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The materials to determine the eastern range border of acidophilous oak forest *Calamagrostio arundinaceae-Quercetum petraeae* in Poland – two new stands of the association in the southern part of Mazovian Voivodeship

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Abstract. Acidophilous oak forests *Calamagrostio arundinaceae-Quercetum petraeae* (Hartm. 1934 Scam. et Pass. 1959) are mostly known from the western part of Poland, while its eastern border has not been determined accurately. In order to address this issue, we performed a phytosociological analysis of two newly identified stands of acidophilous oak forest located in the southern part of the Mazovian Voivodeship near Kiedrzyn (vicinity of Nowe Miasto nad Pilicą) and Mikówka (vicinity of Białobrzegi). For comparison, we also examined the distribution of known patches in the region (Łódź and Mazovian Voivodeships) against this association's background of the eastern range border.

Within the identified sites, a total of 10 phytosociological relevés were taken and soil samples were collected from a depth of 10 cm. The content of organic matter, soil pH and sieving analysis were performed in the laboratory. The phytosociological material was ordered and numerically classified which gave two groups of relevés: typical for this association (seven relevés) and a degenerated form (three relevés), which has an increased share of pine in the stand. All our relevés were similar to acidophilous oak forests from the Wielkopolska region and thus different from oak-pine forests of eastern Poland. Habitat conditions of the patches and the bonitation of oak were analogous to patches of this association from other parts of Poland. Furthermore, the sites we studied are located between known locations from the Bolimowska and Kozienicka Forests and are therefore connecting these two previously known areas of occurrence. This indicates that the range of the *Calamagrostio-Quercetum* association is at least a few dozen kilometers wider in this part of the country than the assumed range.

Keywords: *Quercetea robori-petraeae*, central Poland, sessile oak, pinetization, degeneration forms

1. Introduction

The acidophilous sessile oak forest (acidophilous central European oak forest, central European lowland oak forest) *Calamagrostio arundinaceae-Quercetum petreae* (Hartm. 1934 Scam. et Pass. 1959) was described in Germany (Hartmann 1934; Scamoni 1961) and later in western Poland (Fabiszewski, Faliński 1964). It occurs mainly in areas lacking beeches. The centre of its occurrence in Poland is in the south-western and western part of the country (Matuszkiewicz 1988; Kasprowicz 2010). Among the associations of the *Quercetea robori-petreae* class, it is most similar to the mixed coniferous forests of the *Dicrano-Pinion* alliance within the *Vaccinio -Piceetea* class. In central Poland, there is a wide transitional belt between these communities; hence, it has been difficult to delimit their ranges for years (Matuszkiewicz 1988). The syntaxonomic separation of acidophilous oak and mixed coniferous forests in central Europe, as well as the distinction of their basic associations has been attempted for decades (Matuszkiewicz, Matuszkiewicz 1996; Kasprowicz 2010).

The basic component of the acidophilous oak forest is the sessile oak *Quercus petraea*, possibly with a small admixture of Scots pine *Pinus sylvestris* L. in the stand. The shrub layer is distinguished by the presence of: alder buckthorn *Frangula alnus* Mill., rowan *Sorbus aucuparia* L. or hazel *Corylus avellana* L. The undergrowth is characterized by a significant share of general forest mesotrophic species, such as: the bunchgrass *Calamagrostis arundinacea* (L.) Roth, wavy hair-grass *De-*

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schampsia flexuosa (L.) Trin., common cow-wheat *Melampyrum pratense* L., bracken *Pteridium aquilinum* (L.) Kuhn, May lily *Maianthemum bifolium* (L.) F. W. Schmidt, and a small share of species of the *Vaccinio-Piceetea* class, mainly bilberry *Vaccinium myrtillus* L. and lingonberry *Vaccinium vitisidaea* L., and the presence of species associated with acidophilous oak forests in general, especially the hawkweeds *Hieracium* spp. In addition, some of deciduous forests species sporadically grow there, such as mountain melick *Melica nutans* L. and early dog-violet *Viola reichenbachiana* Jord. ex Boreau. Pill sedge *Carex pilulifera* L. and sheep fescue *Festuca ovina* L., regularly appear in this community, distinguishing it from other acidophilous oak forest associations. The moss layer of the acidophilous oak forest is poorly developed, most often with broom forkmoss *Dicranum scoparium* Hedw., hypnum moss *Hypnum cupressiforme* Hedw. or bank haircap *Polytrichastrum formosum* (Hedw.) G. L. Sm. (Matuszkiewicz 1988, 2001; Matuszkiewicz 2008; Kasprowicz 2010; Matuszkiewicz et al. 2012). In the Wielkopolska region, the acidophilous oak forest is primarily associated with the forest habitat types defined as fresh mixed coniferous forests, fresh mixed deciduous forests and poorer fresh forests (Lasota et al. 2005). It occurs mainly on sandy (loose and weak loamy) formations (Lasota et al. 2005; Rutkowski, Maciejewska-Rutkowska 2007).

The *Calamagrostio arundinaceae-Quercetum petraeae* association has been recorded in many locations in southern, southwestern and western Poland (e.g., Krotoska, Piotrowska 1962; Fabiszewski, Faliński 1964; Kamionka 1971; Kuczyńska 1973; Celiński, Wika 1978; Olaczek 1986; Matuszkiewicz 1988; Cabała 1990; Hereźniak 1993; Kwiatkowski 1995; Brzeg et al. 2001; Greń, Wika 2009; Kurowski 2009; Kasprowicz 2010) and probably in the Świętokrzyskie Mountains (Matuszkiewicz 2001; Przemyski 2011 pers. comm. in Koba 2012). Data on acidophilous oak forests in the Wielkopolska region were collected by Brzeg et al. (2001), followed by Kasprowicz (2010). In this region, the need to extend the boundary of the association to the north was demonstrated (Kasprowicz 2010). Slightly later, patches of *Calamagrostio-Quercetum* were found in central Poland. This community was found in Łódź Voivodeship: in the eastern part of the Kolska Basin (Olaczek 1972), Załęczański Landscape Park (Olaczek 1986), Łagiewnicki Forest in Łódź and the nearby Parowy Janinowskie Reserve (Kurowski 1998; Andrzejewski, Kurowski 2001; Socha 2011; Kurowski, Andrzejewski 2013), the Dąbrowa Reserve in Marianek (Kiedrzyński, Kurowski 2013), the Diabła Góra Reserve (BULiGL 2017) and in the western part of the Bolimowska Forest (Jakubowska-Gabara 1999). In the Mazovian Voivodeship, the acidophilous oak forest was recorded in the eastern part of Bolimowska Forest (Jakubowska-Gabara 1999), and then in the Kozienicka Forest (Koba 2012, 2013). The eastern border of the range of *Calamagrostio arundinaceae-Quercetum* is difficult to establish, due to the existence of transition forms to *Querco roboris-Pinetum* and the small amount of available phytosociological data. For this reason, it is 'provisional' (Matuszkiewicz 1988; Matuszkiewicz, Matuszkiewicz 1996; Matuszkiewicz 2008). There are also reports of the occurrence of acidophilous oak forests in Ukraine (e.g., Matuszkiewicz et al. 2012; Goncharenko, Yatsenko 2020).

During the field work in the south of the Mazovian Voivodeship, two sites of the *Calamagrostio-Quercetum* association were found in the vicinity of the villages of Kiedrzyn (near Nowe Miasto nad Pilicą) and Mikówka (near Białobrzegi). These patches occur outside the 'provisional' boundary of the association's range adopted by Matuszkiewicz (Matuszkiewicz 1988; Matuszkiewicz, Matuszkiewicz 1996). They constitute a spatial link between the known border sites in Kozienicka Forest (Koba 2012, 2013) and the sites in the Łódź Voivodeship at the edge of their range. The aim of this study was to summarize the distribution of the known *Calamagrostio-Quercetum* sites in the area of the eastern border of its range (the Łódź and Mazovian Voivodeships) and to document two newly recognized sites of the association.

2. Materials and methods

The field work was conducted in the 2017 (Kiedrzyn) and 2019 (Mikówka) vegetation seasons. Phytosociological relevés of 400 m^2 each were prepared in accordance with the principles of the Braun-Blanquet school (1928), using the simplified Barkmann et al. scale (1964). Value 'rr' was assumed to be the smallest cover of species, corresponding to an area of about 0.01%, while the limit value between 'r' and '+' was assumed to be a cover area of 0.5%. No species occurring outside the phytosociological relevé area was recorded. Cover was used as the measure of abundance (Barkmann et al. 1964). Soil samples, from a depth of about 10 cm measured from the top of the mineral organic matter horizon, were taken from the central part of the phytosociological relevés for laboratory analyses. The soil samples were dried and divided. The skeletal and sand fractions were determined using the sieve method and compared using the PTG 2008 divisions (Polskie Towarzystwo Gleboznawcze 2009). The remaining part was sifted through a 1 mm diameter sieve. The content of organic matter in the upper soil level was determined by the loss on ignition method at 600°C; pH was measured using an electronic pH-meter in a distilled water solution in a standard ratio of 10:25. Phytosociological data were subjected to arithmetic transformation (Tüxen, Ellenberg 1937). The order of the phytosociological relevés in the table was determined in relation to the main gradient of the results of the PCoA method with the Bray-Curtis distance measure, without additional transformations. The division of the relevés into groups was determined from the re-

sults of the Ward classification (1963). The phytosociological relevés were interpreted on the basis of the studies by Matuszkiewicz (2008) and Kasprowicz (2010), taking into account the lack of an unequivocal diagnostic value of some of the vascular plant species that coexist in the *Calamagrostio-Quercetum* association as well as in mixed coniferous forests from the *Dicrano-Pinion* alliance in central Poland. The next stage of the study was to determine the degree of similarity of the phytosociological relevés of typical acidophilous oak communities of *Calamagrostio-Quercetum* and the *Dicrano-Pinion* mixed coniferous forests. For this purpose, phytosociological relevés of the acidophilous oak forest association from Wielkopolska, compiled in five tables by Kasprowicz (2010), mixed coniferous forests from the southeastern part of the Mazowiecko-Podlaska Lowland (Sokołowski 1963), as well as mixed coniferous and acidophilous oak forest communities from the Kozienicka Forest (Zaręba 1971; Koba 2012, 2013) were used. A total of 14 tables (including 488 phytosociological relevés) were merged and then subjected to arithmetic transformation and Ward's classification. Numerical analyses were performed in PAST 3 software (Hammer et al. 2009). A map of the distribution of the association in central Poland was prepared using the ATPOL (Zając 1978) cartogram, after the mathematical correction of Komsta (2016). GIS work was performed using QGIS 3 software (QGIS Development Team 2019). The names of lichens were taken from Fałtynowicz and Kossowska (2016), mosses from Ochyra et al. (2003), and vascular plants from Mirek et al. (2002).

3. Results

A map of the known sites of acidophilous oak forests in central Poland (Łódź and Mazovian Voivodeships) is presented in Figure 1. In the area of Łódź Voivodeship, the *Calamagrostio-Quercetum* community was recorded within 12 fields of the ATPOL cartogram, while in Mazowieckie Voivodeship – 5 ones. The phytosociological relevés are presented in Table 1. Based on the Ward method of classification, a division into two groups of relevés was adopted. The first group (relevés 1–7) represents a typically formed community of *Calamagro-*

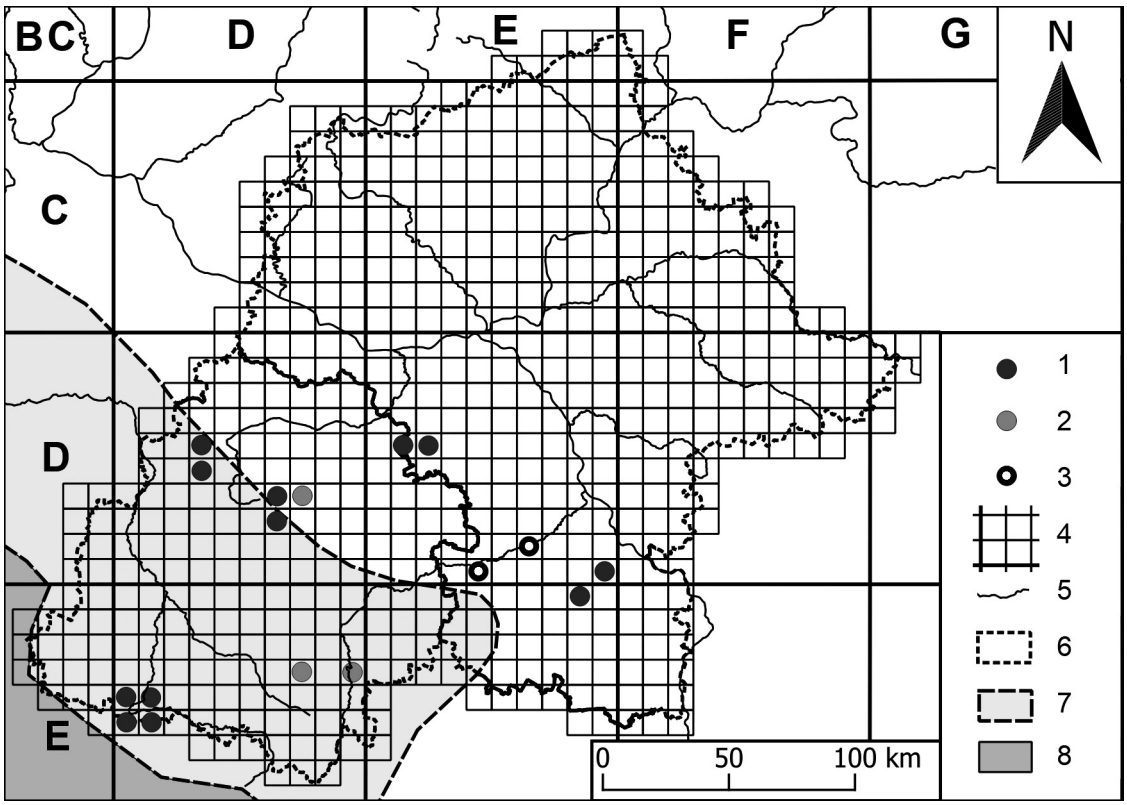

Figure 1. Location of stands of *Calamagrostio-Quercetum* association within eastern range limit (Łódź and Mazovian Viovodeships): 1 – stands with published relevé documentation, 2 – stands without relevé documentation, 3 – new stands in the vicinity of Kiedrzyn and Mikówka villages, 4 – ATPOL grid (Zając 1978; Komsta 2016), 5 – rivers, 6 – borders of voivodeships, 7 – „provisional" association range – minor role in the landscape (Matuszkiewicz 1988; Matuszkiewicz, Matuszkiewicz 1996), 8 – main association range – moderate role in the landscape (Matuszkiewicz 1988, Matuszkiewicz, Matuszkiewicz 1996)

Table 1. Differentiation of *Calamagrostio-Quercetum* within stands in the vicinity of Kiedrzyn and Mikówka villages (relevés 1–7 – typical aspect, 8–10 – aspect with higher share of *Pinus sylvestris*)

Successive number of relevé	1	2	3	4	5	6	7	8	9	10
Number of relevé	F3	F2	F109	F105	F108	M1	M2	F1	M4	M3
Cover of upper tree layer A1 [%]	80	80	83	70	65	80	85	60	90	85
Cover of lower tree layer A2 [%]	0	0	0.5	1	2	5	10	20	0	10
Cover of tree layer in total A [%]	80	80	83	71	66	80	90	70	90	90
Cover of shrub layer B [%]	1	2	5	1	5	5	5	5	5	2
Cover of herb layer C [%]	25	20	30	30	55	70	65	30	50	65
Cover of moss layer D [%]	2	2	1	1	1	10	5	30	10	25
D Ass*, Ch Ass *Calamagrostio-Quercetum* (Kasprowicz 2010), Ch/D Cl. *** *Quercetea robori-petraeae* (Matuszkiewicz 2008)**										
Quercus petraea A1*	5a	4b	5a	4b	4a	5a	4b	3b	3b	3b
Quercus petraea A2*				+	1	1	2a	2a		1
Quercus petraea B*		r	+	r	1	1	1	1	+	+
Quercus petraea C*	+	r	1	2a	1	2a	2b	1	2a	2b
*Hieracium lachenalii***	r	+	r	+	+	+	1	r	1	1
*Hieracium sabaudum*** ***						r				
***Quercetea robori-Petraeae* Ch/D Cl.* (Matuszkiewicz 2008), Ch Cl. ** (Kasprowicz 2010)**										
*Hypnum cupressiforme**	rr	r	r	rr	rr	r	r	rr	r	rr
*Carex pilulifera** **	1	1	1	1	+	2a	2a	r	+	1
*Hieracium murorum**	rr		rr							r
*Holcus mollis** **										r
***Vaccinio-Piceetea* (*D Cl. *Quercetea robori-petraeae* – Wielkopolska – Kasprowicz 2010)**										
Pinus sylvestris A1			1		1	+	2a	2a	3b	2b
Pinus sylvestris A2			r							1
Pinus sylvestris C	rr		rr		rr	rr	r		r	rr
Vaccinium myrtillus	2a	2a	2a	2a	3a	1	2a		r	
*Melampyrum pratense**	rr	r	r	r		2a	1	r	2a	2b
Dicranum scoparium	rr	r	rr	rr		rr	+	rr	r	1
Dicranum polysetum					rr	r	rr	1		r
Pleurozium schreberi		+	r	r	r	r	+	2b	+	2b
Leucobryum glaucum		r		r		r			1	r
Hylocomnium splendens				rr						r
Trientalis europaea						r	r			
Vaccinium vitis-idaea		rr								

Querco-Fagetea										
Melica nutans	r		r		r	1	+		+	
Viola reichenbachiana	rr		r		rr	rr	r		r	
Carex digitata						1	r		1	+
Carpinus betulus B							r			
Carpinus betulus C						r	+		r	r
Poa nemoralis						1	+		r	+
Tilia cordata B	r		r							
Tilia cordata C	rr				r					rr
Carex pilosa		rr								rr
Ajuga reptans	r									
Anemone nemorosa	+									
Dryopteris filix-mas	r									
Molinio-Arrhanatheretea										
Poa pratensis	r	+						r		
Carex hirta									rr	
Lotus corniculatus										rr
Taraxacum sect. ruderalia					rr					
Nardo-Callunetea* et Koelerio-Corynephoretea**										
*Veronica officinalis**	r	rr	+		r			r	r	r
*Agrostis capillaris**			r	rr		rr	rr		r	
*Luzula campestris**	r		rr		r				rr	r
*Pohlia nutans**	rr	rr	r			r			rr	
*Viola canina**	rr		rr		r			rr		
*Cladonia coniocraea**		rr				rr			rr	rr
*Hieracium pilosella**						r				rr
*Ceratodon purpureus***	rr									rr
Trifolio-Geranietea* et Festuco-Brometea**										
*Polygonatum odoratum**	r	rr	+	r	r		r	r		
*Peucedanum oreoselinum**			r		1	r		+	r	
*Sedum maximum***			r		rr					
*Clinopodium vulgare**										rr
Epilobietea angustifolii										
Betula pendula A1		1					1	2a	+	
Betula pendula B				r						
Betula pendula C			rr			r			r	r

Populus tremula A1										+
Populus tremula C										rr
Calamagrostis epigejos	rr	rr			rr			r	r	
Fragaria vesca			r		rr			r		
Stellarietea* et Artemisietea**										
*Conyza canadensis**	rr									
*Fallopia convolvulus**									rr	
*Linaria vulgaris***								rr		
Other (* D. Ass. *Calamagrostio-Quercetum*, **D. Cl. *Quercetea robori-petraeae* – Wielkopolska – Kasprowicz 2010)										
*Festuca ovina**	1	1	1	1	1	2a	2a	2a	2b	2b
*Polytrichastrum formosum***	1	r		+	r	1	1		+	+
*Pteridium aquilinum***	+		2a	2a	2a	2a	1	2a		
*Calamagrostis arundinacea**	+	r		1	+	2a	+		r	
*Hieracium umbellatum***			rr		r	r				
Quercus x rosacea A1						1	1			2b
Quercus x rosacea A2								2a		1
Quercus x rosacea B		+						1		
Quercus x rosacea C	1	+						1		
Convallaria majalis	2a	1	+	1	2a	2a	2a	2a	+	rr
Frangula alnus B	r		1		+	+	r		1	+
Frangula alnus C	r	rr	r		r	r	r		+	r
Juniperus communis B		1	r	+	r			r		
Sorbus aucuparia B					r		r			
Sorbus aucuparia C		rr			r	r	r	rr	r	r
Luzula pilosa	+	rr	+	rr	r	1	+	rr	1	1
Sciuro-hypnum oedipodium			rr		r	r	rr	rr	r	r
Plagiomnium affine			rr		rr	1	+	rr	1	1
Pyrus pyraster C	rr			rr	rr		rr	rr		
Mycelis muralis	r		+			+	r	r		
Rubus saxatilis	r	rr	+		r	+		r		
Maianthemum bifolium	+					2a	1		1	+
Polytrichum juniperinum		r	rr			rr		r		
Solidago virgaurea		rr	r		r					r
Hypericum perforatum			rr				+		r	r
Juniperus communis C		rr	rr	rr						

Moehringia trinervia	rr				rr			r		
Dryopteris carthusiana	rr								rr	
Veronica chamaedrys							+		+	
Pimpinella saxifraga									rr	rr

Sporadic species (group „other"): *Prunus insititia* C 1 – rr; *Carex ovalis* 3 – r; *Chamaecytisus ruthenicus* 9 – r; *Festuca trachyphylla* 7 – r; *Galeopsis bifida* 3 – rr, *Vincetoxicum hirundinaria* 5 – r; *Aulacomium androgynum* 10 – rr; *Brachytheciastrum velutinum* 2 – rr; *Dicranella heteromalla* 6 – rr; *Plagiothecium curvifolium* 10 – rr; *Plagiothecium denticulatum* 9 – rr.

stio-Quercetum, with the dominance of sessile oak *Quercus petraea* in the stand and a high proportion of *Quercetea robori-petraeae* species, including pill sedge *Carex pilulifera*. The second group (relevés 8–10) includes degenerated patches of the association, with an increased share of *Pinus sylvestris* in the stand and a higher coverage of red-stemmed feathermoss *Pleurozium schreberi* (Willd. ex Brid.) Mitt. in the moss layer. There is an almost complete absence of bilberry *Vaccinium myrtillus* visible within this group. The characteristics and selected soil parameters of the sites are presented in Table 2. The results of the analysis of similarity of the relevés to the acidophilous oak forests of Wielkopolska, mixed coniferous forests of the southeastern part of the Mazowiecko-Podlaska Lowland and mixed coniferous forests and acidophilous oak forests of the Kozienice Forest are presented in Table 3.

Sporadic species (group 'other'): *Prunus insititia* C 1 – rr; *Carex ovalis* 3 – r; *Chamaecytisus ruthenicus* 9 – r; *Festuca trachyphylla* 7 – r; *Galeopsis bifida* 3 – rr, *Vincetoxicum hirundinaria* 5 – r; *Aulacomium androgynum* 10 – rr; *Brachytheciastrum velutinum* 2 – rr; *Dicranella heteromalla* 6 – rr; *Plagiothecium curvifolium* 10 – rr; *Plagiothecium denticulatum* 9 – rr.

List of phytosociological relevés (coordinates given according to WGS 84):

1 – Grójec Forest District, Borowina Range, compartment 77a, oak stand of the coppice origin, N: 51°35'13,6'' E: 20°42'13,8''.

2 – Grójec Forest District, Borowina, compartment 74f, oak stand of the coppice origin, N: 51°35'18,2'' E: 20°42'01,7''.

3 – Grójec Forest District, Borowina Range, a patch of an oak stand of the coppice origin in a pine stand, compartment 78d, N: 51°35'10.5'' E: 20°41'53.7''.

4 – Grójec Forest District, Borowina Range, compartment 78a, oak stand of the coppice origin, N: 51°35'15,1'' E: 20°42'08,5''.

5 – Grójec Forest District, Borowina Range, compartment 78c, a patch of an oak stand of the coppice origin in a pine stand, N: 51°35'16,1'' E: 20°41'54,5''.

6 – Dobieszyn Forest District, Turno Range, compartment 69f, a patch of an oak stand within a pine stand, N: 51°38'06.0'' E: 20°59'05.3''.

7 – Dobieszyn Forest District, Turno Range, compartment 73a, a patch of an oak stand within a pine stand, N: 51°38'05.7'' E: 20°59'07.6''.

8 – Grójec Forest District, Borowina Range, compartment 78b, oak stand of the coppice origin, N: 51°35'16,8'' E: 20°41'59,7''.

9 – Dobieszyn Forest District, Turno Range, compartment 73a, a patch of an oak stand within a pine stand, N: 51°38'01.7'' E: 20°59'13.5''.

10 – Dobieszyn Forest District, Turno Range, compartment 73a, a patch of an oak stand within a pine stand, N: 51°38'00.6'' E: 20°59'15.6''.

4. Discussion

The phytosociological material includes relevés representing both typical (relevés 1–7) and degenerated (relevés 8–10) forms of the *Calamagrostio-Quercetum* association (Table 1). The typical form does not differ significantly from the acidophilous oak forest association from Wielkopolska (cf. Kasprowicz 2010). Phytosociological relevés representing it were combined with *Calamagrostio-Quercetum* relevés in group B (Table 3), and were distinguished from the phytosociological relevés representing mixed coniferous forests from the *Dicrano-Pinion* alliance. The degenerated form includes patches with a significant share of Scots pine *Pinus sylvestris* in the stand and a higher cover of red-stemmed feathermoss *Pleurozium schreberi* in the moss layer, but it still belongs to *Calamagrostio-Quercetum*, connected within the boundaries of group B with the relevés from Wielkopolska (Table 3). An artificially increased share of pine in deciduous forest communities is called pinetization and is described as a form of degeneration of forest communities (Olaczek 1972, 1974). In the case of the acidophilous oak forest, an increased share of pine in the stand is considered to be a distinguishing feature of the stands of this association in the eastern part of the range, as well as a possible form of degeneration associated with pine being favoured (Matuszkiewicz 2001; Matuszkiewicz 2008; Kasprowicz 2010; Matuszkiewicz et al. 2012).

When the first sites of acidophilous oak forests were discovered in Poland (Fabiszewski, Faliński 1964), the

Table 2. Characteristic and selected parameters of soils within researched stands of *Calamagrostio-Quercetum* in the vicinity of Kiedrzyn and Mikówka villages (on the basis of BDL 2019 and carried out selected laboratory analyses)

Successive number of relevé			1	2	3	4	5	6	7	8	9	10
Number of relevé			F3	F2	F109	F105	F108	M1	M2	F1	M4	M3
Information based on Forest Data Bank (BDL 2019)												
Forest subcompartment			77a	74f	78d	78a	78c	69f	73a	78b	73a	73a
Stand age [year]			119	94	91	120	80	79	77 (94)	84	77 (94)	77 (94)
Oak bonitation			III	III	III	III	II	II	II	II	II	II
Forest habitat type			LMśw	LMśw	BMśw	LMśw	LMśw	BMśw	LMśw	LMśw	LMśw	LMśw
Soil subtype			RDw	RDw	RDw	RDw	RDw	RDw	RDw	RDw	RDw	RDw
Soil textural class*			plm	plm	pls	plm	ps	pls	pls	plm	pls	pls
Results of laboratory analyses (samples collected at a depth of ca. 10 cm)												
pH			4.42	4.32	4.51	4.15	4.29	4.36	4.68	4.37	4.26	4.29
Organic matter content [%]			3.1	3.4	1.5	1.7	2.7	2.4	2.0	3.2	1.8	2.0
Organic C content [%] (as 58% org.)**			1.8	2.0	0.9	1.0	1.6	1.4	1.2	1.8	1.1	1.2
Fraction diameter mm [%]	skeletal	> 2	1.3	1.3	0.0	1.6	1.0	0.0	0.1	0.9	0.1	0.7
	fine-earth	1-2	3.1	5.0	0.2	2.1	0.9	1.0	2.0	1.7	2.0	2.0
		0.5-1	16.3	27.1	6.2	9.4	4.8	11.1	13.0	10.7	18.0	9.8
		0.25-0.5	34.9	38.7	64.4	30.1	39.2	42.7	36.6	31.2	43.1	28.5
		0.1-0.25	38.0	20.8	28.4	43.5	47.1	39.4	39.9	49.4	31.8	50.2
		< 0.1	6.4	7.1	0.8	13.3	6.9	5.8	8.5	6.1	5.1	8.8

Forest habitat types: LMśw – fresh mixed deciduous forest, BMśw – fresh mixed coniferous forest; Soil subtype (Reference Soil Group): RDw – brunic arenosol (typical rusty soil),

* soil textural group: plm – (loose) sand with layers or aggregations of more loamy materials, pls – (weak loamy) sand, ps – (loose) sand

** value of 58% share of organic matter according to Nelson and Sommers (1982)

concept of degeneration and synanthropization of plant associations had just started to be developed (Faliński 1966, 1972; Olaczek 1972, 1974). For this reason, the correct classification of acidophilous oak forest patches, especially with anthropogenically introduced pine trees, was much more difficult (Wojterski et al. 1981; Kasprowicz 2010). Such communities were usually classified as *Querco-Pinetum* mixed coniferous forests (Kasprowicz 2010). For this reason, the eastern boundary of *Calamagrostio-Quercetum* association's range was only approximated (Matuszkiewicz 1988; Matuszkiewicz, Matuszkiewicz 1996). Zaręba (1988) postulated the distinction of acidophilous oak forests with pine in the northeastern parts of the sessile oak's range (including Mazovia). He proposed to take into account the division of mixed coniferous forests *Pino-Quercetum* (Kozł. 1925 em Mat. Et Pol. 1955) into two communities, by distinguishing the moist forms as *Populo tremulae-Quercetum* in the sense of Sokolowski (1968, 1980) and accepting them as a synonym for *Querco-Pinetum* proposed by Matuszkiewicz, and including *Pino-Quercetum* as acidophilous sessile oak forests with pine *Quercetum sessiliflorae (petraeae?) -Pinetum*. The author acknowledged that this community was not exactly the same as the acidophilous oak forest *Calamagrostio-Quercetum petraeae*, whose range boundaries were accepted to be in Pomerania and Wielkopolska. The relevés of acidophilous oak forests with pine, as presented in Zaręba's collective table (1988), came mainly from unpublished data, including those from the Kozienice Forest. The relevés of Zaręba's mixed coniferous forests (1971) used in the analysis, coming from this area, were largely combined with both Sokołowski's (1963) mixed coniferous forest communities and Kasprowicz's (2010) acidophilous oak

Table 3. Comparison of similarity of carried out relevés to acidopilous oak forests from Wielkopolska (Kasprowicz 2010), mixed oak-pine forests from Mazowiecko-Podlaska Lowland (Sokołowski 1963) and oak-pine forests and acidophilous oak forests from Kozienicka Forest (Zaręba 1971; Koba 2012, 2013): A–F – groups distinguished by Wards classification, the numbers of relevés from the datasets were summarized

No	Name of the dataset*	Author	A	B	C	D	E	F	A–F
1	*C-Q molinietosum*	Kasprowicz (2010)	0	4	38	8	0	6	56
2	*C-Q typicum* (var. typ.)	Kasprowicz (2010)	3	20	6	4	0	3	36
3	*C-Q typicum* (var. *Anemone nemorosa*)	Kasprowicz (2010)	3	9	24	3	0	4	43
4	*C-Q polgonatetosum* (var. typ.)	Kasprowicz (2010)	26	40	3	9	0	0	78
5	*C-Q polygonatetosum* (var. *Anemone nemorosa*)	Kasprowicz (2010)	15	37	31	5	0	3	91
6	*Q-P typicum*	Zaręba (1971)	0	6	0	13	2	2	23
7	*Q-P berberidetosum*	Zaręba (1971)	0	1	0	10	2	1	14
8	*Q-P populetosum* (var. Typ.)	Zaręba (1971)	0	0	1	3	4	1	9
9	*Q-P populetosum* (var. *Abies alba*)	Zaręba (1971)	0	0	0	2	3	8	13
10	*Q-P serratuletosum* (=*S-P*)	Sokołowski (1963)	1	3	4	1	11	29	49
11	*Q-P typicum*	Sokołowski (1963)	0	0	1	3	4	7	15
12	*Q-P populetosum*	Sokołowski (1963)	0	4	2	2	21	19	48
13	*C-Q*	Koba (2012, 2013)	**1**	**2**	0	0	0	0	3
14	*C-Q*	this study	0	**10**	0	0	0	0	10
	1–14		49	136	110	63	47	83	488
Phytosociological interpretation*			*C-Q*	*C-Q*	*C-Q*	*Q-P / C-Q*	*Q-P & S-P*	*S-P & Q-P*	X

**C-Q – Calamagrostio-Quercetum, Q-P – Querco-Pinetum (=Pino-Quercetum), S-P – Serratulo-Pinetum.*

forests. This indicates the transient nature of the communities presented above and/or the phenomenon of the pinetization of the *Calamagrostio-Quercetum* association in this area (Table 3). The presence of acidophilous oak forests in Kozienicka Forest is also supported by the combination of phytosociological relevés prepared by Koba (2012, 2013) documenting this association with a group of relevés of its Wielkopolska analogue (Table 3). On the basis of Zaręba's observations (1988) and comparisons (Table 3), it can be assumed that most likely, acidophilous oak forest patches in a degenerate form were found in southern Mazovia in the second half of the 20th century. The phenomenon of pinetization may have been responsible for the difficulties in distinguishing them. Both Jakubowska-Gabara (1999) and Koba (2012) considered the locations of the acidophilous oak forests (Bolimowski Landscape Park and Kozienicka Forest) to be at the edge of their range. The patches of acidophilous oak forests recorded near the villages of Kiedrzyn and Mikówka are located in a zone between these sites. This may indicate a wider (at least 50–60 km to the east) range of this association in this region of Poland, compared to the assumed 'provisional' range. (cf. Matuszkiewicz 1988; Matuszkiewicz, Matuszkiewicz 1996).

The two main syntaxonomic depictions of acidophilous oak forests in Poland differ slightly from each other (cf. Matuszkiewicz, Matuszkiewicz 1996; Kasprowicz 2010), which is mainly due to the different boundaries of the areas of these studies. In spite of this, the analysed patches of the communities undoubtedly belong to the *Calamagrostio arundinaceae-Quercetum petraeae* association (Table 3), depicted by both approaches in a similar way. A number of species characteristic and differential for acidophilous oak forests were recorded in the patches (Table 1), including *Carex pilulifera* and several species of the genus *Hieracium*. In comparison with Kasprowicz's compilation (2010), the analysed patches are most similar to the Wielkopolska variety, which is related to a small share of *Lathyrus montanus* Bernh., *Fagus sylvatica* L. and *Deschampsia flexuosa*, and in the case of the analysed site – even their absence, as well

as the absence of species with a southern range. The relatively large cover of *Festuca ovina* in the undergrowth indicates the similarity of the noted patches to the *Calamagrostio-Quercetum festucetosum* subassociation distinguished in the Łagiewnicki Forest (NE outskirts of Łódź) (Kurowski 2009). A characteristic feature of the studied sites is also the occurrence of species considered to be associated with mixed coniferous forests (Matuszkiewicz 2008), such as: *Carex digitata* L., *Carpinus betulus* L., *Mycelis muralis* (L.) Dumort. or *Rubus saxatilis* L.

The examined patches of *Calamagrostio-Quercetum* are located in habitats defined in the Forest Data Bank (BDL 2019) as fresh mixed deciduous (8 phytosociological relevés) and fresh mixed coniferous (2 relevés). Thus, the habitat range is almost identical to the previously reported range from Wielkopolska (Lasota et al. 2005; Rutkowski, Maciejewska -Rutkowska 2007), as well as the regions of the lake districts, uplands and highlands of western Poland (Lasota 2013). Moreover, acidophilous oak forest sites were recorded in a fresh mixed forest habitat in Kozienicka Forest (Koba 2012, 2013).

In the sites near Kiedrzyn and Mikówka villages, the superficial deposits studied at a depth of about 10 cm had the character of loose sands (*in situ* organoleptic evaluation). They were characterized by a predominance of medium and fine sand content (Table 2). According to the Forest Management Plan (FMP) for the Grójec and Dobieszyn Forest Districts, these patches were located mainly on deposits of loose and weak loamy sands, loose sands with layers or aggregations of more loamy material and less often, weak loamy sands (BDL 2019). Such differentiation belongs to more frequently recorded granulometric compositions of *Calamagrostio -Quercetum* in Wielkopolska, for example, in the Zielonka Experimental Forest District (Rutkowski, Maciejewska-Rutkowska 2007). Similar granulometric compositions were also recorded in acidophilous oak patches in the habitats of the fresh mixed coniferous forest and fresh mixed deciduous forest in the Jarocin and Czerniejewo Forest Districts (Lasota et al. 2005). The presence of loamy sands deposited on weak loamy and loose sands, as well as loose sands on deeply deposited till, were noted in the acidophilous oak stands in Kozienicka Forest (Koba 2012, 2013). Mixed coniferous forests occur most frequently on river or fluvio-glacial sands, with sites of dunes having a grain size corresponding to strongly permeable deep loose sands or weak loamy sands on loose sands (Matuszkiewicz 2001; Lasota 2013). Acidophilous oak forests, however, are usually recorded in areas of glacial or sandstone formations deposited in the immediate vicinity of the glacier margin, with different grained formations such as loose and weak loamy sands overlaid or lined with clay sands or even clay (Matuszkiewicz 2001; Lasota 2013). The soils of acidophilous oak forests are usually slightly richer (Lasota 2013). The analysed sites are located within the range of loose, weak loamy sands, often with layers or aggregations of more loamy materials (Table 2), which to some extent may indicate that the substrate is slightly more suitable for acidophilous oak forests than for mixed coniferous forests.

The acidophilous oak forest sites near Kiedrzyn and Mikówka villages are characterized by the occurrence of brunic arenosols (typical rusty soils) (RDw, Table 1), in some places with visible signs of podzolization (*in situ s*tudies). Typical rusty soils (RDw) and brown rusty soils (RDbr) were found at the sites located in the Kozienicka Forest (Koba 2012, 2013). Similarly, in Wielkopolska, brown rusty soils, typical rusty soils and podzolic rusty soils were found in the acidophilous oak forest sites, although in some places haplic luvisols (cutanic), brown haplic luvisols and umbric gleysols (arenic) or gleyic umbrisols (arenic) were also found (Lasota et al. 2005; Rutkowski, Maciejewska-Rutkowska 2007). In other parts of western Poland, rusty soils also dominate in acidophilous oak forests, and brown and podzolic soils are also recorded relatively often (Lasota 2013).

In central Wielkopolska (in the Jarocin and Czerniejewo Forest Districts), the pH of the upper soil horizons in fresh mixed coniferous habitat was about 3.3–4.1, while the organic carbon content was between 1.57 and 5.04%. On the other hand, the patches of acidophilous oak forest in the fresh mixed deciduous habitat had a pH of the upper soil horizon from 3.6 to 4.1 and an organic carbon content from 1.66 to 5.36%. (Lasota et al. 2005). As the average share of carbon in organic matter is about 58% (Nelson, Sommers 1982), therefore the organic carbon content at a depth of about 10 cm in the examined patches was from 0.9 to 2.0%. This value is slightly lower than in the case of central Wielkopolska, as well as other areas of acidophilous oak forests in western Poland (Lasota 2013). The studied patches are also characterized by a higher pH, in the range of 4.15 to 4.68, which is comparable to the pH of the upper soil horizons in the acidophilous oak forest sites studied in western Poland by Lasota (2013). The observed differences are likely caused by a slightly higher depth of the soil samples taken from the sites near Kiedrzyn and Mikówka villages, compared to the analogous upper soil horizons of sites from central Wielkopolska.

5. Summary of results and conclusions

1) The patches of oak forests recorded near Kiedrzyn and Mikówka villages, situated in the southern part of Mazovia Voivodeship, belong to the *Calamagrostio arundinaceae -Quercetum petraeae* association; the habitat conditions of the analysed patches as well as the oak site index are analogous to sites of that association in other parts of Poland.

2) The patches from the Bolimowska and Kozienicka Forests, which the authors of cited studies considered to be at the 'border' of this association's range, are outside the 'provisional' range designated for this association in this part of

Poland; the patches recorded near Kiedrzyn and Mikówka villages can be treated as a 'link' between the sites noted above.

3) The range of the *Calamagrostio-Quercetum* association is at least several dozen kilometres wider than the assumed 'provisional' range, reaching deeper into the southern part of the Mazovian Voivodeship.

Conflict of inte est

The authors declare that there are no potential conflicts of interest.

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P.Z. – concept, field work, laboratory analyses, data preparation for numerical analyses, numerical analysis, map development, literature review, manuscript writing;

W.C. – field work, laboratory analyses, moss identification, data preparation for numerical analyses, literature review, manuscript writing;

K.M. – laboratory analyses, literature review, data preparation for numerical analyses, manuscript writing.