associated cobamamides and cobinamides synthesised by rumen microbes. Tryptamine and beta-carboline alkaloids are indole structures, and as such might be incorporated into a variety of cobamamide (or cobinamide)-like structures. Ingested cobalt may assist in the detoxification of the phalaris alkaloids by this process. The compounds produced would be physiologically inactive hence excreted in the faeces, rather than being absorbed from the gastrointestinal tract. It has been shown that sheep on very low cobalt diets use only 15 to 40% of ingested cobalt to produce useful cobamamides and cobinamides. If a diet is high in cobalt, much less still (as little as 3%) is used in this way (4, 11).

The variability in the incidence of phalaris staggers on different farms may be attributable to the influence of the soil cobalt status, or the soil cobalt availability. This could be achieved directly by altering the cobalt status of the plant, or indirectly by acting as an opportunistic oral cobalt supplement for livestock grazing these pastures. The cobalt status of a soil will be strongly associated with the cobalt status of the parent rock from which it is derived. Cobalt in rocks is magnesium associated, rocks rich in the dark coloured magnesium minerals hornblende, augite, and biotite, will also be rich in cobalt. The cobalt status of a variety of rock types is presented in Table?1.

Soil manganese levels can interfere with the availability of cobalt to plants (1). High soil manganese results in low cobalt availability to plants. The manganese content of a plant reflects the relative amount of manganese in the water soluble form in the soil in which it is growing. Consequently the same plant can have a manganese content of >1000 mg/kg when growing on a soil with high manganese availability but only 10 mg/kg when growing on a soil with very low manganese availability. Nicholls and Honeysett (10), and Adams *et al* (1), have compared the cobalt status of subterranean clover growing on krasnozems in Northern Tasmania with that on podzols in the same area. They found krasnozem plants had a mean value of 0.09 mg/kg, whereas podzol plants had a mean of 0.20 mg/kg. This was despite the fact that the krasnozem soils had a cobalt content of 5 to 89 mg/kg, whereas the podzols had only 0.18 to

32 mg/kg cobalt. They attributed the reversal in plant cobalt levels to the high manganese content of the krasnozems (340 to 12,600 mg/kg), compared with the podzols (18 to 2,280 mg/kg).

Table 1 cobalt status of different rock types

PARENT ROCK	ROCK SUB-TYPES	ROCK COBALT STATUS
Igneous	Basalt, Gabbro	High
?	Andesite, Diorite, Tuff	Moderate
?	Granite, Rhyolite, Porphyry	Low
Metamorphic	Gneiss, Schist	Moderate to low
?	Quartzite, Slate	Moderate to low
Sedimentary	Conglomerate, Shale, Greywacke	Moderate to low
?	Sandstone, Limestone	Very low?

Results and discussion

During the period 1981 to 1996, the Regional Veterinary Laboratory at Orange confirmed a diagnosis of phalaris 'staggers' on 37 occasions on farms located within a 50 km radius of Orange. Using the soil landscapes map of Kovac *et al* (5) it was possible to show a significant soil cobalt associated trend for these phalaris 'staggers' outbreaks. This trend is presented in Table 2. It was significant that no outbreaks of 'staggers' occurred on krasnozems, or the euchrozems of the Cudal landscape (basalt derived). This was despite the fact that both of these soil types occur in very close proximity to the Regional Veterinary Laboratory at Orange and represent as great an area sown to phalaris pastures as any of the other soil types listed. The cobalt status of these particular soils is greater than that of the other soil types listed.

Table 2 soil cobalt associated trend for phalaris ?staggers? outbreaks at Orange

SOIL TYPE	LANDSCAPES	PARENT ROCK	SOIL COBALT?	?STAGGERS?
Krasnozem	Spring Hill and Towac	Basalt	High	No
Euchrozem	Cudal Molong and Woodstock	Basalt Andesite, Tuff, Slate, Limestone	High Moderate to very low	No Yes

Red Earths	North Orange and Vittoria-Blayney	Andesite, Tuff, Shale, Greywacke	Moderate to low	Yes
Red Podsolics	Borenore-Lyndhurst, Panuara and Black Rock	Andesite, Tuff, Shale, Sandstone	Moderate to very low	Yes
Non-Calcic Brown	Bathurst, Manildra and Canowindra	Granite, Porphyry, Shale, Limestone	Low to very low	Yes
Soloths	Mullion Creek and Mookerawa	Slate, Shale, Schist, Greywacke, Conglomerate	Moderate to low	Yes

To investigate the possible influence of manganese on phalaris cobalt levels in Central NSW, phalaris samples were collected from 25 'staggers' free Orange district sites and compared with phalaris samples from 25 'staggers' prone Orange district sites. The phalaris pasture samples were collected in June (early winter), the plants sampled were 15 to 30 cm in height, the material was oven dried at $50^{0}C$ and then ground. The samples were sent to the state government analytical laboratory at Adelaide, South Australia for cobalt assay, and to the BCRI at Rydalmere, NSW for manganese assay. The 25 'staggers' free sites were on a krasnozem soil of the Spring Hill landscape (5). The 25 'staggers' prone sites were on a euchrozem soil of the Molong landscape (5).

The plant cobalt content was identical for both locations, with all phalaris samples recording cobalt levels of <0.04 mg/kg. These phalaris cobalt values are very low. The phalaris cobalt values recorded by Lee and Kuchel (6) on cobalt deficient sandy soils at Keith in South Australia ranged from 0.03 to 0.07 mg/kg. These pastures were frequently associated with phalaris staggers outbreaks in sheep flocks. Mitchell (9) cites pasture cobalt levels of < 0.04 mg/kg as likely to cause cobalt deficiency in sheep unless they have the additional option of ingesting soil with a significant cobalt content. Pasture cobalt levels of 0.05 to 0.08 mg/kg are regarded as marginal, and only levels > 0.08 mg/kg as adequate for the prevention of cobalt deficiency. On the basis of this data it could be anticipated that the prevention of phalaris staggers would require a dietary cobalt level of about 0.10 mg/kg or greater. Livestock grazing phalaris on the Spring Hill krasnozem may be supplementing their cobalt intake by ingesting significant amounts of cobalt in the form of soil. Livestock grazing phalaris on the Molong euchrozem would have more difficulty in meeting their cobalt requirements by this means because these soils have significantly lower levels of cobalt.

The plant manganese levels were approximately twice as high at the Spring Hill site compared with the Molong site. At Spring Hill the mean manganese value was 105 mg/kg and the range from 30 to 280 mg/kg. At Molong the mean manganese was 46 and the range 24 to 75 mg/kg. The manganese levels recorded for the phalaris growing at Spring Hill compared with that at Molong would suggest there is more available manganese in the Spring Hill krasnozem but that the total amount available was not particularly high. Consequently the low phalaris cobalt levels at both sites must reflect another soil factor. The availability of soil cobalt and manganese to plants decreases as the pH rises. This effect becomes increasingly noticeable as the pH rises above 5.25. Although the Molong soils (pH 4.6-5.0) are less acidic than the Spring Hill soils (pH 4.3-4.5) the effect of this on cobalt availability at these sites should be insignificant. There is a strong tendency for cobalt to associate with oxides of manganese in the soil. In the oxides of manganese, cobalt is present as Co^{3+} and manganese as Mn^{3+} and Mn^{4+}. To become available to plants these forms must be reduced to Co^{2+} and Mn^{2+} respectively. This process is microbially assisted and should occur in most well drained soils in Central and Southern NSW between November and March. In poorly drained soils it could also occur between July and September. The availability of cobalt and manganese in well drained soils would be anticipated to be lowest during the cold period of June to September.

Little information is available on variations in soil cobalt availability to plants throughout the growing season, but a similar trend to that observed with manganese would be anticipated. That is, the hot dry conditions of summer should favour cobalt availability, whereas the cold wet conditions of winter would be unfavourable to cobalt availability. A decline in availability would predictably occur during autumn (moist but warm conditions) and a rise in availability during spring (waterlogged but warm conditions). In a normal year in Central and Southern NSW, pasture cobalt levels would predictably be very low from June to September. The results of the phalaris cobalt assays in the present study are consistent with this, and this period correlates exactly with the most common months recorded for the first onset of phalaris 'staggers' outbreaks each year in Central NSW. Based upon the disease records of the Regional Veterinary Laboratory at Orange for the period 1981-1996, these 'staggers' outbreaks first occurred between June and September, even though the season of growth for phalaris commenced three months earlier than this (i.e. Feb-March) and even though 1 to 2 weeks of grazing phalaris pastures is all that is required to precipitate an outbreak of 'staggers'. The findings of this investigation have implications for the prevention of phalaris staggers. The recommended preventative strategies arising from it are summarised in Table?3.

Table 3 recommendations for the prevention of phalaris ?staggers?

SOIL PARENT ROCK	COBALT TREATMENT	NECESSITY OF TREATMENT	TIME TO TREAT
Limestone or Sandstone	Rumen bullets	Essential	All year around
Granite, Rhyolite or Porphyry	Rumen bullets	Strongly recommended	All year around
High Manganese Basalt or Gabbro	Lick block supplement	Optional	June to September
Moderate Manganese Basalt or Gabbro	None	Nil	Not at all
Other rocks	Lick block supplement	Recommended	June to September

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