Diversity and community structure of ground surface dwelling arthropods in the agroecosystems of Kerala

Final Technical Report

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INTRODUCTION

Organic (sometimes called ecological) agriculture can be defined as farming systems where the use of pesticides, herbicides and chemical fertilizers is prohibited. These systems rely on crop rotations, natural nitrogen fixation, biologically active soil, recycled farm manure and crop residues, and biological or mechanical weed and pest control, natural pest control and diversifying crops and livestock (Swedish Control Association of Ecological Farming 2003). Conventional agriculture encompasses farming systems where pesticides, herbicides and chemical fertilizers can be used (Mäder *et al.* 2002). Organic agriculture gives priority to long-term ecological health, such as biodiversity and soil quality, contrasting with conventional farming, which concentrates on short-term productivity gains. Conventional farming with mineral fertilizers, herbicides and chemical pesticides adversely affects soil arthropods directly through toxicity and indirectly by decreasing both food availability and habitat quality (Holland & Luff 2000; Chiverton & Sotherton 1991). Similarly, the use of pesticides will not only decrease pest insects but also the predators that feed upon them (Winston 1997).

Organic farming, in contrast, is reported to increase diversity in the agricultural landscape (Paoletti *et al.* 1992; Hyvönen *et al.* 2003; Schönning & Richardsdotter-Dirke 1996; Ahnström 2002) including, for example, invertebrates (Moreby *et al.* 1994), carabid beetles (Purtauf *et al.* 2005; Dritschilo & Wanner 1980; Kromp 1989; Pfinner & Niggli 1996) and vascular plants (Hyvönen & Salonen 2002) and birds (Freemark & Kirk 2001). This is particularly relevant because modern agriculture has resulted in a loss of diversity in the agricultural landscape (Stoate *et al.* 2001; Benton *et al.* 2002; Benton *et al.* 2003) and it has been suggested that large-scale conversion to organic farming could partly reorganize this loss.

Despite these potential advantages of organic farming and the continuous increase of land area managed according to organic farming standards (Willer & Yussefi 2007), there are still surprisingly few scientific studies on the effects of organic agriculture on ground surface dwelling arthropods in different types of agroecosystems and nothing from the Indian subcontinent. In the present study, diversity and guild proposition/community composition of epigeic invertebrates in (organic and conventional farms) conventionally and organically farmed agriculture farms and the hedge rows surrounding the farms were evaluated to test the proposition that organic agricultural methods generally enhance biodiversity, operationally defined as richness, abundance and diversity in a variety of organism groups. In this study, we asked the following questions? (i) Does organic farming generally increase richness, abundance, diversity of the ground surface dwelling arthropods? (ii) Does organic farming generally affect the trophic structure of ground surface dwelling arthropods?

MATERIALS AND METHODS

Study site:

The study site is located in Padetti in the Erumaiyoor village, Palghat district (10° 40′-10°41′ N latitude and 76°32′-76°33′ E longitude). Two plots of five acre size, one organically cultivated and the other conventionally cultivated were selected for the comparative study.

Ground surface dwelling arthropods was sampled during 2009-2011 period. Random quadrate sampling method was used for sampling of ground surface dwelling arthropods. Samples for Berlese extraction of fauna were collected by placing a 50 × 50 cm^2 wooden quadrate frame on the floor and by collecting the litter and loose humus that occurred within the frame. Samples for extraction were sieved in a 1.5 cm mesh wire sieve, the sieved samples were saved in a large cloth bags preventing possible escape of any arthropod. A set of 10 samples was taken randomly from each field. Samples were transported to the laboratory in individually marked cloth bags. Each sample was placed in a series of 15-20 cm diameter Berlese funnel fitted with 4-6 mm mesh screens and a 60 watt light bulb for 24 hour. Organisms living within the sample tend to move downward to escape desiccation and eventually fall into a container of 70% alcohol beneath the funnel. Animals too large to be extracted by this method were removed visually. The preserved faunal samples were emptied into a Petri dish, and searched under a stereo zoom trinocular microscope. Extracted fauna were sorted and categorized up to order level. Coleoptera up to family level and assigned to trophic level according to whether the majority of taxon are predator, fungivore or detritivore (Borror *et al.* 1996). Identified insects were placed in a small vials containing 70% alcohol and members of each category for each sample were lumped together. The identified and categorized taxa were counted and abundance of each taxon was recorded. Larval forms were collectively categorized as insect larvae, as the smaller size of the soft bodied forms and the deformation during the Berlese funnel extraction makes further categorization and grouping unfeasible. Groups with a mean abundance of >1 were categorized as the major groups. <1 were considered as minor groups.

Data analysis:

The individual sample was used to evaluate the abundance of ground surface dwelling fauna. The diversity and evenness was calculated using Shannon diversity and Pielou's evenness indices (Magurran 2004). Bray-Curtis similarity coefficient (Bray and Curtis 1957) was used to compare the similarity of ground dwelling arthropod among habitats. All diversity analysis was done with Primer 5 software version 5.2.9. Rank-abundance plot was plotted with relative abundance of each order against rank of taxa for the study habitat as a whole (Whittaker 1965*)*.

All the data used for statistical analysis were tested for normality with Jarque-Bera test. As the data sets were not normally distributed, non-parametric statistics were used for pair wise comparison of the data. Univariate comparisons through Kruskal-Wallis H tests were used to evaluate the significance level in faunal and guild abundance between the habitats and year wise collections. Variations in diversity among samples were analysed with one-way ANOVA test (Weiss 2007). For all analysis significance was determined at $P<0.05$. Megastat version 10.0 (Orris 2005) was used for all statistical analysis.

RESULTS

Organic farm and Conventional farm

Seventeen ground surface dwelling taxa were recorded in the organic and 13 in the conventional farms (Table 1 & Figure 1). Overall faunal abundance was five times higher in organic farm (95.45± 122.12) than in conventional farm (17.23 ± 23.77) ($H=31.02$, $DF=1$, $P<0.05$). Among the 13 groups, six groups (Acari > Collembola > Coleoptera > Hemiptera > Psocoptera > Insect larvae) were major groups in organic farms in contrast to presence of three major groups (Acari > Psocoptera > Collembola) in conventional farms. Abundance of individual groups revealed that Acari and Collembola contributed towards 85% in organic farm and 77% in conventional farm indicating their prominence. Six groups were abundant in organic farm- four major groups namely, (Acari 5 times> Collembola 20 times> Coleoptera 10 times > Hemiptera; two minor groups namely, Hymenoptera and Pseudoscorpions and abundance of other groups did not vary between the farms. Non-record of Hemiptera, a major group in organic farm, in the conventional farm was distinct. Abundance of other groups except Hymenoptera and Pseudoscorpion did not vary between the farms. Higher diversity in organic farm and evenness in conventional farm was distinct (Table 17). Abundance of fungivores and detritivores was high in organic farm than in conventional farm and abundance of other guild did not vary between the farms (Table 9 & Figure 5). Similarity was low between organic and conventional farm.

Organic farm - I & II Year: Sixteen ground surface dwelling taxa were recorded in the organic farm during first and 12 taxa in the second year period (Table 5). Overall faunal abundance ($H=0.43$, $DF=1$, $P>0.05$); diversity and evenness did not vary between the first year and second year period (Table 19). Seven major groups (Acari> Collembola > Coleoptera > Psocoptera > Araneae > Formicidae > Insect larvae) were present in the first year and six major groups (Acari > Collembola > Hemiptera > Psocoptera > Insect larvae >Coleoptera) in the second year. Abundance of omnivores was high during first year and of other guilds did not vary (Table 13).

Conventional farm - I & II Year: Eight ground surface dwelling taxa were recorded in the conventional farm during first year and eleven groups in the second year period (Table 6). Overall faunal abundance ($H=6.22$, $DF=1$, $P<0.05$); diversity and evenness was higher in first year than second year (Table 19). Four major groups (Acari> Psocoptera>

Collembola> Insect larvae) were present in the conventional farm during the first year and two major groups (Acari> Formicidae) during the second year. Abundance of detritivores and fungivores was high during first year. Omnivores were recorded only in the second year (Table 15).

Organic hedge row and Conventional hedgerow

Fifteen taxa were recorded in the hedge row in organic farm and 18 in the conventional hedge row (Table 2 & Figure 4). Overall faunal abundance (H=0.68, DF=1, P>0.05), diversity and evenness did not vary between the organic and conventional hedge row (Table 17). Four major groups (Acari> Insect larvae> Collembola > Formicidae) were present in the organic hedge row and five major groups (Acari> Formicidae> Insect larvae> Thysanoptera> Collembola) in the conventional hedge row. Herbivore guild was recorded only in the conventional hedge row (Table 10).

Organic hedge row - I & II Year: Twelve ground surface dwelling taxa were recorded in the organic hedge row during the first year and second year period (Table 7). Overall faunal abundance (H=0.52, DF=1, P>0.05) and diversity did not vary between first and second year periods. Evenness was high in the second year period (Table 20). Four major groups (Acari> Collembola> Isoptera > Formicidae) were present in first year and five major groups (Insect larvae >Acari > Collembola> Formicidae> Psocoptera) in second year. Abundance of predator was high in the first year and detritivores in the second year (Table 14).

Conventional hedgerow- I & II Year: Seventeen ground surface dwelling taxa were recorded in the first year and ten in the second year (Table 8). Overall faunal abundance was seven times higher in the first year (60.00 ± 55.84) than during second year (8.20 ± 16.00) (H=49.46, DF=1, P<0.05). Six major groups (Acari> Formicidae> Thysanoptera> Insect larvae> Collembola> Araneae) were recorded in the first year and two major groups (Acari> Insect larvae) in the second year. Diversity did not vary between the periods and evenness was high during second year period (Table 20). Abundance of predators was high during first year. Fungivores and herbivores were recorded only in the first year (Table 16).

Organic farm and Organic hedge row

Seventeen ground surface dwelling taxa were recorded from the organic farm in contrast to 15 from the hedge row (Table 3 & Figure 2). Overall faunal abundance was three times higher in organic farm (95.45 ± 122.12) than in hedgerow (29.95 ± 36.14) (H=8.97, DF=1, P<0.05). Diversity and evenness did not vary between organic farm and organic hedgerow (Table 18). Six major groups (Acari > Collembola > Coleoptera > Hemiptera > Psocoptera > Insect larvae) were present in organic farm and four major groups (Acari> Insect larvae> Collembola > Formicidae) in hedgerow. Abundance of six groups (four major groups and two minor) was higher in organic farm. High abundance of fungivores in the organic farm and detritivores in the hedgerow was recorded. Detritivore followed by fungivore was the dominant guild in hedge row and fungivore followed by detritivore in farm. Herbivore guild was present only in organic farm (Table 11).

Conventional farm and hedgerow

Thirteen taxa were recorded from the conventional farm and and 18 from the conventional hedge row (Table 4 & Figure 3). Overall faunal abundance was higher in conventional hedgerow (34.10 ± 48.28) than in conventional farm (17.23 ± 23.77) (H=14.18, DF=1, P<0.05). Diversity did not vary between conventional farm and hedgerow whereas evenness was high in the conventional farm (Table 18). Three major groups (Acari> Psocoptera> Collembola) were present in conventional farm and five major groups (Acari> Formicidae> Insect larvae> Thysanoptera> Collembola) in conventional hedge row. Abundance of omnivores was high in the conventional hedge row and other guilds did not vary (Table 12).

DISCUSSION

Assessment of the impact of organic farming on the abundance and composition of soil arthropods indicates that organic farming enhances the abundance and diversity of ground surface dwelling arthropods compared to conventional farms in rice farming ecosystems. Our results show that organic farming often has positive effects on overall faunal abundance and abundance of major groups, but its effect differs between groups. On an average, all major groups were 5-20 times more abundant in organic farming systems and responded positively to organic farming, while some groups which were mostly minor groups did not respond positively or negatively. Five times increase in the overall abundance, 5-20 times variations in the abundance of major faunal groups (Acari-Collembola-Coleoptera-Hemiptera), 20% increase in diversity and 20-50 times increase in the abundance of fungivore and detritivore guild in organic farms compared to conventional farms are in agreement with the findings (Paoletti *et al.* 1992; Schönning & Richardsdotter-Dirke 1996) that organic farming enhances biodiversity. Variations in the abundance and diversity of ground surface dwelling arthropods in the organic and conventional farms are an expression of the impact of the farming practices including fertilizing, pesticides/herbicides.

Since higher amounts of organic material in the soil increases soil fauna in general in agricultural soils (Andrén & Lagerlöf 1983) utilization of organic fertilizers, and organic matter quality might have contributed to the overall abundance of fauna and the abundance of major groups namely, Acari, Collembola, Coleoptera and Hemiptera. Though, there are many factors other than organic farming that influence the abundance of organism groups in agricultural landscape such as edge zones and hedgerows (Chiverton 1989), since most of these factors are taken care of in the study field by the farmers, it is clear that the higher amount of detritus and organic materials in organic farm lead to the higher abundance of ground surface dwelling arthropods. Low abundance of [Collembola (20 times), Acari (five times] and the minor groups (Coleoptera and Hemiptera) in conventional farms than any other ground surface dwelling arthropod group indicate that these four groups are the most sensitive groups affected by conventional farming. Their very low abundance in conventional farms is attributed to the non availability of organic detritus and sensitivity of soft bodied organisms to the application of inorganic fertilizer and pesticides/herbicides in conventional farms. Densities of predators, such as carabid beetles and spiders, were usually higher in organic farming systems than in conventional ones (Ostman *et al* 2001, 2003; Bengtsson *et al.* 2005). However, present study shows a different trend with low abundance of these major soil/litter faunal groups in both organic and conventional rice fields under study. Possible reasons could be the impact of tilling on the nesting sites and community structure as tillage decreases the abundance of spiders and beetles (Holland & Reynolds 2003) and ants (Peck *et al.* 1998, Radford *et al.* 1995). We attribute the same reasons for the non-record of termites in rice paddies. Though the benefits of maintaining large populations of spiders in vineyards/agrifarms for pest control are well known (Bolduc *et al.* 2005; Isaia *et al.* 2006), establishment of natural population of spiders and also ants in rice farms is not possible where tillage and filling water is a regular pre-sowing process.

Continuous assessment made during the two year study period revealed that the abundance of fauna and diversity varies in conventional farms in contrast to the organic farms. Lack of fluctuations in faunal abundance between years in organic farms indicates the possibility that faunal abundance has reached equilibrium and further improvement may not be possible. Continued maintenance of the organic fertiliser application and farming in the region for a longer period could lead to further increase in the faunal abundance in organic farms in contrast to conventional farms. Next round of studies after a gap of 2-3 years would give indicate whether stable conditions and crop improvement has happened in the region.

Comparison of hedge rows and farms indicate that organic hedge row has lower abundance compared to conventional hedgerows and the organic farms, and the conventional hedgerow has higher faunal abundance and faunal richness than conventional farms. High faunal abundance and richness in hedgerows in the midst of conventional farm indicate that hedge rows in the midst of conventional farm act as refuges for these groups who might have disappeared from the agrifield following the fertilizer and pesticide application and the soil preparation for sowing. High abundance in conventional hedge rows than in conventional farms indicate that the unfavorable conditions in the conventional farms would have driven the fauna to such less polluted habitats and fauna present in conventional hedgerows could be representing the sink population of the native population of the soil arthropods prevailed in the region before intensification of agriculture with the application of insecticides. It supports the earlier findings that maintenance of biodiversity even in modified conventional agricultural landscapes will depend on the preservation, restoration and management of such habitats

(Baudry *et al.* 2000; Tscharntke *et al.* 2002). High abundance of fungivores and detritivores in organic farms is attributed to the greater availability of organic matter and absence of inorganic fertilizers, herbicides and pesticides as higher amount of organic material in the soil increases detritivores abundance (Lebbink *et al.* 1994; Zwart *et al.* 1994) and soil fauna in general in agricultural soils (Andren & Lagerlof 1983). High abundance of omnivores in hedge rows is indicative of the presence of their natural prey resources and tilling could be the reason for their low abundance in farms. Non segregation of mites into predatory groups could be a major reason for the low abundance of predator guild.

Trend towards high abundance of arthropods in organic farms and low abundance in conventional farms often lead to the common perception that pest damage on many crops is usually greater on organic farms. It is expected that organic farming would lead to rise in the local densities of arthropod predators and soil fauna during in the coming years and it is expected that the higher diversity and abundance of predator groups and omnivores (=natural enemies) will contribute to pest control on organic farms. Our study effort, shows positive effects of organic farming on abundance and diversity of all epigeal arthropods, detritivores-fungivores and the importance of hedge rows as a safe refuge for fauna in conventional farms.

Major findings

1. Higher overall abundance and diversity in organic agriculture farm than in conventional farms.
2. Higher abundance of major groups in Organic farms.
3. Taxa/ faunal group richness was higher in organic farm than in conventional farm.
4. Acari was the major group in both farms
5. Steep decline in the abundance of Collembola in conventional farms (20 times) than any other group indicating Collembola as the most sensitive group to conventional farming.
6. Identification of *Omphra pilosa* (Carabidae) and *Catharsius molossus* (Scarabaeinae) as easily recognisable indicator species with affinities to organic farms for future monitoring.
7. Higher density of fungivores & detritivores in organic farm and no variation for other guilds.

8. Low abundance of ants (omnivore) and spiders (predator) in both farms.
9. Hedge rows in the midst of conventional farms are more speciose and faunal rich than the farms indicating their importance as a refuge for the remnant native fauna.
10. Fluctuations in faunal abundance in conventional farms and stability in organic farms as obvious from the lack of variation in faunal abundance over the two year study period.

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Table 1: Abundance of ground surface dwelling arthropod groups in the organic and conventional agricultural farms during 2009-2011 period (*bold letters represent major groups*).

	Arthropod groups	Organic farm		Conventional farm		Kruskal -Wallis
		Mean ± SD	%	Mean ± SD	%	*P*- value
1	**Acari**	61.28 ± 71.45	64.20	12.13 ± 20.06	70.39	**
2	**Collembola**	22.18 ± 52.68	23.23	1.35 ± 1.98	7.84	**
3	**Coleoptera**	3.03 ± 6.57	3.17	0.30 ± 0.72	1.74	**
4	**Hemiptera**	2.30 ± 9.23	2.41	0.00 ± 0.00	0.00	**
5	**Psocoptera**	2.18 ± 4.63	2.28	1.50 ± 3.21	8.71	n.s
6	**Insect larvae**	1.73 ± 2.85	1.81	0.80 ± 1.11	4.64	n.s
7	Araneae	0.85 ± 2.24	0.89	0.20 ± 0.52	1.16	n.s
8	Formicidae	0.75 ± 1.75	0.79	0.50 ± 2.54	2.90	n.s
9	Thysanoptera	0.35 ± 0.92	0.37	0.25 ± 0.87	1.45	n.s
10	Unidentified	0.30 ± 0.69	0.31	0.03 ± 0.16	0.15	n.s
11	Hymenoptera	0.20 ± 0.52	0.21	0.03 ± 0.16	0.15	**
12	Pseudoscorpion	0.10 ± 0.30	0.10	0.00 ± 0.00	0.00	**
13	Centipede	0.05 ± 0.22	0.05	0.00 ± 0.00	0.00	n.s
14	Lepidoptera	0.05 ± 0.22	0.05	0.00 ± 0.00	0.00	n.s
15	Orthoptera	0.05 ± 0.22	0.05	0.00 ± 0.00	0.00	n.s
16	Diptera	0.05 ± 0.22	0.05	0.00 ± 0.00	0.00	n.s
17	Homoptera	0.03 ± 0.16	0.03	0.05 ± 0.22	0.29	n.s
18	Blattaria	0.00 ± 0.00	0.00	0.05 ± 0.22	0.29	n.s
19	Dermaptera	0.00 ± 0.00	0.00	0.05 ± 0.22	0.29	n.s
	Total	**95.45 ± 122.12**		**17.23 ± 23.77**		**

Table 2: Abundance of ground surface dwelling arthropod groups associated with the hedgerows bordering organic and conventional farms during 2009-2011 period (*bold letters represent major groups*).

	Arthropod groups	Organic hedgerow		Conventional hedgerow		Kruskal-Wallis
		Mean ± SD	%	Mean ± SD	%	*P*- value
1	**Acari**	17.78 ± 24.89	59.35	23.25 ± 34.75	68.18	n.s
2	**Insect larvae**	4.28 ± 18.92	14.27	1.78 ± 2.17	5.21	n.s
3	**Collembola**	3.20 ± 7.98	10.68	1.03 ± 2.11	3.01	n.s
4	**Formicidae**	1.78 ± 3.88	5.93	3.48 ± 10.98	10.19	n.s
5	Psocoptera	0.80 ± 1.38	2.67	0.40 ± 0.78	1.17	n.s
6	Isoptera	0.75 ± 1.28	2.50	0.00 ± 0.00	0.00	**
7	Araneae	0.33 ± 0.57	1.09	0.75 ± 1.37	2.20	n.s
8	Coleoptera	0.30 ± 0.61	1.00	0.18 ± 0.45	0.51	n.s
9	Pseudoscorpion	0.25 ± 0.63	0.83	0.23 ± 0.53	0.66	n.s
10	Unidentified	0.15 ± 0.58	0.50	0.63 ± 1.25	1.83	n.s

11	**Thysanoptera**	0.15 ± 0.95	0.50	1.63 ± 5.62	4.77	**
12	Orthoptera	0.08 ± 0.27	0.25	0.03 ± 0.16	0.07	n.s
13	Hemiptera	0.05 ± 0.22	0.17	0.25 ± 0.49	0.73	**
14	Centipede	0.05 ± 0.32	0.17	0.05 ± 0.22	0.15	n.s
15	Hymenoptera	0.03 ± 0.16	0.08	0.03 ± 0.16	0.07	n.s
16	Worms (unidentified)	0.00 ± 0.00	0.00	0.05 ± 0.22	0.15	n.s
17	Opiliones	0.00 ± 0.00	0.00	0.15 ± 0.66	0.44	n.s
18	Homoptera	0.00 ± 0.00	0.00	0.15 ± 0.43	0.44	**
19	Diptera	0.00 ± 0.00	0.00	0.08 ± 0.27	0.22	n.s
	Total	**29.95 ± 36.14**		**34.10 ± 48.28**		**n.s**

Table 3: Abundance of ground surface dwelling arthropod groups in the organic farm and associated hedgerows during 2009-2011 period (*bold letters represent major groups*).

	Arthropod groups	**Organic farm**		**Organic hedgerow**		**Kruskal-Wallis**
		Mean ± SD	%	Mean ± SD	%	*P*- value
1	**Acari**	61.28 ± 71.45	64.20	17.78 ± 24.89	59.35	**
2	**Collembola**	22.18 ± 52.68	23.23	3.20 ± 7.98	10.68	**
3	**Coleoptera**	3.03 ± 6.57	3.17	0.30 ± 0.61	1.00	**
4	**Hemiptera**	2.30 ± 9.23	2.41	0.05 ± 0.22	0.17	**
5	**Psocoptera**	2.18 ± 4.63	2.28	0.80 ± 1.38	2.67	n.s
6	**Insect larvae**	1.73 ± 2.85	1.81	4.28 ± 18.92	14.27	n.s
7	Araneae	0.85 ± 2.24	0.89	0.33 ± 0.57	1.09	n.s
8	**Formicidae**	0.75 ± 1.75	0.79	1.78 ± 3.88	5.93	n.s
9	Thysanoptera	0.35 ± 0.92	0.37	0.15 ± 0.95	0.50	**
10	Unidentified	0.30 ± 0.69	0.31	0.15 ± 0.58	0.50	n.s
11	Hymenoptera	0.20 ± 0.52	0.21	0.03 ± 0.16	0.08	**
12	Pseudoscorpion	0.10 ± 0.30	0.10	0.25 ± 0.63	0.83	n.s
13	Centipede	0.05 ± 0.22	0.05	0.05 ± 0.32	0.17	n.s
14	Lepidoptera	0.05 ± 0.22	0.05	0.00 ± 0.00	0.00	n.s
15	Orthoptera	0.05 ± 0.22	0.05	0.08 ± 0.27	0.25	n.s
16	Diptera	0.05 ± 0.22	0.05	0.00 ± 0.00	0.00	n.s
17	Homoptera	0.03 ± 0.16	0.03	0.00 ± 0.00	0.00	n.s
18	Isoptera	0.00 ± 0.00	0.00	0.75 ± 1.28	2.50	**
	Total	**95.45 ± 122.12**		**29.95 ± 36.14**		**

Table 4: Abundance of ground surface dwelling arthropod groups in the conventional farm and associated hedgerows during 2009-2011 period (*bold letters represent major groups*).

	Arthropod groups	Conventional farm		Conventional hedgerow		Kruskal -Wallis
		Mean ± SD	%	Mean ± SD	%	*P*- value
1	**Acari**	12.13 ± 20.06	70.39	23.25 ± 34.75	68.18	n.s
2	**Psocoptera**	1.50 ± 3.21	8.71	0.40 ± 0.78	1.17	n.s
3	**Collembola**	1.35 ± 1.98	7.84	1.03 ± 2.11	3.01	n.s
4	**Insect larvae**	0.80 ± 1.11	4.64	1.78 ± 2.17	5.21	**
5	**Formicidae**	0.50 ± 2.54	2.90	3.48 ± 10.98	10.19	**
6	Coleoptera	0.30 ± 0.72	1.74	0.18 ± 0.45	0.51	n.s
7	**Thysanoptera**	0.25 ± 0.87	1.45	1.63 ± 5.62	4.77	n.s
8	Araneae	0.20 ± 0.52	1.16	0.75 ± 1.37	2.20	n.s
9	Blattaria	0.05 ± 0.22	0.29	0.00 ± 0.00	0.00	n.s
10	Dermaptera	0.05 ± 0.22	0.29	0.00 ± 0.00	0.00	n.s
11	Homoptera	0.05 ± 0.22	0.29	0.15 ± 0.43	0.44	n.s
12	Hymenoptera	0.03 ± 0.16	0.15	0.03 ± 0.16	0.07	n.s
13	Unidentified	0.03 ± 0.16	0.15	0.63 ± 1.25	1.83	n.s
14	Centipede	0.00 ± 0.00	0.00	0.05 ± 0.22	0.15	n.s
15	Diptera	0.00 ± 0.00	0.00	0.08 ± 0.27	0.22	n.s
16	Hemiptera	0.00 ± 0.00	0.00	0.25 ± 0.49	0.73	**
17	Opiliones	0.00 ± 0.00	0.00	0.15 ± 0.66	0.44	n.s
18	Orthoptera	0.00 ± 0.00	0.00	0.03 ± 0.16	0.07	n.s
19	Pseudoscorpion	0.00 ± 0.00	0.00	0.23 ± 0.53	0.66	**
20	Worms (unidentified)	0.00 ± 0.00	0.00	0.05 ± 0.22	0.15	n.s
	Total	**17.23 ± 23.77**		**34.10 ± 48.28**		**

Table 5: Abundance of ground surface dwelling arthropod groups in organic agricultural farms during first and second year of the study period (*bold letters represent major groups*).

	Arthropod groups	Organic farm				Kruskal -Wallis
		I-Year		II-Year		
		Mean ± SD	%	Mean ± SD	%	*P*- value
1	**Acari**	62.80 ± 69.41	56.70	59.75 ± 75.21	74.55	n.s
2	**Collembola**	34.90 ± 72.18	31.51	9.45 ± 12.05	11.79	n.s
3	**Coleoptera**	5.10 ± 8.84	4.60	0.95 ± 1.10	1.19	n.s
4	**Psocoptera**	2.05 ± 5.57	1.85	2.30 ± 3.61	2.87	n.s
5	**Araneae**	1.50 ± 3.02	1.35	0.20 ± 0.52	0.25	n.s
6	**Formicidae**	1.25 ± 2.22	1.13	0.25 ± 0.91	0.31	**
7	**Insect larvae**	1.25 ± 1.41	1.13	2.20 ± 3.76	2.74	n.s
8	**Hemiptera**	0.65 ± 1.35	0.59	3.95 ± 12.93	4.93	n.s
9	Unidentified	0.45 ± 0.89	0.41	0.15 ± 0.37	0.19	n.s
10	Hymenoptera	0.20 ± 0.52	0.18	0.20 ± 0.52	0.25	n.s
11	Pseudoscorpion	0.20 ± 0.41	0.18	0.00 ± 0.00	0.00	**
12	Centipede	0.10 ± 0.341	0.09	0.00 ± 0.00	0.00	n.s
13	Lepidoptera	0.10 ± 0.31	0.09	0.00 ± 0.00	0.00	n.s
14	Orthoptera	0.10 ± 0.31	0.09	0.00 ± 0.00	0.00	n.s
15	Diptera	0.05 ± 0.22	0.05	0.05 ± 0.22	0.06	n.s
16	Homoptera	0.05 ± 0.22	0.05	0.00 ± 0.00	0.00	n.s
17	Thysanoptera	0.00 ± 0.00	0.00	0.70 ± 1.22	0.87	**
	Total	**110.75 ± 149.25**		**80.15 ± 88.57**		**n.s**

Table 6: Abundance of ground surface dwelling arthropod groups in the conventional farm during first and second year of the study period (*bold letters represent major groups*).

	Arthropod groups	Conventional farm				Kruskal -Wallis
		I-Year		II-Year		
		Mean ± SD	%	Mean ± SD	%	*P*- value
1	**Acari**	14.50 ± 20.88	66.82	9.75 ± 19.44	76.47	n.s
2	**Psocoptera**	2.70 ± 4.21	12.44	0.30 ± 0.66	2.35	**
3	**Collembola**	2.30 ± 2.20	10.60	0.40 ± 1.14	3.14	**
4	**Insect larvae**	1.20 ± 1.32	5.53	0.40 ± 0.68	3.14	**
5	Coleoptera	0.50 ± 0.95	2.30	0.10 ± 0.31	0.78	n.s
6	Araneae	0.30 ± 0.66	1.38	0.10 ± 0.31	0.78	n.s
7	Dermaptera	0.10 ± 0.31	0.46	0.00 ± 0.00	0.00	n.s
8	Homoptera	0.10 ± 0.31	0.46	0.00 ± 0.00	0.00	n.s
9	Blattaria	0.00 ± 0.00	0.00	0.10 ± 0.31	0.78	n.s
10	**Formicidae**	0.00 ± 0.00	0.00	1.00 ± 3.57	7.84	**
11	Hymenoptera	0.00 ± 0.00	0.00	0.05 ± 0.22	0.39	n.s
12	Thysanoptera	0.00 ± 0.00	0.00	0.50 ± 1.19	3.92	**
13	Unidentified	0.00 ± 0.00	0.00	0.05 ± 0.22	0.39	n.s
	Total	**21.70 ± 25.85**		**12.75 ± 21.20**		**

Table 7: Abundance of ground surface dwelling arthropod groups in the organic hedgerows during the first and second year period (*bold letters represent major groups*).

	Arthropod groups	Organic hedgerow				Kruskal -Wallis
		I-Year		II-Year		
		Mean ± SD	%	Mean ± SD	%	*P*- value
1	**Acari**	28.40 ± 30.73	78.67	7.15 ± 9.44	30.04	**
2	**Collembola**	2.80 ± 5.12	7.76	3.60 ± 10.22	15.13	n.s
3	**Isoptera**	1.50 ± 1.47	4.16	0.00 ± 0.00	0.00	**
4	**Formicidae**	1.20 ± 2.44	3.32	2.35 ± 4.92	9.87	n.s
5	Araneae	0.45 ± 0.69	1.25	0.20 ± 0.41	0.84	n.s
6	**Insect larvae**	0.45 ± 0.69	1.25	8.10 ± 26.53	34.03	**
7	Pseudoscorpion	0.45 ± 0.83	1.25	0.05 ± 0.22	0.21	**
8	**Psocoptera**	0.30 ± 0.57	0.83	1.30 ± 1.75	5.46	**
9	Unidentified	0.30 ± 0.80	0.83	0.00 ± 0.00	0.00	n.s
10	Centipede	0.10 ± 0.45	0.28	0.00 ± 0.00	0.00	n.s
11	Coleoptera	0.10 ± 0.31	0.28	0.50 ± 0.76	2.10	**
12	Orthoptera	0.05 ± 0.22	0.14	0.10 ± 0.31	0.42	n.s
13	Hemiptera	0.00 ± 0.00	0.00	0.10 ± 0.31	0.42	n.s
14	Hymenoptera	0.00 ± 0.00	0.00	0.05 ± 0.22	0.21	n.s
15	Thysanoptera	0.00 ± 0.00	0.00	0.30 ± 1.34	1.26	n.s
	Total	**36.10 ± 34.36**		**23.80 ± 37.69**		**n.s**

Table 8: Abundance of ground surface dwelling arthropod groups associated with the hedgerows bordering conventional farms during the first and second year period (*bold letters represent major groups*).

	Arthropod groups	Conventional hedgerow				Kruskal -Wallis
		I-Year		II-Year		
		Mean ± SD	%	Mean ± SD	%	*P*- value
1	**Acari**	41.45 ± 39.30	69.08	5.05 ± 15.37	61.59	**
2	**Formicidae**	6.25 ± 15.14	10.42	0.70 ± 1.30	8.54	n.s
3	**Thysanoptera**	3.10 ± 7.75	5.17	0.15 ± 0.37	1.83	n.s
4	**Insect larvae**	2.10 ± 2.71	3.50	1.45 ± 1.43	17.68	n.s
5	**Collembola**	2.05 ± 2.63	3.42	0.00 ± 0.00	0.00	**
6	Araneae	1.45 ± 1.67	2.42	0.05 ± 0.22	0.61	**
7	Unidentified	1.25 ± 1.55	2.08	0.00 ± 0.00	0.00	n.s
8	Hemiptera	0.45 ± 0.60	0.75	0.05 ± 0.22	0.61	**
9	Pseudoscorpion	0.40 ± 0.68	0.67	0.05 ± 0.22	0.61	**
10	Homoptera	0.30 ± 0.57	0.50	0.00 ± 0.00	0.00	**
11	Opiliones	0.30 ± 0.92	0.50	0.00 ± 0.00	0.00	n.s
12	Coleoptera	0.25 ± 0.55	0.42	0.10 ± 0.31	1.22	n.s
13	Psocoptera	0.25 ± 0.44	0.42	0.55 ± 1.00	6.71	n.s

14	Diptera	0.15 ± 0.37	0.25	0.00 ± 0.00	0.00	n.s
15	Centipede	0.10 ± 0.31	0.17	0.00 ± 0.00	0.00	n.s
16	Worms (unidentified)	0.10 ± 0.31	0.17	0.00 ± 0.00	0.00	n.s
17	Orthoptera	0.05 ± 0.22	0.08	0.00 ± 0.00	0.00	n.s
18	Hymenoptera	0.00 ± 0.00	0.00	0.05 ± 0.22	0.61	n.s
	Total	**60.00 ± 55.84**		**8.20 ± 15.96**		**

Table 9: Guild-wise abundance of ground surface dwelling arthropod groups in the organic and conventional farms during 2009-2011 period.

Guilds	**Organic farm**		**Conventional farm**		**Kruskal-Wallis**
	Mean ± SD	%	Mean ± SD	%	*P*- value
Fungivore	23.15 ± 17.85	74.86	1.35 ± 0.99	27.98	**
Detritivore	4.88 ± 2.41	15.76	2.35 ± 1.86	48.70	**
Predator	2.03 ± 1.39	6.55	0.53 ± 0.50	10.88	n.s
Omnivore	0.75 ± 0.58	2.43	0.55 ± 0.50	11.40	n.s
Herbivore	0.13 ± 0.12	0.40	0.05 ± 0.04	1.04	n.s

Table 10: Guild-wise abundance of ground surface dwelling arthropod groups in the hedgerows bordering organic and conventional farms during 2009-2011 period.

Guilds	**Organic hedgerow**		**Conventional hedgerow**		**Kruskal-Wallis**
	Mean ± SD	%	Mean ± SD	%	*P*- value
Detritivore	5.23 ± 4.72	47.18	2.33 ± 1.25	27.84	n.s
Fungivore	3.30 ± 2.67	29.80	1.10 ± 1.00	13.17	n.s
Omnivore	1.85 ± 1.29	16.70	3.50 ± 2.76	41.92	n.s
Predator	0.70 ± 0.44	6.32	1.28 ± 1.01	15.27	n.s
Herbivore	0.00 ± 0.00	0.00	0.15 ± 0.14	1.80	**

Table 11: Guild-wise abundance of ground surface dwelling arthropod groups in the organic farm and associated hedgerows during 2009-2011 period.

Guilds	**Organic farm**		**Organic hedgerow**		**Kruskal-Wallis**
	Mean ± SD	%	Mean ± SD	%	*P*- value
Fungivore	23.15 ± 17.85	74.86	3.30 ± 2.67	29.80	**
Detritivore	4.88 ± 2.41	15.76	5.23 ± 4.72	47.18	**
Predator	2.03 ± 1.39	6.55	0.70 ± 0.44	6.32	n.s
Omnivore	0.75 ± 0.58	2.43	1.85 ± 1.29	16.70	n.s
Herbivore	0.13 ± 0.12	0.40	0.00 ± 0.00	0.00	**

Table 12: Guild-wise abundance of ground surface arthropod groups in the conventional farm and associated hedgerows during 2009-2011 period.

Guilds	Conventional farm		Conventional hedgerow		Kruskal-Wallis
	Mean ± SD	%	Mean ± SD	%	*P*- value
Detritivore	2.35 ± 1.86	48.70	2.33 ± 1.25	27.84	n.s
Fungivore	1.35 ± 0.99	27.98	1.10 ± 1.00	13.17	n.s
Omnivore	0.55 ± 0.50	11.40	3.50 ± 2.76	41.92	**
Predator	0.53 ± 0.50	10.88	1.28 ± 1.01	15.27	n.s
Herbivore	0.05 ± 0.04	1.04	0.15 ± 0.14	1.80	n.s

Table 13: Guild-wise abundance of ground surface dwelling arthropod groups in the organic farm during the first and second year period.

Guilds	Organic farm				Kruskal-Wallis
	I-Year		II-Year		
	Mean ± SD	%	Mean ± SD	%	*P*- value
Fungivore	36.80 ± 73.12	79.57	9.50 ± 12.01	60.90	n.s
Detritivore	4.65 ± 7.65	10.05	5.10 ± 6.96	32.69	n.s
Predator	3.50 ± 5.53	7.57	0.55 ± 0.76	3.53	n.s
Omnivore	1.25 ± 2.22	2.70	0.25 ± 0.91	1.60	**
Herbivore	0.05 ± 0.22	0.11	0.20 ± 0.52	1.28	n.s

Table 14: Guild-wise abundance of ground surface dwelling arthropod groups in the organic hedgerow during the first and second year period.

Guilds	Organic hedgerow				Kruskal-Wallis
	I-Year		II-Year		
	Mean ± SD	%	Mean ± SD	%	*P*- value
Fungivore	2.85 ± 5.16	48.31	3.75 ± 10.26	25.08	n.s
Omnivore	1.25 ± 2.51	21.19	2.45 ± 4.88	16.39	n.s
Predator	1.00 ± 1.03	16.95	0.40 ± 0.60	2.68	**
Detritivore	0.80 ± 1.01	13.56	8.35 ± 26.51	55.85	**

Table 15: Guild-wise abundance of ground surface arthropod groups in the conventional farm during the first and second year period.

Guilds	Conventional farm				Kruskal-Wallis
	I-Year		II-Year		
	Mean ± SD	%	Mean ± SD	%	*P*- value
Detritivore	4.00 ± 4.70	55.56	0.70 ± 0.80	29.17	**
Fungivore	2.30 ± 2.20	31.94	0.40 ± 1.14	16.67	**
Predator	0.80 ± 1.58	11.11	0.20 ± 0.41	8.33	n.s
Herbivore	0.10 ± 0.31	1.39	0.00 ± 0.00	0.00	n.s
Omnivore	0.00 ± 0.00	0.00	1.10 ± 3.55	45.83	**

Table 16: Guild-wise abundance of ground surface dwelling arthropod groups in the hedgerow of conventional farms during the first and second year period.

Guilds	Conventional hedgerow				Kruskal-Wallis
	I-Year		II-Year		
	Mean ± SD	%	Mean ± SD	%	*P*- value
Omnivore	6.30 ± 15.24	45.82	0.70 ± 1.30	23.73	n.s
Detritivore	2.60 ± 3.02	18.91	2.05 ± 1.90	69.49	n.s
Predator	2.35 ± 2.39	17.09	0.20 ± 0.41	6.78	**
Fungivore	2.20 ± 2.84	16.00	0.00 ± 0.00	0.00	**
Herbivore	0.30 ± 0.57	2.18	0.00 ± 0.00	0.00	**

Table 17: Diversity and evenness of ground surface dwelling arthropod groups in the organic and conventional farms and the associated hedgerows during 2009-2011 period.

Diversity Index	Organic farm	Conventional farm	ANOVA	Organic hedgerow	Conventional hedgerow	ANOVA
	Mean ± SD	Mean ± SD	*P*- value	Mean ± SD	Mean ± SD	*P*- value
Shannon diversity (H')	0.83 ± 0.39	0.62 ± 0.44	**	0.78 ± 0.40	0.75 ± 0.53	n.s
Pielou's evenness (J')	0.60 ± 0.24	0.71 ± 0.22	**	0.67 ± 0.24	0.67 ± 0.25	n.s

Table 18: Diversity and evenness of ground surface dwelling arthropod groups in the organic and conventional farms and the associated hedgerows during 2009-2011 period.

Diversity Index	Organic farm	Organic hedgerow	ANOVA	Conventional farm	Conventional hedgerow	ANOVA
	Mean ± SD	Mean ± SD	*P*- value	Mean ± SD	Mean ± SD	*P*- value
Shannon diversity (H')	0.83± 0.39	0.81 ± 0.41	n.s	0.62 ± 0.44	0.75 ± 0.53	n.s
Pielou's evenness (1-λ)	0.60 ± 0.24	0.67 ± 0.24	n.s	0.71 ± 0.22	0.67 ± 0.25	**

Table 19: Diversity and evenness of ground surface dwelling arthropod groups in the organic and conventional farms during the first and second year period.

Diversity Index	Organic farm		ANOVA	Conventional farm		ANOVA
	I-Year	II-Year		I-Year	II-Year	
	Mean ± SD	Mean ± SD	*P*- value	Mean ± SD	Mean ± SD	*P*- value
Shannon diversity (H')	0.73 ± 0.38	0.93 ± 0.39	n.s	0.81 ± 0.45	0.43 ± 0.36	**
Pielou's even ness (J')	0.53 ± 0.24	0.66 ± 0.23	n.s	0.75 ± 0.19	0.66 ± 0.26	**

Table 20: Diversity and evenness of ground surface dwelling arthropod groups in the organic and conventional hedgerows during the first and second year period.

Diversity Index	Organic hedgerow		ANOVA	Conventional hedgerow		ANOVA
	I-Year	II-Year		I-Year	II-Year	
	Mean ± SD	Mean ± SD	*P*- value	Mean ± SD	Mean ± SD	*P*- value
Shannon diversity (H')	0.71 ± 0.28	0.86 ± 0.49	n.s	0.90 ± 0.57	0.60 ± 0.45	n.s
Pielou's evenness (J')	0.56 ± 0.22	0.80 ± 0.20	**	0.53 ± 0.22	0.83 ± 0.20	**

Table 21: Species list of selected ground surface dwelling arthropods collected from the organic and conventional farms during 2009-2011 period.

	Organic farm	Conventional farm
Araneae	*Storena* sp. *Linyphia* sp. *Palpimanus* sp.	*Linyphia* sp.
Formicidae	*Paratopula taylori* *Pseudoponera darwini* *Cardiocondyla* sp. *Solenopsis geminata* *Tapinoma* sp.	*Paratopula taylori*
Pseudoscorpionidae	*Calocheiridius* sp.	
Carabidae	*Stenolophus* sp *Omphra pilosa*	*Stenolophus* sp.
Scarabaeinae	*Tibiodrepanus setosus* *Onthophagus cervus* *Onthophagus turbatus* *Onthophagus catta* *Onthophagus pygmaeus* *Onthophagus quadridentatus* *Onthophagus furcillifer* *Tiniocellus spinipes* *Caccobius meridionalis* *Caccobius vulcanus* *Caccobius ultor* *Onthophagus epihippioderus* *Onthophagus centricornis* *Onthophagus dama* *Onthophagus malabarensis* *Onthophagus falsus* *Onthophagus deflexicollis* *Onthophagus laborans* *Onthophagus pacificus* *Copris repertus* *Onthophagus unifasciatus* *Catharsius molossus* *Onthophagus amphicoma* *Onthophagus ensifer* *Onthophagus insignicollis* *Onthophagus oculatus*	*Tibiodrepanus setosus* *Onthophagus turbatus* *Onthophagus dama* *Onthophagus cervus* *Onthophagus furcillifer* *Onthophagus quadridentatus* *Tiniocellus spinipes* *Onthophagus falsus* *Onthophagus catta* *Caccobius ultor* *Onthophagus unifasciatus* *Caccobius vulcanus* *Onthophagus centricornis* *Onthophagus pygmaeus* *Paracopris davisoni* *Onthophagus epihippioderus* *Onthophagus favrei* *Onthophagus oculatus* *Copris repertus* *Onthophagus bifasciatus* *Onthophagus bronzeus* *Onthophagus ensifer* *Onthophagus rectecornutus* *Paracopris signatus* *Caccobius meridionalis* *Onthophagus insignicollis*
Tenebrionidae	*Gonocephalum bilineatum* *Alphitobius diaperinus* *Mesomorphus villiger*	*Gonocephalum bilineatum*

Figure 1: Abundance of ground surface dwelling arthropod groups in organic and conventional farms during 2009-2011 period

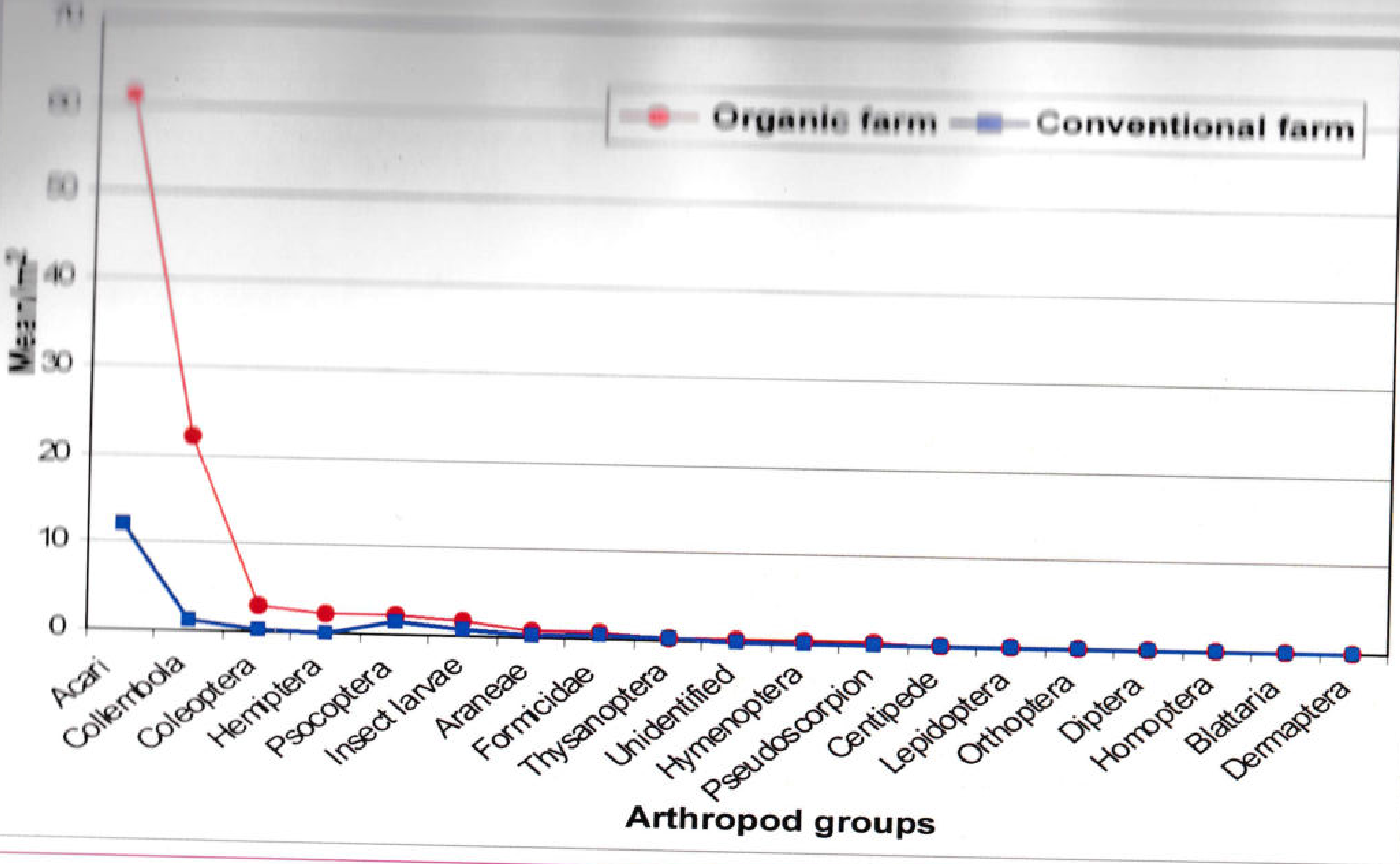


Figure 2: Abundance of ground surface dwelling arthropod groups in organic farm and associated hedgerows during 2009-2011 period.

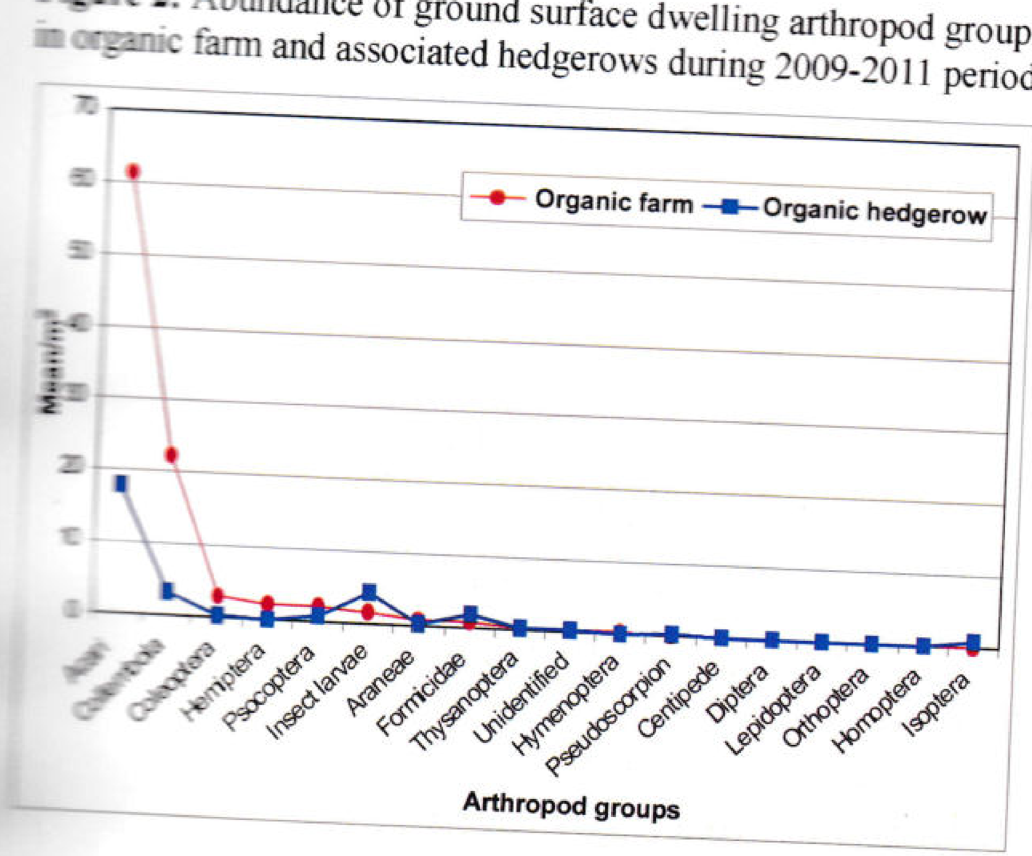


Figure 3: Abundance of ground surface dwelling arthropod groups in conventional farm and associated hedgerows during 2009-2011 period.

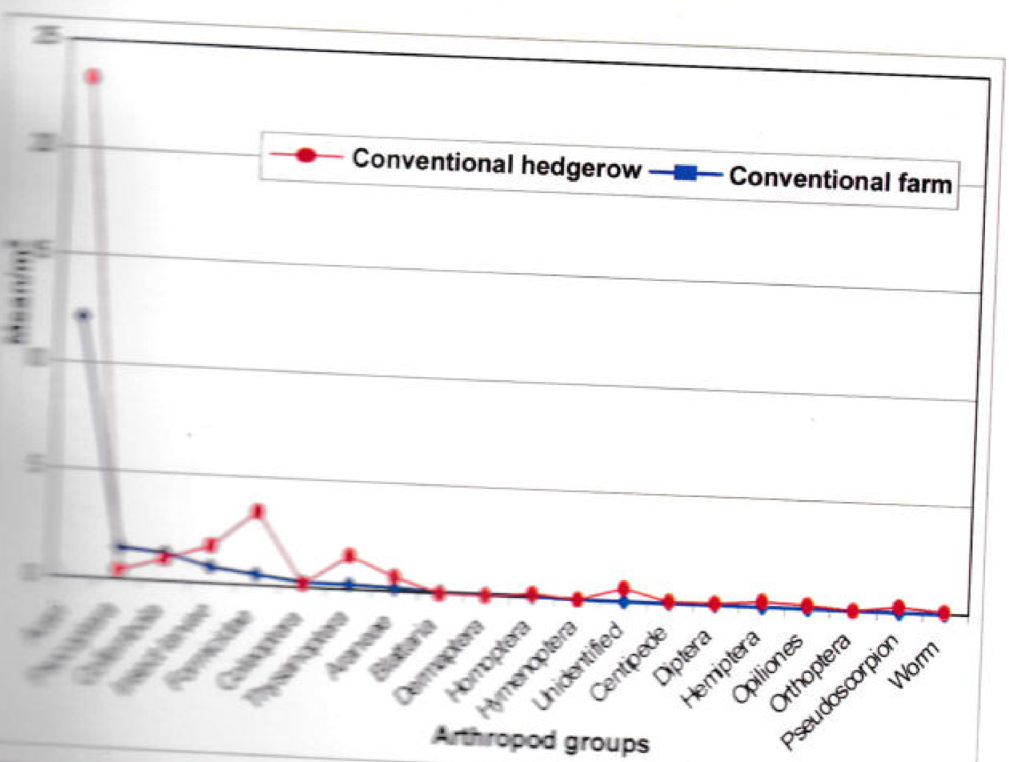


Figure 4: Abundance of ground surface dwelling arthropod groups associated with the hedgerows bordering organic and conventional farms during 2009-2011 period.

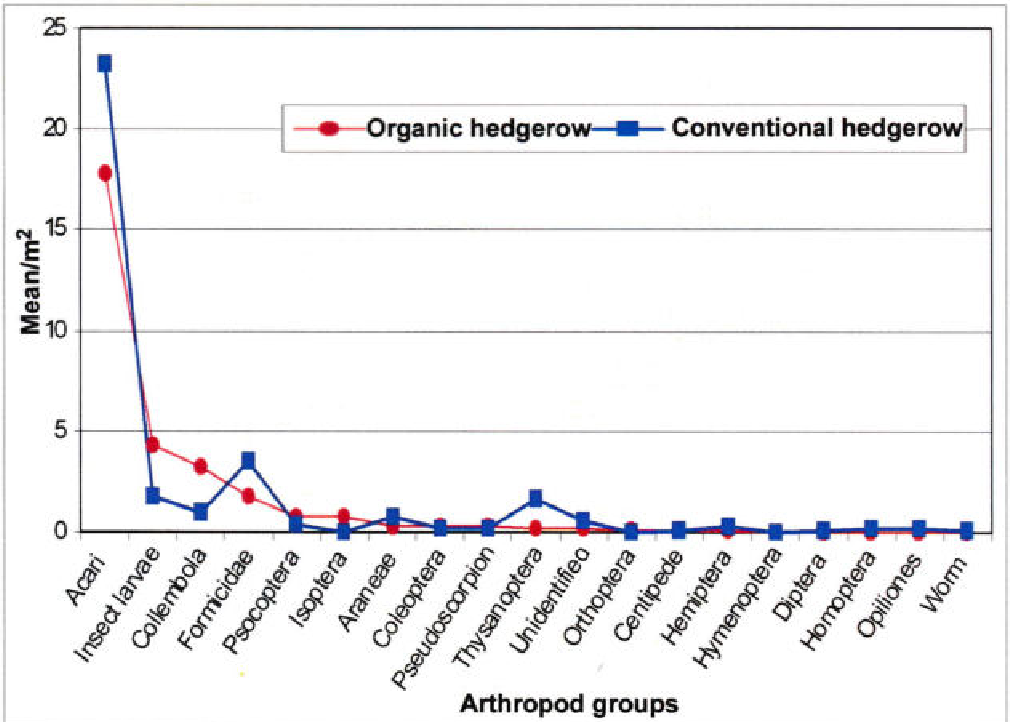
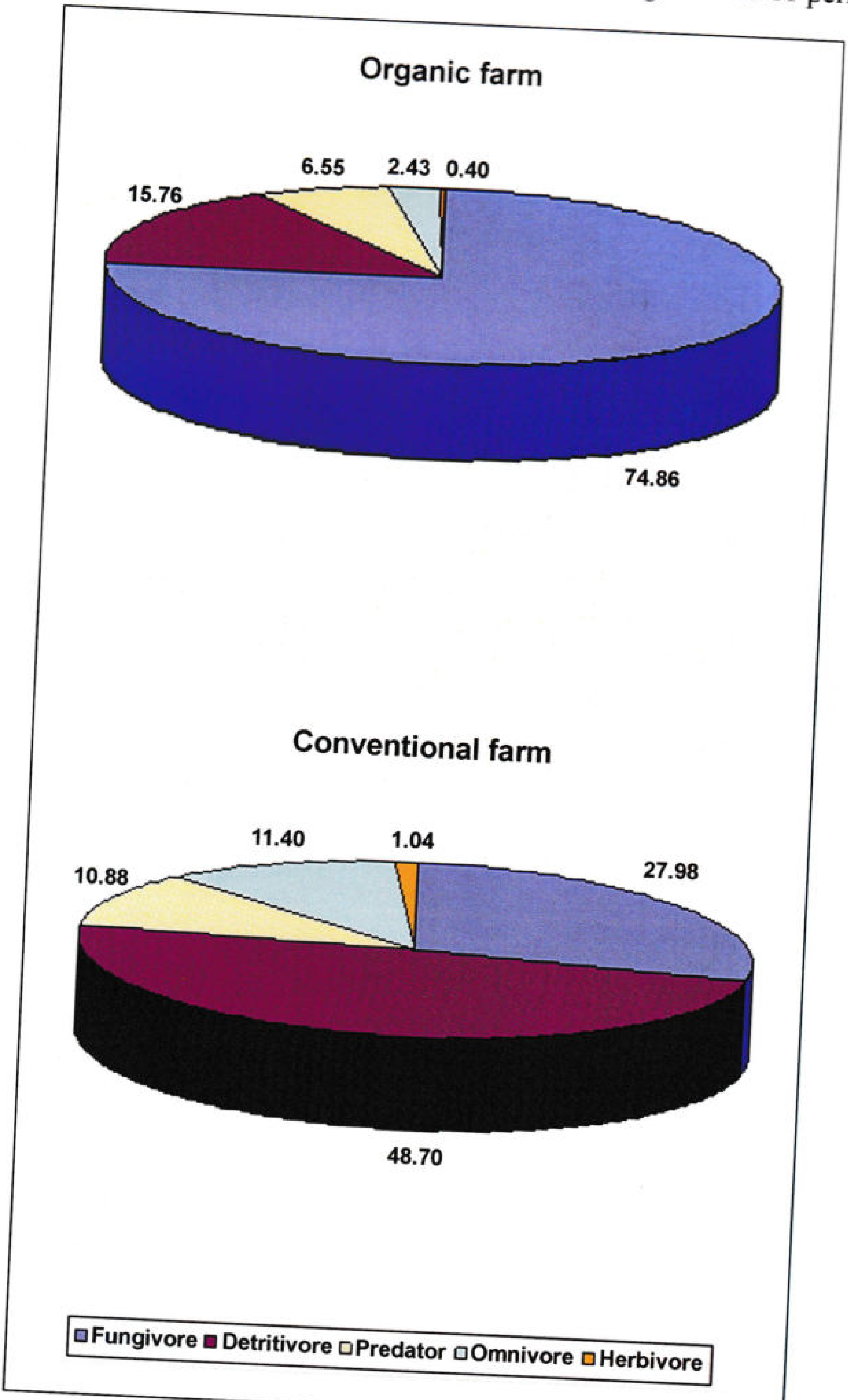
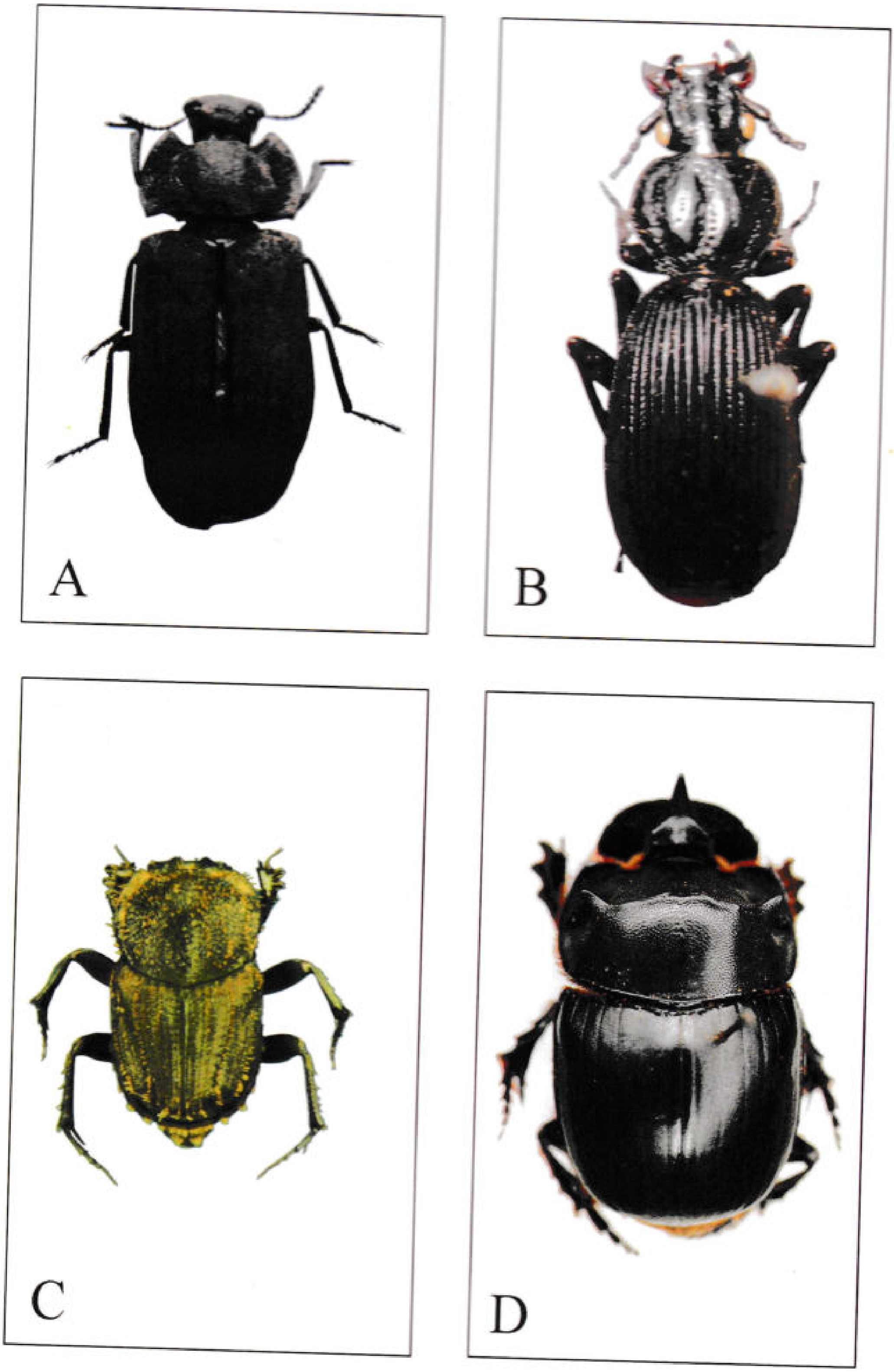


Figure 5: Guild-wise abundance of ground surface dwelling arthropod groups in the organic and conventional farms during 2009-2011 period.





Ground dwelling Coleoptera sensitive to conventional farms-
(A) *Gonocephalum bilineatum* (Tenebrionidae) **(B)** *Omphra pilosa* (Carabidae)
(C) *Tibiodrepanus setosus* and **(D)** *Catharsius molossus* (Scarabaeinae).