TOXIC PLANTS OF NORTH AMERICA

SECOND EDITION

Chapter One

Introduction

We humans have an intimate relationship with the plants that surround us. We take them for granted as we use them for food, clothes, and shelter. We use them medicinally; indeed, more than one-third of our modern pharmacopoeia has its origins in plant products. We please our senses, decorate our living spaces, and express our feelings for one another with them. Plants are an essential part of many of our religious and social rites. Paradoxically, some of the plants we prize for these varied uses may also pose a threat to us or to our domesticated animals. Toxic plants are very much a part of our environment. Until their effects, ranging from mild irritation or discomfort to rapid death, become apparent, they are often ignored or simply overlooked. Because of their ubiquity, there is a need for a comprehensive treatment of toxic plants likely to be encountered in North America, north of the Tropic of Cancer, growing wild or cultivated. The first edition of this book was written in response to that need.

OBJECTIVE AND SCOPE OF THE FIRST EDITION

The objective of this undertaking was to write a comprehensive treatment of toxic plants that brought together the currently available information on (1) their morphology and distribution, (2) the disease problem or problems associated with them, (3) their toxicants and mechanisms of action, (4) the clinical signs and pathologic changes associated with their toxicity, and (5) the principal aspects of treatment. The perspective of the first edition was primarily veterinary science.

Compilation of the information presented in the first edition began in the 1980s as a series of articles for the *Oklahoma Veterinarian* and an agricultural extension publication, *Poisonous Plants of Oklahoma and the Southern Plains*. Well received, these publications dealt primarily with native plants and their toxicity for livestock. Initially, the present book was anticipated to do the same for the United States. Gradually, however, its scope and depth of coverage evolved—larger area, more plant families, and greater detail than first envisioned. These changes came about in part because of the increasing popularity of ornamental plants for both house and garden. There has been a corresponding increase in awareness of toxicity problems associated with some of them.

OBJECTIVE AND SCOPE OF THE SECOND EDITION

In the 11 years since publication of the first edition, a wealth of toxicologic information has been compiled—unknown toxicants identified, mechanisms of intoxication elucidated, and additional reports of problems published. In addition, there has been a corresponding increase in taxonomic knowledge with significant changes in the classification of plant families and genera and associated changes in nomenclature. Because of this almost exponential increase in our knowledge of toxic plants, work on a second edition was initiated in 2009.

In addition to compiling and presenting the literature of the last decade, we have also slightly altered the perspective of this edition. We have included information about four additional aspects of plant toxicology; they are summarized in the following subsections.

Intoxications in Humans—The first edition focused primarily on veterinary science because of our professional backgrounds and the need for such a book in the discipline. In this second edition we have attempted to place increased emphasis on human intoxications because the information acquired about both humans and other animals is often interrelated and supportive. For the most part, plant intoxications in humans, while not uncommon, do not pose the lethal risk (with the exception of *Datura* and *Cicuta*) seen with livestock and other animals, but they nevertheless may be numerous and sometimes serious as revealed in annual

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reports from Poison Control Centers (Litovitz et al. 2001; Bronstein et al. 2007). It may be expected that in most instances similar disease problems will occur in both humans and animals with a few exceptions.

For some taxa, we have included information about problems associated with herbal products as examples of their intoxication potential but a comprehensive discussion of adverse reactions to these products is beyond the scope of this book. In addition we have included some information about potential bioterrorism threats because of the serious problem presented by the extreme toxicity of some plants such as those possessing type 2 ribosome-inactivating proteins—most notably *Ricinus communis* and species of *Adenia* (Pelosi et al. 2005; Stirpe and Battelli 2006; Monti et al. 2007; Stirpe et al. 2007; Ng et al. 2010). Considerable information on the mechanisms of intoxication is emerging because of the interest in effects of plant toxicants as models for various human disease problems such as Huntington's disease, ALS, Alzheimer's disease, and Parkinson's disease (Tukov et al. 2004; Bradley and Nash 2009; Cox 2009; Pablo et al. 2009; Tunez et al. 2010).

Treatments for humans are given in very general terms because physicians and medical institutions may have different treatment protocols. General references for specific procedures include Greene and coworkers (2008) and Lee (2008) for gastrointestinal decontamination and use of ipecac, and Froberg and coworkers (2007) for plant poisonings specifically in humans.

Intoxications in Wildlife and Captive Animals—In this edition, a special effort has also been made to document the effects of poisonous plants on wildlife, both free roaming and captive. References for specific information about particular genera and species are included throughout the book. General references to be consulted include Fowler (1981, 1999) and Van Saun (2006).

The reader should keep in mind that in general most wild herbivores respond similarly to plant toxicants as do our domesticated animals, with a few exceptions such as those compounds produced by *Quercus* (oak), *Centaurea* (star thistle), *Acroptilon* (knapweed), and *Pinus* (pine). Some plants are invariably toxic to most wild animal species, for example, cardiotoxic and cyanogenic plants as well as species of *Lantana* (lantana) and *Nicotiana* (tobacco) (Basson 1987). Other plants, however, may affect wild animal species quite differently as illustrated by responses to tannins, especially those produced by species of *Quercus* (the oaks).

With respect to toxic plants, species of wildlife are not necessarily immune to their effects, but avoid problems associated with their toxic secondary compounds by ignoring some plants, eating only small amounts, and/or exhibiting natural gastrointestinal/hepatic degradation/detoxication of these noxious compounds (Fowler 1981; Laycock 1978). Unfortunately, captive or domesticated wild species may have access to toxic plants with which they have not coevolved or which they have not encountered previously. In some instances, boredom of captive animals may lead to ingestion of toxic plants in their enclosures. Such problems have been reported in a variety of herbivores ranging from elephants to tortoises.

There are also other reasons for ingestion of toxic plants by wild animal species, including poorly nourished, hungry animals which may be nonselective in their eating habits or to seasonal variations in palatability or acceptability of otherwise noxious plants in their environment. Thus management plays a vital role in animal intoxications (Pfister et al. 2002). Additional reviews regarding the role of secondary plant compounds on nutritional toxicology of birds and herbivores are available (Cipollini and Levey 1997; Dearing et al. 2005; Torregrossa and Dearing 2009).

Role of Plant Secondary Compounds in Plant Intoxications—An additional problem given increased attention in this second edition is the role of secondary plant compounds as toxicants in honey and or their affect on bees. A number of general reviews on these subjects are available: Patwardhan and White (1973), White (1981), Detzel and Wink (1993), Faliu (1994), Adler (2000), and Kempf and coworkers (2010). Some attention has been given to the problem of milk and meat tainting but without exhaustive discussion. Reviews are available but this is a subject not given great coverage with respect to noxious noncultivated plant species (Richter 1964; Armitt 1968a,b). Methyl sulfide is clearly a factor in tainting and probably many plants that have sulfur-containing constituents are likely culprits (Patton et al. 1956; Gordon and Morgan 1972).

Role of Fungal Endophytes in Plant Intoxications—Great interest is now directed toward the role of fungal infections of plants as contributors to the synthesis of toxicants in host plants. The fungi involved in these infections may be endophytes or epiphytes. In some instances the toxins may be produced exclusively by the fungus, whereas in others the toxicants may be produced by both the plant and the fungus (Wink 2008). Examples of these situations are the presence of an endophytic fungus in *Hypericum perforatum*, which produces hypericin similar to the host plant, and an endophyte in *Podophyllum peltatum*, which produces podophyllotoxin again similar to the host plant. In contrast, an endophytic strain of the

fungus *Fusarium oxysporum* also produces podophyllotoxin but in *Juniperus recurva*, a totally unrelated species (Eyberger et al. 2006; Kour et al. 2008; Kusari et al. 2008).

Because these fungi, especially the endophytes, are in many instances clearly beneficial to the host plant, there is good reason to expect that more of these symbiotic relationships will be identified in the future (Rodriguez et al. 2009; Rudgers et al. 2009). Likewise, there are probably many fungi–plant–toxicant relationships yet to be demonstrated. Although at present most involve the Poaceae (grasses), other plant families are increasingly being associated with toxin-producing fungi. In some instances, these endophytes are exploited to promote grass protection and production and as potential sources of beneficial natural products (Easton 2007; Kuldau and Bacon 2008; Belesky and Bacon 2009; Aly et al. 2010). Numerous endophytes have been isolated from some plant species, for example, 183 different fungi from *Catharanthus roseus* in India (Kharwar et al. 2008). For additional discussion of this relationship see the treatment in Poaceae (Chapter 58).

COMPILATION OF INFORMATION

The information presented in this treatise on toxic plants is based upon reports extracted from the toxicological, veterinary, human, agronomy, chemical, biochemical, and physiological literature and from our personal observations. References are numerous. In the past, descriptions of intoxication problems were sometimes poorly documented, and a large amount of unsubstantiated anecdotal information was incorporated in earlier publications in such a form that it eventually became accepted as fact. Experimental studies have since confirmed or rejected much of this information. An effort has been made to document each point selectively to avoid being excessive, but it is anticipated that the incorporation of many references provides starting points for readers to delve more deeply into any topic.

The information presented is intended to be of interest to veterinarians, agricultural extension agents, horticulturists, animal scientists, botanists, personnel at poison control centers, physicians, pharmacists, agronomists, range scientists, toxicologists, wildlife biologists, ecologists, farmers, ranchers, students, and the general public. The book may be used as a textbook for graduate-level courses or as a general reference. The incorporation of tables associating the clinical signs and pathology of intoxications with specific plant genera and species permits its use in applied situations.

As always with a book such as this one, the caveat that it is not complete must be stated. As investigations of plants progress, there will be the discovery of new toxic species and the reassessment of the intoxication problems caused by known ones.

ORGANIZATION AND FORMAT

In this edition, the plant family continues to serve as the organizational unit for the toxicological data compiled. Each chapter is devoted to the toxic taxa of one family. To facilitate access and review, the information is organized into seven sections: "Taxonomy and Morphology," "Distribution and Habitat," "Disease Problems," "Disease Genesis," "Clinical Signs," "Pathology," and "Treatment." Embedded in these sections are boxes with salient points of information, photographs, line drawings, distribution maps, and illustrations of chemical structures and toxicologic pathways.

With respect to the taxonomy of the toxic plants being described in this work, concepts of families, genera, and species are based on current classifications. When significant changes in classification and/or nomenclature have occurred, older names are given as synonyms in parentheses below the currently accepted names. Readers, especially those who used the first edition, may discover that "new" scientific names are used for several familiar species, genera, and families in this edition. The majority of these changes reflect the accumulation of additional taxonomic data by taxonomists and thus revised interpretations of character importance and phylogenetic relationships. In some instances, these name changes are mandated by the *International Code of Botanical Nomenclature* (McNeill et al. 2006), and a few changes were made to make the names in this book consistent with those appearing in the *Flora of North America North of Mexico* (Flora of North America Editorial Committee 1993+) and the PLANTS Database (USDA, NRCS 2012). These two works are becoming the standard references for taxonomy and nomenclature in North America. Abbreviated explanations of the reasons for these changes are presented in the "Taxonomy and Morphology" sections.

The common names cited are those based on our experience and their citation in floristic works and standardized lists such as the PLANTS Database and the Weed Science Society of America's (2010) *Composite List of Weeds*. Author citations (name or abbreviation of name of person or persons who published the taxon's name) are taken from Brummitt and Powell's (1992) *Authors of Plant Names*.

The descriptions given for each family describe the range of morphological variation for only its North American species. When a range of values is given for the numbers of genera and species in a family, differences in opinion among taxonomists are indicated. Unless otherwise attributed, information about the taxonomy and

biology of each family was compiled primarily from Cronquist (1981), Kubitzki (1990+), Flora of North America Editorial Committee (1993+), Heywood and coworkers (2007), Mabberley (2008), Judd and coworkers (2008), and Bremer and coworkers (2009).

To avoid repetition and conserve space, morphological features of the genus that are the same as those given for the family are generally not repeated; rather, those features that are characteristic of or unique to the taxon are used. If a genus is monotypic or represented in North America by a single species, its morphological description is based on the species' appearance. The morphological descriptions of the genera and species are composites of those appearing in state and regional floras encompassing the distributional ranges of the taxa. Principal sources are listed in the references.

Should exact identification of a plant suspected to be toxic be needed, it is anticipated that the reader will use floras specific for his or her locale to determine or confirm identification. Perhaps, as some taxonomists predict, plant identification may become almost as simple as reading a universal barcode in the grocery store as technology evolves and we make progress in determining DNA sequences in plants (Bruni et al. 2010).

Line drawings, distribution maps, and chemical structures are based in part upon those appearing in the references cited below. Original line drawings are primarily the work of Bellamy Parks Jansen and Sheryl Holesko. Other drawings were obtained from the government publications listed in the references and were prepared by Regina Hughes and numerous other artists. Drawings have also been used with permission from *Flora of Missouri*, by J.A. Steyermark (1975). The maps and chemical structures are composites of the information available in both the references cited and the general literature.

In addition to the 76 chapters presenting the toxicologic problems associated with each plant family, a chapter is included describing 44 families with species of questionable toxicity or significance, a glossary, diagnostic synopses of the most important families, tables cross-referencing disease syndromes and clinical signs, and a comprehensive index.

HISTORICAL PERSPECTIVE

We would be remiss in this endeavor if we did not recognize those who have gone before us and whose work has served as a foundation for this book. There are many individuals who should be recognized, and it is with some trepidation that we list them, because many who will not be included have also made substantial contributions to our understanding of toxic plants. Certainly L.H. Pammel and J.M. Kingsbury have been instrumental in providing a foundation and model upon which to write a book on toxic plants. Their efforts contributed greatly to our understanding of the effects of plants on livestock. Their work is especially significant because of the meager information they had in many instances upon which to base their conclusions about toxicity. Also of great importance were the efforts of early investigators and observers such as V.K. Chesnut and C.D. Marsh. The remarkable, astute observations of Marsh continue to be the basis for our understanding of the effects of many toxic plants as will be illustrated by the number of literature citations to his work throughout this book.

When reviewing those who have had great impact on our present state of knowledge of plant-caused problems, we cannot fail to recognize the personnel of the U.S. Department of Agriculture's Agricultural Research Service (USDA, ARS) Poisonous Plants Research Laboratory at Logan, Utah. These ARS scientists, both past and present, have had an immense impact on our understanding and ability to deal with the ever-present problems of plant intoxications in livestock. Many individuals have been involved in the lab's work, and the references throughout the book attest to their extensive efforts. With the passage of time, we are becoming increasingly indebted to workers in Australia, Brazil, India, South Africa, and other countries for their vital contributions to our understanding of the effects of toxic plants.

We are also indebted to the many personnel at state experiment stations who have contributed to the body of knowledge on the toxicity of plants, especially those in the western states. Worthy of particular note is the exceptional work conducted in Texas. Names that appear repeatedly in the toxicological literature and our references include I.B. Boughton, W.T. Hardy, and F.P. Mathews. Dr. Mathews was instrumental in opening the Locoweed Research Laboratory in Alpine, Texas, in 1930 and was responsible for many years for investigating the plant-related livestock problems in West Texas and surrounding areas.

DEDICATION

Following in the footsteps of Dr. Mathews was Dr. James W. Dollahite, a young veterinarian from west central Texas and an individual who had a profound influence on the discipline of toxicology. His life and contributions were eloquently summarized by E.M. Bailey (1998) and are excerpted here with permission. Born in 1911, Dr. Dollahite was raised near Johnson City, Texas. He received his DVM. in 1933 from the Agricultural and Mechanical College of Texas. He worked for the U.S. government and practiced until World War II, when he served as an army veterinarian, later retiring as a lieutenant colonel in the Air Force Reserve. Following the war, he went back into veterinary practice in Marfa, Texas, but developed an

interest in toxicology. Dr. Dollahite combined his practice and a part-time position with the Texas Agricultural Experiment Station in Alpine to further his interests in plant toxicology. He also worked for a time at the USDA research facility in Beltsville, Maryland. In 1956 he started a full-time experiment station position and was responsible for moving the Alpine Research Station, begun by Dr. Mathews, to Marfa, where it became the Marfa Toxic Plant Research Station. During this time he drove many miles over West Texas and southern New Mexico, investigating toxic plant problems and conducting his toxic plant research. He closed the Marfa station in 1958 and moved his research endeavors to College Station, where he was a member of the veterinary research section of the College of Veterinary Medicine. Because there was no formal toxicology program at the time, he received his MS in veterinary physiology in 1961. He became an associate professor of pathology in 1964 and a professor in 1965. In 1968 he transferred to the Department of Veterinary Physiology and Pharmacology, where he was instrumental in establishing a doctoral program in toxicology in 1969.

Dr. Dollahite was a charter and founding diplomate of the American Board of Veterinary Toxicology (1966–1967). He continued his research until his retirement from Texas A&M in 1975. He continued to work on toxic plants at the USDA, ARS Veterinary Toxicology and Entomology Research Laboratory until his full retirement in 1980. He died in 1984.

Dr. Dollahite played a very important role in the development of veterinary toxicology in Texas, especially toxic plant research, and in the development of veterinary toxicology as a specialty within the American Veterinary Medical Association. However, these facts, dates, and accomplishments are but one aspect of the real man. One of us (GEB) had the opportunity to spend a week in 1979 traveling with him in a review of the toxic plants of Texas. It was this time that provided a glimpse of the person of whom others had long been aware. The respect paid to him by those with whom he had been associated in the field was impressive. He was truly a remarkable individual, not only for his powers of observation of clinical signs in diseased animals and contributions to our knowledge of toxic plants but also for his personal attributes. The legacy of his life was much more than professional success. He was an exemplary individual in many ways. We are sure that he would like to be remembered as a man of great faith in God, who made every effort to deal with others with respect, kindness, and gentleness. He had great integrity and was a gentleman in every sense of the word. He is truly a worthy role model.

It is with this in mind that we dedicate this book to Dr. J.W. Dollahite.

ACKNOWLEDGMENTS

The writing of both editions of this book have been conducted as traditional academic endeavors, that is, reviews of the literature and an attempt to synthesize in a readable fashion the wealth of information accumulated. Initially the effort involved just the two of us, but as the writing of each edition progressed, more and more individuals volunteered encouragement, support, time, and expertise. It is therefore necessary and certainly most appropriate to recognize formally their contributions at this point.

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