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Carabid beetles (Coleoptera, Carabidae) as bioindicators in biological and conventional farming in Austrian potato fields*

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Summary. Carabid beetles were sampled in 1980 and 1981 by pitfall trapping in two biologically and two conventionally farmed potato fields in B. Zell, Upper Austria. The cultivation differences consisted mainly of a herbicide application to one conventional field in 1980 and higher fertilization levels in both conventional fields in both years. The total carabid catch was 7428 beetles, representing 48 species. In both years the numbers of total carabids and numbers of species were higher in the biologically farmed fields. Of 16 dominant species (representing 96% of all carabids) only 5 (e.g., *Platynus dorsalis, Poecilus cupreus*) showed similar activity densities under both types of cultivation. Five species (e.g., *Carabus* spp., *Amara consularis, Harpalus rufipes*) were frequent only in one field. *Pterostichus melanarius* was the only species more numerous in the conventional fields, whereas five species occurred either more frequently or exclusively in the biological fields. Of these five species, *Poecilus versicolor, Dyschirius globosus, Calathus fuscipes* and, only regionally, *Harpalus aeneus* are considered to be bioindicators for biologically farmed agroecosystems. The frequencies of *Amara consularis* and *Harpalus rufipes* are apparently related to weed vegetation.

Key words: Biological farming – Carabids – Activity densities – Bioindicators – Fertilization level – Potato fields

Due to their predatory feeding habits (Thiele 1977) agroecosystem carabids are importent in the natural control of agricultural pests (Basedow et al. 1976). The economic value of their role can be deduced from the studies of Scherney (1960), Basedow (1973), and Sunderland et al. (1985).

The regulatory potential of field carabids is adversely affected by the cultivation methods of modern intensive conventional farming. This is primarily attributed to pesticide use (Pawlitzki 1984; Basedow 1987).

Naturally occurring antagonists of pests are essential in biological agriculture, which rejects pesticides and mineral fertilizers. In recent years a growing number of investigations has dealt with carabids in biologically farmed agro-ecosystems. Compared to conventionally farmed fields, higher numbers of carabids and of species were found in biologically farmed fields (Dritschilo and Wanner 1980; Kromp 1985; Hokkanen and Holopainen 1986; Basedow 1987; Ammer et al. 1988; Ingrisch et al. 1989; Kromp 1989). In Austria similar comparisons have been detected for protozoans by Foissner et al. (1987).

The present paper is based on comparative catches of carabids in biologically and conventionally farmed potato fields in Upper Austria (Kromp 1985). It focuses on the differences in abundance of the dominant species, emphasizing species with possible value as bioindicators for the impact of farming methods on carabid agrocoenoses.

Materials and methods

Study sites

The investigation was carried out in two pairs of sites (1980: B 1 and C 1; 1981: B2 and C2; 48°21'N and 14°38'E, respectively), in B. Zell, Upper Austria. The research area is located in the hercynic highlands of the Lower Mühlviertel, 560 m above sea level.

The climate is characterized by an average annual temperature of 7.7 °C and a precipitation of 748 mm. The soil of the study fields is silicate brown earth on granite (loamy sand, acid, low water storage capacity).

With the exception of B2 (1 ha), the field sites were each 0.5 ha in size, rectangular, and planted with potatoes. B 1 and B2 were cultivated biologically, the comparable sites C 1 and C2 conventionally. Biological cultivation was carried out according to the official guidelines specified by the Austrian Ministry of Health and Environmental Protection (review by Maurer 1989).

B 1 and C 1 were 300 m apart, and B2 and C2, 500 m. B 1 and B2 (distance: 100 m) were located in a 6-ha field consisting of oats, barley,

* Dedicated to the late Prof. Dr. W. Kühnelt

and rye and bordered by woodland. C1 and C2 (distance: 450 m) were surrounded by maize, clover, pastures, and woodland. (For further details see Kromp 1985.)

The cultivation methods for all plots (Table 1) were very similar with respect to previous crop, ploughing, planting (row distance and plant distance), and mechanical weed control. The differences consisted of previous stubble-breaking by a rotary spade harrow in B1 and B2, a herbicide application in C1, and a higher fertilizer level in C1 and C2.

The different cultivation methods became manifest in differences in the potato stands and in weed growth. In 1980 the potato plants in C1 had grown higher and in July they reached a 100% leaf coverage. This led to a shadier and more humid microclimate close to the ground than in B1, where the potato plants remained smaller and reached only 85% leaf coverage. In 1981, potato plant growth, and consequently the microclimate, were quite similar.

Large qualitative differences in weed grown were observed between the biological and the conventional fields. The weed vegetation was diverse in B1 and B2 (27 species each), but was poor in C1 (7 species) and C2 (9 species), with nitrophilous species dominating (C1: *Galium aparine*, *Agropyron repens*; C2: *G. aparine*, *Fallopia convolvulus*). Due to a partial absence of the last ridging, a dense weed population developed in one-third of the plant rows in B2, reaching a cover of 70%, compared with 15–20% in the rest of B2 and 20% in C2.

Sampling methods

The epigaeic fauna was sampled by pitfall traps (transparent plastic beakers, depth 85 mm, height 80 mm; sheltered by acrylic glass roof 20×20 cm; one-third filled with 4% formaldehyde with several drops of detergent added). The sampling period in both years lasted from late May to early September.

In B1 and C1, 10 traps were set up in two lines along the plant rows. The distance between lines was 10 m, and between traps in each line, 30 m. The distance between the lines and the plot borders was 10 m in B1, and 15 m in C1. In B2 and C2 12 traps were arranged in three groups of four traps, each group forming a 10-m square. The distance between trapping groups was 80 m in B2, and 25 m in C2. The distance from the trapping groups to the plot borders was at least 15 m. At the end of July 1981, one trapping group in B2 was reset in the area of dense weeds; its new location adjacent to a trapping group in the area of normal weed growth allowed a direct comparison between areas of dense weed cover and thin weed cover.

The beakers were changed every 14 days in 1980 and every 7–14 days in 1981.

The trapped carabid beetles were sorted out and determined to species level, according to the nomenclature of Freude (1976). The number of trapped carabids is primarily dependent on locomotory activity. These so-called "activity densities" cannot be related directly to abundances per unit area. Under certain conditions (long trapping period undisturbed by pesticide applications, similar stand densities and microclimate; Basedow and Rzehak 1988), however, activity density and abundance are positively correlated (Baars 1979; Basedow 1987). Since these conditions, with the exception of microclimate in summer 1980 and weed density in the dense weed area of B2, were for the most part given in B. Zell, the different activity densities are considered to reflect true carabid abundances in the two cultivation systems.

Statistics

Each field represented a singular, non-replicated experimental unit. According to Hurlbert (1984) the application of inferential statistics in comparing carabid data between fields is not appropriate.

Results

The following results are based on 7428 trapped carabid beetles representing 48 species.

In both years the number of species and carabids was higher in the biologically farmed fields than in the con-

Table 1. Cultivation details of biologically (B1, B2) and conventionally (C1, C2) farmed potato fields in B. Zell, Upper Austria (all amounts given per ha)

	Site pairs			
	B1	C1	B2	C2
Previous crop	Oats	Winter rye + undersown clover	Winter rye	Barley
Soil cultivation				
Autumn: Rotary spade harrowing	+		+	
Ploughing	+	+	+	+
Spring: Harrowing	+	+	+	+
Ploughing	+	+	+	+
Harrowing	+	+	+	+
Mechanical weed control				
Ridging	4×	4×	3× (3rd time incomplete)	4×
Flexible harrowing	1×	2×	2×	2×
Handhoeing	+	+	+	
Herbicides				
Terbuthylazine + terbutryn		2.5 l		
Fertilization				
Autumn: Staple manure (t)		18		20
Spring: Staple manure (t)	15	18	15	20
Semiliquid manure (l)				4×10^4
N, P, K (12:10:18) (kg)		1000		1500
P, Ca (32:45) (kg)			300	
Powder of diabase (kg)			570	

Table 2. Numbers (total catches per field) of the dominant (>2%) carabid species sampled in biologically (B1, B2) and conventionally (C1, C2) farmed potato fields

	Site pairs				
	B1	C1	B2	C2	Total
Sampling period	28/5–21/8/80		26/5–9/6, 25/6–9/9/81		
Number of traps per field	10	10	12	12	
A. Species with similar activity densities in all fields					
Platynus dorsalis (Pontoppidan)	3	63	113	93	272
Trechus quadristriatus (Schrank)	13	27	62	108	210
Poecilus cupreus (Linné)	84	70	26	9	189
Bembidion quadrimaculatum (Linné)	19	11	42	34	106
Loricera pilicornis (Fabricius)	37	16	2	11	66
B. Species with higher activity densities in conventional fields					
Pterostichus melanarius (Illig.)	378	609	308	811	2106
C. Species with high activity densities in single fields only					
Carabus scheidleri Panzer	257	74	43	50	424
Amara consularis (Duftschmid)	9	–	360	15	384
Carabus cancellatus Illiger	34	221	12	16	283
Harpalus rufipes (De Geer)	18	2	235	20	275
Calathus melanocephalus (Linné)	5	1	69	12	87
D. Species with higher activity densities in biological fields					
Poecilus versicolor (Sturm)	408	117	491	49	1065
Bembidion lampros (Herbst)	287	124	519	70	1000
Calathus fuscipes (Goeze)	75	19	181	58	333
Dyschirius globosus (Herbst)	98	–	147	6	251
Harpalus aeneus (Fabricius)	17	–	74	–	91
Further species/individuals	13/44	12/61	21/103	17/78	32/286
Total species	29	25	37	32	48
Total individuals	1786	1415	2787	1440	7428
Beetles $trap^{-1}$ day^{-1}	2.4	1.8	2.9	1.4	

ventionally farmed ones (Table 2). In 1980 the trapping rate (number of beetles per trap per day) in B1 exceeded that in C1 by 25%; in 1981 there was 52% more beetles in B2 than in C2. These differences in total carabids were not equally reflected in all carabid species, as shown by the trapping numbers of the 16 dominant species (representing 96% of all carabids) in Table 2.

A comparison of the neighbouring trap groups in the areas of dense and thin weed cover in B2 (Table 3) showed considerably higher catches of *Amara consularis* and *Harpalus rufipes* in the dense weeds; the other species show no clear differences.

Discussion

The complex influence of site- and cultivation-specific parameters on carabids appears to create a rather accidental pattern of carabid frequencies in agroecosystems. Since the first quantitative agro-ecological investigations on carabids (Heydemann 1953; Tischler 1958; Kirchner 1960), however, certain basic patterns in frequency distributions of carabid species (e.g., distinction between species of winter crops and root crops; Thiele 1977) have been established. The results of the comparative studies already mentioned and of further recent agro-ecological investigations (Hempel et al. 1971; Gärtner 1980; Heydemann and Meyer 1983; Tietze 1985; Croy 1987; Hance and Gregoire-Wibo 1987; Sekulić et al. 1987; Luff and Rushton 1989) indicate that intensified agriculture since the 1950s (Diercks 1983; Kaule 1986) has been reflected in changed frequency patterns of certain carabid species.

Table 3. Carabid catches in four pitfalls in an area of dense weed (Dw) cover and four pitfalls in an area of thin wead (Tw) cover in a biologically farmed field (B2)

Species	Sampling date (day/month)									
	30/7		7/8		14/8		18/8		Total	
	Dw	Tw	Dw	Tw	Dw	Tw	Dw	Tw	Dw	Tw
Amara consularis	18	–	34	5	24	7	21	2	97	14
Harpalus rufipes	7	–	25	5	21	5	31	7	84	17
Other species	86	38	120	117	72	82	34	38	312	275

The results from B. Zell are discussed in the light of these known changes. The biologically farmed fields represent a moderate, extensive farming system, whereas the conventionally farmed fields represent an intensive system, primarily with regard to the fertilization level. Certain factors inherent in the position of the plots may have influenced the comparability of the carabid data with regard to the effects of different farming methods. One of these factors is the different nature of the surrounding crops, which may have had different effects on the migration of carabids into the respective plots. However, only for two of the dominant species (*Carabus cancellatus*, *C. scheidleri*) did an increase in trapping numbers indicate that migration from the surrounding fields might have taken place after the grain harvest (Kromp 1985).

According to Thiele (1977) the 16 dominant species of B. Zell are typical components of arable systems all over Europe or of Eastern Europe only (*A. consularis*, *C. scheidleri*).

The five species of group A (Table 2) showed similar trapping numbers in both the biologically and conventionally farmed fields. *Trechus quadristriatus* and *Loricera pilicornis* are apparently not adversely affected by conventional cultivation (Basedow 1987; Weber 1983), and may possibly even be favoured. A great increase in the abundance of *Trechus quadristriatus* has been recorded in the area of Leipzig since 1952 (Croy 1987); this species has also shown increased densities in sugar-beet fields, corresponding to an increasing degree of farmland consolidation and intensification of farming (Gärtner 1980). Further, the species was recently introduced into North America (Bousquet et al. 1984), where it is spreading in farmland. *Loricera pilicornis* is favoured by an intensification of grassland (Hempel et al. 1971; Tietze 1985) and pasture improvement (Luff and Rushton 1989).

As a pioneer species characteristic of vegetation-free plots, *Bembidion quadrimaculatum* increases after crop rotation (Kirchner 1960). *Poecilus cupreus* and *Platynus dorsalis* are among the most abundant European field species (Basedow et al. 1976; Thiele 1977). In spite of fundamental structural changes in farming practice (farmland consolidation, deep ploughing, use of chemicals) the abundance of these species has not changed around Leipzig (Croy 1987). *Platynus dorsalis*, a species preferring cereals (Thiele 1977), has recently invaded Norway, possibly because of the high percentage of cereals in modern crop rotation (Andersen 1987). In Schleswig-Holstein, however, *Platynus dorsalis* has decreased significantly, due to a strong increase in pesticide applications since the mid-1970s (Basedow 1987).

Pterostichus melanarius was the only species (group B) which was more abundant in both conventional fields in B. Zell. The euryoecious nature of *Pterostichus melanarius* apparently enables it to profit from habitat changes due to intensified farming. It has shown increased abundance in intensively farmed grassland (Hempel et al. 1971; Tietze 1985), fruit plantations (Mader 1984), and arable sites (Pawlitzki 1984; Powell et al. 1985; Croy 1987). It has recently expanded its range in Norway (Andersen 1987) and is apparently rather unsusceptible to pesticides (Freitag 1979). In contrast, decreasing abundance was registered by Basedow (1987) in Schleswig-Holstein.

The species in group C (Table 2) were dominant only in one field. *Carabus* spp. are generally on the decrease in cultivated land (Heydemann and Meyer 1983; Tietze 1985; Basedow 1987; Croy 1987; Luff and Rushton 1989). This is particularly valid in the case of *Carabus cancellatus*, which disappeared from Schleswig-Holstein's fields as early as the late 1950s (Hossfeld 1963). This species is now also disappearing rapidly in Slovakia, where it is restricted to "extensively managed, undestroyed habitats free of chemical treatment" (Kleinert 1987). The abundances found in B. Zell cannot be correlated with farming effects; trapping numbers of the highly mobile *Carabus* give an extremely unrealistic estimation of abundance (Basedow and Rzehak 1988).

The high trapping rates of *Harpalus rufipes* and *Amara consularis* in B2 are very likely due to the high weed density in the immediate vicinity. Adults of *Amara* are known to be phytophagous (Mühle 1944). Gersdorf (1937) first reported the correlation between weeds and the occurrence of *Amara* spp. in fields; this has been confirmed by recent investigations (Powell et al. 1985; Bosch 1987; Kromp 1989; Kokta 1990). Larvae of *Harpalus rufipes* were reported to feed on weed seeds (Luff 1980), whereas the omnivorous adults are efficient aphid predators (Loughridge and Luff 1983). The absence of weeds in herbicide-sprayed fields could be responsible for the decreasing abundance of *Harpalus rufipes* (Gärtner 1980; Basedow 1987; Croy 1987) in Central Europe. Ingrisch et al. (1989) and Basedow (1987) found that this species was significantly more abundant in biologically farmed wheat fields in northern Germany, whereas in eastern and southeastern Europe it is dominant in intensively managed maize and grain fields (Lövei 1984; Sekulić et al. 1987).

The species of group D were trapped either in higher numbers or exclusively in the biologically farmed fields in B. Zell (Table 2). *Poecilus versicolor* and *Dyschirius globosus* are eurytopic species of grassland; *Bembidion lampros*, *Calathus fuscipes*, and *Harpalus aeneus* are common in arable habitats (Thiele 1977). *Dyschirius globosus* and *Calathus fuscipes* disappeared after an intensification of grassland management (high doses of mineral fertilizers and semi-liquid manure, mowing/grazing rotation, irrigation and drainage), and *Poecilus versicolor* and *Bembidion lampros* decreased in abundance (Tietze 1985). Similar results were obtained by Hempel et al. (1971). *Dyschirius globosus*, a soil-dwelling species (Thiele 1977), was found in large numbers only in biologically farmed meadows and fields (Porret 1977; Hokkanen and Holopainen 1986) or was absent in cultivated areas altogether (Van Dijk 1986). *Calathus fuscipes* was more numerous in biologically farmed fields (Basedow 1987; Stachow 1987; Kromp 1989). *Poecilus versicolor* occurred more frequently in a biologic-dynamically cultivated meadow than in a comparable conventionally cultivated one (Porret 1977). Stachow (1987, p. 103) found that *Poecilus versicolor* was "strikingly numerous" in a biologically farmed wheat field. According to Van Dijk (1986), *Poecilus versicolor* prefers extensively managed arable sites with low nutrient levels. Its distinct numerical increase in a field recently withdrawn from cultivation "undoubtedly resulted from impoverishment of the field" (Van Dijk 1986, p. 425).

Bembidion lampros showed a significant decrease in Schleswig-Holstein wheat fields, apparently due to its sensitivity to pesticides (Basedow 1987), a reaction which has also been established by Hance and Gregoire-Wibo (1987). This species is more numerous in biologically farmed wheat fields (Basedow 1987; Stachow 1987). The same was true of *Harpalus aeneus* (Basedow 1987; Kromp 1989), which is well known in most European cultivated fields, although typically in low densities. Croy (1987), however, recorded a great increase in this species around Leipzig.

The differences in the trapping rates of the group D species in B. Zell were in accord with the results of a parallel investigation in Carinthia, 190 km away, except that *Bembidion lampros* preferred the conventional potato field there (Kromp 1985).

Consequently, *Poecilus versicolor, Dyschirius globosus, Calathus fuscipes* and, only regionally, *Harpalus aeneus* are considered to be indicator species (Bick 1982) for biological cultivation, i.e., species reflecting ecological conditions in biologically farmed agro-ecosystems by their occurrence and/or their densities (quantitative indicators, Heydemann 1955).

Basedow (1987) considers pesticide application to be the main factor in the reduced carabid numbers in the conventionally farmed wheat fields of Schleswig-Holstein. Since only low amounts of pesticides were used in B. Zell, other factors must be taken into consideration. Among these, apart from the differences in weed vegetation, is the high level of fertilization in conventionally farmed fields. The greater differences in carabid trapping rates between B2 and C2 compared with B1 and C1 are conspicuous. They might be correlated with the higher amount of fertilizers and the springtime application of semi-liquid manure in C2. Knowledge of fertilizer effects on epigaeic arthropods of fields is, with the exception of the studies of Honczarenko (1975) and Kajak (1981), much too limited to allow accurate conclusions. The key to understanding the differences in carabid numbers may possibly lie in the specific requirements of carabid larvae. Their hemi- and euedaphic way of life would make them more susceptible to cultivation effects (e.g. soil compaction, Tietze 1985) than adults. Moosbeckhofer (1983) established the susceptibility of the early developmental stages of carabids to pesticides.

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