Chapter 14: Mechanical Weed Control: Post-Plant

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Summary

Mechanical weed control used after the cash crop is a common practice to control germinated weed seeds or weeds that have already emerged. The types of tools employed generally kill weed seedlings or small weeds before they are well established and competitive with the crop. Like most other forms of weed control, effectiveness of mechanical weed control is higher when performed at the optimum timing. Blind weed control tactics need to be performed after the seed have germinated but before the roots have become established. Likewise, between-row cultivation is most effect on weeds up to three inches. Dry soil conditions and higher air temperatures that enhances weed desiccation create the best conditions for post-plant mechanical weed control.

Introduction

Cultivation practices used to control weeds after a crop has been planted is known as post-plant tillage. There are two types of post-plant tillage intended for weed control: blind cultivation and between-row (also known as inter-row) cultivation. Both tactics are more suited for tilled seedbeds, although some post-plant tillage equipment is available for no-till or high-residue cover crop systems. Other reasons for using blind cultivation are to break up soil crust for aeration and to promote faster drying, and incorporating wheat and other small crop seeds that have been broadcast on the soil surface.

Successful post-plant tillage requires diligent monitoring of field conditions and the weather, which are both important for effective mechanical cultivation. In addition to suitable soil and weather conditions, weed size or growth stage is critical for successful control of the weeds. The need to monitor the weather and soil conditions is critical because there may only be a small window that is ideal or appropriate to cultivate. For grain crops such as corn and soybean in the Mid-Atlantic region, the months of May and June are when most post-plant tillage takes place prior to crop canopy development. Like pre-plant mechanical weed control, Dry soil conditions and higher air temperatures that enhances weed desiccation create the best conditions for post-plant mechanical weed control.

The success of post-plant tillage requires the use of proper equipment. Many different tools have been developed to control weeds after crop planting. Choosing the right equipment and having it properly adjusted will help farmers take advantage of those ideal times to get into the field and achieve good weed control. Relying on mechanical weed control requires thoughtful consideration about time, labor, tractor horsepower needs, and implement size. The size of the tractor and implement must match to optimize implement performance as well as energy use. Larger sized implements can save time, but also require a larger tractor with more horsepower. Having multiple tractors available can allow for the use of more than one rotary hoe, tine weeder, and cultivator to cover all of the ground in a timely fashion. The right piece of equipment will pay for itself by improved weed control when only a narrow window is available to perform the operation. In addition, having skilled tractor operators who knows when crop, weed, and environmental conditions are optimum to achieve effective mechanical weed control is critical.

Considerations for Blind Cultivation

Blind cultivation controls weed seedlings germinating near the soil surface. Their roots are above those of the crop. An implement is "blindly" (not worried about driving on the crop rows) pulled through the soil, dislodging small weed seedlings both in the crop row and the area between the crop rows. The initial blind cultivation takes place at the same time as cash crop germination and root development but before crop emergence. Subsequent blind cultivation events may continue after the crop has emerged every five to seven days (or as weather allows) for a period of two to four weeks. Use of blind tillage to control early weed flushes can be successful if done at the proper time and with precision. In an organic soybean system, North Carolina researchers reported that two passes of a rotary hoe reduced the density of redroot pigweed by 56% and broadleaf signalgrass by 65% (Place et al. 2009). Inaccurate operation can result in damage or removal of young cash crop plants, reducing populations and, potentially, yield (Martens and Martens 2005). Some research has reported up to a 14% reduction in corn population from the use of a rotary hoe in tilled systems (Mulder and Doll 1993; VanGessel et al. 1995; Cox et al. 1999; Mohler et al. 1997). Bates et al. (2012) observed an 8% reduction in corn population from a combination of rotary hoe plus high residue cultivation. The conditions of the soil as well as crop growth stage dictate whether crop injury will be a concern. Increasing the cash crop seeding rate may help overcome some stand loss. This is especially true for crops such as corn, where adequate plant population is critical to maintain yield.

Once the crop reaches a certain size, blind cultivation can cause crop damage. Emerged weeds also become established and too big to control. In general, blind cultivation can be used from planting time to 8-inch tall corn and 4-inch tall soybean as long as weeds are in the cotyledon stage or earlier. Farmers should make sure that they

do not cultivate any bean crop from cracking through the crook stage (Figure 14.1). At this stage, cultivation can snap the stem of the bean and kill the plant.

Some crops are better candidates than others for blind cultivation. In general, crops that quickly develop large taproots after germination, including corn and soybean, and crop seeds that are planted at a depth of one inch or more will tolerate blind cultivation. It is not used with small-seeded crops that are planted at shallow depths such as alfalfa, clover, and canola because it can reduce the crop population. Blind cultivation is especially effective in controlling small-seeded annuals such as pigweed species and common lambsquarters. It is less effective on large-seeded annuals such as velvetleaf, common and giant ragweed, and annual morningglories because these seedlings often root more than an inch deep in the soil. Blind cultivation is not effective on perennial weeds with well-established roots.

The growth stage of the weed and crop are important factors in determining timing of blind cultivation. The *white thread* stage when a small uprooted seedling resembles a white thread is the ideal time for weed control (Figure 14.2). In this stage, the weed seed has germinated but has not yet emerged from the soil or developed its first true leaves. Weeds that have emerged are not as easily killed by blind cultivation. The typical window for blind cultivation is 5 to 14 days after the previous tillage operation. Careful field scouting will determine optimal timing. Scout for the weeds' growth stage by gently digging through the soil with a knife and checking for weed seed germination and white thread stage seedlings (a general rule of thumb is that if the weeds are visible from the seat of the tractor, a rotary hoe will not be effective).

Figure 14.1. Soybean in the emergence through crook stages are susceptible to injury from blind cultivation (Photo credit: W. Curran, Penn State).

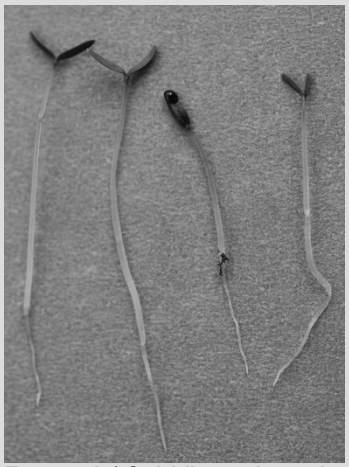

Figure 14.2. White thread stage of a pigweed (Photo credit: W. Curran, Penn State).

Weather and soil conditions play an important role in the success of blind cultivation. Ideal conditions for cultivation are when the soil is friable (dry to slightly

moist but not wet), the weather is sunny and breezy, and no rain is forecast for the next two days. In dry soil, the cultivator will uproot weeds without creating clods (also known as root balls). If the soil is too wet, the weed may be uprooted with a root ball, which will allow the weed to survive. Sunny and breezy weather helps desiccate and kill the weed seedling. Rain soon after cultivation may allow weeds to resprout and survive, but even if conditions are less than ideal, cultivate if possible -- some weed removal is better than no weed control at all.

Cultivation frequency may also be determined by soil and weather conditions. Rainfall can prevent timely cultivation. The ideal schedule is to cultivate once a week as soon as the crop germinates. Typical pattern of cultivation when relying extensively on mechanical weed control is are two to three blind cultivations followed by two to three between-row cultivations.

Tools for Blind Cultivation

The two primary tools used for blind cultivation in field crops are the flex-tine weeder and the rotary hoe. Both are available in a range of sizes from 10 to 40 feet and are typically operated at a speed of 5 to 15 mph.

Flex-tine weeder

The flex-tine weeder (also called tine weeder) is designed to remove weeds in and outside the crop row (Figure 14.3). It has a series of flexible metal tines that are pulled through the soil to uproot newly germinated weeds in the white thread stage. Dry soil conditions are best. Tines can be added or removed and the pressure of each tine increased or decreased based on the settings needed for each implement, crop, and targeted weeds (Figure 14.3). The adjustments allow for aggressive cultivation behind the tire pass and light cultivation through the crop row. Effective weed control is determined by the downward pressure on the tines, soil moisture, and tractor speed. Faster tractor speeds increase the vibration of the tines as they are pulled through the soil. The vibrating tines uproot small

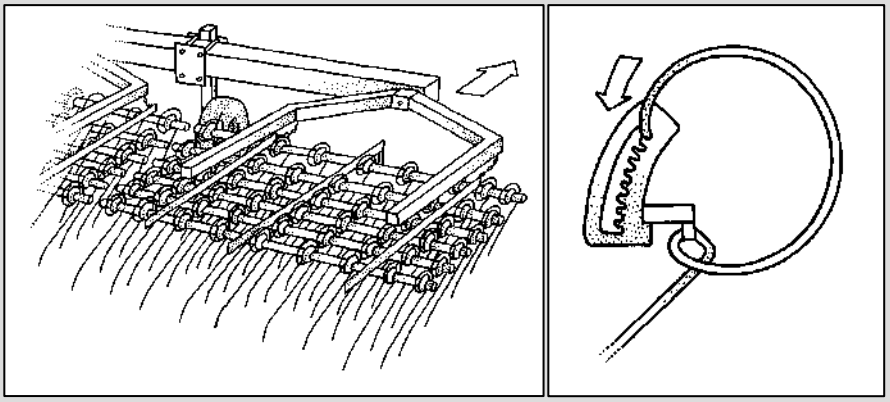

Figure 14.3. One section of a flex-tine weeder (left) and 0n some models of tine weeders, the pressure of each tine can be adjusted by changing the setting of the coil (right) (SARE 2002).

plants and shake soil loose from newly germinated weeds, bringing them to the soil surface to desiccate and die. Tine weeders perform best in clean-tilled seedbeds (i.e. seedbeds free of plant residue). Plant residue can get caught in the tines and result in damage to the young crops and ineffective weed control. The tine weeder can be used on a number of crops including barley, wheat, oats, corn, soybean, sorghum, and sugar beets. In general, tine weeders are less aggressive than rotary hoes.

Rotary hoe

The rotary hoe (Figure 14.4) is a ground-driven implement that uses a series of wheels with metal spoons radiating out (Figure 14.4). The spoons are oriented on the wheel so that they enter straight into the soil and then emerge at a slight angle. As ground speed increases, the tips of the spoons penetrate the soil and kick out newly germinated weed seedlings. Like the flex-tine weeder, the rotary hoe also is most effective during the white thread stage of weed development. Avoid using a rotary hoe in soybean during the plant's crook stage. Blind cultivation can be resumed in soybean once cotyledons are completely unfolded and is best during the afternoon as the plants tend to be slightly flexible and limber during the hotter part of the day. This will lower the risk of stems snapping. Cultivate a small section of the field initially to monitor the crop and ensure that it is not being damaged. Like flex-tine weeders, rotary hoes generally perform best under dry soil conditions and with little residue. However, there are various types of rotary hoes that can work in high-residue environments. With the high-residue rotary hoe, the distance between the gangs of hoe wheels is greater to avoid the wheels becoming plugged by crop residue. Place et al. (2009) reported four passes of a rotary hoe on a stale seedbed reduced weed cover by 57%.

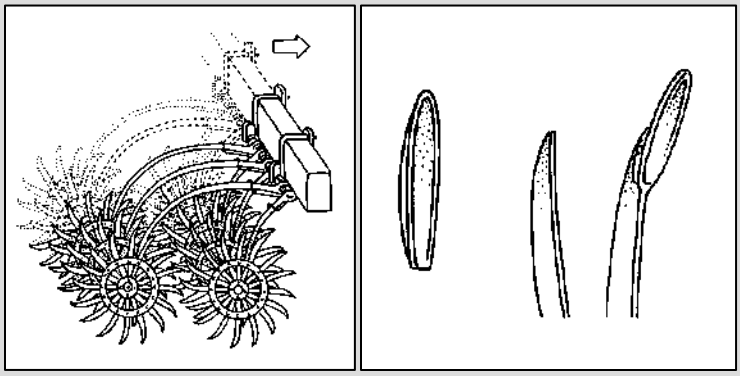

Figure 14.4. A rotary hoe (left) and the spoons on a rotary hoe radiate out from the wheel and penetrate the soil to kick out newly emerged weeds. Spoons wear out over time and should be replaced with new ones periodically (SARE 2002).

Considerations for Inter-Row Cultivation

Tilling the soil between crop rows to control emerged weeds is known as inter-row cultivation. Only the area between the crop rows is disturbed. Spacing between the crop rows determines the feasibility of using these tools. Adding guidance systems

provides greater precision, increased operation speed, and reduced potential for crop damage. Inter-row cultivation is less effective in controlling larger, well established weeds. In addition, larger weeds can become entangled in the equipment and result in crop damage and reduced weed control.

A conventional cultivator is designed for low-residue environments. The shanks are spaced less than six inches apart. These cultivators are designed for conventionally tilled fields with loose soil and little to no plant residue. The typical operating depth for these units is one to two inches, which allows for adequate control of weeds up to three inches tall and that are rooted shallowly. This method avoids bringing up weed seeds from deeper in the soil profile that could subsequently germinate and become established. Typical tractor speed for this type of cultivator is 2-8 mph. Slower operating speeds may be necessary for smaller crops. Faster operating speeds may be acceptable for larger crops that can tolerate contact with the cultivator sweep.

Cultivators are equipped with sweeps (or shovels) attached to the end of the shank on the cultivator unit. The aggressiveness of the between-row weed control is determined by the orientation of the shanks on the toolbar and the type of sweep selected. In addition to the sweeps, some cultivators are equipped with weeding disks to control weeds close to the crop rows. Other disks are sometimes added to the cultivator to form furrows for irrigation, ridges, or beds (disk-hillers).

Increasing tractor speed increases aggressiveness of the cultivators as a result of more vibrations and more soil disturbance. Attachments can be added to most cultivators to prevent or limit the amount of soil moved into the crop row when the crop stems cannot withstand the soil movement. Moving soil into the row to bury small weed seedlings is a common practice one the crop is well established. Moving soil and burying weed seedlings is best with dry, friable soil.

Cultivation can disrupt the layer of herbicide treated soil and allow for additional weed emergence (see Chapter Chapter 3: *Weed Emergence, Seedbank Dynamics, and Weed Communities*). Adjusting cultivators so they do not dilute herbicides or bring untreated soil to the surface will help to maintain herbicide's residual control.

Weeds with fibrous root systems are more tolerant to cultivation than weeds with taproot. It is more challenging to dislodge fibrous root systems from the soil than taproots. Furthermore, taproots are easier to separate form aboveground tissue than fibrous roots.

There is generally more time and flexibility for inter-row cultivation than for blind cultivation because these tools can control larger weeds than flex-tine harrows and rotary hoes. There are a number of different shanks and sweeps that are available for between-row cultivation. Shanks connect the sweeps to the body of the cultivator and are designed in various styles. The shanks can be rigid or flexible, allowing the sweep to remain stable or to vibrate through the soil. The type of weed control needed determines what type of shank should be used.

Common shanks and sweeps include the following:

- The Danish S-tine shank cultivates loose and residue-free soil (Figure 14.5). The shank, in combination with a moderate profile crown (middle area of the sweep), will vibrate and mix the soil, uprooting weeds and shaking soil loose from their root systems. This shank controls small seedlings and weeds with shallow root systems.
- The C-shank is more rigid and vibrates less than the S-tine shank, but it can still flex around rocks and other obstructions (Figure 14.5). It is designed for harder soil or fields with greater amounts of plant residue. The C-shank resists flexing and holds the sweep flat to slice through the soil, cutting the weeds.

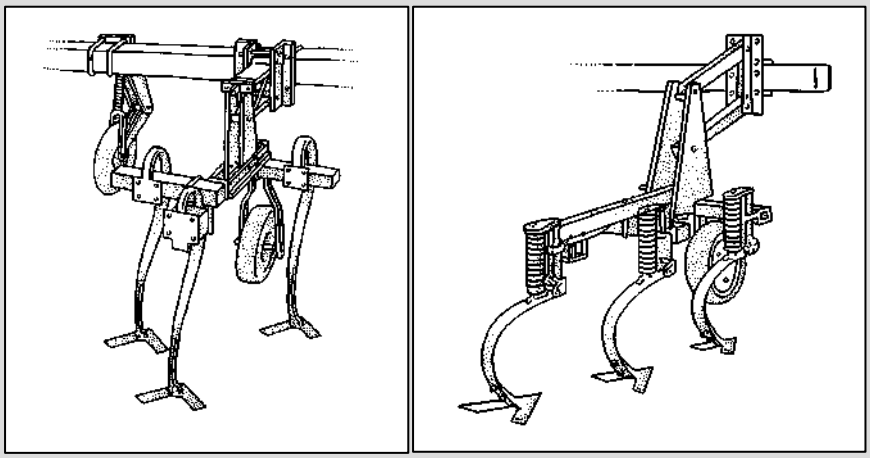

Figure 14.5. A Danish S-tine shank (left) and conventional C-shank cultivator (right) (SARE 2002).

- The V-shaped row crop sweep (Figure 14.6) can be used on C, S-tine, and straight shanks. Widths available range from 6 to 28 inches. The row crop sweeps slice through the soil, uprooting smaller weeds and cutting root systems of larger weeds. The sweep is designed with a flattened crown, and the angle of the V-shaped wings in relation to the crown is low. As a result, the sweep cuts more than it mixes the soil, which causes less soil disturbance.
- The Danish tine sweep is used in cultivation (Figure 14.6). It was developed for use with the Danish S-tine shank and is available in widths from one to nine inches wide. The sweeps are designed with either a low or moderate profile crown. With the lower crowned sweep, soil mixing and weed control is similar to that of the V-shaped row crop sweep. The moderate crowned sweep offers greater soil mixing and better soil penetration than the wider flatter sweeps.
- A variation of the Danish sweep is the duckfoot, or goosefoot, sweep (Figure 14.6). This type of sweep also was designed for the Danish S-tine and comes in widths from two to seven inches wide. Because of its moderately sloped crown,

the duckfoot sweep offers better soil penetration, especially in hard soil. It also is better at uprooting rather than slicing or cutting weeds. The sweep mixes the soil. The shape of the S-tine allows it to vigorously vibrate, knocking soil from the weed roots and leaving them exposed to desiccate on the surface of the soil.

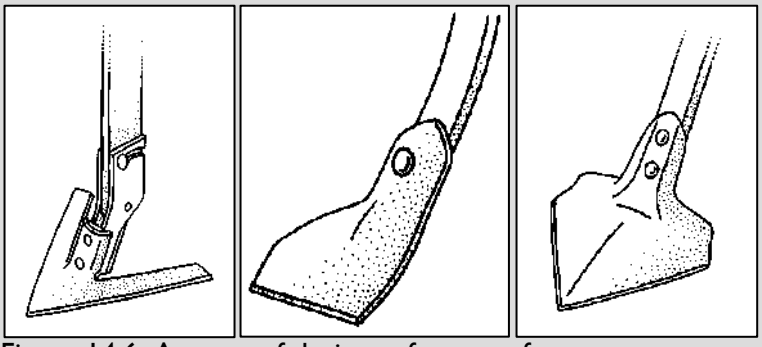

Figure 14.6. A range of designs of sweeps for row-crop cultivators include V-shaped sweep (left), half sweep (center), and duckfoot sweep (right) (SARE 2002).

High Residue Cultivation

Cultivators designed for use in high plant residue environments have been on the market for more than 30 years. These cultivators work in no-till, ridge-till, or tilled fields with a large amount of plant residue. Initially, they were more commonly used in ridge-till systems and designed with a moderate crown and V-shaped wings to throw soil, forming a "ridge". The no-till sweeps on the cultivator were more recently redesigned with a flat crown for less soil disturbance. These types of cultivators typically have one large sweep between two crop rows compared to three or more shanks between crop rows with conventional cultivators. The action of the high residue cultivators is based on slicing through the weeds and separating the root system from the above ground tissue. As a result, high residue cultivators use typically used on slightly larger weeds than standard row-crop cultivators.

The three-piece sweep, or high residue sweep, is designed with low disturbance straight shanks (Figure 14.7). As the name implies, the sweep is made up of three components: a replaceable point and two double-edged reversible shares. The point penetrates the soil, while the shares lie flat just below the soil surface and slice weeds, leaving the surface residue somewhat in place. The shares come in widths ranging from 14 to 28 inches, which determine how close shares travel next to the crop row. These types of sweeps are mounted on either a curved or straight rigid shank.

In no-till cultivation, dual gauge wheels in front of the cultivator unit keep the plant residue in place, while a coulter cuts through the residue allowing the sweep to penetrate the soil (Figure 14.7).

Each additional pass with the cultivator will reduce the amount or redistribute any surface plant residue. For ridge-till farmers, an extended wing can be attached to the sweep to create an elevated ridge in the crop row. Ridging wings are usually used

during the last pass with the cultivator when the crops are well established and can withstand soil being thrown into the crop row to form the ridges.

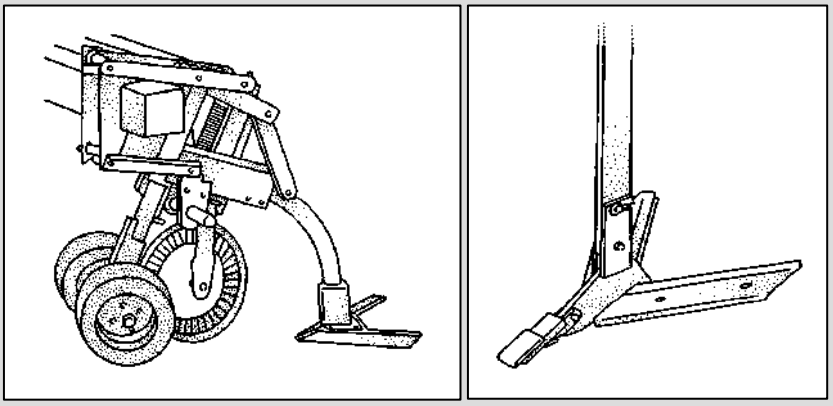

Figure 14.7. A high residue cultivator (left) with gauge wheels, coulter, and sweep; and a three-piece sweep (right) typically used for high residue cultivators (SARE 2002).

Specialized Cultivator Technology

Several mechanical weed control tools have been developed for higher valued horticultural products. These tools are designed to control small in-row weeds or weeds right next to the crop row in tilled seedbeds. Spyder, torsion, finger, and spring hoe weeders are examples of tools often used in high value crops where effective herbicides are not registered for use or in organic production. These tools require precision, which may mean using smaller equipment or slower operational speeds. These specialized tools are much less common in agronomic crops.

Various guidance systems also are available to ensure accuracy in the operation and allow faster operating speeds. Technology that can allow precision guidance with numerous field operations (including cultivation) is developing quickly. Faster operating speeds reduce operation costs (Paarlberg et al. 1998; Hanna et al. 2000). According to Bates el al. (2012), a six-row high residue cultivator equipped with a hydraulic guidance system operated at 7 mph greatly reduced the amount of necessary time and labor when compared with operating the same equipment at 3 to 4 mph. More effective weed control and less crop injury from cultivation or other operations can also be reduced with sensory guidance systems (Liebman et al. 2001).

Integrated Systems

Combining inter-row cultivation with herbicides and cultural weed control tactics diversifies a weed management program and prevents herbicide-resistant weed evolution. Nord et al. (2011) compared high residue cultivation in an organically managed soybean crop with 30-inch rows to soybean planted in narrow rows (7.5

inches) with no cultivation. In the study, soybean were no-till planted into a rolled rye cover crop. Weed biomass generally declined when cereal rye biomass increased. Added cultivation was necessary when weed density was high, reducing weed biomass by 38 to 62%.

Banding herbicides is one method of applying less total active ingredient per acre (see Chapter 7: *Chemical Control*) and it has been used mainly with conventionally tilled systems. But studies have found favorable results with no tillage and use of high residue cultivators (Snyder et al. 2016). Keene et al. (2016) compared high residue cultivation in both no-till corn and soybean planted into cover crop residue. Two passes with a high residue cultivator in combination with banded herbicide achieved similar cash crop yield as a postemergence herbicide application.

Mowing as a Method to Suppress Weeds

Mowing is a mechanical tactic that can play a critical role in managing weeds in forage crops or noncrop areas. Repeated mowing reduces the weed's competitive ability, depletes carbohydrate reserves in the roots, and can prevent seed production. The success of mowing for weed control depends on the target weed species, timing, and frequency. Mowing is more effective on annuals and biennials that are beginning to flower than on plants in the vegetative stages. When weeds are mowed in the vegetative stages, they are more likely to recover and regrow.

Mowing also tends to be more effective on dicots (broadleaves) than on monocots (grasses and sedges), which tend to be more adapted to cutting. A number of creeping perennials and dicots also can be suppressed with mowing. Successful control of these weeds depends on mowing frequency to prevent regrowth and flowering and seed production. One goal when mowing perennials is to deplete carbohydrate reserves in the vegetative portions of the plant by frequent mowing (every 30 days). Another goal is to prevent seed production. Simple perennials such as dandelion and the plantains are less susceptible to control by mowing, as they tend to be adapted to low and more frequent cutting.

Several different types of tools are available for mowing:

- *Rotary mowers* are the most common and range in size from a common push or self-propelled lawn mower to large disk mowers that are used to mow hay. These mowers all have rapidly rotating blade(s) that cut plant material a few inches or more off the ground. The sharper the blades, the better the cut. These mowers typically cut plant material into medium sized pieces and propel them back to the ground, to the side, or out the back of the machine.
- *Flail mowers* have small blades on the end of chains attached to a horizontal axis. They are available in various sizes, ranging from a few feet wide to 20 feet. These types of mowers are excellent at cutting large material and pulverizing it into small pieces. These mowers typically propel the cut material toward the ground

to the rear of the mower. Some of the larger models are called "stalk choppers" and are used to mow crop residue after harvest.

Key Points

- Post-plant cultivation involves blind tillage shortly after cash crop planting and inter-row cultivation after the weeds and crop have emerged.
- Blind cultivation is used shortly after the cash crop is planted to control germinated weed seeds and small weed seedlings. Blind cultivation should be repeated every five days or more or until the weeds have mostly emerged.
- Inter-row cultivation is used after the cash crop and seedling weeds have emerged and is repeated once a week until the critical period for weed control in the cash crop has passed.
- High residue cultivators can control weeds with shallow soil disturbance in reduced till environments.
- Integrated approaches combine mechanical weed control tactics with cultural and chemical approaches to diversify the weed management program.
- Mowing is most effective on annuals and biennials that are beginning to flower.
- Mowing is more effective on annual broadleaf weeds than on grassy weeds.
- Mow perennials to deplete carbohydrate reserves in the vegetative portions of the plant by frequent mowing and to prevent seed production

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