WEED BIOLOGY AND CONTROL

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PREFACE

Man's welfare depends on his ability to control plant growth. This book was written for those who would like to gain a better understanding of the different systems presently employed for this purpose. I have not tried to give an exhaustive coverage of any particular technique or to give recipes for any particular locality. Rather I have tried to give a better perspective on the world problem of controlling weeds than is now provided by existing texts. Therefore, details applying to specific regions have been omitted, and illustrations have been drawn from all over the world.

Chemicals are tools. Used wisely they give man a greater dimension of power than is provided by older methods of vegetation control, e.g., machinery, fire, flooding, and mulching. Improperly used, they can cause great damage. Herbicides may be used not only to increase food production and improve visibility along roadsides but also to improve the quality of life more directly by making surroundings more attractive, improving recreational opportunities, and providing better cover for wildlife.

The sheer fun of working with plants is not to be underestimated. The farmer and the city gardener alike gain a good deal of pleasure from growing plants. Much of the joy, however, is tempered by the growth of weeds. Herbicides are a weapon that can relieve the grower of much of the drudgery and back-breaking labor involved in cultivating, hoeing, or weed pulling.

I have attempted to present as simply as possible the principles of the successful use of physical and chemical methods of controlling plant growth. Emphasis is placed on principles, since practices vary in different areas and at different times. Such changes in methods are occurring very rapidly. The principles, however, endure. An understanding of the factors that affect plant responses to chemicals will help the grower to use new chemicals wisely and efficiently.

As any field of science develops, a certain amount of chaos ensues as a result of the vast accumulation of unassorted information. I have attempted to put into perspective as much of the available information as possible. Therefore, principles and broad categories of chemicals and weeds are emphasized. In Chapter 9, for example, I have attempted to relate taxonomy, ontogeny, and chemical response in the plant kingdom. This attempt, even if only partially successful, should be especially useful for the beginning student. This is a very broad canvas indeed, and the picture I have painted will undoubtedly be refined in the future. I firmly believe, however, that emphasizing taxonomic relationships and life cycles is a sound approach to an understanding of the action of chemicals on plants.

Agriculture has been defined as a "controversy with weeds." Weeds cause more crop losses than diseases and insects combined. The efficient practice of weed control using the most modern techniques and tools available could advance world food production more than any other single practice. Freeing people of underdeveloped countries from spending most of their time growing enough food for a bare living would make it possible for each to develop a new spirit, to advance culturally and scientifically, and to take their places in improving the quality of civilization. Hunger, or the threat of hunger, stifles all the higher aspirations of mankind.

Few people, except perhaps the professional plant scientist, have any real understanding of the vital role that plants play in our lives. This is partly a result of increased specialization and urbanization in highly technological societies. The city dweller, surrounded by concrete, misses a lot of pleasure as well as spiritual fulfillment through his ignorance of and separation from plants. More ominous is the lack of this understanding by the people and governments of the developing nations which have little agricultural technology. Therefore we see the enormous waste of wealth devoted to "prestige projects" such as huge buildings, factories, and superhighways, with little consideration given to improving or strengthening the basic foundation for national progress—a sturdy and efficient agriculture. With 90 percent or more of the population devoting nearly full time to pulling or hoeing weeds, it is unlikely that the remaining 10 percent will build much of a country.

As a citizen who is deeply concerned about the desperate condition of many of the world's peoples, it is my hope that this volume will lessen in some small measure their deplorable situation, much of which is unnecessary and can be relieved by an application of readily available knowledge. Environmental changes, such as increased or more timely rainfall, may temporarily boost food production, but world food supplies will be increased on a long-term basis only through wise use of modern pesticides and machinery.

I wish to acknowledge the assistance of the many friends and

colleagues who critically read all or portions of the manuscript. Special thanks go to R. B. Tukey, G. W. Fischer, and B. R. Bertramson for their encouragement and invaluable help in the initial stages of the preparation of the manuscript. I am especially grateful to G. W. Burt, C. L. Foy, A. S. Crafts, and O. A. Leonard for a critical review of the entire manuscript. For help with various chapters I wish to thank C. S. Agbakoba, W. C. Anliker, V. F. Bruns, N. C. Gomness, H. R. Guenthner, R. G. Harvey, A. G. Law, D. G. Peabody, B. F. Roché, W. C. Robocker, T. J. Sheets, and J. W. Whitworth, as well as the many students who suffered through the evolution of this material. The quotations on weeds were supplied by L. W. Rasmussen. In a field as complex as weed biology and control, no one man can hope to be an expert on all its phases, and therefore much of the value of this book is due to the willing assistance I received.

To my wife, Peggy, whose forbearance, understanding, and forgiveness made it possible, I dedicate this volume.

Thomas J. Muzik

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CONTENTS

CHAPTER ONE
WEEDS IN RELATION TO MAN

This chapter introduces the history and development of weed control, prefaced by a definition of what a weed is, how weeds cause their deleterious effects, and how these effects are related to man.

WHAT IS A WEED?

Definitions

Without man there would be no weeds. All definitions of weeds are predicated on the relationship of the plant to the activities or desires of mankind. Thus, the common definitions are *a plant out of place*, or *an undesirable plant*, or *a plant with a negative value*, or *plants which compete with man for the soil.* Weeds are plants that thrive best in an environment disturbed by man. Man is the greatest disturber of environments that the world has ever known. The only characteristic common to all weeds is their excellent adaptation to the disturbed environment in which they are growing. Not shared by all, however, are the other so-called weed characteristics, such as abundant seed production, dormancy, ability to survive unfavorable growing conditions, competitive ability, shattering, and ability to spread vegetatively. Sometimes crop plants may be considered weedy if they are growing where they are not wanted, as, for example, asparagus in grape vineyards and orchards where it is considered one of the worst weeds.

As Harlan and DeWet (1965) point out, the concept of a weed

might be extended to animals as well, for there are also animals that are well adapted to human disturbance. The English sparrow, starling, Norway rat, house mouse, and rabbits in Australia are examples. A weed, therefore, in the broadest sense, may be considered as an organism that diverts energy from a direction desired by man. Further discussion in this volume will be restricted to plants. Man, too, thrives best in a disturbed habitat. The success of particular cultures or civilizations is measured by their ability to modify the natural environment in the direction necessary to ensure their own well-being. On the other hand, the population explosion may lead to man being considered undesirable. Some individuals such as thieves and other criminals, or even the modern-day "hippie," may be considered weedy.

Origin of weeds

Man is probably as responsible for the evolution of weeds as for the evolution of crops. To repeat, weeds are plants adapted to disturbed habitats. In prehistoric times, glaciers were the prime disturbers of established vegetation. Pleistocene glaciation provided pioneer habitats by alternately covering and exposing great areas of Europe and North America. Thus in the temperate zone, the major weeds are species that developed in or near the areas of disturbance caused by glaciation.

Agriculture has caused a far vaster and more rapid disturbance than glaciation. Most of the modern weeds did not exist before agriculture. Weeds probably evolved along with the crops or in some instances may actually have been the ancestors of the cultivated varieties. It has been suggested that crop plants may have arisen from weeds by a mutation to gigantism. Thus, cultivated carrots are larger than wild carrots, tame watermelon larger than the weedy species. This increase in size was not accompanied by an increase in competitive ability, and as a result man must give these plants special care so they will survive.

Weeds, then, come from (1) wild species long adapted to sites of natural disturbance, (2) new species or varieties that have evolved since agriculture was developed.

Obligate weeds

Many weeds have never been found in the wild stage, and grow only in association with man. These so-called *obligate weeds* (Zohary, 1962) include bindweed (*Convolvulus arvensis*), wild radish (*Raphanus raphanistrum*), canarygrass (*Phalaris paradoxa*), ryegrass (*Lolium temulentum*), and many others. The original habitat of these plants is not known but they resemble some of the cultivated crops which have not been found anywhere in the wild state.

Facultative weeds

Facultative weeds are those that grow both wild (in primary habitats) and with man (in cultivated habitats). The prickly pear (*Opuntia* spp.) and various species of wild onion (*Allium*), vetch (*Vicia*), etc., are examples of facultative weeds.

Weedy forms of crop plants

Many of our crops have weed forms; for example, weed potatoes, sunflowers, carrots, watermelons, wheats, barleys, rice, oats, and many others. Races of weeds frequently develop which mimic the crop sufficiently well that the seed is harvested along with the crop and sown with it at harvest time. For example, shattercane, a new weed in the Great Plains area, is considered an escaped forage sorghum. It is well adapted to row crops such as corn and sorghum, but shows more dormancy and shattering than the forage sorghums (Claasen, 1965).

Harlan (1929) describes a barley nursery in which the wild oat population closely mimicked the barley. When growing with winter barley, the wild oat formed a low winter rosette; in adjacent rows of tall spring barley, the wild oats grew tall and headed out. When the early barley matured, the oats matured along with it. All stages could be seen on the same day. This adaptive ability of weeds is very important to their survival.

Why we have weeds

The plant community is a complex association. Under a particular set of environmental conditions—climate, extremes of temperature, total rainfall and rainfall pattern, soil characteristics, fertility, etc.—there is a natural progression to a "climax" vegetation. When man attempts to change this natural progression in order to grow his crops, fruits, trees, and ornamentals, he is fighting an uphill battle against the natural succession of plant growth. For example, certain climates favor trees or brush over grasses. In these areas, it is very difficult to grow grasses along the roadsides, since the natural ecology leads to a woody plant as the climax. In other, drier areas, grasses are favored and the householder who wants trees find that they are difficult to establish.

Man has been forced to adapt his agriculture to the climatic conditions of certain regions. Thus we have regions or "belts" which produce certain crops, such as corn, wheat, rice, fruits, lumber, etc. The crops are seldom as well adapted as the species native to the area. It is doubtful that any major crop species would long survive without man's help, for they are not as well adapted to the environment as certain other plants which invade, compete, and would eventually "take over" the

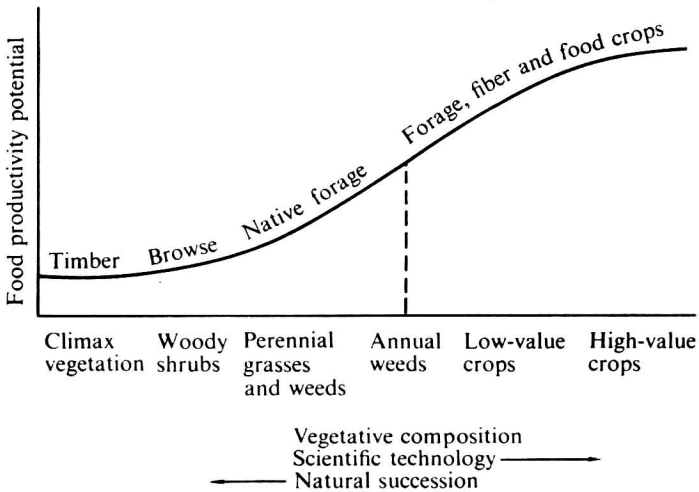

Figure 1-1 *Depending on the climatic variations involved, the "climax" vegetation may be grass, brush, timber, or a combination of all three. In drier regions, for example, grasses may dominate the lower areas, shrubby vegetation is frequently found on north-facing slopes, and trees appear at higher elevations. Nature moves in the direction of a climax vegetation, while man struggles against this natural progression and expends energy (muscular, mechanical, and chemical) to raise high-value crops. (Modified from Shaw and Danielson, 1961.)*

fields. These are the weeds. The invasion of crops by weeds is a replacement of less-adapted organisms—a kind of plant succession (Figure 1-1).

Left to her own devices, i.e., without the activities of man, nature would probably eliminate many of the weeds as major components of the vegetation.

Various aspects of modern agriculture favor invasion by weeds: (1) Crops are usually sown in rows leaving gaps that are available for colonization by other species. (2) Crops are usually grown in pure stands. A single species generally fails to fully exploit the habitat; for example, it may not use the available sunshine because its leaf area develops slowly, or it may have too short a growth cycle to use all the available water or nutrients because of the distribution of its root system. Weeds may then successfully use these wasted resources.

HOW WEEDS CAUSE THEIR EFFECTS

Competition

Weeds cause their effects primarily by competing with crops

for light, nutrients, water, and space. More water and nutrients are required to raise a ton of weeds than to raise a ton of most crops.

Weeds, like crops, vary in their competitive ability, but characteristically they exhibit, when young, a rapidly spreading and deeply penetrating root system which gives them an early advantage in obtaining water and nutrients.

Competition for light and space with the concomitant reduction in photosynthesis leads to crop losses.

Inhibitors

Many weeds such as quackgrass, false flax, and blue-flowering lettuce exude inhibitors from their living or dead roots which further reduce crop growth (Grummer and Beyer, 1959; Welbank, 1959; Kulp, 1961).

Interference with agriculture

Weeds cause greater losses than either insects or plant diseases (Table 1-1). They are the major barrier to food production and economic development in many regions of the world. Particularly in underdeveloped countries lacking in machinery and chemicals, weeds must be pulled by hand or cultivated with very simple tools. Most of the agriculturist's time is spent fighting weeds. Insects and plant diseases may be very serious from time to time but they do not present the eternal problems that weeds do. To name a few:

1. In dairying areas a serious problem is caused by weeds which give an off-flavor to milk. Wild onion and wild garlic, bitterweed *(Actinea odorata)*, and frenchweed *(Thlaspi arvense)* are examples of this kind of weed.

Table 1-1 Losses from weeds, insects, and diseases compared with pesticide sales and research efforts

SOURCE OF LOSS	ANNUAL LOSSES AND COST OF CONTROL, $ *Million*	1965 PESTICIDE SALES, $ *Million*	RESEARCH SUPPORT USDA AND STATE, $ *Thousand*	RESEARCH PERSONNEL*
Weeds	5,064	210,753	8,707	205
Insects	4,298	237,317	34,368	510
Plant diseases	3,779	48,603	44,164	656

*The number of research personnel in the field of weed control is far less than in either entomology of plant pathology. Further research in all aspects of vegetation control is of prime importance to mankind.

(Modified from W. R. Furtick, 1967. National and International Weeds for Weed Science. A Challenge for WSA. *Weeds*, **15**:291–295.)

2. Serious illness or even death may be caused in cattle, horses, and sheep by excessive amounts of poisonous constituents or spines, including horsetail (*Equisetum arvense*), *halogeton*, or horse nettle (*Solanum carolinense*). St. Johnswort (*Hypericum perfoliatum*) may injure the soft tissues of the mouth. Difficulties in processing also are caused by burs or spines of various weeds getting caught in the wool or hair.

3. Spiny weeds such as Canada or creeping thistle (*Cirsium arvense*) interfere with harvesting, especially in hand-harvested crops such as orchard and bush fruits or vegetables. In the tropics, workers refuse to enter sugarcane fields infested with pica-pica (*Mucuma pruriens*). The irritating hairs on this legume fall off on the slightest contact and cause severe inflammation and itching (Velez and Van Overbeek, 1950).

4. Unripe seeds or stems of seeds may be harvested along with the cereal or legume crops. The decay of these moisture-containing plant parts causes undesirable high temperatures in the stored crops and may lead to spoilage. Many annuals and perennials, such as Canada thistle and bindweed, are often found growing vigorously in ripe grain or legumes.

5. The contamination of seed stocks by weed seeds is discussed in some detail in Chapter 3. Suffice it to say here that weeds are spread more through contaminated seed stocks than by any other method. This was especially true in the days before the importance of clean seed was recognized. Many weeds were undoubtedly spread in this fashion. The movement of armies with feed grain for horses caused much weed spread in the days before mechanization.

6. Hay containing mature thick hard stems is less attractive to livestock. Foliage of certain weeds, such as bracken fern and various sedges, makes the hay less palatable.

7. Damage to machinery or clogging of harvest equipment may occur when substantial stands of old perennial weeds or brush are cut, thus necessitating a delay for cleaning or repairing the equipment.

Alternate hosts for insects and diseases

Many weeds serve as alternate hosts for insects and fungi. The leaf hopper, which lives on shepherd's purse (*Capsella bursa-pastoris*), carries a virus which causes curly top in sugar beets, beans, and tomatoes. The insect survives on the weed between crop periods. The common barberry is an alternate host for wheat rust, and black currant for white pine blister rust. A number of cruciferous weeds and numerous grasses (*Agropyron* sp.) act as hosts for foot rot (*Ophiobolus* and *Helminthosporium*).

Water losses

Weeds of waterways cause enormous losses of water. In irrigated areas they reduce the stream flow, cause silt deposition, and furnish protec-

tion to rodents which burrow in the bank. It is estimated that enough water to irrigate 330,000 to 780,000 acres is lost annually in the irrigated areas of the 17 western states of the United States (Timmons, 1960; see also Chapter 8). Boat transport is severely limited by aquatic weeds in many regions. Fishing, swimming, and recreation may be almost eliminated by weed infestations.

Human and animal health

Human health is affected by poisonous plants, especially those which cause allergies. Indeed, more than half the world population is affected by plant allergies. Most of these are caused by pollen, but contact with the leaves of poison ivy, poison oak, or poison sumac can cause considerable distress. In the tropics, the manchineel tree (*Hippomane mancinella*) causes severe burns to cattle or humans who rest under it during rains, and it is said to kill anyone who sleeps under it. Accidental ingestion of poisonous fruits such as nightshade or use of stems of poisonous plants such as hemlock as blowguns occasionally cause illness, particularly among children. A number of weeds such as corn cockle (*Agrostemma githago*), darnel (*Lolium temulentum*), and certain species of *Senecio* produce seeds which are poisonous when present in flour and bread. Many people in South Africa have been killed by such poisoning (King). Nightshade berries (*Solanum* spp.) are difficult to remove from fresh or canned peas. Seeds or fruit with characteristics similar to the crop are difficult to separate and often necessitate the installation of expensive machinery.

HISTORY OF AGRICULTURE AND THE DEVELOPMENT OF WEED CONTROL

Man—a hungry creature in search of food

The history of mankind is basically the story of a hungry creature in search of food (Van Loon, 1945). Until he began to use tools and later to domesticate plants, he was weak and few in number. A million years ago approximately 125,000 people inhabited the earth. It is about this period of time that the records have been found of the first use of simple stone tools.

As he spread out over more of the earth's surface, man slowly increased in population until 10,000 years ago he numbered about 3 million. Nomadic and hunting peoples need an estimated 10 square miles of land to support one person, and there are about 30 million square miles of usable land on the earth's surface (exclusive of oceans, deserts, mountains, and other uninhabitable areas). Thus the total population of nomadic peoples which the earth could support is about 3 million or 0.1 percent of the present population.