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# ORGANIC, INTEGRATED AND CONVENTIONAL MANAGEMENT IN APPLE ORCHARDS: EFFECT ON PLANT SPECIES COMPOSITION, RICHNESS AND DIVERSITY

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## Abstract

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The study was conducted to assess the effect of conventional, integrated and organic management on differences in plant species composition, richness and diversity. The plants were studied in triads of orchards situated in three regions of the Czech Republic. Data about species occurrences were collected on 15 permanent plots in the tree rows and 15 plots between tree rows in each of the apple orchards during 2009. A total of 201 vascular plant species (127 native species, 65 archaeophytes, and 9 neophytes) were found. Management type and also different regional conditions had a significant effect on plant species composition and on diversity parameters of orchard spontaneous vegetation. Species richness and species pool was significantly higher in the organic orchards than in the differently managed orchards. Management type had significant effect on proportions of archaeophytes, and also neophytes in apple orchards. The results showed that a change from conventional to integrated and organic management in apple orchards lead to higher plant species diversity and to changes in plant species composition.

orchards, Czech Republic, invasive plants, ordination, weeds

The intensity of agricultural practices involved in differently managed farming systems impact plant and animal species found in habitats of these agroecosystems. Nature-friendly management may be a viable practice to conserve or enhance plant diversity. Organic farming is reported to increase diversity of many taxonomical groups (e.g. Bengtsson *et al.*, 2005; Hole *et al.*, 2005).

Since the beginning of the 21th century, there has been an active transition from conventional to integrated and organic farming systems in the Czech Republic. Tab. I documented that integrated and organic production increase, also in the frame of fruit production in the Czech Republic. Aims of integrated as well as organic farming systems are to stabilize the crop yield while reducing the input of synthetic chemicals, mainly nitrogen, phosphorus, and pesticides into the ecosystems, improving the quality of soil, and increasing the biodiversity of agricultural land.

I: *Development of the orchard area in the Czech Republic in different farming systems (according to Ministry of Agriculture, SISPO)*

| Year | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|
| Total area of orchards (ha) | 24 984 | 21 948 | 20 678 | 20 368 | 21 140 | 21 738 |
| Total area of integrated orchards (ha) | 7 752 | 9 312 | 10 244 | 10 662 | 10 757 | 11 042 |
| Total area of organic orchards (ha) | 1 170* | 820* | 1 196* | 1 625 | 2 764 | 3 678 |

* including vineyards

Conventional system is limited only by economical aspects regardless of environment protection, biodiversity and agroecosystem stability. There are no restriction in pesticides and mineral fertilizers use. Integrated production is transitional between conventional and organic production. It prefers ecologically acceptable methods and minimizes undesirable secondary effects of agrochemicals. The farming rules in fruit growing are strictly given according to SISPO (Union for integrated systems of fruit-growing; Ludvík *et al.*, 2008). Common features of organic farming are elimination in use of chemical pesticides and mineral fertilizers and strong emphasis on natural character of production.

There exist many separate studies which determine effects of different agricultural practices on spontaneous vegetation in many agricultural land use types (see Moreby *et al.*, 1994; Hald, 1999; Hole *et al.*, 2005; Nečasová *et al.*, 2007; Tyšer *et al.*, 2008). These studies determined the significant differences especially in annual plant species richness and in occurrences of rare and declining species in organic agroecosystems. The changes in plant species composition of grassland systems were less remarkable (Frieben, Kopke, 1995; Younie, Armstrong, 1995). An opposite pattern for pastures in Sweden showed Weibull *et al.* (2003). Studies comparing effects of management on spontaneous vegetation of orchards in Central Europe are still missing. Our research is focused to the apple orchards, which are the most common orchards in the Czech Republic and it is focused to such areas in our country, where orchards are widespread. The aims of the present study are (1) to evaluate differences in the diversity of flora and vegetation in apple orchards subjected to the different management practices, and (2) to determine effect of management on changes in species composition and on proportion of native and alien species in orchard spontaneous vegetation.

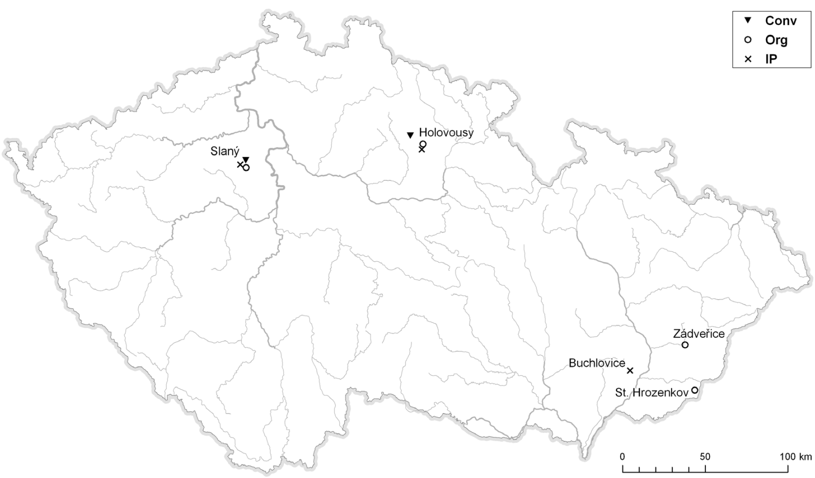
## MATERIAL AND METHODS

### Study area

The survey was carried out in three triads of selected apple orchards in the Czech Republic. The orchards were situated in Moravia (localities Buchlovice, Starý Hrozenkov, Zádveřice) and in Central (locality Slaný) and Eastern (locality Holovousy) Bohemia (Tab. II, Fig. 1). In these

II: *Climatic conditions of studied orchards*

| | | Geographical position | Elevation (m a s.l.) | Rainfall (mm/year) | Mean annual temperature (°C) |
|---|---|---|---|---|---|
| Conventional | Holovousy | N 50°23”11.9’ E 15°31”45.1’ | 312 | 700 | 8.0 |
| | Slaný | N 50°14”28.2’ E 14°07”31.3’ | 263 | 483 | 8.2 |
| Integrated | Holovousy | N 50°18”44.8’ E 15°37”24.8’ | 261 | 700 | 8.0 |
| | Slaný | N 50°13”51.1” E 14°06”42.8’ | 278 | 483 | 8.2 |
| | Buchlovice | N 49°05”22’ E 17°20”02’ | 368 | 628 | 8.2 |
| Organic | Holovousy | N 50°20”25.2’ E 15°38”12.9’ | 274 | 700 | 8.0 |
| | Slaný | N 50°13’13.2’ E 14°08’19.2” | 265 | 483 | 8.2 |
| | Zádveřice | N 49°12”59.5’ E 17°47”49.0’ | 269 | 795 | 8.0 |
| | St. Hrozenkov | N 48°58”08.0’ E 17°51”50.0’ | 557 | 843 | 7.6 |




1: *Map of studied orchards*

III: *Treatments in the studied orchards applied during the vegetation season 2009. IP – integrated, Org – organic, Conv – conventional*

| Orchards | Area | Insecticides | Fungicides | Herbicides | Mowing | Mulching |
|---|---|---|---|---|---|---|
| IP Buchlovice | 7 ha | 7 × | 11 × | 2 × [1] | 2 × | 2 × |
| Org St. Hrozenkov | c. 8 ha | 0 × | 0 × | 0 × | 0 × | grazing |
| Org Zádveřice | c. 4 ha | 0 × | 0 × | 0 × | 0 × | 0 × |
| IP Slaný | 21.32 ha | 11 × | 14 × | 2 × [2] | 4 × | 4 × |
| Org Slaný | 12.3 ha | 0 × | 0 × | 0 × | 4 × | 4 × |
| Conv Slaný | 4 ha | 6 × | 15 × | 3 × [3] | 2 × | 3 × |
| IP Holovousy | 28 ha | 8 × | 18 × | 2 × [4] | 2 × | 2 × |
| Org Holovousy | 4 ha | 0 × | 0 × | 0 × | 2 × | 3 × |
| Conv Holovousy | c. 6 ha | 6 × | 11 × | 1 × [5] | 1 × | 2 × |

[1] 15. 6. – Glyfogan 480 SL (0.3 L $ha^{-1}$), 27. 7. – Glyfogan 480 SL (0.3 L $ha^{-1}$)
[2] 24. 4. – Glyfogan 480 SL (5 L $ha^{-1}$) + Agritox 50 XL (2.5 L $ha^{-1}$), 7. 8. – Glyfogan 480 SL (6 L $ha^{-1}$)
[3] 7. 5. – Touchdown Quattro (3 L $ha^{-1}$), 22. 6. – Touchdown Quattro (3 L $ha^{-1}$), 15. 8. – Touchdown Quattro (3 L $ha^{-1}$)
[4] 13. 5. – Touchdown Quattro (3 L $ha^{-1}$) + Agritox 50 SL (1.5 L $ha^{-1}$), 10. 6. – Touchdown Quattro (3 L $ha^{-1}$) + Agritox 50 SL (1.5 L $ha^{-1}$)
[5] 20. 4. – Roundup Klasik (1,3 L $ha^{-1}$)

localities fruit cultivation is widespread and traditional. In each Bohemian region one conventional, one integrated and one organic orchard were chosen. In Moravia, two organic and one integrated orchard were observed. Climatic conditions see in Tab. II. Mean annual temperature and rainfall for each orchard were obtained from digitalized maps based on *Climate atlas of the Czech Republic* (Anonymus, 2007) in ArcGIS.

### Data sampling

Thirty permanent plots of 1 × 1 m were established in each of the studied orchards. Fifteen plots were situated in tree-rows and fifteen between rows of apple trees. They were located randomly. Species composition and cover of vascular plants were sampled in the plots repeatedly throughout the growing season 2009. Nomenclature of plants follows Kubát *et al.* (2002). The management during the season in each of studied orchards is shown in Tab. III.

### Statistical analyses

As we don't study seasonal changes in vegetation on the plots, data from all three censuses for each plot were pooled together to have information about all plant species occurred on the plot during the whole vegetation season.

We calculated the mean number of species per plot (alpha diversity) and the total number of species occured on all 30 plots in one orchard (gamma diversity). Plants were classified according to their residence time to three groups; natives, archaeophytes (exotics introduced to the Czech Republic before 1500), and neophytes (exotics introduced after 1500; Pyšek *et al.*, 2002).

Two-factor analyses of variance were conducted to test significance of differences among plots in orchards of three regions of the Czech Republic and among plots with different management type of orchards. These analyses were carried out using Statistica 8 software (www.statsoft.com).

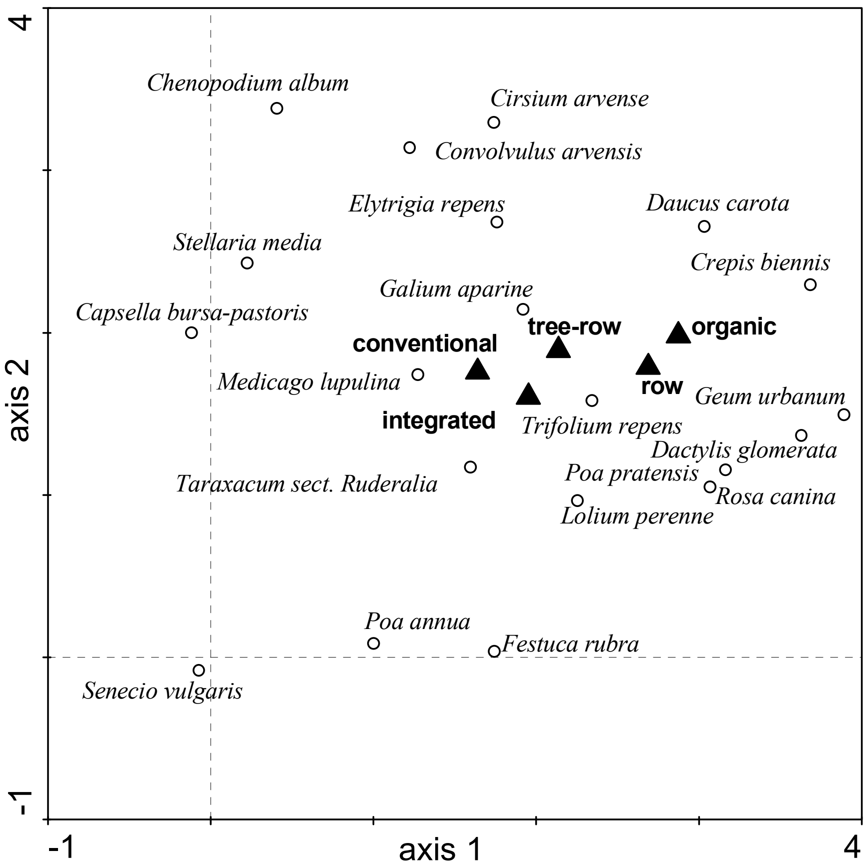
Ordination techniques were used to show main gradients in changes in species composition. As the first gradient was rather long (more than 5 SD units), we used unimodal ordination techniques in further calculations: detrended correspondence analysis (DCA) and canonical correspondence analysis (CCA). The effect of particular factors on species composition was evaluated by randomization tests with 1000 permutations. These analyses were done using CANOCO program (ter Braak, Šmilauer, 2002).

## RESULTS

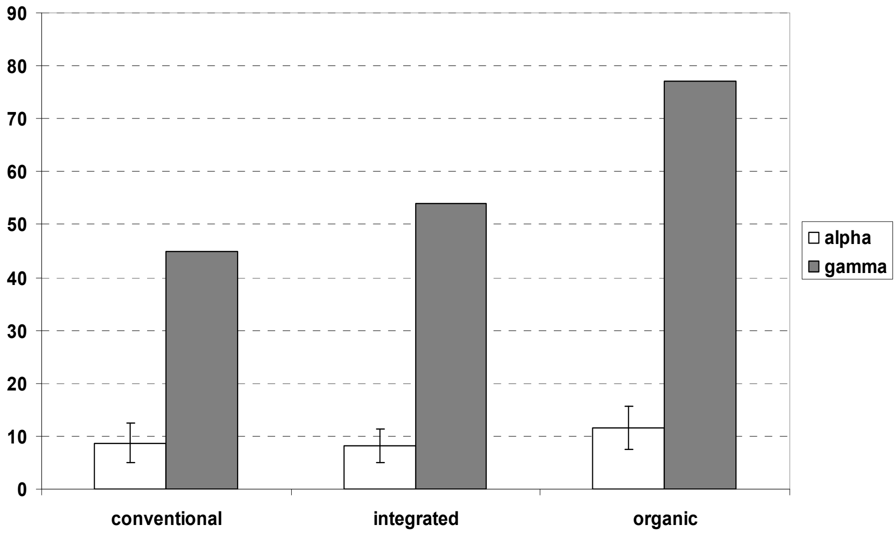
Detrended correspondence analysis reveals the main gradients in changes in species composition of spontaneous vegetation of apple orchards (Fig. 2). Fig. 2 shows that the main gradient which is associated with first ordination axis of diagram goes from plots of conventional and integrated orchards on the left part of the diagram to plots of organic orchards situated in the right part. This gradient is partly associated also with difference in vegetation between rows and tree-rows plots. The conventional and integrated plots are characterized by common weed species e.g. *Stellaria media*, *Convolvulus arvensis*, and *Senecio vulgaris*. Organic plots host mainly common perennial species (*Crepis biennis*, *Geum urbanum*, *Rosa canina*).

Management type but also differences between regions had a significant effect on changes in species composition of studied vegetation. The effect of different region with the different local soil and climatic condition was found more important using CCA and Monte Carlo permutation tests than effect of management type (not shown).

A remarkable difference between average species richness within a plot (alpha diversity) and total number of species found on all 30 plots in each orchard (gamma diversity) of conventional,




2: *Ordination diagram of detrended correspondence analysis (DCA) with passively projected environmental variables onto the diagram. Only species having the highest weight in the analysis are given.*




3: *Alpha and gamma diversity of vascular plants in each type of studied orchards. White columns show mean number of species per plot (alpha diversity) and grey columns show total number of species found on all 30 permanent plots in orchard (gamma diversity). Bars show standard deviation for alpha diversity values.*

integrated and organic orchards was found (Fig. 3; Tab. IV). The highest values of both alpha and gamma diversity were in organic orchards, followed by integrated and conventional ones. The significant differences in diversity measures were also found between all three compared regions. The lowest

IV: *Diversity parameters, and proportions of different species groups in each plot of compared orchards. Means and standard deviations (SD) are given. Significance of the differences in these characteristics was tested using ANOVA tests.*

| | Conventional | | | | IP | | | | | | Organic | | | | | | | | Management effect | | Region effect | | Region x management effect | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Holovousy | | Slaný | | Holovousy | | Slaný | | Buchlovice | | Holovousy | | Slaný | | Zádveřice | | St. Hrozenkov | | | | | | | |
| | mean | SD | mean | SD | mean | SD | mean | SD | mean | SD | mean | SD | mean | SD | mean | SD | mean | SD | F | p | F | p | F | p |
| No of species per plot | 11.6 | | 5.8 | | 6.2 | | 6.9 | | 11.4 | | 11.5 | | 7.6 | | 15.4 | | 12.1 | | 75.55 | 0.001 | 253.52 | 0.001 | 178.84 | 0.001 |
| No of all species of orchard | 54 | | 37 | | 38 | | 42 | | 82 | | 51 | | 44 | | 110 | | 103 | | | | | | | |
| Proportion of natives | 74.73 | 17.94 | 59.35 | 20.64 | 74.40 | 26.28 | 74.58 | 18.00 | 62.13 | 13.19 | 48.99 | 18.46 | 77.70 | 15.66 | 66.74 | 11.06 | 87.62 | 9.42 | 1.79 | n.s. | 4.14 | 0.001 | 6.03 | 0.001 |
| Proportion of archaeophytes | 23.68 | 17.42 | 36.47 | 20.45 | 25.20 | 26.03 | 25.09 | 18.00 | 34.24 | 12.34 | 36.13 | 15.85 | 18.59 | 14.75 | 29.77 | 10.99 | 7.22 | 7.52 | 10.94 | 0.001 | 6.59 | 0.002 | 3.59 | 0.01 |
| Proportion of neophytes | 1.51 | 3.25 | 2.88 | 6.75 | 0.12 | 1.17 | 0.00 | 0.00 | 2.34 | 4.73 | 14.88 | 7.27 | 2.32 | 5.15 | 3.08 | 4.21 | 1.94 | 3.76 | 53.52 | 0.001 | 29.7 | 0.001 | 3.59 | 0.01 |

alpha and gamma diversity values were found for vegetation of central Bohemian orchards (locality Slaný); 5.8–7.6 species per plot (number of all species 37–44) while the highest alpha and gamma diversity values were found in Moravian region: 11.4–15.4 species per plot (number of all species 82–110). All the differences between diversity measures were statistically significant ($P < 0.001$; ANOVA).

There have been found 201 vascular species; among them 127 natives, 65 archaeophytes, and 9 neophytes. The most common archaeophytes in our data set are *Capsella bursa-pastoris*, *Senecio vulgaris*, and *Cirsium arvense*; the most common neophytes are *Amaranthus retroflexus*, *Veronica persica*, *Oxalis fontana*, and *Conyza canadensis*.

Proportion of native species varried between 49 and 87% per plot, while archaeophytes and neophytes built 7–36% and 0–14% of species per plot, respectivelly. Tab. IV presents the mean numbers of native and alien (both archaeophytes and neophytes) species in studied orchards. Only inconspicuous differences in proportion of native species were recorded between differently managed apple orchards. There was a significant difference in proportions of archaeophytes and neophytes under different management systems.

## DISCUSSION

Our data suggest that transition from conventional to integrated and organic management in apple orchards of the Czech Republic caused remarkable changes in plant species composition and an increase in species richness and diversity. Such results are in accordance with many studies comparing different taxonomical groups under different management type of agroecosystems (Bengtsson *et al.*, 2005; Hole *et al.*, 2005; Tasseva, 2005; Boutin *et al.*, 2008). However, changes in species composition and differences in biodiversity measures in agricultural habitats are obviously affected by many factors other than the management type. Our data showed that not only management type but also different climatic and soil conditions or different landscape structure of compared regions significantly affect species composition of studied agricultural habitats. Such results sound with data of Weibull *et al.* (2003), who emphasize importance of controlling for landscape features when comparing the effect of management and the effect of landscape. Anyway, the differences between vegetation of organic, integrated and conventional orchards were remarkable. The conventionally managed plots were dominated by annual ruderal species, whereas organic and integrated management resulted in dominance of perennial species, mostly grasses. Such results are in accordance with study of weed vegetation in mulched vineyards (Lososová *et al.*, 2003) and for changes in species composition of differently managed cereal fields (Hald, 1999).

It is suggested that organic farming management lead to increase of all diversity parameters. Such pattern was repeatedly documented for annual weed vegetation of organic cereal fields from many European countries (e.g. Bengtsson *et al.*, 2005; Hole *et al.*, 2005, Clough *et al.*, 2007; Boutin *et al.*, 2008). Roschewitz *et al.* (2005) showed that diversity parameters increased with increasing heterogeneity of landscape. Although he found that alpha and gamma diversity was higher in organic fields, the beta diversity was higher in conventional fields.

It is not easy to assess a clear relationship between diversity of weed vegetation and management type for grasslands, pastures and other perennial agricultural habitats. Our results from perennial weed vegetation of orchards showed significant but weak increase of alpha and gamma diversity in organically managed orchards compared to conventional or integrated ones. The differences between conventional and integrated orchards in the Czech Republic are not always sharp. Usually, it depends on particular orchard owners and farmers. Thus, biodiversity level in particular farming system isn't given just by the system itself but by concrete applied intensity, accuracy and consequentiality of agrotechnical operations (Callauch, 1981; Tyšer *et al.*, 2008).

Except of agrochemicals, other factors may affect the diversity parameters of vegetation. Dense stands of grass mixtures between rows (*Festuca rubra, Lolium perenne* etc.) affected decrease in total species richness at observed plots – thanks to canopy closure and strong competitiveness of grass couldn't other plant species assert. Similarly at organic arable fields, dense undersowing (*Trifolium, Lolium* etc.) in cereals reduces species diversity (van Elsen, 2000).

There was a clear difference in proportions of archaeophytes and neophytes between compared three management types. Numerous archaeophytes were found in conventional and integrated orchards. Most of them are annual weed species of Mediterannean origin. In the Czech Republic they occur preferably in cereal fields (Lososová, Grulich, 2009). Comparable results were found by Hald (1999) for weed vegetation of organic and conventional cereal fields in Denmark. An extremely different species composition was found in organic orchard Holovousy (eastern Bohemia), where high occurrence of both archaeophytes and neophytes was recorded. While in organic orchard Holovousy self-grassing was applied, in other orchards grass mixtures were sown. These dense stands of grass mixtures occurred in majority of apple orchards reduce seedling of alien weed species.

Comparing to annual weed vegetation in cereal and root crop arable fields, orchard weed vegetation contains relatively low proportion of both archaeophytes and neophytes (Lososová, Cimalová, 2009). It is built mainly by native species. From this point of view, preferably organic orchards seem to be the suitable secondary habitats for surviving of many native species in agricultural areas of the Czech Republic.

## SUMMARY

The survey was carried out in three triads of selected apple orchards in the Czech Republic in 2009. The orchards were situated in Moravia and in Central and Eastern Bohemia. In each Bohemian region one conventional, one integrated and one organic orchard were chosen. In Moravia, two organic and one integrated orchard were observed. Thirty permanent plots of 1 × 1 m were established in each of the studied orchards. Fifteen plots were situated in tree-rows and fifteen between rows of apple trees. Species composition and cover of vascular plants were sampled in the plots repeatedly throughout the growing season. We calculated the mean number of species per plot (alpha diversity) and the total number of species occured on all 30 plots in one orchard (gamma diversity). Plants were classified according to their residence time to three groups; natives, archaeophytes, and neophytes. Management type but also differences between regions had a significant effect on changes in species composition of studied vegetation. The effect of different region with the different local soil and climatic condition was found more important using CCA and Monte Carlo permutation tests than effect of management type.

The highest values of both alpha and gamma diversity were in organic orchards, followed by integrated and conventional ones. The significant differences in diversity measures were also found between all three compared regions. There have been found 201 vascular species; among them 127 natives, 65 archaeophytes, and 9 neophytes. The most common archaeophytes in our data set are *Capsella bursa-pastoris*, *Senecio vulgaris*, and *Cirsium arvense*; the most common neophytes are *Amaranthus retroflexus*, *Veronica persica*, *Oxalis fontana*, and *Conyza canadensis*. Proportion of native species varried between 49 and 87% per plot, while archaeophytes and neophytes built 7–36% and 0–14% of species per plot, respectivelly.

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