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CERTAIN POISONOUS PLANTS OF WYOMING ACTIVATED BY SELENIUM AND THEIR ASSOCIATION WITH RESPECT TO SOIL TYPES.

BY O. A. BEATH, J. H. DRAIZE, H. F. EPPSON, C. S. GILBERT AND O. C. MCCREARY.

In 1917, the senior author published a brief treatise[1] on the poisonous properties of the two-grooved milk vetch (*Astragalus bisulcatus*). The toxic principles

[1] Wyoming Experiment Station Bulletin 112.

were reported to be soluble in water and not found to be precipitated by basic acetate of lead. Studies and observations made since that time led to the publication of an experiment station bulletin[1] in May 1932, on "Three Poisonous Vetches," by Beath, Draize and Eppson. The authors pointed out that *A. bisulcatus* collected in some areas had an extremely offensive odor, while in other places this feature was lacking entirely. It was further stated that this variation was in a degree due to soil and climatic factors. From the viewpoint of experimental physiological data it was pointed out that at the "past-seeding stage" *A. bisulcatus* plants produced an accumulative type of poisoning accompanied by severe irritation to the gastro-intestinal tract. Members of the chemical research staff then set about to determine the reasons for such behavior in *A. bisulcatus* and other poisonous plants associated with it in habits of growth.

It has now been demonstrated that those *A. bisulcatus* plants yielding a decidedly offensive odor are more toxic than plants of this species lacking in this characteristic. The only variable factor contributing to this difference, so far determined, is the presence of selenium.

With the coöperation of the State Geologist, Dr. S. H. Knight, and his staff, a correlation of some range plants bearing selenium has been made in conjunction with the geological formation upon which the plants grow. Three species of Astragali, *A. bisulcatus*, *A. Grayi* and *A. pectinatus*, *Xylorhiza Parryi*, *Oonopsis condensata*, *Stanleya bipinnata* and *Mentzelia decapetala* represent at this point in our investigations definite indicator plants that have shown the constant presence of selenium when collected on one or more of the following formations: Niobrara, Steele, Pierre, Morrison, Wasatch (as represented by Cooper Basin), Benton, Hilliard-Cody, Lewis, Bridger, and the dark band of the Dakota. These formations are mostly shale. The so-called indicator plants are the richest in selenium when they occur on the undecomposed shale. The element selenium is distributed throughout the entire makeup of these plants. The amount in the above-ground portion of a plant exceeds that found in the root system and quantitatively[2] varies from a trace to a tenth of one per cent selenium (air-dry basis). Poisonous range plants, containing selenium, occurring on the Niobrara, Steele or Pierre shales are more poisonous to live stock, on the average, than the same plants found on the other formations listed above. Whether or not, or to what extent *Stanleya bipinnata*, *Mentzelia decapetala*, *Oonopsis condensata*, *Astragalus pectinatus* and *A. Grayi* are poisonous to live stock when occurring as selenium-free plants has not been determined. *Xylorhiza Parryi* (woody aster) adheres so closely in Wyoming to definite shale zones that the authors have been unable to collect woody aster, selenium-free, in sufficient amounts to conclude feeding trials. Out of twenty-five samples collected in various sections of the state twenty-three were found to contain varying amounts of selenium, depending upon the geological formation from which collections were made. Selenium in woody aster is presumably combined with a toxic saponaceous[3] compound.

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[1] Wyoming Experiment Station Bulletin 189.

[2] Essentially the method of M. Taboury, "Sur la presence accidentelle du selenium dans certains vegetaux," *Compt. rend.*, 195 (1932), 171.

[3] A. J. Ewart, "The Poisonous Action of Ingested Saponins," Council for Scientific and Industrial Research, Melbourne, Australia, 50 (1931), 18.

It is known that *Astragalus bisulcatus* free from selenium is poisonous to live stock, although very much less so, as brought out in this experiment: Forced feeding trials demonstrated that fifty ounces of green *A. bisulcatus* (blooming) selenium-free, per hundredweight of sheep failed to seriously affect an animal, whereas twenty-five ounces per hundredweight of sheep of the same plant, same stage of growth, containing selenium, produced death in a few hours.

The toxic principle or principles of five out of seven of the selenium-bearing range plants (*Astragalus bisulcatus, A. Grayi, A. pectinatus, Oonopsis condensata, Xylorhiza Parryi*) may be extracted freely with water. Similar data for *Stanleya bipinnata* and *Mentzelia decapetala* have not been obtained. This physical aspect introduces a problem of economic significance because it is evident that through the annual decay of the foliage, seeds and roots of these selenium-bearing plants a considerable amount of this element goes back to the soil in a form readily available to any vegetative growth. Water extracts of green *A. bisulcatus* mixed with crude undecomposed Niobrara shale in experimentally controlled plats imparted to barley grown on these plats recognizable amounts of selenium. Barley grown on the same shale composite without the addition of the vetch extract was found not to contain selenium.

Grasses (native) growing in close proximity to type selenium-bearing range plants were found poisonous to guinea pigs when these pigs were allowed to feed on such areas.

Vicia linearis, Thermopsis divaricarpa, Solidago mollis, Melilotus sp., *Iris missouriensis, Juncus balticus* and some native grasses represent a partial list of plants that have been found to contain selenium which were apparently influenced by those plants yielding soluble selenium compounds. This conclusion is based upon the fact that our tests have failed to detect selenium in this same series of plants taken from uncontaminated shales. It is not to be inferred that only the indicator plants listed take up selenium from the original shales. The authors, however, wish to point out the unique selectivity for selenium shown by certain native plants. Among the Astragali closely allied with *A. bisulcatus, A. Grayi* and *A. pectinatus* ecologically may be mentioned *A. carolinianus, A. flexuosus* and *A. Drummondii*, and yet careful tests have failed in detecting the presence of selenium in these last-named vetches.

The following is a partial list of representative plants collected on well-defined shales found to be negative for selenium:

Erigeron microlonchus, Scirpus sp., Glycyrrhiza sp., Sporobolus sp., Glaux maritima, Sarcobatus vermiculatus, Medicago sativa, Artemisia frigida, Arenaria Hookeri, Sium cicutaefolium, Cicuta occidentalis, Delphinium Geyeri, Zygadenus gramineus, Senecio sp., Musineon sp., Oxytropis sp., Chrysothamnus sp., Eurotia lanata, Valeriana sp. and *Plantago sp.*

SELENIUM POISONING.

The fact that a selenium-bearing plant like *Astragalus bisulcatus* has, so far as our studies have gone, given a positive reaction for selenium when collected on either the basal, mid or top zone of a representative shale, *e. g.*, Steele, would sug-

NOTE: *Atriplex Nuttallii* (salt bush) occurring in close proximity to the unaltered Niobrara shales has been found to contain selenium in varying amounts irrespective of other plant associations.

gest that selenium is not restricted to limited areas in these shales. Its original occurrence in such a comparatively few range plants further suggests the firmness with which it must be combined in the soil.

There appear to be several manifestations of selenium poisoning of live stock. Live stock grazing upon selenium-bearing plants may exhibit slightly different types of poisoning, depending upon the species of such plant ingested. Since such variations do occur, it would seem evident that one of two conditions applies. *First*, the various selenium-bearing plants may carry the element in different chemical combinations, or *second*, the selenium may be present in all plants in a similar chemical combination but the presence of other toxic substances may account for variations in the manifestations of poisoning.

In Wyoming the live stock exhibiting this general type of poisoning reveal the following symptoms and lesions at autopsy: The animals, particularly cattle, exhibit early in the stage of poisoning a dullness and a lack of vitality. It is evident early in the stage of poisoning that there is a stasis of the gastro-intestinal tract. There is considerable abdominal pain, with grunting, grating of teeth and salivation. Shortly before the paralytic stage animals exhibit excitement, with a tendency to constantly wander, often aimlessly in circles. The animal may or may not show impairment of vision. Prior to death the animal exhibits varying degrees of paralysis, which becomes serious when it involves the swallowing mechanism. In the cases observed by the authors the immediate cause of death was failure of the respiration.

In general the autopsy findings of animals dying on the range of "Blind Staggers" (the term used locally to denote this type of poisoning) or of the experimental animals dying from the administration of small quantities of the sodium salt of selenious acid are in fair agreement. The parenchymatous organs exhibit varying degrees of congestion, indicating a failing heart and circulation. In cattle the stomachs, particularly the rumen, suggest a rather severe stasis. The entire gastro-intestinal tract exhibits varying degrees of irritation, leading in some cases to hemorrhage. The liver is often severely congested and the gall bladder distended with bile which may or may not exhibit normal color and consistency. The bladder is usually distended with urine. Whether the above conditions are due to lack of smooth muscle tone is not known. Acutely poisoned animals resulting from one exclusive feeding show no marked pathology.

The acute and chronic forms of poisoning mentioned above are responsible for heavy annual live stock losses in Wyoming.

In a recent article in *Science* on "Selenium as an Insecticide"[1] a form of selenium poisoning is reported which would appear to be quite a different form than that noted with the selenium-bearing range plants of Wyoming. The disease referred to in this article is not known to be common in this state, but where cereals, hay, etc., have produced it there is considerable evidence available which indicates that such selenium-carrying feeds were grown upon geological formations which had previously carried a stand of native selenium-bearing plants or had been contaminated by irrigation waters and rains passing over and through soils contaminated by woody aster, vetches, etc.

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[1] E. M. Nelson, A. M. Hurd-Karrer and W. O. Robinson, *Science*, 78 (1933), 124.