Weed management requires a multifaceted approach, built upon an understanding of weeds and the crop. Weed management may involve non-chemical methods, chemical methods (herbicides), or a combination of the two. Their aim should be to manage the weed population so it is below a level that will cause a reduction in your economic return (economic threshold). The decision on which methods to use depends on environmental concerns, marketing opportunities, desired management intensity, labor availability, weed pressure, and the crop. In some instances, the cost of controlling weeds may be more than the economic return obtained from any yield increase. This situation occurs when a few weeds are present or the weeds germinate late in the season. In those instances, the best strategy may be to do nothing. In other situations, weed populations and other considerations may require combining herbicides with nonchemical approaches.

The first step in weed management is to identify the weeds and understand their life cycles. Consult identification guides, such as *Weeds of the North Central States* (Bulletin 772, College of Agriculture, University of Illinois at Urbana-Champaign), for assistance. Weeds can be categorized by life cycles, and management strategies developed accordingly.

Annual weeds complete their life cycles in one year and reproduce solely by seeds. Annuals can be divided into summer or winter annuals, depending on when they grow. Primary tillage operations often control winter annuals before a crop is planted in the spring. The most common vegetable crop weeds (e.g., barnyard grass, giant foxtail, common purslane, redroot pigweed, and common lambsquarters) are summer annuals.

Perennial weeds live for more than two years and can reproduce by seed or vegetative structures (stolons, rhizomes, corms, bulbs, tubers, or roots). Because perennial weeds are difficult to manage in vegetable crops, it is usually better not to use a field with severe perennial weed problems.

Many non-chemical weed management methods are common sense farming practices. These practices are of increasing importance due to consumer concerns about pesticide residues, potential environmental contamination from pesticides, and unavailability of many older herbicides.

Cultural Practices

Farm practices should aim to establish a vigorous crop that competes effectively with weeds. This starts with *land selection*. A general rule is not to plant vegetables on land with a history of heavy weed infestation, especially perennial weeds. *Crop selection* can reduce the effects of weed competition. One criterion in selecting a crop should be the weed problems of the field. Plant the most competitive crops in the most weed-infested fields and the least competitive crops in the cleanest ones. Consider planting heavily infested fields as long-term set-aside acres or in non-row crops such as alfalfa. Permanent cover should help prevent buildup of annual weeds.

Table 1. Botanically Related Vegetables

Corn	**Cucurbits**	**Crucifers**	**Legumes**
Sweet corn	Cucumber	Rutabaga	Soybean
Dent corn	Winter squash	Kale	Pea
Amaryllidaceae	Summer squash	Broccoli	Snap bean
Onion	Pumpkin	Cauliflower	Lima bean
Garlic	Muskmelon	Cabbage	Dry bean
Chenopodiaceae	Watermelon	Brussels sprout	
Beet	**Solanaceae**	Radish	
Chard	Potato	Horseradish	
Spinach	Tomato		
	Pepper		
	Eggplant		

Crop rotation is another practice that can reduce weed problems. The characteristics of the crop, the methods used to grow it, and the herbicides used inadvertently allow certain weeds to escape control. Rotation also affects the weed management tools at your disposal. Rotating between crops will improve crop growth and competitiveness. Related vegetables should not be grown in the same location in successive years (Table 1).

Wild proso millet is an example of a problem weed where rotation is important for management. Rotation from sweet corn to small grains, early-planted peas, or alfalfa almost completely eliminates wild proso millet because these crops are established before the soil is warm enough for wild proso millet seed germination. A rotation from sweet corn to broadleaf crops would allow use of postemergence grass herbicides to manage wild proso millet.

Once a crop is selected, use adaptive, vigorous varieties resistant to diseases. Disease-infected plants cannot effectively compete with weeds. Varieties suited for cultivation in Illinois, Indiana, Iowa, and Missouri are listed in each crop section of this production guide.

Narrower row spacings and proper plant densities assure crop closure. A closed canopy shades out later emerging weeds and prevents germination of weed seeds requiring light. Weeds seldom are a problem once canopy closure occurs. Proper row spacing and plant density also allow row cultivation.

Table 2. Classification of Vegetable Crops According to Their Adaptive Field Temperatures

Cool-season		Warm-season	
Hardy*	**Semi-Hardy**	**Tender**	**Very Tender**
Asparagus	Carrot	Snap bean	Cucumber
Broccoli	Cauliflower	Sweet corn	Eggplant
Cabbage	Chinese cabbage	Tomato	Lima bean
Horseradish	Lettuce		Muskmelon
Onion	Potato		Okra
Pea			Pumpkin
Spinach			Squash
			Watermelon

* Hardy crops are most tolerant of cool temperatures and frost, while very tender crops are most susceptible to frost and cool temperatures.

Another cultural method to improve crop competitiveness is to use the correct planting time. Crops can be divided into warm- or cool-season plants, depending on the optimum temperature for their growth. Planting date affects the time to emergence and early seedling vigor of the crop, which are important in determining crop competitiveness. Cool-season crops germinate at cooler soil temperatures and thus compete better against early emerging weeds than warm-season crops. Table 2 lists crops according to their adaptation to field temperatures. Time plantings so that temperatures are favorable for crop growth. *Adequate fertilization and appropriate insect and disease management* are important in assuring a competitive crop. Adequate fertility assures rapid, uniform germination and good crop growth, which enhance the crop's competitive ability. Disease management information and insect management information are contained in this guide. While poor insect and disease control reduce a crop's competitiveness, inadequate weed control can also cause insect and disease problems.

Mulching can be useful in managing weeds. Mulches can be classified as either natural (straw, leaves, paper, and compost) or synthetic (plastics). Because natural mulches are difficult to apply over large areas, they are best for small, specialized areas. Natural mulches should be e spread evenly at least 1 to 1.5 inches thick over the soil to prevent light penetration. Natural mulch materials must be free of weed seeds and other pest organisms and be heavy enough so they will not be easily displaced by wind or water. A major advantage of natural mulches is that they add organic matter to the soil and do not need to be disposed of at the end of the season.

Synthetic mulches are easy to apply, control weeds within the row, conserve moisture, and increase soil temperature. Black or clear plastic mulches are the most common and are effective in improving early-season growth of warm-season crops such as tomato, muskmelon, watermelon, or pepper. Fast early-season growth of these crops improves their competitive ability against weeds. Plastic mulches used in combination with trickle irrigation can also improve water use efficiency.

A disadvantage of plastic mulch is disposal at the end of the season. Many landfills do not accept plastic mulches. Photodegradable plastic mulches have been developed, but their season-long persistence has been a problem, and they degrade into small pieces of plastic that contaminate the environment. Biodegradable plastic mulches are not yet widely available.

Mechanical Practices

Mechanical weed management relies on primary and secondary tillage implements such as the rotary hoe and the row cultivator. Mechanical weed management starts with seedbed preparation. Few no-till systems have been developed for vegetable crops. No-till suggestions are included in the section on reduced tillage systems.

Moldboard plowing is usually the first step in mechanically managing weeds. Moldboard plowing is particularly useful in controlling emerged annual weeds. *Rotary hoeing* is often an important second step in mechanically managing weeds in large-seeded vegetable crops (sweet corn, snap bean, lima bean, and pea). Rotary hoeing should be done after the weeds germinate but before they emerge. Rotary hoeing does not control large-seeded weeds such as velvetleaf and shattercane.

Once the crop has emerged or transplants are established, a *row cultivator* can be used to manage emerged weeds. Adjust the cultivator sweeps or teeth to dislodge or cover as many weed seedlings as possible. Seedling weeds can be killed by cultivating 1 to 2 inches deep. Best weed control is obtained with a row cultivator in relatively dry soils by throwing soil into the crop row to cover small weed seedlings. Avoid crop injury from poor cultivation, which will reduce crop yields.

In some vegetable crops, such as asparagus, *mowing* can be an effective weed management tool. Mowing can prevent the production of weed seeds and kill upright weeds, reducing competition. Mowing must be carefully timed to eliminate perennial, biennial or annual weeds that would compete strongly in vegetables because of their upright growth habit. Timely, repeated mowing also helps deplete the food reserves of perennial weeds (root systems).

Mechanical control has many limitations that must be considered when designing weed management systems. Because mechanical management relies on relatively dry soil, a rainy period may prevent the use of mechanical weed management options and lead to severe weed competition. Relying entirely on mechanical practices to manage weeds is labor intensive, and many growers will use herbicides combined with nonchemical approaches to control especially difficult weeds. Some of these difficult-to-control weeds include wild proso millet in sweet corn, Canada thistle, hemp dogbane, field bindweed, quackgrass, and johnsongrass. Newly introduced problem weeds often show up in scattered patches along headlands and field borders. These are best controlled or eradicated with herbicides before large areas are infested.

Biological Practices

Currently, no management system tools exist in the Midwest for using insects or diseases to control weeds common in vegetable crops. Most biological weed management systems to date have been developed to control problem weeds in rangeland areas in the West. One biological system that has potential in the Midwest is the use of cover crops to suppress the development of weeds. These systems are still experimental, but have promise for reducing herbicide use once they are fully developed.

The most promising cover crop system is the use of winter rye. Winter rye is planted in late summer or early fall and overwintered as a cover crop. In the spring, the rye is killed with either Roundup or Poast one week prior to planting the crop. The rye is left as a mulch on the soil surface, and the crop is no-till planted. The system, although experimental, does appear to provide early season control of many annual weeds.

Problems have been encountered that are still being investigated. These problems include the duration of weed control obtained, the spectrum of weeds controlled, and the requirement of herbicides to initially kill the cover crop and possibly for managing weeds that escape control by the rye. Because the system is experimental, it should be evaluated in small areas before anyone extensively adopts its use. Table 3 summarizes some of the nonchemical weed management practices. (See page 27.) The most effective weed management system is an integrated approach that combines many different practices. This approach must be adaptive, aiming to prevent weed problems or cope with any that occur.

Chemical Weed Management Strategies

Several herbicides are often labeled for a particular crop. Scouting your area to determine which weeds are present will allow you to select the herbicide that will give you the best control.

All the herbicides labeled for a crop are not necessarily listed in this guide. If you are unfamiliar with a herbicide, conduct a small test under your environmental conditions and cultural practices before using the herbicide extensively.

Herbicide Labels

Always Read and Understand the Herbicide Label Before Use. Reading the herbicide label is a very profitable use of your time. Information on the label will direct you to the correct uses, application methods, rates, and potential environmental hazards. Follow label directions for the best possible control with minimal crop injury and environmental contamination. The label contains restrictions on use and discusses environmental and soil conditions that affect crop injury, influence the effectiveness of weed control, and can cause nontarget site effects.

Do Not Use Any Herbicide Unless the Label States That It Is Cleared for Your Particular Use and Crop. Using a nonregistered pesticide can cause harmful residues in the vegetable crop, which can result in crop seizure and consumer injury. The label also states whether the herbicide is a restricted-use or general-use pesticide. Restricted-use pesticide labels contain a statement that the products are restricted and that only licensed applicators can buy them and supervise their application. The information in this production guide is current as of the date of publication. Watch for notices of changes in the U.S. Environmental Protection Agency (EPA) registration of herbicides in the *Illinois Fruit and Vegetable News*, the *Pest Management and Crop Development Bulletin*, the *Iowa Newsletter for Commercial Vegetable and Fruit Growers*, or the Indiana *Vegetable Crops Hotline*.

Reduced Tillage Systems

Reduced tillage systems are a method to combat soil erosion. **Glyphosate** or **Gramoxone Extra** can be applied outside the normal growing season to control emerged weeds in reduced tillage systems. Weeds should be growing actively, and the application must be made before the crop

has emerged. If you are applying glyphosate to control perennial weeds, it is recommended that it be applied before the soil is disturbed. After it is applied, glyphosate must be allowed to translocate throughout the perennial weed for several days, or incomplete control may result. Follow glyphosate label directions carefully for the rates and timing of application. If perennial weeds are not a major problem, you can eliminate early flushes of weeds by applying glyphosate or Gramoxone Extra to all weeds that emerge. Plant the crop with minimal working of the soil. Never apply glyphosate or Gramoxone Extra to an emerged crop because severe crop injury or death will occur.

Glyphosate and Gramoxone Extra will control most annual broadleaf and grass weeds. Neither herbicide has any soil residual activity, so other weed control measures will be necessary during the growing season. Gramoxone Extra will also suppress perennials by killing their shoots, but it does not control regrowth of perennial weeds from rhizomes or other underground storage organs. Glyphosate is better for controlling perennials because it will kill shoots and translocate to destroy underground parts. Glyphosate will only suppress some particularly hard-to-control perennials such as bindweed, hemp dogbane, and milkweed. To obtain control of these perennials, applications of high rates, repeat applications of glyphosate (within label guidelines), or mechanical removal may be necessary.

Herbicide Rates and Guidelines for Use in Vegetable Crops

All herbicide rates given in this guide are in amount of product per broadcast acre. Adjust amounts accordingly for banded applications. Make pre-emergence applications before weeds emerge or after removing any weeds present. Make postemergence applications after weeds have emerged. Make stale seedbed treatments only if weeds have emerged, but no crop plants are present. The herbicide recommendations given in this guide are not intended to replace careful reading of a current herbicide label. Re-registration of older herbicides has affected the availability of many products. Some of the older herbicides not re-registered are not listed in this bulletin, but may be available, and old stocks can still be used.

Environmental and Health Hazards of Herbicides

Non-targeted effects can occur from the use of herbicides. With the increased attention directed toward non-targeted effects of pesticides, it is very important that you educate yourself about these effects and consider them when designing weed management systems. The following section contains discussions of some of the potential environmental and health hazards of herbicides.

Environmental Hazards

Adverse environmental effects from herbicides can have long-term consequences that are difficult to correct and must be avoided. Some environmental hazards, such as herbicide drift and carryover, will affect mainly your operation, while other hazards, such as water contamination, affect all residents. The following sections discuss some of the potential hazards and methods to avoid them.

Herbicide carryover. Herbicide carryover from persistent herbicides has been a particular problem to growers of vegetable crops. Persistence is dependent on herbicide characteristics (method of degradation, water solubility, and rate of application) and site characteristics (soil type, rainfall, and temperature). Avoid carryover because correction of carryover problems once they occur is virtually impossible. The most important method to avoid herbicide carryover is to follow label rotation restrictions. Table 4 summarizes some of the label restrictions. (See page 28s.) Always refer to the label for specific information. If differences between the table and herbicide label occur, always follow label informations.

Herbicide drift. Another frequent hazard to vegetable growers is crop injury from herbicide drift. Certain herbicides, if not used correctly, can cause injury to non-target plants. Herbicides such as clomazone (Command), dicamba, and 2,4-D can drift up to a mile and cause serious damage to grapes, tomatoes, peppers, other vegetables, fruit trees, and ornamental plants. Before spraying clomazone, dicamba, or 2,4-D, survey the area for desirable plants.

Spray only on calm days, and use drift inhibitors when appropriate. Minimize drift by applying herbicides with nozzles that produce large droplets. Use an amine formulation of 2,4-D to reduce vapor drift. Spray clomazone, dicamba, and 2,4-D when the temperature is expected to be lower than 80 to 85°F for several days after treatment. Avoid applying clomazone to wet soils. Incorporate clomazone soon after application.

Spray tank residuals. Dicamba or 2,4-D residues in spray tanks can also injure susceptible vegetable crops. Carefully follow label directions for cleaning spray equipment after using dicamba or 2,4-D. If possible, do not use the same spray equipment to apply 2,4-D or dicamba that you use to apply other pesticides.

Herbicide resistance. There are now more than 50 documented reports worldwide of weeds developing resis-

tance to herbicides. Herbicide resistance tends to occur when a persistent herbicide is used year after year in the same field. Thus, continued use of the same herbicide on a perennial crop, such as asparagus, should be avoided. Many of the resistant problems have occurred with triazine herbicides, such as simazine and atrazine. The labels of those herbicides contain information about avoiding resistance problems.

Approaches to prevent herbicide resistance combine herbicides, mechanical (cultivation), and cultural (crop rotation) weed management practices. Rotate between or use tank mixes of herbicides with different mechanisms for killing the plant. For example, in asparagus rotate between Sencor and Treflan. Use tillage to control weeds that escape from herbicide applications. Especially important in minimizing any weed resistance that does occur is to scout your fields, paying special attention to any patches of a weed normally controlled by the herbicide.

Water quality. Residues of some herbicides such as atrazine, metolachlor, alachlor, cyanazine, and metribuzin have been found in surface and/or groundwater. The levels detected have normally been low, but contamination of water resources is a growing concern. For example, groundwater contamination from pesticides and nitrates is a particular concern in areas of the Midwest with sandy soils and shallow groundwater.

Factors determining the potential for groundwater and surface water contamination include herbicide solubility in water, rate of degradation, volatility, and tendency for the herbicide to attach to soil particles or organic matter. Herbicides that have high water solubility and long persistence are a particular concern.

Site characteristics (soil type, soil depth, water table depth, slope, and weather) also can lead to contamination of water resources from herbicides. You should be aware of the potential problem of herbicide contamination and take all possible steps to avoid contamination of surface and subsurface water resources.

TABLE 3. SUMMARY OF NONCHEMICAL WEED MANAGEMENT PRACTICES

PRACTICE	COMMENTS
Cultural	
• Land selection	Avoid fields with a history of weed problems.
• Crop selection	Grow the most competitive crops in fields with history of weed problems.
• Crop rotation	Rotate between vegetables and non-row crops such as alfalfa. Rotate between vegetables in different botanical categories.
• Adapted crop varieties	Select crop varieties adapted for your area.
• Proper row spacings and plant densities	Use row spacings and plant densities that assure rapid crop canopy closure.
• Correct planting times	Plant crops when soil temperatures favor rapid germination and emergence. Do not plant warm-season crops too early in the season.
• Appropriate fertility, disease, and insect management	Vigorous, healthy crops are more competitive against weeds.
• Mulch	Natural mulches are difficult to use over large acreages. Synthetic (plastic) mulches are useful to manage weeds within the row in warm-season crops. Consider disposal problems when using plastic mulches.
Mechanical	
• Moldboard plowing	This can eliminate emerged annual weeds.
• Rotary hoeing	This is useful to manage small-seeded weeds in large-seeded crops such as sweet corn, snap bean, lima bean, and pea.
• Row cultivator	Dislodge or cover as many weed seedlings as possible. Avoid damaging crop root systems.
• Mowing	Mow weeds as soon as flowers appear so no viable weed seed is produced.
Biological	
• Cover crops	This is still experimental. Winter rye system is the most promising and most effective against small-seeded broadleaf weeds.
• Insect or disease pests of weeds	No current systems use insects or diseases to manage weeds common to vegetables.

TABLE 4. LABEL RESTRICTIONS (IN MONTHS) ON ROTATING TO VEGETABLE CROPS

Herbicide	Tomato	Pea	Snap Bean	Sweet Corn	Pumpkin	Melon	Cole Crops
Soybean Herbicides							
Authority	30	30	30	18	18	18	30
Backdraft	18-26V	18	11	18	18	18	18-26V
Broadstrike Treflan	26+FB	26+FB	26+FB	26+FB	26+FB	26+FB	26+FB
Canopy	10[2]	12	12	18	18	18-30	18-3
Canopy XL	12[2]	30	30	18	18	18-30	30
Classic	15[2]	FB	FB	FB	FB	FB	FB
Command	NNY	AT	9	9	AT	9	NNY
Domain	NNY	NNY	NNY	NNY	NNY	NNY	NNY
Dual (II) Magnum	6	AT	AT	AT	18	18	18
Extreme	18-40+FB,V	18-40+FB,V	18-40+FB,V	18-40+FB,V	18-40+FB,V	18-40+FB,V	18-40+FB,V
First Rate	30	9	9	18	30	30	30
Flex Star	18	10	10	18	18	18	18
Gauntlet	NNY	NNY	NNY	18	NNY	NNY	NNY
Lorox	NNY	NNY	NNY	4	NNY	NNY	NNY
Passport	26	AT	AT	18	18	18	26
Pursuit DG[3]	40+FB	4	4	18	40+FB	40+FB	40+FB
Pursuit Plus	26	4	4	18	18	18	26
Python	26	4	4	10.5-18V	26	26	26
Raptor	9	0	9	9	9	9	18
Reflex	18	10	18	10	18	18	18
Salute	4	8	12	4	12	12	12
Sencor	4-10	4-10	12	12	12	12	12
Scepter	18	18	11	18	18	18	18
Squadron	18	18	11	18	18	18	18
Synchrony STS	9[2]	15	15	15	15	15	15
Tri-Scept	18	18	11	18	18	18	18
Valor	12+FB	12+FB	12+FB	4	12+FB	12+FB	12+FB
Corn Herbicides							
Aatrex and others	NNY	NNY	NNY	AT	NNY	NNY	NNY
Accent, soil pH < 6.5	10	10	10	10	10	10	10
Accent, soil pH > 6.5	18	18	18	18	18	18	18
Aim	12	12	12	0	12	12	12
Axiom/Axiom AT	NNY	NNY	NNY	NNY	NNY	NNY	NNY
Balance	18V	18V	18V	6	18V	18V	18V
Basis	18	8	8	10	18	18	18
Beacon	18	18	18	8	18	18	18
Bicep, Bicep II	18	18	18	AT	18	18	18
Callisto	18	18	18	NY	18	18	18
Celebrity, Celebrity Plus	10-18V	10	10	10-15V	10-18V	18-18V	18-18V
Define	12	12	12	AT	12	12	4-12V
Epic	NNY	NNY	NNY	NNY	NNY	NNY	6
Exceed	10	10	10	3	18	18	10
Hornet	26	10.5-18V	10.5-18V	10.5-18V	26	26	26
Harness Xtra	NNY	NNY	NNY	NY	NNY	NNY	NNY
Lariat, Bullet	NNY	NNY	NNY	AT	NNY	NNY	NNY
Leadoff	NNY	NNY	NNY	AT	NNY	NNY	NNY
Lightning	40	9.5	9.5	18	40	40	40
Marksman	18	18	18	AT	18	18	18
Northstar	18	8	18	8	18	18	18
Permit	8[2]	9	9	3	9	18	12-18
Princep	NNY	NNY	NNY	AT	NNY	NNY	NNY
Spirit	10-18V	10V	10V	8V	18	18	18
Steadfast	10-18V	10	10	10-15V	10-18V	10-18V	10-18V
Stinger	18	18	18	10.5	18	18	10.5
Surpass, TopNotch, Ful-Time	NNY	NNY	NNY	NY	NNY	NNY	NNY

[1]The rotation restrictions are in months after application. [2]Transplanted tomatoes only. [3]In Indiana, replant restrictions for transplanted tomatoes and peppers, cabbage, melons, and cucumbers is 18 months. NOTE: AT = anytime herbicide labeled for the crop or no rotation restriction exists, FB = a field bioassay required before planting the crop, NY = the crop can be planted the year after application, NNY = not next year, the crop cannot be planted the following year, V=variable, intervals vary by variety or conditions specified on label.