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Short Communication

Ground arthropod communities in paddy fields during the dry period: Comparison between different farming methods

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ABSTRACT

The ground arthropod communities in paddy fields during the dry period and the effects of different farming methods adopted during the cropping season on these communities were evaluated. Pitfall traps were used in six conventional, two herbicide-only, and four organic paddy fields in early November and early May at two sites in Niigata Prefecture, Japan. A total of 202 ground arthropods belonging to 18 taxa were collected, with eight taxa identified at the species level. The most abundant taxa were two predator groups, spiders and carabid beetles. Farming methods did not affect taxon richness, total abundance, abundance of individual taxa, or species composition, but the site marginally affected the abundance of some taxa. These results suggest that during the dry period paddy fields contained abundant predatory arthropods, and that the communities were not affected by the use of pesticides during the cultivation period. Because these predators are important natural enemies of rice pests, management strategies should be focused on both the cultivation period and the uncropped, dry period to enhance predator populations.

Introduction

Paddy fields are representative agricultural lands in Asia, with 90% of paddy fields worldwide being located in this region (Yano, 2002). In Japan, the paddy field area was 24,700 km^2 in 2012 (MAFF, 2012), which represented more than half of the total farmland or 6% of the land surface of the nation. Despite this dominance, studies of organisms in these fields have been almost exclusively conducted in the flooded portion during the cultivation period to substitute for wetland habitats (Moriyama, 1997; Hidaka, 1998; Natuhara, 2013, but see Bambaradeniya et al., 2004; Stenert et al., 2009). Flooded fields are used as breeding and feeding habitats by fish (Saitoh et al., 1988; Nagayama et al., 2012), waterbirds (Lane and Fujioka, 1998; Toral et al., 2011), amphibians (Fujioka and Lane, 1997; Matsuhashi and Okuyama, 2002), aquatic insects (Hirai and Hidaka, 2002; Nishihara et al., 2006; Watanabe et al., 2013), and aquatic micro-organisms (Yamazaki et al., 2004a, 2004b). Other studies have focused on pest and/or predator populations in rice plants (Kajimura et al., 1993; Murata, 1995; Motobayashi et al., 2006). However, information on the faunal community of paddy fields during the dry period remains limited; few studies have been conducted on soil organisms (Bambaradeniya et al., 2004; Stenert et al., 2009) and carabid beetles (Yahiro et al., 1992). This is despite the fact that the dry period lasts for approximately half a year, from early autumn after harvest until spring before rice transplanting, due to the introduction of modern drainage systems since the 1950s and 1960s in Japan (Fujioka and Lane, 1997; Kiritani, 2004).

The effects of agrochemicals on non-target organisms are an important issue for biodiversity conservation in agroecosystems (Kleijn et al., 2001, 2006; Hole et al., 2005). The negative effects of pesticides on non-target aquatic organisms are known in paddy ecosystems (Relyea, 2005; Hayasaka et al., 2012a, 2012b), where pesticide residues can accumulate in soil for more than a year (Hayasaka et al., 2013). Pesticide residues in soil may have delayed effects on ground arthropods utilizing paddy fields during the dry season by direct contacts with residues or through the interactions with soil invertebrates that have absorbed agrochemicals. However, little is known regarding the effects of pesticide use during the cultivation period on the ground arthropod fauna during the dry period in these paddy fields. Paddy fields that are farmed in an environmentally friendly manner provide a good opportunity to examine the effects of pesticides on the ground fauna during the dry period, although these fields usually exist as small islands in a sea of conventionally farmed paddy fields.

In this study, ground arthropod communities during the dry period in autumn (after harvest) and spring (before rice transplanting) were surveyed in paddy fields that were farmed in a conventional and

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environmental friendly manner during the cropping season. The objective of this study was to determine (1) the ground arthropod fauna in paddy fields during the dry period, and (2) the effects of pesticide use during the cultivation period on ground arthropods in the dry period. I hypothesize that environmentally friendly farmed paddy fields have richer ground arthropod fauna than conventionally farmed paddy fields because pesticide residues in soil accumulated in conventionally farmed paddies may have adverse effects on ground arthropods.

Materials and methods

Study area

The study area was located in a region in Tokamachi City in temperate Japan (37°02′ N, 138°42′ E), which receives heavy snowfall continuously from late December to late March. Two sites, Araya and Kamiyama (elevation 220 and 380 m asl, respectively), in different terrace plains within the same river terrace system along the Shinano River, were established. The two sites were 2 km apart. Four organically farmed and four conventionally farmed paddy fields were selected in Araya, and two herbicide-only and two conventionally farmed paddy fields were selected in Kamiyama. The fields were referred to as organic, herbicide, and conventional paddy fields, as appropriate. Organic farming had been practiced in the organic paddy fields for five or six years before being sampled. Less information was available for the herbicide paddy fields, although the herbicide-only farming method had been practiced for at least a few years before sampling. The selected paddy fields in Araya were located 60–100 m apart from narrow secondary or riparian forest belts (20–40 m wide), whereas those in Kamiyama were adjacent to a 200 m-wide secondary forest belt on the slope between terrace plains. Organic and herbicide paddies are rare in this region; the studied fields were entirely surrounded by conventional paddies. The size of the studied paddies ranged from 0.1 ha to 0.39 ha (43 to 105 m long by 20 to 39 m wide).

Fields were flooded beginning in early to mid-May, and drained in early September. Rice seedlings were transplanted in mid- to late May irrespective of farming methods. In the conventional paddy fields, insecticides were applied twice (fipronil or imidacloprid applied to rice seedlings in nursery boxes in mid-May, and dinotefuran in mid-August), herbicides were applied once about one week after rice transplanting (a mixture of indanofan, bensulfuron-methyl, and clomeprop in Araya, and a mixture of daimuron, bensulfuron-methyl, and fentrazamide in Kamiyama), fungicides were applied twice (probenazole in mid-June, and basic copper sulfate in mid-July), and chemical fertilizers (nitrogen, phosphorus, potassium, and magnesium) were applied four times during the rice growing season. In the herbicide paddy fields, the same herbicides used in the conventional paddies in Araya were applied once about one week after rice transplanting and organic fertilizers were applied twice in mid May (before rice transplanting) and July, but insecticides and fungicides were not used. In the organic paddy fields, the same organic fertilizers used in the herbicide paddies were applied twice at the same timing as herbicide paddies. In all types of paddy fields, fertilizers (chemical fertilizers in conventional paddies and organic fertilizers in herbicide and organic paddies) were also applied twice during the dry period (mid-October, and early May at the timing of plowing). Midsummer drainage occurred for 10 days during July in the conventional and herbicide paddy fields only. All paddies were drained before harvest and left dry from mid-September to early May, although the paddies were covered with snow from late December to late March. The studied paddy fields had no vegetation with only bare soil during the sampling periods irrespective of farming methods and stubbles were plowed into soil before the autumn samplings in all paddies.

Arthropod sampling and classification

Four pitfall traps (500-mL plastic bottles, internal diameter 9 cm, height 11 cm) containing 150 ml 10% ethylene glycol solution were placed at the center of the paddy fields in a line at 5-m intervals, parallel to the long side of the rectangular paddy fields. The traps were opened for five days in late autumn (4–10 November, 2008) and for two days in mid-spring (1–3 May, 2009). The contents of the four traps were pooled as one sample.

The collected arthropods were classified into ground (spiders, carabid beetles, staphylinids, weevils, ants, crickets, erythaeid mites, and amphipods) or non-ground arthropods (adults of Diptera, Lepidoptera, aphids, plant hoppers, pond skaters, parasitic wasps, small family-unidentified Coleoptera, and small unidentified insects). Although the majority of the non-ground arthropods were collected as two or less individuals and omitted from the analyses, dipteran adults (approximately 67% of total organisms collected; probably Sciaridae) and parasitic wasps (13 individuals) were included in the analyses because they were abundant and because small dipteran adults were important prey for paddy-dwelling wolf spiders (Ishijima et al. 2006) and parasitic wasps may use ground arthropods as hosts. Ground arthropods were classified into species (all carabid species, two weevil species and two spider species), genus (wolf spider: *Alopecosa* and *Pirata*), family (insects: unidentified weevil, Staphylinidae and Formicidae; mites: Erythraeidae), superfamily (cricket Grylloidea), and order (unidentified spiders and Amphipoda). Both ground and non-ground organisms collected in this study are listed in Appendix A.

Data analysis

In the following analyses, the pooled number of individuals from four traps per paddy was used to represent the abundances of each species for each paddy. In the four paddies where one or two traps were ruined in November, possibly by ravens, the arthropod abundances were corrected for the values per four traps (i.e., if one trap was ruined in a certain paddy, arthropod abundances of the remaining three traps were summed and multiplied by four over three, and these values were used as the arthropod abundances at the paddy). The biased sampling design (i.e., organic paddies in Araya only and herbicide paddies in Kamiyama only) made it impossible to compare the organic, herbicide, and conventional paddies as individual balanced factors in a single analysis. Therefore, I constructed two separate ANOVA models to test the effects of farming methods on species richness, total abundance and abundances of each taxon. In the first model, the data from the organic and herbicide paddies were combined because pesticides were not applied to either of these types of paddies. The effects of farming methods (organic/herbicide or conventional) and sites (Araya or Kamiyama) were used as the explanatory variables, and taxon richness, total arthropod abundance, and the abundance of species or taxa captured in more than three paddies were used as the response variables. In the second model, the effects of farming methods (organic or conventional) were tested using only the data from Araya to avoid the bias from lack of organic paddies in Kamiyama. In both ANOVA models, abundance data were transformed into square-root values. If a species or taxonomic group was observed in more than three paddies during both November and May, the statistical significance was tested for each date and the total for the two dates.

To compare taxon composition of ground arthropods among the different farming methods and sites, the taxon composition was analyzed separately in the November and May samples using principal coordinate analysis (PCoA) based on a Bray–Curtis percentage dissimilarity matrix. PCoA ordinations were done separately for the two datasets, i.e., only ground arthropods or those plus dipteran adults and parasitic wasps. No transformation was performed for