The effect of natural toxins on reproduction in livestock

L. F. James, K. E. Panter, D. B. Nielsen and R. J. Molyneux

The Effect of Natural Toxins on Reproduction in Livestock

Lynn F. James*, Kip E. Panter*, Darwin B. Nielsen†, and Russell J. Molyneux‡
*USDA, ARS, Poisonous Plant Research Laboratory, Logan, UT 84321; †Department of Economics, Utah State University, Logan 84322; and ‡USDA, ARS, Western Regional Research Center, Albany, CA 94710

ABSTRACT: Reproductive efficiency is the most important economic factor in livestock production. Thus, the hypothalamo-pituitary-gonadal regulatory axis, accessory sexual organ functionality, and the complex events involved in fertilization, implantation, and embryonic and fetal development may be sensitive to therapeutic agents, environmental pollutants, and natural toxicants. There are many factors that adversely affect reproduction, one of which is toxic substances in the diets of animals. Toxic materials can affect reproductive success by causing abortions, interfering with libido, estrus, oogenesis, or spermatogenesis, causing emaciation and subsequent abnormal mating behavior, birth defects, and increasing the time between parturition and rebreeding. Examples of natural toxicants in poisonous plants interfering with reproduction are numerous. Abortion in livestock from locoweeds, ponderosa pine needles, broom snakeweeds, fescue, and others are reported in studies. Selenium and seleniferous forage inhibit estrus in cattle and swine. Emaciation and temporary illness from sneezeweeds, bitterweed, locoweed, larkspur, lupines, and others may interfere with mating. Embryonic loss and birth defects from *Veratrum*, lupines, locoweeds, poison hemlock, and so on, may occur. As suggested, toxins have many diverse and economically adverse effects on reproductive performance in livestock.

Key Words: Poisonous Plants, Toxins, Reproduction, Cattle, Sheep

Introduction

Today's economic environment dictates that those in livestock production manage their enterprises for optimum economic returns if they are to survive. Reproductive efficiency is one of the most important economic factors in livestock production. This discussion will deal with the effect of natural toxins derived from plants on reproduction. Nielsen and James (1992), using 1989 prices, estimated that annual losses in livestock due to poisonous plants in the 17 western states were $340,000,000 based on a 1% death loss in cattle, a 3.5% death loss in sheep, and a 1% decrease in calf and lamb crops. This figure could be low because 1) the estimators are probably low, 2) all losses are not included, such as decreased weaning weights and lengthened calving or lambing intervals, 3) cost with respect to prevention is not included, and 4) only part of the livestock in the United States is included in the estimate. The above cost includes only direct effects of plant poisons on livestock. Indirect costs such as fencing, additional feed costs, medical costs, and labor that are associated with increased management to prevent losses are not included in the estimate. It could be concluded that any discussion on the economy of livestock production must include losses due to the effects of poisonous plants on reproduction.
Factors that Affect Reproductive Efficiency

In an effort to assess the importance of various factors on livestock production, the following values for cattle (with 10 being the highest) for the principal economic factors have been suggested: reproduction, 10; yearling weight, 3; and carcass quality, 1. The correctness of these values can be debated, but if there is no reproduction, the other values have no meaning.

There are several factors involved in reproductive efficiency. The following are some of the more important: 1) dietary factors essential for normal reproduction, 2) infectious diseases, 3) heredity, 4) management, 5) environment, and 6) toxic dietary factors.

Much is known and much can be done to correct nutritional deficiencies that affect reproduction in livestock. Modern technology has provided new vaccines, technologies, and information to help prevent infectious disease that adversely affect reproduction in livestock. Genetic factors detrimental to reproduction can be corrected. Adverse environmental factors can often be modified or controlled. Of the factors listed, toxic dietary factors and natural toxins have received the least attention, and that only recently. They are probably the least understood, and could be the most important of these factors. This is complicated by the fact that there are many different plants containing a variety of toxins that can adversely affect reproduction, so there are many differences in the mechanisms involved. The level of toxins in the plant varies considerably with environmental conditions, site and stage of growth. The plants containing these toxins vary considerably, as does the plant’s acceptability as forage for livestock. Each problem requires a different management strategy to prevent intoxication.

Natural toxins can affect nearly all reproductive processes. The principal reproductive processes that might be considered are 1) spermatogenesis and oogenesis (Panter et al., 1988), 2) fertilization, 3) fertility (Cox, 1978), 4) placentation (James, 1972), 5) embryonic and fetal development (Binns et al., 1965), 6) pregnancy (abortions and embryonic deaths) (James et al., 1967), 7) postpartum interval (James et al., 1989), and 8) neonatal survival (James et al., 1989).

Plants that Affect Spermatogenesis and Oogenesis

Spermatogenesis and oogenesis are inhibited in sheep and presumably in other species of livestock that have grazed locoweed over a period of weeks (James and Van Kampen, 1971). There is a marked decline in libido and fertilization and placentation is delayed when locoweed is fed at 0 to 30 or 20 to 50 d of gestation in sheep. The toxin in locoweed, the indolizidine alkaloid swainsonine, is thought to be the cause of the problems. This hypothesis is based on the well-established property of swainsonine as an inhibitor of glycoprotein processing, a requirement for proper cellular function. Gossypol, which is found in cottonseed, has been shown to interfere with testicular development in the ram and bull (Kennedy et al., 1983; Arshami and Reittle, 1988; Kramer et al., 1991). Subterranean clover, which contains plant estrogens such as genistein and formononetin, causes infertility and uterine prolapse in the ewe (Cox, 1978). Neil et al. (1974) reported a reduction of fertility from 89 to 0% in a flock of ewes grazing Dwalagunup and certain other cultivars of subterranean clover. The locoweed, Astragalus lentiginosus, has been shown to have estrogenic properties (James and Foote, 1972). One of the principal toxic effects of seleniferous plants is a marked decline in reproduction in livestock (Moxon, 1937; Olsen, 1978).

Plants that Affect Embryonic and Fetal Development

Natural toxins have been shown to cross the placental membranes and interfere with embryonic and fetal development. Facial, skeletal, and tracheal defects have been induced in ewes consuming Veratum californicum, false hellebore, on gestation d 14, 27 to 33, and 31 to 33, respectively (Binns et al. 1963; Keeler et al., 1985; Keeler and Stewart, 1987). Cows consuming certain species of lupine between the 40th and 70th d of gestation may give birth to calves with skeletal abnormalities and cleft palates (Shupe et al., 1967). Conium maculatum, poison hemlock, and Nicotiana glauca, tree tobacco, have produced the same teratogenic effect in sheep and goats, as does lupine in cows (Panter et al., 1990a). Fetuses from ewes fed locoweed all had the same pathologic lesions as those present in the dams (James, 1971; Hartley and James, 1973).

Ultrasound imaging techniques have shown some of the feto-toxic effects of poisonous plants on fetal physiology, growth, and development (Panter et al., 1987, 1990a). Locoweed ingestion by pregnant ewes was shown to slow the fetal heart rate with resultant changes in placental function, fetal edema, fetal death, and abortion (Panter et al., 1987). Further, locoweed fed to sheep has been shown to cause enlargement of the right ventricle of the fetal heart, indicative of congestive right heart failure (James, 1972). The edema and congestive heart failure is suggestive of high mountain disease in cattle (James et al., 1986, 1991). Inges-
tion of the piperidine-containing plants such as Conium maculatum, Nicotiana glauca, and Lupinus formosus during specific periods of gestation induced fetal abnormalities (i.e., cleft palate and limb, spine, and neck contractures). Periodic ultrasound scanning through this critical gestational period during gavage treatment with these plants showed that fetal movement was severely inhibited. Suppression of fetal movement during critical gestational periods is thought to be the cause of the plant-induced cleft palate and skeletal contractures seen with the feeding of these plants (Panter et al., 1990b). There is good evidence that the behavior of the offspring of rats fed locoweed may be altered (Nelson et al., 1980). Table 1 lists plant toxins and their effect on embryonic and fetal development. The list has grown considerably as a result of recent research.

Plants that Cause Abortion or Embryonic Death in Livestock

A number of plant toxins are potent abortifaciants or cause embryonic or fetal death in livestock. Abortions may occur in up to 100% of the animals consuming some of these plants. Table 2 lists some of the more important plants. Locoweeds, broom snakeweed, and ponderosa pine all have the potential of interrupting pregnancy if grazed by cattle, and also sheep and horses in the case of locoweed poisoning. With locoweed, the incidence can vary from low, rather insignificant, levels to very high levels. Broom snakeweed and ponderosa pine cause abortion mainly when grazed during the last trimester of gestation, whereas locoweeds can induce it at any time during pregnancy. These plants are all readily grazed under appropriate conditions. Embryonic death occurs in sheep grazing Veratrum at approximately the same incidence as do the congenital malformations (Van Kampen et al., 1969). It has been suggested in the literature and from field observations (L. F. James, 1972 and unpublished data) that Juniperus utahensis and Chrysothamnus nauseosum can cause abortion. Both of these plants are unpalatable and are grazed only under extreme conditions.

Plants that Cause Lengthened Postpartum Interval

The interval between parturition and estrus increases after abortion caused by the plants listed above. Some ewes consuming Veratrum on the 14th d of gestation will show estrus from 60 to 85 d after being bred, due to death of the embryo (Van Kampen et al., 1969). The incidence of dystocia is greater in cows that give birth to calves with skeletal malformations due to the consump-
Table 1. Natural toxins affecting embryonic and fetal development

<table>
<thead>
<tr>
<th>Toxic plant</th>
<th>Toxin</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Veratrum californicum</em></td>
<td>Jervine and cyclopamine</td>
<td>Facial defects, skeletal defects, tracheal stenosis</td>
</tr>
<tr>
<td>False hellebore</td>
<td>(steroidal alkaloids)</td>
<td></td>
</tr>
<tr>
<td><em>Lupinus</em> spp.</td>
<td>Anagyrine</td>
<td>Skeletal defects, cleft palate</td>
</tr>
<tr>
<td>Lupine</td>
<td>(quinolizidine alkaloid),</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ammodendrine (piperidine alkaloid)</td>
<td></td>
</tr>
<tr>
<td><em>Conium maculatum</em></td>
<td>Conine, γ-coniceine (piperidine alkaloids)</td>
<td>Skeletal defects</td>
</tr>
<tr>
<td>Poison hemlock</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Astragalus</em> spp. Locoweed</td>
<td>Swainsonine (indolizidine alkaloid)</td>
<td>Skeletal defects, fetal edema, enlarged right ventricle of heart</td>
</tr>
<tr>
<td><em>Nicotiana</em> spp. Tree tobacco</td>
<td>Anabasine (piperidine alkaloid)</td>
<td>Skeletal defects, cleft palate</td>
</tr>
<tr>
<td>Selenium-accumulating spp.</td>
<td>Selenium</td>
<td>Deformed hooves</td>
</tr>
<tr>
<td><em>Pinus ponderosa</em> Ponderosa*</td>
<td>Unknown</td>
<td>Light birth weight</td>
</tr>
</tbody>
</table>

The nature of the toxin. It must be borne in mind that during early neonatal life, milk is the sole source of nourishment. Thus, the health and well-being of the neonate are at risk if the dam consumes plants whose toxins are excreted in the milk. Table 3 lists some of these plants.

Milk is a route whereby such toxins can be excreted (Dickenson and King, 1978; White and Cheeke, 1983; Hirono and Yamada, 1987). We have listed some of the more important plants whose toxins are excreted in milk. It is quite possible that many other compounds that may be toxic to the neonate are so excreted.

A number of poisonous plants when consumed by the dam, especially during late pregnancy, may result in the birth of small and weak offspring. In some cases, there is a higher than normal mortality in the offspring from dams grazing certain plants.

Examples of plants that when grazed by the dam result in the birth of small and weak offspring include 1) the locoweeds, certain *Astragalus* species whose toxin is the indolizidine alkaloid swainsonine; 2) ponderosa pine, *Pinus* spp., whose toxin is not known; 3) broom snakeweed, *Gutierrezia* spp., whose toxin is not known; and 4) plants that cause wasting, such as sneezeweed (*Helenium hoopesii*).

The locoweed plants, when consumed by a ewe, cause not only a rather high incidence of small

Table 2. Plants causing abortion or embryonic deaths in livestock

<table>
<thead>
<tr>
<th>Planta</th>
<th>Toxin</th>
<th>Effect</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Astragalus</em> spp. Locoweed</td>
<td>Swainsonine (indolizidine alkaloid)</td>
<td>Abortion, embryonic death, delayed placentation</td>
<td>James et al., 1967</td>
</tr>
<tr>
<td><em>Gutierrezia</em> spp. Broom snakeweed</td>
<td>Unknown</td>
<td>Abortion, premature birth</td>
<td>Kingsbury, 1964</td>
</tr>
<tr>
<td><em>Pinus</em> spp. <em>Pinus ponderosa</em></td>
<td>Unknown</td>
<td>Abortion, premature birth</td>
<td>James et al., 1969</td>
</tr>
<tr>
<td><em>Tetradymia glabrate</em> Little leaf horsebrush</td>
<td>Unknown</td>
<td>Abortion</td>
<td>Johnson, 1974 and unpublished data</td>
</tr>
<tr>
<td><em>Veratrum californicum</em> False hellebore</td>
<td>Jervine, cyclopamine</td>
<td>Embryonic death, fetal death</td>
<td>Binns et al., 1963</td>
</tr>
<tr>
<td>Nitrate-containing plants</td>
<td></td>
<td>Varied effects on developing young</td>
<td>Fon et al., 1967</td>
</tr>
</tbody>
</table>

*Other plants such as *Conium maculatum* (poison hemlock), *Juniperus* spp., *Agave lecheguilla lecheguilla* (creeping indigo) are reported to cause abortion.

Downloaded from jas.fass.org at National Animal Disease Center 43-6395-1-3882 on July 25, 2008.
Copyright © 1992 American Society of Animal Science. All rights reserved. For personal use only. No other uses without permission.
Table 3. Plants whose toxins are excreted in milk

<table>
<thead>
<tr>
<th>Plant</th>
<th>Toxin</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eupatorium rugosum</td>
<td>Unknown</td>
<td>Poisoning in nursing offspring</td>
</tr>
<tr>
<td>White snakeroot</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pteridium aquilinum</td>
<td>Unknown</td>
<td>Poisoning in nursing offspring</td>
</tr>
<tr>
<td>Bracken fern</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Haplopappus heterophyllus</td>
<td>Unknown</td>
<td>Poisoning in nursing offspring</td>
</tr>
<tr>
<td>Rayless goldenrod</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colchicum autumnale</td>
<td>Colchicine</td>
<td>Poisoning in nursing offspring</td>
</tr>
<tr>
<td>Autumn crocus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laburnum anagyroides</td>
<td>Cytisine</td>
<td>Locoism, congestive heart failure</td>
</tr>
<tr>
<td>Goldenchain</td>
<td>quinolizidine alkaloid</td>
<td></td>
</tr>
<tr>
<td>Astragalus spp.</td>
<td>Swainsonine, indolizidine alkaloid</td>
<td></td>
</tr>
<tr>
<td>Locoweeds</td>
<td>Pyrrolizidine alkaloid</td>
<td>Liver damage</td>
</tr>
<tr>
<td>Senecio jacobaea</td>
<td>Glucosinolates</td>
<td>Goitrogenic</td>
</tr>
<tr>
<td>Brassica</td>
<td>Selenium</td>
<td>Weight loss, lameness, hair loss</td>
</tr>
<tr>
<td>Seleniferous plants, grasses, grain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Astragalus bisulcatus</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

and weak lambs, but also an increased mortality among lambs with normal birth weight and normal appearance. A number of lambs born to such ewes will have what originally appear to be skeletal malformations, but will eventually become normal. They are more subject to predators during this time and often starve because they are unable to keep up with the other sheep under range grazing situations.

Any plant toxin that causes wasting of the dam, especially during the latter part of gestation, can result in the birth of small and weak offspring. Among those that cause wasting or debilitation are most of the *Astragalus* spp., plants such as sneezeweed, and bitterweed containing sesquiterpene lactones, which are gastrointestinal irritants, as their toxin. Pine needles, broom snakeweed, and locoweeds all cause birth of lightweight calves.

In the case of consumption of pine needle and broom snakeweed by cows and locoweeds by cows and sheep, neonatal mortality is higher than normal, even in full-term, normal-appearing offspring. Pine needle abortion and broom snakeweed abortion are in a sense misnomers, because many of the calves born near term are alive, but small and weak, and will survive with care. By definition an abortion is the expulsion from the uterus of a nonviable fetus. The same may be true of offspring from cows going to full term.

The effect of plant toxins on the immune system has not been investigated to any extent. Apparently, locoweed depresses the immune system (Sharma et al., 1984). Field observations suggest that pine needles may also depress the immune system in the pine-needle abortion syndrome. Any plant toxin that causes wasting of the dam and results in decreased production of colostral milk could adversely affect the immune status of the newborn.

It is reasonable to expect that the embryo and fetus are subjected to most toxins that the dam consumes. For example, the fetal lamb from a ewe fed locoweed has the same microscopic lesions as does the dam (Hartley and James, 1973). In fact, the fetus is affected in nearly all the same ways as is the dam. It is quite possible that the neonate could exhibit some of the same physiological effects of poisoning as does the dam (Nelson et al., 1980).

The term "fertility" can have more than one meaning. It may be used to denote overall population growth, or it can be used to identify the fertility of individuals or groups of individuals, such as those that have a high rate of conception, or, in the case of males, those that are capable of being highly successful in inseminating females and having them conceive. In considering the effects of natural toxins on fertility, the word can be used in both ways. Toxins from plants such as locoweed, pine needles, and broom snakeweed can affect fertility both in terms of individual reproductive capacity and of overall population growth.

There are several plants whose toxins have an adverse effect on fertility. Some of the more important of these are 1) *Trifolium subterraneum*, subterranean clover (estrogen); 2) *Astragalus* spp., locoweed (estrogen); and 3) fescue (endophytes).

These plant toxins can cause alteration in the reproductive organs and result in infertility. There are probably other clovers or legumes that contain levels of plant estrogens high enough to interfere with fertility. We have a tendency to take note of dramatic effects and ignore those that are borderline or marginal and are hard to identify. These
borderline effects may be the most important economically. For example, preliminary research results suggest that the female reproductive tract is deformed in the offspring of pigs fed locoweed, but this aspect has long been overlooked (James and Panter, 1987 and unpublished data).

Reproductive problems have been associated with ingestion of tall fescue (Festuca arundinacea) in cattle, horses, and sheep (Hemken et al., 1984). The association of reproductive problems and other fescue-induced diseases seems to be related to alkaloid content of the grass resulting from endophyte infestation. Infected fescue causes agalactia, reduced conception rates, weight loss, elevated body temperature, abortion, fat necrosis, and vasoconstriction of the extremity vasculature. In horses, tall fescue has been implicated in prolonged gestation, abortion, thickened placenta, agalactia, dystocia, and foal and mare death (Hemken et al., 1984).

Maintaining the fertility of a breeding herd of livestock is difficult. There are many factors that cause females to be removed from the herd. The factors that we have listed can be of importance in the removal of females sooner than normal. It is costly to replace these animals, whether from within the herd or with newly purchased cattle (Nielsen and James, 1992).

In this discussion we have listed and discussed some of the ways plant toxins can adversely affect reproduction in livestock. There are many other plants suspected of causing reproductive disturbances in livestock. It is reasonable to expect that there are many other plants that can affect reproductive efficiency in livestock remaining to be investigated, because they have not yet been identified as problems.

Implications

Poisonous plants cause an estimated $340,000,000 annual loss to livestock producers in the 17 western states. This value includes death losses and some losses due to decreased reproduction. It does not include losses in performance, some losses in reproduction, or indirect losses associated with the cost of preventing or minimizing losses.

Literature Cited


