CROPPING ALFALFA TO ENHANCE ABOVE AND BELOWGROUND BIODIVERSITY

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ABSTRACT

Biodiversity is a key factor to maintain healthy, resilient, and stable cropping systems. As biodiversity decreases, cropping systems are more susceptible to biotic and abiotic stresses that can lead to reduced productivity and detrimental effects to the environment. Alfalfa (*Medicago sativa* L.) is a key component in crop rotations offering numerous ecosystem services including enhanced above and belowground biodiversity. Aboveground, the high protein content in alfalfa leaves attracts many arthropods, including predators of insect's pests and pollinators. Many other arthropods live below the alfalfa's canopy such as ground beetles, spiders, and crickets to mention a few, which provide many functions to the microecosystem. Researchers have shown that species number and diversity is greater for ground arthropods in alfalfa than in other annual crops. Belowground, the ability of alfalfa to fix atmospheric N_2 in symbiosis with *Sinorhizobia* and other microbial communities increases the availability of nutrients for crops, soil microarthropods, and microbes. Biogeochemical processes in the soil are driven by different groups of bacteria and fungi. These processes alter the soil structure promoting soil aggregation, which in turn provides a habitat for different functional groups of microorganisms ultimately responsible for overall soil health. Previous research has found that cropping systems including alfalfa have significantly greater fungal and bacterial biomass, diversity index, and richness in the soil compared with cropping systems including annual crops such as corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.]. Although efforts to integrate alfalfa into cropping systems are underway, greater efforts are needed to disseminate the benefits of including alfalfa in crop rotations to growers.

Key Words: alfalfa, biodiversity, arthropods, pollinators, soil microbiome

INTRODUCTION

Biodiversity is defined as all the different kinds of living organisms you find in one area, including plants, animals, fungi and microorganisms like bacteria. Biodiversity is a key factor to maintain a healthy, resilient, and stable cropping system. As biodiversity decreases, cropping systems are more susceptible to biotic and abiotic stresses that can lead to reduced productivity and detrimental effects to the environment. Alfalfa offers numerous ecosystem services including biodiversity restoration (Baldwin-Kordick et al., 2022).

Prior to the 1970's, crop rotations in the Midwest U.S. generally included 5-8 crops with alfalfa as a main component of the rotation (Aguilar et al., 2015). However, as conventional intensification of crop production shifted to short-rotations of row crops that rely heavily on

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chemical fertilizers and pesticides, technological improvements, and market forces, diversity drastically declined in rotational cropping systems. Compared with other regions in the USA, the Midwest Corn Belt Region currently has the least crop diversity and the steepest decline in diversity since 1978 (Aguilar et al., 2015).

In addition to the importance of alfalfa in human food production (milk, meat, cheese, etc.), alfalfa also is at the beginning of the food chain that supports many types of arthropods (insects, spiders, mites, and others), small herbivores such as ground squirrels and mice, and large mammals such as deer (Putnam et al. 2001). Indirectly, many other species including birds, mammals, reptiles, and others feed on the small herbivores that feed on alfalfa, which is usually the only crop that is green in the late fall and early spring when no other crop is available for feed. The year-round cover of alfalfa also provides important habitat for many insects, birds, mammals, and others. In California, for example, 182 species of birds, mammals, amphibians and reptiles were observed using the alfalfa crop and borders of fields for feeding, reproduction, or cover (Putnam et al., 2001).

Niemuth et al. (2021) demonstrated that non-native planted cover such as alfalfa can substantially enhance pollinators providing nectar sources and serving as a buffer from pesticides associated with croplands. The high protein content in alfalfa leaves and the cover provided by the canopy attracts many arthropods, including many predators of insect's pests. In fact, beneficial insects compose 99% of the insects present in the alfalfa canopy with pests representing only about 1% (Putnam et al., 2001). Alfalfa is a cross pollinated plant and its flowers attract many pollinators providing them with pollen and nectar (Fig. 1). However, in alfalfa hay production areas where alfalfa is generally cut at late bud or early blooming, alfalfa does not contribute to increase the diversity of pollinators (Mogren et al., 2016). Many other arthropods live below the alfalfa's canopy such as ground beetles, spiders, and crickets, to mention a few and provide many functions to the microecosystem. Researchers have shown that species number and diversity of ground insects and spiders is greater in alfalfa than in other annual crops. In fact, researchers in California have identified over 1000 species of arthropods inhabiting alfalfa fields (Putnam et al., 2001).

Belowground, microarthropods, earthworms, and microorganisms thrive in alfalfa fields and contribute to soil health. The ability of alfalfa to fix atmospheric N_2 in symbiosis with *Sinorhizobia* and its association with arbuscular mycorrhizal fungal (AMF) communities increases the availability of nutrients for alfalfa, crops that follow in the rotations, and soil microarthropods and microorganisms. The rhizosphere (area surrounding the roots) of alfalfa has trillions of microorganisms, 10 to 100 times more than in the soil not associated with the root system (Putnam et al., 2001). The biological activity in the root rhizosphere increases due to the release of nitrogen- and carbon-rich exudates from alfalfa. However, changing the cropping system can alter microbial communities with specific functions such as N_2O reduction to N_2 (Graf et al., 2019). For example, intercropping alfalfa with orchardgrass (*Dactylis glomerata* L.) increased N_2O emissions compared with either crop alone. This resulted from the shift of rhizosphere bacterial communities towards incomplete denitrifiers rather than N_2O reducers (Graf et al., 2019).

Important biogeochemical process occurring in the soil are driven by different groups of bacteria and fungi. These processes are critical for altering soil structure and promoting soil aggregation, which in turn provides habitat for different functional groups of microorganisms that are ultimately responsible for overall soil health (Potter et al., 2021). In addition, the higher diversity index in topsoil due to greater belowground C from alfalfa serves as source material for microbes and reduces vulnerability of communities to tillage.

Previous research has found that cropping systems including alfalfa have significantly greater fungal and bacterial biomass, diversity index, and richness in the soil compared with cropping systems including annual crops such as corn and soybean (Niu et al., 2020; Potter et al., 2022). A different study reported a 62% increase in microbial biomass after 4 years in a rotation including two years of alfalfa and manure application (Baldwin-Kordick et al., 2022). Niu et al., (2020) concluded that 14-years of continuous alfalfa had greater microbial biomass, Shannon-Wiener diversity index and richness at 0-30 cm and 30-60 cm, and functional diversity compared with a 4-5 years of annual crops wheat (*Triticum aestivum* L.)-corn-potato (*Solanum tuberosum* L.) and millet (*Panicum miliaceum* L.).

In addition, alfalfa suppresses weeds that are common in annual crops, by shading them or avoiding seed production by the frequent cuttings. Weed suppression can lead to less use of herbicides benefiting other organisms in the microecosystem. The use of chemical products reduces the diversity of organisms in plants and soils, and limiting chemical use also reduces herbicide-related aquatic toxicity (Liebman et al., 2021). Diversity in the soil weed seed bank can be used as an indicator of cropping system sustainability, with greater diversity indicating greater sustainability in comparison with a less diverse weed seed bank. Liebman et al. (2021) reported that going from a 2-year to 4-year rotation including 2 years of alfalfa increased weed seed bank diversity.

Increasing the acreage of alfalfa in rotation with other crops is needed to reduce the negative environmental effects of row crop monocultures. Many farmers are reluctant to grow alfalfa because they do not have cattle, equipment required to cut and bale alfalfa, and a market to sell the hay. However, there are creative ways to integrate alfalfa into cropping systems. For example, even just adding alfalfa to the non-productive headlands, which have low yield of corn or soybean anyway, can benefit wildlife and soil health. Many growers are starting to plant alfalfa in headlands and usually neighbors are interested in harvesting and taking the hay. With many states under moderate to severe drought conditions any hay is valuable and can be sold.

Preliminary Results of Arthropods Biodiversity in Different Crops in North Dakota

A study was conducted in Hickson and Prosper, ND in the summer of 2022. One of the objectives was to evaluate the biodiversity of arthropods in alfalfa in comparison to summer fallow (no crop), soybean, corn, wheat, forage sorghum (*Sorghum bicolor* L.) and sunflower (*Helianthus annuus* L.) Insects were recorded weekly using pitfall traps for crawling arthropods and sticky traps for flying insects (Fig. 2). Pitfall traps consisted of a cup placed in the soil at soil level with a cover that only left about 2-cm space between the cup surface and the lid. The sticky traps were all placed 60-cm above the soil on a stick (Fig. 2).

In the pitfall traps, 30 different families of arthropods were collected among all crops and at both locations, but the number of families in each crop ranged between 6-7 for all crops. Four families of arthropods accounted for 98% of the collected specimens averaged across locations and crops (Fig. 3). Insects in the Gryllidae and Carabidae families declined over time in all crops while those in the Phlocideae and Sciaridae families increased at the end of the growing season. Phlocidae are a family of araneomorph spiders commonly known as cellar spiders, whereas Sciaridae are a family of flies known as dark-winged fungus gnats. The increase of these last two families at the end of the season is likely related to the presence of dead plant material, since several crops had been harvested by the last three recordings with only residues left in the field. Wheat had the greatest number of specimens collected through the summer (Fig. 4). The last collection on 29 September was equal for all crops. Interestingly, the greater number of collected insects in wheat was due to crickets (Gryllidae) and ground beetles (Carabidae) inhabiting the under canopy of wheat (Fig. 5). Both families of insects declined over time, which might be related to the plant senescence at the end of the season or drier conditions that interrupt the insect's life cycles. The sticky traps in treatments including corn, sorghum, alfalfa, and corn-alfalfa and sorghum-alfalfa intercropping are yet to be analyzed but visual observation indicates greater diversity of arthropods in alfalfa than in corn and forage sorghum monoculture (Fig. 6).

In conclusion, these preliminary results show a trend of increased diversity of arthropods in alfalfa compared with other annual row crops. However, variation in insect's population and diversity is probably also related to other factors such as temperature, rainfall, crop's growth stage and insect's life cycle. The study will be repeated in 2023 at two locations.

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Figure 1. Pollinators visiting alfalfa flowers (Photos, Marisol Berti)

Figure 2. Soil pitfall traps and sticky traps (Photos of sticky traps, Anastasia Kurth).

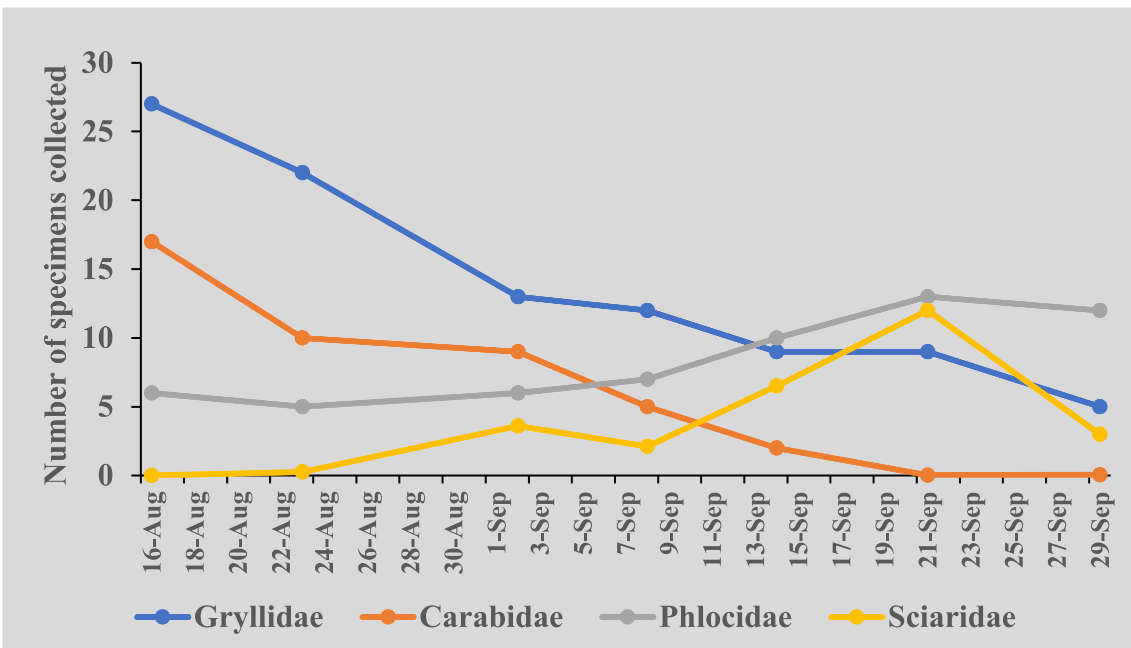

Figure 3. Number of specimens collected weekly in four families averaged across all crops.

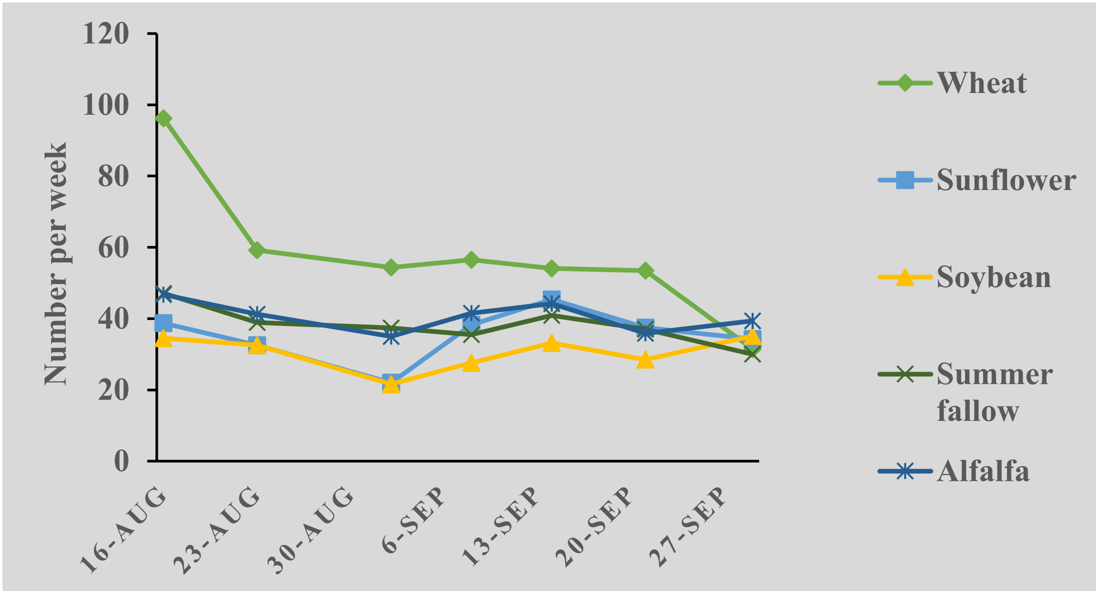

Figure 4. Total number of arthropods by sampling date in pitfall traps averaged across locations

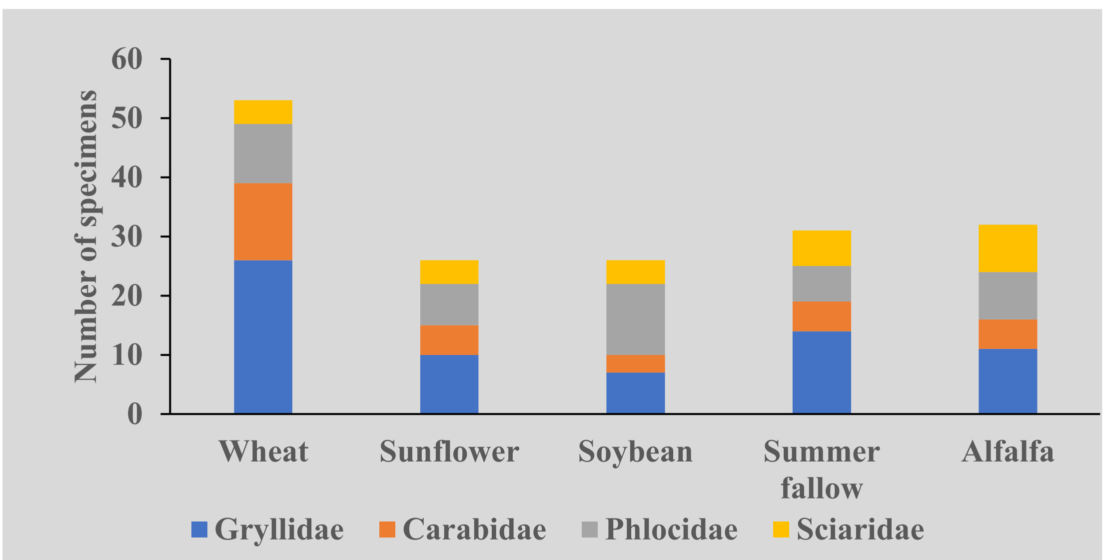

Figure 5. Number of specimens in each crop by family averaged across locations.

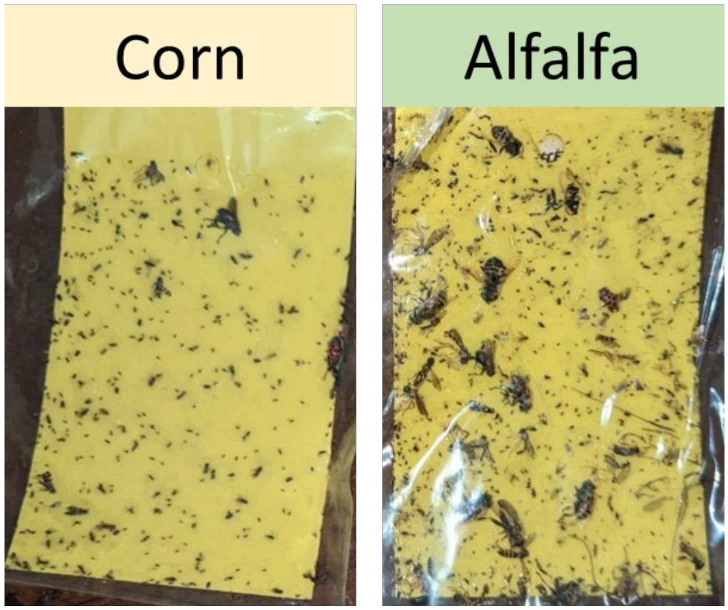

Figure 6. Diversity of insects collected on sticky traps in corn and alfalfa (Photos, Haley Mosqueda).