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Enhancing the Functional Biodiversity of Ground-Dwelling Arthropods with Henbit (*Lamium amplexicaule*) Conservation

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Abstract

In European countries, considerable research has focused on the conservation and improvement of biodiversity of functional groups which are useful organisms in agricultural lands. In contrast, there is little research in this field in Asia. Living mulches using cover plants have been indicated to be an effective way to increase the density of functional groups in Europe. However, most of the living mulches used in Japan are non-native species native to Europe. There is concern that these alien plants may have a negative impact on the functional groups of native organisms. In this study, researchers investigated the impact of a community of henbit (*Lamium amplexicaule*), a winter weed native to Japan, on the maintenance of functional ground-dwelling arthropods. In a study of vegetable fields grown with radishes, Chinese cabbage, and onions, plastic mulch, henbit communities, and weeding areas were compared. In vegetable fields, henbit communities increased the number of functional arthropods, including carnivorous native enemies and weed seed predators, compared with plastic mulched or weeding bare ground. Weeds were removed from vegetable fields, whereas the undergrowth was often managed in tree orchards to prevent soil erosion. In a chestnut orchard study, a henbit-dominated area was compared with an area containing a mixed plant community. In the chestnut orchard, the area with henbit-dominant communities had more functional species than areas with other weed species. These results reveal that the henbit community has a positive effect on the maintenance of functional ground-dwelling arthropods.

Keywords: functional biodiversity; ground-dwelling arthropod; living mulch; pitfall trap

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INTRODUCTION

Among organisms that live on agricultural land, those that contribute to agriculture, such as pest control, pollination, and the decomposition of organic matter, are called ‘functional groups’ (Snyder, 2019; Boetzl et al., 2020). Such diversity of functional groups called ‘functional biodiversity’ is important for providing specific agroecosystem services (Barberi, 2015; Duru et al., 2015). Under the Convention on Biological Diversity, signed in 1993, ‘functional biodiversity’ has been recognized as an important resource for sustainable agriculture in each country (Ministry of Foreign Affairs of Japan, 2021). Since then, considerable research has focused on the conservation and improvement of functional biodiversity in agricultural lands in European countries (Laureto et al., 2015; Martin et al., 2019). In contrast, there is little research in this field in Asia. In Japan, a national project was carried out from 2008 to 2011 to select

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indicator species of useful organisms (Ministry of Agriculture, Forestry and Fisheries of Japan, 2012). However, methods for conserving these organisms are currently the subject of research.

Ground-dwelling arthropods, including carnivores that prey on pests, seed predators that prey on harmful weed seeds, and decomposers that break down organic matter, are important factors in functional biodiversity (Ministry of Agriculture, Forestry and Fisheries of Japan, 2012). The type and abundance of biodiversity and its function in an agroecosystem differ according to vegetation type. The ground-dwelling arthropods have low dispersal ability because they move mainly by foot (Ishitani, 2010). Therefore, ground-dwelling organisms are likely to be sensitive to the effects of weed vegetation and its management in and around agricultural fields (Perera-Fernández et al., 2023). Ground-dwelling arthropods are one of the groups that are most affected by cover crops because they are susceptible to practices such as mulching, tillage, and the use of herbicides (Fiera, 2020).

Cover plants have traditionally been used for soil conservation and as green manure. Moreover, recently, living mulches using cover plants have been evaluated as an effective method of increasing densities of native carnivorous natural enemies in European countries (Burgio, 2014; Holland, 2016; Šálek et al., 2018; Triquet et al., 2022). In Japan, clover, ryegrass, and rattail fescue are used as living mulch (Shibata, 2005). Although these plants are native to Europe, they are alien plants in Japan. Therefore, there are concerns about adverse impacts on native biodiversity, including functional groups.

In fact, because biodiversity is evolutionarily related to the native plants of a given area (Tallamy, 2004), it has been pointed out that a decline in native plants leads to a decline in the functional group of ground-dwelling arthropods (Samways et al., 1996). Moreover, alien plants pose several risks as they are harmful weeds for crops, spread outside of cultivated land, and destroy existing ecosystems (Shimizu, 1998). Therefore, from the perspective of conserving functional biodiversity in Japan, it is necessary to consider using native plants as living mulches. However, to date, no native plants have been reported to be effective as cover plants.

In this study, researchers focused on henbit (*Lamium amplexicaule*), an annual winter weed of the Lamiaceae family native to Japan that grows in colonies in cultivated fields from autumn to spring (Hayashi, 1989), and investigated the impact of henbit communities in vegetable fields and orchards on the maintenance of functional ground-dwelling arthropods. As a result, researchers found that henbits may be effective in conserving ground-dwelling organisms, which researchers report here.

MATERIALS AND METHOD

Study area

This study was conducted in a vegetable field and a chestnut garden at the Center for Education and Research in Field Sciences, Shizuoka University (Kariyado, Fujieda City, Shizuoka Prefecture, Japan).

Experimental design

Vegetable field

This test was conducted in 2021. Each plot approximately measured 1 m × 2 m. Radishes (‘Yumasari’), Chinese cabbage (‘CR-Okiniiri’), and onions (‘Haruichiban’) were cultivated in vegetable gardens. Radish seeds were sown on October 29 in two alternating rows, with each plant 25 cm and each row 40 cm apart. Chinese cabbage seeds were sown on October 29, with each plant 35 cm apart. Onion seeds were sown on November 5 in two rows, maintaining 15 cm between plants and 40 cm between rows. Basal fertilizer with N, P, and K was applied to all test plots at 16 kg 10 a^{-1}. The three experimental plots included a plastic mulch plot where plastic mulch was used, a henbit plot where the henbit communities were preserved, and a weeding plot where weeds were always removed manually. All experimental plots had two replicates for each vegetable.

Chestnut garden

The test was conducted in 2023. Chestnut trees in the study area have been cultivated in this orchard since 1974. The undergrowth in chestnut gardens is managed by mowing approximately once a month from spring to autumn. In the chestnut garden, an area of 56 m^2, dominated solely by henbit, was designated as the henbit plot, while a 64 m^2 area with a mixed plant community was defined as the control plot. In the henbit plot, the dominance of henbit was over 90%. Other plants, including *Capsella bursa-pastoris* (4.7%) and *Senecio vulgaris* (3.5%), were present in the henbit plot. In the control plot, the following plants were the constituent species before the survey conducted

on March 2, 2023: *Nuttallanthus canadensis* (dominance 57.0%), *Lamium amplexicaule* (henbit) (23.3%), *Poa annua* (18.5%), *Senecio vulgaris* (16.7%), *Cerastium glomeratum* (4.1%), *Trigastrotheca stricta* (3.1%), *Stellaria media* (0.5%), *Lactuca indica* (0.10%), *Erigeron annuus* (0.07%), *Capsella bursa-pastoris* (0.01%), and *Gnaphalium japonicum* (0.01 %). There were no replicates of either test plot.

Pitfall trap

Pitfall traps are the most common survey method for ground-dwelling arthropods (Uetz and Unzicker, 1976). A plastic cup, 70 mm in diameter and 80 mm in height, was embedded in the ground and filled with 100 ml of 70% ethanol to kill and preserve the captured insects. Six traps were set up in each plot. The traps were collected after 6 days in the vegetable field and 3 days in the chestnut garden, and the captured ground-dwelling arthropods were identified. The traps were set up on February 22 and March 15, 2021, in the vegetable field and on March 31, 2023, in the chestnut garden.

Data analysis

The data obtained in this study were analyzed using BellCurve in Excel 5.0 (Social Survey Research Information Co., Ltd.). After analysis of variance (ANOVA), Tukey's multiple range test was performed to detect significant differences among the treatments at a confidence interval of 95% ($\alpha = 0.05$).

RESULTS AND DISCUSSION

Figure 1 shows the number of carnivorous and seed-feeding ground-dwelling arthropods in the vegetable field. In the survey conducted in February, very few living organisms were captured in the weeding or plastic mulch plots. In contrast, wolf and jumping spiders were observed in the henbit plot, suggesting that henbit communities serve as habitats for ground-dwelling spiders during winter.

Ground-dwelling spiders, especially wolf spiders (Figure 2), are considered one of the most important organisms for the functional biodiversity of agricultural ecosystems in Japan because they are natural enemies of several insect pests (Ministry of Agriculture, Forestry and Fisheries of Japan, 2012). This indicates that henbit communities positively affect the maintenance of the functional biodiversity of agricultural land during winter. In the survey conducted in March, at the beginning of spring, no organisms were captured in the weeding or plastic mulch plots. In contrast, ground-dwelling spiders, centipedes, and Staphylinoidea, which are carnivores preying on natural enemies, were captured in the henbit plot.

In the past, the functional groups have been mainly carnivorous natural enemies that prey on pest insects. However, herbivore organisms that eat weed seeds are currently attracting attention (Kulkarni et al., 2017; Sarabi, 2019).

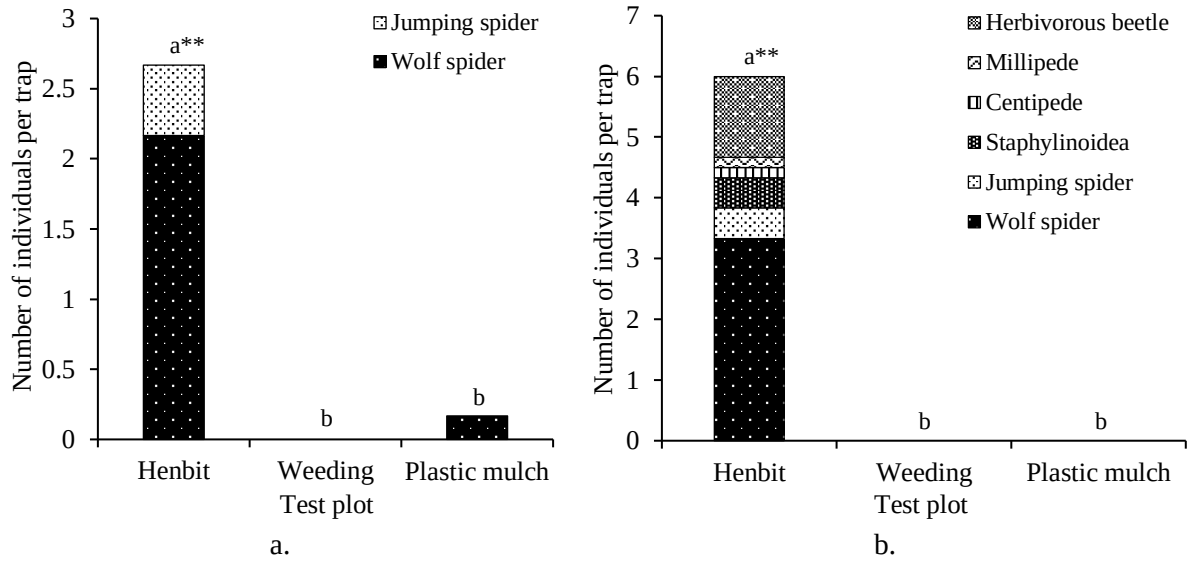

Figure 1. The number of individuals of ground-dwelling arthropods includes carnival and seed predators in vegetable fields on February 14 (a) and March 15, 2021 (b)

Note: **Indicates a significant difference according to the ANOVA at a confidence level of 1%. Different letters indicate significant differences among treatments, based on Tukey's multiple range test at a 5% level

Figure 2. Wolf spiders, which are the most important organisms for the functional biodiversity of agricultural ecosystems in Japan

In this study, researchers captured herbivorous beetles, which are representative seed predators, in the henbit plot. In addition, millipedes, which have been reported to be seed predators (Koprdová et al., 2010), were only found in the henbit plot. These results demonstrated that henbit entrecote is effective in maintaining functional biodiversity in vegetable fields.

The experimental plots in the vegetable fields were designed with small-plot replicates. Interestingly, even in small experimental plots, there were clear differences in the abundance of ground-dwelling arthropods. Studies in Europe have shown that the semi-natural grasslands in and around agricultural lands are suitable habitats for many organisms (Holland, 2016). The edges of agricultural land, such as field margins, edges, and boundaries, are important habitats for functional biodiversity (Burgio, 2014; Holland, 2016; Šálek et al., 2018; Triquet et al., 2022). Researchers have also proposed the creation of green areas in fields to provide effective habitats for ground-dwelling arthropods (Collins et al., 2003). Based on these studies, it may be possible to maintain the henbit community in parts of the field and use it as a bunker plant. However, in the present study, no functional organisms were captured in the adjacent plastic mulch or weeding plots, suggesting that the movement of ground-dwelling arthropods during winter is limited in Japan.

Figure 3 shows the number of carnivorous and seed-feeding ground-dwelling arthropods in the chestnut garden. In vegetable fields, weeds are removed, whereas undergrowth management is often performed to prevent soil erosion in tree orchards. In the chestnut garden, the henbit plot had a greater number of functional species compared to the control plot with other weed species. In the control plot, carnivores included wolf spiders, small spiders, carnivorous beetles, and earwigs. In contrast, only wolf and purse web spiders were captured in the henbit plot. However, the henbit plot was characterized by a large number of spiders. Henbit communities exerted a positive effect on maintaining functional biodiversity because ground-dwelling spiders, such as wolf spiders, have been recognized as among the most important organisms for maintaining the functional biodiversity of agricultural ecosystems in Japan (Ministry of Agriculture, Forestry and Fisheries of Japan, 2012).

In this study, seed predators, such as herbivorous beetles, pill bugs, millipedes, slugs, and snails, were observed. Millipedes and pill

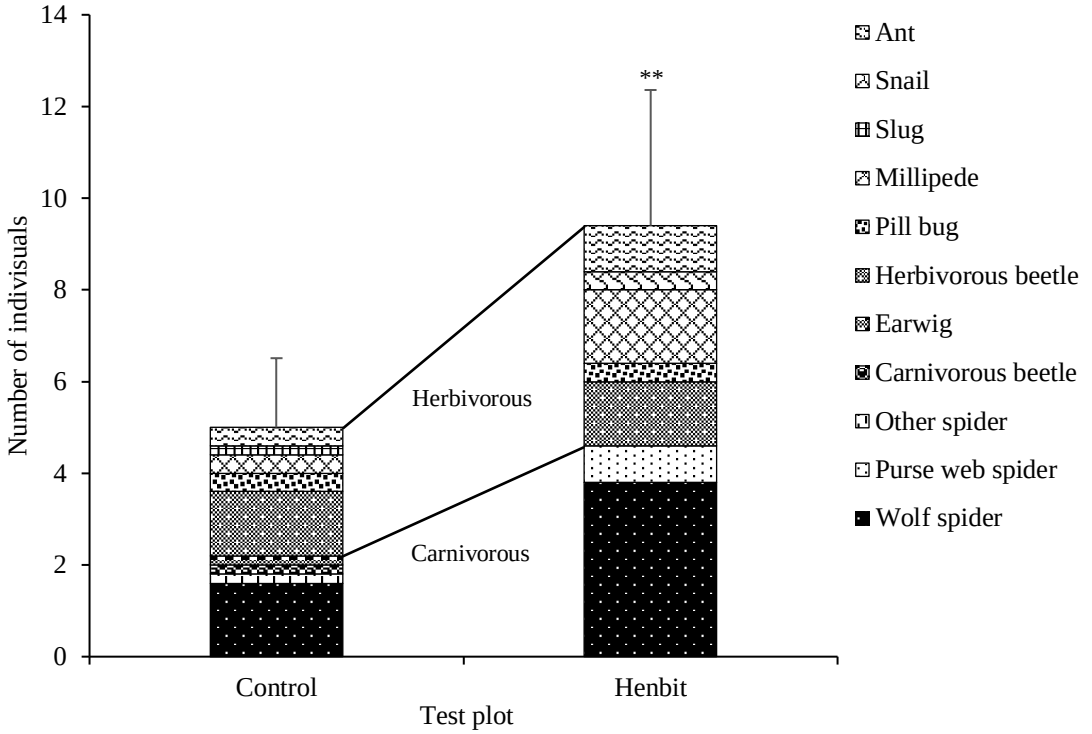

Figure 3. The number of individuals of ground-dwelling arthropods includes carnival and seed predators in a chestnut garden on March 31, 2023

Note: Error bars indicate standard deviation. **Significant difference between the henbit plot and control according to the t-test at a confidence level of 1%

bugs are decomposers that feed on plant residues; however, recent studies have shown that they also prey on weed seeds (Koprdová et al., 2010). Researchers also counted the abundance of *Monomorium nipponense*, an ant that feeds on seeds. Among the seed predators, herbivorous beetles were the most abundant in both the henbit and control plots. There was no difference in the number of herbivorous beetles between the henbit and control plots. An abundance of millipedes and ants characterized the henbit plot.

It has been already reported that weeds in cover crops are increasingly being adopted to provide multiple ecosystem services such as improving soil health (Baraibar, 2021). In addition, Depalo (2020) reported that cover crops have positive effects on increased populations of ground-dwelling arthropods. In conclusion, the findings suggest that henbit, a weed species, has a positive effect on the maintenance of functional ground-dwelling arthropods. However, there are areas where henbit is unable to grow naturally due to unfavorable conditions. In the future, it will be necessary to consider sowing henbit seeds to make them a dominant cover crop.

CONCLUSIONS

Living mulches are an effective way to improve functional biodiversity. However, most living mulches in Japan have used alien plants native to Europe. In this study, henbit communities exert a positive effect on maintaining functional biodiversity in the agroecosystems. Future research topics will require evaluating the extent to which the functional groups whose populations have increased due to *Lamium amplexicaule* contribute to pest and weed suppression.

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