DYNAMICS OF GIANT RAGWEED AND COMMON SUNFLOWER IN KANSAS:

DISTRIBUTION, PLANT-SOIL FEEDBACK AND DEMOGRAPHY

by

ANALIZA HENEDINA M. RAMIREZ

B. S., University of the Philippines Los Banos, 1992
M.S., University of the Philippines Los Banos, 2000

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Agronomy
College of Agriculture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2010

Abstract

Success of plants depends largely on their environment. A survey, field and greenhouse studies were conducted from 2006 to 2010 to characterize the dynamics of giant ragweed (AMBTR) and common sunflower (HELAN) in KS through determining their distribution, plant-soil feedback response and demography. The survey revealed a distinct distribution pattern within the state with HELAN being more dominant than AMBTR. Populations of AMBTR and HELAN from KS could be grouped by their emergence characteristics. Plant-soil feedback response of AMBTR and HELAN varied across sites with HELAN having a consistent positive feedback response while AMBTR had negative feedback response in IL, KS, MI-a, MI-B, OR and SD but not in MT. Interaction coefficient analysis was neutral for IL, KS and MI-b while positive for OR and SD and negative for MI-a and MT. Plant-soil feedback response of KS-derived populations of AMBTR and HELAN indicated that both KS-AMBTR and KS-HELAN seemed to grow best in soil preconditioned by another species. Seed survivorship over winter and summer, emergence, and population growth rates of both weed species varied over three years with HELAN having higher growth rates that AMBTR. This study showed that demographic success of HELAN and AMBTR was greatly influenced by the climatic conditions more than any other factors. AMBTR from IL, if introduced to the state can adapt to KS conditions. Further studies including impacts of soil biota, nutrient dynamics and biochemical processes such as allelopathy are needed to better understand the mechanism behind the plant-soil feedback response of the two weed species and its contribution to the demographic success of AMBTR and HELAN.

DYNAMICS OF GIANT RAGWEED AND COMMON SUNFLOWER IN KANSAS:

DISTRIBUTION, PLANT-SOIL FEEDBACK AND DEMOGRAPHY

by

ANALIZA HENEDINA M. RAMIREZ

B. S., University of the Philippines at Los Banos, 1992
M.S., University of the Philippines at Los Banos, 2000

A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Agronomy
College of Agriculture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2010

Approved by:

Major Professor
J. Anita Dille

Abstract

Success of plants depends largely on their environment. A survey, field and greenhouse studies were conducted from 2006 to 2010 to characterize the dynamics of giant ragweed (AMBTR) and common sunflower (HELAN) in KS through determining their distribution, plant-soil feedback response and demography. The survey revealed a distinct distribution pattern within the state with HELAN being more dominant than AMBTR. Populations of AMBTR and HELAN from KS could be grouped by their emergence characteristics. Plant-soil feedback response of AMBTR and HELAN varied across sites with HELAN having a consistent positive feedback response while AMBTR had negative feedback response in IL, KS, MI-a, MI-B, OR and SD but not in MT. Interaction coefficient analysis was neutral for IL, KS and MI-b while positive for OR and SD and negative for MI-a and MT. Plant-soil feedback response of KS-derived populations of AMBTR and HELAN indicated that both KS-AMBTR and KS-HELAN seemed to grow best in soil preconditioned by another species. Seed survivorship over winter and summer, emergence, and population growth rates of both weed species varied over three years with HELAN having higher growth rates that AMBTR. This study showed that demographic success of HELAN and AMBTR was greatly influenced by the climatic conditions more than any other factors. AMBTR from IL, if introduced to the state can adapt to KS conditions. Further studies including impacts of soil biota, nutrient dynamics and biochemical processes such as allelopathy are needed to better understand the mechanism behind the plant-soil feedback response of the two weed species and its contribution to the demographic success of AMBTR and HELAN.

Table of Contents

List of Figures

List of Tables

Acknowledgements

The long journey towards the successful completion of my doctoral studies has been truly challenging and a humbling experience. Through the years of my stay at K-State, I have met and interacted with so many wonderful people, whom I would like to sincerely thank.

First and foremost, I would like to thank Dr. J. Anita Dille, my adviser, for her patience, guidance and understanding. For always being there to provide the much needed support (intellectual, emotional and otherwise), that in spite of the personal challenges she had to face, she was still there for me. She has given me so many opportunities for professional growth during my stay at K-State. Dr. Gregory Zolnerovich, for his time and effort in serving as the outside Chair of my advisory committee, Drs. Dallas Peterson, David Hartnett and Mark Ungerer, the members of my advisory committee, for the support and constructive criticisms on the manuscript.

My countless statistical questions have been answered by Dr. Leigh Murray and Ms.Girly Ramirez and for this I thank you both.

My maps would not have been more beautiful without the help of Dr. Jonathan Aguilar and Mr. Arnold Salvacion. I know it was difficult to deal with my persistence when I needed the maps.

I owe a great deal of appreciation to the University of the Philippines Los Banos (UPLB), my home institution, for allowing me to pursue my doctoral studies on an official study leave; I also thank the UP system Doctoral Studies Fund Grant for the partial financial support.

I would be remiss if I do not thank the USDA-CSREES-NC 1026 group for giving me the chance to explore the wonderful world of weed demography. I would like to thank all the collaborators for sharing their data and wonderful insights on the plant-soil feedback study, and for the opportunity of interacting with beautiful minds.

The K-State Department of Agronomy, to its faculty for encouraging great learning, for the financial assistance through scholarship offerings. Special thank goes to Mr. Stan Rundquist, Mr. Neil Wickstrum and Ms. Cathy Minihan for their assistance during the field experimentation. The friendliness of the office staff: Ms. Deb Scott, former staff Patty Woydziak, Heidi Bean and the late Pam Upham will never be forgotten.

I would like to extend my sincere appreciation to the former Weed Science graduate students: Drs. John Frihauf, Doug Shoup and Chris Schuster, Mr. Mike Duff, Ms. Molly Marple-Drimmel and Ella Ruf-Pachta, for the camaraderie and intellectual discussions. Special thanks are due to Dr. Dwain Rule for teaching me what patience is all about and for the helping me harvest my plants during the first year.

My weekly weed counts and seed numbers would not have been done without the help of the Weed Ecology student workers: Ben Cornelius, Jenny Piper, Bobby White, Dayna New, Anna Berry, Mike Popelka, Dusty Witthun, Valerie Meyer, Srivani Lokeni, Brandy Valek, Jacob Gouldie, Jessie Vipham, Chelsey Weeden and Chelsea Kleusch.

The countless study nights and late night stay in the office during crunch times had been most enjoyable due to the company of former fellow graduate students (who are now Drs in their own right) whom I have been friends with: Dr. Jamie Dusterhaus for cracking the silliest jokes. My true cohort, Dr. Aifheli Meshack Ndou, for the coffee and bagels lunch, for the endless discussions on life, family and love, and for pushing me not to give up. Dr. Kellan Kershner, my other cohort, for the friendship that started with a statistical hello, for the movie nights (remember that?), for sharing with us your Grandma's special treats, and for the gentle push once in awhile. Mr. Justin Petrosino, for sharing the joys and pains of thesis writing, beating deadlines, and the agony of dealing with a writer's mental block.

To the members of the Agronomy Graduate Student Association, International Coordinating Council and K-State Philippine Student Association for harnessing my leadership abilities. To the Pinoy wildcats for being my family away from home. Special thanks are due to Dr. Ronaldo and Mrs. Elizabeth Maghirang, Ms. Ronell Joey Cainong, Dr. Amy Bernardo and Mr. Jeff Godoy for the prayers and encouragement. Dr. Camilla Yandoc-Ables and Ms. Ma. Lourdes Edano for the words of encouragement.

Dr. Joi Abit, my roommate and best friend, for sharing with me three wonderful and whacky years at Jardine. For lifting my spirits up during my most trying times, for not giving up on me when most people would have, for believing that I can make it in spite of the many challenges I faced.

My family back in the Philippines, most especially my sister Precy Barcial and Buena Maningas for being the surrogate mothers of my kids. Mr. Guy Ramirez for taking care of my kids while I am gone. Kiel, Charise and Anna for enduring five years of not having a mother by their side.

To those whom I may have forgotten to mention but whose help I truly appreciate. I thank you.

And above all, to my Lord God, my source of knowledge, wisdom and strength, to You be the glory.

Thank you very much!

Dedication

This humble piece of work is lovingly dedicated to my three angels: Ezekiel Guy, Charise Anne and Anna Daniella. The real treasure, inspiration and joy in my life. The reason for this endeavor.

Also, this is dedicated in loving memory of my parents, Juanito and Rosita Maligalig who taught me the value of a good education and whose dream has now been fulfilled.

CHAPTER 1 - Introduction

Weeds are unwanted plants at a certain time and place. They are unwanted because they reduce yield and quality of agricultural products through competition, serve as alternate hosts of other pests and affect human lives in various ways. Weeds are the most important pest group that reduces yield in crops such as wheat, corn, barley, cotton, sugarbeet and soybean, with loss potential reaching 32% worldwide (Oerke and Dehne 2004). In any crop production system, excellent control of weeds is a must to maximize profit. Most often, weed control strategies are aimed at reducing weed populations below levels that will cause economic losses. Weed control methods such as manual removal, herbicide applications, and cultural practices, alone or in combination, have been widely used however weeds still continue to persist in agricultural systems. Hence, a thorough understanding as to the mechanism involved in weed seed germination and establishment, reproduction, survival, competition and spread will aid in developing appropriate and effective weed control strategies. A way to understand this is through the study of a weed's demographic success in a particular environment.

Population dynamics or demography is the study of the numerical changes in a population through time. Success of a weed species can be measured through its ability to establish, survive, reproduce and persist in an environment. Monitoring numerical changes in the population size can be done by first determining the number of individuals at a given time using the following equation (Radosevich et al. 1997; Silvertown and Charlesworth 2001):

$$N_t = B - D + I - E \qquad \text{(Equation 1.1)}$$

where N_t is the number of individuals at time t, B is the number of births or new individuals, I is immigration or the number of new individuals entering population from outside the given area, D is death or number of individuals dying, E is emigration or, the number of individuals leaving the population. Second, predicting the number of individuals in the future by extending Equation 1.1 (Radosevich et al. 1997; Silvertown and Charlesworth 2001) to:

$$N_{t+1} = N_t + B - D + I - E \qquad \text{(Equation 1.2)}$$

where N_{t+1} is the number of individuals at time ($t+1$). Lastly, the rate of change in the number of individuals is determined by calculating lambda (λ) and its value can be used to describe whether a population is increasing (($\lambda>1$) or decreasing ($\lambda<1$) over time. Lambda can be calculated by (Radosevich et al. 1997; Silvertown and Charlesworth 2001):

$$\lambda = \frac{N_{t+1}}{N_t} \qquad \text{(Equation 1.3)}$$

The basic framework for the study of weed population dynamics is its life cycle which is made up of several stages (seed, seedlings, and mature plants) and each stage is linked by specific processes such germination, establishment, survival, reproduction and dispersal (Figure 1.1). The rate at which weed species transitions from one stage to another gives insights as to how populations behave over time (Rodosevich et. al. 1997).

Current studies on weed population dynamics usually focus on a particular stage in the life cycle and the impacts of various factors such as cropping systems or predation on that specific stage or aspect of weed demography (Alexander and Schrag 2003; Ballare et al. 1987; Moody-Weiss and Alexander 2007). The impacts of these stages and factors are then projected on the overall dynamics of the population (Navas 1991). For example, the role of seed bank, and the mechanisms and consequences of seed bank formation on population dynamics of common sunflower were examined by Alexander et al. (2003; 2007). It was reported that seed banks were important for annual plants by first increasing the seed pool available for germination for succeeding years if reproduction in the previous years was successful and second, if reproduction fails, the seed bank may allow a species to persist, given favorable germination conditions. Furthermore, the effect of other factors such as of density-dependent processes on seed bank size impacted population growth. In general for annual species, increase in seed production could lead to greater seed dispersal in larger areas and thus result in an increase in common sunflower predominance in the area (Moody-Weiss and Alexander 2009).

Very few studies attempted to monitor the fate of individual plants through its life cycle (Ballare et al. 1987; Lindquist et al. 1995; Mack and Pyke 1983). Such an approach could be more relevant to understanding the mechanism behind weed dynamics. Understanding how each of the stages affects weed population increase or decrease can be used in designing weed management strategies. Timing weed control efforts during the stage which has the greatest impact on population growth rates can lead to more effective and efficient control over time. Studies focusing on just one stage of growth often have limitations. Alexander and Schrag (2003) suggested that seed bank studies which monitor plants only until the seedling stage, should be integrated with research on the entire life cycle of the plant. They theorized that the contribution of seeds from the seed bank to the number of seedlings and the contribution to final fecundity may not be the same due to density-dependent processes that operate as plants transitions from seedling to reproductive maturity.

Weed populations are impacted by agricultural practices, such as use of green manures and tillage timing (Davis and Liebman 2003), crop rotation (Westerman et al. 2005), cropping systems (Jurado-Exposito et al. 2005), weed management (Buhler, 1999; Davis et al. 2007; Werth et al. 2008; Westra et al. 2008), crop-weed competition (Lindquist et al. 1995) and other practices such as grazing and occurrence of disease (Mack and Pyke 1984). These practices may contribute to either a decrease or an increase in population growth rates of weed species and ultimately influence persistence of weed populations over time.

Weed population dynamics have also been shown to vary across landscapes, time scales and genotypes in various plant species including weed species (Alexander et al. 2009; Mack and Pyke 1983; Vavrek et al. 1997). Often, these studies attributed such variation to existing climatic (Mack and Pyke 1983) and environmental differences across sites where the studies were conducted and to phenotypic plasticity in species (Lee and Hamrick 1983). Mack and Pyke (1983) found that year to year variation in the environment, such as weather and biotic factors such as presence of predators, had greater impact than the intrinsic differences in habitat types on the recruitment, survivorship and fecundity of downy brome (*Bromus tectorum* L.). For a perennial species such as dandelion (*Taraxacum officinale* L.*)*, seasonal variation in the finite rate of population increase was observed to have greater impact than annual variation on population distribution and persistence, since survival during the most adverse seasons contributed more to population growth and stability (Vavrek et al. 1997). Geographic differences in demography were observed in common sunflower populations along roadsides of Nebraska (NE) and KS. In the NE site, spring precipitation contributed largely to yearly variation in population size while landscape characteristics were more important in accounting for within year variation in presence of common sunflower in KS (Alexander et al. 2009).

In recent years, understanding the success of plants in their environment has also focused on the contribution of its local soil environment. Plants interact with its soil environment in such a way that it is able to change the soil’s physical, chemical and biological components and these changes subsequently result in changes in plant demography and physiology. This phenomenon is referred to as plant-soil feedback (Ehrenfeld et al. 2005). Two things must happen for feedback to exist. First, the soil condition must change due to the presence of the plant and second, this change must in turn affect the growth rate of the plant species. Hence, a given plant species may either increase its growth relative to other species (positive feedback) or decrease its growth (negative feedback) (Bever 1994; Ehrenfeld et al. 2005; Kardol 2007; Reynolds et al. 2003). Feedback is made possible through pathways involving soil physical properties, soil chemical and biogeochemical properties and processes and biological properties, including the composition of the soil biota and fauna (Ehrenfeld et al. 2005; Mills and Bever 1998). Hence, it was suggested that plant-soil feedback could act as a selective force either against the plant species that caused the change in soil conditions or against other plants (Van der Puten 1997). The current literature on the existence of plant-soil feedbacks is far reaching and includes studies involving annual to perennial species, from native to invasive plants species, and from grassland ecosystems to other unmanaged systems (Belnap and Philips 2001; Reinhart et al. 2005).

The role of plant-soil feedback on various aspects of plant demography and ecology has been highlighted in numerous studies worldwide. Plant soil-feedback proved useful in explaining variation in species composition (Klironomos 2002) as well as the dynamics and structure of plant communities over time (De Deyn et al. 2004; Kardol 2007; Reynolds et al, 2003). Plant-soil feedback accounted for the invasion success of several invasive species such as *Centaurea* spp. (Reinhart and Callaway 2004 and 2006), *Acer* spp. (Reinhart and Callaway 2004) and other species (Callaway et al. 2004; Wolfe and Klironomos 2005).

The contribution of the soil environment to plant growth and development cannot be overlooked. The soil serves as a resource pool from which plants draw nutrients and water for growth and subsequent development. Soil is highly heterogeneous and supports a rich microbial population (Reynolds and Haubensak 2008). Changes in the physical and chemical properties occur as plant composition changes such as during a plant invasion (Ehrenfeld 2003). Among the changes observed were increased biomass, net primary productivity, and growth rate along with increased phosphorous and nitrogen content of the litter favoring the exotic species over the native species (Ehrenfeld 2003).

Bezemer et al. (2006) showed with their work on two grassland communities involving grasses and forbs that the mechanism of plant-soil feedback can depend on plant species, plant taxonomic or functional groups and site-specific variation in abiotic and biotic soil properties. In their study, plant-soil feedback differed in the two soil types used in the study. In sandy soils, plant-soil feedback was highly correlated with soil nutrients, particularly potassium, and grasses were observed to cause higher depletion of potassium than forbs. In the chalk soil, plant–soil feedback was more strongly impacted by the soil biota rather than soil nutrients as evidenced by distinct differences in the composition of phospholipids between grass and forb monocultures. Additionally, among the plant species studied, small burnet (*Sanguisorba minor* Scop.) and perennial quakinggrass (*Briza media* L.) performed best in soils previously grown to plants of the same species, while erect brome (*Bromus erectus* Huds.) performed best in soil previously grown to other species. This indicated that within grassland communities, direction of feedback response may vary. In an earlier review, Van Breemen and Finzi (1998) showed that feedback from soils to plant via the soil's chemical properties involved mechanisms that affect nutrient availability and changes in soil pH and that these changes in soil properties frequently had negative effects on competitors. In the majority of literature they reviewed, nutrients such as nitrogen and pH decreased below levels that can be tolerated by potential competitors, but favored growth of plants (Van Breemen and Finzi 1998).

The role of microbial populations in plant-soil feedback response has been the focus of many recent studies. Outcomes varied with plant species and ecological systems studied. Klironomos (2002) showed that feedback between soil microbes and old-field herbaceous plants was able to explain almost 60% of the variation in species abundance in an old field meadow community. Furthermore, positive feedback was observed in four out of five invasive plants tested while all rare species demonstrated strong negative feedback under a monoculture setting. These responses were evident when the soil was further inoculated with fungi isolated from the roots of invasive plant species. (Klironomos 2002). Bever et al. (1997) reported negative feedback of *Danthonia* sp. and *Panicum* sp. when planted in soil inoculated with *Pythium* sp. Different crop production systems tend to favor development of deleterious rhizobacteria, that is nonparasitic bacteria that affect weed growth (Li and Kremer 2000). Also, arbuscular mycorrhizal fungi (AMF) have been shown to affect weed communities by impacting key physiological processes such as seed germination, growth and survival rates in AMF host and non-host weed species (Jordan et al. 2000), thereby influencing weed community dynamics in agroecosystems (Jordan and Huerd 2008).

Plant-microbe interactions can be described by two conceptual models: the microbially-mediated niche partitioning model (Reynolds et al. 2003) and the feedback dynamics model (Bever et al. 1997). In the microbially-mediated niche partitioning model, differentiation of realized ecological niche results from nutrients becoming more available to plants through enhanced enzymatic activity brought about by specific soil biota, thereby allowing different plants to utilize various sources and forms of N, P and other nutrients. In the feedback dynamics model, dynamics result from changes in the soil microbial community generated by the changes in plant composition and in turn causing changes in the rate of growth of the plant or population (Bever et al. 1997; Reynolds et al. 2003). A particular plant community will be able to maintain local diversity due to development and accumulation of beneficial microbial populations (positive feedback dynamics) or plants may succumb to species replacement over time due to accumulation of harmful pathogenic microbial population (negative feedback dynamics) (Bever 2002; 2003).

Weeds are considered to be invasive when they are expanding their range. Weeds that have become naturalized can be accidentally introduced to other areas, hence the invasion process begins. They also are subjected to the same rigors of the invasion process. Weeds need to establish, adapt and successfully reproduce in the new environment. Weeds are also known to harbor specific microbial population within their soil environment, which includes groups reported to be responsible for creating feedback response.

Several questions exist about how weed population dynamics is related to weed distribution across a larger landscape. For example, can the demographic success of weed species in their native and invaded range be explained by their adaptation to local environments only? If so, how much of this success is impacted by the environment like climate? Are there other important processes such as plant-soil feedbacks that can help explain variability in the distribution and occurrence of weeds in a larger landscape like the North Central region of the US? How does plant-soil feedback impact demographic success of weeds?

Giant ragweed and common sunflower were used as model species in this study. These are two important weed species in the Midwestern USA (Nice and Johnson 2005). Both weed species are considered to be widely present (Lorenzi and Jeffery 1987) however, both weed species seem to follow a distinct pattern of distribution and weediness (Barkley 1977). Common sunflower is mostly present in the western part while giant ragweed is predominant in the eastern part of the north central region of the US (Barkley 1977; Chomas et al. 1998). These two weeds species share commonalities that make them ideal weed species for this study. Both are annuals and have developed adaptation to both natural and unmanaged ecosystems such as along roadsides, waste lands, and in agricultural fields. They are highly competitive and cause significant yield loss in annual crops such as corn and soybean (Baysinger and Sims 1991; Geier et al.1996; Johnson et al. 2007). Baysinger and Sims (1991) reported yield reduction in soybean by 46 and 50% in two succeeding years due to competition with giant ragweed at a density of less than 1 plant per meter row. Common sunflower on the other hand was able to reduce soybean yield by 19% at 0.3 plant m^{-2} and up to 95% at a population of 4.6 plants m^{-2} (Geier et. al. 1996). In corn, season long interference with giant ragweed at a density of 0.5 m^{-1} resulted in yield loss of up to 19% (Johnson et al. 2007). Many researchers attribute the competitiveness of these two weed species against crops or other plants, to prolonged emergence, fast vegetative growth, prolific seed production (Abul-Fatih and Bazzaz 1979; Johnson et al. 2007), and development of resistance to commonly used herbicides such as glyphosate (Heap 2008) and ALS-inhibiting herbicides (Al-Khatib et al. 1998; Baumgartner et al. 1999; Taylor et al. 2002; Zelaya and Owen 2004) which ensures their continued presence and predominance in agricultural fields. Because these two weeds species vary in distribution across the North Central region, it would be interesting to understand what factors on their population dynamics, local adaptation to the environment or their interaction with the soil through feedback response?

This study generally aimed to quantify and characterize the population dynamics of giant ragweed and common sunflower. Specifically, the objectives of this study were to: 1) determine the occurrence and distribution of giant ragweed and common sunflower in Kansas; 2) compare the emergence patterns of selected giant ragweed and common sunflower populations in KS; 3) determine the plant-soil feedback response of KS-common sunflower and IL- giant ragweed as part of the regional study using soil from six states; 4) determine the plant-soil feedback response of KS populations of common sunflower and giant ragweed in KS soil; 5) determine the seed survival in soil, emergence, seedling survival and seed production of giant ragweed and common sunflower in Kansas corn or fallow conditions, and, 6) determine the population growth rates for giant ragweed and common sunflower based on field observations.

References

Abul-Fatih, and F.D. Bazzaz. 1979. The biology of *Ambrosia trifida* L. II. Germination, emergence, growth and survival. New Phytol. 83:817-827.

Alexander, H. and A.M. Schrag. 2003. Role of soil seed banks and newly dispersed seeds in population dynamics of the annual sunflower, *Helianthus annuus*. J. Ecol. 91:987-998.

Alexander, H.M., D. Pilson, J. Moody-Weiss and N.A. Slade. 2009. Geographic variation in dynamics of annual plant with a seed bank. J. Ecol. 97:1390-1400.

Al-Khatib, K., J.R. Baumgartner and R. Currie. 1998. Imazethapyr resistance in common sunflower (*Helianthus annuus*). Weed Sci. 46:403-407.

Ballare, C.L., A.L. Scopel, C.M. Ghersa and R.A. Sanchez. 1987. The demography of *Datura ferox* (L.) in soybean crops. Weed Res. 27:91-102.

Barkley, T.M, editor. 1977. Atlas of the Flora of the Great Plains. Ames, IA: The Iowa State University Press. Pages 333 and 377.

Baumgartner, J.R., K. Al-Khatib and R. Currie. 1991. Survey of common sunflower resistance to imazethapyr and chlorimuron in northeastern Kansas. Weed Technol. 13:510-514.

Baysinger, J.A. and B.D. Sims. 1991. Giant ragweed (*Ambrosia trifida* L.) interference in soybean (*Glycine max*). Weed Sci 39: 358-362.

Belnap, J. and S.L. Phillips. 2001. Soil biota in an ungrazed grassland:response to annual grass (*Bromus tectorum*) invasion. Ecol. Appl.11:1261-1275.

Bever, J.D. 1994. Feedback between plants and their soil communities in an old field community. Ecology 75:1965-1977.

Bever, J.D. 2002. Negative feedback within a mutualism: host-specific growth of mycorrhizal fungi reduces plant benefit. Proc R. Soc. London B. 269:2595-2601.

Bever, J.D. 2003. Soil community feedback and the coexistence of competitiors: conceptual frameworks and empirical tests. New Phytol. 157:465-473.

Bever, J.D., K.M. Westover and J. Antonovics. 1997. Incorporating the soil community into plant population dynamics: utility of the feedback approach. J. Ecol. 85:561-573.

Bezemer. T.M., C.S. Lawson, K. Hedlund, A.R. Edwards, A.J. Brooks, J.M. Igual, S. R. Mortimer, and W.H. Van der Puten. 2006. Plant species and functional group effects on abiotic and microbial soil properties and plant-soil feedback responses in two grasslands. J. Ecol. 94:893-904.

Buhler, D.D. 1999. Weed population responses to weed control practices. I. Seedbank, weed populations, and crop yields. Weed Sci. 47:416-422.

Callaway, R.M., G.C. Thelen, A. Rodriguez and W.E. Holben. 2004. Soil biota and exotic plant invasion. Nature 427:731-733.

Chomas, A.J., J.J. Kells, and J.B. Carey. 1987. Common weed seedlings of the north central states. Michigan: Department of Crop and Soil Sciences, Michigan State University.

Davis, A.S. and M. Liebman. 2003. Cropping systems effects on giant foxtail (*Setaria faberi*) demography: I. Green manure and tillage timing. Weed Sci. 51:919-929.

Davis, V.M., K.D. Gibson, T.T. Bauman, S.C. Weller and W.G. Johnson. 2007. Influence of weed management practices and crop rotation on glyphosate-resistant horseweed population dynamics and crop yield. Weed Sci. 55:508-516.

De Deyn, G.B., C.E Raaijmakers and W.H. Van der Puten. 2004. Plant community development is affected by nutrients and soil biota. J. Ecol. 92:824-834.

Ehrenfeld, J. G. 2003. Effects of exotic plant invasions on soil nutrient cycling processes. Ecosystems 6:503-523.

Ehrenfeld, J.G., B. Ravit and K. Elgersma. 2005. Feedback in the plant-soil system. Annu. Rev. Environ. Resourc. 30:75-115.

Geier, P. W., L.D. Maddux, L.J. Moshier and P.W. Stahlman. 1996. Common sunflower (*Helianthus annuus*) interference in soybean (*Glycine max*). Weed Technol. 10:317-321.

Heap, I. 2008. International survey of herbicide resistant weeds. Online. November 9, 2009. Available at www.weedscience.net.

Johnson, W.G., E.J. Ott, K.D. Gibson, R.L. Nielsen, and T.T. Bauman. 2007. Influence of nitrogen application timing on low density giant ragweed (*Ambrosia trifida*) interference in corn. Weed Technol. 21:763-767.

Jordan, N.R., J. Zhang and S. Huerd. 2000. Arbuscular-mycorrhizal fungi: potential roles in weed management. Weed Res. 40:397-410.

Jordan, N. and S. Huerd. 2008. Effects of soil fungi on weed communities in corn-soybean rotation. Renewable Agriculture and Food Systems 23:108-117.

Jurado-Exposito, M., F. Lopez-Granados, J.L. Gonzalez-Andujar and L. Garcia-Torres. 2005. Characterizing population growth rate of *Convolvulus arvensis* in wheat-sunflower no-tillage systems. Crop Sci. 45:2106-2112.

Kardol, P., N.J. Cornips, M.M.L., van Kempen, J.M.T. Bakx-Schotman, and W.H. Van der Puten. 2007. Microbe-mediated plant-soil feedback causes historical contingency effects in plant community assembly. Ecol. Monographs 77:147-162.

Klironomos, J.N. 2002. Feedback with soil biota contributes to plant rarity and invasiveness in communities. Nature 417:67-70.

Lee, J.M. and J.L Hamrick. 1983. Demography of two natural populations of musk thistle (*Carduus nutans*). J. Ecol. 71:923-936.

Li, J. and R.J. Kremer. 2000. Rhizobaceria associated with weed seedlings in different cropping systems. Weed Sci. 48:734-741.

Lindquist, J.L., B.D. Maxwell, D.D. Buhler and J.L. Gunsolus. 1995. Velvetleaf (*Abutilon theophrasti*) recruitment, survival, seed production and interference in soybean. Weed Sci. 43:226-232.

Lorenzi, H.J., and L.S. Jeffery. 1987. Weeds of the United States and their control. New York: Van Nostrand Reinhold. pp 292 and318.

Mack, R.N. and D.A. Pyke. 1983. The demography of *Bromus tectorum*: variation in time and space. J. Ecol. 71:69-93.

Mack, R.N. and D.A. Pyke. 1984. The demography of *Bromus tectorum*: the role of microclimate, grazing and disease J. Ecol. 72:731-748.

Mills, K. and J.D. Bever. 1998. Maintenance of diversity within plant soil communities: soil pathogens as agents of negative feedback. Ecology 79(5):1595-1601.

Moody-Weiss, J. and H.M. Alexander. 2007. The mechanisms and consequences of seed bank formation in wild sunflowers (*Helianthus annuus*). J. Ecol. 95:851-864.

Navas, M.L. 1991. Using population biology in weed research: a strategy to improve weed management. Weed Res. 31:171-179.

Nice, G. and B. Johnson. 2005. Indiana's top ten most problematic weeds. Online. September 23, 2010. Available at www.purdue.edu/weed sciences.

Oerke, E.C. and H.W. Dehne. 2004. Safeguarding production-losses in major crops and the role of crop protection. Crop Prot. 23:275-285.

Radosevich, S., J. Holt and C. Ghersa. 1997. Weed Ecology: Implications for Management. 2nd ed. New York, NY:John Wiley and Sons, Inc. p 62-64.

Reinhart, K.O and R.M. Callaway. 2004. Soil biota facilitate exotic *Acer* invasions in Europe and North America. Ecol. Appl. 14:1737-1745.

Reinhart, K.O and R. M. Callaway. 2006. Tansley review: soil biota and invasive plants. New Phytol. 170:445-457.

Reinhart, K.O., A.A. Royo, W. H. Van Der Puten and K. Clay. 2005. Soil feedback and pathogen activity in *Prunus serotina* throughout its native range. J. Ecol. 93:890-898.

Reynolds, H.L. and K.A. Haubensak. 2008. Soil fertility, heterogeneity and microbes: towards an integrated understanding of grassland structure and dynamics. Applied Vegetation Sci. 12:33-44.

Reynolds, H.L., A. Packer, J.D. Bever and K. Clay. 2003. Grassroots ecology: plant-microbe-soil interactions as drivers of plant community structure and dynamics. Ecol. 84:2281-2291.

Silvertown, J.W. and D. Charlesworth. 2001. Introduction to Plant Population Biology. 4th ed. Ames, IA: Iowa State University Press. Pp1-3 and 72-77.

Taylor, J.B., M.M. Loux, S.K. Harrison and E. Regnier. 2002. Response of ALS-resistant common ragweed (*Ambrosia artemisiifolia*) and giant ragweed (*Ambrosia trifida*) to ALS-inhibiting and alternative herbicides. Weed Technol. 16:815-825.

Van Breemen, N. and A.C. Finzi. 1998. Plant-soil interactions: ecological aspects and evolutionary implications. Biogeochemistry 42:1-19.

Van der Puten, W.H. 1997. Plant soil feedback as a selective force. Trends Ecol. Evol. 12:169-170.

Vavrek, M.C., J.B. McGraw and H.S. Yang. 1997. Within-population variation in demography of *Taraxacum officinale*: season- and size-dependent survival, growth and reproduction. J. Ecol. 85:277-287.

Werth, J.A., C. Preston, G.N. Roberts and I.N. Taylor. 2008. Weed management impacts on the population dynamics of barnyardgrass (*Echinochloa crus-galli*) in glyphosate-resistant cotton in Australia. Weed Technol. 22:190-194.

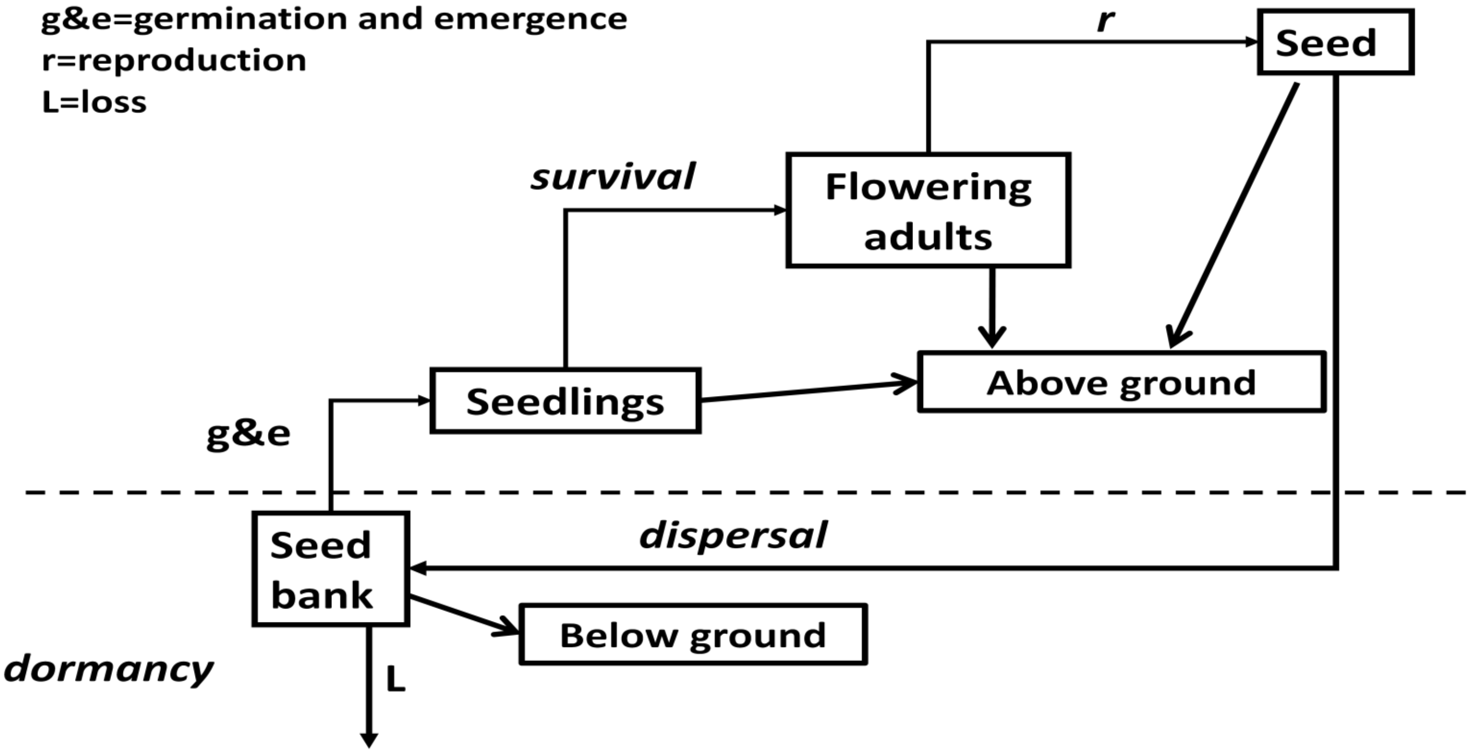
Westerman, P. R., M. Liebman, F.D. Menalled, A.H. Heggenstaller, R.G. Hartzler and P.M. Dixion. 2005. Are little hammers effective? Velvetleaf (*Abutilon theophrasti*) population dynamics in two- and four- year crop rotation systems. Weed Sci. 53-382-392.

Westra, P., R.G. Wilson, S.D. Miller, P.W. Stahlman, G.W. Wicks, P.L. Chapman, J. Withrow, D. Legg, C. Alford and T.A. Gaines. 2008. Weed population dynamics after six years under glyphosate- and conventional-herbicide-based weed control strategies. Crop Sci. 48:1170-1177.

Wolfe, B.E. and J.N. Klironomos. 2005. Breaking new ground: soil communities and exotic plant invasion. BioScience 55:477-487.

Zelaya, I.A. and M.D.K. Owen. 2004. Evolved resistance to acetolactate synthase-inhibiting herbicides in common sunflower (*Helianthus annuus*), giant ragweed (*Ambrosia trifida*), and shattercane (*Sorghum bicolor*) in Iowa. Weed Science 52:538-548.

Figure 1.1 Population dynamics of an annual weed species.



CHAPTER 2 - Survey and Emergence Characteristics of Giant Ragweed (*Ambrosia trifida* L.) and Common Sunflower (*Helianthus annuus* L.) Populations in Kansas

Abstract

A roadside survey determined the distribution pattern of giant ragweed (AMBTR) and common sunflower (HELAN) in Kansas, and a field emergence study compared the emergence patterns of selected AMBTR and HELAN populations from KS. Major roads across the state were traversed and surveyed. Once populations were located, geographical coordinates were taken. These data on distribution were compared to the data from the KSU Herbarium Database. During the roadside survey, seeds were collected from randomly selected plants at a location, cleaned and sown in the field to characterize their emergence patterns. Ten AMBTR and 16 HELAN populations were assessed. The survey revealed that HELAN and AMBTR were distributed in different regions across KS, with HELAN being more common overall than AMBTR. Most often, both weed species were found along roadsides. In agricultural fields, these weed species were located along edges and if found within, the field either had a known history of herbicides resistance or was unmanaged. The emergence study revealed that AMBTR and HELAN emerged in mid-March and ceased to emerge by mid-May. Logistic curves described the cumulative emergence patterns of these populations and grouped AMBTR into two distinct groups with one having longer duration of emergence (286 GDD) than the other (182 GDD). Four HELAN groups were described with different start dates of emergence and durations. HELAN-B emerged earlier (299 GDD to 10% emergence) but finished emergence last (558 GDD to 90% emergence) and had the longest duration of emergence at 259 GDD. HELAN- A was the last to emerged (453 GDD to 10% emergence) but was the first to complete emergence (516 GDD to 90% emergence) and had the shortest duration of emergence at 63 GDD. HELAN- C and -D were in between. The results of this study indicated that in KS, both AMBTR and HELAN emerged early enough to be controlled. Continued presence of these two weed species within the state is expected due to their presence in both agricultural and non-agricultural areas. Roadside and field edge populations may serve as source of seeds for the next cropping season since these areas are rarely managed.

Nomenclature: giant ragweed, *Ambrosia trifida* L., AMBTR; common sunflower, *Helianthus annuus* L., HELAN.

Keywords: emergence pattern, geographic distribution, occurrence.

Introduction

Common sunflower (HELAN) and giant ragweed (AMBTR) are two important weed species of the mid-western USA with very different distribution patterns (Figure 2.1). Common sunflower can be found throughout North America and is considered native from Minnesota to Saskatchewan, and south to Missouri and Texas. It is considered as an introduced species eastward to Nova Scotia, New Brunswick, and the Atlantic states as well as westward (USDA-ARS 1970). Charles et al. (1982) further described its distribution as being predominant in the mid- to the northwestern states starting from Wisconsin to Nebraska, Kansas, Missouri, South Dakota and southward into Oklahoma, Texas and New Mexico. Giant ragweed on the other hand can be found throughout the USA except along the Pacific coast, areas in the southwest, Florida and northern Maine. Giant ragweed is considered a weed of economic concern in the eastern states of Michigan, Illinois, Indiana and Ohio (USDA-ARS 1970). Both weed species are able to compete with most crops grown in KS such as soybean and corn and are able to significantly reduce yields.

Surveys are commonly conducted not only to document weed occurrence, but also to assess extent of weed infestations, to identify current and possible weed problems (Loux and Berry 1991), to identify farmer perceptions on and concern with problematic weed species (Gibson et al. 2005) and in some cases document herbicide resistance issues (Baumgartner et al. 1999; Heap 2008). By locating and mapping weed species occurrences, patterns of invasion as well as area covered can be examined and management strategies can be developed to prevent possible spread to other areas which have not been previously invaded. Periodic and regular weed surveys are important since weed populations are very dynamic. The presence and persistence of weeds in an area is influenced by a number of factors such as cropping system, weed control practives, and climate change (Burkart and Buhler 1997; Chancellor and Froud-Williams 1994). In the case of AMBTR and HELAN, previous reports indicate that these two weed species are distributed throughout KS (Barkley 1977; 1983; Rogers et al. 1982), however random field visits and driving by fields in KS show that HELAN was more commonly observed and more widespread than AMBTR. The current location of these two weed species has not been documented within the state and hence, a survey will provide information as to their exact occurrence and distribution.

The objectives of this study were to 1) determine the occurrence and distribution of AMBTR and HELAN in Kansas and, 2) compare the emergence patterns of AMBTR and HELAN populations from KS.

Materials and Methods

Roadside survey

A visual survey was conducted from 2006 to 2008. Major roads within the state were traversed from September to October to identify populations of both HELAN and AMBTR. The four major areas (NE, NW, SE and SW) in Kansas were visited and fields were surveyed. When populations were found the following data were gathered: size of the patch, other weed species present, and location of the patch (roadside, pasture, crop area, etc). If the populations were in a crop area, the location of the population was further classified as within the field or along field edge. The crop in which they were found was also noted. Geographic coordinates for the location were taken using a handheld GPS[1] unit. Data on the distribution of these two weed species were also obtained from the Kansas State University (KSU) Herbarium database (www. K-state.edu/herbarium/database.html) and compared to the survey data obtained. Comparisons were made by putting both the survey data points and the data from the KSU Herbarium database in one map and similarities between the two were visually noted. Maps for the distribution of the two weed species and locations of the populations were created using ArcGIS[2] program.

Emergence pattern

When populations of the two weed species were found and if plants were physiologically mature, seeds from at least 20 randomly selected plants were collected, cleaned and placed in cold storage until they were ready for planting in the field. Among the 16 AMBTR populations documented in the survey, seven were used in the emergence study while for HELAN, 13 out of the 50 populations surveyed were used. Additionally, two AMBTR populations collected in 2004 and 2005 and three HELAN populations collected in 2004, 2005 and 2007 were also included. A total of 26 populations consisting of 10 AMBTR and 16 HELAN were used in the emergence study.

On December 18, 2008, seeds of each weed species were sown in an established winter wheat field. Plots measured 0.76 by 1.32 m were laid out in a randomized complete block with four replications. Seed trays made from wire mesh[3] measuring 12.5 by 12.5 by 5.0 cm were buried in the middle of the plots and were filled with soil up to 2.5 cm level. One hundred seeds of AMBTR or HELAN were then sprinkled on the seed trays, filled with another 2.5 cm layer of soil and lightly mixed.

Emergence counts were taken weekly starting March 15 until June 18, 2009. Seedlings emerging in each seed tray were counted and pulled carefully to prevent soil disturbance.

Weather data were obtained from the Kansas State Weather Data Library (M. Knapp, personal communications). Maximum and minimum air temperatures were used to calculate growing degree days (GDD) and cumulative GDD and was initiated on the date when seeds of both weed species were sown, December 18, 2008. Base temperature used was 0°C for AMBTR and HELAN (Schutte et al., 2008). Growing degree days were calculated as (Lawson et al 2006):

$$GDD_{daily} = \left[\frac{(T_{max} + T_{min})}{2}\right] - T_{base} \qquad \text{(Equation 2.1)}$$

$$Cumulative\ GDD = \sum_{i=1}^{n} GDD_{daily} \qquad \text{(Equation 2.2)}$$

where T_{max} is the maximum daily air temperature, T_{min} is the minimum daily air temperature, and T_{base} is the base temperature at which plant growth and development was deemed not to occur (0 °C); n is the number of days elapsed since December 18; and GDD_{daily} was a nonnegative value (daily GDD values that were negative were replaced by 0).

Data on total cumulative emergence was analyzed using the Mixed procedure in SAS[4] with populations as fixed effects and replications as random effects separated out by species. Population means for total cumulative emergence were then separated using

LSMEANS at 5% level of significance. The relationship of percent total cumulative emergence to GDD was analyzed by fitting a logistic model as described by Seefeldt et al. (1995) using the NLIN procedure in SAS:

$$\mathrm{y} = \frac{(C+D)}{\left[1+(\frac{\mathrm{x}}{E_{50}})^{b}\right]} \qquad \text{(Equation 2.3)}$$

where y is the cumulative percent emergence, x is the cumulative GDD, C is the lower limit (asymptote) of the response curve, $C + D$ is the upper asymptote (maximum emergence), E_{50} is the value of x (GDD) at the midpoint or inflection point of the curve and b is the slope (Seefeldt et al. 1995). This model has been successfully used to describe emergence data of volunteer canola (*Brassica napus* L.) (Lawson et al. 2006) and kochia (*Kochia scoparia* L.) (Schwinghammer and Van Acker 2008). Individual curves were tested systematically for common estimates of parameters C, D, E_{50} and b with the use of the lack-of-fit F test at the 0.05 level of significance as outlined by Seefeldt et al. (1995). A coefficient of determination (R^2) was calculated for the model as described by Kvalseth (1985), with the use of the residual sum of squares from the SAS output.

Emergence patterns were characterized in terms of start, end, and duration of emergence. Growing degree days when 10 and 90% emergence occurred were calculated from the total cumulative emergence over the observation period and used as basis for the start (10%) and end (90%) of emergence. The duration of emergence was calculated as the number of GDD between 10 and 90% emergence. GDD values corresponding to 10 and 90% emergence were determined by first solving the fitted Equation 2.3 for x and then calculating these values.

Results and Discussion

Roadside survey

The survey revealed that both AMBTR and HELAN were found across KS (Figure 2.1). Common sunflower was found in the northern half while giant ragweed was found in the eastern third and both weed species were found in the southern part of the state. Populations of these two weed species were either found in agricultural fields, pasture areas, areas in transition to wildlife management areas, or along roadsides. In the agricultural areas, populations were mostly in field edges, and borders, that is, areas where they were not frequently managed. Some populations were found within fields (Figure 2.1). Agricultural fields where these two weeds were found either had a history or were suspected of herbicide resistance or were poorly managed (abandoned or lack of control). Populations of both weed species were also frequently found along roadsides. They were found near major highways across the state. Between the two species, HELAN was observed more often across KS than AMBTR (Figure 2.1).

The KSU Herbarium database, which is based on submitted plant samples per county, indicated that both species could be found throughout the state but the roadside survey results indicated otherwise. The difference in distribution could be due to the source of data. The KSU Herbarium distribution data were primarily based on plant samples submitted since the 1800s and were presented on a per county basis, indicating that AMBTR populations may have once been present in these counties, however, the populations and the location where these samples were taken may not exist anymore when the roadside survey was conducted. Often herbarium specimens were sent in because of unusual observations and may not represent widespread occurrences in a given county. No indication of area infested was provided with herbarium specimens.

A total of 16 AMBTR and 50 HELAN populations were found. Size of the patches of both species surveyed ranged from 100 to 50,000 m^2 (Table 2.1). Majority of the AMBTR patches had sizes of 500 m^2 while HELAN patches were >1000 m^2. The two large patches (>1000 m^2) of AMBTR were confirmed to be resistant to glyphosate (Al-Khatib 2008 personal communications). These populations were found in a soybean field in NE KS growing with soybean.

Emergence pattern

The geographical locations of the AMBTR and HELAN populations used in the emergence study, description of the site and year of collection are summarized in Figure 2.2. AMBTR populations started to emerge in mid-March and stopped emerging in mid-May with peak emergence occurring in the latter half of April except for AMBTR-8 which had the peak of emergence in the first week of April (Figure 2.3). Seven out of 10 populations had two peaks of emergence while three populations, AMBTR-4, AMBTR-7 and AMBTR-10 had single peaks of emergence (Figure 2.3).

Nine out of the 10 AMBTR populations used in the study had seedlings emerge while none emerged from the AMBTR-1 (2004) population. AMBTR-1 collected in 2004 may have lost its viability due to prolonged storage. Total seedling emergence varied from 19.3% (±2.3) to 63.0 % (±4.9) (Table 2.3). The most westerly population from

Hesston (AMBTR-8) had the most seedlings emerged while the populations from Topeka (AMBTR- 2) and Ottawa (AMBTR-3) had the least number of seedlings.

Comparison of the slopes (parameter b) from emergence curves revealed that the nine individual AMBTR populations could be combined into two groups (Figure 2.4). The first group (AMBTR-A) was comprised of populations AMBTR 2, 3, 5, 6, 8 and 9 while the second group combined populations AMBTR 4, 7 and 10. Test for lack of fit revealed that the logistic curve which combined the different AMBTR populations into groups fitted the data. The fitted logistic curve revealed that AMBTR-A emerged earlier than AMBTR-B with parameter estimates for the fitted curve for both groups given in Table 2.4. Estimates of the start, end, and duration of emergence also showed that AMBTR-A had fewer GDD to 10% emergence indicating earlier emergence compared to AMBTR-B (Table 2.5). However, the duration of AMBTR-B emergence was shorter than AMBTR-A. A closer look at where these populations were collected from revealed that giant ragweed populations combined into AMBTR-B were from agricultural fields and widespread within the field (Table 2.2). One population (AMBTR- 4 from Ottawa) was even confirmed to be resistant to glyphosate (Al-Khatib, 2008 personal communication). AMBTR-A were from different sites, with some from non-agricultural populations (AMBTR 2, 8 and 9) while the others were agricultural (AMBTR -3, 5 and 6). Furthermore, those from agricultural fields were usually found along field edges.

Variability in emergence in AMBTR populations has been observed elsewhere (Hartnett et al. 1987; Hartzler 2003). Hartnett et al. (1987) reported that an old field population of giant ragweed emerged earlier and had greater total emergence than a population from an annually plowed field when grown in a common garden experiment.

Hartzler (2003) summarized the emergence patterns of agricultural and non-agricultural biotypes of giant ragweed from IA, OH and IL. He reported that all of the OH and two of the IL- agricultural biotypes had longer emergence periods than that of the IA biotypes. Furthermore, Hartzler (2003) suspected that the observed difference in emergence duration was genetically-based since all biotypes from one state behaved similarly.

Common sunflower populations began emerging in mid-March and were finished by May 14, 2009 (Figure 2.5). Total seedling emergence significantly varied from 9.4 % (± 1.3) to 59 % (±10.2) among HELAN populations. Population HELAN-3 collected near Blaine, KS had the greatest emergence while the populations collected in 2004 (HELAN-1) and 2005 (HELAN-2) had the least emergence. Differences among these populations could be due to the viability and/or dormancy status of the seeds such that HELAN-3 was collected in 2007 and dormancy could have been broken while HELAN-1 and HELAN-2 populations were relatively old and might have reduced viability hence low emergence.

Comparison of the slopes (parameter b) from emergence curves of individual HELAN populations revealed that they could be combined into four groups (Figure 2.6). Lack of fit test revealed that the logistic curve which combined the different populations onto groups fit the data. Parameter estimates of the different logistic curves describing each group are given in Table 2.4. Common sunflower populations belonging to HELAN-B (3 and 6) were the earliest to emerge, followed by HELAN-D (1, 2, 7, 8, 10, 11, 12, 13, 15 and 16) then HELAN-C (4 and 14) and HELAN-A (5 and 9) (Figure 2.6).

In terms of end of emergence, HELAN-A was the first to complete emergence followed by HELAN-B and HELAN-C and the latest to complete emergence were the populations belonging to HELAN-D (Table 2.4). HELAN-A had the shortest duration of emergence while HELAN-B had the longest.

Common sunflower groupings varied by where they occurred in the state and did not group according to type of field (agricultural or non-agricultural). Only the HELAN-C group (4 and14) had populations that were from agricultural fields but were not from the same geographical area.

In this study, variation in emergence pattern seemed to be distinct for non-agricultural and agricultural populations and for in field and field margin populations most especially for AMBTR. It is interesting to note that AMBTR populations which were widely distributed throughout the field differed in their emergence pattern from those populations from field margins. However, this was not observed in HELAN populations. Further studies on the morphological variation coupled with genetic analysis may show that these collected plants may or may not be distinct populations of giant ragweed and common sunflower.

The continued presence of giant ragweed and common sunflower in the state is almost always guaranteed due to occurrence of these two weed species in both agricultural and unmanaged non-agricultural areas such as roadsides, continued build up of the seed bank of these two weed species most especially in unmanaged sites and hybridization occurring between crop and wild sunflower and among sunflower species that may possess traits favorable for greater survival and adaptation.

Conclusion

Distinct distribution patterns of giant ragweed and common sunflower were observed within Kansas, such that, there were locations where both species occurred, as well as separately. These weed species were mostly found along roadsides and less often in agricultural fields. When found around agricultural fields, these weed species were present along field edges and in areas which were normally left unmanaged. They can also be found within the fields but these fields had either documented history of herbicide resistance or were poorly managed. Although these two weed species were generally present in the state, they may not be a problem in agricultural fields especially when these fields are well managed and do not have a history of occurrence of herbicide resistance.

Both weed species emerged in mid-March and completed emergence in mid-May. Total seedling emergence among AMBTR and HELAN populations varied. For both weed species, there exist unique groupings based on emergence pattern characteristics with populations from agricultural areas. Further study on morphological variation coupled with genetic analysis of the populations in this study is recommended.

Literature Cited

Arias, D.M. and L.H. Rieseberg. 1994. Gene flow between cultivated and wild sunflowers. Theor. Appl. Genet. 89:655-660.

Barkley, T.M. ed. 1977. Atlas of the Flora of the Great Plains. Ames, Iowa: The Iowa University Press. Pp. 333 and 377.

Barkley, T.M. ed. 1983. Field Guide to the Common Weeds of Kansas. Lawrence, KS: University Press of KS. Pp. 106 and 119.

Burkart, M.R. and D.D. Buhler. 1997. Regional framework for analyzing weed species and assemblage distribution using a geographic information system. Weed Sci. 45:455-462.

Burke, J.M., K.A. Gardner and L. H. Rieseberg. 2002. The potential for gene flow between cultivated and wild sunflower (*Helianthus annuus*) in the United States. Am. J. Bot. 89:1550-1552.

Chancellor, R.J. and R.J. Froud-Williams. 1994. A second survey of cereal weeds in central Southern England. Weed Res. 76:29-36.

Gay, C., F. Corbineau and D. Come. 1991. Effects of temperature and oxygen on seed germination and seedling growth in sunflower (*Helianthus annuus* L.). Environ. Exp. Bot. 31:193- 200.

Gibson, K.D., W.G. Johnson, and D.E. Hillger. 2005. Farmer perception of problematic corn and soybean weeds in Indiana. Weed Technol. 19:1065-1070.

Hartnett, D.C., B.B. Hartnett and F.A. Bazzaz. 1987. Persistence of *Ambrosia trifida* populations in old fields and responses to successional changes. Amer. J. Bot. 74:1239-1248.

Hartzler, R. 2003. Giant ragweed emergence patterns. Online. October 20, 2009. Available at www.weeds.iastate.edu/mgmt/2003/ragweedresults.htm.

Heap, I. 2008. International survey of herbicide resistant weeds. Online. November 9, 2009. Available at www.weedscience.net.

Heiser, C.B. 1954. Variation and subspeciation in *H. annuus*. Amer. Midland Nat. 51:287-305.

Kvalseth, T.O. 1985. Cautionary note about R^2. Amer. Stat. 39:279-285.

Lawson, A.N., R.C. Van Acker and L.F. Friesen. 2006. Emergence timing of volunteer canola in spring wheat. Weed Sci. 54:873-882.

Loux, M.M. and M.A. Berry. 1991. Use of a grower survey for estimating weed problems. Weed Technol 5:460-466.

Muller, M.H., F. Delieux, J.M. Fernandez-Martinez, B. Garric, V. Lecomte, G. Anglade, M. Leflon, C. Motard and R. Segura. 2009. Occurrence, distribution and distinctive morphological traits of weedy *Helianthus annuus* L. populations in Spain and France. Gen. Resour. Crop. Evol. 56:869-877.

Rogers, C.E., T.E. Thompson and G.J. Seiler. 1982. Sunflower Species of the United States. Fargo, ND: National Sunflower Association. Pages 4-5.

Schutte, B. J., E.E. Regnier, S.K. Harrison, J.T. Schmoll, K. Spokas and F. Forcella. 2008. A hydrothermal seedling emergence model for giant ragweed (*Ambrosia trifida*). Weed Sci. 56:555-560.

Seefeldt, S.S., J.E. Jensen and E. P. Fuerst. 1995. Log-logistic analysis of herbicide dose-response relationships. Weed Technol. 9:218-227.

Schwinghamer, T.D. and R.C. Van Acker. 2008. Emergence timing and persistence of kochia (*Kochia scoparia*). Weed Sci. 56:37-41.

[USDA] U.S. Department of Agriculture-ARS. 1970. Selected weeds of the United States. Washington, D.C.

Source of Materials

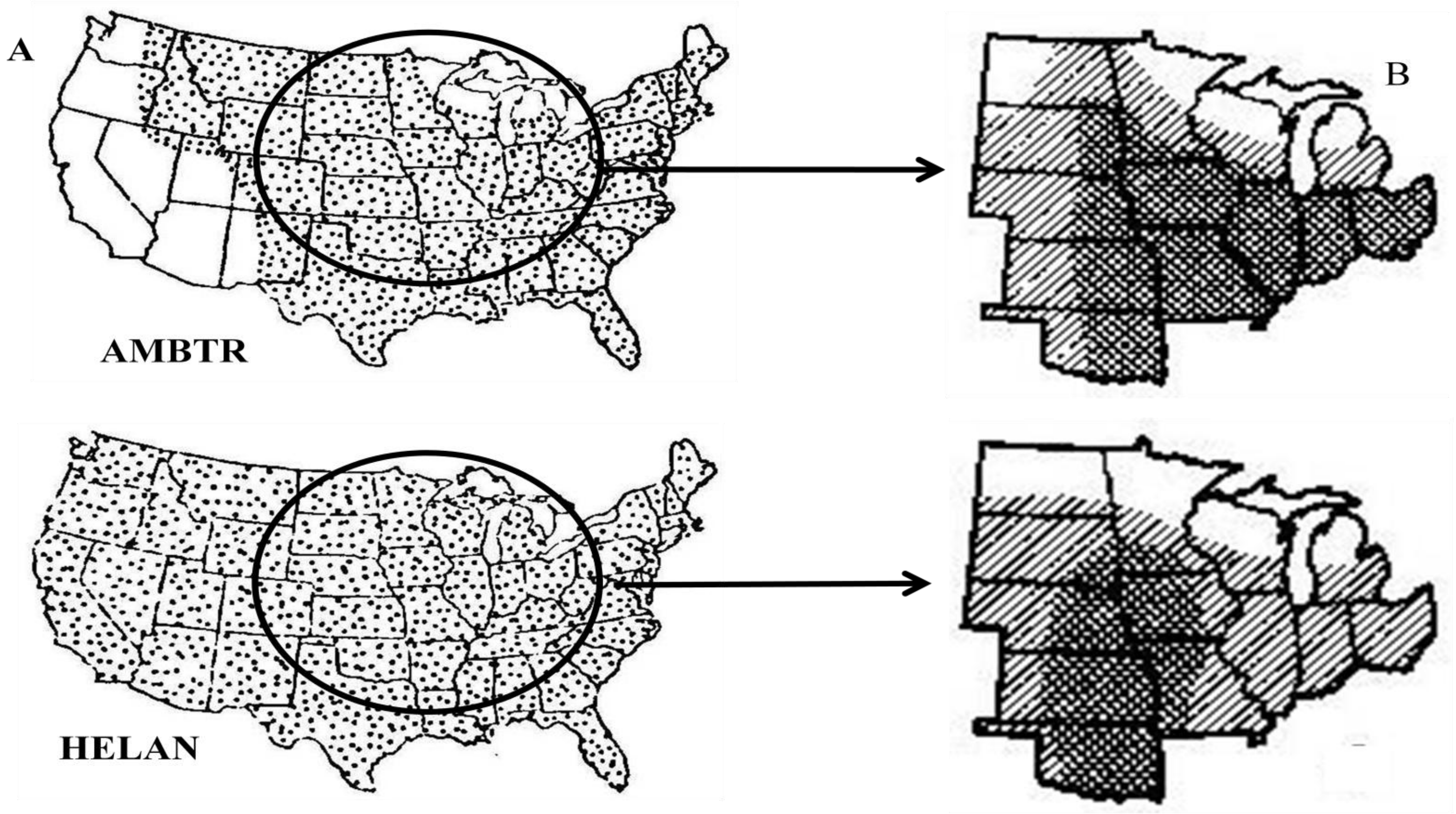
[1] Farm Works Software version 11.40. CTN Data, LLC. 6795 State Road 1. P.O. Box 250 Hamilton, IN 46742-0250.

[2] ArcGIS version 9.3, Environmental Systems Research Institute, 380 New York Street, Redlands, CA 92373-8100.

[3] Wire screen.18 x 16 mesh. PHIFER Incorporated. P.O. Box 1700, Tuscaloosa, Alabama 35403-1700.

[4] SAS version 9.1, SAS Institute Inc, 100 SAS Campus Drive, Cary, NC 27513.

Figure 2.1. Distribution and occurrence of giant ragweed (AMBTR) and common sunflower in the US (A) and in the North Central Region (B)**.**



Source: Lorenzi & Jeffery 1987

Source: Weeds of the North Central States

Figure 2.2. Geographical distribution of giant ragweed (AMBTR) and common sunflower (HELAN) in Kansas. Data points were collected from a roadside survey and shaded counties indicated data from the Kansas State University Herbarium database.

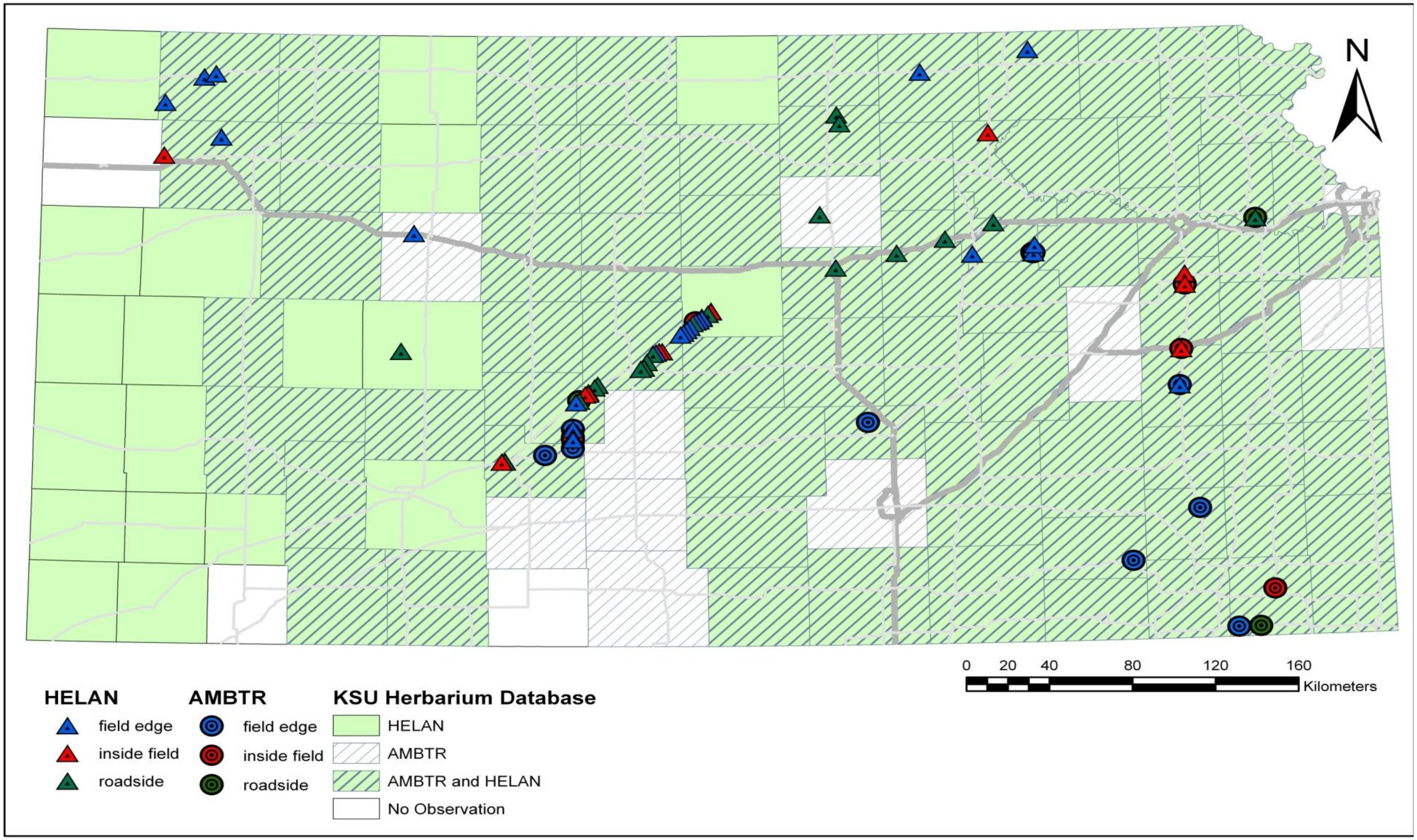


Figure 2.3. Geographical locations of giant ragweed (AMBTR) and common sunflower (HELAN) populations used in the emergence study.

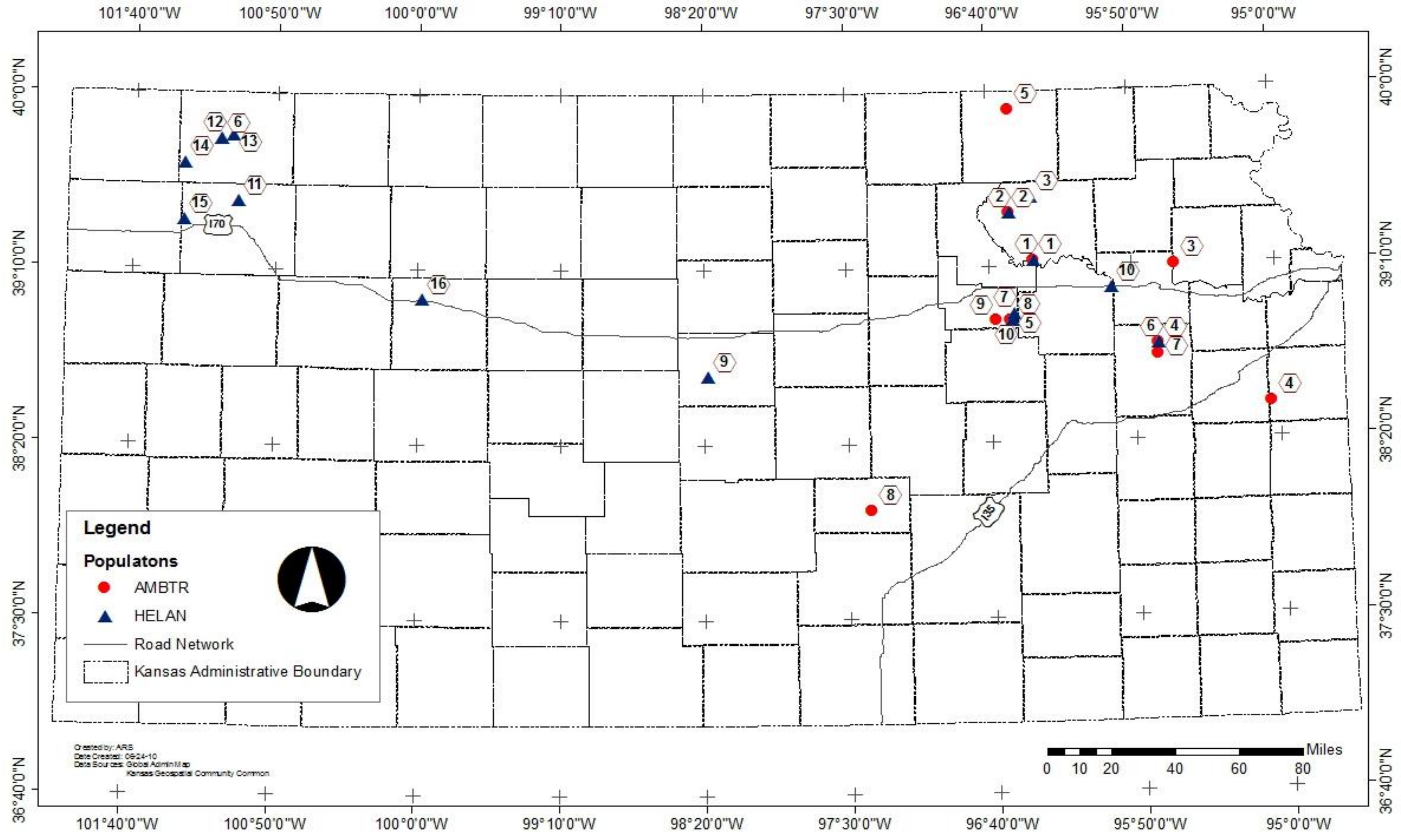


Figure 2.4. Observed weekly seedling emergence (# 0.016 m^{-2}) from March 16 to June 18, 2009 of giant ragweed (AMBTR) populations collected from 2004 to 2008 from KS.

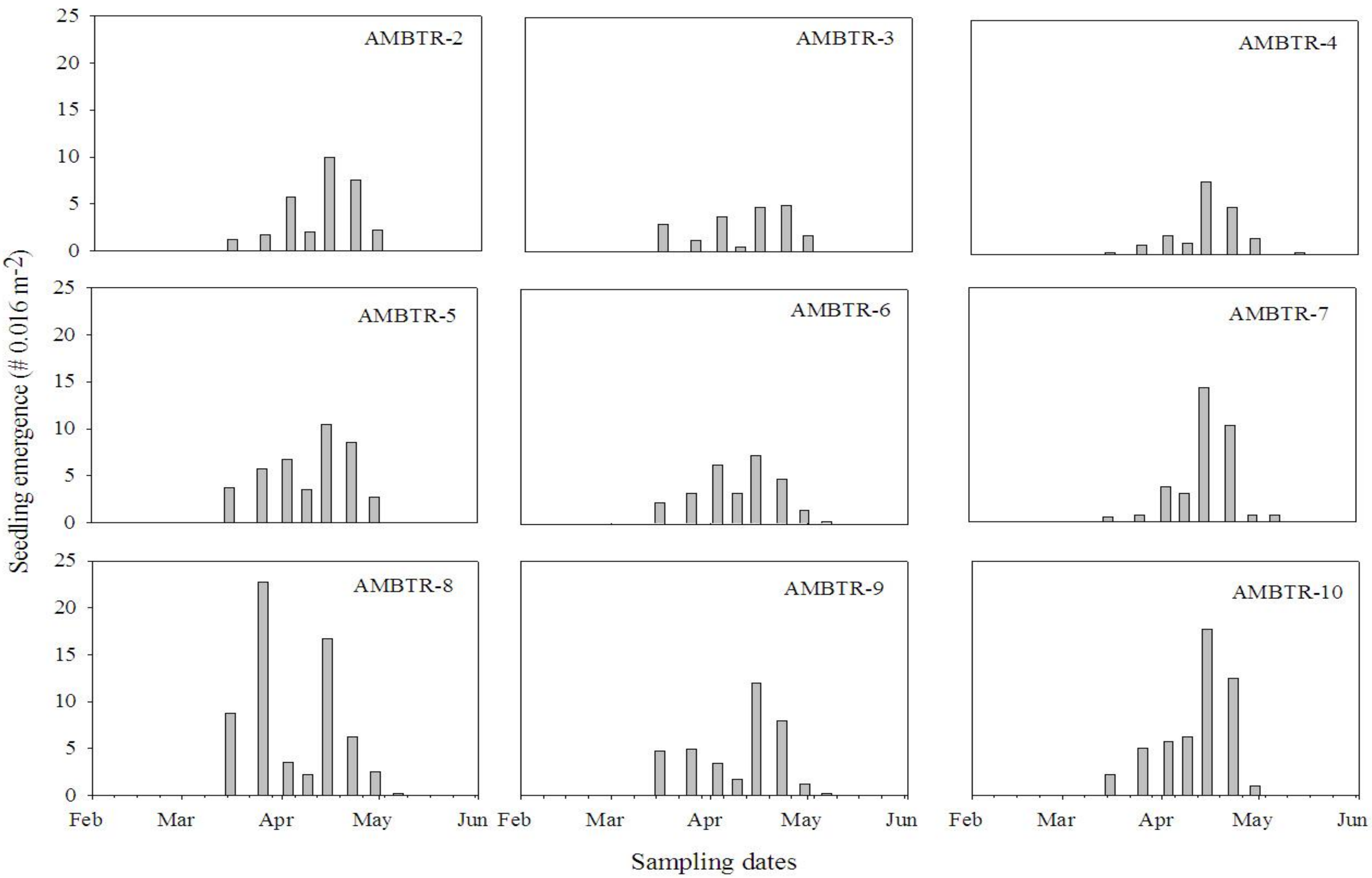


Figure 2.5. Fitted logistic curve (Equation 2.3) describing the relationship of cumulative emergence and GDD for two groups of giant ragweed (AMBTR) populations. A is for giant ragweed populations 2, 3, 5, 6, 8 and 9 and B is for population 4, 7 and 10.

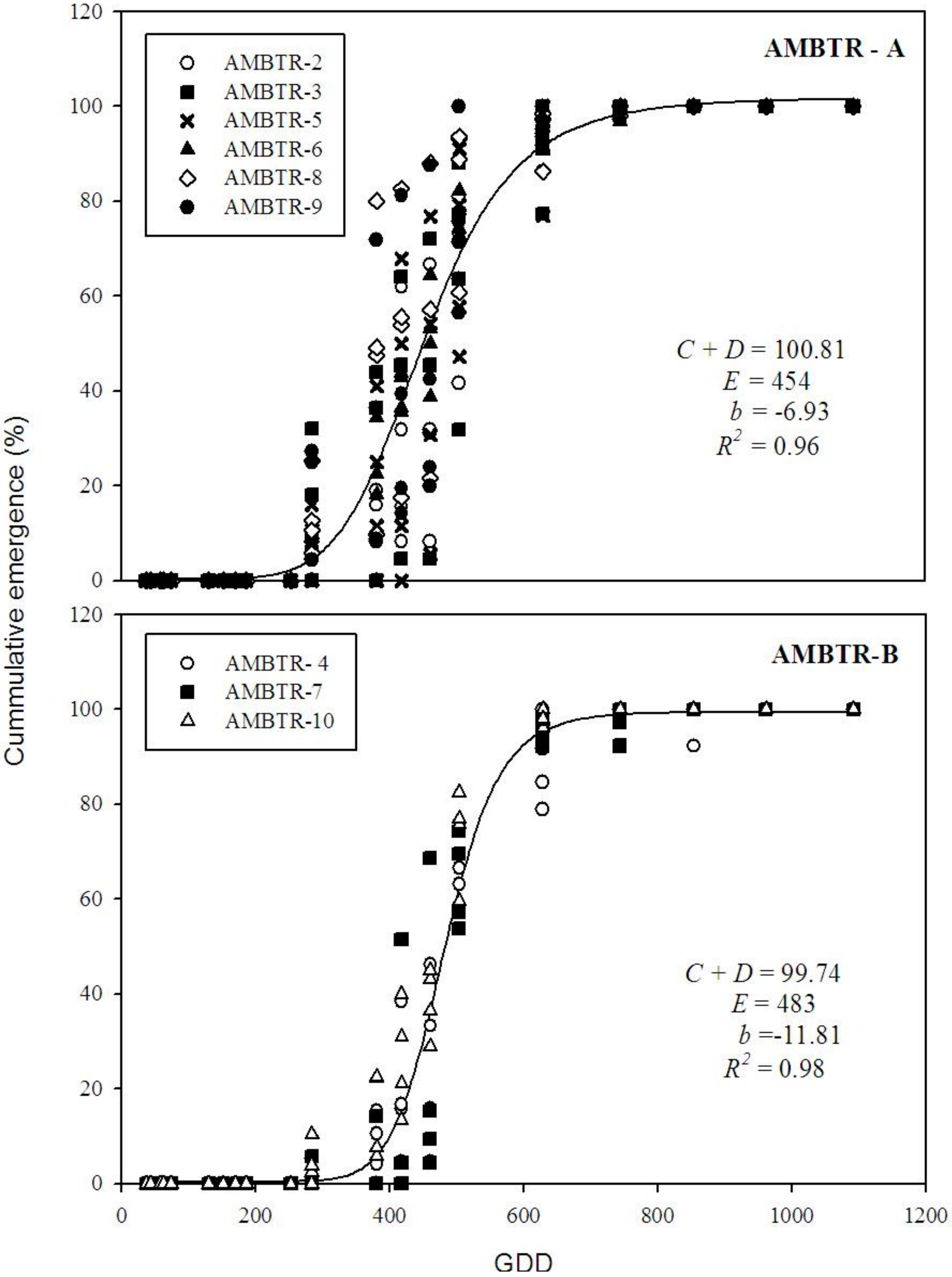


Figure 2.6. Observed weekly seedling emergence (#/ 0.016 m^2) from March to May 31, 2009 of common sunflower (HELAN) populations collected from 2004 to 2008 in KS.

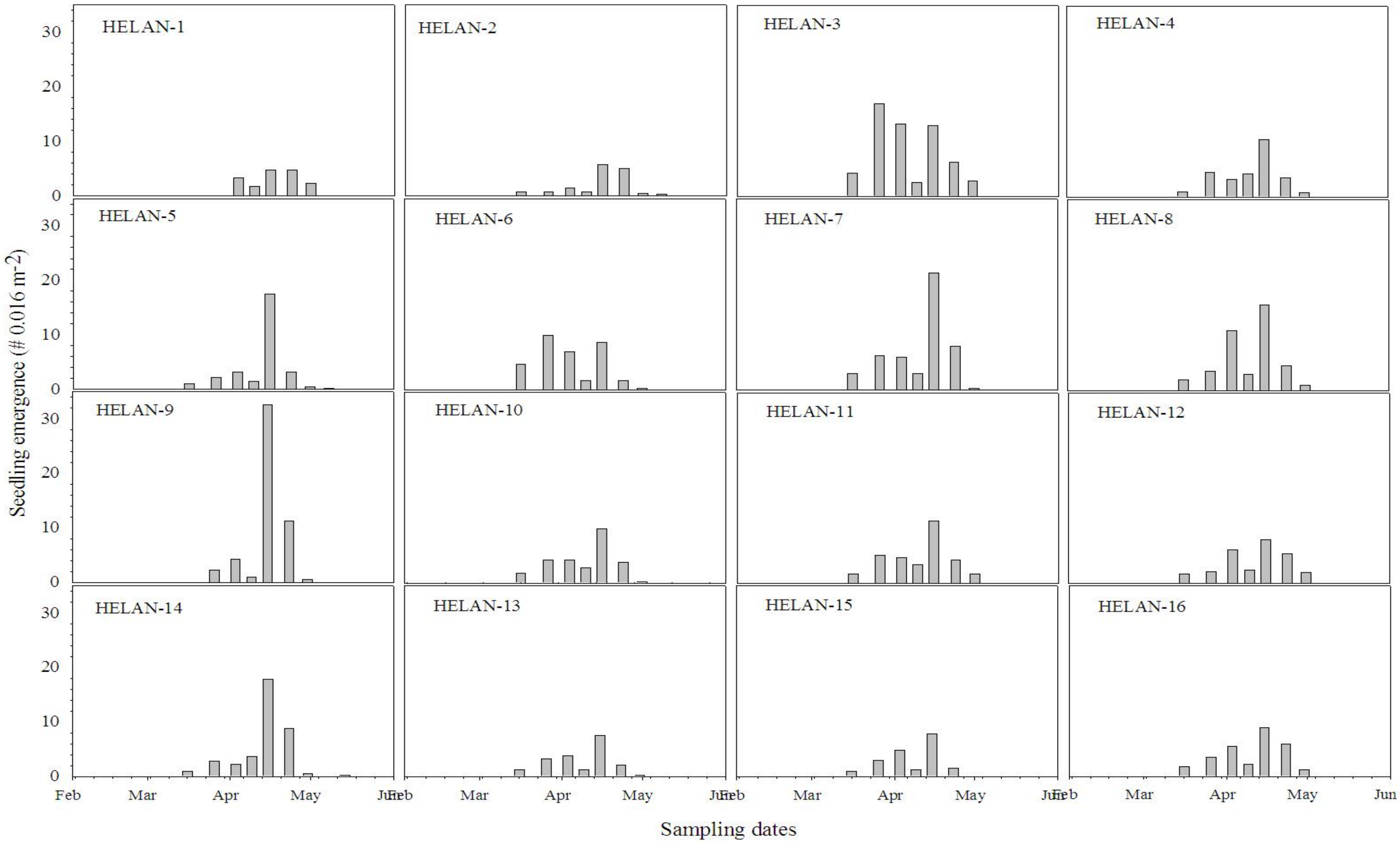


Figure 2.7. Fitted logistic curve (Equation 2.3) describing the relationship of cumulative percentage emergence and GDD for four groups of common sunflower (HELAN) populations. Population groupings are HELAN-A (5 and 9), HELAN-B (3 and 6), HELAN-C (4 and 14) and HELAN-D (1, 2, 6, 7, 8, 10, 11, 12, 13, 15 and 16).

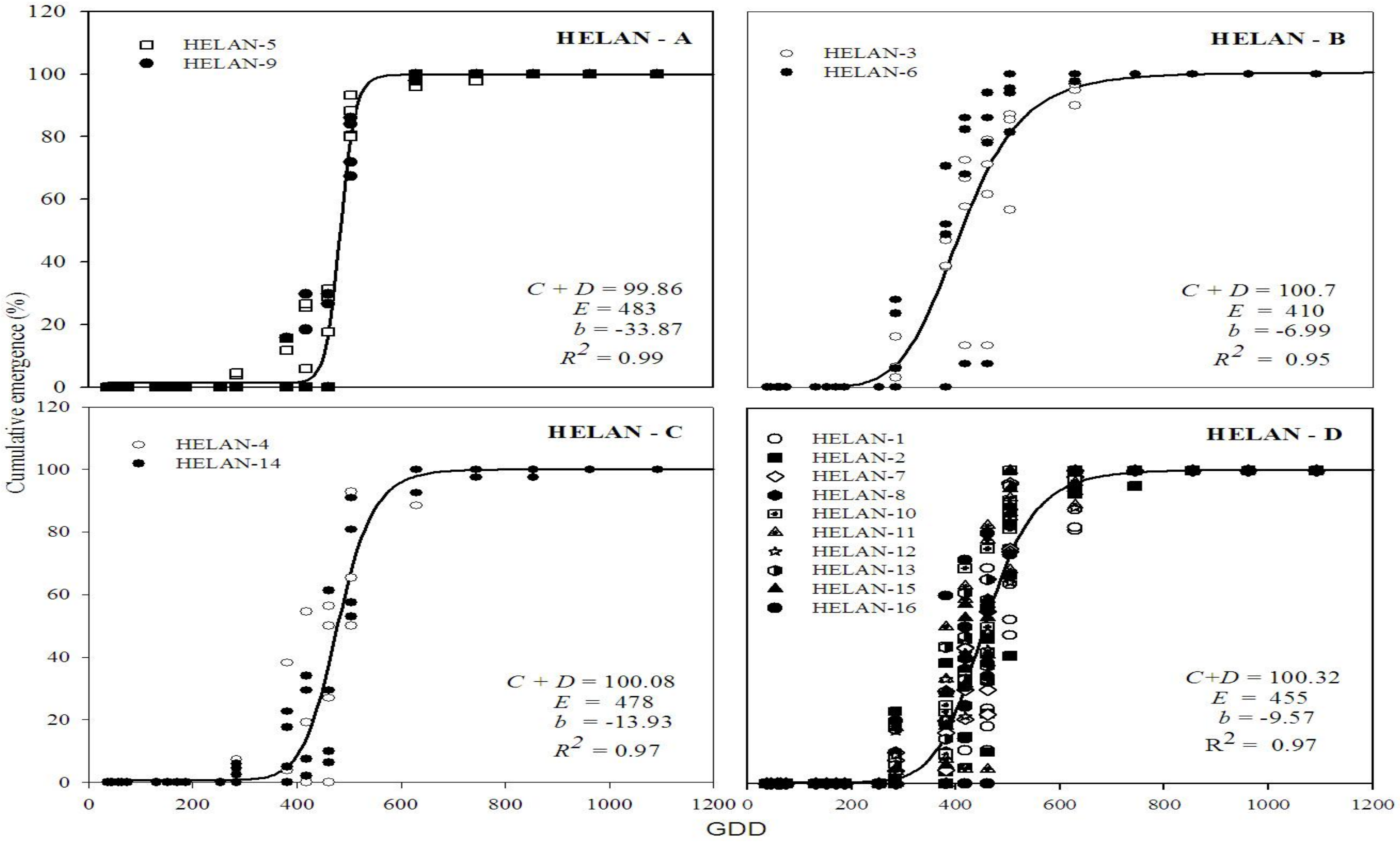


Table 2.1. Number of patches of giant ragweed (AMBTR) and common sunflower (HELAN) grouped by size (m^2).

Weed species	Size of patch (m^2)			
	0-100	101-500	501-1000	>1001
	no. observed			
AMBTR	6	6	2	2
HELAN	13	21	2	14

Table 2.2. Location, site description, and year of collection of giant ragweed (AMBTR) and common sunflower (HELAN) populations used in the emergence study.

Population	Location	Site description Type	Site description Location	Year of collection
AMBTR-1	NE	Agricultural	Inside field	2004
AMBTR-2	NE	Non-agricultural		2005
AMBTR-3	NE	Agricultural	Inside field	2006
AMBTR-4	NE	Agricultural	Inside field	2006
AMBTR-5	NE	Agricultural	Inside field	2008
AMBTR-6	NE	Agricultural	Field edge	2008
AMBTR-7	NE	Non-agricultural		2008
AMBTR-8	SE	Non-agricultural		2008
AMBTR-9	NE	Agricultural	Field edge	2008
AMBTR-10	NE	Agricultural	Inside field	2008
HELAN-1	NE	Agricultural	Inside field	2004
HELAN-2	NE	Non-agricultural		2006
HELAN-3	NE	Non-agricultural		2007
HELAN-4	NE	Agricultural	Inside field	2008
HELAN-5	NE	Agricultural	Inside field	2008
HELAN-6	NW	Agricultural	Field edge	2008
HELAN-7	NE	Agricultural	Inside field	2008
HELAN-8	NE	Agricultural	Field edge	2008
HELAN-9	SE	Non-agricultural		2008
HELAN-10	NE	Agricultural	Field edge	2008
HELAN-11	NW	Non-agricultural		2006
HELAN-12	NW	Agricultural	Field edge	2006
HELAN-13	NW	Agricultural	Field edge	2006
HELAN-14	NW	Agricultural	Inside field	2006
HELAN-15	NW	Agricultural	Inside field	2006
HELAN-16	NW	Non-agricultural		2006

Table 2.3. Average percent (± S.E) total seedling emergence of giant ragweed (AMBTR) and common sunflower (HELAN) populations collected from 2004-2008 in KS. Means within a column by weed species followed by the same letter were not significantly different at 0.05% level.

Population	Total seedling emergence	
	%	
AMBTR-1	0	e
AMBTR-2	30.5 (± 8.3)	cd
AMBTR-3	20.0 (± 3.1)	d
AMBTR-4	19.3 (± 2.3)	d
AMBTR-5	41.5 (± 6.6)	bc
AMBTR-6	28.8 (± 2.5)	cd
AMBTR-7	34.0 (± 7.4)	c
AMBTR-8	63.0 (± 4.9)	a
AMBTR-9	36.5 (± 3.2)	c
AMBTR-10	50.5 (± 3.8)	ab
HELAN-1	16.8 (± 2.1)	f
HELAN- 2	15.3 (± 5.5)	f
HELAN-3	59.0 (± 10.2)	a
HELAN- 4	27.8 (± 10.8)	def
HELAN-5	29.5 (± 11.0)	cdef
HELAN-6	34.3 (± 7.5)	bcdef
HELAN-7	48.0 (± 9.3)	abc
HELAN-8	40.8 (± 5.0)	abcd
HELAN-9	51.8 (± 3.2)	ab
HELAN-10	27.0 (± 8.2)	def
HELAN-11	32.8 (± 4.2)	bcdef
HELAN-12	28.3 (± 6.0)	de
HELAN-13	19.3 (± 1.7)	e
HELAN-14	37.0 (± 6.8)	bcde
HELAN-15	9.37 (± 1.3)	e
HELAN-16	29.3 (± 5.7)	cdef

Table 2.4. Parameter estimates (±S.E) for the fitted logistic curve (Equation 2.3) for giant ragweed (AMBTR) and common sunflower (HELAN) populations groups.

Population group	D	C	b	E_{50}
	%	%		GDD
AMBTR-A	100.40 (± 0.99)	0.41 (±0.61)	-6.93 (± 0.38)	454 (± 3.22)
AMBTR-B	99.30(±0.85)	0.44(± 0.54)	-11.81 (± 0.69)	483 (± 2.33)
HELAN-A	98.48(± 0.79)	1.38 (± 0.51)	-33.87 (± 2.01)	483 (± 1.31)
HELAN- B	100.60 (± 1.89)	-0.10(± 1.23)	-6.99 (± 0.75)	410 (± 5.84)
HELAN-C	99.27 (±1.28)	0.81 (± 0.83)	-13.93 (± 1.27)	478 (± 1.23)
HELAN-D	99.89 (± 0.59)	0.43 (±0.38)	-9.57 (± 0.34)	455(±1.63)

Table 2.5. Start, end, and duration of emergence (E) for the giant ragweed (AMBTR) and common sunflower (HELAN) population groups. Values were calculated from the fitted logistic curve for each population group (Table 2.4).

Population groups	Start	End	Duration
	GDD to 10% E	GDD to 90% E	GDD
AMBTR-A	330	616	286
AMBTR-B	410	583	182
HELAN-A	453	516	63
HELAN-B	299	558	259
HELAN-C	409	560	151
HELAN-D	362	571	209

CHAPTER 3 - Soil Feedback Response of Giant Ragweed (*Ambrosia trifida* L.) and Common Sunflower (*Helianthus annuus* L.)

ABSTRACT

Differences in plant-soil feedback response might explain differences in occurrence of giant ragweed and common sunflower in the north central region. Separate greenhouse experiments were conducted in IL, KS, MI, MT, and OR from 2006 to 2010 to quantify the plant-soil feedback response of giant ragweed (AMBTR) and common sunflower (HELAN). Two separate studies were conducted with the first conducted at each five states with seven soil types using seeds of HELAN from Kansas (KS) and AMBTR from Illinois (IL), while the second study was only done in KS using local populations of both species. The experiment was composed of two phases, the preconditioning phase and the feedback phase. In the preconditioning phase unique soil history of either AMBTR or HELAN was created, while in the feedback phase each soil history was divided into two subsets and was planted to either AMBTR or HELAN creating the following treatments: SAME-AMBTR, DIFF-AMBTR, SAME-HELAN and DIFF-HELAN. Feedback scores were based on biomass produced by each weed species and plant-soil interaction coefficient (I_S) was calculated. HELAN consistently performed better in home soil except in MT and AMBTR performed better in away soil in IL, KS, MI-a, MI-b, OR and SD but not in MT. Interaction coefficients using SAME-HELAN were neutral for KS, IL and MI-b, positive for OR and SD and negative for MI-a and MT. Both KS-AMBTR and KS-HELAN seemed to grow best in soil preconditioned by the other species (away soil). Results of this study indicated that differences in occurrence and predominance of HELAN and AMBTR were not due to expected plant-soil feedback responses and that in KS, AMBTR may be able to spread in areas previously predominated by HELAN.

Nomenclature: common sunflower, *Helianthus annuus* L., giant ragweed, *Ambrosia trifida* L.

Keywords: occurrence, plant-soil microbe interaction, plant-soil feedback, predominance.

INTRODUCTION

Success of plants in a soil environment is due to many soil factors that influence plant species occurrence, abundance and persistence. Plants interact with their soil environment in such a way that the plant is able to change the physical, chemical and biological components of the soil and these changes subsequently result in changes in the plant demography and physiology. This phenomenon is referred to as plant-soil feedback (Ehrenfeld et al. 2005). Two things must happen for feedback to exist. First, the soil condition must change due to the presence of the plant and second, this change must in turn affect the growth rate of the plant species. Hence, a given plant species may either increase its growth relative to another species (positive feedback) or decrease its growth (negative feedback) (Bever 1994; Ehrenfeld et al. 2005; Kardol 2007; Reynolds et al. 2003). Feedback is made possible through pathways involving soil physical properties, soil chemical and biogeochemical properties and processes, and soil biological properties, including the composition of the soil biota and fauna (Ehrenfeld et al. 2005; Mills and Bever 1998). Hence, it was suggested that plant-soil feedback could act as a selective force either against the plant species that caused the change in soil conditions or against other plants (Van der Puten 1997). The current literature on the existence of plant-soil feedback is far reaching and includes studies involving annual to perennial plant species, from native to invasive plant species, and from grassland ecosystems to other unmanaged systems (Belnap and Philips 2001; Reinhart et al. 2005).

The role of plant-soil feedback in various aspects of plant demography and ecology has been highlighted in numerous studies worldwide. Plant soil-feedback proved useful in explaining variation in species composition (Klironomos 2002), as well as the dynamics and structure of plant communities over time (De Deyn et al., 2004; Kardol 2007; Reynolds et al. 2003). Plant-soil feedback accounted for the invasion success of several invasive species such as *Centaurea* spp. (Reinhart and Callaway 2004; 2006), *Acer* spp. (Reinhart and Callaway 2004) and other species (Callaway et al. 2004; Wolfe and Klironomos 2005).

The contribution of the soil environment to plant growth and development cannot be overlooked. The soil serves as a resource pool from which plants draw nutrients and water for growth and subsequent development. The soil is highly heterogeneous and supports a rich microbial population (Reynolds and Haubensak 2008). Changes in the physical and chemical properties occur as changes in plant composition occur such as during a plant invasion (Ehrenfeld 2003). Among the changes observed were increased biomass, net primary productivity, and growth rate along with increased phosphorous and nitrogen content of the litter favoring exotic species over the native species (Ehrenfeld 2003).

Bezemer et al. (2006) showed that the mechanism of plant-soil feedback can depend on plant species, plant taxonomic or functional groups and site-specific variation in abiotic and biotic soil properties. In their study, plant-soil feedback differed in the two soil types used in the study. In sandy soils, plant-soil feedback was highly correlated with soil nutrients particularly potassium, and grasses were observed to cause higher depletion of potassium than forbs. In the chalk soil, plant–soil feedback was strongly impacted by the soil biota rather than soil nutrients as evidenced by distinct differences in the composition of phospholipids which accounting for the microbial population, between grass and forb monocultures. Among the plant species studied, small burnet (*Sanguisorba minor* Scop.) and perennial quackinggrass (*Briza media* L.) performed best in soils previously grown to plants of the same species while erect brome (*Bromus erectus* Huds.) performed best in soil previously grown to other species. This indicated that within grassland communities, direction of feedback response may vary. In an earlier review, Van Breemen and Finzi (1998) showed that feedback from soils to plant via the soil chemical properties involved changes in nutrient availability and soil pH which frequently had negative effect on competitors. In the majority of literature they reviewed, nitrogen and soil pH decreased to levels below which can be tolerated by potential competitors but favored growth of plants causing the changes (Van Breemen and Finzi 1998).

The role of microbial populations in plant-soil feedback response has been the focus of many recent studies. Outcomes varied with plant species and ecological systems studied. Klironomos (2002) showed that feedback between soil microbes and old-field herbaceous plants was able to explain almost 60% of the variation in species abundance in an old field meadow community. Furthermore, positive feedback was observed in four out of five invasive plants tested while all rare species demonstrated strong negative feedback under a monoculture setting. These responses were evident when the soil was further inoculated with fungi isolated from the roots of the invasive plant species (Klironomos 2002). Bever et al. (1997) reported negative feedback of *Danthonia* sp. and *Panicum* sp. when planted in soil inoculated with *Pythium* sp. Different crop production systems tend to favor development of deleterious rhizobacteria, that is a nonparasitic bacteria that affects weed growth (Li and Kremer, 2000). Also arbuscular mycorrhizal fungi (AMF) have been shown to affect weed communities by impacting key physiological processes such as seed germination, growth and survival rates in AMF host and non-host weed species (Jordan et al. 2000), thereby influencing weed community dynamics in agroecosystems (Jordan and Huerd 2008).

Plant-microbe interactions can be described by two conceptual models: the microbially-mediated niche partitioning model (Reynolds et al. 2003) and the feedback dynamics model (Bever et al. 1997). In the microbially-mediated niche partitioning model, differentiation of realized ecological niche results from nutrients becoming more available to plants through enhanced enzymatic activity brought about by specific soil biota, thereby allowing different plants to utilize various sources and forms of N, P and other nutrients. In the feedback dynamics model, dynamics result from changes in the soil microbial community generated by the changes in plant composition and in turn causing changes in the rate of growth of the plant or population (Bever et al. 1997; Reynolds et al. 2003). A particular plant community will be able to maintain local diversity due to development and accumulation of beneficial microbial populations (positive feedback dynamics) or plants may succumb to species replacement over time due to accumulation of harmful pathogenic microbial population (negative feedback dynamics) (Bever 2002; 2003).

Common sunflower (HELAN) and giant ragweed (AMBTR) are two important weed species in the north central region of the US with very distinct distribution patterns. These two weed species follow a decreasing gradient of abundance and weediness from south to north and west to east. HELAN is found to be abundant in Kansas and rare in Illinois. AMBTR is a major weed in Illinois, but not as important in Kansas. Within

Kansas itself, HELAN appears to be present everywhere while giant ragweed is found in the southeastern part of the state (Chapter 2. A. Ramirez, personal observation). Since plant-soil feedback has been shown to be a driving force behind many ecological processes such as invasion, succession and evolution, it may help explain the observed geographical differences in distribution and abundance of these two plant species across the north central region of the US. It is hypothesized that growth of these two weed species will have a positive feedback score when grown in soil where they are predominant and commonly found (AMBTR in IL and MI, HELAN in KS and SD) and will have negative feedback score when grown in soils where they are rarely found or are not a serious problem. Furthermore, it is hypothesized that plant-soil feedback might be a mechanism that could help regulate weed population dynamics in the North Central region.

The general objective of this study was to examine soil feedback mechanisms of giant ragweed and common sunflower as it relates to variation in species demography. This study was part of a regional research project (NC 1026) that aimed to identify the driving forces behind differences in geographical distribution, abundance, and weediness of common sunflower and giant ragweed in addition to demographic success. If the hypothesis stated above is true then it will help explain the observed predominance of these two weed species in specific states within the mid-western USA. The objectives of this research are aimed to 1) determine the plant-soil feedback response of KS-HELAN and IL-AMBTR using soil from IL, KS, MI, MT, OR and SD, and 2) determine the plant-soil feedback response of KS populations of HELAN and AMBTR in KS soil.

Materials and Method

Separate greenhouse experiments were conducted during 2006 to 2010 to quantify the plant-soil feedback response of giant ragweed and common sunflower across the North Central region. The first experiment was conducted in five states with seven different soils (IL, KS, MI-(a) East Lansing, MI-(b) Saginaw, MT, OR, and SD) using AMBTR population from Urbana, IL and HELAN population from Manhattan, KS (Table 3.1). Collaborators from four other states (IL, MI, MT and OR) conducted the experiment in their respective greenhouse and sent the data to KS for analysis. The KS and SD soils were tested in Manhattan, KS. The second experiment was conducted only in KS and used locally collected populations of AMBTR and HELAN. Both experiments followed the same method for pretreatment of seeds, soil mixing and plant-soil feedback testing.

Both experiments were composed of two phases, the preconditioning phase and the feedback phase (Figure 3.1). The preconditioning phase involved growing either common sunflower or giant ragweed plants in pots for two 10-week cycles. Soil for the experiments was mixed with sand in various proportions, either to improve drainage and aeration or to increase total soil volume as was the case for SD (Table 3.2). Also, the different sites followed various fertilizer application schemes in terms of type, amount, frequency and timing (Table 3.2).

AMBTR and HELAN seeds required pretreatment to break dormancy prior to initiation of each phase of the experiment. Method of pretreatment chosen varied with each location and by weed species: a wet method, a dry method, or chemical scarification (Table 3.2). The wet method involved placing seeds between paper towels in layers of moist sand and placed in cold storage at 4°C for at least one month prior to sowing in pots. The dry method involved placing seeds in bags or containers and storing them in the freezer for one to two months. Chemical scarification involved soaking seeds in either sulfuric acid or bleach (NaOCl) for a certain length of time after which seeds were thoroughly rinsed with water. For the Michigan site, the seeds were further soaked in a gibberillic acid solution (Buhler and Hoffman 1999). After pretreatment, the seeds were then sown in pots and grown for ten weeks. After the first 10-week cycle, the aboveground parts were removed, soil in each pot was stirred, new seeds of either of the two weed species were sown, and plants grown for a second 10-week cycle. Two sets of soil were thus created, one with a history of common sunflower and another with a history of giant ragweed.

For the feedback phase, each set of soil was divided into two with a subset being planted to either the same species previously grown in that soil (SAME treatment) or with the other (DIFF treatment). A total of four treatments were established SAME-AMBTR, DIFF-AMBTR, SAME-HELAN and DIFF-HELAN. Common sunflower or giant ragweed plants grew for 10 weeks in the feedback phase after which aboveground plant parts in each pot were harvested and individually measured for height, bagged and dried at 70°C for 7 days and weighed to obtain dry weights. Soil samples were collected from each pot at initiation and after each phase of the experiment for nutrient and microbial analysis. Samples for nutrient analysis were bulked per treatment and submitted to the local soil testing laboratories for determination of pH, organic matter content, total nitrogen, total phosphorous, potassium, $NO_{3,}$ and NH_4OH. Samples for microbial analysis were sent to the USDA-ARS Global Change and Photosynthesis Research Unit based at University of Illinois in Urbana, IL (data to be reported elsewhere).

The experiment was laid out in a randomized complete block design with ten replications and was repeated two or three times (runs) depending on location. Aboveground biomass and height data were analyzed using Mixed procedure of SAS[1] (SAS 2009) with runs and replications within runs as random effects and four treatment combinations of weed species and soil history as fixed effects. In determining plant-soil feedback, scores (*F*) were calculated for a given weed species (*i*) (Harrison and Bardgett 2010) as:

$$F_i = \frac{response_i\ (SAME) - response_i\ \ (DIFF)}{response_i\ (SAME)}\ \text{x } 100 \qquad \text{(Equation 3.1)}$$

where F_i is the feedback score for weed species *i*, $response_i$ is measured biomass for a given weed species *i* in SAME or DIFF soil history treatment. Feedback scores were regarded as performance in home (SAME) vs. away (DIFF) soils. Values of $F_i > 0$ corresponds to a positive feedback score while $F_i < 0$ corresponds to a negative feedback score.

Overall interaction coefficient (Bever et al. 1997) was also calculated as:

$$I_S = G(A)_\alpha - G(A)_\beta - G(B)_\alpha + G(B)_\beta \qquad \text{(Equation 3.2)}$$

where $G(A)_\alpha$ is biomass (SAME-HELAN), $G(A)_\beta$ is biomass (DIFF-HELAN), $G(B)_\alpha$ is biomass (DIFF-AMBTR) and $G(B)_\beta$ is biomass (SAME-AMBTR). Since biomass from all the sites vary, I_S was standardized as;

$$I_S* = \frac{I_S}{\text{SAME}-\text{HELAN treatment}} \qquad \text{(Equation 3.3)}$$

In the second experiment the effect of preconditioning phase on above ground biomass of KS accessions of AMBTR and HELAN were determined. Biomass data were analyzed using the Mixed procedure of SAS[1] with runs and replications within runs as random effects and phase and species as fixed effects. Biomass from the four treatments were used to calculate feedback score (*F*) for each weed species and interaction coefficient (I_S) using the equations used in Experiment 1.

Results and Discussion

Experiment 1: Feedback response of IL-AMBTR vs. KS-HELAN

At a given location, significant differences for biomass among the four treatments were observed except for IL (Table 3.2). Giant ragweed biomass did not differ when grown in either SAME or DIFF soil except for MT. In MT, giant ragweed was larger when grown in SAME soil (Table 3.2). Common sunflower biomass was not different when grown in SAME or DIFF soil for IL, KS, and MI-a, while common sunflower was larger when grown in SAME soil at MI-b, OR and SD and it was smaller in MT. In MI-a and MI-b, giant ragweed produced significantly more biomass than common sunflower no matter the soil history. In KS and OR, common sunflower produced more biomass than giant ragweed no matter the soil history. For MT, plants grown in AMBTR-history soil were largest (DIFF-HELAN and SAME-AMBTR) compared to plants grown in HELAN-history soil. In SD, giant ragweed grown in HELAN-history soil was the largest across the four treatments.

Performance in home versus away soil revealed that AMBTR consistently performed better in soil preconditioned by HELAN except in MT where AMBTR grew better in soil preconditioned by itself (Table 3.3). Among the different states, MI-a gave the highest percent increase in AMBTR biomass when grown in soil preconditioned by HELAN while SD gave the least. HELAN on the other hand grew better in soil preconditioned by itself in KS, OR and SD while in IL, MI-a and -b and MT, growth of HELAN was better in soil preconditioned by AMBTR. MT gave the highest increase in biomass for HELAN while MI-b gave the lowest.

In all sites, the direction of the individual feedback score for was consistent, that is negative for AMBTR and positive for HELAN (Table 3.3) except in MT where AMBTR feedback response was positive and HELAN feedback response was negative.

Interaction coefficient (I_S*) analysis revealed that KS, MI-b, OR and SD had positive interaction coefficients while IL, MI-a and MT had negative I_S*. However, the negative I_S* for IL may be regarded as more neutral since the magnitude is so close to zero. The positive I_S* for KS and MI-b were also regarded as more neutral since magnitude is close to zero. OR and SD had positive I_S because the biomass of plants grown in HELAN soil was consistently heavier than plants in AMBTR soil. This indicated that HELAN was able to create a favorable environment for both AMBTR and HELAN plants and that growth of HELAN was more favored than AMBTR. Under these conditions, either AMBTR or HELAN will dominate. For sites having negative I_S, two distinct causes for the negative I_S were observed. In MT, AMBTR made the soil more beneficial to the growth of either AMBTR or HELAN while in MI-a, HELAN seemed to provide a better soil condition for the growth of either weed species however, the growth of AMBTR was always better than HELAN regardless of soil history.

These results show that several scenarios of weed dynamics can be observed based on feedback response of AMBTR and HELAN. HELAN would always predominate in KS, OR and SD. HELAN is a predominant weed species in KS but in OR and SD, it is not common but given the chance to be introduced there is a possibility that it could predominate. In MT, AMBTR will likely predominate compared to HELAN. In MI, the two sites differed in the direction of interaction effects, such that MI-a was negative while MI-b was positive but in both sites AMBTR consistently grew better regardless of history confirming the current predominance status of the two weed species. These scenarios were consistent with those described by Bever et al. (1997). According to Bever et al. (1997) under conditions of a positive feedback, growth of one species is greater than another species, hence predominance of that species is expected and will lead to the predominant plant replacing the existing plant composition. If there is reciprocal positive feedback, the rate of population growth of one plant increases over time and this could lead to loss of diversity while in a negative reciprocal feedback, the relative population growth rate of a particular plant decreases with its own local community that leads to greater diversity in plant composition.

The hypothesis that there would be geographical differences in plant-soil feedback response between common sunflower and giant ragweed was not supported by these results. Instead, giant ragweed appears to grow better in new (non-giant ragweed) soils, whereas, common sunflower appears to grow better in its own soil. The interesting result for MT, with feedback responses for giant ragweed and common sunflower that were opposite of all other sites suggests that there is something unique in the MT soil that elicited such response. The positive feedback response of HELAN in almost all sites indicates that soil history had a small impact on the growth response of HELAN and could be due to other factors not directly measured in this experiment. Negative feedback response of HELAN in MT indicates that HELAN will have difficulty in establishing in this site since it is rarely found there.

Experiment 2: KS-HELAN vs. KS-AMBTR

There was a significant preconditioning phase by species interaction for aboveground biomass of giant ragweed and common sunflower grown during the two preconditioning phases (Table 3.4). Common sunflower grown during the first preconditioning phase had larger biomass than when grown during the second preconditioning phase. It had the largest biomass among the different treatments. Giant ragweed biomass in the first preconditioning phase did not differ from the second preconditioning phase.

Aboveground biomass of giant ragweed from Kansas (KS-AMBTR) grown in SAME and DIFF soils did not differ while common sunflower (KS-HELAN) grown in DIFF soil had greater biomass than those grown in SAME soil (Table 3.5). Individual feedback scores of KS populations were negative for both weed species. Growth of AMBTR and HELAN were enhanced in soil conditioned by the other species (Table 3.6). Interaction coefficient was also negative and indicated that the two KS populations of AMBTR and HELAN tended to provide a better soil environment for the growth of the other species than itself (Table 3.5). This result, especially for HELAN however, was not consistent with the results obtained from the first study.

Other soil-mediated factors likely contributed to the plant-soil feedback responses observed across the region. Anecdotally, giant ragweed and common sunflower are often observed to occur in dense monoculture stands if not controlled (Rasmussen and Einhellig 1979; A. Ramirez personal observation). This could indicate exclusion of other species based on soil-mediated factors such as release of allelopathic compounds. Both weed species are known to be allelopathic to crops (Irons and Burnside 1982; Rasmussen and Einhellig 1979) and other weed species (Leather 1983). Irons and Burnside (1982) observed that sunflower roots apparently released exudates into a nutrient solution and soil since root exudates inhibited sunflower emergence, and reduced height of sorghum, soybean and sunflower and reduced fresh and dry weight in greenhouse experiments. Similarly, Ashrafi and his co-workers (2008) reported that at 35 days after planting, growth of sunflower and germination and growth of wild barley (*Hordeum spontaneum*) were significantly reduced when grown in soil previously planted to sunflower. Inhibition of germination and plant growth were also observed when either extracts or residues (whole or from various plant parts) were incorporated into growing media. Extracts made from dried leaf and stem tissue of native and cultivated sunflower varieties stimulated germination in some weed species including redroot pigweed (*Amaranthus retroflexus* L.), jimsonweed (*Datura stramonium* L.) and red sorrel (*Rumex acetosella* L.) while grass weed seeds of giant foxtail (*Setaria faberi* Herrm.), green foxtail (*S. viridis* (L.) Beauv) and johnsongrass (*Sorghum halepense* (L.) Pers.) were unresponsive (Leather 1983). Germination of wild mustard seed (*Brassica kaber* (DC.) L.C. Wheeler var. *pinnatifida* (Stokes) L.C. Wheeler) however, was inhibited by undiluted common sunflower leaf-tissue extracts but stimulated with dilutions of the extracts (Leather 1983).

Fresh sunflower residues incorporated into the soil reduced wild barley germination, height and dry weight (Ashrafi et al. 2008). It is not certain what impacts root tissue may have on dynamics in the soil. It is clear that shifts in species are possible with the influence of common sunflower on soil chemical properties. Rasmussen and Einhellig (1979) hypothesized that because giant ragweed reduced crop yields and can exist in pure stands, allelopathic mechanisms may also function along with direct competition. They demonstrated that aqueous extracts from leaves of giant ragweed reduced growth in grain sorghum seedlings, and reduced germination in grain sorghum and radish.

Differences in soil nutrient status during preconditioning and feedback phase could also contribute to differences in aboveground productivity of AMBTR and HELAN. Nutrient impact on plant species could also be the cause of differences in feedback response of AMBTR and HELAN. However, the lack of sufficient replications of soil sample and consistent protocol for soil nutrient analysis in each of the sites prevents inferences to be drawn and conclusions to be made. Unless a consistent protocol for soil nutrient sampling and analysis is used, then there is no way that the current results can be correlated to nutrient effects.

The role of soil microbial populations on the observed differences in feedback response and interaction between the two weed species should be evaluated.

Conclusion

Several soil factors could influence feedback response between plants and soil, including soil physical properties, soil chemical and biogeochemical properties and soil biological characteristics such as soil biota and fauna. We hypothesized that regional differences in occurrence of giant ragweed and common sunflower could be explained in part by plant-soil feedback focused on soil microbial changes caused by pre-conditioning the soil with either two weed species. However this hypothesis was not supported since only Montana demonstrated a completely different feedback response for AMBTR and HELAN compared to other locations. Rather, giant ragweed always performed better in DIFF soil compared to SAME, while common sunflower always performed better in SAME soil compared to DIFF when using common accessions of weed species across the region.

Acknowledgements

I would like to thank USDA-CSREES NC 1026 for funding and the collaborators Drs. Adam Davis (IL), Christy Sprague (MI), Richard Smith and Fabian Menalled (MT), and Joel Felix (OR) from different states for providing the data for the regional study. Thank you to Sharon Clay for providing the SD soil.

References

Ashfari, Y.Z., S. Sadeghi, R.H. Mashhadi and A.M. Hassan. 2008. Allelopathic effects of sunflower (*Helianthus annuus*) on germination and growth of wild barley (*Hordeum spontaneum*). J Agric. Technol. 4:219-229.

Belnap, J. and S.L. Phillips. 2001. Soil biota in an ungrazed grassland:response to annual grass (*Bromus tectorum*) invasion. Ecol. Appl.11:1261-1275.

Bever, J.D. 1994. Feedback between plants and their soil communities in an old field community. Ecology 75:1965-1977.

Bever, J.D. 2002. Negative feedback within a mutualism: host-specific growth of mycorrhizal fungi reduces plant benefit. Proc R. Soc. London B. 269:2595-2601.

Bever, J.D. 2003. Soil community feedback and the coexistence of competitors: conceptual frameworks and empirical tests. New Phytol.157:465-473.

Bever, J.D., K. M. Westover and J. Antonovics. 1997. Incorporating the soil community into plant population dynamics: utility of the feedback approach. J. Ecol. 85:561-573.

Bezemer. T.M., C.S. Lawson, K. Hedlund, A.R. Edwards, A.J. Brooks, J.M. Igual, S. R. Mortimer and W.H. Van der Puten. 2006. Plant species and functional group effects on abiotic and microbial soil properties and plant-soil feedback responses in two grasslands. J. Ecol. 94:893-904.

Buhler, D.D. and M.L. Hoffman, 1999. Andersen's guide to practical methods of propagating weeds and other plants. Weed Science Society of America. Lawrence, KS: Allen Press Inc.

Callaway, R.M., G.C. Thelen, A. Rodriguez and W.E. Holben. 2004. Soil biota and exotic plant invasion. Nature 427:731-733.

De Deyn, G.B., C.E. Raaijmakers and W.H. Van der Puten. 2004. Plant community development is affected by nutrients and soil biota. J. Ecol. 92:824-834.

Ehrenfeld, J. G. 2003. Effects of exotic plant invasions on soil nutrient cycling processes. Ecosystems 6:503-523.

Ehrenfeld, J.G., B. Ravit and K. Elgersma. 2005. Feedback in the plant-soil system. Annu. Rev. Environ. Resourc. 30:75-115.

Harrison, K.A. and R.D. Bardgett. 2010. Influence of plant species and soil conditions on plant-soil feedback in mixed grassland communities. J. Ecol. 98:384-395.

Irons, S.M. and O.C. Burnside. 1982. Competitive and allelopathic effects of sunflower (*Helianthus annuus*). Weed Sci. 30:372-377.

Jordan, N.R., J. Zhang and S. Huerd. 2000. Arbuscular-mycorrhizal fungi: potential roles in weed management. Weed Res. 40:397-410.

Jordan, N. and S. Huerd. 2008. Effects of soil fungi on weed communities in corn-soybean rotation. Renewable Agric. and Food Systems 23:108-117.

Kardol. P., N.J. Cornips, M.M.L. van Kempen, J.M.T. Bakx-Schotman, and W.H. Van der Puten. 2007. Microbe-mediated plant-soil feedback causes historical contingency effects in plant community assembly. Ecol. Monographs 77:147-162.

Klironomos, J.N. 2002. Feedback with soil biota contributes to plant rarity and invasiveness in communities. Nature 417:67-70.

Leather, G.R. 1983. Sunflowers (*Helianthus annuus*) are allelopathic to weeds. Weed Sci. 31:37-42.

Li, J. and R.J. Kremer. 2000. Rhizobacteria associated with weed seedlings in different cropping systems. Weed Sci. 48:734-741.

Mills, K and J.D. Bever. 1998. Maintenance of diversity within plant soil communities: soil pathogens as agents of negative feedback. Ecology 79:1595-1601.

Rasmussen, J.A. and F.A. Einhellig. 1979. Allelochemic effect of leaf extracts of *Ambrosia trifida* (Compositae). Southwestern Naturalist 24:637-643.

Reinhart, K.O and R.M. Callaway. 2004. Soil biota facilitate exotic *Acer* invasions in Europe and North America. Ecol. Appl. 14:1737-1745.

Reinhart, K.O and R.M. Callaway. 2006. Tansley review: soil biota and invasive plants. New Phytol. 170:445-457.

Reinhart, K.O., A.A. Royo, W.H. Van der Puten and K. Clay. 2005. Soil feedback and pathogen activity in *Prunus serotina* throughout its native range. J. Ecol. 93:890-898.

Reynolds, H.L. and K.A. Haubensak. 2008. Soil fertility, heterogeneity and microbes: towards an integrated understanding of grassland structure and dynamics. Appl.Vegetation Sci. 12:33-44.

Reynolds, H.L., A. Packer, J.D. Bever and K. Clay. 2003. Grassroots ecology: plant-microbe-soil interactions as drivers of plant community structure and dynamics. Ecol. 84:2281-2291.

Smith, R.G., D.A. Mortensen and M.R. Ryan. 2009. A new hypothesis for the functional role of diversity in mediating resource pools and weed-crop competition in agroecosystems. Weed Res. 50:37-48.

[USDA] US Department of Agriculture-ARS. 1970. Selected weeds of the United States. Washington DC.

Van Breemen, N. and A.C. Finzi. 1998. Plant-soil interactions:ecological aspects and evolutionary implications. Biogeochemistry 42:1-19.

Van der Puten, W.H. 1997. Plant soil feedback as a selective force. Trends Ecol Evol. 12:169-170.

Wolfe, B.E. and J.N. Klironomos. 2005. Breaking new ground: soil communities and exotic plant invasion. BioScience 55:477-487.

Sources of Material

[1] SAS version 9.1, SAS Institute Inc, 100 SAS Campus Drive, Cary, NC 27513, USA.

Figure 3.1. Schematic diagram outlining the conditioning phase (two 10-week periods) and the feedback phase (one 10-week period) of the greenhouse experiment.

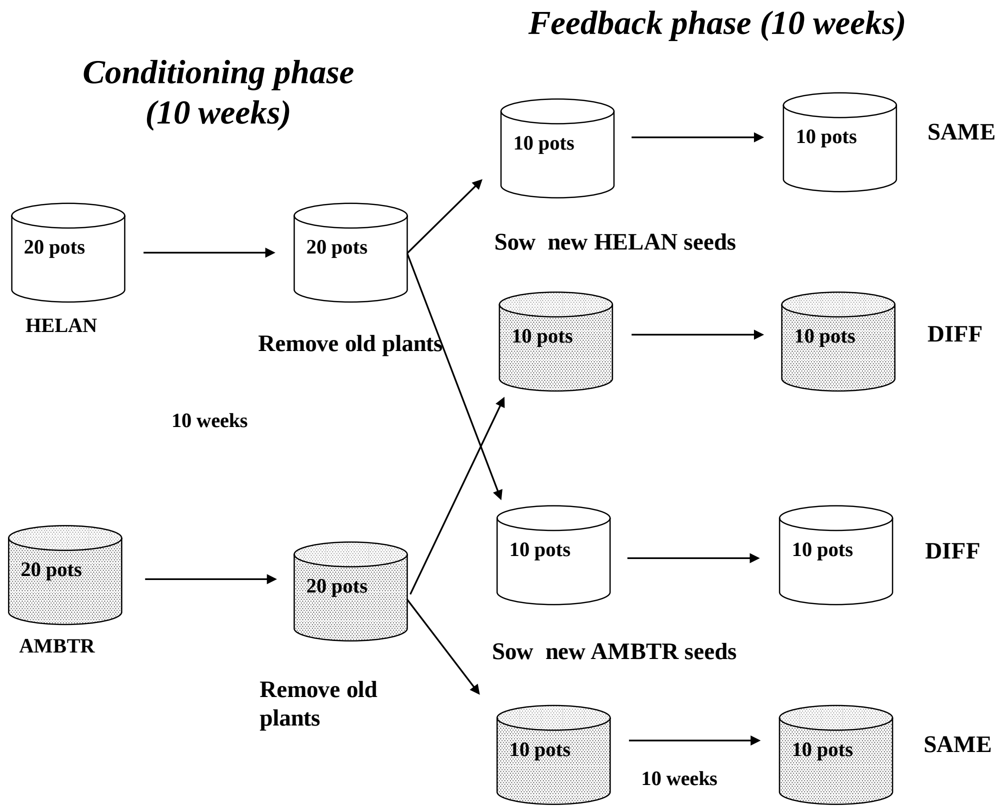


Table 3.1. Location, number of runs conducted, method to pre-treat seeds, additive, fertilization scheme, day/night temperature and photoperiod of the regional study on soil feedback response of giant ragweed (AMBTR) and common sunflower (HELAN).

		Seed Pretreatment[1]		Additives		Fertilization scheme[2]				
Location	Runs	AMBTR	HELAN	Type	Ratio	PC1	PC 2	A	Day/night temperature	Photoperiod
	#								°C	hours
Urbana, IL	2	Wet	Scarification (NaOCl)	Sand	1:1	1X 1DAP	1X 1DAP	1X 1DAP	25/15	12
Manhattan, KS	3	Wet	Wet	Sand	1:2	1X 1DAP	1X 1DAP	1X 1DAP	25/15	12
East Lansing, MI	2	Dry	Scarification (H_2SO_4) + GA_3	Sand	1:2	Weekly	Weekly	0	25/15	16
Saginaw, MI	2	Dry	Scarification (H_2SO_4) + GA_3	Sand	1:1	Weekly	Weekly	0	25/25	16
Bozeman, MT	3	Wet	Scarification (NaOCl)	MSU	1:3	0	0	0	35/14	16
Ontario, OR	1	Wet	Wet	0	0	1X	1X	1X	30/15	16
Brookings, SD	1	Wet	Wet	Sand	1:2	1X 2WAP	1X 2WAP	1X 2WAP	25/15	12

[1] Wet method is placing seeds in layers of moist paper towel and sand and kept in 4C; Dry method is placing seeds in bags or containers and storing them in the freezer for one to two month.

[2] Fertilization occurred one time (1X) one day after planting (DAP), weekly, or two weeks after planting (WAP) depending on location. PC1, PC2 and A corresponds to preconditioning 1 and 2 and feedback phase, respectively.

[3] MSU mix is a soil blend of a 1:1:1 ratio of mineral soil, Canadian sphagnum peat moss, and washed concrete sand.

Table 3.2. Mean (± S.E) for biomass (g pot^{-1}) and performance in home vs. away soil of giant ragweed (AMBTR) and common sunflower (HELAN) grown in same (SAME) and different (DIFF) soil history, and interaction coefficient for Illinois (IL), Kansas (KS), East Lansing, MI (MI-a), Saginaw, MI (MI-b), Montana (MT), Oregon (OR), and South Dakota (SD). Means within a column followed by the same letter are not significantly different at α =0.05.

Treatments	IL	KS	MI-a	MI-b	MT	OR	SD
				g pot^{-1}			
SAME -AMBTR	18.69 (± 2.95) a	27.50 (± 2.23) b	3.37 (± 0.27) a	3.27 (± 0.14) a	5.69 (± 0.20) a	54.90(± 4.07) c	46.04 (± 3.16) b
DIFF-AMBTR	21.64 (± 3.56) a	30.15 (± 1.69) b	3.72 (± 0.18) a	3.76 (± 0.25) a	4.13 (± 0.34) b	59.30(± 5.08) c	48.18 (± 1.99) b
SAME-HELAN	23.20 (± 3.66) a	41.25 (± 3.58) a	2.90(± 0.36) b	2.58 (± 0.28) b	3.01 (± 0.34) b	93.70(± 4.45) a	60.01(± 2.35) a
DIFF-HELAN	20.31(± 3.42) a	37.45 (± 3.52) a	2.89 (±0.35) b	2.03 (± 0.11) c	6.43 (± 0.66) a	75.50 (± 5.61) b	51.62 (± 2.40) b
I_S (g)	-0.06	1.15	-0.34	0.06	-1.86	13.80	6.25
I_S* (%)	-0.26	2.79	-11.72	2.35	-61.79	14.73	10.41

Table 3.3. Performance in home vs. away soil of giant ragweed (AMBTR) and common sunflower grown in same (SAME) and different (DIFF) soil history from Illinois (IL), Kansas (KS), East Lansing, Michigan (MI-a), Saginaw, MI (MI-b), Montana (MT), Oregon (OR) and South Dakota (SD).

Weed species	IL	KS	MI-a	MI-b	MT	OR	SD
AMBTR	-15.78	-9.64	-10.38	-14.98	27.42	-8.01	-4.71
HELAN	12.46	9.21	0.34	21.32	-113.62	19.42	13.98

Table 3.4. Biomass (±S.E.) of Kansas giant ragweed (KS-AMBTR) and common sunflower (KS-HELAN) as influenced by preconditioning phase. Means followed by the same letter are not significantly different at α = 0.05.

Phase	KS-AMBTR	KS-HELAN
	g pot^{-1}	
Pre-conditioning 1	50.82 (± 2.95) b	78.80 (± 3.63) a
Pre-conditioning 2	53.89 (± 3.61) b	54.08 (± 3.02) b

Table 3.5. Mean (± S.E) biomass (g pot^{-1}), performance in home vs. away soil of giant ragweed (KS-AMBTR) and common sunflower (KS-HELAN) grown in KS soil as influenced by soil history effects and the interaction coefficient (I_S).

Treatments	Biomass (g pot^{-1})
SAME-KS-AMBTR	10.71 (± 0.62) c
DIFF-KS-AMBTR	20.04 (± 2.52) bc
SAME-KS-HELAN	23.97 (± 3.26) b
DIFF-KS-HELAN	45.32 (± 6.91)a
I_S	-30.68

Table 3.6. Performance in home (SAME) vs. away (DIFF) soil of KS populations of giant ragweed (AMBTR) and common sunflower (HELAN) grown in same (SAME) and different (DIFF) soil history.

Weed species	Biomass (%)
AMBTR	-87.11
HELAN	-89.07

CHAPTER 4 - Population dynamics of giant ragweed (*Ambrosia trifida* L.) and common sunflower (*Helianthus annuus* L.)

ABSTRACT

Field experiments were conducted in 2006, 2007 and 2008 at the Department of Agronomy Ashland Bottoms Research Farm near Manhattan, KS to determine the seed survival in soil, emergence, seedling survival and seed production of giant ragweed (*Ambrosia trifida* L., AMBTR) and common sunflower (*Helianthus annuus* L., HELAN) under corn or fallow habitats, and to determine population growth rates for AMBTR and HELAN based on field observations. In each habitat, below ground (BG) and above ground (AG) plots were established where known quantities of seeds of AMBTR from IL and HELAN from KS were sown in April 2006 and in October of 2006 and November 2007. In BG plots, seeds were sown in the overwinter (OW) and spring-summer (SS) study areas and were subsequently recovered in March from the OW and in October from the SS area. In AG plots, seeds of AMBTR and HELAN were allowed to emerge and seedlings grow to maturity and fecundity measured. Seed survival in the soil through winter and spring-summer, and seedling recruitment were monitored in the BG plots while seedling recruitment, seedling survival to maturity and fecundity were observed from plants growing in the AG plots.

Results show that in both corn and fallow habitats, the proportion of recovered seeds from the OW and SS areas that were damaged or remained viable but dormant varied across years and varied with weed species. Emergence varied from 2006 to 2008 for both weed species indicating increasing seedling recruitment, however, not all of these seedlings reached maturity. Fecundity of both weed species varied across years in fallow habitat with HELAN producing more seeds that AMBTR. Fecundity ranged from 1849 to 2977 seeds plant^{-1} for AMBTR and from 9568 to 22,513 seeds plant^{-1} for HELAN. In corn habitats, fecundity ranged from 554 to 2695 seeds plant^{-1} for AMBTR and from 4946 to 14944 seeds plant^{-1} for HELAN. Seed production per g of biomass production varied from year to year. Population growth rates for both weed species varied from 2006 to 2007 in both corn and fallow habitats with HELAN having a higher growth rate than AMBTR. In corn habitats population growth rate ranged from 27 to 758 for AMBTR and from 59 to 1327 for HELAN, while in fallow habitat population growth rate varied from 146 to 866 in AMBTR and from 232 to 2677 for HELAN. Variability in weather conditions across years impacted the various demographic parameters and subsequently impacted growth rate of both weed species in corn and fallow habitats.

Nomenclature: giant ragweed, *Ambrosia trifida* L, AMBTR; common sunflower, *Helianthus annuus* L., HELAN; corn, *Zea mays* L.

Key words: Demography, fecundity, population growth rate, seed bank, seedling recruitment, seedling survival to maturity.

Introduction

A population is a group of individuals belonging to the same species and found in the same place. Population dynamics or demography is the study of the numerical changes in a population through time. Its basic unit for study is the life cycle which is made up of several stages. Numbers occurring at each stage can be quantified and the rate at which individuals transition from stage to stage can be measured. The environment in which an organism lives impacts these stages of development. The rate at which an organism progresses from one stage to another determines population dynamics and structure and subsequently influences the community to which it belongs (Radosevich et al.1997).

Population dynamics of an annual weed are regulated by five demographic processes: seedling recruitment, seedling survival, seed production, dispersal, and seed survival in soil (Lindquist et al. 1995). Each of these processes represents transition events from one stage to another in the life cycle of annual weeds. They can be quantified and used in monitoring changes in weed populations over time. Population growth rate can be measured by how many individuals in a population transitions from one developmental stage to another, complete their life cycle and produce new individuals for the next cycle. Population growth rate can be used to forecast population trends and can serve as guide in developing weed control strategies (Jurado-Exposito et al. 2005).

Population dynamics of annual weeds are impacted by crop and management decisions. Westra et al. (2008) reported a buildup of common lambsquarters (*Chenopodium album* L.) and wild buckwheat (*Polygonum convolvulus* L.) populations when glyphosate was applied at a low rate of 0.4 kg ae ha^{-1} twice each year and recommended that this practice be avoided to better manage these weeds. Use of soil-applied residual herbicide resulted in 100-fold reduction in barnyardgrass (*Echinochloa crus-galli* (L.) Beauv.) seedbank densities in glyphosate-resistant cotton (Werth et al. 2008). Davis and Liebman (2003) reported that use of red clover in combination with spring tillage reduced green foxtail (*Setaria viridis* (L.) Beauv.) seedling emergence by 30% and delayed time to 50% emergence by a week but green foxtail fecundity was increased to 200% due to suppressed early corn growth. This further leads to green foxtail seed buildup in the soil and changes in its demography (Davis and Liebman 2003).

Most of the studies on weed demography focus on a specific stage in its life cycle and its impact is then projected on the overall population growth rate and dynamics (Navas 1991). This approach does not give a holistic view or mechanistic understanding as to how each particular stage may affect or be affected by other stages in the life cycle and ultimately impact population growth rate. For example, the success of an annual weed with a seed bank may depend largely on seed survival in the soil. The ability of the seeds to remain viable during winter and summer months until conditions become favorable for germination may be deemed critical. However at later stages of development, competition, environmental conditions and density-dependent processes may also affect seedling and mature plant survival and reproduction, and thus may lead to decline in population in the next season despite high seed survival rates over winter and summer (Alexander and Schrag 2003; Moody-Weiss and Alexander 2007). Hence, by following the demographic processes of a weed population throughout its life cycle and understanding impacts on the population growth rate, successful weed management decisions can be developed such as applying weed control tactics at the stage which has the greatest impact on population growth rate decline. Magda et al. (2004) reported that management of two invasive weed species in a grassland ecosystem varied when based on demographic information. They proposed that mowing should coincide with the peak seedling height to reduce population density the following season and eradicate the species in three years. A better understanding of the biology of the weed and the factors that drive its growth and development will allow better management of weed populations through development of appropriate, timely and cost-effective control measures (Buhler, 1999).

Giant ragweed and common sunflower are important annual weed species in the US. Both weed species are highly competitive and have developed resistance to commonly used herbicides. Giant ragweed is regarded as an aggressive colonizer and an early emerger (Abul-Fatih and Bazzaz 1979a). It can dominate field areas it infests by suppressing and eliminating any neighboring species. It is considered as a keystone species which influence species composition, biomass and diversity of the plant community (Abul-Fatih and Bazzaz 1979b). Its growth form is very plastic such that it is multi-branched in less dense situations and single stemmed in very dense situations. Height ranged from 1.7 (low density) to 2.5 m (high density). It is able to produce 5,000 seeds m^{-2}, which subsequently can germinate under a wide range of temperature and moisture conditions (Abul-Fatih and Bazzaz 1979a, b and c). Giant ragweed was able to reduce soybean yield by 46 and 50% in two succeeding years at a density of less than 1 plant per meter row (Baysinger and Sims 1991). In Indiana, it was considered one of the most problematic weeds by farmers (Gibson et al. 2005) and is ranked among the five most costly agricultural weeds in Illinois, Kentucky and Oklahoma (Loux and Berry 1991).

Common sunflower is commonly found in waste lands, roadsides and in agricultural fields. It can grow up to 4.5 m in height and has a canopy diameter reaching over 1 m. Large plants are able to produce up to 500 flower heads each having 600 achenes (Irons and Burnside 1982). It is a troublesome weed in major crops such as corn, soybean, spring wheat and sugarbeet. It is able to reduce soybean yield by 19% at 0.3 plant m^{-2} and up to 95% at a population of 4.6 plants m^{-2} (Geier et. al. 1996).

Both weed species have developed resistance to acetolactate synthase-inhibiting herbicides (Al-Khatib et al. 1998; Baumgartner et.al. 1999; Zelaya and Owen 2004). Additionally, giant ragweed has been documented to be resistant to glyphosate in several states including Kansas (Heap 2009). These characteristics together with their rapid growth make these weed species difficult to control.

The general objective of this study was to quantify the demography of AMBTR and HELAN in Kansas. Specifically, this study aimed to: 1) determine the survival of seed in soil, seedling emergence, seedling survival and seed production of AMBTR and HELAN in Kansas corn or fallow habitats, and 2) determine population growth rates for AMBTR and HELAN based on field observations.

Materials and Methods

Field experiments were conducted in 2006, 2007 and 2008 at the Department of Agronomy Ashland Bottoms Research Farm near Manhattan, KS. Seeds of HELAN were collected from two locations in Kansas and seeds of AMBTR were obtained from Dekalb, IL for this study.

Life stages of HELAN and AMBTR were observed in fallow and in corn habitats. The fallow and corn areas were established annually in a side by side arrangement in April 2006, October 2006, and November 2007. An experimental unit for each weed species consisted of adjacent 1 m^2 below-ground (BG) and above-ground (AG) plots, each measuring 0.76 m wide by 1.32 m long established in corn and fallow areas in each year.

In the fallow areas, no additional tillage or crop planting took place. Both the fallow and corn areas did not receive any herbicide treatments prior to corn planting. Corn was no-till planted with locally adapted hybrids in 0.76 m rows at a target population of 59,400 plants ha^{-1}. Corn was planted on April 13, 2006, April 4, 2007 and May 1, 2008. It was fertilized with 100-60-0 kg ha^{-1} NPK at planting. Hand-weeding was done as needed to remove non-target broadleaf and grass species.

Seed survival in soil

The BG plots were used to monitor seed survival of common sunflower and giant ragweed in the soil. Two seed study areas were established each year - an overwinter (OW) area and a spring-summer (SS) area, each consisting of a 0.016 m^{-2} seed enrichment zone within a 0.04 m^{-2} area inside each experimental unit. In the first year, 200 fresh new seeds of each weed species were sprinkled into separate seed enrichment zones in April 2006. After seeds were spread on the soil surface they were mixed into the top 2.5 cm of soil. In the second and third years, 100 fresh new seeds were sown in October 2006 and in November 2007, using seed trays rather than direct sowing of seeds in the enrichment zones. This prevented seed movement down through the soil profile and offset low seed recovery rates observed in first year. Seed trays were made of wire mesh measuring 12.5 by 12.5 by 5 cm deep. Soil was removed from the area, placed into the seed trays and seeds of either HELAN or AMBTR were sprinkled on the surface and mixed into the upper 2.5 cm layer.

In general, seed enrichment zones from the OW areas were extracted in March and seed enrichment zones were extracted from the SS area in October of each year. Seeds were recovered by washing the soil through several layers of mesh screens or with the use of an elutriator. Recovered seeds were counted and classified as either damaged or intact. Viability of intact seeds was tested using a tetrazolium test. Damaged and the non-viable portion of intact seeds were considered as lost while intact viable seeds were considered dormant seeds of the seedbank. Seed survival in the soil was measured as seed survival through winter (S_W) and seed survival through spring-summer (S_S). S_W was calculated as the ratio of viable seeds recovered in March to the total number of seeds buried in October less the number of seedling that emerged throughout the season. S_S was calculated as the ratio of seed remaining viable in October relative to the viable seed recovered in March.

Seedling recruitment

Weed seedlings emerging in the SS area of the BG plots area were counted and pulled on a weekly basis starting March 15 until no more seedlings of either weed species emerged. Total number of seedlings that emerged was used to calculate proportional emergence (e), which is the ratio of total seedling emergence in the SS area of the BG plot to the total number of seeds sown in the BG plot.

Seedling survivorship to maturity and fecundity

Seedling establishment of AMBTR and HELAN were observed in the AG plots where 100 seeds of each weed species were spread over the entire 1- m^2 area raked into the top 2.5 cm on April 13, 2006, October 22, 2006 and November 8, 2007. Seedling emergence began one week after sowing in 2006 and began March 15, 2007 and March 15, 2008. Plants were counted continuously on a weekly basis. Emerged seedlings were not pulled out but were allowed to grow to maturity.

Seedling counts from the AG plots represented both current and any newly emerged seedlings with no distinction made to separate them. The number of seedlings that died through the growing season was not counted. At physiological maturity, the final number of plants in the AG plots was counted. Proportional seedling survivorship to maturity (S_{sdl}) was calculated as the ratio between final number of plants and maximum seedling number observed in the AG plots.

Aboveground plant parts were harvested beginning September of each year, oven dried in70°C and weighed to obtain biomass. Prior to drying, four representative mature plants were selected and sampled for seed production by stripping the seeds from plants as in the case of AMBTR and harvesting the flower heads for HELAN. Fecundity (f) was expressed as number of seeds produced per plant.

Population growth rate

Using the values for each demographic process, population growth rate (lambda) for each weed species in each study areas and year was calculated as:

$$\lambda = [(e * s_{sdl} * f) + (s_W * s_S)] \qquad \textbf{(Equation 4.1)}$$

where e is proportional emergence, S_{sdl} is proportional seedling survivorship to maturity, f is fecundity (seed production per plant), S_W is proportional seed survival through winter, and S_S is proportional seed survivorship through spring-summer. Lambda (λ) values greater than 1 indicate an increasing population while λ values less than 1 indicate a declining population (Silvertown and Charlesworth 2001).

Experimental design and statistical analysis

The experiment was laid out as a randomized complete block design with four replications. Data on seed survival in the soil, emergence, total number of plants in BG plots, maximum number of plants in the AG plots, final number of mature plants, seed production, demographic parameters estimated and population growth rates from the two habitats (corn and fallow) were analyzed separately using the Mixed Model procedure in SAS with replication as random effect (SAS 2009). Means were separated using LSD at 5% level of significance. Regression analysis was carried out to establish an allometric relationship between seed production and biomass. An F-test was done to determine whether the slope of the regressions for each year were significantly different from each other at α=0.05.

Sensitivity analysis was carried out by decreasing or increasing values of the different demographic parameters by 10 and 20% and calculating the sensitivity coefficients. Sensitivity coefficient is defined as the ratio of the proportional change in the simulation results (output of the model) to the proportional change in each parameter and is calculated as:

$$Sensitivity\ coefficient = \frac{\frac{\Delta\ \text{output}}{\text{output}}}{\frac{\Delta \text{parameter}}{\text{parameter}}} \qquad \text{(Equation 4.2)}$$

where output is the lambda value and the parameter is the demographic parameter estimates. The parameter that gives the largest sensitivity coefficient is considered as the one parameter with the most impact on lambda, or in other words, a small variation in the parameter estimate will result in a large change in the population growth rate (Cousens and Mortimer, 1995; Gonzalez-Andujar and Fernandez-Quintanilla, 1991;).

Results and Discussion

Seed survival in soil

Seed recovery for AMBTR in 2006 was low, with only 45% from SS corn and 56% for SS fallow habitats while 95 and 100% of HELAN seeds were recovered from the SS corn and SS fallow habitats in 2006, respectively. Seed recovery in the succeeding years for both weed species was greater than 98%. The use of seed trays in 2007 and 2008 prevented the vertical and horizontal movement of seeds away from the seed enrichment zone and resulted in higher seed recovery.

The proportion of damaged and proportion of viable seeds in the recovered seeds from the OW seed bank had a significant year by weed species interaction (Figure 4.1). In both corn and fallow habitats, a large proportion of recovered AMBTR seeds were viable while a large proportion of recovered HELAN seeds were damaged in 2006. The proportion of viable seeds was higher in 2007 and 2008. In the fallow habitats, there was greater rate of seed survival for AMBTR than HELAN in the OW period with seeds of both weed species viable but dormant.

The damaged, viable, and emerged portions of recovered seeds from the SS seed bank in both corn and fallow habitats had a significant year by weed species interaction

(Figure 4.2). In the corn habitat, a large proportion of AMBTR seeds were damaged, with very few seeds remaining viable, and few seedlings emerged in 2006, while a large proportion for HELAN were viable and only a small proportion emerged (Figure 4.2). In 2007 and 2008, the proportion of damaged AMBTR seeds was lower and there was a significantly higher proportion of viable and emerged seed in 2007 and 2008. For HELAN, the viable portion was significantly lower in 2007 and 2008, while the emerged portion was similar in 2007 and 2008.

In the fallow habitats, the proportion of viable, emerged and damaged AMBTR seeds varied from 2006 to 2008. Recovered HELAN seeds had a higher proportion of viable seeds in 2006 than in 2007 and 2008. A significantly higher proportion of HELAN seeds emerged and the proportion of damaged seeds fluctuated over the three years.

Abul-Fatih and Bazzaz (1979b) reported that a large proportion of AMBTR seeds were lost or damaged between seed rain and emergence. Seed mortality ranged from 20 to 90%. Seed loss was due to predation by small and large animals as well as decay by fungi and bacteria. In this study, most of the damaged seeds found have some indication of predation. Viability of AMBTR seeds buried at various depths (2.5 to 15 cm) was reported to decline significantly (Harrison et al. 2003; Stoller and Wax 1974). While viability of buried HELAN seed was 75 to 80% after 1 year (Teo-Sherrell et al. 1996) and decreased to about 47% after four years (Alexander and Schrag 2003). Burnside et al. (1981) considered the HELAN seed bank to be short-lived (3 years) due to rapid initial loss of germination followed by very low germination in the subsequent years.

Seedling recruitment

Total seedling emergence from the BG plots in the corn habitats had a significant year by weed species interaction. Total seedling emergence in the fallow habitat had a significant year effect such that emergence varied from 2006 to 2008 regardless of weed species. In general, AMBTR emergence was higher than HELAN in the corn habitat (Table 4.1). Emergence of AMBTR varied from 2006 to 2008 while emergence of HELAN was lowest in 2006 and the 2007 emergence was comparable to the 2008 emergence in the corn areas. In 2007 and 2008, seed was sown in the fall of the previous year thereby subjecting both weed species to cold preconditioning which resulted in higher emergence.

HELAN and AMBTR emerged as expected during the early part of spring of each year (Figure 4.3). Both weed species emerged late in 2006 since seed was sown in the spring compared to earlier emergence in March of 2007 and 2008 when they were sown in the previous fall. Longer periods of exposure to cold temperatures from December to March likely broke seed dormancy of both species, hence early and higher seedling emergence. In 2006, spring sowing of the weed species resulted in exposure to higher temperatures, instead of cold temperature, which may have induced secondary dormancy. Changes in the degree of dormancy have been observed in weed species. This involves breaking of innate dormancy followed by a period of germinability and re-induction of dormancy (secondary dormancy) over a period of one year due to environmental conditions such as temperature, soil moisture etc (Benech-Arnold et al. 2000). Giant ragweed seeds are highly dormant at maturity and require an after- ripening period. However, germination may still be delayed or inhibited by high temperature effects on the seed coat. Failure to germinate under such conditions induces the embryo to develop secondary dormancy which is more pronounced than the primary dormancy (Davis 1930).

Differences in emergence can be tied to environmental factors. In this study, differences in amount of precipitation and temperature were observed over three years (Table 4.2). Total annual precipitation increased from 2006 (747 mm) to 2008 (1086 mm). Temperature during the time of emergence of the two weed species was lowest in 2008 and highest in 2006. The first year of the study (2006) can be considered as a dry and warm year. There was low precipitation from March to June (>100 mm), the months when emergence of both AMBTR and HELAN typically occurs. Air temperature was increasing until July. Low precipitation coupled with high temperature resulted in low emergence of both AMBTR and HELAN. The two succeeding years were cold and wet years, with 2008 being wetter by 42 mm and colder by 1.7°C than 2007. Sufficient moisture in the ground and favorable temperature during emergence time of both weed species triggered germination and sustained growth of seedlings resulting in a higher number of mature plants.

Seedling survivorship to maturity

Maximum seedling emergence in the AG plots in both corn and fallow habitats had significant year by weed species interaction (Table 4.3). In corn habitats, maximum seedling for AMBTR were similar across years while maximum seedling emergence for HELAN increased with 2006 having significantly lower emergence than in 2007 and 2008. Maximum seedling emergence in 2007 was similar to 2008. In fallow habitats, maximum seedling emergence increased from 2006 to 2008 for both weed species with HELAN having significantly greater total emergence than AMBTR (Table 4.3).

Final number of mature plants in the fallow habitat had a significant year by weed species interaction (Table 4.3). The number of AMBTR plants that reached maturity varied significantly from 2006 to 2008 with more plants reaching maturity in 2006 and 2007 than in 2008. The number of HELAN plants that reached maturity increased from 2006 to 2007 and decreased from 2007 to 2008. Also, AMBTR had more plants that reached maturity. In the corn habitat, number of mature plants had a significant year effect indicating that regardless of weed species, the number of mature plants varied from 2006 (9 plants) to 2007 (20) and decreased from 2007 to 2008 (16).

The proportional seedling survival to maturity (S_{sdl}) was based on maximum seedling emergence and number of plants reaching maturity, and had a significant year by weed species interaction in the fallow habitats (Table 4.3). The proportion of AMBTR and HELAN seedlings that reached maturity varied from 2006 to 2008. For AMBTR, there was higher rate of seedlings reaching maturity in 2007 and 2008 than in 2006. There was a decrease in the proportion of HELAN seedlings reaching maturity from 2006 to 2008. There were more HELAN seedlings that reached maturity than AMBTR in 2006 while in 2007 and 2008 more AMBTR seedlings reached maturity than HELAN seedlings. In corn habitats there were significant main effects of year and weed species (Table 4.3). The proportion of seedlings that reached maturity decreased from 2006 to 2008, with 72% of the seedlings that came up in 2006 reaching maturity. In the succeeding two years only 64 (2007) and 51 % of the seedlings that emerged reached maturity. These results are likely due to 1) weather conditions prevailing during the three years of study. Although there was low seedling emergence in 2006, these seedlings were able to become established without any weather-related growth disturbance. There was high emergence in 2007 and 2008 however, not all of the seedlings that emerged were able to reach maturity due to the occurrence of unfavorable weather conditions such as heavy rains and occurrence of a tornado that hit Manhattan in June 2008. Secondly, competition with corn may have impacted growth and establishment of these weed species.

Fecundity

The number of seeds produced per plant in fallow habitat had a significant year by weed species interaction with HELAN producing more seeds than AMBTR (Table 4.4). Seed production per plant varied from 2006 to 2008 for both species. Seed production for both weed species in the corn habitat had a significant year effect such that fecundity varied from 2006 to 2008 regardless of weed species.

Regression analysis revealed that there was a linear relationship between seed production per plant and biomass produced per plant, and it varied from year to year for each weed species and habitats (Figure 4.3). For AMBTR in corn habitat, 2006 and 2008 seed production were similar at 10 seeds produced per g of biomass, while in 2007 seed production significantly lower at 7 seeds per g of biomass (Figure 4.3). Giant ragweed in fallow habitat had significantly more seed production per g of biomass in 2006 (9 seeds per g of biomass) than in 2007 and 2008 with 6 seed per g of biomass.

Common sunflower seed production as a function of biomass production in corn habitat was more in 2006 and 2008 with 28 seed produced per g of biomass compared to 2007 with 20 seeds produced per g biomass (Figure 4.4). Seed production in fallow habitat varied, with 2007 having the least and 2008 having the most seed production per g of biomass.

Previous studies have shown that AMBTR in a pure stand can produce 5000 seeds m^{-2} (Abul-Fatih and Bazzaz 1979b). When grown with soybean, it produced 7980 seeds m^{-2} (Baysinger and Sims 1991) and when grown with corn, it produced 3,500 seeds m^{-2}. In this study seed, production values for AMBTR were greater than published values likely due to differences in density. But on a per plant basis, obtained values which ranged from 1,840 to 5,700 seed $plant^{-1}$, were comparable with those reported by Baysinger and Sims (1991).

HELAN produced 22, 964 seed per plant when grown in monocultures (Alexander and Schrag 2003) and an ALS-resistant HELAN grown with soybean produced 44 to 24,893 seeds per plant depending on duration of interference (Allen et al. 2000). Values obtained in this study (9,570 to 22,510 seeds $plant^{-1}$) were comparable with these published data.

Demographic parameters

In corn habitats, the demographic parameters S_W, and S_S had a significant year by weed species interaction while parameters S_{sdl} and f had significant year and weed species effects (Table 4.5). In fallow habitats, parameters S_W, S_{sdl} and f had significant year by weed species interaction, while parameter e had significant year and weed species effects and S_S did not differ for either weed species and across years.

In corn habitats, there was significantly greater S_W and S_S for both AMBTR and HELAN in 2006 and 2008 than in 2007. Proportional emergence (e) rates were similar for both AMBTR and HELAN. A small proportion of seeds sown emerged in 2006 and gradually increased in 2007 and 2008. Seedling survivorship to maturity was similar in all three years with AMBTR having a significantly higher rate than HELAN. Fecundity varied from 2006 to 2008 with HELAN having greater seed production than AMBTR.

In fallow habitats, S_W was greater in 2008 than in the other two years for both weed species with 2007 having the smallest S_W (Table 4.4). Seed survival through spring-summer (S_S) had the same trend, with HELAN having higher survival rate than AMBTR. Emergence rate did not reach 50% for either species and gradually increased from 2006 to 2008 with 2006 having the lowest emergence and 2007 and 2008 being similar. The number of seedlings surviving to become mature plants increased from 2006 to 2008 for AMBTR, it decreased from 2006 to 2008 for HELAN. Fecundity for both weed species increased from 2006 to 2008.

The population growth rate (λ) in fallow habitat had significant year and weed species main effects. Both AMBTR and HELAN populations were growing ($\lambda > 1$) over the three years with HELAN having the greater population growth rate than AMBTR across years (Table 4.5). In the corn habitat, population growth rate had a significant year effect. Population growth rate regardless of weed species varied from 2006 to 2008.

Population growth rates more than doubled from year to year with the highest rate in 2008 in both corn and fallow areas except for a decrease in λ for AMBTR in the fallow habitat. Considering variations in weather conditions in 2006 and the succeeding years, increasing λ could be attributed to more favorable weather conditions in 2007 and 2008 than in 2006. Higher λ was observed in fallow than in corn habitats for both weed species indicating that in the absence of competition greater growth and reproduction can be expected from the two weed species leading to increase in population size. HELAN had higher λ values than AMBTR, this could be due to greater adaptability of HELAN in the field conditions where the study was conducted although given the right conditions AMBTR could also persist.

Sensitivity analysis

Sensitivity analysis revealed that several demographic parameters impacted λ of AMBTR and HELAN in corn and fallow habitats (Table 4.6 to 4.8). Increasing the different demographic parameters by 10 or 20% generally resulted in an increase in the population growth rate while decreasing them resulted in decreased population growth rate. In all situations, seed survival over spring-summer (S_{SS}) was the only parameter which impacted λ the least. All the other parameters that contribute to λ had comparable impacts. This indicates that all the other parameters were critical in determining success of both AMBTR and HELAN in any habitat be it in corn or fallow.

Variability in environmental conditions in the three years impacted seed survival in soil, seedling growth and seed production of both AMBTR and HELAN. Average daily temperature and amount of monthly precipitation was very different in all three years (Table 4.2). Seeds of both AMBTR and HELAN were sown late in 2006 hence seeds of both AMBTR and HELAN did not receive the cold preconditioning which could have broken dormancy. In addition, very high temperature and low precipitation during the months of April to June in 2006 resulted in low seedling emergence which in turn resulted in low number of mature plants and low seed production. In 2007, the occurrence of lower temperature and adequate moisture during emergence and in the subsequent months resulted in high emergence for both weed species and higher seed production. Conditions in 2008 were very similar to 2007. It appears that environmental conditions had a great impact on the demography of AMBTR and HELAN in corn and fallow areas.

Demographic parameters have been used in modeling weed population dynamics in response to various factors such as herbicidal control of the seed bank in sterile oats (*Avena sterilis*) (Gonzalez-Andujar and Perry 1995), cropping systems and rotation impact on weed and seed bank (Davis et. al. 2004; Gonzalez-Andujar and Fernandez-Quintanilla 1991; Jordan et. al. 1995; Westerman et. al. 2005). Each of these studies identified demographic parameters that were critical to population growth. For example, Jordan et al (1995) reported that simulation analysis using a population-projection model identified overwinter survivorship of the seeds in the upper 10 cm of the soil to have the greatest impact on weed seed bank and recommended that weed control practices that enhance winter seed bank mortality should be developed.

Conclusion

Variation in population growth rates across years was observed for AMBTR and HELAN when grown in corn and fallow systems. In three years, populations of both AMBTR and HELAN were observed to be growing, especially in the fallow areas with no crop restricting biomass and seed production potential. Impact of weather conditions on processes such as emergence, germination and growth were observed for both weed species. Variation in weather conditions during 2006, 2007 and 2008 resulted in lower population growth rate in 2006 which was a dryer and hotter year than in 2007 and 2008.

Different management strategies particularly involving timing of application of weed control should be used for these two weed species. Common sunflower may be controlled with an early control practice such as preemergence herbicide or a burndown herbicide application. Giant ragweed on the other hand would require an additional control within the growing season (postemergence herbicide application) to address possible problems with escapes and late emergers.

References

Abul-Fatih, H.A and F.A. Bazzaz, 1979a. The biology of *Ambrosia trifida* L. I. Influence of species removal on the organization of plant community. New Phytol. 83:813-816.

Abul-Fatih, H.A. and F.A. Bazzaz. 1979b. The biology of *Ambrosia trifida* L. II. Germination, emergence, growth and survival. New Phytol. 83:817-827.

Abul-Fatih, H.A. and F.A. Bazzaz. 1979c. The biology of *Ambrosia trifida* L. III. Growth and biomass allocation. New Phytol. 83:829-838.

Alexander, H.M. and A.M. Schrag. 2003. Role of seed banks and newly dispersed seeds in population dynamics of the annual sunflower, *Helianthus annuus*. J. Ecol. 91:987-998.

Allen, J.R., W.G. Johnson, R.J. Smeida and R.J. Kremer. 2000. ALS-resistant *Helianthus annuus* interference in *Glycine max*. Weed Sci. 48:461-466.

Al-Khatib, K., J.R. Baumgartner and R. Currie. 1998. Imazethapyr resistance in common sunflower (*Helianthus annuus*). Weed Sci. 46:403-407.

Baumgartner, J.R., K. Al-Khatib and R. Currie. 1999. Survey of common sunflower resistance to imazethapyr and chlorimuron in northeastern Kansas. Weed Technol. 13:510-514.

Baysinger, J.A and B.D. Sims. 1991. Giant ragweed (*Ambrosia trifida* L.) interference in soybean (*Glycine max*). Weed Sci. 39: 358-362.

Benech-Arnold, R.L., R.A. Sanchez, F. Forcella, B.C. Kruk and C.M. Ghersa. 2000. Environmental control of dormancy in weed seed banks in soil. Field Crops Research 67:105-122.

Buhler, D.D. 1999. Expanding the context of weed management. J. Crop Production 2:1-7.

Burnside, O.C., C.R. Fenster, L.L. Evetts and R.F. Mumm. 1981. Germination of exhumed weed seeds in Nebraska. Weed Sci. 29:577-586.

Davis, W.E. 1930. Primary dormancy, after-ripening, and the development of secondary dormancy in embryos of *Ambrosia trifida*. Am. J. Bot. 17:58-75.

Davis, A.S., P.M. Dixon, and M. Liebman. 2004. Using matrix models to determine cropping system effects on annual weed demography. Ecol. Appl. 14:655-668.

Geier, P.W., L.D. Maddux, L.J. Moshier and P.W. Stahlman. 1996. Common sunflower (*Helianthus annuus*) interference in soybean (*Glycine max*). Weed Technol. 10:317-321.

Gibson, K.D., W.G. Johnson, and D.E. Hillger. 2005. Farmer perception of problematic corn and soybean weeds in Indiana. Weed Technol. 19:1065-1070.

Gonzalez-Andular, J.L. and C. Fernandez-Quintanilla. 1991. Modeling the population dynamics of *Avena sterilis* under dryland cereal cropping systems. J. Appl. Ecol 28:16-27.

Gonzalez_Andujar, J.L. and J.N. Perry. 1995. Models for the herbicidal control of the seed bank of *Avena sterilis*: the effects of spatial and temporal heterogeneity and of dispersal. J. Appl. Ecol. 32:578-587.

Harrison, S K., E.E. Regnier, J.T. Schmoll and J.M. Harrison. 2007. Seed size and burial effects of giant ragweed (*Ambrosia trifida*) emergence and seed demise. Weed Sci. 55:16-22.

Harrison, S.K., E.E. Regnier, J.T. Schmoll and J. E.Webb. 2001. Competition and fecundity of *Ambrosia trifida* L. in corn. Weed Sci. 49:224-229.

Heap, I. 2008. International survey of herbicide resistant weeds. Online. November 9, 2009. Available at www.weedscience.net.

Irons, S.M. and O.C. Burnside. 1982. Competitive and allelopathic effects of sunflower (*Helianthus annuus*). Weed Sci. 30:372-377.

Jordan, N., D.A. Mortensen, D.M. Prenzlow and K.C. Cox. 1995. Simulation analysis of crop rotation effects on weed seedbanks. Am. J. Bot. 82:390-398.

Lindquist, J.L., B.D. Maxwell, D.D. Buhler and J.L. Gunsolus. 1995. Velvetleaf (*Abutilon theophrasti*) recruitment, survival, seed production and interference in soybean (*Glycine max*). Weed Sci. 43(226-232.

Loux, M.M and M.A. Berry. 1991. Use of grower survey for estimating weed problems. Weed Technol. 5:460-466.

Magda, D., M. Duru and J-P. Theau. 2004. Defining management rules for grasslands using weed demographic characteristics. Weed Sci. 52:339-345.

Moody-Weiss, J. and H.M. Alexander. 2007. The mechanism and consequences of seed bank formation in wild sunflowers (*Helianthus annus*). J. Ecol. 95:851-864.

Navas, M.L. 1991. Using plant population biology in weed research: a strategy to improve weed management. Weed Res. 31:171-179.

Radosevich, S., J. Holt and C. Ghersa. 1997. Weed ecology: implications for weed management. 2nd ed. John Wiley and Sons, Inc. p 62-67.

Silvertown, J.W. and D. Charlesworth. 2001. Introduction to plant population biology. 4th ed. Ames, IA: Iowa State University Press. Pp1-3.

Stoller, E.W. and L. M. Wax. 1973. Periodicity of germination and emergence of some annual weeds. Weed Sci. 21:574-579.

Teo-Sherrell, C.P.A., D.A. Mortensen amd M.E. Keaton. 1996. Fates of weeds in soil: a seeded core method of study. J. Applied Ecol. 33:1107-1113.

Westra,P., R.G. Wilson, S.D. Miller, P.W. Stahlman, G.W Wicks, P.L. Chapman, J. Withrow, D. Legg, C. Alford and T.A. Gaines. 2008. Weed population dynamics after six years under glyphosate- and conventional herbicide-based weed control strategies. Crop Sci. 48:1170-1177.

Westerman, P.R., M. Liebman, F.D. Menalled, A.H. Heggenstaller, R.G. Hartzler and P.M. Dixon. 2005. Are many little hammers effective? Velvetleaf (*Abutilon theophrasti*) population dynamics in two-and four-year rotation systems. Weed Sci. 53:382-392.

Zelaya, I.A. and M.D.K. Owen. 2004. Evolved resistance to acetolactate-inhibiting herbicides in common sunflower (*Helianthus annuus*), giant ragweed (*Ambrosia trifida*) and shattercane (*Sorghum bicolor*) in Iowa. Weed Sci. 52:538-548.

Table 4.1. Average total seedling emergence in below ground (BG) plot for giant ragweed (AMBTR) and common sunflower (HELAN) in the corn habitat in 2006, 2007 and 2008. Means followed by the same letter are not significantly different at α = 0.05.

Weed species	Total seedling emergence		
	2006	2007	2008
		# 0.016 m-^{2}	
AMBTR	3 d	12 cd	38 a
HELAN	1 d	24 b	24 b

Table 4.2. Monthly precipitation and average daily temperature for Manhattan, KS in 2006, 2007, and 2008.

Months	Rainfall (mm)			Temperature (°C)		
	2006	2007	2008	2006	2007	2008
January	1	18	5	4.6	-2.3	-2.2
February	0	24	26	0.3	-1.4	-1.3
March	62	102	59	7.1	11.5	5.2
April	70	78	53	15.0	11.0	10.4
May	73	375	121	18.6	19.7	17.4
June	37	92	304	23.9	23.3	23.4
July	94	105	129	27.2	25.5	25.7
August	283	55	117	26.0	28.1	23.8
September	51	44	178	17.5	20.9	19.1
October	64	101	53	12.3	15.2	13.1
November	2	1	21	6.7	5.9	6.1
December	11	51	21	3.1	-2.1	-2.1
Total	748	1046	1087			

Table 4.3. Maximum seedling emergence (# m^{-2}), total mature plants and proportional seedling survivorship to maturity (S_{sdl})from the aboveground (AG) plots in corn and fallow habitats for giant ragweed (AMBTR) and common sunflower (HELAN) in 2006, 2007 and 2008. Means within an area for each parameter followed by the same letter are not different at α = 0.05.

Habitat	Weed species	Maximum seedling emergence			Total mature plants			Proportional seedling survival to maturity		
		2006	2007	2008	2006	2007	2008	2006	2007	2008
		# m^{-2}								
Corn	AMBTR	11 b	24 b	24 b	10 a	21 a	16 a	0.85 a	0.87 a	0.69 a
	HELAN	13 b	50 a	48 a	8 a	21 a	15 a	0.56 a	0.40 a	0.34 a
Fallow	AMBTR	10 d	18 cd	29 bc	5 c	15 b	24 a	0.48 b	0.81 a	0.82 a
	HELAN	8 d	43 b	64 a	7c	21 a	19 ab	0.84 a	0.49 b	0.31 b

Table 4.4. Seed production (# plant^{-1}) of giant ragweed (AMBTR) and common sunflower (HELAN) in fallow habitats in 2006, 2007 and 2008. Means followed by the same letter are not different at α=0.05.

Weed species	Weed seed production		
	2006	2007	2008
		# plant^{-1}	
AMBTR	1,840 d	5,700 cd	2,980 d
HELAN	9,570 bc	12,810 b	22,510 a

Table 4.5. Demographic parameters of mean seed survival through winter (S_W) or spring-summer (S_S), proportional emergence (e), seedling survivorship to maturity (S_{sdl}), fecundity (F) and population growth rate (λ) of giant ragweed (AMBTR) and common sunflower (HELAN) in corn and fallow habitats in 2006, 2007 and 2008. Means within each habitat and for each demographic parameters followed by the same letters are not different at $\alpha = 0.05$.

Area	Weed Species	Parameter	2006	2007	2008
Corn	AMBTR	S_W	0.75 ab	0.64 bc	0.88 a
		S_S	0.01 c	0.29 a	0.82 a
		e	0.07 c	0.12 bc	0.39 a
		S_{sdl}	0.85	0.87	0.69
		F	554	2731	2695
		λ	26.75	368.57	758.26
	HELAN	S_W	0.07 d	0.41 c	0.87 a
		S_S	0.73 a	0.38 b	0.92 a
		E	0.02 c	0.24 b	0.23 b
		S_{sdl}	0.59	0.40	0.34
		F	4946	8857	14944
		λ	58.77	967.93	1327.32
Fallow	AMBTR	S_W	0.83 a	0.49 b	0.86 a
		S_S	0.13 b	1.57 a	0.86 a
		e	0.17	0.28	0.36
		S_{sdl}	0.48 b	0.81 a	0.82 a
		F	1842 d	5695 cd	2977 d
		λ	146.37	1192.20	865.66
	HELAN	S_W	0.21 c	0.29 bc	0.95 a
		S_S	0.73 ab	0.60 ab	0.76 ab
		e	0.03	0.28	0.38
		S_{sdl}	0.84 a	0.49 b	0.31 b
		F	9568 bc	12807 b	22513 a
		Λ	231.67	1582.22	2677.39

Table 4.6. Original λ, resulting population growth rate (new λ) when the demographic parameters were either increased or decreased by 10 and 20%, and sensitivity coefficient (SC) for giant ragweed (AMBTR) and common sunflower (HELAN) grown in corn and fallow habitats in 2006.

Habitat	Weed species	Parameter	Original λ	New λ	SC	New λ	SC	New λ	SC
				10 % increase		20% increase		20% decrease	
Corn	AMBTR	S_W	31.78	31.78	0.00	31.78	0.00	31.78	0.00
		S_S	31.78	31.78	0.00	31.78	0.00	31.78	0.00
		e	31.78	34.95	1.00	38.13	1.00	25.42	1.00
		S_{sdl}	31.78	34.95	0.91	38.13	0.83	25.42	1.25
	HELAN	S_W	58.15	58.15	0.00	58.16	0.00	58.14	0.00
		S_S	58.15	58.15	0.00	58.16	0.00	58.14	0.00
		e	58.15	63.96	1.00	69.77	1.00	46.53	1.00
		S_{sdl}	58.15	63.96	1.00	69.77	1.00	46.53	1.00
		F	58.15	63.96	1.00	69.77	1.00	46.53	1.00
Fallow	AMBTR	S_W	144.74	144.75	0.00	144.76	0.00	144.72	0.00
		S_S	144.74	144.75	0.00	144.76	0.00	144.72	0.00
		e	144.74	159.20	1.00	173.67	1.00	115.81	1.00
		S_{sdl}	144.74	159.20	1.00	173.67	1.00	115.81	1.00
		F	144.74	159.20	1.00	173.67	1.00	115.81	1.00
	HELAN	S_W	242.23	242.24	0.00	242.26	0.00	242.20	0.00
		S_S	242.23	242.24	0.00	242.26	0.00	242.20	0.00
		e	242.23	266.44	1.00	290.64	1.00	193.81	1.00
		S_{sdl}	242.23	266.44	1.00	290.64	1.00	193.81	1.00
		F	242.23	266.44	1.00	290.64	1.00	193.81	1.00

Table 4.7. Original λ, resulting population growth rate (new λ) when the demographic parameters were either increased or decreased by 10 and 20%, and sensitivity coefficient (SC) for giant ragweed (AMBTR) and common sunflower (HELAN) grown in corn and fallow habitats in 2007.

Habitat	Weed species	Parameter	Original λ	New λ	SC	New λ	SC	New λ	SC
				10 % increase		20% increase		20% decrease	
Corn	AMBTR	S_W	280.91	280.93	0.00	280.95	0.00	280.87	0.00
		S_S	280.91	280.93	0.00	280.95	0.00	280.87	0.00
		e	280.91	308.98	1.00	337.05	1.00	224.76	1.00
		S_{sdl}	280.91	308.98	1.00	337.05	1.00	224.76	1.00
		F	280.91	308.98	1.00	337.05	1.00	224.76	1.00
	HELAN	S_W	837.92	837.94	0.00	837.96	0.00	837.89	0.00
		S_S	837.92	837.94	0.00	837.96	0.00	837.89	0.00
		e	837.92	921.70	1.00	1005.48	1.00	670.37	1.00
		S_{sdl}	837.92	921.70	1.00	1005.48	1.00	670.37	1.00
		F	837.92	921.70	1.00	1005.48	1.00	670.37	1.00
Fallow	AMBTR	S_W	1269.37	1269.45	0.00	1269.52	0.00	1269.22	0.00
		S_S	1269.37	1269.45	0.00	1269.52	0.00	1269.22	0.00
		e	1269.37	1396.23	1.00	1523.09	1.00	1015.65	1.00
		S_{sdl}	1269.37	1396.23	1.00	1523.09	1.00	1015.65	1.00
		F	1269.37	1396.23	1.00	1523.09	1.00	1015.65	1.00
	HELAN	S_W	1738.94	1738.95	0.00	1738.97	0.00	1738.90	0.00
		S_S	1738.94	1738.95	0.00	1738.97	0.00	1738.90	0.00
		e	1738.94	1912.81	1.00	2086.69	1.00	1391.18	1.00
		S_{sdl}	1738.94	1912.81	1.00	2086.69	1.00	1391.18	1.00
		F	1738.94	1912.81	1.00	2086.69	1.00	1391.18	1.00

Table 4.8 Original λ, resulting population growth rate (new λ) when the demographic parameters were either increased or decreased by 10 and 20%, and sensitivity coefficient (SC) for giant ragweed (AMBTR) and common sunflower (HELAN) grown in corn and fallow habitats in 2008.

Habitat	Weed species	Parameter	Original λ	New λ	SC	New λ	SC	New λ	SC
				10 % increase		20% increase		20% decrease	
Corn	AMBTR	S_W	724.82	724.89	0.00	724.96	0.00	724.67	0.00
		S_S	724.82	724.89	0.00	724.96	0.00	724.67	0.00
		e	724.82	797.22	1.00	869.63	1.00	580.00	1.00
		S_{sdl}	724.82	797.22	0.91	869.63	0.83	580.00	1.25
		F	724.82	797.22	1.00	869.63	1.00	580.00	1.00
	HELAN	S_W	1147.58	1147.66	0.00	1147.74	0.00	1147.42	0.00
		S_S	1147.58	1147.65	0.00	1147.74	0.00	1147.42	0.00
		e	1147.58	1262.26	1.00	1376.93	1.00	918.22	1.00
		S_{sdl}	1147.58	1262.26	1.00	1376.93	1.00	918.22	1.00
		F	1147.58	1262.26	1.00	1376.93	1.00	918.22	1.00
Fallow	AMBTR	S_W	879.25	879.32	0.00	879.40	0.00	879.10	0.00
		S_S	879.25	879.32	0.00	879.40	0.00	879.10	0.00
		e	879.25	967.10	1.00	1054.95	1.00	703.55	1.00
		S_{sdl}	879.25	967.10	1.00	1054.95	1.00	703.55	1.00
		F	879.25	967.10	1.00	1054.95	1.00	703.55	1.00
	HELAN	S_W	2635.72	2635.79	0.00	2635.86	0.00	2635.57	0.00
		S_S	2635.72	2635.79	0.00	2635.86	0.00	2635.57	0.00
		e	2635.72	2899.22	1.00	3162.72	1.00	2108.72	1.00
		S_{sdl}	2635.72	2899.22	1.00	3162.72	1.00	2108.72	1.00
		F	2635.72	2899.22	1.00	3162.72	1.00	2108.72	1.00

Figure 4.1. Proportion of recovered seed that was damaged or viable from the overwinter seed bank in corn and fallow habitats. Seeds were buried in April 2006, October 2006, and November 2007 and were excavated March 2007, March 2007 and March 2008, respectively**.**

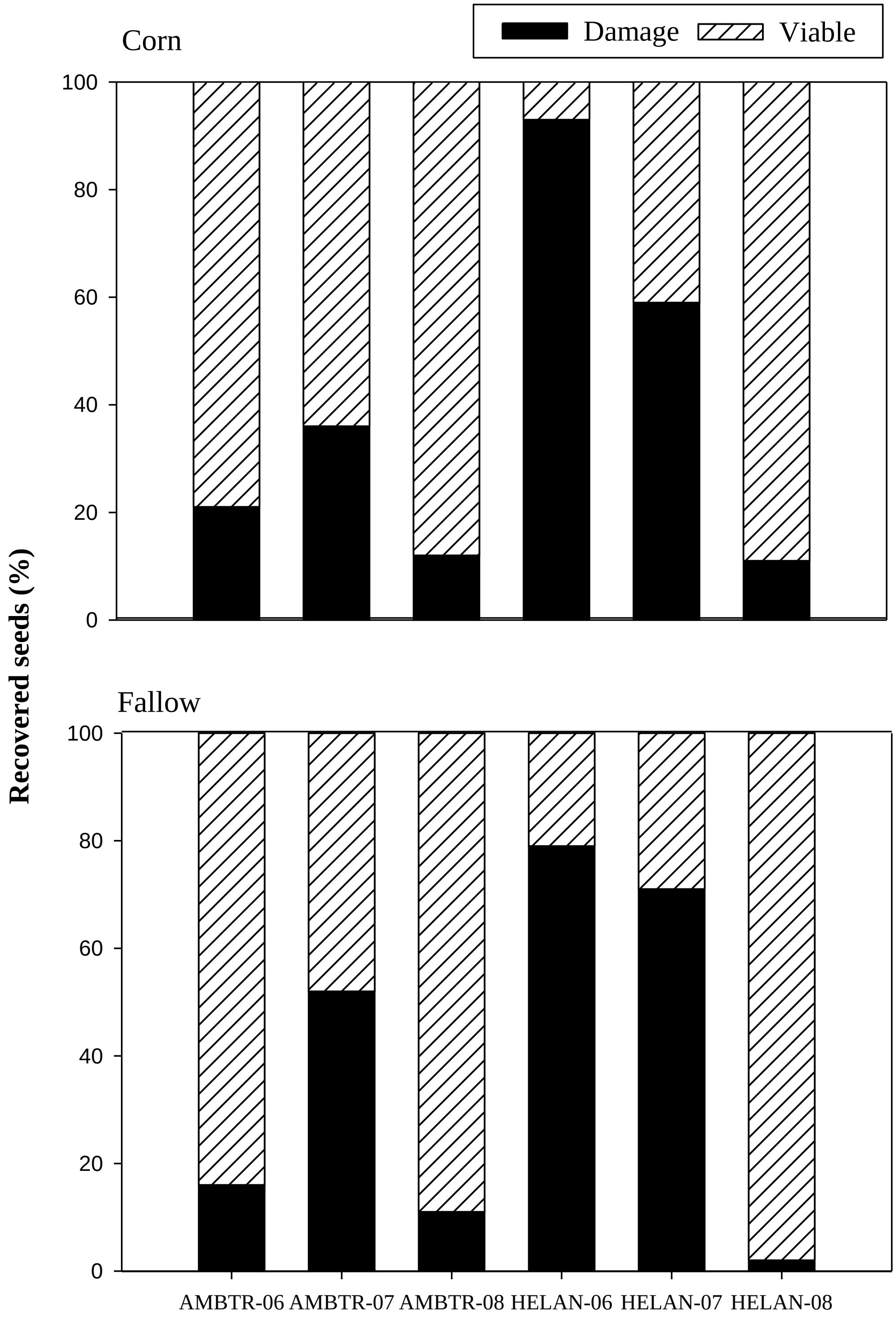


Figure 4.2 . Proportion of recovered seed that was damaged, viable or emerged from the spring-summer seed bank in corn and fallow habitats. Seeds were buried in April 2006, October 2006, and November 2007 and were excavated October 2006, October 2007, and October 2008, respectively.

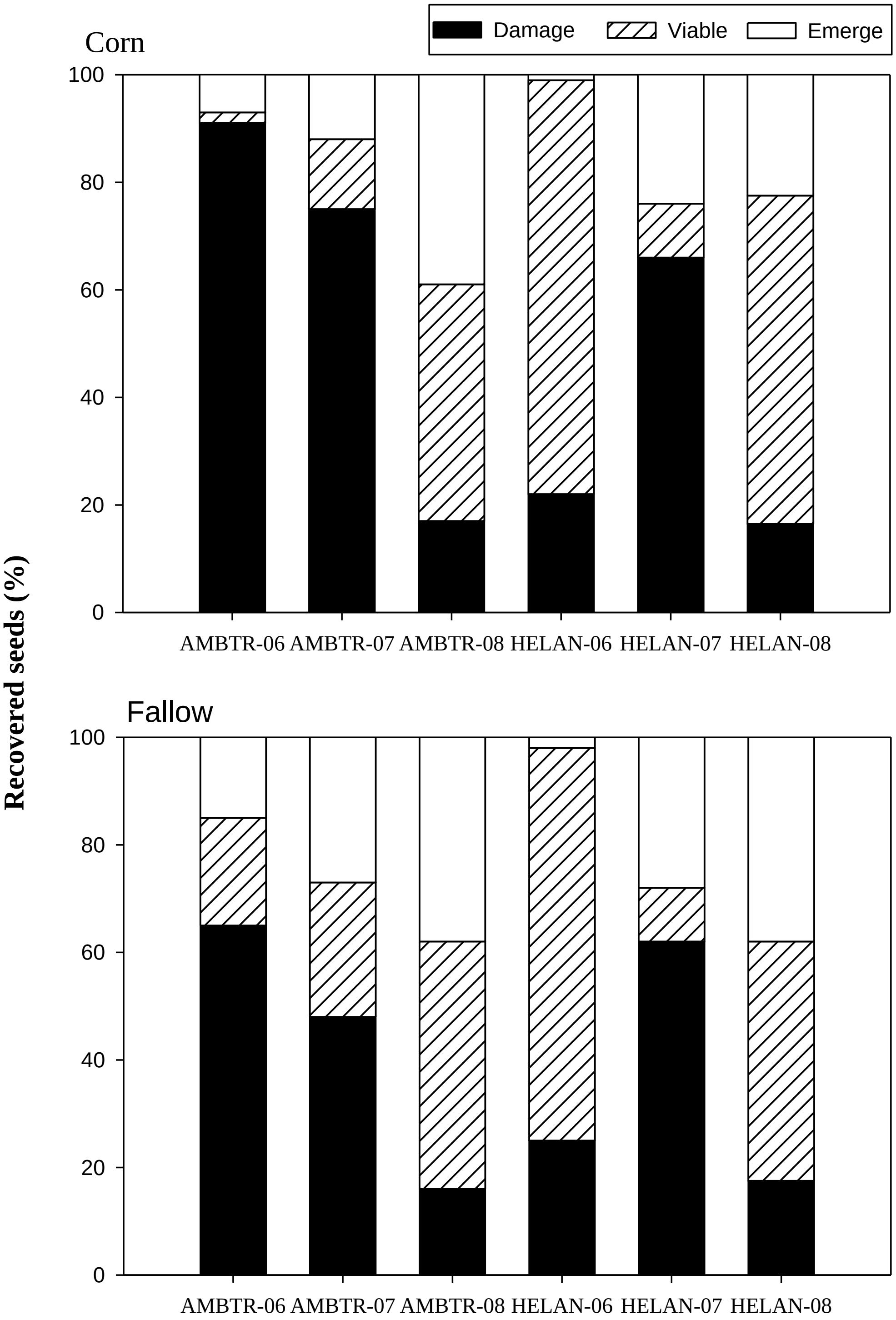


Figure 4.3. Weekly seedling emergence of giant ragweed (AMBTR) and common sunflower (HELAN) in corn and fallow habitats for 2006, 2007 and 2008. Week 1 represents March of each year and bars represent standard error.

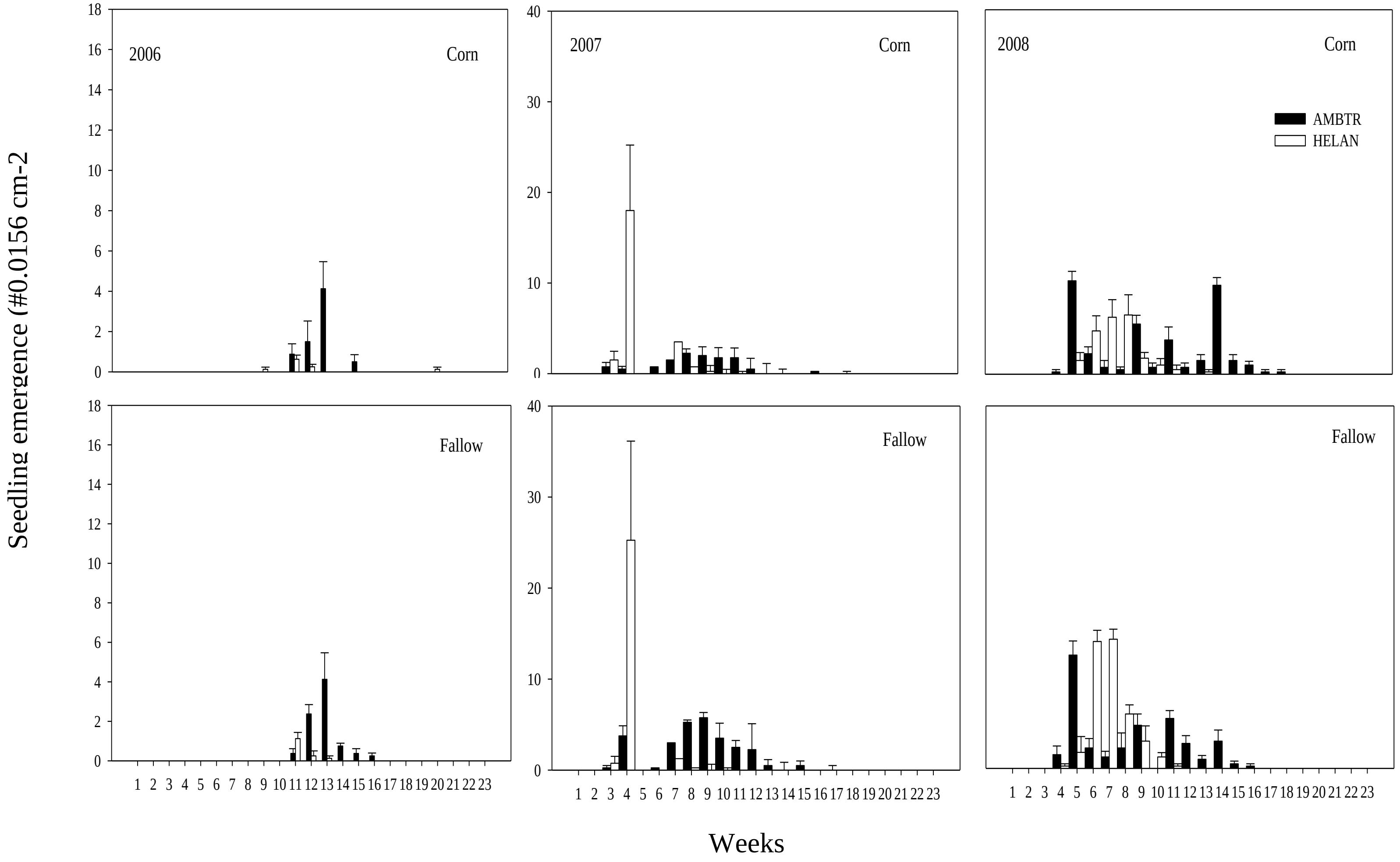
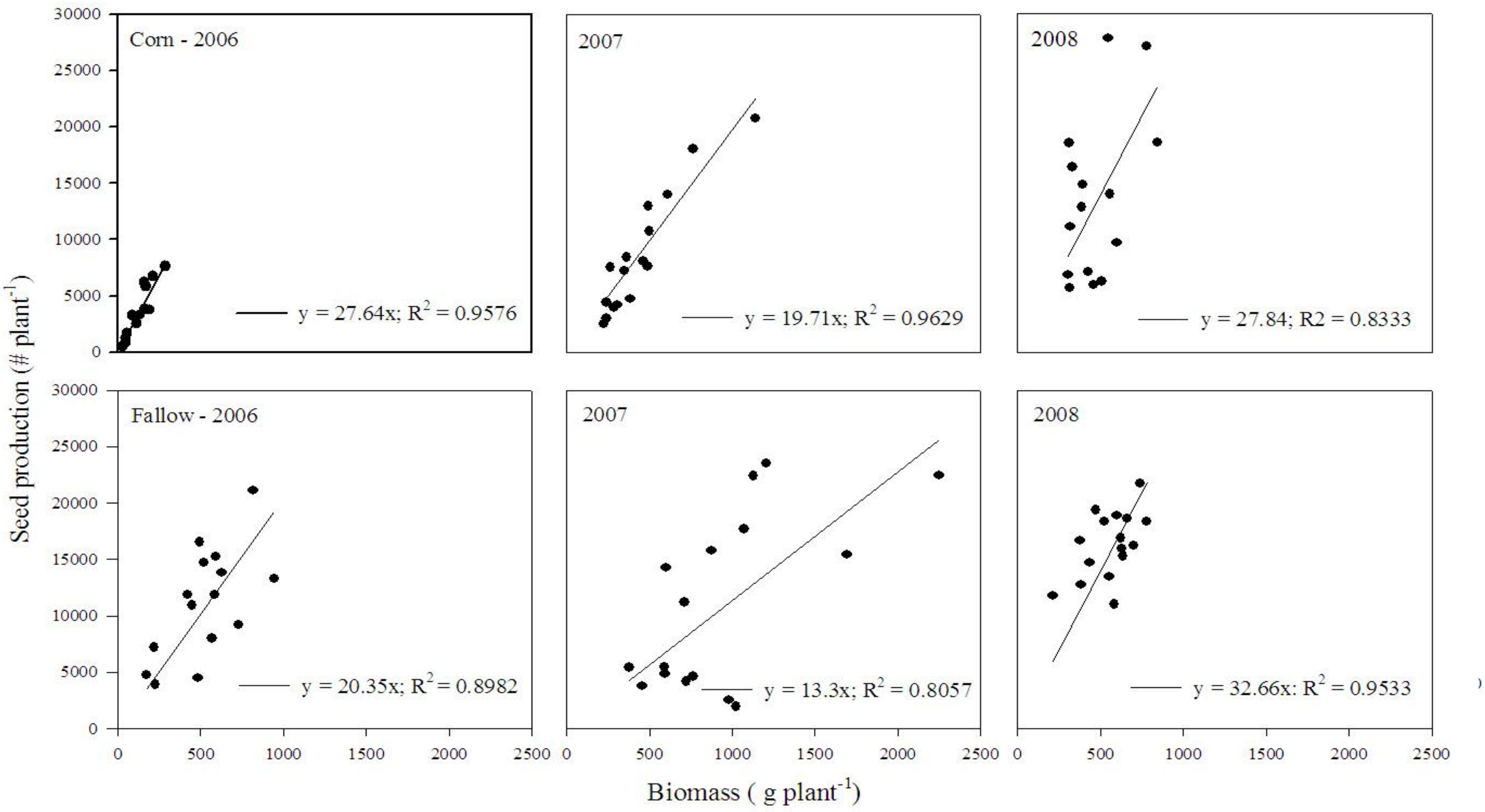


Figure 4.5. Common sunflower seed production (# plant^{-1}) in corn and fallow habitats in 2006, 2007 and 2008 as a linear function of dry biomass (g plant^{-1}). Points represent individual observation and lines represent no intercept linear fit.

biomass (g plant^{-1}). Points represent seed production and biomass of each plant sampled and lines represent no intercept.



CHAPTER 5 - Conclusion

A thorough understanding of weed biology and demography could lead to implementation of a more effective weed control. This entails a better understanding of the weed species life cycle and its population dynamics. This research focused on common sunflower (from Kansas) and giant ragweed (from Illinois), two important weed species of the North Central region of the US. Their competitive ability lies in their capacity for vigorous growth and high fecundity, which assures their presence during the growing season. Across the Midwest, it is commonly observed that these two weeds follow a distinct pattern of distribution and abundance. Giant ragweed is a serious weed of corn and soybean in Illinois and Iowa while common sunflower is a problem weed and is most commonly found in Kansas and Nebraska. The research done included three studies that investigated the overall population dynamics of these two weed species in Kansas. These studies included a survey and characterization of the emergence pattern of common sunflower and giant ragweed populations from KS; soil feedback response across the North Central region and examining the population dynamics of the two weed species in KS.

The survey highlighted that there was distinct distribution patterns for these two weed species within KS. Common sunflower is considered as a predominant weed in the state and was found everywhere, while giant ragweed was found in the southeastern part of Kansas. The results of this survey disagreed with the data obtained from the KSU Herbarium database, which showed that both weed species could be found all throughout the state. Collected accessions of the two weed species differ in their emergence. Giant ragweed populations were grouped into two distinct groups with AMBTR-A emerging early with longer duration of emergence than AMBTR-B. Four groups were described for HELAN with different first emergence and durations. It is interesting to note that AMBTR populations from non-agricultural areas had similar emergence behavior with those populations collected from agricultural areas but found in field edges.

Plant-soil feedback response of common sunflower from KS was found to be consistently positive while giant ragweed from IL had consistently negative feedback response in all sites except in MT where the feedback response was reversed. Interaction coefficient analysis revealed three scenarios. In sites where there was neutral interaction such as in IL, KS and MI-b, either AMBTR or HELAN may predominate while in sites where strong positive interaction was observed (OR and SD), HELAN seemed to provide a better environment for both species but the growth of HELAN is more favored than AMBTR. Under these conditions HELAN would always predominate over giant ragweed. In sites where negative interaction was observed (MI-a and MT), AMBTR will predominate.

The population dynamics study revealed that population growth rates in both weed species varied across years. Weather conditions in 2007 and 2008 proved to be conducive to growth of the two weed species. Attention should be given to the fact that the giant ragweed population used was not from KS, therefore if giant ragweed from IL will be introduced to KS, there is a large probability that it can adapt and persist in KS conditions. However, its expansion and predominance within the state can be thwarted if succeeding flushes within the season can be controlled and species prevented from setting seeds. Common sunflower being native to KS will continue to persist. It has become so adapted to KS conditions that even under adverse conditions such as in 2006, it would still be able to produce seeds and persist in the next cropping season. Control measures that reduce overwintering seed survival, germination and fecundity should be applied to reduce the population growth rate of the two weed species.

The current research focused on the year to year variation in demographic parameters due to environmental factors. A research to evaluate the fate of remaining seeds in the seed bank would be useful in quantifying variation in demographic rates of the two weed species in one environment setting. Also, the demographic data from this study can be used to model the population growth rates of these two weed species under various scenarios. This will lead to the development of a more effective approach in controlling these weed species. The soil feedback response of the weed species should be examined more closely to determine the underlying mechanism for such response. In general, the differences in distribution and predominance of these weeds seemed to be caused by variability in the environmental conditions across the sites and that the contribution of plant-soil feedback is minimal. However, the mechanism behind the observed soil-feedback response should still be examined by exploring the impact of various abiotic and biotic soil factors. A uniform protocol for soil sampling and soil nutrient analysis should be used. Also, the possible contributions of nutrient dynamics, allelopathic chemicals and soil microbial population to the response should be evaluated to better understand the mechanism of soil feedback response of these two weed species. Studies that would characterize the morphology, physiology and genetics of the collected populations of giant ragweed and common sunflower should be done. This will further examine whether the observed differences in emergence pattern has genetic basis and if these populations vary morphologically, physiologically or genetically.