Common waterhemp (*Amaranthus tuberculatus* (Moq.) J.D. Sauer) is an agronomically challenging weed species whose soil seedbank can be rapidly replenished under favorable conditions, so multiple tactics are required to effectively limit the number of seeds entering the soil seedbank (Davis 2008). Seedbank persistence is often influenced by multiple factors, such as burial depth, tillage regime, and crop environment (Steckel et al. 2007). Determining the most influential factors on changes in population dynamics could be useful in targeting efforts to accelerate seedbank depletion.

The high fecundity, high relative growth rate and opportunistic emergence of waterhemp can maintain an affluent seedbank (Bagavathiannan and Norsworthy 2013; Korres et al. 2018; Menalled et al. 2005), and thus, multiple control tactics are needed throughout it life cycle. 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).

A heuristic model for common waterhemp population dynamics in corn (*Zea mays* L.) and soybean (*Glycine max* (L.) Merr.) with or without rye (*Secale cereale* L.) cover crop in between corn and soybean phases concluded that rye cover crop could provide minimal suppression against common waterhemp abundance. Prospective analysis using a population matrix approach can be used to examine how a population would change over a period given the input parameters, but without extensive field trials (Caswell 2001; **davisCroppingSystemEffects2002?**; Ullrich 2000).

Interseeding red clover with wheat 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). Our exhaustive search of the current literature does not return any information on waterhemp’s population dynamics in other cool-season crops so we attempted to empirically measure those. In addition, we measured how much time waterhemp emergence can be delayed in cool-season crops that can be planted overwinter or very early in spring to limit waterhemp’s exposure to sunlight when come the time of its emergence.

This study was pursued to examine how waterhemp population might changes in cool-season crops suitable for the Midwestern US climates, such as oat and red clover or oat and alfalfa intercrops, and alfalfa sole crop. The data used in this exercise were collected from empirical experiment and the literature. 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 (**werlePredictingEmergence232014?**) at different depths, plant survival rates (Hartzler, Battles, and Nordby 2004; Nordby and Hartzler 2004), plant size, and fecundity of different cohorts (Hartzler, Battles, and Nordby 2004; Nordby and Hartzler 2004).

A periodic matrix model (Caswell 2001; Cousens and Mortimer 1995) was used to study waterhemp population dynamics because periodic matrices 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 population change, from one period to another.

Elasticity analysis, which provides a closer look at how changes in , would response to proportional perturbations in the lower-level demographic parameters (represents the sub-annual responses of the population to weed management practices) 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 . Sensitivity analysis only reveals ’s response to each sub-annual transition matrix, , so whenever a involves more than one non-zero element, it is impossible to evaluate the individual contribution to .

The modeling exercise presented here combines demographic parameters from the literature and empirical experiment. We hypothesized that extending a conventional 2-year rotation of corn and soybean with cool-season crops can accelerate soil seedbank depletion.

Bagavathiannan, Muthukumar V., and Jason K. Norsworthy. 2013. “Postdispersal Loss of Important Arable Weed Seeds in the Midsouthern United States.” *Weed Science* 61 (4): 570–79. <https://doi.org/f5c394>.

Buhler, Douglas D., and Robert G. Hartzler. 2001. “Emergence and Persistence of Seed of Velvetleaf, Common Waterhemp, Woolly Cupgrass, and Giant Foxtail.” *Weed Science* 49 (2): 230–35. <https://doi.org/dmnt6f>.

Caswell, Hal. 2001. *Matrix Population Models: Construction, Analysis, and Interpretation*. Second. Sunderland, Mass.: Sunderland, Mass. : Sinauer Associates.

Cousens, Roger, and Martin Mortimer. 1995. *Dynamics of Weed Populations*. Cambridge: Cambridge University Press. <https://doi.org/10.1017/CBO9780511608629>.

Davis, Adam S. 2008. “Weed Seed Pools Concurrent with Corn and Soybean Harvest in Illinois.” *Weed Science* 56 (4): 503–8. <https://doi.org/bmncpf>.

Davis, Adam S., and Matt Liebman. 2003. “Cropping System Effects on Giant Foxtail (*Setaria Faberi*) Demography: I. Green Manure and Tillage Timing.” *Weed Science* 51 (6): 919–29. <https://doi.org/bxq7q8>.

Hartzler, Robert G., Bruce A. Battles, and Dawn Nordby. 2004. “Effect of Common Waterhemp (*Amaranthus Rudis*) Emergence Date on Growth and Fecundity in Soybean.” *Weed Science* 52 (2): 242–45. <https://doi.org/cmhpxk>.

Korres, Nicholas E., Jason K. Norsworthy, Bryan G. Young, Daniel B. Reynolds, William G. Johnson, Shawn P. Conley, Reid J. Smeda, et al. 2018. “Seedbank Persistence of Palmer Amaranth (Amaranthus Palmeri) and Waterhemp (*Amaranthus* *Tuberculatus*)across Diverse Geographical Regions in the United States.” *Weed Science* 66 (4): 446–56. <https://doi.org/gd2hgf>.

Menalled, Fabián D., Keith A. Kohler, Douglas D. Buhler, and Matt Liebman. 2005. “Effects of Composted Swine Manure on Weed Seedbank.” *Agriculture, Ecosystems & Environment* 111 (1): 63–69. <https://doi.org/c3x6zk>.

Nordby, Dawn E., and Robert G. Hartzler. 2004. “Influence of Corn on Common Waterhemp (*Amaranthus Rudis*) Growth and Fecundity.” *Weed Science* 52 (2): 255–59. <https://doi.org/10.1614/WS-03-060R>.

Steckel, Lawrence E., Christy L. Sprague, Edward W. Stoller, Loyd M. Wax, and F. William Simmons. 2007. “Tillage, Cropping System, and Soil Depth Effects on Common Waterhemp (Amaranthus Rudis) Seed-Bank Persistence.” *Weed Science* 55 (3): 235–39. <https://doi.org/bhs6vt>.

Ullrich, Silke. 2000. “Weed Population Dynamics in Potato Cropping Systems as Affected by Rotation Crop, Cultivation, and Primary Tillage.” PhD thesis, The University of Maine.

Yenish, Joseph P., Jerry D. Doll, and Douglas D. Buhler. 1992. “Effects of Tillage on Vertical Distribution and Viability of Weed Seed in Soil.” *Weed Science* 40 (3): 429–33.