In arable land, a low-density seedbank is highly desired. A weed species’ seedbank persistence is often influenced by multiple factors, such as burial depth, tillage regime, and crop environment (Steckel et al. 2007). Common waterhemp (*Amaranthus tuberculatus* (Moq.) J.D. Sauer) is an agronomically challenging weed species (Johnson et al. 2009; Prince et al. 2012) whose high fecundity, high relative growth rate [heneghanGrowthDevelopmentFive2017], rapid herbicide resistance development (Tranel 2021), and extended emergence pattern (Buhler and Hartzler 2001) can help maintain an affluent seedbank (Davis 2008; Korres et al. 2018).

Interseeding red clover (*Trifolium pratense* L.) with wheat (*Triticum aestivum* L.) followed by spring tillage delayed and reduced seedling emergence as compared with three other interseeding and tillage timing combinations by fall tillage (Davis and Liebman 2003). A heuristic model for common waterhemp population dynamics in corn (*Zea mays* L.) and soybean (*Glycine max* (L.) Merr.) (two warm-season annual crops) with or without rye (*Secale cereale* L.) cover crop in between the corn and soybean phases concluded that rye cover crop could provide minimal suppression against common waterhemp abundance and the minimum chemical herbicide efficacy was required above 99% to keep the waterhemp population from growing.

Our exhaustive search of the current literature did not return any information on waterhemp’s population dynamics in other cool-season crops so we measured the following characteristics of waterhemp in oat (*Avena sativa* L.) intercroped with red clover, oat intercropped with alfalfa (*Medicago sativa* L.), and alfalfa environments: plant fecundity (Nguyen and Liebman 2022a), soil seedbank density, seedling emergence and timing, and plant survival.

Extending a conventional 2-year rotation of corn and soybean to contain oat, red clover, and alfalfa effectively maintain weed community at a level of abundance that did not coincidence with crop yield decline (Nguyen and Liebman 2022b). The effects of cropping system diversification on common waterhemp abundance was not clearly defined (Nguyen and Liebman 2022b), even though their reproductive potentials could be compromised without over-reliance on chemical herbicide (Nguyen and Liebman 2022a).

In order to increase labor use efficiency in waterhemp management, it is helpful to know possible choke points throughout waterhemp’s life cycle, where intervention can substantially reduce the population growth. Following the population in full life cycles in different crop environments can help identifies the choke points where management could be focused (Caswell 2001). Combining demographic parameters from multiple sources and organizing them in different scenarios can provide a quick evaluation of population responses without extensive field measurement (Ullrich 2000; Caswell 2001; Davis 2002). In addition, retrospective perturbation analysis can be used to examine how a population would change if changes occurred at different points throughout the species’ life cycle (Ullrich 2000; Caswell 2001; Davis 2002).

A periodic matrix model (Cousens and Mortimer 1995; Caswell 2001) was used to study waterhemp population dynamics to accommodate the examination of the effect of various events, i.e., crop management activities, that occur throughout the life cycle of waterhemp on the population change rate, . We used the general equation of (Caswell 2001) to study from one period to another. The waterhemp populations in this study were depth-structured for the soil seedbank and cohort-structured for plants to accommodate the variation in seed survival (Yenish, Doll, and Buhler 1992; Buhler and Hartzler 2001) and emergence rates (Werle et al. 2014) at different depths, plant survival rates, plant size, and fecundity of different cohorts (Hartzler, Battles, and Nordby 2004; Nordby and Hartzler 2004).

Elasticity analysis, which provides a closer look at how changes in , , would response to proportional perturbations in the lower-level demographic parameters (represented by a sub-annual matrix ) can help evaluating to each sub-annual intervention. In addition, since elasticity analysis involves each element of matrix , it is more convenient than sensitivity analysis in identifying the contribution of each to , especially when a matrix involves more than one non-zero element.

This study was pursued to examine how waterhemp population might changes in cool-season crops suitable for the Midwestern USA climates. The modeling exercise presented here combines demographic parameters from the literature and empirical experiments. We hypothesized that extending a conventional 2-year rotation of corn and soybean with cool-season crops can accelerate soil seedbank depletion.

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