The association of soil cobalt with the incidence of phalaris 'staggers', on phalaris pastures in Central NSW.

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Phalaris staggers is one of several forms of phalaris poisoning that can sometimes affect sheep grazing phalaris dominant pastures. It is caused by the ingestion of the tryptamine and beta-carboline alkaloids in this grass, and can occur with any of the phalaris cultivars currently in use (Bourke *et al* 1988 and 1990). 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'. Injected cobalt, or the administration of Vit B12 (a cobalt dependant vitamin), do not prevent phalaris 'staggers', but orally administered cobalt does (Lee *et al* 1953, 1956, and 1957). This indicates that the detoxifying action of cobalt occurs in the rumen, rather than elsewhere in the body, but it does not explain how cobalt achieves this outcome.

How cobalt might prevent staggers

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 they could be incorporated into a variety of cobamamide (or cobinamide)-like structures. Cobalt may detoxify these alkaloids by this process. These synthesised compounds would be physiologically inactive and neither absorbed from the gastrointestinal tract, nor used by the animal in any other way. It has already been shown that sheep on adequate cobalt diets produce only 3% of useful cobamamides and cobinamides, the other 97% are not absorbed and are excreted in the faeces (Gawthorne 1970, Smith and Marston 1970). When a diet is very low in cobalt only 15 to 40% of the ingested cobalt is used 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 (Gawthorne 1970, Smith and Marston 1970).

'Staggers' and soil type association at Orange

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* (1989-90) for the Bathurst 1:250,000 sheet, it is possible to show a significant soil cobalt associated trend for these phalaris 'staggers' outbreaks. There were 13 incidents on Non-Calcic Brown soils (Bathurst, Canowindra and Manildra landscapes), 14 incidents on Red Earths (North Orange and Vittoria-Blayney landscapes), 4 incidents on Red Podzolics (Panuara, Black Rock and Borenore - Lyndhurst landscapes), 4 incidents on Euchrozems (Molong and Woodstock landscapes), and 2 incidents on Soloths (Mookerawa and Mullion Creek landscapes). It was significant that no incidents occurred on Krasnozems (both Spring Hill and Towac landscapes occur within the 50 km radius), nor on Euchrozems of the Cudal landscape. This is despite the fact that Krasnozems occur in very close proximity to the Regional Veterinary Laboratory at Orange and represent as great an area, or an even greater area, sown to phalaris pastures, than any of the other soil types listed.

Soil cobalt is derived from parent rock cobalt

This pattern of phalaris 'staggers' outbreaks follows a predictable soil cobalt trend, based upon soil parent rock types and their relative cobalt contents. The Euchrozems exemplify this quite well, with 'staggers' occurring on Molong and Woodstock landscapes which are andesite, tuff, slate and limestone derived, hence low to moderate in cobalt content, but 'staggers' not occurring on the Cudal landscape which is basalt derived, hence predictably high in cobalt. Likewise, the Krasnozem soil landscapes are all basalt derived, hence high in cobalt, and not associated with phalaris 'staggers' incidents. The Non-Calcic Brown soil landscapes are either granite, porphyry, shale, or limestone derived. The Red Earths are andesite, tuff, greywacke, shale, or limestone derived. The Red Podzolics are andesite, tuff, shale, sandstone, or limestone derived. The Soloths are slate, greywacke, shale, schist, conglomerate, phyllite, or siltstone derived. All of these parent rock materials are only low to moderate in their cobalt content, consequently incidents of phalaris staggers would be anticipated on the soils derived from them .

Parent rock type will indicate 'staggers' risk

The relative cobalt status of soils in other districts hence the risk of phalaris staggers, can be predicted from a knowledge of the parent rock material from which they have been derived. The following trends will occur. Rocks high in magnesium containing minerals are high in cobalt. Igneous rocks of basalt or gabbro, which are rich in the dark coloured magnesium associated minerals hornblende, augite, and biotite, contain large amounts of cobalt. Igneous rocks of andesite or diorite, contain only moderate amounts of cobalt. Igneous rocks of granite or rhyolite, may contain small amounts of cobalt. Metamorphic rocks such as gneiss, schist, quartzite and slate, will contain moderate to low amounts of cobalt. Likewise sedimentary rocks such as conglomerate, shale, sandstone and limestone, will also contain only moderate to low amounts of cobalt. Sandstone and limestone (including dolomite) are usually very low in cobalt.

The cobalt and manganese association

Soil manganese levels can interfere with the availability of cobalt to plants. Soil manganese minerals are associated with the sorption of cobalt such that 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 ppm when growing on a soil with high manganese availability but only 10 ppm when growing on a soil with very low manganese availability. Nicholls and Honeysett (1964), and Adams *et al* (1969), have compared the cobalt status of subterranean clover growing on krasnozems in Northern Tasmania with that on podzols in the same area. They found the former had a mean value of 0.09 ppm, whereas the latter had a mean of 0.20 ppm. This was despite the fact that the krasnozem soils had a cobalt content of 5 to 89 ppm, whereas the podzols had a content of only 0.18 to 32 ppm. They attributed the reversal in plant cobalt levels to the high manganese content of the krasnozems (340 to 12,600 ppm), compared with the podzols (18 to 2,280 ppm). To address this possibility in Central NSW, phalaris samples were collected from a 'staggers' free Orange district location and compared with phalaris samples from a 'staggers' prone Orange district location for their cobalt and manganese content.

Cobalt and manganese content of phalaris at Orange

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 50^0C 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 sites sampled at the 'staggers' free site were on a krasnozem soil of the Spring Hill landscape as per the Bathurst 1:250,000 sheet of Kovac *et al* (1989). The 25 sites sampled at the 'staggers' prone site were on a euchrozem soil of the Molong landscape as per the Bathurst 1:250,000 sheet of Kovac *et al* (1989). The cobalt content was identical for both locations, with all phalaris samples recording cobalt levels of 0.04 ppm. The manganese levels were twice as high at the Spring Hill site compared with the Molong site. At Spring Hill the mean manganese value was 105 ppm and the range from 30 to 280 ppm. At Molong the mean manganese was 46 and the range 24 to 75 ppm.

The significance of phalaris cobalt values

These phalaris cobalt values are very low. The phalaris cobalt values recorded by Lee and Kuchel (1953) on cobalt deficient sandy soils at Keith in South Australia ranged from 0.03 to 0.07 ppm. These pastures were frequently associated with phalaris staggers outbreaks in sheep flocks. Mitchel (1945) cites pasture cobalt levels of 0.04 ppm 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 ppm are regarded as marginal, and only levels 0.08 ppm as adequate for the prevention of cobalt deficiency. It could be anticipated that the prevention of phalaris staggers would require a dietary cobalt level of about 0.10 ppm 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.

Factors affecting soil cobalt availability

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 are less acidic than the

Spring Hill soils the effect of this on cobalt availability at these sites should be insignificant. The former soils tend to have pH values of 4.6 to 5.0 and the latter 4.25 to 4.5. 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 are unfavourable to cobalt availability (possibly as low as 10-20% of summer levels). 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.

Seasonal correlations between cobalt availability and 'staggers'

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 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. On the same basis the availability of cobalt and manganese would be anticipated to be at their lowest during the cold period of June to September. 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 commences three months earlier than this (*ie.* Feb-March) and even though 2 to 3 weeks of grazing phalaris pastures is all that is required to precipitate an outbreak of 'staggers'.

Conclusions

If phalaris pastures are being grown on soils derived from either limestone or sandstone parent rock materials, the use of rumen cobalt bullets is essential to avoid significant problems with phalaris 'staggers' in sheep and cattle. In addition, if phalaris pastures are being grown on soils derived predominantly from granite or rhyolite, regardless of whether the parent rock is in the igneous, metamorphic or sedimentary form, then the use of rumen cobalt bullets is strongly recommended. Livestock grazing phalaris pastures growing on soils derived from other parent rock materials, with the exception of those that are basalt or gabbro derived, should ideally receive some form of dietary cobalt supplementation during the months of June, July, August and September, for example lick blocks that have cobalt incorporated into them. Livestock grazing phalaris pastures growing on basalt or gabbro derived soils that have a high manganese content will also benefit from dietary cobalt supplementation in the winter months. Livestock on basalt or gabbro derived soils that have only a moderate to low manganese content, should not require any cobalt supplementation and should be able to graze these phalaris pastures without the risk of developing phalaris 'staggers'.

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