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THE GROWTH CHARACTERISTICS OF *FUMANA PROCUMBENS* (DUNAL) GREN. ET GODRON UNDER DIFFERENT CLIMATIC CONDITIONS

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Growth characteristics, such as basal stem diameter, total length of wooded branches and root/shoot ratios in different ecological populations of *Fumana procumbens* were studied in the perennial open sand grassland *Festucetum vaginatae* under different climatic conditions in Hungary. The age of individual plants was determined by counting the annual rings in the basal section of stems. Basal stem diameters and their average yearly increment as well as the total length of wooded branches with individuals of the same age were significantly higher under wet conditions. The close relation of basal stem diameters and branch length with age could be described by linear regression both under wet and dry conditions. There was no significant differences in the root/shoot ratios between the dry and wet sites. Having established a reliable relation between basal stem diameter and age of *Fumana* individuals, authors developed a simple, quick and non-destructive field method for age determination of *Fumana*.

Key words: age/stem diameter ratio, climate change, *Fumana procumbens*, root/shoot ratio, water limitation

INTRODUCTION

The responses of species and ecosystems to climate change have become a central issue in ecological research recently. The number of field studies or experiments providing evidence for developing hypotheses and making prognoses, however, is still very limited. Historical records, results from long-term ecological studies and the space for time substitution approach are usually the convenient means used for this purpose (Likens 1989, Magnuson 1990).

Our present study is a part of a long-term ecological research programme aiming at the characterization of the structural and functional changes in the semiarid sand grassland community, *Festucetum vaginatae*, in the forest-steppe zone along a climatic gradient in Hungary (Kovács-Láng *et al.* 1999, 2000, Gosz *et al.* 2000, Kröel-Dulay *et al.* 1999).

Water limitation is a basic feature of *Festuca vaginata* grasslands (Kovács-Láng and Szabó 1973, Várallyai 1984, Kovács-Láng *et al.* 2000) due to climatic and edaphic reasons, and it can be supposed that there are differences in the

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patterns of water supply as well as in the population and community responses of the grassland along the climatic gradient.

Changes due to climatic differences in the growth characteristics and phytomass allocation of the dominant grass, *Festuca vaginata* have already been documented (Lhotsky *et al.* 1998). On the climate induced responses of the subshrub and dwarf shrub components of the *Festucetum vaginatae* grassland, however, we have no information, although their growth responses and age can be more exactly determined than that of the perennial grasses and herbs. *Fumana procumbens* is of particular interest, because its mass occurrence is characteristic after certain disturbances, so we could gain information on the age of the stands developed after disturbances.

Motivated by the work of Babos (1990–1991) who published the first results on the age determination of *Fumana procumbens*, a characteristic species of the perennial open sand grassland, we put forward the hypotheses that in a given ecological population of *Fumana* certain growth characteristics change proportionally with the age of the individuals and climatic conditions affect the growth characteristics of *Fumana* populations.

Therefore the specific objectives of our work were:

- to establish relationships between the growth characteristics and age of *Fumana* individuals, and
- to analyse growth characteristics such as basal stem diameter, total length of aboveground wooded branches and root/shoot ratios for *Fumana procumbens* populations growing under different climatic conditions.

To test our hypotheses we performed a combined field and laboratory study on *Fumana procumbens* individuals originating from two long-term ecological research sites, at Gönyű and at Fülöpháza, in Hungary under different climatic conditions.

MATERIAL AND METHODS

The study areas

A total of 0.50 km^2 study areas was selected in the forest-steppe mosaic at Gönyű (47°43′N; 17°49′E) on the Small Hungarian Plain (belonging to the Fertő–Hanság National Park) and at Fülöpháza (46°53′N; 19°23′E) in the Danube–Tisza Interfluve region, the central part of the country (belonging to the Kiskunság National Park). Both sites are located on the Pleistocene calcareous sand deposit of the Danube river. Their distance is 200 km.

Table 1
The climatic characteristics of the study sites (Gönyű and Fülöpháza), based on the records between 1961–90 of the nearest (19–20 km) meteorological stations (Győr and Kecskemét)

Site	mean ann. temp. (°C)	mean ann. precip. (mm)	Index of Semiaridy (Borhidi 1961)	Moisture Index (Bailey 1979)
Győr (Gönyű)	10.1	565	1	6.35
Kecskemét (Fülöpháza)	10.3	535	7	6.11

Their climate is temperate with continental and sub-Mediterranean influence (Zólyomi *et al.* 1997). Due to the basin effect a climatic gradient with increasing aridity can be detected from the NW (Gönyű) to the SE (Fülöpháza) direction. There are only slight differences in the climatic averages, but the changes both of the Index of Semiaridity (Borhidi 1961) and the Moisture Index of Bailey (1979) indicate well the higher semiaridity in Fülöpháza compared to Gönyű (Table 1). During the 1901–1970 period number of dry years, when annual precipitation was less than 550 mm was 12 for Győr (Gönyű) and 29 for Kecskemét (Fülöpháza) (Kovács-Láng *et al.* 2000). The present climatic difference between the study sites corresponds to the regional climate scenario for the next 20–30 years for the region (Mika 1988, Molnár and Mika 1997), what makes the sites suitable for comparisons in estimating certain possible effects of climate change.

The soil types both at Gönyű and Fülöpháza are slightly humous sandy soils with high (>96%) coarse (>0.05 mm) sand fraction and 7.9–8.5 pH values. Humus content is considerable higher at the wet site of Gönyű than that of Fülöpháza, 1.91 and 0.66%, respectively, in the upper 0–10 cm horizon.

Due to climatic differences the landscape scale pattern of vegetation of the selected 0.5 km^2 study areas is different. At Gönyű forest patches cover about 60% of the area enclosing smaller but rather dense grassland patches, while with increasing semiaridity at the dry Fülöpháza the open sand grassland dominates with sparse juniper-poplar woodland fragments.

The grassland component of the vegetation at both sites is the open perennial sand grassland, *Festucetum vaginatae* Rapaics 1923 ex Soó 1929. Species richness, canopy cover and diversity of the grassland is significantly higher at the wet site Gönyű, however.

More detailed description of the climate, soil and vegetation characteristics of the study sites is given in Kovács-Láng *et al.* (2000).

The target species

Fumana procumbens (Dunal) Gren. et Godron is a dwarf shrub, native, protected but still not threatened species in the Hungarian flora (Horváth *et al.* 1995, Simon 1988, 2000). The area of its distribution within the European floristic region has a sub-Mediterranean centre, northwards to North France, Öland and Gotland (Tutin *et al.* 1968). Its area in Hungary covers less than 2/3 of the country, occurring in dry open rocky or sandy habitats (Festucetalia vaginatae, Soó 1968, 1980).

According to Borhidi's classification (1995) *Fumana procumbens* is a stress tolerant, moderately disturbance tolerant specialist.

Perennial woody stems make the individuals suitable for exact age determination and width of annual rings can indicate environmental effects, mainly water availability.

Field sampling

Individuals of different sizes (supposed of different ages) were collected from the *Festucetum vaginatae* grassland patches of the 0.5 km^2 sampling areas in June of 1997 and 1998.

The number of collected individuals was limited to a total of 24 specimens (10 from Fülöpháza, and 14 from Gönyű) because of the protected status of the study areas.

Laboratory measurements

Basal stem diameters, the total length of the wooded aboveground branches and the dry weight of aboveground (shoots) and belowground (roots) parts were measured in the laboratory after drying the samples in oven on 50 °C.

Yearly increment of stems and wooded branches was calculated using these measurements and the age of individuals.

For exact age determination the counting of annual rings in the basal section of the stems was used (Babos 1990–91). Preparation of the samples included softening, staining and colouring in 3% alcohol solution of toluidine blue.

Statistical evaluation

For the evaluation of stem diameter/age as well as total length of wooded branches/age ratios at the two sites linear regression analysis was used (Sokal and Rohlf 1981). The means and steepness of the regression lines was compared by *t*-test, while the comparison of variances was made using F-test.

RESULTS

The well-detectable annual rings of *Fumana* stems make the age determination possible. Figure 1 demonstrates the differences in the cross section of the basal part of stem from individuals of the same age from the two sites. The radius of the xylem is longer and the yearly increment seems to be more equal inside the annual rings at Gönyű, while the annual rings are narrower and the growing process is more irregular at Fülöpháza.

In the course of counting the annual rings we have faced some difficulties: separation of rings sometimes uncertain, because *Fumana procumbens* has semi-ring-porous wood. In addition the width of a given ring can vary around the xylem. According to our experiences the accuracy of age determination with *Fumana* proved to be ±2 years. The probability of less accurate age determination increases with age. Sometimes, when warm and rainy autumns occur, the secondary growing process can produce "false annual rings" which do not run continuously around the xylem, therefore can be definitely distinguished from the real ones.

Basal stem diameter of the *Fumana* individuals varied between 1.6–11.2 mm at Fülöpháza and 1.5–11.5 mm at Gönyű, and that with individuals of the same age occurred bigger at Gönyű. The relation between basal stem diameter and age is rather close, and can be described by linear regression (Fig. 2).

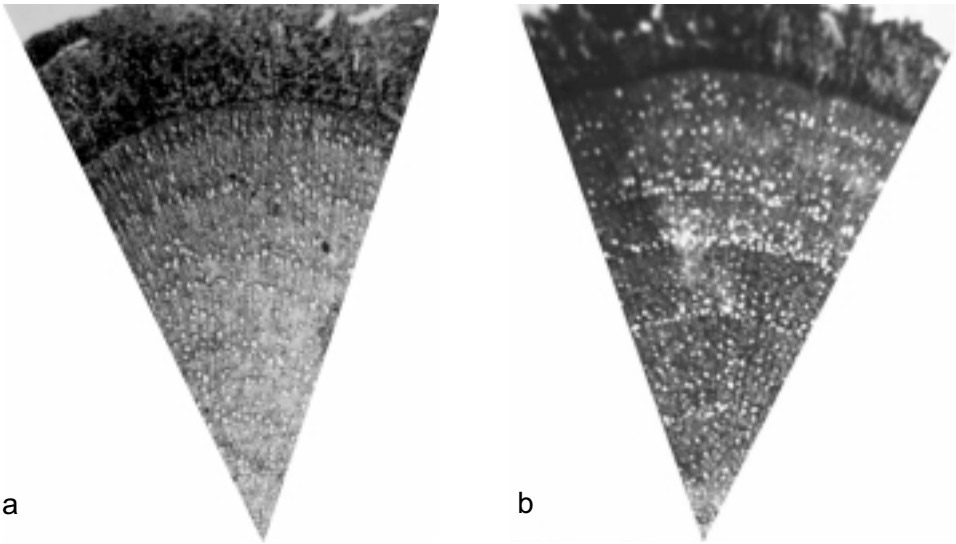

Fig. 1. Cross section of basal stem of *Fumana procumbens*, 8-year-old. Magn. ×48. a = Collected at Fülöpháza 1997. b = Collected at Gönyű 1998

The coefficients of correlation (r) are 0.94 at Fülöpháza and 0.98 at Gönyű, what shows, that the basal stem diameter of *Fumana* closely correlates with age in both sites.

The steepness of regression lines differs significantly ($p < 5\%$), what indicates the difference in growth characteristics of *Fumana* populations at the two sites.

The average yearly increment of stem diameters is 0.63 mm at Gönyű and 0.47 mm at Fülöpháza, that is significantly higher at the wet site. The variability in yearly increment of the individual plants does not show any relationship with age, seems to be stable, the variability is significantly higher at Gönyű (Table 2).

The total length of the wooded branches of the individuals varied between 4.5–643 cm at Fülöpháza and 13–1045 cm at Gönyű. It is noticeable, the more than 10 m (1045 cm) total length found at a Gönyű individual of 17-year-old, what is far exceeds any data measured at Fülöpháza. The relation between the total length of wooded branches and age of individuals is also close. The bigger variance of data can be detected at Gönyű (Table 2, Fig. 3). The coefficients of correlation (r) are 0.84 at Fülöpháza and 0.85 at Gönyű, and the steepness of regression line is significantly different on $p < 0.1\%$ level.

The yearly calculated increment of wooded branches is an average of 27.4 cm at Gönyű and 13.6 cm at Fülöpháza, i.e. the increment rate is double at the wet site. The variance of data is very high, the individual differences are much bigger than that in the case of stem diameter increments (Table 2).

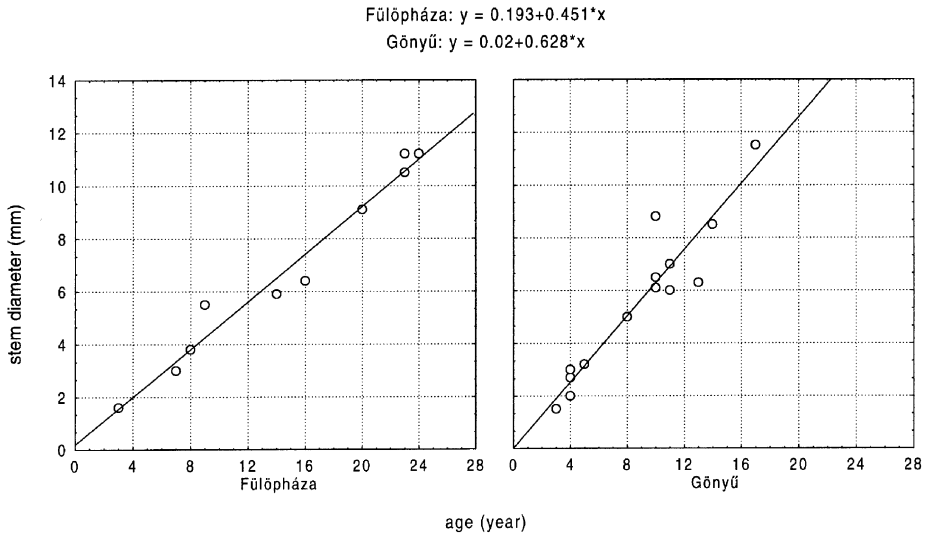

Fig. 2. Relation between basal stem diameter and age in *Fumana procumbens* populations

Table 2
The calculated yearly increment of stem diameters, length of wooded branches and root/shoot ratios of *Fumana procumbens* in *Festucetum vaginatae* grasslands under different climatic conditions

Site	Increment of stem diameters (mm/year)	Increment of the length of wooded branches (cm/year)	Root/shoot ratios
Gönyű (wet site)	n = 14	n = 10	n = 10
	$\bar{x}$ = 0.63	$\bar{x}$ = 27.39	$\bar{x}$ = 0.653
	s = 0.1063	s = 24.27	s = 0.248
	CV% = 16.87	CV% = 88.61	CV% = 37.97
Fülöpháza (dry site)	n = 10	n = 9	n = 9
	$\bar{x}$ = 0.47	$\bar{x}$ = 13.56	$\bar{x}$ = 1.041
	s = 0.0615	s = 8.59	s = 0.601
	CV% = 13.08	CV% = 63.35	CV% = 57.78

The root/shoot ratio of the individuals occurred 0.65 at Gönyű and 1.04 at Fülöpháza as an average, the difference between the sites statistically was not significant. A slight prevalence of roots can be detected at the dry site of Fülöpháza. The variance at both sites is rather high particularly at Fülöpháza. Close relation between the root/shoot ratio and age also was not proved statistically, but data can suggest a tendency of decreasing importance of root mass with age at both sites (Fig. 4).

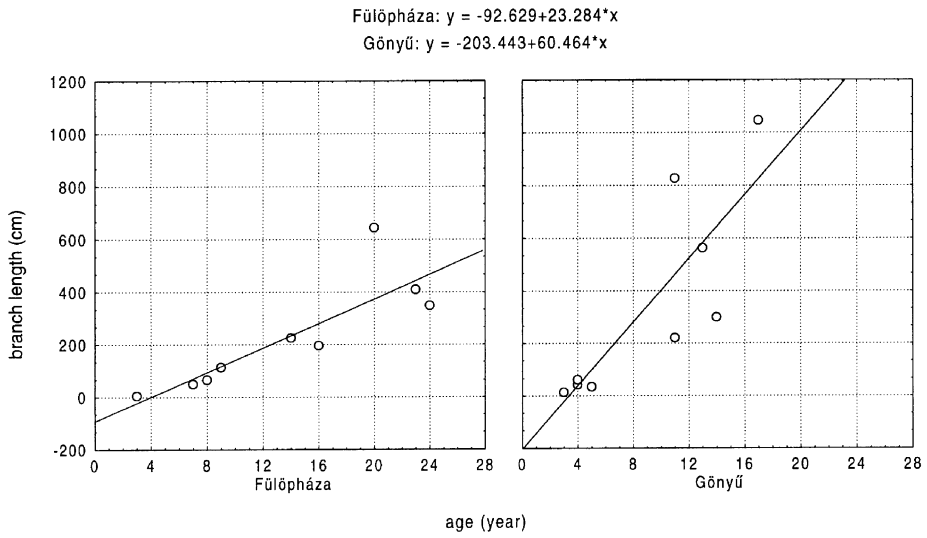

Fig. 3. Relation between total branch length and age in *Fumana procumbens* populations

DISCUSSION

There are different factors which can affect the growth characteristics of *Fumana* and other woody plants. Among others temperature, water and nutrient supply, photoperiodicity and age of the individuals seem to be relevant (Cannell and Willett 1976, Ágren and Zackrisson 1990, Wallén 1980, Bengttson 1993), although such field data concerning dwarf shrubs are rather difficult to find.

The stem diameter of woody plants usually correlates with age, but the character and closeness of the relationship can change with growing age and hardly comparable due to the different life spans of the species. Wallén (1980) found that with wooded *Calluna* tillers second order regression curves gave the best fit for data on basal diameter/age relationship. Due to the continuous rejuvenation process, however, the age of *Calluna* tillers did not exceed 12 years.

Pinus sylvestris, on the other hand, can reach an age over 300 year on peatlands in Sweden (Ágren and Zackrisson 1990) and in the first 100 years its stem diameter shows close correlation with age. After about 150 years the growth both in height and stem diameter slows down.

The oldest individual of *Fumana procumbens* we found in the sand grassland of Fülöpháza was 24 year old. Within this period at the sand grassland habitat in Hungary the stem diameter/age relationship with *Fumana* seems to

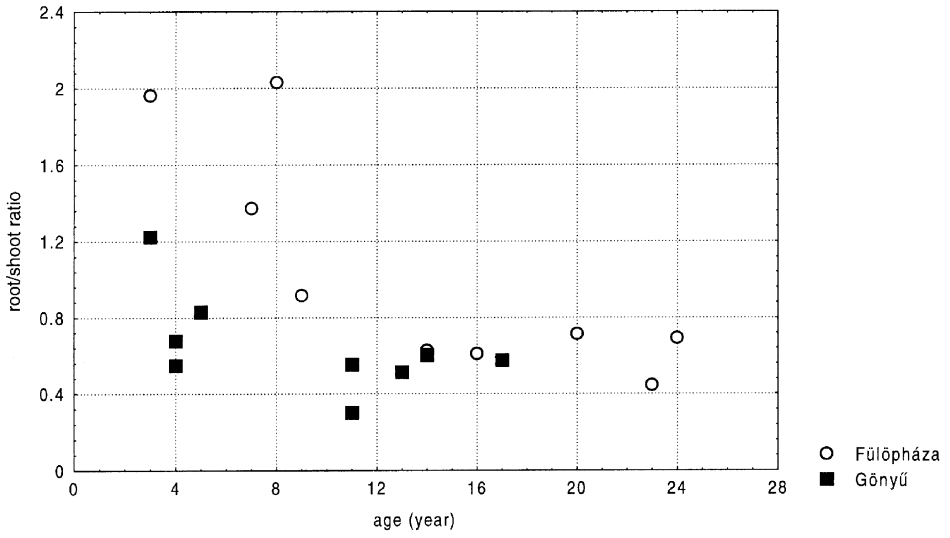

Fig. 4. Relation between root/shoot ratio and age in *Fumana procumbens* populations

be linear, but the intensity of growth is higher under the more humid climatic conditions.

Among the probable background factors explaining differences between the two sites we could name not only the direct climatic differences existing between the two study sites, but the better water holding capacity of the soil (due to the higher humus content) and the favourable mesoclimatic effect of the denser forest cover in Gönyű (Kröel-Dulay *et al.* 1999). However, these latter can also be considered the indirect effects of climate.

Similarly to stem diameters the length and growth rate of wooded branches of *Fumana* also occurred bigger at Gönyű. The length and architecture of branches can be affected several additional factors than those affect stem diameter. Although we cannot quantify, but have to take into consideration the possible turnover of branches, i.e. in extreme dry years some branches can die and break off, and the probability of such losses is higher at the dryer Fülöpháza. Furthermore, besides the better water availability at Gönyű, we also have to take into consideration light competition depending on the density of plant cover, shading effect of forest patches in the landscape and effects of herbivory as well. The species richness and the plant cover are much higher at the wet site Gönyű (Kovács-Láng *et al.* 2000), what implies the stronger biotic effects including even possible higher "light foraging" activity of *Fumana* branches. The bigger variance in the total length of branches at Gönyű may reflect to higher microsite diversity there.

The root/shoot ratio, what is an important indicator of water limitation with perennial grasses in semiarid grasslands (Kovács-Láng *et al.* 1989, Lhotsky *et al.* 1998) can also be meaningful with woody plants as well. There are seasonal differences in the growing intensity of roots and shoots, the latter can be highly affected by photoperiodicity (Cannell and Willett 1976).

Barbour (1973) presented extensive data on semidesert shrubs in the US showing that root/shoot ratios vary over a wide range. They do not necessarily possess high root/shoot ratios, the measured mean values were between 0.4 and 1.4 for the different species in different habitats. Chew and Chew (1965) found that much of the variation in root/shoot ratios of *Larrea tridentata* is due to age related differences. They reported about the tendency of decreasing ratio with age.

Comparing the root/shoot ratios of perennial grasses with perennial woody *Fumana* in the semiarid grassland *Festucetum vaginatae* we can find essential differences. Perennial grasses can be characterised with overwhelming root masses, but the root/shoot ratio shows considerable seasonal and inter-annual fluctuations according to the actual weather conditions. *Fumana* as a woody plant with long-lasting anatomical structures and functions of branches and roots has not such a plasticity. The growing intensity both of the

branches and roots could differ from year to year but the resulting woody phytomass is accumulated and conserved, therefore the root/shoot ratio is a more conservative feature, it can serve as a "memory" of past events and environmental effects.

The slight prevalence of roots at the arid Fülöpháza site, although because of the high variance statistically non significant, may reflect on longer-time dry climatic effect.

The tendency of decreasing importance of root mass with age at both sites could be explained by increasing rooting depth. Roots of older individuals penetrate deeper, and in the sand soil deeper horizons contain enough water for properly supplying *Fumana* even in case of lower root density.

Based on the climate induced differences between growth characteristics of *Fumana* populations of the "wet" Gönyű and the "dry" Fülöpháza sites we can expect certain changes with the prognostized climate change.

Regional climate change scenario predicts an increasing aridity for the Hungarian Plain (Mika 1988). The duration of drought in the summer months is predicted to increase from the recent 1.4 to 2.2 months per year (Molnár and Mika 1997). As a consequence we can expect a decrease in species richness and plant cover of the *Festucetum vaginatae* community.

The habitat for *Fumana* will be more open and of simplified structure. Due to the increasing aridity the reduced growing activity of *Fumana* probably produces shorter branches and smaller stem diameter, while the average mass of roots not necessarily increases, instead the variability in root mass and rooting depth may increase.

Important perspective of our recent work is, that having established a reliable relation between basal stem diameter and age of *Fumana* individuals, we developed a simple, quick and non-destructive field method for age determination. This can serve as methodical basis for further ecological studies on *Fumana* populations and their role in age determination of the stands of community, undergoing regeneration processes following disturbances.

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