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Grassy-floral soil covering as a tool for increasing herbaceous diversity in agroforestry

Gyepes, virágos takarónövényzettel növelhető a lágyszárú diverzitás az agrárerdészetben

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ABSTRACT

Intensive agricultural technologies lead to a simplification of landscape and a decrease in biodiversity. Besides economic benefits, alley cropping might increase species richness, improving pollination in agriculture. In this research, a traditional apricot plantation combined with crop fields was studied in Burgenland, focused on herbaceous diversity and species composition, which have a crucial role in promoting pollination. The vegetation of the grassy strips under the tree rows was compared to control grass and tree plantation habitats. The results show that the loose canopy layer of the fruit trees promotes the appearance of several herbaceous species, which results in a more diverse understory layer compared to the control tree plantation. However, the intensity of the management significantly impacts the species richness and composition of the understory vegetation.

Keywords: orchard, alley cropping, understorey vegetation, species richness

ABSZTRAKT

Az intenzív mezőgazdasági technológiák a táj és a biodiverzitás elszegényedéséhez vezetnek. Gazdasági előnyei mellett a köztes termesztés növelheti a fajgazdagságot, elősegítve a beporzást a mezőgazdaságban. Kutatásunkban megvizsgáltuk egy tradicionális, mezőgazdasági parcellákkal kombinált sárgabarack ültetvény lágyszárú diverzitását és fajösszetételét, amely kulcsfontosságú a beporzók számára. A fasorok alatti gyepes sávok növényzetét kontroll gyep és faültetvény vegetációjával is összevetettük. Az eredmények azt mutatják, hogy a fasorok laza lombkoronája lehetővé teszi számos lágyszárú faj megjelenését, ami a kontroll faültetvényhez képest diverzebb aljnövényzetet eredményez. Az alkalmazott kezelések intenzitása azonban erősen befolyásolja a lágyszárú szint fajgazdagságát és fajösszetételét.

Kulcsszavak: gyümölcsös, köztes termesztés, aljnövényzet, fajgazdagság

INTRODUCTION

Several studies highlight the decline of the herbaceous diversity in the European agroecosystems, both in terms of species richness and abundance (Baessler and Klotz, 2006, Chamorro, 2016). The main factors causing this phenomenon, besides the intensive cultivating methods (for example, chemical herbicides and fertilizers, use of commercial seeds, and the monoculture of species or varieties), are the reduction of landscape diversity, causing habitat-specialist species slowly disappear from farms (Robinson and Sutherland, 2002). However, some species have become common in the last decades (Sutcliffe and Kay, 2000).

In agroecosystems, weeds have a key role in providing the primary production of the food chain as their different parts are nutrients for a range of the associated fauna (Willis and Memmott, 2005). Besides that, weeds in an intensively cultivated environment provide heterogeneity in space and time, supporting many other species (Marshall et al., 2003). While some weeds can uniquely support the life cycle of a range of insect species, their diversity strictly correlates with the heterogenity of plant communities, affecting the insectivorous bird and other animal communities too (Marshall et al., 2003). Also, seeds are crucial for granivorous bird species during the winter or the year (Buckingham et al., 2011). Besides the diversity and species composition of the vegetation, the density and structure of the plant community are significant for many arthropods that are nutrients for vertebrate animals (Marshall et al., 2003).

In the case of alley cropping systems, the uncropped strips in the tree rows can be reservoirs for weeds and prove opportunities for biodiversity conservation. The understory layer in agroforestry is often forgotten; however, it is essential to promote ecosystem services (Boinot et al., 2020). A sowed wildflower mix can increase the positive effect of these understory vegetation strips, but the use of local seeds is important. The wider strip is left uncropped, the greater is the contribution to biodiversity, and with the increasing width of the strip, the negative effect of the management of the adjacent crop field is decreasing (Schulz et al., 2020). A longer period without disturbance in the understory vegetation strips benefits vegetation development (Quinkenstein et al., 2009). Extensive management increases the proportion of herbs in the strip, promoting butterflies and wild bees (Schulz et al., 2020). Though the diversity of the vegetation communities decrease it with longer rotation periods, older stands decrease due to the shadow influences of more giant trees (Quinkenstein et al., 2009).

Our research aimed to assess the impact of the understory layer on the herbaceous vegetation of an alley cropping agroforestry system, which can be considered as a remnant of the former mowing orchards (Dolan et al., 2012). The diversity and species composition of the grassy strips under the tree rows were compared to that of a semi-natural grass and a planted forest patch to observe which one can improve herbaceous flora in an agricultural landscape. The results showed that the tree rows with grassy understory layers are appropriate habitats for a wide range of weed species. Regarding herbaceous vegetation, extensively managed tree rows have a much higher positive impact than a forest plantation.

MATERIALS AND METHODS

Study site

"Kittseer Marille" lies southeast from the limestone massif of Hainburg, on the Danube Lajta plain, on a slightly young, prominent fill terrace of the Danube. Thin loess mud settled on the sandy gravel of the Danube, and this is the parent material of the humus-rich alluvial soil (Berki and Konkoly-Gyuró, 2017).

Kittsee's local chronicle (Kittseer Marille 2022) in 1924 mentions the large-scale planting out of apricot trees first. Between the single or twin rows of apricot trees, cereals, alfalfa, and sugar beet are cropped. Between the cultivated alleys, mowed grassy vegetation forms the understory layer of the tree rows (Figures 1 and 2). Coenological relevés were made in three alleys, in a control grass and forest patch with three repeats, in the spring, summer and autumn of 2019.

The climatic characteristic of the studied period is shown in Figure 3. The GPS coordinates of the quadrats can be found in the Appendix.

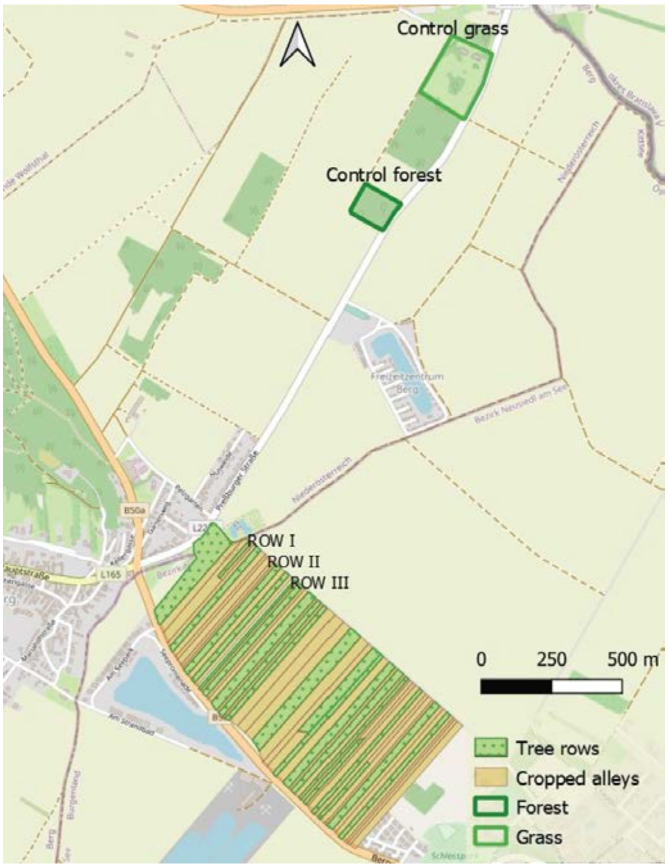
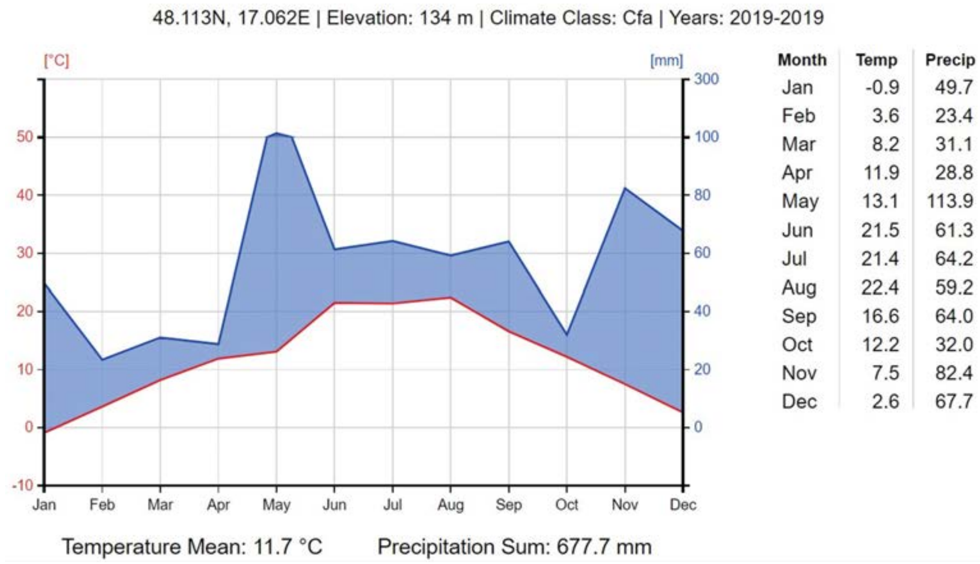


Figure 1. Examined habitats in Kittsee

Figure 2. Intensively and extensively mowed grassy vegetation under the tree rows



Month	Temp	Precip
Jan	-0.9	49.7
Feb	3.6	23.4
Mar	8.2	31.1
Apr	11.9	28.8
May	13.1	113.9
Jun	21.5	61.3
Jul	21.4	64.2
Aug	22.4	59.2
Sep	16.6	64.0
Oct	12.2	32.0
Nov	7.5	82.4
Dec	2.6	67.7

Figure 3. Climatechart of the study site in 2019. Source: Zepner et al. (2020).

Sampling and data generation

Soil samples were collected from each plot in the autumn of 2019, from the upper 10 cm layer of the soil to check that the examined area was homogenous enough for comparisons. The collected soil samples were air-dried before chemical and physical analysis. Clay and silt %, soil pH (KCl), organic matter content (SOM), soluble nitrogen (NO_2+NO_3, potassium-cloride extract), P_2O_5, and K_2O (ammonium-lactate acetate acid extract) content were determined.

Coenological samplings were investigated in 25 m^2 (5 m × 5 m) quadrats with three replicates in each sampling plot. The foliar cover method was used for determinate the abundance of the species. This method measures a vertical projection of exposed leaf area, expressed in % of the area (Daubenmire 1959). The data collection was repeated in three vegetation periods: early spring, summer, and autumn. The species and their cover values were recorded. The data collected in the three vegetation periods were summarized for each habitat, and the highest cover values for each species were considered. Finally, the means of the three quadrats for each studied habitat were calculated. In total, data collected from 15 quadrats with three repeats were analyzed. In the case of the control forest patch, the woody vegetation data regarding the whole stand. The nomenclature of the plant species follows the Hungarian Flora Database (Horváth et al., 1995).

Analysis

Diversity profiles were used to compare the herb layers of the different habitats, calculated with PAST software. PAST uses the exponential of the so-called Renyi index, which includes the number of species, Shannon diversity, quadratic diversity, and Berger-Parker diversity. The value of the index depends upon the parameter "alpha". For alpha =0, this function gives the total species number. Alpha =1 (in the limit) gives an index proportional to the Shannon index, while alpha =2 gives an index that behaves like the Simpson index. With this method, the studied communities can be ranked in partial order. A community is more diverse than another when its diversity profile is above or equal to the other community's diversity profile (Tóthmérész, 2013).

The similarity of different habitats is presented with hierarchical cluster analysis based on Bray-Curtis similarity indices.

The plant sociological method was used to perform herbaceous species composition. The social behavior type (SBT) categories are derived from the CSR plant functional system (Grime, 1979), adapted to the Pannonian flora by Borhidi (1995). The number and proportion of categories represented in a habitat prove information about the stability, the level of disturbance, or deviation from the natural state of the community.

The SBT categories, the naturalness value of each category, and the main traits of the plants belonging to the different categories are summarised in Table 1.

RESULTS

Woody vegetation of the control forest

In the control forest, the total cover of the canopy (A) layer is 80%. *Acer platanoides* is present with the highest cover (60%), complemented by *Quercus cerris* (20%) *Ulmus minor* (10%) and *Fraxinus excelsior* (10%). The shrub layer consists of *Acer platanoides* (20%), *Quercus cerris* (10%), *Sambucus nigra* (5%), and *Crataegus monogyna* (5%).

Soil parameters

The measured soil parameters show that the studied area is homogenous, slightly alkaline, clay loam soil dominates the fields. Based on the results of the measurements, the examined plots are pretty similar; the spread of the data within the plots is higher than the differences among the plots (Table 2).

Herbaceous diversity

A total of 74 herbaceous species appeared in this area. Seven of them appeared only in the control forest and five in the control grass. The majority of the species were common in all habitats.

Table 1. Social behaviour type (SBT) categories based on Borhidi (1995)

	SBT	Main traits
Natural habitats	Specialists (S)	Low competitiveness, sensitive indicators of certain ecological factors.
	Competitors (C)	Dominant species of natural communities.
	Generalists (G)	Species of wide ecological range or tolerance in the natural plant communities.
	Natural pioneers (NP)	Species of initial stages of succession series.
Disturbed, secondary and artificial habitats	Disturbance tolerants (DT)	Pioneer elements of secondary succession
	Weeds (W)	Plant species living in heavily disturbed, artificial habitats.
	Introduced alien species (I)	Plants alien to a region and flora intentionally introduced and acclimatized as potential useful crops.
	Adventives (A)	Alien species to region and flora. Not intentionally introduced.
	Ruderal competitors (RC)	Dominant weeds of natural flora, with the ability to transform the habitat and modify successional trends.
	Aggressive alien species (AC)	Alien to region or flora, invading the gaps of natural or semi-natural communities and became dominant.

The Borhidi's SBT categories were obtained from the Hungarian Flora Database (Horváth et al., 1995)

Table 2. Mean (±SD) of the measured soil parameters on the study area

	Row I	Row II	Row III	Forest	Grass
pH (KCl)	7,24±0,06	7,37±0,03	7,48±0,13	7,31±0,07	7,30±0,08
S+C (%)	72,28±5,14	65,02±4,39	63,75±5,05	68,21±6,11	70±5,01
$CaCO_3$ (m/m %)	12,83±1,88	13,4±1,94	12,26±2,13	11,69±1,38	12,30±2,03
SOM (m/m %)	4,13±0,98	3,02±0,14	2,96±0,86	3,69±0,25	3,01±0,52
NO_2+NO_3 (mg/kg)	5,46±5,09	1,36±0,76	2,71±1,72	7,05±2,9	3,11±2,01
P_2O_5 (mg/kg)	167,31±22,94	221,25±82,91	289,75±116,45	279,32±203,17	200,01±45,1
K_2O (mg/kg)	291,33±37,58	191,33±41,96	192,67±48,22	299,67±107,64	190,11±33,21

S+C= proportion of the silt + clay fractions, SOM: soil organic matter, AL-N, P, K: soluble nitrogen, phosphorus and potassium. m/m%= mass percent concentration

The diversity profiles show that the grassy habitats are more diverse than the control forest. One of the grassy belts under the tree rows (ROW I) is extremely diverse compared with the control grass and the other alleys too (Figure 4).

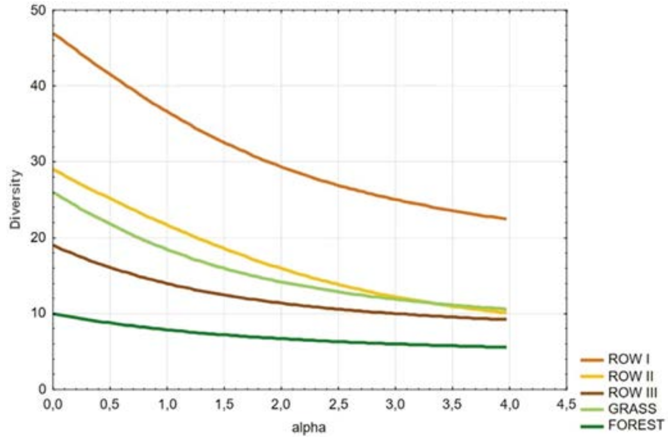


Figure 4. Diversity profiles of the herbaceous vegetation in the tree rows and control habitats

The cluster analysis based on the Bray-Curtis similarity indices shows that the vegetation of the control forest and grass is significantly different from that of the tree rows, but the mowed strips (ROW I-III) are in the same main group, regardless of the management intensity (Figure 5).

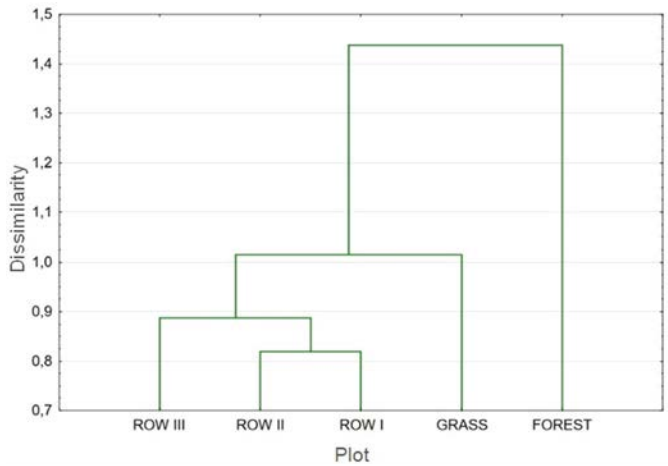


Figure 5. Cluster analysis based on Bray-Curtis dissimilarity indices of the different plots

Species composition

Specialist herbaceous species did not appear at the study site. Although the diversity is significantly higher in ROW I, the number of species belonging to the competitor and generalist SBT categories is similar to the other plots. The control grass contains the highest number of species in these categories: *Centaurea scabiosa*, *Festuca rupicola*, and *Ononis arvensis* were found only in this habitat, while *Corydalis cava* appeared only in the control forest. *Pimpinella saxifraga*, *Salvia pratensis*, *Viola odorata* were present in most of the alleys. The majority of the species belong to the disturbance tolerant and weed categories. The most frequent ones are *Achillea millefolium*, *Arrhenatherum elatius*, *Dactylis glomerata*, *Galium verum*, *Knautia arvensis*, and *Ranunculus arvensis*. Ruderal competitors appear scattered, except for *Bromus sterilis*, which was found with significant cover in the control grass. The adventive competitor *Impatiens parviflora* was present only in the control forest, while *Erigeron annuus* appeared in the alleys (Figure 6).

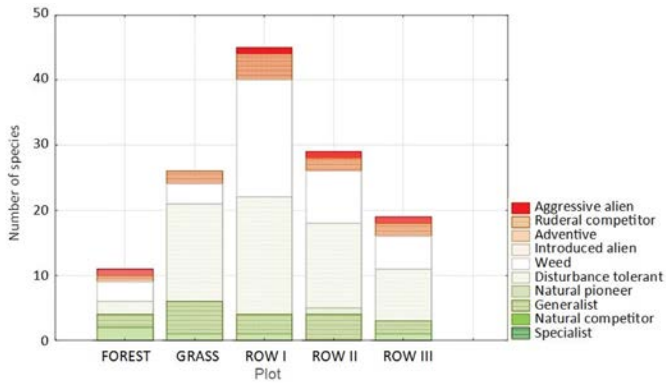


Figure 6. Distribution of herbaceous species numbers by social behaviour type categories

DISCUSSION

Grassy, floral strips of alley cropping systems can be interpreted as field margins, which appear even in most homogenous agricultural landscapes on the side of roads or other linear facilities or at the borders of different land-use forms. In more heterogeneous landscapes, the semi-natural and natural habitats also define the edges of agricultural fields. These margins not only historically had essential functions but also have a significant role nowadays in preserving biodiversity (Marshall and Moonen, 2002, Sutyinszki et al., 2013).

Our results show that the diversity of the grassy strips enormously exceeds that of the control forest. This phenomenon can be explained by the loose structure of the canopy layer in the tree rows, which allows the appearance of a high number of light-demanding herbaceous species. In addition, extensive mowing helps the settlement of segetal weeds, too (Pinke and Pál, 2005).

Both the diversity and naturalness value of the understory layer of the tree rows are similar to the control grass, except for the most extensively mowed ROW I, which exceeds all the other habitats. The reason for the high species richness can be, on the one hand, the sowing of weed seeds for increasing pollination. On the other hand, the intensity of mowing has a high impact on the diversity and species composition of the grassy strips, as highlighted in several studies on grasslands and lawns. On average, more frequent mowing results in lower herbaceous species richness (Karami et al., 2021). The reason is that mowing has a selective effect on herb species as only a few, mainly ruderal plants, can tolerate frequent disturbance. Too infrequent mowing also might cause a decrease in species richness. At least yearly mowing is necessary to avoid the rapid disappearance of species with low competitiveness (Chollet et al., 2018), but the timing of the grass management is also a significant factor. Mowing should be ended before the flowering period of the herb species (Nakahama et al., 2016). The benefits of decreasing mowing frequency on intensively managed lawns occur after a few years. Not only does the species richness increase, but the species composition also changes; typical meadow species appear in higher cover (Sehrt et al., 2019).

Despite the similar diversity and naturalness value of the species found in the tree rows and the control grass, the cluster analysis separated the two habitat types based on the species composition and cover. This result also shows the similarity of the grassy strips with field margins, which, as human-created habitats with diverse appearance, size, or structure, cannot be characterized by a specific plant community. Species of former grassy vegetation can appear in field margins long after the area's transformation into agricultural land (Gustavsson et al., 2007). In the case of alley cropping, sown flower strips as biodiversity edges also increase the species richness and abundance of arable flora (Wietzke et al., 2020). Although these grassy strips cannot be determined as natural habitats, they have excellent potential for increasing pollination (Lerman et al., 2018). The associated fauna varies accordingly to the species composition and structure of vegetation. The diversity of the edges may have a significant role in the economic sustainability of farming (Marshall and Moonen, 2002).

Farmers often mention the disservices of uncropped habitats, such as higher weed pressure. Smith et al. (1999) showed that uncropped edges do not increase the number of weed species and abundance in the crop field. Chaudron et al. (2020) also concluded that agro-environmental (extensive) mowed margins do not increase the cover of unfavorable species in crop fields but can promote pollination.

CONCLUSIONS

Farmers often consider the wild herbaceous vegetation in agroforestry as a threat; however, it is essential to promote agricultural ecosystem services. We aimed to assess the impact of the understory layer on the herbaceous vegetation of a traditional fruit-producing agroforestry landscape. The diversity and species composition of the grassy strips under the tree rows were compared to semi-natural grass and a forest plantation to observe which one can improve herbaceous flora in an agricultural landscape. The results showed that the tree rows with grassy understory layers are appropriate habitats for a wide range of plant species. Regarding herbaceous vegetation, extensively managed tree rows have a much higher positive impact than a forest plantation. The diversity and naturalness value of the herbaceous species found in the tree rows are similar to the control grass. Despite this, the cluster analysis separated the two habitat types based on the species composition and cover. The flora of the grassy strips is similar to field margins, which, as human-created habitats with diverse appearances, sizes, or structures, cannot be characterized by a specific plant community. The intensity of the management significantly impacts the species richness and composition of the understory vegetation.

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Appendix

Table A1. GPS coordinates of the examined quadrats in Kittsee

ROW I		ROW II		ROW III		FOREST		GRASS	
A	48.10312, 17.04951	A	48.10277, 17.0508	A	48.10276, 17.05211	A	48.11483, 17.05491	A	48.11826, 17.05898
B	48.10259, 17.04886	B	48.10252, 17.05053	B	48.10179, 17.05084	B	48.11501, 17.05517	B	48.11856, 17.05878
C	48.10223, 17.04826	C	48.10237, 17.0503	C	48.10127, 17.04993	C	48.11526, 17.05514	C	48.1187, 17.0586

Table A2. Species list and average cover values (%) of the herbaceous vegetation in Kittsee

Species	FOREST	GRASS	ROW I	ROW II	ROW III
Achillea millefolium	0	7	13	3	13
Allium scorodoprasum subsp. *scorodoprasum*	0	2	0	0	0
Anthemis arvensis	0	0	5	0	3
Arrhenatherum elatius	0	0	13	37	0
Artemisia absinthium	0	0	2	0	0
Artemisia vulgaris	0	0	0	2	0
Ballota nigra	7	0	0	0	0
Bellis perennis	0	0	2	5	5
Berteroa incana	0	0	2	0	0
Bromus sterilis	2	27	7	0	0
Calamagrostis epigeios	0	7	0	0	0
Capsella bursa-pastoris	0	0	0	2	0
Centaurea cyanus	0	0	5	0	5
Centaurea scabiosa	0	12	0	0	0
Chaerophyllum bulbosum	0	0	3	7	0
Cichorium intybus	0	2	3	0	0
Cirsium arvense	0	0	5	3	10
Cirsium vulgare	0	0	3	0	0
Consolida regalis	0	0	2	0	0

Continued. Table A2

Species	FOREST	GRASS	ROW I	ROW II	ROW III
Convolvulus arvensis	0	0	2	3	17
Corydalis cava	2	0	0	0	0
Dactylis glomerata	0	5	7	3	37
Daucus carota subsp. *carota*	0	0	2	0	0
Dorycnium herbaceum	0	0	0	3	0
Equisetum arvense	0	2	0	0	0
Eragrostis minor	0	0	3	7	30
Erigeron annuus	0	0	8	7	23
Erodium cicutarium	0	0	7	0	0
Erophila verna subsp. *spathulata*	0	0	0	13	0
Falcaria vulgaris	0	0	3	7	7
Festuca rupicola	0	20	0	0	0
Galium aparine	10	0	2	0	0
Galium verum	0	2	17	13	10
Geranium pusillum	0	0	7	0	23
Geranium sanguineum	17	0	0	0	0
Geum urbanum	10	0	0	0	0
Impatiens parviflora	23	0	0	0	0
Knautia arvensis	0	13	0	10	17
Lamium purpureum	7	0	0	0	0
Lathyrus tuberosus	0	7	3	0	0
Lepidium campestre	0	0	0	7	0
Linaria vulgaris	0	0	2	0	0
Lotus corniculatus	0	3	2	3	0
Medicago lupulina	0	12	0	7	3
Mercurialis perennis	0	0	2	0	0
Ononis arvensis	0	3	0	0	0
Ononis spinosa	0	8	3	0	0
Onopordum acanthium	0	0	0	7	0
Panicum miliaceum	0	0	3	0	0
Papaver rhoeas	0	0	2	0	0

Continued. Table A2

Species	FOREST	GRASS	ROW I	ROW II	ROW III
Pimpinella saxifraga	0	0	13	10	3
Plantago lanceolata	0	7	10	0	10
Plantago media	0	2	10	8	0
Ranunculus arvensis	0	3	5	13	7
Ranunculus ficaria	0	0	0	0	2
Reseda lutea	0	0	2	0	0
Rhinanthus minor	0	2	0	3	0
Salvia pratensis	0	15	7	13	0
Scabiosa canescens	0	0	2	0	0
Securigera varia	0	0	3	0	0
Stellaria media	0	0	2	0	0
Taraxacum officinale	0	0	2	0	0
Thalictrum minus	3	0	0	0	0
Thlaspi perfoliatum	0	0	2	0	0
Thymus glabrescens	0	0	0	0	3
Tragopogon orientalis	0	2	3	0	0
Trifolium pratense	0	5	3	10	0
Trifolium repens	0	2	7	0	0
Tripleurospermum inodorum	0	0	2	0	0
Veronica arvensis	0	0	2	2	0
Veronica persica	0	0	0	3	0
Vicia cracca	0	0	0	3	0
Vicia hirsuta	0	5	7	0	0
Viola odorata	10	2	0	0	0