CHAPTER 2

Weeds—The Beginning

FUNDAMENTAL CONCEPTS

- The most basic concept of weed science is embodied in the term *weed*.
- Weeds are defined in many ways, but most definitions emphasize behavior that affects humans.
- All weeds share some characteristics.
- Weeds express their undesirability in at least nine distinct ways.
- Although it is difficult to estimate total weed cost, in the United States, losses due to weeds exceed $8 billion per year.

OBJECTIVES

- To understand the definitions of weeds.
- To identify the common characteristics of weeds.
- To understand how weeds cause damage
- To appreciate the enormous cost of weeds and how costs are estimated.

. . . and nothing teems
But hateful docks, rough thistles, kecksies, burs,
Losing both beauty and utility.
And as our vineyards, fallows, meads, and hedges
Defective in their natures, grow to wildness;
Even so our houses, and ourselves, and children,
Have lost, or do not learn, for want of time,
The sciences that should become our country.
King Henry V, Act 5, Scene 2. Play by William Shakespeare

I will go root away the noisome weeds,
which without profit suck the soil's fertility from wholesome flowers.
Richard II, Act 3, Scene 3. Play by William Shakespeare

There are laws in the village against weeds
The law says a weed is wrong and shall be killed
The weeds say life is a white and lovely thing
And the weeds come on and on in irrepressible regiments.
"Weeds" Poem by Carl Sandburg

I. DEFINITION OF THE WORD *WEED*

To be fully conversant with a subject, one must understand its basic concepts, and the most basic concept of weed science is embodied in the word *weed* itself. Each weed scientist has a clear understanding of the term, but there is no universal definition that is accepted by all scientists. In 1967 the Weed Science Society of America defined a weed as "a plant growing where it is not desired" (Buchholtz, 1967). In 1989 the Society's definition was changed to define a weed as "any plant that is objectionable or interferes with the activities or welfare of man" (Humburg, 1989, p. 267; Vencill, 2002, p. 462). The European Weed Research Society defined a weed as "any plant or vegetation, excluding fungi, interfering with the objectives or requirements of people" (EWRS, 1986). Although the definitions are clear, they are not accepted by all scientists. These definitions leave their interpretations with people, so they must be the ones to determine when a particular plant is growing where it is not wanted or where it interferes with their activities or welfare.

The *Oxford English Dictionary* (Little et al., 1973) defines a weed as a "herbaceous plant not valued for use or beauty, growing wild and rank, and regarded as cumbering the ground or hindering the growth of superior vegetation." The human role is again clear because it is we who determine use or beauty and which plants are to be regarded as superior. It is important that weed scientists and vegetation managers remember the importance of definitions as determinants of their views of plants and attitudes toward them.

How one defines something largely determines his or her attitude toward the thing defined, and, for the weed scientist and vegetation manager, determines which plants are weeds and therefore must be controlled. Weeds, like other plants, lack consciousness and cannot enter the court of public opinion to claim rights. Humans can assign rights to plants and serve as their counsel to determine or advocate their rights or lack thereof in our environment. Our attitude toward weedy plants need not always be shaped by another's definition because people seldom agree on definitions.

Once in a golden hour,
I cast to earth a seed.
Upon there came a flower,
The people said a weed.

Read my little fable:
He that runs may read
Most can raise the flowers now,
For all have got the seed.

And some are pretty enough,
And some are poor indeed:
And now again the people
Call it but a weed.

"The Flower" Poem by Alfred
Lord Tennyson

Not all people agree about what a weed is or what plants are weeds. Harlan and de Wet (1965) assembled several definitions to show the diversity of definitions of the same or similar plants. The array of definitions emphasizes the care weed scientists and vegetation managers must take in equating how something is defined with a right or privilege to control.

Definitions from plant scientists

W.S. Blatchley	1912	"A plant out of place or growing where it is not wanted."
A.E. Georgia	1916	"A plant that is growing where it is desired that something else shall grow."
W.W. Robbins et al.	1942	"These obnoxious plants are known as weeds."
W.C. Muenscher	1946	"Those plants with harmful or objectionable habits or characteristics which grow where they are not wanted, usually in places where it is desired that something else should grow."
J.L. Harper	1960	"Higher plants which are a nuisance."
E.J. Salisbury	1961	"A plant growing where we do not want it."
G.C. Klingman	1961	"A plant growing where it is not desired; or a plant out of place."

Definitions by enthusiastic amateurs

R.W. Emerson	1912	"A plant whose virtues have not yet been discovered."
F.C. King	1951	"Weeds have always been condemned without a fair trial."

Ecological definitions

A.H. Bunting	1960	"Weeds are pioneers of secondary succession, of which the weedy arable field is a special case."

W.S. Blatchley	1912	"A plant which contests with man for the possession of the soil."
T. Pritchard	1960	"Opportunistic species that follow human disturbance of the habitat."
E.J. Salisbury	1961	"The cosmopolitan character of many weeds is perhaps a tribute both to the ubiquity of man's modification of environmental conditions and his efficiency as an agent of dispersal."

Godinho (1984) compared the definitions of the French words *d'aventice* and *le mauvaise herbe* with the English *weed* and the German *unkraut*. No single definition was found for *weed* and *unkraut* because both words have two distinct meanings:

1. In the ecological context, *weed, unkraut*, and *d'aventice* mean a plant that grows spontaneously in an environment that has been modified by man.
2. In the weed science context, *weed, unkraut*, and *malherbe* (Italian) or *le mauvaise herbe* mean an unwanted plant.

In some languages weeds are just bad (*mal*) plants. In Spanish, it is *mala hierba* or *malezas*, and in Italian, *malherbe*. One must agree with Godinho (1984), Fryer and Makepeace (1977), Anderson, (1977), and Crafts and Robbins (1967) that neither the word *weed* nor the plants to which the word is assigned are easy to define.

Aldo Leopold (1943, as cited in Falder and Callicott, 1991) made the point well in an article written in 1943 that was critical of the 1926 bulletin *Weeds of Iowa*. Many of the native plants of Iowa are included in the bulletin, and Leopold noted that these plants, in addition to their inherent beauty, have value as wildlife food, for nitrogen fixation, or as makers of stable plant communities. He admits that many of the plants people consider weeds are common in pastures, but soil depletion, overgrazing, and needless disturbance of advanced successional stages often make control necessary. Leopold (1943) argues that the definition of *weed* is part of the problem because not all plants that some call weeds "should be blacklisted for general persecution." Leopold's view is supported by McMichael (2000), who noted, with supporting evidence, that "in many rural cultures, noncrop plants (often termed weeds) represent food, fodder, and medicine.

About 3,000 of the 350,000+ recognized plant species have been or are cultivated, and one cannot assume that the rest are weeds. Specific, unknown, and noncultivated plants must also be considered.

The ulterior etymology of the word *weed* is unknown, but an exposition of what is known was provided by King (1966). He traced the word to a Germanic romance language and Asian roots, but he concluded that *weed* is an "example of language as an accident of usage." He was unable to find a common word in any ancient language for the collective term *weed*.

It is logical to assume that even if one cannot define *weed*, it should still be possible to identify the origin of individual species and determine certain characteristics of weeds. They come from both native and naturalized flora. Some plants succeeded as weeds because they were able to evolve forms adapted to disturbed environments more readily than other species. Baker's (1965, 1991) definition emphasizes success in disturbed environments, a point he reiterated in the later paper:

> A plant is a "weed" if, in any specified geographical area, its populations grow entirely or predominantly in situations markedly disturbed by man (without, of course, being deliberately cultivated plants). Thus, for me, weeds include plants which are called *agrestals* by some writers of floras (they enter agricultural land) as well as those which are *ruderals* (and occur in waste places as well as along roadsides). It does not seem to me necessary to draw a line between these categories and accept only the agrestals as weeds (although this is advocated by some agriculturally oriented biologists) because in many cases the same species occupy both kinds of habitat. Ruderals and agrestals are faced with many similar ecological factors, and the taxa which show these distributions are, in my usage, "weedy."

If one considers weeds in the Darwinian sense of a struggle for existence, they represent one of the most successful groups of plants that have evolved simultaneously with human disruption of areas of indigenous vegetation and habitats and creation of disturbed habitats (King, 1966).

Aldrich (1984) and Aldrich and Kremer (1997, p. 8) offered a definition that does not deny the validity of others but introduces a desirable ecological base. A weed is "a plant that originated in a natural environment and, in response to imposed or natural environments, evolved, and continues to do so, as an interfering associate with our crops and activities." This definition provides "both an origin and continuing change perspective" (Aldrich, 1984). Aldrich wants us to recognize weeds as part of a "dynamic, not static, ecosystem." His definition departs from those that regard weeds as enemies to be controlled. Its ecological base defines weeds as plants with particular, perhaps unique, adaptations that enable them to survive and prosper in disturbed environments. Navas (1991) also included biological and ecological aspects of plants and effects on man in his definition. A weed was defined as "a plant that forms populations that are able to enter habitats cultivated, markedly disturbed or occupied by man, and potentially depress or displace the resident plant populations which are deliberately cultivated or are of ecological and/or aesthetic interest."

Although all do not agree on precisely what a weed is, most know they are not desirable. Those who want to control weeds must consider their definition. When the term *weed* is borrowed from agriculture and applied to plants in natural communities, a verification of negative effect on the natural community should be a minimal expectation. Simple yield affects are not acceptable, but the effects of the presumed weed in a natural community can be estimated in terms of a management goal such as establishment of presettlement conditions, preserving rare species, maximizing species diversity, or maintaining patch dynamics (Luken and Thieret, 1996). Many recognize the human role in creating the negative, often deserved, image. Weeds are detrimental and often must be controlled but only with adequate justification for the site and conditions.

II. CHARACTERISTICS OF WEEDS

Crop agriculture is based on a very few plants that thrive in a disturbed habitat (a cropped field) and produce an abundance of seed. Weeds also thrive in disturbed habitats and produce an abundance of seed that is not useful to humans (Manning, 2004, p. 55). Why is it that some plants that thrive in disturbed habitats are weeds? What is it that makes some plants capable of growing where they are not desired? Why are they difficult to control? What are their modes of interference and survival? The most consistent trait of weedy species is not related to their morphology or taxonomic relationships. It is, as Baker (1965) noted, their ability to grow well in habitats disturbed by human activity. They are plants that are growing where someone does not want them, and often that is in areas that have been disturbed or altered intentionally. Weeds grow especially well in gardens, cropped fields, golf courses, and similar places. Their ability to grow in habitats that have been disturbed by man makes them a kind of ecological Red Cross: They rush right into disturbed places to restore the land.

Two nonindigenous species, kudzu and purple loosestrife, illustrate the ability of weeds to spread to new areas and habitats. (See Chapter 7 for a discussion of the role of these plants as invasive species.) Both were introduced to the United States, and both now grow all over the country (see Figure 2.1; U.S. Congress, 1993).

Not all weeds possess every single characteristic that is considered undesirable, but in addition to growing in disturbed habitats, all have at least some of the following characteristics (see Baker, 1965):

1. Weeds have rapid seedling growth and the ability to reproduce when young. Redroot pigweed can flower and produce seed when less than 8 inches tall. Crops cannot do either.
2. Quick maturation or only a short time in the vegetative stage. Canada thistle can produce mature seed two weeks after flowering. Russian thistle seeds can germinate very quickly between 28° and 110°F in late spring (Young, 1991). It would spread more, but the seed must germinate in loose soil because the coiled root unwinds as it pushes into soil and is unable to do so in hard soil.

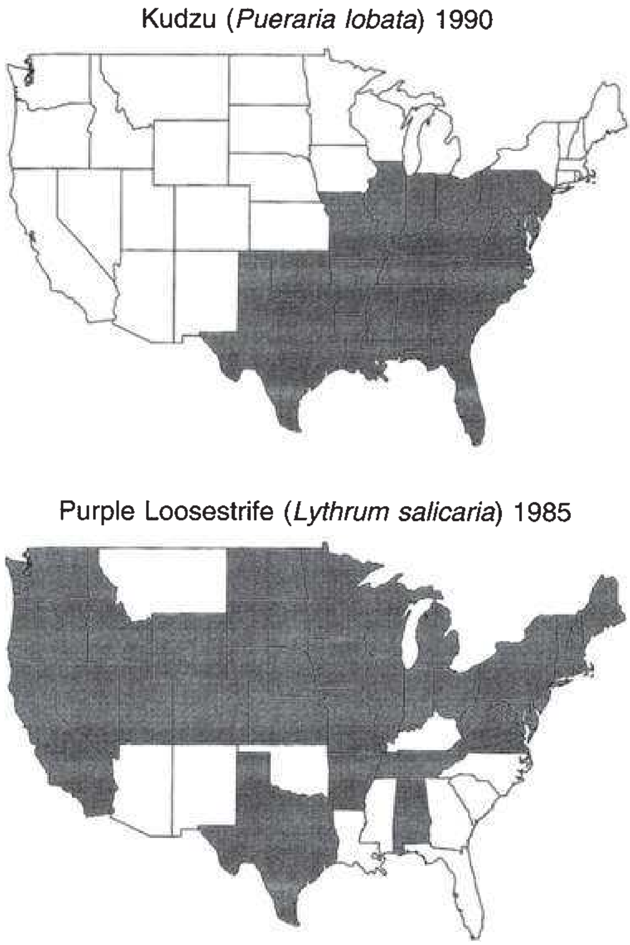

FIGURE 2.1. US distribution of kudzu and purple loosestrife (U.S. Congress, 1993; Thompson et al., 1987; also see Anonymous, 1990).

3. Dual modes of reproduction. Most weeds are angiosperms and reproduce by seed. Many also reproduce vegetatively (e.g., Canada thistle, field bindweed, leafy spurge, quackgrass).
4. Environmental plasticity. Many weeds are capable of tolerating and growing under a wide range of climatic and edaphic conditions.
5. Weeds are often self-compatible, but self-pollination is not obligatory.
6. If a weed is cross-pollinated, pollination is accomplished by nonspecialized flower visitors or by wind.
7. Weeds resist detrimental environmental factors. Most crop seeds rot if they do not germinate shortly after planting. Weed seeds resist decay for long periods in soil and remain dormant.
8. Weed seeds exhibit several kinds of dormancy or dispersal in time to escape the rigors of the environment and germinate when conditions are most favorable for survival. Many weeds have no special environmental requirements for germination.

9. Weeds often produce seed that is the same size and shape as crop seed, making physical separation difficult and facilitating spread by man.
10. Some annual weeds produce more than one seed crop per year, and seed is produced as long as growing conditions permit.
11. Each generation is capable of producing large numbers of seed per plant, and some seed is produced over a wide range of environmental conditions.
12. Many weeds have specially adapted long- and short-range seed dispersal mechanisms.
13. Roots of some weeds are able to penetrate and emerge from deep in the soil. While most roots are in the top foot of soil, Canada thistle roots routinely penetrate 3 to 6 feet and field bindweed roots have been recorded over 10 feet deep. Roots and rhizomes are capable of growing many feet per year.
14. Roots and other vegetative organs of perennials are vigorous with large food reserves, enabling them to withstand environmental stress and intensive cultivation.
15. Perennials have brittleness in lower stem nodes or in rhizomes and roots, and, if severed, vegetative organs will quickly regenerate a whole plant.
16. Many weeds have adaptations that repel grazing, such as spines, taste, or odor.
17. Weeds have great competitive ability for nutrients, light, and water and can compete by special means (e.g., rosette formation, climbing, allelopathy).
18. Weeds are ubiquitous. They exist everywhere that we practice agriculture.
19. Weeds resist control, including resistance to herbicides.

In spite of the anthropomorphic aspects of the definitions of weed and the multiple traits that weeds share, weed scientists have a clear idea of which plants are weeds. It seems that weeds are everywhere in almost every place, and many books have been written about weeds:

Common weed seedlings of the Central High Plains (Nissen and Kazarian, 2000)

Major Weeds of the Philippines (Moody et al., 1984)

Major Weeds of Thailand (Noda et al., 1985)

Striga *Identification and Control Handbook* (Ramaiah et al., 1983)

The Arable Weeds of Europe—with their Seedlings and Seeds (Hanf, 1983)

The Identification of Weed Seedlings of Farm and Garden (Chancellor, 1966)

Weeds of Colorado, A Comprehensive Guide to Identification (Zimdahl, 1998)

Weeds of Hawaii's Pastures and Natural Areas (Motooka et al., 2003)

Weeds of Karnataka (Krishna Sastry et al., 1980)
Weeds of Nebraska and the Great Plains (Stubbendieck et al., 1994)
Weeds of North India (Arora et al., 1976)
Weeds of Rice in Asia (Caton et al., 2004)
Weeds of the West (Whitson et al., 1991)

The Weed Science Society of America has published a weed identification CD that includes an interactive format for identification of 1,000 weeds of North America (https://timssnet.allenpress.com/ECOMWSSA/timssnet/products/tnt_products.cfm), click on identification, photo gallery.

III. HARMFUL ASPECTS OF WEEDS

Definitions of weeds usually include trouble with crops, harm to people, or harm to animals. Most people do not consider plants to be bad. They are assigned the descriptive, derogatory term weed because of something they do to us or to our environment; they interfere with the activities or welfare of man. If they were benign we wouldn't be so concerned about them because there would be no detrimental effects. The nature of weeds' harmful effects will be explored briefly in this section. That harmful effects exist is not questioned. It is important to understand specific effects so appropriate action can be taken.

A. Plant Competition

From an agricultural perspective, we are concerned about weeds because they compete with crop plants for nutrients, water, and light. If they did not, those who grow things would be more willing to tolerate their presence. Weed-crop competition will be discussed in Chapter 6. If weeds did not compete, they would not need to be managed because crop yield would not be affected by their presence. But it is, and often complete crop failure (100% loss of marketable yield) can occur if weeds are not controlled.

B. Added Protection Costs

Weeds increase protection costs because they harbor other pests. A partial listing of diseases, insects, and nematodes that use weeds as alternate hosts is in Tables 2.1, 2.2, and 2.3. Weeds harbor a wide range of organisms thereby increasing opportunities for those organisms to persist in the environment and reinfest crops in succeeding years.

TABLE 2.1. Plant Diseases Harbored by Specific Weeds.

Plant disease	Weed host	Crop infested	Reference
Blackleg	Black nightshade Common Lambs quarters Mare's tail Redroot pigweed Smartweed	Potato	Dallyn and Sweet, 1970
Wilt diseases	Netseed lambs quarters Common purslane Redroot pigweed	Potato, alfalfa	Oshima et al., 1963
Stem canker	Netseed Lambs quarters	Potato, beans	Oshima et al., 1963
Soft rot	Annual sowthistle Dayflower Common Lambs quarters	Chinese cabbage and other vegetables	Kikumoto and Sakamoto, 1969
Powdery mildew	Wild oats	Wheat, oats, barley	Eshed and Wahl, 1975
Stripe mosaic virus	Common Lambs quarters	Barley	ARS, 1966
Leaf curl virus	Common Lambs quarters	Sugarbeet	ARS, 1966
Cucumber mosaic virus	Black nightshade	Several	ARS, 1966
Potato virus X and leaf roll virus	Redroot pigweed	Potato	ARS, 1966
Maize dwarf mosaic virus	Johnsongrass	Corn	Bendixen et al., 1979
Maize chlorotic dwarf virus			
White rust Early blight Leaf spot Vascular wilts Cottony rot White mold Watery rot	Redroot pigweed	Potato, tomato, annual vegetables and flowers, beans, cabbage, carrot, peanut	Commers, 1967
Leaf spot and Leaf blight Stalk rot Vascular wilt Damping off Soft rot	Tall morning glory	Sugarbeet, celery, peas, peanut, corn, tobacco, beans, fruits and vegetables	Commers, 1967
Stem rust Leaf spot and Leaf blight	Cocklebur	Wheat, barley, rye, celery, beets, tomato, soybeans	Commers, 1967
White rust Banana Leaf spot Takeall Stem rust Rusts	Canada thistle	Crucifers, banana, wheat, rye, barley, legumes, beans, peas, fava bean	Commers, 1967

TABLE 2.2. Insects Harbored by Specific Weeds.

Insect	Vector of	Weed host	Crop infested	Reference
Cabbage maggot	Blackleg	Common lambsquarters	Potato	Bonde, 1939
Seed				
Corn				
Colorado potato beetle		Black nightshade Buffalobur	Potato	Brues, 1947
Beet leaf hopper Corn borer	Curly top	Russian thistle	Sugarbeet	Brues, 1947

TABLE 2.3. Nematodes Harbored by Specific Weeds.

Nematode	Weed host	Crop infested	Reference
Criconemoides onoensis	Nutsedges, Junglerice	Rice	Hollis, 1972
Ditylenchus dipsaci	9 weeds from 7 genera	Soybeans, snapbeans, peas	Edwards and Taylor, 1964
Heterodera glycines	Bittercress Common foxglove Common pokeweed Oldfield toadflax Purslane Rocky Mountain beeplant Spotted geranium	Soybeans	Riggs and Hamblen, 1966
Heterodera marioni	47 weeds from 42 genera	Pineapple	Godfrey, 1935
Heterodera schachtii	Black nightshade Lamb's quarters Mustards Purslane Redroot pigweed Saltbush	Sugarbeet	Anderson, 1977
Hoplolaimus columbus	Henbit Johnsongrass Purple nutsedge Yellow nutsedge	Soybeans, cotton	Bendixen et al., 1979 Bird and Högger, 1973 Högger and Bird, 1974
Meloidogyne incognita	Chickweed Johnsongrass Purple nutsedge Yellow nutsedge	Soybeans, cotton	Bird and Högger, 1973 Högger and Bird, 1974
Pratylenchus sp.	Johnsongrass	Corn	Bendixen et al., 1979
Trichodorus spp.	19 weeds from 18 genera	Potato	Cooper and Harrison, 1973

Weeds that exist on the edges of crop fields serve as hosts when crops are not present and as sources of reinfestation. Volunteer wheat is a primary host of wheat streak mosaic virus. Its presence can be seen in disease transmission up to one-quarter mile from a stand of volunteer wheat. A virus carried by wheat curl mite (*Aceria tulipae*) causes the disease, and volunteer wheat must be controlled three weeks before planting to eliminate the mites and prevent crop infection. This is a complex management problem in which a disease, an insect, and a weed host interact. Another illustration is spread of potato black-leg disease (*Erwinia carotovora* var. *atroseptica*) and potato soft rot (*Erwinia carotovora* var. *carotovora*) by *Erwinia* bacteria via enduring infestations of common lambsquarters, redroot pigweed, or black nightshade that harbor the disease organisms (Cooper and Harrison, 1973).

In addition to direct attack on crops, insects are a primary means of dispersal for many pathogenic organisms. Aster yellows virus is carried by the leafhopper *Macrosteles fasifrons* from lettuce to broadleaf plantain after lettuce emerges and during lettuce harvest. Several aphids carry pepper veinbanding mosaic virus and potato virus Y from weeds to crops (Broadbent, 1967). Fungal spores such as the conidia of *Claviceps purpurea* (the cause of ergot in rye) are transported by fungal gnats. The insects are attracted to sticky substances secreted by wounds. The fungal disease caused by the spores infects a wide range of grasses, including wild species. Piemiesel (1954) found that leafhoppers and curly top virus of sugarbeets used weeds as breeding grounds to increase inoculum density for later crop infection.

A classic case of a weed serving as a host for a pathogen is the heteroecious stem rust fungus (*Puccinia graminis* var. *tritici*) of wheat which uses European barberry as an alternate host. King (1966) estimated that wheat yield losses from this fungal disease were over 600 million bushels per year in the early 1960s.

Over 20 years, from the 1970s to the 1990s, wheat rust has caused $100 million in crop losses annually. Eradication of European barberry and related species dramatically reduced stem rust and consequent epidemics. Several US states joined in an effort that was estimated to have saved farmers well over $30 million per year (Stakman and Harrar, 1957).

Russian thistle (Table 2.2) is an alternate host for the curly top virus of sugarbeets and tomatoes (Young, 1991) and the beet leafhopper (*Circulifer tenellus*) (Goeden, 1968). Goeden (1968) points out that hosting a potentially damaging insect may not be a sufficient reason to control a weed. Russian thistle hosts 32 economically important insects from five different orders. These are not all harmful because some may be entomophagous enemies of harmful insects, both of which are hosted by Russian thistle.

Crested wheatgrass is widely planted in the western United States for soil conservation. It and other species of *Agropyron* harbor the Russian wheat aphid

(*Diuraphis woxia*), an important wheat pest (U.S. Congress, 1993). Johnsongrass, a major weed in the southern United States, can hybridize with cultivated sorghum to produce the annual weed shattercane. Thus, a weed produces another weed (Mack, 1991).

C. Reduced Quality of Farm Products

Most grain growers are familiar with weed seed in grain crops and resultant decreases in quality and losses from dockage and cleaning. Weed seed in grain crops perpetuate the problem when the crop seed is replanted. A particularly bad problem is wild onion or wild garlic in wheat. Seeds and aerial bulblets of these weeds are similar in size to wheat grains and difficult to separate. They impart an onion flavor to flour made from grain and an onion odor to milk after cows have grazed them or eaten feed containing them.

Wild oats affect the quality of bread and other wheat products and infest many acres of small grains, most notably spring wheat. Wild oats also infest barley used for feed and for malting, and any brewer will verify that wild oats make bad beer.

Weeds reduce the quality of seed crops. Purchasers of hybrid or certified seed expect to receive a high-quality product that will give high yields and not be infested with weed seed. This necessitates weed control in seed crops, and failures lead to high cleaning costs before sale.

Weeds cause loss of forage and reduce the carrying capacity of pastures and rangeland. Surveys in the 1990s by the Nebraska Department of Agriculture showed over 2 million acres infested with musk thistle and over 400,000 with leafy spurge. Rangeland and pasture were the dominant sites, and carrying capacity (number of animals supported by the land) was reduced 8 to 100% by musk thistle and 10 to 70% by leafy spurge.

D. Reduced Quality of Animals

Many acres of western US rangeland are infested with poisonous larkspur that causes cattle death because cattle like it and often eat it selectively. In early growth stages as little as 0.5% of an animal's weight ingested as larkspur can, within an hour, lead to toxicity, and 0.7% may be fatal (Kingsbury, 1964). Locoweeds and crazyweeds are important poisonous range weeds. All ruminants are susceptible to loco poisoning but only when large amounts are consumed over weeks or even months. Horses are also poisoned, and symptoms appear at lower levels of intake for shorter periods of time than is true for ruminants (Kingsbury, 1964).

Halogeton grows on arid, alkaline soils and is found in many parts of the world, including the western United States. It is especially toxic to sheep due to its high oxalate content. Photosensitization or excessive sensitivity to light by cattle can be caused or aggravated by St. Johnswort and Mock bishopsweed (Anonymous, 1977).

Weed science usually emphasizes the negative effects of weeds on animals grown for profit and human food, but game animals are also affected by weeds. In western Montana, elks' use of rangeland decreased as spotted knapweed increased. On native bunchgrass sites, 1,575 pellet groups were found on each acre. On sites infested with spotted knapweed, there were only 35 pellet groups per acre (Hakim, 1975).

Poisonous plants may contain one or more of hundreds of toxins from nearly 20 major chemical groups, including alkaloids, glucosides, saponins, resinoids, oxalates, and nitrates (Kingsbury, 1964). There is no way to determine if a plant may be poisonous by noting where it grows, when it grows, or how it changes during growth.

Because poisonous plants can occur in many habitats, one must learn to recognize the important ones in each area. There are no good antidotes after ingestion of poisonous plants by humans or animals. Signs of poisoning differ in intensity, depending on the species, its stage of growth, when it is eaten, the soil the plant grew in, the amount of other food eaten with or before the poisonous plant, and each individual's tolerance. Once they have been identified, poisonous weeds can be managed. A few of the common poisonous weeds found in the United States, their toxic principle, the plant source, and some clinical signs of poisoning are shown in Table 2.4.

Weeds can affect animals by providing an inadequate diet or a diet that is unpalatable because of chemical compounds in the weed. They can directly reduce the quality of animal products by affecting milk production and fleece, or hide quality. Reproductive performance is affected through toxins that cause abortion or kill animals (see Table 2.4).

In addition to direct poisoning, weeds cause mechanical damage to grazing animals. Sharp spines on seed-bearing burs of puncture vine and sandbur are strong enough to penetrate tires and shoe-leather. Anyone who has ever stepped on a seed bur in bare feet can appreciate the pain and damage it can cause to tender mouth tissues. Seed burs of these weeds and those of common cocklebur and burdock also become entangled in the sheep's wool, decreasing cleanliness and saleability.

It is well known that many plants are poisonous to mammals. What is more interesting is that green plants dominate the terrestrial landscape. There are numerous insect and herbivore species that feed on plants, and it is interesting that the plants somehow still dominate the landscape. As this section notes, weeds can and do reduce the quality of animals through their toxic principles,

TABLE 2.4. Characteristics of Some Poisonous Weeds (Evers and Link 1972; Kingsbury 1964).

Name	Toxic principle	Source	Signs
Arrowgrass	Hydrocyanic acid	Leaves	Nervousness, trembling, spasms or convulsions
Bouncing bet	Saponin	Whole plant seeds are most toxic	Nausea, vomiting, rapid pulse, dizziness
Bracken fern	Unknown	Fronds	Fever, difficulty in breathing, salivation, congestion
Buffalobur	Solanin	Foliae and green berries	Most serious in nonruminants
Buttercup	Proto-anemonin	Green shoots	Loss of condition, production drops, reddish milk, diarrhea, nervousness, twitching, labored breathing
Chokecherry and other cherries	Glucoside-amygdalin, a cyanogenic compound	Leaves	Rapid breathing, muscle spasms, staggering, convulsions, coma
Cocklebur	Hydroquinone	Seeds and seedlings	Nausea, depression, weakness, especially in swine
Corn cockle	A glucoside githagin and a saponin	Seeds	Poultry and pigs are most affected, inability to stand, rapid breathing, coma
Horsetail	Thiaminase activity—an alkaloid	Shoots	Loss of condition, excitability, staggering, rapid pulse, difficult breathing, emaciation
Indian tobacco	Alkaloids similar to nicotine	Leaves and stems	Ulcers in mouth, salivation, nausea, vomiting, nasal discharge, coma
Jimsonweed	Alkaloids	All parts	Rapid pulse and breathing, coma
Larkspur	Alkaloid	All parts	Staggering, nausea, salivation, quivering, respiratory paralysis
Nightshade	Solanine—a glycoalkaloid	Foliage and green berries	Usually in sheep, goats, calves, pigs, and poultry, anorexia, nausea, vomiting, abdominal pain, diarrhea
Ohio buckeye	Alkaloid	Sprouts, leaves, nuts	Uneasy or staggering gait, weakness, trembling
Water hemlock	Cicutoxin	Young leaves and roots	Convulsions
Whorled milkweed	A resinoid—galitoxin	Shoots, especially near top	Poor equilibrium, muscle tremors, depression and then nervousness, slobbering, mild convulsions

but it is worthy of note that the toxic principles also protect plants from severe predation by insects and herbivores. Plants that are relatively harmless to humans and other mammals may be and often are highly toxic to other animals, birds, fish, and especially to insects (Harborne, 1988). These defensive toxicities of weeds and other plants are important determinants of ecological relationships. The harm that may be caused is trivial to humans and our animals but vital to ecological stability, which explains why plants dominate the terrestrial landscape.

E. Increased Production and Processing Costs

We are concerned about weeds because they do things to us or our products and increase production costs. Any weed-control operation, from hand hoeing to herbicide application, costs money. These costs are often necessary to prevent greater crop loss or even crop failure and are regarded as necessary to gain a profit. However, if the weeds weren't there, there would be no control cost. Unfortunately, the complete absence of weeds is rare, and the costs of their competition and control must be included when calculating profit or loss. Costs of control are relatively easy to calculate if hourly labor, equipment, fuel, and herbicide costs are known. It has been estimated that the cost of tilling cultivated land may equal as much as 15% of a crop's value. While tillage may be required on some soils for crop production, most is done only for weed control. There are sound agronomic reasons for tillage, including seedbed preparation, trash burial, soil aeration, promotion of water infiltration, and, of course, weed control. The ascendancy of minimum and no-tillage farming and availability of appropriate herbicides have brought many traditional tillage practices into question. Prior to herbicides, an experiment to investigate effects of tillage was always confounded by weeds and the need to control them by tillage. Experiments with herbicides in many soils have shown little benefit from tillage other than weed control.

There are other, less-obvious costs associated with weeds. Wild oats seed in wheat or barley, or black nightshade fruit in beans, leads to increased costs due to the necessity of cleaning. Failure to remove these can lead to loss in quality, dockage losses at the point of sale, or even loss of the crop if it should heat and spoil in storage because of unripened weed seed. If a harvested crop has large amounts of weed seed in it, one can assume that some of the crop was lost in the field from weed competition and that some additional quality was lost due to weeds at harvest and consequent harvest difficulty. Another cost of weeds at harvest is wear and tear on machinery. The extra bulk of weedy plants that pass through mechanical harvesting systems is bound to

TABLE 2.5. Soybean Harvest Losses from Two Weeds (Nave and Wax, 1971).

	LOSS (%)		
Weed	Header	Threshing and separating	TOTAL
Redroot pigweed	5.35	.73	6.08
Giant foxtail	1.55	.81	2.36

cause machinery to break down more frequently and wear out sooner. These kinds of things are not usually attributed to weeds because they are not recognized as contributors to increased costs of machinery breakdown, repair, and replacement. Weeds also cost money when they remain in the field and interfere with harvest (see Table 2.5).

F. Water Management

Weeds interfere with water management in irrigated agriculture. Water is consumed and flow is impeded by weeds growing in and along irrigation ditches. Weeds consume water intended for crops, cause water loss by seepage via root channels, transpire water, and reduce water flow in irrigation ditches, leading to increased consumption by weeds and more evaporative water loss. Aquatic weeds may impede navigation and can ruin fisheries.

Terrestrial criteria for assessing weed competition cannot be employed in aquatic environments. There are no known appraisals of direct crop losses due to aquatic weeds. However, Timmons (1960) reported nearly five decades ago, that manmade lakes above dams across major rivers in Africa, Asia, and Central and South America became so badly infested with weeds within 5 to 10 years of construction that their usefulness for power development, boat transport, and irrigation was greatly reduced, and, therefore, one must conclude that national development was impeded by weeds. Aquatic weeds quickly reduced designed flow of some irrigation canals in India by 40% to 50% and in others up to 80% (Gupta, 1973). Submerged weeds retard water flow up to 20 times, whereas floating weeds only retard it 2 times (Gupta, 1976). Decreased flow reduced the possibility of irrigating distant fields and accelerated opportunities for leakage and evaporation. In addition to agricultural concerns, those who use water for recreation or enjoy the aesthetic appeal of aquatic habitats are often disturbed by weeds. Aquatic weeds are often ugly, and their rotting remains are smelly, but the more important problem is that their presence and inevitable decay hasten eutrophication. There is more public concern about aquatic weeds in recreational waters than in agricultural waterways.

G. Human Health

Those not associated with agriculture may often think of weeds, if they think of them at all, as plants that impair human health. One who has never experienced the runny nose, sneezing, and watery eyes of plant allergies (often called hay fever) cannot fully appreciate the animosity sufferers may develop toward plants. The pollen that causes hay fever often (but not always) comes from weedy plants. Ragweed and goldenrod are common causes in many parts of the United States. Sagebrush is a leading cause in the western United States. While allergies may be an obvious weed menace to some people, others would choose poison ivy as the worst weed. Swelling and itching after contact with poison ivy are always bothersome and can lead to serious discomfort. The rash can be caused by contact with any portion of live plants or with smoke from fire in which plants are burned. Most people are quick to put poison ivy or poison oak in the category of unwanted plants after one or the other has disturbed their picnic or camping trip.

Many plants that poison when consumed are common garden plants that can be especially hazardous to children. Some weedy species can lead to aberrant behavior or death when consumed by people. Examples of household plants that are poisonous when consumed include narcissus, oleander, lily-of-the-valley, and iris.

Dead and dry weeds can be serious fire hazards, as anyone in the arid western United States knows. Fires spread rapidly in dry plants. Fire prevention is why weeds are controlled on roadsides, in vacant areas, and around homes in forested areas.

H. Decreased Land Value and Reduced Crop Choice

Perennial weeds (field bindweed, johnsongrass, or quackgrass) or the annual parasitic weeds dodder, witchweed, or broomrape can lead purchasers to discount offers to buy or bankers to reduce the amount of a loan because each recognizes a loss of productive potential. They also recognize the costs required to restore otherwise valuable land to full productivity. These weeds reduce land value and sale price because they restrict crop choice and increase the costs of crop production. Severe infestations of almost any perennial or parasitic weed will reduce yield of most crops, and dodder may completely eliminate successful growth of some crops.

I. Aesthetic Value

Weeds in recreation areas often must be controlled. No one wants their soccer field or baseball diamond to be weedy. Weeds are fire hazards around power substations and equipment, oil, or chemical storage areas. A very practical need for weed control exists near traffic intersections, where, in addition to being aesthetically unappealing, weeds reduce visibility and may contribute to vehicular accidents. Weeds can have serious environmental/ecological effects when they replace native vegetation (see Chapter 7 for a discussion of invasive species).

IV. COST OF WEEDS

There are no completely accurate estimates of the total cost of weed control and losses in agriculture due to weed competition, although several attempts have been made. One of the first estimates is reported in the 1969 United Nations Food and Agriculture Organization (FAO) International Conference on Weed Control. For example, US losses due to weeds in potatoes were estimated to be $65,000,000 in 1969 (Dallyn and Sweet, 1970).

In 1967, weeds caused an estimated 8% loss of potential US agricultural production (Irving, 1967). In 1967, Cramer summarized losses attributed to pests of all kinds in the world's major crops. He calculated that 9.7% of potential world crop yield was lost due to weeds. Parker and Fryer (1975) used Cramer's data and calculated that weeds eliminated 14.6% of the world's potential crop production. They estimated that weeds eliminated 11.5% of world crop production in 1975 (Table 2.6). A comparison made in 1980 (Ahrens et al., 1981) for wheat and rice shows losses were still about 10%, despite developments in control. Combellack (1989) estimated the total cost of Australian weeds to be $2 billion in 1986, of which $137 million was for herbicides.

An estimate of crop yield losses from weeds in Canada in 1935 was $69 million (Hopkins, 1938). In 1949, the cost had risen 2.7 times to $186.2 million (McRostie, 1949), and it rose to $255 million in western Canada alone (Wood, 1955). By 1956 the total loss was estimated to be $468.6 million, a 150% increase over 1949 (Anderson, 1956).

Friesen and Shebeski (1960) estimated the annual loss due to weeds in Manitoba grain fields was $32.3 million in 1959. Renney and Bates (1971) estimated losses due to weeds in British Columbia were $72 to $78 million per year in 1969. Their study showed that 38 to 42% of weed-caused yield losses in British Columbia were due to yield reduction of agricultural crops,

TABLE 2.6. Estimated Food Losses Caused by Weeds in Three Classes of Crop Production.

Class of crop production	Total cultivated area (%)	Relative production per unit area (%)	Total food production (%)	Loss to weeds (%)	Loss as of world food supply (%)	Estimated food loss per year (metric tons × million)
A. Most highly developed	20	×1.5	30	5	1.5	37.5
B. Intermediate	50	×1.0	50	10	5.0	125.0
C. Least developed	30	×0.67	20	25	5.0	125.0
Total	100		100		11.5	287.5

Note: Estimates in this table are not based on any firm statistical data but are approximations suggested by the authors. Where food loss is estimated in terms of metric tons, this is based on an approximate world total food production of 2,500,000,000 metric tons per year (Parker and Fryer, 1975).

TABLE 2.7. Estimated Average Annual Losses Due to Weeds in Several Commodity Groups (Chandler et al., 1984).

	United States	Western Canada	Eastern Canada
Commodity group		Average Annual Loss ($ × 1,000)	
Field crops	6,408,183	616,331	69,647
Vegetables	619,072	20,972	29,956
Fruits and nuts	441,449	8,418	—
Forage seed crops	37,400	75,661	—
Hay	—	—	89,507
TOTAL	7,506,104	722,634	189,110

increased insect and disease problems, dockage, harvest losses, and costs of control. If forest weeds were included, losses in yield and costs of control accounted for an additional 45 to 49% of total loss. By 1984, Canadian losses were estimated to be $911.7 million per year (722.6 + 189.1; see Table 2.7) in 36 crops, nearly double what they had been in 1956.

A US soybean loss survey (Anonymous, 1971) found weed competition caused an estimated 3.3 bu/A yield reduction in 28 states. Weeds were responsible for a 12% crop loss each year. Chandler (1974) summarized other estimates and concluded that weed competition in some southern US states caused as much as 20% soybean yield loss. For the entire country, 5% was regarded as an optimistically low level of loss, except on perhaps half of the most intensively farmed acreage.

Peanut farmers in the southeastern United States spend about $50 per acre for weed control. Annual losses from weeds were estimated to be $20,000,000 in Alabama, $8,000,000 in Florida, and $72,000,000 in Georgia in 1991 (Dowler, 1992). There are good herbicide choices for peanut weed control, so the reasons for the large losses are of concern to farmers and weed scientists.

A US Department of Agriculture report for the 1950s (Agric. Res. Serv., 1965) estimated annual losses due to reduced crop yield and quality and costs of weed control in the United States were $5.1 billion. This value, an educated guess, became enshrined in early weed science textbooks. While the estimate was never proven wrong, changes in the value of crops and inputs, as well as methods employed to arrive at such figures, have increased the loss due to weeds. In 1954, it was estimated that weeds caused an annual loss >$2 billion in 11 major US agronomic crops (Anonymous, 1962).

In the 1970s, poisonous plants alone may have caused a $118 million loss to livestock producers in the Great Plains area of the United States (Deloach, 1976). Shaw (1976) estimated that weeds caused a loss of 10% of the value of food, feed, and fiber crops and ornamental plantings. The total annual loss was >$6 billion. He also projected that $2.7 billion was spent for cultural, ecological, and biological control and another $2.3 billion for chemical control. The total cost of weeds was estimated to be $11 billion per year. In 1980, Shaw (1982) raised the estimated total annual loss to $18.2 billion, with $12 billion due to competitive loss, $3.6 billion for chemical control, and $2.6 for other controls.

From 1975 to 1979, the competitive loss due to weeds in US agriculture for 64 crops was estimated to be $7.5 billion per year (see Table 2.7; Chandler et al., 1984). In a separate publication, Chandler (1985) estimated total losses of $14.1 billion, with $8 billion due to weed competition, $2.1 billion to herbicide cost, and $4 billion for equipment and labor.

Bridges (1992) estimated the cost of weeds in the United States from 1989 to 1991. The report covered all US states, except Alaska, and 46 crops, including field crops, vegetables, fruits, and nuts. Research or extension weed scientists from each state estimated the percent yield loss from weeds competing in crops where the current best-management practices were employed. The same scientists also estimated losses with best-management practices without herbicides. The loss was $4.2 billion annually, just in field, nut, and fruit crops, with best-management strategies, and 82% of the total was lost in field crops. Without herbicides the loss rose to $19.6 billion. Total losses with best-management practices were $6.2 billion, and costs of control were above $9 billion, for a total loss of $15.2 billion per year.

By any measure, this is a large amount of money and significantly greater than the 1984 estimate. Pimentel et al., (2000) estimated that at least $5 billion is spent annually in the United States to control nonindigenous weeds introduced to the United States that are in pastures, and another $1.5 billion is spent just on lawns, gardens, and golf courses. Control costs for nonindigenous weeds in crops were estimated to be $3 billion, and weeds caused an additional $23.4 billion in crop losses (yield not obtained) and damage to crops. While the paper (Pimentel et al., 2000) specifically addresses nonindigenous weeds, the results can be applied to weeds in general because so many are nonindigenous. All estimates (by definition) are not absolutely accurate, but they are the best information available. Because they are estimates (educated guesses) rather than quantitative experimental data, they cannot be regarded as absolutely true.

Regional or more local estimates are often more accurate but extrapolation to other areas, while tempting, is often unwarranted. For example, leafy spurge now occupies more than 150 million acres of rangeland in the northern US Great Plains. Direct livestock production losses and indirect economic effects approached $110 million in 1990 (Bangsund and Leistritz, 1991). In North Dakota, losses of income by cattle producers due to leafy spurge were $8.7 million, and the producers reduced personal spending $14.4 million. That translates to reduced income for merchants who sell to cattlemen.

In 1990 leafy spurge reduced cattle-carrying capacity about 580,000 animal unit months, or by 63,100 cows over a 7.5-month grazing season. The total annual direct grazing land losses were $23.1 million. Indirect grazing land losses were $52.2 million, and wildland losses were $2.9 million. A 40% leafy spurge infestation reduced rangeland-carrying capacity by 50%, and leafy spurge can reduce carrying capacity 75%. Due only to leafy spurge, North Dakota lost $87.3 million and 1,000 jobs in 1980 (Leistritz et al., 1992).

World literature concerning domestic and international food production leaves no doubt that weeds cost money—*lots* of money! They are ubiquitous, and their effects on yield create large losses borne by producers and by consumers because production costs are inevitably reflected in food price. Present globalization trends and lack of a world or country database for each crop make it unproductive to attempt more accurate estimates of world, country, region, or crop losses due to weeds, even though present estimates lack precision.

Weed costs are calculated in dollars associated with commodities. There are other ways to estimate costs and associated benefits of weed management. One is to examine the number of acres of crops treated for weed control. This estimates the value of weed-management to farmers and is an accurate estimate of the extent of market penetration by herbicides (Table 2.8). These data do not estimate the use of other weed management techniques. Table 2.9 shows losses due to weeds by comparing weeded and unweeded crops in the Philippines and other Asian countries (Mercado, 1979) and more recent information (Baltazar, 2006) confirms the scale, if not the actual cost, of the 1979 estimates. The percent increase in yield due to weeding is an impressive statement about the value of weeding, regardless of the technique by which it is done. Similar data are shown in Table 2.10 for studies done on several crops in India where

TABLE 2.8. Percentage of Crop Acreage Treated with Herbicides and Total Herbicide Use in the United States in 1971 and 1982 (Chandler, 1985).

	Proportion of hectares treated with herbicide		Herbicide applied	
Commodity	1971 (%)	1982 (%)	1971 (%)	1982 (million kg ai)
Row Crops				
Corn	79	95	45.8	110.4
Cotton	82	97	8.9	7.8
Sorghum	46	59	5.2	6.9
Soybeans	68	93	16.6	56.8
Peanuts	92	93	2.0	2.2
Tobacco	7	71	0.1	0.7
Total	**71**	**91**	**78.6**	**184.8**
Small Grain Crops				
Rice	95	98	3.6	6.3
Wheat	41	42	5.3	8.2
Other grain	31	45	2.5	2.7
Total	**38**	**44**	**11.4**	**17.2**
Forage Crops				
Alfalfa	1	1	0.2	0.1
Other hay	[a]	3	[a]	0.3
Pasture and range	1	1	4.8	2.3
Total	**1**	**1**	**4.0**	**1.7**
TOTAL	**17**	**33**	**94.0**	**204.7**

[a]Included in alfalfa.

TABLE 2.9. A Comparison of Yield in Weeded and Unweeded Crops (Mercado, 1979).

	Yield (T/ha)		
Crop	Weeded	Unweeded	Increase from weeding (%)
Lowland rice			
Transplanted	3.9	2.9	34
Direct-seeded	4.1	1.0	310
Upland rice	2.8	0.6	367
Corn	5.1	0.53	862
Soybean	1.15	0.48	140
Mung bean	0.75	0.57	32
Transplanted tomato	9.2	5.5	67
Direct-seeded tomato	5.1	1.5	240
Transplanted onion	10.8	0.44	2,355

TABLE 2.10. Benefits from Weed Control at Various Dryland Centers in India, 1971–1981.

		Crop yield with		
Location	Crop	Traditional weed	Improved control (kg/ha)	Increase (%)
Varanasi	Upland rice	1,700	2,700	59
Dehra Dun	Maize	1,760	4,600	161
Hyderabad	Sorghum	1,500	3,740	149
Sholapur	Pearl millet	180	950	428
Dehra Dun	Soybean	920	1,840	100
Bangalore	Peanut	420	1,910	355

Unpublished data from Friesen, G.—Manitoba.

improved methods may mean only better cultivation and are not to be interpreted as a recommendation for all modern technology.

THINGS TO THINK ABOUT

1. What commonalities and differences can be found in the several definitions of the word *weed*?
2. How does the way we define something determine our attitude toward it?
3. What taxonomic, biological, morphological, and physiological traits do weeds share?

4. What is the best estimate of what weeds cost in the United States?
5. How are cost estimates obtained?
6. What are the problems with estimates of the cost of weeds?

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CHAPTER 3

Weed Classification

FUNDAMENTAL CONCEPTS

- The order in the world of weeds is recognized through systems of classification.
- Weeds can be classified in at least four ways. The most important and oldest system is based on phylogenetics or evolutionary ancestry.

OBJECTIVES

- To learn the fundamentals of weed classification based on phylogenetics or ancestral relationships.
- To learn why and how other weed classification systems are used and why they are important to weed management.
- To understand the unique habitat and role of parasitic weeds.
- To know the major groups of parasitic weeds.
- To understand the importance of a plant's scientific name.

One of the great, often unspoken, hypotheses of modern science is that there is order in the world. With careful study, scientists believe they can discover and describe the order. With each discovery and consequent description, science will improve our understanding of how our world functions. Among those who study the order in the natural world are taxonomists, who describe and classify species. Although not everyone agrees on whether a particular plant is a weed or exactly what a weed is, as members of the plant kingdom, most weeds have been classified by plant taxonomists.

There are at least 450 families of flowering plants and well over 350,000 different species. Only about 3,000 of them have been used by humans for food. Fewer than 300 species have been domesticated, and of these, there are about 20 that stand between humans and starvation. There are at least 100 species of great regional or local importance, but only a few major species dominate the human food supply. Only about 15 plants provide most of the food that humans have consumed for many generations.

Twelve plant families include 68% of the 200 species that are the most important world weeds (Holm, 1978). These weeds share certain characteristics, including the following:

1. Long seed life in soil
2. Quick emergence
3. Ability to survive and prosper under the disturbed conditions of a cropped field
4. Rapid early growth
5. No special environmental requirements for seed germination

They are also competitive and react similarly to crop cultural practices. Weeds are usually defined primarily by where they are and how that makes someone feel about them. The fact that they may have shared characteristics means we may be able to define and classify them based on what their genotype enables them to do. Some characteristics that weeds share are discussed in Chapter 9.

Table 3.1 lists the 12 plant families that include 68% of the world's important weed problems. The Poaceae and Cyperaceae account for 27% of the world's weed problems, and when the Asteraceae are added, 43% of the world's worst weeds are included. Nearly half of the world's worst weeds are in only 3 families, and any 2 of these include over a quarter of the world's worst weeds.

TABLE 3.1. Families of the World's Worst Weeds (Holm, 1978).

Family	Number of species	Percent of total*		
Poaceae	44			
Cyperaceae	12	27		
Asteraceae	32		43	
Polygonaceae	8			
Amaranthaceae	7			
Brassicaceae	7			68
Leguminosae	6			
Convolvulaceae	5			
Euphorbiaceae	5			
Chenopodiaceae	4			
Malvaceae	4			
Solanaceae	4			
Total	138**			

The Poaceae is the family with the most weedy species and also the family that includes many of the important crops that feed humans: wheat, rice, barley, millet, oats, rye, corn, sorghum, and sugar cane.

About two-thirds of the world's worst weeds are single-season or annual weeds. The rest are perennials in the world's temperate areas, but in the tropics, they are accurately called several-season weeds. The categories *annual* and *perennial* do not have the same meaning in tropical climates, where growth is not limited by cold weather but may be limited by low rainfall. About two-thirds of the important weeds are broadleaved or dicotyledonous species. Most of the rest are grasses, sedges, or ferns. The United States has about 70% of the world's important weeds and they may be classified in different ways.

I. PHYLOGENETIC RELATIONSHIPS

Weeds are classified by taxonomists and weed scientists the same way as all other plants and species. Based on phylogenetic (from the Greek *phylo* or *phulon*, meaning "race" or "tribe," plus the Greek *gen*, meaning "be born of" or "become") relationships, or a plant's ancestry. All good identification manuals include a key to the species, and all keys are based on a classification developed over many years and, for plants, brought near its present form by the Swedish botanist Carl von Linné [or in its Latinized form, Linnaeus (1707–1778)], who established the binomial system of nomenclature (Genus + species) that is based, primarily, on floral characteristics, especially the presence, number, and characteristics of stamens and pistils. Prior to Linnaeus, all creatures were described in Latin with names that were what Bryson (2005, p. 448) calls "expansively descriptive." Bryson's example is the common weed cutleaf groundcherry, which botanists now agree is known as *Physalis angulata* L. Before Linnaeus, it was known as *Physalis amno ramosissime ramis angulosis glabris foliis dentoserratis*. Students may abhor binomial nomenclature, but, as difficult as it is, it is much easier than descriptive names in Latin with eight terms.

Phylogenetic keys to plant species, based on ancestry and ancestral similarity, include division, subdivision, class, family, genus, and species. A brief description of a plant key for weed species follows:

Division I—Pteridophyta
- Description—Fernlike, mosslike, rushlike, or aquatic plants without true flowers. Reproduce by spores.
- Representative families:
  - Salviniaceae
  - Equisetaceae
  - Polypodiaceae

Division II—Spermatophyta
Description—Plants with true flowers with stamens, pistils, or both. Reproduce by seed containing an embryo.
Subdivision I—Gymnospermae
Description—Ovules not in a closed ovary. Trees and shrubs with needle-shaped, linear, or scalelike, usually evergreen leaves.
Representative families: Pinaceae, Taxaceae
Almost no weedy species.
Subdivision II—Angiospermae
Description—Ovules borne in a closed ovary that matures into a fruit.
Class I—Monocotyledoneae
Description—Stems without a central pith or annular layers but with woody fibers. Embryo with a single cotyledon. Early leaves always alternate. Flower parts in threes, or sixes, never fives. Leaves mostly parallel veined.
Representative families:
Poaceae
Cyperaceae
Juncaceae
Liliaceae
Commelinaceae
Class II—Dicotyledoneae
Description—Stems formed of bark, wood, and pith with the wood between the other two and increasing with annual growth. Leaves net-veined. Embryo with a pair of opposite cotyledons. Flower parts mostly in fours and fives.
Representative families
Polygonaceae
Chenopodiaceae
Convolvulaceae
Asteraceae
Solanaceae

All classified plants have a genus and specific name. By convention, the genus is always capitalized (e.g., *Amaranthus*) and is commonly written in italics or underlined. The species name is not capitalized.

II. A NOTE ABOUT NAMES

The first question one asks about a weed is "What is it?" Of course, the most logical and best answer to this question is the weed's name. But which name? Most plants have several names. Each has its own, distinctive scientific name plus one to several common names. Common names vary between languages and between regions that share a language. For example, *Zea mays* is the plant Americans call corn, but the British, and most of the rest of the world's people, call the plant maize or (in Spanish) *maíz*. In England, wheat and other small grains are often known as corn. The weed *Vulpia myuros* (L.) K.C.Gmel. is called rattail fescue in the United States but silvergrass in Australia. When common names dominate, more confusion arises when two different weeds share a common name. Southern sandbur and bristly starbur are different plants but have the same common name in the north and south of Brazil.

Reluctantly, but for the reader's convenience, common names have been used throughout this book. The scientific names for all plants mentioned in the book are included in Appendices A and B. The scientific name is accepted throughout the world or, at least, it is the name that can be used to resolve confusion that often occurs when just the common name is used.

Students resist learning scientific names because they are regarded as useless, boring, and perhaps even nonsense words designed to confuse and make remembering more difficult. The arguments against learning them are manifold. The first defense is that the names are difficult because they are in Latin, which, after all, is a dead language. Outside of the Roman Catholic Church, few speak it, and knowing Latin certainly doesn't score many points with one's peers. Besides, the argument continues, common names are widely accepted and convey real meaning. Latin is difficult, but difficulty should be dismissed as an objection not worthy of one engaged in higher education. Similar to most worthy goals, obtaining an education will not be achieved without some effort. Latin is dead, but therein lies its advantage as a medium to name things. A dead language doesn't evolve and assume new forms as daily use modifies it and introduces variation. The rules are fixed, and while the language can be manipulated, it is not pliable like a living language (Zimdahl, 1989).

As opposed to common names, scientific names have a universal meaning. Those who know scientific names will be able to verify a plant's identity by reference to standard texts or will immediately know the plant in question when the scientific name is used. Those who do not share the same native language can make use of Latin, an unchanging language, to share information about plants.

Scientific plant names have been derived from a vocabulary that is Latin in form and usually Latin or Greek in origin. Other peculiarities that make scientific nomenclature difficult are the frequent inclusion of personal names, Latinized location names, and words derived from other languages. Taxonomists have developed and accepted rules for name creation that provide latitude for imagination and innovation but not license for their neglect (Zimdahl, 1989).

III. CLASSIFICATION METHODS

Other common, and less systematic classification methods for weeds are based on life history, habitat, morphology, or plant type. Knowledge of classification is important because a plant's ancestry, length of life, the time of year during which it grows and reproduces, and its method or methods of reproduction provide clues about management methods most likely to succeed.

A. Type of Plant

The type of plant or general botanical group is an essential bit of knowledge but not very useful as a total classification system. It is important that we know whether a weed is a fern or fern ally, sedge (Cyperaceae), grass (monocotyledon), or broadleaved (dicotyledon). One should not even begin to attempt control or try to understand weedy behavior until this has been determined. However, when one knows the general classification, other questions about habitat or life cycle must be answered to acquire understanding necessary to control the weed or to create a weed management system.

B. Habitat

Cropland

The first, and most important, weedy habitat is cropland, where many annual and perennial weeds grow. While it is important to know the crop and whether it is agronomic or horticultural, it is not particularly useful. It tells us where the weed is, but it doesn't tell us much about it. It is not a precise way to classify because there is so much overlap among crops. Few, if any, weeds grow exclusively in agronomic or horticultural crops or in just one crop. Redroot pigweed, velvetleaf, Canada thistle, and quackgrass are commonly associated with agricultural crops. Others such as crabgrass, common mallow, prostrate knotweed, dandelion, and creeping woodsorrel commonly associate with horticultural crops. Each can occur in many different crops and environments.

Rangeland

Some weeds are almost exclusively identified with rangeland, a dry, untilled, and extensive environment. Sagebrush and gray rabbitbrush are rarely weeds in corn or front lawns. Only the worst farmer or horticulturalist would create an environment in which these weeds could thrive. Range weeds include those

TABLE 3.2. **Rangeland Weeds.**

Weed	Life cycle	Family
Big sagebrush	Perennial	Asteraceae
Sand sagebrush	Perennial	Asteraceae
Fringed sagebrush	Perennial	Asteraceae
Broom snakeweed	Perennial	Asteraceae
Gray rabbitbrush	Perennial	Asteraceae
Yucca	Perennial	Liliaceae
Greasewood	Perennial	Chenopodiaceae
Halogeton	Annual	Chenopodiaceae
Mesquite	Perennial	Leguminosae
Locoweed	Perennial or annual	Leguminosae
Larkspur	Perennial	Ranunculaceae

shown in Table 3.2, and while the list is not exhaustive, it shows that rangeland weeds are commonly perennial and include many members of the Asteraceae. There are poisonous weeds such as locoweed and larkspur on rangeland and many others including thistles (of several species), dandelion, groundsel, buttercup, vetch, and so on, but these also occur in other places.

Forests

There are over 580 million acres of forest in the United States, and in addition to common herbaceous annual and perennial weeds, there are others, unique to the forest environment (see Table 3.3). The woody perennials such as alder, aspen, bigleaf maple, chokecherry, cottonwood, oaks, and sumac, and the herbaceous perennial bracken fern (common in the acidic soils of Pacific Northwest Douglas fir forests) are unique forest weeds.

Red alder was nearly eliminated by herbicides from Douglas fir forests in the 1970s. Red alder can fix atmospheric nitrogen in soils that are deficient in nitrogen, and Douglas fir will grow better with than without red alder. In the 1990s, red alder wood increased in value, and some companies now cultivate it. Some weeds do so well that they become crops! Red alder has been the target of biological control with a fungus (Dorworth, 1995).

Aquatic

Agriculture is the largest user of fresh water in the world, and crops are sensitive to supply variation. Most of the world's major cities are located on a lake,

TABLE 3.3. **Aquatic Weeds.**

Growth habit	Weed	Life cycle	Family
Free floating	Waterhyacinth	Perennial	Ponterderiaceae
	Salvinia	Annual/Perennial	Salviniaceae
	Waterlettuce	Perennial	Araceae
	Duckweed	Annual	Lemnaceae
Submersed	Hydrilla	Annual/Perennial	Hydrocharitaceae
	Elodea, Western	Perennial	Hydrocharitaceae
	Pondweed	Perennial	Potamogetonaceae
	Eurasian watermilfoil	Perennial	Haloragaceae
	Coontail	Perennial	Ceratophyllaceae
Emersed	Cattail	Perennial	Typhaceae
	Alligatorweed	Perennial	Amaranthaceae
	Arrowhead	Perennial	Olismataceae

ocean coast, or major river. Water, a finite resource, has been and will continue to be essential for urban and agricultural development. Aquatic weeds (Table 3.3) interfere with crop growth because they impede water flow or use water before it arrives in cropped fields. They can interfere with navigation, recreation, and power generation. Free-floating plants (e.g., waterhyacinth) attract attention because their often massive infestations are so obvious. They move with wind and floods, and some have stopped river or lake navigation. They float free and never root in soil. Submersed plants (e.g., hydrilla) complete their life cycle beneath the water. Emersed aquatic weeds (e.g., common cattail) grow with their root system anchored in bottom mud and have leaves and stems that float on water or stand above it. They grow in shallow water, but all can impede flow, block boat movement, clog intakes of electric power plants and irrigation systems, and hasten eutrophication.

Environmental Weeds

This category includes plants particularly obnoxious to people, such as poison ivy and poison oak, both of which cause itching and swelling when many people come into contact with them. Other plants in the environmental group are goldenrod, ragweed, and big sagebrush—primary causes of hay fever-type allergies.

Parasitic Weeds

Parasitic weeds are often placed in other sections in weed science texts. They are here because theirs is a particular and peculiar habitat. Phanerogamic parasites, from the Greek *phaneros*, meaning “visible,” and *gamos*, meaning “marriage,” include more than 3,000 species distributed among 17 families, but only 8 families include important parasitic weeds. The economically important species (see Table 3.4) that damage crop and forest plants are all dicotyledons from five families (Sauerborn, 1991). Parasitic weeds from four families will be discussed briefly. Those who want more detailed information are directed to Parker and Riches (1993).

The Cuscutaceae, dodders, are noxious in all US states except Alaska and are distributed throughout the world’s agricultural regions. A mature dodder plant, a true parasite, is a long, fine, yellow, branching stem. A single stem of field dodder, one of the most important species, can grow up to 10 cm in one day. It is nonspecific regarding hosts, and it coils and twines on many plants. Dodder flowers and reproduces by small, sticky seeds. Haustoria penetrate a host’s cortex to the cambium, and the fine stems dodder (tremble) when the wind blows. Dodder seed emerges from as deep as 4 feet in soil as a rootless, leafless seedling. The fine, yellow stem, 1 to 3 inches long, emerges as an arch, straightens and slowly rotates in a counterclockwise direction (called circumnutation) until it touches another plant, which must be within about 1.25 inches. Seeds have sufficient resources to search for a host for four to nine days, after which they die (Sauerborn, 1991). After contact and attachment, the soil connection withers, and dodder lives as an obligate stem parasite.

The most important parasite in the Loranthaceae is mistletoe. Mistletoes occur in two families: the Loranthaceae and the Viscaceae. Some taxonomies

TABLE 3.4. Important Families of Parasitic Weeds.

Family	Genera	Common name
Cuscutaceae	Cuscuta	Dodder
Loranthaceae/Viscaceae	Loranthus	Mistletoe
	Arceuthobium	Mistletoe
	Viscum	Mistletoe
Orobanchaceae	Orobanche	Broomrape
	Aeginetia	Orobanche
Schrophulariaceae	Striga	Witchweed
	Alectra	Witchweed

combine both families in the Loranthaceae. Dwarf mistletoe is a photosynthetic, flowering plant that parasitizes ponderosa pine in the southwestern United States. It occurs on the trunk and branches as a dense tangle of short brown to yellow-brown stems. Seeds are dispersed by birds or by explosion of seed pods and expulsion of sticky seeds that adhere to adjacent trees. Seeds that burst from pods can travel up to 60 mph over 45 feet. The seeds are usually dispersed in August or early September in southwestern United States.

Witchweed is one of three weedy hemiparasitic species of the Scrophulariaceae in the world. It is called witchweed because it damages crop plants before it even emerges from the ground. There are 35 species of Striga; 23 are found in Africa, and at least 11 of them parasitize crops (Parker and Riches, 1993). Other important Striga species are *S. hermonthica*, which parasitizes sorghum, millet, and corn in Africa, and *S. gesnerioides* (cowpea witchweed), which is the only one that parasitizes dicots. The latter is important on cowpeas and groundnut in East and West Africa and Asia.

The desert locust (*Schistocerca gregaria*) gains a great deal of publicity when it swarms in Africa. Massive efforts are made to combat it, but in any single year, witchweed is more destructive to crops in Africa than desert locusts. The genus has the narrowest host range of the important parasitic weeds and a narrower range of distribution than dodder. Witchweed is a root parasite on corn, sorghum, and other grasses in Africa, India, and Asia. In the United States, it is limited to parts of North and South Carolina. Witchweeds are widely distributed in the world's tropical and subtropical regions. Secretions from corn (and some other grasses) roots encourage germination of witchweed seed. After parasitization, the corn is stunted, yellow, and wilted because of loss of nutrients and water. Many weeds, including crabgrass, serve as alternate hosts. Witchweed seeds are small (about $.2 \times .3$ mm). Therefore, 1,000 to 1,500 seeds placed end to end would be only 1 foot long. They survive up to 14 years in soil, and one witchweed plant can produce up to 58,000 seeds. It easily parasitizes corn because its 90- to 120-day life cycle is similar to corn's. One corn plant can support up to 500 witchweed plants. Witchweed seed will not germinate in soil without the host-excreted stimulant, but it may be induced to germinate with the artificial stimulant ethylene gas. USDA regulations currently have witchweed under quarantine in North and South Carolina to prevent its spread throughout the United States. The quarantine has been successful, and the infested area is decreasing.

Plant parasites such as witchweed have not been controlled in susceptible crops with standard herbicides or weed management methods prior to the occurrence of damage. Crop seed coating with the benzoate herbicide pyrithiobac or the imidazolinone herbicide imazypyr offers promise for control of witchweed in Africa (Kanampiu et al., 2003). Maize seeds were coated with very low rates of one of the herbicides to achieve season-long control of striga and three- to fourfold increases in maize yield over no striga control.

The Orobanchaceae (from the Latin *orobos*, meaning "bitter vetch, and the Latin *anchein, meaning* "to strangle") or broomrapes include over 100 species, 5 of which are important, obligate root holoparasites (lacking all chlorophyll) that attack carrots, broadbeans, tomatoes, sunflowers, red clover, and several other important small-acreage crops in more than 58 countries (Parker and Riches, 1993; Sauerborn, 1991). The broomrapes have the broadest host range of the parasitic families. They cause major yield losses and often complete loss of some crops in many developing countries where control is not possible. They are the most important weed of cool-season food legumes (e.g., cowpea, fava bean). Broomrape is found in California but is not a concern in most of the United States. It is, however, important in South and East Europe, West Asia, and North Africa. Seeds of some species can live in soil for up to 10 years. One plant can produce up to 200,000 seeds that are as small as witchweed seed, and 1 gram of seed contains up to 150,000 seeds. Similar to witchweed, germination of Orobanche seed is stimulated by secretions from the host's root or from roots of nonhost plants. Germination will not occur in the absence of host-excreted chemical stimulants. Most damage from root parasites occurs before the parasite emerges, and only 10 to 30% of attached parasites emerge (Sauerborn, 1991).

An important aspect of parasitic weeds is the present inability to manage them with other than sophisticated chemical technology or extended fallow periods. It has been noted that as little as 100 grams of glyphosate per ha (a sublethal dose) applied three times after rimsulfuron (a sulfonylurea herbicide) selectively reduced broomrape shoot numbers in potato (Haidar et al., 2005). Many of the world's people live in areas where food is scarce and agricultural technology is not sophisticated. These are the same places where parasitic weeds cause the greatest yield losses. Fields have been taken out of production, and production area of some crops has been reduced severely due to parasitic weeds.

C. Life History

Another way to classify weeds is based on their life history. A plant's life history determines in which cropping situations it might be a problem and what management methods are likely to succeed. All temperate weeds can be categorized as annual, biennial, or perennial. These groups are easy to define and observe and are very useful in temperate zone agriculture. As just mentioned, the concept of perennation is not as useful in tropical agriculture, where seasons do not change as they do in temperate zones.

Annuals

An annual is a plant that completes its life cycle from seed to seed in less than one year or in one growing season. They produce an abundance of seed, grow quickly, and are usually, but not always, easier to control than perennials. Summer annuals germinate in spring, grow in summer, flower, and they die in fall, and thus go from seed to seed in one growing season. Many common weeds such as common cocklebur, redroot pigweed and other pigweeds, crabgrass, wild buckwheat, and foxtails are annuals. The typical life cycle of an annual weed is shown in Figure 3.1. Weed ecologists are working to quantify many of the steps in this cycle. The sequence of events is qualitatively accurate, but neither rates nor quantities are defined for most annual weeds. For example, it is known that not all seeds produced by a weed survive in soil. Some die from natural causes at an unknown rate. Others suffer predation by soil organisms or enter the soil seed bank, where their life may be prolonged by dormancy. Quantitative understanding of the steps in a weed's life is essential to wise management.

Winter annual weeds germinate in fall or early winter and flower and mature seed in the spring or early summer of the following year. Downy brome, shepherd's-purse, pinnate tansymustard, and flixweed are winter annual weeds. They are particularly troublesome in winter wheat, a fall-seeded crop, and in alfalfa, a perennial.

Some parts of the world (southern European and North African Mediterranean countries) have a winter rainy season with little snow or subfreezing

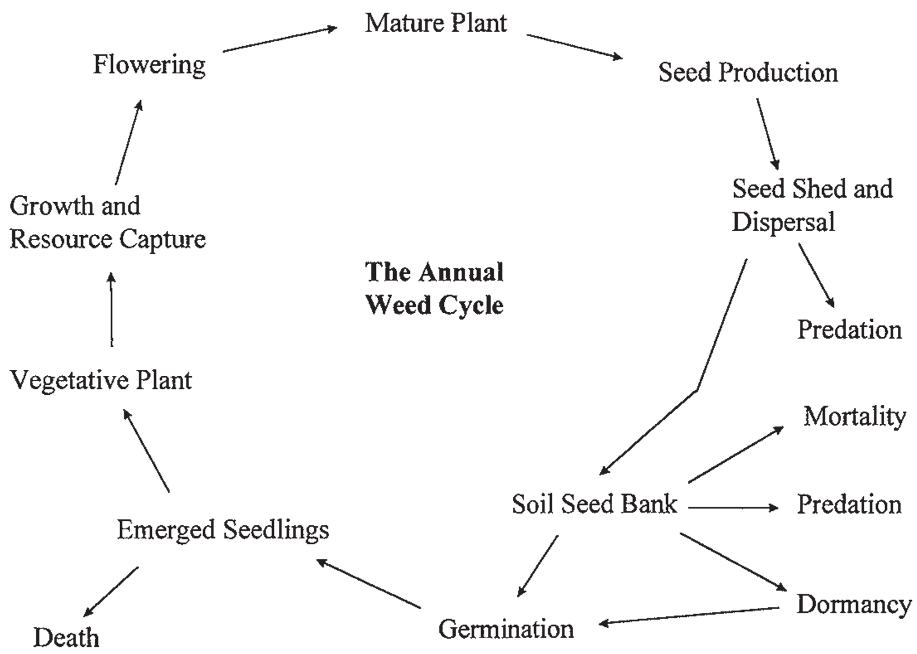

FIGURE 3.1. Life cycle of an annual weed.

temperatures. This is followed by a long, dry period. Crops are planted in the fall when, or just before, the rains begin, so the crops and their weeds begin to grow with the rain. Because the rains don't begin until late fall, the annual weeds live into the next calendar year, and their life cycle fits part of the definition of a winter annual. They are, however, best regarded and managed as annuals because their growth is continuous and not interrupted by a cold period when plants live but do not grow.

Biennials

Biennials live more than one but not more than two years. They should not be confused with winter annuals, which live during two calendar years but not for more than 12 months. Musk thistle, bull thistle, and common mullein are biennials. It is important to know that one is dealing with a biennial rather than a perennial. Spread of a biennial can be prevented by preventing seed production, which is not true for creeping perennials.

Perennials

Perennials are usually divided into two groups: simple and creeping. Simple perennials spread by seed and by vegetative reproduction. If the shoot is injured or cut off, simple perennials may regenerate a new plant vegetatively, but the normal mode of reproduction is seed. Simple perennials include dandelion, buckhorn and broadleaf plantain, and curly dock. Creeping perennials reproduce by seed and vegetatively. Vegetative reproductive organs include creeping above-ground stems (stolons), creeping below-ground stems (rhizomes), tubers, aerial bulblets, and bulbs. The life cycle of a typical perennial plant is shown in Figure 3.2. An excellent summary of the characteristics of 28 perennial weed species can be found in Anderson (1999). The following are the important kinds of vegetative reproduction and the weeds that use them (Leakey, 1981):

A. Rooting of detached shoots	
1. turion	A scaly, often succulent shoot produced from a bud on an underground rootstock. *Eurasian watermilfoil*
B. Creeping stems	
1. layers	Shoots that contact soil root at nodes *annual bluegrass*
2. runner	A plagiotrophic (tendency to grow obliquely or horizontally) shoot that may root, in some shoot areas, when in contact with soil *European blackberry, hedge bindweed*

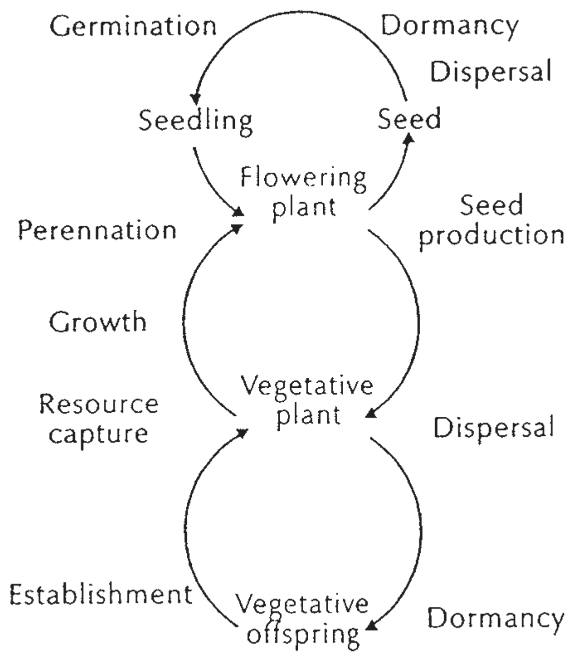

FIGURE 3.2. Life cycle of a perennial weed that produces seed and vegetative progeny (Grime, 1979).

3. stolons	Horizontally growing stems that root at stolon nodes *creeping buttercup, creeping bentgrass, waterhyacinth*
4. rhizomes	Horizontal subterranean stems that give rise to aerial shoots *leafy spurge, quackgrass, field bindweed, johnsongrass*
5. rhizomes and stolons	*bermudagrass*
6. tubers	Swollen portions of underground stems *purple and yellow nutsedge*

C. Creeping roots

Creeping roots that give rise to new shoots
Canada thistle, field bindweed, Russian knapweed

D. Taproot reproduction

Roots that generate a new plant from root fragments
dandelion

E. Modified shoot bases

1. Bulbs	Underground storage organs composed of swollen leaf bases or scales *wild garlic*
2. Corms	Swollen stems with dormant bulbs in the axils of scale-like leaf remnants *bulbous buttercup, tall oatgrass*

THINGS TO THINK ABOUT

1. How are weed classification systems used?
2. What classification system is most likely to be used by horticulturalists, agronomists, and weed scientists?
3. Why are parasitic weeds such difficult problems, and where do they exist?
4. If parasitic weeds are not important problems in most developed countries, why do we bother to study them?
5. Why should we bother to learn the scientific names of plants?
6. How are the scientific names of plants created?

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