

# Poisonous plants

Refer lecturer for course updated notes.

Students are obliged to follow the courses for evaluation process and presented notes are preliminary drafts for the whole evaluation process.

# Definition

- A poisonous plant is defined as a plant that when touched or ingested in sufficient quantity can be harmful or fatal to an organism or any plant capable evoking a toxic and/or fatal reaction
- Poisonous plants and the toxins they produce result in major economic losses to the livestock industries throughout the world
- Animals graze poisonous plants for a number of reasons. In some cases, it is a matter of survival.

- Poisonous plant problems are often exacerbated during periods of below normal rainfall when the abundance of grasses is reduced.
- Frequently, the animal's diet selection changes during the season when grasses and palatable forbs mature and senesce; for example, the consumption of some poisonous plants such as lupines, locoweeds, or larkspurs, which stay green longer into the season, may increase as the season progresses.
- Pine needles and junipers are often consumed in the winter.

- For most plant poisonings, there is no specific antidote, and treatment is supportive.
- As a generalization, plant toxins are adsorbed by activated charcoal. The contraindications of using activated charcoal should be borne in mind.
- Ruminal emptying by rumenotomy may be indicated in the case of highly toxic material, if the value of the animal justifies it.

## Poisonous Plants

Rosalind Dalefield BVSc PhD DABVT DABT, in [Veterinary Toxicology for Australia and New Zealand](#), 2017

# Reduce the risk of poisonous plants

- 1. Recognize the plants on your range or pastures or seek appropriate help from extension, university, or federal agencies and know the potential hazards of grazing where poisonous plants grow. Know the conditions under which poisoning may occur.
- 2. Avoid introducing naive animals into unfamiliar pastures or ranges where poisonous plants grow.
- 3. Do not introduce animals into poisonous plant–infested ranges before adequate quality feed is available. Many toxic plants emerge before grasses are adequate for grazing.
- 4. Do not discard grass, shrubs, or tree clippings where livestock have access, e.g., yew clippings are a common cause of poisoning in cattle and horses.
- 5. Provide free choice access to fresh water and trace mineral salt.
- 6. Do not overstock or overgraze pastures.
- 7. Avoid bedding, lambing/calving, watering, salting, or unloading hungry animals near poisonous plant populations.
- 8. Avoid excess stress to affected animals, especially when animals may be showing clinical effects.
- 9. Control poisonous plants if economically feasible, either through hand grubbing, mechanical clipping, or herbicide treatment.

## Toxic plants

Kip E. Panter, ... Dale R. Gardner, in [Reproductive and Developmental Toxicology \(Second Edition\)](#), 2017

# Plants That Cause Irritation of the Oral Cavity

- Araceae family contain needle-shaped calcium oxalate crystals in their leaves- *Dieffenbachia picta* (cucaracho)
  - *Alocasia macrorrhiza* (rascadera, bore, taro gigante), *Caladium* spp. (caladio, rascadera), *Monstera deliciosa* (abalazo, balazo), and *Philodendron* spp. (balazo)
- livestock is rare, the ingestion of its leaves has caused intoxication in humans and pets.
- In dogs, the oxalates of *D. picta* can cause severe inflammation and necrosis of the epithelium of the tongue and oral cavity and may even cause death
- proteolytic enzymes that induce histamine release causing a severe inflammatory response that may lead to asphyxia and death

# Plants That Affect the Gastrointestinal Tract

- *Ricinus communis* (castor, higuera, palma-cristi, ricino)
- ricin, one of the most potent lectins
- cause necrosis of the cells lining the gastrointestinal tract
- Clinical signs include weakness, salivation, profuse aqueous diarrhea, dehydration, mydriasis, teeth grinding, hypothermia, and recumbence; the major postmortem finding is severe gastroenteritis
- responsible for the cathartic properties of ricin oil. Ricinoleic acid is an irritant that alters the intestinal epithelium causing loss of water and electrolytes, increased loss of luminal DNA, and decreased enzymatic activity of enterocytes
- lectins -*Jatropha curcas* (piñón de fraile, purga de fraile), *Abrus precatorius* (chochos de pinta negra, jetiriquí) and *Canavalia ensiformis* (canavalia, frijol blanco)

# Plants Causing Hemolytic Anemia

## culled onions- *Allium cepa*

- capable of causing toxicosis in both large and small animals due to its content of organic sulfoxides, especially alkyl or alkenyl cysteinyl sulfoxides
- After ingestion, the organosulfoxides are transformed into a complex mixture of organic sulfur compounds, some of which are capable of causing intravascular hemolysis in cattle, sheep, and horses
- toxicosis occurs because cattle readily eat onions and usually prefer them to high-quality forages or grains
- hemolytic anemia and methemoglobinemia
- cattle include diarrhea, hemoglobinuria, ataxia, and coma. Cattle are more sensitive than horses, and goats are the most resistant. The hemolytic anemia caused by onion ingestion can also occur in dogs and cats



# Plants Causing Hemolytic Anemia

## **Brassica oleracea (col silvestre)**

B. oleracea contains the non-protein amino acid S-methyl cysteinyl sulfoxide (SMCO), which is reduced in the rumen to dimethyl disulfide, a hemolysin

lethal in cattle

# Plants Causing Methemoglobinemia

- nitrite ion, which is formed by bacteria in the rumen from plant nitrate, is the major cause of methemoglobinemia in ruminants.
- Methemoglobin is an abnormal form of hemoglobin in which its normal ferrous moiety ( $\text{Fe}^{2+}$ ) oxidized to the abnormal ferric form ( $\text{Fe}^{3+}$ ).
- The oxidized form is not capable of transporting oxygen and there is a decrease in the oxygenation capacity of the blood.
- The severity of the clinical signs and effects depends on the amount of methemoglobin formed.
- Signs of hypoxia develop when 20 to 30 percent of the hemoglobin is converted to methemoglobin, and death can occur at 70 to 80 percent methemoglobin levels

# Plants Causing Methemoglobinemia

- forage grasses

<b>Family</b>	<b>Latin name</b>	<b>Common name</b>
Amaranthaceae	<i>Amaranthus dubius</i>	Adormidera, bledo liso
	<i>Amaranthus hybridus</i>	Amaranto, bledo chico
	<i>Chenopodium album</i>	Quenopodio
Boraginaceae	<i>Heliotropium indicum</i>	Verbena, rabo de alacrán
Malpighiaceae	<i>Mascagnia concinna</i>	Mindaca, mataganado
Poaceae	<i>Andropogon bicornis</i>	Barba de indio, cola de zorro
	<i>Brachiaria mutica</i>	Pasto pará
	<i>Lolium perenne</i>	Balico, raigrás inglés, raigrás perenne
	<i>Panicum maximum</i>	Pasto guinea, siempreverde
	<i>Paspalum paniculatum</i>	Paja brava, paja del camino
	<i>Paspalum virgatum</i>	Gramalote, yerba peluda
	<i>Penisetum purpureum</i>	Pasto elefante
	<i>Sorghum bicolor</i>	Sorgo, sorgo forrajero
	<i>Sorghum halepense</i>	Pasto Johnson, capim argentino
Phytolaccaceae	<i>Petiveria alliacea</i>	Anamú
Solanaceae	<i>Solanum nigrum</i>	Campano, yerbamora

# Cardiotoxic Plants

- cardenolide and bufadienolide glycosides
- *Digitalis purpurea* (dedalera, digital, guargüeron), *Nerium oleander* (oleander, delfa, adelfa, azuceno de La Habana), *Thevetia peruviana* (catapis, oleander amarillo), and *Asclepias curassavica* (bencenuco, mataganado)

# Hepatotoxic Plants

- hepatocellular necrosis or intrahepatic cholestasis
- Pyrrolizidine alkaloids (PAs) are a large group of hepatotoxins characterized by the presence of a pyrrolizidine nucleus in their structure and are capable of causing hepatocellular necrosis
- intrahepatic cholestasis are the lantadenes from *Lantana* spp.; sporidesmin, a mycotoxin formed by a fungus on grasses; and the steroidal saponins present in several grasses
- hepatotoxins may cause secondary photosensitization in ruminants due to an alteration in the metabolism of chlorophyll leading to skin damage when ruminants are exposed to the sun

# Plants Containing Substances That Cause Hepatocellular Necrosis

- PAs induce hepatocyte necrosis that progresses to the destruction of the parenchymal cells of the organ and eventually to liver failure
- Asteraceae family (formerly known as Compositae) the most important hepatotoxic genera are Senecio and Eupatorium

Family	Latin name	Common name
Asteraceae	<i>Eupatorium spp.</i>	Amarguero, chilico, hierba de chivo
	<i>Senecio formosus</i>	Arnica, árnica de páramo, árnica de Bogotá
	<i>Senecio madagascariensis</i>	Manzanilla del llano
Boraginaceae	<i>Borago officinalis</i>	Borraja
	<i>Cynoglossum spp.</i>	Cinoglosa, lengua de perro
	<i>Heliotropium europeum, H. indicum</i>	Verbena, rabo de alacrán
	<i>Symphytum officinale</i>	Consuelda, consuelda mayor
Fabaceae	<i>Crotalaria spp.</i>	Crotalaria, cascabel, cascabelillo

# Plants Containing Substances That Cause Hepatocellular Necrosis

- *Crotalaria* spp- *C. spectabilis*, *C. retusa*, *C. sagittalis*, and *C. Pallida*
- Boraginaceae- *Heliotropium*, *Symphytum*, and *Cynoglossum*

# Plants That Cause Intrahepatic Cholestasis

- *Lantana camara* (*venturosa*, *sanguinaria*, *lantana*)
  - triterpenes, mono and sesquiterpenes, iridoid and phenyl ethanoid glycosides, naphthoquinones, and flavonoid
  - biotransformed by hepatic cytochrome P-450 enzymes into toxic compounds that damage the bile canaliculi, producing intrahepatic cholestasis and impairment of the normal flow of bile
- steroidal saponins- metabolism in the rumen- rapid hydrolysis in the rumen that releases the corresponding sugars and aglycones (sapogenins). The sapogenins are then absorbed and transported to the liver where they are conjugated with glucuronic acid and excreted in the bile. Once in the bile, they form insoluble calcium salts of sapogenin glucuronate that precipitate inside and around the biliary ducts
- glucuronate crystals block the normal secretion of bile, which in turn disrupts the normal secretion of phylloerythrin, the compound responsible for the secondary photosensitization.



- steroidal saponins -Poaceae family (grasses) and include *Brachiaria brizantha* (pasto alambre), *Brachiaria decumbens* (braquiaria), *Panicum coloratum* (pasto Klein), *Panicum maximum* (pasto guinea), and *Pennisetum clandestinum* (kikuyo).

# Plants That Affect the Urinary System

## *Pteridium aquilinum*

- a thiaminase capable of destroying vitamin B1 and a mutagenic carcinogenic glycoside known as ptaquiloside
- cattle known as bovine enzootic hematuria

soluble oxalates that chemically correspond to sodium or potassium salts of oxalic acid

Precipitation of calcium oxalate crystals in the kidney leads to anuria, uremia, and acute renal failure

*Brachiaria humidicola* (braquiaria alambre), *Cenchrus ciliaris* (pasto buffel), *Digitaria decumbens* (pasto pangola), *Panicum maximum* (pasto guinea, india, siempreverde), *Pennisetum clandestinum* (kikuyo), *Pennisetum purpureum* (pasto elefante), and *Setaria sphacelata* (setaria, pasto miel)

# Plants That Affect the Urinary System- Oxalate

- In horses, prolonged intake of tropical grasses containing soluble oxalates can lead to secondary hyperparathyroidism or osteodystrophia fibrosa
  - Levels of 0.5 percent or more soluble oxalate in forage grasses
  - may cause nutritional hyperparathyroidism in horses, while levels of 2 percent or more may cause acute toxicosis in ruminants
- The oxalate content in grasses is highest during rapid growth, such as after the onset of the rainy season, and may reach levels of 6 percent or more dry weight.
- Halogeton glomeratus, Amaranthus species including A. retroflexus and A. Hybridus- soluble oxalates and nitrates

# Plants That Block the Neuromuscular Junction

- **Conium maculatum**

- piperidine alkaloids, of which the most important are coniine (mainly in the seeds) and  $\gamma$ -coniceine (in vegetative tissue). The other three alkaloids are Nmethylconiine, conhydrine, and pseudoconhydrine
- cause paralysis of the musculature due to the blockade of the neuromuscular junctions
- muscle weakness, tremors, incoordination, and mydriasis, followed by bradycardia, depression, coma, and death from respiratory failure
- Poultry species (turkeys, geese, and quail) show ataxia and inability to fly

# Plants That Affect the Central Nervous System (CNS)

- Ipomoea carnea- affects the central nervous system of cattle, sheep, and goats
- Ipomoea spp. can also accumulate ergot alkaloids and calystegines. Other plants known to accumulate swainsonine include species of the genera Astragalus, Oxytropis, Swainsona, and Sida.

# Grasses That Cause Neurological Signs

- *Phalaris aquatica* and *P. Arundinacea*
- acute toxicosis with sudden death, subchronic toxicosis with transient neurological signs, or chronic toxicosis with permanent neurological damage
- ataxia, aimless walking, muscular fasciculation, tremors, opisthotonus, excessive salivation, tetanic spasms, and limb paddling

# Plants That Induce Thiamine Deficiency

- Pteridium aquilinum and Equisetum spp.
- Neurological signs, especially in horses
  - anorexia, weight loss, and emaciation that lead to progressive motor incoordination and posterior paralysis or prostration. In terminal cases there are opisthotonus, convulsions, and death.
- Ruminants are highly resistant to thiaminases because they synthesize the vitamin in the rumen

# Other Neurotoxic Plants

- *Bambusa vulgaris* (bamboo, guauda amarilla)
- *Taraxacum officinale* (Asteraceae). *H. radicata*



# Plants That Affect the Musculoskeletal System and Connective Tissue

- Senna (formerly known as Cassia) includes several species of plants known to induce myopathy in cattle, horses, and pigs that graze on them or that eat feed contaminated with their seeds.
- myocardial degeneration, congestive heart failure, and generalized degeneration of skeletal muscles
- The muscle damage is accompanied by high serum activity of the enzymes aspartate amino transferase (AST) and creatine kinase (CK) and myoglobinuria. At postmortem examination, the affected muscles look pale and show whitish striations
- *Petiveria alliacea* (anamú)- toxin (or toxins) is excreted in the milk.

# Plants That Affect the Skin

- Toxic plant-induced primary and secondary photosensitization is a common cause of skin lesions in livestock throughout the world. Secondary photosensitization results from impaired excretion of phylloerythrin
- *Fagopyrum esculentum* (alforjón, trigo sarraceno, trigo negro), formerly known as *Polygonum fagopyrum*
- Euphorbiaceae- phorbol- skin-irritating
- *Croton* spp

# Primary photosensitization

- caused by the reaction of the photoreactive compound in non-pigmented skin when it is exposed to solar radiation in the ultraviolet range.
- The photoactive compounds absorb solar energy, forming reactive molecules (free radicals) that react with nearby macromolecules, causing inflammation, erythema, edema, serous exudation, scar formation, and skin necrosis.
- *Hypericum perforatum* (St. Johnswort) contains a pigment similar to fagopyrin known as hypericin, also capable of inducing primary photosensitization.

# Plants That Affect Reproduction

- Phytoestrogens are compounds present in some plants that mimic the action of estradiol and may cause adverse reproductive effects. *Medicago sativa* (alfalfa) and *Trifolium pratense*
- Alfalfa
- Genistein and daidzein are also present in soybeans
- Even though phytoestrogens in general are considered to be low to moderately estrogenic, they can affect reproduction in cattle and have been associated with impairment of ovarian function, cystic ovaries, irregular estrous cycles, decreased conception rates, embryonic mortality, and mammary gland development in heifer
- *Solanum aphyodendron*- produces uterine contractions and other effects such as mydriasis, hypotension, tachycardia, increased respiratory rate, and depression

# Plants That Contain Systemic Poisons

- interfere with biochemical processes common to all cells and usually do not have a particular target organ
- monofluoroacetic acid, a compound capable of blocking the Krebs cycle, and cyanide, an inhibitor of the respiratory chain in the mitochondria
- Upon hydrolysis in the rumen, cyanogenic glycosides release cyanide (HCN), which is readily absorbed into the systemic circulation. In the plasma, HCN dissociates into hydrogen and nitrile ion (CN<sup>-</sup>), the latter of which binds strongly to the terminal cytochromes of the mitochondrial respiratory chain, thereby inhibiting tissue cellular respiration and causing anoxia. Levels of 20 mg HCN/100 g of fresh plant or higher are considered potentially toxic.
- *Sambucus canadensis* and *S. nigra*
- *Tanaecium* spp. reported to be toxic is *T. nocturnum*

**Tablo 1. Türkiye'nin Değişik Bölgelerinden Temin Edilen Yem Bitkilerindeki Siyanür Düzeyleri.**

Bitki Numunesi	Türkçe Adı	Numunenin Alındığı yer	HCN Düzeyi (ppm)
Prunus Amygdalus	Acı Badem	Elazığ	48.96
Vicia Ervilia	Burçak	Elazığ	4.60
Petroselinium Sativum	Maydanoz	İstanbul	1.55
Capsicum Annuum	Kırmızı biber	K.Maraş	0.90
Vicia Sativa	Fiğ	Elazığ	0.77
Gossypium Sp.	Pamuk	Elazığ	0.72
Helianthus Annuus	Ayçiçeği	Elazığ	0.71
Cannabis Sativa	Kendir	Malatya	0.70
Vicia Sp.	Fiğ	Elazığ	0.70
Medicago Sp.	Yonca	Kayseri	0.70
Malva Sylvestris	Gilgil	Elazığ	0.68
Zea Mays	Mısır	Malatya	0.68
Lens Esculenta	Mercimek	Urfa	0.68
Raphanus Sativus	Turp	Gaziantep	0.67
Hardeum Sp.	Arpa	Elazığ	0.66
Artemisa Sp.	Süpürge Darısı	Elazığ	0.66
Avena Tutua	Yulaf	Konya	0.65
Sorghum Sp.	Akdarı	Konya	0.64
Daucus Carrota	Havuç	İstanbul	0.62
Lolium Sp.	Çim	Eskişehir	0.62
Rebinia Pseudo Acacia	Akasya	Elazığ	0.61
Lactuca Sativa	Marul	Konya	0.60
Glycine Max.	Soya	Adana	0.57
Cicer Sp.	Beyaz Nohut	Elazığ	0.55
Vigna Sinensis	Lobik	Elazığ	0.50
Spinach Sp.	İspanak	Adana	0.46
Cicer Aritenium	Kara Nohut	Malatya	0.37
Triticum Sp.	Buğday	Elazığ	0.35
Phaseolus Vulgaris	Fasulye	Elazığ	0.33
Pisum Sativum	Bezelye	Adana	0.33

**Tablo 2. Türkiye'nin Değişik Bölgelerinden Temin Edilen Yem Maddeleri ve Karma Yemlerdeki Siyanür Düzeyleri.**

Yem Maddeleri ve Karma Yem Numuneleri	HCN Düzeyi (ppm)
Yumurta Piliç Büyütme Yemi (İnce, Malatya)	1.42
Topioca (Manioc, Pelet, Elazığ)	0.84
Tavuk Yumurta Yemi (İnce Elazığ)	0.82
Yemlik Maya (Toz, İstanbul)	0.80
Buğday Kepeği (İnce, Elazığ)	0.72
Etlük Piliç yemi (Pelet, Elazığ)	0.70
Piliç Büyütme Yemi (İnce, Malatya)	0.70
Soya Fasulseyi Küşpesi (Elazığ)	0.65
Yumurta Yemi (İnce, Elazığ)	0.62
Civciv Büyütme Yemi (İnce, Elazığ)	0.62
Buzağı Büyütme Yemi (İnce, Elazığ)	0.61
Sığır Karma Besi Yemi (İnce, Elazığ)	0.61
Sığır Süt Yemi (İnce, Malatya)	0.60

# Sago Palm

- Cycad palms, also called sago palms, belong in the family Cycadaceae
- *Cycas revoluta*, *Cycas circinalis*, and *Zamia floridana* are the most common species.
- cycasin, betamethylamino- L-alanine, and an unidentified high molecular weight compound
- metabolized by the intestinal flora to the active hepatotoxic, carcinogenic, mutagenic, teratogenic, and neurotoxic compound, methylazoxymethanol (MAM).
- documented in several animal species (dogs and ruminants) and humans. In dogs, gastrointestinal disturbances and hepatic damage predominate; nervous system involvement is less common

# Lily toxicity in cats

- Lilies, that is, species of *Lilium* (Liliaceae) (true lily) and *Heimerocallis* (Heimerocallidaceae) (day lily), cause renal damage in cats.
- All parts of the plant are toxic and a small amount of plant material can have serious consequences if ingested.
- The mechanism of toxicity remains unknown.
- Signs develop rapidly with gastrointestinal irritation, followed by polyuria, dehydration and then acute kidney injury.
- Seizures can occur in severe cases. Treatment is aimed at reducing absorption with emesis and/or activated charcoal and enhancing renal perfusion with intravenous fluid diuresis for at least 48 h.
- Once acute kidney injury has occurred treatment options are limited and referral should be considered.
- Prognosis is good in cats where decontamination is prompt and treatment has been started before the onset of renal impairment.
- Cats with acute kidney injury have a more guarded prognosis.



<b>Plant scientific names</b>	<b>Plant common names</b>	<b>Class of toxin</b>	<b>Examples of toxin</b>
<i>Delphinium</i> spp.	Larkspurs	Norditerpenoid alkaloids	Methyllycaconitine, deltaline
<i>Astragalus</i> and <i>Oxytropis</i> spp.	Locoweeds	Indolizidine alkaloids	Swainsonine
<i>Astragalus</i> spp.	Vetches	Nitrotoxins	3-Nitropropanol
<i>Astragalus</i> spp.	Selenium accumulator plants	mineral	Selenium
<i>Lupinus</i> spp.	Lupines	Quinolizidine and piperidine alkaloids	Anagyrine, ammodendrine
<i>Senecio</i> spp., <i>Crotalaria</i>	Tansy ragwort, Riddell's groundsel	Pyrrrolizidine alkaloids	Riddelliine
<i>Zigadenus</i> spp.	Death camas	Steroidal alkaloids	Zygacine
<i>Veratrum</i> spp.	Skunk cabbage, corn Lily, false hellebore	Steroidal alkaloids	Cyclopamine, veratramine
<i>Pinus</i> and <i>Juniperus</i> spp.	Ponderosa pine, juniper trees	Labdane acids	Isocupressic acid
<i>Conium maculatum</i>	Poison hemlock	Pyridine alkaloids	Coniine
<i>Cicuta maculata</i>	Water hemlock	Acetylenic alcohols	Cicutoxin

**History of the poisoning incident:** (this includes all information and analyses already performed)

Pertinent facts: breed, sex, age, number, condition, vaccination status, mineral supplements, feeding or pasture changes, and other treatments

Clinical disease: number affected, signs, clinical course and progression, lesions, and mortality

Clinical tests: blood tests to evaluate inflammation and organ function and to evaluate immunologic responses to infectious agents (blood cell counts and serum element, metabolite and biochemical analyses, and serologic tests)

**Field studies:** (this includes additional evaluations and analyses to be performed)

Animals: general condition of affected animals, unusual behaviors, clinical signs, and lesions. Additional clinical tests may be indicated to analyze samples for plant toxins or metabolites in the tissues, blood, urine, or feces

Pasture:

1. Determine forage availability, plant species composition, and evidence of grazing patterns
2. Collection of potential problem plants or unidentified plants (dried samples for identification, frozen samples for chemical analysis)
3. Note physical location, weather conditions at the time of the incident (for example, snow depth) and their effect on forage and forage availability

Prepared feeds such as hay, silage, or concentrate feed samples (frozen for analysis)

Water, salt, and mineral supplements including location and use (samples frozen for analysis)

Check for other potential hazards, such as old batteries and pesticide-laced feed

**Postmortem examination:**

Animal condition and lesions

Rumen and gastrointestinal tissues and contents

Tissues for histologic studies fixed in 10% neutral buffered formalin (brain, lung, heart, liver, spleen, gastrointestinal tract, kidney, skeletal muscle, and any gross lesions)

Tissues for chemical or microscopic studies stored in plastic bags and frozen (rumen and gastrointestinal contents, complete eye, liver, kidney, serum, whole blood, body fat, bone, urine, and milk if lactating)

- (1) developing science-based guidelines for grazing livestock on rangelands infested with toxic plants; (2) reducing the risks of livestock losses due to variations in quantitative and qualitative differences in toxin accumulation over time and in plant species by quantifying the influence of endophytes, climate changes, and genotype on plant toxin accumulation; (3) enhancing feed and food safety by improving risk assessment and diagnosis of plant-induced poisoning to livestock by improving analytical methods for analyzing plant and animal tissues, measuring toxicokinetics, assessing carcinogenic and genotoxic potential, and identifying toxin metabolites and biomarkers of toxicoses; (4) developing improved procedures and guidelines for diagnostic and prognostic evaluation to reduce negative impacts of poisonous plants on livestock reproduction and embryo/fetal growth; and (5) developing guidelines to aid producers and land managers in making genetic-based herd management decisions to improve livestock performance and animal safety on rangelands infested with poisonous plants.