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Selection on plant traits in hedgerow ground vegetation: The effect of time since conversion from conventional to organic farming

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Abstract

This paper aims at characterizing the response of hedgerow ground flora to conversion of the surrounding fields from conventional farming to an organic farming practice. The effect of time since conversion from conventional to organic farming on the neighbouring hedgerow vegetation was examined by measuring selection on plant species and plant traits in the ground flora of 57 hedgerows adjacent to agricultural fields subject to organic or conventional management. Species richness increased significantly with time since conversion to organic farming until a maximum was reached. There were significant changes in community weighted average trait value in seven out of fifteen plant traits, and in functional diversity in two out of three groups of traits. In contrast to hypotheses, transition to organic farming generally selected for plant species that are less adapted to competing for light, whereas there were no effects on life form and lifespan. When all plant traits were analyzed together in a regression tree analysis, 31% of the variance was explained by five plant traits in the pruned tree, indicating that factors other than farming practice have a large influence on hedgerow ground flora.

Zusammenfassung

Das Ziel dieser Untersuchung ist es, die Reaktion der Bodenflora in Hecken auf die Umstellung von benachbarten Feldern von konventioneller auf biologische Bewirtschaftung zu beschreiben. Der Effekt der Zeit seit Umstellung auf die Vegetation der benachbarten Hecken wurde untersucht, indem die Selektion auf Pflanzenarten und Pflanzenmerkmale gemessen wurde. Der Artenreichtum stieg signifikant mit der Zeit seit Umstellung auf biologische Bewirtschaftung bis ein Maximum erreicht war. Es gab signifikante Änderungen des gewichteten mittleren Merkmalswertes der Gemeinschaften bei sieben von fünfzehn Merkmalen und der funktionellen Diversität bei zwei von drei Merkmalsgruppen. Im Gegensatz zu unseren Hypothesen erfolgte durch die Umstellung auf biologische Bewirtschaftung generell eine Auslese von Pflanzenarten, die weniger gut an die

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Konkurrenz um Licht angepasst sind, während es keine Auswirkungen auf Lebensform und Lebensdauer gab. Bei der gemeinsamen Analyse aller Pflanzenmerkmale in einem Regressionsbaum mit Pruning wurden 31% der Varianz durch fünf Merkmale erklärt. Dies zeigt an, dass andere Faktoren als die Bewirtschaftungsweise einen starken Einfluss auf die Bodenflora der Hecken haben.

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Introduction

Plants and animals in hedgerows and other small habitats in the agricultural landscape are affected by neighbouring intensively managed fields because treatments such as pesticide application and fertilization are not confined to the field but unintentionally enter the neighbouring habitats. Decades of agricultural intensification have led to a decrease in biodiversity (e.g. Rich & Woodruff 1996; Burel et al. 1998; Chamberlain, Fuller, Bunce, Duckworth, & Shrubbs 2000; Donald, Green, & Heath 2000; Krauss et al. 2010; Flohre et al. 2011; Meyer, Wesche, Krause, & Leuschner 2013). Thus, if field management is altered, e.g. by conversion from conventional farming to an organic farming practice, the plant communities in neighbouring hedgerows are expected to respond to the alteration. The aim of this paper is to characterize the response of the herbal plant community at the ground of the hedgerow to conversion of the adjacent field from conventional farming to an organic farming practice. Previous studies have documented that hedgerows at organically managed farms have a richer ground vegetation, and transition from conventional to organic farming resulted in higher species richness in the hedgerow plant communities (Hole et al. 2005; Boutin, Baril, & Martin 2008; Aude, Tybirk, & Pedersen 2003) and recently we documented that time since transition significantly affects species richness of hedgerow ground flora (Strandberg, Damgaard, & Dalgaard, *in press*).

Environmental changes may lead to the selection of new functional plant types in plant communities (Garnier et al. 2007), but since different plant species share a similar set of plant traits, a deterministic selection process at the plant trait level does not necessarily lead to the colonization and establishment of the same group of species in different sites (Shipley 2010). In an analysis of the occurrence of forest herbs in hedgerows along a climatic gradient in Europe, Wehling and Diekmann (2010) found that the local species pool was important for floral composition, and that light availability had the highest explanatory value with regard to the occurrence of forest herbs in the hedgerow flora. The change (and the rate of change) in species composition will vary among sites and depend on the existing plant community, the content in the seed bank, and the possibility of new plant species to immigrate from neighbouring semi-natural habitats in the agricultural landscape (Milchunas & Lauenroth 1995). However, the plant traits of the different species are characteristic features of the survival, growth and reproductive strategies of the particular species, and thus expected to

respond to an altered environment in a more predictable way than the observed change in species composition (Shipley, Vile, & Garnier 2006; Vile, Shipley, & Garnier 2006; Garnier et al. 2007; Shipley 2010). Consequently, when comparing the floral diversity across hedgerows it may be useful to use plant species traits instead of actual species present.

Thus, although the general trend when converting from conventional to organic management is an increase of hedgerow plant diversity, the effect of field management on plant species composition varies between studies (e.g. Aude et al. 2003; Bengtsson, Ahnström, & Weibull 2005), i.e. it is uncertain which plant species will be affected by a transition to organic farming. Therefore, we investigated the effect of time since transition from conventional to organic farming on hedgerow biodiversity by examining the selective forces on different plant traits in hedgerows at conventional and organic farms previously studied in order to assess effects of the conversion on species richness (Bruus Pedersen, Aude, & Tybirk 2004; Strandberg et al., *in press*). That is, we focused on the change in abundance of different plant traits rather than examining the change in the abundance of the different plant species in order to be able to characterize the selection responses of the hedgerow plant community after neighbouring fields had shifted from conventional farming to an organic farming practice. Thus, the selection regime has shifted from including artificial fertilizers and pesticides to omitting them. Among these factors, the effect of herbicides may be assumed to play the most important role in the selection on the hedgerow ground flora, since hedgerow treatment and fertilizer levels are not expected to be altered significantly. This assumption seems plausible, since we know that fertilizer levels are generally high in both organically and conventionally cultivated Danish hedgerows (Aude et al. 2003). Assuming that herbicide use has a disturbing effect on the hedgerow ground flora, our hypothesis was that turning to organic management would result in a lower abundance of ruderal plant species and a higher abundance of competitive species. Since herbicides are normally more efficient towards smaller plants, the transition to organic farming may also be expected to result in more annual and biennial species, since such species are forced to reproduce from seeds and consequently often appear as seedlings at the time of herbicide treatment.

If farming practice has an effect on the distribution of plant traits of hedgerow vegetation it may be relevant to ask whether the ecological versatility or functional diversity of the vegetation likewise is affected by farming practice,

and whether, e.g. organic farming promotes farming functionally more diverse hedgerow vegetation than conventional farming. This is interesting since it has been proposed that functional diversity may have a large impact on ecosystem processes (Tilman et al. 1997), and has been found to be positively associated with species richness (Isbell et al. 2011; Maestre et al. 2012).

The general investigation of the selection forces operating on the plant traits in the hedgerow plant communities outlined above is coupled to more applied ecological questions that are currently investigated, i.e. what is the effect of different agricultural practices on the biodiversity and the type and level of ecosystem services provided by small natural and semi-natural habitats close to agricultural fields? More specifically, the applied objective of this paper was to examine whether the traits of the plant species in the hedgerow plant community may be used as a reliable indicator for the agricultural practices in the neighbouring field.

Materials and methods

The study was carried out in farmland hedgerows and permission to visit the areas was obtained from the farmers. The sampling did not involve endangered or protected species.

This study has re-visited hedgerows used in two previous studies (Bruus Pedersen et al. 2004; Strandberg et al., in press) in order to obtain the plant cover data necessary for the trait-based analysis of differences between hedgerows at organically and conventionally managed farms as well as the effect of the duration of organic management.

Hedgerow descriptions

In the studies presented in Bruus Pedersen et al. (2004) and Aude et al. (2003), 26 hedgerows in the south-western part of Jutland on sandy soils (Saalian moraines or Weichelian outwash plains) and 30 hedgerows on loamy soils (Weichelian moraines) east and north of the ice limit of the latest glaciation in Denmark were sampled. On both soil types, half the hedgerows were situated at organically managed farm, the other half at conventionally managed farms. In order to ensure that the variation in landscape characteristics, climatic conditions and soil types was covered by both types of hedgerows, hedgerows at organic farms were localized first, and subsequently hedgerows at nearby conventional farms were selected. Hedgerows at organic farms had been established 6–22 years earlier (the majority 10–15 years). The farms had been managed organically for at least 10 years, and for the large majority of hedgerows the farm had been managed organically for the whole life-time of the hedgerow. All hedgerows were >100 m long and consisted of multiple (3–5) rows of deciduous trees. The hedgerows were oriented north–south, i.e. perpendicular to the prevailing

western winds. Thirty of these 56 hedgerows were re-visited in 2010.

The study by Strandberg et al. (in press) included 30 hedgerows within two geographically separated, rural areas, Bjerringbro and Kalø, in central Jutland, Denmark. The hedgerows within each area were selected as groups of one conventional and two organic hedgerows. The two organic hedgerows in a group were surrounded by fields that varied as much as possible in time since transition to the organic practice. With respect to other variables, the hedgerows in a group were as similar as possible. This includes orientation (all North–South running, being the typical direction because of the prevailing western winds in Denmark), composition of trees and bushes, age of the hedgerow (all hedgerows were between 80 and 150 years old) and crops on the neighbouring fields (all were cereals). Time since transition varied between 3 and 30 years in the Bjerringbro area and between 5 and 23 years within the Kalø area. All hedgerows in each area were located close to each other within a 10 by 10 km quadrat. Twenty-seven of these 30 hedgerows were re-visited for the present study.

In both studies, the main difference between the hedgerows adjacent to the conventionally and organically cultivated fields, respectively, was the use of herbicides. Since in organic farming mineral fertilizers are not allowed, while they are commonly used in conventional farming, the form of fertilizer applied is also likely to have differed. Furthermore, some differences in crop distribution, crop rotation and cultivation procedures cannot be ruled out, despite our efforts to overcome this by carefully selecting the hedgerows for the studies. Based on interviews and the size of the trees in the hedgerows, the planting time of hedgerows was estimated. The oldest hedgerows were estimated to be from 1850 and the youngest were from 1996. There was no significant relationship between the planting time of the hedgerows and the time the hedgerow had been managed by organic practice ($P=0.36$) (more detailed information on the environmental characteristics of the selected hedgerow is provided in Aude et al. 2003; Bruus Pedersen et al. 2004; Strandberg et al., in press).

The investigated hedgerows are listed in Appendix A: Table A1.

Plant cover measurements

For the analyses of plant cover 57 of the previously studied hedgerows were revisited. Eighteen hedgerows were situated next to conventionally managed fields, and 39 hedgerows were situated next to fields that varied with respect to the time they had been managed by organic practice; the longest period was 33 years and the shortest period was one year. The cover of vascular plant species in the hedgerow ground vegetation on the west side of the hedgerows was measured in the summer of 2010 using the pin-point method in ten plots per hedgerow (Levy & Madden 1933; Kent & Coker

Table 1. The selected plant traits used in the analysis.

Plant trait	Unit	Database
<i>LHS traits</i>		
Plant height	m	LEDa
Seed mass	mg	LEDa
Specific leaf area (SLA)	mm ² mg ^{−1}	LEDa
<i>Ellenberg traits</i>		
Ellenberg L	Index	Naturdata
Ellenberg F	Index	Naturdata
Ellenberg R	Index	Naturdata
Ellenberg N	Index	Naturdata
Ellenberg S	Index	Naturdata
<i>Grime CSR traits</i>		
Grime's C-strategy	Index	Naturdata
Grime's S-strategy	Index	Naturdata
Grime's R-strategy	Index	Naturdata
<i>Life history traits</i>		
Age of first flowering	Ordered year classes	LEDa
Plant lifespan	Ordered year classes	LEDa
Annual plant	Categorical	Naturdata
Raunkjær's life forms	Index	Naturdata

1992). The distance between plots was approximately 7 m. Each plot consisted of a 0.5 m × 0.5 m quadrat with 25 regularly spaced intersections at a distance of 10 cm. At each intersection a sharply pointed pin with a diameter of 1 mm was passed vertically through the vegetation and the species that touched the pin were recorded.

Plant traits

The selected plant traits used in the analysis are listed in Table 1. The investigated species specific plant traits were either measured characters (e.g. specific leaf area), life history characters (e.g. age at the first flowering event), or index values assessed by experts. The quantitative traits include leaf-height-seed (LHS) traits (Westoby 1998), Ellenberg indicator values (Ellenberg 1979) Grime's plant species CSR strategies (Grime 2001), and life history traits. To avoid unnecessary correlation among traits the analyses were split in sub-groups of traits that were analyzed independently. We find that it is meaningful to base the investigation on these groups although some of them are based on expert opinion rather than measured traits. The leaf, height and seed mass traits implied by the LHS strategy are basic plant traits that are simple to measure. This contrasts to the Ellenberg ecological indicator values (EIV), which are semi-quantitative composite traits that cannot be strictly understood as basic plant traits. Rather they represent an assembly of structural and physiological traits that together improve tolerance to soil acidity, salinity, drought tolerance etc. A nine point scale is applied for each of six gradients: soil acidity (Ell-R), soil productivity or fertility (Ell-N), soil humidity (Ell-F), soil

salinity (Ell-S), light availability (Ell-L) and climatic continentality (not included in this investigation) (Ellenberg 1979). The interpretation of the Ellenberg indicator values is not always simple (Ertsen, Alkemade, & Wassen 1998; Schaffers & Sýkora 2000); for example, the moisture indicator Ell-F, indicates a combination of high groundwater table and soil ability to retain water, and correlation is strongest to the soil moisture content in a dry period (Schaffers & Sýkora 2000). Likewise, the CRS-strategies suggested by Grime (2001) are also composite plant traits. The CSR-triangle theory predicts that the degree of competition, stress and disturbance characterizing a habitat will determine which species will occupy the habitat. In this scheme, the plant species have values in the three dimensions Competition, Stress and Ruderal (disturbance). Generally, Grime's C and Ellenberg's N indicators are positively correlated and an increase in both indicators suggests an increase in plant biomass and general competitive ability (Timmermann et al., unpublished). Like EIV's, the CSR-triangle theory has been subject to criticism, e.g. for the lack of obvious tests to apply to validate the values (Wilson & Lee 2000). CSR- and EIV-values have been treated as traits in comparable analyses by some authors (e.g. Pywell et al. 2003), and we have chosen to follow the example of Pywell et al. (2003) in this study.

The species specific plant trait values were found either in the LEDa database (Kleyer et al. 2008), or in a Danish database of plant traits (Nielsen et al. 2012). All qualitative characters were transformed to ordered index values to allow calculations of average values. The trait values of plant height, seed mass, and specific leaf area (SLA) were log-transformed.

Functional diversity of the three trait subgroups was calculated by Rao's quadratic entropy method using both the range-standardised Euclidean distance measure and the Mahalanobis distance measure (Botta-Dukát 2005).

Since the hedgerows are situated in a relatively large geographical region, it was not possible to define a common regional species pool from where the local species pool could be assumed to come from. Therefore, it was not possible to generate null-models for testing ecological hypotheses on the distribution of the individual plant traits (Bernard-Verdier et al. 2012). Consequently, we chose to display only the community-weighted mean trait values and not the associated variances since we did not have a clear hypothesis to test.

Effect of selection on plant traits

The community-weighted mean trait value of a single plant trait at time t was defined by

$$\bar{T}(t) = \sum_{i=1}^S p_i(t) T_i,$$

where T_i is the trait value of species i , $p_i(t)$ is the relative cover of species i in a plot at time t , and S is the number of species (Garnier et al. 2007).

If selection is operating on the different plant species, the relative cover of the different species is expected to change (Shipley 2010), and the possible effect of an altered agricultural management practice on a neighbouring semi-natural plant community may be monitored by observing the change in the average trait value.

Missing community-weighted mean trait value data may arise due to an incomplete trait database with missing values for some plant species. However, except for crown height ($n=267$), all other traits only had few missing community-weighted mean trait values.

Statistical analyses

The relationship between the plant traits of hedgerow plant communities and the number of years since the start of organic farming in the neighbouring fields was analyzed using single-trait linear and quadratic regression analyses assuming normally distributed residual variance, and in a regression tree analysis using the R package *rpart* (Therneau & Atkinson 1997), where plots were assumed to be independent observations. The regression tree was pruned with a pruning constant of 0.02 and the resulting model was cross-validated using the procedure *xpred.rpart*.

The effect of time since the start of organic farming in the neighbouring fields on community-weighted mean trait values or the functional diversity of the three traits groups were analyzed in two complementary linear (and quadratic) models with two different assumptions on the level of experimental unit: in the first model, the selection response on the traits was assumed to be independent of the local species pool and each plot was assumed to be an independent observation, whereas in the second, more conservative model, the selection response was assumed to depend on the local species pool in a hierarchical mixed model with hedgerow as the random effect using the R-package *nlme* (Pinheiro, Bates, DebRoy, & Sarkar 2013). The statistical inferences of the study are based on a combined assessment of both analyses, and the significance levels of both analyses are reported.

The relationship between species richness at each hedgerow and the number of years since the start of organic farming in the neighbouring fields was analyzed using a generalized linear and quadratic regression model where species richness were assumed to be Poisson distributed.

Results

The plant communities of the studied hedgerows were dominated by perennial herbs and grasses, including some species also seen as weeds in agriculture (e.g. couch grass, creeping thistle, common nettle and mugwort), but with low

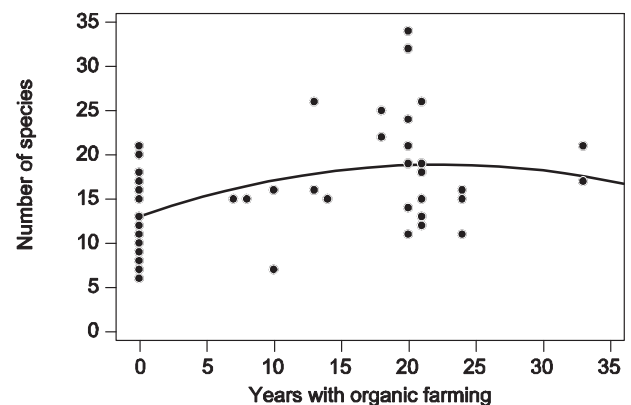


Fig. 1. Hedgerow species richness based on pin-point data plotted against years since the start of organic farming of the neighbouring fields. The quadratic regression fit is shown (linear and quadratic term in the generalized quadratic regression: $P=0.0005$, $P=0.037$).

cover of common annual weeds. A total of 136 vascular plant species were observed in the pin-point frames.

Species richness of the hedgerow ground vegetation increased with the number of years since transition to organic farming of the neighbouring fields (Fig. 1). The number of years since the start of organic farming in the neighbouring field had a significant concave effect on species richness in the hedgerows (generalized quadratic regression, $P<0.0001$).

The relationship between the community-weighted mean trait values of all the plant traits and the number of years since transition to organic farming of the neighbouring field were analyzed in single-trait quadratic regression analyses. Eleven out of fifteen plant traits showed a significant relationship with the number of years since transition in a simple regression analysis where all plots were treated as independent observations (Fig. 2), or seven out of fifteen traits, if the hierarchical structure was taken into account in a more conservative mixed model (Table 2).

When all plant traits were analyzed together in a regression tree analysis, 31% of the variance was explained by five plant traits in the pruned tree (Fig. 3). Overall, the regression analyses suggest that transition to organic farming selects for plant species that are less adapted to competition for light measured by a decrease in community-weighted mean Grime's C and Ellenberg's N indicators as well as an increase in Ellenberg's L indicator. A significant increase in Ellenberg's F indicator value was found with years since the transition to organic farming and, additionally, both the community-weighted mean seed mass and SLA decreased with years since transition to organic farming. The proportion of annual plants did not increase with years since transition (Fig. 2).

The applied objective of the study was to investigate whether hedgerow vegetation plant traits may be used as an indicator for the number of years the fields adjacent to the hedgerow have been farmed organically. However, if the pruned regression tree was cross-validated then a plot of the

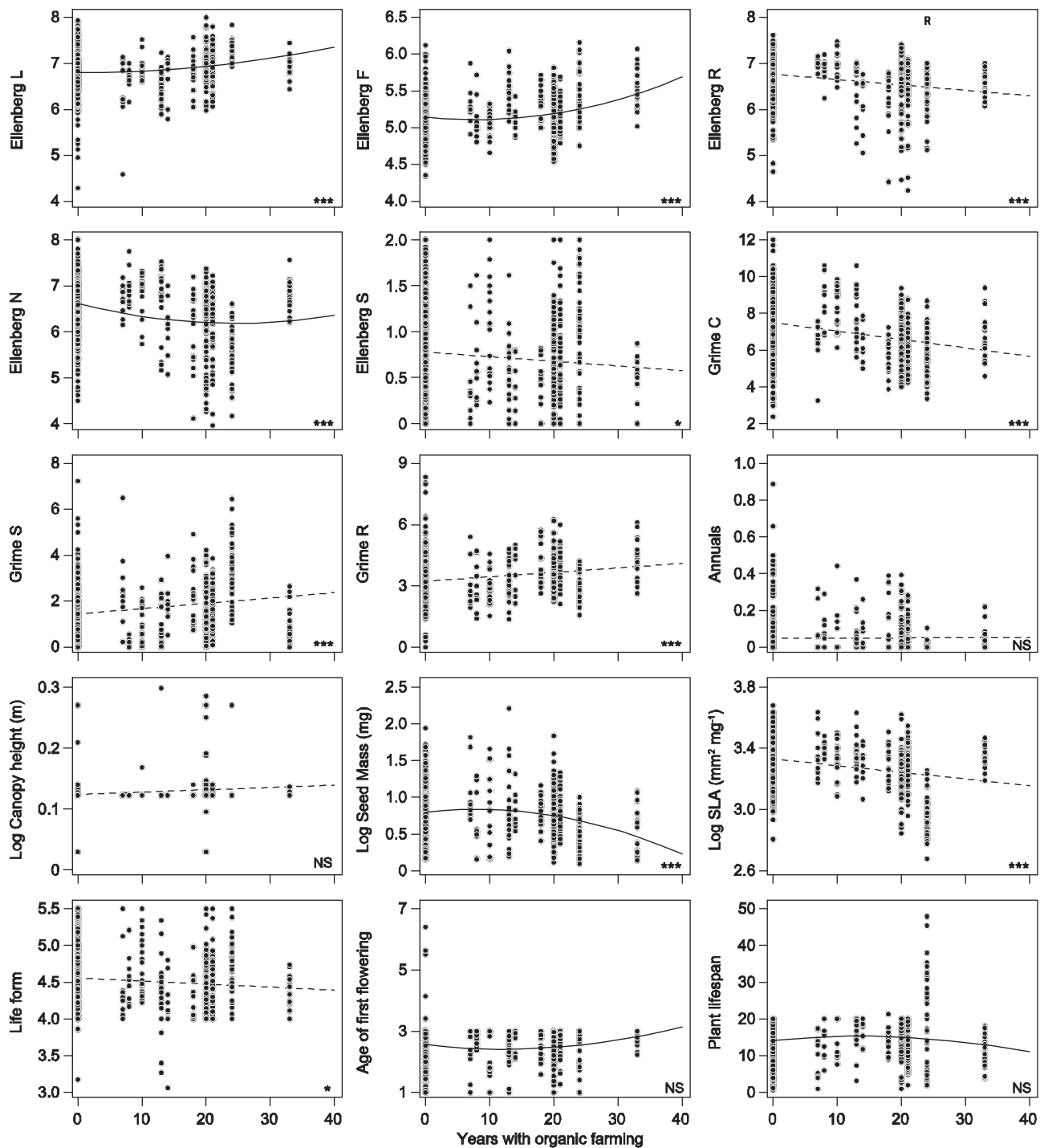


Fig. 2. Quadratic regression of community-weighted mean plant traits against time since the start of organic farming in the neighbouring fields, *** $P < 0.001$, ** $P < 0.01$, and * $P < 0.05$. The inclusion of a possible quadratic term in the best fitted line was decided according to the AIC model selection criterion (See Appendix A: Table A2; linear model: dashed line, quadratic model: full line). See also Table 2 for the results when the same data were analyzed in a more conservative mixed model.

known vs. predicted number of years with organic farming did not show a concurrent pattern (See Appendix A: Fig. A1).

The functional diversity of the three quantitative subgroups of plant traits (leaf-height-seed (LHS) values (Westoby 1998), Ellenberg values (Ellenberg 1979), and Grime CSR (Grime 2001)) were all significantly concavely affected by

the number of years since the shift to organic farming practice if analyzed in a simple regression analysis were all plots were treated as independent observations (Fig. 4). However, when the hierarchical structure was taken into account in a mixed model, then only the Ellenberg and Grime groups of traits showed a significantly positive linear effect (Table 2).

Table 2. The *P*-values in a linear and quadratic model of community-weighted mean plant traits or functional diversity of time since the transition to organic farming in the neighbouring fields. The data are analyzed in a mixed model with hedgerow as the random effect.

Trait	<i>P</i> (linear)	<i>P</i> (quadratic)
Ellenberg L	0.035	0.476
Ellenberg F	0.109	0.114
Ellenberg R	0.006	0.803
Ellenberg N	0.006	0.392
Ellenberg S	0.294	0.963
Grime C	0.001	0.987
Grime S	0.044	0.615
Grime R	0.009	0.498
Annuals	0.920	0.402
Log Canopy height (m)	0.164	0.837
Log Seed Mass (mg)	0.107	0.105
Log SLA (mm ² mg ⁻¹)	0.007	0.950
Life form	0.255	0.651
Age of first flowering	0.851	0.184
Plant lifespan	0.705	0.372
Functional diversity: LHS	0.218	0.192
Functional diversity: Ellenberg	0.008	0.067
Functional diversity: Grime	0.007	0.246

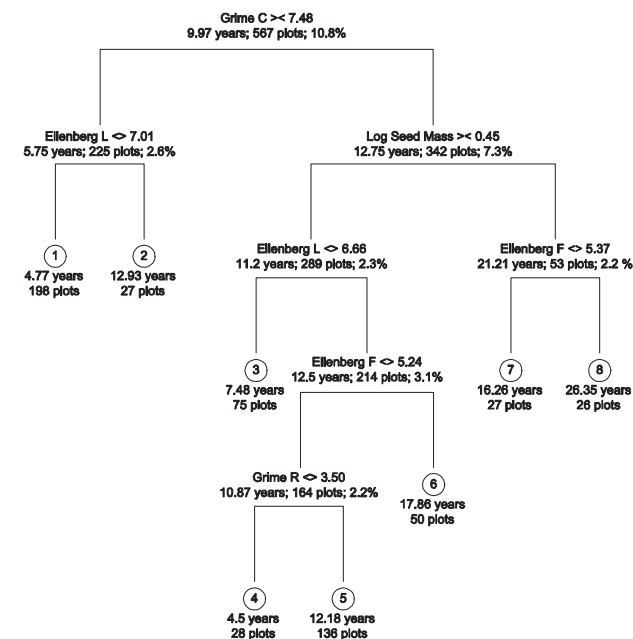


Fig. 3. Regression tree of years since the start of organic farming of all the factors listed in Table 1. “variable < value” when cases with lower values go left, or “variable > value” when cases with lower values go right.

Discussion

The main result of this study was that there were significant effects of the number of years the neighbouring field have been farmed organically on the under-lying species richness

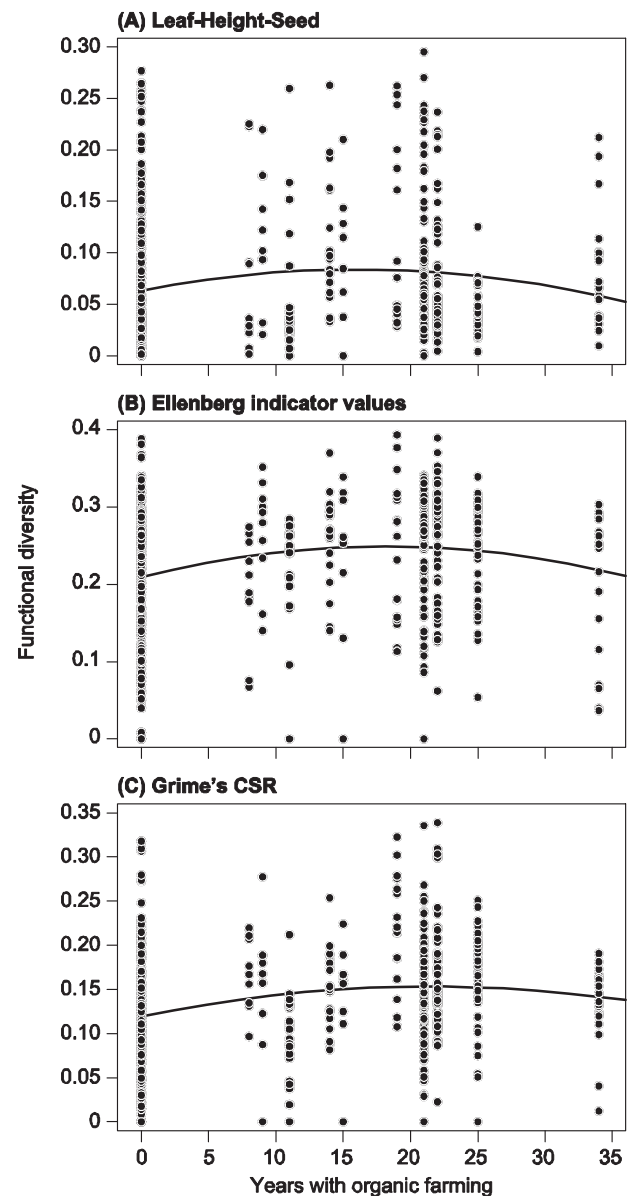


Fig. 4. The functional diversity of the three quantitative sub-groups of plant traits plotted against years since transition to organic farming. Functional diversity was calculated from leaf-height-seed (LHS) values (Westoby 1998), Ellenberg values (Ellenberg 1979), and Grime CSR (Grime 2001) using the range-standardised Euclidean distance (Botta-Dukát 2005) (linear and quadratic term; Ellenberg: $P=0.0002$, $P=0.004$; Grime: $P=0.0002$, $P=0.0.02$; LHS: $P=0.001$, $P=0.008$). See Table 2 for the results when the same data were analyzed in a more conservative mixed model.

of the hedgerow ground vegetation as well as several plant traits and functional diversities.

The change in functional diversity indicates that organic farming may have an effect on the complexity of the hedgerow vegetation. From another study we know that significantly more plant species flower in hedgerows at organic farms and that plants in hedgerows at organic farms have

significantly more flowers, start flowering earlier and flower for a longer period of time than the same species do in hedgerows adjacent to conventionally herbicide-treated fields (Boutin, Strandberg, Carpenter, Mathiassen, & Thomas 2014). Taking all this into account, secondary effects on insect pollinators and predators and thereby on important ecological services are to be expected.

As may be expected, species richness based on pinpoint data was lower than species richness based on all species found in earlier studies of the same hedgerows (Aude et al. 2003; Bruus Pedersen et al. 2004; Strandberg et al., *in press*), since pin-pointing is performed within small frames, and only plants species actually touched by the pin are counted. Whether the response curve of species richness as a function of years since transition is best described by a quadratic or a linear curve remains unclear, especially since the earlier study of some of the same hedgerows found a linear relationship (Strandberg et al., *in press*). Moreover the number of hedgerows with long organic continuity is scarce in the data set. One may argue that at least a saturation level is to be expected after a certain period of time, but the available data cannot sufficiently elucidate this.

Transition from conventional to organic management may be seen as a decrease in the disturbance in the hedgerow ground due to cessation of the pesticide drift from adjacent fields. According to the intermediate disturbance hypothesis (Connell 1978), it may result in increased species richness if pesticide exposure leads to a disturbance above the intermediate (optimal) level. The present study, as well as previous studies of hedgerow ground flora (Aude et al. 2003; Hole et al. 2005; Boutin et al. 2008), documents that transition to organic farming results in significantly increased species richness of hedgerow ground vegetation.

However, the transition to organic farming generally selected for ruderal and stress tolerant strategies and against competition tolerant plants (Fig. 2), according to the CSR strategy classification (Grime 2001), which does not indicate a decrease in disturbance level. This also contradicts our initial hypothesis, as does the fact that there was no significant correlation between time since transition to organic farming and the abundance of annual plant species.

Several factors may explain the results. The selection forces that operate under organic farming practice are not necessarily opposite to the selection forces that operate when conventional farming is carried out. This is supported by the fact that even in fields that were cultivated organically for many years, hedgerow ground flora is still dominated by nitrophilous, competitive perennial plant species. Thus, even though the use of herbicides may be classified as a disturbance event, i.e. resulting in increased mortality, reduced reproduction, removal of biomass and/or reduced growth of sensitive plant species, the cease of using herbicides does not necessarily lead to selection for late-successional plants or a higher cover of annual plants, although the latter may be considered more susceptible to herbicides due to their smaller size and repeated presence as seedlings at the time

of herbicide treatment. It should, however, be mentioned that although cover does not increase, the number of annual and biennial species present may have increased, as found by Strandberg et al. (*in press*). Since fertilizer levels are generally high in both organically and conventionally cultivated Danish hedgerows (Aude et al. 2003), all hedgerows are highly dominated by competitive species, independently of cultivation practice. Thus, because soil fertility has the major impact on the species composition of hedgerows (Aude et al. 2003), turning from conventional to organic farming practice does not lead to changes in the dominating species, but may allow more species to become established due to the cease of herbicide use. Whether the additional species occurring in organic hedgerows are more sensitive to herbicides than the other species is presently not known, but in any case newly established and therefore smaller plants are generally more affected by herbicides than well-established plants, and consequently cease of herbicide use may favour the establishment of new species. Obviously, other factors than herbicide use may differ between hedgerows at organically and conventionally cultivated fields, for example the width of the vegetation between hedgerow trees and the field edge (in the present study the hedgerows were selected so that the vegetation width did not differ between cultivation practices), the species composition of hedgerow trees, and the treatment (cutting etc.) of the hedgerows trees. One factor known often to differ is the form of fertilizer applied, since in organic farming only manure and other organic fertilizers are allowed, while conventional farmers often use mineral fertilizers. Potentially, this may lead to differences, e.g. in soil structure, micro-climate and content of organic carbon, which may affect plant species composition. However, the difference we found in plant traits between the two farming practices is probably more related to deletion and dilution of sensitive species, since no clear differences in soil characteristics were found in earlier studies (Aude et al. 2003; Bruus Pedersen et al. 2004).

Even though there were a number of significant selection responses from the conversion to organic practice at the level of single traits (Fig. 2) and 31% of the variance in years since transition was explained by a subset of the investigated traits in a regression tree, this subset of traits could not be used for predicting the years since transition to organic farming, and the hypothesis that the time since the cease of conventional farming may be predicted by the plant traits that are currently available in species trait databases was rejected (Fig. 4). Consequently, it is not possible to use the currently available plant traits of hedgerow vegetation as an indicator for organic farming, but inclusion of other traits, especially traits related to herbicide sensitivity, may be a feasible approach. Another useful approach may be to predict time since conversion from the number of plant species in the hedgerow ground flora, provided that the soil type is also known, since these factors seem to interact, with more species in hedgerows on loamy soil than in hedgerows on sandy soil (Bruus Pedersen et al. 2004).

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.baae.2014.04.003>.

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