Functional impacts of biodiversity: Indigenous mice and insects reduce weed population growth rates in low-external-input cropping systems

M Liebman, A H Heggenstaller
Iowa State University, Department of Agronomy, Ames, IA, 50011, USA
Email: mliebman@iastate.edu

B J Danielson
Iowa State University, Department of Ecology, Evolution, and Organismal Biology, Ames, IA, 50011, USA

P R Westerman
Universitat de Lleida, Departamento de Hortofruticultura, Botánica y Jardinería, Av. Alcalde Rovira Roure 191, 25198 Lleida, Spain

Herbicides are the most heavily used class of pesticide in American agriculture and pervade the production of agronomic crops. This is especially true in the Midwestern states, where farmers annually apply an estimated 68 million kg of herbicide active ingredients to 39 million ha of maize and soyabean. Herbicides have increased the productivity of agricultural labour, fostered the development of soil-conserving zero-tillage systems, and simplified the process of crop production. Nevertheless, many scientists, farmers and policy makers now seek alternatives to heavy reliance on herbicides, due to concerns over resistance evolution in weeds, environmental contamination and threats to human health. Information concerning the performance of alternative cropping systems and ecologically based weed management strategies is needed if substantial reductions in herbicide use are to be realised.

We conducted a multi-year, 9-ha field experiment near Boone, Iowa, to test the hypothesis that weeds could be suppressed as effectively in diversified, low-external-input (LEI) cropping systems as in less diverse systems that relied on conventional rates of herbicides. The experiment included a 2-year rotation system (maize/soyabean) that received herbicides and synthetic fertilisers at conventional rates, and a 3-year rotation (maize/soyabean/small grain + red clover) and a 4-year rotation (maize/soyabean/small grain + alfalfa/alfalfa) treated with less herbicide and fertiliser. Averaged over 2003-2006, herbicide inputs were 76% lower in the 3-year rotation (0.50 kg a.i. ha^{-1} yr^{-1}) and 82% lower in the 4-year rotation (0.38 kg a.i. ha^{-1} yr^{-1}) than in the 2-year rotation (2.09 kg a.i. ha^{-1} yr^{-1}). Triticale was used as the small grain crop in 2003-2005; oat was used in 2006.

Particular attention was directed toward understanding the effects of contrasting rotation systems and attendant ecological processes on the population dynamics of two common annual weed species, velvetleaf (*Abutilon theophrasti*) and giant foxtail (*Setaria faberi*). In November 2002 we measured weed seed densities in the surface 20 cm of soil and then added a pulse of velvetleaf and giant foxtail seeds (470 + 1,876 viable seeds m^{-2}, respectively) to 7 m x 7 m areas of each experimental plot. Subsequently, during 2003-2006, we monitored densities of velvetleaf and giant foxtail seeds, seedlings, and reproductive adults, production of new seeds and losses of seeds to predators.

As compared with initial seed bank densities, velvetleaf seed densities in April 2006 were reduced 68% in the 2-year rotation, 31% in the 3-year rotation, and 51% in the 4-year

To continue to a second page, once the last line of text fills the box above you must move to the next page

rotation. For giant foxtail, seed densities were reduced 97% in the 2-year rotation, 55% in the 3-year rotation, and 81% in the 4-year rotation between 2002 and 2006. These reductions in weed seed bank densities occurred despite cumulative additions, in the 3-year and 4-year rotations, of as many as 519 velvetleaf seeds m^{-2} and 6,983 giant foxtail seeds m^{-2}.

Measured rates of velvetleaf and giant foxtail seedling emergence and literature values for rates of seed decay failed to explain the discrepancies between observed and expected seed densities. Substantial losses of velvetleaf and giant foxtail seeds to predators were detected, however. To determine rates of weed seed loss to predators during spring, summer and autumn, we placed velvetleaf and giant foxtail seeds on 6 cm x 8 cm sandpaper cards that were protected by narrow mesh wire screen or exposed to predators on the soil surface. Averaged over different crops, rotation systems and 27 sampling periods during May–November 2003 and April–November 2004, mean rates of seed removal were 33% per 48 hours for velvetleaf and 53% per 48 hours for giant foxtail. To determine rates of seed losses to predators during late autumn, winter and early spring, we placed velvetleaf and giant foxtail seeds in 60 cm x 60 cm wire mesh trays that were covered by wire mesh exclosure cages or "sham" cages that allowed passage of seed predators through small doors. Averaged over crops and rotation systems, cumulative losses of seeds from November 2005 to March 2006 were 72% for velvetleaf and 62% for giant foxtail; seed losses to predators from November 2006 to April 2007 were 90% for velvetleaf and 84% for giant foxtail. Data obtained from pitfall traps and Sherman live traps indicated that field crickets, carabid beetles and prairie deer mice were the most important seed predators, with activity-densities of the different taxa exhibiting contrasting temporal patterns. Modelling analyses indicated that weed seed predation could account for the observed declines in soil seed banks and had particularly marked suppressive effects on weed dynamics in the LEI systems. Without seed predation, giant foxtail density in the LEI 3-year rotation would be expected to increase.

Measurements of weed biomass made in September and October of 2003-2006 in areas of the plots that were not intentionally infested with velvetleaf and giant foxtail indicated that weed productivity in maize and soyabean did not differ among rotation systems and was low ($\leq$4.2 g m^{-2}) in all years. Weed growth in small grain stubble was more variable than in other crop types and in 2003 reached the highest levels measured in the experiment (32.0 g m^{-2}). In contrast, weed biomass in established alfalfa was low ($\leq$3.2 g m^{-2}) in all years and similar to levels measured in maize and soyabean.

Crop data taken to complement the weed studies indicted that maize and soyabean yields in the LEI 3-year and 4-year rotation systems matched (2003 and 2004) or exceeded (2005 and 2006) levels obtained from the conventionally managed 2-year rotation system. Labour requirements were higher for the LEI systems, but without government crop subsidy payments, net returns to land and management during 2003-2006 were greatest in the 4-year system (\$540 ha^{-1} yr^{-1}), least in the 3-year system (\$475 ha^{-1} yr^{-1}), and intermediate in the 2-year system (\$504 ha^{-1} yr^{-1}). With subsidies, the economic advantage of the 4-year system was reduced, but not eliminated. We conclude that certain types of diversified LEI systems can be agronomically and economically competitive with less diverse, conventionally managed systems, and that ecological processes such as seed predation can contribute to effective weed management with less reliance on herbicides.