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Original Articles

Evaluation of Environments by the Species Composition of Carabid Beetles in Different Husbandry Fields

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ABSTRACT

To clarify whether the species composition of carabid beetles can be used to evaluate the field environments of 3 different husbandry practices (fertilizer (F), tillage (T) and green manure (Gr)), pitfall trappings were taken between June and October 2003 in Nagano Prefecture, Japan. The surveyed field was divided into 8 plots (7.5 m×14 m) growing the same kinds of vegetables, and combinations of the 3 husbandry practices were decided using an experimental design based on 3 factors and 2 levels. ANOVA based on a table of orthogonal arrays of the L^8 (2^7) type was used for the numbers of carabid beetles, species richness and species diversity. A total of 821 carabid beetles of 6 subfamilies representing 31 species were captured during the survey period. The three dominant species were *Dolichus halensis, Pterostichus microcephalus* and *Harpalus tridens.* Through cluster analysis using an α index, the 8 plots were classified into a green manure group and a non-green manure group, except for 1 plot. The numbers of captured beetles of Pterostichinae, especially *D. halensis*, were significantly more abundant in chemical fertilizer plots and non-green manure plots. For Zabrinae and Harpalinae, more individuals were captured in tillage plots and green manure plots. In the tillage plots and green manure plots, the values of the species diversity index ($1/\lambda$ and H') were significantly higher. These results suggest that carabid assemblages may be used as a bio-indicator for evaluating the field environments of different husbandry practices.

Key words: Carabid beetle, husbandry practice, bio-indicator, fertilizer, tillage, green manure

Introduction

Carabid beetles have been studied as a bio-indicator of the environment and as potential predators in the agroecosystem. Recently, much interest has been created in bio-indicator research using insect groups such as butterflies (*e.g.* Tanaka, 1988 ; Nakamura, 2001). Carabid beetles have also been proposed as an indicator insect (Dufrenê *et al.*, 1990 ; Sunose, 1992), because they are widely distributed in the environment and the numbers of species and individuals vary (Luff, 2002 ; Ishitani, 2003). In addition, carabid beetles are relatively immobile and disperse mainly by walking, rendering them easy to sample (Thomas *et al.*, 2002).

The pitfall trap method has contributed to quantitative studies on carabid beetles, including their seasonal abundance, spatial distribution, population estimation and community compositions, and the results have provided important information for environmental evaluation. Regarding carabid beetle communities assessed using pitfall traps, several important studies in various agroecosystems have been reported by Yahiro *et al.* (1992) and Ishitani & Yano (1994). Furthermore, carabid communities have been studied as indicators of the effects of farming systems and the use of pesticides (Ogilvy *et al.*, 1994).

Ishitani (1996) conducted a series of studies in various environmental conditions in Yamaguchi Prefecture to clarify the role of ground beetles as an environmental indicator. Regarding such environmental evaluation,

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several other studies have also been conducted to launch ground beetles as a bio-indicator (Ishii *et al.*, 1996; Villa-Castillo and Wagner, 2002). In these studies, gradients of the forest flora or differences among cultivated plants in fields were evaluated for their carabid communities. However, few studies have surveyed the species compositions of carabids in fields that are managed strictly according the local rules.

In the present study, to clarify whether the species composition of carabid beetles could be used to evaluate the field environments of different husbandry practices, we investigated carabid assemblages in fields growing the same kinds of vegetables under different husbandry managements based on a specific experimental design.

Materials and Methods

1. Experimental Design

The study was conducted in a field at the International Nature Farming Research Center in Hata Town, Nagano Prefecture, Japan (lat. 36° 11'46"N, long. 137° 52'2"E, altitude 695 m). The experimental field, which had not been treated with any chemical fertilizers for 5 years, was divided into 8 treatment plots of 14 m in length and 7.5 m in width. Three husbandry practices, i.e. fertilizer (F), tillage (T) and green manure (Gr), were selected as factors that may influence the carabid assemblage. The combination of the 3 husbandry practices at each treatment plot was decided as shown in **Fig. 1**, according to an experimental design based on 3 factors and 2 levels (**Table 1**).

Five kilograms N/10 a of chemical fertilizer (N : P : K = 15 : 15 : 12) was applied in May and June 2003, and the same amount of organic fertilizer (a fermented mixture of rice bran, rape cake and fish meal) was applied in April and June 2003. Italian ryegrass and red clover were used as the green manure crops. Green manure was plowed into the soil in tillage plots and cut down to cover the soil in non-tillage plots. Dried rye was used to cover the troughs between the ridges in non-tillage plots.

The same kinds of vegetables were grown in the 8 plots, namely corns, kidney beans, green soybeans, eggplants and radishes, and the same planting pattern was followed in each plot. **Fig. 2** shows the vegetables grown in 2 different plots. Thin plastic sheets were placed in the ground at the boundary of the plots, but they were low enough (about 10 cm from the ground) for carabid beetles to move over the boundary into neighboring plots. In addition, there were paths along the north and south sides of the study field that had no boundaries (**Fig. 1**), such that the carabid beetles could move anywhere in the study field or into the adjacent fields.

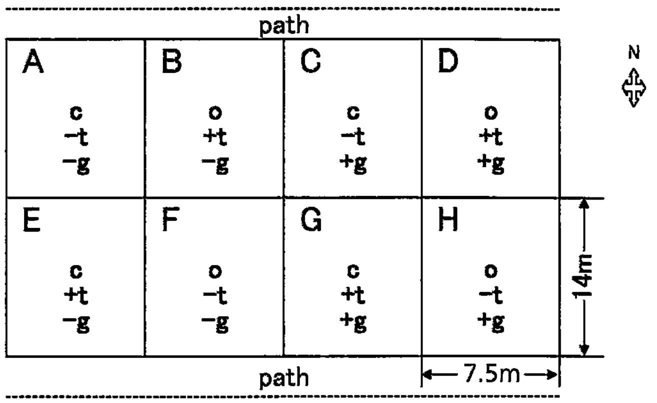

Fig. 1 Treatment design of the 3 husbandry practices in the 8 plots. A-H : Plot name ; c: chemical fertilizer ; o : organic fertilizer ; +t : conventional tillage ; -t : non-tillage ; +g : with green manure ; -g : without green manure.

Table.1 Treatment design condition

Factor	Level	
	1	2
Tillage or not(T)	Non tillage(-t)	Tillage(+t)
Fertilizer(F)	Organic(o)	Chemical(c)
Green manure(Gr)	Non green manure(-g)	Green manure(+g)

2. Trap Setting

Five pitfall traps in each plot were set at 1 m intervals among the eggplants, which were also spaced at 1 m intervals. A transparent plastic cup (13.5 cm deep) which was 9 cm in diameter at the upper side and 6 cm at the lower part without bait was used as the trap. A plastic cover was placed 10 cm above each trap to protect it from rainfall and falling leaves. The species names and numbers of carabid beetles captured in the traps were recorded.

The pitfall traps were set on 6 June 2003 and collections at 10 day intervals were continued until 10 October 2003. In total, 14 collections were made during the total study period.

3. Analysis Methods

We used a cluster analysis with an *α* index (Pianka, 1973) as a similarity matrix to compare the species compositions of carabid beetles in the 8 treatment plots.

To test the 3 factors (T, F and Gr) and their interactions, ANOVA based on a table of orthogonal arrays of the L^8 (2^7) type was used for the numbers of carabid beetles, species richness and species diversity. **Table 2** shows the table of orthogonal arrays used. In the table of arrays, 3 factors (T, F and Gr), 3 mutual interactions (T×F, T×Gr and F×Gr) and the plot name corresponding to the number of experiment are shown.

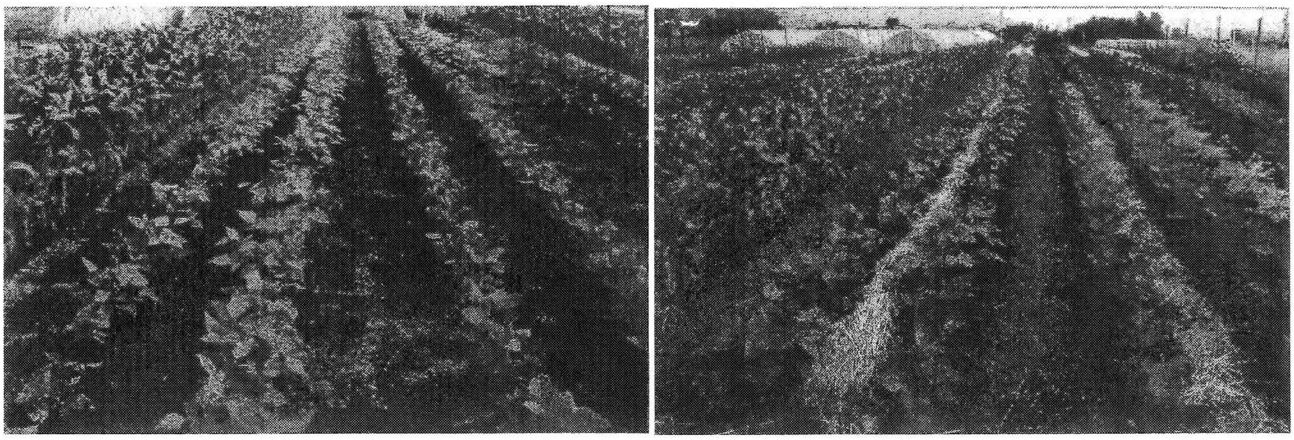

Fig. 2 Vegetables in treatment plots E (left) and H (right) on 29 July 2003. The same kinds of vegetables, namely corns, kidney beans, green soybeans, eggplants and radishes, were planted in each plot following the same planting pattern. The grass between the ridges in plot H is Italian ryegrass used as green manure.

Table 2 Table of orthogonal arrays and corresponding polt and factor

No. of experiment	No. of Collum							Plot
	1	2	3	4	5	6	7	
1	1	1	1	1	1	1	1	F
2	1	1	1	2	2	2	2	H
3	1	2	2	1	1	2	2	A
4	1	2	2	2	2	1	1	C
5	2	1	2	1	2	1	2	B
6	2	1	2	2	1	2	1	D
7	2	2	1	1	2	2	1	E
8	2	2	1	2	1	1	2	G
Factor	T	F	T×F	Gr	T×Gr	F×Gr	T×F×Gr	

The number 1 and 2 in the table indicate level 1 and 2 of each factor shown in table 1.

Results

1. Species Compositions

An overall total of 821 carabid beetles from 6 subfamilies representing 31 species were captured in all plots during the survey period (**Table 3**). The 13 species from Harpalinae represented the highest species number, but the highest individual number of 371 was captured from Pterostichinae. The number of individuals captured in plot G was the highest among all the plots, while that in plot F was the lowest. The number of species captured in plot D was the highest, while that in plot B was the lowest.

The 5 dominant species were 240 individuals (29.23 % of the total) of *Dolichus halensis*, 113 individuals of *Pterostichus microcephalus*, 101 individuals of *Harpalus tridens*, 88 individuals of *Harpalus griseus* and 73 individuals of *Harpalus sinicus*.

The 3 most dominant species in each plot were: *D. halensis, P. microcephalus* and *H. tridens* at plot A; *D. halensis, P. microcephalus* and *H. griseus* at plot B ; *D. halensis, P. microcephalus* and *H. tridens* at plot C ; *H. griseus, D. halensis* and *H. sinicus* at plot D ; *D. halensis, P. microcephalus* and *H. griseus* at plot E ; *D. halensis, P. microcephalus* and *Harpalus jureceki* and *Asaphidion semilucidum* at plot F ; *H. tridens, D. halensis* and *H. griseus* at plot G ; and *H. tridens, H. sinicus* and *P. microcephalus* at plot H. *D. halensis* and *P. microcephalus* were common to almost all plots, while *H. griseus* and *H. sinicus* were common to several plots.

2. Species Diversity

The species diversity indexes of the carabid beetles captured in the 8 plots are also shown in **Table 3**. Simpson's diversity index ($1/\lambda$) and Shannon-Weaver's function (H') were highest for plot D, while Pielou's index (J') was highest for plot B. On the other hand, $1/\lambda$ and J' were lowest for plot A, while H' was lowest for plot F.

3. Cluster Analysis

The classification results for the 8 plots by cluster analysis using an α index as the similarity matrix are shown in **Fig. 3**. In the dendrogram, the 8 plots were classified into 2 groups at a similarity of 0.85. The first group was composed of 3 plots (D, G and H) and the second contained the remaining 5 plots (A, B, C, E and F). Green manure was used in the first group but not in the second group, except for plot C.

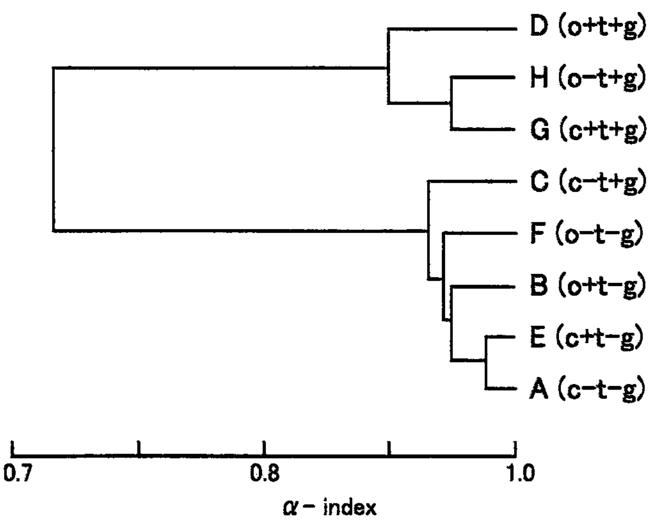

Fig. 3 Dendrogram of the clustering of the 8 treatment plots by cluster analysis (nearest neighbor method) using an α index as the similarity matrix. Capital letters and letters in parentheses indicate the plot names and their treatment designs, respectively.

4. ANOVA Results

Number of captured beetles. The ANOVA results for total individuals and subfamily groups of carabid beetles are shown in **Table 4**. The total individuals of carabid beetles were not significantly influenced by the 3 factors (T, F and Gr), although there were small differences in the means between levels 1 and 2 of each factor.

For the number of captured beetles of Pterostichinae, there were significant differences between the chemical fertilizer (level 1 of factor F) and organic fertilizer (level 2 of factor F), and between non-green manure (level 1 of factor Gr) and green manure (level 2 of factor Gr). For Zabrinae and Harpalinae, there were significant differences for factor Gr, and for Callistinae, there was a mutual interaction of factors T and F.

Species diversity. Table 5 shows the ANOVA results for species diversity. There were significant differences for factor Gr in species richness, factors T, F and Gr in $1/\lambda$ and factors T and Gr in H'. There was no evidence of any effects of the factors on J'.

Captured individuals of each species. ANOVA was performed on species for which more than 25 individuals were captured (**Table 6**). The number of individuals of D. halensis significantly depended on factors F, Gr and T×F, and those of *H. griseus*, *H. tridens* and *H. sinicus* showed significant effects for factor Gr. Significantly more *H. griseus* were captured in tillage plots (level 2 of factor T) than in non-tillage plots (level 1 of factor T). Although not significant, the same tendency was observed for the other 4 species of the genera *Harpalus*.

Discussion

It is supposed that, during the survey period in this study, the carabid beetles in the survey field could move to any plot and become randomly distributed, if they remained unaffected by any of the factors of the husbandry practices. Therefore, we calculated the C_A index of aggregation (Kuno, 1968) , which was used to judge the distribution pattern. An index value of 0 indicates random distribution, while a value of <0 shows a

Table 4 Results of ANOVA for the number of carabid beetles using orthogonal arrays shown in Table 2

Subfamily	Level	Mean of individuals					
		Factor					
		T	F	T×F	Gr	T×Gr	F×Gr
Pterostichinae	1	47.3	37.0*	43.5	58.8*	44.8	43.0
	2	45.5	55.8*	49.3	34.0*	48.0	49.8
Zabrinae	1	2.0	2.5	2.8	0.5**	3.8	3.3
	2	4.3	3.8	3.5	5.8**	2.5	3.0
Harpalinae	1	33.5	48.0	50.0	22.3*	47.3	41.3
	2	55.5	41.0	39.0	66.8*	41.8	47.8
Callistinae	1	5.0	7.8	2.8*	9.8	6.3	6.5
	2	8.0	5.3	10.3*	3.3	6.8	6.5
All carabid veetles	1	90.3	97.5	102.0	93.5	104.5	95.3
	2	115.0	107.8	103.3	111.8	100.8	110.0

Means followed by* and**are significantly different between level 1 and level 2 for the factor at P<0.05 and P<0.01, respectively.

Table 3 Species composition and diversity index of carabid beetles captured in each treatment plot.

Subfamily	Species	Plot*								Total
		A	B	C	D	E	F	G	H	
Bembidiinae	*Asaphidion semilucidum* (Motschulsky)	1	0	0	1	3	3	1	3	12
	Subtotal	1	0	0	1	3	3	1	3	12
Pterostichinae	*Trigognatha cuprescens* Motschulsky	2	0	0	0	0	0	0	0	2
	Pterostichus planicollis (Motschulsky)	3	2	0	0	5	0	2	0	12
	Pterostichus microcephalus (Motschulsky)	18	13	13	5	17	15	13	19	113
	Pterostichus nimbatidius (Chaudoir)	0	0	0	0	0	1	1	0	2
	Dolichus halensis (Schaller)	54	38	29	19	43	23	22	12	240
	Synuchus cycloderus (Bates)	0	0	0	0	1	0	0	0	1
	Synuchus arcuaticollis (Motschulsky)	0	0	0	1	0	0	0	0	1
	Subtotal	77	53	42	25	66	39	38	31	371
Zabrinae	*Amara congrua* Morawitz	0	0	2	2	1	0	4	1	10
	Amara chalcites Dejean	0	0	1	3	1	0	1	0	6
	Amara simplicidens Morawitz	0	0	2	2	0	0	2	1	7
	Amara mocronota ovalipennis Jedlička	0	0	1	1	0	0	0	0	2
	Subtotal	0	0	6	8	2	0	7	2	25
Harpalinae	*Anisodactylus signatus* (Panzer)	1	3	1	4	0	0	5	1	15
	Anisodactylus sadoensis Schauberger	0	0	1	0	1	1	2	0	5
	Anisodactylus tricuspidatus Morawitz	0	0	0	0	0	0	2	1	3
	Harpalus vicarius Harold	0	0	0	0	1	0	0	1	2
	Harpalus jureceki (Jedlička)	0	6	4	7	1	3	5	4	30
	Harpalus griseus (Panzer)	5	12	3	24	10	2	18	14	88
	Harpalus eous Tschitschérine	0	0	0	2	0	0	1	0	3
	Harpalus tridens (Morawitz)	7	6	12	13	3	1	33	26	101
	Harpalus sinicus (Hope)	1	8	5	17	5	1	17	19	73
	Harpalus corporosus (Motschulsky)	3	0	0	1	1	1	3	2	11
	Harpalus bungii Chaudoir	1	0	2	3	1	1	1	4	13
	Harpalus tinctulus Bates	0	0	2	1	2	0	2	3	10
	Harpalus discrepans Morawitz	0	0	1	0	1	0	0	0	2
	Subtotal	18	35	31	72	26	10	89	75	356
Licininae	*Diplocheila zeelandica*	2	0	0	1	0	0	1	1	5
	Subtotal	2	0	0	1	0	0	1	1	5
Callistinae	*Epomis nigricans* (Wiedemann)	2	1	0	2	1	1	0	0	7
	Chlaenius pallipes Gebler	1	1	0	1	0	2	0	1	6
	Chlaenius abtersas Bates	0	0	1	0	0	0	0	0	1
	Chlaenius virgulifer Chaudoir	3	6	1	2	0	0	0	1	13
	Chlaenius naeviger Morawitz	7	11	0	2	3	0	2	0	25
	Subtotal	13	19	2	7	4	3	2	2	52
Total		111	107	81	114	101	55	138	114	821
	Species richness	16	12	17	22	19	13	21	18	31
	$1/\lambda$	3.704	5.793	5.654	9.072	4.533	4.057	8.142	7.641	7.029
	H'	2.677	2.948	3.076	3.595	2.940	2.579	3.448	3.259	3.490
	J'	0.669	0.822	0.753	0.806	0.692	0.697	0.785	0.781	0.705

*Plot A~Plot H; see Fig.1

uniform distribution and a value of >0 reveals an aggregated distribution. In addition, we tested the departure from randomness using an F-test of the variance:mean ratio. **Table 7** shows that the distribution patterns of the number of carabid beetles captured in each plot were significantly non-random, but rather gregarious, except for *P. microcephalus* and *H. jureceki*. From these results, the 3 factors appear to have affected the distributions of the carabid beetles in the 8 plots.

From the results of **Tables 4** and **6**, factor T (level 1: non tillage and level 2: tillage) appeared to affect the distribution of *Harpalus* species. The number of *H. griseus* captured in tillage plots was significantly higher than that in non-tillage plots, and the other 3 *Harpalus* species showed similar tendencies, although the differences were not statistically significant (**Table 6**).

Table 5 Results of ANOVA for species diversity using orthogonal arrays shown in Table 2

Species deversity	Level	Mean of species diversity: Factor T	F	T×F	Gr	T×Gr	F×Gr
Species richness	1	16	16.25	17.75	15.0*	18	15.75
	2	18.5	18.25	16.75	19.5*	16.5	18.75
$1/\lambda$	1	5.264**	6.641*	6.093	4.522**	6.244	5.912
	2	6.885**	5.509*	6.056	7.627**	5.905	6.238
H'	1	2.898**	3.095	3.056	2.786**	3.075	3.013*
	2	3.233**	3.035	3.074	3.344**	3.056	3.008*
J'	1	0.725	0.777	0.739	0.720	0.739	0.764
	2	0.776	0.725	0.763	0.781	0.762	0.737

Means followed by * and** are significantly different between level 1 and level 2 for the factor at P<0.05 and P<0.01, respectively.

Table 6 Results of ANOVA for individuals of abundant species using orthogonal arrays shown in Table 2

Subfamily	Species	Level	Mean of individuals of each species: Factor T	F	T×F	Gr	T×Gr	F×Gr
Pteroatichinae	*Pterotichus microcephalus*	1	16.3	13.0	16.0	15.8	12.8	13.5
		2	12.0	15.3	12.3	12.5	15.5	14.8
	Dolichus helensis	1	29.5	23.0*	25.0*	39.5*	29.5	28.0
		2	30.5	37.0*	35.0*	20.5*	30.5	32.0
Harpalinae	*Harpalus jureceki*	1	2.8	5.0	3.3	2.5	3.8	4.5
		2	4.8	2.5	4.3	5.0	3.8	3.0
	Harpalus griseus	1	6.0*	13.0	11.0	7.3*	12.3	8.8
		2	16.0*	9.0	11.0	14.8*	9.8	13.3
	Harpalus tridens	1	11.5	11.5	15.8	4.3*	13.5	13.0
		2	13.8	13.8	9.5	21.0*	11.8	12.3
	Harpalus sinicus	1	6.5	11.3	10.5	3.8*	9.0	7.8
		2	11.8	7.0	7.8	14.5*	9.3	10.5
Callistinae	*Chlaenius naeviger*	1	1.8	3.3	1.3	5.3	2.8	3.3
		2	4.5	3.0	5.0	1.0	3.5	3.0

Means followed by * and** are significantly different between level 1 and level 2 for the factor at P<0.05 and P<0.01, respectively.

There have been many studies on how cultivation methods influence the species composition of carabid beetles. Brust *et al.* (1985) showed that deep tillage reduced the density of carabid predators. On the other hand, Baguette and Hance (1997) reported that the total number of carabids was higher in ploughed plots than in non-tillage plots, and also that the most abundant species in deep ploughing areas were autumn breeders. In this study, therefore, it is likely that the species of the genera *Harpalus* were abundant in tillage plots because they were autumn breeders (Ishitani, 1996).

For factor Gr (green manure), the number of Pterostichinae beetles was significantly more abundant in non-green manure (level 1) plots than in green manure (level 2) plots (**Table 4**). On the other hand, the results for Zabrinae and Harpalinae (**Table 4**), and especially for the 3 *Harpalus* species (**Table 6**), were the opposite. Boyd (1957) reported that there were differences between the carabid fauna of grazed and ungrazed grassland, in that carabid beetles preferred areas covered by long thick grasses. Furthermore, Booji *et al.* (1997) recorded a higher diversity of carabids in intercropping plots of cabbage and clover than in cabbage monocrop plots. In this study, the species diversity index ($1/\lambda$ and H') in green manure plots was significantly higher than that in non-green manure plots (**Table 5**). Yano *et al.* (1989)

Table 7 CA index and variance:mean ratio on abundant species

Subfamily	Species	CA index	variance:mean
Predoatichinae	*Pterostichus microcephalus*	0.026	1.364
	Dolichus halensis	0.189	6.514**
	All Pteroatichinae species	0.127	6.789**
Zabrinae	All Zabrinae species	0.974	3.606**
Harpalinae	*Harpalus jureceki*	0.142	1.505
	Harpalus griseus	0.418	5.325**
	Harpalus tridens	0.807	10.160**
	Harpalus sinicus	0.608	6.088**
	All Harpalinae species	0.448	19.820**
Callistinae	*Chlaenius naeviger*	1.589	4.977**
	All Callistinae species	0.891	6.110**
	All species	0.049	6.038**

Variance: mean ratios followed by** are significantly different for the factor at P<0.01 by the test of the departure from 1.0.

reported that vegetation cover caused the diversity of carabid beetles to increase in a vineyard. The results of the present sutdy support that factor Gr affects the number of captured beetles of Zabrinae and Harpalinae, but there have been few reports regarding the preference for non-green manure conditions of species of Pterostichinae, especially *D. halensis* (**Tables 4** and **6**). Amstrong and McKinly (1997) reported a positive effect on carabid abundance after under-sowing cabbages with clover, but also reported that some carabid species were abundant in the hoed treatment.

Thiele (1977) classified carabids according to their main food types into polyphagous predators, oligophagous predators (mollusk, Collembola and caterpillar specialists) and phytophagous carabids. According to this classification, the species of the genera *Harpalus* of Harpalinae and genera *Amara* of Zabrinae are granivores of phytophagous carabids (Habu and Sadanaga, 1963, 1965). It may be said that phytophagous carabids prefer green manure plots to non-green manure plots. On the other hand, the species of Pterostichinae and Callistinae captured in this study were polyphagous predators (Habu and Sadanaga, 1961). *D. halensis* is one of most common insectivores in crop fields (Habu and Sadanaga, 1963) and some species of the genera *Chlaenius* are known to be important predators of *Plutella xylostella* (Suenaga and Hamamura, 1998). Further studies on predator carabids are needed in order to clarify the reason why they did not prefer the green manure plots in the current study.

There have been some positive reports for the effects of organic fertilizers on carabid abundance (Humphreys and Mowat, 1994), but the influence of chemical fertilizers on carabids is poorly documented. Idinger and Kromp (1997) did not detect any influence of either organic or inorganic fertilizers on the total carabid number. The reason why the number of *D. halensis* captured in the chemical fertilizer plots (level 2 of factor F) was significantly higher than that in the organic fertilizer plots (level 1) in the present study is unknown (**Table 6**). Niemela *et al.* (1992) reported that variation in soil moisture was an important factor in determining carabid distribution. Therefore, this result will be further studied with respect to the effects of the soil conditions (*i.e.* soil moisture) after fertilization on the species composition of carabid beetles.

It is considered that carabid beetles represent a suitable insect group for evaluating agroecosystems, since most species found in agricultural areas are permanent residents and spend most of their life cycle within crop fields (Holland *et al.*, 2002). In this study, it was found that the species composition, abundance and diversity of carabid beetles were affected by different husbandry practices under the same vegetation. These results suggest that carabid beetles may be useful as a bio-indicator for evaluating differences in the soil environmental conditions caused by cultivation and various husbandry practices.

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異なった耕作法が行われた圃場環境のゴミムシ群集による評価

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ゴミムシ群集を指標種として栽培されている植物は全く同じであるが，異なった耕作法が実施された圃場環境の評価の可能性を検討するため，有機肥料と化学肥料，耕起と不耕起，緑肥ありと緑肥なしという 3 要因 2 水準の実験計画法に沿った 8 区画を長野県波田町に設け，ゴミムシ群集の調査を 2003 年の 6 月から 10 月まで行った．結果の解析は，L_8（2^7）型直交配列表に従った分散分析を用いた．ゴミムシは合計で 31 種 821 個体捕獲され，優占種は多い順にセアカヒラタゴミムシ，コガシラナガゴミムシ，コゴモクムシであった．類似度指数 α をもとにしたクラスター分析では，8 区画は緑肥ありグループとなしグループに分かれた．分散分析の結果，ナガゴミムシ亜科，特にセアカヒラタゴミムシでは化学肥料区と緑肥なし区で個体数が多く，反対にマルガタゴミムシ亜科とゴモクムシ亜科では耕起区と緑肥あり区で個体数が多かった．また耕起区と緑肥あり区では多様度指数（$1/\lambda$ と H'）が有意に高くなった．以上の結果から，ゴミムシ群集を指標種として耕作法が異なった圃場環境を評価できる可能性が示唆された．