ABSTRACT: The investigations of structure of the genets and populations of *Iris sibirica* L. were carried out in the period 1999–2002. The studies were conducted in *Molinietum caeruleae* patches localized in Southern Poland. The patch labelled MW ("more wet") measured 5,600 m² and was characterised by presence of large depressions filled with stagnant water, concentrated chiefly in the central part of the site. In this locality species with a high competitive potential (like *Phragmites australis* Trin., *Chamaenerion angustifolium* (L.) Scop., *Epilobium hirsutum* L., *Filipendula ulmaria* (L.) Maxim. and others) prevailed. The patch called LW ("less wet") measured 1,800 m² and was characterised by small number of depressions scattered throughout the site. In this locality dominated the plants of minor competitive abilities (like *Lathyrus pratensis* L., *Lotus corniculatus* L. and others).

The spatial pattern of populations was described on the basis of the locations of all ramet clusters in 100 m² square plots. Each ramet cluster was attributed to a developmental stage. The differences in height of ramets between stages was estimated on the basis of length of the tallest leaf and generative shoot measured in all genets and ramet clusters in both populations (30 leaves and all generative shoots in 5 clusters of ramet at generative and senile stages and 4 – at fragmentation phase in both populations).

In study year 2000 *Iris sibirica* population in LW locality was consisted of 26 ramet clusters and showed an aggregation structure, while population growing in MW site was consisted of 502 ramet clusters and presented the group-aggregation spatial structure constituted by groups of dozen or so ramet clusters, forming large aggregations. Both populations showed signs of senility in effect of absence of genets in prereproductive stages. In 2001 and 2002 the seedlings and juvenile genets appeared only in artificially made gaps. The genets in initial stage are much lower (about 40 %) than older ones and the ramet in MW locality reached greater height (6 to 23%) than in LW site.

The evaluation of structure of populations taken as indicator of their vitality, show that the population from less wet locality was in better condition despite of low abundance. Domination of ramet cluster at generative stage and vicinity of plants with low competitive potential enables longer existence of *Iris sibirica* in occupied site. In more wet locality the *I. sibirica* population is worse equipped to survive. Advanced senility and the vicinity of plants with high competitive potential might inhibit the proliferation of *I. sibirica* ramet clusters, accelerate their fragmentation or even eliminate from occupied site.

KEY WORDS: clonal plant, genet, *I. sibirica*, ramet cluster, population structure
1. INTRODUCTION

The relationship between the structure of plant population and the vegetation of which they are the part was first described for a clonal plants, representing a more convenient subject for studies, because of their unitary growth, short life span, and solely generative manner of reproduction. The structure of clonal plant populations was described by many authors such as Mack and Harper (1977), Watkinson and Harper (1978), Symonides (1979a, b, c), Mahdi and Law (1987), Falińska and Pirożnikow (1983) and Wilkoń-Michalska (1985). Much less known is the population structure of clonal species, characterized by a multi-shoot architecture of genets, longevity of individuals, as well as genetative and vegetative propagation (Harper 1977). Towpasz and Szymka (1983), Falińska (1985, 1986, 1991), Czarnecka (1989), Jankowska-Błaszczuk (1991), Brzosko (1991, 2001), Bühler and Schmid (2001), Bissel et al. (2004) represent authors who carried out observations of population structure of clonal species.

The evaluation of age, size and spatial structure of population might be considered as an indicator of viability of populations. It is important, particularly with respect to endangered or rare species, because it is useful tool in their conservation and management (Hutchings 1991, Owen and Rosentrer 1992). The effective programs for protection of threatened plants were formed for many of species such as Isotria medeoloides (Pursh) Raf. (Merhoff 1989), Peucedanum palustre L. (Harvey and Meredith 1981) or Gentiana pneumonanthe L. (Oostermaier et al. 1994).

Iris sibirica belongs to clonal species strictly protected in Poland. It is a Euro-Siberian sub-element. Most of the localities for this taxon occur in Lower Silesia (S. Poland), the Lublin upland and the Roztocze upland regions (Central and East Poland), whereas the least number of localities are found along the Baltic Sea coast and in the Western Pomerania regions (Zając and Zając 1997). Although the populations of this species can occur within various types of vegetation, they are the most often in blue moor-grass meadows (Molinietum caeruleae). Long-living individuals of Iris sibirica consist of numerous leaf rosettes and flowering shoots linked with permanent rhizomes with short internodes. They reproduce in generative or by vegetative way through the growth and fragmentation of individuals (Klimeš et al. 1997, Klimeš and Klimešów 1999).

The objective of this research project was to study 1) how the structure of genets and ramet clusters unfold through the consecutive age stages of Iris sibirica; 2) how the spatial structure of populations occurring in different conditions change over time; 3) what is the age structure of studied populations and 4) what is the size of genets and ramet clusters in studied populations.

2. STUDY AREA

The studies were carried out on blue moor-grass meadows, in two localities in southern Poland. In the Podgórze Bocheńskie foreland, (49º58' N, 20º22' E), (local name Stanisławice) the study area measured 5,600 m² was localised; it was characterised by large and numerous wet depressions occurring chiefly in the central part of the studied site. It was labelled MW – “more wet”. In the southern part of Kraków (50º04' N, 19º50' E); (local name Opatkowice) the study area measured 1,800 m² and characterised by a small number of depressions scattered throughout the area was localised. It was called LW – “less wet”.

At both sites there are patches of Molinietum caeruleae, being remnants of vast meadows once stretching along the Vistula River (Zarzycki 1958). In both patches of Molinietum caeruleae, the presence of a large number of rare and protected species was noted, such as: Dianthus superbus L., Gentiana pneumonanthe L., Gladiolus imbricatus L., Trollius europaeus L. and Orchis latifolia L. (Dubiel 1991, 1996, Kostrakiewicz 2000). Nowadays in Europe the blue moor grass meadows are endangered by the agricultural practises, such as intensification of management, forest plantation or land abandonment (Fuller 1987, Green 1990, Prah 1993, Joyce and Wade 1998, Muller 2000). The International Union for the Conservation of Nature (IUCN) has listed them as being among the most endangered plant communities in Europe (Denisiuk 1991).
The study patches were of similar floristic composition, but with different dominant species (cover of each dominant species exceeded 50%). In MW site fleshy, deeply rooted tall perennials spreading vegetatively by creating long radially rhizomes predominated (like *Phagmites australis* Trin., *Chamaenerion angustifolium* (L.) Scop., *Epilobium hirsutum* L., *Filipendula ulmaria* (L.) Maxim.). Also the plants creating robust primary root and strongly developed adventitious roots (i.e. *Lythrum salicaria* L.), as well as perennials forming a large compact tussocks (*Molinia caerulea* (L.) Moench., *Deschampsia cespitosa* (L.) P.B., *Juncus conglomeratus* L. and *Carex gracilis* Curt.) and aggregations of willow (*Salix rosmarinifolia* L., *S. cinerea* L.) were numerous. In the LW site plants of a less competitive potential prevailed. The dominant species there were ones with delicate, shallowly rooted rhizomes or stolons (i.e *Lathyrus pratensis* L., *Lotus corniculatus* L.), small-tussock species (i.e *Briza media* L., *Holcus lanatus* L.) or rosette-forb species (i.e *Lychnis flos-cuculi* L., *Succisa pratensis* Mnch.). The density of the herb layer in both patches was ca. 100%, and the substrate was covered by a litter layer whose thickness varied from several to a dozen or so centimetres.

3. MATERIAL AND METHODS

The studies were carried out during the period 1999–2002. Observations of structure of populations were performed during the period 2000–2002 in populations from both sites. In 2000, in MW site, there were

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### Fig. 1. Spatial structure of population in LW ("less wet", Table 1) locality.

A. Distribution of ramet clusters in whole area 1,800 m².

B. Distribution of ramet clusters and genets in square A 4 in consecutive years.

- the 100 m² square
- the genet at initial stage
- the genet at juvenile stage
- the ramet cluster at generative, senile or fragmentation stage

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**A.**

<table>
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<th>5</th>
<th>6</th>
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</tbody>
</table>

**Year 2000**

**Year 2001**

**Year 2002**
502 clusters of ramets of Iris sibirica covering 5,600 m², whereas in LW site, 26 clusters were recorded in an area of 1,800 m². To measure spatial pattern of populations, square-based method was used. Areas of both study sites were divided into the net of squares and measured respectively (Figs 1, 2). The locations of all ramet clusters were noted in 100 m² squares, and the points representing them were plotted on cartogrammes. The effect of gaps on spatial structure was also investigated. In 2000, all vegetation cover and litter surrounded each ramet cluster of Iris sibirica were removed in squares A4 in LW site (Fig. 1) and A11 in MW site (Fig. 2). Experimentally created gaps measured approximately 1 m². In order to describe the age structure of populations each ramet cluster was attributed to the developmental stage. The size of genets and ramet clusters was estimated on the basis of height (in cm) of leaves and generative shoots.

The longest leaf and generative shoot in ramet clusters at generative, senile and fragmentation stages were measured in the year 2000. The longest leaf in genets at initial stage
Population structure of \textit{Iris sibirica} L. were measured in the year 2001, while in juvenile individuals – in the year 2002.

The statistical analysis of differences in the height of ramets in consecutive stages was performed using the Mann-Whitney U test. The differences in the height of ramets between studied populations were defined. In the year 2000, in both populations 5 clusters of ramet at generative and senile stages and 4 – at fragmentation phase were selected and marked. Each year, 30 leaves and all generative shoots were measured. The Student t-test was applied to the statistical analysis of differences of height of leaves forming by ramet clusters from both sites populations. The statistical analysis of differences of height of generative shoots was performed using the Mann-Whitney U test.

4. RESULTS

The spatial structures of the studied \textit{Iris sibirica} populations was of cluster type. In 2000, the population growing in the LW locality, showed an aggregation structure formed by several clusters of ramets, isolated

![Diagram](image_url)
one from another (Fig. 1). The population situated in MW locality demonstrated the group-aggregation spatial structure. Groups of dozen or so ramet clusters were close to each other, forming large agglomerations (Fig. 2). In 2001 and 2002 the dimensions of aggregations increased in effect of seedling recruitment. This phenomenon was observed only in square A 11 in MW locality and A 4 in LW site (Fig. 2).

Age pyramids indicate that in 2000 both populations showed signs of senility. Genets in prereproductive stages were not found; there were only ramet clusters in generative, senile and fragmentation stages. During next two years the seedlings and juvenile genets appeared (Fig. 3). In 2000 population growing in the MW locality consisted of 191 generative, 206 senile and 105 disintegrating ramet clusters. The ratio of ramet clusters in generative stage to ramet clusters in senile and fragmentation stages was 1:1. In 2001, 31 individuals in initial stage were found. In 2002, 2 individuals in initial stage and 24 juvenile genets were observed.

On the basis of height of 30 leaves and all generative shoots it was found that cluster of ramets in MW site reached greater height than in LW locality (Table 1). The average height of leaves achieved from 66.9 cm to 71.3 cm in generative stage in LW site and from 78.9 cm to 89.8 cm in MW locality (Fig. 4). The mean lenght of leaves in senile stage in population growing in LW site ranged from 60.7 cm to 82.7 cm, whereas in population growing in MW locality – from 81.7 cm to 89.3 cm. The average height of leaves in fragmentation stage in LW locality reached from 67.9 cm to 84.1 cm and in population from MW site it achieved from 81.1 cm to 89.3 cm. Also the analysis of the height of generative shoots confirmed that in MW locality ramet clusters reached the greater height than in LW site (Fig. 5). The mean lenght of generative shoots in generative stage in LW site ranged from 67.2 to 79.3 cm, whereas in MW locality – from 84.2

Table 1. The height of the tallest leaf and generative shoot of genets and ramet clusters of Iris sibirica in LW 1 and MW 1.

<table>
<thead>
<tr>
<th>Site</th>
<th>Stage</th>
<th>Year</th>
<th>Number of genets or ramet clusters</th>
<th>The height of the tallest leaf (cm)</th>
<th>The height of the tallest generative shoot (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Range</td>
<td>Mean</td>
</tr>
<tr>
<td>LW locality</td>
<td>Initial</td>
<td>2001</td>
<td>31</td>
<td>28–39</td>
<td>32.2</td>
</tr>
<tr>
<td></td>
<td>Juvenile</td>
<td>2002</td>
<td>24</td>
<td>69–98</td>
<td>82.9</td>
</tr>
<tr>
<td></td>
<td>Generative</td>
<td>2000</td>
<td>13</td>
<td>69–97</td>
<td>82.1</td>
</tr>
<tr>
<td></td>
<td>Senile</td>
<td>2000</td>
<td>9</td>
<td>78–90</td>
<td>83.6</td>
</tr>
<tr>
<td></td>
<td>Fragmentation</td>
<td>2000</td>
<td>4</td>
<td>79–99</td>
<td>91.5</td>
</tr>
<tr>
<td>MW locality</td>
<td>Initial</td>
<td>2001</td>
<td>29</td>
<td>30–40</td>
<td>35.2</td>
</tr>
<tr>
<td></td>
<td>Juvenile</td>
<td>2002</td>
<td>24</td>
<td>73–98</td>
<td>87.4</td>
</tr>
<tr>
<td></td>
<td>Generative</td>
<td>2000</td>
<td>191</td>
<td>69–120</td>
<td>92.6</td>
</tr>
<tr>
<td></td>
<td>Senile</td>
<td>2000</td>
<td>205</td>
<td>70–118</td>
<td>96.7</td>
</tr>
<tr>
<td></td>
<td>Fragmentation</td>
<td>2000</td>
<td>105</td>
<td>80–110</td>
<td>98.6</td>
</tr>
</tbody>
</table>

1 MW “more wet” = depressions with stagnant water numerous
LW “less wet” = depressions with stagnant water not numerous

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Fig. 4. The mean height of 30 leaves in *Iris sibirica* ramet clusters from LW ("less wet") and MW ("more wet") localities – differences statistically significant between ramet clusters in pair. *P* <0.05; ** <0.01; *** <0.001.
Fig. 5. The height of generative shoots in pairs of ramet clusters of *Iris sibirica* in LW ("less wet") and MW ("more wet") localities – differences statistically significant between ramet clusters in pair. *P* < 0.05; ** < 0.01; *** < 0.001, NS – not significant.
to 94.8 cm. The average height of generative shoots in senile stage measured from 62.8 to 86.8 cm in LW site and from 84.3 to 95.3 cm in MW locality.

5. DISCUSSION

The spatial structure of the Iris sibirica populations coincides with the pattern of depressions filled with water, that stagnates throughout the whole year. A similar trend to occupy the depressions was also observed among individuals of Iris pseudacorus L., Filipendula ulmaria, Carex cespitosa L., C. acutiformis Erch., and C. versicaria L. (Falińska 1985, 1991, 2003, Brzosko 1991, 1998, 1999a). The iterative growth of genets affects also the spatial structure of the Iris sibirica populations. It contributes to changes in the spatial distribution of above-ground units: from the formation of a compact ramet cluster in the early stages of development, via the formation of regular ring at the mature stage and the appearance of group of ramets at senile stage to their full separation at the fragmentation phase. Similar changes in the structure of genets were noted in other species of the same architecture such as Iris pseudacorus, Filipendula ulmaria, and Carex cespitosa (Falińska 1985, 1995, 1997, Brzosko 1999b). The division of individuals leads to changes in the spatial structure of a population and is modified by neighbouring plants. Robust underground parts of tall plants invade rhizomes of Iris sibirica, accelerating their divisions, whereas species with delicate underground organs, did not accelerate their fragmentation. Similar phenomenon was observed in population of Carex cespitosa, Filipendula ulmaria, Cirsium rivulare and C. palustre in abandoned meadows (Brzosko 1999c, Falińska 2003). The second factor contributing to enlarging the aggregations is recruitment of new genets next to places where mature plants are growing. The same phenomenon was found in other clonal species, such as: Iris pseudacorus, Filipendula ulmaria, Carex cespitosa and Adonis vernalis L. (Falińska 1985, 1986, 1991, Jankowska-Błaszczyk 1991).

Age structure of Iris sibirica populations in first year of study showed signs of senility in effect of absence of genets in prereproductive stages. Generative ramet clusters dominated in LW (“less wet”) site, while in MW (“more wet”) locality – senile ramet clusters. These results corespond with the investigations of the age structure in populations of Iris pseudacorus, Filipendula ulmaria, and Carex cespitosa in different habitat conditions (Falińska 1985, 1986, Brzosko 1999b). Domination of individuals in generative stage was found in the meadow, while the senile ones in brushwood or dwarf shrubs communities. During study period a gradual aging of Iris pseudacorus and Carex cespitosa populations was observed (Falińska 1985, 1986, Brzosko 1999b). Changes in the age structure resulted primarily from the fact that individual plants moved into subsequent phases of development and as the result of the apparence of new genets (Falińska 1986, Brzosko 1999b). In Iris sibirica population rejuvenation of age structure was the effect of seedlings recruitment only in artificially created gaps.

The increase of the height of Iris sibirica ramets in consecutive stages was similar to Iris pseudacorus and Carex cespitosa (Falińska 1986, Brzosko 1999a). Additionally the ramet clusters growing in the vicinity of tall, strong competitors were higher than surrounded by plants with low competitive potential. The heigth of leaves observed in LW (“less wet”) locality was similar to values recorded by Sporek and Rombel-Bryzek (2005). It worth to be mentionned that many annuals and biennials as well as perennials presents the correlation between plant size and fecundity (Aarsen and Jordan 2001, Obeso 2002). The efficiency of generative reproduction increased with plant size in Plantago major L. (Reekie 1998), Ranunculus acris L. (Hemborg and Karlson 1998a) and Trollius europaeus L. (Hemborg and Karlson 1998b), whereas it decreased in Asphodelus albus (Obeso 1993).

To sum up, the different moisture conditions of ground as well as the vicinity of plants with various competitive ability affected spatial organization of Iris sibirica populations, their age structure as well as size of genets and ramet clusters. Values of these features, taken as indicators of the vitality of a population, show that the popu-
lation from less wet locality was in better condition despite of low abundance. Domination of ramet cluster at generative stage and vicinity of plants with low competitive potential enables longer existence of Iris sibirica in occupied site. In more wet locality the I. sibirica population is worse equipped to survive. Advanced senility and the vicinity of plants with high competitive potential might inhibit proliferation of I. sibirica ramet clusters, accelerate their fragmentation or even eliminate from occupied site.

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