Cover Crop Mixture Diversity and its Effects on Biomass Production, Weed Suppression, Soil Fertility, Soil Microbial Biomass and Community Structure, and Performance Stability

Final Report for GNC13-182

Project Type: Graduate Student
Funds awarded in 2013: $10,000.00
Projected End Date: 12/31/2015
Grant Recipient: University of Nebraska-Lincoln
Region: North Central
State: Nebraska
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Project Information

Summary:

This study evaluated the effect of cover crop mixture diversity on biomass productivity, weed suppression, nutrient cycling, soil microbial community characteristics, and stability of biomass productivity. Up to forty cover crop treatments—a no cover control, eighteen species in monoculture, and twenty-one mixtures—were planted at eleven sites in Nebraska. While increasing diversity was associated with increased average productivity it was not associated with increased potential productivity. While increasing cover crop mixture diversity was often correlated with increases in weed suppression, nutrient retention, soil microbial biomass, and stability, once variations in biomass productivity were controlled for, these apparent associations disappeared.

Introduction:

The diversity-productivity hypothesis proposes that greater diversity should lead, on average, to greater total biomass productivity (Tilman, 2001). The diversity-invasibility hypothesis proposes that greater diversity should lead to increased resistance to invasion (Elton, 1958).

Both of these hypotheses are predicated on the hypothesis that more diverse systems capture more resources through niche complementarity than less diverse systems. It’s by capturing a greater amount of available resources it is thought that diverse mixtures might be both more productive and more resistant to invasion.

The diversity-stability hypothesis proposes that more diverse systems are more stable systems (Tilman, 2001). This hypothesis is based on the idea that if one species fails in a certain context, another species might be able to compensate for it in a mixture.

The increased abundance hypothesis proposes that increasing plant mixture diversity should increase soil microbial biomass while the altered microbial community hypothesis proposes that it should also alter soil microbial community structure predictably (Chapman and Newman, 2010). These hypotheses are predicated on the idea that the litter of different plants will provide different kinds of habitats and resources for soil microbes—supporting both more of them and a wider variety of them.

The goal of this study was to test all of these hypotheses in the context of cover crop mixtures—that is, to ask the question: “Does increasing cover crop mixture diversity (1) increase average biomass productivity, (2) increase weed suppression, (3) increase nutrient uptake and therefore soil nutrient retention, (4) increase soil microbial biomass and alter soil microbial community structure predictably, and (5) increase the stability of biomass productivity?”

Chapman, S. K., and G. S. Newman. 2010. Biodiversity at the plant-soil interface: microbial abundance and community structure respond to litter mixing. Oecologia 162:753-769.

Elton, C.S. 1958. The ecology of invasions by plants and animals. Chapman and Hall, London, UK.

Tilman, D. 2001. Functional Diversity. p. 109-121. *In* S. A. Levin (ed) Encyclopedia of Biodiversity, Vol. 3. Academic Press: Waltham, MA.

Project Objectives:

The primary objective of this study was to evaluate the effect of cover crop mixture diversity on a variety of parameters pertaining to the function of a cover crop. Specifically, this study evaluated the effect of cover crop species and functional richness on productivity, weed suppression, nutrient cycling, soil microbial community structure and stability.

The performance targets of this study were to share the findings of this study through presentation at academic conferences, presentation at farmer-oriented conferences, publication in scientific journals, and publication in popular press formats.

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Research

Materials and methods:

Twenty to forty cover crop treatments were replicated three to four times at eleven sites across southeastern Nebraska using a pool of eighteen species representing three cover crop species each from six pre-defined functional groups: cool season grasses (barley, oats, wheat), cool season legumes (Austrian winter pea, red clover, yellow blossom sweetclover), cool season brassicas (radish, rapeseed, turnip), warm season grasses (proso millet, sorghum sudangrass, teff), warm season legumes (chickpea, cowpea, sunn hemp), and warm season broadleaves (buckwheat, safflower, sunflower).

Each species was planted in monoculture and the most diverse treatment contained all eighteen species. The rest of the treatments represented intermediate levels of species and functional richness. Additionally in order to address the effect of sampling bias—i.e., the increased probability of a high impact species at higher levels of diversity—each species was equally represented at each level of species and functional richness.

Cover crop monoculture seeding rates were based on recommended broadcast rates (Clark, 2007). Cover crop mixture seeding rates were proportional to the rates used in monoculture. For example, in a three species mix, each species was planted at one-third the full rate listed.

Of the eleven sites planted, two were on the property of the University of Nebraska and the remaining nine were on the property of farmer cooperators.

Cover crop planting dates ranged from July 19 to September 20 with species specific biomass being taken approximately two months after each planting date.

Biomass productivity was assessed at the seven sites with cover crop establishment. Weed suppression was assessed at the three of those sites that also had weeds present. Soil nutrient cycling and soil microbial community characteristics were assessed at the site with the best combination of large amounts of cover crop biomass but relatively minimal weed presence. Stability was assessed by evaluating variation in cover crop biomass productivity across sites and across plots within each site.

The soil samples taken to characterize soil nutrient cycling and soil microbial characteristics were taken the spring after cover crop winterkill and prior to the planting of the next crop. Soil samples taken from 0-10, 10-20, 20-30, and 30-60 cm were analyzed for extractable nitrate, phosphorus, potassium, chloride, and sulfate. Soil samples taken from 0-10 cm were additionally subjected to fatty acid methyl esters (FAMEs) extraction to estimate soil microbial biomass and characterize soil microbial community structure.

Clark, A., editor. 2007. Managing Cover Crops Profitably. 3rd ed. Sustainable Agriculture Network, Beltsville, MD.

Research results and discussion:

Increases in cover crop mixture diversity were positively correlated with increased biomass productivity. However, I argue that this was the simple result of the average performance of monocultures (and to a lesser extent, low diversity mixtures) being drawn down by low yielding species—rather than the result of the more complex mechanisms frequently cited in the diversity-productivity literature—i.e., niche complementarity and increased resource use efficiency. At none of the sites was there an instance where a mixture produced significantly more than the highest yielding monoculture at that site.

Increasing cover crop biomass was associated with increased weed suppression, increased nutrient retention of the relatively mobile nutrients (nitrate, sulfate, and chloride), increased soil microbial biomass, altered soil microbial community structure, and increased stability. Since increasing cover crop mixture diversity was correlated in this study to increased cover crop biomass, it appeared in many instances that cover crop mixture diversity was positively related to these metrics of cover crop function. However, once we took into account variations in productivity between the treatments, the apparent effects of cover crop species and functional richness on these parameters disappeared.

That is, a productive monoculture had just as much of an effect on weed suppression, nutrient retention, soil microbial biomass, soil microbial community structure, and stability as a productive mixture.

Participation Summary

Educational & Outreach Activities

PARTICIPATION SUMMARY:

Education/outreach description:

Florence, A., and J. L. Lindquist. 2016. Cover crop mixture diversity and nutrient cycling. Paper scheduled to be presented at: UMN Production Agriculture

Symposium. Cover Crops: Economic and Environmental Management. Falcon Heights, MN. 22 Mar. 2016.

Florence, A., and J. L. Lindquist. 2015. Cover crop mixture diversity and biomass production. Paper presented at: ASA, CSSA, and SSSA Annual Meeting, Minneapolis, MN. 15-18 Nov. 2015.

Florence, A., and J. L. Lindquist. 2015. Cover crop mixture diversity and weed suppression. Paper presented at: ASA, CSSA, and SSSA Annual Meeting, Minneapolis, MN. 15-18 Nov. 2015.

Tran, A., and J. L. Lindquist. 2014. Effect of cover crop mixture species and functional diversity on cover crop biomass production and weed suppression. Paper presented at: Soil Water Conservation Society Annual Conference, Lombard, IL. 27-30 July 2014.

Tran, A. 2014. Research explores potential benefits of mixing cover crops. Organic Broadcaster. July/August 2014.

Tran, A., and J. L. Lindquist. 2014. Cover crop mixture diversity, biomass production, and weed suppression. Poster presented at: MOSES Organic Farming Conference. Lacrosse, WI. 27 Feb. - 1 Mar. 2014.

Manuscripts in Preparation

Florence, A. 2016. Cover crop mixture diversity and function. Ph.D. diss., Univ. of Nebraska, Lincoln, NE.

Florence et al. 2016. Cover crop mixture diversity and biomass productivity.

Florence et al. 2016. Cover crop mixture diversity and weed suppression.

Florence et al. 2016. Cover crop mixture diversity and nutrient cycling.

Florence et al. 2016. Cover crop mixture diversity and soil microbial biomass and community structure.

Florence et al. 2016. Cover crop mixture diversity and stability.

Florence et al. 2016. Untangling the effects of cover crop mixture diversity.

Project Outcomes

Project outcomes:

In the initial proposal for this study, we listed three general targeted outcomes.

1. To increase awareness, knowledge, and skills regarding the use and management of cover crop mixtures among farmers and researchers. In this objective, we have met with reasonable success. The three oral presentations given on the topic in academic settings have been met with good attendance and audience engagement with an additional academic presentation being scheduled for March 2016. As for sharing the results of this study with farmers, parts of this work were shared early on with farmers through a conference and a popular press article. Now that the study is complete, further sharing of the results with farmers is planned through an electronically available extension

publication, which will summarize all findings.

2. To increase the adoption of cover crop mixtures into agricultural systems. In hindsight, this outcome seems naïve because it presumes that adopting cover crop mixtures is desirable regardless of context. There's no evidence that this study has increased the adoption of cover crop mixtures into agricultural systems, but in retrospect this isn't necessarily a desirable outcome. What we have shown with this study is that many of the benefits of cover cropping can be obtained with a single species of cover crop.

3. To stimulate further study into the relationship between diversity and function. Through four conference presentations we have started an interesting conversation about how the relationship between diversity and function is traditionally researched and interpreted. Once we publish our five planned scientific articles, I think we'll inspire some re-evaluation of past diversity-function research as well as interesting further research.

Farmer Adoption

It's difficult to estimate the number of farmers reached by this project but the opportunities to reach farmers rested primarily in presentation at one farmer oriented conference (2014 MOSES Organic Farming Conference) and publication in one popular press article (Organic Broadcaster, July/August 2014 Issue). Additional plans to share this research with farmers include one electronically available extension publication, which will summarize all the findings of this study.

As for specific recommendations to farmers, the data indicates that many of the effects of cover crops (i.e., weed suppression, soil nutrient retention, soil microbial biomass increase) are positively related to cover crop biomass productivity. To manage cover crop biomass productivity, we recommend focusing on species selection, seeding date, planting conditions, and to a limited extent, seeding rate.

Recommendations:

Areas needing additional study

1. BIOMASS PRODUCTIVITY. Seeding rate studies for cover crop species to improve current recommended seeding rates. This information would be helpful in understanding diversity-productivity relationships, which may be driven in part by the relationship between seeding rate and biomass productivity.

2. WEED SUPPRESSION. Studies characterizing factors affecting weed suppression abilities of winterkilled cover crops. This study looked only at weed suppression during the growth of the cover crops. A natural extension of this research would be to look at how winterkilled cover crops suppress weeds in the subsequent spring and summer.

3. NUTRIENT CYCLING. Studies characterizing factors that affect soil nutrient retention capacity of cover crops. While this study showed that increasing cover crop biomass increased the retention of nitrate, chloride, and sulfate, there was still a lot of unexplained variability in the soil nutrient retention data. What might other factors that determine the magnitude of cover crop soil nutrient

retention be?

4. SOIL MICROBIAL BIOMASS & COMMUNITY STRUCTURE. Meta-analysis evaluating the effect of plant species on soil microbial biomass and community structure (controlling for variations in plant productivity). Past studies have concluded that different plants have different effects on soil microbial biomass and community structure, but these studies overwhelmingly do not take into account variations in productivity between plants. This study showed that once variations in productivity were taken into account, there was no consistent effect of plant type on soil microbial biomass or community structure. I suggest a meta-analysis that revisits these studies and takes into account variations in plant productivity.
5. STABILITY. Meta-analysis evaluating the effect of diversity on stability (controlling for variations in plant productivity). Many studies have concluded that intercrops are more stable than monocultures and more diverse mixtures are more stable than less diverse mixtures, but these studies mostly do not take into account the effect of productivity on stability. That is, these studies ignore the fact that stability tends to increase with increasing biomass. I suggest a meta-analysis that revisits these studies and takes into account the effect of productivity on stability.