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Bob Hartzler

*Iowa State University, hartzler@iastate.edu*

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WEED SEEDS - THE SOURCE OF ALL PROBLEMS

Bob Hartzler
Associate Professor/Extension Weed Management Specialist
Department of Agronomy
Iowa State University

Introduction

The primary reason for controlling weeds during crop production is to prevent crop yield losses due to competition with weeds. However, the majority of Iowa farmers strive to obtain higher levels of weed control than necessary to protect crop yields. The rationale for this contradiction is the concern about the production of seeds by weeds left in the field. Since the majority of weeds found in Iowa row crops are summer annuals, the seedbank is the source of new weed infestations each spring. The seedbank influences both the weed populations that occur in a field and the success of weed management programs.

The weed seed cycle is depicted in Figure 1. The size of the seedbank fluctuates widely depending on the magnitude of seed introductions and seed losses. Weeds are legendary for their capacity to produce seeds and for the longevity of these seeds in the soil. While there is no doubt that weeds can be quite remarkable in these aspects, the capabilities of weeds are often exaggerated. This paper will discuss the different components of the weed seed cycle and the importance of the seedbank to weed management.

Inputs to the Seedbank

New seeds may enter the seedbank through many sources, but by far, the largest seed source is weeds found within the field. A characteristic of many weed species is prolific seed production. Table 1 lists the seed production potential of several weed species. While these numbers are impressive, weeds present in agricultural fields usually will produce fewer seeds than listed in the table due to competition from the crop, damage from herbicides and other factors. For example, an Arkansas study found that cocklebur growing in the absence of crop competition produced over 7000 seeds per plant, whereas seed production of cockleburs growing with soybeans was reduced to 1100 seeds. A delay in weed emergence compared to the crop will greatly reduce the competitiveness and seed production capacity of weeds. Redroot pigweed that emerged at the same time as corn produced over 24,000 seeds per plant, whereas plants that emerged four weeks after corn produced less than 3000 seeds. It should be pointed out that although the reproductive capability of many weeds may be overstated, seed production is still great enough to allow rapid increases in the seedbank with even moderate weed infestations.

Seeds may also enter fields from external sources, such as being carried by farm equipment, animals, wind, or in manure. The number of seeds introduced into the seedbank by these sources is much smaller than from seed produced by weeds found in the field; however, these sources are important in establishing new infestations of weeds. Many weeds (e.g. Canada thistle, horseweed, dandelion) have seeds that are adapted to wind dispersal. Noxious weed laws...
originally were directed primarily towards wind-blown species with the intent of protecting farmers from neighbors who failed to control weeds. Dandelion and horseweed have become widespread problems in no-till partially due to the long-distance wind transport of their seeds.

Manure can be an important source of weed seeds. While the majority of seeds are killed when passing through the digestive tracts of animals, a small percentage typically survive (Table 2). A study of 20 New York dairy farms found that, on the average, spreading manure introduced approximately 34 weed seeds per square foot. Although this may seem like a high number, it is relatively low compared to the number of seeds already present in the seedbank. If manure is spread on the same fields from where the feed was harvested, the number of seeds returned to the field will be of little consequence. However, manure can be a source of new weed problems if feed is contaminated with weed seeds not already found on the farm.

Another mechanism of weed seed transport is farm machinery moving between fields. This transport mechanism has become more important as farm size has increased and machinery is moved longer distances. Movement of woolly cupgrass seed on equipment probably is largely responsible for the rapid spread of this weed. The risk of spreading weed seeds into non-infested fields can be reduced by working infested fields last or by thoroughly cleaning machinery after working in infested fields.

**Losses from the Seedbank**

Although the seeds of many weed species have the potential for long-term survival in the seedbank, the majority of seeds have a relatively short life-span in the soil. Several factors account for the loss of weed seeds in the soil, including germination, decay, predation and movement. The relative importance of these mechanisms varies with species and environmental conditions.

**Germination and dormancy.** Agronomists are primarily interested in those seeds that germinate, since it is these seeds that result in new weeds that must be controlled. Most weed species possess dormancy, a trait that prevents seeds from germinating even when placed under favorable environmental conditions. Dormancy ensures that once a weed becomes established in a field, it will continue to be a problem for the foreseeable future. Without dormancy, a farmer could use intensive management for a single year with the goal of preventing any weed seed production, therefore ridding the field of the weed problem.

Dormancy is a complex process and poorly understood in most weed species. There are several different mechanisms that may prevent germination - dormancy in some species may be controlled by one factor, whereas other species may have several mechanisms. Seeds of some species, particularly small-seeded weeds, may require light to break dormancy. This mechanism reduces the likelihood of a seed germinating deep in the soil profile where survival is unlikely. The seedcoat may enforce dormancy by preventing the absorption of water or oxygen. Velvetleaf and morningglory are examples of weeds with impervious seedcoats. Dormancy may also be due to the presence of germination inhibitors in the seed or seeds having immature embryos at the time of seed shed.
The level of dormancy in a group of seeds is influenced by both genetics and environment. Seeds coming from the same mother plant may have different degrees of dormancy depending upon environmental conditions at the time of seed ripening and seed position on the seedhead. The complexity of dormancy has limited our ability to predict weed emergence, however; current research on seed dormancy and the seedbank is getting us closer to having this ability.

The percentage of seeds in the seed bank that germinates in a given year is influenced by both the species and environment that the seed encounters. For most species, it is believed that approximately 1 to 40% of the seed bank will emerge in a given year. A study conducted near Ames during 1995 illustrates the difference in emergence of four weed species (Figure 2). In October of 1994, 2000 freshly-harvested seeds of each species were buried in the top two inches of soil, and emergence was monitored throughout the 1995 growing season. Velvetleaf emergence began on April 28, followed by woolly cupgrass (May 2), giant foxtail (May 15) and finally common waterhemp (May 22). Over the entire growing season, approximately 40, 35, 8 and 6% of the cupgrass, foxtail, velvetleaf and waterhemp seeds emerged.

One of the reasons common waterhemp has become a major problem in Iowa is that it emerges relatively late in the season. By June 15, cupgrass, foxtail and velvetleaf had reached 90% emergence for the year, compared to only 60% for waterhemp (Figure 2). Late emergence is an excellent mechanism for weeds to escape postemergence herbicides due to the lack of residual activity in most products. Other sources of losses. The majority of weed seeds fail to develop into a mature plants, but the fate of weed seeds in the seedbank is poorly understood. Seeds are an important food source for many insects, birds and small mammals. In natural settings, more than 70% of seeds may be consumed by animals. Seed predation is much less in agricultural settings due to the intensive soil disturbance and lack of habitat for predators. However, studies have found significant weed seed losses (nearly 50%) from feeding by insects in some no-till systems. Many seeds simply decay in the soil after being infected by fungi or other microorganisms. Research is being conducted to isolate microorganisms that are more efficient at infecting seeds in the soil. If found, these pathogens could be used to inoculate soils and reduce the seedbank size. As with any biological control organism, an organism must be found that will infect weed seeds but will not attack seeds of desirable species (crops).

Some weed seeds may be removed from fields by various mechanisms. Water moving through a field is an efficient carrier of weed seeds. Fields that are occasionally flooded by rivers or streams frequently have a more diverse weed population due to deposition of new species in the field. Field machinery, particularly harvesting equipment, also can carry seed out of a field. Losses due to movement generally will be small in relation to the size of the total seedbank, but these seeds are important in starting new infestations.

Seedbank Dynamics

Because of the magnitude of seed losses and inputs to the seedbank, the size of the seedbank can change dramatically in a two to three year period. It is estimated that approximately two-thirds of the existing seedbank is lost every year due to germination, predation or decay. 'Weedy'
fields can be cleaned up with a few years of good management; conversely, a clean field can become a problem field following one or two years of poor control.

A long-term study in Colorado evaluated changes in the weed seedbank continuous-corn (Figure 3). The seedbank dropped by approximately 70% after three years of standard management practices (2 lbs atrazine + cultivation). After three years, atrazine use was discontinued in a portion of the plots and weeds were managed with one or two cultivations. After three years of no herbicide use the seedbank was approximately 25 times greater than where atrazine use was continued.

A study in Iowa evaluated the impact of a single year’s velvetleaf seed production on future velvetleaf populations (Table 3). Velvetleaf were planted in soybeans at a population of one plant every 10 feet of row (0.4 velvetleaf/m²). For the next four years, the field was maintained in a corn-soybean rotation and velvetleaf plants were counted as they emerged and then removed to prevent any additional seed production. Each plant that went to seed in 1990 resulted in more than 1000 new plants over the four year period. Velvetleaf emergence dropped by 80% between years 2 and 4 of the experiment. After four years, emergence from the seed bank accounted for only 25% of the introduced seed. The majority of remaining seeds probably were lost due to decay and other losses by the end of the four years.

These studies illustrate the fairly rapid decline in the seedbank when seed introductions are minimized or prevented. However, a small number of seeds generally will survive for long periods in the soil. It is these seeds that produce plants that replenish the seedbank when the management program allows weeds to escape control. This is one reason why it is nearly impossible to eradicate weeds from a field once they become established.

Impact of the Seedbank on Weed Management

Since the seedbank is the source of all annual weeds, it is critically important to crop production. We know that more inputs are required to achieve acceptable levels of control in fields with a large seedbank than in fields with a small seedbank. Less clear is the impact that a small increase in the seedbank size has on the efficiency of weed management programs.

In order to evaluate the influence of the seedbank on weed control, a study was conducted in two fields with large differences in weed seedbank size. In the first year of the study, plots were established with either 0% or 100% weed control. During the second year of the study, the influence of the previous year’s weed control on herbicide performance was evaluated. In the field with a large initial seedbank, Dual provided 75% foxtail control in plots where heavy infestations of giant foxtail (60 plants/ft²) had gone to seed the previous year. In the same field, Dual provided 95% control in plots maintained weed free the previous year. In this field, a large increase in the seedbank reduced herbicide performance. In the field with a small seedbank, low grass populations (1 plant/ft²) the previous year did not influence grass control by Dual. This study supports the idea that small increases in the size of the seedbank probably will not significantly influence herbicide performance.

The economic threshold is defined as the weed population that causes a yield loss with a value equal to the cost of an effective control strategy for that weed population. According to the
threshold theory, weed populations less than the economic threshold should be left in the field. Economic thresholds have been criticized for not accounting for the cost of weed seeds on future weed management programs. Economic optimum thresholds are thresholds that consider the impact of seed production on future weed populations. Researchers at the University of Nebraska calculated that the economic optimum threshold for veleleaf in soybean would be $1/7$ that of a single year economic threshold.

A better understanding of weed biology is critical for the development of more efficient weed management systems. Two areas of critical importance are seed dormancy and soil seedbank dynamics. The knowledge gained through weed biology research will not allow us to eliminate the inputs (herbicides and tillage) currently used to manage weeds. However, it will provide the foundation for the development of new strategies and more efficient techniques to use these tools, resulting in more reliable weed management systems that are cost effective and pose less threat to the environment.

Table 1. Seed production capability of several weed species.

<table>
<thead>
<tr>
<th>Species</th>
<th>Seeds/plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Redroot pigweed</td>
<td>229,175</td>
</tr>
<tr>
<td>Lambsquarter</td>
<td>38,000</td>
</tr>
<tr>
<td>Penn. smartweed</td>
<td>6,500</td>
</tr>
<tr>
<td>Black nightshade</td>
<td>40,000</td>
</tr>
<tr>
<td>Sunflower</td>
<td>9,100</td>
</tr>
<tr>
<td>Woolly cupgrass</td>
<td>40,000¹</td>
</tr>
<tr>
<td>Giant foxtail</td>
<td>4,030</td>
</tr>
</tbody>
</table>

Stevens, N. Dak., 1958.
¹ISU estimate.

Table 2. Influence of passing through animal digestive tract on weed seed viability.

<table>
<thead>
<tr>
<th>Weed species</th>
<th>% Viable Seeds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Calves</td>
</tr>
<tr>
<td>Velvetleaf</td>
<td>11.3</td>
</tr>
<tr>
<td>Bindweed</td>
<td>22.3</td>
</tr>
<tr>
<td>Smartweed</td>
<td>0.3</td>
</tr>
<tr>
<td>Peppergrass</td>
<td>5.4</td>
</tr>
</tbody>
</table>

Harman and Keim, U. of Neb., 1934.

Table 3. Number of velvetleaf emerging following seed production by a single plant in 1989. Kanawha, IA.

<table>
<thead>
<tr>
<th>Year</th>
<th>No. velvetleaf per 1990 plant</th>
<th>% emergence of 1990 seeds¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>347</td>
<td>8</td>
</tr>
<tr>
<td>1991</td>
<td>490</td>
<td>11</td>
</tr>
<tr>
<td>1992</td>
<td>137</td>
<td>3</td>
</tr>
<tr>
<td>1993</td>
<td>87</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>1060</td>
<td>25</td>
</tr>
</tbody>
</table>

¹Assuming seed production of 4300 seeds per plant.
Survivors

Mortality events

SEED RAIN (SEED PRODUCTION)
- predation
- degradation
- germination

creates diversity in age

SEED IN SPRING (AVAILABLE POOL FOR GERMINATION)
- predation
- degradation
- germination w/o emergence

Germination with emergence
( env. and management drivers)

SEED CARRYOVER
predation, degradation

Figure 1. Weed seed cycle
Figure 2. Emergence of four weed species from seedbank. Ames, 1995. Hartzler and Buhler, ISU and USDA-ARS.

Cumulative % emergence

Woolly cupgrass
Giant foxtail
Velvetleaf
Waterhemp

Figure 3. Seedbank fluctuations with standard management practices in continuous corn. Schwizer and Zimdahl. 1984.

Cultivation only treatment initiated in 1978.