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Biologically intensive manipulation of foxtail seed banks for enhanced mortality

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Biologically intensive manipulation of foxtail seed banks for enhanced mortality

Abstract

Studies were conducted at several Iowa locations to determine the fates and long-term carry-over of giant foxtail in agricultural soil weed seed banks, and the variability of these seed fates.

Keywords

Agronomy, Weed control alternatives (not GMOs)

Disciplines

Agricultural Science | Agriculture | Agronomy and Crop Sciences | Weed Science



Biologically intensive manipulation of foxtail seed banks for enhanced mortality

Abstract: *Studies were conducted at several Iowa locations to determine the fates and long-term carry-over of giant foxtail in agricultural soil weed seed banks, and the variability of these seed fates.*

Background

Current weed management systems are not sustainable. There is a need for biologically intensive strategies that either complement or replace herbicides or alternative weed control measures, particularly for persistent weed species.

The weedy foxtails are among the most aggravating weed groups affecting U.S. agriculture and the giant foxtail is a particular problem in Iowa. Giant foxtail is extremely successful because of its ability to form long-lived soil seed banks, reservoirs of highly heterogeneous seed.

Little is known about foxtail emergence factors, mortality, dispersal, and longevity in agricultural fields. Also poorly understood are the influences of factors such as the environment, location (field and soil depth), cropping systems, tillage systems, weed control practices, and population (genetic) diversity on soil seed bank dynamics. Understanding what motivates the appearance and disappearance of the giant foxtail in the soil would allow farmers to manipulate those factors to manage seed banks for improved, sustainable crop productivity.

Project objectives were to:

- Determine the fates and long-term carryover of giant foxtail in agricultural soil seed banks, and the variability of these seed fates due to differences in giant foxtail populations (annual seed rains), Iowa field site locations, soil depth of burial,

and long-term time (two-year fate), and

- Use this information to guide subsequent research and technology transfer to enhance seed mortality, to improve management of weed seed banks, and to implement sustainable crop and weed management strategic and tactical goals.

Approach and methods

The six fates of foxtail seed were determined in seed banks created in three Iowa locations. The potential fates include foxtail seed that 1) germinate and emerge, 2) germinate and do not emerge (“fatal” germination), 3) are dead and present in the soil, 4) are absent (decayed and rotted, predation, dispersal out of the seed bank), 5) are alive, present, and germinable, and 6) are alive, present, and dormant.

For each year of the project, two different giant foxtail seed populations were used at each site. The differing populations were used to assess the variation in seed fates due to genotype, as well as the seasonal influences of the August-October environmental conditions on those genotypes. The germination and dormancy of the seed shed in a particular year can be highly variable. The populations selected represent the diversity of giant foxtails as assessed in related ongoing research utilizing the germination thermogradient table facility in ISU’s Agronomy Hall.

Seed banks created at three diverse locations in Iowa were placed in fields previously dominated by sod that has been shown to contain little or no giant foxtail seed. Seed was ex-

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\$21,600 for year one
\$22,000 for year two
\$22,600 for year three

tracted periodically (17 or 18 times per year) from each location. The numbers and proportions of each seed fate were assessed to see how they changed over time in each of the two years, at different soil depths, for each of the different foxtail populations and sites.

Results and discussion

Some of the new information gained from this project:

1. Foxtail seed, shed in vast numbers every year throughout Iowa, have deep and highly variable dormancy levels that allow germination over the entire growing season.
2. Foxtails adapt quickly to individual fields and fine-tune their behavior for even more effective weed emergence patterns. The majority of seed that are shed remain hidden in the soil, waiting for the most favorable conditions for to emergence to ensure maximum seed production.
3. Early season seed is the most numerous and the most dormant.
4. Foxtail seedlings can emerge any time in the season that the soil is unfrozen, but most come up early (April through June). Seed buried deeply by tillage emerges less readily than more shallow seed, but the deeper seeds also remain alive in the soil longer, constituting a continuing threat in those fields.
5. Foxtail emergence differs depending on the age of the seed.
6. Foxtail seed behavior is driven by oxygen in soil water. Cool water is rich in oxygen, and the cool wet soils of spring precede the big foxtail seedling flushes every year. This behavior might guide management systems in the future. Cropping systems that warm the soils quickly will inevitably clip the end of this spring flush, and will inhibit late emerging seedlings, especially those troublesome ones emerging after lay-by cultivation.

Conclusions

Foxtail seed dormancy is highly variable, requiring from 0 to 12 weeks of after-ripening (i.e., time at 4° C, dark moist conditions) to germinate the heterogeneous seed produced by an individual plant. Project investigators discovered that giant foxtail adapts very quickly to an individual field, and seed collected in the same fields consistently ranked the same (in terms of relative dormancy) compared to other fields over the years. This variable dormancy differs among foxtail populations, and populations adapted to a field are consistent year to year so a farmer can make some predictions on foxtail emergence knowing that a field is consistently more or less dormant than other fields.

Seed produced early in the season (August) is consistently more dormant than seed produced later in the season (October). Green and giant foxtail varieties are similar in terms of dormancy in seed produced, while yellow foxtail seed is usually the most dormant. Seed produced on primary panicles is more dormant than that produced on secondary and subsequent tillers of the same plant. Seed produced in the shade is more dormant than that in full sunlight. Nutrient status of the soil and stress on the plants appear to have little effect on the dormancy of seed produced. Seed buried relatively deeply emerges to a lesser extent than that at shallower depths, but the seed placed more deeply survives longer.

Emergence of seedlings can occur any time the soil is unfrozen, but the typical pattern is large numbers early with decreased emergence after the lay-by period. This generalization is from the aggregate of all seed in the soil, while seed of different ages (time in the soil) has distinctive patterns of emergence that differ from the average to varying degrees. This observation has implications for management.

Among the new insights gained from this project: There is good evidence that foxtail seeds in the soil change their strategy of emerging as they age. One-year-old seed jumps up in big numbers in the first spring. The two-year-old seed emerges more uniformly over the season. Three-year-old seed emerges late, after lay-by, when it has a free run to autumn seed production.

The signal in the soil that triggers all foxtail seed behaviors (dormancy, germination, emergence, etc.) is the amount of oxygen dissolved in water taken into the seed. In the spring, the soils are cold and unfrozen, and times of maximum water and oxygen availability (oxygen solubility are inversely correlated with temperature). Large daily changes in soil temperature in the spring pump even more into the foxtail seed and soon the large spring flush of seedling emergence occurs. As the soil warms up in July and water availability and oxygen solubility decrease, the secondary (summer) dormancy period occurs in most of the seed. Some small portion of the seed, however, may have received enough oxygen to allow continuous seedling emergence for the rest of the season.

Impact of results

The project gathered information linking the dormancy of many foxtail populations (gathered over years and times of the season) with their behavior (seedling emergence time, dormancy cycling in the soil for years, mortality, effect of soil burial depth, etc.). The analysis of seedling emergence is contained in the thesis of a graduate student who worked on the project. Analysis of the soil-seed core information on mortality and dormancy cycling still is being conducted.

The first foxtail emergence prediction will be made in the autumn preceding the growing season, and will be based on dormancy state heterogeneity as the seed falls, a big determinant of subsequent behavior. The fine-tuned prediction will come as the late winter and early spring (soil thaw) proceeds. The spring prediction will be based on soil temperature, hence oxygen solubility; and on diurnal temperature fluctuations in the top two inches of the soil—the “Big Oscillator” as project investigators refer to the soil oxygen pump driving the seeds out of the ground.

The major impact of the results lies within the rich data set derived on the various fates of foxtail populations and species from several locations grown in common nurseries at several locations, and the predictive tools they will support in future development efforts. Further resources are needed to interpret the data, develop tools, and help transfer this technology to farmers.

Principal investigator Jack Dekker currently is using this extensive data set to develop several computer tools that will help growers predict foxtail emergence in real time. The computer models used will be based on dormancy states in foxtail seed falling to the ground in the fall.

Education and outreach

Publications detailing work and results from this foxtail project have appeared in the *American Journal of Botany*, *Weed Science*, *Journal of Crop Production*, and in several books and proceedings volumes.

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