*overview*

The ultimate goal of any weed control program is to prevent the target population from growing. One approach to doing so is to deplete the soil seedbank. Seedbank depletion can be promoted by inducing seed fatal germination so that seeds germinate, but the seedlings fail to reach the soil surface and thus die (Davis and Renner 2007), and by fostering granivore activities so that viable, dormant seeds are consumed or damaged (Bagavathiannan and Norsworthy 2013; **kurstjensPreciseTillageSystems2007?**). Seedbank depletion can also be promoted by targeting attacking the weed population at multiple other life-history stages which eventually limits the total number of seeds entering the soil seedbank (Liebman and Gallandt 1997).

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). For waterhemp management, seed shattering reduction, removal of seeds on the soil surface, and customization of tillage systems are all important because the persistence of waterhemp seedbank is highly dependent on the local crop management techniques (Bagavathiannan and Norsworthy 2013; Korres et al. 2018; Menalled et al. 2005).

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). In this case, the input parameters for waterhemp population dynamics are seedbank density, emergence rate, seed and plant survival rates, fecundity, and seed viability loss.

*waterhemp in different contexts and information gaps*  
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 (**davisCroppingSystemEffects2003?**). Our exhaustive search of the current literature does not return any information on waterhemp’s population dynamics in other crops.

*importance of the present study*

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.

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 (**yenishEffectsTillageVertical1992?**; 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.

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 Karen A. Renner. 2007. “Influence of Seed Depth and Pathogens on Fatal Germination of Velvetleaf (Abutilon Theophrasti) and Giant Foxtail (Setaria Faberi).” *Weed Sci.* 55 (1): 30–35. <https://doi.org/cdzbdn>.

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>.

Liebman, Matt, and Eric R. Gallandt. 1997. “Many Little Hammers: Ecological Management of Crop-Weed Interactions.” In *Ecology in Agriculture*, edited by Louise E. Jackson, 291–343. Physiological Ecology. Academic Press. <https://doi.org/10.1016/B978-012378260-1/50010-5>.

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.