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Velvetleaf Responses to 2-Year and 4-Year Crop Rotation Systems

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Abstract
In 1938, C.E. Leighty described crop rotation as "the most effective means yet devised for keeping land free of weeds." Despite the accumulation of a considerable amount of evidence to support this assertion, little has been learned over the past six decades about why, mechanistically, cropping system diversity suppresses weeds. The field experiment and modeling work described here were initiated to address this issue and focused particularly attention on the question of whether diverse rotations can achieve effective weed control through greater reliance on ecological interactions, such as seed predation, rather than herbicides.

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Introduction

In 1938, C.E. Leighty described crop rotation as "the most effective means yet devised for keeping land free of weeds." Despite the accumulation of a considerable amount of evidence to support this assertion, little has been learned over the past six decades about why, mechanistically, cropping system diversity suppresses weeds. The field experiment and modeling work described here were initiated to address this issue and focused particularly attention on the question of whether diverse rotations can achieve effective weed control through greater reliance on ecological interactions, such as seed predation, rather than herbicides.

Materials and Methods

A 9-hectare field experiment and matrix models are being used to examine how 2-year (corn-soybean) and 4-year (corn-soybean-triticale/alfalfa-alfalfa) crop rotations affect velvetleaf (*Abutilon theophrasti*). In 2003, herbicides were broadcast-applied at labeled rates to corn and soybean in the 2-year rotation. In contrast, banded herbicide applications and cultivation were used for corn and soybean in the 4-year rotation; triticale and alfalfa received no herbicides and were mowed for weed control. Consequently, the 4-year rotation received 82% less herbicide than the 2-year rotation (2.39 vs. 0.42 kg a.i. ha^{-1}).

In November 2002, the soil seed bank was characterized and a pulse of velvetleaf seeds was added (500 seeds m^{-2}) to 7 × 7-m areas of each 18 × 85-m plot. During the 2003 field season, velvetleaf seed, seedling, and reproductive adult densities; seed production; and losses to seed predators were monitored. Only seed production and seed predation are reported here. Velvetleaf seed production was determined by collecting seeds as they matured, counting them, and replacing them on soil near where they were collected. Removal of velvetleaf seeds by vertebrate and invertebrate seed predators was assessed by placing sandpaper cards that contained 50 velvetleaf seeds at several locations within each plot during 12, 2-day periods from May through November. The number of seeds remaining on each card was determined at the end of each 2-day trial.

Velvetleaf population dynamics were studied using demographic data from the field experiment to parameterize a depth-structured periodic matrix model.

Results and Discussion

In 2003, weed seed production ($X \pm SE$, seeds m^{-2}) was greatest in the soybean phase of the 4-year rotation (1,804 $\pm$ 860) and markedly lower in the soybean phase of the 2-year rotation (32 $\pm$ 26), as well as in the corn phase of the 2-year rotation (0 $\pm$ 0), and the corn, triticale, and alfalfa phases of the 4-year rotation (21 $\pm$ 18, 11 $\pm$ 4, and 0 $\pm$ 0, respectively).

Over the period from May through November, the mean rate of seed predation ($X \pm SE$, % per 2 days) was greatest in alfalfa of the 4-year rotation (43 $\pm$ 5), least in soybean of the 2-year rotation (13 $\pm$ 3), and intermediate in the 2-year corn (19 $\pm$ 3), 4-year soybean (21 $\pm$ 3), 4-year triticale (32 ± 4), and 4-year corn (35 ± 4). Field crickets, carabid beetles, and prairie deer mice were the dominant seed predators recovered in traps.

Modeling analyses indicated that in the absence of seed predation, velvetleaf populations should decline in the 2-year rotation (λ=0.93), but increase moderately in the 4-year rotation (λ=1.17)(the population is in equilibrium when λ=1). However, if seed predation in all crop phases exceeded 24%, or if predation of velvetleaf seeds produced in the soybean phase exceeded 40%, velvetleaf density in the 4-year rotation should also decline. Achieving such a level of seed predation appears possible, given the observed daily rates of seed removal and the fact that no tillage occurs in the 4-year rotation for 26 months after soybean harvest, thus favoring seed exposure on the soil surface to predators.

Models that included estimates of seed predation indicated that to prevent increases in velvetleaf density, weed control efficacy in soybean must be ≥93% in the 2-year rotation, but could drop to 86% in the 4-year rotation. These results support the hypothesis that diverse rotations that exploit multiple stress and mortality factors, including weed seed predation, can contribute to effective weed suppression with less reliance on herbicides.

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