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Floristic Biodiversity of Weed Communities in Relation to Conventional and Organic Farming

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ABSTRACT

This experiment was conducted at the Superior Institute of Agronomy at Chott-Meriem (Sousse, Tunisia). Weed abundance, species richness and diversity in conventional and organic irrigated vegetable crops in Chott-Meriem were compared in spring by means of a relative abundance index for each species. Shannon's index was used to assess the effect of intensification on the floristic composition and structure of weed vegetation, while a community coefficient was used to evaluate the degree of resemblance between the two floras and to evaluate the role of organic farming in preventing the continued loss of biodiversity caused by intensive farming practices. 8 paired crops were selected and the samples were arranged in randomized complete design. Each pair contained one long-term established organic (for at least 20 years) site and one conventional site. 160 samples were collected from primary plots and analyzed separately or together. 64 samples of 100 g soil were used for analysis of organic matter, nitrogen, pH and electrical conductivity. The weed species were identified and classified according to their importance and type of distribution. Results showed that abundance, species richness and diversity were higher in organic than in conventional fields. This study also showed that the conversion from conventional to organic farming inverted the weed flora. The organic matter content and the salinity were higher in organic soils. The abundant biomass present in organic farming may promote biodiversity and help to biologically control pests and favor insect pollination. A better understanding of changes occurring in the composition of the weed flora could result in a better weed control strategy.

Keywords: conventional farming, diversity, organic farming, weeds

INTRODUCTION

Intensive agriculture tends to have negative impacts on biodiversity within agricultural systems (Firbank 2008; Storkey 2012). The primarily reason is low crop and structural diversity but also because of pesticide use and agricultural practices (Ammann 2004). Agricultural intensification and expansion of agriculture are often considered to be an important factor contributing to a rapid decline and loss in biodiversity in agro-ecosystems (Benton *et al.* 2003; Mattison and Norris 2005; Hole *et al.* 2005; Flohre *et al.* 2011) and simplifying landscapes (Flohre *et al.* 2011). The loss of plant species biodiversity has attracted particular attention in recent years with the conversion of conventional agriculture to organic agriculture (Tilman *et al.* 2002; Storkey *et al.* 2012). Organic agricultural methods generally increase biodiversity (Ahnström 2002; Bengtsson 2005) while plant biodiversity of cultivated land can be divided into planned and associated biodiversity; the former refers to planned crop diversity and the latter appears spontaneously within production systems and refers to weed species that colonize crops (Vandermeer *et al.* 2002; Lockie and Carpenter 2010). Weed species, which are collectively all non-cultivated species encountered within the crop, are an important part of the associated biodiversity of cultivated land, and their presence in these fields are very important for the conservation of rare and damaged species (Wilson 1991) and are an important source of food for a high diversity of insects (Sotherton 1990; Wilson *et al.* 2003; Marshall *et al.* 2003; Hole *et al.* 2005; Boatman *et al.* 2007).

There has been a marked intensification in the cropping practices of Tunisian agriculture and a tremendous decline in weed abundance, the decline being attributed to the application of herbicides and a higher rate of nitrogen fertilizer application (Anonymous 1992). Changes in farming techniques affect weed communities (Firbank 2008; Storkey 2012).

The application of herbicides has a great effect on the abundance of species in a community of weeds (Owen 2008; Abbas *et al.* 2009; Vanaga *et al.* 2010). The application of herbicides in conventional cropping is regarded as one of the most important factors affecting species richness relative to organic cropping (Hyvönen 2004). The number of species per unit area is lower after the application of post-emergence herbicides (Derksen *et al.* 1995; Hald 1999; Boström and Fogelfors 1999; Boström and Fogelfors 2002; Draycott 2006). Similarly, the application of pre-emergence herbicides changes the composition and structure of these weed communities (Svensson and Wigren 1986; Sotherton 1990; Dessaint *et al.* 2007). Herbicides may contain different active ingredients and weed species react differently toward these herbicides. The selective application of herbicides reduces the density of susceptible species and increases the density of tolerant species (Chancellor 1979; Hume 1987; Salonen 1993; Christoffoleti *et al.* 2008). Herbicides, particularly when applied against broadleaf plants, results in an increase in the abundance of grasses (Haas and Streibig 1982; Ortega and Pearson 2011). Herbicides are a popular tool in agriculture and gardening as a method for controlling weeds, and even though they are indispensable weapons in weed control in a bid to save crops, they are accompanied by certain drawbacks as well, among which is that weeds targeted by herbicides can often develop resistance to the herbicide or to the active compound / principle within it. The loss of herbicide effectiveness due to selection of herbicide-resistant weed populations has a negative impact on farmers, forcing growers to use more and more products to achieve the same effect and this issue becomes more acute when noxious weed plant species emerge with resistance against selective herbicides (Chaudhry 2011).

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Table 1 Vegetable crops used in this weed survey.

Latin names	English names	Source	Cultivars	Density (plants/ha)
Lycopercicum esculentum Mill.	tomato	field	Bochra	12,000
Lycopercicum esculentum Mill.	tomato	greenhouse	Bochra	30,000
Capsicum annuum L.	pepper	greenhouse	StarterHF1	20,000
Solanum tuberosum L.	potato	field	Spunta	40,000
Cynara scolymus L.	artichoke	field	Violet d'hyéres	10,000
Lactuca sativa L.	lettuce	field	Longifolia	150,000
Cucumis sativus Gurke	cucumber	greenhouse	locale	30,000
Cucurbita pepo L.	squash	greenhouse	Top Kapi	12,000

Moreover, arable weed seedbanks have been significantly depleted by intensive herbicide use so that some weeds are now species of conservation concern such as *Stellaria media*, *Polygonum aviculare* and *Chenepodium album* (Hester and Harrison 2011).

Fertilization plays an important role in the dynamics of weed communities, affecting the weed flora composition and density, the former primarily due to nitrogen (N) (Nie 2009). N is the most important fertilizer used in conventional farming, although other elements such as phosphorus are important (Banks *et al.* 1976; Hoveland *et al.* 1976; Goldberg and Miller 1990; Hyvönen 2004). The increase in N fertilizer has encouraged the production of biomass crops and weeds (Mahn 1988; Jørnsgård *et al.* 1996), which leads to a major competition for light between weeds and crops (Haas and Streibig 1982; Pyšek and Leps 1991; van Delden *et al.* 2002; Zimdahl 2007). The competition for nutrients is not independent of competition for light and water and weed species respond differently to additional N supplementation (Pennings 2005). This great competition for light favors species with an erect growth form such as *Apera spica-venti* and *Avena fatua* compared with laterally prostrate species such as *Medicago lupulina* and *Vicia angustifolia* as N fertilizer increases (Pyšek and Leps 1991; McGinley and Codella 2008), the N fertilizer in conventional fields is high enough to create dense crop stands and thus limits the amount of light for weeds, this situation favors shade-tolerant species (Haas and Streibig 1982; Hyvönen 2004). In addition, N fertilization promotes and increases the occurrence and abundance of nitrophilous species (e.g. *Chenopodium album*, *Elymus repens*, *Fumaria officinalis*, *Raphanus raphanistrum*) (Haas and Streibig 1982; Moss *et al.* 2004; Hyvönen 2007). However, the biological systems increases the non-nitophilous species (e.g. *Centaurea cyanus*, *Vicia hirsuta* (Rydberg and Milberg 2000). This increased use of N fertilizer has reduced certain weeds that became rare weed species (e.g. *Scandix pectin-veneris*, *Torilis arvensis*, *Filago pyramidata*) (Svensson and Wigren 1986; Marshall 2001; Wilson *et al.* 2003).

Farming activities have increased N availability dramatically in agro-ecosystems and simultaneously increased herbicide use to increase food production, and such increases in agrochemical inputs affect weed species composition and structure; these in turn can affect weed diversity and nutrient cycling in agro-ecosystems. Chemical fertilizer is an excellent tool for increasing herbicide efficiency (El-shahaway 2008). For example, Sønderskov *et al.* (2012) found that the susceptibility of *Tripleurospermum inodorum* and *Anagallis arvensis* to tribenuron-methyl increased with increasing N rate.

Organic farming uses crop rotation and well-rotted farmyard manure or compost to improve soil fertility and the fight against weeds. The diversity of crop rotations has a minor effect on the composition of weeds (Barberi *et al.* 1997) and species diversity (Doucet *et al.* 1999) unless the rotation includes crops planted in different seasons (Hald 1999).

The weed flora in conventional systems has been widely studied, but there are few scientific studies pertaining to the weed flora in biological systems. The objective of this study was to examine the weed communities of some vegetable crops cultured in conventional and organic farming in the area of Chott-Meriem. The diversity and species composition of weed communities were compared. The number of species and individuals were used as a measure of species diversity. The total and average number of species between cultures was compared with an emphasis on the presence and frequency. In essence, this paper deals with the impact of organic farming on weed biodiversity compared to conventional agriculture to determine whether organic agriculture can contribute to maintaining biodiversity since biodiversity provides a range of ecosystem services which has the potential to improve agro-ecosystem health.

MATERIALS AND METHODS

A census of weed plants was performed at 16 different crop locations in Chott-Meriem. The crops were either managed organically or conventionally. To test whether or not crop management had any effect on weed diversity, 8 matched pairs of vegetable crops were used. Each matched pair contained a vegetable crop grown organically and another vegetable crop from a nearby conventional farm with similar soil and climate. The crop surfaces within a pair were of approximately the same size and they were located fairly close to each other (100-200 m within pairs). Moreover, they were similar with respect to land use and landscape features.

Weed flora

This study compared the weed flora of organic and conventional farming. Weed flora were studied in both systems as described above (organic and conventional farming systems).

160 primary samples were taken from 8 vegetable crops conducted either in conventional or organic farming. The weed survey was done on the following crops: tomatoes in the field, tomatoes in the greenhouse, peppers in the greenhouse, potatoes in the field, artichoke in the field, lettuce in the field, cucumber in the greenhouse, and squash in the greenhouse (**Table 1**). Each transect touches 2, 3, 2, 4, 1, 15, 3, 2 tomatoes in the field, tomatoes in the greenhouse, peppers in the greenhouse, potatoes in the field, artichoke in the field, lettuce in the field, cucumber in the greenhouse, and squash in the greenhouse, respectively. Weeds were inventoried with the point intercept method (Bonham 1989). The transect consisted of a 1-m long string having marks every 5 cm (20 points/transect) and suspended at a height of 10 cm between two metal rods. A stick is extended perpendicular to the transect at each mark and the first plant touched by the sharp point of the stick, regardless of the part touched (leaf, stem, flower), constitutes the sample unit. 10 transects were used per vegetable crop. As a result, 10 m of the transect were within each vegetable crop. Each species was assigned a coefficient of abundance (total number of individuals of each species in the complete sample), of presence and of frequency. The systematic positioning of samples is used to ensure that samples are placed independently of the experimenter avoiding or choosing unknowingly certain areas while increasing sampled areas (Scherrer 1983). Systematic selection was used as the diagonal method in which samples were selected on two diagonals of the field or greenhouse (Colbach *et al*. 2000; **Fig. 1**). With limited area for each type of crop, the entire planted area is used in estimating the number of weeds according to **Fig. 1**.

Weed communities in different types of vegetable crops were

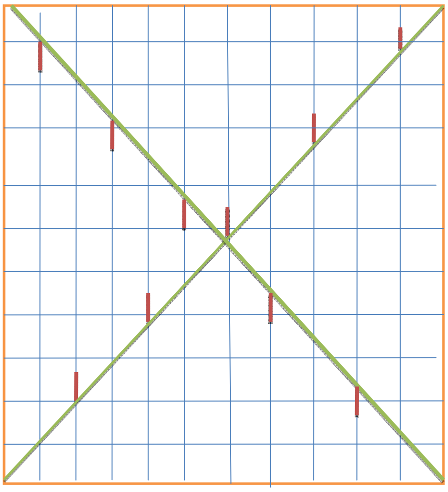

Fig. 1 Diagram of a systematic sampling plan (n=5) selecting 10 samples (N= 2n=10) and using diagonals. Red bar indicates the position of the transect, (n = number of transects per diagonal, N = total number of transects per crop).

investigated from April to June 2010, a period corresponding to the existence of almost the majority of weeds of these crops and to easy identification. The weed species encountered were identified in the laboratory according to a weed flora in the library of the High Institute of Agronomy of Chott-Meriem (Cuenod *et al*. 1954; Pottier-Alapetite 1979, 1981).

The values of diversity and evenness indices were calculated according to the following formulae:

*Shannon-Wiener diversity index (H): $H = -\Sigma [p_i (\ln p_i)]$

where pi is proportional abundance of a given species ($p_i = n_i/N$). A high value of "H" indicates that the community is more diverse (Schwall 2004).

Evenness (E): $E = H/\ln S$

where S is species richness (Schwall 2004).

The values of evenness can range between 0 and 1: a value of 0 corresponds to a community of one species (total dominance), and a value of 1, a community where all species are equally abundant.

Also the degree of similarity between the two weed communities was observed in our study. It was calculated according to the following formula (Sørensen 1948):

$Cs = [2*c / (a + b)] * 100$

where a is the number of species from List A, b is the number of listed species B, c is the number of species common to the lists A and B. Cs = 0 if the two lists have no species in common and Cs = 100 if both lists are identical.

Soil analysis

32 soil samples were taken from the field and greenhouse plots carried out either in organic or conventional farming with 4 samples of each vegetable crop for analysis of electrical conductivity, pH, the rate of organic matter (OM) and total N. The analysis was performed in the laboratory of Soil Science, Higher Institute of Agronomy of Chott-Meriem. Each sample weighed 1 kg; soil was taken from the soil layer 30 cm deep from field and greenhouse plots. The 32 samples (8 crops *4 simples) of each farming system were mixed in such a way to make four composite samples. From each composite sample, 100 g of soil was analysed using the methods recommended by the Laboratory of Soil Science of the High Institute of Chott-Meriem.

The content of OM and the soil pH were also determined. Topsoil samples (from a depth of 0–10 cm) were taken from five conventional and five organic vegetable fields in April 2010 with a 55.8 mm diameter soil core sampler. Soil samples were dried at 50°C, ground to pass a 2-mm sieve and stored until analysis. OM was analyzed by the soil laboratory of the Institute as follows:

1. Soil samples were dried at 105°C in a drying oven for a minimum of 24 h. After drying, samples were crumbed by hand and passed through a 2-mm sieve to remove large fragments of organic and inorganic material.
2. A definite amount of dry soil was added to the crucible.
3. The sample was placed carefully into a pre-heated muffle furnace set at 400°C and ashed for 1 h.
4. The sample was removed carefully and allowed to cool to room temperature. After cooling, the ash was determined
5. Loss on ignition (LOI) content was calculated as follows:

%LOI (%OM) = (dry weight – ash weight)/ dry weight × 100

Kjeldahl nitrogen determination was performed on soil samples (Sarkar and Haldar 2005).

Statistical analysis

The data in this study was statistically analyzed using analysis of variance appropriate for a sample arrangement in complete randomized design (Steel *et al.* 1997) and significant differences between means for main and interaction effects were compared using Fisher's LSD test at $P = 0.05$.

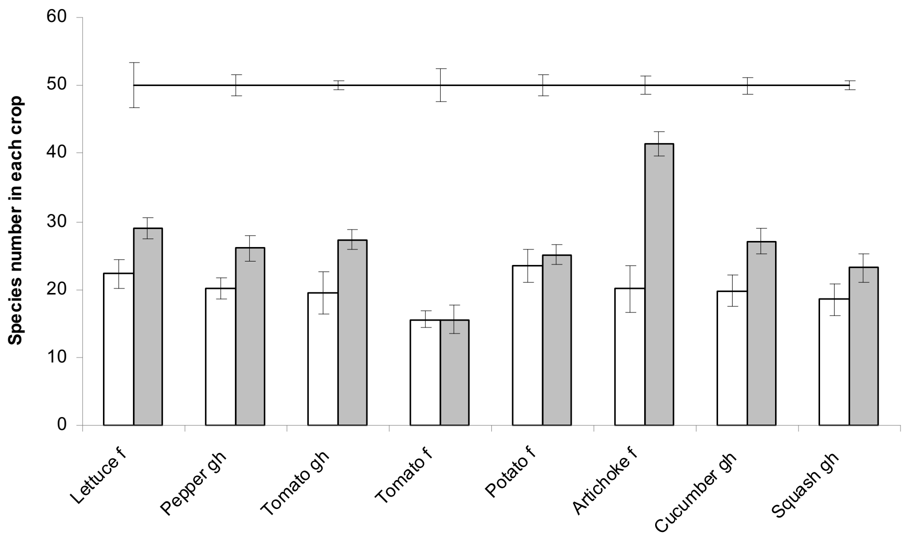

Fig. 2 Weed species number in each type of cultural farming. Vertical bars on bar column represent standard errors of means and vertical bars on straight line represent LSD. Crops in conventional (white) and biological (grey) farming. f: field; gh: greenhouse.

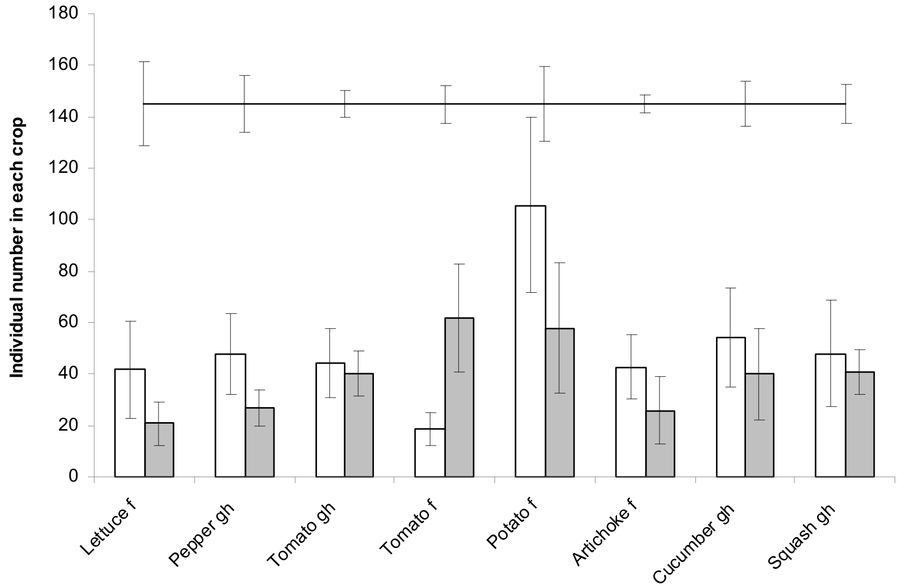

Fig. 3 Number of plants (individuals) encountered in each type of crop. Vertical bars on bar column represent standard errors of means and vertical bars on straight line represent LSD. Crops in conventional (white) and biological (grey) farming. f: field; gh: greenhouse.

RESULTS

Weed flora

The results of the weed species investigation in both types of agriculture are shown in **Fig. 2**. The results showed that organic farming had positive effects on species richness and abundance. Organic agricultural methods increased species richness of weed plants compared with conventional methods (**Table 2**). The crops grown in organic farming showed that the number of weed species was much higher than that found in conventional cropping. However, the number of individuals was lower in conventional plots (**Fig. 3**). In total, in conventionally managed fields, 575 weed plants were recorded (570 broad-leaved and 5 grasses) while in organically managed fields, 823 weed plants were recorded (818 broad-leaved, 5 grasses). 41 weed species were not detected in conventional plots but only in organic farming while 11 species were detected in organic farming plots but not in conventional farming plots (see **Appendix**). Organic farming tends to increase the number of weed families. The structure of the weed flora changed (**Table 3**): 63 annual weed species were found in biological plots but only 40 in conventional plots. Moreover, 7 stationary weed species (fixed perennials) were inventoried in biological farming but not in conventional farming. The number of creeping perennials was almost the same in both farming systems. Only 33/86 weed species were common to both farming systems, with a low coefficient of similarity (55.4), implying that the two modes are not similar (**Table 4**). The nitratophilous weed species were similar but not identical (**Table 5**). Diversity was higher in organic farming than in conventional farming, shown by higher species richness and Shannon's diversity index (**Table 6**).

Table 2 Importance of botanical species inventoried in the two farming modes.

	Conventional farming	Organic farming
Famillies	19 a	26 b
Species	46 a	75 b
Individules	576 a	823 b
Monocotyledons	7 a	8 a
Dicotyledons	39 a	67 b

* values within a row followed by different letters are significantly different at $P < 0.05$ based on the F-test and LSD

Table 3 Biological spectrum of weed species inventoried in the two farming modes.

Weed classification	Conventional farming	Organic farming
Therophytes	40 (90.9%)	63 (84.0%)
Geophytes	4 (9.0%)	5 (6.6%)
Chamephytes	0	1 (1.3%)
Hemicryptophytes	0	6 (8.0%)
Total	44	75

* values in parentheses represent percentages.

Table 4 Common species of both conventional and organic methods.

	Conventional farming	Organic farming
Species in	44	75
Species are not in	42	11
Species only in	2	31
Species in both	33	
Total number of species	86	

Table 5 Nitratophilous species.

Species	Conventional farming	Organic farming
Nitratophiles in	16 a	18 a
Nitratophiles exist only in	4 a	6 a
Nitratophile communes	12	

* values within a row followed by different letters are significantly different at $P < 0.05$ based on the F-test and LSD

Table 6 Mean of species richness and diversity indices in organic and conventional irrigated vegetable fields in 2010.

Indicies	Conventional farming	Organic farming
Number of species	43	75
H	3.730	4.552
E	0.99	1.00

Soil analysis

Soil analysis (**Table 7**) showed that the soil from the organic farming plot contained more OM and N than the conventional farming plot. In addition, soil salinity, which is expressed by electrical conductivity, is higher in organic farming soil. There was no significant difference between the acidity of both soil types.

Table 7 Soil analysis.

Nature	Conventional farming	Organic farming
Organic matter	1.5	2.2
Nitrogen	0.9	1.5
pH	8.8	8.7
Electrical conductivity	1.9	3.2

DISCUSSION

Organic farming in the area of Chott-Meriem was introduced in 1990 following a ministerial act (Anonyme 2006). It differs from conventional farming in that it does not use synthetic chemical fertilizers, pesticides or additives. Organic farming only uses the rules of agricultural sciences together with other cultivation techniques such as weed control. In conventional farming, weed control is mainly carried out manually or mechanically in the Chott-Meriem area. Herbicides are not used. Control is also achieved by crop rotation and use of farmyard manure free of synthetic products from animal feed or compost.

This change in farming techniques had resulted in a change in the weed flora. This study in Chott-Meriem indicates that organic systems had more weed species and more individual weed plants than conventional systems. A similar increase in weed species was reported by others (Hyvönen *et al.* 2003; Bengtsson *et al.* 2005) in which the cropping system had a greater influence on the weed community than if the farm was managed organically or not. Bengtsson *et al.* (2005) found in their study that organic farming usually increased species richness, having on average 30% higher species richness than conventional farming systems. Similarly, Hyvönen *et al*. (2003) compared weed communities in spring cereal fields cultivated by organic and conventional cereals in Finland, and found that in organically cultivated fields the mean number of species per field exceeded that in conventionally cultivated fields and that the total number of species was higher in organically cultivated fields. In our study, organic farming tended to encourage annual and stationary perennial weeds, this latter group being absent in conventional fields. Similarly, the organic farming system tends to reduce the number of individuals per sample.

This conversion from conventional to organic farming favored nitrophilous species unlike those found in other publications. However, Rydberg and Milberg (2000) found in their study that there was a tendency for weed species that dominate in conventional farming to be more nitrophilous than those species characteristic in organic farming (Rydberg and Milberg 2000). Also, Hyvönen *et al*. (2003) found that a weak support was found for the hypothesis that organic cropping favors less-nitrophilous weed species. In low input farming, Barberi *et al*. (1997) found that there were less nitrophilous weed species than high input farming.

When comparing weed species richness in conventional and biological farming, it is possible to deduce different trends in the number of weed species. Mean values of the Shannon-Wiener diversity (H) and evenness (E) indexes of weeds in tested crops are presented in **Table 5**. They indicated that in organic crops these values are superior to that in conventional crops. Our results confirmed that on organic sites weed communities have a higher diversity than on the conventional sites (H = 3.7 in conventional farming and 4.52 in organic farming). Values reported in the literature for Shannon's H for weed communities are generally inferior to 2.0 (Clements *et al.* 1994). In comparison, H for plant communities in other habitats may have a range of 3.0-4.0 in grasslands, 2.0-3.0 in deciduous forests, and potentially superior to 7.0 in Pacific forests. Low plant diversity appears to be typical of arable land and intensively managed farms (Wilson *et al.* 2003), and is likely to be the result of planned disturbances (Légère *et al.* 2005). Menalled *et al.* (2001) found a Shannon diversity index of 0.18 and 0.32 in conventional and organically farmed areas, respectively. Pollnac *et al*. (2008) found in organic wheat fields that the floristic diversity was superior to that found in conventional wheat fields. Calculated values of evenness (E) are 0.90 and 1.0 in conventional and in organic crops, respectively. This indicates that weed species are equally abundant since no herbicides were used in both types of crops.

Soil is probably one of the most important natural resources but is also one of the most neglected. Organic farming resulted in rapid changes in some soil properties. Our results showed that the organic farming practices resulted in lower pH and higher OM. This was caused by higher inputs of OM, an energetic substrate for microbial communities that are activated to assure the turnover of applied nutrients. This improvement in soil fertility and the greatest biodiversity in organic plots makes it less dependent on external inputs (Hole *et al.* 2005; Belfrage *et al.* 2005; Gabriel *et al.* 2006; Wahba 2007; Mueller *et al.* 2009). Wahba (2007) found that the application of compost to sandy soils improved the soil chemically, the pH values decreased from 8.35 to 8.28, and OM increased from 0.50 to 1.01% compared to the control. Similarly, in a Rodale farming systems trial in the temperate Unites States, the level of OM changed from 2.0 to 2.5% when compost was used; however, this level decreased to 1.9% when using synthetic chemical fertilizer (Mueller *et al.* 2009).

FIBL studies in Germany showed that organic farming allows the development of a relatively diverse weed flora, 9/11 weed species were found in organically managed wheat plots and one species in conventional plots (Hole *et al.* 2005). More than twice the herbaceous plant species were found on organic than on conventional farms in Sweden (Belfrage *et al*. 2005). Gabriel *et al*. (2006) in Germany found that weed diversity was higher in organic than in conventional fields, 37 and 25%, respectively.

This increase in the content of OM in soil plays an important role in maintaining soil fertility and system stability. Its relevance is based on the environmental capacity of the soil OM to limit physical damage and to improve nutrient availability and biological activity.

The basis of fertilization in organic farming is compost that contains a variety of elements useful to plant and soil microorganisms (Arslan *et al.* 2008). The concentration of nutrients in the soil is generally validated by measuring the electrical conductivity. The electrical conductivity of a soil is related to the amount of salt it contains (Bashour and Sayegh 2007). It reflects the presence of non-nutrient ions (sodium and chloride) in the soil. This high electrical conductivity observed in the plots organically is caused by intensive input of organic fertilizers such as compost. The presence of certain species such as halophytes *Cressa cretica*, *Spergularia* ssp., *Spergula* ssp., *Mesembryanthemum* ssp., and *Hordeum* ssp. proves that the soil is salty (Novikoff 1961). Although this phenomenon is difficult to avoid, it could be limited by reducing the concentration of nutrient solutions, as "chemical" organic. The choice of an organic fertilizer less loaded these ions could therefore improve this result (Shamim and Akae 2009). The preservation of soil fertility is essential because the soil is the backbone of the production system. Organic farmers are facing more and more questions about the impact of their cultural practices on soil quality because structural problems may be particularly important (Gosai *et al.* 2009). In the case of vegetable crops, the rapid succession of many cultures over the year resulting in repeated passages gear under conditions of soak and lift sometimes inappropriate to the origin of smoothing problems related to the fight against weeds (Davies and Welsh 2002)

CONCLUSIONS

These results imply that the conversion from conventional to organic farming preserves, promotes floristic biodiversity and changes the composition and structure of weed species that can host many pollinating insects and biological control assistance. It increases the rate of OM and electrical conductivity. A broader spectrum of weed species, including rare species in conventional farming was recorded on organic plots. The limited availability and input of N, the application of mechanical and thermal weed control and more diverse crop rotation and a higher crop diversity lead to more favorable conditions for many weed species.

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Appendix I Scientific names of weeds encountered in conventional and organically farming systems.

No.	Life cycle§	Nitrato-phyte	Species (families)	Conventional farming system		Organic farming system	
				Present	No. of individuals encountered	Present	No. of individuals encountered
1	an	*	*Amaratus retroflexus* (Amaranthaceae)	x	15	x	9
2	an	*	*Amarantus lividus* (Amaranthaceae)	x	45	x	45
3	an		*Amarantus graecizanss* (Amaranthaceae)	x	31	x	34
4	an	*	*Anagallis arvensis* (Primulaceae)	x	21	x	40
5	geo		*Allium roseum* (Liliaceae)	*		x	1
6	an		*Avena sterilis* (Gramineae)	x	5	*	
7	an		*Aster squamatus* (Asteraceae)	x	1	*	
8	an		*Anacyclus clavatus* (Asteraceae)	*		x	1
9	geo		*Arisarum vulgare* (Araceae)	*		x	2
10	an		*Brachypodium distachyon* (Poaceae)	*		x	4
11	an		*Bromus madritensis* (Poaceae)	*		x	1
12	an	*	*Beta vulgaris* (Chenopodiaceae)	*		x	4
13	geo	*	*Convolvulus arvensis* (Convolvulaceae)	x	31	x	50
14	an		*Convolvulus lanatus* (Convolvulaceae)	*		x	1
15	an		*Cressa cretica* (Convolvulaceae)	*		x	4
16	an		*Chrysanthemum coronarium* (Asteraceae)	x	1	x	15
17	an		*Sherardia arvensis* (Rubiaceae)	*		x	2
18	an	*	*Chenopodium murale* (Chenopodiaceae)	x	39	x	45
19	an	*	*Chenopodium album* (Chenopodiaceae)	x	27	x	25
20	an	*	*Calendula arvensis* (Asteraceae)	x	9	x	14
21	an		*Coronilla scorpioides* (Fabaceae)	x	1	*	
22	an		*Datura stramonium* (Solanaceae)	x	2	x	6
23	bian		*Daucus carota* (Apiaceae)	x	12	x	6
24	an		*Daucus aurea* (Apiaceae)	*		x	1
25	an		*Diplotaxis harra* (Fabaceae)	*		x	1
26	an	*	*Euphorbia peplis* (Euphorbiaceae)	*		x	3
27	an		*Erodium moschatum* (Geraniaceae)	*		x	1
28	an	*	*Emex spinosa* (compositeae)	x	21	x	31
29	an		*Erigeron bonariensis* (Asteraceae)	x	14	x	27
30	an		*Fumaria densiflora* (Fumariaceae)	x	21	x	37
31	an		*Fumaria officinalis* (Fumariaceae)	x	2	*	
32	an		*Galium tricorne* (Rubiaceae)	*		x	6
33	an	*	*Glaucium flava* (Papavéraceae)	*		x	1
34	an	*	*Hordeum murinum* (Poaceae)	*		x	2
35	an		*Hiericenum pillosa* (Asteraceae)	*		x	1,37
36	an		*Heliotropium europeum* (Boraginaceae)	*		x	3
37	an		*Lolium rigidum* (Poaceae)	x	24	x	31
38	hem		*Launaea nudicaulis* (Asteraceae)	*		x	7
39	hem		*Launaea resedifolia* (Asteraceae)	*		x	5
40	an	*	*Melilotus indica* (Fabaceae)	x	7	x	40
41	cham	*	*Marrubium vulgare* (Labiaceae)	*		x	1
42	an	*	*Malva parviflora* (Malvaceae)	x	12	x	4
43	an		*Medicago hispida* (Fabaceae)	x	28	x	17
44	an		*Médicago ciliaris* (Fabaceae)	x	3	x	5
45	an		*Medicago minima* (Fabaceae)	*		x	1
46	an	*	*Mesembryanthemum cristallinum* (Aiazoaceae)	x	1	*	
47	geo		*Oxalis cernua* (Oxalidaceae)	x	3	x	24
48	an		*Onobrychis argentea* (Fabaceae)	*		x	1
49	an		*Papaver hybridum* (Papaveraceae)	*		x	14
50	an	*	*Papaver rhoeas* (Papaveraceae)	x	8	x	6
51	an		*Papaver dubium* (Papaveraceae)	*		x	1
52	an		*Picris picroides* (Asteraceae)	*		x	6
53	an		*Poa annua* (Poaceae)	x	3	x	10
54	an		*Polygonum aviculare* (Polygonaceae)	x	5	*	
55	an		*Phalaris paradoxa* (Poaceae)	x	3	*	
56	an		*Portulaca oleracea* (Portulacacreae)	*		x	8
577	hem		*Plantago albicans* (Plantaginaceae)	*		x	1
58	an		*Raphanus raphanistrum* (Cruciferaceae)	x	3	x	7
59	an		*Rapistrum rugosum* (Cruciferaceae)	x	1	x	8
60	an		*Rumex conglomerata* (Polygonaceae)	x	5	x	2
61	an		*Reseda alba* (Resedaceae)	*		x	3
62	an		*Scandix pecten-veneris* (Apiaceae)	*		x	3
63	an		*Sonchus tenerrimus* (Asteraceae)	*		x	5
64	an		*Sonchus asper* (Asteraceae)	x	1	x	2
65	bian	*	*Silybum marianaum* (Asteraceae)	*		x	1
66	geo		*Cynodon dactylon* (Poaceae)	x		x	18
67	an	*	*Sisymbrium irio* (Cruciferaceae)	x	29	x	9
68	an		*Sinapis alba* (Cruciferaceae)	x	2	x	25
69	an		*Sonchus oleraceus* (Compositeae)	x	13	x	21
70	an		*Stellaria media* (Caryophyllaceae)	x	19	x	16

Appendix I Scientific names of weeds encountered in conventional and organically farming systems.

No.	Life cycle[§]	Nitrato-phyte	Species (families)	Conventional farming system		Organic farming system	
				Present	No. of individuals encountered	Present	No. of individuals encountered
70	an		*Stellaria media* (Caryophyllaceae)	x	19	x	16
71	an	*	*Solanum nigrum* (Solanaceae)	x	7	*	
72	geo		*Cyperus rotundus* (Cyperaceae)	x	4	*	
73	an		*Scorpiurus muricatus* (Fabaceae)	*		x	1
74	an		*Senecio vulgare* (Asteraceae)	*		x	1
75	an		*Scorpiurus vermiculatus* (Fabaceae)	*		x	4
76	an		*Centaurea nicaeensis* (Asteraceae)	*		x	2
77	hem		*Centaurea acaulis* (Asteraceae)	*		x	1
78	an	*	*Spergularia diandrus* (Caryophyllaceae)	*		x	5
79	an	*	*Spergula arvensis* (Caryophyllaceae)	x	1	*	
80	an		*Setaria verticillata* (Poaceae)	x	26	x	39
81	hem		*Taraxacum officinalis* (Asteraceae)	*		x	5
82	an		*Torilis nodosa* (Apiaceae)	x	3	x	8
83	an	*	*Urtica urens* (Urticaceae)	x	64	x	29
84	an		*Urespermum picroides* (Asteraceae)	x	1	*	
85	hem		*Verbascum undulattum* (Caryophyllaceae)	*		x	1
86	an		*Vicia sativa* (Fabaceae)	*		x	1
			Total	44	576	75	823

[§]An = annual, bian = biannual, Cham = Chamephytes, hem = Hemicryptophyte, Geo = Geophyte