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Vegetation diversity of conventional and organic hedgerows in Denmark

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Abstract

Many attempts have been made to reduce the impact of modern conventional farming on the environment and semi-natural ecosystems. One of them is organic farming, known primarily for the absence of pesticides and artificial fertilisers. The objective of this study was to study and test the differences in the spontaneous vegetation of comparable hedgerows in the same area situated within organic and conventional farming systems. The hedge bottom vegetation was surveyed during August 2001 in 13 hedgerows of each farming system. Farming type had not changed on either side of the hedgerows for the lifetime of the hedges (10–14 years). Sampling was associated with a set of 16 measured environmental variables. In the two farming systems hedgerows were comparable in terms of landscape, age, soil type, nutrient status and width. A mixed analysis of variance (ANOVA) found no significant difference in measured soil and radiation variables between farming types. Farming types only differed in the use of pesticides. Significant differences between farming types in plant species diversity at alpha, beta and gamma levels were found. More species that are normal in semi-natural habitats were found on organic farms. There was an overlap in species composition between farming type, but a slightly higher species turnover on conventional farms. The ordination axes were highly correlated with calibrated Ellenberg values of fertility, light and soil moisture. Soil fertility and farming type were important factors to explain variation in species composition. Organic farming had a significantly reduced impact on hedge bottom vegetation compared to conventional farming. Higher extinction due to pesticide drift and immigration rates may be responsible for the significantly higher species diversity and different species composition in hedges on organic farms. The differences in species diversity and plant types are briefly discussed.

Keywords: Farming type; Fertility; Hedge bottom; Naturalness; Pesticide; Species diversity

1. Introduction

Hedges have a multitude of functions (Baudry et al., 2000) and are receiving increasing attention as refuges for wildlife in countries with intensive agricultural production. Most studies on hedgerows originate from the UK, France and Canada (McCollin et al., 2000; Barr and Petit, 2001; Boutin et al., 2001). The ecological function of hedgerows in the agricultural landscape matrix has received increased attention since landscape ecology developed as a research field during the 1980s (Baudry et al., 2000; Le Coeur et al.,

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2002) and spontaneous vegetation in hedgerows can be considered as part of a metapopulation matrix. The function of hedgerows as dispersal corridors of forest species (McCollin et al., 2000; Smart et al., 2001) and refuges of grassland species (Smart et al., in press) has recently been described. Likewise, the neighbourhood of potential sources for species immigrating to hedges has also been investigated (Mercer et al., 1999; Boots, 2001).

Neighbouring land-use is known to exert a strong impact on hedgerow vegetation, especially on the hedge bottom flora (Boatman et al., 1994; Cummins and French, 1994; Hegarty et al., 1994; McAdam et al., 1994; Le Coeur et al., 2002) and other linear biotopes (De Snoo and van der Poll, 1999; Hald, 2002). Two of the major impact factors of modern conventional agriculture on existing habitats are displacement of fertilisers and pesticides drift (Pollard et al., 1974; Timmermans and Cuppen, 1988; Boatman, 1992; Hegarty et al., 1994; Baudry et al., 2000; McCollin et al., 2000). Fertilisation is held as the most influential factor (Hegarty et al., 1994) and its impact has been illustrated for a range of semi-natural vegetation types (Traczyk and Kotowska, 1976; Virtanen et al., 2000) including hedge bottom vegetation (Tsiouris and Marshall, 1998). The boundary vegetation in intensive agricultural areas is characterised by a relatively species-poor, nitrophilous vegetation (Hegarty et al., 1994; Kleijn and Verbeek, 2000; Tybirk et al., 2001). The drift of pesticides has also been found to influence the organisms of hedges (Hald et al., 1994; Jobin et al., 1997; Boutin and Jobin, 1998), and its impact on non-crop species is well documented (Marrs et al., 1989; Marrs and Frost, 1997). The influence of pesticide drift is also well known for other field boundary vegetation (Fischer and Milberg, 1997; Kleijn and Snoeijing, 1997; De Snoo, 1999) and semi-natural vegetation (Marrs et al., 1989). The use of fertiliser (Keeney and Hatfield, 2001) and pesticides (Boutin and Rogers, 2000) has increased tremendously since the Second World War and it is not clear whether fertilisation and pesticide drift interact or whether pesticides alone affect the hedge bottom vegetation.

Continuity in time and space is very important in terms of species composition and botanical diversity in hedges (Warming, 1919; Pollard et al., 1974; Dowdeswell, 1987; Bunce et al., 1994; Tybirk et al., 2001). Some studies indicate that the age effect on tree diversity is quite weak (Willmot, 1980). Nevertheless, the removal of older hedgerows is an irreversible process since new hedgerows contain different vegetation compared to old ones (Boutin et al., 2001). In Great Britain, management plays an important role for hedgerow vegetation (Moonen and Marshall, 2001).

To reduce the impact of modern conventional farming on semi-natural ecosystems buffer zones, such as conservation headlands, unsprayed field margins (Marshall and Moonen, 2002) and selective plant control (Boatman, 1989) have been shown to improve or at least preserve the natural biodiversity (Schumacher, 1984; Hald et al., 1994; De Snoo, 1997; De Snoo and de Wit, 1998). Integrated (Ogilvy et al., 1995) and organic farming system (Lampkin, 1990) are also ways to reduce the impact on semi-natural ecosystems. Organic farming covers today about 3% of the European agricultural land (Yussefi and Willer, 2003). While there are indications of a positive influence on biodiversity conservation on cultivated fields and uncultivated semi-natural biotopes (Stolze et al., 2000; Azzez, 2000; Mäder et al., 2002), the impact on semi-natural biotopes is poorly documented. Likewise there is hardly any evidence of long-term effects of organic farming on semi-natural species assemblages in hedgerows (Tybirk and Ejrnæs, 2001). This study aimed at investigating the potential influence of conventional and organic farming on adjacent hedgerow vegetation during the first 10–14 years after the hedgerow was planted and to test the following null hypotheses: (1) the type of farming (organic versus conventional) does not affect alpha, beta and gamma plant species diversity and (2) it does not influence species composition or plant types in hedge bottom vegetation.

2. Methods and material

Thirteen organic hedges on five organic farms and 13 conventional hedges on eight conventional farms were investigated. Organic hedgerows were selected first and then in the conventional hedgerows were randomly selected in the same district and, where possible on the same roads, at a median distance of 850 m. All hedges were located in the southwestern part of Jutland on sandy Saalian moraines or Weichelian outwash

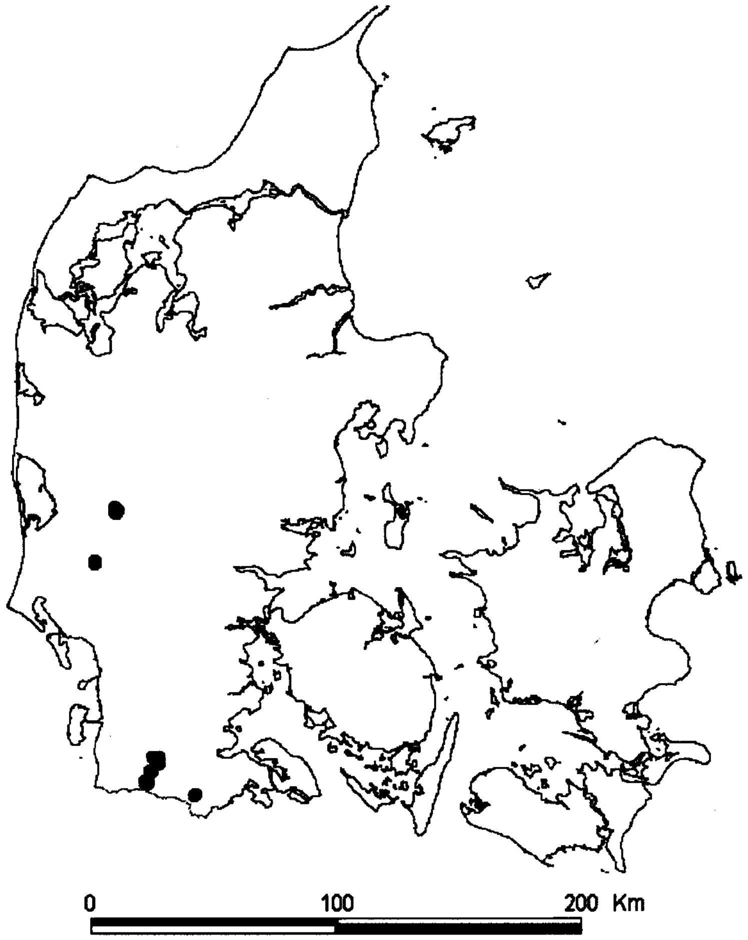

Fig. 1. Map of Denmark, the dots showing location of sampling sites.

plains (Fig. 1). Average temperature for January and July was −0.1 and 15.2 °C, respectively and yearly average precipitation 823 mm (Frich et al., 1997; Laursen et al., 1999).

Hedgerows included on organic farms had been established and cultivated without any pesticide. Neighbouring fields on both sides had also been managed organically or conventionally since establishment of the hedgerow. Hedgerows had agricultural fields on both sides and none of the farmers used headlands or unsprayed field margins. All hedgerows had been established 10–14 years ago by a company (Hedeselskabet), using the same technique and all contained three to four rows of a mixture of exotic and native deciduous woody species. The planting distance between mixtures of 15 and 25 woody species was 1 × 1.2 m with a minimum hedge length of 120 m and ploughing to a depth of 0.5 m to avoid seed from the seed bank. The starting point was hence similar and the recorded species have colonised from the surrounding landscape.

Data were collected in August 2001 of six sampling plots (three pairs) of 10 square metre (0.5 m × 20 m) placed along each hedgerow, 20 m apart. In each pair one plot was placed 0.2 m from the field edge, and one was placed in the centre of the hedgerow, between the first and second planted row. All vascular plants and bryophytes were recorded in each 10 square metre plot and species abundance was evaluated by the number of rooted species (soil contact for bryophytes) in 10 Raunkjær circles of 1/10 square metre (Raunkjær, 1910). Other species outside the Raunkjær circles but inside the plot were noted and given the lowest frequency score (=1). Planted woody species and their regeneration were not included. A total list of species from 120 m on one side of the hedgerows was obtained by noting supplementary species between plots. To optimise comparison between hedges the most south-orientated was considered.

Photosynthetic active radiation (PAR) was measured with a LI-191SA Line Quantum Sensor (LI-COR 1991). The sensor was 1 m long, and double measurements were performed at a height of 0.5 m in three positions along the centre of each plot. Measurements were expressed as a percentage of open field measurements perpendicular to the sample plot.

The orientation of the hedgerows was measured with a compass. Hedge bank height was measured in two positions along the sample plot and averaged. Hedge width was measured at both ends of the hedgerows. Height of hedges was estimated in four classes (<3 m, 3–5 m, 5–7 m and >7 m).

Soil samples from each sampling plot were collected in October 2001. Five sub-samples of soil were collected 0–5 cm below the A_0-horizon, lumped and sifted through a 2 mm sieve to remove roots and stones. Water content of the soil was measured gravimetrically. Soil pH and conductivity were measured in mixtures of soil and H_2O (1:5 v/v). Fresh soil (10 g) was immediately extracted for 1 h in 50 ml of 0.5 mol/l K_2SO_4 to recover soil inorganic N and P. The extracts were filtered through Whatman GF-D filters and frozen until their $NH_4{}^+$-N content could be analysed with the indophenol method, $NO_3{}^-$-N with the cadmium reduction method (Allen, 1989). A fraction of each soil sample was dried at 70 °C to constant weight and finely ground. About 4 g of the dried soil was burnt at 550 °C for determination of the organic content. Another fraction, about 200 mg dry soil, was digested in a sulphuric acid and selenous acid mixture for 1 h (Kedrowski, 1983) to analyse total P with the molybdenum blue method and total N with the indophenol method, using a Hitachi U-2000 spectrophotometer. Soil carbon content (total C) was measured with a LECO CNS-1000 according to Sørensen and Bülow-Olsen (1994). Soil texture was finally obtained from the marginal plots and centre plots by lumping the soils from the three central plots and three marginal plots resulting in two samples per hedgerow. Soil was sieved to find the proportion of coarse sand (200–2000 μm), fine sand (63–200 μm), coarse silt (20–63 μm), silt (2–20 μm) and clay (<2 μm) (Sørensen and Bülow-Olsen, 1994). Coarse sand and fine sand were correlated and therefore only coarse sand was used. Every vegetation sample was associated with a set of 16 environmental variables (Table 1).

The identification and taxonomy of vascular plants was based on Hansen (1993), Hubbard (1984), Pedersen and Schou (1988) and for mosses on Andersen et al. (1976).

2.1. Data analysis

Plant species diversity in the hedgerow was calculated on three levels: α (plot level), β (species turnover) and γ (hedge level). A mixed model analysis of variance (ANOVA) was used to test differences in alpha and gamma diversity between management types. ANOVA was also used to test differences in explanatory variables and plant types between management types. In both cases random variables were hedge and block number within hedge. Fixed variables were management type and position in hedgerow (central or boundary plot). The overall statistical model applied was

$$Y_{ijkl} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + C_{ik} + D_{ikl} + \varepsilon_{ijkl}$$

where μ is the mean, α_i denotes the effect of management system i, β_j is the effect of position in hedgerow (j, boundary or central), $(\alpha\beta)_{ij}$ represents the interaction between management and position, C_{ik} is the effect of hedgerow number k in management system i, D_{ikl} represents the effect of pair (block) l in hedgerow k in management system i, and ε_{ijkl} is the residual effect. C_{ik} was assumed to be mutually independent and normally distributed with a mean of 0 and a variance of σ^2_B, ε_{ijkl} being assumed to be mutually independent and normally distributed with a mean of 0 and a variance of σ^2, D_{ikl} is mutually independent and normally distributed with a mean of 0 and a variance of σ^2_D.

The use of beta diversity followed Whittaker (1972) and Ejrnæs et al. (2002). For comparison of the two farming types, 12 random subsets of 10 sample plots were drawn from each farming type, and beta diversity was calculated as the total number of species in the 10 sample plots divided by the average number. The t-test was used to compare beta diversity per farming type.

Table 1
Explanatory variables and variance explained ranked according to percent of explained variation (sixth column) evaluated by running forward selection of all variables followed by Monte Carlo Permutation test

Explanatory variables	Units	Range (minimum and maximum)	Mean	Trans-formations	Variance explained by this variable	Level of significance
Total P	mg/g	0.036–0.857	0.283	$\sqrt{x}$	12.0	***
Location	Nominal	0–1	–	–	10.4	***
Total C	g/100 g soil	0.842–9.386	3.22	log(*x*)	10.2	***
Coarse silt	g/100 g soil	1–9.1	2.09	log(*x*)	9.5	***
Type of farming (organic vs. conventional)	Nominal	0–1	–	–	9.4	***
Bank height	m	0–0.8	0.086	$\sqrt{x}$	7.5	***
Coarse sand	g/100 g soil	40.1–81.1	66.88	–	7.0	***
Clay	g/100 g soil	2.5–8.9	3.96	log(*x*)	5.5	***
Total N	mg/g	0.072–3.729	1.493	$\sqrt{x}$	4.6	**
Conductivity	MicroSiemens/cm	14.6–74.8	32.88	log(*x*)	4.3	**
Silt	g/100 g soil	0.9–6.8	2.87	log(*x*)	3.9	*
Loss on ignition	%	1.5–9.8	6.31	–	3.7	**
Orientation	°	60–260	137	log(*x*)	3.5	*
pH_{H_2O}	$[H^+]$	4.3–6.85	5.43	exp(*x*)	3.5	*
Light (average)	Percentage of field	0.5–78.5	15.23	log(*x*)	3.2	NS
Water content	Percentage of dry weight	5.4–35.5	17.0	log(*x*)	1.7	NS

NS: not significant.
* *P* values between 0.01 and 0.05.
** *P* values between 0.001 and 0.01.
*** *P* values <0.001.

The vegetation data comprised 156 plots with 144 taxa. Prior to multivariate analysis 71 species with less than four occurrences were deleted according to Økland (1990). A detrended correspondence analysis (DCA) (Hill, 1979) was performed with default options, that is, detrending by 26 segments, non-linear rescaling and rescaling of axes for species abundance data. All explanatory variables were examined for kurtosis and skewness. Variables with numerical values >1 were transformed to reduce kurtosis and skewness. The type of transformations that resulted in the smallest kurtosis and skewness value was chosen (Table 1). Hereafter variables were centred and standardised to obtain unit variance. A constrained ordination (CCA) was used to estimate the explanatory value of the variables followed by forward selection and Monte Carlo Permutation test with 999 unrestricted permutations (Ter Braak and Smilauer, 1997–1999). The indicator values of Ellenberg et al. (1991) for temperature (*T*), moisture (*F*), fertility (*N*), light (*L*) and acidity (*R*) were used to calculate a weighted mean for all plots. Product–moment correlations were calculated between ordination axes and explanatory variables.

3. Results

Out of 26 hedgerows, 12 were adjacent to ley (5 conventional and 7 organic) with a typical lifetime of 2–3 years, and 14 adjacent to barley, rape and vegetables (8 conventional and 6 organic). Mean hedge width (furrow to furrow) was 5.2 m (S.E. = 0.19), and the median height class was 3 (5–7 m). All hedgerows had been established in a standardised way in the same period and have a very similar and comparable structure. Thus, width and height data were not included in the following analysis, but are mentioned for comparison with other countries (Baudry et al., 2000). The mean orientation of organic and conventional hedgerows was 148° (SSE) and 125°(ESE), the mean bank heights were 0.06 and 0.12 m, respectively and were the only factors for which mean values differed significantly between farming types (Table 2).

Table 2
Mean values of explanatory variables and results of mixed analysis of variance of transformed values

Explanatory variables	Mean values		Component of variance (random effects)			P-values		
	Organic	Conventional	Hedge number	Block	Residual	Type of farming	Position	Type of farming × position
pH_{H_2O}	5.40	5.46	0.4	0.1	0.5	0.6	<0.0001	0.7
Conductivity	34.25	31.52	0.5	0.004	0.5	0.4	0.1	0.07
Water content	23.11	18.17	0.6	0.04	0.4	0.08	0.9	0.3
Total P	0.30	0.27	0.8	0	0.2	0.6	<0.0001	0.4
Total N	1.55	1.44	0.5	0	0.5	0.7	0.005	0.9
Loss on ignition	4.9	5.3	0.7	0.08	0.2	0.2	0.1	0.8
Coarse sand	65	69	0.9	–	0.09	0.3	0.002	0.03
Coarse silt	2.1	2.0	0.9	–	0.2	0.9	<0.0001	0.03
Clay	4.2	3.8	1.0	–	0.09	0.5	0.007	0.2
Silt	3.2	2.6	0.7	–	0.2	0.2	<0.0001	0.2
Total C	3.7	2.8	0.9	–	0.08	0.2	<0.0001	0.3
Light	14	17	0.3	0	0.3	0.2	<0.0001	0.3
Bank height	0.06	0.12	6.0	0.3	0	<0.0001	1.0	1.0
Orientation	148	125	0.3	0	0	<0.0001	1.0	1.0

Estimated relative importance of random variables and level of significance are shown. "Position" refers to inside and outside the hedgerow.

Median values were equal for both bank height (zero) and orientation (120°).

A total of 144 plant species were found of which 14 were spontaneous woody, 118 herb and 12 bryophyte species, 101 of which occurred in conventional, 128 in organic hedgerows. Ecological classification and preference of species were evaluated according to Hansen (1993) and Smith (1978). Of all the species, 73 were found in semi-natural habitats, 40 being exclusively found in semi-natural habitats, 12 of which being forest species. Seventy-one species were considered as arable and ruderal species, one protected species was found (*Epipactis helleborine* (L.) Crantz.) in an organic hedgerow. Total numbers of hedge bottom species (gamma diversity) ranged from 24 to 53 ($\bar{x}$ = 38.7, S.E. = 1.6) in organic, from 20 to 36 ($\bar{x}$ = 28.8, S.E. = 1.1) in conventional hedgerows, the difference being highly significant (Table 3). The difference in average species richness of sample plots (alpha diversity) was also highly significant (organic 15.1 versus conventional 12.5, $P = 0.013$), boundary samples also being significantly different (organic

Table 3
Analysis of variance of plant types and species diversity between organic and conventional farming (estimated relative importance of random variables made on presence-absence data in all sampling plots, with P-values for fixes variables)

	Mean values in plots		Component of variance (random effects)			P-values		
	Organic	Conventional	Hedge number	Block	Residual	Type of farming	Position	Type of farming × position
Weed and ruderal species	8.3	6.4	4.9	0	6.2	0.041	<0.0001	0.0056
Semi-natural species	5.1	3.9	1.4	0	2.0	0.018	0.0041	0.236
Forest species	0.41	0.47	0.1	0	0.3	0.82	<0.0001	0.79
Bryophytes	0.96	0.65	0.3	0.03	0.4	0.33	<0.0001	0.79
Alpha diversity total	15.1	12.5	7.3	0	11.9	0.013	0.0003	0.006
Alpha diversity (outside)	17.2	12.8	12.8	6.5	1.0	0.0064	–	–
Alpha diversity (central)	13.7	12.2	12.5	5.1	1.0	0.33	–	–
Gamma diversity	38.7	28.8	–	–	–	0.0011	–	–

"Position" refers to inside and outside the hedgerow.

Table 4
Mixed analysis of variance of weighted mean values of Ellenberg et al. (1991) values for all sampling plots (estimated relative importance of random variables and *P*-values of fixed variables is given)

	Component of variance (random effects)			*P*-values		
	Hedge number	Block	Residual	Type of farming	Position	Type of farming × position
Light	0.03	0	0.04	0.87	<0.0001	0.12
Temperature	0.02	0	0.02	0.34	<0.0001	0.1585
Soil moisture	0.02	0	0.08	0.53	<0.0001	0.048
pH	0.7	0	1.3	0.09	0.38	0.95
Nitrogen	0.3	0.02	0.1	0.52	<0.0001	0.31

17.2 versus conventional 12.8, $P = 0.0064$). There was no difference between species richness in samples from inside the hedgerow (organic 13.7 versus conventional 12.2, $P = 0.33$). Organic hedgerows were significantly richer in weedy, ruderal and semi-natural species but there was no difference in frequency of bryophytes and forest species (Table 3). There was no significant difference in soil variables between the farming types (Table 2), whereas samples taken at the field edge and centrally in the hedgerows differed for most soil parameters.

There was no significant difference in weighted mean Ellenberg values between farming types (Table 4). The overall correlation between species richness of sampling plots and explanatory variables was highest for soil variables and insignificant for variables concerning hedge structure (Table 5). There was a significantly higher beta diversity (Whittaker, 1972) on conventional farms (*t*-test, d.f. = 11, $P = 0.0074$). The contribution of block number within the hedge to the total random variance was low compared to hedge number and residual effect (Tables 2–4) which means that differences within hedges were small compared to differences between hedges.

Species occurring in less than four samples were deleted from the data matrix, leaving 156 samples with 73 species. Gradient lengths were 5.1, 5.2 and 3.4 for DCA axes 1–3. It is obvious from Fig. 2 that there was a great overlap in species composition between the two management types. DCA1 sample scores had the highest negative correlation with soil nutrient status (Ellenberg *N* value, P total and amount of coarse sand) and measured light variables (Table 5), indicative of a major gradient in soil fertility and light. DCA2 sample scores had the highest correlation with Ellenberg (*L*) indicating a light gradient but also high correlation to soil fertility. DCA3 sample scores had a high correlation with variables related to soil moisture-related variables (Ellenberg *F* value, C total). There was a higher species turnover among the abundant species on conventional farms than on organic farms (Fig. 2), and organic plot were positioned toward the higher fertility end of the gradient.

Total inertia was 8.28 and the variance explained by all explanatory variables was 2.03 (=25%). Fertility, location, farm type, four soil variables and bank

Table 5
Correlation coefficients between explanatory variables and sample ordination score for DCA1–DCA3 and species richness

Explanatory variables	DCA1	DCA2	DCA3	Species richness
DCA1	1.00	0.05	0.11	0.003
DCA2	0.05	1.00	−0.07	0.12
DCA3	0.11	−0.07	1.00	0.03
pH	−0.13	−0.13	0.15	0.10
Conductivity	0.02	−0.09	−0.19	0.04
Water content	0.11	0.20	**−0.38**	0.17
Light	**0.38**	−0.18	0.27	0.12
Bank	0.01	0.29	0.09	−0.12
Exposition	0.23	0.13	−0.11	0.04
Total P	**−0.32**	**−0.36**	−0.07	0.17
Total N	0.29	0.19	**−0.30**	0.12
Loss on ignition	0.16	0.20	−0.33	0.09
Coarse sand	**0.42**	0.22	0.29	**−0.34**
Coarse silt	−0.15	−0.02	−0.26	0.12
Clay	−0.27	0.03	−0.27	0.19
Silt	−0.28	−0.27	−0.04	0.42
Total C	0.21	0.20	**−0.36**	0.10
Ellenberg (*L*)	−0.09	**−0.53**	**0.38**	0.09
Ellenberg (*T*)	0.24	**−0.31**	**0.35**	0.15
Ellenberg (*F*)	−0.14	0.15	**−0.50**	0.20
Ellenberg (*R*)	**−0.35**	−0.29	**−0.38**	**0.34**
Ellenberg (*N*)	**−0.57**	**−0.39**	−0.12	0.22

Values above 0.3 are represented in bold.

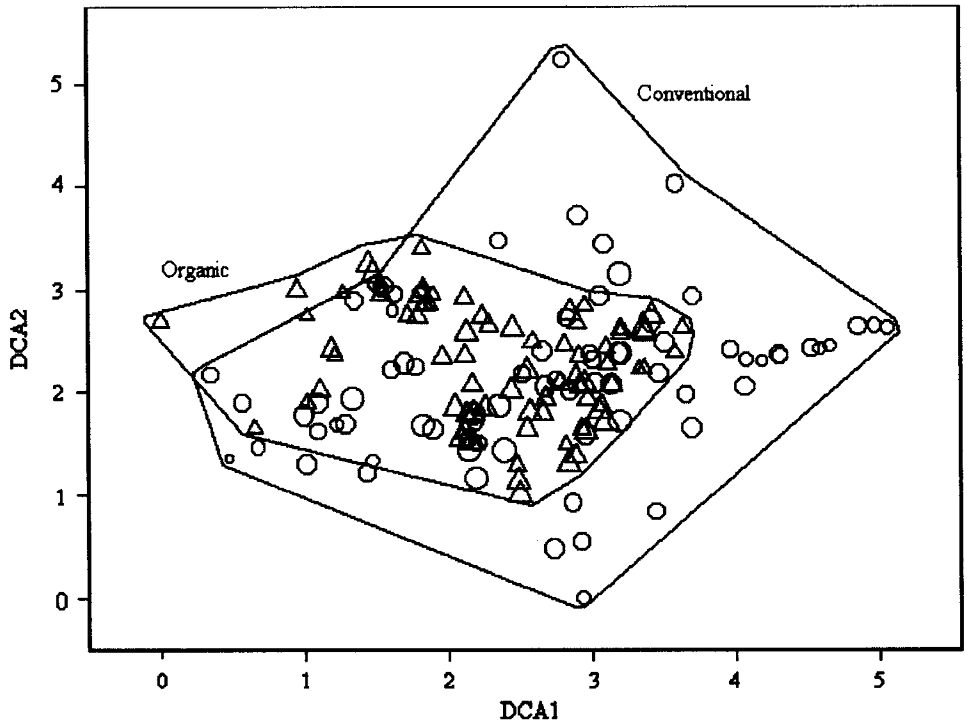

Fig. 2. Ordination diagram with 156 sampling plots along the two most important gradients, DCA1 and DCA2. O: conventional hedgerow; Δ: organic hedgerow; polygons: surface covered by the each management types. Sizes of circles and triangles reflecting number of species in the sample plot.

height explained a significant fraction of the variation in species composition (Table 1). Soil phosphorous content was the variable that explained most of the variation (12%). Location of the sampling plots (inside the hedgerow or outside in the open vegetation) was second (10.4%), farming type being only the fifth most important variable explaining 9.4% of the variation (Table 1).

4. Discussion

Both null hypotheses have to be rejected because farming type significantly affected alpha, beta and gamma plant species diversity in the hedge bottom vegetation. Farming type explained a significant part of the variation in the species composition.

Farming type had a highly significant influence on the hedge bottom vegetation. A significantly higher species diversity was found in hedgerows without pesticide impact and adjacent to organic fields compared to hedgerows on conventional farms. This difference in species diversity was significant in alpha and gamma diversity. The difference was even more obvious when only samples from hedgerow edges were compared. Other studies also found significantly higher species diversity in hedge bottom vegetation associated with more extensive farming systems (Hegarty et al., 1994; Boutin and Jobin, 1998; French and Cummins, 2001). However, the highly significant difference in hedge bottom vegetation between conventional and organic farming in this study had not been observed before. In many cases the effect of management can be difficult to interpret because hedges often have different land use on either side (Mercer et al., 1999) but that was not the case in this study.

Bank height and orientation differed significantly between farming types. Species diversity also correlated positively to bank height in Mercer et al. (1999) study. In our study there was only 0.06 m difference in bank heights between farming types, no difference in median values, there was a small negative correlation between species richness and bank height, and the highest mean value of banks was found in conventional hedgerows. The significant difference in orientation was unlikely to explain differences in species richness as already recorded by other European workers (Mercer et al., 1999; Marshall et al., 2002).

All hedges were located in the same Main Terminal Moraine, on the same soil (Madsen and Jensen, 1992) and with only minor differences in climatic conditions (Lysgaard, 1979). Hedgerows had the same width, age and measured soil variables did not differ between farm managements. The potential local and regional plant species pool (Zobel, 1997; Zobel et al., 1998) was assumed to be the same and differences in species number must be explained by either extinction or immigration or both (MacArthur and Wilson, 1967; Hanski and Gilpin, 1997). Higher extinction on conventional farms could be due to pesticide drift but also from the phase of hedgerow establishment. Herbicides were applied to the conventional hedgerows 2 or 3 years after establishment, whereas organic farmers only used non-chemical weed control, the two weed control strategies favouring different plant species (Kleijn and Snoeijing, 1997). It is impossible to tell whether it is difference in the establishment of organic and conventional hedgerows or the following 10–14 years differences in farming type that is most important. However, the use of herbicides was the main difference during both establishment and adolescence. Field margins and non-target plants could receive up to 20–25% of the applied pesticide field dosage (De Snoo and de Wit, 1998; De Snoo, 1999; Boutin et al., 2001), which may influence diversity and cover of non-target plant of field margins (Marrs et al., 1989, 1991; Marrs and Frost, 1997; Hald et al., 1994; Jobin et al., 1997; Kleijn and Snoeijing, 1997; De Snoo and van der Poll, 1999). Spray drift also influences the performance, survival and reproductive potential of some non-crop species (Fletcher et al., 1996). On the other hand, some studies found that reduced pesticide drift were of minor importance for the boundary flora (Hald, 1988; Marshall, 1992) which can be explained by the inertia of established plant communities (Milchunas and Lauenroth, 1995).

Organic fields often have higher weed species density and diversity (Hald, 1999; Rydberg and Milberg, 2000) and the potential immigration rate of weeds from the fields is likely to be higher compared to conventional hedgerows. This is consistent with the higher richness of weedy species recorded in the hedge bottom of the organic farms. Despite the barriers of movement encountered by many plant species in modern fragmented landscapes (Primack and Miao, 1992; Wiens, 2001) there is a high probability that non-weedy species have dispersed from nearby semi-natural habitats.

There were few forest species and no difference between farming type could be detected. Fertilising can affect the plant species diversity (Marshall et al., 2002), but is unlikely to explain the differences between farming types. There was no significant difference between farming types in either measured soil fertility or calibrated Ellenberg values of fertility. A difference in available P and N fractions between conventional and organic farms cannot be excluded totally, but Mäder et al. (2002) suggested that with equal total phosphorous contents a higher available P is expected on organic farms due to higher microbial activity.

Some studies indicate relations between landscape ecological features and species diversity (Dzwonko and Loster, 1988; Skånes, 1990) and composition (Dzwonko, 1993; Dzwonko and Loster, 1997; Graae, 2000; Le Coeur et al., 1997, 2002). In this study, hedgerows were positioned close to each other in the same type of landscape and differences in species diversity can hardly be explained by differences in the landscape context.

Disturbance can also be important in terms of species diversity (Grime, 1979; Eriksson, 1997), because a closed sward may prevent recruitment of species. Hedgerows near cereal fields could contain more ruderal species than hedgerows close to grass ley. In this study, more conventional hedgerows were close to cereal fields than organic hedgerows (eight versus six). Therefore, differences in disturbance regime are not likely to explain the differences in species diversity.

This study included more conventional than organic farms (eight versus five) which may result in a higher probability of finding different local species pools. Conventional farming may include a more diverse group of farming practices than organic farms but it is more likely that the 25% lower alpha diversity in conventional hedgerows resulted in lower beta diversity.

The higher difference in species richness between margin and centre plots in conventional than organic hedgerows indicated a stronger agricultural impact from the field to the centre of the hedgerow.

The higher frequency of species occurring in semi-natural habitats and the hosting of a protected species (*E. helleborine*) imply that a slightly higher naturalness (*sensu*, Angermeier and Karr, 1994; Anderson, 1991) occurred in hedge bottoms associated with organic farming systems. A higher number of species could also act as a potential buffer against environmental fluctuations as suggested by Loreau et al. (2001) and changing landscapes. On this background it cannot be excluded that organic farming contribute to a higher biological integrity and a more sustainable development of the landscape.

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