Solutions to Locoweed Poisoning in New Mexico and the Western United States

Collaborative research between New Mexico State University and the USDA–Agricultural Research Service Poisonous Plant Lab

By David Graham, Rebecca Creamer, Daniel Cook, Bryan Stegelmeier, Kevin Welch, Jim Pfister, Kip Panter, Andres Cibils, Michael Ralphs, Manny Encinias, Kirk McDaniel, David Thompson, and Kevin Gardner

Introduction

By D. Graham

Locoweed is the most widespread poisonous plant problem in the western United States. White locoweed (*Oxytropis sericea*) is abundant along the eastern slope of the Rocky Mountains from Montana southward to northeastern New Mexico. Woolly locoweed (*Astragalus mollissimus*) is locally abundant on shortgrass prairies through eastern Colorado down through eastern New Mexico and west Texas. Its population is cyclic, increasing in wet years and dying back during drought or from insect damage.

A collaborative locoweed research effort between New Mexico State University (NMSU) and the USDA–Agricultural Research Service (USDA-ARS) Poisonous Plant Research Lab was initiated in 1990 as a result of a "grassroot" producer effort and a congressional appropriation, due to the efforts of New Mexico Congressman Joe Skeen. A symposium was held at the Society for Range Management annual meeting in Albuquerque, New Mexico, 2009, to highlight this research and present recent solutions to locoweed poisoning. This paper presents highlights of that symposium, with each section being a summary of individual presentations.

New Mexico Department of Agriculture and the NMSU Extension Service reported widespread locoweed poisoning involving both livestock and wildlife in 1985: over 10% of the cow/calf and 40% of the stocker operators reported economic losses over US$20 million from locoism. In 2004, only 4% of cow/calf and 25% of stocker operations had economic losses from locoism totaling $8 million (response from producers, D. Graham, unpublished data, 2004). Much of this reduction can be attributed to the "technology transfer" to producers from the ongoing collaborative research efforts.

Genetics of the Fungal Endophytes of Locoweed

By R. Creamer

Endophytic fungi growing inside plant tissues produce the toxic alkaloid swainsonine in several species of locoweed.[1] The fungi grow very slowly, producing two distinct structural or morphological types of the reproductive part of the body known as mycelia and variable lengths of conidia or asexually produced spores.

Preliminary genetic and morphological analyses suggested that the locoweed endophytes were most related to *Alternaria* or *Embellisia* species.[1,2] However, a comprehensive analysis of both genetic and morphological characters has shown that the endophytes belong to a new genus, *Undifilum*.[3]

Swainsonine-producing endophytes isolated from *Oxytropis* in China were essentially identical to those collected in the United States, and both were given the name *Undifilum oxytropis*.[3] Endophytes isolated from *Astragalus* species will likely be classified into several additional species of the fungal genus.

Swainsonine in Locoweeds

By D. Cook

Locoweeds contain the toxic alkaloid swainsonine. Swainsonine concentrations differ between locoweed species. Levels of swainsonine are generally greater in *Astragalus*

Collaborative locoweed research between New Mexico State University and the USDA–Agricultural Research Service Poisonous Plant Lab in northeastern New Mexico.

White locoweed is the most widespread locoweed in the western United States, occurring on short-grass prairies, gravely foothills, and shallow windswept mountain ridges.

spp., with garbancillo (*A. wootonii*) having the greatest concentration, woolly (*A. mollissimus*) and spotted (*A. lentiginosus*) locoweed moderate concentrations, and white locoweed having the lowest concentration.[4]

The concentration of swainsonine also varies within a species and within a population of a species. For example, some populations of Lambert locoweed (*O. lambertii*), and plants within each population of white, woolly, and spotted locoweed, contain very low levels of the endophyte, thereby producing only trace amounts of swainsonine.[4] This suggests that the endophyte must grow and colonize the plant at some critical threshold before swainsonine is produced at toxic levels. Offspring from these plants also had low levels of the endophyte and only traces of swainsonine. If we can discover why and how the endophyte is suppressed, this may lead to techniques and tools to block endophyte infection and subsequent swainsonine production. Thus, it may be possible to render these locoweed species nontoxic, allowing their use as high quality forages in early spring and late fall when grasses are dormant.

Locoweed Pathology and Animal Susceptibility

By B. Stegelmeier

Swainsonine inhibits key cellular enzymes, resulting in a specific disease called locoism. Animals must eat locoweed for several weeks to become poisoned. Animals that eat locoweed over longer periods of time show symptoms that are more severe and have little chance of recovery. Intoxication is initially characterized by depression, loss of appetite, and weight loss. Continued exposure damages nerves that affect depth perception and causes intention tremors, dull hair coat, decreased libido, infertility, abortion, cardiovascular disease, and death. Livestock, especially horses, may be easily excited, frightened, or even become violent. Poisoned animals may recover following removal from areas with locoweed; however, the neurologic changes do not completely disappear. With specific stresses or stimuli, animals may intermittently relapse and demonstrate neurologic signs similar to those seen earlier. Behavioral problems may continue after evidence of the disease in nervous tissue is no longer visible.[5]

Few gross lesions are seen in animals poisoned with locoweed. However, there are many characteristic microscopic lesions. Affected cells become swollen and filled with dilated vacuoles, which has been described as cellular constipation. Neurons are highly susceptible, and they degenerate and die. Vacuolation is also seen in many other tissues including thyroid, pancreas, kidneys, testes, and ovaries, and in macrophages in nearly all tissues.[5]

All animals are susceptible to locoweed poisoning; however, there are species differences in susceptibility, symptoms, and tissue damage. Horses are uniquely sensitive and develop clinical signs and neurologic lesions at relatively low doses of short duration. In contrast, rodents and mule deer develop similar neurologic lesions, but only at much higher doses over longer durations, and are more likely to show signs of wasting and emaciation.[6] Though less susceptible than horses, cattle and sheep are also easily poisoned and develop neurologic disease. Differences in animal susceptibility are likely due to swainsonine binding affinities between species.

Development of a Biomarker for Locoweed Poisonings

By K. Welch

There is a need to develop better diagnostic procedures to determine how poisoned an animal is and whether it is likely to recover from locoweed poisoning. The toxin swainsonine inhibits cellular mannosidase enzymes, resulting in altered protein metabolism. These alterations can result in cell damage and leakage of proteins into the blood. Additionally, there may be alterations in the normal secretion of proteins into the blood.

We have identified differences in proteins in the blood of poisoned animals and those in the blood of control animals, which may be useful as potential biomarkers of locoweed poisoning. These potential biomarkers are currently being validated. Further studies will be performed to determine if the biomarker(s) correlates with the extent of intoxication and/or if it provides information regarding the prognosis of the animal's recovery.

The potential benefit of these biomarkers will be very important to livestock owners. Locoweed-specific biomarkers will be used to identify animals that have been poisoned. Additionally, a good biomarker could potentially aid in determining the extent of intoxication; that is, how badly the animal is compromised and consequently, the likely prognosis for recovery and productivity. This will help ranchers make rational decisions on treatment, disposition, productivity, and marketing of poisoned animals.

Reproduction and Neonate Behavior

By J. Pfister and K. Panter

Reproductive efficiency is the most important factor affecting profitability of most livestock operations. Hormones and organ functions involved in fertilization, implantation, and embryonic and fetal development are adversely affected by swainsonine. In females, swainsonine causes fetal resorption, abortion, birth defects, and altered estrus and egg development.[7] Consumption of locoweed by females often prolongs the time between calving and rebreeding. Water belly (*hydrops amnii*) is often observed in pregnant females, along with prolonged pregnancy that results in fetal and maternal death. In males, intake of locoweed for one to several weeks will decrease libido, and cause temporary infertility by altering sperm formation and development. Further intake (>2–3 weeks) may result in permanent neurological lesions that impair the ability to mate. Once sperm are altered by the toxin, at least 60–90 days are required for sperm formation and maturity (spermatogenesis) to return to normal.[7]

Swainsonine crosses the maternal barrier and poisons the fetus. A series of sheep studies[8] showed that pregnant ewes given locoweed for 30 days mid-pregnancy delivered weak lambs with low birth weights. At parturition the ewes were nervous and excitable, and lambs were unable to stand and suckle normally. Most lambs born to mothers eating locoweed during pregnancy would not survive at birth without human intervention. However, if lambs survive, in spite of their small size they can rapidly recover normal behavioral functions, sometimes within about 2 weeks.

Animal Variation in Locoweed Selection Patterns of Yearling Cattle

By A. Cibils

Most yearling cattle that are raised on locoweed-free rangelands avoid consuming locoweed when first exposed to it. However, approximately 20% of animals readily select this plant (locoweed-eaters) despite its novelty.[9,10] Although locoweed-eaters are a minority, they can induce their peers to begin consuming locoweed and can therefore promote fairly rapid herd-wide intoxications. Over the past 5 years, we investigated the behavioral basis for animal-to-animal variation in dietary preferences for locoweed to determine whether culling locoweed-eaters from a herd is a viable way to reduce intoxication.

We found that yearlings classified as locoweed-eaters were more willing to sample new foods than animals that naturally avoided locoweed (locoweed-avoiders).[10] Locoweed-eaters also appeared to spend less time standing around while feeding, a behavioral trait that allowed them to feed at faster rates and possibly induced them to be less selective than locoweed-avoiders.[9,10] Collectively, these trials (which included both heifers and steers) suggested that locoweed-eaters exhibit bolder foraging behaviors compared to their apparently more cautious peers that avoid locoweed.

We think that behavioral differences between locoweed eaters and avoiders could be associated with specific stress coping styles or animal behavioral characteristics. Locoweed-eaters appear to be bolder and more aggressive foragers, which are characteristics of better performers (higher weight gain) in rangeland environments. This presents a paradox for ranchers, to cull the better performers to prevent them from becoming poisoned, and also to prevent them from facilitating other cattle to graze locoweed and become intoxicated.

Grazing Management Recommendations

By M. Ralphs

During the particularly destructive locoweed years in the early 1990s, cattlemen in northeastern New Mexico organized under the leadership of David Graham and listed questions about locoism to reduce the risk of poisoning. Collaborative grazing studies between USDA-ARS Poisonous Plant Lab and NMSU answered those questions in subsequent publications listed in the bibliography. The following management recommendations were developed from this research to reduce the risk of poisoning:[11]

1. Restrict access to locoweed in spring and fall when it is relatively more palatable than dormant warm-season grasses. In 13 grazing studies, cattle readily grazed white locoweed during March, April, and May when it was green and actively growing and warm season grasses were dormant, but ceased grazing it in June when it matured and warm season grasses began rapid growth. Encinias (see later section) reported cattle started grazing woolly loco in the fall as warm season grasses senesced.
2. Save locoweed-free pastures for these critical periods, or create "clean" pastures using herbicides. Graze locoweed-infested pastures in summer when green grass is abundant.
3. In winter, the dead and dry stalks retain their toxicity, and can be relatively palatable.

White locoweed is relatively more palatable than dormant warm-season grasses in the spring.

Woolly locoweed is locally abundant on short-grass prairies.

4. Never overstock locoweed-infested ranges. Heavy grazing pressure leads to shortage of desirable feed and can force livestock to start grazing locoweed.
5. "Eat-and-pull" strategy—when locoweed is abundant, ride through cattle regularly and remove those that start eating locoweed. This will prevent intoxication, and prevent social facilitation or peer pressure influencing others to eat it.
6. If locoweed is abundant and causes persistent poisoning problems, animals can be trained to avoid eating the plant through conditioned food aversion.

Managing Woolly Locoweed

By M. Encinias

Locoweed toxicity in northeastern New Mexico is commonly observed during periods when native, warm-season grasses are dormant, a period of approximately 7 months stretching from early fall through late spring. As a result of dormancy, the nutritional composition of these grasses does not meet the protein requirements for most beef cattle. Woolly locoweed is high in crude protein and digestible nutrients that are needed to meet nutritional deficiencies, especially when nutrient demand is greatest during late gestation.

Presently, our research program is focused on developing a better understanding of the nutritional triggers (i.e., nutritional requirements, physiological status, body condition, stress, and previous environment) causing beef cattle to graze locoweed when grass is dormant. Recently, we evaluated the impact of supplementing pregnant heifers (125% of National Research Council crude protein requirements) during late fall and early winter.[12] Heifers were all approximately 90 days pregnant at the time of turn out. Highlights from this project include the following: 1) nonsupplemented heifers started grazing locoweed earlier, and consumed double the amount of locoweed, compared to supplemented cows (15% vs. 8% of bites); 2) 40% abortion rate from nonsupplemented cows, compared to 0% abortion and 100% calving of supplemented cattle; 3) increased calf performance at weaning (170 days of age: 448 pounds vs. 438 pounds [203 kg vs. 198 kg]; and 282 days of age: 684 pounds vs. 665 pounds [310 kg vs. 301 kg]) for those calves whose dams were supplemented during locoweed exposure. These preliminary data suggest timely protein supplementation may play a role in minimizing pregnancy losses and depressed calf performance commonly associated with locoweed toxicity on dormant, native rangelands in northeastern New Mexico.

Herbicidal Control of Locoweed

By K. McDaniel

When the proper herbicide is applied during optimum growing and environmental conditions, control of most *Astragalus* and *Oxytropis* species can be achieved. From 1990 to the present, numerous herbicides were compared in research trials conducted in northern New Mexico. Applications were timed to coincide with three locoweed growth stages: early vegetative (April to mid-May), bloom or flowering (late May and June), and late vegetative (September to mid-October). Averaged across years and spray locations, picloram (0.375 pounds per acre) applied alone or mixed with 2,4-D (1:4 ratio at 1.25 pounds per acre) provided excellent control of white and woolly locoweed when applied across all growth stages. By mixing dicamba or clopyralid with picloram, herbicide cost can be reduced and still provide satisfactory locoweed control. Metsulfuron (0.375 ounces per acre) and clopyralid (0.25 pounds per acre) also give excellent control when sprayed during and after flowering.[13]

Environmental conditions at the time of spraying are a critical consideration when applying foliar active herbicide. Ideal conditions are high relative humidity (above 50%), low wind speed (<8 mph), and moderate air temperatures (60–70°F). These conditions keep droplets wet longer, thereby increasing herbicide absorption into the leaves. Soil that is moderately moist with a temperature above 55°F at 6-inch depth ensures that plants are growing vigorously.

The duration of herbicide control depends on two separate but equally important considerations: first, the effectiveness of the initial treatment; and second, how often the environmental conditions occur that trigger locoweed germination. Environmental conditions suited for widespread propagation occur infrequently, about once or twice per decade. In a separate study we showed that white locoweed and its soil seed source can be reduced from an area by repeated spraying when new seedlings emerge to prevent them from flowering and producing seed.

Managing livestock to prevent locoweed poisoning should always be considered before investing in herbicide control, but striving to obtain locoweed-free pastures for critical periods should be a management consideration.

Native Insects for the Biological Control of Locoweed

By K. Gardner and D. Thompson

Several insects feed on both white and woolly locoweed.[14] Although many of these suppress locoweed populations to some degree through reduced seed production and plant vigor, only one, the four-lined locoweed weevil (*Cleonidius trivittatus*), can reduce locoweed density by killing plants.[15] The weevil impacts most varieties of woolly locoweed throughout its range.[16] It will decrease woolly locoweed populations in 3 years from high plant densities to a few scattered plants. As few as two larvae per plant will kill most plants; however, 25 larvae per plant are common in heavily infested locoweed populations. Their presence can be checked by digging up a few plants and looking for the cream colored "c"-shaped larvae in and around the root. Weevils do not increase the toxicity of plants.

Although weevils can be reared in the lab or collected from the field, neither is practical at this time for augmenting or introducing weevils to locoweed populations due to labor costs. Conservation of existing weevil populations offers the best method for biocontrol of woolly locoweed. This can be accomplished with judicious use of insecticides for grasshoppers and range caterpillars.

The four-lined locoweed weevil will control woolly locoweed without intervention from managers. Controlling woolly locoweed with herbicides may limit the usefulness of the weevils by killing their food source during development. In most instances the weevils will control the weed population, thus reducing the need and cost of spraying. Where weevils are present, it may be less expensive to use temporary fencing to exclude livestock until the plants have been removed by the weevils.

The four-lined locoweed weevil, or one very closely related to it, infects white locoweed in north central Colorado and south central Wyoming, but has never been detected in white locoweed in New Mexico, even where woolly locoweed and the weevils are interspersed throughout the white locoweed populations.[14] Multiple attempts at introducing the northern weevils to white locoweed in New Mexico have failed, whether in the field or in greenhouse-grown plants. At this time, there are no viable biocontrol options for white locoweed in New Mexico, but we will continue to examine differences in the northern weevils and improve methods for introduction to new areas.

Conclusion—Solutions to Locoweed Poisoning

Knowledge from the above research will allow ranchers to manage around locoweed and reduce the risk of poisoning and catastrophic livestock loss. Critical periods were identified in spring and fall when locoweeds are relatively more palatable than dormant grass. Restricting access to locoweed-infested areas during these periods will prevent most poisoning. Ranchers should save "clean" pastures for these critical periods, or create them using the herbicide recommendations provided. Supplemental nutrients during the dormant season may help to maintain their nutrient status, and reduce the tendency for livestock to seek out locoweeds. If losses are high and locoweed populations are persistent, cattle and horses can be trained to avoid eating locoweed through conditioned food aversion. The four-lined locoweed weevil will kill most woolly locoweed populations within 2–3 years; thus, ranchers should manage around these populations until they decline. Additional knowledge of the four-lined locoweed weevil may lead to strains that will adapt to white locoweed and produce a natural biological control for this species.

Future research may provide even more solutions to the locoweed problem. Potential biomarkers may be used to identify poisoned animals, determine the severity of intoxication, and help make the decision for recovery or disposal of animals. Additional knowledge of the different endophyte strains and their responses to environmental stresses, and basic research into biosynthetic pathways and transmission of the endophyte, may lead to opportunities to reduce or block toxin synthesis.

One of the original requests of the northeast New Mexico locoweed advisory committee was to create a repository of locoweed research papers and information. The supplemental bibliography (available at www.srmjournals.org) contains all of the published research from this collaborative project and from the USDA-ARS locoweed research project. Additional information can be obtained from the respective websites at NMSU (http://weeds.nmsu.edu – Publications – NMSU Publications – Locoweed Research Updates and Highlights), and the USDA-ARS Poisonous Plant Research Lab (www.pprl.ars.usda.gov – Research – Locoweed Published Research).

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