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PONDEROSA PINE AND BROOM SNAKEWEED: POISONOUS PLANTS THAT AFFECT LIVESTOCK

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ABSTRACT

Ponderosa pine (*Pinus ponderosa*) and the snakeweeds (*Gutierrezia sarothrae* and *G. microcephala*) are two groups of range plants that are poisonous to livestock. Ponderosa pine causes late-term abortions in cattle, and the snakeweeds are toxic and also cause abortions in cattle, sheep, and goats. Research is underway at the USDA-ARS-Poisonous Plants Research Laboratory to better understand livestock poisonings caused by grazing ponderosa pine needles and the snakeweeds and to provide methods of reducing losses to the livestock and supporting industries. This review includes the history of the problem, a brief description of the signs of poisoning, the research to identify the chemical toxins, and current management practices on prevention of poisonings.

INTRODUCTION

Ponderosa pine (*Pinus ponderosa*), broom snakeweed (*Gutierrezia sarothrae*), and threadleaf snakeweed (*G. micro-cephala*) induce abortions in cattle. Snakeweeds are also believed to cause abortions in other livestock such as goats and sheep and are also toxic for livestock. The total economic losses resulting from livestock poisonings have been estimated to be as high as $20 million for the direct losses from pine needle abortions (Miner et al., 1987; Lacey et al., 1988) and closer to $40 million in losses from the snakeweeds (Torrell et al., 1988). The indirect losses from increased management costs, supplemental feeding, lost forage, veterinary care, increased postpartum interval, and smaller weaning weights should also be considered in the overall effect these plants have on the economic losses for the livestock and supporting industries. This review provides a brief summary of these two plants, their effect on livestock and current research underway to better understand and control the problems associated with the grazing of pine needles and broom snakeweed plants.

PONDEROSA PINE

Description of the Plant

Ponderosa pine is a large coniferous tree recognized by its yellowish-green needles (18 - 28 cm long) in bundles of three and its yellow and black bark (some common names include yellow pine and black jack pine). Ponderosa pine is an extremely important tree for the lumber industry and can be found throughout the western US, southern British Columbia, and northern Mexico growing at elevations of 7,000 - 9,000 ft. Many of the rangelands in eastern Oregon, central and eastern Montana, northeast Wyoming, parts of Arizona and New Mexico, the Black Hills of South Dakota, and southern British Columbia have dense ponderosa pine forests where cattle have access to the trees.

In pen studies, cattle fed hay and pine needles free choice selected up to 20% of their diet as pine needles (MacDonald, 1952). Field

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grazing studies found that cows will eat up to 40% of the diet as pine needles (Pfister and Adams, 1993). Pine needle consumption and grazing times were related to ambient temperature, snow depth, and wind speed. Consumption of pine needles increased as snow depth increased and temperature decreased. Thus, the risk of pine needle consumption and possible poisonings appears to be greater during severe winters and during cold and snowy fall or spring storms.

Poisonous Effects of Pine Needles

Since the early 1900s, there has been concern that the grazing of ponderosa pine needles by pregnant cattle caused them to abort their calves (Bruce, 1927). The abortifacient effects of the pine needles were experimentally demonstrated in controlled feeding trials by MacDonald (1952) and again in numerous other feeding trials (James et al., 1977, 1989). The abortifacient effect is species specific in that ponderosa pine needles appear to abort only cattle and buffalo (James et al., 1989; Short et al., 1992). Attempts to reproduce the abortions in other animal species such as sheep, goats, and elk have failed (Panter et al., 1987; James et al., 1989; Short et al., 1992; Bellows et al., 1996). Both the fresh green needles and old dry needles that have been shed from the tree are considered to be abortifacient.

Pine needle abortion often occurs during the late winter or early spring time when pregnant cattle are nearing calving periods and winter storms may have forced animals into the pine trees for shelter (Stevenson et al., 1972; James et al., 1977, 1989). After pregnant cows begin to graze pine needles, abortions may occur as soon as 24 hours and then up to two weeks after eating the needles. Cows in late gestation seem to be most susceptible with some abortions occurring after a single exposure to the needles. The clinical signs of the abortion include weak uterine contractions, occasional incomplete cervical dilation and excessive mucus discharge. The abortion often results in a stillbirth or the birth of small weak calves, depending on period of gestation. Cows that have aborted will have retained fetal membranes. Further complications subsequent to the abortion are frequent and include septic metritis, agalactia, rumen stasis, and sometimes death if symptoms are untreated. The death of the calf and/or the cow from the abortion is believed to be the result of the prematurity and not necessarily related to any toxic effects from the pine needles.

Pine needles can have an adverse effect on nutrition. Steers fed 15% and 30% of their diet as pine needles had reduced ruminal ammonia-nitrogen concentrations, and digestibility and fluid passage rate was decreased (Pfister et al., 1992). Pine needles were also toxic to populations of ruminal microbes *in vivo* (Wiedmeier et al., 1990).

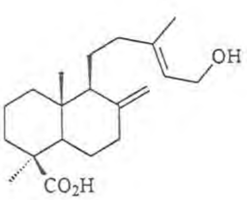
Chemistry

Numerous attempts have been made to identify the abortifacient toxin in ponderosa pine needles starting in the early 1960s. A major obstacle in this process was the lack of a suitable small animal bioassay to test compounds or extracts from the pine needles for abortifacient activity. Most of the earlier work used mice or rats as the bioassay system. There were reports that the aqueous extracts of pine needles had antiestrogenic activity (Allen and Kitts, 1961; Allison and Kitts, 1964; Cook and Kitts, 1964); some reported that pine needles contained phytoestrogens (Wagner and Jackson, 1983); and many others reported on the various solvent extracts as they affected reproduction in mice (Chow et al., 1972; Cogswell, 1974; Anderson and Lozano, 1977; Kubik and Jackson, 1981; Wagner and Jackson, 1983). More recently, ponderosa pine needles were found to contain a group of new vasoactive lipids (Al-Mahmoud et al., 1995), but these lipids were not abortifacient after oral dosage in pregnant cattle (Short et al., 1996).

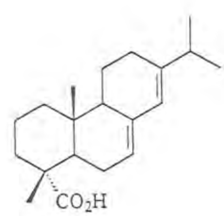
Research at the Poisonous Plant Research Laboratory focused on developing the bovine assay since no suitable small animal assay appeared to provide acceptable results. In using cattle, the abortifacient effects of ponderosa pine needles could be consistently demonstrated upon feeding 1.8 - 2.7 kg of freshly ground pine needles daily, via gavage, starting on day 250 of gestation and continuing for 10 days or until initiation of the abortion (James et al., 1994). Abortions occurred on average 6 - 8 days after the start of treatment. Continued efforts demonstrated that the active abortifacient compounds could be effectively removed from the plant after extraction with methylene chloride (James et al., 1994). Progress continued with further extraction and separation of compounds and testing in the bovine assay until the abortifacient compound was eventually isolated and identified as isocupressic acid (Fig. 1) (Gardner et al., 1994). Isocupressic acid is one of several diterpene acids which occur in ponderosa pine. The abortifacient activity of isocupressic acid was verified by oral feeding trials and as well as intravenous injection (Gardner et al., 1997).

Two naturally occurring ester derivatives of isocupressic acid, the acetyl and succinyl compounds, were also shown to be abortifacient (Gardner et al., 1996). However, further research demonstrated that these derivatives of isocupressic acid are simply hydrolyzed in the rumen of the cow to isocupressic acid. The acetyl and succinyl esters of isocupressic acid also failed to induce abortions when given intravenously. A summary of the abortifacient effects of isocupressic acid and related diterpene acids from ponderosa pine needles was recently reported (Gardner et al,. 1997).

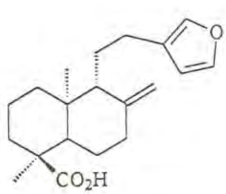
Research on the abortifacient compounds continues and analysis of isocupressic acid in other suspected abortifacient plants is in progress (Gardner and James, 1999). An interesting correlation is now emerging between several previously known or suspected abortifacient plants and the presence of isocupressic acid in those plants. For example, Monterey cypress (*Cupressus macrocarpa*) trees in New Zealand have been known to cause abortions for almost as long as ponderosa pine trees (MacDonald, 1956). Furthermore, the clinical signs of macrocarpa-induced abortion are identical to those observed with ponderosa pine needles. Recently, isocupressic acid was



1 isocupressic acid



2 abietic acid



3 polyalthic acid

Figure 1. Structures of some abortifacient and toxic diterpene acids from ponderosa pine needles and snakeweeds: (1) isocupressic acid, abortifacient compound in pine needles; (2) abietic acid, toxic compound of pine needles; (3) polyalthic acid, furano-diterpene acid from snakeweed.

detected in numerous samples of *C. macrocarpa* from New Zealand at concentrations similar to those found in ponderosa pine (Parton et al., 1996). Another tree widely planted for timber in New Zealand, *Pinus radiata* (Monterey pine), is also believed to be associated with cattle abortions in that country (Knowles and Dewes, 1980), but the one sample we have analyzed had no isocupressic acid. More recently, isocupressic acid was detected at abortifacient levels in lodgepole pine (*Pinus contorta*) and common juniper (*Juniperous communis*). Both lodgepole pine and common juniper have now been tested and confirmed to induce abortions in cattle (Gardner et al., 1998).

Other Possible Toxic Effects of Compounds from Ponderosa Pine Needles

In the case of ponderosa pine, very few poisonous effects other than the induced abortions have been reported from the field. Only in controlled experiments where very high levels of pine needles had been gavaged, or in the feeding of new growth pine branch tips, were some toxic effects reported (Panter et al., 1990). A mixture of other abietane-type diterpene acids, such as abietic acid (Fig. 1), found in ponderosa pine needles at relative lower concentrations than isocupressic acid were isolated, fed to pregnant cattle but did not cause abortions; however, at higher doses than occur naturally in ponderosa pine, toxicity was observed (Stegelmeier et al., 1996). Clinical signs of the intoxication included anorexia, mild rumen acidosis, dyspnea and hepatic and muscular disease. Histologically, affected animals had nephrosis, vacuolation of basal ganglia neuropil with patchy perivascular and myelinic edema, and skeletal myonecrosis. These clinical signs and histological changes were similar in cows treated with new growth pine tips, rosin gum, and dehydroabietic acid and demonstrate the toxic effects of this class of diterpene acids. Under the normal grazing conditions of ponderosa pine needles, and given the relative concentration of these compounds in the needles, intoxication from these other diterpene acids rarely occurs in the field. However, the toxic effects of these compounds are clinically similar to those observed from broom snakeweed plants and may have some importance in elucidating the etiology of the toxic/abortifacient effects of snakeweeds. The toxicity of the diterpene acids may also explain earlier results observed when pine needles were toxic to populations of ruminal microbes *in vivo* (Wiedmeier et al., 1990).

Mechanism of Abortion

James et al. (1989) suggested that many factors may be associated with and/or predispose cattle to abort following ingestion of pine needles: the stage of gestation, amount of needles ingested, environmental stress, nutritional status of the cows, and current management practices. Abortions may occur as soon as two days or up to two weeks after ingesting pine needles. Cows in late gestation have a higher incidence of abortion when exposed to pine needles (Short et al., 1992). It is speculated that pine needles affect the fetal/placental unit reducing blood flow to the fetus and subsequently initiating the parturition mechanism (Ford et al., 1992, 1997). Christensen et al. (1992, 1993) demonstrated that pine needles reduced uterine blood flow by up to 56%, and this is believed to initiate the fetal parturition mechanism during pregnancy. Caruncular arterial blood flow is regulated by short-term (phasic) and long-term (tonic) contractile mechanisms controlled by a balance of adrenergic receptors, potential-sensitive Ca^{++} channels, and various hormone sensitive receptors (Ford et al., 1997). The pine needle toxins or their metabolites are thought to disrupt uterine vascular flow resulting in decreased placental perfusion. Isocupressic acid does not appear to act directly at the site of the uterine artery muscle (Short et al., 1996) and its specific abortifacient mechanism remains unknown at this time.

Gardner et al. (1997) reported that isocupressic acid is metabolized after being administered intravenously to at least three compounds, with one metabolite being identified as agathic acid. It was suggested that these metabolites might actually be the active compounds that induce the abortion in cattle. Dihydroagathic acid has been recently identified as the sole metabolite in plasma from a cow fed ponderosa pine needles (Lin et al., 1998), and it was suggested that isocupressic acid is metabolized in the bovine rumen first to agathic acid and then to dihydroagathic acid which is then absorbed into the bloodstream. However, since the same metabolites have been identified in serum samples after intravenous injection of isocupressic acid, we suggest that isocupressic acid may be absorbed directly from the rumen, then metabolically transformed to agathic acid and dihydroagathic acid.

Prevention

There are no known methods to prevent abortions after pregnant cattle consume pine needles. Currently, the best method to prevent abortions is to deny cows access to pine needles during the late periods of pregnancy (third trimester) by either removing pregnant cows from the pines or eliminating the pine trees by burning or clear cutting. Providing adequate food and shelter can help reduce losses from pine needle abortions. If cows abort from grazing pine needles, it is advised to seek professional care for postpartum complications. The survival of the calf is usually dependent on the stage of gestation (fetal maturity) and the neonatal care received.

SNAKEWEEDS

Description of the Plant

Broom snakeweed (*Gutierrezia sarothrae*) can be found growing from west Texas to California and in Saskatchewan to northern Mexico (Lane, 1985). This species inhabits the salt desert shrub, sagebrush, pinyon-juniper and shortgrass prairie plant communities. Threadleaf snakeweed (*Gutierrezia microcephala*) extends from central Texas and New Mexico, reaching into southern Nevada, Utah, and Colorado, and is usually found among the dry-desert areas. Both plants are short-lived (about 2.5 years) perennial shrubs (6"- 24" in height) with many branches growing from a singular woody stalk in a "broom" shape manner with clusters of small yellow flowers. The botanical classification of snakeweeds has undergone many revisions and the most authoritative is based on morphological characteristics (Lane, 1985). Some doubt has been cast on the identity of snakeweeds used in early animal feeding experiments because of taxonomic uncertainty, which may explain some of the problems in reproducing experimental animal poisonings.

Snakeweeds are prolific seed producers, spread rapidly into areas disturbed by overgrazing, fire, off-road vehicles, or other such disturbance and are considered noxious weeds in some states. They are highly competitive with forage species and losses resulting from the reduced carrying capacities of rangelands exceed that of the poisonous effects on livestock (Torell et al., 1988).

Snakeweeds are unpalatable and are usually avoided by livestock; however, conditions on many rangelands where snakeweeds grow are such that alternative forage is scarce forcing livestock to graze snakeweeds. For example, during the winter and early spring good forage is scarce. A light snow cover may cover grasses leaving snakeweeds exposed just above the surface for the livestock to graze. Cattle will eat some snakeweed (up to 10% of diets) even when no snow is present during the winter and spring (Pfister, 1979). Typically, snakeweeds remain green over the winter in southern regions and begin growth early in the spring in northern regions. This early growth depletes moisture before other plants begin to grow.

Poisonous Effects of Broom Snakeweed

Snakeweeds have been reported to be both toxic and abortifacient (Mathews, 1936; Dollahite and Anthony, 1956, 1957; Dollahite and Allen, 1959). If large amounts of plant material are eaten, the plant may be toxic. Clinical signs of intoxication include anorexia, mucopurulent nasal discharge, loss of appetite and listlessness, diarrhea, then constipation and rumen stasis, which may lead to death if proper care is not taken. Consumption of smaller amounts of snakeweed may cause pregnant animals to abort. The clinical signs of snakeweed-induced abortions have some similarities to those caused by pine needle ingestion, although poor nutritional status is believed to be a significant factor in snakeweed abortion in sheep and cattle (Williams et al., 1993; Martinez et al., 1993). While experimental feeding trials have verified the toxic effects of the plant, the conditions that cause abortions have been difficult to reproduce (Smith et al., 1994).

Chemistry

The toxic and abortifacient compounds from snakeweeds have not been clearly identified. Dollahite et al. (1962) extracted a crude saponin fraction from snakeweed that was demonstrated to induce abortions and death in cows, goats, and rabbits by intravenous injection. Saponins can have deleterious effects on animals (Cheeke, 1998); however, saponins are a very complex mixture of compounds and more work needs to be completed on the identification of individual sapogenin components and their possible role in toxicity and abortion. Molyneux et al. (1980) compared the volatile oil composition between broom snakeweed and ponderosa pine needles and concluded that it was unlikely that this fraction was responsible for the abortions from either of these plants. Roitman et al. (1994) reported on the diterpene acid content of *G. sarothrae* and found furano-diterpene acids and made some comparisons between sandy and gravelly soils.

Of those compounds identified in broom snakeweed, the furano-diterpenes are interesting because of their structural similarities to the abortifacient compound of ponderosa pine needles, isocupressic acid (Fig. 1). Based on observations from animal feeding trials, it seems likely that the relationship between abortion and/or toxicity is one of relative dose between toxic and abortifacient compound(s). A similar case, to a limited degree, is observed in ponderosa pine needles when a comparison is made between the effects of feeding needles, branch tips, or bark (Panter et al., 1990). Each contains abortifacient levels of isocupressic acid, but the new growth tips also contain relatively high levels of toxic abietane-type diterpene acids. Cows fed the new growth tips became intoxicated and aborted; two of the four cows died (Panter et al., 1990). Cows fed pine needles or pine bark showed no signs of toxicity. It may be that one of the furano-diterpenes of the broom snakeweed is an abortifacient compound, whereas the others are toxic and the relative concentrations are important in determining the effect of that particular plant when it is being grazed. It is most likely that the relative concentration of the diterpene acids varies significantly depending on the environmental conditions and soil type where snakeweeds grow.

Prevention of Poisoning

Snakeweeds are not very palatable to livestock but may be grazed when other green forage is unavailable or dormant. Livestock losses often occur when snakeweeds are grazed in early spring before other forage emerges from dormancy. Toxicity and abortions can be prevented if adequate feed is available during critical grazing periods. Herbicide control of snakeweeds can significantly reduce losses and greatly increases native grass production.

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