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Seasonal dynamics and diversity of weed vegetation in tilled and mulched vineyards

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Seasonal dynamics of weed vegetation and their response to tilling and mulching were studied in a vineyard in the south-eastern part of the Czech Republic. The objective of the study was to determine shifts in the diversity of weed vegetation, associated with the transition from intensive agricultural management with frequent tilling and herbiciding, to a more environment-friendly management by mulching. Vegetation was studied in permanent plots of 1 × 1 m. First sampling was done in 1994, when even lanes, between the rows of grapevine, were still tilled while mulching was newly introduced in odd lanes. After the entire vineyard had been converted into mulching in 1995, permanent plots were re-sampled in 1999 and 2000. The plots were repeatedly sampled 5 to 7 times a year. In this way, three variants could be compared, including tilling, recently introduced mulching, and mulching lasting for 4–6 years. Redundancy analysis and variance partitioning showed that 49.5% of the variation in species composition could be explained by management and 22.6% by seasonal changes. Mulching led to increased species richness and to an increased proportion of hemicryptophytes at the expense of therophytes. Species associated with particular management types and particular seasons were determined.

Key words: management, ordination, plant community, weed control, Czech Republic.

Introduction

The grapevine, *Vitis vinifera* L., is traditionally planted in the warmest and driest areas of Central Europe. The composition of weed flora in the vineyards is strongly affected by agricultural practices (FISCHER, 1983; WILMANNS, 1989). Vineyard weed communities are formed of species adapted to the life cycle of the grapevine and to human interventions in the crop (ELIÁŠ, 1983). In some areas, these relationships result in the development of specific weed communities confined to vineyards. For example, the *Geranio rotundifolii-Allietum vinealis*, which is traditionally recognized as a vineyard weed community in southern Germany, is remarkable through the abundance of vernal bulbous geophytes (FISCHER, 1983; WILMANNS, 1989; WILMANNS & BOGENRIEDER, 1992).

In southern Moravia, a traditional wine-growing area of the Czech Republic, no evidence exists that vineyards support the development of specific weed communities. Current management practices, used since the late 1950s and early 1960s, have included frequent soil tilling combined with herbicide treatment during the growing season. Under this management, weed vegetation is very poor in species and includes mainly generalist annual species, more or less resistant to herbicides. Syntaxonomically, most stands belong to the alliance *Fumario-Euphorbion* (Vilčeková, 1981; Eliáš, 1983; Otýpková, 2001). Earlier reports on weed vegetation in this area (Laus, 1908; Stummer, 1932) are mainly concerned with flora, and do not allow the reconstruction of weed vegetation before the current management practices were adopted.

Since the beginning of the 1990s, a new, environment-friendly management system has been introduced in some vineyards of southern Moravia, making use of the experience of the viniculturists of Switzerland, Germany, and France (Hampl et al., 1995). It includes mulching of herbaceous vegetation between the rows of grapevine, instead of tilling and herbiciding, in association with the biological control of insect parasites and limited use of pesticides. The objective of this paper is (1) to characterize the changes in vineyard weed vegetation after introduction of this new management and (2) to compare seasonal dynamics in tilled and mulched vineyards.

Material and methods

Study site

For the weed vegetation studies, a vineyard near the town of Mikulov, near the Czech-Austrian border (48°48′15″ N, 16°38′46″ E) was chosen. Situated on the southern slope of Svatý kopeček Hill at an altitude of 246–266 m, it is part of a large area covered mainly with vineyards and bordered by shrubberies in the lower part. The rows of grapevine run down the hill. The hill above the vineyards is covered with seminatural dry grasslands. The study site is situated in the warmest and driest part of the Czech Republic. The mean annual temperature is 9.3 ℃, and the mean annual precipitation amounts to 571 mm (Vesecký et al., 1961). The bedrock is Jurassic limestone, covered with Pleistocene stony slope deposits.

Sampling

Until 1993, the entire vineyard was regularly tilled. In 1994, the even lanes between the rows of grapevine were tilled, while the odd lanes were mulched, and since 1995, all the lanes have been mulched. Vegetation sampling started in 1994. A total of 60 permanent plots of 1 × 1 m were established, randomly located across the vineyard, and always in the middle of the distance between two adjacent rows of grapevine. Of these, 30 were located in tilled and 30 in mulched lanes. The observations started after an agreement with the owner of the vineyard, who originally intended to keep the pattern of alternating mulched and tilled lanes unchanged for several years. The originally planned experiment was aimed at testing the interaction of treatment and time, however, it could not be accomplished due to an unexpected conversion of the entire vineyard to mulching in 1995. Therefore, sampling was interrupted in 1995–1998, but all the plots were sampled again in 1999 and 2000 to determine changes in weed vegetation after a few years of mulching. All the permanent plots were repeatedly sampled in roughly regular intervals between April and October; the sampling procedure was repeated seven times in 1994, six times in 1999 and five times in 2000. Cover-abundance of all species was estimated using the Braun-Blanquet scale. All the data were stored in an electronic database managed by the TURBOVEG program (Hennekens & Schaminée, 2001).

Taxonomy and nomenclature

Scientific names of vascular plants follow Ehrendorfer (1973) except for *Taraxacum* sect. *Ruderalia* Kirschner et al. In some cases we could only use species aggregates because individuals of some genera, such as *Chenopodium* and *Atriplex*, were difficult to identify in the juvenile stage or when damaged by severe agrotechnical treatments. For the same reasons, *Bromus sterilis* and *B. tectorum* were aggregated as *Bromus* species.

Data analysis

Changes in species composition were analysed in synoptic vegetation tables, prepared with the JUICE program (Tichý 2002). To measure species concentration in the partitions of these tables and to determine diagnostic capacity of the species, the phi coefficient of association (Sokal & Rohlf 1995, Chytrý et al. 2002) was used. Most descriptive and univariate statistical calculations were performed in the SPSS program (SPSS Inc., 1998).

Some of the permanent plots contained no species in at least one census, which would generate problems in the ordination analysis of individual plots. Therefore all the plots within one census were combined, using species frequencies, and the entire censuses, instead of individual plots, were analysed as the basic sampling units. For the 1994 census, 30 tilled and 30 mulched plots were combined separately, while for the 1999 and 2000 censuses, all 60 mulched plots were merged. In this way the data set was divided into four categories, representing tilling (1994, tilled plots), newly introduced mulching (1994, mulched plots), and mulching lasting for 5–7 years (1999 and 2000 censuses). These four categories may be considered as a single categorical variable which is referred to as *Management* in further analyses.

Another variable, called *Season*, represents the time of the year when the census was done, thus describing the seasonal dynamics. This variable was measured on an ordinal scale of 15-day intervals from the beginning of the year. For example, censuses on 10 May and 20 June were given values of 9 and 12, respectively.

The data were subjected to ordination analysis, using the CANOCO 4 package (TER BRAAK & ŠMILAUER, 1998). In order to remove large differences in the number of species between the tilled and mulched plots, the data were standardized by samples. The differences between common and infrequent species were reduced by a square-root transformation of the *species* × *censuses* matrix. As the length of the first gradient in the detrended correspondence analysis was rather short (2.18 SD units), linear methods, namely principal components analysis (PCA) and redundancy analysis (RDA) were used.

First, effects of the environmental variables on species composition were tested by the Monte Carlo permutation test in RDA. As the species composition of weed vegetation in autumn is somewhat similar to that in spring, the species response to the variable *Season* can be non-linear; therefore the squared variable *Season* was also considered. Its effect was tested only in addition to the variance explained by the linear variable *Season*. Monte Carlo permutations were performed in blocks defined by *Management* categories, using cyclic shifts to take account of possible temporal autocorrelation between the censuses.

Then, the variance in species data explained by individual variables was calculated both in the analyses with other variables defined as covariables to determine pure effects, and in the analyses without covariables. The method of variance decomposition proposed by BORCARD et al. (1992) was used to determine the effects of individual variables.

Relationships between individual variables and species were visualised in the PCA ordination diagram where environmental variables were projected as supplementary (passive). These variables did not affect the extraction of ordination axes, i. e. the diagram shows an unconstrained variation pattern of sampling units and species.

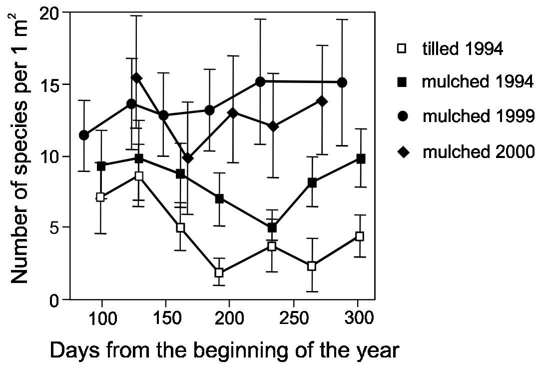

Fig. 1. Changes in species richness during the season. Error bars represent standard deviation for mean.

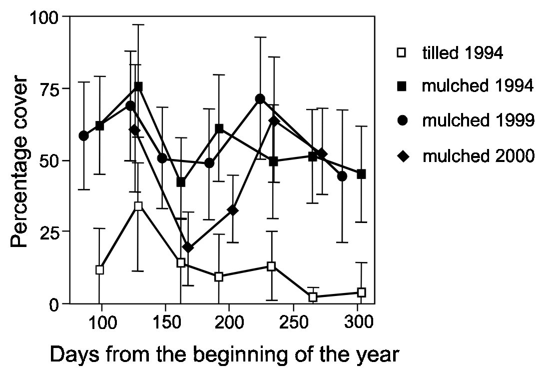

Fig. 2. Changes in vegetation cover during the season. Error bars represent standard deviation for mean.

Results

Changes in weed vegetation

Fig. 1 shows the remarkable increasing trend in the number of species between 1994 and 1999/2000. While the number of species per plot in the tilled rows fluctuated between 1 and 9 in 1994, there were 5–10 species per plot in the mulched rows in the same year. In 1999 and 2000 there were 10–15 species per plot. During the growing season, the highest number of species was found in May. It decreased in summer, and increased again in September and October. This trend was apparent in all the growing seasons monitored in this study.

Seasonal dynamics of vegetation cover reflected the differences in management (Fig. 2). The cover in 1994 of tilled plots fluctuated on average between 0 and 30% throughout the year, while in the mulched plots it ranged on average between 40 and 70%. After seven years of mulching the cover in the mulched plots was similar as in the plots with newly introduced mulching.

Percentage proportions of plant life forms (Fig. 3) have changed due to mulching. Therophytes were the most common life form encountered in the vineyard, followed by hemicryptophytes, geophytes, and juvenile woody plants (the latter category is not shown in Fig. 3, as it was represented by very few species). Therophytes dominated the tilled plots, but after a few years of mulching the proportion of hemicryptophytes increased at the expense of therophytes. Proportions of geophytes and juveniles did not change significantly.

The differences in species composition are summarized in Tab. 1. In 1994, tilled plots were characterized only by the occurrence of *Fumaria*

Table 1. Differences in species composition due to management. Values represent species frequencies. 1994t – tilled in 1994; 1994m, 1999m, 2000m – mulched in respective years. Values for species with the phi coefficient of association in particular columns higher than 10 are shown in bold; these species are ranked by decreasing phi values. Species not exceeding 5% frequency in any of the columns are not shown.

Management	1994t	1994m	1999m	2000m
Number of plots	210	210	360	300
Species associated with tilled plots in 1994				
Fumaria sp.	**17**	4	.	.
Species associated with mulched plots in 1994				
Amaranthus retroflexus	38	**69**	25	2
Chenopodium album	10	**36**	11	2
Papaver rhoeas	3	**14**	1	.
Thlaspi arvense	11	**20**	1	1
Sisymbrium orientale	3	**19**	7	5
Capsella bursa-pastoris	35	**50**	38	21
Chenopodium hybridum	9	**10**	1	2
Species associated with mulched plots in 1999				
Lactuca serriola	2	19	**48**	13
Conyza canadensis	2	45	**58**	33
Erodium cicutarium	16	49	**69**	52
Veronica polita	19	46	**51**	28
Setaria viridis	.	1	**17**	13
Geranium pusillum	.	3	**15**	11
Stellaria media	55	70	**73**	53
Tripleurospermum inodorum	1	2	**16**	15
Sonchus oleraceus	.	.	**3**	1
Lathyrus tuberosus	.	.	**5**	3
Setaria verticillata	.	.	**4**	2
Veronica triloba	.	.	**2**	.
Cirsium arvense	11	13	**25**	23
Cardaria draba	12	14	**22**	15
Species associated with mulched plots in 2000				
Atriplex sp.	5	23	36	**66**
Artemisia vulgaris	.	3	17	**39**
Polygonum aviculare agg.	10	30	32	**57**
Crepis rhoeadifolia	.	.	14	**27**
Medicago lupulina	1	1	18	**29**
Tragopogon dubius	.	1	15	**24**
Carduus acanthoides	1	5	16	**23**
Geum urbanum	.	.	4	**8**
Calamagrostis epigejos	.	.	3	**6**
Picris hieracioides	.	.	.	**2**
Agropyron repens	1	2	9	**12**
Melica ciliata	.	.	2	**4**
Crepis biennis	.	.	1	**3**
Plantago lanceolata	.	.	1	**3**
Poa pratensis agg.	.	.	5	**6**
Species associated with both tilled and mulched plots in 1994				
Descurainia sophia	**20**	**20**	4	1
Asperugo procumbens	**26**	**39**	4	2
Lamium amplexicaule	**45**	**49**	32	15
Species associated with mulched plots both in 1999 and 2000				
Taraxacum sect. *Ruderalia*	1	7	**89**	**80**
Torilis arvensis	.	1	**56**	**51**
Hordeum murinum	.	3	**65**	**74**
Bromus sp.	1	3	**50**	**50**
Bromus japonicus	.	1	**43**	**39**

Table 1. (continued)

Management	1994t	1994m	1999m	2000m
Number of plots	210	210	360	300
Arenaria serpyllifolia agg.	.	4	**37**	**32**
Achillea pannonica	.	.	**28**	**39**
Lolium perenne	.	.	**40**	**65**
Ballota nigra	1	3	**17**	**18**
Arctium tomentosum	.	2	**24**	**33**
Falcaria vulgaris	.	2	**13**	**14**
Other species				
Convolvulus arvensis	87	83	74	88
Malva neglecta	1	16	12	11
Veronica sublobata	22	24	30	19
Reseda lutea	1	4	9	9
Rosa canina	1	3	8	8
Senecio vulgaris	1	2	6	2

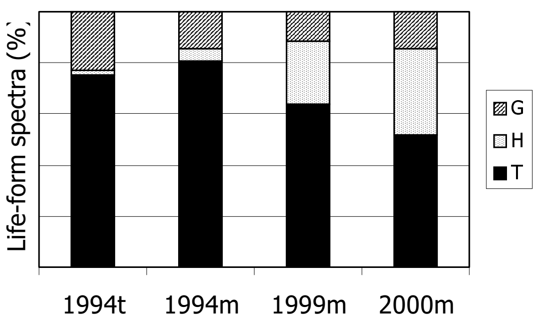

Fig. 3. Changes in plant life-form spectra. Life forms: therophytes (T), hemicryptophytes (H), geophytes (G). 1994t – tilled in 1994; 1994m, 1999m, 2000m – mulched in respective years.

species. In the same year ruderal species, *Amaranthus retroflexus*, *Chenopodium album, Papaver rhoeas*, *Thlaspi arvense, Sisymbrium orientale*, *Capsella bursa-pastoris*, and *Chenopodium hybridum*, occurred mainly in the mulched plots. The group of species associated with the mulched plots in 1999 included some ruderals, mainly annual ones, such as *Conyza canadensis*, *Veronica polita*, *Erodium cicutarium*, and *Sonchus oleraceus*, as well as the annual grasses *Setaria viridis* and *S. verticillata*. Perennial species of adjacent grasslands, e.g. *Poa pratensis* agg., *Melica ciliata, Calamagrostis epigejos*, *Tragopogon dubius*, and *Plantago lanceolata*, were associated with mulched plots in 2000. The 1999 and 2000 mulched plots shared common annual species, such as *Hordeum murinum* and *Polygonum aviculare* agg., and perennial species, such as *Taraxacum* sect. *Ruderalia*, *Lolium perenne*, and *Ballota nigra*. *Convolvulus arvensis* and *Veronica sublobata* showed no affinity to any particular treatment or year.

Seasonal dynamics

During the vegetation season there were remarkable differences in species composition in each of the plots (Tab. 2). In the tilled plots frequent disturbances strongly affected species composition during the growing season, and the seasonal changes were less pronounced. On the other hand, seasonal dynamics in the mulched plots showed a typical pattern of appearance and disappearance of annual species in the course of the season. In spring, there was a characteristic aspect made up mainly of *Veronica sublobata*, *Asperugo procumbens, Descurainia sophia, Holosteum umbellatum*, and *Valerianella locusta*. Some species of the spring aspect, such as *Veronica polita, Capsella bursa-pastoris, Stellaria media*, and *Lamium amplexicaule*, re-appeared in October, but with a lower frequency. In mid-summer, thermophilous annuals, such as *Chenopodium album, C. hybridum, Bromus japonicus,* and *Atriplex* sp., and some hemicryptophytes, including *Tragopogon dubius, Crepis rhoeadifolia,* and *Lolium perenne*, dominated the mulched plots. *Amaranthus retroflexus* and *Setaria viridis* were recorded from late summer to autumn. Only a few species were confined to autumn, including *Echinochloa crus-galli* and *Setaria verticillata.*

Permutation tests in the redundancy analysis showed that each of the variables *Management* and *Season* (both linear and quadratic) had significant effects on species composition ($P < 0.05$). The

Table 2. Differences in species composition during the growing season. Values are species frequencies. 1 – spring, 2 – summer, 3 – autumn. Values for species with the phi coefficient of association in particular columns higher than 10 are shown in bold; these species are ranked by decreasing phi values. Species not exceeding 5% frequency in any of the columns are not shown.

Season	1	2	3
Number of plots	358	482	240
Species associated with spring season			
Veronica sublobata	**73**	0	.
Bromus sp.	**54**	18	24
Descurainia sophia	**24**	3	1
Asperugo procumbens	**28**	5	14
Fumaria sp.	**11**	1	.
Holosteum umbellatum	**4**	.	.
Lactuca serriola	**34**	26	5
Thlaspi arvense	**12**	3	6
Papaver rhoeas	**7**	3	.
Thlaspi perfoliatum	**2**	.	.
Arenaria serpyllifolia agg.	**29**	21	13
Valerianella locusta	**3**	0	.
Veronica triloba	**2**	.	.
Torilis arvensis	**40**	33	22
Sisymbrium orientale	**12**	7	3
Erodium cicutarium	**57**	44	52
Species associated with summer season			
Convolvulus arvensis	66	**91**	88
Atriplex sp.	20	**46**	39
Polygonum aviculare agg.	16	**44**	42
Lolium perenne	22	**39**	31
Tragopogon dubius	7	**17**	9
Bromus japonicus	25	**32**	13
Chenopodium album	5	**18**	17
Chenopodium hybridum	1	**7**	4
Crepis rhoeadifolia	8	**16**	11
Species associated with autumn season			
Echinochloa crus-galli	.	1	**4**
Setaria verticillata	.	2	**5**
Species associated with spring and autumn seasons			
Veronica polita	**71**	2	**58**
Capsella bursa-pastoris	**62**	10	**44**
Stellaria media	**85**	43	**72**
Lamium amplexicaule	**47**	19	**41**
Species associated with summer and autumn seasons			
Amaranthus retroflexus	2	**46**	**39**
Setaria viridis	.	**14**	**16**
Other species			
Taraxacum sect. *Ruderalia*	60	52	47
Hordeum murinum	45	43	39
Cardaria draba	22	14	14
Geranium pusillum	12	5	11
Medicago lupulina	9	18	15
Artemisia vulgaris	9	20	22
Conyza canadensis	33	41	36
Malva neglecta	8	11	13
Cirsium arvense	15	21	22
Geum urbanum	3	4	5
Rosa canina	4	6	7
Falcaria vulgaris	8	9	10

Table 2. (continued)

Season	1	2	3
Number of plots	358	482	240
Arctium tomentosum	13	20	18
Carduus acanthoides	11	13	13
Achillea pannonica	18	23	18
Tripleurospermum inodorum	11	11	7
Ballota nigra	11	12	11
Agropyron repens	7	7	6
Reseda lutea	6	7	6

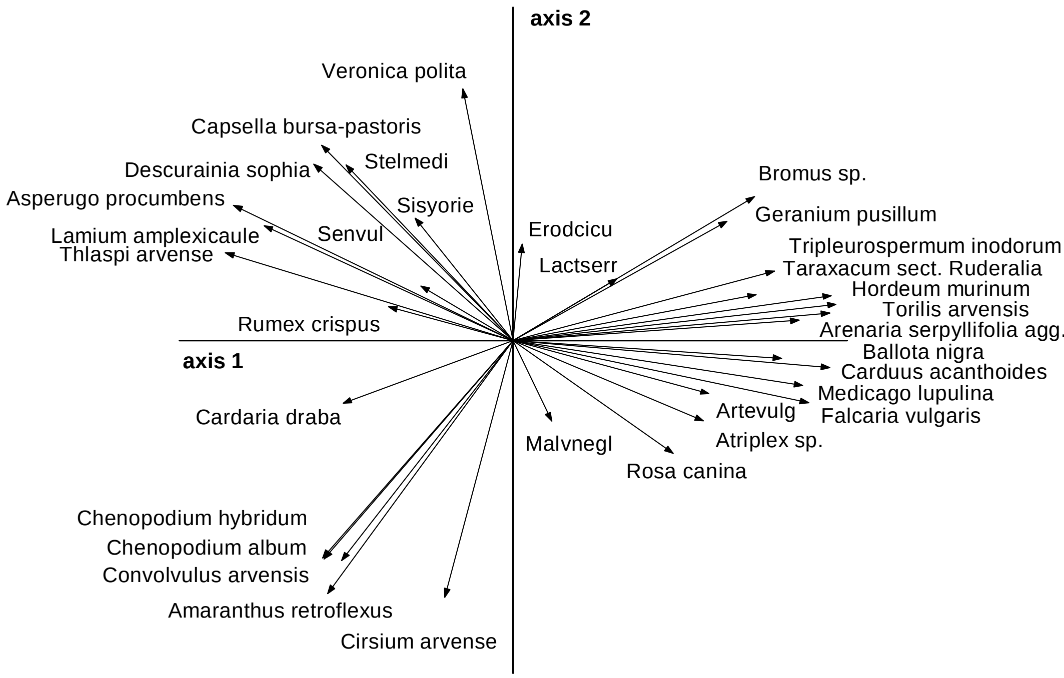

Fig. 4. Principal components analysis: species. Abbreviations: Artevulg *Artemisia vulgaris*, Erodcicu *Erodium cicutarium*, Lactserr *Lactuca serriola*, Malvnegl *Malva neglecta*, Senvul *Senecio vulgaris*, Sisyorie *Sisymbrium orientale*, Stelmedi *Stellaria media*.

Table 3. Decomposition of variance in species data explained by management and seasonal dynamics.

Management – pure effects	49.5%
Season + Season^2 – pure effects	22.6%
Management and Season + Season^2 – shared variance	1.8%
Residual	26.1%

management explained 49.5% of the variance in species data, while another 22.6% of variance was attributed to the seasonal dynamics. The shared effect of the management and season was negligible (Tab. 3). This indicates the management practice to be the most important factor affecting weed species composition in a vineyard, but the seasonal dynamics of the weed community is also remarkable.

Results of the principal components analysis are presented in Figs. 4 and 5. The most important gradient of species composition in the vineyard, associated with the PCA axis 1 (eigenvalue 0.434), is that between the tilled plots in 1994 and mulched

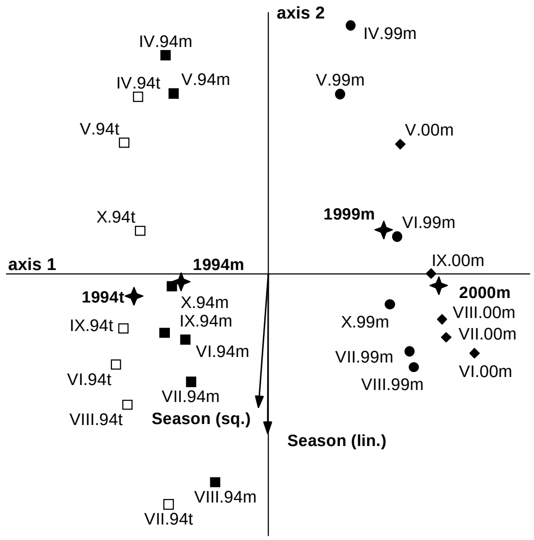

Fig. 5. Principal components analysis of individual censuses. Each census is coded by a Roman numeral denoting month, two-digit number denoting year, and *m* for mulching or *t* for tilling. Environmental variables were added after extraction of the axes, i.e. they did not influence calculations. Dummy variables denoting *Management* are represented by asterisks, variable *Season* and its quadratic term are represented by arrows.

plots in 2000. The second most important gradient (axis 2, eigenvalue 0.246) reflects the seasonal dynamics of the weed community.

Discussion

The differences between weed communities in tilled and mulched plots were remarkable. The tilled plots were dominated by ruderal species with a high resistance to herbicides. Mulching resulted in an increase in species richness and cover of the weed vegetation. There was a higher proportion of perennial species, notably grasses, in plots mulched for 4–6 years, whereas the proportion of annuals was higher in tilled and newly mulched plots. The life-form spectrum in the tilled rows was comparable with the data by Orgis (1977) on the weed vegetation of tilled vineyards in Franken (Germany).

Seasonal dynamics of weed vegetation was similar to the pattern observed in tilled vineyards in Slovakia (Eliáš, 1971, 1983, 1996) and southwestern Germany (Wilmanns, 1990). It is evident that the seasonal pattern of weeds in the mulched plots is generally similar to that in the tilled plots.

An analysis of the species composition of vineyard weeds in the Rhine valley (Wilmanns, 1989, 1993) showed that vineyards, hoed or tilled several times a year, and herbicided vineyards without mulching were rather similar in species composition, both being habitats of bulbous geophytes, such as *Allium oleraceum, A. rotundum, A. vineale,* and *Gagea villosa.* On the other hand, mulched vineyards in that area are covered with grasslands composed of common meadow, weed, and ruderal species, all of them with broad ecological ranges. Their value for biodiversity conservation is lower than of hoed/tilled or herbicided vineyards. However, our results suggest that this is not the case in southern Moravia.

We are not aware of any detailed reports on the weed flora of vineyards in southern Moravia from the period before the advent of intensive management. Therefore, no comparison of the present state with the period of pre-intensive agriculture was possible. The scarce data from the early 20th century (Laus, 1908) are quite similar to the present ones from the tilled vineyards. However, it is possible that a species-rich community with bulbous geophytes used to be also present in southern Moravia. An analysis of herbarium records by Duchoslav (2001) showed that before 1950, and notably before 1900, *Allium vineale* was much more frequent in arable fields than in other habitats in the Czech Republic. *Allium oleraceum* also preferred fields, although the preference was less pronounced. Nowadays, these two species and other bulbous geophytes mentioned above still occur in southern Moravia but mostly in dry grasslands, ruderal vegetation of road verges, or in *Robinia pseudacacia* groves rather than in arable fields and vineyards.

This evidence supports the view that intensive agriculture considerably changed the past species-rich communities of southern Moravian vineyards in a similar manner as documented in the Rhine valley (Fischer, 1983; Wilmanns, 1989). The species composition of the weed community in mulched vineyard in Mikulov corresponds to the herbicided rather than mulched type of the Rhine valley vineyards. An important factor is probably the duration of mulching; after a few more years of this management, the southern Moravian community would probably develop into a ruderal grassland with a lower proportion of annual species, as what happened in the Rhine valley. However, as no traditional weed vegetation with bulbous geophytes is currently present in the southern Moravian vineyards, such a ruderal grassland would not be less valuable from the viewpoint of biodiversity conservation than the tilled weed vegetation. A restoration of traditional biodiversity is, indeed, not the goal of the present transition to mulching. This substantial change in weed control is rather aimed at preventing soil erosion and improvement of soil quality. At the same time, however, it is no threat to biodiversity, at least from the botanical point of view.

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