Plant Poisoning of Small Ruminants

Anthony P. Knight, *BVSc, MS, MRCVS, DACVIM*
College of Veterinary Medicine & Biomedical Sciences, Colorado State University, Fort Collins, CO

Abstract

Sheep goats, llamas and alpacas are in general, capable of grazing or browsing a wide variety of toxic plants without any problem. So long as there are a variety of plants on which the animals can feed, they appear capable of varying the quantity of plants consumed, thereby avoiding a toxic dose of any one particular plant. However, small ruminants are susceptible to plant poisoning under conditions where there is overgrazing, drought, or access to areas where toxic weeds predominate. Historically, and even today, significant mortality in unadapted sheep can be associated with areas where plants such as Halogeton (*Halogeton glomeratus*) comprise the majority of the available forage. The Halogeton is palatable, and if it becomes the predominant forage, high sheep mortality results from the high level of oxalates in the plant. Small ruminants are susceptible to poisoning from plants that contain nitrates, cyanogenic glycosides, cardiac glycosides, photosensitizing agents and a variety of other plants toxins affecting the reproductive, urinary, hemic and nervous systems.

Introduction

Small ruminants can be used as biological controls for noxious and poisonous plants because of their ability to graze and browse on toxic plants without apparent ill-effect. Flocks of sheep or herds of goats can successfully depopulate an area of plants in a short period, thereby controlling the plant's growth, seed production and biomass available to other animals. Sheep and goats are used to control noxious weeds such as leafy spurge (*Euphorbia esula*), Russian knapweed (*Acroptilon repens*), fringed sage (*Artemisia frigida*), field bindweed (*Convolvulus arvense*) and oak brush (*Quercus specie*). This is possible because they consume relatively small quantities of the plants because the density of animals eating the problem plant reduces the total amount of plant consumed by an individual animal. In addition, sheep and goats have rumen microflora that rapidly adapt to variations in diet, enabling metabolism of plant toxins faster than larger herbivores. An example of this is the ability of sheep to thrive on a diet purely of cull onions, while cattle on a ration with more than 20% onions will develop a fatal Heinz-body anemia. Sheep are susceptible to the toxic effects of N-propyl disulphide in onions and develop Heinz-body anemia, but after a short period on the onion diet the proportion of sulfur-reducing (*Desulfovibrio* spp) organisms in the rumen increase rapidly, and are able to metabolize toxic N-Propyl disulfide, therefore preventing the development of fatal anemia. Similarly sheep and goats are able to eat 300% more tansy ragwort (*Senecio jacobaea)* than cattle without developing pyrrolizidine alkaloid poisoning because rumen microorganisms metabolize the alkaloids. Sheep can adapt to forage high in oxalates (*Halogeton glomeratus*) through the rapid proliferation of oxalate reducing bacteria in the rumen when rumen oxalate levels increase as sheep are allowed to gradually increase the quantity of plant consumed over several days.

Drought conditions, over-grazing and poor pasture or range management contribute to plant poisoning of sheep, goats, camelids and other animals. Plant poisoning should be considered a year-round problem because toxic plants may be incorporated in hay and can cause poisoning during the winter when plant poisoning would be least expected. A wide variety of indigenous and introduced plants have been associated with plant poisoning of small ruminants. This paper will address plant poisoning in small ruminants in North America, categorizing the major toxic plant toxicities by the most common clinical presenting sign.

Plants Causing Sudden Death

Nitrate Poisoning

Most common weeds and crop plants can accumulate significant levels of nitrate and are a risk to all ruminants, especially if the plants are rapidly growing, droughted, heavily fertilized, or have been treated with herbicides. Annual weeds, crop plants and legumes are the most likely sources of nitrate poisoning for ruminants. Water nitrate levels can add to the toxic effects of plant nitrates.

Plant nitrates are reduced in the rumen in a series of steps from nitrate to nitrite, to ammonia and eventually to microbial proteins. It is the rapid formation and absorption of large quantities of nitrite (NO_2) that causes poisoning. The rate at which nitrate is converted to nitrite depends on the rate of adaptation of rumen microorganisms to nitrate, and the rate and amount of nitrate ingested. Carbohydrates such as corn enable rumen microorganisms to rapidly convert nitrates to

ammonia and microbial proteins without accumulation of nitrite. Conversely, low-energy diets increase an animal's susceptibility to nitrite poisoning. Experimental data suggest that nitrate poisoning is more likely to occur in ruminants after several days of feeding forages high in nitrate as more nitrite is produced. The amount of nitrate that can be safely consumed in forages is 45 g nitrate/100 lb body weight. Plants or hay containing more than 1% nitrate (10,000 ppm) dry matter are potentially toxic and should be fed with caution, especially to pregnant animals. Plants containing over 200 ppm of nitrate should be considered potentially toxic to pregnant animals. Forages containing more than 1% nitrate should only be fed if the total nitrate intake can be reduced to less than 1% by diluting the nitrate forage with nitrate-free forages, or if the diet is supplemented with a concentrate carbohydrate.

Nitrate Unit Conversions

Nitrate ppm = nitrate mg/kg = nitrate mg/l
% nitrate x 10,000 = ppm ppm x 0.0001 = % nitrate
Nitrate nitrogen (N0-N) x 4.45 = nitrate

The nitrite ion rapidly reacts with hemoglobin, oxidizing it to form methemoglobin, which is incapable of oxygen transport. Once 30-40% or more of hemoglobin is converted to methemoglobin, clinical signs of poisoning develop. Brownish discoloration of the mucous membranes occurs when 20% or more methemoglobin has formed. This brownish discoloration occurs well before other clinical signs become evident. Death occurs as methemoglobin levels approach 80%. Sheep and goats appear to be less susceptible to nitrate poisoning than cattle, while camelid species are rarely affected.

Fetal death and abortion may occur at any stage of gestation as a result of the combined effects of decreased placental oxygen transport and the limited ability of the fetus to metabolize nitrite. Sub-lethal doses of nitrate induce abortion because nitrate readily crosses the placenta and causes fetal methemoglobinemia, as well as decreased progesterone production induced by impaired luteal production of progesterone.

The best sample to collect for nitrate analysis is aqueous humor. Nitrate levels in aqueous humor of 20 - 40 ppm should be considered suspect, and over 40 ppm diagnostic of nitrate poisoning if typical clinical signs are present, and evidence of high nitrate levels is found in the forage and/or water.

Treatment of nitrate poisoning is best accomplished with methylene blue (4 - 15 mg/kg body weight administered as a 2 - 4% solution). In sheep, the half-life of methylene blue is about two hours, indicating that small doses of the solution can be repeated as needed every few minutes to reduce methemoglobinemia and the severe respiratory distress. Oxygen to optimize oxygen saturation of remaining hemoglobin is beneficial. In severe cases, epinephrine intravenously may counter the hypotensive effects of the nitrite. A gallon of cold water with added broad-spectrum antibiotics given via stomach tube will decrease nitrate reduction by rumen microorganisms. Similarly dilute vinegar given orally via stomach tube will help prevent nitrate reduction in the rumen.

Plants Containing Cyanogenic Glycosides

Ruminants in general are more susceptible to hydrogen cyanide (HCN) poisoning from plant cyanogenic glycosides than other species because rumen microorganisms contain the enzymes b-glucosidase and hydroxynitrile lyase that in the presence of water reduce the cyanogenic glycosides to HCN. Enzymatic conversion of the glycosides is enhanced when plant cells are damaged or stressed as occurs when the plant is chewed, crushed, droughted, wilted, or frozen. In the process, the glycosides, which are normally isolated in cell vacuoles, come into contact with the cell enzymes and HCN is produced. Most parts of the plant contain cyanogenic glycosides; the young rapidly growing portion of the plant and the seeds attain the highest concentrations. Once formed, HCN is rapidly absorbed from the digestive tract and has a strong affinity for binding with trivalent iron of the cytochrome oxidase molecule, thus inhibiting its enzymatic action and preventing cellular respiration. The lethal dose of HCN is in the range of 2 to 2.5 mg/kg body weight. If other plant material and carbohydrates are present in the rumen, formation and absorption of cyanide may be slowed, allowing animals to tolerate higher doses.

At least 2000 plant species are known to contain cyanogenic glycosides with the potential for causing cyanide poisoning. Those that are more commonly associated with poisoning in ruminants are listed below.

Botanical name	**Common name**
Acacia species	Acacia, cat claw
Amelanchier alnifolia	Service, or June berry
Cercocarpus spp	Mountain mahogany
Linum spp	Flax
Lotus spp	Bird's foot trefoil
Malus spp	Crab apples
Prunus spp	Choke cherry
Sambuccus spp	Elderberry
Sorghum spp	Johnson, Sudan grass (Figure 1)
Suckleya suckleyana	Poison Suckleya
Triglochin maritima	Arrow grass

Common cultivated plants are a source of cyanide poisoning because clippings, branches, etc., may be fed to small ruminants. Common garden plants that con-

Figure 1. Johnson grass (*Sorghum halapense*).

tain cyanogenic glycosides include hydrangea, roses, all cherry (*Prunus*) species, heavenly bamboo (*Nandina domestica*), lima or butter bean (*Phaseolus* spp.), Christmas berry (*Photinia* spp) and broom corn (*Sorghum bicolor*).

The most frequent presenting sign of acute cyanide poisoning is sudden death. If observed early, poisoned animals show rapid labored breathing, frothing at the mouth, dilated pupils, ataxia, muscle tremors and convulsions. The heart rate is usually increased and cardiac arrhythmias may be present. The mucous membranes are bright red in color because oxygen saturates the hemoglobin. Cyanosis of the mucous membranes occurs terminally when the animal's tissues become depleted of oxygen.

Levels of cyanide in liver or blood exceeding 1 ppm are diagnostic for cyanide poisoning. Cyanide poisoning can be confirmed by demonstrating toxic levels of HCN in the rumen content and the suspect plants. Plant material containing more than 20 mg HCN/100 g is potentially toxic to all animals. Liver or blood levels greater than 1 ppm are highly suggestive of cyanide poisoning. The most diagnostically significant HCN levels can be obtained from the brain and ventricular myocardium. Levels of HCN in excess of 100 mg/100 g wet tissue are diagnostic of cyanide poisoning.

The intravenous administration of a mixture of 1 ml of 20% sodium nitrite and 3 ml of 20% sodium thiosulfate given intravenously per 100 lb of body weight is an effective treatment for cyanide poisoning. The dose may be repeated after a few minutes if the animal does not respond. Equally good results have been obtained in sheep experimentally poisoned with cyanide by administering 660 mg/kg sodium thiosulfate and 22 mg/kg sodium nitrite intravenously. It is also beneficial to administer a solution of sodium thiosulfate (1-5 gm for adult sheep) orally via stomach tube to detoxify free cyanide still present in the rumen. Animals suspected of consuming cyanogenic plants but that show no clinical signs should also receive oral sodium thiosulfate prophylactically. Administering 0.5-1.0 liters of a diluted vinegar solution via stomach tube (one gallon of vinegar diluted in 3 to 5 gallons of water) will help acidify the rumen and reduce the production of hydrogen cyanide.

Water Hemlock (*Cicuta douglasii*) poisoning

Water hemlock is perhaps the most poisonous of indigenous plants in North America. (Figure 2). All parts, but especially the roots, of water hemlock contain cicutoxin ($C_{17}H_{22}O_2$), a highly unsaturated alcohol, one of the most toxic naturally occurring plant compounds known. The newly emerging plant in the spring of the year is the most toxic, whereas the mature leaves in late summer seem to have minimal toxicity. The tuberous roots are always very toxic. The lethal dose of fresh green water hemlock (*C. douglasii*) is 2 oz for adult sheep. When dosed with 6.4 g/kg of hemlock tuber, sheep develop severe seizures and die in about 90 minutes. Consequently, most animals that have eaten a lethal dose of water hemlock are seldom seen clinically, and are usually found dead. Death occurs from acute myocardial necrosis and respiratory failure. There is no specific antidote, but, if seen in the early stages of intoxication, and the animal is anesthetized immediately, recovery may be expected as the anesthetized animal does not experience myocardial degeneration as severe as conscious animals.

Figure 2. Water hemlock (*Cicuta douglasii*).

Poison Hemlock (*Conium maculatum*)

Poison or spotted hemlock is a noxious weed introduced from Europe. (Figure 3). It contains two toxic alkaloids, coniine (mature plant and seeds) and g-coniceine (young growing plant), that block spinal cord reflexes. After an initial stimulatory effect, the autonomic nervous system ganglia become depressed. Salivation, abdominal pain, muscle tremors and incoordination will occur initially, followed by difficulty in breathing, dilated pupils, weak pulse, and frequent urination and defecation. In sheep, 10 g/kg body weight of *Conium* is lethal but there is variability in the toxicity of the plant, depending on growing conditions.

In small quantities, poison hemlock causes birth defects by decreasing fetal movements *in utero*. Lambs born to ewes fed poison hemlock from 30 to 60 days of gestation showed varying degrees of excessive carpal joint flexure and lateral deviation that corrected itself by the time the lambs were two months old. Sheep appear to be quite tolerant of the teratogenic and toxic effects of poison hemlock compared to cattle.

Cocklebur (*Xanthium* spp) poisoning

Cocklebur seedlings that have the cotyledons attached (2-4 leafed stage; Figure 4) contain carboxyatractiloside that causes acute diffuse necrosis of the liver. A lethal dose of cocklebur seedlings for sheep is 2% of the animal's body weight. Animals that have eaten a toxic dose of cocklebur seedlings are seldom seen alive because of the severity of the liver necrosis. Cockleburs are most likely a hazard to livestock in the spring or late summer when large numbers of the burs germinate at once, as might occur at the receding waters edge in a pond or reservoir. The plants are prolific seed producers!

Figure 3. Poison or spotted hemlock (*Conium maculatum*).

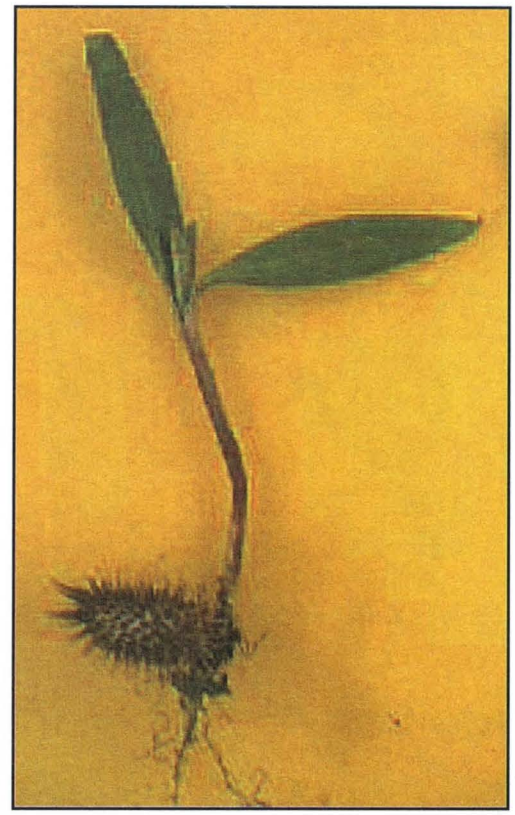

Figure 4. Cocklebur (*Xanthium strumarium*) Toxic "2-leafed" stage.

Plants causing cardiac abnormalities

A diverse group of plants found growing wild or as cultivated ornamentals can be a problem to animals, and should be considered when an animal is found dead, or is severely hypotensive, with bradycardia and dysrhythmias.

As*clepias* spp	Milkweeds (Figure 5)
Amianthium muscaetoxicum	Stagger grass
Kalmia spp	Laurel (Figure 6)
Nerium oleander	Oleander
Ornithogallum umbellatum	Starof Bethlehem
Pieris japonicus	Japanese pieris
Rhododendron spp	Rhododendron, azalea
Taxus spp	Yew
Zephranthes atamasco	Rain lily
Zigadenus spp.	Death Camas (Figure 7)

Plants producing neurologic signs

Some 370 species of the genera *Astragalus* and *Oxytropis,* collectively known as locoweeds, vetches, or milk vetches, occur in the arid regions of North America (Figure 8). Locoweeds cause more economic losses to the livestock industry than all other plant-induced toxicities combined. Many locoweeds contain the alkaloid

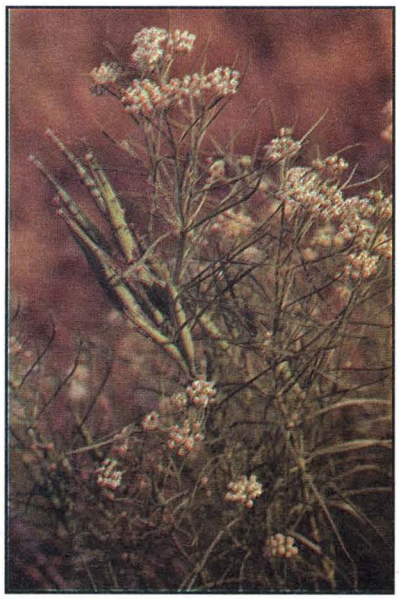

Figure 5. Whorled milkweed (*Asclepias subverticillata*).

Figure 6. Laurel (*Kalmia* spp).

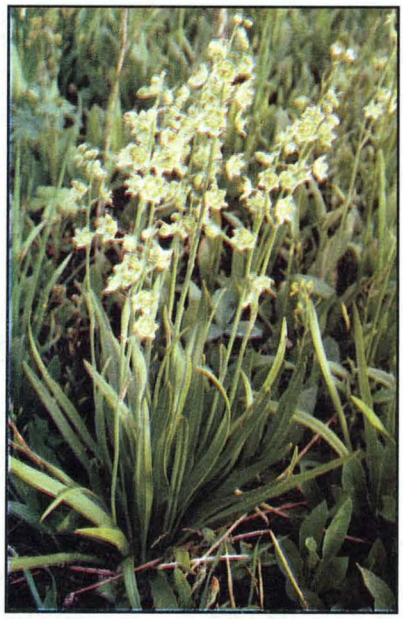

Figure 7. Death camas (*Zigadenus venosus*).

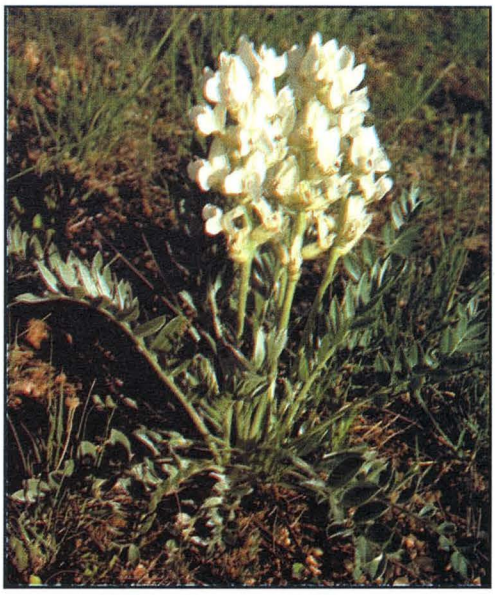

Figure 8. White locoweed (*Oxytropis sericea*).

swainsonine that is produced by endophytic fungi (*Alternaria* spp) that has a symbiotic relationship with the locoweed plant. Swainsonine acts by inhibiting the action of two lysosomal enzymes (alpha-mannosidase and Golgi mannosidase II) that aid in the metabolism of saccharides. Consequently, oligosaccharides accumulate in the cells of the brain and many other organs, interfering with normal cellular function and causing a generalized lysosomal storage disease. Although affected sheep show abnormal behavior and weight loss, the greatest effect of swainsonine is on reproduction.

Lambs born to locoweed-poisoned ewes may be born alive but weak, and often die after a few days. Others may be smaller than normal or have deformities of the limbs and head. Rams consuming locoweed (*A. lentiginosus*) for prolonged periods undergo testicular atrophy with decreased spermatogenesis. Abnormal sperm and decreased motility of sperm are attributable to cytoplasmic vacuolation of the seminiferous tubules, epididymis and vas deferens. These changes are transitory and disappear after 70 days once locoweed is removed from the diet.

Normal placentation may be affected causing fetal resorption, abortion, or hydrops allantois. The placenta appears to be most susceptible to the effects of locoweed during the first 90 days of pregnancy, but may be affected at any stage.

White snake root (*Eupatorium rugosum*)

Common in the northeastern states, white snake root (Figure 9) contains tremorgenic toxins that induce muscle tremors, myodegeneration and death. Tremorgenic toxins are also found in rayless goldenrod (*Haplopappus heterophylus*), Jimmy fern (*Notholaena*

Figure 9. White snake root (*Eupatorium rugosum*).

sinuata), western mountain laurel (*Sophora secundiflora*) and silky sophora (*Sophora sericea*).

Various fungi growing on plants produce tremorgenic toxins that cause muscle tremors in livestock that can resemble those encountered in white snakeroot poisoning. Fungal tremorgens include those produced by the fungus *Claviceps paspalli* in Dallis grass (*Paspalum dilitatum*) and Bahia grass (*Paspalum notatum*). Perennial ryegrass (*Lolium perenne*) staggers is caused by the endophytic fungus *Acremonium loliae*, whereas annual ryegrass (*Lolium rigidum*) staggers is caused by a toxin produced by a bacterium (*Corynebacterium rathayi*) growing on the grass. Bermuda grass (*Cynodon dactylon*) and Phalaris or canary grass (*Phalaris* spp) staggers are similar to other tremorgenic syndromes.

Caltrop (*Kallstroemia* spp)

Sheep and goats are susceptible to poisoning when they eat large quantities of caltrop, a plant of the southern states from Florida to Texas (Figure 10). The toxin is not known, and affected sheep develop weakness of the hind legs and knuckling of the fetlock joints. Paralysis of the hind legs and convulsions occur before death.

Figure 10. Caltrop (*Kallstroemia* spp).

Coyotillo (*Karwinskia humboldtiana*)

Coyotillo, a shrub of the southwestern states, contains unknown toxins that cause nervous signs characterized by progressive impaired function of the cerebellum and peripheral nerves. Goats poisoned with coyotillo show hypersensitivity to stimuli, muscle tremors, tachypnea and a high stepping gait with exaggerated flexing of the legs develops. A progressive polyneuropathy causes a progressive decrease in neuromuscular reflexes, with paralysis developing especially in the rear quarters. Segmental demyelination, degeneration of axons in peripheral nerves and myodegeneration are characteristic.

Other neurotoxic plants that have the potential to affect small ruminants include Kentucky coffee tree (*Gymnocladus dioecea*), Carolina Jessamine (*Gelsemium sempervirens*), Carolina allspice (*Calycanthus* spp), golden chain tree (*Laburnum anagyroides*), buckeye (*Aesculus* spp) and bracken fern (*Pteridium aquilinum*).

Teratogenic and abortifacient plants

Western false hellebore (*Veratrum tenuipetalum*)

Pregnant ewes, does or llamas that consume false hellebore (Figure 11) in the first month of gestation will produce lambs, kids, or crias with shortened legs, cyclopia, or tracheal agenesis. Lambs with cyclops result from the pregnant ewe consuming Veratrum during days 12 and 13 of gestation. Tracheal agenesis is associated with the ewe eating the plant around days 30-32 of pregnancy.

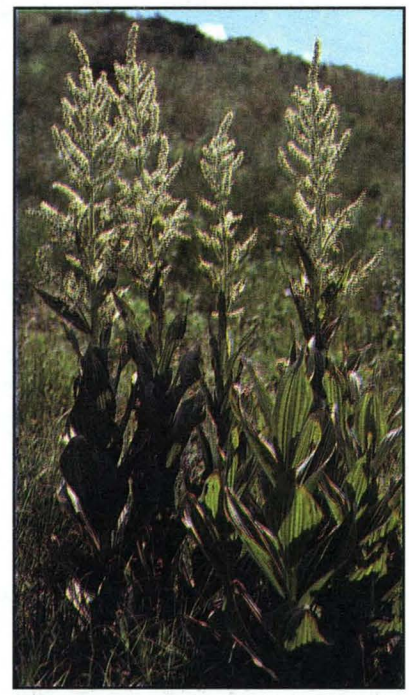

Figure 11. Western false hellebore (*Veratrum tenuipetalum*).

Broom snake weed *(Gutierrezia sarothrae)*

Broom snakeweed is an indigenous plant of dry alkaline soils of the intermountain and southwestern states that contains saponins capable of causing abortion in sheep and cattle, and severe hepatopathy.

Other teratogenic plants affecting small ruminants include locoweeds (*Astragalus* and *Oxytropis* spp), tree tobacco (*Nicotiana glauca*), cultivated tobacco (*Nicotiana tabacum*) and poison hemlock (*Conium maculatum*).

Lupine (*Lupinus* spp), common wild flowers in the western states, are not commonly teratogenic to sheep as they are to cattle. Pregnant goats consuming lupine in early gestation are susceptible to teratogenicity, including cleft palate and limb deformities.

Plants causing vomiting

Bitterweeds (*Helenium* spp, *Hymenoxys richardsonii*)
Orange sneezeweed (*Dugaldia hoopesii*) (Figure 12)

Bitterweeds and sneezeweeds contain sesquiterpene lactones that have an irritant effect on the digestive tract causing projectile vomiting ("spewing sickness") in sheep that eat the plants. Weight loss and inhalation pneumonia make sneezeweed a significant problem in over grazed range conditions

Plants causing photosensitization

Small ruminants are not as susceptible to pyrrolizidine alkaloid containing plants, such as groundsels (*Senecio* spp; Figure 13) and hounds tongue (*Cynoglossum officinale*; Figure 14), because they have anerobic rumen microorganisms that metabolize the alkaloids before they reach the liver. For this reason sheep and goats can be used to graze plants like tansy ragwort as a means of controlling the weeds. Sheep are, however, susceptible to pyrrolizidine alkaloid poisoning if their rumen microflora is overwhelmed by the quantity of alkaloid.

Figure 12. Orange sneeze weed (*Dugaldia hoopesii*).

Figure 13. Tansy ragwort (*Senecio jacobaea*).

Figure 14. Hounds tongue (*Cynoglossum officinale*). Inset shows flower and adherent seeds.

Primary photosensitizing plants such as buck wheat (*Fagopyrum esculentum*) and Klamath weed or St Johns wort (*Hypericum perforatum*) will induce photosensitization in small ruminants.

Sheep and goats are susceptible to a group of saponin containing plants that cause cholecystitis and biliary occlusive photosensitization. Lantana (*Lantana camara*), agave, (*Agave lecheguilla*), bear grass (*Nolina texana*) and puncture vine (*Tribulus terrestris*) are the

plants most commonly associated with this form of secondary photosensitization. Sheep develop photosensitivity (big head) when eating horse brush (*Tetradymia* spp). Photosensitization occasionally occurs in goats being fed rape or alsike clover.

Plants causing renal failure

Sheep or goats exhibiting azotemia, hypocalcemia and death with evidence of pale kidneys and generalized tubular nephrosis at post-mortem should be suspected of having consumed plants high in oxalates. The most troublesome oxalate containing plant is Halogeton (*Halogeton glomeratus,* Figure 15), a noxious weed in the high alkaline desert soils of the western United States. Grease wood (*Sarcobatus vermiculatus*), curly leafed dock (*Rumex crispus*), rhubarb (*Rheum rhaponticum*), pigweed (*Amaranthus* spp), and purslane (*Portulacca oleraceae*) are common plants that have high oxalate content.

Figure 15. Halogeton (*Halogeton glomeratus*). Inset shows detail of the leaves with a characteristic terminal hair.

Oaks (*Quercus* spp) contain gallotannins that are strong astringents and cause tubular nephrosis and hemorrhagic gastroenteritis. Small ruminants can be poisoned by eating large quantities of leaves or acorns. Goats once adapted to eating oak are effective browsers of oak and have been used to control red oak in the southeastern states.

Miscellaneous toxic plants

Avocado (*Persea americana*)

Goats consuming as little as 30g/kg body weight of avocado leaves develop hard, swollen, edematous udders with thick clotted milk and high somatic cell counts. Non-inflammatory necrosis of the mammary gland and myocardium are typical of avocado toxicity.

Poison ivy, Poison oak (*Toxicodendron* spp)

Sheep and goats have been used to control poison ivy without any detrimental effects. The toxin in poison ivy, urushiol, does not cause the dermatitis seen in people who are exposed to it. However, people handling the goats or sheep may contact the urushiol from the animal's hair or wool.

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