Weed Seed Biology, Seedbanks and Management

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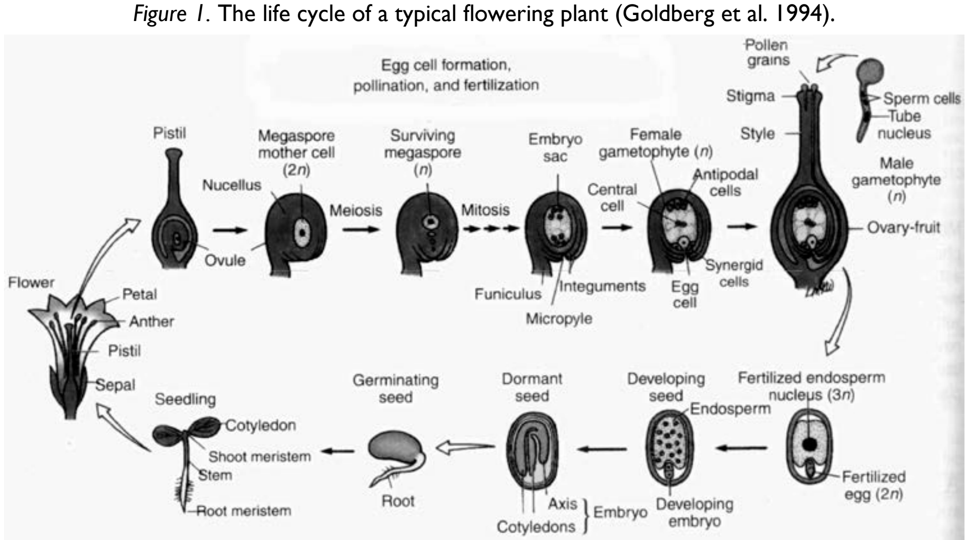
Introduction

Annual weeds reproduce and disperse as seeds. Weed seed buried in the soil is called the weed seedbank and is the source of most weeds. Most of the seeds in the seedbank were likely produced in the same field, and lesser numbers of weed seeds are those that entered from outside the field. Seeds disperse via wind, water, animals or spread as contaminants in other materials such as irrigation water or manure. Seeds in the seedbank do not all germinate in one flush, but over a longer period of time. Seed dormancy allows viable weed seed to survive tillage or herbicide application and then germinate later when conditions are safe. The seedbank reflects the "memory" of recent weed management practices in the field and will determine future weed infestations. This paper will outline some of the factors that influence weed seedbanks, as well as outline how management of weed seedbanks can improve weed control.

Weeds like many other annual plants must complete the seed cycle to reproduce. A mature seed represents the successful completion of one life cycle and the beginning of a second cycle. Weeds are very good at making lots of seed–if we let them. A general description of the life cycle begins at the ovule where the process of meiosis and mitosis produces a female gamete (fig. 1). Pollen from the same plant (self-pollination) or from another plant (cross pollination) results in a zygote and eventually a mature seed. Most weed seed are shed soon after maturity, but seed from many species cannot germinate immediately, i.e., they are dormant. High seed production and seed dormancy are major reasons weeds succeed–dormancy helps weed seed to germinate over long periods of times and weeds keep emerging. Lots of weed seed emerging over a long time period means a higher chance that some will successfully reproduce.

Figure 1. The life cycle of a typical flowering plant (Goldberg et al. 1994).

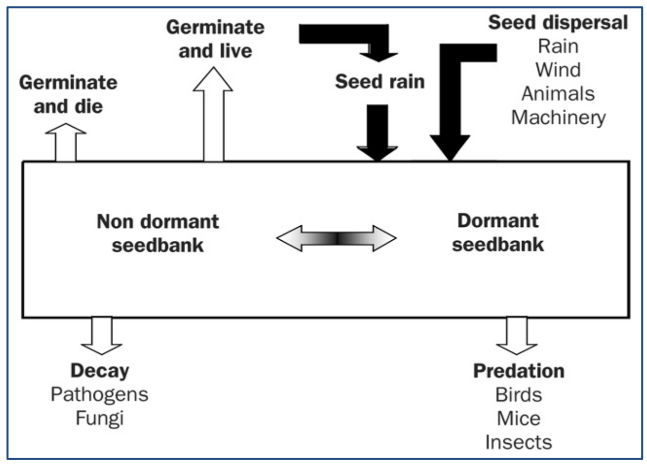


After a weed seed is shed, many things can happen to it including: insects or birds can eat the seeds, it can disperse away from the mother plant, and the seed can germinate (in some species) or enter the seedbank. Harper (1977) called places where weeds survive and reproduce “safe sites”. A safe site for seed survival provides: 1) protection against being eaten or harvested before the seed reaches the soil; 2) a place for the weed to live on the soil surface; 3) protection against being eaten after reaching the soil; and 4) temperature and moisture conditions favorable for germination (Aldrich and Kremer 1997). For weed seedlings to survive, they must be in a physiological state such that the seed can germinate if conditions permit. Weed germination often happens in short time periods, a “flush of weeds” that coincide with the proper environmental conditions (Thompson and Grime 1979).

Weed seedbanks

Harper (1977) said that the soil seedbank is similar to a bank account to which deposits and withdrawals can be made (fig. 2). Deposits occur as weeds go to seed in the same field or disperse in from outside the field. Withdrawals occur by germination, death, and predation.

Figure 2. Flow chart for the dynamics of weed seeds in the soil (Harper 1977)



The quantity of seed buried in the soil seedbank varies from field to field. Measurements of the densities of weed seed at eight locations in the Sacramento Valley found seed densities that ranged from 181 to 1,402 seed ft^{-2} (Battista 1998). Weed densities in the Salinas Valley were found in the range of 143 to 3,220 seed ft^{-2} (Fennimore, unpublished data). Organic farms in the Northeastern USA found up to 2,293 seed ft^{-2} (Jabbour et al. 2014). Most seedbanks consist of many species with a few dominant weeds comprising 70-90% of the total. A second group of weeds comprises 10-20% of the seedbank, but are not as well adapted to the production system as the dominant species. The final group of seed is a small percentage that consists of newly introduced species and seed from previous crops (Wilson 1988).

Management of weed seedbanks requires a long-term approach to weed management that goes beyond just the current crop. For example, disking down a field soon after harvest to prevent escaped weeds from setting seed is the practice of preventative weed management. A grower who consistently prevents weeds from going to seed will increase the odds of having a clean field. A survey of organic growers in New England revealed that growers who had the lowest seedbanks were those growers who attempted to prevent weed seed production whenever possible (Jabbour et al 2014). Researchers in The Netherlands compared standard organic farmer weed management practices to a no tolerance for weed seed production treatment. They found that seedbanks in the standard treatment increased while seedbanks in the no seed production treatments declined (Riemens et al. 2007). Weed management is far easier in a clean field with a small weed seedbank than in a field with a severely infested seedbank. For example a grower farming a coastal California field with a clean seedbank, will have a greater range of crop choices than where the weed seedbank is severe. A grower can raise lettuce or spinach in the clean field during the wettest part of the winter when cultivation and handweeding are difficult and herbicide options limited. Prevention of weed seed set and depletion of the seedbank is one of the more important weed management tools for vegetable growers.

Seasonal and environmental factors interact to influence weed seed germination. If we know which conditions favor germination or lack of germination of troublesome weed species we can manage our crop production in such a way as to both favor germination of weeds and subsequently destroy them with tillage, or to maintain them as non-germinated seed during the cropping season. For example, if we want to grow lettuce in a field infested with pigweed (*Amaranthus* spp.), and shepherd's-purse (*Capsella bursa-pastoris*) we can choose from Kerb and Prefar as soil-applied preemergence herbicides. Kerb is weak on pigweed species and Prefar is weak on shepherd's-purse. If we know that very little pigweed germinates in January, but that shepherd's-purse germinates readily at that time, then we would likely choose Kerb as our lettuce herbicide. In June both pigweed and shepherd's-purse germinate readily, so we might need to consider a tank mix of Kerb and Prefar to control both weeds.

In my research program we studied the seasonal emergence characteristics of common Salinas Valley weeds. Annual bluegrass germinates during the fall and winter in the Salinas Valley (fig. 3). We can determine by studying the seed in the seedbank that annual bluegrass in Salinas goes dormant in the spring, but becomes nondormant by late summer. Common purslane emerges mostly in the summer (Figure 4). The common purslane seedbank is fairly dormant in the fall and winter. Applications of this information are relevant to conventional and organic growers. For conventional growers choice of herbicides may be dictated by the expected weed spectrum. For organic growers, this information may dictate the choice of crops to plant in a particular field. Cilantro is a difficult crop to hand weed. A fall cilantro crop should not be planted in a field with a history of annual bluegrass, since it will be difficult to provide economical weed control.

Figure 3. Salinas valley annual bluegrass field emergence from June 1998 to Nov. 2001. The line is predicted emergence and the symbols are actual emergence (Shem-Tov and Fennimore, 2003)

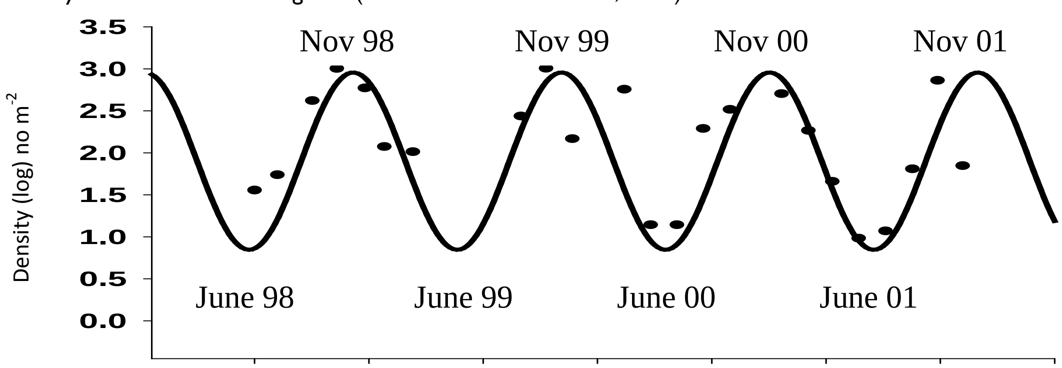
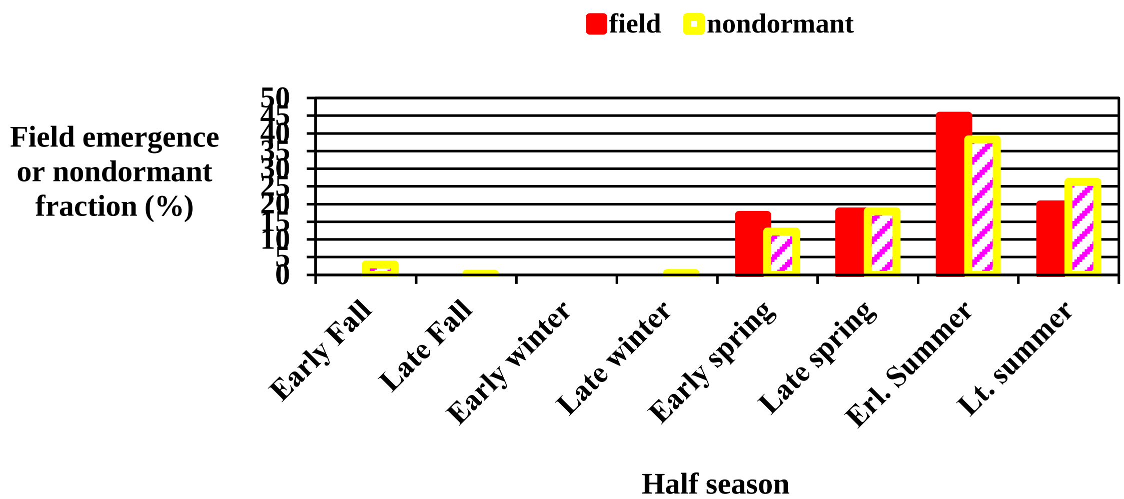


Figure 4. Salinas valley common purslane emergence by half-season in the field and nondormant percentages in the soil seedbank during September 1999 to September 2000.



Additions to the seedbank

Seed can enter the seedbank by many routes, though the largest source is from weeds that produce seed nearby (Cavers, 1983). Ninety-five percent of seed entering seedbanks in farmland were produced in the same field (Hume and Archibold 1986). Weeds can produce large numbers of seed when grown without competition (Table 1). Crop competition and damage from cultivators and herbicides often reduces the amount of seed set by weeds, but weeds are still capable of producing large amounts of seed. In California, barnyardgrass at 1 plant per 30 ft of sugarbeet row, the economic threshold, produced 40,600 to 182,000 seeds per barnyardgrass plant (Norris 1992).

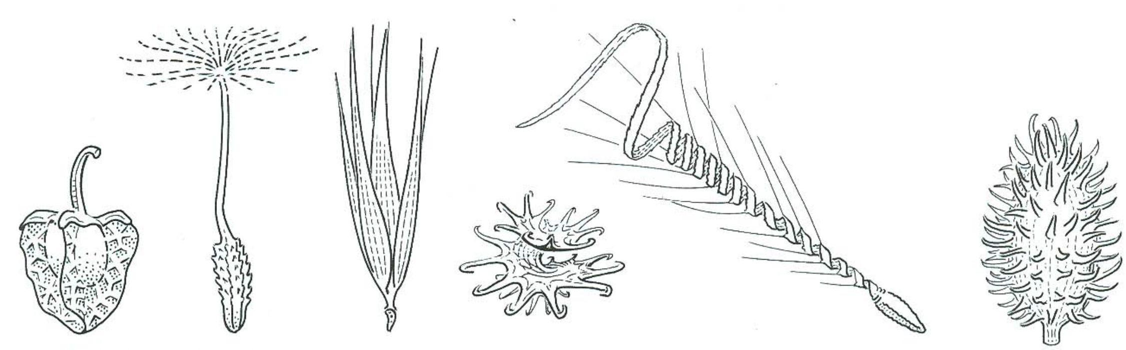
Table 1. Seed production and seed survival (Wilson 1988).

Weed species	No. of seed produced per plant (Stevens 1954, 1957)
Common lambsquarters	72,450
Common purslane	52,300
Common ragweed	3,380
Pennsylvania smartweed	19,300
Prickly lettuce	27,900
Redroot pigweed	117,400
Shepherd's-purse	38,500
Wild oat	250
Yellow foxtail	6,420

Weed seed can enter a field, i.e., dispersal, from sources such as mud on equipment, as a contaminant in crop seed, animals, wind, and manure. Many weed seeds have special attachments that allow them to be dispersed by wind, water or animals (fig. 5). Wind dispersal (fig. 5) allows a few seed to move far. Weeds with wind dispersed seed such as common groundsel and common sowthistle often are invaders into fumigated fields that otherwise have clean weed seedbanks (fig. 6). Horseweed, a common weed in California crops and rights-of-way, has wind dispersed seed capable of moving distances of more than 300 ft in a 10 mph wind (Daur et al. 2006). Wind dispersed weed seeds are a particular problem in crops such as strawberry where weed control is largely provided by soil fumigation and plastic mulch. Soil disinfestation with fumigants will kill weed seedbanks in just a few hours or days. However, once fumigants have dissipated and the fumigant is gone, weed seed that blow into the field can survive (see section on SOIL DISINFESTATION). Depending upon the method of transport, weed seed can be moved from inches to hundreds of miles (fig. 7). Water can move a considerable number of seed. Researchers in Washington State sampled irrigation water, and found that in a three-year period that irrigation water had the potential to add 4,210 to 38,280 seeds per acre (Kelley and Bruns 1975). Animals can move seeds externally on their fur (figs. 5&7) and through their feces. Researchers in the San Joaquin Valley found dairy manure infested with 4,174 to 21,755 viable seed per ton of manure. On San Joaquin Valley farms manure is typically applied at 10 tons per acre, and as a result 41,700 to 217,500 viable weed seed per acre were applied with the manure (Cudney et al. 1992). The introduction and dispersal of noxious weeds is the greatest threat from dispersed seed.

A great deal of weed seed can be harvested with the crop. Currie and Peeper (1988) found that the fraction of wild buckwheat (*Polygonum convulvulus*) seed harvested with the crop by five different combines ranged from 25 to 55%. Due to advanced seed cleaning technology the problem of crop seed contaminated with weed seed is not the problem it once was. Mechanical harvesting of some weed seeds modifies the germinability of those seeds by scarifying them. The germination of hand-harvested curly dock (*Rumex crispus*) seed was 0% and that of combine harvested curly dock seed 27% (Currie and Peeper 1988).

Figure 5. Characteristics that aid dispersal of weed seeds by water, wind and attachment (sticky seed).



Destruction of weed seed at crop harvest is being evaluated as a method of reducing weed seed return to the seedbank (Walsh and Powles 2014). In this system weed seed is captured in the chaff as it exits the combine and crushed to destroy the seed. Walsh and Powles (2014) found >75%

weed seed retention at time of crop maturity, which was favorable for destruction of weed seed with the seed destructor. However, within 30 days of crop maturity, weed seed is shed at a steady rate.

Figure 6. Common groundsel and annual sowthistle–very common weeds that disperse windblown weed seed (photo source: UCIPM Program).

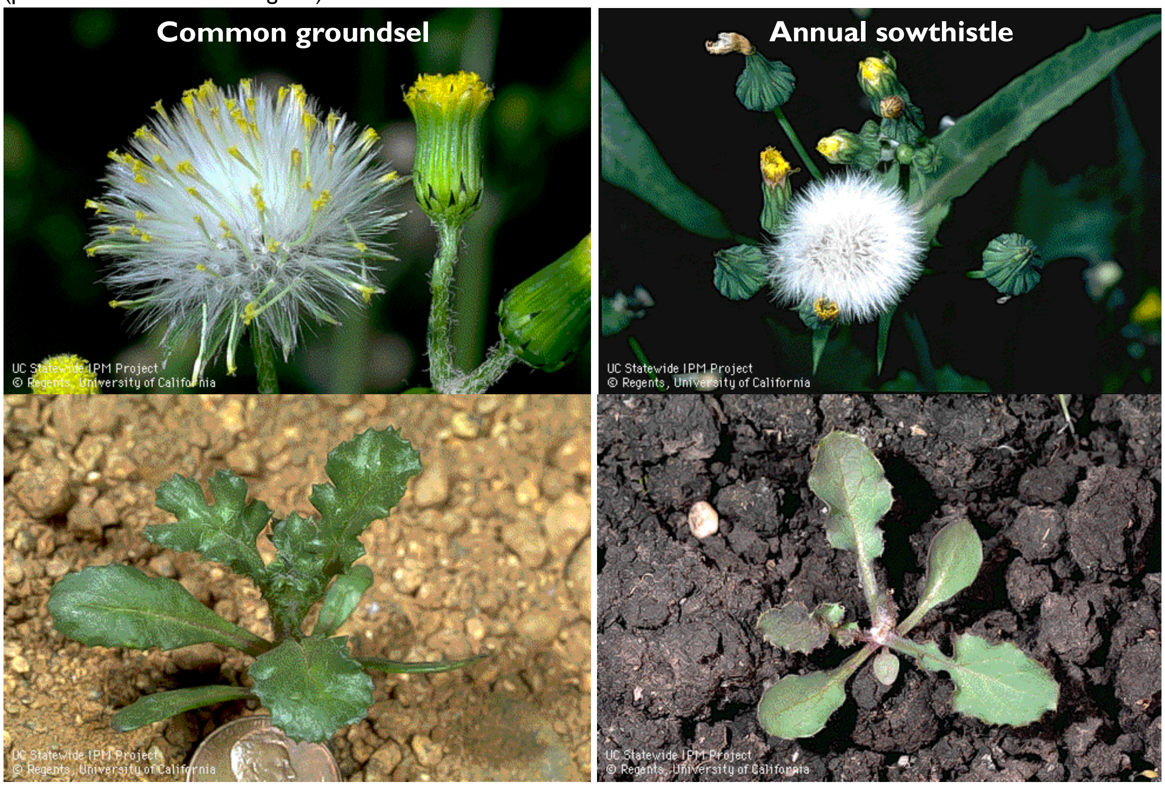
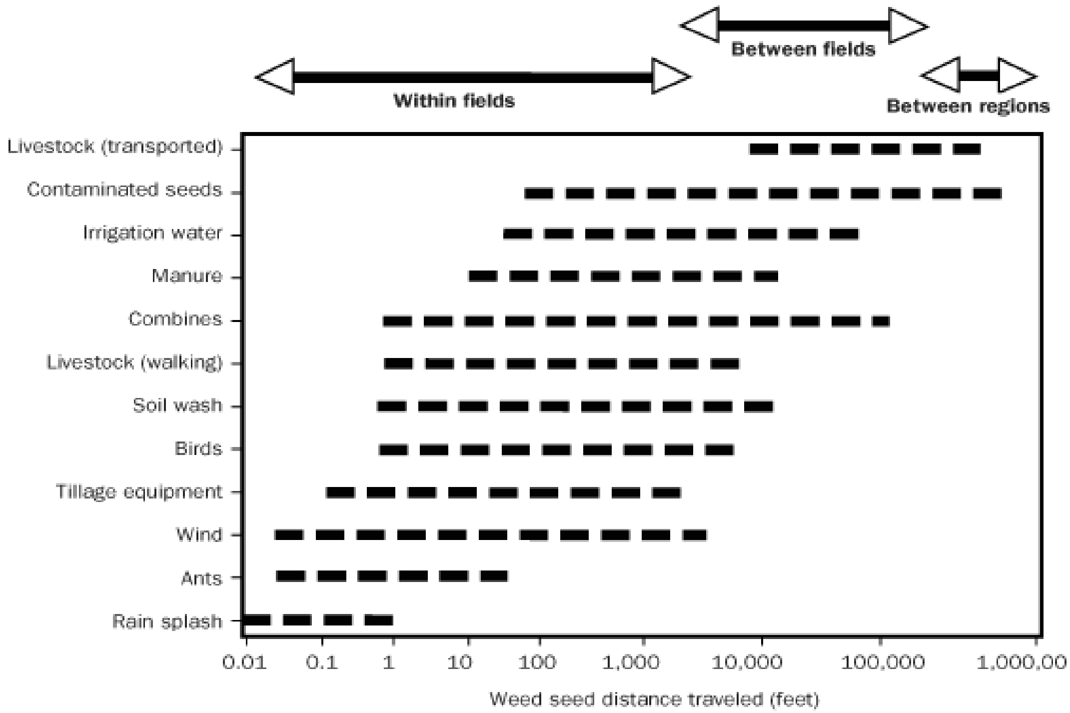


Figure 7. Dispersal of weed seeds over a range of distances by several methods of transport (Mohler 2001).



Seed losses

What is meant by "seed losses" is that weed seeds can't and don't stay in the seedbank forever. Although seed of many weed species, such as clovers, have the potential for long-term survival in the seedbank, most seed have a short life (Murdoch and Ellis 1992). Factors accounting for the loss of weed seed in the soil include germination, microbial decay, and predation by birds or insects. The relative importance of each factor varies with species and environmental conditions (Buhler et al. 1997).

In a weed management program we are primarily interested in those seed that germinate and emerge. Germinated weed seed produce weeds that require control to prevent competition with the crop. Weed seed in the soil seedbank are mostly dormant or dead with a small fraction of nondormant seed that are ready to germinate. Several types of dormancy exist and most weeds possess one or more types. Seed dormancy terms:

Dormancy: Dormant seeds fail to germinate in light, temperature, water, and oxygen conditions that normally favor germination of a nondormant seed.

Primary dormancy (class): freshly harvested seed that is dormant

Secondary dormancy (class): the condition of a formerly nondormant seed that encountered unfavorable conditions such as flooding or high temperature that induced dormancy.

Coat-imposed dormancy (mechanism): Seed dormancy is maintained by plant structures that enclose the embryo. Clover and little mallow seed have coat imposed dormancy.

Embryo dormancy (mechanism): Control of seed dormancy lies within the embryo itself.

Afterripening: release of dormancy under warm-dry conditions

Chilling (stratification): release of dormancy in low temperatures (33-50°F) and moist conditions.

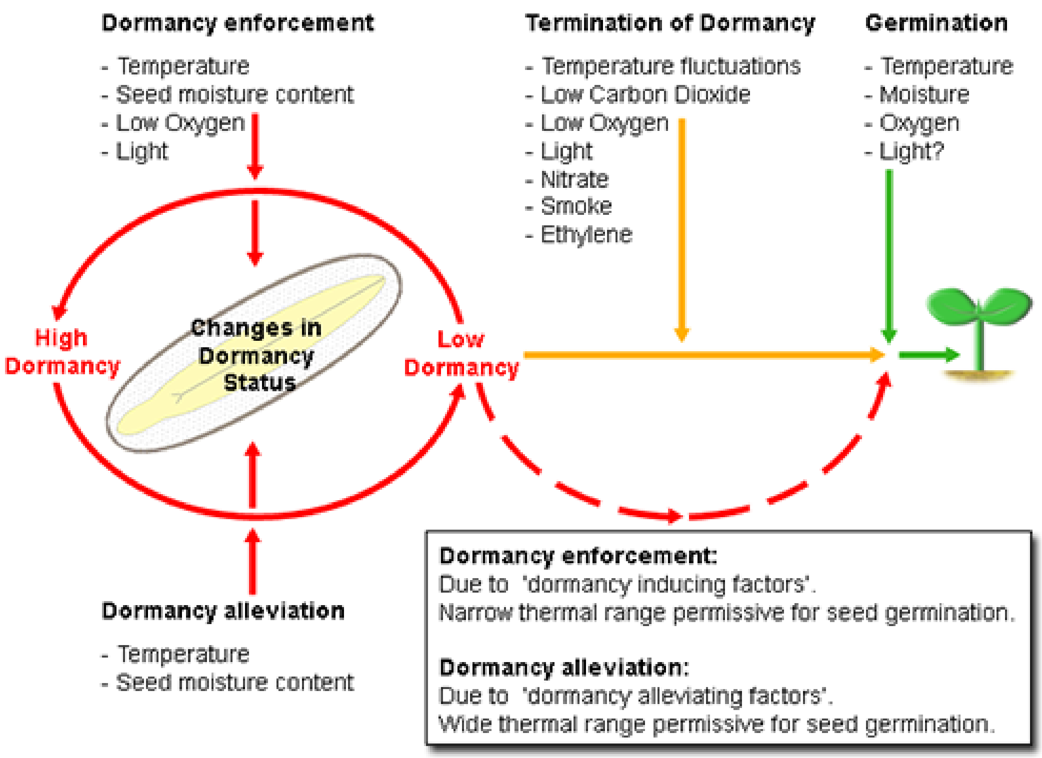
Light: Many seed, especially small seed, require light stimulus to relieve dormancy and germinate.

Temperature: Has many effects. All species have optimal germination temperatures below and above which the germination rate slows. Temperature controls the rate at which a dormant seed population becomes nondormant. Temperature can also control the rate of secondary dormancy induction.

Water: Required for germination in moderate amounts. Flooding can create anoxia (low oxygen) and induce secondary dormancy.

Source: Bewley and Black, 1994

Figure 8. Dormancy and germination (Royal Tasmanian Botanical Gardens).

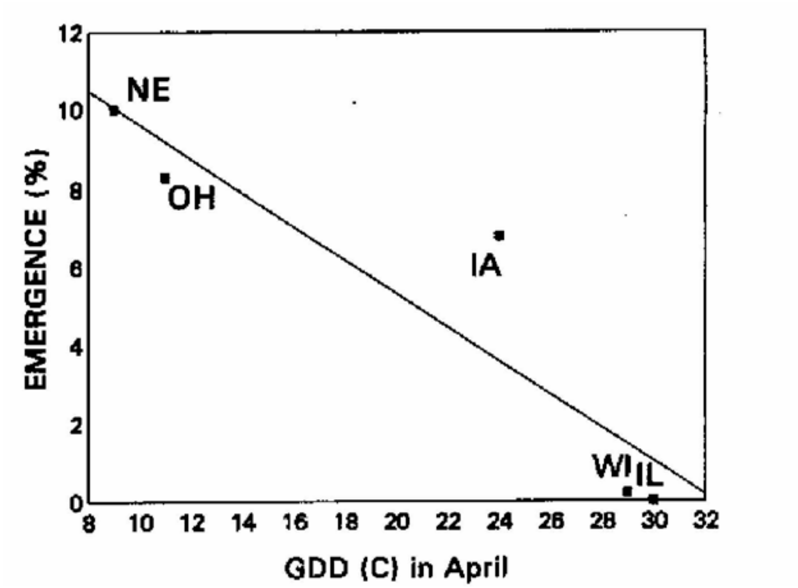


From the moment a seed is shed its dormancy status is one of the key factors that determine when the seed will germinate (fig. 8). Many of the weed seed released by maturing weeds are in a state of primary dormancy. Forcella et al. (1997) found, depending on the weed species, that 3 to 31% of the viable seedbank germinated in a given year (Table 2). This means that 69 to 97% of the viable seedbank was dormant. In the Salinas Valley we have found that the nondormant fraction of burning nettle varied from 11 to 52% (not shown) and that of common purslane from 0 to 26% (fig. 4). Seed dormancy is a method used by weeds to increase the likelihood that it can successfully reproduce in a changing environment. Dormancy is relieved by appropriate environmental conditions such as chilling, afterripening, light or scarification (break in seed coat). For example, chilling prevents a summer annual weed from germinating before the last killing frost, and a light requirement to break dormancy prevents a small seed from germinating too deep in the soil for the seed to emerge (Harper 1977). Embryo dormancy is a complex system that is often reversible and represents a flexible system that allows a weed seed to adapt to its environment. The induction of secondary dormancy is the response of many weeds species to poor environmental conditions such as flooded soils. Secondary dormancy and weather conditions are responsible for much of the variation in weed germination from year to year. Forcella et al. (1992) found a relationship between common lambsquarters emergence and April growing degree days (GDD) (fig. 9). They found that the greater the number of GDD in April, the lower the common lambsquarters emergence, presumably due to secondary dormancy. In other words, if April is cool, lambsquarters is likely to be more of a problem than when April is warm.

Table 2. The % of the seedbank that emerge each year in seven states (Forcella et al. 1997).

Weed species	Emergence percentage
giant foxtail	31%
velvetleaf	28%
common ragweed	15%
pigweed	3%
common lambsquarters	3%

Figure 9. The relationship between % of common lambs-quarters that emerged over the growing season and total growing degree days in 10 days in April at 5 Midwestern locations (Forcella et al. 1992)



Seed are a food source for many insects, birds, and small mammals. In natural systems more than 70% of the seed may be consumed (Crawley 1992). Carabid beetles are among the most effective seed predators. Consumption of up to 74% of common chickweed and shepherd's-purse seed has been documented (Johnason et al. 2013). Some studies have found significant weed seed loss from predation when weeds were left on the soil surface as in no-till agriculture (see 'TILLAGE' section). For example in no-till 69% of the seed was lost to predation, and in conventional till 27% was lost to predation (Brust and House 1988). Researchers in the Salinas Valley found an indirect relationship between soil microbial biomass and reduced weed emergence (Fennimore and Jackson, 2003). Finding methods to use soil microbes and insects to manage weeds is an active area of research.

Weed management

Weed seedbanks can be greatly reduced by eliminating seed production for a few years; conversely, fields can be quickly reinfested with weed seed if weeds are allowed to set seed. Burnside et al. (1986) found that broadleaf and grass seed density declined 95% after 5 weed-free years. In the sixth year herbicide use was discontinued and seedbank density rebounded to within 90% of the original density (fig. 10). Although seed production from most weed species can be reduced by management factors, seed production will likely remain high enough to maintain or increase the seedbank with low to moderate weed infestations. Hartzler found that velvetleaf grown at densities of 810 and 1620 plants per acre and allowed to set seed in year 1 resulted in >93,111 weeds per acre during years two to five even though no velvetleaf plants were allowed to set seed during years two to five (Table 3, Hartzler 1990).

Figure 10. Weed seed germination in plots maintained weed free from 1975 to 1979 (Burnside et al. 1986).

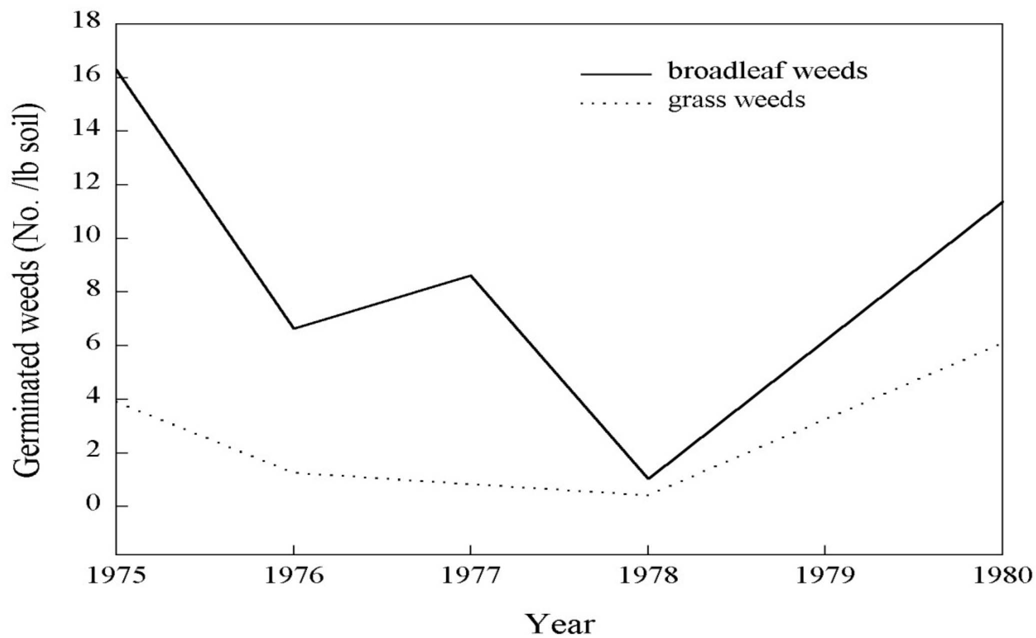


Table 3. Effect of velvetleaf seed rain on velvetleaf emergence (Hartzler 1996).

	Velvetleaf emergence[a] 1990 velvetleaf population (no./m²)			
Year	**0**	**0.2**	**0.4**	**LSD 0.05**
		no./m²		
1991	6	91	145	25
1992	7	128	203*	40
1993	7	34*	62*	10
1994	2	23*	37*	7

[a] Means with * are significantly different from prior year's mean at the 0.05 level.

The management intensity level affects the soil seedbank. A long-term study, the Sustainable Agriculture Farming System project at UC Davis, compared three input levels: organic, low input and conventional. In 1996 after 8 years of cropping, soil seedbanks were sampled to determine the effects of these three input levels on the soil seedbank. Generally greater numbers of seed were found in the organic and low input treatments (Battista 1998) (Table 4).

Table 4. Weed species seed density for corn in 1996 (Battista 1998).

	Seed density/m^2 [a]		
Management level	**C. lambsquarters**	**Redroot pigweed**	**Barnyardgrass**
Organic	8,103 a	9,897 a	330 a
Low-input	1,097 b	9,897 a	1,097 a
Conventional	898 b	1,097 b	67 b

[a] Back transformed data from ln transformation of original data

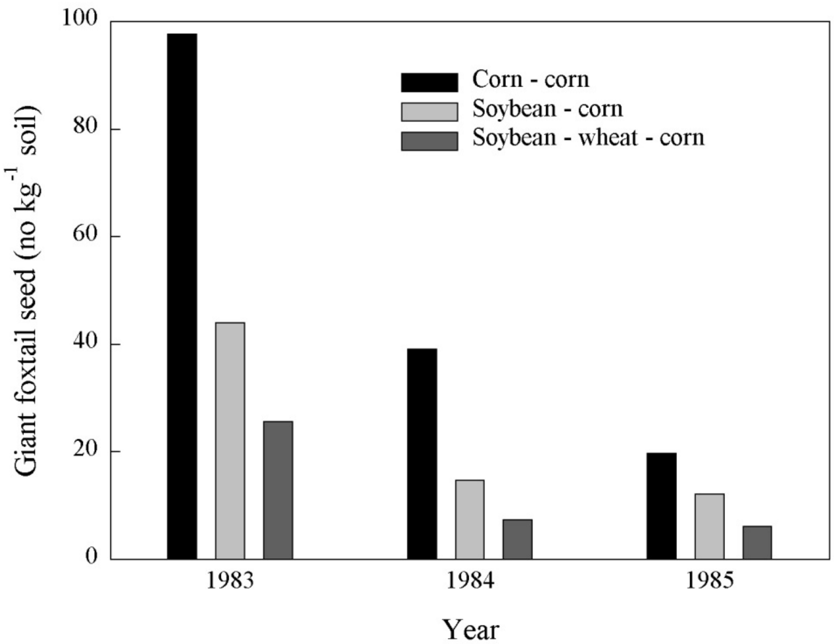
An example of the use of cultural practices to manage the soil seedbank is the use of pre-irrigation and preplant tillage. A common practice in Salinas Valley lettuce production is to list up the beds and preirrigate the field (Shem-Tov et al. 2006). After several days the field is lightly tilled to prepare a smooth seedbed and kill emerged weeds. This practice is a very beneficial weed management tool since it acts to deplete the upper soil layer of nondormant weed seeds and can result in as much as 50% weed control.

Soil disinfestation

With the struggle to find replacements for methyl bromide, to reduce volatile organic compounds (VOCs) and to find new weed control tools for specialty crops, it is appropriate to pause and think what it is we seek to accomplish when we perform “weed control” operations. With most weed control tools such as herbicides, cultivators, tillage equipment, hoes, propane flaming and hand weeding, we are actually killing weeds after the weed seed germinates. For example, a weed that emerges a day after a paraquat application is perfectly healthy because paraquat has no soil activity and does not kill any weed seeds in the soil seedbank. Preemergence herbicides with soil activity, such as oxyfluorfen, have no effect on the weed seedbank and act only on weed seedlings *after* they germinate. The only tools that can kill a weed seed in the seedbank are heat and fumigants–tools that create temporary lethal conditions in the soil. Heat from solarization with clear tarp and moist soil or heat from a steam generator kills viable weed seeds in the soil by “cooking” the seeds. Fumigants such as methyl bromide, 1,3-dichloropropene + chloropicrin (Telone C35) and metam sodium (Sectagon, Vapam) also kill weed seeds in the soil by creating a temporary lethal condition in the soil. Heat and fumigants are therefore used to disinfest soil of weed seeds as well as pathogens and nematodes. With disinfestants the lethal conditions in the soil created by heat or fumigants must be allowed to dissipate so that conditions are not lethal at the time the crop is planted. With heat the soil simply must be allowed to cool. For solarization one simply removes the clear mulch or paints it white to stop solar heating of the soil, and to stop steam heat simply turn off the steam. With fumigants it is more complex as the fumigant must be present in the soil in lethal concentrations long enough to kill the weed seeds. After killing the weed seeds, the fumigant degrades and/or dissipates into the air so that by 1 to 4 weeks after application the field can be planted. It is the dissipation into the air that has caused problems for fumigants with the VOC regulations due to the fact that too many fumigant volatiles escape into the atmosphere.

After the disinfestation process has been completed, the crop can then be planted into soil that has been disinfested of viable weed seeds. The "residual" effect of soil disinfestation, that is season long weed control, occurs because of the depletion of viable weed seeds in the soil seedbank. However soil disinfestation has no "residual" activity as would be true of an herbicide with soil activity. A fumigated or solarized field can quickly be reinfested with wind-blown weed seeds such as common groundsel or hairy fleabane which is why these weeds are so troublesome in crops grown on fumigated soils.

Figure 11. Effects of crop rotation on weed seedbanks 0-2.5 cm deep (Schreiber 1992).

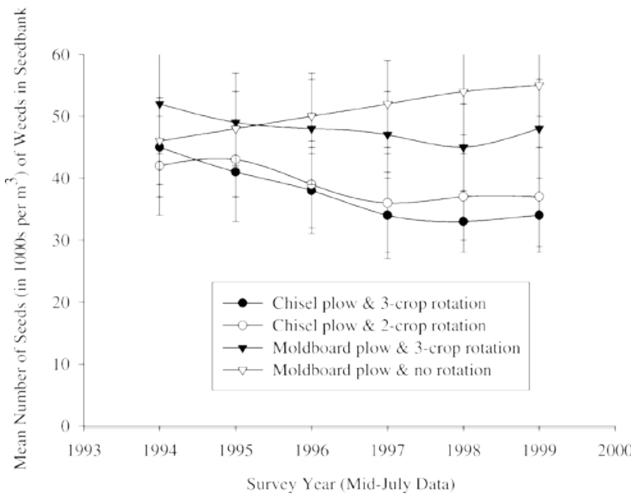


One more concept to introduce is that of depletion of the soil seedbank. Depletion is the cleaning of the weed seedbank either by using a soil fumigant or heat to quickly kill the seedbank, or by carefully preventing weeds from setting seed over a period of several years so that weed seed in the seedbank are depleted to the extent possible. Soil disinfestation is fast but depletion of the seedbank with herbicides, tillage and cultural practices takes several years to conduct. Either way a field with a relatively clean weed seedbank requires constant effort to maintain, as allowing weeds to set seed for a short period of time will quickly reinfest the field.

Crop rotation

Crop rotation is effective for weed management because changing patterns of disturbance diversifies selection pressure. This diversification prevents the proliferation of weed species well suited to the practices associated with a single crop. Schreiber (1992) found that growing corn in rotation with soybean and wheat significantly reduced the number of giant foxtail seed in the soil compared to continuous corn (fig. 11). Similarly Jordan et al. (1995) found that two or more crops in rotation reduced green foxtail but not velvetleaf. Murphy et al. 2006 working in Ontario, Canada found that continuous corn with plowing resulted in increases in the seedbank while 2 or 3 crop rotations with reduced tillage resulted in reductions in the seedbank (fig. 12). The mechanism by which crop rotation reduces the size of the weed seedbanks is related to the use of crop sequences that employ varying patterns of resource competition, allelopathic interference, soil disturbance, and variable weed management strategies. Proliferation of otherwise well-adapted weed species is reduced by these processes that produce a more diverse environment (Buhler 1997).

Figure 12.
Changes in mean number of weed seeds (±SE) in the seedbank from 1994-1999 in no till, chisel and plowed fields (Murphy et al. 2006).



Cover crops. These are rotational crops grown for the purpose of improving soil quality, trapping nutrients such as nitrates to prevent groundwater pollution, preventing erosion (wind and water), increase water infiltration, fix nitrogen (legumes) and suppressing pests including weeds (Bugg and Smith 2011). Examples of cover crops are barley (*Hordeum vulgare*), bell beans (*Vicia faba*), buckwheat (*Fagopyrum esculentum*), cereal rye (*Secale cereal*), sorghum (*Sorghum bicolor*), sudangrass (*Sorghum bicolor* ssp. drummondii) , clovers (*Trifolium* spp. and *Medicago* spp.), vetches (*Vicia* spp.) and many others. Often these crops are planted at high densities and used in mixtures (Radosevich et al. 2007).

Cover crops that rapidly establish a canopy or can be grown at high densities, can be used to suppress weeds. These crops are often called “smother crops” (Radosevich et al. 2007). Means by which cover crops can be made to be more competitive with weeds are by selecting mixtures of cover crops that are well adapted to the area and which rapidly establish a canopy (Brennan et al. 2011). Factors that enhance weed suppression in cover crops are listed in Table 5.

Table 5. Effect of selected factors on weed suppression during cover crop production (Brennan et al. 2011).

Factor	**Effect on weed suppression in the cover crop**
Cover crop variety or mixture	Varieties and mixtures that rapidly develop a canopy are more weed suppressive
Seeding rate	Up to a certain point, higher seeding rates are more weed suppressive than lower rates
Planting date	Plant at the optimal date for rapid establishment of the cover crop, eg. Early fall.
Row spacing	Narrow spacing (15cm) minimizes cover crop competition with itself and maximizes competition against weeds.
Irrigation	Irrigation can help establish cover crops an increase competition against weeds
Planting method	Drilling in rows results in a more uniform cover crop planting than broadcast seeding.

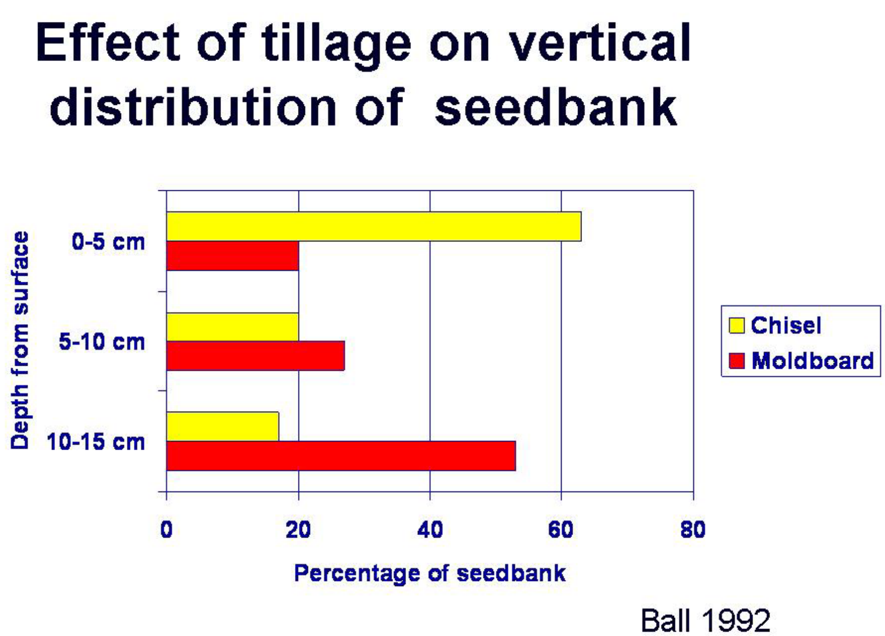
Organic vegetable producers in California often use a cover crop mixture of 35% bell bean, 25% pea, 30% vetch, 10% oat planted at 112 kg/ha which results in a seed density of 151 plants m^2. This cover crop density results in poor weed suppression. Means of increasing the competiveness of this mixture would be to: a) add more oats to the mixture, b) increase the seeding rate to 220 kg/ha, c) use a drill to ensure optimal plant spacing and planting depth (Brennan et al. 2011).

After cover crop planting and emergence, blind cultivation with a rotary hoe or tine weeder can be used to control up to 80% of the weeds in the cover crop with little damage to the cover crop (Brennan et al. 2011). Reduction of weed seed return in the cover crop can lead to less weed seed return to the weed seedbank (Brennan and Smith 2005).

Tillage

Tillage is the primary cause of vertical distribution of weed seed in the soil. Yenish et al. (1992) found that after 5 years, plots tilled with a moldboard plow had fewer weed seed in the upper 20 cm of soil than chisel plow or no-till. In no-till more than 60% of all seed were found in the upper 1 cm of soil, and few were below 10 cm. Ball (1992) compared the effect of plowing and chiseling on the distribution of weed seed in the soil. He found that chiseling left most of the seed near the soil surface, whereas plowing resulted in a more uniform distribution of weed seed within the soil seedbank. (Figure 13).

Figure 13. Influence of primary tillage on vertical distribution of total weed seed to a 15 cm depth. The numbers indicate the % of total seed at each soil depth (Ball, 1992).



Limiting the amount of tillage leaves weed seed close to the soil surface. Therefore, the behavior and fate of weed seed at or near the surface is of great importance in conservation tillage systems. Buhler (1995) found that no-till favored giant foxtail but not velvetleaf. Giant foxtail germinates readily from the soil surface but not from 6 cm deep in the soil. Velvetleaf germinates readily from 2 to 6 cm deep within the soil and grows vigorously, but velvetleaf that germinates on the soil surface often fails to establish seedlings. Weed species that have the ability to germinate and become established when seed are at or near the soil surface have the greatest potential for increase under reduced tillage systems, while those that don't tolerate surface conditions are not favored. Table 6 suggests that shallow germinating species like chickweed and shepherd's-purse might be depleted by shallow tillage, but not wild oat. Researchers in the Salinas Valley found that preplant sprinkler irrigation followed by shallow tillage, reduced weed densities by 16-50% in a lettuce crop planted after shallow tillage (Shem-Tov et al. 2006).

Table 6. The optimum and maximum depths of emergence for several weeds (Radosevich and Holt 1984).

Weed	**Optimum emergence depth** (cm)	**Maximum emergence depth** (cm)
Common chickweed	1.0	2.0
Common lambsquarters	0.5	5.0
Large crabgrass	1.0	4.0
Shepherd's-purse	0.5	2.0
Wild mustard	1.0	6.0
Wild oat	2.5	17.5

Advantages to limited tillage:

1. Easier to use subsurface drip irrigation
2. Reduced nitrate leaching
3. Increased microbial activity
4. Improved soil structure
5. Reduced tillage costs
6. Less dust

Disadvantages to reduced tillage:

1. More difficult to manage weeds
2. Lack of grower experience with reduced tillage systems
3. Requirement for specialized equipment
4. A rough seed bed that may be incompatible with some crops such as vegetables
5. More problems with weeds such as marestail

Conclusions

- Seedbanks are the source of most annual weed species.
- Most seedbanks are dominated by one or two species.
- Seedbank densities in farmland are variable but often high.
- Most weed seeds in the seedbank were produced in the same field.
- The greatest threat from weed seed dispersal is the introduction of new weed species.
- Seed losses occur from germination, decay, predation, fumigation and solarization.
- Dormancy is a key factor that determines when a seed will germinate and allows weeds to persist.
- A small number of weeds can produce lots of seeds, and given the opportunity can restore the weed seedbank to high levels in a short time.

- Fumigation and solarization are among the only treatments that can be used to kill dormant weed seeds in the seed bank.
- Organic and low input systems can result in high density weed seedbanks.
- Crop rotation minimizes the opportunities for one weed species to dominate a field.
- Plowing results in more even weed seed distribution in the soil profile, while chisel plows leave most weed seeds near the surface.

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