

COMMON SENSE PEST CONTROL QUARTERLY

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Non-Toxic Weed Control





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Herbicide-Free Lawns

By William Quarles

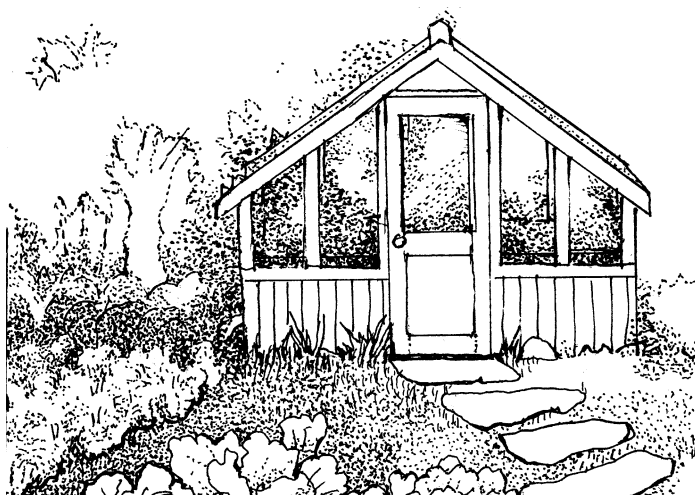
Of the approximately \$23 billion spent on pesticides each year in the U.S., 47% goes for herbicides (Duke et al. 1993). Herbicides are used nearly everywhere. They are applied to control weeds in turfgrass, forests, pastures, lakes and waterways, schoolyards, parks, along rights-of-way, and on home lawns. In agriculture, herbicides have become commonplace, primarily due to the expansion of no-till cropping systems (Franz et al. 1997).

With increased herbicide use has come problems. Herbicides are increasingly being found in groundwater and in wells. Alachlor (Lasso®), atrazine (Gesaprim®), cyanazine (Bladex®), metolachlor (Dual®) and simazine (Caliber®) have been detected in groundwater more than 7,000 times, and these herbicides have been classified as possible human carcinogens in animal tests. Between 50,000 and 3 million people may have been exposed to drinking water contaminated with these chemicals at concentration levels above approved drinking water standards (EPA 1996; Barbash and Resek 1996).

Herbicides are also appearing in surface waters. Levels in the Mississippi river show seasonal surges with production of corn and soybeans. These herbicides may have environmental impacts at very low concentrations. Water concentrations of atrazine as low as 1 part per billion can harm amphibians (Hayes et al. 2002; see Quarles 2002). Another problem is that herbicides can drift in the air during application or volatilize and reappear in non-target areas (Larson et al. 1997).

Persistent Herbicides

Herbicides have become a problem in water, but they can also contaminate compost. Most problematic are the persistent herbicides clopyralid (Confront) and picloram. Clopyralid is used on lawns to control dandelions, clovers, and other broadleaf plants. Because of its persistence, one or two applications can last a whole season. Unfortunately, clopyralid can damage sunflower, beans, tomatoes and potatoes at extremely low soil concentrations—about 10 parts per billion. These



minute concentrations can appear in municipal composts or in home composts produced from treated grass clippings (Bezdicsek et al. 2001; Houck and Burkhart 2001).

Resistant Weeds

Another problem with herbicides is that either weeds become resistant or that continued use changes the weed spectrum so that susceptible annual weeds are killed, and more difficult perennial weeds invade the area. There are at least 55 weed species resistant to atrazine alone (LeBaron and McFarland 1990). Worldwide, there are at least 216 herbicide-resistant weed species (Barber 1999).

Application of herbicides to lawns can encourage some weeds. Use of the herbicide 2,4-D (2,4-dichlorophenoxyacetic acid) encourages oxalis and clovers. Nutsedges have become more common in California partly due to overreliance on herbicides that kill competing weeds but are not very effective on nutsedge (Elmore 1994).

Chemical-Free Lawns

Fortunately, herbicides are not necessary to produce a healthy, good-looking lawn. An alternative is an integrated program including choice of the proper lawn grass, good cultural controls, spot weeding, and if needed, application of a least-toxic herbicide (Daar 1992; Quarles 1999).

Turf species chosen for your lawn should be adapted to your climate. Kentucky bluegrass, *Poa pratensis*, is a favorite cool season grass. Other popular cool season grasses are fescues, bentgrasses, and ryegrasses. Warm season grasses include bermudagrass, zoysiagrass, centipedegrass, bahiagrass, and St. Augustinegrass (Christians 1998). Grass mixtures are often used for turfgrass. One popular mix is 80% fine bladed tall fescue, *Festuca arundinacea*, and 20% perennial ryegrass, *Lolium perenne*. This mixture is hardy and resistant to trampling and wear. New seedings begun in late summer will be denser and less prone to weed infestation

than turfgrass planted at other times of the year (Daar 1992; Swiaddon 1996).

Plant in the fall or spring for cool-season grasses, and in the spring or early summer for warm-season grasses. Generous use of seeds will help crowd out weeds. Using sod instead of seeds can also help stop weed emergence (Elmore 1993).

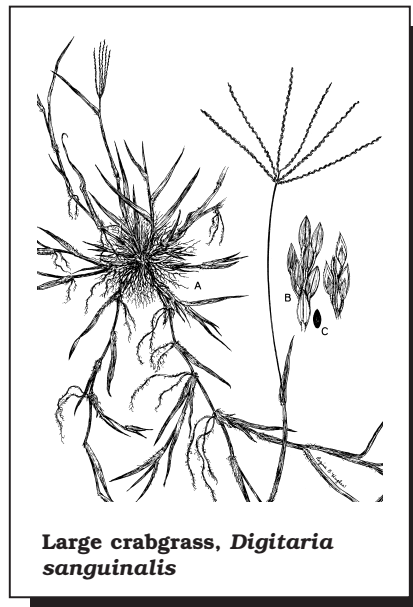
Allelopathic Turfgrass

Allelopathic turfgrass such as ryegrass and tall fescue can help with weed problems. Lawn mixtures of tall fescue, *Festuca arundinacea*, and perennial ryegrass, *Lolium perenne*, will suppress prostrate pigweed,

Amaranthus blitoides. Oxalis and large crabgrass are suppressed by the tall fescue cultivars "Falcon" and "Olympic" (Elmore 1990).

Tall fescue cultivars "Missouri-96" and "Kentucky 31" have suppressed large crabgrass, *Digitaria sanguinalis*; birds-foot trefoil, *Lotus corniculatus*; and red clover, *Trifolium* sp. Ryegrass and fescue cultivars containing endophytic VAM fungi are commercially available

(see Resources). Although effects are complicated, and might be site-specific, lawns constructed of these cultivars are more resistant to weeds, diseases, and some insects (Dilday et al. 1997).



Large crabgrass, *Digitaria sanguinalis*

Cultural Methods

Weeds in lawns can be discouraged by reducing stress on the turfgrass, by proper watering and fertilization. For example, drought in California lawns encourages dandelion, clover, bermudagrass and knotweed. Excess water encourages annual bluegrass, crabgrass and bentgrass (Elmore 1994).

Appearance of weeds in a lawn is often a sign of compacted soil, poor drainage or improper nutrition (see Weed Signatures in the second article). Fertilize well with slow-release fertilizers such as corn gluten meal, or use a top dressing of composted steer manure. Lawn clippings are a good source of fertilizer, and less fertilization is necessary if they are left on the surface. Do not overwater, but do not let the lawn wilt. Infrequent, deep watering is best for weed control (Daniel and Freeborg 1975; Daar 1992; Christians 1998; Sachs and Luff 2002).

Fertilization can affect the weed spectrum on a lawn. Field experiments have shown that dandelions,

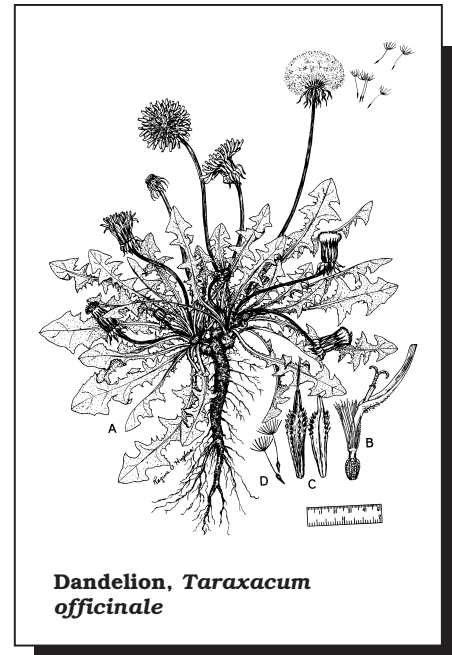
Taraxacum officinale, may be encouraged by potassium rich fertilizers or additions of lime. This is another reason to use composts and other natural fertilizers for lawns (Tillman et al. 1999). In general, fertilization of cool season turfgrass is best in spring and fall, warm season grasses should be fertilized in the summer (Christians 1998).

Aeration and Thatch Removal

Healthy turf is more resistant to weeds, insects and diseases. Coring the soil with either a machine or a hand tool can help aerate the lawn, reduce soil compaction, and break up thatch (see Resources).

The soil cores can then be broken up and worked back into the soil with a top dressing of screened compost and new grass seeds (Daar 1992).

Coring turf to improve aeration can also bring weed seeds to the surface. To reduce problems, aeration should be done when the grass is growing vigorously. Aeration should not be done when weed seeds are germinating. Thus, if most of the weeds are spring annuals, aeration should be done in the late summer (Christians 1998).



Dandelion, *Taraxacum officinale*

Mowing Height

For weed control, the higher the mowing height the better, because the taller grass shades weed sprouts from sunlight and helps to crowd them out. However, the best height varies with the turfgrass species, the site and the climate. Bluegrasses withstand weeds better when cut to 2 inches (5.1 cm) or higher. Bentgrass, bermudagrass, and zoysiagrass that have prostrate growth habits should not be mowed higher than 1 inch (2.54 cm) to avoid excessive accumulation of thatch (Daar 1992; Christians 1998).

Active Controls

The easiest treatment for lawn weeds is to ignore or tolerate them. Some "weeds" are even aesthetically pleasing and break up the monotony of a "perfect" lawn. When lawn weeds reach levels where they cannot be tolerated, active controls such as hand pulling,

mechanical removal, flaming, hot water or least-toxic herbicides can be used. Flaming can kill broadleaf weeds while sparing turfgrass (see the second article for more on flaming). The Weed Hound and the dandelion knife make mechanical weeding easier (see Resources).

Some lawn weeds can be stressed and killed with hot water. Before using the water, rake and chop into the weedy area. Then pour about a half gallon of boiling water per square foot on the weeds. After adding water, cover with a tarp or other material to hold the heat (Freeborg and Daniel 1975).

Corn Gluten Meal

Though vinegar, soap and other least-toxic post-emergent herbicides are commercially available (see the second article for more on these), the only least-toxic pre-emergent herbicide is corn gluten meal. Corn gluten meal (CGM) is a waste product left over from the

processing of corn to produce corn syrup. Since sugars and starch are removed, protein is concentrated. Corn gluten meal is 60% protein and approximately 10% nitrogen (N) by weight. It is a fine, yellow powder that is a waste product obtained from corn milling. It has been used as an ingredient in dog food, fish food, and other animal feeds (Christians 1991; Christians 1995).

Its high nitrogen content and herbicidal properties make corn gluten meal a near ideal "weed and feed" product. The product can be applied to

mature turfgrass as a top dressing and fertilizer. Over time, it acts as a pre-emergence herbicide that suppresses growth of annual weeds such as crabgrass, *Digitaria* spp. (Christians 1991; Christians 1995).

Corn Gluten on Lawns

Corn gluten meal is more effective for some weeds than others. Barnyardgrass, *Echinochloa crus-galli*; quackgrass, *Agropyron repens*; velvetleaf, *Abutilon theophrasti*; and woolly cupgrass, *Eriochloa villosa* are some of the most resistant weeds (Bingaman and Christians 1995).

Good control of lawn weeds is expected for "annual bluegrass, *Poa annua*; black nightshade, *Solanum nigrum*; buckhorn plantain, *Plantago lanceolata*; catchweed bedstraw, *Galium aparine*; common lambsquarters, *Chenopodium album*; curly dock, *Rumex crispus*;

dandelion, *Taraxacum officinale*; giant foxtail, *Setaria faberi*; orchardgrass, *Dactylis glomerta*; purslane, *Portulaca oleracea*; redroot pigweed, *Amaranthus retroflexus*; and smooth crabgrass, *Digitaria ischaemum*. In addition, competition from the mature grasses in turfgrass areas may increase the degree of weed control" (Bingaman and Christians 1995).

Field tests have shown that application rates of 40 lbs/1000 ft² (18.2 kg/93.6 m²) can reduce numbers of common weeds such as crabgrass, clover, *Trifolium* spp.; and dandelion in plots of Kentucky bluegrass, *Poa pratensis*. Over a 4-year period crabgrass was reduced by 86% or more. Clover and dandelion were reduced by 90% or more. The reduction in numbers of broadleaf weeds was likely due to a combination of the herbicidal action of corn gluten meal and the competition from the Kentucky bluegrass. No detrimental effects on Kentucky bluegrass was seen even at application rates of 120 lbs/1000 ft² (54.6 kg/93.6 m²) (Christians 1995).

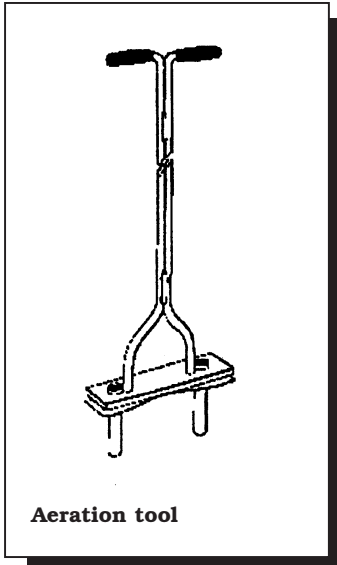
Corn gluten meal has no postemergence effect. Since it is a fairly wide-spectrum herbicide, this feature makes CGM appropriate for application to established lawns, playing fields, greens and fairways. If CGM killed mature turfgrass or other crops, it would not be useful (Christians 1995).

How to Apply

On turf and lawns, recommended application rates are 20 lbs/1000 ft² (9.1 kg/93.6 m²) in the spring a few weeks before annual weeds germinate, followed by a second application of the same amount late in the summer. According to Christians (1995), "...apply the material a few weeks before germination. Water it in if there is no rain. When the weeds have germinated, allow a short drying period for plants without a root to die before irrigation is continued."

Timing Important

Applications of corn gluten meal must be properly timed to be effective. According to Nick Christians (1995), "if the material is applied after the weed has rooted, no control can be expected. In fact, the weeds will be worse because germinated weeds thrive on the nitrogen in corn gluten meal." Weed control is also less effective if the herbicide is applied too early in the season. After the CGM is



Aeration tool

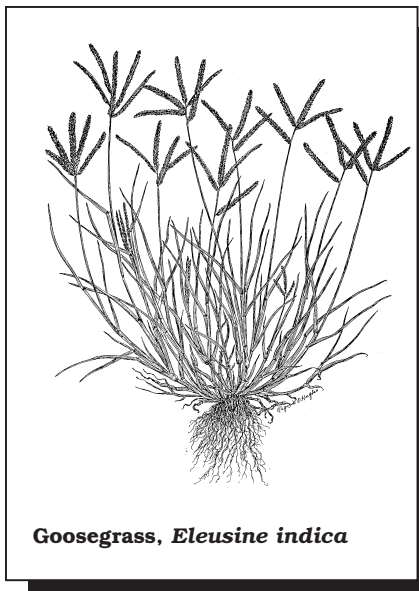


Lambsquarters, *Chenopodium album*

added to soil, it is slowly inactivated by soil microorganisms. According to Christians (1995), "experience has shown that best results follow applications three to five weeks before weed germination. Under extremely wet conditions, weeds that are initially prevented from forming a root can grow out of the problem and control is reduced. It was also observed in early studies that if the material is allowed to sit on the surface for several weeks during dry conditions, effectiveness is limited."

California Experience

Much of the field testing on corn gluten meal was conducted in Iowa. However, consumers in California have also found it effective. Ken Thornberry of K & D Enterprises of Ceres, CA has tried corn gluten meal



Goosegrass, *Eleusine indica*

under the climatic conditions of California's Central Valley. He applied 15 lbs/1000 ft² (6.8 kg/93.6 m²) to his lawn on November 1 just before the seasonal rains. He watered in the first application, let it dry, and then left it for the winter. Thornberry applied corn gluten meal again in January. Corn gluten meal suppressed crabgrass and clovers but was less effective for dandelions. As corn gluten meal

effects on annual weeds can accumulate, he is hoping for better success with dandelions in the future. Thornberry recommends using granules instead of pellets, as granules degrade and work into the lawn faster.

Problems and Availability

When we look just at toxicity, corn gluten meal is an ideal herbicide. It is so non-toxic, it is an animal feed. It is effective as a preemergent herbicide at concentrations that are not toxic to turf and other crops. It is biodegradable, and thus is not persistent in the environment. An additional advantage is its role as a slow release fertilizer. Problems include lack of post-emergent activity, and the large application rates needed to suppress resistant weeds. Large application rates can make it expensive to use in some situations.

Corn gluten meal can now be purchased at feed stores and from a number of garden suppliers (see Resources). The suppliers may or may not choose to label it an herbicide, but in any case, no EPA registration is needed. On May 6, 1996, corn gluten meal and a number of other least-toxic pesticides were exempted from registration by the EPA (Quarles 1996). In 1999

the California Department of Pesticide Regulation also excluded corn gluten meal from pesticide registration requirements because it is a "reduced-risk" pesticide (DPR 1999).

Alternate Lawns

If you are tired of the constant mowing, fertilizing and watering that a well-maintained lawn demands, you might want to try an alternate groundcover. Although these "alternate lawns" will not take the wear and tear of grass, if you have low traffic they might be

Resources

Lawn Seed—Peaceful Valley Farm Supply, PO Box 2209, 110 Springhill Drive, Grass Valley, CA 95945; 530/272-4769. Harmony Farm Supply, 3244 Gravenstein Hwy, No. B, Sebastopol, CA 95472; 707/823-9125.

Endophytic Lawn Grasses—Lofts Seeds, 9327 US route 1, Suite J, Laurel, MD 27114; Turf Seed, PO Box 250, Hubbard, OR 97032; 503/651-2130.

Weeding and Aeration Tools—local hardware store
Weed Hound (weeding tool)—Hound Dog Products, 6435 Cecilia Circle, Edina, MN 55439.

Turf Hound (aeration tool)—Hound Dog Products, 6435 Cecilia Circle, Edina, MN 55439.

Corn Gluten Meal

Bioscape Inc. (Bioweed), 101 Lombard St., No. 17E, San Francisco, CA 94111; 877/246-7227.

Blue Seal Feeds (Safe 'N Simple™), PO Box 8000, Londonderry, NH 03053; 603/437-3400, 603/437-3403.

Fertrell, Inc. (WeedzStop™), Box 265, Bainbridge, PA 17502; 717/367-1566.

Floyd Rogers, 22W213 Glen Valley Dr., Glen Ellyn, IL 60137; 630/858-3538.

Gardens Alive (WOW™), 5100 Schenley Place, Lawrenceburg, IN; 812/537-8650, Fax 812/537-8660.

Grain Processing Co., 1600 Oregon St., Muscatine, IA 52761; 319/264-4254, Fax 319/264-4130.

Manning Agricultural Center (ProPac), 619 Julia St., Manning, IA 51455; 800/248-4409; 712/653-2981, Fax 712/653-2981.

Peaceful Valley Farm Supply (Corn Gluten Meal), PO Box 2209P, Grass Valley, CA 95945; 916/272-4769.

Rhode's Services Inc.(GreenSense), 1651 Wall St., Garland, TX 75071; 972/864-1934, Fax 972/864-1028.

Safe Earth Lawn and Gardens (SafeEarth), 900 52nd St., W. Des Moines, IA 50265; 515/222-1997, Fax 515/223-1669.

Soil Technologies (DynaWeed), 2103-185th St., Fairfield, IA 50265; 515/472-3963; 800/221-7645, Fax 515/472-6189.

Walt's Organic Fertilizer Co., PO Box 31480, Seattle, WA 98103; 206/783-6685.

what you need. Among the possibilities are chamomile, *Chamaemelum nobile*; dichondra, *Dichondra micrantha*; lippia, *Phyla nodiflora*; irish moss, *Sagina subulata*; thyme, *Thymus serpyllum*; and bugleweed, *Ajuga* spp. (Arbuckle 1993).

Conclusion

Lawn weeds can often be controlled by cultural methods and mowing. In some cases, limited physical controls such as hand pulling, flaming, or a weeding tool may be necessary. For some situations, a least-toxic herbicide may be the best approach. For those who want to give up the constant mowing that a lawn entails, an alternative groundcover can be planted. By combining good planning and non-toxic methods, toxic herbicides will not be needed for weed control in most gardens and lawns.

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Integrated Weed Control for the Home and Garden

By William Quarles

Weeds are everywhere. Around the home, weeds find their way into ornamental plantings, vegetable gardens, and lawns. They spring up between cracks in the sidewalks and along fence edges. They are problems in urban areas on golf courses, in parks, and along the roadside. Rangeland weeds such as yellow starthistle, *Centaurea solstitialis*, invade pastures making forage toxic to horses and other livestock. Broadleaf weeds, grasses, and woody shrubs compete for resources in forests. Without weed control, growth of young trees can be suppressed and enjoyment of the forest is reduced due to reduced access. Weeds can also be an economic problem in agriculture, competing with crop plants for nutrients and resources. Though weeds are a problem, it is not necessary to rely on herbicides to control them. This article discusses the non-toxic options currently available to manage weeds near the home and in the garden.

What is a Weed?

A weed is often defined as a plant that is out of place, or a plant that grows where it is not wanted. Weeds also tend to be hardy, aggressive, and reproductively prolific. Their capacity for rapid spread, and their tendency to displace more desirable plants may be their most basic characteristic. Some plants get a reputation as weeds also because they are not aesthetically pleasing, are poisonous, cause allergies or contact dermatitis, or have other noxious properties. There are federal, state, and county laws that define particularly noxious weeds, and make it the responsibility of homeowners to get rid of them. A plant can also be a weed because it competes with agricultural crops, reducing yields, contaminating seed grains, and reducing quality (Dunham 1973; James et al. 1991) (see Box A Biology of Weeds).

Tolerance levels for weeds can vary. There is generally less tolerance for weeds that are poisonous or cause large crop losses. Some weeds, such as snake-weed, *Eupatorium rugosum*; locoweeds, *Astragalus* spp.; bracken fern, *Pteridium aquilinum*, and others are grazed by cattle, can result in poisonous milk and can



be dangerous to humans as well as livestock (James et al. 1994; Mandava 1985; Wink 1987).

Beneficial Weeds

On the other hand, some weeds are a just a nuisance, or even beneficial. Some people find weeds such as dandelions aesthetically pleasing, eat the leaves in salads, and make dandelion wine out of the flowers. Leaves of lambsquarters, *Chenopodium album*, are good to eat when boiled. Wild fennel or dill can be used to flavor foods. Some weeds such as coneflowers, *Echinacea* spp., have a reputation in herbal medicine. Feverfew, *Chrysanthemum parthenium* and fleabane, *Erigeron speciosus* will repel pest insects (Dunham 1973; Klocke 1987).

Weeds can also be refuges for beneficial insects by providing them with pollen, nectar, prey and alternate hosts (William 1981; Bugg 1992). Pondweeds might be a nuisance for humans, but valuable food for waterfowl (Dunham 1973).

Some weed problems shift with time and fashion. Today's striking ornamental could be tomorrow's noxious weed. Today's weed can be tomorrow's crop. For instance, potatoes, sunflower, barley, oats, wheat and rye were all once considered weeds, and some of these, such as wild oats, can still be a weed problem (Dunham 1973; Hill 1977).

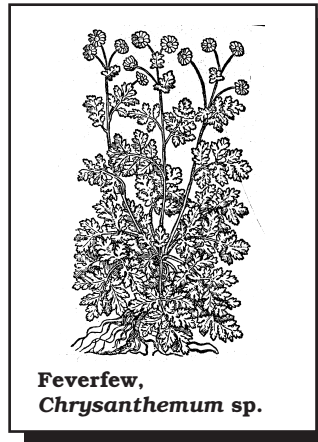
Invasion of Exotics

Most of the weeds in your garden came from somewhere else. Over half the weeds listed as important in the 1895 USDA yearbook were of foreign origin. European weeds such as quackgrass, *Agropyron repens*; dandelion, *Taraxacum officinale*; shepherd's-purse, *Capsella bursa-pastoris*; sowthistle, *Sonchus oleraceus*; knotweed, *Polygonum* spp.; chickweed, *Stellaria* sp.; dock, *Rumex* sp.; buckhorn plantain, *Plantago lanceolata*; groundsel, *Senecio vulgaris*; and mullein, *Verbascum* sp. were established in the eastern states a few years after the colonists had settled in New England (Dunham 1973). Many of these arrived in

ships' ballast. In the early days of shipping, light cargoes were supplemented with a load of soil. When European ships arrived at the first port of call, the soil was shoveled overboard (Fogg 1975). As the original U.S. forests were clear-cut by settlers, sun-loving European weeds soon found a new home (Devine 1998).

Some U.S. weeds are part of the northern migration of tropical species that followed recovery from the last ice age. Mexican tea, *Chenopodium ambrosioides*; bristly mallow, *Sida spinosa*; hairy galinsoga, *Galinsoga ciliata*; carpet weed, *Mollugo verticillata*; and various morningglories, *Ipomoea* spp. have invaded in this way from the tropics (Fogg 1975).

A number of our weeds are escaped cultivated plants that were also exotics. Some were introduced ornamentals such as yellow toadflax, *Linaria vulgaris*; forage plants such as clover, vegetables such as car-



**Feverfew,
Chrysanthemum sp.**

rots, herbs such as dill, fennel, or mustard; and medicinal plants such as henbane, *Hyoscyamus niger* (Fogg 1975; Radosevich and Holt 1984). Since some weeds are close relatives of crop plants, there is concern that crops genetically engineered for herbicide resistance may pass this characteristic on to weeds, forming superweeds (Daniels and Sheail 1999).

How do They Spread?

Though exotic weeds have been introduced by trade, travel, or deliberate plantings of alien ornamentals, once weeds have found a new home, they continue to disperse. Seeds are often spread by crop cultivation, contaminated fertilizers, tools, and machines. Crop seeds are often contaminated with weed seeds. An analysis of wheat seed samples in Minnesota in 1946 showed that nearly 70% were contaminated with wild buckwheat, and 12% had barnyardgrass seed. Combines and cultivators can be covered with several pounds of weed seed after use in the field. Weed seeds can also be spread in animal manure, by birds, and by water. Many lawn and garden weed seeds are dispersed by the wind (Dunham 1973; Radosevich and Holt 1984).

Box A. Weed Biology

About 60% of problem weeds in the U.S. belong to seven plant families: Compositae (daisy), Graminae (grasses), Cruciferae (mustard), Labiatae (mint), Leguminosae (clover), Caryophyllaceae (chickweed), and Scrophulariaceae (snapdragon). These are all quick growing annuals, biennials or perennials, not woody plants. They are also plants of recent evolutionary origin (Fogg 1975).

There are basically three kinds of weeds, annuals, biennials and perennials. Annual weeds germinate from seed and mature in one season. Spring annuals germinate in the spring and mature through the summer and fall. Examples are foxtail, *Alopecurus* sp.; crabgrass, *Digitaria* spp.; ragweed, *Ambrosia* sp.; wild buckwheat, and mustards. Winter annuals germinate in the fall, then overwinter as seedlings, maturing early in the next year. Examples are pennycress, *Thlaspi* sp.; chickweed, *Stellaria* sp.; and yellow rocket, *Barbarea vulgaris*.

Each year an annual weed produces thousands of seeds, and these accumulate in the soil, making a seed bank. Weed seeds from annuals can remain viable for long periods of time. Experiments started in 1879 have shown that seeds of curly dock remain viable for at least 70 years, black mustard, *Brassica nigra*, will germinate after 50 years, ragweed germinates after 40 years, and foxtail after 30 years (Dunham 1973). A single pigweed can produce over 100,000 seeds. Soil samples taken from well managed farms in Minnesota show more than 70 million weed seeds per acre in the top 6 inches of cultivated fields (Dunham 1973; Miller 1975). The best way to

control annual weeds is to destroy them before they have a chance to produce seeds.

Biennials

Biennials also propagate from seed, but require two years to complete their lifecycle. Burdock, *Arctium* sp.; evening primrose, *Oenothera* sp. and others are biennials.

Perennials

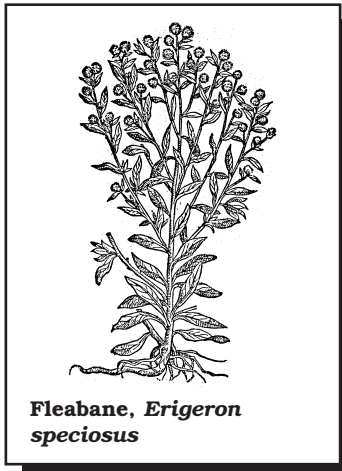
Perennials are plants that live more than two years. Perennials reproduce from seeds and by vegetative reproduction. Cut pieces can develop roots and stems to become new plants. If the green, growing top of a perennial is removed, a new plant can sprout from the buried roots. Some grassy weeds reproduce from stolons (prostrate stems) and rhizomes (underground stems), bulbs, and tubers. Quackgrass, Canada thistle, johnsongrass, buttercup and nutsedge are perennials. The best time to control perennials is after they have sprouted, and just before they have bloomed. Resources stored underground in tubers and roots will be lowest just before blooming (Radosevich and Holt 1984).

Frequent cultivation will discourage perennials. In fact, Dunham (1973) relates a story appropriate to perennial control. An entrepreneur advertised "a fool-proof" method of removing Canada thistle. "Wait for a full moon in June, go out with a hoe, and chop down the thistle. At the next full moon, repeat the process. Continue until thistle can no longer be seen."

Integrated Vegetation Management

The best way to manage weeds is with an IPM program. IPM for weeds is often called integrated vegetation management or IVM. Prevention can be combined with monitoring, proper landscape design, mulching, mechanical and physical methods, flaming, and least-toxic herbicides in an overall approach to control weeds without applying toxic herbicides. Though biological control of weeds with insects and pathogens can be useful, this approach is probably beyond the resources of the average homeowner.

The best way to manage weeds is to prevent them. Make sure that your garden seeds are not contaminated with weed seeds. If you apply manure, make sure it has been disinfected by hot composting. Avoid using soil contaminated with weed seeds. Inspect nursery stock to make sure it is free of weed seeds or the vegetative parts of perennial weeds. If weeds have sprouted in your garden, make sure you remove them before they go to seed (Miller 1975; Elmore 1993b).



Fleabane, *Erigeron speciosus*

For lawns, use grass seed of known composition. Topsoil added to lawns should come from reliable sources, and should be inspected for weed seeds before use. Topsoil is a major source of nimblewill, *Mulenbergia* sp.; bermudagrass, *Cynodon dactylon*; and quackgrass.

Good cultural practices such as proper watering and fertilization can help prevent lawn weeds. Bermudagrass weeds in bluegrass lawns are encouraged by summer fertilization. Bluegrass should be fertilized in the fall or early spring (Deal 1966; Daar 1992a). (See the first article for more on lawn weeds.)

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Thresholds and Monitoring

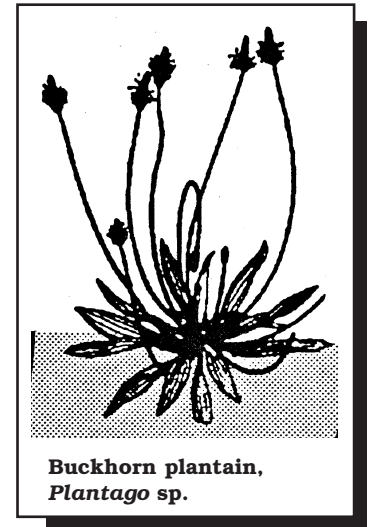
The IVM approach involves monitoring and setting thresholds. The idea of monitoring is to reproducibly scout a defined area for weeds, and record the results. If your lawn or garden is large, you might decide to divide it into transects, which are lines of division which can be imagined or defined by string. With monitoring and a weed map you are able to quantify what otherwise will be a more subjective weed threshold. Monitoring also allows treatments to be more quantitatively evaluated.

To monitor weeds in your lawn or garden, make a map of the unwanted vegetation. Note which weed species are present and decide upon a level of tolerance. As mentioned above, some weeds are actually beneficial for your garden. Sunflower (Asteraceae), parsley (Apiaceae) and mustard (Cruciferae) weed families provide nectar for beneficial insects. Weeds such as

English daisy, *Bellis perennis*; cornflower, *Centaurea cyanus*; and yarrow, *Achillea millefolium* have attractive flowers (Bugg 1992).

Weed Signatures

A weed map can also be a map of nutrients and conditions. Weed appearance can define conditions just as though a sign were posted. For instance, spurge, *Euphorbia* spp.; black medic, *Medicago lupulina*; goosegrass, *Eleusine indica* and knotweed, *Polygonum* spp. are indications of sites that are too dry. Moneywort, *Lysimachia* sp; annual bluegrass, *Poa annua*; liverwort, *Hepatica* sp. and alligatorweed, *Alternanthera* sp. are indications of chronically wet conditions. Broadleaf plantain, *Plantago* sp.; annual bluegrass, corn speedwell, *Veronica arvensis*; and goosegrass show up when soil is too compacted. Red sorrel, *Rumex acetosella*, often shows up in soils that are too acidic. Sites low in nitrogen support clovers, birdsfoot trefoil, *Lotus corniculatus*; and black medic. If you know weed signatures, you can change the conditions that led to their establishment (Neal 1993; see Quarles 2001).



Buckhorn plantain, *Plantago* sp.

Landscape Design

Weeds can be designed out of ornamental beds by proper choice of plants. Groundcovers, trees, and shrubs can be used to shade the ground so weeds will not grow. Newly planted shrub beds can be seeded with fast-growing annuals such as sweet alyssum, *Lobularia maritima*; farewell-to-spring, *Clarkia amoena*; and scarlet flax, *Linum grandiflorum* var. *rubrum* to smother and crowd out weeds. Fast-growing groundcovers can be used along pathways and in areas hard to access and cultivate (Daar 1995).

In landscapes, intelligent use of irrigation water can minimize weeds. Drip irrigation allows water to be delivered only to ornamentals, not to weeds. Pruning and shaping plants to increase their vigor will help reduce weed germination and growth (Elmore 1993b).

Flowers can be chosen that suppress weeds. For instance, sunflowers are allelopathic, and root exudates tend to suppress competing weeds (Rice 1987; Saggese et al. 1985). Shrubs such as manzanita, *Arctostaphylos glauca*; *Salvia leucophylla*; *S. apiana*; *S. millifera*, and *Artemisia californica* will suppress annual weeds (Friedman 1987; Muller 1971; Hanawalt 1971). Weeds can also be suppressed in new plantings by landscape fabrics or other mulches (see Mulches below).

Native Plants

A good weed control strategy is to remove weeds by cultivation and replant with hardy native species adapted to the site. California alone has 5,000 species of native plants belonging to more than 1100 genera, and other states also have a rich botanical bounty.

Native plants are generally very hardy, and hardy plants compete well against aggressive exotic weeds. In California, some lawns have been entirely replaced by plantings of California poppy, *Eschscholzia californica*, and other native plants.

For groundcovers and borders to crowd out invasive weeds, California has 31 native *Clarkia* spp. These free-

Box B. History of Weed Control

Weed control methods developed with agriculture. Hand weeding was probably the first method of weed control, followed by sharpened sticks, crude hoes and other tools for stirring the soil. A book by Jethro Tull in 1731 led to the proliferation of tillage equipment in Europe. A steel moldboard plow had been developed by 1837, and within 35 years the wheel cultivator, two-wheel mower, row cultivator, spring tooth harrow, riding plow and riding cultivator appeared.

In the first half of the 20th century, weed control machines such as the crusher boat (1900), rodweeder (1912), tractor cultivator (1918), field cultivator with duck foot shovels or spring teeth (1925), flame cultivator (1943), electrovator (1945), and finger weeders, weed saws, underwater sickles, canal rakes, ditch dozers, and weed forks for irrigation and drainage channels were developed.

The first herbicides were inorganic compounds. Common salt was used as early as 1850. In the late 18th century salts of copper and iron, sulfuric acid, nitric acid, sodium arsenite, sodium arsenate, and sodium chlorate were tried. Commercial fertilizers such as sodium nitrate and ammonium sulfate were shown to kill weeds. In the early 19th century kainite and calcium cyanamide were added to the inorganic herbicide list. The most successful of these was the oxidizing salt sodium chlorate, which was used for perennials, especially field bindweed. During the Second World War sodium chlorate was needed to make explosives and was replaced with borax treatments (Dunham 1973).

The herbicide culture that we all live in started with the Second World War. The broadleaf selective herbicide 2,4-D (2,4-dichlorophenoxyacetic acid) was developed along with many other interesting chemicals by the U.S. Army Chemical Warfare Division in Fort Detrick, MD (US Army 1946). Parallel research also took place in England (Slade et al. 1945). These experiments were not declassified and made public until after the War. It was introduced commercially in 1946 with a national advertising campaign, and herbicides have been with us ever since (Dunham 1973).

Problems with Herbicides

When 2,4-D and subsequent herbicides were marketed, little attention was given to any toxic problems because these compounds often have low acute toxicity to mammals. In fact, E.J. Kraus, one of the first promoters of 2,4-D ate 1/2 gram of pure

2,4-D daily for three weeks to show that it was harmless to humans, or at least to E.J. Kraus (Dunham 1973).

Herbicides, however, can make some toxic plants more palatable to livestock, increasing livestock poisoning. Herbicide sprays can sometimes drift during application into areas where desirable plants are located. Herbicides can cause chlorosis, necrosis and stunting in crop plants. Herbicides can sometimes volatilize and reappear on crops several miles away (Dunham 1973; Larson et al. 1997). Herbicides from crop applications can move with runoff into wildlife preserves, destroying plants that are food for wildlife. Only in 1964 did the USDA start sampling pesticides in soil and water. Market basket pesticide residue studies by the FDA started in 1961 (Dunham 1973).

Public attention really got drawn to herbicides during the Vietnam War. Agent orange and other defoliants were sprayed from airplanes, killing vegetation but also exposing troops. Newspaper stories of the time reported an increase of Vietnamese birth defects. These stories led to animal tests and the banning of the herbicide 2,4,5-T (2,4,5-trichlorophenoxyacetic acid). Problems came perhaps not from the herbicide, but from the dioxin contaminants produced during manufacture (Dunham 1973).

Other herbicides that have been banned because of toxicity and high dermal absorption are dinoseb, bromoxynil-butyrates, and nitrofen (Tok). Some of these may cause birth defects or cancer (Haskell 1991).

Herbicides such as alachlor (Lasso®), atrazine (Gesaprim®), cyanazine (Bladex®), metolachlor (Dual®) and simazine (Caliber®) have shown up in groundwater samples more than 7000 times. These herbicides have been classified as possible human carcinogens (EPA 1996; Barbash and Resek 1996). On April 29, 1999 the EPA published a proposed rule to suspend food tolerances and thus registrations of the herbicides cyanazine, diquat, oxadiazon, picloram, prometryn and trifluralin for use in a number of food crops (EPA 1999).

Another problem with herbicides is that either weeds become resistant or that continued use changes the weed spectrum so that susceptible annual weeds are killed, and more difficult perennial weeds invade the area. There are at least 55 weed species resistant to atrazine alone (LeBaron and McFarland 1990). Worldwide, there are at least 216 herbicide-resistant weed species (Barber 1999).



Raised beds make weeding easier.

flowering annuals bloom from late spring and into summer. They can be grown from seed and will thrive in sunny areas. Especially striking is red ribbons Clarkia, *C. concinna*. Other good native annual ground covers are blue lips, *Collinsia grandiflora*; California gilia, *G. achilleaefolia*; tidy tips, *Layia* spp.; and baby blue eyes, *Nemophila menziesii* (Schmidt 1980). Some of these plants also encourage beneficial insects (Quarles and Grossman 2002).

Drought-resistant plants such as native fremontia, *Fremontia californicum*; California lilacs, *Ceanothus* spp.; sages, *Salvia* spp., buckwheats, *Eriogonum* spp.; and manzanitas, *Arctostaphylos* spp. can be planted to crowd out invasive weeds. Difficult areas such as slopes can be covered with coyote bush, *Baccharis pilularis*, a plant that grows quickly with or without water and is considered to be indestructible. This genus secretes substances that suppresses weeds growing around it (Schmidt 1980; Jarvis et al. 1985). Native grasses and forbs have been established on many California roadways, reducing herbicide applications (Brown et al. 1994; Daar 1994).

California perennials that can be used to combat weeds include one of the earliest spring flowers, grand hound's tongue, *Cynoglossum grande*. One of the 76 species of wild California buckwheat, *Eriogonum* spp. can be combined with other hardy perennials such as yellow yarrow, *Eriophyllum confertiflorum*; coyote mint, *Monardella villosa*; and fragrant sage, *Salvia clevelandii* (Schmidt 1980).

Organic Mulches

Mulches are a good way to control weeds in ornamentals, lawn borders, around trees and in a vegetable garden. A mulch can be any protective substance that covers the soil. Organic mulches include straw, sawdust, rice hulls, and shredded bark. Mulches should be

applied deep enough to prevent weeds, but not so deep as to prevent moisture from reaching the soil. A mulch 4 inches thick is usually sufficient. Organic mulches are best for prevention of annual or biennial weeds. Perennial weeds such as quackgrass, thistles, or milkweed push up through organic mulches. At the end of the season, mulches can be worked into the soil to provide valuable organic material. Good areas to mulch are in-between rows of row crops, borders, and around trees to give a buffer zone for mowing (Synder 1975).

Prunings from trees, lawn clippings, leaves and other greenwaste materials from your yard can be effective mulches (Elmore 1996). Relatively inexpensive electric shredders are available from garden supply stores to make a good mulch from yard prunings (see Resources). Old newspapers can be used for mulch. Several layers must be used, and an organic mulch and stones can be added to the top to prevent papers from blowing in the wind. Materials such as rice hulls and Ewe Mulch™, a mulch made from wool, are commercially available (see Resources).

Synthetic Mulches

Plastic mulches consist of polyethylene sheets, or polypropylene and polyester fabrics. Fabrics may be spunbound, woven, or non-woven materials. For weed control, black polyethylene or other opaque material is used. Clear polyethylene is used for solarization (see below), but cannot be used as a mulch for weed control, as weeds will germinate and grow underneath this material. Black plastic also helps warm the soil, speeding germination and early root development. Black polyethylene mulch works best on row crops or in new ornamental plantings, as it is difficult to cut and fit around existing shrubbery or plants in a flower border, unless it is used in new planting beds (Synder 1975; Ellmore 1993b).

Comparative studies have found that black polyethylene suppresses weeds better than polypropylene in some cases (Elmore and Tafoya 1993). But the various plastic landscape fabrics are better than black polyethylene in areas where irrigation is practiced, as they



Quick-growing annuals can be planted to smother weeds.

allow the water to drain through. Landscape fabrics often have longer lifetimes than polyethylene and are also sold in sheets of convenient sizes that may be easier to use in ornamental plantings (Hembree 1995). Spunbound nonwoven landscape fabrics suppress perennials such as johnsongrass, *Sorghum halapense*, better than meshed, non-woven fabrics. In some California tests, woven polypropylene fabric suppressed purple nutsedge, *Cyperus* sp. better than 10 cm (4 in) of organic mulch (Elmore and Tafoya 1993).

Usually, an organic mulch of some type is used on top of the landscape fabric to prevent sun damage to the material and to help with weed control. Annual weeds are controlled well by synthetic mulches, but perennials may not be completely suppressed (Elmore 1991).

Woven polypropylene lasted longer than Typar® landscape fabric in California's hot San Joaquin Valley (Hembree 1995). Both these mulches effectively suppressed broadleaved weeds, grasses, and nutsedge (Walker and Prather 1996). In general, black polyethylene and any of the landscape fabrics will suppress weeds. Choice should be guided by expense and effective lifetime of the material.

Which Mulch?

Although any organic mulch will suppress weeds, there is some evidence that bark may be more effective than straw, because the bark contains allelopathic substances (see Allelopathy below). Many gardeners also prefer bark or pine needles because they feel it is more aesthetically pleasing than straw or other mulches.

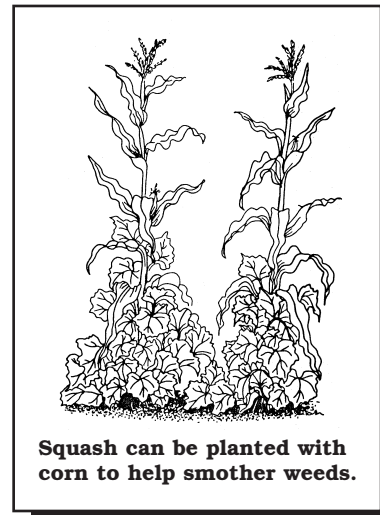
Deeper mulches are more suppressive than shallow ones. A 2-inch (5.1 cm) mulch is usually ineffective, 4 or 6 inch (10.1- 15.2 cm) mulches are needed. Both synthetic or organic mulches will help control water loss and reduce irrigation needs. Synthetic combined with organic conserves moisture better than either alone. Straw stops evaporation better than grass clippings or wood shavings. Finely pulverized mulches exclude light better than coarse ones, but weed seeds tend to germinate in these mulches (Elmore and Tafoya 1993).

Living Mulches

Mulches can also be planted. Low growing crops can be used as living mulches, or they can be mowed and left as a weed-suppressive residue. This approach is used more in vegetable production than in ornamental beds. For instance, dwarf brassicas have been used to smother weeds in corn production. The living mulch forms a dense mat, smothering weeds during the first weeks of corn growth. The dwarf brassicas then die off, leaving a surface mulch that suppresses weeds. Corn needs to grow without weed competition for 4-8 weeks to avoid significant yield loss. At 500 brassica seeds/m² (46/ft²), there is 80% weed control with no loss of corn yield. Dwarf brassicas are a cross between dwarf field mustard, *Brassica campestris* and Chinese cabbage, *Brassica campestris* subsp. *pekinensis* (Grossman 1993).

Allelopathic Mulches

Allelopathic mulches can also be used for weed suppression in the vegetable garden. As plants grow, they release biochemicals that either suppress or encourage the plants growing around them (Muller 1971; Rice 1987; Putnam and Weston 1986; Einhellig 1995). This phenomenon has been



Squash can be planted with corn to help smother weeds.

observed and written about since Theophrastus in 300 BC, but it was given the name "allelopathy" by Molisch in 1937 (Rizvi et al. 1992). For the purpose of this article, only weed suppressive allelopathic effects are considered. Weed allelopathy is one reason that crop rotation is such a successful pest control strategy. Weeds adapted to one crop may not thrive with another crop. In gardens, the same crop should not be grown in the same area each year, as weeds adapted to the crop will proliferate (Dunham 1973; Kempen 1992).

Allelopathy can be manipulated to reduce weeds in crops in several ways. One way is to plant allelopathic cover crops that suppress weeds. The cover crop is then either used as a living mulch, or the cover crop is killed and left as a weed suppressive residue while an economic crop such as corn, soybeans, fruit crops and vegetables are planted (Weston 1996).

Good allelopathic crops are rye, *Secale cereale*; wheat, *Triticum aestivum*; buckwheat, *Fagopyrum esculentum*; black mustard, *Brassica nigra*; and sorghum-sudangrass hybrids. For instance, yields of broccoli in California were increased up to 50% just by intercropping allelopathic wild mustard, *Brassica campestris* (Weston 1996; Jiménez-Osornio and Gliessman 1987).

Tomatoes transplanted into a rye mulch, then hand weeded gave yields greater than with herbicide production. Corn has been raised in rye mulch with good yields. Less success has been seen with squash (Weston 1996; Shilling et al. 1985; Dilday et al. 1997). In cold climates, sorghum-sudangrass can be planted in late summer. Crops can then be planted in the freeze-killed allelopathic mulch (Weston 1996).

Weed Suppressive Crops

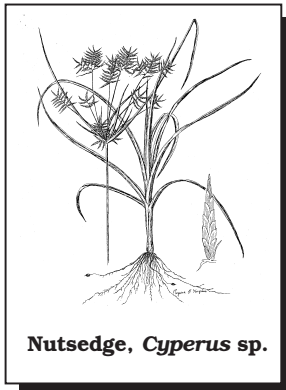
Another way to exploit allelopathy is to chose weed-suppressive crop varieties. Reports of allelopathic cucumbers, rice, oats, soybeans, Jerusalem artichokes, and sunflowers have been published (Weston 1996; Aldrich 1987; Saggese et al. 1985; Dilday et al. 1997; Walker and Buchanan 1982; Putnam and Tang 1986a). Celery and celery residues will suppress weeds and other crops, such as radishes and lettuce, but not cel-

ery or carrots (Bewick et al. 1994). In warm climates, squash interplanted with corn helps suppress weeds (Anaya et al. 1992).

The best way to get rid of a persistent perennial weed such as yellow nutsedge, *Cyperus esculentus*, in a garden is to grow sweet potatoes. Sweet potatoes are allelopathic to this weed and plantings can reduce nutsedge by 90% (Harrison and Peterson 1991). Pigeon pea, *Cajun cajunus*, also suppresses nutsedge (Hepperly et al. 1992).

Soil Incorporation

Another way allelopathy can be used is deliberate incorporation of allelopathic weed residues into the soil.



Nutsedge, *Cyperus sp.*

About 90 weed species show some degree of allelopathy (Putnam and Weston 1986). Shoots of fresh marigolds, *Tagetes patula*, when worked into the soil, cause pre-emergent suppression of a number of broadleafed weeds, but do not inhibit growth of corn and beans (Altieri and Doll 1978). Cutleaf evening primrose, *Oenothera laciniata*; and bulbous buttercup, *Ranunculus bulbosus*; are selectively allelopathic. Incorporation of residues reduce sicklepod and

cocklebur growth, but increase soybean yields (Dilday et al. 1997). Citral, citronellol and geraniol, which are components of lemongrass, *Cymbopogon citratus*, inhibit germination of spiny pigweed, *Amaranthus spinosus*; but do not interfere with the growth of tomato. Coffee beans contain weed-suppressive alkaloids, but are too expensive to be used in this way unless coffee plants are grown in the garden (Rizvi and Rizvi 1992b).

Shaded Tillage

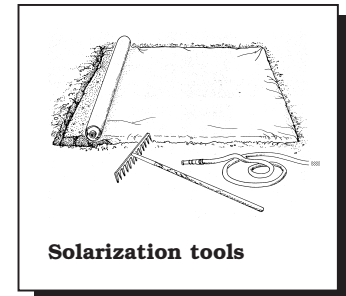
One reason that mulches suppress weeds is that many weed seeds need light in order to germinate. Tillage at night can reduce weed germination by 80% (Hartmann and Nezdal 1990). Shaded tillage can also help prevent the germination of weeds. Just shading the rototiller or plow with a tarp or cloth can reduce the number of broadleaf weeds by 40% (Ezzell 1992). Shaded tillage is more effective at suppressing small-seeded weeds such as lambsquarters and annual bluegrass than weeds with larger seeds (Ascard 1994).

Shaded tillage is sometimes used in an integrated program with flaming and brush weeding to control weeds in row crops such as onions. Brush weeding involves weed removal with motor-driven rotating brushes on an adjustable axis of rotation. Weeds are literally brushed away. Brush weeding has the advantage of less crop disturbance than disking, harrowing or other mechanical weed control measure (Melander 1998). Brush weeding is extremely successful where the working depth of the brush is set properly (Weber

1994). Brush weeders are not currently available for small gardens, but flaming and shaded tillage are possible on a small scale.

Solarization

At least 30 common broadleaved weeds and grasses can be controlled by solarization (Bell 1991). Some of these are perennial weeds that are very difficult to manage. The best time to get rid of them is before a desirable crop is planted. Plots can be rototilled to 4 inches (10.2 cm), leveled, then irrigated. After irrigation and before plots dry out cover with clear plastic, at least 1.5 mil (0.0015 in) thick. Edges of the plastic sheets are buried in soil trenches to keep them in place. In California experiments, plots were solarized in June, July or August. Six weeks of solarization was just as good as 9, 12 or 14 weeks. Success was seen with bermudagrass and johnsongrass (Elmore 1993a).



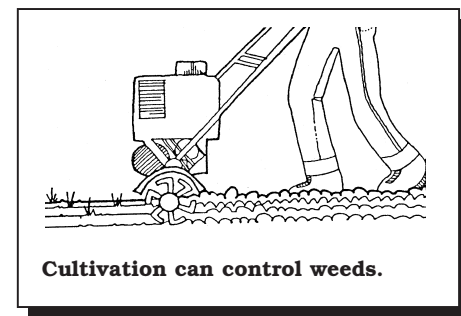
Solarization tools

Solarization for weed control is best where there is abundant sunshine. Difficult weeds such as purple nutsedge, *Cyperus rotundus*, and yellow nutsedge, *C. esculentus* have been controlled in Florida with solarization (see Quarles 1997). The disadvantage of solarization is the land must remain without a crop for at least 4-6 weeks during the summer.

Physical and Mechanical Methods

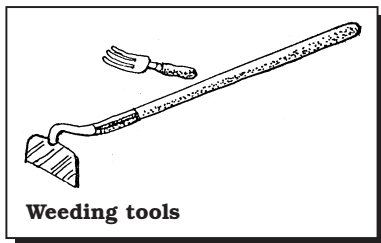
Pulling weeds by hand is the oldest method of weed control. Hand pulling is very effective for annual weeds before they have set seed. On some young perennials, hand pulling can also be effective. Plants are best removed when the ground is moist, and with perennials, vegetative parts must be removed from the garden to prevent resprouting.

Simple hand tools also have a long history (see Box B History of Weed Control). Hand tools and farm machinery are used to uproot plants, bury them, or destroy topgrowth. In agriculture, tillage implements such as the spike-toothed harrow, the disk harrow, the rod-weeder, the rotary hoe and shovel culti-



Cultivation can control weeds.

vators are commonly used. Flame cultivators cultivate between rows and kill weeds in crop rows by heat (Dunham 1973).



Weeding tools

For backyard gardening, a standard hoe, a hula hoe, a trowel, a dandelion knife, and an electric flail mower can handle many weed problems. For deep-rooted weeds or brush removal, an axe-like pulaski might

be useful. In a larger vegetable garden, a powered rototiller might be necessary to provide cultivation.

A hoe can be used to scrape broadleaf annual weeds off at the soil surface. The weeds are destroyed as they dry in the sun. Annual weedy grasses should be chopped out just below the soil surface. For larger areas, a rototiller can be used. Cultivating when moist, then allowing to the soil to dry will increase the control. Larger weeds may be mowed or flailed with a weed-whip such as the Weedeater (see Resources) (Elmore 1993 b).

For weeds such as Canada thistle in a garden, repeated hoeing may be enough for control. It may be necessary to put in erect growing plants such as okra, eggplant, corn, zinnias, and cosmos that will tolerate regular cultivations (Sylwester 1966).

In ornamental gardens and lawns, one troublesome weed early in the year is bermuda buttercup, *Oxalis pes-caprae*. These plants can be controlled by either pulling them up or cutting them down. They can be best pulled up when the parent bulb on this perennial is exhausted, usually in December. Oxalis is best cut down when the plant has 15-30 leaves. Use a Weed Whacker™ or other brand of flail mower. To avoid spreading the weed, do not move soil infested soil from one part of the garden to another (Drlik 1996).

For removing brushy weeds around the home, there is no need to use herbicides. With tools like the Weed Wrench™ (see Resources), tough weeds such as French broom, *Cytisus scoparius*, can be removed within three minutes without greatly disturbing the soil and encouraging other weeds to germinate (Daar 1992b). For removing dandelions, the Weed Hound is very convenient (see Resources).

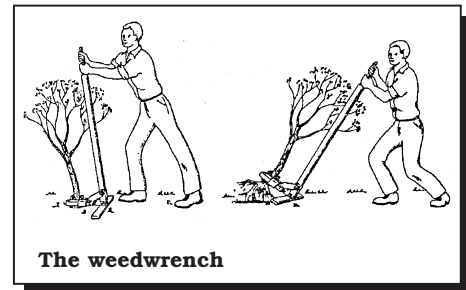
Flame Weeding

For weeds in sidewalks, gardens or lawns, flaming is inexpensive and is not labor intensive. Flame weeders can now be purchased at hardware stores or ordered from national suppliers (see Resources). The object of flaming is to burst plant cells, causing loss of fluids and thermal denaturation of proteins and DNA. Disrupting the photosynthetic apparatus in this way causes the weed to wilt and die. Overheating and charring the plant may cause a stimulation of growth from the remaining roots, requiring another flaming of the sprout. For optimum heating, hold the wand about an inch or more above the plants and move it slowly back and forth. To treat large areas, waving the wand back and forth over an area in a scythe-like motion may be the most effective way. After flaming, the weed may not wilt and die for several hours. Dead weeds can either

be removed and composted, or incinerated to ashes on the spot, leaving a mineral source for further plantings (Daar 1992; Swiaddon 1998).

Flaming works best on broadleaf annual weeds, but can also kill grasses and perennial weeds in some circumstances. Most weeds are most susceptible when they are at an early growth stage. This means that most weeds should be flamed when they are 1-2 inches high. Some weeds, such as lambsquarters, *Chenopodium album*, or common groundsel, *Senecio vulgaris*, are especially susceptible and can be killed at later stages. Mature grasses are especially resistant, as they form a protective sheath that shields the growing tip from the flame. Resistance of grasses means that flammers can be used to remove broadleaf weeds without damaging a lawn.

Resistant weeds and grasses can still be killed by flaming, but several treatments may be necessary. The first flaming causes the weed to dieback, but the root is not killed, and resprouting occurs. The weed should then be flamed again before photosynthesis resupplies the plant with nutrients. Even resistant mature annuals such as johnsongrass and Canada thistle, *Cirsium arvense* can be killed with repeated flaming (Daar 1992; Swiaddon 1998).



The weedwrench

Other Uses for Flaming

Flamers can also be used in vegetable planting beds for pre-emergent weed control. The planting bed is cultivated, then watered. When the young weeds have germinated and emerged, they are then flamed, and the crop is planted. Flamers can be used after crops such as carrots that have a long germination time have been planted. Corn and onions can tolerate some flaming after the crop has sprouted (Parish 1990). Weed control in lettuce, corn, cabbage, and onions by flaming produced yields similar to those obtained with herbicides (Balsari et al. 1994).

The handheld flamer can be used to weed between the rows as the crop develops. Flaming infested soil in gardens can also kill disease-causing pathogens. When pathogens are killed, opportunistic beneficial microbes can then rapidly recolonize (Daar 1992; Quarles and Daar 1996).

Flamers can reduce incidence of diseases such as apple scab caused by *Venturia inaequalis*. Apple scab overwinters inside of fallen apple tree leaves. Thermal treatment of leaves on the ground in the spring at temperatures about twice that of boiling water or 200°C (392°F) reduces ascospore levels by about 87% (Desilets et al. 1997). This ground temperature is easily reached by a flamer.

Handheld flamers are manufactured by Red Dragon, Flame Engineering, and others. Peaceful Valley Farm Supply sells several different models, including one very inexpensive one (see Resources).

Least-Toxic Herbicides

There are two kinds of herbicides, preemergent and postemergent. The only preemergent least-toxic herbicide available may be corn gluten meal (see the first article). When spread at about 40 lbs/1000 ft², corn gluten meal will suppress many of the common grasses and herbaceous weeds. Corn gluten meal should be applied just before weed seeds germinate, the area should be thoroughly watered, then left to dry (see Quarles 1999).

Various soaps have been used as least-toxic postemergent herbicides. These materials are relatively

benign, and in fact, soaps are fatty acid salts. Herbicidal soaps work best on annual weeds, since they only destroy exposed foliage. They do not translocate to kill perennial roots, but will kill perennial foliage. Woodstream Corporation sells an herbicidal soap (see Resources).



occurs naturally in foods, and in seeds, where it may act as a germination inhibitor. The material has low toxicity to mammals, and like other fatty acids is metabolized for energy, releasing carbon dioxide and water. It is a moderate skin irritant, and a severe eye irritant. It has low toxicity to birds, bees and fish and does not persist in the environment.

It is a fast-acting broadspectrum herbicide that has no soil activity. It can be used in seedbeds, next to shrubs and other ornamentals. It is non-volatile, and will not harm plants unless it is sprayed on them. Best results are seen when applied on a hot day, and results are seen in minutes. Spray foliage to wet, but not to the point of runoff. It should not be applied just before rain, as it will just wash away. Recommended spraying rates are 5-10% in water.

Scythe can be hazardous to aquatic invertebrates, and should not be applied directly to water. Protective gloves, clothing and goggles should be used when applying it. Scythe is not labelled for weed control in food crops (Mycogen 1999; Savage and Zorner 1996).

Vinegar as an Herbicide

Vinegar (acetic acid) has possibilities as an inexpensive, environmentally safe herbicide for spot treatment on organic farms and on lawns. Acetic acid shows little potential for bioaccumulation and easily biodegrades to carbon dioxide and water. It could be used to control

unwanted vegetation along roadsides and range lands; for control of weeds by homeowners around yards, brick walls and patios; for weed control in cracks in pavements (USDA 2002).

The acetic acid in vinegar can kill several important weed species. Vinegar from the grocery store contains 5% acetic acid. More concentrated solutions are more effective weed killers. USDA researchers have shown that water containing 10, 15 or 20% acetic acid killed 80-100% of annual weeds tested, including giant foxtail, *Setaria faberi*; up to 3 inches in height, common lambsquarters, *Chenopodium album*; up to 5 inches, smooth pigweed, *Amaranthus hybridus*; up to 6 inches, and velvetleaf, *Abutilon theophrasti*; up to 9 inches.

For its tests, the USDA used a commercially supplied white vinegar distilled from grain, with acetic acid concentrations ranging from 5-30%. They also made use of an apple vinegar at concentrations up to 14% acetic acid. Acetic acid should be handled carefully, as concentrated solutions could burn the skin or eyes. It has very strong "vinegary" smell, but when used outside the smell dissipates quickly. Concentrated vinegar can be obtained from Bradfield Enterprises (see Resources). Vinegar is also part of several least-toxic formulations (see Resources).

Citric Acid

Another organic acid, citric acid, is now being sold commercially as a least-toxic herbicide. The formulation contains 5% citric acid, 0.2% garlic, yucca extracts, and an unspecified amount of acetic acid. It has been effectively used as a spot treatment for thistles and other weeds, and is permitted for use as an herbicide in organic crop production (see Resources).

Essential Oils

In high enough concentration, essential oils such as orange oil and oil of cloves are phytotoxic. These ingredients are active components of some least-toxic herbicides (see Resources). Essential oils are volatile, and leave very few residuals. However, they should not be used if you have any sensitivity to orange oil, oil of cloves, thyme or other active ingredients. Commercial formulations often combine essential oils with vinegar (see Resources). Some of the formulations are so concentrated, they can burn or irritate the skin and eyes, so care in handling should be used.

Conclusion

Weed problems around the home and in the garden can be solved without using toxic herbicides. An IPM approach including prevention, designed plantings, organic, synthetic, allelopathic, and living mulches, flaming, hand-pulling, mechanical control, cultivation, and the least-toxic herbicides soap and corn gluten meal can be combined with weed mapping, monitoring and thresholds. Quite often a knowledge of what to plant, how, and where, is all that is needed for weed control.

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Resources

Organic Mulch

- Coca Bean Hulls—Peaceful Valley Farm Supply, PO Box 2209, Grass Valley, CA 95945; 530/272-4769
- Cover Crop Seeds—Peaceful Valley (see above).
- Electric Shredder—Gardener's Supply, 128 Intervale Road, Burlington VT 05401; 800/955-3370; 800/955-3370; 802/863-1700.
- Ewe Mulch—Appleseed, 55 Bell St., PO Box 101, Plymouth, OH 44865; 800/881-9665; 419/687-9665. Peaceful Valley (see above).
- Paper Mulch—Peaceful Valley (see above).
- Rice Hull Mulch—Penny Newman Grain Company, 3400 Bradshaw, Suite C, Sacramento, CA 95827; 916/362-1891.

Flamers

- Hand Held Flamers—Flame Engineering, PO Box 577, LaCrosse, KS 67548; 800/255-2469; 785/222-2873; Fax 785/222-3619. Peaceful Valley (see above). Gempler's, 100 Countryside Dr., PO Box 328, Belleville, WI 53508; 608/424-1544; Fax 608/424-1555.

Plastic Mulch and Landscape Fabric

- Black Plastic Mulch—Weedblock, Peaceful Valley Farm Supply, PO Box 2209, Grass Valley, CA 95945; 530/272-4769.
- Red Plastic Mulch (for tomatoes)—Harmony Farm Supply, 3244 Gravenstein Hwy, No. B, Sebastopol, CA 95472; 707/823-9125, Fax 707/823-1734.
- Tree Circles—BBA, 70 Old Hickory Blvd., Old Hickory, TN 37138; 615/847-7000; Fax 615/847-7068. Peaceful Valley (see above)
- Tyvar Landscape Fabric—BBA (see above)
- Spunbonded Polyester (Weed Stopper)—Harmony Farm Supply, see above
- Weed Mat—Gardener's Supply, see above.

Seed Mixes and Plants

- Lawn Seed Mixes—Peaceful Valley (see above).
- Alternate Lawns—Under a Foot Greenhouse and Gardens, 5326 72nd Ave. SE, Salem, OR 97301; 503/581-8915; High Country Gardens (see below).
- Weed Suppressive Plants—Cornflower Farms, PO Box 896, Elkhorn, CA 95759; 916/689-1015. High Country Gardens, 2902 Rufina St., Santa Fe, NM 87505; 800/925-9387; 505/438-3031; Fax 505/438-9552.
- Johnny's Selected Seeds, 1 Foss Hill Road, RR1 Box

2580, Albion, ME 04910; 207/437-4395; Fax 800/437-4290.

- Beneficial Weeds—R.H. Shumway's, PO Box 1, Graniteville, SC 29829; 803/663-9771.

Weeding Tools

- Weed Hound—Hound Dog Products, 6435 Cecilia Circle, Edina, MN 55439
- Weed Wrench—New Tribe, 5517 Riverbanks Rd., Grants Pass, OR 97527; 541/476-9492, Fax 541/476-9492.
- Hoes, etc.—Hardware Store, A.M. Leonard, 241 Fox Drive, PO Box 816, Piqua, OH 45356; 800/543-8955; Fax 800/433-0633.
- Weed Eaters—Poulan Weed Eater, PO Box 91329, Shreveport, LA 71149; 800/554-6723; 800/554-6723, 318/687-0100. Peaceful Valley
- Roto-Tillers—A.M. Leonard (see above)

Least-Toxic Herbicides

- AllDown (5% citric acid, 0.2% garlic)—Summerset Products, 4817 Normandale Highlands Dr., Bloomington, MN 55437; 952/820-0363.
- Bioganic (10% acetic acid, 2% each eugenol and thyme oil)—EcoSmart, 318 Seaboard Lane, Suite 208, Franklin, TN 37067; 888/326-7233.
- Bradfield (20% acetic acid)—Bradfield Industries, 610A E. Battlefield, No. 203, Springfield, MO 65807; 417/882-1442.
- Burnout (25% acetic acid, 12% inert)—St. Gabriel, 14044 Litchfield Rd., Orange, VA 22960; 800/801-0061.
- EcoExempt (21% eugenol, 21% 2-phenethylpropionate)—Ecosmart, see above
- Matran (67.3% acetic acid, 33.7% clove oil)—Ecosmart, see above
- Ringer/Safer (Superfast Weedkiller)(liquid soap)—Woodstream, 69 Locust St., Lititz, PA 17543; 800/800-1819.
- Scythe Herbicide (57% pelargonic acid)—Mycogen Corporation, 5501 Oberlin Drive, San Diego, CA 92121; 800/745-7476. Harmony Farm Supply, 3244 Gravenstein Hwy, No. B, Sebastopol, CA 95472; 707/823-9125.

Solarization

- Solarization Plastic—Polywest, 4883 Ronson Court, Suite R, San Diego, CA 92111; 800/765-9937.
- IRT Mulch—AEP, 14000 Monte Vista Avenue, Chino, CA 91710; 909/465-9055. Peaceful Valley (see above).

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