



## Crop and field border effects on weed seed predation in the southeastern U.S. coastal plain



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### ABSTRACT

Weed seed predation was studied in nine organic crop fields (three each of maize, soybeans and hay; 2.5–4.0 ha each) surrounded by four experimental field border types (planted native grass and prairie flowers, planted prairie flowers only, fallow vegetation, or mowed vegetation) during the fall of 2009 and 2010 in eastern North Carolina. We used predator exclusion cages to determine the amount of weed seed removal caused by invertebrates and vertebrates. Three common agricultural weed species, red-root pigweed (*Amaranthus retroflexus*), broadleaf signalgrass (*Urochloa platyphylla*), and sicklepod (*Senna obtusifolia*), were adhered to individual cards and placed inside the enclosure cages once a month for two weeks. Activity-density of invertebrate weed seed predators was measured with pitfall traps. Results show that field border type had no effect on seed removal rates, but that crop type heavily influenced both weed seed predation and invertebrate seed predator activity-density. Weed seed predation was highest in the dense, perennial hay fields and lowest in the more open harvested maize fields. Activity-densities for field crickets (*Gryllus* sp.) and the ground beetle *Harpalus pennsylvanicus* were also high in the hay fields and low in the maize fields, while the red imported fire ant (*Solenopsis invicta*) seemed to prefer the open maize fields. These results show that increasing vegetative diversity in field borders is not always an effective method for conserving weed seed predators, but that higher quality habitat inside the crop field can be achieved by increasing ground cover.

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### 1. Introduction

Preventing weed seeds from entering the soil is an important weed management strategy because the weed seedbank is the main source of new weeds in agricultural fields. Increases in the weed seedbank lead to greater management costs in subsequent seasons (Hartzler and Roth, 1993; Taylor and Hartzler, 2000). Westerman et al. (2003) found that post-dispersal weed seed predation in organic cereal fields accounts for greater losses to seedbanks than aging, microbial decay or even disturbances like cultivation. Menalled et al. (2000) showed that fields adjacent to complex border vegetation experienced increased seed predation. However, other studies have been unable to replicate these results, possibly due to small plot sizes (e.g. Kollmann and Bassin, 2001),

and it is not clear if increasing vegetative diversity in areas around crop fields augments weed seed predation in all systems.

Compared to more temperate areas where winter refuge sites are critical for invertebrate survival, warmer average temperatures and infrequent ground freezes in the humid subtropical zone mean that many insects are active all year long (Keller, 1986; Kimura, 1988). Furthermore, while an earlier study confirmed that carabid beetles are the predominant weed-seed-eating invertebrate in the Southeast (Brust and House, 1988), a more recent study found that the invasive fire ant, *Solenopsis invicta* Buren, is now the dominant weed seed predator in the region (Pullaro et al., 2006). This study was undertaken to examine how field border management in the southeastern U.S. affects seed predator abundance and weed seed predation services. Managed habitats along fields are increasingly common due to cost-share programs designed to enhance wildlife habitat in the region, particularly for quail. Multiple field border types were tested, varying in vegetative diversity and management practices. This project was part of a multidisciplinary effort to find a crop field border conservation strategy that maximizes ecosystem services. Our objectives were to (1) determine how vegetative

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diversity along field borders affects seed predator activity-density and seed removal rates and (2) if this effect changes with crop type.

## 2. Methods

Research was conducted at the Center for Environmental Farming Systems' (CEFS) Organic Research Unit (ORU) in Goldsboro, NC during 2009 and 2010. Three crops and three replicate plots of 2–4 ha in the ORU were used for this study. The experimental design was a split-plot design with multiple levels of nesting. The hierarchy of variables was crop type, field border type, distance (repeated measure), weed species, and month (repeated measure). Each factor was randomly assigned within the level above except for the two repeated measure factors (distance and month). The crops in these fields followed a typical organic rotation for the southeastern United States: soybeans (*Glycine max* (L.) Merr.) followed by maize (*Zea mays* L.) followed by hay. Each of these crops was planted in three of the nine fields every year. The first year the hay crop was planted in the fall and consisted of orchard grass (*Dactylis glomerata* L.) and white clover (*Trifolium repens* L.). The second year the hay crop was planted in late summer and consisted of sorghum sudangrass (*Sorghum bicolor* subsp. *drummondii* (Steud.) de Wet ex Davidse), cowpea (*Vigna unguiculata* (L.) Walp.), and forage soybean. The maize was harvested and stubble was tilled under prior to the start of the experiment each year. In both years, the soybeans began to senesce in October, reached full maturity after the last trial, and were harvested in late November or December.

Four experimental field border types were established around each field in the spring of 2008. The first was a frequently mowed grassy border (Mowed), mowed two weeks prior to each trial. The other three represented various levels of vegetative diversity: (1) unmanaged vegetation (Fallow), (2) a mix of planted native prairie flowers (Flowers Only), and (3) planted native prairie flowers plus native-warm season grasses (NWSG/Flowers). The flower species used for the Flowers Only and NWSG/Flowers borders were lance-leaved coreopsis (*Coreopsis lanceolata* L.), purple coneflower (*Echinacea purpurea* (L.) Moench), black-eyed susan (*Rudbeckia hirta* L.), butterfly milkweed (*Asclepias tuberosa* L.), common milkweed (*Asclepias syriaca* L.), swamp sunflower (*Helianthus angustifolius* L.), white heath aster (*Symphiotrichum pilosum* (Willd.) G.L. Nesom), and showy goldenrod (*Solidago speciosa* Nutt.). The perennial bunch grasses planted in the NWSG/Flowers borders were indiagrass (*Sorghastrum nutans* (L.) Nash) and little bluestem (*Schizachyrium scoparium* (Michx.) Nash).

In both years, seed predation assays were conducted during the first two weeks of October and November; a September trial was added the second year. Assays were conducted when mean daily temperature was  $>10^{\circ}\text{C}$  and average weekly precipitation was  $<1$  cm. Seed removal was measured with point estimates using weed seeds glued to  $10\text{ cm} \times 15\text{ cm}$  cards (Westerman et al., 2003; Davis and Raghu, 2010). Twenty-five seeds of three prevalent weed species, redroot pigweed (*Amaranthus retroflexus* L.), broadleaf signalgrass (*Urochloa platyphylla* (Munro ex C. Wright) R.D. Webster), or sicklepod (*Senna obtusifolia* (L.) H.S. Irwin and Barneby) were adhered to each card. Seeds were bought from Azlin Seed Service (Leland, MS). *A. retroflexus* and *S. obtusifolia*, are the dominant summer annual broadleaf weeds in our system and *U. platyphylla* is one of the most common summer annual grasses. These three species also represent a range of seed sizes and seed coats: *A. retroflexus* is a small seed ( $\sim 1$  mm long) with a hard seed coat; *S. obtusifolia* is a large seed ( $\sim 5$  mm long) with a very hard seed coat; and *U. platyphylla* is a 'medium' sized seed ( $\sim 3$  mm) with a soft seed coat. After the seeds were adhered to the cards, weed-free soil was sprinkled on each card to remove any stickiness. Three cards, each carrying a different weed species, were placed in every enclosure cage.

Enclosure cages followed the design of Davis and Raghu (2010). Each cage consisted of a coarse wire mesh cylinder (20 cm tall by 20 cm in diameter) with a square base and top (40 by 40 cm) made of the same material. The coarse wire mesh had 10 by 10 cm openings. The tops were covered with aluminum window screen (mesh size  $<0.25$  cm) and had a 20 by 20 cm opening in their centers covered with a square piece (23 by 23 cm) of removable aluminum window screen secured with Velcro® strips around its perimeter. Three types of cages were used for this experiment. The first (ALL) included only the basic 10 by 10 cm coarse wire mesh which allowed all seed predators, including vertebrates, inside to feed on the seeds. The sides and base of the second cage type (INV) were covered with 1.25 by 1.25 cm hardware cloth, which excluded vertebrates, such as mice and birds. However, the cage could easily be entered by invertebrates (Gallandt et al., 2005). The third type of cage (NONE) served as a control and used aluminum window screen (mesh size  $<0.25$  cm) to exclude all seed predators.

Each of the three cage types were placed at measured intervals along transects extending from the middle of each experimental field border into adjacent crop fields. The first set of cages was placed at the interface of the field border and the crop field (6 m from the field border center). The second set of cages was placed 12 m from the field border center, and the third set 35 m from the field border center. The third set was placed so the cage was  $>40$  m from a neighboring field border type. In total there were 324 total cages per trial, each with three seed cards (972 total seed cards per trial).

After two weeks of field exposure all cards were collected, placed individually into labeled plastic bags, and returned to the laboratory. The number of seeds remaining on each card was counted. Any missing seeds from the cards in the control cages (NONE) were attributed to abiotic factors. Seed removal rates for invertebrates,  $M_i$ , were calculated using Abbott's correction formula:  $M_i = (C_i - R_i)/C_i$ , where  $R_i$  was the number of seeds remaining on the INV card, and  $C_i$  was the average number of seeds (by crop and date) remaining on the NONE cards (Abbott, 1925). Removal rates for vertebrates,  $M_v$ , were calculated with a similar equation,  $M_v = (R_i - R_a)/R_i$ , where  $R_a$  was the number of seeds remaining on the ALL card, and  $R_i$  was the number of seeds left on the INV card for that field and field border type at the same distance along the transect. The fraction of seed removal by invertebrates was assumed to be equal in the ALL and INV cages. Following Saska et al. (2008), if  $R_i$  ever exceeded  $C_i$  or if  $R_a$  ever exceeded  $R_i$  by more than 5:4 then the data point was thrown out and if by 10:9 then that rate was converted to zero.

Catches from pitfall traps (10 cm diameter) were used to measure the relative abundance (i.e. activity-density [Spence and Niemelä, 1994]) of ground-dwelling invertebrates. Traps were placed along the transect extending from the middle of each experimental field border. One trap was placed in each of the following locations: in the center of the field border (0 m), at the interface of the field border and crop field (6 m from the field border center), and 12, 20, and 35 m from the field border center. Traps were made of two nested 450 ml plastic containers. To prevent rain overflow, the inside container had holes around the top rim and the outside container had holes in the base. These traps were sealed with a 10 cm diameter Petri dish bottom and buried in the ground so that their tops were flush with the soil surface. Traps were opened at the beginning of each month's predation assay, filled with 50% ethylene glycol solution to a depth of 5 cm, and resealed after 96 h. Invertebrate specimens from each trap were preserved in alcohol and brought back to the laboratory to be identified and counted. Ground beetles (Carabidae) were identified to species, crickets (Gryllidae) to genus. Ants were counted as one group because the vast majority were red imported fire ants. Identifications were confirmed by David Stephan of the North Carolina State University Plant Disease

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