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Effect of Traditional Rice-Straw Mulch on the Functional Biodiversity of Ground-Dwelling Arthropods in Tea Gardens.

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Abstract

In some tea gardens in Shizuoka prefecture, traditional rice-straw mulch is carried out for the purposes of 1) inputting organic substances, 2) preventing soil erosion, 3) retaining water and heat in the root area of tea plants, and 4) controlling weeds. The study was aimed to investigate effects of rice-straw mulch cultivation, traditionally used in Japan, on predators of pests and weed seeds in tea gardens. Carnivorous beetles (Pheropsophus jessoensis, Chlaenius naeviger, and Dolichus halensis), wolf spiders (Lycosidae sp.), earwigs (Anisolabididae sp.), centipedes (Chilopoda sp.), and house centipedes (Scutigeromorpha sp.) were captured as examples of carnivorous ground-dwelling arthropods. The number of these carnivorous predators was lower in the tea gardens with rice-straw mulch than in those without rice-straw mulch. In contrast, herbivorous ground beetles (Amara sp. and Harpalinae sp.) and crickets were captured as examples of weed-seed predators. In addition, many millipedes and woodlice, known to prey on weed seeds, were captured. In particular, a large number of woodlice were present regardless of the presence or absence of rice straw. Furthermore, the number of crickets was higher in tea gardens with rice-straw mulch than in those without rice-straw mulch. In contrast, members of the Harpalinae (ground beetles), which are also weed-seed predators, are less abundant in tea gardens with rice-straw mulch than in tea gardens without rice straw. In general, the bedding straw mulch served as a hideout and feeding ground for living organisms, and it would be expected that the functional organisms would increase. However, in this study, the pest and weed-seed predators tended to be less common in tea gardens with rice-straw mulch. Thus, traditional rice-straw mulching was not effective in improving functional biodiversity.

Keyword: *functional biodiversity, functional ground-dwelling arthropods, tea gardens, rice-straw mulch, traditional ecological knowledge.*

INTRODUCTION

Agricultural land conserves agroecosystem biodiversity. However, in some cases, biodiversity abundance can indicate large populations of pests and weeds. Therefore, functional biodiversity is important, not the biodiversity itself (Southwood and Way, 1970). Researchers have anticipated that biodiversity improvement in agroecosystems will lead to the conservation of natural enemy communities and their prey biodiversity, enhancing natural pest control, which is an ecosystem service (Altieri, 1994; Miguel, 1999). Such "functional biodiversity" is important in relation to the provision of specific agroecosystem services (Miguel, 1999; Camilla and Bàrberi, 2008; Rouphael, 2008; Duru et al., 2015; Paolo, 2015). Therefore, extensive research has been conducted on the conservation and improvement of functional biodiversity in agricultural land (Southwood and Way, 1970; Maira et al., 2015; Martin et al., 2019).

Habitat management efforts, such as the creation and conservation of green areas, are intended to conserve and enhance functional biodiversity through vegetation management (Thomas et al., 1991; Sotherton, 1995; Collins, 2003.; Fischer et al., 2010). In contrast, in Japan, few studies have been conducted on the conservation of functional biodiversity through habitat management practices (Ministry of Agriculture, Forestry and Fisheries et al. 2012. Tanaka, 2012; Tanaka and Ihara, 2012).

The type and abundance of biodiversity in agriculture and its functions differ across agroecosystems with different management systems (Southwood and Way, 1970; Miguel, 1999). Excellent functional biodiversity can be found in traditional farming methods (Ramos et al., 2016). For example, traditional mowing management in rice terraces has been reported to enrich functional biodiversity and maintain the functionality of weed seed predators (Ichihara et al., 2015, Ichihara et al., 2021, Inagaki, 2021). Traditional ecological knowledge systems are now being reevaluated for potential applications in future sustainable agriculture practices (UNU 2011, Altieri 2015. FAO, 2020).

Tea cultivation in Japan provides an example of traditional Japanese agriculture. Although many tea cultivation practices are being modernized and mechanized, traditional knowledge is still a part of the overall system (Inagaki and Kusumoto, 2015). For example, in Shizuoka Prefecture, a typical tea-producing area in Japan, plant mulch is used in cultivation (Inagaki and Kusumoto, 2015). In mountainous parts of Shizuoka Prefecture, silver grass in the Satoyama area is used for plant mulch, and this traditional tea-grass integrated system has been registered as a Globally Important Agricultural Heritage Site. (Inagaki and Kusumoto, 2015; Kusumoto and Inagaki, 2016; Inagaki and Kusumoto, 2019). In contrast, a traditional practice exists in tea gardens of mulching rice straw from paddy fields in the area near the flat land in Shizuoka prefecture. Traditional plant mulch is effective in 1) inputting organic substances, 2) preventing soil erosion, 3) retaining water and heat in the root area of tea plants, and 4) controlling weeds (Hayashi, 2015). In addition, it can be expected that plant mulch provides more habitats for functional ground-dwelling arthropods, including natural enemies and weed-seed predators, than bare land. In fact, it has been reported that rat-tail fescue mulch in citrus gardens and living wheat mulch in vegetables and crop fields increases natural pest control (Ono, 2007; Tsuchida et al., 2015; Katayama et al., 2018). However, it is largely unknown about relationship between traditional rice-straw mulch and functional biodiversity. Therefore, in this study, we investigated the effect of traditional rice-straw mulch on the functional biodiversity of ground-dwelling arthropods in tea gardens.

MATERIALS AND METHODS

Study site

The research site was the tea garden at the Center for Education and Research in Field Sciences at Shizuoka University (Kariyado, Fujieda City, Shizuoka Prefecture, Japan; 34.9052333N,138.2721461E. This garden has cultivated tea according to the practice of Fujieda City since 1974. We made a distinction between a tea garden where rice-straw mulch cultivation was carried out (rice-straw mulch plot) and a tea garden where rice-straw mulch was not used (control). In keeping with local practice, both test plots were sprayed with 250-fold diluted glyphosate-isopropylammonium ('Roundup Max Road', Nissan Chemical Corporation) on June 15 and September 4, 2017.

Pitfall trap

A plastic cup with a diameter of 90 mm and a height of 120 mm was embedded in the ground, and 70% ethanol was placed at the bottom of the cup as a preservative. A paper plate with a diameter of 18 cm was placed on the trap as a rain shield. Five traps were set in one plot. One week later, traps were recovered, species of the captured surface-wandering organisms were identified, and the population was investigated. Another week later, we identified the ground-dwelling arthropod species and counted their populations. Traps were set up seven times: on April 28, 2017, May 23, June 28, July 21, August 21, September 29, and October 30, 2017.

RESULTS AND DISCUSSION

Table 1 shows the number of ground-dwelling arthropods caught by pitfall traps. In this study, carnivorous ground-dwelling arthropods, such as carnivorous beetles (*Pheropsophus jessoensis*, *Chlaenius naeviger*, and *Dolichus halensis*), wolf spiders (Lycosidae sp.), earwigs (Anisolabididae sp.), centipedes (Chilopoda sp.), and house centipedes (Scutigeromorpha.sp.) were captured. Earwigs were the most abundant arthropods throughout the tea garden. In Japanese agricultural fields, carnivorous ground beetles and spiders are considered particularly important for functional biodiversity (Ministry of Agriculture, Forestry and Fisheries et al., 2012). Carnivorous ground beetles are natural enemies in agricultural fields (Sa'adah, 2021) and prey on aphids and caterpillars (Sunderland and Vickerman, 1980; Chiverton, 1987; Sunderland et al., 1987; Fuller, 1988; Holland et al., 1996). Carnivorous ground beetles were more abundant in the control plots than in the spread-straw plots for all species (*P. jessoensis*, *C. naeviger*, and *D. halensis*) (Table 1). Wolf spiders are natural enemies of aphids and planthoppers (Nyffeler and Benz, 1988; Dennis and Wratten, 1991; Holland and Thomas, 1997; Inagaki et al., 2010) and were more abundant in control plots than in the spread-straw plots (Table 1). In addition, earwigs (Anisolabididae sp.), centipedes (Chilopoda sp.), and house centipedes were also more abundant in the control plots than in the spread straw plots. Pest caterpillars, such as *Adoxophyes honmai*, *Caloptilia theivora*, *Arna pseudoconspersa*, and Geometridae, are mainly found on tea trees, and it is unclear whether the carnivorous natural enemies can catch these insect pests on the trees. Wolf spiders could be observed on trees and might function as natural enemies of planthoppers and mites, which are the main pests in tea cultivation.

So far, research on ground-dwelling arthropods in functional biodiversity has focused on carnivorous predators of pests. It is known that herbivorous ground-dwelling arthropods are predators of weed seeds (Pausch, 1979; Holland, 2004), and it is becoming clear that they occupy an important position in the agroecosystem (Ichihara, et al. 2015). In this study, herbivorous ground beetles, such as *Amara* sp., Harpalinae, and crickets (Gryllidae), were captured as weed-seed predators (Table 1).

Millipedes and woodlice are generally known as decomposers that feed on plant residues, but recent studies have shown that they also prey on weed seeds (Saska 2008; Koprdová et al. 2010). If we regard millipedes and woodlice as weed-seed predators, the woodlice were the most common, followed by the millipedes. In particular, the number of woodlice was much higher than that of other arthropods, so if the woodlice feed on weed seeds, they may be quite effective in controlling the weed population. Further research is required to determine the function of woodlice in tea gardens. Among the seed-feeding "insects," the Harpalinae family was the most abundant.

Weed-seed predators are not listed as indicator species for functional biodiversity in Japan because there are few reports on the function of herbivorous arthropods (Ministry of Agriculture, Forestry and Fisheries et al., 2012). However, in recent years, it has been reported that crickets are the major weed-seed predators in Japanese agricultural lands (Ichihara et al., 2011; Ichihara et al., 2012; Ichihara et al., 2014a; Ichihara et al., 2014b; Ichihara et al., 2015). In addition, it has been reported that Harpalinae species (ground beetles) feed on major weed seeds in agricultural land, including tea gardens (Kagawa et al., 2008; Lee et al., 2008; Yahiro et al., 1992; Yamazaki et al., 2003). In our study, the number of crickets was higher in the rice-straw mulch plot than in the control plot. In contrast, the number of Harpalinae was higher in the control plot than in the rice-straw mulch plot. The number of millipedes and woodlice was also higher in the control plot than in the rice-straw mulch plot. Many woodlice were caught throughout the survey period, and no significant seasonal increase or decrease was observed (data not shown).

Fig.1 shows the seasonal variation in the emergence of major functional ground-dwelling arthropods, including carnivorous beetles, wolf spiders, earwigs, centipedes, house centipedes, seed predator beetles, crickets, and millipedes. Carnivorous beetles were found in control plots without rice straw from June to August and showed two peaks of seasonal succession in June and August. Carnivorous beetles were rarely observed in the rice-straw mulch plots. Wolf spiders were found to occur from April to August in both the rice-straw mulch plot and control plot. The occurrence of wolf spiders from June to August was slightly higher in the control plot than in the rice-straw mulch plot. The earwig population tended to increase after August. The peak season for earwigs between the rice-straw mulch plots and the control plots differed. Hence, August was the peak season in the control plot, while September was the peak season in the rice-straw mulch plot. Centipedes were observed from April to July in the control plot; however, only a few were observed in June in the rice-straw mulch plot. The occurrence of house centipedes peaked in July in the control plot. Only a few house centipedes were observed in the rice-straw mulch plot. The pest caterpillars occurred in the tea garden from April to August. Since pest caterpillars are arboreal, it is not known whether the carnivorous ground-dwelling arthropods control pests; however, the occurrence of the pest caterpillars and the carnivorous ground-dwelling arthropods tended to coincide.

The herbivorous ground beetles were more common in the control plots than in the rice-straw mulch plots. The herbivorous ground beetles in the control plots showed a seasonal succession that peaked in May. *Sonchus oleraceus*, *Stellaria neglecta*, and *Lamium amplexicaule* are common weeds in tea gardens (Inagaki and Tsushi 2020). Since these weeds disperse their seeds at the end of spring, weed seeds in tea gardens may be consumed by herbivorous ground beetles. Crickets were relatively abundant in the rice-straw mulching plot in July, but very few crickets were observed in the control plots during this month. Millipedes were abundant in the control plot from April to June. By contrast, there were only a few millipedes in the rice-straw mulch plot.

Conclusion

Our results clarify the species and seasonal dynamics of functional ground-dwelling arthropods in tea gardens. However, in this study, predators on pests and weed-seed predators, except for crickets, tended to be lower in tea gardens with rice-straw mulch. Thus, traditional rice-straw mulching was not effective in improving functional biodiversity. It is not clear why the application of rice straw reduces ground-dwelling arthropods. However, rice-straw mulching physically suppressed the occurrence of weeds, and the fact that fewer weeds and pests were found might be the reason for fewer functional ground-dwelling arthropods. Elucidation of this reason is a subject for future research.

Table 1 Species and total number of catches of ground-dwelling arthropods in tea gardens during the survey period

		species	rice straw mulch	control	
Carnivorous	Beetle	*Pheropsophus jessoensis*	0	3	
		Chlaenius naeviger	1	7	**
		Dolichus halensis	1	2	
	Spider	*Lycosidae*. sp.	10	18	
	Earwig	*Anisolabididae*	44	57	
	Centipede	*Chilopoda*. sp.	10	23	**
	House centipede	*Scutigeromorpha*. sp.	11	53	**
Seed predator	Beetle	*Amara*. sp.	5	12	
		Harpalinae. sp.	4	69	
	Cricket	*Gryllidae*. sp.	7	1	**
	Millipede	*Diplopoda*. sp.	22	58	**
	Wood louse	*Armadillidium vulgare*	3375	5460	**

Total number of 5 traps × 7 times (April-October)

** indicates a significant difference according to the chi-square test at a confidence level of 1 %.

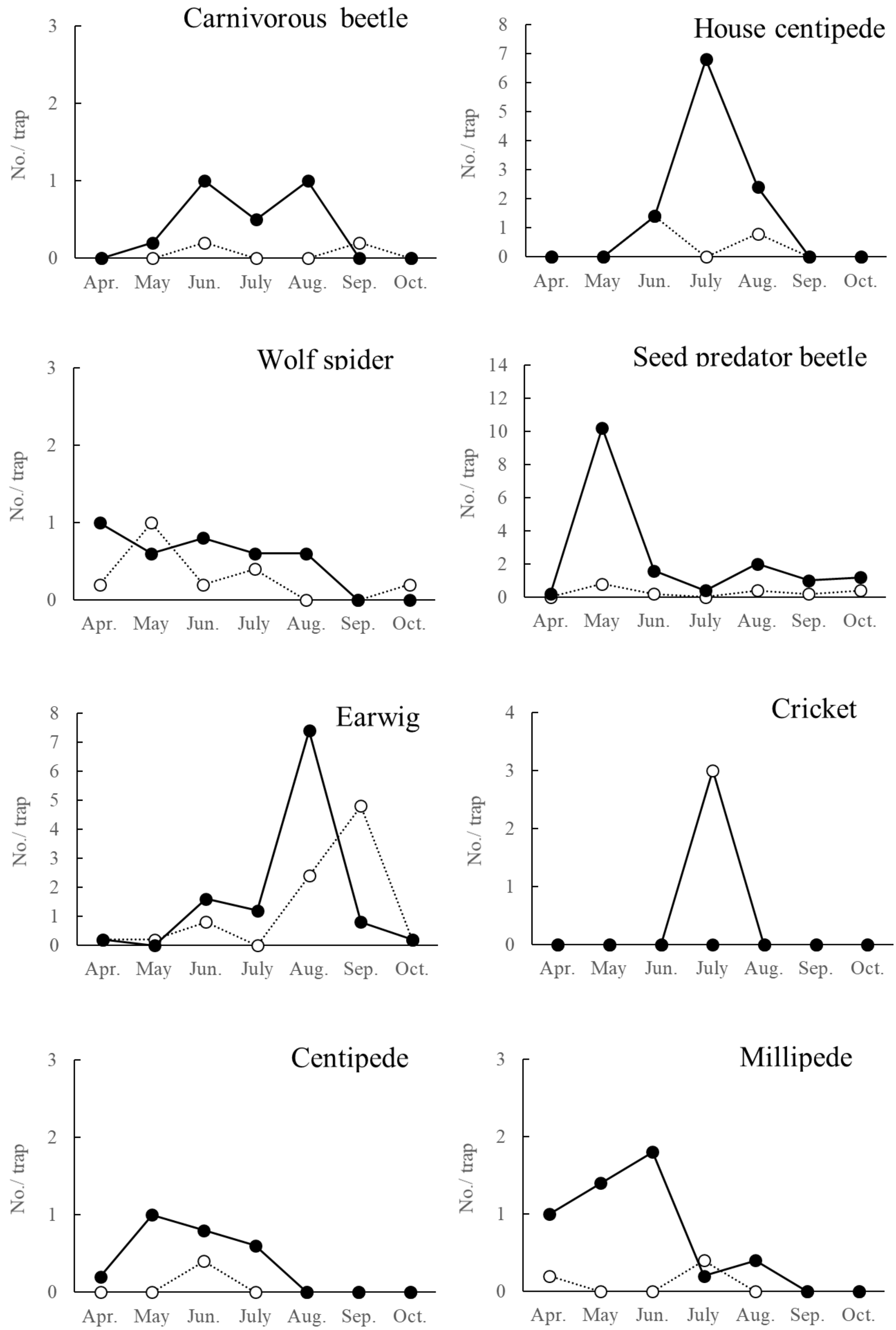

Fig.1 Seasonal variation in emergence of major functional ground-dwelling arthropods including carnivorous beetle, wolf spider, earwig, centipede, house centipede, seed predator beetle, cricket, and

millipede.

○:rice-straw mulch plot, ●:control plot (without rice-straw mulch).

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