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Structure of arthropod communities in Bt maize and conventional maize – results of redundancy analyses of long-term field data from the Oderbruch region in Germany

Die Struktur von Arthropodengesellschaften in Bt-Mais und konventionellem Mais – Ergebnisse von Redundanzanalysen von mehrjährigen Felddaten aus dem Oderbruch

Abstract

The arthropod biodiversity was investigated in half-fields planted with Bt maize (BT) and non-insecticide treated conventional maize (CV) and in one-third fields planted with BT and CV plus either isogenic (IS) or insecticide-treated conventional maize (IN) in the Oderbruch region in the state of Brandenburg, Germany, an important outbreak area of the European corn borer, *Ostrinia nubilalis* (Hübner), from 2000 to 2008. Three different arthropod communities – plant dwelling arthropods (PDA), epigeic spiders (ES) and ground-dwelling carabids (GDC) – were enumerated by counting arthropods on maize plants during flowering (PDA, 2000 to 2007) or by pitfall trapping four weeks after the beginning of flowering (ES and GDC, 2000 to 2008). The counted arthropods (PDA) were determined to different taxonomic levels, and the spiders and carabids captured in pitfall traps were identified to species level. The data were systematized and verified for choice of appropriate statistical method. Redundancy analysis (RDA) proved to be a suitable method. The results showed that 83.2% of species variation in PDA was explained by year-site-date combinations and maize variant. Bt maize contributed only 1.2% to species composition, but this low rate was significant. Regarding the spiders and carabids communities, 66.3% and 82.7% of species variation was caused by year-site combinations and maize variant, respectively. The contribution of Bt maize was low but significant in both communities (1.5% and 1.2%, respectively). The results correspond with those of other studies. They show the enormous dynamics of arthropod communities on maize plants and on the ground and the relatively low effect of maize variant.

Key words: Arthropods, spiders, carabids, community composition, Bt maize, biodiversity, redundancy analysis

Zusammenfassung

Im Oderbruch, ein wichtiges Befallsgebiet des Maiszünslers (*Ostrinia nubilalis* (Hübner)), wurde in den Jahren 2000 bis 2008 die Biodiversität der Arthropoden in halben Feldern jeweils mit Bt-Mais (BT) und nicht mit Insektiziden behandelten konventionellen Mais (CV) und teilweise in dreigeteilten Feldern mit BT und CV plus einer isogenen (IS) oder insektizid-behandelten Sorte (IN) untersucht. Drei unterschiedliche Arthropodengesellschaften – Pflanzenbewohner (PB), epigäische Spinnen (ES) und epigäische Laufkäfer (EL) – wurden mittels Bonituren der Pflanzen zu Beginn der Blüte (PB, 2000 bis 2007) und durch wöchentliche Bodenfallenfänge über vier Wochen nach Beginn der Blüte (ES und EL, 2000 bis 2008) erfasst. Die PB wurden je nach den Möglichkeiten auf unterschiedlichem taxonomischen Niveau und die ES und EL nach Arten bestimmt. Die Daten wurden systematisiert und für die Wahl der geeigneten statistischen

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Auswertungsmethode verifiziert. Die Redundanzanalyse erwies sich als geeignete Methode. Die Ergebnisse zeigten, dass 83,2% der Artenvariation der PB aus den Jahr-Ort-Termin-Kombinationen und Maisvarianten zu erklären waren. Bt-Mais steuerte nur 1,2% zur Artenkomposition bei, dennoch war dieser Anteil signifikant. Im Hinblick auf die ES und EL verursachten die Jahr-Ort-Kombinationen und die Maisvarianten 66,3% und 82,7% der Artenvariation. Der Beitrag von Bt-Mais war mit 1,5% und 1,2% in beiden Gesellschaften gering aber signifikant. Die Ergebnisse stimmen überein mit denen anderer Studien. Sie zeigen die enorme Dynamik der Arthropodengesellschaften in Maisbeständen und den geringen Effekt von Bt-Mais auf die Biodiversität.

Stichwörter: Arthropoden, Spinnen, Laufkäfer, Zusammensetzung von Arthrodengesellschaften, Bt-Mais, Biodiversität, Redundanzanalyse

1 Introduction

Since the beginning of Bt maize growing around the world, numerous laboratory experiments (Hilbeck et al., 1998; Meier and Hilbeck, 2001; Romeis et al., 2004) and field studies have been performed to study its effects on non-target arthropods and other organisms in the fields (Ludy, 2005; Rauschen et al., 2010; Wendt et al., 2010), in the adjacent field boundaries (Losey et al., 1999; Saxena et al., 1999; Felke and Langenbruch, 2001, 2003), and in nearby aquatic systems (Chambers et al., 2010). In 2003, an IOBS/WPRS working group was established to better communicate research findings on the ecological impact of genetically modified organisms, particularly Bt maize.

Field studies on Bt maize (Cry1Ab) have generally focused on possible direct side-effects of the associated toxin on non-target lepidoptera species that are especially sensitive to toxin (Waquil et al., 2002; Szenazi et al., 2004) and other non-target organisms. Most of these studies were designed as field plot experiments with replicates or as field-field comparisons with replicates in different years and sites and aimed to assess and compare densities of species or higher taxonomic units in Bt maize and other maize-growing systems (Higgins et al., 2009; Wendt et al., 2010). In general, no significant impact of Bt maize on non-target arthropods was found (Sandivo et al., 2007; Romeis and Shelton, 2009) except in lepidopteran larvae feeding maize or maize pollen which contents a toxic amount of toxin (Eizaguirre et al., 2010).

Apart from density analysis, the impact of maize-growing systems including Bt maize (Cry1Ab, Cry3Bb, Cry 1F) on biodiversity parameters in arthropod communities has been investigated in field studies (Leslie et al., 2010). However, such investigations are costly and must be carried out on sufficiently large fields. Multivariate statistical methods such as correspondence analysis are generally used for analysis of arthropod community structure (Freier et al., 2004; Volkmar et al., 2004; Toschki et al., 2007; Aviron et al., 2009; Higgins et al., 2009). Previous studies have shown that there is a special need for long-term field studies to evaluate the risks of Bt maize on arthropod communities under typical field conditions.

The aims of the present investigation was to analyze the structure and dynamics of arthropod communities in fields planted with Bt maize and conventional maize based on data collected by counting arthropods on maize plants and in pitfall traps (ground-dwelling spiders and carabids) in the years 2000 to 2008.

2 Material and Methods

2.1 Sampling

The field studies were conducted at different farms in the Oderbruch region in the state of Brandenburg, Germany, east of Berlin, near the Polish border from 2000 to 2008. An additional field study was carried out at site Spickendorf (near Halle, Germany, in the state of Saxony-Anhalt) in the year 2000. Fields were divided into two parts (half-fields) planted with Bt maize (BT) and non-insecticide treated conventional maize (CV) or into three parts (third-fields) planted with BT and CV plus either isogenic conventional maize (IS, 2000 or insecticide-treated conventional maize (IN, 2004–2006). Baythroid 50 (2004) and Steward (2005, 2006) were used to control *Ostrinia nubilalis* in IN maize. Tab. 1 summarizes the fields investigated and samplings performed in the study. All half-fields and third-fields were subjected to the same agricultural management measures, and all fields had a similar previous cropping and management history.

Arthropods were sampled in the maize fields by the following methods:

Arthropod counting on plants: At 5 or 10 (only in 2001) sampling points in each half- or third-field, arthropods on three or four maize plants each were counted and determined by the naked eye. Counts were performed at the time of flowering in all years, and also during the late flowering and milk stages in 2001 to 2005 (Tab. 1).

Pitfall trapping: Ten (2000 to 2002) or six (2003 to 2008) 10-cm traps containing 2% formaldehyde solution were installed in each half- or third-field for four or six (2000, 2001) weeks after the beginning of maize flowering. Traps were emptied at weekly intervals. All trapped spiders and carabids were determined to species level. In each case, the distance between each of the sampling points was about 20 meters. Furthermore, sampling points were arranged along the mid-line of each half- or third-field to ensure inclusion of arthropod communities within the fields and to exclude the influence of those from surrounding habitats and field borders.

Taxonomic determination of carabids species was carried out by Joachim Gruel, Andreas Schober and Ismail Hussein based on the classification guides of Freude et al. (1976, 2004), Trautner and Geigenmüller (1987) and Wachmann et al. (1995). The spiders were determined

Tab. 1. Summary of samplings in maize fields in the Oderbruch region (state of Brandenburg, Germany) unless otherwise specified

Year	Site (abbr.)	Maize variant	Number of pitfall traps (dates)	Number of sampling points (dates)
2000	Neulewin (NL), Spickendorf[1] (SP)	BT, IS, CV	10 (6)	5 (1)
2001	Seelow (SE)	BT, CV	10 (6)	10 (3)
2002	Altreetz (AR), Neureetz (NR)	BT, CV	10 (4)	5 (5)
2003	Altreetz (AR), Mädewitz (MW)	BT, CV	6 (4)	5 (3)
2004	Altreetz (AR), Altmädewitz (MW)	BT, CV (AR) BT, CV, IN (MW)	6 (4)	5 (3)
2005	Seelow (SE), Mallnow (MA), Gusow (GU), Heinersdorf (HE), Hohenstein (HO)	BT, CV, IN	6 (4)	5 (2)
2006	Seelow (SE), Mallnow (MA), Gusow (GU), Hohenstein (HO), Hohenstein 2 (HH)	BT, CV, IN	6 (4)	5 (1)
2007	Mallnow (MA), Hohenstein (HO), Gladowshöhe (GH), Platkow (P), Wriezen (W)	BT, CV	6 (4)	5 (1)
2008	Crostiller (CR)	BT, CV	7 (4)	5 (not analyzed)

BT: Bt maize, IS: Isogenic variety of conventional maize, CV: Conventional maize, IN: Insecticide-treated conventional maize
[1] Spickendorf (state of Saxony-Anhalt, Germany)

according to Heimer and Nentwig (1991) and Roberts (1987) using the nomenclature of Platnick (1993).

2.2 Statistical analyses

CANOCO 4.5 (Ter Braak and Šmilauer, 2002) was used for multivariate statistical analysis of arthropod communities. The three communities studied – plant-dwelling arthropods, epigeic spiders and ground-dwelling carabids – were investigated separately and jointly (ground-dwelling arthropods).

Taxa represented by less than 30 individuals summarized over all environments were excluded from the analysis because counts of rare species are strongly influenced by chance and often do not reflect their actual distribution. Furthermore, their influence on the ordination results is small unless the data are modified by upweighting. Because each weighting is attended with a subjective choice of the weights we did not use this method. Thus, a total of 17 plant-dwelling arthropod taxa, 23 spider species and 50 carabid species (Tab. 2) were included in the community analysis.

The analysis of plant-dwelling arthropods revealed 20, 94, 0 and 17 ocurrences (total: 131) of *Ostrinia nubilalis* on BT, CV, IS and IN, respectively. To prevent the excessive influence of taxa caught in large numbers on the ordinations and to reduce the sometimes strong skewness to the right, faunal counts were square-root transformed. As the plant-dwelling arthropods were sampled on non-stationary points in the field on one to three dates, the potential influence of sampling date has to be taken into account. All summed, there were 51 environmental variables: four maize variants and 47 year-site-date combinations for a total of 600 sampling points (see Tab. 1). The average numbers counted on three to four plants at each sampling point and for each species were used in the statistical analysis.

Ground-dwelling spiders and carabids were sampled using stationary pitfall traps. To obtain a comparable level of all data, it was necessary to make adjustments for sporadic trap losses and for different emptying intervals and frequencies. Due to the stationarity of the traps, comparability was achieved by using the average count numbers per day of the respective time interval for each species and trap. Therefore, the environmental variables were defined by the 25 year-site-combinations (mean of the analyzed dates) and the four maize variants (cf. Tab. 1). Due to the total loss of some of the original 428 trap catches, the number of trap catches available for the separate analyses of ground-dwelling spiders and carabids was 425 and 415, respectively, and that for the combined analysis 415.

Generally, ordination methods aim to reveal major patterns in community structure. A direct gradient analysis was appropriate for our study because the effects of different environmental conditions had to be determined, whereby the role of the maize varieties in relation to the other conditions defined by year-site or year-site-date combinations was of special interest. All species data were centered by their mean. To determine which direct method was appropriate, the lengths of the gradients for species reaction were calculated using a detrended correspondence analysis. The lengths were smaller than 3 in all analyses performed. Following the recommendations of Ter Braak and Šmilauer (2002), a linear method – redundancy analysis (RDA) – was deemed appropriate. Statistical inferences were made based on forward selection of environmental variables using Monte Carlo permutation tests with 1,000 permutations. This procedure

Tab. 2. List of all ground-dwelling carabids identified in the Oderbruch region (state of Brandenburg, Germany) and abbreviations in Fig. 3

Taxon	No.	Taxon	No.
Amara apricaria	1	*Harpalus affinis*	26
Amara aulica	2	*Harpalus calceatus*	27
Amara bifrons	3	*Harpalus distinguendus*	28
Amara consularis	4	*Harpalus frölichi*	29
Amara ovata	5	*Harpalus griseus*	30
Amara similata	6	*Harpalus rubripes*	31
Anchomenus dorsalis	7	*Harpalus rufipes*	32
Bembidion femoratum	8	*Harpalus tardus*	33
Bembidion lampros	9	*Loricera pilicornis*	34
Bembidion obtusum	10	*Microlestes minutulus*	35
Bembidion properans	11	*Notiophilus biguttatus*	36
Bembidion quadrimaculatum	12	*Ophonus azureus*	37
Bembidion tretracolum	13	*Ophonus rufibarbis*	38
Broscus cephalotes	14	*Ophonus schaubergerianus*	39
Calathus ambiguus	15	*Poecilus cupreus*	40
Calathus cinctus	16	*Poecilus lepidus*	41
Calathus erratus	17	*Poecilus punctulatus*	42
Calathus fuscipes	18	*Poecilus versicolor*	43
Calathus melanocephalus	19	*Pseudoophonus rufipes*	44
Carabus auratus	20	*Pterostichus melanarius*	45
Carabus granulatus	21	*Pterostichus niger*	46
Carabus nemoralis	22	*Stomis pumicatus*	47
Cincindela hybrida	23	*Synuchus vivalis*	48
Clivina fossor	24	*Trechus quadristriatus*	49
Dolichus halensis	25	*Zabrus tenebrioides*	50

incorporated the environmental effects in the model step-by-step according to their ability to explain the species variation. All environmental variables were nominal, so they had to be dummy-coded. Therefore, when interpreting the results of the tests, it has to be taken into account that collinearities exist due to the use of dummy variables. A given maize variant, year-site combination or year-site-date combination is collinear with the others.

3 Results

3.1 Analysis of plant-dwelling arthropod communities

Tab. 3 shows the results of the RDA.

The analysis based on year-site-date combinations will be outlined in detail in this section. The first two ordination axes explain 77.1% and 2.7% of the total variance of species reaction, so these axes capture 79.9% of the variance (see biplot in Fig. 1). The remaining axes contain no substantial information. The sum of all canonical eigenvalues is 0.832, which means that the 51 environmental variables (year-site-date combinations and maize variants) explain 83.2% of the species reaction. Forward selection showed that the most important environmental variables are 15 year-site-date combinations which cover 89.2% of the explained species variation. The maize variants were selected in steps 16 (BT), 32 (IN) and 38 (CV). IS had the smallest influence of all maize variants and was not included in the model because of collinearity. The inclusion of both BT and IN increased the cumulative explained variance by 1.2%, respectively. The increase for CV was smaller than 0.04%. The corresponding p-values were 0.001 for BT, 0.019 for IN, and 0.124 for CV.

For clearness of representation, the biplot of the species and environmental variables (Fig. 1) was been split into two parts. Both parts use the same axis scaling and focus the scaling on the inter-species correlation. The top part shows the maize and species relations. The angles α between two species arrows indicate their correlations. If $\alpha = 90°$, then there is no correlation, and if $\alpha = 0°$ or $\alpha = 180°$, then the correlation is 1 or −1, respectively. For example, *Aphidina* had a positive correlation with *Coccinellidae*, a weak negative correlation with *Thysanoptera*, and strong negative with *Araneae*. The direction of an arrow corresponds to the direction of the strongest increase of the species data, and its length is equal to the multiple correlation of this species with the two ordination axes. Taking direction of the species arrow into

Tab. 3. Plant-dwelling arthropods in maize fields in the Oderbruch region (state of Brandenburg, Germany) from 2000 to 2007: results of redundancy analyses using different environmental combinations as explanatory variables

Axes	1	2	3	4	Total variance
Eigenvalues					
Year-site-date	0.771	0.027	0.012	0.008	1.000
Year-site	0.398	0.016	0.009	0.006	1.000
Year-date	0.649	0.026	0.009	0.007	1.000
Cummulative percentage variance of species data					
Year-site-date	77.1	79.9	81.0	81.8	
Year-site	39.8	41.5	42.3	42.9	
Year-date	64.9	67.5	68.4	69.1	
Sum of all canonical eigenvalues					
Year-site-date					0.832
Year-site					0.434
Year-date					0.700

account, the perpendicular projections of environmental centroids on an arrow indicate the ranked abundances of this species. A projection near the origin (0.0) means that the environmental variable has an abundance corresponding to the mean over all environmental variables. When interpreting the centroid positions of maize variants, it should be remembered that only BT and CV are directly comparable. Both were present in all year-site-date combinations, whereas IS and IN had much smaller sample sizes. In particular, the centroid of IS lies between the centroids of 00NL and 00SP because these are the only combinations where IS existed. Because the scaling focused on inter-species correlation, the distances between the centroids of the environmental variables can be interpreted only as tendencies. The smaller the distance between two centroids, the more similar the species communities are. Although the differences in community composition among the three maize variants are small, the additional explained variance by BT and IN was significant.

The bottom part of the biplot (Fig. 1) includes only those 36 year-site-date combinations detected by forward selection as sources of species variation with p-values smaller than 0.05. To interpret these combinations in relation to the species data, it is necessary to overlay both parts of the figure. Regarding the year-site-date combinations, we found that data from the same year and site but from different dates often have extremely different species compositions. For example, the centroids of 03MW_1 and 03MW_3 were mainly determined by the largest and smallest abundance of *Thysanoptera*, whereas those of 04AR_1 and 04AR_2 were influenced by the abundance of *Aphidina* to a great extent. To check this impression, we analyzed the data as year-site combinations while ignoring the date and as year-date combinations by ignoring the site. The results confirmed the large influence of date (Tab. 3). The original analysis explained 83.2% of the species variation, whereas the analyses ignoring the date or the site explained only 43.4% and 70.0%, respectively. Thus, the date had a greater influence on species variation than the sites.

Regarding the maize variants, forward selection for these two approaches yielded a result smilar to that of the original approach. When we ignore the dates (28 environmental variables) in step 11, the cumulative explained species variation was 90.7%. BT was incorporated in step 12 ($p = 0.006$), but the gain was smaller than 0.1%. When we ignore the sites (23 environmental variables), BT was selected in step 9 ($p = 0.002$). The cumulative explained variance in step 8 was 95.7%, and, the gain from BT was also smaller than 0.1%. The other maize variants had p-values larger than 0.05 in both approaches.

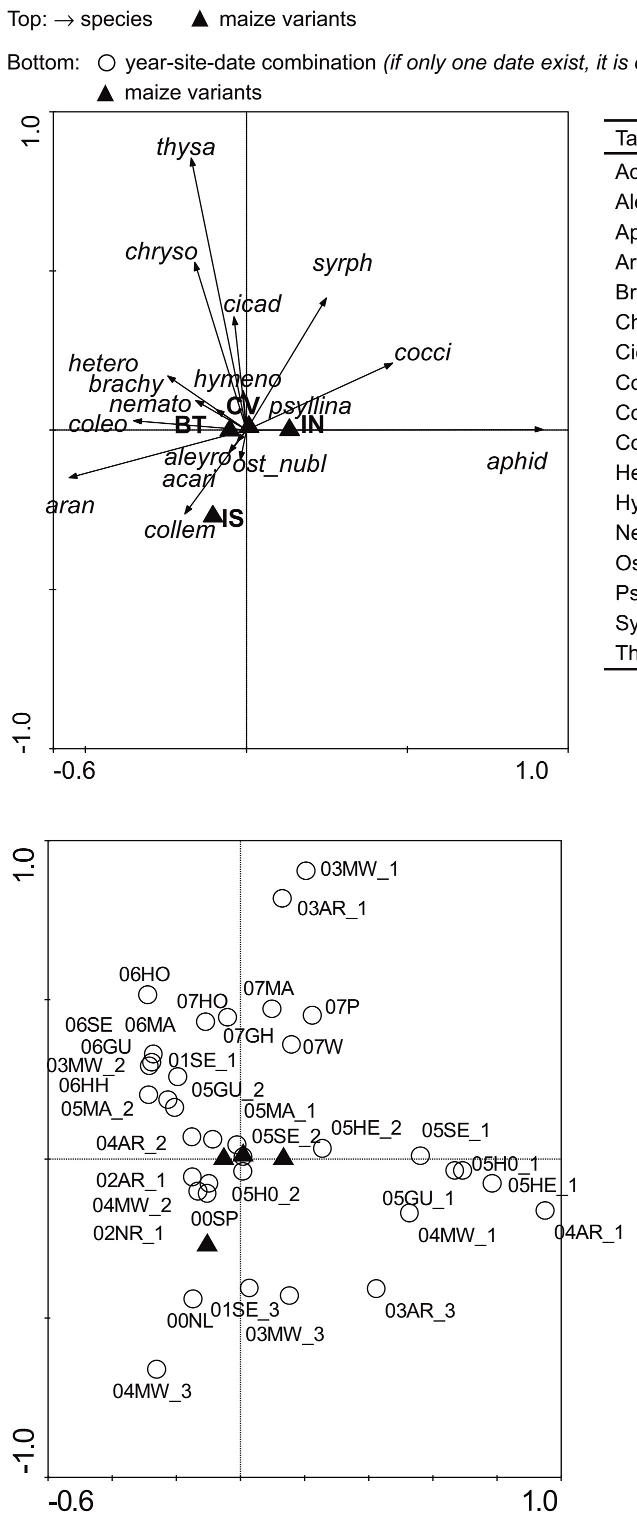
3.2 Analysis of ground-dwelling spiders and carabids

The results of the separate and combined RDAs are shown in Tab. 4.

Regarding all canonical eigenvalues of the 27 non-collinear environmental variables, the explained variation was 82.7% for carabids, but only 66.3% for spiders. The first two axes captured 59.5% and 54.2%, respectively. These two axes are represented in the biplots in the same manner as described in Chapter 3.1 (Fig. 2 and Fig. 3).

Forward selection for the spiders showed that the most important variables are the 21 year-site-combinations with a cumulative explained species variation of 97.0%. Only in steps 22, 23 and 24 were the maize variants IN, IS and BT included with p-values of 0.001, 0.002 and 0.008, respectively. They explained 1.5%, < 0.01% and 1.5% of the species variation. CV had the smallest influence of all maize variants and was collinear with the others. The relative proximity of BT and CV shows that the community structure was very similar (Fig. 2).

The small separation of IN results from the smaller abundance of *Oedothorax apicatus*. The results for IS



Taxon	Abbreviation
Acari	acari
Aleyrodidae	aleyro
Aphidina	aphid
Araneae	aran
Brachycera	brachy
Chrysopidae	chryso
Cicadina	cicad
Coccinellidae	cocci
Coleoptera	coleo
Collembola	collem
Heteroptera	hetero
Hymenoptera	hymeno
Nematocera	nemato
Ostrinia	ost_nubl
Psyllina	psyllina
Syrphidae	syrph
Thysanoptera	thysa

Fig. 1. **Biplot of all plant-dwelling arthropods in maize fields in the Oderbruch region (state of Brandenburg, Germany) from 2000 to 2008.**

should not be interpreted for the aforementioned reasons. The abundances of *Oedothorax apicatus*, *Erigone atra* and *Pardosa agretis* had largest correlation with the ordination axes. After overlaying the top and bottom plots in Fig. 2, it becomes apparent that, for example, *Oedothorax apicatus* occurred most frequently in 00SP and 02AR and least often in 07MA, or that *Erigone atra* and *Erigone dentipalpis* were notably present in 00SP.

For the carabids, the most important variables were the 20 year-site combinations which cause 96.4% of the species variation. BT and IN were incorporated only in the 21st and 24th place with p-values of 0.001, resulting, respectively, in a gain of 1.2% and < 0.01% of the explained variation. CV and IS were collinear and provided no additional information, and 07P and 07W did not contribute to any improvement either. The interpretation

Tab. 4. Ground-dwelling spiders and carabids in the Oderbruch region (state of Brandenburg, Germany) from 2000 to 2008, results of separate and combined redundancy analyses for both groups

Axes	1	2	3	4	Total variance
Eigenvalues					
carabids	0.415	0.180	0.072	0.040	1.000
spiders	0.419	0.123	0.053	0.021	1.000
carabids and spiders	0.333	0.127	0.059	0.050	1.000
Cummulative percentage variance of species data					
carabids	41.5	59.5	66.7	70.7	
spiders	41.9	54.2	59.4	61.6	
spiders + carabids	33.3	46.0	51.8	56.9	
Sum of all canonical eigenvalues					
carabids					0.827
spiders					0.663
spiders + carabids					0.705

of the two parts of biplot was analogous to the comments above (Fig. 3). For reasons of clarity, the arrow heads were replaced by X-marks.

The highest abundance of *Pterostichus melanarius* was found in 01SE and 02NR and the smallest in 06HH. The greatest frequency of *Poecilus cupreus* was observed in 06MA.

In the combined analysis of ground-dwelling spiders and carabids, the sum of all explainable species variation ranged between that of the two separate analyses, and the first two axes explained only 46% of the species variation. Therefore, the biplot of the combined analysis was not as informative as that of the separate analyses and is not shown.

4 Discussion

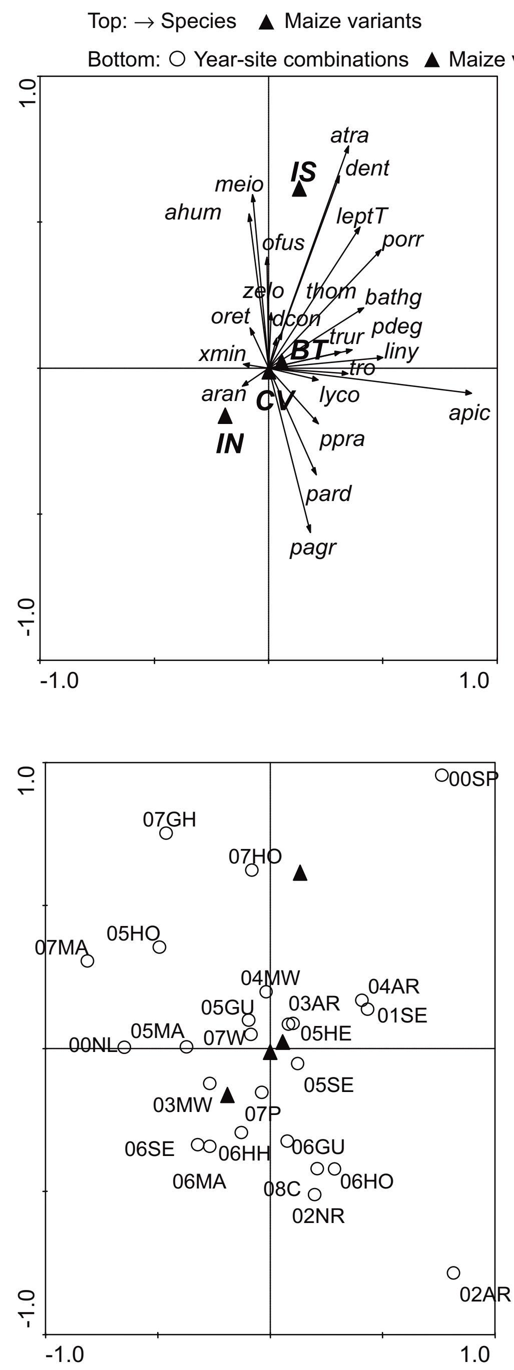
Field-field comparisions or plot experiments make it possible to determine the influence of year, site and maize-growing variant on the composition of arthropod communities. Because field-field comparisons are carried out without real replicates, a relatively large number of parallel studies is needed for statistical analysis (ROTHERY et al., 2002; PERRY et al., 2003). In the present long-term study, the number of replications was sufficient for comparisons only in the years 2005 to 2007. The use of half- and third-field comparisons represents a methodological compromise between a field-to-field comparison and plot design. Comparing whole fields is possible only if the environmental conditions (soil type, surrounding habitats, agricultural practice, etc.) are nearly identical. The use of half- or third-fields minimizes the differences in environmental conditions as already explained by PERRY et al. (2003). A plot design, on the other hand, allows for exact statistical analysis but poses difficulties regarding the minimum plot size, which depends, amongst other things, on the mobility of the investigated species. An individual carabid, for example, may easily travel up to 300 m (KENNEDY, 1994).

Counting arthropods on maize plants is suitable method to gather data on more than 100 well-visible taxa. Unfortunately, the determination of species with the naked eye is limited. Furthermore, some insects such as aphids and thrips lie hidden under leaf sheaths and on tassels and thus are often overlooked in arthropod field counts, resulting in underestimation of their densities. Due to these limitations of determination, we had to pool the data to higher taxonomic levels. This approach, however, runs the risk of missing the effects of an influence factor on specific species. In addition, the sampling units (three plants each at five sampling points) often yielded insufficient numbers of individuals of certain taxa. Thus, many of the observed taxa had to be excluded from the statistical analyses due to a small sample size.

Pitfall traps delivered utilizable information on the epigeic arthropods in the present study. Its low costs and easy handling makes pitfall trapping the most practicable approach to epigeic arthropod sampling in spite of its known limitations (SUNDERLAND et al., 1995).

Our study focused on the relationship between arthropod community structure and the maize-growing variants. RDA revealed that plant-dwelling and ground-dwelling arthropods exhibited the same general pattern: arthropod communities were primarily shaped by the annual changes in environmental characteristics and not by maize variety. Nonetheless, maize variant did have a small but significant influence. It seemed that epigeic spider communities are influenced not only by year and site, but also by maize-growing variants. Previous crop and tillage could also be influential factors.

Caution is necessary when comparing the results of the year-site combination analyses for the plant- and the ground-dwelling species. The sums of all canonical ei-



Taxon	Abbreviation
Araeoncus humilis	ahum
Oedothorax apicatus	apic
Araneidae	aran
Erigone atra	atra
Bathyphantes gracilis	bathg
Diplostyla concolor	dcon
Erigone dentipalpis	dent
Lepthyph. tenius-Gr.	leptT
Linyphiidae	liny
Lycosidae spec.	lyco
Meioneta rurestris	meio
Oedothorax fuscus	ofus
Oedothorax retusus	oret
Pardosa agrestis	pagr
Pardosa spec.	pard
Pachygnatha degeeri	pdeg
Porrhomma microphthalmum	porr
Pardosa prativaga	ppra
Thomisidae	thom
Trochosa spec.	tro
Trochosa ruricola	trur
Xerolycosa miniata	xmin
Zelotes spec.	zelo

Fig. 2. Biplot of all ground-dwelling spiders in maize fields in the Oderbruch region (state of Brandenburg, Germany) from 2000 to 2008.

genvalues were 0.663 (spiders), 0.827 (carabids), and 0.705 for the combined investigation (second analysis) compared to 0.434 in the initial analysis. These differences were not caused by a different species variation but by the different aggregation levels of the data. In the first case the differences between dates are part of the unexplained variation. In the second case, the data for the dates were averaged, so the variation between the dates vanished. Therefore, only the results of year-site-date combinations of the plant-dwelling arthropods and of year-site combinations of ground-dwelling species which were actually in the same order of magnitude should be compared.

In respect of the general tendency of our results, we analyzed our earlier findings (Freier et al., 2004; Volkmar et al., 2004, 2009) and those of other field studies with Bt maize or Bt soybean where correspondence analyses of arthropod communities yielded similar results (French et al., 2004; Pristley and Brownbridge, 2009). Surprisingly, not many multivariate analyses of arthropod communities in maize have been performed up to now. The low effects of maize variant in the present study is in agreement with the results of most laboratory studies, plot experiments and field studies showing no or low effects of Bt maize on arthropods (Sandivo et al., 2007). Unfortunately, lepidoptera other than the European corn

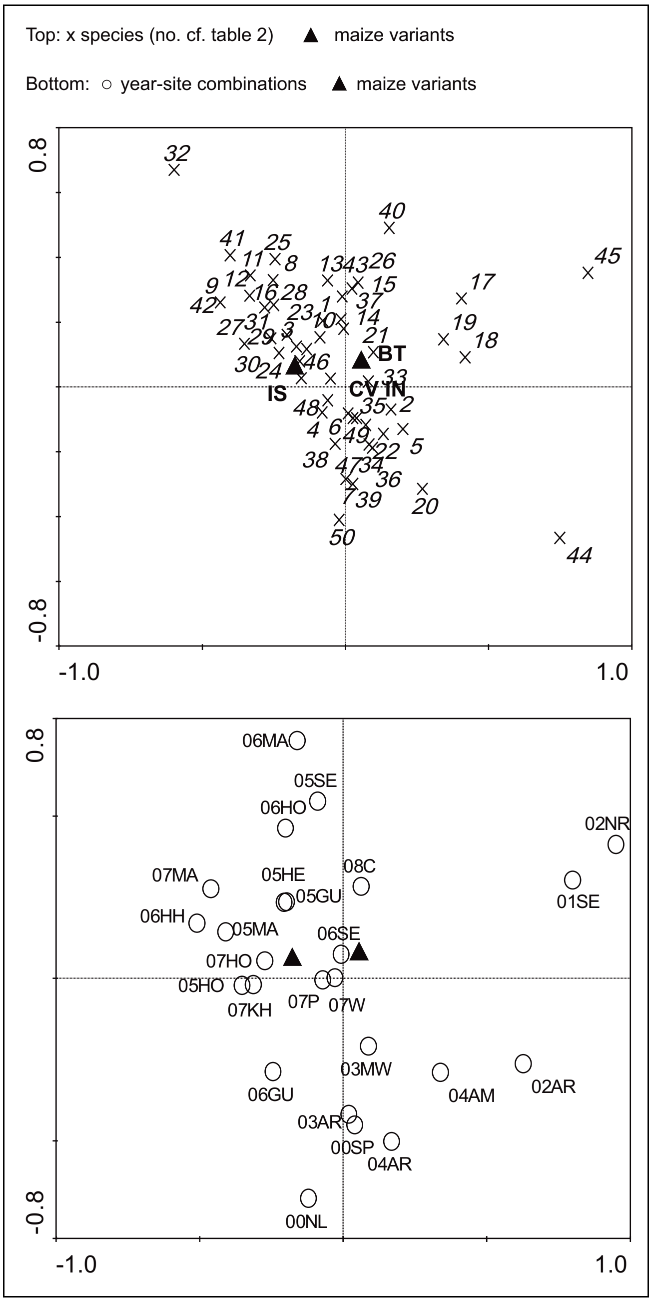


Fig. 3. Biplot of all ground-dwelling carabids in maize fields in the Oderbruch region (state of Brandenburg, Germany) from 2000 to 2008.

borer known to be sensitive to Bt toxin (Lang et al., 2004; Felke and Langenbruch, 2003; Gathmann et al., 2004) were very rare occurrences in the investigated maize fields. Thus, the present study could not provide findings on the sensitive lepidopterean community. Surprisingly, the low effect of insecticides (Baythroid 50 and Steward) was not higher than the effect of the other maize variants BT, IS, and CV. However, this may be due to the low number of fields treated with insecticides in this study.

In conclusion, our study revealed small but statistically significant differences in arthropod community composition in Bt and conventional maize fields. This is in agreement with similar studies in other regions. Long-term programs for monitoring of arthropod biodiversity patterns in fields of Bt maize and other maize varieties are needed and could provide more details.

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