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Spatiotemporal aspects of the occurrence of clonal steppe plant *Adonis vernalis* L. in the southern Poland

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Abstract: The research was carried out in three steppe nature reserves in the Nida Basin (southern Poland) aiming at determine an impact of geomorphological conditions and spatial arrangement on selected parameters of life history of *Adonis vernalis* in the year 2007-2008. In each reserve 10 1-m^2 permanent plots, using stratified-random sampling method, were established and frequency of particular developmental phases were noted in April and May. In 2007 and 2008 total 1145 and 1132 ramets were counted respectively. We observed negative relationships between density of clumps per 1 m^2 and number of specific developmental phases and height of clumps. Phenology of *Adonis vernalis* shows distinct year-to-year changes what is probably connected with sensitivity of plants to weather fluctuations. Our study revealed that relations between ramets and density of clumps are similar independently on local biotopic conditions, relief structure, differences in abundance of population, and type of vegetation in neighbourhood.

Keywords: phalanx, clonal plant, xerothermic grasslands, phenology

Introduction

The biology and ecology of so-called clonal plants intrigued researchers for a long time. Lovett-Doust (1981) distinguished two categories of clonal growth form: phalanx and guerrilla. They are opposite strategies of growth; first one is typical for clump plants and the second one for plants spreading using stolons or stolon-like rhizomes (Harper 1986; Jankowska-Błaszczuk 1995). A phalanx growth form enables clonal plants to make better use of resource-rich patches, whereas a guerrilla growth form provides them with opportunities to escape from resource-poor sites (Ye et al. 2006). Such strategy has crucial implications for determination of plant individuals in the field. Therefore, concept of genets, ramets, modules was developed (Falińska 1998). Spatial arrangements of various types of ramets, their occupied area, height, belowground clonal architecture and number depend not only on age of genetic individual but also process of growth and vegetative fragmentation (Klimeš, Klimešová 1999; Kostrakiewicz 2007; Czarnecka 2008; Ikegami et al. 2009). Interesting is question to what extend spatial arrangement of clump is affected by microhabitat factors, natural weather changes over the years and density of ramets in subpopulation. This study partially seeks to fill this gap exemplified by one of rare, clonal species.

One of clonal plants is *Adonis vernalis* (spring pheasant's eye, false hellebore). This species is a herbaceous perennial of the family Ranunculaceae, early flowering (beginning of April) and ripening of diaspores takes place in June. Its seeds germinate underground, with the pericarp remaining in the soil and seed leaves emerging on the surface. Seed productivity and the time of emergence of sprouts depend on ecological conditions of plant growth, usually it produces two kohorts (Jankowska-Błaszczuk 1991). *Adonis vernalis* is a plant characterized by clump growth; individuals consist of 1-4 modules (Jankowska-Błaszczuk 1995). It is wide ranged from the eastern part of Middle Europe, and western Siberia reaching the Yenissei region. In a middle and southwest part of Europe the area is disjunctive with some isolated growing places in mainly azonal habitats scattered from Southeast Sweden to Southeast Spain (Melnik 2004). *Adonis vernalis* is a species of steppe origin. In Poland it occurs in xerothermic plant communities, among others, it is a characteristic species for grasslands

from the Festucetalia valesiacae order, growing dry lime or loess soils rich in calcium carbonate (Matuszkiewicz 2002). This species is treated as a relic of steppe flora, occurs in the xerothermic habitats in the localities in Małopolska, Lubelszczyzna and to the north in valley of Vistula (Forycka et al. 2004), however, their populations significantly decreased in the last 50 years (Denisow et al. 2008).

The objectives of the work were seeking answers to the following questions: (1) which microhabitat factors i.e. slope, aspect (flat sites vs. southern facing sites), altitude influence interactions between number of vegetative and generative ramets? (2) how density of clumps influence on mean number and mean height of ramets; (3) to examine if there are differences in year-to year relations of ramets in a clump of focal species?

Methods

The studies were carried out in spring 2007 and were continued in spring 2008 in three localities; nature reserves, (Krzyżanowice, Skowronno, Polana Polichno) in southern Poland. Skowronno reserve (50°32'44"N, 20°29'42 E") is a strict reserve occupying 1.93 ha and it was established in 1960. It is situated near Pińczów in southern-western end of Pińczów Hummock in the southern part of Nida Basin. The area is surrounded mostly by arable fields. The relief is differentiated with rocks outcrops, sloped area. The vegetation included phytocoenoses of the Thalictro-Salvietum and the Sisymbrio-Stipetum associations which both occupy the largest patches and small patch of the Scorzonero-Seslerietum. These plant communities occur on calcareous rendzinas with light clay in upper top soil. *Adonis vernalis* grows abundantly in the patches of Thalictro-Salvietum (Jankowska-Błaszczuk 1995).

Krzyżanowice is a strict reserve (50°27’12”N, 20°33’30” E)(18.0 ha), founded in 1954 near villages Krzyżanowice and Leszcze in Pińczów district. It is located in western part of hill, built by marlstone, limestone and gypsum. This hill has flat top and steep slopes and is grown by, among others, Adonido-Brachypodietum pinnati, Inuletum ensifoliae, Thalictro-Salvietum and Sisymbrio-Stipetum. This is the largest steppe reserve in Ponidzie region.

Polana Polichno (50°28'4.51"N, 20°28'5.15"E) occupies 9.54 ha of an area and it was established in 1974 near village Młodzawy Duże close to Pińczów. The area of the reserve is a glade situated in the middle of forest complex. This glade is grown by steppe and grassland vegetation on shallow and dry soil formed on calcareous rock.

Randomly 10 plots 1 m x 1 m were laid out in each nature reserve. The method close to random-stratified metod was used. The plots were chosen in that way to differ in slope (southern slopes and flat sites), altitude, degree of insolation due to abiotic variation in a stand and they were located each other at least 10 metres to avoid psudoreplication. They were numbered and marked in the field. For each plot exposure (aspect) and slope was determined. Slope was measured as a difference between the highest point and the lowest point within area of 1 m radius. Also geographical coordinates and altitude above sea level using GPS device were characterized. Aspect was measured in 16 degree scale (~22.5º). In each plot clumps (ramet clusters) were counted and their distribution was determined and marked on cartogramm. The clump was defined as spatially distinguishing group of shoots (Jankowska-Błaszczuk 1995). In April the following parameters were measured: number of total ramets, number of vegetative and flowering ramets, number of budding ramets and mean height of a clump, in May all flowering and fruiting ramets were counted.

The relations between continuous variables e.g. slope, altitude and abundance or height of clumps of *Adonis vernalis* were analyzed using Spearman rank correlation. The influence of ordinal variables e.g. exposure and categorical variables were analyzed by means of ANOVA or Kruskal-Wallis test then in case data did not meet assumptions for parametrical tests. HSD Tukey or Conover test (Munzel et al. 2001) were used for pair-wise comparisons. In order to compare mean number of ramets per a clump between years in April and in May separately Mann-Whitney *U* test was used. To study the effect of density of clump on mean number of ramets and height of clump Spearman rank correlation test was employed. All analyses were done with R software (R Development Core Team 2008).

Results

Basic habitat parameters of stands are shown in Table 1. In 2007 total 265 clumps were counted which consisted of 1145 of all types ramets, whereas in 2008 total 248 clumps comprising 1132 ramets were recorded. The highest number of clumps and ramets was recorded in Krzyżanowice (130 clumps), Skowronno has 99 clumps and in Polana Polichno

there were 34 clumps. The mean number of clumps per plot was similar over the two years 8.8±6.4 and 8.5±2.6 respectively in 2007 and 2008 (p = 0.97).

We found that number of clumps in1m^2 plots positively is correlated with slope and negatively with altitude (Tab. 2). Whereas, relation between aspect of plot and abundance of clumps demonstrate that higher number of clumps is associated with SSE-facing plots (χ^2=117.2, p<0.0001)(Tab. 2). The mean height of clumps were at flat and south-western facing plots (Tab. 3); with increasing slope mean height decreases and increases with altitude a.s.l. but only in 2007 (Tab. 2). Number of ramets within a clump decreases with slope and increases with altitude. In April, mean number of vegetative shoots per clump did not differ between the years and amounted to ca. 2.2 ramets. Flowering ramets increased in clumps in 2008 in comparison with 2007 likewise mean number of budding ramets, but fruiting ramets decreased (Fig. 1). In May there were very small mean number of flowering ramets and it was estimated ca. 0.01 in 2007 but in 2008 their number was much higher ca 0.1 per a clump, whereas the number of fruiting ramets increased significantly from ca. 1.7 in 2007 to 3.0 ramets in a clump (Fig. 1). Height of ramets amounted to 16.07±6.5 cm in 2007 and 15.61±5.5 cm in 2008. It did not change significantly (p = 0.76).

Although total and mean number of clumps including particular types of ramets and height varied between the years, interrelations between them are similar for both years (Tab. 3). With the increase of number of clumps in plots, the mean number of particular types of ramets in clumps decreases. The only exceptions are: influence of density of clumps on mean number of budding ramets in 2007 and response of mean number of fruiting ramets in 2008 (Tab. 3).

Tab. 1: Basic parameters of abiotic conditions and clump characteristics of *Adonis vernalis* in studied nature reserves.

Variable	Krzyżanowice (n=10)	Polana Polichno (n=10)	Skowronno (n=10)
Slope [°]	31.6±14.5	0	32.4±16.6
Altitude [m a.s.l.]	247.9±3.4	278.1±3.1	260.7±2,4
Aspect:			
flat	0	10	0
S	5	0	3
SE	1	0	1
SSE	3	0	2
SW	0	0	1
SWW	1	0	3
Mean number of vegetative ramets per a clump	1.788±1.419	5.559 1±3.526	1.767±1.236
Mean number of generative ramets per a clump	0.780± 1.564	4.588± 4.955	2.343± 3.267
Mean heigt of clumps	13.326±4.418	26.941±8.934	17.151±6.019

Tab. 2: Mean (±SD) of clump parameters of *Adonis vernalis* due to aspect (the values with the same letters do not differ at p<0.05 (Kruskal-Wallis test and Conover test) and values of Spearman rank correlation coefficients, * -p<0.05, **-p<0.01, ***p<0.001, ns – non-significant.

	Number of ramets in clump				Height of clump				Number of clumps in 1m plots			
	2007		2008		2007		2008		2007		2008	
Flat	10.4±7.9	a	8.9±7.3	a	26.9±17.5	a	17.3±5.1	a	3.4±1.5	e	3.6±1.7	c
S	5.4±4.9	b	6.7±5.7	a	17.6±7.0	b	18.8±5.1	a	10.9±2.5	b	9.7±2.2	b
SE	2.4±1.5	c	2.6±1.7	c	14.4±3.0	cd	12.4±3.9	b	12.5±9.9	c	14.5±10.4	b
SSE	1.7±1.3	d	2.0±1.5	c	12.1±5.0	e	12.4±4.6	b	21.3±2.4	a	19.0±5.3	a
SSW	2.1±1.5	cd	2.2±1.6	c	13.4±7.5	de	14.4±4.5	b	9.0±4.6	c	9.3±5.5	b
SW	4.1±3.6	b	4.0±3.2	b	16.0±9.0	bc	17.8±6.4	a	6.3±1.0	d	7.0±1.7	b
slope	-0.27***		-0.19**		-0.2***		-0.2***		0.65***		0.65***	
altitude	0.39***		0.30***		0.41***		ns		-0.62***		-0.64**	

Tab. 3: Impact of density of clumps per 1m on mean number and mean height of ramets of *Adonis vernalis* within a clump. *-p<0.05; **-p<0.01; ***-p<0.001, ns-non-significant.

Year	2007	2008
Variable	**Rs**	**Rs**
vegetative ramets	-0.50***	-0.59***
flowering ramets	-0.43*	-0.63***
fruiting ramets	-0.55**	-0.05 ns
budding ramets	0.07 ns	-0.45*
Height	-0.60***	-0.44*
Total number of ramets	-0.61***	-0.59***

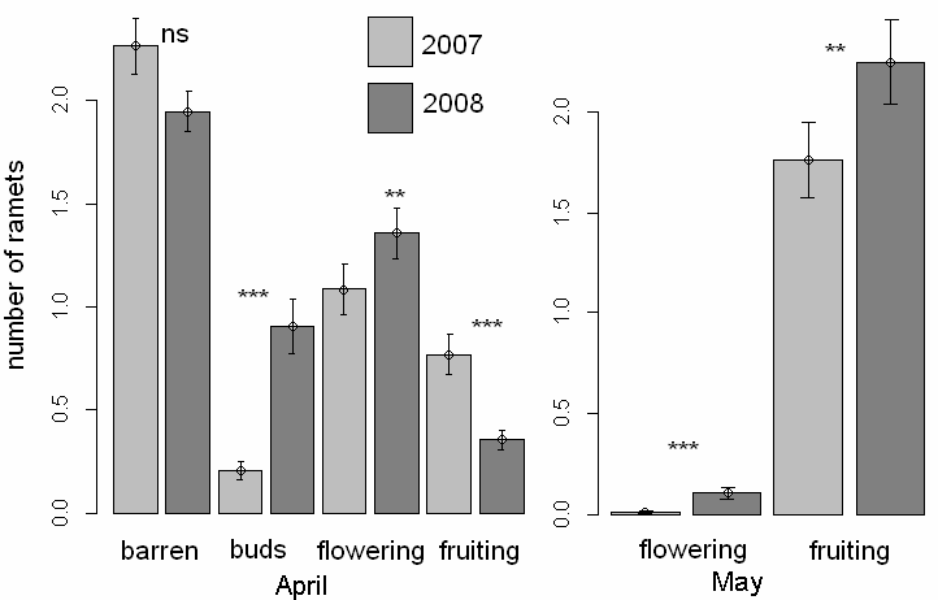

Fig. 1: Comparison of mean numbers (±SE) of ramets in clumps of *Adonis vernali*s between 2007 and 2008 in April and May. *-p<0.05; **-p<0.01; ***-p<0.001, ns-non-significant

Discussion and conclusions

In the studied nature reserves *Adonis vernalis* grows in different biotopic habitats including altitude, slope and aspect. All these parameters affected density, frequencies of particular developmental stages and height of ramets of plants. It could be expected that these microhabitat traits should not have constrained growth of *Adonis vernalis*. Clonal plants are characterized by the ability to propagate by vegetative means resulting in the production of new ramets within a genet. Their growth is known as a mechanism of foraging for resources, competition and compensation of environmental heterogeneity (Schmid 1990). Despite this, Jankowska-Błaszczuk (1991) stated that differentiated spatial structure of *Adonis vernalis* is strongly influenced by various forms of management and microclimatic conditions. She included, among others, N and NE slopes as well as flat areas on the tops of hills which are characterized by lower temperature and thinner layer of soil limit growth of underground organs. In our study it was demonstrated that slope constrained not only number of vegetative ramets in clumps, as was shown by Jankowska-Błaszczuk (1991), but also had an negative impact on the height of clumps. It should be connected that thin layer of soil on rock outcrops also hamper growth of aboveground organs. The most favorable conditions for growth of *Adonis vernalis* are in flat areas what is reflected in higher spatial density of ramets, larger their mean height and greater number of both types of ramets. On southern slopes height of

clumps is lower what generally confirms other studies which revealed that some plant traits as leaf size (Auslander *et al*. 2003), seed mass (Csontos *et al*. 2004) or height of plants (Chmura 2008) amount lower values on southern slopes than on northern slopes. However, density of clumps is higher on southern-facing slopes than on flat sites. It could be explained that above-mentioned factors associated with slope and aspect controlling growth of biomass of perennial rhizomes has not an impact on seedling recruitment and development of small, in terms of number and biomass of ramets, individuals. Spring pheasant's eye is a species considered as a phalanx type strategist i.e. (modules tightly aggregated within clones) (Schmidt 1986) as it was revealed by Jankowska-Błaszczuk (1995) in her study on morphological characters of this plants. Development of clumps undergo several phases when number of virginile and juvenile individuals in clumps increases with increase of the clump area and spatial structure of subpopulation become more dense and aggregate (Jankowska-Błaszczuk 1995). Therefore, situation when there are many small clumps with low number of ramets (individuals) and on the opposite when there are few ones but large in area and number of ramets within them should be associated with biology of growth and sequencing of spatial structures types in *Adonis vernalis*. Surprising observed fact was the difference in mean number of developmental phases per clump between the years. It proves that vegetation season both in April and May in 2008 year was delayed (In 2007 mean temperature in May was 14.9°C but in 2008 only 12.8°C). In April of 2007 higher fraction of ramets entered into phase of fruiting than those which were in blossom phase when compared to 2008. Also in 2008 year higher mean number of budding ramets were recorded. Higher mean number of flowering ramets and lower number of fruiting shoots in 2008 is a consequence of delay in appearance of particular developmental phases in April. Jankowska-Błaszczuk (1995) states that phenology of *Adonis vernalis* is adapted to weather hesitations as long and frequent droughts. It is reflected, among others, by more intensive growth of aboveground shoots due to higher moisture in soil in spring in comparison with summer. However, phenology may be changeable dependently on geographical region. According to Poluyanova & Lyubarskii (2008) active development of vegetative parts proceeds throughout summer. More unexpected fact was very small number of flower visitors observed on flowers of *Adonis vernalis*.

To sum up, we conclude that our results are agreed with results of Jankowska-Błaszczuk (1991, 1995) about spatial arrangement and mutual relations between particular developmental phases in *Adonis vernalis*. Her research was conducted in one of the studied object in the present work i.e. Skowronno Dolne. These relations between ramets and density of clumps are similar independently on local biotopic conditions, differences in abundance of population, type of vegetation in neighbourhood, relief structure. Above-mentioned parameters which contributes to the differences between three studied populations do not change relationships in a scale of clump. Phenology of *Adonis vernalis* between shows year-to-year changes what is connected with sensitivity of plants to weather fluctuations.

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