Chapter 13: Mechanical Weed Control: Pre-Plant

Charlie Cahoon, William Curran, and David Sandy

Summary

Tillage, or mechanical weed control, is an important component of integrated weed management. While most primary tillage is used for seedbed preparation, tillage can kill weed seedlings and bury weed seeds. However, it also can stimulate weed seed germination or bring weed seeds closer to the soil surface where they may be more likely to emerge. No-tillage production uses herbicides to replace primary and secondary tillage for controlling emerged weeds prior to cash crop planting. The goal is to incorporate mechanical weed control tactics that diversify the cropping system and reduce the potential for herbicide resistance while keeping soil conservation and productivity at the forefront.

Introduction

Mechanical weed control generally uses some type of machine pulled by a tractor to physically slice, chop, or uproot small weeds. Hand hoeing or hand removal is also considered mechanical weed control, but this chapter will only focus on mechanized tactics before crop planting.

Mechanical weed control is an important component to an integrated weed management system. Before herbicides were commercialized, preplant tillage and inter-row cultivation were the primary methods of weed control. These methods are still used in many organic systems. However, it is difficult to use mechanical cultivation tools and maintain conservation compliance in continuous no-till systems.

Preplant tillage for weed control includes plowing, disking, and field cultivating. These primary and secondary types of tillage can kill emerged weed seedlings and bury weed seeds below the depth of successful germination and emergence and help reduce the rate and spread of some perennial weeds. Inversion tillage, which generally means using a moldboard plow, can bury weeds deeper into the soil profile, but also can bring weed seeds to the surface where they can germinate. Preplant tillage also can spread vegetative structures of some perennial weed species.

Preplant tillage can be divided into two categories: primary and secondary. Primary tillage occurs between harvest of one crop and planting of a second crop. Often this method is intense because it breaks open compacted soils, loosens the top soil layer in preparation for secondary tillage, and chops and incorporates crop residue. Examples of primary tillage implements are moldboard plow and chisel plow.

Secondary tillage occurs after primary tillage. It is shallower and less aggressive than primary tillage. This method is used to crush soil clods left by primary tillage, incorporate fertilizer, create a homogenous seedbed, or firm the soil in preparation for planting. Field cultivators, finishing disks, harrows, and cultipackers are examples of secondary tillage implements. Secondary tillage implements can be used mechanically incorporate herbicides into the top 1 to 2 inches of soil. Incorporating herbicides need to be done with care to prevent moving the herbicides too deep in the soil where its effectiveness will be reduced. Field cultivators and finishing disks should be set for a 3 to 4 inch depth; generally herbicides will be incorporated half the depth that the cultivator is operated.

Tillage Implements

Preplant tillage implements vary in their roles in preparing fields for planting and in weed control methods. Many implements have been developed to control weeds, manage residue, and prepare a seedbed. Below are descriptions of a few tillage implements as defined by *Steel in the Field: A Farmer's Guide to Weed Management Tools* (SARE 2002):

- *Moldboard plow*. Considered the primary tool for inverting the soil, the moldboard plow (Figure 13.1) consists of a large contoured shank (plow bottom) that cuts the furrow bottom and wall, flips the furrow slice, and inverts the soil surface (Walters 2017). This plow was developed to bury plant residue and is great for either uprooting small and large weeds or completely burying seedlings and seed.

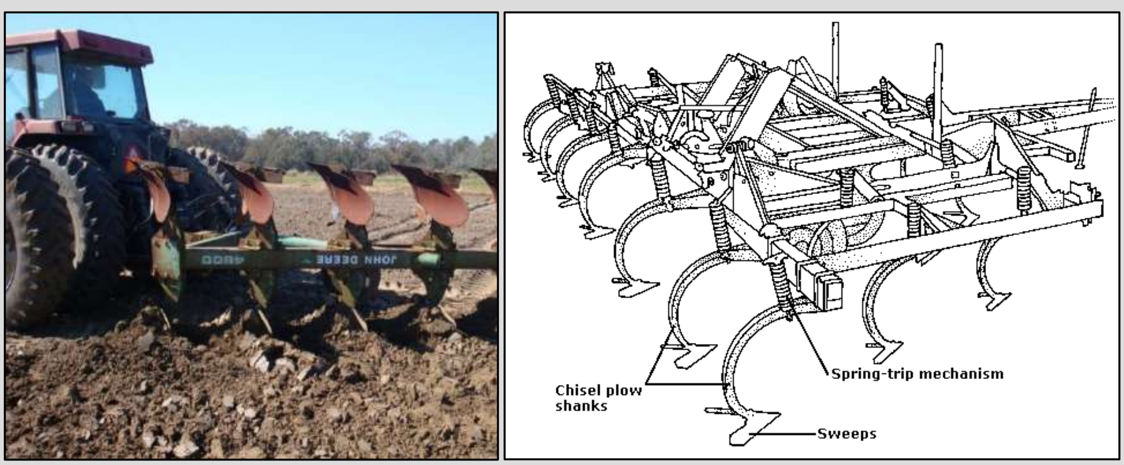

Figure 13.1. Primary tillage implements include moldboard plow (Photo credit: S. Culpepper, Univ. Georgia), left and chisel plow with sweeps (SARE 2002).

- *Chisel plow.* The chisel plow (Figure 13.1) consists of a series of C-shaped shanks spaced 12 inches apart with chisel points or sweeps. The addition of sweeps improves weed control. Chisel plows can shatter hardpan soils and improve water infiltration. The addition of 12- to 18-inch wide sweeps improves weed control, but the chisel plow is not as effective as other implements for controlling weeds.
- *Disk harrow***.** Concave blades (known as a disk harrow gang) cut, mix, and incorporate crop residue. A disk harrow's cutting and mixing action varies with diameter, weight, concavity, blade angle, and speed at which the implement is pulled. Harrows can chop weeds or uproot small weed seedlings. Plant residues can prevent disk harrows from creating a smooth seedbed. They can be used to control small weeds on the soil surface prior to planting if there is little plant residue present (Figure 13.2).

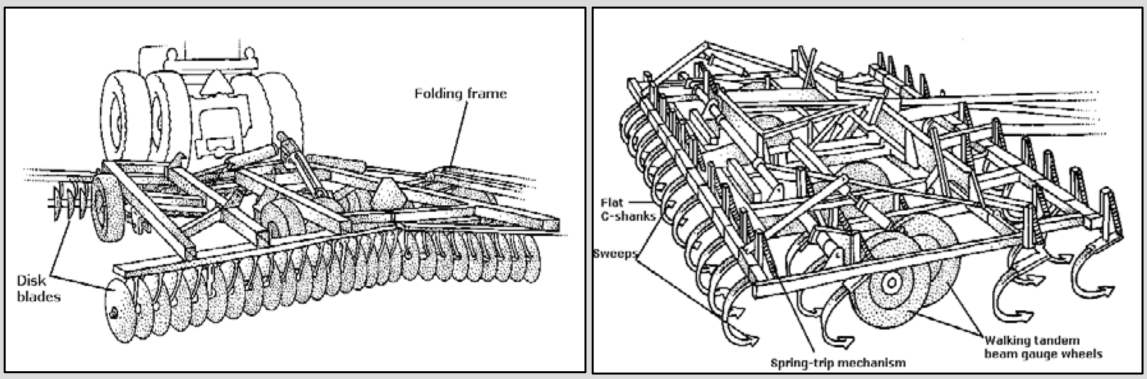

Figure 13.2. Disk harrow (left) and field cultivator (SARE 2002).

- *Field cultivator.* Like the chisel plow, a field cultivator (Figure 13.2) consists of C-shaped shanks, which are less rigid than those of a chisel plow. The shanks work along the full width of the implement, as well as two to five inches deep, to open up soil or incorporate plant residue. Weeds are uprooted and weed seedlings are killed. The addition of sweeps facilitates weed control and shovels are used more often for field prep.

Effect of Tillage on Weeds

Primary tillage buries weed seeds and vegetative parts and chops weeds into small pieces unable to regrow. Small annual weeds, small-seeded species, and simple perennials are more susceptible to tillage than perennials with stolons, rhizomes, or tubers (Klingman 1961). Dry soil conditions and higher air temperatures create the best conditions for weed control. Weeds sliced or uprooted by tillage during these environmental conditions are less likely to recover from tillage operations than weeds tilled when soils are wet and temperatures are moderate.

Secondary tillage disturbs weed roots by loosening or cutting the root system, causing the plants to desiccate, or dry out, before roots can re-establish (Klingman 1961). Because this process involves desiccation, it is most effective when soils are dry and temperatures are high. Similar to primary tillage, small annual weeds and simple perennial weeds are more easily controlled than creeping perennials by secondary tillage. Disking or chopping rhizomes, stolons, and tubers without adding other weed control methods may worsen creeping perennial infestations.

Farmers should know the weed control limitations of each tillage operation and implement. See Table 13.1 for the relative effectiveness of various tillage implements for control of different types of weeds and weed seed burial. The key to effective weed control with tillage starts with selecting the right tool for the job.

Table 13.1. Tillage implement effectiveness for control of various weed types. Based on authors' experiences. (For weed type definitions, see Chapter 2: *Identification and Characteristics of Weeds*)

	Control of existing weeds				
Tillage implement	Seedlings	Established annuals or biennials	Simple perennials	Creeping perennials	Burying annual weed seed
Moldboard	Good	Good	Good	Fair	Good
Chisel	Good	Fair	Fair	Poor	Fair
Disk harrow	Good	Good	Good	Poor	Poor
Field cultivator	Good	Poor	Poor	Poor	Poor

Effect of Tillage on Weed Seeds

Tillage is the primary cause for weed seed movement throughout the soil profile, including vertical distribution (Buhler et al. 1997). This movement can affect germination and establishment. Some tillage implements can bury weed seed to a depth not conducive to germination (Table 13.1), while at the same time brining buried seeds to the soil surface. There, the soil environment is more conducive to germination. A single pass of a moldboard plow buries surface weed seeds to the depth of the tillage implement (greater than 6 inches) and is very effective at reducing seedling density. However, tillage systems used over multiple seasons also can influence the distribution of weed seeds in the soil profile. As seen in Figure 13.3, Wisconsin researchers observed a more even vertical distribution of weed seed after multiple years of moldboard plowing than after multiple years of chisel plowing and no-tillage, with weed seeds more concentrated at the top of the soil profile in both systems (Yenish et al. 1992). It should be noted that burying weed seeds to a depth of six inches or more may prolonged the time for seed decay due to a less disturbed environment.

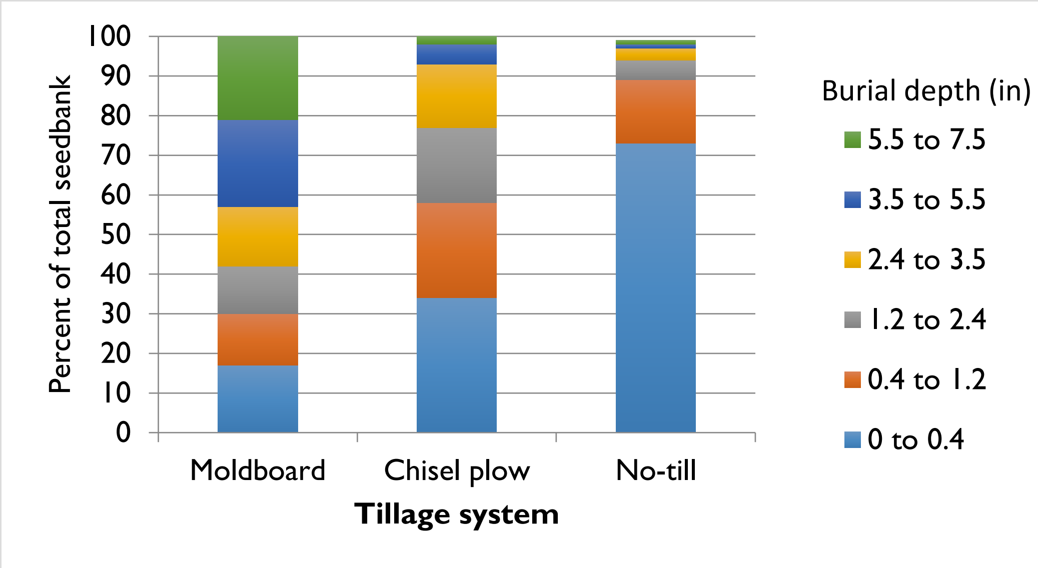

Figure 13.3. Vertical distribution of weed seed as affected by tillage system in a silt loam soil (Adapted from Yenish et al. 1992).

Seed size determines the depth from which seedlings can emerge. This depth varies by species. Smaller seeds do not have enough energy reserves to emerge from deep within the soil. For example, the greatest germination rates for the small seeds such as Palmer amaranth and slender amaranth, were at depths less than one inch (Keeley et al. 1987; Thomas et al. 2006). Sicklepod seed, much larger than slender amaranth, can germinate from deeper than one inch. In a sandy loam soil, Arkansas researchers observed 50% sicklepod germination at a depth of 1.8 inches, and 6% at a depth of 4 inches (Norsworthy and Oliveira 2006). Likewise, pitted morningglory, which also has large seeds, germinated from as deep as 4 inches (Oliveira and Norsworthy 2006) (See Table 13.2 for optimum emergence depth for several weed species). Generally large seeds, such as common cocklebur and pitted morningglory, had higher emergence if seeds were buried compared to on or near the soil surface (Bararpour and Oliver 1998; Lovelace and Oliver 2000).

Table 13.2. Emergence depth for several common weed species.

Weed species	**Emergence depth (in)**	**Reference**
Broadleaf signalgrass	0 to 0.4	Burke et al. 2003a
Common ragweed	0 to 1.6	Guillemin and Chauvel 2011
Horseweed (or marestail)	0 to 0.2	Nandula et al. 2006
Palmer amaranth	0 to 0.5	Keeley et al. 1987
Pitted morningglory	0 to 4.0	Oliveira and Norsworthy 2006
Slender amaranth	0.2 to 0.8	Thomas et al. 2006

Tillage affects soil temperature, soil moisture, oxygen levels, and light, environmental conditions that are cues for weed seed germination. Tillage reduce seed germination by placing the seed deeper in the soil profile. There, temperatures are cooler, less temperature fluctuation, less oxygen is available and no light penetration. However, tillage can stimulate weed seeds to germinate if the seeds are exposed to light, higher oxygen levels, and warmer soil temperatures (see Chapter 3: *Weed Emergence, Seedbank Dynamics, and Weed Communities*). Farmers should consider the effects of tillage germination cues for various weed species when considering tillage.

Effect of Tillage Systems on Problem Weed Species

Tillage systems often are classified by the amount of plant residue left on the soil surface and are defined as follows:

- *Conventional tillage.* A conventional-till system disturbs the soil surface across the entire width of the implements used and leaves less than 15% residue on the soil surface. Conventional tillage includes multiple operations (often primary tillage followed by secondary tillage). An example is a three-pass system using a moldboard plow for primary tillage and then a finishing disc harrow and field cultivator for secondary tillage.
- *Reduced till.* Similar to conventional till, reduced-till systems disturb the soil across the full width of the implement. However, 15 to 30% surface residue remains after tillage. Chisel plowing without sweeps, leaves much of the soil surface undisturbed and is considered reduced tillage.
- *Mulch-till.* As in conventional- and reduced-till systems, the entire soil surface is tilled, but mulch-till is less aggressive, leaving more than 30% residue on the soil surface.
- *Ridge-till.* In the ridge-till system, the cash crop is planted on established ridges that are formed by between-row cultivation. These ridges help drain and warm the soil for better crop emergence. Between-row cultivation also can control weeds.
- *Strip-till.* In strip-till systems, the majority of the soil surface is left undisturbed. Strip-till equipment often includes no-till coulters mounted in front of the planter unit to create a narrow tilled zone where the seed is to be planted. This tilled zone helps warm the soil and provides better seed placement. Strip-till often includes a shank in the tilled zone to alleviate soil compaction and place fertilizers deeper in the soil profile.
- *Vertical till.* This is generally shallow tillage used to chop residue from a previous crop into smaller pieces and distribute it more evenly over the soil surface. Chopping and mixing residue facilitates decomposition, allowing the subsequent cash crop to be planted into more easily. Vertical tillage also can alleviate surface

compaction and soil crusting. Vertical tillage implements do not generally control emerged weeds.

- *No-till.* Soil disturbance is minimized in no-till systems. Residue covers 70% of the soil surface. Row cleaners, coulters, and seed-furrow openers create slots for planting seeds in this heavy residue.

The tillage system often dictates what type of weeds can be problematic. In general, reduced and no-till systems may have more problems with perennial weeds and some small-seeded annuals while they have fewer problems with large-seeded annual weeds. Many perennial weeds thrive in no-till systems because their roots are left undisturbed (Glenn and Anderson 1993; Glenn and Heimer 1994). The spread of rhizomes, stolons, and tubers of creeping perennials in a no-tillage system often increases the infestation. In no-till or reduced-till systems, herbicides are usually needed to effectively control perennial weeds. In a Maryland study with no-till corn, herbicides were needed to adequately control Canada thistle (Glenn and Anderson 1993). Hemp dogbane and wild blackberry also were difficult to control in no-till corn and required herbicides for effective control (Glenn and Heimer 1994). In Pennsylvania, researchers reported quackgrass was more difficult to control in no-till than reduced-till corn (Curran et al. 1994). Using tillage in combination with herbicides or other weed control methods is often necessary to deplete the energy reserves of perennial species.

Of the many ways tillage influences the weed seedbank, seed depth in the soil may be most important (Buhler et al. 1997). Weed species that can germinate from the soil surface or shallow depths will flourish in no- or reduced-tillage systems. Farmers in Indiana reported horseweed (or marestail), a small-seeded annual, was present in 61% of no-till fields compared to 24% of reduced-till fields and 8% of conventionally tilled fields (Loux et al. 2006). In contrast, large-seeded species at or near the soil surface in no-tillage systems are less successful (Buhler et al. 1997). A Maryland study reported 72% smooth pigweed control in a moldboard plow system compared to 63 to 64% in reduced till and 44% in no-till (Ritter et al. 1985), demonstrating the short-term benefits of tillage for small-seeded species (Figure 13.4). For a large-seeded species like common cocklebur or burcucumber, no-till can reduce overall emergence compared to tillage. Norsworthy and Oliveira (2007) reported a decrease in common cocklebur density under no-tillage by 59 to 69% compared with tillage and Esbenshade et al. (2001) reported similar trends with burcucumber (2001).

Effect of the tillage system on weed emergence are trends and may not produce consistent results (Messersmith et al. 2000). At the end of a nine-year study, Swanton et al. (1999) found common lambsquarters and redroot pigweed were more prevalent in conventionally tilled plots than in no-till, while large crabgrass was more common in the no-tillage system. Farmers should identify the effects of their tillage systems on the presence of certain weed species and the potential alternative weed management practices needed once species shift.

Figure 13.4. Deep burial of Palmer amaranth seed can significantly influence germination. Notice the density of Palmer amaranth in the nontreated control research plot (left) compared to a plot in which seeds were buried 10 to 12 inches by a moldboard plow (right) (S. Culpepper, Univ. of Georgia).

Tillage and the Weed Seedbank

Stale seedbed systems have long been used for weed control and involve early seedbed preparation using tillage approximately 30 days prior to planting. Tilling the seedbed early stimulates nondormant weeds in the germination zone to emerge, providing the opportunity to control these prior to crop planting (Boyd et al. 2006). These weeds can be controlled by light tillage, herbicides, or flaming.

In a stale seedbed system, light tillage has not been as effective as flaming or herbicides because it often stimulates additional weed germination. In a New York study, glyphosate and flaming in a stale seedbed system reduced weed biomass 46 to 91% compared to the untreated control (Caldwell and Mohler 2001). In the same study, the rotary tiller, tine weeder, and spring tooth harrow treatments either increased or had no effect on weed biomass when compared to the untreated control.

Stale seedbed systems are useful for reducing weed seedbanks. However, the success of this system depends on the control of newly emerged weeds. Tillage, herbicides, or other methods must be used to ensure the weed seedbank is not replenished by a few escaped weeds (see Chapter 6: *Prevention of Weeds*).

Tillage remains an effective tactic for controlling weeds and an important component of IWM. However, farmers should consider the effects of each tillage operation on individual weeds, weed seeds, and weed species dynamics. They also should factor in the environmental impacts of tillage and whether the advantages of tillage outweigh the disadvantages before using tillage equipment in their fields.

Key Points

- Tillage was the primary method of weed control prior to herbicides.
- Primary and secondary tillage can be used to control existing weeds.
    - Primary tillage buries weeds or chops weeds into small pieces
    - Secondary tillage disturbs weed roots and leads to plant desiccation
    - Annual weeds, simple perennial weeds, and small weeds are more susceptible to tillage than are creeping perennials and large weeds
- Weed seed germination and longevity also are affected by tillage.
    - Tillage influences soil temperature, soil moisture, oxygen, and light, all of which are germination cues for weed seeds.
    - Tillage affects weed seed distribution in the soil profile.
- Weed species and soil weed seedbanks can shift in response to tillage systems employed over multiple seasons.
    - Horseweed and many perennial weeds prefer long-term no-till systems.
    - Tillage can spread rhizomes, stolons, and tubers of creeping perennial weeds and worsen infestations.
- Soil weed seedbanks can be reduced via mechanical manipulation of a stale seedbed.

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