NATURAL TOXICANTS IN FEEDS AND POISONOUS PLANTS

Natural Toxicants in Feeds and Poisonous Plants

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Natural Toxicants in Feeds and Poisonous Plants

Frontispiece:

1. A tansy ragwort (*Senecio jacobaea*) seedling.
2. The rosette stage of tansy ragwort, formed in the first growing season.
3. The second-year plant, from which a flowering stalk emerges.
4. Flowering tansy ragwort has very distinctive flowers. Each plant may produce up to 150,000 viable seeds, which are dispersed long distances by wind.
5. Tansy ragwort leaves are deeply lobed and are usually a very dark green. Under conditions of low soil nitrogen, a purplish color of the leaf stalk and stem is evident, as is slightly visible in (1).
6. Larvae of the cinnabar moth feed on tansy ragwort and other plants containing pyrrolizidine alkaloids. Coevolution of poisonous plants and herbivores has resulted in evolution of detoxification mechanisms and in some cases a dietary requirement for the plant toxins by herbivores.
7. Flowers of common groundsel (*Senecio vulgaris*) lack the petal rays of tansy ragwort flowers.
8. Common tansy (*Tanacetum vulgare*), an herb, is sometimes confused with tansy ragwort. It is desirable to use botanical names to prevent confusion of this type.


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Preface

This book has evolved from a course on Toxicants in Feeds and Poisonous Plants taught for several years at Oregon State University. In the development of this course, a void was encountered which this book will attempt to fill. Existing textbooks on poisonous plants and natural toxicants are oriented either toward the botanical aspects or to a veterinary perspective with emphasis on clinical and pathologic signs of toxicity. This book is written from the perspective of animal scientists who are concerned with an appreciation of all aspects of toxicants that can influence animal production. These include consideration of botanical characteristics of crop plants, range and pasture weeds; the chemical nature and metabolism of toxicants; the pathology induced by particular toxicants; and an over-all appreciation for the significance of particular toxicants in animal production. We have endeavored to integrate these aspects in a manner that will make the book useful and interesting to a diverse readership. The intended readership includes students in animal science, range management and veterinary medicine, livestock and range extension specialists, toxicologists, veterinarians, and livestock producers. A major effort has been made to write in a style and technical language that will be in keeping with the diversity of the target audience.

It is planned that this book will be revised at intervals and will continue to be available for many years. I would appreciate comments and criticisms, including suggestions for improvement of the next edition. I would also appreciate slides and photographs that would enhance future editions.

I plan to make available slide sets covering each of the categories of toxicants covered in the book. These should be very useful to instructors using this book as a text. You may contact me directly for information on slides.

Many people have made important contributions to the preparation of this manuscript. I would like to thank Grace Hayes and Halcyon Hambleton for typing the manuscript, and Donald G. Kirsch for preparing the artwork. Many scientists responded to my request for photographs for use in the book; their helpfulness is gratefully acknowledged. I regret that because of space limitations many of their illustrations could not be included in the volume.

I am most appreciative of the time spent with a number of poisonous plant researchers in Australia during my trip there in 1981; discussions with them were most valuable in enlarging my horizons. In particular, I thank Dr. C.C.J. Culvenor for his efforts in showing me a number of toxicological problems in Australia. It is appropriate to acknowledge the assistance of the staff of the USDA Poisonous Plants Research Laboratory in Logan, Utah in providing information for use in this book.

It is a pleasure to have had the collaboration of Lee R. Shull in the preparation of this text. Dr. Shull wrote the chapter on mycotoxins and assisted with several others. I also want to recognize his contributions to the development of my research program in the toxicology area, during the conduct of his graduate work at Oregon State University. I take pleasure in acknowledging the contributions of other former graduate students, including G.W. Buckmaster, M.L. Pierson-Goeger, D.E. Goeger, R.A. Swick, B.J. Garrett, R.D. White, and M.A. Grobner, whose work on pyrrolizidine alkaloids has in large part been responsible for my continued involvement in toxicology. The efficient and thorough work of Harriet D. Shields in facilitating the editing process is much appreciated. Finally, I want to express my gratitude to my family for their help and understanding while I was home on sabbatical writing the manuscript.

PETER R. CHEEKE

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1

Natural Toxicants and Their General Biological Effects

A toxicant is a substance which under practical circumstances can impair some aspect of animal metabolism and produce adverse biological or economic effects in animal production. This is a broad definition, but encompasses those aspects that are relevant in livestock production. Virtually everything is toxic, including oxygen, water, and all nutrients, if given in a large enough dose. Thus, the term "toxicant" refers only to those substances which might normally be encountered at toxic levels. Other terms used synonymously with toxicant are "poison" and "toxin."

Toxicants can be classified in various ways, including by chemical structure. An outline of the various chemical categories is presented in this chapter, with a brief description of their general biological effects. The remainder of the book is concerned with a more detailed treatment of each toxicant, including historical and contemporary perspectives on livestock problems, the chemical nature of the toxins, their biochemistry and mode of action, the pathological signs of toxicity, and the treatment and prevention of toxicity.

Toxicants discussed have been selected on the basis of their importance in livestock production in North America and to some extent in the rest of the world. Also, consideration has been given to including representative examples of toxicants of particular chemical types or unique biochemical metabolism in order to illustrate the diversity of structure and biological effects of toxicants. The compounds discussed are overwhelmingly of plant origin, with only a few toxins of animal origin considered. This is not a book on poisonous plants per se, as many of the important toxins affecting livestock production occur in

common feedstuffs. In fact, very few feedstuffs do not contain one or more substances that have deleterious effects.

Toxicants can influence animal agriculture in several ways. They can directly intoxicate animals, resulting in mortality or decreased production of animal products. Toxicants may be implicated in reducing the wholesomeness of meat, poultry products, and dairy products due to the presence of hazardous residues. Natural toxins may reduce the availability or usability of nutritious feedstuffs, or may necessitate the use of costly feed processing techniques to eliminate their effects.

In the past few years, the focus of toxicology has widened dramatically. The importance of chronic toxicoses has been realized, with greater emphasis placed on delayed responses such as mutations, cancer, birth defects, and neurological and immunological effects. Modern toxicology seeks to define the disruption of the homeostatic condition by determining the specific site (receptor) of the disturbance, the dose–effect relationship, and the specific chemical nature of the toxicant–receptor interaction. Thus large animal toxicology is an extremely broad discipline, incorporating pharmacology, botany, physiology, pathology, chemistry, biochemistry, immunology, range and animal management, veterinary medicine, and economics.

The advances in the study of toxicants have in large part been due to developments in analytical techniques and instrumentation. Sophisticated methodology allows detection of toxicants at extremely low levels and the identification of short-lived and reactive metabolites. In spite of these advances, there are still important natural toxicoses, such as fescue foot, summer fescue toxicosis, bracken poisoning, and vetch poisoning of cattle, for which the toxic agents have not been conclusively identified. There are also several natural toxicants for which no method of analysis exists. Many opportunities exist for further advances in the understanding of the roles of toxicants in animal production.

HISTORICAL ASPECTS OF NATURAL TOXICANTS IN LIVESTOCK PRODUCTION

Natural toxicants have had significant effects on livestock production in North America. In the frontier days, extensive stock losses occurred due to consumption of poisonous plants. In the settlement of new areas, both the livestock and the ranchers were inexperienced as to the toxicity of native plants, and some spectacular losses occurred as this experience was gained. In the late 1800s and early 1900s, some of the major toxicity problems in the U.S. included milk sickness in hu-

mans caused by milk transfer of a toxin from white snakeroot, and livestock poisonings from consumption of such plants as locoweed, larkspur, water hemlock, lupine, death camas, bitterweed, and sleepy grass. An early function of the United States Department of Agriculture (USDA), which was organized in 1862, was the investigation of toxic plants. Numerous field stations in the western U.S. were established by the USDA in the early 1900s for the study of specific local problems (Fig. 1.1). Some of these included stations in Hugo, Colorado to study locoweed, in Gunnison National Forest, Colorado to study larkspur, lupine, and water hemlock poisoning, in Greycliff, Montana to investigate lupine and death camas, and in Salina, Utah to study oak, sneezewood, locoweed, and milkweed problems. In 1955, the USDA Poisonous Plants Research Laboratory was established in Logan, Utah. In cooperation with Utah State University in Logan, scientists at this laboratory have conducted in-depth investigations of many plant toxins and poisonous plants, including locoweed, larkspur, lupine, halogeton, pyrrolizidine alkaloid-containing plants, and numerous others. Considerable effort has been placed on the study of teratogens in plants, such as those in lupine and poison hemlock responsible for crooked calf disease, and *Veratrum* alkaloids which cause birth defects in sheep. Numerous other institutions have embarked on significant investigations of natural toxicants affecting livestock. With the inevitable risk of omission, some of these are: Texas A&M Univer-

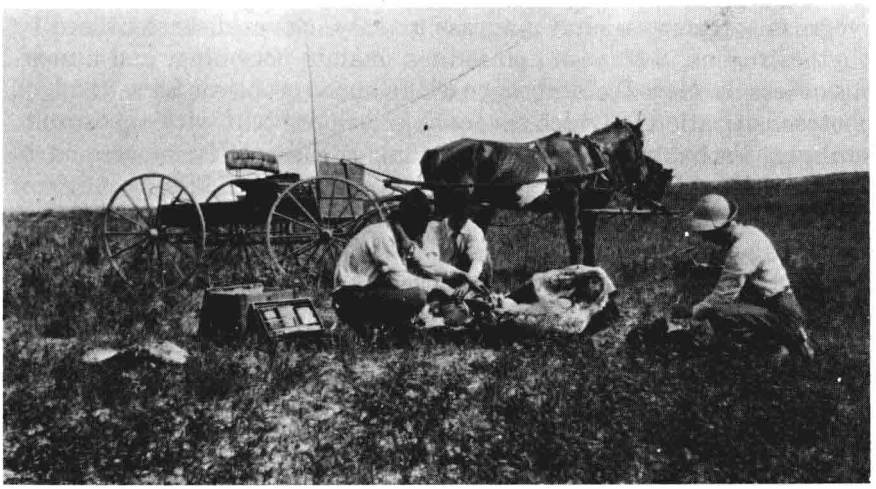

FIG. 1.1. USDA poisonous plant investigators performing an autopsy—1906.
Courtesy of R. F. Keeler.

sity, southwestern toxic plants with emphasis on bitterweed; University of California, Davis, pyrrolizidine alkaloids, milkweeds, and cyanogens; Washington State University, acute bovine pulmonary emphysema; Oregon State University, pyrrolizidine alkaloids; Cornell University, calcinogenic glycosides; University of British Columbia, phytoestrogens, pine needle abortion; Agriculture Canada, Kamloops, British Columbia, timber milk vetch, cyanogens, and pine needle abortion; and the University of Alberta and University of Saskatchewan, rapeseed glucosinolates. In addition, many universities in the U.S. and Canada have programs on mycotoxins, which since 1960 have become increasingly recognized as major problems.

TOXICANT PROBLEMS AROUND THE WORLD

Natural toxicants are and have been responsible for livestock problems in many parts of the world. Australia might be regarded as the land of poisonous plants. Its arid, hostile environment and extensive pastoral industries contribute to the scope of the problems. In times of drought, stockmen might regard the availability of poisonous plants as being better than nothing at all. This could account for the common names of Paterson's curse and Salvation Jane for *Echium plantagineum,* a pyrrolizidine alkaloid-containing plant. Among the significant Australian toxicity situations are disorders in all livestock species caused by pyrrolizidine alkaloids, and fluoroacetate toxicity, lupinosis, ryegrass staggers, annual ryegrass toxicity, clover disease caused by phytoestrogens, *Swainsona* poisoning, oxalate poisoning, and numerous others. In New Zealand, some of the major problems have involved photosensitization in which severe skin lesions occur with exposure to sunlight. Probably the most important of these is facial eczema in dairy cattle and sheep, caused by a mycotoxin, sporidesmin. Another mycotoxin problem of significance in New Zealand is perennial ryegrass staggers. Brassica poisoning occurs in those areas where *Brassica* spp. such as rape and kale are used as forage. In the past, *Senecio jacobaea* poisoning has been a significant problem in parts of New Zealand. In Southeast Asian countries such as Indonesia, the Philippines, Papua New Guinea, and tropical areas of Australia, toxins in tropical forages such as *Leucaena leucocephala* are of concern. In South Africa, numerous poisonous plant problems have affected the extensive livestock industries of that country; many of these problems are similar to those seen in Australia. Some of the conditions reported from South Africa include annual ryegrass toxicity, poisoning from various *Senecio* spp., and mycotoxin contamination of feedstuffs. Pho-