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Arthropod Diversity Varies with Distance from On-Farm Floral Enhancements at Small Spatial Scales[1]

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Agricultural expansion negatively affects on-farm biodiversity, ecosystem services, and soil health (Kremen 2020, Emerg. Top. Life. Sci. 4: 229–240; Semper-Pascual et al. 2020, Biodivers. Conserv. 29: 3669–3688; Xue et al. 2022, Agric. Ecosyst. Environ. 339: 108118). Specifically, the conversion of natural lands to agricultural lands decreases arthropod diversity and is one of the primary drivers of insect declines globally (Bellamay et al. 2018, Environ. Sci. Pollut. Res. 25: 13426–13438; Outhwait et al. 2022, Nature 605: 97–102; Redhead et al. 2020, J. Environ. Manage. 265: 110550; Sanchez-Bayo and Wyckhuys 2019, Biol. Conserv. 232: 8–27). Losses in insect and other arthropod diversity and abundance, particularly of arthropod pest natural enemies and pollinators, can drive subsequent losses in ecosystem services in farmscapes (Rusch et al. 2016, Agric. Ecosyst. Environ. 221: 198–204; Steffan-Dewenter and Tscharntke 1999, Oecologia 122: 432–440). Agricultural intensification practices, such as monocropping, limit on-farm habitat resources for beneficial arthropods and have been shown to decrease both pollination services to pollinator-dependent crops and natural enemy control of crop pests (Connelly et al. 2015, Agric. Ecosyst. Environ. 211: 51–56; Geiger et al. 2010, Basic Appl. Ecol. 11: 97–105). Such changes in arthropod communities and losses in the ecosystem services they provide have the potential to drive yield declines in some cropping systems. On-farm habitat

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enhancements have been explored as a tool for combating losses in biodiversity and ecosystem services associated with agricultural expansion and intensification.

On-farm habitat enhancements are commonly implemented as adjacent natural habitats, hedgerows, untilled field margins, and floral enhancements (Sidhu and Joshi 2016, Front. Plant Sci. 7: 363). Emphasis has been placed on enhancing plant diversity on farms, which is thought to be highly effective in mitigating losses in ecosystem services by providing beneficial arthropods with consistent food and habitat resources (Letourneau et al. 2011, Ecol. Appl. 21: 9–21). Previous work has shown that floral enhancements increase the prevalence of pollinators and beneficial predators and parasitoids in nearby target crop fields (Kremen et al. 2018, Front. Ecol. Evol. 6: 170). Within a farm, proximity to floral enhancements strongly affects beneficial arthropod communities such as pollinators in the target crop (Heller et al. 2019, Sci. Rep. 9: 17232), and one review suggests that floral plantings should be placed within 500 m of target crops to elicit positive impacts on the arthropod community (Fountain 2022, Insects 13: 304). However, many arthropods are central-place foragers that cover very short distances. For example, some species of small, solitary bees have foraging distances of $<$150 m (Hofmann et al. 2020, J. Hymenopt. Res. 77: 105–117; Zurbuchan et al. 2010, Biol. Conserv. 143: 669–676;). Additionally, the abundance and diversity of flying pollinators have been shown to drop by more than 80% at a 500-m distance from natural habitat, resulting in drastic pollination declines in a target fruit crop (Carvalheiro et al. 2010, J. Appl. Ecol. 47: 810–820). Densities of predators and parasitoids have also been shown to significantly differ between plots that were 0–60 m or 60–120 m from natural habitat, indicating that small distances from habitat enhancements may have a significant impact on these groups as well (Miliczky and Horton 2005. Biol. Contr. 33: 249–259). However, many studies examining the effects of habitat enhancements on arthropod communities in target crops are not done at the relatively small spatial scales that may affect some important arthropod groups (Fountain 2022). Our goal is to better inform the placement of floral enhancements within farmscapes by assessing the potential distance effects of on-farm floral enhancements on arthropod communities at a fine spatial scale.

To evaluate the influence of distance from on-farm floral enhancements to target crops on arthropod communities, we assessed arthropod community diversity, richness, and composition in six target crop plots at varying distances from a 90-m^2 floral enhancement. All plots were established at the University of Arkansas Milo J. Shult Agricultural Research & Extension Center in Fayetteville, AR. Sampled target crop plots were established at varying distances from the floral enhancement such that the nearest edges of the plots were 5, 11, 17, 58, 74, and 90 m from the floral enhancement. Each distance was represented by a plot that was sampled 14 times during the study period. Target crop plots were composed of 30–32 m^2 of established rows of common *Brassica* crops, either Jersey kale, kale, or Swiss chard. Arthropod communities within target crop plots were assessed by counting the number of individuals within a taxonomic family observed within each plot two to three times per week for a period of 5 weeks from 12 July to 19 August 2022.

The floral enhancement was established by sowing the 90-m^2 plot with a seed mix (Insectopia, Prairie Moon Nursery, Prairie Moon, Winona, MN). This seed mix was composed of 60.4% by wt. wildflower seeds and 39.6% by wt. grasses, sedges, and rushes. The five wildflower species with the greatest percent by weight in the seed mix were partridge pea (*Chamaecrista fasciculata* [Michx.] Greene) (11.96% by wt.), lance-leaf coreopsis (*Coreopsis lanceolata* L.) (5.79% by wt.), golden alexanders (*Zizia aurea* L.) (4.4.8% by wt.), early sunflower (*Heliopsis helianthoides* L.) (3.74% by wt.), and purple prairie clover (*Dalea purpurea* Vent.) (3.36% by wt.). The grasses, sedges, and rushes included in the seed mix were little bluestem (*Schizachyrium scoparium* [Michx.] Nash) (16.44% by wt.), side-oats grama (*Bouteloua curtipendula* [Michx.] Torr.) (7.47% by wt.), Canada wild rye (*Elymus canadensis* L.) (5.98% by wt.), rough dropseed (*Sporobolus compositus* [Poir.] Merr.) (5.98% by wt.), and field oval sedge (*Carex molesta* Mack.) (3.74% by wt.). The seeds were planted at a rate of 9.37 kg/ha during fall 2021, and the floral enhancement plot was flowering during the duration of the observation period for this study. During the sampling period, observed blooming flowers included early sunflowers and purple prairie clover.

All observed arthropod families in target crop plots were classified as being neutral, pests, or beneficial to *Brassica* crops. We calculated the proportion of *Brassica* pests and beneficials observed in each plot on each day as the number of pests or beneficial individuals observed divided by the total number of individuals observed. We also calculated the total arthropod richness and Shannon diversity for each plot on each day. We assessed the responses of richness and diversity to distance from the floral enhancement using separate linear mixed-effects models that included distance as a fixed effect and date of collection as a random effect. We assessed the proportion of pests and beneficials using separate generalized linear models that included distance as a fixed effect and date of collection as a random effect and used a beta distribution, which is appropriate for modeling proportions (Douma and Weeden 2019, Methods Ecol. Evol. 10: 1412–1430; Ferrari and Cribari-Neto 2004, J. Appl. Stat. 31: 799–815). Because beta distributions cannot handle values equal to 0 and 1, we performed a data transformation by adding 0.00001 to all proportions equal to 0 and subtracting 0.00001 from all proportions equal to 1 (Douma and Weeden 2019). All statistical analyses included data collected from target crop plots. All analyses were completed in R Version 4.2.2.

The five most observed arthropod families in the target crop plots were Pentatomidae, Cicadellidae, Meloidae, Coccinellidae, and Noctuidae (Table 1). Of these five commonly observed families, only Coccinellidae are definitively not pests of *Brassica*. Although we did not identify all individuals to species, we noted that *Murgantia histrionica* (Hahn) (Hemiptera: Pentatomidae), *Epicauta vittata* (F.) (Coleoptera: Meloidae), and *Trichoplusia ni* (Hübner) (Lepidoptera: Noctuidae), all known pests of *Brassica* crops, were commonly observed in the target crop plots.

There was a marginally significant decrease in arthropod diversity (estimate = -0.003, $P = 0.059$) with distance from the floral enhancement (Fig. 1). There was no effect of distance from the floral enhancement on overall arthropod richness (estimate = -0.005, $P = 0.410$), the proportion of pest arthropods (estimate = -0.001, $P = 0.770$), or the proportion of beneficial arthropods (estimate = 0.001, $P = 0.864$) observed within the plots. The mean diversity and richness of arthropod communities sampled in plots were 0.689 and 3.429, respectively.

Table 1. Number of individuals observed in target crop plots organized by distance from the enhancement. Counts are the numbers of individuals recorded across all observation days.

Observed Families	Arthopod Count at Different Distances						Target Plots Total
	5 m	11 m	17 m	58 m	74 m	90 m	
Acrididae	19	0	3	0	1	0	23
Aphididae	0	0	0	0	0	0	0
Apidae	0	0	0	1	0	0	1
Berytidae	0	0	1	0	0	0	1
Cantharidae	1	2	0	0	0	0	3
Chrysomelidae	8	12	8	9	8	8	53
Chrysopidae	0	0	0	0	0	1	1
Cicadellidae	58	69	74	5	7	7	220
Coccinellidae	3	6	3	31	16	13	72
Coreidae	0	0	1	24	3	0	28
Crambidae	0	1	0	0	0	2	3
Curculionidae	2	0	0	1	0	0	3
Cydnidae	0	0	0	0	1	0	1
Dolichopodidae	1	8	5	1	2	0	17
Drosophilidae	0	0	0	0	1	0	1
Elateridae	0	0	0	1	0	0	1
Geometridae	1	0	0	0	0	0	1
Gryllidae	0	0	0	1	0	0	1
Hesperiidae	0	0	1	0	0	0	1
Ichneumonidae	1	1	0	0	1	0	3
Lampyridae	0	1	1	0	1	0	3
Meloidae	39	51	52	0	0	0	142
Melyridae	0	0	0	0	1	0	1
Miridae	1	2	2	7	4	1	17
Nabidae	5	2	1	0	0	0	8
Noctuidae	0	3	7	13	14	24	61
Nymphalidae	0	0	0	0	0	0	0
Pentatomidae	7	5	0	375	213	181	781
Pieridae	1	0	0	6	0	1	8

Table 1. Continued.

Observed Families	Arthopod Count at Different Distances						Target Plots Total
	5 m	11 m	17 m	58 m	74 m	90 m	
Rhopalidae	0	0	0	0	1	1	2
Scarabaeidae	1	0	0	2	0	0	3
Syrphidae	0	2	1	0	0	0	3
Tachinidae	0	0	1	0	0	0	1
Tettigonidae	1	12	5	2	1	5	26
Tetrigidae	1	1	2	0	0	0	4
Tortricidae	1	0	0	0	0	0	1
Ulidiidae	0	0	0	1	0	0	1
Vespidae	0	0	1	0	0	0	1

Our finding that arthropod diversity decreased with increasing distance from the floral enhancement suggests that the positive benefits of on-farm floral enhancements on arthropod communities may diminish over relatively small distances. Thus, the distance of floral enhancements relative to target crops within farmscapes may affect the potential benefits derived from these habitat enhancements and should be carefully considered by growers who implement this tool. Additionally, observed variation in arthropod diversity at distances of $<$100 m from the floral enhancement suggests that future studies should consider distance effects at more minor spatial scales than have been previously examined. We also found that the proportions of beneficial and pest arthropods did not vary with distance from the floral enhancement. On-farm floral enhancements have the potential to be harmful to agricultural production if they harbor populations of crop pests. However, most studies have demonstrated that floral enhancements either decrease the presence of pests, increase the presence of beneficials, or do not influence the arthropod community in target crops near floral enhancements (Albrecht et al. 2020, Ecol. Lett. 23: 1488–1498; Herz et al. 2019, Insects 10: 247). On the basis of our findings, we postulate that the impacts of on-farm floral enhancements on the relative abundance of pests and beneficials are likely system dependent and may be outweighed in this study by the broader landscape context surrounding the site, as has been observed in other studies (Schubert et al. 2022, Basic Appl. Ecol. 60: 76–86).

Future work assessing the role of floral enhancements in farmscapes should also take into consideration the impacts on production space and other possible downsides of establishing floral enhancements, such as the potential for increased weed pressure as well as tangential benefits of floral enhancements including crop protection against high winds. Taken as a whole, our preliminary results suggest that floral enhancements can mediate arthropod communities in nearby target crops to some degree at relatively small spatial scales. However, we did not

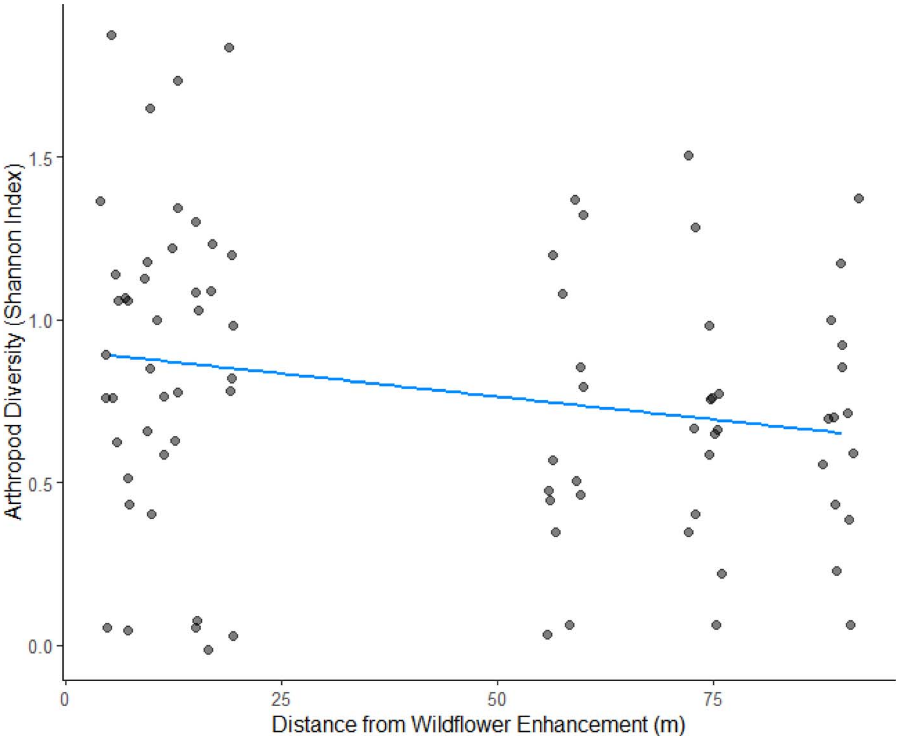

Fig. 1. Estimate and model residuals for the response of arthropod diversity (Shannon index) to distance from the on-farm floral enhancement. Date of collection is included as a random effect in the model.

observe differential impacts of floral enhancements on beneficial and pest insect groups, suggesting that floral enhancements at the limited scale presented may not alter arthropod community composition in agriculturally meaningful ways.

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