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Biodiversity and structure of ground beetle assemblages (Coleoptera Carabidae) in Bt corn and its effects on non target insects

Abstract - During the years 1997-1998 an in-field evaluation was made of the effects of transgenic corn on non-target arthropods and on soil fauna. Coleoptera Carabidae, typical soil fauna, were studied and a comparison made of their community structures and degree of specific biodiversity in transgenic and isogenic corn crops. The taxa normally present on corn plants, particularly Aphididae and Cicadellidae, Aranea and Coleoptera (Chrysomelidae, Coccinellidae, Staphilinidae), and other insects living in close contact with these or with the European Corn Borer (*Ostrinia nubilalis*), such as Hymenoptera parasitoids and Diptera Syrphidae, were considered as aerial fauna.

The statistical analyses revealed no significant differences in the abundance of the non-target entomofauna in isogenic corn and transgenic corn. The ground beetle assemblages were quite similar, and any differences appeared to have no correlation with the presence of Bt maize. The biodiversity of the Carabidae communities was quite low for both types of crops and, on comparing the two types of hybrid corn crops, no significant differences were found in any of the indices analysed.

Riassunto - *Biodiversità e struttura delle comunità di Coleoptera Carabidae presenti in campi di mais Bt e suoi effetti su insetti non bersaglio.*

Durante il biennio 1997-1998 sono stati valutati gli effetti sia in campo che in laboratorio del mais transgenico sull'artropodofauna non target.

Sono stati presi in considerazione sia taxa normalmente presenti sulle piante di mais, quali Afidi, Rincoti Cicadellidi, Ragni, alcune famiglie di Coleotteri (Chrysomelidae, Coccinellidae, Staphilinidae), sia insetti che vivono in stretto rapporto con questi ultimi e con la piralide, come gli Imenotteri parassitoidi ed i Ditteri Sirfidi. Quali rappresentanti della fauna edafica sono stati considerati i Coleoptera Carabidae, comparando il grado di biodiversità specifica in campi di mais transgenico e normale.

Dai risultati delle analisi statistiche è emerso che non esistono differenze significative sull'entomofauna non target presente nelle coltivazioni di mais transgenico e di mais tradizionale. La biodiversità è abbastanza bassa per entrambi i tipi di coltivazione, ma non presenta differenze imputabili al mais transgenico.

Key words: Bt corn, non target insects, Carabidae, species diversity, dominance, biodiversity indices.

INTRODUCTION

Field corn, *Zea mays* L., is one of the main crop plants genetically engineered to express the Cry 1Ab protein derived from *Bacillus thuringiensis* Berliner var. *kurstaki* (Koziel *et al.*, 1993) with an insecticide activity against *Ostrinia nubilalis* Hb. (European corn borer). The use of such transgenic corn crops should preserve natural enemies of the European corn borer, and more in general non target arthropods. (Orr & Landis, 1997; Gould F, 1998; Hilbeck *et al.*, 1998; Lozzia *et al.*, 1998).

Relative large numbers of natural enemies and different insects, having some relationship with maize or other arthropods linked to corn and ECB, have been recorded in different conditions and places (Martelli, 1938; Jarvils & Guthrie, 1987; Coll & Bottrell, 1991). For this reason the effects of transgenic crops on non target entomofauna must be given due consideration, especially as some authors have reported the importance of natural enemies in controlling the development of resistance to engineered plants (Mascarenhas & Luttrell, 1997; Gould, 1998).

Although Cry 1Ab protein expressed in transgenic corn is usually only against a well-defined taxonomic group such as Lepidoptera (MacIntosh *et al.*, 1990), some side effects from Bt toxin to non target species have been noted (Salama *et al.*, 1982; Flexner *et al.*, 1986; Hilbeck *et al.*, 1998). MacIntosh *et al.* (1990) and Sims reported (1995) the susceptibility of several agronomically important insects to purified *B. thuringiensis* proteins (Cry1Ab, Cry1Ac, Cry1AcT, Cry13). However no acute detrimental effects were found in other laboratory studies (Pilcher *et al.*, 1997, Yu *et al.*, 1997; Lozzia *et al.*, 1998). Until now few studies have evaluated the effect of transgenic corn on non target species directly in the field (Orr & Landis, 1997, Pilcher *et al.*, 1997) and there are none on biodiversity. As the impact of transgenic corn could directly affect phytophagous and detritivores species, affecting different trophic levels, or, indirectly, toxic decomposition products, the measuring of biodiversity could be a helpful indication of the environmental impact of the transgenic corn crop. In addition, expanding the taxonomic diversity of the analysed species would further guarantee its safety in the field. Few studies have been done regarding the influence of Bt protein on soil fauna (Yu *et al.*, 1997).

Coleoptera Carabidae is an extensive group inhabiting soil (Thiele, 1977) and its presence determines whether the possible presence of Bt toxin in the soil affects community structure and biodiversity. In fact, the ecological exigencies of this group of Coleoptera are known and well defined for many species commonly living in cultivated fields, making them excellent bioindicators (Thiele, 1977; Den Boer, 1979; Brandmayr, 1980). Moreover species belonging to Carabidae can be phytophagous, detritivores and predators, that even control corn pests, thus being an appropriate group for describing the trophic relationships and degree of biodiversity in the soil.

The effects of transgenic plants on insect coenosis cannot be fully understood through laboratory studies only. To better describe the ecological impact of Bt corn on the natural population of non target insects it is necessary to test them directly in the field, thus widening the study to biodiversity. This paper reports the results of a

two year field study aimed at better understanding the influence of transgenic corn on non target entomofauna, with particular emphasis on the community structures and biodiversity of Carabidae.

MATERIALS AND METHODS

The survey was carried out in 1997 and 1998 in two North Italian areas near Pavia and Treviso. In both stations two experimental fields, each of 10 hectare and subject to normal cultivation practices, were selected. One field was sown with transgenic corn, hybrid Bt 176 maize* and the other with isogenic corn. Each field was divided into four plots of 2.5 hectare each to obtain four replicates for each trial performed. Sampling was done every fourteen days from sowing to harvest.

CARABIDAE. Pitfall trapping of Carabidae was conducted using plastic glasses buried in the soil surface. One pitfall trap with an opening of 10 cm² and 8 cm deep was placed in the approximate centre of each subplot. The traps, baited with 6% acetic acid, were changed in the occasion of each sampling. First year collection commenced the week of 15 May and continued through the week of 15 September. Second year collections started 30 May and continued through to the week of 10 October 1998. The insects collected were counted and identified at the species level.

AERIAL FAUNA. The monitoring of aerial fauna was performed by a motorised blower-vac aspirator, Malaise traps and visual checking.

The sucks were meant to monitor the arthropod populations that live in this crop, or that visit it by chance. Two minute aspirations were done for each block. The arthropods collected were counted and identified to Order or Family level. Special attention was given to potentially harmful Arthropods, such as aphids and leaf hoppers, and to those beneficial, such as spiders, Coccinellidae and Hymenoptera parasitoids and Diptera Sirphidae.

Malaise traps were collocated in the middle of the transgenic and isogenic corn crops and placed at the beginning of July, when the corn was almost two meters tall, in a square plot of 10 m².

Ten randomly sampled corn plants, one for each replicate of both the isogenic and transgenic corn, were visually controlled. The visual control was done in order to verify that no species were missed in the other sampling methods.

DATA ANALYSIS

CARABIDAE. The total number of ground beetles and the number of dominant species collected were analysed with regard to hybrid of corn crops (isogenic and

* Bt 176 maize is Trade Mark Novartis.

transgenic), locality (Pavia, Treviso) and years (1997-1998), using general linear model procedures (ANOVA). Carabids data were transformed to $\log(X+1)$ before analysis.

The diversity of Carabidae biocenosis in transgenic and isogenic corn crops was evaluated by comparing different biodiversity indices. To better characterise a community it is advisable to give different measures of diversity (Hill, 1979; Hulbert, 1991), thus diversity was calculated, to species level, for all the following indices: Shannon - Weaver index (H') calculated as $H' = -\sum (p_i \log_2 p_i)$ where p_i = the proportional abundance of each species, Hill diversity numbers (Hill, 1979): N_0 = number of species, $N_1 = \exp(H' \times \ln 2)$ with H' (Shannon-Weaver index), $N_2 = 1/\sum (p_i)^2$, $N_{inf} = 1/\text{the proportional abundance of the most common species}$, Simpson's dominance index $D = \sum (p_i)^2$, Margalef's species-richness diversity index $SR = (S-1)/\ln N_0$.

In addition to the diversity indices Sørensen's index (Q_s) was calculated. This gives an idea of the similarity of the two populations: $Q_s = 2C \times 100 / A + B$, where A is the number of species in isogenic corn crop, B is the number of species in transgenic corn crop, C is the number of species present in both the normal and the transgenic corn crop.

AERIAL FAUNA. The data collected did not show a normal distribution so a non parametric test, in our case the Mann-Whitney test, was applied.

RESULTS

CARABIDAE

A total of 3,768 ground beetles belonging to 42 species and 23 genera were collected during 1997 and 1998 (Table 1). In 1997 the total number of carabids collected in Pavia was 416 for the isogenic corn crop and 1,335 for the transgenic, while in Treviso 179 ground beetles were recorded in isogenic corn and 457 in the other hybrid corn crop. During 1998, 721 carabids were collected in the isogenic corn crop and 588 in the transgenic one in Pavia, while in Treviso the catches were lower, 29 carabids from the isogenic corn crop and 43 from the transgenic one. The number of carabids found in transgenic corn crops was higher than that collected from the isogenic corn crops, except for the one case in Treviso in 1998. Carabids were more abundant in Pavia than in Treviso. However although the number of captures was quite different, no statistical difference was evident considering the total number of carabids and the hybrid type ($F = 0.4$, $df = 1$, $126 P > 0.05$), the locality ($F = 0.6$; $df = 1$, 61 , $P > 0.05$) and the years ($F = 0.4$; $df = 1$, 65 , $P > 0.05$).

DOMINANT SPECIES. Figs. 1 and 2 show the six dominant carabid species - *Pseudophonus rufipes* Degeer, *Poecilus cupreus* L., *Pseudophonus griseus* Panzer, *Platysma melanarium* Illiger, *Bembidion quadrimaculatum* L., *Carabus granulatus interstitialis* Duftschmid. Their normal relative abundance was between 40 and 60%.

Table 1 - Carabidae collected from pitfall traps during 1997 and 1998 in isogenic and transgenic corn crops of Pavia and Treviso showing percentage of total. * Values <5%.

	Isogenic	Transgenic
<i>Agonomum mulleri</i> Dft.	*	*
<i>Agonum moestum</i> Dft.	*	-
<i>Amara aenea</i> Deg.	*	*
<i>Amara familiaris</i> Dft.	*	-
<i>Amara nitida</i> Sturm	*	*
<i>Anchomenus dorsalis</i> Dft.	*	*
<i>Anisodactylus signatus</i> Panz.	*	*
<i>Argutor vernalis</i> Dft.	*	-
<i>Bembidion quadrimaculatum</i> L.	13.0	6.5
<i>Brachinus crepitans</i> L.	*	-
<i>Brachinus ganglbaueri</i> Apfbk.	-	*
<i>Brachinus psophia</i> Serv.	*	-
<i>Calathus fuscipes</i> Goeze	*	*
<i>Calathus melanocephalus</i> L.	*	-
<i>Carabus germari</i> Sturm	*	*
<i>Carabus granulatus interstitialis</i> Dft.	1.4	5.6
<i>Chlaeniellus nitidulus</i> Schrank	*	*
<i>Chlaenius spoliatus</i> Rossi	-	*
<i>Clivina fossor</i> L.	*	*
<i>Cylindera germanica</i> L.	*	*
<i>Dolichus halensis</i> Shall.	*	*
<i>Elaphropus parvulus</i> Dej.	*	-
<i>Harpalus affinis</i> Dej.	*	-
<i>Harpalus dimidiatus</i> Rossi	*	*
<i>Harpalus distinguens</i> Dft.	*	*
<i>Harpalus oblitus</i> Dej.	-	*
<i>Metallina properans</i> (Steph)	*	-
<i>Microlestes corticalis</i> Duf.	*	*
<i>Microlestes minutulus</i> Goeze	*	*
<i>Ophonus azureus</i> F.	*	*
<i>Phonias strenuus</i> Panzer	*	*
<i>Platynus assimilis</i> Paykull	-	*
<i>Platysma macrum</i> Marsham	*	*
<i>Platysma melanarium</i> Illiger	6.4	11.5
<i>Platysma nigrum</i> Schaller	*	*
<i>Poecilus cupreus</i> L.	30.7	22.8
<i>Pseudophonus griseus</i> Panzer	17.8	29.4
<i>Pseudophonus rufipes</i> Degeer	20.5	17.9
<i>Scybalicus oblongiusculus</i> L.	*	*
<i>Stenolophus teutonius</i> Dejan	*	*
<i>Steropus melas</i> Creutzer	*	*
<i>Trechus quadristriatus</i> Schrank	*	*
Total percent	69.0	70.1
Total individuals	1351	2425

In 1997 the ground beetle assemblages of the transgenic and isogenic corn crops in Pavia had a quite similar spectrum species. The transgenic corn crop of Pavia was dominated by the species *P. rufipes* (52,4%), *P. cupreus* (28,7%) and *C. granulatus* (9%); *P. rufipes* (57,5%) also being dominant in the isogenic corn crop, followed by *P. griseus* (15,8%). All these species have a principally zoophagous diet and are typical of cultivated fields.

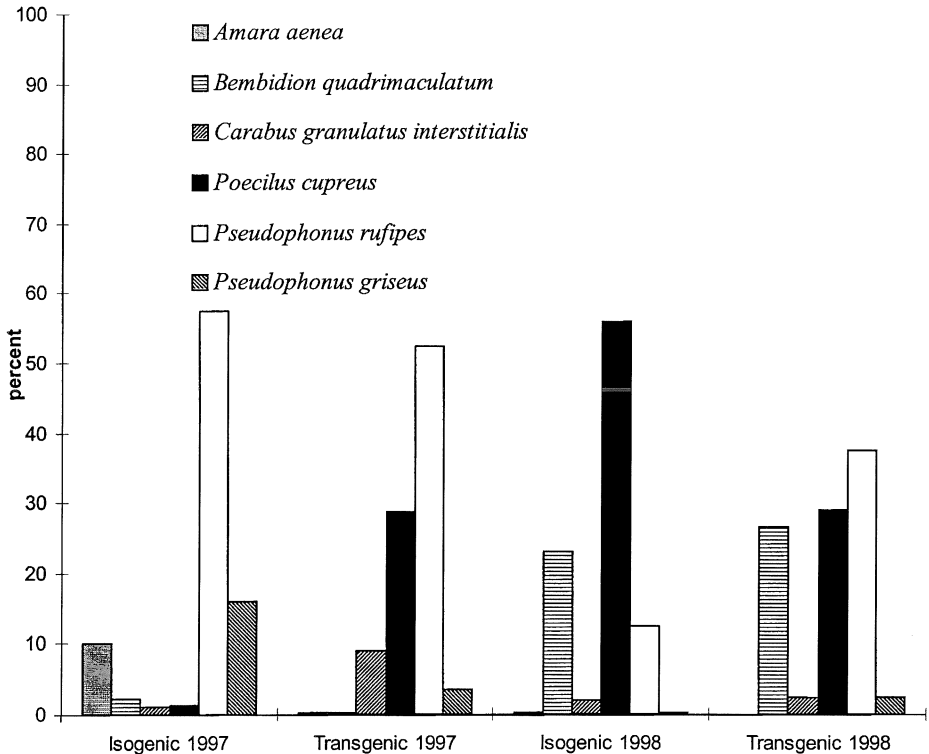


Fig. 1 - Percentage comparison of Carabidae species captured in isogenic and transgenic corn crops in Pavia. Only the most abundant species are presented.

In 1998 the specific spectrum was rather restricted compared to that of 1997, especially in the Treviso corn crop, this could have been due to a rather dry season. In 1998 only twelve species of Carabidae were collected in Treviso while in 1997 there were twenty-six species. In both years the Carabidae assemblages were dominated by *P. melanarium* and *P. rufipes*, the former in the isogenic corn crop during 1997 and in the transgenic one in 1998, the latter in the other two fields. Moreover several species such as *Agonum mulleri* Duftschmid, *Platysma macrum* Marsham and *Poecilus cupreus* L. were present only in the isogenic corn crop, while in the transgenic corn crop only

Bembidion quadrimaculatum L., *Calathus fuscipes* Goeze, *Carabus germari* Sturm, *Microlestes minutulus* Goeze, *Ophonus azureus* F. and *Trechus quadristriatus* Schrank were collected.

In both the isogenic and the transgenic corn crops the abundance of many species was less than 3% of the total catch, and several species were collected only in either the transgenic corn crop or the normal one (see Table 1). Although the number of catches and the ground beetle assemblages were quite different, a common situation in Carabidae studies, this demonstrates the similarity of the isogenic and transgenic crops. However the data for both years show that *P. rufipes* was more abundant in the transgenic corn crop than in the isogenic. This situation was also confirmed in Treviso, where this species was the dominant one in the transgenic crop during both 1997 and 1998. Also *B. quadrimaculatum* was always present, though it was dominant only in one case (Fig. 2).

Table 2 - Diversity indices for Carabid species collected in 1997 and 1998 from isogenic and transgenic corn crops in two different localities.

		H'	N ₀	N ₁	N ₂	N _{inf}	D
1997							
Isogenic	Pavia	0.66	19	1.58	2.78	1.75	0.36
	Treviso	0.68	21	1.60	3.03	2.44	0.33
Transgenic	Pavia	0.59	22	1.51	2.70	1.91	0.37
	Treviso	0.50	17	1.41	2.27	1.69	0.44
1998							
Isogenic	Pavia	0.58	20	1.49	2.56	2.86	0.39
	Treviso	0.63	6	1.54	3.44	2.22	0.29
Transgenic	Pavia	0.91	13	1.88	3.45	2.70	0.29
	Treviso	0.53	9	1.44	2.00	1.45	0.55
1997-98							
Isogenic	Pavia	0.80	29	1.74	4.76	2.85	0.21
	Treviso	0.79	22	1.73	3.26	2.44	0.31
Transgenic	Pavia	0.73	26	1.66	4.00	2.70	0.25
	Treviso	0.53	20	1.44	2.42	1.81	0.41

Number of Carabid collected were grouped by dates. The sample were taken every two weeks from mid - May to the end of September. H' Shannon-Weaver diversity index. N₀-N_{inf} Hill's numbers.

DIVERSITY AND SPECIES RICHNESS. Table 2 shows diversity of the cumulative data, gathered in terms of date, locality and year, measured by the Shannon- Weaver index (H').

Carabidae diversity was relatively low, the diversity index $H' < 0.99$; H' was highest for the transgenic corn crop in Pavia during 1998 and the lowest in the transgenic corn crop of Treviso during 1997. Considering the two years the values of H' were higher for isogenic corn crop than for the transgenic ones, although the difference is tangible only for the transgenic corn crop of Treviso.

The total number of species identified was 42, the minimum being 6 species in Treviso during 1998 and the maximum 22 in the transgenic corn crop of Pavia during 1997. If the two years are plotted together the maximum value was 29 in the isogenic in Pavia.

The value of N_1 ranged between a maximum of 1.88 (transgenic - Pavia - 1998) and a minimum of 1.41 (transgenic - Treviso - 1997). The value of N_2 was generally higher for the isogenic corn crop than for the transgenic corn crops considering both years. The lowest value was found in isogenic corn crop in Pavia during 1997 while the highest was in the same locality but for the transgenic corn crop during 1998. N_{inf} (dominance diversity) had the highest value in isogenic corn crop of Pavia (1998) and was lowest in the same locality, but in the isogenic corn crop, during 1997

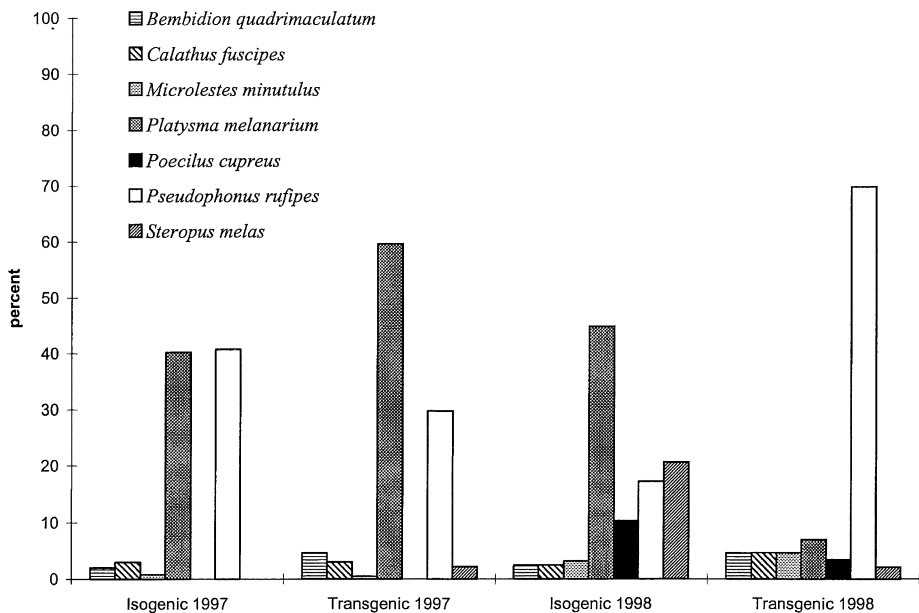


Fig. 2 - Percentage comparison of Carabidae species captured in isogenic and transgenic corn crops in Treviso. Only the most abundant species are presented.

There was no decreasing trend in the biodiversity indices (Table 2) from the first to the second year, and considering the data as a whole the two years appear comparable. The difference in biodiversity recorded for some indices is not due to the presence of transgenic corn; in fact the H' calculated for the transgenic crop in Pavia was the highest.

The values of the Sørensen similarity index were: Pavia $Q_s = 71.42$ for 1997 and $Q_s = 62.85$ for 1998; Treviso $Q_s = 68.4$ during 1997 and $Q_s = 40$ in 1998. The

similarity index is quite high for Pavia and also in the 1997 Treviso case, demonstrating a correspondence in Carabidae biocenosis between transgenic and isogenic corn crops. In both years the Sørensen index shows a close similarity between the coenosis of the two types of crops. During 1998 the similarity index was lower in Treviso; this could have been due to the lower number of captures.

AERIAL FAUNA. Many different taxa were collected through the sucking method and Malaise traps; only the most numerous groups and the taxa ecologically connected to maize are reported.

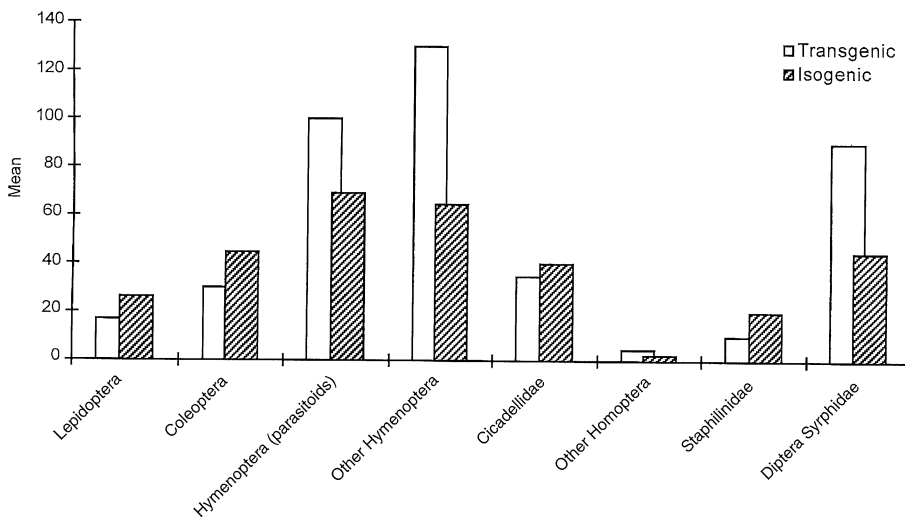


Fig. 3 - Comparing of abundance of different Taxa captured in isogenic and transgenic corn crops. Means among the dates and the replicates in Pavia and in Treviso.

Table 3 shows the data of the captures using the blower-vac aspirator. The most abundant taxon in isogenic and transgenic corn crop was Diptera, especially the Culicidae (that do not represent a typical corn crop fauna), followed by leaf hoppers and Chrysomelidae, that are characteristic of this crop. There were no observed differences in the number of arthropods colonising either isogenic (13.61 ± 3.2) or transgenic corn (12.9 ± 2.6) calculated for both years and the two localities. These data are confirmed by the results of the Mann - Whitney U test calculated for each group ($U = 17$, $W = 39$, 2-tailed $p = 0.65$). Nor were there statistical differences in the abundance of aphids ($U = 18$, $W = 39$, 2-tailed $p = 0.73$), leaf hoppers ($U = 16.5$, $W = 44.5$, 2-tailed $p = 0.55$), other Homoptera ($U = 16$, $W = 38$, 2-tailed $p = 0.9$), thrips ($U = 8.5$, $W = 29$, 2-tailed $p = 0.13$), leaf beetles ($U = 16$, $W = 44$, 2-tailed $p = 0.8$), spiders ($U = 16$, $W = 37$, 2-tailed $p = 0.8$), lady bird beetles ($U = 18.5$, $W = 39.5$, 2-tailed $p = 0.8$), Hymenoptera parasitoids ($U=17$, $W=38$, 2-tailed $p = 0.94$),

Table 3 - Mean \pm SE number of arthropodofauna caught using a Blower-vac aspirator on isogenic and transgenic corn crops on different sampling dates.

	1997				1998			
	Isogenic		Transgenic		Isogenic		Transgenic	
	Pavia	Treviso	Pavia	Treviso	Pavia	Treviso	Pavia	Treviso
Thrips	2.33 \pm 2.7	0.67 \pm 0.8	2.17 \pm 1.8	0.17 \pm 0.2	0.33 \pm 0.4	0.67 \pm 0.8	0.17 \pm 0.2	1.17 \pm 1.5
Aphids	0.17 \pm 0.2	5.17 \pm 4.1	0.50 \pm 0.8	4.17 \pm 5.2	5.00 \pm 3.6	0.83 \pm 0.5	4.17 \pm 5.2	0.17 \pm 0.2
Cicadellidae	66.20 \pm 49.0	61.17 \pm 39.2	59.67 \pm 31	72.67 \pm 48.3	77.67 \pm 40	50.00 \pm 42	72.67 \pm 48	38.50 \pm 25
Other Homoptera	8.83 \pm 8.1	8.00 \pm 5.0	7.67 \pm 4.6	7.67 \pm 3.5	4.67 \pm 2.5	4.00 \pm 2.3	7.67 \pm 3.5	4.83 \pm 2.1
Chrysomelidae	5.17 \pm 3.5	38.33 \pm 21.4	7.50 \pm 4.3	31.17 \pm 9.8	35.83 \pm 19.4	4.00 \pm 2.6	31.17 \pm 9.8	5.00 \pm 3.0
Coccinellidae	0.33 \pm 0.4	3.67 \pm 1.6	1.17 \pm 0.8	3.33 \pm 2.1	2.00 \pm 1.6	0.33 \pm 0.4	3.33 \pm 2.1	0.50 \pm 0.6
Other Coleoptera	1.50 \pm 1.1	4.67 \pm 4.3	0.50 \pm 0.6	6.17 \pm 5.2	6.00 \pm 5.0	1.83 \pm 0.6	6.17 \pm 5.2	0.33 \pm 0.5
Diptera	112.33 \pm 59.3	20.67 \pm 14.3	73.00 \pm 33	21.50 \pm 14.8	22.50 \pm 13.8	69.83 \pm 55.8	21.50 \pm 14	44.67 \pm 27
Lepidoptera	0.00 \pm 0.0	0.00 \pm 0.0	0.00 \pm 0.0	0.00 \pm 0.0	0.00 \pm 0.0	0.00 \pm 0.0	0.00 \pm 0.0	0.00 \pm 0.0
Hymenoptera parasitoids	2.33 \pm 1.4	1.83 \pm 1.5	3.17 \pm 2.8	1.00 \pm 0.3	1.33 \pm 1.4	1.17 \pm 1.2	1.00 \pm 0.3	1.00 \pm 1.0
Other Hymenoptera	1.50 \pm 1.5	2.83 \pm 1.8	1.67 \pm 0.7	2.83 \pm 1.5	2.17 \pm 1.5	0.83 \pm 1.1	2.83 \pm 1.5	1.00 \pm 1.3
Other Insects	1.17 \pm 0.8	2.50 \pm 1.6	1.33 \pm 1.0	1.83 \pm 0.5	2.17 \pm 0.8	1.67 \pm 1.0	1.83 \pm 0.5	2.17 \pm 1.2
Aranea	1.33 \pm 1.4	1.83 \pm 1.7	1.50 \pm 0.8	2.67 \pm 0.4	2.33 \pm 1.1	2.83 \pm 1.8	2.67 \pm 0.4	2.5 \pm 1.5

Means of dates and replicates in the same field.

other Hymenoptera ($U = 16$, $W = 37$, 2-tailed $p = 0.93$) and Diptera ($U = 15.5$, $W = 36.5$, 2-tailed $p = 0.45$), in the transgenic and isogenic corn crops for both years for both localities. In fact the value of 2-Tailed P was never significant ($p < 0.05$).

The number of arthropods collected in transgenic corn crops, using Malaise traps, was higher than the number of isogenic ones (Fig. 3). The most abundant taxon in both the theses was Hymenoptera followed by Coleoptera (Fig. 3). Moreover no statistical differences were observed in the abundance of insects in the isogenic and transgenic plots (value of 2-Tailed P in Table 4).

Throughout 1998 only one crysopid larva and two adults were observed, the crysopid larva being in the isogenic corn crop of Pavia and the adults in the isogenic and transgenic corn crops of the same locality. The Coccinellid larvae were recorded by visual observations. Only *Adalia bipunctata* L. were found during the sampling period, the average per plant being 0.31 ± 0.2 in the transgenic corn crop of Pavia and 0.29 ± 0.25 in Treviso. There was no statistical difference in the abundance of Coccinellidae recorded in the transgenic and isogenic corn crops ($F = 0.78$, $df = 1.120$, $P = 0.3$).

All the sampling methods and the statistical analysis, supported by visual checking, show that there was no significant difference in abundance, composition or biodiversity of non target arthropods in isogenic and transgenic corn crops.

Table 4 - Results of the Mann-Whitney U test of the captures of insects using the Malaise traps in Treviso and Pavia.

TAXA	1997 Hierarchic mean					1998 Hierarchic mean				
	Transgenic	Isogenic	U	W	2 Tailed P	Transgenic	Isogenic	U	W	2- Tailed P
Lepidoptera	4.00	3.00	3	9	0.51 ns	5.20	5.80	11	26	0.84 ns
Coleoptera	3.67	3.33	4	10	0.82 ns	5.00	6.00	10	25	0.69 ns
Staphilinidae	3.33	3.67	4	10	0.81 ns	5.20	5.80	11	26	0.84 ns
Hymenoptera	2.33	4.67	1	7	0.23 ns	4.90	6.1	9.5	24.5	0.60 ns
Cicadellidae	3.00	4.00	3	9	0.84 ns	5.20	5.80	11	26	0.84 ns
Other Homoptera	3.00	4.50	1.5	7.5	0.81 ns	6.20	4.8	9	24	0.51 ns
Hymenoptera parasitoids	2.50	4.33	2	9	0.51 ns	4.60	6.40	8	23	0.42 ns
Syrphidae	2.67	4.30	2	8	0.26 ns	5.80	5.20	11	26	0.84 ns

Means among the dates and the replicates of the transgenic and isogenic corn crop.

U of Mann-Whitney test; W of Wilcoxon test.

DISCUSSION

Our results show that there is no potential for plant antibiosis (Bt corn), neither to influence phytophagous species nor for predatory species over the 3 or 4 trophic level confirming the findings of other authors (Orr & Landis, 1997; Pilcher *et al.*, 1997;

Gould, 1998; Lozzia *et al.*, 1998). In fact our two-year survey revealed no difference in the abundance of arthropods, predators (as well parasitoids) or the phytophagous species living in transgenic and isogenic corn crops. Neither aerial fauna nor Carabidae were significantly affected by the presence of transgenic corn.

From our results it appears that the transgenic character itself does not lead to an increase or decrease of any insect populations. The Cry 1Ab protein expressed in transgenic corn had neither a deleterious nor beneficial effect for any of the considered non-target arthropods. This means that CryIAb proteins do not directly affect the phytophagous species, such as thrips, aphids or corn pollen feeders, nor does it have any indirect influence on other trophic levels or activities such as behaviour, oviposition, predators-prey. Also Pilcher *et al.* (1997) observed that there was no adverse effect, neither in the field nor in the laboratory, of Bt corn pollen on Coccinellidae, finding predators more abundant in the transgenic corn crop during the 2-yr field study.

Some differences were recorded in the structure of the Carabidae assemblages and in their biodiversity, although these differences were more evident between the place and the year rather than on comparing the two types of hybrid corn. In fact the ecology of Carabids is often restricted (Thiele, 1977), not depending on the corn crop itself, thus the differences would not necessarily depend on the presence of transgenic corn. Although the observed differences were not statistically significant they could reflect a diversity in the environmental conditions, or even the presence of different niches within the corn crop. The low values of Carabidae abundance and the biodiversity found in Treviso during 1998 appear correlated to the dry, warm season rather than to the presence of the transgenic corn crop; in fact during the 1998 sampling period it did not rain for over two months in this region. *Pseudophonus rufipes* was more abundant in the transgenic corn crop than in the isogenic one. *P. rufipes* is one of the most eurytopic species, thus it can move from the neighbouring surrounds, however the high level of its capture in the transgenic fields should demonstrate the absence of negative effects of this crop on *P. rufipes*.

The values of the calculated biodiversity indices are quite low, as expected for an agricultural environment. Moreover our data are comparable with the biodiversity indices of ground beetle assemblages in corn fields, calculated by Ellesbury *et al.* (1998). The biodiversity of Carabidae was even higher during the second year of study (Pavia) where the values of N_2 and N_{inf} demonstrate that the species was quite well spread across the community, its dominance being lower than for the corresponding isogenic corn crop.

Observations concerning the impact of agricultural management on soil fauna populations and communities, claim that high input such as insecticides and intensively managed systems tend to promote low diversity, while low input systems like integrated pest management tend to maintain diversity (Den Boer, 1979; Brandmayr, 1980). From our results it appears that effect of the transgenic corn crop is comparable with a situation of integrated pest management. However one of the major goals of ecologists is to understand all the variables that affect biodiversity. In fact, even recently, Bardgett and Cook (1998) claimed that research is needed to test the hypothesis that soil biodiversity

is positively associated with stability, and to elucidate relationships between productivity, community integrity and the functioning of soil biotic communities.

The potential use of the ground beetle as a natural control agent for crop pests is generally recognised (Best & Beegle, 1977; Thiele, 1977; Brandmayr P., 1980; Ellsbury *et al.*, 1998).

Moreover recent studies have shown that in insecticidal transgenic cultivars the activity of natural antagonists could have a positive effect on the control of the several pests, and on the development of pests resistant to genetically modified plants (Brust *et al.*, 1986; Johnson *et al.*, 1997). Transgenic insecticidal cultivars could maintain a natural density population of predators and parasitoids, allowing, in such a way, the control of the European corn borer and, eventually, of Bt resistant individuals (Johnson *et al.*, 1997; Orr & Landis, 1997; Gould, 1998). Thus a most important tactic in modern Integrated Pest Management could be the conservation of biodiversity and, more specifically, of natural ECB enemies and other corn crop pests.

In conclusion our results show that transgenic corn crops appear to have no deleterious effects on non target entomofauna studied or on biodiversity, however further studies are needed, both on a longer time scale and on larger fields, to confirm our data.

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