Toxic Plants of Veterinary and Agricultural Interest in Colombia

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Abstract

Colombia has the second largest plant biodiversity of any country in the world, with about 25,000 species of vascular plants. This is due in part to its equatorial location, and large variation in elevation and associated gradients in temperatures and rainfall. Livestock in Colombia graze vast tracts of land with a wide variety of herbaceous and woody plants. Although the annual cattle mortality from plant poisoning in Colombia is estimated at 130,000, the economic impact on the entire livestock industry has not been fully evaluated. Information on toxic plants is scarce in Colombia, and livestock poisoning by plants is seldom documented. This review presents the current knowledge on the identity of plants known to have poisoned livestock in Colombia and on research conducted into these toxic plants. To the extent known, the toxic component(s), major clinical signs and circumstances of poisoning, location, and environmental factors are discussed. Many of the plants identified in Colombia are considered toxic on the basis of world literature, but toxicosis in Colombia has not always been documented. The information on toxic plant chemistry in Colombia is mostly limited to the plant's nitrate or cyanide content. Research is needed to determine not only which plants represent a potential risk for animal health and production but also their phytochemistry and toxicology. It is strongly recommended that veterinarians document plant poisoning cases through government reporting services and that university and government veterinarians, scientists, and extension agents investigate episodes of plant toxicosis and publish their findings. This would help identify toxic species for further phytochemical and toxicological studies and possibly pharmacological activity.

Keywords: toxic plants, Colombia, plant poisoning, livestock, pets

Introduction

Toxic plants affecting both large and small animals are a major concern for the practicing veterinarian and livestock producer in every country. In countries with higher plant biodiversity, the number of problematic toxic plants may be greater. Plant biodiversity in Colombia is very high, as there are about 25,000 species of vascular plants in Colombia, both native and naturalized (Bernal et al. 2006). This biodiversity corresponds to about 8 percent of the total vascular plants on earth, which makes the country the second largest in plant biodiversity in the world, the largest being Brazil. However, information on toxic plants in Colombia is scarce and is usually published only in local, Spanish-

language journals. Further, it is not customary among local veterinarians to write case reports, thus most of the plant poisonings that occur in Colombia are not documented in the literature.

The impact of toxic plants on Colombian livestock production has not been fully evaluated. It is estimated that more than 40 million hectares of the country are used for livestock production, with a bovine population of about 26 million animals (Ministerio de Agricultura y Desarrollo Rural, 2005). Colombia ranked ninth in the world for cattle population. However, livestock production is mostly extensive with a very low population of animals kept under intensive production systems. Land used for cattle grazing contains complex mixes of native and invasive plants (Peña et al. 1980), which may increase the risk of exposure to toxic plants, many of which have not been characterized or have only been partially characterized. Conservative estimates indicate that in Colombia, toxic plants cause an annual mortality rate of about 0.5 percent (Peña et al. 1980), which is currently equivalent to about 130,000 cattle. This percentage is in agreement to that reported by Tokarnia et al. (2002) in Brazil, who estimated that between 800,000 to 1,120,000 cattle of the 160-million population die annually from plant poisoning, a mortality rate corresponding to 0.5 to 0.7 percent.

The aim of the present review is to briefly describe the most important native and introduced toxic plants present in Colombia that affect animals and to summarize the published research on these toxic plants, highlighting research conducted in Colombia.

Major Toxic Plants Affecting Animal Health and Production in Colombia

Plants were grouped based on the major organ system affected by consumption of the plant. Common names given to these plants in Colombia are provided in parentheses after the Latin botanical name or indicated in one of the tables. It is important to note that Colombia is a tropical country located on the Equator, which means that there are no seasons such as winter, spring, summer, or fall, and that annual plants behave as perennials under these conditions. The average environmental temperature is mostly determined by elevation with distinct temperature gradients from low- to high-elevation rangelands. There are, however, “dry” and “rainy” seasons when low or high precipitation is expected every year. The times of the year with higher precipitation rates are April through May and October through November. The start of the rainy period is accompanied by intense growth of some plant species used for animal feed (especially grasses), a situation that is usually associated with increased accumulation of potentially toxic compounds such as nitrates. However, some plants accumulate more toxins during the dry periods, for example, the native plant *Mascagnia concinna*, which accumulates more cyanogenic glycosides during these periods. Colombia is politically divided into “departments” (states), and sometimes this word is used to indicate a specific geographical region.

Plants That Affect the Digestive System

Plants That Cause Irritation of the Oral Cavity

Many plants belonging to the Araceae family contain needle-shaped calcium oxalate crystals in their leaves. These crystals are known as raphides and are housed inside specialized cells known as idioblasts (Genua and Hillson 1985). When the plant leaves are chewed, the idioblasts are broken and the oxalate crystals are expelled, causing an immediate burning sensation in the oral cavity tissues. Plants that accumulate calcium oxalates are fairly common in Colombia and some of them are even native to the country, such as *Dieffenbachia picta* (cucaracho), recognized as the most toxic of all Araceae plants (Cao 2003). The genus *Dieffenbachia* comprises about 135 species, most of them present in South America. Colombia has the highest biodiversity with 37 species, followed by Ecuador with 34, Peru with 30, Brazil with 27, Panama with 20, and Costa Rica with 13 (Croat 2004). Although toxicosis by *D. picta* in 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 (Loretti et al. 2003). Besides calcium oxalates, *D. picta* contains proteolytic enzymes that induce histamine release causing a severe inflammatory response that may lead to asphyxia and death (Loretti et al. 2003).

Other plants of the Araceae family common in Colombia are *Alocasia macrorrhiza* (rascadera, bore, taro gigante), *Caladium* spp. (caladio, rascadera), *Monstera deliciosa* (abalazo, balazo), and *Philodendron* spp. (balazo). With the exception of *Alocasia macrorrhiza*, these plants are all native

to tropical America. These plants contain reduced concentrations of calcium oxalate compared with *D. picta*, and they are rarely associated with toxicological problems.

Plants That Affect the Gastrointestinal Tract

Ricinus communis (castor, higuerilla, palmacristi, ricino) is a naturalized plant common in Colombia from sea level to 2600 m elevation. *R. communis* seeds contain ricin, one of the most potent lectins known. In general, lectins cause necrosis of the cells lining the gastrointestinal tract. Ricin is comprised of two subunits: Unit B (for binding) is the actual lectin that binds to galactosyl residues in cellular membranes, whereas unit A (for activity) is an enzyme capable of inactivating ribosomes in eukaryotic cells (Barbieri et al. 1993). All animal species are sensitive to the effects of ricin. The toxicosis, however, is uncommon and it is usually associated with feeding garden clippings or with contamination of forage grasses with *R. communis* trimmings (Aslani et al. 2007). Clinical signs include weakness, salivation, profuse aqueous diarrhea, dehydration, mydriasis, teeth grinding, hypothermia, and recumbence; the major postmortem finding is severe gastroenteritis (Aslani et al. 2007). Other plants present in Colombia that contain potentially toxic lectins in their seeds are *Jatropha curcas* (piñón de fraile, purga de fraile), *Abrus precatorius* (chochos de pinta negra, jetiriquí) and *Canavalia ensiformis* (canavalia, fríjol blanco). The lectins present in these plants correspond to curcin, abrin, and concanavalin A, respectively. However, toxicosis with these plants has not been documented in Colombia.

Another plant compound highly irritating to the gastrointestinal mucosa is ricinoleic acid, a fatty acid present in *Ricinus communis* seeds, considered to be 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 (Bretagne et al. 1981).

Plants That Affect the Blood

Plants Causing Hemolytic Anemia

Feeding culled onions has been associated with hemolytic anemia in cattle and other animal species. *Allium cepa*, which includes all types of onions, is capable of causing toxicosis in both large and small animals due to its content of organic sulfoxides, especially alkyl or alkenyl cysteinyl sulfoxides (Rae 1999, Parton 2000). 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. Onion toxicosis, which occurs sporadically in cattle in Colombia, has been extensively documented in the literature with the first case reported in 1909 (Goldsmith 1909). The toxicosis occurs because cattle readily eat onions and usually prefer them to high-quality forages or grains (Rae 1999). The excessive intake of onions leads to hemolytic anemia and methemoglobinemia, which develops within a week of onion ingestion. Clinical signs in 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 (Parton 2000).

Another plant that causes intravascular hemolysis is *Brassica oleracea* (col silvestre), several varieties of which are used as forage for ruminants. *B. oleracea* contains the non-protein amino acid *S*-methyl cysteinyl sulfoxide (SMCO), which is reduced in the rumen to dimethyl disulfide, a hemolysin (Duncan and Milne 1993). The anemia induced by the intravascular hemolysis may be lethal in cattle, which are very sensitive to the hemolytic effects of SMCO (Prache 1994).

Plants Causing Methemoglobinemia

The 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 (Fe^{2+}) oxidized to the abnormal ferric form (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 methemogloblin, and death can occur at 70 to 80 percent methemoglobin levels (Vermunt and Visser 1987). Many plants have been identified as accumulators of toxic nitrate levels in Colombia (table 1), this being one of the most common plant toxicosis recognized in cattle.

As shown in table 1, the most important group of plants responsible for nitrate poisoning in cattle are forage grasses with at least nine species known to be associated with nitrate poisoning. An example of the high nitrate levels present in Colombian grasses is the study of Trheebilcock et al. (1978), who analyzed samples of *Panicum maximum* from the northern part of the country (Departments of Córdoba and Sucre). The average nitrate levels found were 1209 and 5260 ppm for fresh plants collected during the dry season and after the onset of the rainy season, respectively. Also in Colombia, Guzmán et al. (1978) reported a case in the Valle del Cauca Department that caused acute mortality in 19 of 64 steers that were fed cut *Pennisetum purpureum*. The grass was found to contain 445 ppm nitrate and 971 ppm nitrite; the high nitrite content was attributed to microbial processes.

The Amaranthacea family also contains plants associated with nitrate poisoning in cattle. *Amaranthus dubius* and *A. spinosus* are two species of *Amaranthus* common in Colombia that have been associated with nitrate intoxication, especially during the transition between the dry and the wet seasons (Torres 1984a). Another Amaranthacea is *Chenopodium album*, a plant recently reported in Colombia (Fernández-Alonso and Hernández-Schmidt 2007), which can cause lethal intoxication in ruminants because of its high nitrate levels (although it can also accumulate soluble oxalates). Levels of 2,500 ppm nitrate-nitrogen were reported in *Chenopodium album* hay associated with mortality in cattle (Ozmen et al. 2003). Other *Chenopodium* spp. such as *C. ambrosoides* and *C. quinoa* are considered native to Colombia but have not been reported as toxic.

Another plant associated with high nitrate content is *Mascagnia concinna*, a vine of the Malpighiaceae family native to the Magdalena Valley of Colombia. Nitrate concentrations ranging from 5,300 to 29,200 ppm dry matter were reported by Torres (1984a) and from 1,555 to 10,763 in fresh material by Trheebilcok et al. (1978).

The Phytolaccaceae *Petiveria alliacea* can also contain toxic levels of nitrate. Studies conducted in Colombia with fresh plants showed that during the dry season, the plant accumulates an average of 1,155 ppm nitrate but during the rainy season, the average levels are 7,867 ppm (Trheebilcock et al. 1978). *Heliotropium indicum* is a Boraginaceae also known to accumulate toxic concentrations of nitrates. In samples collected in the northern part of the country, Trheebilcock et al. (1978) found average nitrate levels of 178 and 7,195 ppm in fresh material collected before the rainy season and immediately after the start of the rainy season, respectively.

Plants That Affect the Coagulation of Blood

Cumarinic glycosides can be found in *Anthoxanthum odoratum* (Poaceae) and in *Melilotus* spp. (Fabaceae). *Anthoxanthum odoratum* (oloroso) was introduced in Colombia during colonial times,

Table 1. Major nitrate-accumulating plants affecting livestock in Colombia

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

and it is common in cold regions of the country at altitudes from 2,600 to 3,500 m above sea level (Fernández-Alonso and Hernández-Schmidt 2007). *Melilotus albus* and *M. officinalis* (trébol dulce) were also introduced, and they are currently considered part of the naturalized flora of Colombia (Bernal et al. 2006, Fernández-Alonso and Hernández-Schmidt 2007). When hay from these plants becomes moldy, the cumarinic glycosides can produce dicumarol, an anticoagulant that causes depletion of active vitamin K in the liver resulting in reduced clotting factors being released into the blood (Hallak and Wedlund 1991). The toxicosis by *A. odoratum* and *Melilotus* spp. in cattle has been well documented in the world literature (Pritchard et al. 1983, Puschner et al. 1998, Runciman et al. 2002). Affected animals are weak and reluctant to move, show petechial hemorrhages in mucosal surfaces, may bleed from natural orifices, and show increased prothrombin and partial thromboplastin time. At postmortem examination, multiple petechial and ecchymotic hemorrhages are seen. Uncoagulated blood may also be seen in any of the body tissues and cavities including the chest and abdomen, depending on the activity of the animal.

Cardiotoxic Plants

Cardiac glycosides are a specific type of toxic glycosides that affect the cardiac muscle, sometimes causing fatal toxicosis. Cardiac glycosides increase the contraction force of the heart by inhibiting the myocardial Na-K ATP-ase, which can lead to cardiac arrest (Poindexter et al. 2007). Two types of cardiac glycosides are recognized depending on their chemical characteristics, namely, cardenolide and bufadienolide glycosides. At least four plants containing cardenolide cardiac glycosides are present in Colombia: *Digitalis purpurea* (dedalera, digital, guargüeron), *Nerium oleander* (oleander, delfa, adelfa, azuceno de La Habana), *Thevetia peruviana* (catapis, oleander amarillo), and *Asclepias curassavica* (bencenuco, mataganado). All have sporadically caused toxicosis in herbivores.

Digitalis purpurea was introduced into Colombia as an ornamental by British engineers around 1856; and it currently grows wild in highlands, including the high plateau where Bogotá is located, at 2,640 m above sea level. *D. purpurea* contains cardiac glycosides in all parts of the plant but the concentration is higher in the leaves.

Nerium oleander is a perennial bush native to the Mediterranean region and Asia but now is common in all tropical and subtropical regions of the world. In Colombia it is cultivated as an ornamental for its colourful flowers, which can be white, pink, yellow, or red. All parts of the plant contain cardiac glycosides with oleandrin being the most abundant. Toxicosis has occurred in horses and cattle usually due to contamination of pastures with plant clippings from *N. oleander* bushes. *Thevetia peruviana* (= *T. nereifolia*, *Cascabela peruviana*, and *C. thevetia*) is a bush native to South America, similar to *Nerium oleander* but smaller, with narrower leaves and only yellow flowers. This plant contains cardenolide cardiac glycosides, primarily thevetin A and thevetin B, especially in the seeds (Roberts et al. 2006). There are reports of human toxicosis caused by this plant, generally associated with the intake of the seeds. Intake of one or two seeds causes gastrointestinal symptoms, and intake of three or four seeds affects the heart and may cause death (Roberts et al. 2006). In the city of Medellín (Department of Antioquia), seeds of *T. peruviana* were sold as a weight loss aid and several women died after eating the seeds (López 2002).

Asclepias curassavica is a plant native to the Caribbean but now is commonly found in Colombia at elevations up to 1,600 m. This plant contains asclepine, a cardiac glycoside with higher potency than strophantin, digoxine, digitoxine, and digitoxigenine (Patnaik and Köhler 1978), which are some of the most potent cardiac glycosides known. Even though the plant is not palatable for herbivores, it has been associated with sporadic cases of toxicosis in cattle.

Hepatotoxic Plants

The main hepatotoxic plants present in Colombia affect the liver by causing either 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. Compounds in plants known to cause 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. All 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

The PAs are a large group of hepatotoxins present in plants found in Colombia, and PA toxicosis has been reported in livestock, poultry, pigs, and humans in Colombia. Extensive literature reviews on the chemistry, mechanism of action, and effects of PAs in animals and humans have been published (Mattocks 1986, Diaz 2001, Fu et al. 2004, Rietjens et al. 2005). In general, PAs induce hepatocyte necrosis that progresses to the destruction of the parenchymal cells of the organ and eventually to liver failure. PAs are also potent carcinogens at levels below those causing hepatic necrosis. Even though PAs are mainly hepatotoxic, some of them can also affect the lungs, especially monocrotaline.

More than 6,000 plants are believed to contain PAs, many of which are present in Colombia in all kinds of ecosystems. The most important PA-producing plants from the toxicological standpoint belong to one of the families Asteracea, Fabaceae, or Boraginaceae. Table 2 summarizes the major PA-containing plants present in Colombia.

Among the Asteraceae family (formerly known as Compositae) the most important hepatotoxic genera are *Senecio* and *Eupatorium*. Two toxic species of *Senecio* common in Colombia are *Senecio formosus* and *S. madagascariensis*. The former is a plant native to the highlands between 3,000 and 4,000 m above sea level and commonly found in the Colombian Andean regions of Cundinamarca, Cauca, and Nariño. There are no reports of toxicosis in animals caused by this plant; however, *Senecio formosus* has caused irreversible hepatic damage in human patients who ingested infusions made with its dry leaves. The clinical history, symptoms, signs, lesions, and postmortem findings of almost 20 fatal cases reported in Bogotá were documented by Toro et al. (1997).

Senecio madagascariensis is an annual or perennial herb native to South Africa reported for the first time in Colombia in the 1980s. It is an aggressive weed that propagates rapidly, and it has already colonized all the high plateau of the departments of Cundinamarca and Boyacá (Fernández-Alonso and Hernández-Schmidt 2007).

Horses are highly sensitive to the PA of *S. madagascariensis* and can even be intoxicated in utero. In Australia, Small et al. (1993) reported a case where a foal exhibited growth retardation and jaundice at birth and died at 2 months of age with liver damage. During gestation the mare was kept in a field heavily infested with *S. madagascariensis*, which resulted in fetal exposure in utero. In Colombia, *S. madagascariensis* has been associated with sudden death in cows immediately after parturition. The cause of this sudden death syndrome is unknown, but it is possible that the metabolic changes associated with parturition and the onset of lactation pose an extra load to a liver that has been severely affected by the chronic ingestion of the plant. Burgueño-Tapia et al. (2001) analyzed *S. madagascariensis* plants collected in Colombia and found that the plants contain chemical substances known as calolides. However, the toxicological with plants from Australia or Hawaii although the concentration was lower. The total concentration of PAs in samples from Australia, Hawaii, and Colombia was 3,089, 2,133, and 805 µg/g, respectively. The major PAs found in the Colombian samples were senecivernine, senecionine, integerreimine, mucronatinine, and usaramine (D.R. Gardner and G.J. Diaz, 2009, unpublished data). The other genus of the Asteracea family reported to accumulate PA is *Eupatorium*. Several species of this genus have been reported in Colombia (Powell

Table 2. Major pyrrolizidine alkaloid-producing plants reported in Colombia

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

and King 1969), including *E. inulaefolium*, which has been reported as hepatotoxic for cattle in other countries (Sharma et al. 1998). Another toxic *Eupatorium* species in Colombia is *E. stochaedifolium*, whose leaves and flowers were reported by Pérez-Arbeláez (1931) as toxic. However, no information on the toxic components of the plant or its effects in animals or humans was provided.

Within the Fabaceae family, the genus *Crotalaria* is notorious for the high PA content of some of its plants. In Colombia, *Crotalaria* spp. grow from sea level to about 3,000 m above sea level, especially in areas with clearly defined dry periods such as the inter-Andean valleys, the northern part of the country, and the eastern savannas known as the llanos. These plants grow as weeds in well-fertilized soils used to grow corn, sorghum, or soybeans, and their seeds may contaminate these agricultural crops. At least 19 species of *Crotalaria* are present in Colombia (Bernal 1986) and some are recognized as toxic, including *C. spectabilis*, *C. retusa*, *C. sagittalis*, and *C. pallida*. *Crotalaria* poisoning in Colombia has been reported in pigs, goats, laying hens, and broiler chickens. In 2001 large losses were caused to the poultry and pig industry when sorghum grain contaminated with *C. retusa* seeds was used to prepare mixed rations for monogastric animals. The level of contamination in sorghum lots with *C. retusa* seeds ranged from 2 to 5 percent (G.J. Diaz, 2009, unpublished data). These levels are extraordinarily high since a level of just 0.05 percent (equivalent to one *C. retusa* seed per 65,000 sorghum seeds) was associated with lethality in pigs (Hooper 1978). *Crotalaria pallida* is another toxic *Crotalaria* sp. present in Colombia. A natural outbreak of *C. pallida* poisoning was reported in goats in the Department of Santander (Canchila 2001), and experimentally, *C. pallida* seeds were found to be highly toxic to broiler chickens (Diaz et al. 2003).

The third family of plants known to accumulate high levels of PAs is the Boraginaceae . A total of 13 genera of this family have been reported in Colombia, including the toxic genera *Heliotropium*, *Symphytum*, and *Cynoglossum* (Barajas-Meneses et al. 2005). The *Heliotropium* genus is represented by at least 9 species, which are widely distributed from 0 to 3,200 m above sea level (Barajas-Meneses et al. 2005). The main toxic *Heliotropium* species reported in Colombia are the introduced species *H. europaeum* and *H. indicum*, the latter containing not only PAs but also toxic concentrations of nitrates. The other *Heliotropium* species present in Colombia (e.g. *H. angiospermum*, *H. peruvianum*, *H. procumbens*, *H. salicioides*, and *H. ternatum*.) have not been studied to determine their potential adverse effects in animals or humans. Another toxic Boraginaceae present in Colombia is *Symphytum officinale*, a perennial herb native to Europe and recently reported in Colombia (Fernández-Alonso et al. 2007). Similar to *Senecio formosus*, *Symphyum officinale* represents mainly a risk for humans and no cases of toxicosis in animals have been reported. The ingestion of tea made with *S. officinale* leaves has caused liver damage in human patients, and the sale of the dry leaves of the plant has been banned in countries such as Germany and Canada (Stickel and Seitz 2005). *Cynoglossum officinale* is another Boraginaceae known to contain hepatotoxic PA. Calves dosed with 60 mg/kg of PA from *C. officinale* died within 24 h with massive hepatocellular necrosis and liver hemorrhages (Baker et al. 1991). *C. officinale* has not been reported in Colombia but two other species of *Cynoglossum* (*C. amabile* and *C. trianaeum*) were reported by Barajas-Meneses et al. (2005). The presence of *C. officinale* in Colombia cannot be ruled out because it is considered a cosmopolitan plant. The toxicology of *C. amabile* and *C. trianaeum* has not been investigated.

Plants That Cause Intrahepatic Cholestasis

Lantana camara (venturosa, sanguinaria, lantana) is a tree or bush of the Verbenaceae family native to tropical America. In Colombia, it is a common plant in all ecosystems from sea level to 2,500 m elevation. The phytochemistry of *L. camara* is complex as it contains a wide variety of chemical substances, including triterpenes, mono and sesquiterpenes, iridoid and phenyl ethanoid glycosides, nafthoquinones, and flavonoids, among other compounds (Ghisalberti 2000, Sharma and Sharma 2007). The hepatotoxic action of *L. camara* has been attributed to two pentacyclic triterpenes known as lantadene A and B. The lantadene content in *L. camara* plants is variable, and potentially toxic plants contain at least 80 and 200 mg/kg of lantadenes A and B, respectively (Ghisalberti 2000). In practice, this is equivalent to a dosage of 40 g of

fresh material per kilogram of weight. Lantadenes are 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 (Sharma and Sharma 2007). The primary toxic action of the lantadenes may result in secondary photosensitization due to the reduced excretion of phylloerythrin, a natural metabolite product of the anaerobic fermentation of chlorophyll and normally excreted in bile (Johnson 1982). Disruption in the biliary elimination of phylloerythrin increases its blood level and deposition in subcutaneous tissues. In non-pigmented areas of the skin or in areas without dark hair, phylloerythrin reacts with solar light, forming reactive molecules that damage the local tissue causing erythema, edema, inflammation, and necrosis of the epidermis. *Lantana camara* toxicosis can affect cattle, sheep, goats, horses, and buffaloes. Apart from *L. camara,* there are at least 14 species of *Lantana* present in Colombia (Bernal et al. 2006), whose toxicology and potential adverse effects in animals have not been investigated.

Plants that contain steroidal saponins may also cause intrahepatic cholestasis in cattle but through a different mechanism of action than lantadenes. The toxic effect of the steroidal saponins is related to their normal metabolism in the rumen (Graydon et al. 1991). The first step in the metabolism of steroidal saponins is a 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 (Graydon et al. 1991). These glucuronate crystals block the normal secretion of bile, which in turn disrupts the normal secretion of phylloerythrin, the compound responsible for the secondary photosensitization. The major sapogenin responsible for hepatogenous photosensitization is epismilagenine (Miles et al. 1992). Most of the plants that contain toxic levels of steroidal saponins in Colombia belong to the Poaceae family (grasses) and include *Brachiaria brizantha* (pasto alambre), *Brachiaria decumbens* (braquiaria), *Panicum coloratum* (pasto Klein), *Panicum maximum* (pasto guinea), and *Pennisetum clandestinum* (kikuyo). Toxic effects have been reported but not confirmed. Alternatively, *B. brizantha* and *B. decumbens* can also induce secondary photosensitization in cattle, sheep, and goats due to hepatic damage from the hepatotoxic compound sporidesmin, a mycotoxin produced by the fungus *Pithomyces chartarum*. This toxicosis has been observed sporadically in Colombia. The mechanism of action of sporidesmin involves the formation of reactive oxygen species that damage the biliary canaliculi (Morris et al. 2004). *Sapindus saponaria* (chambimbe, jaboncillo, pepo) is a tree native to the tropical humid forests of Colombia (600-2,000 m above sea level) that grows up to 12 m in height. In Colombia, ingestion of *S. saponaria* by cattle has been associated with hepatotoxicity and photosensitization (Torres 1984b), which could be explained by its content of saponins (Tsuzuki et al. 2007). However, the toxic component of *S. saponaria* to cattle is still not confirmed. Phytochemical studies conducted by Wahab and Selim (1985) showed that this plant contains flavonoids (in leaves and twigs), tannins, essential oils, anthraquinones (in twigs), β-sitosterol, α and β-amirin (in seeds), rutin, luteolin, and 4'-methoxyflavon (in seeds and leaves). The saponins of *S. saponaria* are toxic to fish and have traditionally been used by indigenous people for fishing (Quigley 1956).

Trema micrantha (Ulmaceae), a plant reported as hepatotoxic for horses and ruminants in Brazil (Gava et al. 2010), occurs in Colombia where it is known as zurrumbo, majagua, verraquillo, and other names depending on the geographical region (Bernal et al. 2006). *Xanthium* spp. (Asteraceae) containing the hepatotoxic compound carboxyatractyloside (Witte et al. 1990) are also found in Colombia: *X. cavanillesii* (cadillo), *X. spinosum* (casamarucha), and *X. strumarium* (cadillo, cardo) (Bernal et al. 2006). However, no cases of toxicosis associated with these plants have been documented.

Plants That Affect the Urinary System

Urinary bladder tumors in cattle have been associated with the intake of *Pteridium aquilinum* (helecho macho, helecho liso). This weedy plant found worldwide grows in well-drained, acid soils and open lands and is common in the eastern part of Colombia. Cattle readily eat the plant when it is still young; old plants are normally not eaten unless there are no other plants in the pasture. This plant contains at least two important toxic components: a thiaminase capable of destroying vitamin B1 and a mutagenic carcinogenic glycoside known as ptaquiloside (Smith 1997). In Colombia the toxicosis

by *P. aquilinum* has been mainly associated with a disease in cattle known as bovine enzootic hematuria, which causes economic losses in some Departments where dairy cattle are raised (Pedraza et al. 1983). The toxicosis results from the chronic intake of ptaquiloside and its major sign is hematuria caused by the development of multiple bleeding tumors in the bladder mucosa (Pedraza et al. 1983, Smith 1997). The glycoside can be excreted in the milk (Alonso-Amelot et al. 1997) and in Costa Rica and Venezuela, the intake of milk from cows feeding on *P. aquilinum* has been associated with an increased incidence of gastric cancer (Alonso-Amelot 1997). The incidence of gastric cancer in humans who consume milk from cows exposed to *P. aquilinum* has not been investigated in Colombia.

High levels of soluble oxalates that chemically correspond to sodium or potassium salts of oxalic acid (Diaz 2001) are a common cause of plant-induced nephrotoxicity. Soluble oxalates are readily absorbed in the systemic circulation where they can react with blood calcium, causing hypocalcemia and tetania. Oxalates eventually form insoluble calcium oxalate crystals that block the renal tubules (James and Butcher 1972). Precipitation of calcium oxalate crystals in the kidney leads to anuria, uremia, and acute renal failure. Soluble oxalate toxicosis is more common in ruminants because the plants that contain them are usually more palatable and readily eaten compared with plants containing insoluble oxalates. At postmortem examination there are edema and hemorrhages of the ruminal mucosa and kidney inflammation (James and Butcher 1972). Most of the soluble oxalate-accumulating plants of toxicological interest in Colombia belong to the Poaceae (grasses), Amaranthaceae, and Polygonaceae families.

Native or naturalized grasses known to accumulate potentially toxic levels of soluble oxalates include *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). In horses, prolonged intake of tropical grasses containing soluble oxalates can lead to secondary hyperparathyroidism or osteodystrophia fibrosa (Cheeke 1995). This problem is caused by reduced calcium absorption from the gut due to the reaction of the soluble oxalate with the dietary calcium, forming calcium oxalate. 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 (Cheeke 1995). 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. However, soluble oxalate toxicosis has not been documented in Colombia.

From the Amaranthaceae family, the highly toxic plant *Halogeton glomeratus* (James and Butcher 1972) has not been reported in Colombia, but there are about 20 *Amaranthus* species including *A. retroflexus* and *A. hybridus*, two introduced invasive and toxic weeds. These two weeds contain both soluble oxalates and nitrates although the toxicosis is generally associated with their oxalate content. Acute renal failure and perirenal edema have been reported worldwide in cattle, sheep, pigs, and horses that ate these plants (Last et al. 2007). Signs and lesions in cattle include weakness, ataxia, high blood urea levels, proteinuria, perirenal edema, and nephrosis.

Another common plant in Colombia that accumulates potentially toxic levels of soluble oxalates is the Polygonaceae *Rumex crispus* (lengua de vaca, romaza). The toxicosis by *R. crispus* affects mainly sheep although it can also affect cattle, which can die acutely after eating high amounts of the plant. The soluble oxalate content in *R. crispus* can be as high as 6.6 to 11.1 percent dry matter (Panciera et al. 1990); however, levels of soluble oxalate in *R. crispus* in Colombia have not been investigated.

Plants That Affect the Nervous System

Plants That Block the Neuromuscular Junction

Conium maculatum is native to Europe and naturalized in Colombia and is commonly found along roadsides and close to irrigation waters, usually between 1,200 and 2,800 m above sea level. *Conium maculatum* contains at least five main piperidine alkaloids, of which the most important are coniine (mainly in the seeds) and γ-coniceine (in vegetative tissue). The other three alkaloids are *N*-methylconiine, conhydrine, and pseudoconhydrine. In world literature, the toxicosis has been reported in horses, pigs, sheep, and cattle, with cattle the most sensitive species. The clinical signs of *Conium maculatum* poisoning in domestic animals and humans were reviewed by Panter et al. (1988) and more recently by Vetter (2004). Coniine, γ-

coniceine, and *N*-methylconiine cause paralysis of the musculature due to the blockade of the neuro-muscular junctions. The initial signs of the acute toxicosis include muscle weakness, tremors, incoordination, and mydriasis, followed by brady-cardia, depression, coma, and death from respiratory failure. Poultry species (turkeys, geese, and quail) show ataxia and inability to fly (Frank and Reed 1987). The closely related toxic plant of the same family (Apiaceae), known as waterhemlock (*Cicuta* spp.), has not been reported in Colombia.

Plants That Affect the Central Nervous System (CNS)

Ipomoea carnea (batatilla, tapabotija, bejuco pupú, campanuela) is native to tropical and subtropical America and grows spontaneously in the eastern part of Colombia and other warm parts of the country. It is used as an ornamental and can become a weed in pastures, especially in the eastern region of the country. Antoniassi et al. (2007) and Armién et al. (2007) showed that *Ipomoea carnea* subsp. *fistulosa*, a subspecies present in Colombia, affects the central nervous system of cattle, sheep, and goats in Brazil. The toxic compound of this plant was found to be the indolizidine alkaloid swainsonine that inhibits lysosomal hydroxylases, particularly the enzyme α-mannosidase. Swainsonine causes a cellular alteration known as lysosomal storage disease, characterized by excessive carbohydrate accumulation within the lysosomes (Jolly and Walkley 1997). Livestock exposed to the toxin fail to gain weight and exhibit neurological alterations including failure to apprehend and swallow feed, hypermetria, and ataxia (Antoniassi et al. 2007). Postmortem examination reveals no macroscopic changes but histological lesions in neurons can be seen. In Colombia, *Ipomoea carnea* is considered to be one of the most important toxic plants for cattle in the Arauca river valley (Vargas et al. 1998). *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*. Of these genera, only *Sida* has been reported in Colombia (Bernal et al. 2006) but not the toxic species *Sida carpinifolia* (Seitz et al. 2005).

Grasses That Cause Neurological Signs

Phalaris aquatica (formerly known as *P. tuberosa*) and *P. arundinacea* are two species of *Phalaris* naturalized in Colombia. These grasses are of low palatability, and consumption causes diarrhea. In cattle and sheep these grasses may cause acute toxicosis with sudden death, subchronic toxicosis with transient neurological signs, or chronic toxicosis with permanent neurological damage (Bourke et al. 2003). Clinical signs are mostly neurological and include ataxia, aimless walking, muscular fasciculation, tremors, opisthotonus, excessive salivation, tetanic spasms, and limb paddling (Bourke et al. 2005). The toxic effects of *P. aquatica* and *P. arundinacea* are attributed to their alkaloid content. These plants contain at least five indole alkaloids, three β-carboline alkaloids, and several phenolic amines including hordenine, tyramine, and *N*-methyl-tyramine (Bourke et al. 2006).

Another grass sporadically associated with nervous signs in Colombian cattle is the introduced species *Pennisetum clandestidum* (kikuyu). Mejía (1985) reported high mortality in dairy cattle foraging on *P. clandestinum* in the high plateau of Bogotá and the valleys of Ubaté and Chiquinquirá. The main signs included tremors, ataxia, ruminal stasis, recumbence, decreased milk production, and piloerection. Sporadic episodes of kikuyu poisoning similar to the one reported in Colombia have been reported in the literature but the cause of the problem is still unknown (Cheeke 1998, Bourke 2007).

Cynodon dactylon is an introduced grass recently reported in Colombia by García-Ulloa et al. (2005) that can be found from sea level to 2,000 m elevation. This grass causes a disease in cattle known as bermuda grass tremor, a form of convulsive ergotism (Porter 1997). The main clinical signs include fasciculations of the neck and chest muscles and inability to move or stand due to paralysis of the rear limbs. The disease is caused by ergot alkaloids, mainly ergonovine and its epimer ergonovinine, which are produced by toxic strains of *Claviceps* sp. growing in the grass (Porter et al. 1974). Another grass reported to cause ergot-induced toxicosis, mainly due to the alkaloid ergovaline, is *Festuca arundinaceae* (Tor-Agbidye et al. 2001). Although this grass is common in Colombia, the toxicosis has not been reported, which means that either the disease has been overlooked or not documented. Alternatively, since the grasses that do not contain the endophyte fungus *Neotyphodium coenophialum* are not toxic, it is possible that the

varieties introduced in Colombia are not toxigenic. The same is true for *Lolium perenne*, a naturalized forage grass native to Europe, Asia, and North Africa. This grass may contain tremorgenic mycotoxins called lolitrems when infected with the endophyte *Neotyphodyum lolii* (Hovermale and Craig 2001), but this toxicosis has not been documented in Colombia. *Lolium perenne*, however, has been associated with high levels of nitrate in Colombia (table 1).

Plants That Induce Thiamine Deficiency

Plants that accumulate thiaminases may induce thiamin deficiency with the subsequent development of neurological signs, especially in horses. Ruminants are highly resistant to thiaminases because they synthesize the vitamin in the rumen. At least two plants present in Colombia have been reported to contain thiaminases: the previously mentioned *Pteridium aquilinum* and *Equisetum* spp. (cola de caballo). Several species of *Equisetum* are found in Colombia including *E. bogotense*, *E. myriochaetum*, and *E. giganteum* (Hauke 1969). *Equisetum* spp. are not palatable and therefore the toxicosis is infrequently reported worldwide. The toxicosis is subchronic and has been associated with the intake of hay contaminated with 20-percent *Equisetum* or more during 2 to 5 weeks (Cheeke 1998). Initial signs in horses include 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.

Other Neurotoxic Plants

Bambusa vulgaris (bamboo, guauda amarilla) is a Poaceae reported to have caused neurologic disorders in horses in Brazil (Barbosa et al. 2006); major signs include motor incoordination, paresis of the tongue, depression, ataxia, and incoordination. Although this plant is common in Colombia, no reports of toxicosis have been documented.

Hypochaeris radicata (Asteracea) is present in Colombia under the common names of centella, chicoria, chicria, and diente de león (Bernal et al. 2006). This plant should not be confused with the "true" diente de león, *Taraxacum officinale* (Asteraceae). *H. radicata* produces a toxicosis in horses known as stringhalt, whose major clinical signs are high stepping with hyperflexion of the hind limbs (Araújo et al. 2008). The disease was recently diagnosed in horses imported from Argentina at the College of Veterinary Medicine of the National University of Colombia in Bogotá but has not been documented in native horses. Two plants of the Fabaceae family known to produce neurological signs in horses and other animals are present in Colombia: *Indigofera spicata* (añil, añalito, azul) and *Lathyrus sativus* (arveja de monte) (Diaz 2010). However, no cases of toxicosis caused by these plants have been reported yet.

Plants That Affect the Musculoskeletal System and Connective Tissue

The genus *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. *Senna* toxicosis causes 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 (Barth et al. 1994). The *Senna* spp. recognized as toxic that have been reported in Colombia include *S. occidentalis* (bicho de café, café de brusca, cafelillo), *S. obtusifolia* (bicho, chilinchil), *S. reticulata* (bajagua, dorancé), *S. tora*, and *S. roemeriana*. The weed *S. obtusifolia* is commonly seen in corn, sorghum, and soybean fields in Colombia, and the seeds have been found contaminating harvested crops. Studies conducted in Colombia with broiler chickens and laying hens have demonstrated the adverse effects of *Senna* seeds on poultry production (Torres et al. 2003).

Petiveria alliacea (anamú) is an herb native to tropical America known in some places as "garlic weed" because of its strong garlic odor. Reported only in Colombia, *P. alliacea* produces a unique subchronic toxicosis in young cattle known as dystrophic muscular emaciation. The disease is observed mainly in calves 2 to 12 months old and sometimes even in calves suckling lactating cows that eat the toxic plant, which suggests that the toxin (or toxins) is excreted in the milk. The toxicosis has been reproduced by feeding 3 g of the plant daily for 30 days (Torres 1984a). Experimental intoxication of cattle and sheep shows decreased activity of serum cholinesterases, incoordination, severe flexion

of the fetlock, and severe muscle atrophy. Also, the meat from these animals develops a strong garlic odor and is usually rejected by the consumer. The compound responsible for the toxic effects of *P. alliacea* has not been identified but it could potentially be dibenzyltrisulfide (DBTS), a bioactive compound with insecticidal activity isolated from the plant by Johnson et al. (1997). Two *Phytolacca* spp. have been reported as toxic in Colombia: *P. icosandra* (altasara, cargamanta, yerba de culebra) and *P. bogotensis* (altasara, cargamanta, guaba, yerba de culebra). Pérez-Arbeláez (1931) indicated that the roots, leaves, and fruits of these two species are toxic but did not detail either the signs of the toxicosis or the animal species affected.

Two plants of the Malpighiaceae family native to Colombia have been associated with a disease of cattle and sheep characterized by the deposition of an abnormal pink or violet pigment in connective tissues (including bones and teeth): *Bunchosia pseudonitida* (mamey, tomatillo, pateperro, cuatrecasas) and *Bunchosia armeniaca* (mamey de tierra fría, manzano de monte). Mortality is usually low (less than 5 percent) but morbidity, represented by animals abnormally pigmented, can be higher than 90 percent (Peña 1982). This disease occurs in the departments of Tolima and Huila, particularly during periods of drought, and is known as bovine chromatosis. Besides producing a discoloration of the connective tissues, *B. pseudonitida* has been associated with ataxia and incoordination, excretion of discoloured urine, and hepatic toxicity characterized by increased activity of serum gamma glutamyl transpeptidase (GGT) and mild degenerative histologic lesions (Mejía 1984). The disease causes losses to the cattle producer not only because of the mortality but also because pigmented carcasses are confiscated by the authorities. The chemical composition of the pigment is still unknown but it is suspected that the alkaloid 2,3-dehydro-4β-piperidone might play a role. This alkaloid was isolated from *B. pseudonitida* leaves and takes on a violet color on contact with air. The pigment is eliminated very slowly, and pigmented animals require at least 9 months of uncontaminated food to completely eliminate the pigment from their tissues (Torres 1984b).

Conium maculatum may affect the musculo-skeletal system. In addition to being neurotoxic, the alkaloids from *Conium maculatum* can also cause congenital malformations in calves, particularly contractures of the musculoskeletal system and cleft palate. The sensitive periods for congenital malformations during gestation are days 40 to 100 for contractures and cleft palate and days 40 to 50 for cleft palate only (Panter et al. 1988). However, these malformations have not yet been documented in Colombian livestock.

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, as previously discussed under hepatotoxic plants. *Fagopyrum esculentum* (alforjón, trigo sarraceno, trigo negro), formerly known as *Polygonum fagopyrum*, is a Polygonaceae native to central Asia and naturalized in Colombia. The flowers and seeds of *F. esculentum* contain a conjugated photo-reactive quinone known as fagopyrin (Hagels et al. 1995), which has been known to induce primary photosensitization in cattle, sheep, goats, and other animal species for many years (Sheard et al. 1928). Primary photosensitization is 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. Although *H. perforatum* has not been reported in Colombia, there are about 20 species of *Hypericum* present in the country (Bernal et al. 2006) whose phytochemistry has not been investigated.

Several plants of the Euphorbiaceae family are potentially toxic due to their content of phorbol type diterpene esters, which are highly irritating to the skin and mucosa, and some are tumor promoters (Goel et al. 2007). *Croton* spp. are among the Euphorbiaceae known to contain skin-irritating substances. Some of the *Croton* spp. reported in Colombia include *C. argenteus* (hierba de cotorra), *C. bogotanus* (croto, tapamucro), *C. eluteria* (cascarilla, quina aromática), *C. funckianus* (croto, drago), *C. hirtus* (= *C. glandulosus*, come-mano, drago, guacamayo), *C. lechleri* (drago, drago sangregado), *C. leptostachyus* (drago, mosquerillo),

C. magdalenensis (drago, guacamayo), and *C. schiedeanus* (almizclillo, sabaleto).

Another genus of Euphorbiaceae family is *Euphorbia* from which at least two species have been reported as toxic in Colombia: *E. dichotoma* (teología, tafura) and *E. prostrata* (golondrina, leche de sapo). *Euphorbia dichotoma* was reported as toxic by Pérez-Arbeláez (1931), but there are no toxicological studies for this species. *Euphorbia prostrata* has been reported to produce a latex that irritates the skin of the animals and produces diarrhea and colic when ingested. The latex of *Hura crepitans* (ceiba blanca, ceiba lechosa, tronador), a huge tree of the Euphorbiaceae family, is also considered toxic and highly irritating to the skin and mucosa. In humans, the intake of *H. crepitans* seeds produces a burning sensation in the mouth, vomition, diarrhea, dyspnea, and headache (Fowomola and Akindahunsi 2007). The phorbol esters from another Euphorbiaceae tree known as *Jatropha curcas* (piñón de fraile, purga de fraile, tártaro emético) are also highly irritating to the skin, and its seeds contain a caustic oil (Pérez-Arbeláez 1931). Other *Jatropha* spp. reported as toxic in Colombia are *J. multifida* (avellano purgante) and *J. urens* (Pérez-Arbeláez 1931), but their phytochemistry and toxicology are unknown.

Solanum verbascifolium (miao de perro) is a bush used sporadically in Colombia as a forage plant during the dry season. The leaves of this plant are rough and cause skin irritation. Steroidal and triterpenoid saponins have been isolated from *S. verbascifolium* (Shultes and Raffauf 1990), as well as the glycoalkaloid solasonine, a cinnamic acid derivative, p-coumaramide, and vanillic acid (Zhou and Ding 2002). Although empirically this plant is considered toxic for cattle in Colombia, the toxicosis by *S. verbascifolium* has not yet been documented. In a review on calcinogenic plants, Mello (2003) indicates that *S. verbascifolium* is a calcinogenic plant and cites a study by Tustin et al. (1973); however, Tustin et al. (1973) do not mention *S. verbascifolium* anywhere in their publication and there are no reports in the literature indicating that this plant is, in fact, calcinogenic.

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* (trébol rojo) are two of the phytoestrogen-containing plants that have been associated with reproductive problems in cattle in Colombia. Alfalfa contains at least four phytoestrogens: one derived from coumestan (coumestrol) and three from isoflavone (apigenin, luteolin, and quercetin). The concentration of each phytoestrogen varies from 15 to 225 μg/g dry matter with reduced concentrations at the beginning of the flowering period (Seguin et al. 2004). *Trifolium pratense* contains isoflavone-type phytoestrogens including genistein, daidzein, biochanin A, and formononetin. 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 heifers (Adams 1995).

Solanum aphyodendron (mata de tinto, tinto, frutillo) is a common species found on roadsides in Colombia, which often forms large monospecific stands in open areas (Knapp 1985). In Colombia, this plant has been reported to cause abortion in cows (Torres 1984b), and in the Boyacá Department aqueous extracts of the plant are used to treat retained placentas in cattle, which usually results in the expulsion of the retained placenta within hours. Sarmiento et al. (1982) investigated the effect of aqueous extracts of *S. aphyodendron* on female dogs and found that it produces uterine contractions and other effects such as mydriasis, hypotension, tachycardia, increased respiratory rate, and depression. The compound responsible for the effect on the uterine muscle is still unknown.

Plants That Contain Systemic Poisons

Systemic poisons interfere with biochemical processes common to all cells and usually do not have a particular target organ. Examples of these poisons are monofluoroacetic acid, a compound capable of blocking the Krebs cycle, and cyanide, an inhibitor of the respiratory chain in the mitochondria. The Rubiaceae *Palicourea margravii*, also known as *P. crocea* (café de monte, cafecillo, café bravo, flor de muerto), contains monofluoroacetic acid and is considered one of the main toxic plants for cattle in the Arauca River valley (Vargas et al. 1998). This plant typically

Table 3. Major cyanogenic glycoside-accumulating plants in Colombia

Family	Latin name	Common name
Adoxaceae	*Sambucus canadensis, S. nigra*	Sauco, saúco
Bignoniaceae	*Tanaecium exitiosum, T. jaroba**	Mataganado, bejuco blanco
	*Tanaecium nocturnum**	Unknown
Euphorbiaceae	*Manihot esculenta*	Yuca agria, yuca blanca
Fabaceae	*Lotus spp.*	Trébol pata de pájaro, trébol de cuernos
	Phaseolus lunatus	Fríjol lima
	Trifolium repens	Trébol blanco
Linaceae	*Linum usitatissimum*	Lino, linaza
Malpighiaceae	*Mascagnia concinna*	Mindaca, mataganado
Poaceae	*Cynodon dactylon*	Pasto argentina, pasto bermuda
	Digitaria sanguinalis	Guardarocío, pata de gallina
	Sorghum bicolor	Sorgo, sorgo forrajero
	Sorghum halepense	Pasto Johnson, capim argentino
	Zea mays	Maíz
Rosaceae	*Prunus spp.*	Cerezo, duraznillo, manzano criollo

*It is thought that these plants contain cyanogenic glycosides but this has not been demonstrated.

causes sudden death, especially if the poisoned animals are forced to walk or run.

Several plant species containing cyanogenic glycosides are present in Colombia, some of which are known to cause livestock losses (table 3). 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^-), 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* are two trees of the Adoxacea family naturalized in Colombia. They can accumulate toxic amounts of cyanogenic glycosides, especially in their leaves, roots, and green fruits. The major cyanogenic glycosides present in *Sambucus* spp. are sambunigrine, holocaline, and prunasine (Dellagreca et al. 2000). Though the toxicosis by *Sambucus* spp. has not been documented in Colombia, it has been reported in both animals and humans in other countries (Atkinson and Atkinson 2002). *Tanaecium exitiosum* (bejuco blanco, mataganado) and *T. jaroba* (calabacillo, bejuco blanco) are two plants of the Bignonaceae family native to Colombia that are toxic to livestock. *Tanaecium exitiosum* is a vine native to the Magdalena River valley that was reported for the first time by the Colombian botanist Armando Dugand in 1942 (Dugand 1942). Even though the plant is known to be toxic and highly palatable to cattle (hence the common name "mataganado," which means "cattle killer"), no studies have been conducted to determine its phytochemistry. In the only study so far conducted with this plant, Mora (1943) found that 70 g of the plant is lethal for cows and goats when given in two separate dosages within 24 h. Mora (1943) postulated that the plant accumulates cyanogenic glycosides, but no attempt was made to isolate these compounds.

Alwyn Gentry, a U.S. botanist who studied extensively the Bignonacea from Colombia and other Andean countries, reported that *T. exitiosum* is currently virtually extinct in the Magdalena River valley due to the systematic destruction to prevent cattle mortality (Gentry 1992). There are no references to *T. exitiosum* in the literature after the one published by Gentry in 1992. *Tanaecium jaroba* is a plant native to the northern region of the country also known to be toxic by cattle growers; however, no studies have been conducted to determine its chemical composition.

Another *Tanaecium* spp. reported to be toxic is *T. nocturnum*. It is native to the Amazon Basin, where the Tikuna Indians report it as toxic, as it apparently contains cyanogenic glycosides (Schultes and Raffauf 1990). Another native Colombian plant known to contain cyanogenic glycosides is *Mascagnia concinna*, a plant also known to accumulate toxic concentrations of nitrate. Torres (1984a) reported that this plant may accumulate levels of HCN greater than 40 mg of HCN/100 g. In a study conducted by Gómez (1975), it was found that less than 2 g of fresh leaves per kg body weight is lethal for cattle during the dry season. He also found that the plants accumulate more cyanogenic glycosides during the dry season as compared with the rainy season.

Conclusions

The present review describes some of the potentially toxic plants present in Colombia, a country that possesses the second-largest botanical biodiversity in the world. Toxic plants can adversely affect every organ system and pose a risk to animal health and production. Even though many of the toxic plants present in Colombia have been described and studied in other countries, it is important to investigate if the same toxic compounds reported elsewhere are present in the plants that actually grow in Colombia. Some of the plants, however, are only known in Colombia and their toxicology needs to be further investigated. These include, for example, three *Tanaecium* spp. reported as toxic (*T. exitiosum*, *T. jaroba*, and *T. nocturnum*), two *Bunchosia* spp. (*B. pseudonitida* and *B. armeniaca*), two *Phytolacca* spp. (*P. bogotensis* and *P. icosandra*), and *Mascagnia concinna*.

The information on toxic plant chemistry in Colombia is mostly limited to their nitrate or cyanide content. Research is needed not only to determine which plants represent a potential risk for animal health and production but also to investigate their phytochemistry and toxicology. It would be very useful if veterinarians were able to document plant poisoning cases through government reporting services. Furthermore, university and government scientists, veterinarians, and extension personnel could fully investigate the various toxicoses and publish their findings in specialized journals. This would help to identify toxic species for further phytochemical and toxicological studies and possibly pharmacological activity.

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References

Adams, N.R. 1995. Detection of the effects of phytoestrogens on sheep and cattle. *Journal of Animal Science* 73:1509-1515.

Alonso-Amelot, M.E. 1997. The link between bracken fern and stomach cancer: milk. *Nutrition* 13:694-696.

Antoniassi N.A.B., E.V. Ferreira, C.E.P. dos Santos, et al. 2007. Intoxicação espontânea por *Ipomoea carnea* subsp. *fistulosa* (Convolvulaceae) em bovinos no Pantanal Matogrossense. *Pesquisa Veterinaria Brasileira* 27:415-418.

Araújo, J.A.S., B. Curcio, J. Alda, et al. 2008. Stringhalt in Brazilian horses caused by *Hypochaeris radicata*. *Toxicon* 52:190-193.

Armién, A.G., C.H. Tokarnia, P. Vargas Peixoto, and K. Frese K. 2007. Spontaneous and experimental glycoprotein storage disease of goats induced by *Ipomoeae carnea* subsp *fistulosa* (Convolvulaceae). *Veterinary Pathology* 44:170-184.

Aslani, M.R., M. Maleki, M. Mohri, et al. 2007. Castor bean (*Ricinus communis*) toxicosis in a sheep flock. *Toxicon* 49:400-406.

Atkinson, M.D., and E. Atkinson. 2002. Biological flora of the British Isles. *Journal of Ecology* 90:895-923.

Baker, D.C., J.A. Pfister, R.J. Molyneux, and P. Kechele. 1991. *Cynoglossum officinale* toxicity in calves. *Journal of Comparative Pathology* 104:403-410.

Barajas-Meneses, F., J.L. Fernández-Alonso, and R. Galindo-Tarazona. 2005. Diversidad y composición de la familia Boraginaceae en el Departamento de Santander (Colombia). *Caldasia* 27:151-172.

Barbieri, L, M.G. Battelli, and F. Stirpe. 1993. Ribosome-inactivating proteins from plants. *Biochimica et Biophysica Acta* 1154:237-282.

Barbosa J.D., C.M.C. de Oliveira, M.D. Duarte, et al. 2006. Poisoning of horses by bamboo, *Bambusa vulgaris*. *Journal of Equine Veterinary Science* 26:393-398.

Barth, A.T., G.D. Kommers, M.S. Salles, et al. 1994. Coffee senna (*Senna occidentalis*) poisoning in cattle in Brazil. *Veterinary and Human Toxicology* 36:541-545.

Bernal, H.Y. 1986. Flora de Colombia. 4. *Crotalaria*. Instituto de Ciencias Naturales, pp. 18-19, Universidad Nacional de Colombia, Bogotá, Colombia.

Bernal, R., G. Galeano, Z. Cordero, et al. 2006. Diccionario de nombres comunes de las plantas de Colombia. Versión en línea. Instituto de Ciencias Naturales, Universidad Nacional de Colombia, Bogotá, Colombia. http://biovirtual.unal.edu.co/diccionario/

Bourke, C.A. 2007. A review of kikuyu grass (*Pennisetum clandestinum*) poisoning in cattle. *Australian Veterinary Journal* 85:261-267.

Bourke, C,A, S.M. Colegate, and R.A. Culvenor. 2006. Evidence that N-methyltyramine does not cause *Phalaris aquatica*-related sudden death in ruminants. *Australian Veterinary Journal* 84:426-427.

Bourke, C.A., S.M. Colegate, D. Rendell, et al. 2005. Peracute ammonia toxicity: a consideration in the pathogenesis of *Phalaris aquatica*. Australian Veterinary *Journal* 83:168-171.

Bourke, C.A., D. Rendell, and S.M. Colegate. 2003. Clinical observations and differentiation of the peracute *Phalaris aquatica* poisoning syndrome in sheep known as "polioencephalomalacia-like sudden death." *Australian Veterinary Journal* 81:698-700.

Bretagne, J.F., N. Vidon, C. L'Hirondel, and J.J. Bernier. 1981. Increased cell loss in the human jejunum induced by laxatives (ricinoleic acid, dioctyl sodium sulphosuccinate, magnesium sulphate, bile salts). *Gut* 22:264-269.

Canchila, A. 2001. Intoxicación en cabras por consumo de *Crotalaria pallida* en Santander. *Revista Colombiana de Ciencias Pecuarias* 14(Supl. 2001):65.

Cao, H. 2003. The distribution of calcium oxalate crystals in genus *Dieffenbachia* Schott and the relationship between environmental factors and crystal quantity and quality. University of Florida. Master's thesis.

Cheeke, P.R. 1995. Endogenous toxins and mycotoxins in forage grasses and their effects on livestock. *Journal of Animal Science* 73:909-918.

Cheeke, P.R. 1998. Natural Toxicants in Feeds, Forages, and Poisonous Plants, 2nd ed., Interstate Publishers, Inc., Danville, IL.

Croat, T.B. 2004. Revision of *Dieffenbachia* (Araceae) of Mexico, Central America, and the West Indies. *Annals of the Missouri Botanical Garden* 91:668-772.

Dellagreca, M., A. Fiorentino, P. Monaco, et al. 2000. Cyanogenic glycosides from *Sambucus nigra*. *Natural Product Letters* 14:175-182.

Diaz, G.J. 2001. Naturally occurring toxins relevant to poultry nutrition. *In* S. Leeson and J.D. Summers, eds., Scott´s Nutrition of the Chicken, 4th ed., pp. 544-591, University Books, Guelph, Ontario, Canada.

Diaz, G.J. 2010. Plantas tóxicas de importancia en salud y producción animal en Colombia. Editorial, pp. 113-117, Universidad Nacional de Colombia, Bogotá, Colombia.

Diaz, G.J., L.P. Roldán, and A. Cortés. 2003. Intoxication of *Crotalaria pallida* seeds to growing broiler chickens. *Veterinary and Human Toxicology* 45:187-189.

Dugand, A. 1942. Dos nuevas Bignonaceas del Valle del Magdalena. *Caldasia* 1:29-35.

Duncan, A.J., and J.A. Milne. 1993. Effects of oral administration of brassica secondary metabolites allyl cyanide, allyl isothiocyanate and dimethyl disulphide, on the voluntary food intake metabolism of sheep. *British Journal of Nutrition* 70:631-645.

Fernández-Alonso, J.L., and M. Hernández-Schmidt. 2007. Catálogo de la flora vascular de la cuenca alta del río Subachoque (Cundinamarca, Colombia). *Caldasia* 29:73-104.

Fernández-Alonso, J.L., A. Galindo, and J.M. Idrobo. 2007. Las plantas como evidencia legal. Desarrollo de la botánica forense en Colombia. *Revista de la Academia Colombiana de Ciencias* 31:181-198.

Fowomola, M.A., and A.A. Akindahunsi. 2007. Nutritional quality of sandbox tree (*Hura crepitans* Linn). *Journal of Medicinal Food* 10:159-164.

Frank, A.A., and W.M. Reed. 1987. *Conium maculatum* (poison hemlock) toxicosis in a flock of range turkeys. *Avian Diseases* 2:386-388.

Fu, P.P., Q. Xia, G. Lin, and M.W. Chou. 2004. Pyrrolizidine alkaloids–Genotoxicity, metabolism enzymes, metabolic activation and mechanisms. *Drug Metabolism Reviews* 36:1-55.

García-Ulloa, J.A., C. Lastra, C. Salas, and M. Medina. 2005. Estudios de gramíneas (Poaceae) de Colombia: veinte novedades corológicas. *Caldasia* 27:131-145.

Gava, A., J. Lucioli, F.H. Furlan, et al. 2010. Intoxicação por *Trema micrantha* (Ulmaceae) em caprinos no Estado de Santa Catarina. *Pesquisa Veterinaria Brasilera* 30:191-194.

Gentry, A.H. 1992. A synopsis of Bignoniaceae ethnobotany and economic botany. *Annals of the Missouri Botanical Garden* 79:53-64.

Genua, J.M., and C.J. Hillson. 1985. The occurrence, type and location of calcium oxalate crystals in the leaves of fourteen species of Araceae. *Annals of Botany* 56:351-361.

Ghisalberti, E.L. 2000. *Lantara camara* L. (Verbenaceae). *Fitoterapia* 71:467-486.

Goel, G., H.P.S. Makkar, G. Francis, and K. Becker. 2007. Phorbol esters: structure, biological activity, and toxicity in animals. *International Journal of Toxicology* 26:279-288.

Goldsmith, W.W. 1909. Onion poisoning in cattle. *Journal of Comparative Pathology and Therapeutics* 22:151.

Gómez, B. 1975. *Mascagnia concinna*, (Morton), planta tóxica al ganado vacuno. *Revista ICA* 10:513-514.

Graydon, R.J., H. Hamid, P. Zahari, and C. Gardiner C. 1991. Photosensitization and crystal-associated cholangiohepatopathy in sheep grazing *Brachiaria decumbens*. *Australian Veterinary Journal* 68:234-236.

Guzmán V.H., G.A. Morales, and R. Ochoa. 1978. Intoxicación en bovinos por nitratos acumulados en pasto elefante (*Pennisetum purpureum*, Shum). *Revista ICA* 13:113-118.

Hagels, H., D. Wagenbreth, and H. Schilcher. 1995. Phenolic compounds of buckwheat herb and influence of plant and agricultural factors (*Fagopyrum esculentum* Moench and *Fagopyrum tataricum* Gärtner). *In* T. Matano and A. Ujihara, eds., Current Advances in Buckwheat Research: Proceedings of the 6th International Symposium on Buckwheat , pp. 801-809, Shinshu University Press, Shinshu, China.

Hallak, H.O., and P.J. Wedlund. 1991. Vitamin K epoxide reductase activity and its inhibition by warfarin in young and old rats. *Drug Metabolism and Disposition* 19:278-279.

Hauke, R.L. 1969. Gametophyte development in Latin American horsetails. *Bulletin of the Torrey Botanical Club* 96:568-577.

Hooper, P.T. 1978. Pyrrolizidine alkaloid poisoning–pathology with particular reference to differences in animal and plant species. *In* R.F. Keeler, K.R. van Kampen, and L.F. James, eds., Effects of Poisonous Plants on Livestock, pp. 161-176, Academic Press, New York, NY.

Hovermale, J.T., and A.M. Craig. 2001. Correlation of ergovaline and lolitrem B levels in endophyte-infected perennial ryegrass (*Lolium perenne*). *Journal of Veterinary and Diagnostic Investigation* 13:323-327.

James, L.F., and J.E. Butcher. 1972. Halogeton poisoning of sheep, effect of high level oxalate intake. *Journal of Animal Science* 35:1233-1238.

Johnson, A.E. 1982. Toxicological aspects of photosensitization in livestock. *Journal of the National Cancer Institute* 69:253-258.

Johnson, L., L.A.D. Williams, and E.V. Roberts. 1997. An insecticidal and acaricidal polysulfide metabolite from the roots of *Petiveria alliaceae*. *Pesticide Science* 50:228-232.

Jolly, R.D., and S.U. Walkley. 1997. Lysosomal storage diseases of animals, an essay in comparative pathology. *Veterinary Pathology* 34:527-548.

Knapp, S. 1985. New species of *Solanum* Section Germinata (G. Don) Walp. (Solanaceae) from South and Central America. *Annals of the Missouri Botanical Garden* 72:558-569.

Last, R.D., J.H. Hill, and G. Theron. 2007. An outbreak of perirenal oedema syndrome in cattle associated with ingestion of pigweed (*Amaranthus hybridus* L.). *Journal of the South African Veterinary Association* 78:171-174.

López, N.A. 2002. "Dieta / Intoxicación con catapis." News article published in the newspaper "El Tiempo" on September 19, 2002.

Loretti, A.P., I.M.R. da Silva, and R.E. Ribeiro. 2003. Accidental fatal poisoning of a dog by *Dieffenbachia picta* (dumb cane). *Veterinary and Human Toxicology* 45:233-239.

Mattocks, A.R. 1986. Chemistry and Toxicology of Pyrrolizidine Alkaloids. Academic Press, San Diego, CA.

Mejía, A.B. 1985. Intoxicación por nitratos en los bovinos. *Ganados y Praderas* 4:43-45.

Mejía, B. 1984. Toxicología de la *Bunchosia pseudonitida*, estudio clinico-patológico de la cromatosis bovina. Programa Universidad Nacional de Colombia / Instituto Colombiano Agropecuario, Bogotá, Colombia. Master's thesis.

Mello, J.R.B. 2003. Calcinosis–calcinogenic plants. *Toxicon* 41:1-12.

Miles, C.O., A.L. Wilkins, S.C. Munday, et al. 1992. Identification of calcium salt of epismilagenin β-D-glucuronide in the bile crystals of sheep affected by *Panicum dichotomiflorum* and *Panicum schinzii* toxicoses. *Journal of Agricultural and Food Chemistry* 40:1606-1609.

Ministerio de Agricultura y Desarrollo Rural. 2005. La cadena de la carne bovina en Colombia. Una mirada global de su estructura y dinámica 1991–2005. Observatorio Agrocadenas Colombia, Documento de Trabajo No. 273. Bogotá, Colombia.

Mora, C.R. 1943. Contribución al estudio de las plantas tóxicas en medicina. *Revista de Medicina Veterinaria* 12:5-38.

Morris, C.A., N.R. Towers, W.D. Hohenboken, et al. 2004. Inheritance of resistance to facial eczema, a review of research findings from sheep and cattle in New Zealand. *New Zealand Veterinary Journal* 52:205-215.

Ozmen, O., F. Mor, and U. Ayhan. 2003. Nitrate poisoning in cattle fed *Chenopodium album* hay. *Veterinary and Human Toxicology* 45:83-84.

Panciera, R.J, T. Martin, G.E. Burrows, et al. 1990. Acute oxalate poisoning attributable to ingestion of curly dock (*Rumex crispus*) in sheep. *Journal of the American Veterinary Medical Association* 196:1981-1984.

Panter, K.E., R.F. Keeler, and D.C. Baker. 1988. Toxicoses in livestock from the hemlocks (*Conium* and *Cicuta* spp.). *Journal of Animal Science* 66:2407-2413.

Parton, K. 2000. Onion toxicity in farmed animals. *New Zealand Veterinary Journal* 48:89.

Patnaik, G.K., and E. Köhler. 1978. Pharmacological investigation on asclepin - a new cardenolide from *Asclepias curassavica*. Part II. Comparative studies on the inotropic and toxic effects of asclepin, g-strophantin, digoxin and digitoxin. *Arzneimittel-Forschung* 28:1368-1372.

Pedraza, C., F. Villafañe, and R.D. Torrenegra. 1983. Hematuria vesical bovina y su relación con algunas especies vegetales. *Revista ACOVEZ* 7:11-19.

Peña, N.E. 1982., Contribución a la epidemiología de la cromatosis bovina en algunos municipios del Huila y Tolima (Colombia). *Revista Colombiana de Ciencias Pecuarias* 4:51-63.

Peña, N.E., L.C. Villamil, D. Parra, and C.A. Lobo. 1980. Las Enfermedades de los Animales en Colombia. Situación por Regiones Naturales. Ministerio de Agricultura, Instituto Colombiano Agropecuario - ICA. Bogotá, Colombia.

Pérez-Arbeláez, E. 1931. Plantas venenosas de Colombia. *Revista de Medicina Veterinaria* 3:189-198.

Poindexter, B. W. Feng, A. Dasgupta, and R. Bick. 2007. Oleandrin produces changes in intracellular calcium levels in isolated cardiomyocytes, a real-time fluorescence imaging study comparing adult to neonatal cardiomyocytes. *Journal of Toxicology and Environmental Health A* 70:568-574.

Porter, J.K. 1997. Endophyte alkaloids. *In* J.P.F. D'Mello, Handbook of Plant and Fungal Toxicants, pp. 51-62, CRC Press, Boca Raton, FL.

Porter, J.K., C.W. Bacon, and J.D. Robbins. 1974. Major alkaloids of a *Claviceps* isolated from toxic bermuda grass. *Journal of Agricultural and Food Chemistry* 22:838-841.

Powell, A.M., and R.M. King. 1969. Chromosome numbers in the Compositae, Colombian species. *American Journal of Botany* 56:116-121.

Prache, S. 1994. Haemolytic anaemia in ruminants fed forage brassicas, a review. *Veterinary Research* 25:497-520.

Pritchard, D.G., L.M. Markson, P.J. Brush, et al. 1983. Haemorrhagic syndrome of cattle associated with the feeding of sweet vernal (*Anthoxanthum odoratum*) hay containing dicumarol. *Veterinary Record* 113:78-84.

Puschner, B., F.D. Galey, D.M. Holstege, and M. Palazoglu. 1998. Sweet clover poisoning in dairy cattle in California. *Journal of the American Veterinary Medical Association* 212:857-859.

Quigley, C. 1956. Aboriginal fish poisons and the diffusion problem. *American Anthropologist. New Series* 58:508-525.

Rae, H.A. 1999. Onion toxicosis in a herd of beef cows. *Canadian Veterinary Journal* 40:55-57.

Rietjens, I.M.C.M., M.J. Martena, M.J. Boersma, et al. 2005. Molecular mechanisms of toxicity of important foodborne phytotoxins. *Molecular Nutrition and Food Research* 49:131-158.

Roberts, D.M., E.S. Southcott, J.M. Potter, et al. 2006. Pharmacokinetics of digoxin cross-reacting substances in patients with acute yellow oleander (*Thevetia peruviana*) poisoning, including the effect of activated charcoal. *Therapeutic Drug Monitoring* 28:784-792.

Runciman, D.J., A.M. Lee, K.F.M. Reed, and J.R. Walsh. 2002. Dicumarol toxicity in cattle associated with the ingestion of silage containing sweet vernal grass (*Anthoxanthum odoratum*). *Australian Veterinary Journal* 80:28-32.

Sarmiento, R., M. Trebert, and L. Serrano. 1982. Efectos farmacológicos de la planta *Solanum chamaecerasus* Bitter, y su posible aplicación en patología genital. *Revista de la Facultad de Medicina Veterinaria y Zootecnia* 35:51-56.

Schultes, R.E., and R. F. Raffauf. 1990. The Healing Forest: Medicinal and Toxic Plants of the Northwest Amazonia, p. 108, Dioscorides Press, Portland, OR.

Seguin, P., W. Zheng, and A. Souleimanov. 2004. Alfalfa phytoestrogen content, impact of plant maturity and herbage components. *Journal of Agronomy and Crop Science* 190:211-217.

Seitz, A.L., E.M. Colodel, M. Schmitz, et al. 2005. Use of lectin histochemistry to diagnose *Sida carpinifolia* (Malvaceae) poisoning in sheep. *Veterinary Record* 156:386-388.

Sharma, O.P., and S. Sharma. 2007. A review of the hepatotoxic plant *Lantana camara*. *Critical Reviews in Toxicology* 37:313-352.

Sharma, O.P., R.K. Dawra, N.P. Kurade, and P.D. Sharma. 1998. A review of the toxicosis and biologial properties of the genus *Eupatorium*. *Natural Toxins* 6:1-14.

Sheard, C., H.D. Caylor, and C. Schlotthauer. 1928. Photosensitization of animals after the ingestion of buckwheat. *Journal of Experimental Medicine* 47:1013-1028.

Small, A.C., W.R. Kelly, A.A. Seawright, et al. 1993. Pyrrolizidine alkaloidosis in a two month old foal. *Zentralblatt für Veterinärmedizin. Reihe A* 40:213-218.

Smith, B.L. 1997. The toxicity of bracken fern (genus *Pteridium*) to animals and its relevance to man. *In* J.P.F. D'Mello, ed., Plant and Fungal Toxicants, pp. 63-76, CRC Press, Boca Raton, FL.

Stickel, F., and H.K. Seitz. 2000. The efficacy and safety of comfrey. *Public Health Nutrition* 3:501-508.

Tokarnia, C.H., J. Döbereiner, and P.V. Peixoto. 2002. Poisonous plants affecting livestock in Brazil. *Toxicon* 40:1635-1660.

Tor-Agbidye, J., L.L. Blythe, and A.M. Craig. 2001. Correlation of endophyte toxins (ergovaline and lolitrem B) with clinical disease, fescue foot and perennial ryegrass staggers. *Veterinary and Human Toxicology* 43:140-146.

Toro, G., E. Rojas, and G. Arango. 1997. Seneciosis. Enfermedad veno-ocusiva del hígado (EVOH) en Colombia. 1964-1996. Identificación, manejo y solución de un problema. *Revista de la Academia Colombiana de Ciencias* 21:35-56.

Torres, J.E. 1984a. Plantas tóxicas para el ganado. I Parte. *Carta Ganadera* 21(4):14-19.

Torres, J.E. 1984b. Plantas tóxicas para el ganado. III Parte. *Carta Ganadera* 21(5):15-17, 23-27.

Torres, L.M., P. Diaz, and G.J. Diaz. 2003. Efectos de la adición de semillas de *Senna obtusifolia* (cafelillo, bajagua) en la dieta para aves de postura y pollos de engorde. *El Cerealista* 67:35-38.

Trheebilcock, E., F. Villafañe, and A. Gil. 1978. Síndrome caída del ganado–Contribución a su estudio. *Revista ICA* 13:119-125.

Tsuzuki, J.K., T.I.E. Svidzinski, C.S. Shinobu, et al. 2007. Antifungal activity of the extracts and saponins from *Sapindus saponaria* L. *Anais da Academia Brasileira de Ciências* 79:577-583.

Tustin, R.C., C.H. Pienaar, J.M. Schmidt, et al. 1973. Enzootic calcinosis of sheep in South Africa. *Journal of the South African Veterinary Association* 44:383-395.

Vargas, O.M., L.M. Quiñonez, and J.L. Parra. 1998. Plantas tóxicas para los bovinos en la vega del río Arauca. Manual de Asistencia Técnica No. 03, CORPOICA Regional 8, Villavicencio, Meta, Colombia, 31 p.

Vermunt, J., and R. Visser. 1987. Nitrate toxicity in cattle. *New Zealand Veterinary Journal* 35:136-137.

Vetter, J. 2004. Poison hemlock (*Conium maculatum* L.) – Review. *Food and Chemical Toxicology* 42:1373-1382.

Wahab, S.M.A., and M.A. Selim. 1985. Lipids and flavonoids of *Sapindus saponaria*. *Fitoterapia* 56: 167-168.

Witte, S.T., G.D. Osweiler, H.M. Stahr, and G. Mobley. 1990. Cocklebur toxicosis in cattle associated with the consumption of mature *Xanthium strumarium*. *Journal of Veterinary and Diagnostic Investigation* 2:263-267.

Zhou, L.X., and Y. Ding. 2002. A cinnamide derivative from *Solanum verbascifolium* L. *Journal of Asian Natural Products Research* 4:185-187.

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