

Plant Community Dynamics in Agricultural and Successional Fields

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Understanding the drivers and consequences of diversity and productivity in plant communities remains a central challenge in ecological research (Thompson et al. 2001, Mittelbach 2012). Interest in how the diversity and composition of plant communities regulate ecological processes and ecosystem services that different ecosystems provide has expanded over the past two decades (Loreau et al. 2001). This question has remained relatively unexplored in agricultural systems—particularly the annual row crops that supply much of the world’s food (Power 2010). This is likely because factors known to influence weed and crop production—such as soil fertility, precipitation, and pests (weeds, pathogens, and insects)—are primarily managed with external inputs (fertilizer, irrigation, and pesticides) rather than by relying on ecological processes (Robertson and Swinton 2005). Growing concerns about the negative environmental impacts of using external inputs to sustain crop productivity have stimulated interest in the development of an ecological framework for agricultural management (Robertson and Swinton 2005, Swinton et al. 2006, 2007, Robertson and Hamilton 2015, Chapter 1 in this volume). In addition to crop yield, an ecological framework would consider other ecosystem services that can be managed and enhanced both in the field and in surrounding landscapes (Swinton et al. 2006, 2007, Power 2010). Plant diversity and composition are likely to play an important role in the actualization and sustainability of these services, particularly from landscapes that surround crop fields (Power 2010, Egan and Mortensen 2012).

Row-crop systems are designed and managed to maintain the dominance of a particular species (the crop), with the goal of maximizing productivity (crop yield). Although row-crop systems can provide an array of other ecosystem services (Swinton et al. 2006, 2007, Power 2010), promotion or enhancement of these

services is rarely an explicit goal of intensive agriculture (Costanza et al. 1997, Daily et al. 2000). An exception may be high value crops, such as fruits and vegetables, where management practices such as planting or maintaining diverse plant communities along field edges have enhanced pollinators and fruit set (NRC 2007, Ricketts et al. 2008, Garibaldi et al. 2011). Communities in the landscape surrounding crops are important for biological control services, especially for beneficial insects that rely on the floral resources and habitat that plants provide (Landis et al. 2008, Meehan et al. 2011, Landis and Gage 2015, Chapter 8 in this volume). Thus, both economic and environmental incentives exist for ecological research on the functioning of row-crop systems and the contribution of plant diversity within and surrounding row-crop fields to the ecosystem services from agricultural landscapes.

What are the ecological factors that control diversity and productivity in plant communities, and how do they interact to affect the ecosystem services provided by row crops? For plant communities in general, much evidence exists that disturbance regimes (frequency, magnitude, and timing), soil fertility, and biotic interactions (competitors and consumers; see Mittelbach 2012) influence local diversity, and that these local factors interact with regional factors such as seed sources, landscape connectivity, and climate to determine species composition and diversity (Davis et al. 2000, Vellend 2010). But for weed communities, much less is known about how these factors—both local and regional—interact to determine their diversity, composition, and abundance in agricultural systems (Ryan et al. 2010, Egan and Mortensen 2012).

In this chapter, we examine how disturbance and nutrient additions influence plant species diversity, composition, and productivity of herbaceous plant communities typical of agricultural landscapes in the upper midwestern United States. We focus primarily on studies at the Kellogg Biological Station Long-Term Ecological Research site (KBS LTER) in successional fields and row crops. We compare results from the Main Cropping System Experiment (MCSE, Table 7.1; details in Robertson and Hamilton 2015, Chapter 1 in this volume) with smaller-scale experimental studies established within and adjacent to the MCSE. We also provide a broader context for our research on fertilizer manipulations by summarizing results from cross-site analyses of resource enrichments in herbaceous communities across a broad geographic gradient in North America, including a number of other LTER sites. We end the chapter by discussing how interacting processes might shape the future of agriculture, particularly in the context of global climate change and grassland restoration and management. Understanding how disturbance and nutrient availability interact and affect herbaceous plant communities is fundamental to the development of biologically based management of row crops and other agricultural systems.

Experimental Design and Research Approaches

The annual cropping systems of the MCSE provide us with the opportunity to compare the effects of disturbance (tillage) and nutrient input (cover crops vs. inorganic fertilizers), and their interaction, on weed communities and crop yield. Other KBS LTER researchers have evaluated how these management practices affect

Table 7.1. Description of the KBS LTER Main Cropping System Experiment (MCSE).^a

Cropping System/Community	Dominant Growth Form	Management
<i>Annual Cropping Systems</i>		
Conventional (T1)	Herbaceous annual	Prevailing norm for tilled corn–soybean–winter wheat (c–s–w) rotation; standard chemical inputs, chisel-plowed, no cover crops, no manure or compost
No-till (T2)	Herbaceous annual	Prevailing norm for no-till c–s–w rotation; standard chemical inputs, permanent no-till, no cover crops, no manure or compost
Reduced Input (T3)	Herbaceous annual	Biologically based c–s–w rotation managed to reduce synthetic chemical inputs; chisel-plowed, winter cover crop of red clover or annual rye, no manure or compost
Biologically Based (T4)	Herbaceous annual	Biologically based c–s–w rotation managed without synthetic chemical inputs; chisel-plowed, mechanical weed control, winter cover crop of red clover or annual rye, no manure or compost; certified organic
<i>Perennial Cropping Systems</i>		
Alfalfa (T6)	Herbaceous perennial	5- to 6-year rotation with winter wheat as a 1-year break crop
Poplar (T5)	Woody perennial	Hybrid poplar trees on a ca. 10-year harvest cycle, either replanted or coppiced after harvest
Coniferous Forest (CF)	Woody perennial	Planted conifers periodically thinned
<i>Successional and Reference Communities</i>		
Early Successional (T7)	Herbaceous perennial	Historically tilled cropland abandoned in 1988; unmanaged but for annual spring burn to control woody species
Mown Grassland (never tilled) (T8)	Herbaceous perennial	Cleared woodlot (late 1950s) never tilled, unmanaged but for annual fall mowing to control woody species
Mid-successional (SF)	Herbaceous annual + woody perennial	Historically tilled cropland abandoned ca. 1955; unmanaged, with regrowth in transition to forest
Deciduous Forest (DF)	Woody perennial	Late successional native forest never cleared (two sites) or logged once ca. 1900 (one site); unmanaged

^aSite codes that have been used throughout the project's history are given in parentheses. Systems T1–T7 are replicated within the LTER main site; others are replicated in the surrounding landscape. For further details, see Robertson and Hamilton (2015, Chapter 1 in this volume).

soil fertility and biogeochemical processes (Cavigelli et al. 1998, Harwood 2002, Snapp et al. 2010, Robertson et al. 2015, Chapter 2 in this volume). Using the Early Successional system as a reference community, we evaluate the long-term effects of disturbance and nutrient enrichment on species diversity, composition, and productivity in herbaceous plant communities.

Row Crops and Weed Communities

Research at KBS LTER has documented how management practices affect the composition and diversity of weeds in agricultural systems, both aboveground and in the soil seed bank (Smith and Gross 2006, Davis et al. 2005). While many studies have examined the effects of different cropping systems on weed communities, few have followed these changes over decades. This extended temporal focus allows us to detect whether weed community composition and productivity respond to longer-term drivers, including changes in climatic factors such as precipitation (Robinson 2011).

Although the MCSE allows us to make such comparisons, the lack of rotation “entry point” replication limits our ability to compare systems across years (i.e., each year has only one crop in the rotation). Also, the design of the MCSE (see Table 7.1) limits our ability to draw conclusions about the role of cropping system diversity in enhancing ecosystem services from agriculture. To address these constraints, in 2000 we established the Biodiversity Gradient Experiment to directly examine how variations in crop diversity (number of crops in a rotation) affect weeds, crop yields, and other agronomic and ecological factors.

Biodiversity Gradient Experiment

The Biodiversity Gradient Experiment includes a total of 21 treatments with monocultures and rotations of three grain crops (corn, soybean, and wheat), with and without cover crops, as well as spring and fall fallow treatments and a bare soil treatment (Table 7.2). All entry points of the rotations are included in the design, so we can quantify treatment effects on all crop yields in every year and directly determine how interannual variation in climatic factors affects crop yield and weed biomass. Crop treatments are classified into six systems that differ in the number of annual grain and cover crop species in the rotation (Table 7.2). Additional details on the management and design of this experiment are described in Smith et al. (2008) and at <http://lter.kbs.msu.edu>.

Early Successional Plant Communities

The MCSE Early Successional system allows us to quantify successional trajectories and dynamics in a midwestern U.S. landscape (Huberty et al. 1998, Gross and Emery 2007). Since 1997 these plots have been burned annually (or nearly so) in early spring to prevent colonization by trees and shrubs (see Foster and Gross 1999). Although historically the frequency and season of burning of midwestern grasslands likely varied depending on climate and other factors (Andersen and Bowles 1999), today annual spring fires are used to manage them (Packard and Mutel 1997).

When the MCSE was initiated (1989), an experiment was established within the Early Successional system with subplot manipulations of disturbance (tillage) and nitrogen (N) fertilization (the Disturbance by N-Fertilization Experiment). This experiment allows us to examine how disturbance and resource enrichment affect (1) productivity and species richness in successional communities (Gough et al. 2000, Dickson and Gross 2013), (2) the composition and stability of aboveground

Table 7.2. Species composition and rotational diversity treatments of the KBS biodiversity gradient experiment.^a

Treatment Description ^b	Number of Treatments ^c	Crops per Year	Cover Crops per Year	Total Species per Year	Crops over Rotation	Cover Crops over Rotation	Total Species over Rotation
Spring or fall plowed fallow ^d	2	0	0	10–12	0	0	20+
C–S–W with 2 cover crops	3	1	1–2	2–3	3	3	6
C–S–W with 1 cover crop	3	1	1	2	3	2	5
C–S–W rotation	3	1	0	1	3	0	3
C–S, S–C, W–S rotations	3	1	0	1	2	0	2
C, S, or W with 1 cover crop	3	1	1	2	1	1	2
C, S, or W monoculture	3	1	0	1	1	0	1
Bare soil ^e	1	0	0	0	0	0	0

^aAll treatments replicated in each of four blocks; see Smith et al. (2008) for a detailed description of treatments and rotations.

^bCrops planted in rotations are Corn = C, Soybean = S, and Wheat = W and, when included, either 1 (legume) or 2 (legume and small grain) cover crops. Rotations are indicated by a hyphen; all entry points of rotations are planted each year.

^cNumber of treatments = number of entry points.

^dFallow treatments are tilled once a year (spring or fall), allowing weeds to establish.

^eBare soil treatment is repeatedly tilled to prevent weed establishment and to serve as a “no plant” reference for soil and microbial studies.

production (Grman et al. 2010), and (3) successional trajectories (Huberty et al. 1998). This experiment has shown the influence of landscape position or initial colonization events on successional trajectories (Foster and Gross 1999) and how these factors can constrain the restoration of native grasslands (Gross and Emery 2007, Suding and Gross 2006a, b; Suding et al. 2004). Participation in cross-site synthesis projects across the LTER Network has allowed us to compare results from the KBS LTER to those observed in other grasslands and has broadened our understanding of the response of herbaceous plant communities across North America to increases in N deposition and why these responses may differ across sites (e.g., Gough et al. 2000, 2012; Suding et al. 2005; Clark et al. 2007; Cleland et al. 2013).

Disturbance as a Driver of Plant Community Diversity

Disturbance, particularly fire and grazing, has been shown to be important in determining the composition and diversity of a variety of grasslands (Huston 1979, Miller 1982, Pickett and White 1985). Fire frequency (Collins 1992,

Howe 2000) and grazing intensity and the type of grazer (Collins et al. 1998, Knapp et al. 1999, Burns et al. 2009) have all been shown to affect the diversity, composition, and productivity in prairies. Reduction in fire frequency has been linked to the conversion of grasslands to woodlands and the loss of native species (Anderson and Bowles 1999, Packard and Mutel 1997, McPherson 1997). As a result, fire and the reintroduction of grazing are important management tools for restoring and maintaining native diversity in grasslands (Suding and Gross 2006a, b, Martin and Wilsey 2006).

In cropping systems, tillage and herbicide applications are disturbances that, like fire and grazing, affect not only the composition and diversity of existing weed communities but also those of the subsequent emergent weed community (“emergent” refers to a germinated and established weed in a crop field, as opposed to the potential weed community in the seed bank; Johnson et al. 2009, Hilgenfeld et al. 2004, also Mortensen et al. 2012). While such management changes can alter the composition and diversity of weed communities (see Smith and Gross 2006, 2007; Smith et al. 2010), growers are generally less interested in how management affects diversity and more interested in the effect on crop yield. Nevertheless, to manage for ecosystem services from agriculture, we need a better understanding of how the disturbance from agronomic practices affects the diversity and productivity of the overall plant communities—weeds as well as crops—in agricultural landscapes.

Effects of Disturbance on Weed Communities

The MCSE annual cropping systems provide the opportunity to compare the impact of tillage and herbicides on weed community structure under four different management regimes (Smith and Gross 2007). However, in these four systems, it is difficult to distinguish the effect of tillage alone because herbicides and fertilizer are also included in the management (see Table 7.1). The annually tilled plots in the Disturbance by N-Fertilization Experiment and the Biodiversity Gradient Experiment (Table 7.2) thus serve as reference communities to examine the effects of tillage alone (Smith and Gross 2007), or of tillage plus N fertilizer, on weed communities (Grman et al. 2010), and to relate long-term changes in species composition and dominance not only to annual disturbance (tillage), but also to longer-term drivers such as climate change (Robinson 2011, Cleland et al. 2013, Dickson and Gross 2013).

Despite major differences in management—including chemical inputs and tillage (Table 7.1)—differences in weed biomass and composition among the four annual cropping systems of the MCSE have been relatively small (Davis et al. 2005). This suggests that disturbance, whether created by tillage or herbicide, has similar effects on the emergent weed community. Ordinations of aboveground weed biomass and composition over the first 13 years of the study (1990–2002) did not show a strong association with management, although overall weed biomass was lower in the Conventional and No-till systems than in the Reduced Input and Biologically Based systems (Davis et al. 2005). There is, however, considerable interannual variation in weed biomass (Table 7.3) and weed species composition (Fig. 7.1) in the four annual cropping systems. This may reflect differences in what

Table 7.3. Temporal changes in seed bank density and aboveground weed biomass across systems of the MCSE.^a

Variable/System	1990	1993	1996	1999	2002	2008
Seed bank(10^3 seeds m^{-2}) ^b						
Conventional	5.9 (1.2)	2.2 (0.5)	1.4 (0.6)	19.7 (2.3)	23.2 (2.5)	34.2 (2.5)
No-till	13.9 (3.1)	6.0 (1.4)	3.1 (1.6)	38.9 (4.2)	22.8 (2.7)	13.1 (3.1)
Reduced Input	11.3 (1.5)	6.5 (1.3)	1.6 (0.3)	28.1 (3.2)	29.7 (1.9)	24.7 (4.2)
Biologically Based	6.2 (0.8)	10.7 (2.0)	0.4 (0.1)	19.1 (1.5)	19.7 (2.2)	16.9 (1.6)
Early Successional	15.1 (6.0)	26.0 (5.3)	110 (14.0)	47.7 (8.2)	21.6 (2.4)	29.6 (6.7)
Aboveground biomass (g m^{-2}) ^c						
Conventional	46.6 (12.3)	34.7 (5.6)	3.3 (1.5)	4.9 (1.6)	23.5 (6.0)	0.0
No-till	5.2 (3.2)	156 (45.7)	59.8 (20.2)	227 (41.0)	16.2 (4.8)	0.0
Reduced Input	147.8 (55)	148 (36.7)	2.6 (0.9)	11.4 (4.5)	42.7 (8.4)	21.5 (5.8)
Biologically Based	184 (65.9)	161 (20.2)	83.8 (15.7)	20.6 (6.0)	154 (27.0)	56.9 (16.7)
Early Successional	416 (53.5)	450 (44.3)	340 (23.8)	642 (74.3)	701 (73.7)	772 (38.9)

^aCorn planted in all of these years, except 1990 when soybean was planted in the Conventional and No-till systems. Values are mean (SE), $n = 6$ replicated plots. For annual crops, biomass is for weeds only and does not include crop or cover crop production.

^bSeed bank density determined by elutriation (Gross and Renner 1989); sampling occurred in the spring (April).

^cAboveground biomass determined at peak weed biomass in each system; in August–September for annual cropping systems and early August for the Early Successional system.

crop was planted (i.e., stage of the rotation; see Fig. 7.1), interannual differences in total precipitation or its timing, and/or how those factors interact with the timing of management efforts to control weeds.

In contrast, seed banks in the Reduced Input and Biologically Based systems have diverged in species composition from those in the Conventional and No-till systems (Fig. 7.2), indicating that in the MCSE annual systems, herbicides can be a stronger determinant (or filter) of weed species composition than tillage. When examined alone, however, tillage has been shown to have either strong (Murphy et al. 2006, Sosnoskie et al. 2006) or weak (Thomas et al. 2004) effects on weed community composition and diversity. This makes it difficult to predict how the trend toward reduced tillage—and consequent increased herbicide use (e.g., shifts to no-till and planting crops genetically modified for herbicide resistance)—will impact weed communities in annual row crops. Further studies comparing management systems and their effects on emergent weed communities are needed to elucidate the long-term effects of herbicide use and tillage on weed communities in row crops (Davis et al. 2005).

The Biodiversity Gradient Experiment allows us to examine the effects of tillage timing on weed communities in row crops, and over the first 5 years of this experiment, weed community composition was strongly affected by the timing of primary tillage (Smith 2006, Smith and Gross 2007). Spring tillage (coinciding with corn and soybean planting) favored the establishment of spring-emerging annual

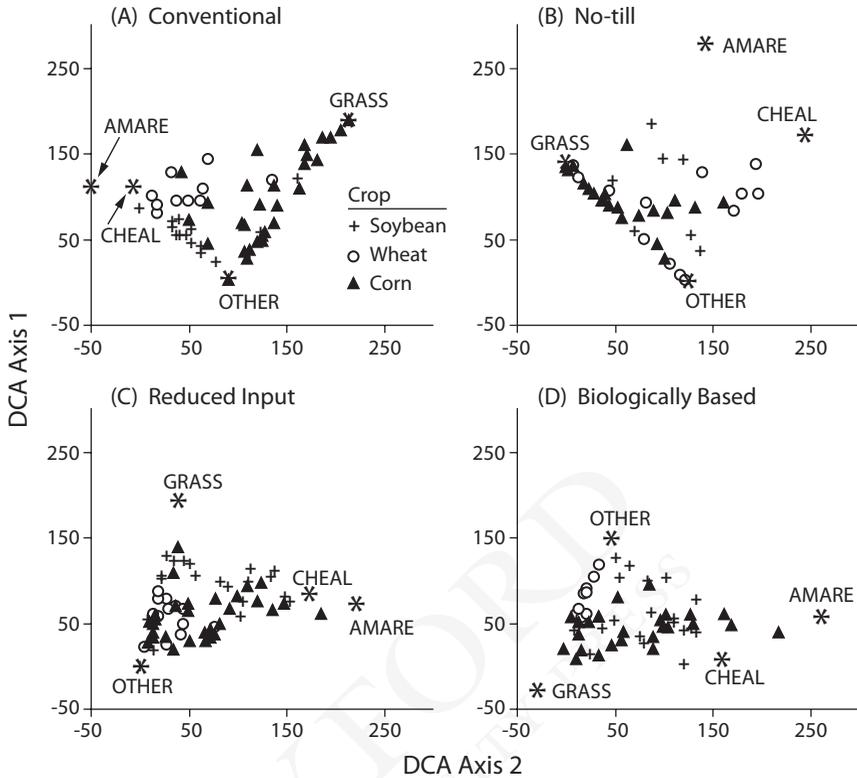


Figure 7.1. Variation in weed species composition in relation to crop grown in the four annual cropping systems of the Main Cropping System Experiment (MCSE). Plot scores are from detrended correspondence analysis (DCA) of weed species composition from 1990–2002 for each crop in A) Conventional, B) No-till, C) Reduced Input, and D) Biologically Based systems. Symbol legend for all panels appears in panel A. Asterisks indicate scores for the four dominant weeds used in the ordination. AMARE = *Amaranthus retroflexus*; CHEAL = *Chenopodium album*; Other = Other dicots; Grass = all grass species. Modified from Davis et al. (2005).

forbs and C_4 grasses, while fall tillage (coinciding with the winter wheat planting) favored winter-annual forbs and C_3 grass species (Smith 2006). The importance of tillage timing in determining weed species composition is indicated by strong similarities in species composition between corn, soybean, and the spring fallow treatment (spring tillage) as well as between wheat and the fall fallow treatment (fall tillage) (Fig. 7.3).

In the MCSE Early Successional system, a small area (20×30 m) at the northern border of each replicate plot has been annually tilled to maintain dominance by annual weeds as part of the Disturbance by N-Fertilization Experiment. Although the species composition of the annually tilled plots has varied over time (Grman et al. 2010), they are consistently dominated by giant foxtail (*Setaria faberi*; Table 7.4), a C_4 annual grass that is a common weed in corn and soybean in the

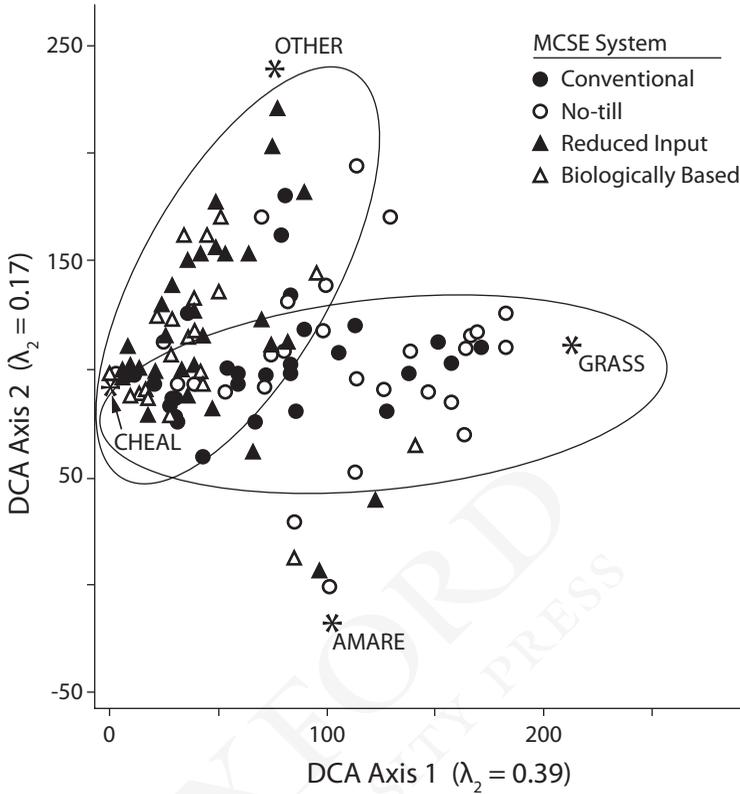


Figure 7.2. Detrended correspondence analysis (DCA) of weed seedbank species composition in four annual row-crop systems on the MCSE. Data are scores for replicate plots ($n=6$) of each system for the 5 years sampled (every three years, 1990–2002). Asterisks indicate scores for the four dominant weeds used in the ordination. AMARE = *Amaranthus retroflexus*; CHEAL = *Chenopodium album*; Other = Other dicots; Grass = all grass species. Ovals group data points (majority) of Conventional and No-till and of Reduced Input and Biologically Based systems to highlight divergence in weed seed banks. Modified from Davis et al. (2005).

upper U.S. Midwest (Nurse et al. 2009). This species dominates in the both the fertilized and unfertilized tilled plots (48% and 60% of total biomass, respectively; Table 7.4). And while precipitation does not predict plot biomass production (fertilized and not), the abundance of *S. faberi* across years is correlated with early spring rainfall and temperature (Robinson 2011). Interestingly, *S. faberi* was not a dominant weed in either the emergent or seed bank communities of the adjacent annual row-crop systems (Davis et al. 2005), even though the abundance of grass weed species, in general, differed among crops and cropping systems (Figs. 7.1 and 7.2), suggesting that the presence of a crop—or management of these systems—inhibits or reduces the abundance of this species.

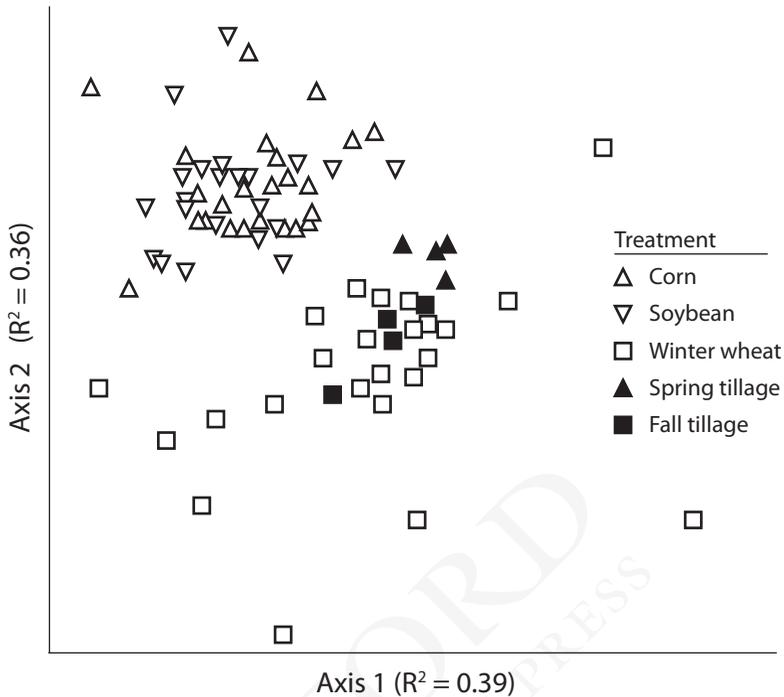


Figure 7.3. Weed species composition in response to agronomic and fallow treatments in the Biodiversity Gradient Experiment. Plot scores are from non-metric multidimensional scaling (NMDS) ordination of weed community composition and abundance in 2004 in relation to crop type (soybean, wheat, corn) and tillage time (spring, fall) for fallow treatments. Ordination based on Bray-Curtis dissimilarity in species composition.

Temporal Dynamics and Community Assembly

The plant community that assembles in response to a particular disturbance regime, whether in a row crop or an abandoned agricultural field, will depend on the nature of the disturbance; the local and regional species pool; and climatic (e.g., temperature and precipitation), abiotic (soil fertility), and biotic factors (e.g., competitors, mutualists, predators, and pathogens). Long-term KBS LTER studies allow us to compare, in replicated plots, how different management practices (Table 7.1) affect the colonization, establishment, persistence, and extinction of plant species in both successional and row-crop communities. When chronic or repeated disturbances cease, sites undergo a successional sequence of changes in both species composition and traits (Connell and Slatyer 1977). Long-term experiments within MCSE plots allow us to examine how nutrient enrichment (fertilization) and climatic factors interact to affect these trajectories. We can also determine how variation in chemical inputs to row crops affects the composition and diversity of weeds in agronomic systems.

Table 7.4. Indicator species in (A) untilled and (B) annually tilled treatments, both with (fert) and without (no fert [control]) N fertilization, in the disturbance by N-fertilization experiment in the MCSE Early Successional system.

Species ^a	Indicator Group ^a	Unfertilized Plots (% total biomass) ^a	Fertilized Plots (% total biomass) ^a	Life History ^b	Life Form ^b	Native or Introduced ^b
(A) Untilled (Perennial-dominated community)						
<i>Solidago canadensis</i>	Fert	25.90	36.87	P	F	N
<i>Phleum pretense</i>	No fert	10.06	2.70	P	G(C ₃)	I
<i>Trifolium pretense</i>	No fert	7.80	0.66	P	L	I
<i>Apocynum cannabinum</i>	Fert	6.02	8.98	P	F	N
<i>Elymus repens</i>	Fert	4.57	6.43	P	G(C ₃)	I
<i>Hieracium</i> spp.	No fert	1.31	0.01	P	F	I
<i>Achillea millefolium</i>	No fert	0.95	0.21	P	F	N
<i>Hypericum perforatum</i>	No fert	0.88	0.24	P	F	I
<i>Rumex crispus</i>	Fert	0.85	2.72	P	F	I
<i>Trifolium hybridum</i>	No fert	0.84	0.06	P	L	I
<i>Poa compressa</i>	No fert	0.83	0.07	P	G(C ₃)	I
<i>Potentilla recta</i>	No fert	0.72	0.21	P	F	I
<i>Lotus corniculatus</i>	No fert	0.60	0.00	P	L	I
<i>Solidago juncea</i>	No fert	0.54	0.00	P	F	N
<i>Trifolium repens</i>	No fert	0.19	0.03	P	L	I
<i>Melandrium album</i>	Fert	0.15	2.03	P	F	I
<i>Asclepias syriaca</i>	Fert	0.14	1.33	P	F	N
<i>Ambrosia artemisifolia</i>	Fert	0.07	0.41	A	F	I
<i>Chenopodium album</i>	Fert	0.00	0.13	A	F	I
<i>Lactuca serriola</i>	Fert	0.00	0.09	A/B	F	I
<i>Rubus occidentalis</i>	Fert	0.00	1.97	P	F	N
(B) Tilled (Annual-dominated community)						
<i>Setaria faberi</i>	Fert	47.80	59.46	A	G(C ₄)	I
<i>Chenopodium album</i>	Fert	12.22	15.58	A	F	I
<i>Ambrosia artemisifolia</i>	Fert	6.96	8.69	A	F	I
<i>Amaranthus retroflexus</i>	Fert	1.38	3.27	A	F	N
<i>Apocynum cannabinum</i>	No fert	0.59	0.01	P	F	N
<i>Panicum capillare</i>	No fert	0.25	0.02	A	G(C ₃)	N
<i>Erigeron annuus</i>	No fert	0.22	0.01	A	F	I
<i>Echinochloa crus-galli</i>	Fert	0.12	0.81	A	G(C ₃)	I
<i>Taraxacum officinale</i>	No fert	0.12	0.01	P	F	N,I

^aAll species were significant indicator species (at $p = 0.01$) in a given treatment. For both treatments, species are listed in rank order (most to least % total biomass) in the control (No Fert) plots. Percentage total biomass determined from the average biomass over 18 years (1992–2009). Species names are accepted nomenclature (USDA PLANTS Profile: <http://plants.usda.gov>).

^bLife history, life form, and native status determined from databases (e.g., USDA PLANTS) and field observations; A = annual, B = biennial, P = perennial; F = forb, G = grass (C₃ or C₄), L = legume; and Native = N; Introduced = I. See also Cleland et al. (2008).

Temporal Dynamics in Weed Communities

The seed bank is an important source for weed infestations in agricultural fields (Buhler et al. 1997). Although the linkage between composition of the weed seed bank and weed pressure can be difficult to gauge (Davis 2006), understanding the factors affecting the persistence and species composition of weed seed banks in arable soils is important for weed management (Buhler 2002, Davis 2006).

When the MCSE was established, weed seed banks in all four annual row-crop systems were dominated by *Chenopodium album* (lambquarters), likely reflecting its ability to persist with the previous 20 + years of herbicide use typical of weed management in conventional row-crop agriculture (Davis et al 2005). Over time, the composition of the weed seed banks in the four annual row-crop systems diverged in response to management (Menalled et al. 2001, Davis et al. 2005). In the Conventional and No-till systems, seed banks shifted to dominance by annual, C₄ grasses (mainly *Panicum dichotomiflorum* (fall panicgrass) and *Digitaria sanguinalis* (large or hairy crabgrass), and some *S. faberi*, whereas the Reduced Input and Biologically Based systems became dominated by small-seeded dicot species (Fig. 7.2) such as *Stellaria media* (common chickweed), *Veronica perigrina* (purslane speedwell), and *Arabidopsis thaliana* (mouse-ear cress). Despite the important role that seed banks play in determining weed communities and the observed divergence in weed seed bank composition (Fig. 7.2) and differences in emergent weed biomass (Table 7.3), there is little divergence in the weed species composition among annual systems (Fig. 7.1; see also Davis et al. 2005). This suggests that interannual variation in these communities is strongly controlled by cropping system management (Davis et al. 2005) and climatic variation (Robinson 2011).

The timing of tillage and the use of cover crops can have dramatic effects on the composition of the emergent weed community in row crops (Smith 2006, Smith and Gross 2007), which may result from interactions between the disturbance regime (e.g., whether and how tillage or herbicides are used to control weeds) and the source of N (legume cover crop vs. inorganic fertilizer). Both the type (herbicides vs. interrow cultivation) and timing of weed management disturbances can alter the composition of the weed community, which in turn affects its response to differences in N availability.

Temporal Dynamics in Successional Communities

Within 4–5 years after abandonment from agriculture, the MCSE Early Successional system underwent a typical shift in species composition from initial dominance by annual weeds to dominance by herbaceous perennials (Huberty et al. 1998, Gross and Emery 2007). Although species composition initially differed among the six replicate plots, within 5 years all plots converged to a similar composition (Fig. 7.4) and were dominated by perennial forbs and relatively few grasses (see also untilled treatment, Table 7.4).

Although native species are relatively rare in these communities (Table 7.4), they produce about 50% of the aboveground biomass (Gross and Emery 2007). The low number of native species in these fields probably results from the lack

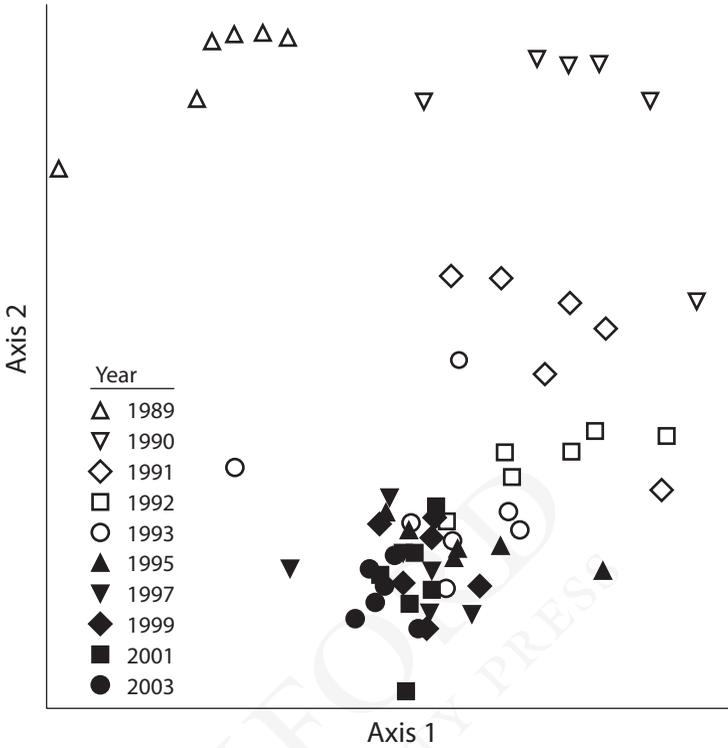


Figure 7.4. Changes in species composition in the first decade following abandonment of agricultural practices in the Early Successional system of the MCSE. Data are for each of 6 replicate plots with year indicated by different symbols. Species composition compared using non-metric multidimensional scaling (NMDS) analysis of annual biomass harvest averaged across 4–5 sampling stations in each replicate (see Gross and Emery (2007) for details). From *Old Fields*, edited by Viki A. Kramer and Richard J. Hobbs. Copyright © 2007 Island Press. Reproduced with permission of Island Press, Washington, D.C.

of native-dominated communities in the surrounding landscape (Burbank et al. 1992, Foster 1999, Gross and Emery 2007) as dispersal limitation can be an important controller of diversity in abandoned fields in this region (Suding and Gross 2006a, b; Houseman and Gross 2011). The introduction of spring burns to control colonization by woody species in this system (1997) has had no effect on the establishment of native species (Gross and Emery 2007) or on the composition of these communities (Dickson and Gross 2013). This is consistent with results from Suding and Gross (2006b) who found that only when seeds of native species are added to burned areas is there an increase in recruitment of native species. Fire may have promoted the convergence (greater similarity) in species composition among replicates (Fig. 7.4) by selecting for species that were favored by annual burning, but did not promote native species recruitment (Gross and Emery 2007). Native C_4 grasses that are consistently favored by annual burning in other midwestern

grasslands (Symstad et al. 2003, Collins et al. 1998) remain rare in KBS MCSE Early Successional communities (Table 7.4), likely because of their absence from the surrounding landscapes.

Controls on Productivity

Voluminous evidence exists that the productivity of terrestrial ecosystems is limited by nutrients (Chapin et al. 1986, Elser et al. 2007) and N has repeatedly been shown to be a critical limiting nutrient in both natural and agricultural temperate ecosystems (Drinkwater and Snapp 2007, LeBauer and Treseder 2008). Across North American grasslands and other “low-stature” herbaceous plant communities, the response to N-fertilization can depend on species composition, soil nutrient status (Clark et al. 2007), and interannual variation in precipitation (Cleland et al. 2013). While the magnitude of a productivity response to N-fertilization can vary across communities, generally there is an increase in aboveground biomass production and a decrease in species richness (Gough et al. 2000, Suding et al. 2005). Thus, N fertilizing agricultural systems to enhance productivity may come at the expense of diversity, which may reduce or limit the ecosystem services they provide (Robertson et al. 2015, Chapter 2 in this volume). Few studies have examined how enhancing plant species diversity can increase crop productivity or yield. In fact, increasing the diversity of weed species is generally assumed to have a negative effect on crop yield, the primary ecosystem service expected from row-crop agriculture.

Results from the MCSE cropping systems and Early Successional communities have been included in several meta-analyses and cross-site syntheses of fertilization experiments, allowing our results to be interpreted in a broader regional context (Gough et al. 2000, Davis 2005, Suding et al. 2005, Smith 2006, Clark et al. 2007, Smith and Gross 2007, Gough et al. 2012). We summarize studies from both the cropping and Early Successional systems here to address our overall goal of applying lessons learned and insights gained from research in noncrop plant communities to the management of cropping systems, and vice versa.

Productivity in Successional Grasslands

The Disturbance by N-Fertilization Experiment, established within the MCSE Early Successional plots, provides clear evidence that productivity in these systems is limited by N (Fig. 7.5). Although the magnitude of this effect varied across years—likely driven by variation in seasonal precipitation (Robinson 2011, see Cleland et al. 2013)—on average, the addition of fertilizer increased aboveground production in both the untilled and annually tilled plots by approximately 50% (Dickson and Gross 2013). There was a significant correlation between aboveground production in the fertilized and unfertilized plots across years in the untilled treatment (Fig. 7.5A; $r = 0.60$), but not in the annually tilled treatment. Annual precipitation is a significant predictor of productivity in both fertilized and unfertilized plots in the untilled treatment ($r = 0.49$ and 0.37 , $p < 0.025$ and 0.05 , respectively), but not in

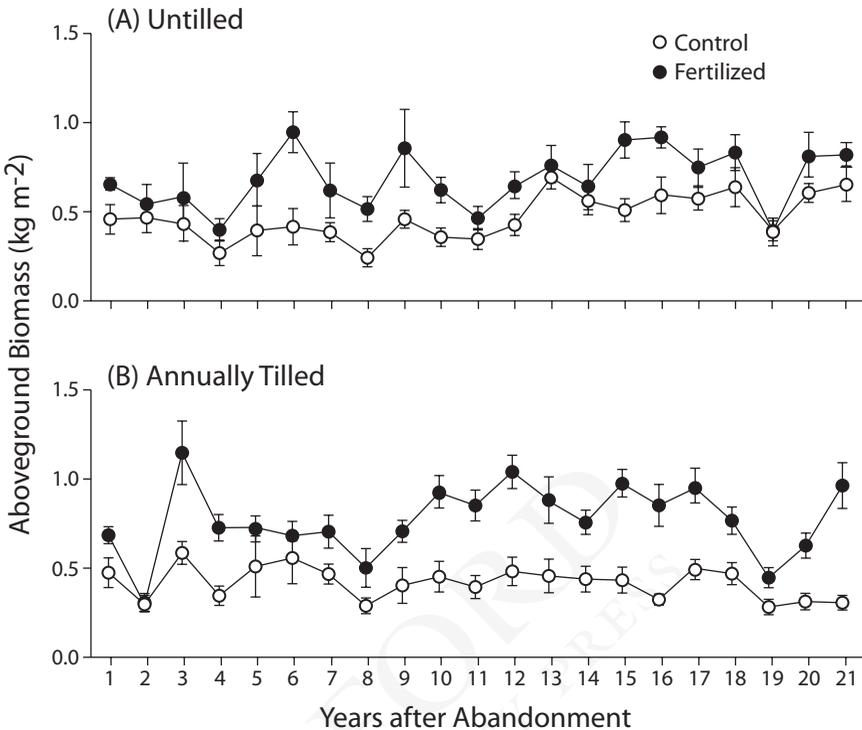


Figure 7.5. Interannual variability in aboveground biomass production in the Disturbance by N-Fertilization Experiment in the MCSE Early Successional system following abandonment (Year 1=1989) from control (unfertilized) and fertilized (nitrogen added) in A) untilled, successional and B) annually tilled treatments. Samples were harvested at peak biomass, typically late-July (untilled) and mid-August (tilled). Values are means \pm SE, $n = 6$.

the annually tilled treatment, suggesting that different external drivers controlled productivity in these communities. This difference may be due to species-specific differences in recruitment of annual weeds in response to precipitation, as exemplified by the dominant grass species *S. faberi*, which as discussed earlier, accounts for much of the weed productivity in these systems (Robinson 2011).

Nitrogen fertilization reduced species richness approximately 20% in both the untilled and annually tilled treatments (Fig. 7.6). While this response was relatively rapid in the annually tilled community (Fig 7.6B), it took 14 years before fertilization had a detectable effect on species richness in the untilled community (Fig. 7.6A). A recent meta-analysis of fertilization experiments in grasslands suggests that community composition, specifically the presence of “tall runners” (i.e., clonal populations of plants of tall stature interconnected underground by horizontal roots), can influence the magnitude of fertilization-driven changes in species diversity (Gough et al. 2012). Tall-runner species appeared in MCSE fields a few years after abandonment from agriculture, but as a functional group, they

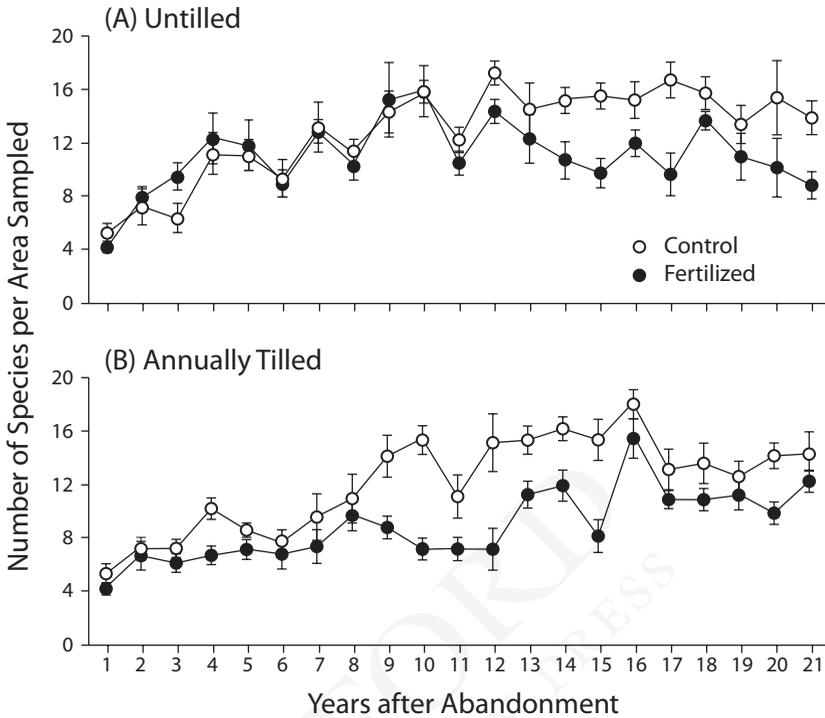


Figure 7.6. Temporal changes in species richness (number of species per harvested sample) in the Disturbance by N-Fertilization Experiment in the MCSE Early Successional system in control (unfertilized) and fertilized (nitrogen added) treatments in the A) untilled, successional plots and B) annually tilled plots. The area sampled varied for the first 3 years (Yr. 1 = 0.2 m², Yrs. 2 and 3 = 0.3 m²); from Yr. 4 onward sampling area was 1.0 m²; Year 1 = 1989. Values are means \pm SE, n=6.

varied in abundance over time (Dickson and Gross 2013). *Solidago* (goldenrod) species, which initially made up over 80% of the tall-runner biomass in these fields, declined in abundance after 5 years. The reemergence of *S. canadensis* and other tall runners in these fields after 14 years coincided with a decline in species richness in fertilized treatments (Dickson and Gross 2013).

The delayed effect of fertilization on species richness in untilled plots of the MCSE Early Successional system may be a consequence of the low abundance of C₄ grasses and greater abundance of herbaceous perennial dicots and C₃ grasses (Table 7.4), as compared to other successional grasslands in the area (see Gross and Emery 2007; Clark et al. 2007). Cross-site synthesis work has shown that there is an environmental context to species responses to N addition (Pennings et al. 2005). For example, *Elymus* (formerly *Agropyron*) *repens* (quackgrass), a nonnative C₃ grass that dominates following fertilization of successional fields at Cedar Creek LTER in Minnesota (Tilman 1984, 1987), occurs in—but does not dominate—the fertilized MCSE Early Successional plots at the KBS LTER

(Table 7.4). Native C_4 grasses that dominate tallgrass prairies of Konza LTER in Kansas and show a strong positive response to fertilization (Clark et al. 2007) are rare at KBS LTER, likely reflecting their absence in the surrounding landscape (Foster 1999).

Cross-Site Analyses of Fertilization Effects on Grasslands

Many sites in the LTER Network have established and maintained long-term N addition experiments in grasslands and similar herbaceous communities, providing opportunity for cross-site analysis of the relationship between productivity and diversity across wide geographic and climatic gradients (Gross et al. 2000, Gough et al. 2000, Suding et al. 2005). An initial synthesis of these data showed a unimodal relationship between productivity and plant species diversity across sites (Gross et al. 2000) and that N addition had similar effects on herbaceous communities ranging from Arctic heathlands to tallgrass prairie and coastal marshes, although the magnitude of their responses differed (Gough et al. 2000, Suding et al. 2005). Although these experiments differed in sampling area, similar amounts of N were added (10–12 g m⁻²), so it was possible to identify mechanisms that drive the magnitude of the response to fertilization across communities (Suding et al. 2005, Clark et al. 2007, Gough et al. 2012).

On average, N addition resulted in a 50% increase in aboveground production and a consistent decline in species richness across sites (except for coastal marshes) despite a broad range in initial aboveground productivity (Suding et al. 2005, Clark et al. 2007). The magnitude of the productivity increase was strongly correlated with the magnitude of the decrease in species richness, except in several of the coastal marsh systems (Suding et al. 2005). Although functional groups differed in their probability of being lost from a fertilized plot, overall species abundance in unfertilized control plots was the strongest predictor of species loss in response to fertilization. Species that were rare in the unfertilized community were more likely to be excluded in fertilized plots, regardless of their functional group (Suding et al. 2005). Subsequent analyses of this dataset showed that the loss of species following N addition was greatest in communities with lower soil cation exchange capacity, colder regional temperature, and a larger production increase following N addition (Clark et al. 2007).

Species composition also was an important determinant of the productivity response, specifically the abundance of C_4 grasses (Clark et al. 2007); however, the photosynthetic pathway (C_3 vs. C_4) did not appear to be the causal factor (Suding et al. 2005). In a recent meta-analysis, Gough et al. (2012) found that the form of clonal growth (having a spreading or clumping growth form vs. nonclonal) combined with height (relative position in the canopy) were strong predictors of both species and community responses to N addition. However, neither clonality nor height alone predicted the probability of species loss following N addition (Suding et al. 2005).

A shift from soil resource limitation to light limitation is often assumed to be important in determining plant species composition following nutrient enrichment. However, that plant communities become less diverse with N addition,

regardless of their initial productivity (Gough et al. 2000, Suding et al. 2005) or life history composition (Suding et al. 2005), suggests that other processes besides light limitation may be mediating species and community responses to increase N, such as species associations with soil biota (e.g., Johnson et al. 2008, Johnson 2010) and plant–soil feedbacks (Bever et al. 2010). Plant–soil interactions are likely also important determinants for agricultural weed communities (Kremer 1993, Kremer and Li 2003, Jordan and Vátovec 2004), both because agronomic management typically (but not always) keeps weed abundance below thresholds where strong competitive interactions can occur and because low diversity of cropping systems can promote pathogens specific to particular species (Bever et al. 2010, Johnson 2010).

Effects of Weed Abundance and Diversity on Crop Yield

Agricultural management systems are designed to increase crop yield by reducing soil resource limitation and competition from weeds, and often achieve this by combining control (herbicides and tillage) with fertilization. This combination, however, confounds our ability to distinguish the effects of disturbance (herbicides and tillage) from fertilization on crop yield, and limits our ability to determine how weed production and composition may interact to influence crop yields. For example, the higher weed biomass that is usually found in the lower chemical input MCSE systems (the Reduced Input and Biologically Based systems) compared to the Conventional and No-till systems (Table 7.3) may reflect the efficacy of herbicides for weed control compared to tillage. However, in some years, weed biomass in the Reduced Input system was equal to that in the Conventional system (tillage and herbicide), and much higher in the No-till (herbicide only) system (e.g., 1996, Table 7.3). Nonetheless, herbicide use clearly is important in the overall control of weed abundance in row crops of the MCSE, although other factors also play a role in determining the production and composition of weed communities and their effects on yield.

Of agronomic importance in lower chemical input and organic systems (particularly those using manure) is knowing how crop yield is affected by competition with weeds under relatively nutrient-limited conditions (Smith and Gross 2006, Posner et al. 2008, Smith et al. 2010). While high weed biomass generally has a negative effect on crop yield (Zimdahl 2004), some evidence exists that management-induced changes in weed species composition can also prevent potentially dominant weed species from reaching abundances where they reduce crop yield (Davis et al. 2005, Pollnac et al. 2009). There is limited evidence that more diverse weed communities may have less of an effect on crop yields than low diversity weed communities with a few dominant (and abundant) species (Smith and Gross 2006; see also Smith et al. 2010). However, experimental studies in grasslands have shown that more diverse communities can result in increased total productivity (Fargione and Tilman 2005), and every additional weed species occurring in the community increases the possibility of introducing a species that is highly competitive with the crop.

Cropping System Diversity and Yield

Species diversity is important in determining the productivity of unmanaged herbaceous communities, but what about managed systems? How does cropping system diversity, via crop rotation and cover crops, affect productivity and agronomic yields? An important component of an ecological framework for understanding crop production and other ecosystem services from agriculture involves understanding how cropping system diversity affects these services. The annual row-crop systems in the MCSE provide insights into the potential for biological processes (e.g., N-fixation or weed suppression by cover crops) to replace reliance on chemical inputs (e.g., pesticides and fertilizers) in row crops. However, they cannot be used to evaluate the role of cropping system diversity (via crop rotation or cover crops), because they differ in a variety of inputs and all follow the same crop rotation (Table 7.1). The Biodiversity Gradient Experiment was established to explicitly test the effects of crop species and diversity (Table 7.2), not only on yield but also on a suite of ecosystem variables. Because no fertilizers or pesticides are used in these treatments, variation in crop yield and other system responses is directly attributable to the number of different crops planted in the rotation (Smith et al. 2008), providing insight into the potential for biological processes (e.g., N-fixation or weed suppression by cover crops) to replace or reduce reliance on chemical inputs.

For the first 3 years of the Biodiversity Gradient Experiment, cropping system diversity showed no effect on the yield of any of the crops (Smith et al. 2008). But by the fourth year (2003), the number of species in the rotation had a significant effect on grain yield in corn (Fig. 7.7). Although the magnitude of this effect has varied annually, typically corn grain yields have been highest in the two highest diversity treatments (five and six species over a 3-year rotation; Fig. 7.7). In

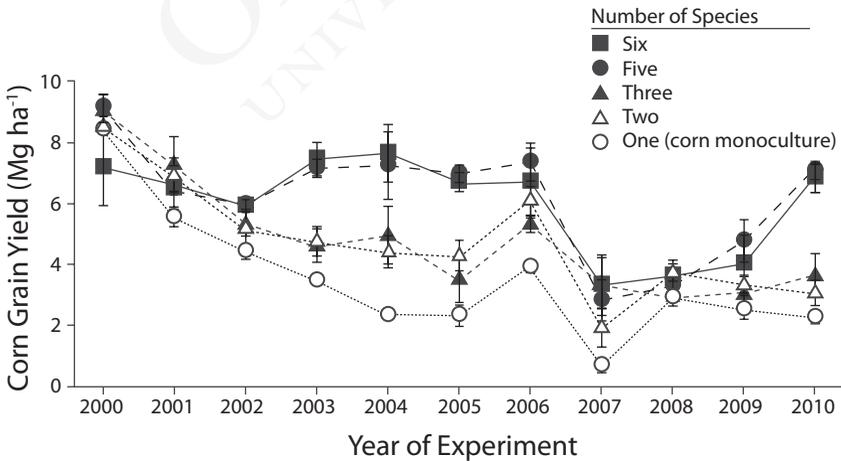


Figure 7.7. Effects of rotational diversity treatments on average annual corn grain yield from 2000–2010 in the Biodiversity Gradient Experiment. Treatments are coded based on the number of species in the rotation. Values are means \pm SE, $n = 4$. See Table 7.2 for description of treatments.

contrast, corn grain yield has steadily declined in the monoculture treatment over time ($R^2 = 0.56$). A severe drought in 2007 reduced yields in all treatments, but yields in the two highest diversity systems rebounded to predrought levels the next year (Fig. 7.7). This suggests that more diverse cropping systems (four to six species) may be more resilient (*sensu* Scheffer et al. 2001) to drought (and presumably other environmental perturbations) than continuous monocultures.

What causes these differences in overall yield and in capacity to recover from stress? That remains to be determined. Smith et al. (2008) proposed that the higher grain yield in corn, but not in other crops, may result from greater reliance on spring soil N levels, which tend to be higher in the more diverse cropping systems. Spring soil N levels and cropping system diversity are positively correlated, and the strength of the relationship depends on the number of legumes (grain crops and cover crops) in the rotation (Smith et al. 2008). Parker (2011) confirmed that soils from the more diverse corn treatments had higher N-mineralization rates, but in a greenhouse experiment detected no effect of N fertilizer on corn grown in soils from these different treatments, suggesting that some factor other than N must be responsible for reduced yields in less diverse cropping systems. Although disease and/or pest buildup can be a major concern in continuous monocultures, to date we have seen no evidence that pathogens and/or pests are higher in the less diverse systems. Instead, it may be that changes in the diversity and/or composition of the soil microbial community—and its ability to process carbon and nitrogen—are important determinants of corn grain yield across these treatments.

Other Factors Affecting Diversity and Productivity of Agricultural Landscapes

Landscape Structure and Community Composition

Landscape structure, past land use, and management history are increasingly recognized as important drivers of local species diversity that affect successional trajectories (e.g., Myster and Pickett 1993, Foster and Gross 1999), the restoration of native ecosystems (Suding et al. 2004, Gross and Emery 2007), and weed composition in crop fields (Poggio et al. 2010). Overcoming seed limitation may be as or more important than reestablishing natural disturbance regimes for the successful restoration of a native plant community (Suding et al. 2004, Suding and Gross 2006b, Houseman and Gross 2006, 2011). Intentionally seeding restoration areas with native species may be necessary to overcome their dispersal limitations and to increase the ratio of native to nonnative plants in these communities (Suding and Gross 2006b).

Past land use, the absence of fire, and changes in surrounding landscape diversity have all been shown to influence the composition and diversity of restored and successional grasslands in the U.S. Midwest. Although seed addition and fire are often used in grassland restoration (Leach and Givnish 1996), experimental studies in degraded grasslands near KBS found that neither fire nor seed addition alone increased native species richness. In some sites, fire increased the number

of nonnative species, but only when fire and seed addition were combined was there an increase in the number of native species relative to nonnatives (Suding and Gross 2006b).

Our understanding of how landscape factors regulate weed community dynamics and composition in agricultural systems is still in its infancy (Gabriel et al. 2005). Much of the research in this area has been conducted outside of the United States. In these studies, local plant species and genetic richness in agricultural fields have been shown to be strongly affected by processes operating at landscape scales, even across distances as short as 2 km (Gabriel et al. 2005, Poggio et al. 2010). Recent studies in the midwestern USA have found evidence that weedy species in the landscape surrounding an agricultural field may provide ecosystem services, such as biocontrol and pollinator services (Isaacs et al. 2009, Gardiner et al. 2009, Landis and Gage 2015, Chapter 8 in this volume). This has sparked interest in understanding how an agricultural landscape that supports multiple functions and ecosystem services can be established. Understanding the economic, social, and ecological processes to promote this type of landscape is an important focus of agroecological research in the United States (Jordan and Warner 2010).

Climate Change and Precipitation

At the global scale, there is a strong correlation between primary productivity and mean annual precipitation (MAP) in terrestrial plant communities in general (Melillo et al. 1993), and in grasslands in particular (Knapp and Smith 2001, Cleland et al. 2013, Robinson et al. 2013). How plant communities respond to altered precipitation patterns—particularly, increases in precipitation variability, as predicted by global change models—has heightened interest in this relationship (Knapp and Smith 2001, Huxman et al. 2004). Although in a cross-site analysis, Knapp and Smith (2001) found a positive correlation between aboveground net primary production (ANPP) and MAP across temperate biomes at a continental scale, they found no relationship between interannual variation in productivity and annual precipitation at the local scale. Their analysis revealed that some biomes—specifically, temperate grasslands—were more responsive to pulses (maxima) in precipitation than others and that this was driven by abundant, highly responsive species in ecosystems where precipitation and evapotranspiration were approximately balanced. A more recent cross-site synthesis (Cleland et al. 2013) across a broad range of grasslands showed that while species richness was strongly correlated with MAP, only the most xeric sites were responsive to interannual variation in MAP. Much of this response was driven by annual species whose emergence was sensitive to precipitation variation, suggesting that annual and perennial communities may respond differently to changes in precipitation variability.

Although the relationship between MAP and productivity is well studied in both grasslands and agricultural systems (e.g., Laurenroth and Sala 1992, Knapp and Smith 2001, Motha and Baier 2005), considerably less is known about how predicted changes in precipitation variability, particularly seasonal distribution, will affect not only productivity but other ecosystem processes as well (Cleland et al. 2013, Robinson et al. 2013). Only a few studies at KBS have manipulated

precipitation patterns directly (see Aanderud et al. 2011, Robinson 2011), but long-term data on precipitation and productivity across the broad range of MCSE plant communities provide insight into how the changes in precipitation patterns predicted for this region may influence their productivity and diversity. For example, in the untilled successional treatment of the Diversity by N-Fertilization Experiment, which is dominated by perennial species, MAP is positively related to ANPP in both unfertilized ($R^2 = 0.25$, $p < 0.025$) and fertilized ($R^2 = 0.14$, $p < 0.05$) plots. However, in the annually tilled plots where annual species dominate, there is no relationship, regardless of fertilizer addition. Instead of MAP, one might expect growing season precipitation to be a better predictor of ANPP in tilled communities because their growth is strongly controlled by tillage, which is a seasonal event. But it is not—there is no significant relationship between growing season precipitation (i.e., April–September) and ANPP. Precipitation totals during specific periods of the growing season prove to be better predictors of aboveground productivity than either annual and growing season totals (Robinson et al. 2013). It is not surprising that the amount of precipitation during specific life stages (e.g., germination) is a key driver for annual communities. Analyses of long-term data and of short-term manipulation experiments show that precipitation during the first weeks of the growing season has long-lasting effects on annual community development (Robinson 2011).

Only in the No-till system, which includes both annual and perennial weed species, is weed biomass related to precipitation variation (growing season: $R^2 = 0.44$; annual: $R^2 = 0.14$). The lack of a correlation between precipitation and weed biomass in the Conventional, Reduced Input, and Biologically Based cropping systems may result from differences in weed management (Table 7.1). All three include tillage as part of their management, although the timing and frequency of tillage events differ among them, whereas the No-till system relies only on herbicides for weed control. This difference between systems suggests that management, particularly the timing and implementation of weed control practices, affects the response of weed communities to external drivers such as variability in the amount and seasonal distribution of precipitation. The response, however, may be due more to changes in the composition of the weed community than in its total biomass.

That no relationship exists between annual or growing season precipitation and weed biomass in the row-crop systems or plant biomass in annually disturbed successional plots stands in direct contrast to the strong relationship observed in more water-limited systems (deserts and grasslands) (Noy-Meir 1973). In more mesic systems such as KBS, it is likely that the timing and intensity of precipitation events, as well as the intervals between them, impact productivity (Robinson et al. 2013). Climate shifts that affect the timing of snowmelt and the frequency and intensity of storms (Easterling et al. 2000, Weltzin et al. 2003, IPCC 2007) will likely affect productivity, as well as composition, of annual weed communities in agricultural systems. Annual communities may be particularly responsive to the frequency and intensity of precipitation events, as this can affect the timing and percentage of seed germination in annual species, which can differ in their response to variability in precipitation (see Pake and Venable 1996, Robinson and Gross 2010, Robinson 2011). Because the germination of

many annual weed species varies with temperature and moisture (Baskin and Baskin 1999), understanding how early season precipitation and temperature interact with tillage (disturbance timing and frequency) is important for determining how climate change may affect the composition and abundance of weed species in row crops.

Summary

Understanding the processes that determine the diversity and productivity of plant communities remains an important challenge in plant community ecology, and is fundamental to the sustainable management of agroecosystems. In this chapter, we have focused primarily on comparisons of ecological processes in annual row crops (corn, soybean, and wheat) and successional fields, which are important components of the agricultural landscape of the upper U.S. Midwest.

Research at the KBS LTER has shown that agroecosystems and successional grasslands generally conform to our understanding of how disturbance and nutrient availability interact to determine productivity and species diversity in terrestrial plant communities. Disturbance, whether caused by tillage or herbicide use, has a very strong effect on plant community composition in both the Early Successional community and the weed communities of annual row crop systems. Fertilization generally increases production and decreases species diversity in grasslands (Gough et al. 2000, Clark et al. 2007), and while nutrient inputs certainly increase crop yield, the nutrient source (inorganic or legume-based) confounds our interpretation of the fertilizer effect of the abundance and composition of weed communities. This constrains our ability to use results from unmanaged successional grasslands to predict how crop grain yield or weed biomass will respond to particular changes in agricultural management. However, research on the ecology of weeds in agricultural ecosystems may provide insights into how to manage invasive species in remnant, degraded, or restored ecosystems (Smith et al. 2006).

Our experiments on row-crop and successional systems at the KBS LTER have provided important insights into the mechanisms by which diversity may influence crop yield. For example, studies of seed bank dynamics in the MCSE annual row-crop systems have shown that disturbance and fertilization interact with soil biota to influence seed mortality (Davis et al. 2005). Although this mechanism has not been widely explored in natural plant communities, it may be among the plant–soil feedbacks (Bever et al. 2010) that can be managed in reduced input or organic cropping systems. Findings such as these can lead to the development of management practices that rely less on chemical inputs and more on manipulation of ecosystem processes. These insights inform future research on factors influencing plant communities in sustainable agricultural systems, as well as natural systems. However, while there is growing evidence of the importance of regional species pools and other landscape factors to the composition and diversity of grassland communities, considerably less is known about how these regional processes influence the composition of weed communities.

Predicting how species and communities will respond to changes in global climate (particularly, temperature and precipitation patterns) remains one of the grand challenges in ecology. Improving our ability to make these predictions has important consequences for agriculture because climate changes are likely to affect crop production not just directly, but also indirectly by affecting the type and abundance of pests. As crops become either more intensively managed or more widely planted across the landscape to meet increasing demand for food and fuel, we will be challenged to better understand how landscape factors influence the dynamics of plant communities in agricultural landscapes. Increasing temporal variability in precipitation and other environmental factors may make it more difficult to manage these systems and to predict how they will respond to changes in both biotic and abiotic drivers, including crop management practices. The work to date at the KBS LTER—and cross-site syntheses to place it in a continental scope—provides a context for further investigation on how plant communities in agricultural landscapes can be managed to provide a wide range of ecosystem services.

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