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SPECIES COMPOSITION OF WOODY VEGETATION OF THREE TYPES OF MID-FIELD WOODLOTS IN INTENSIVELY MANAGED FARMLAND (WROCŁAW PLAIN, SOUTH-WESTERN POLAND)

ABSTRACT: The paper presents the results of studies devoted to woody species composition in three types of mid-field woodlots (N = 183), located on the area of 5480 ha in the intensively managed agricultural landscape of Wrocław Plain (Lower Silesia, south-western Poland). The woodlots studied were divided into mid-field clumps (n = 74), water-edge hedgerows (n = 75) and avenues (n = 34). In general, in the three types of woodlots 77 woody plant species were found. To the most common species (50% frequency in all the woodlots) belonged: elder (*Sambucus nigra*), single-neck hawthorn (*Crataegus monogyna*), blackberry (*Rubus* spp.) and blackthorn (*Prunus spinosa*). For 21 species, statistically significant differences between frequency of occurrence in water-edge hedgerows and clumps were found. Ten species differed in frequency of occurrence between water-edge hedgerows and avenues. Differences between clumps and avenues were documented for 15 species. No significant differences were found in the occurrence of species dispersed by wind, animals and water, and between native species and those of foreign origin, in the respective types of woodlots. For the three types of woodlots studied, high statistically significant correlations were found between the size of woodlots (length for water-edge hedgerows and avenues, and area for mid-field clumps) and the number of recorded woody species. Based on the results obtained and literature data the mechanisms of the floristic diversity of mid-field woodlots were discussed.

KEY WORDS: woody species, woodlots, hedgerows, mid-field clumps, dispersal mode, native flora, agricultural landscape, landscape ecology

1. INTRODUCTION

The contemporary agricultural landscapes are under a strong influence of human activity. In the last decades, a substantial reduction of natural resources in ecosystems has been observed in western Europe, which is connected with elimination of uncultivated areas, resulting from intensive farming (Burel and Baudry 1990, Macdonald and Johnson 2000, Haines-Young *et al.* 2003, Petit *et al.* 2003). The mid-field woodlots are the main refuges for fauna and flora, and their existence in agricultural landscapes is essential for the high level of biological diversity (Barr and Petit 2001, Ryszkowski 2002). The woodlots in farmed landscape can be divided into patch woodlots (mid-field clumps) and linear ones, known as *hedgerows* in English literature (Pollard *et al.* 1974, Baudry *et al.* 2000, Marshall and Moonen 2002). In the countries of western Europe (France, England) linear woodlots (hedgerows) are most of all of cultural origin (Baudry *et al.* 2000). In North America (United States and

Canada), more rarely in western Europe, the term "hedgerows" is also applied to the spontaneous woody vegetation, accompanied by herbs, that grows on the boundaries of crop fields (Boutin *et al.* 2002, de Blois *et al.* 2002, Marshall and Moonen 2002, Schmucki *et al.* 2002). Boutin and others (2002) on the farming areas of Quebec (eastern Canada) distinguish three kinds of hedgerows: 1) *natural woody hedgerows*, that constitute the remnants of woodland habitats or develop spontaneously on boundaries between crop fields and associations of woody species, 2) *planted woody hedgerows* introduced artificially by farmers, mainly to protect against wind (called also *windbreaks* and *shelterbelts*) and 3) *herbaceous hedgerows* devoid of the tree layer, where single shrubs may appear, being the most numerous group of woodlots. In the countries of western Europe hedgerows constitute the characteristic element of farmed landscapes, being an integral part of agricultural management and marking crop-fields boundaries for centuries (Baudry *et al.* 2000, Le Coeur *et al.* 2002, Marshall and Moonen 2002). Many authors emphasize the role of hedgerows as ecological corridors that enable survival and dispersion of woodland species of flora in agricultural areas (Corbit *et al.* 1999, Marshall and Moonen 2002, Boutin *et al.* 2003).

In agricultural landscapes woodlots play a number of protecting functions, among others they participate in pollution control of the environment, modify the ways of energy flow and matter circulation, and curb soil erosion (Dąbrowska-Prot 1987, Ryszkowski and Bałazy 1998, Bałazy 2002, Orłowski 2003). The presence of woodlots improves soil conditions in the surrounding crop fields, as a result of increase of organic matter in the soil and number and activity of soil microorganisms (Karg *et al.* 2003, Wojewoda and Russel 2003). In Poland, an example of area with exceptionally rich and diverse structure of mid-field woodlots is the Gen. D. Chłapowski Landscape Park (Wielkopolska, western Poland). Due to the presence of the network of historical woodlots of various types, introduced in the first half of the XIX century, localized among intensively farmed fields, that area is regarded as a leading example of compromise between the requirements of modern agriculture and those of nature and landscape conservation (Ryszkowski and Bałazy 1998, Ryszkowski *et al.* 2003). In the last few years, a series of new tree belts have been introduced in the Landscape Park, both along the small watercourses and drainage ditches, and between crop fields (Kujawa 1998, Ryszkowski *et al.* 2003). The park area has become a specific testing ground, where since the late fifties of the XX century interdisciplinary studies are conducted, devoted to the functioning and the role of the biotic and abiotic elements of farmed landscape, including mid-field woodlots. Many of the studies dealt with the role of mid-field woodlots in functioning of farmed areas, including energy and matter flow and mechanisms of their regulation (Ryszkowski and Bałazy 1998, Ryszkowski *et al.* 2003).

In Poland the issue of surface woodlots, termed "forest islands" or "mid-field clumps", has been dealt with a number of times, the presented topics concerned mainly with species composition, phytosociological and botanical characteristics, succession rate and dispersion of forest species of flora (Dzwonko and Loster 1992, Bałazy *et al.* 1990, Kujawa 1998, Banaszak 2000). In Masurian Lakeland (north-eastern Poland) broad ecological surveys were conducted on the importance and functioning of forest islands, including the ecotonal zones between woodlots and cropfields. Those studies included both the floristic and fauna aspects (entomofauna) (Dąbrowska-Prot 1991, 1995). Not much data were, however, collected on species composition of the woodlots occurring in large farmed areas (over 20 km^2) and of woodlots and vegetation along the linear elements of landscape (small watercourses, drainage ditches and roads) (e.g. Bałazy *et al.* 1990, Kujawa 1998, Ratyńska and Szwed 2000, Ryszkowski *et al.* 2002). In Poland, in spite of the little tradition in maintaining and caring for linear woodlots (hedgerows), in many regions of intensive agriculture (e.g. in Wrocław Plain area) such landscape elements are the last remnants of natural and subnatural plant populations that play an especially important biocenotic function. In most areas of Poland that vegetation develops

Fig. 1. Study arable area with linear and patch landscape elements: 1 – built-up area, 2 – mid-field clumps, 3 – railway line, 4 – roads (with avenues), 6 – watercourses and drainage ditches (with water-edge hedgerows).

spontaneously, constituting ecotonal zones between farmland and minor watercourses, or country roadsides. In general, those habitats are subject to strong anthropopressure, because of the regular agro-irrigation treatments. The ongoing transformation of agricultural landscapes, consisting in increasing the area of cropfields and elimination of uncultivated biotopes, implies an urgent need for qualitative and quantitative evaluation of the existing woodlots, and in perspective also estimation of the changes induced by human activity.

The aim of the work was to determine: 1) species composition, 2) frequency and 3) differences in occurrence of woody plant species in three types of mid-field woodlots of different structure (mid-field clumps, water-edge hedgerows and avenues) and size, localized in an intensively farmed area of Wrocław Plain (SW Poland), and to analyze 4) the effect of the dispersal mode and 5) origin of the respective woody species and the impact on the floristic richness of the woodlots discussed.

2. MATERIAL AND METHODS

2.1. Study area

The studies were conducted on a 5480 ha fragment of Wrocław Plain. According to a regionalization by Kondracki (1988) the area discussed is localized within Silesian Lowland (Fig. 1). The terrain contains 20 small settlements (*ca.* 6500 inhabitants in total). The dominant form of land use is arable land that occupies about 92% of the studied area. That area is characterized by a share of forests and woodlots that is one of the lowest in Poland and amounts to barely 1.3%.

The rest (*ca.* 6.7%) is made up of village areas and communication routes. Due to the good and very good soils (Haplaquals and Hapludalphs), most of the land is used for intensive farming. Especially in the western and southern parts of the study area, large-scale farms prevail, that may at times exceed 100 ha. Small, few-hectare farms survived mainly around villages. In the year 2000 the largest-area crops were: wheat (40%), maize (15%), sugar beet (20%), rape (10%) and potatos (10%).

2.2. Characteristics of the woodlots studied

The studies included all the mid-field woodlots occurring outside village areas. In general they are characterized by the exclusive occurrence of deciduous trees and bushes. 183 mid-field woodlots were studied, that developed as a result of spontaneous growth of woody vegetation within the uncultivated landscape elements (riparian habitats, road verges); some are also subject to intensive forest management. The studied objects are characterized by a relatively great differentiation of age and origin, both between the types and within one type of woodlots. Some hints about the age of woodlots can be gained from analysis of dimensions and distribution of champion (historical) specimens of trees. The analysis has shown that champion trees belonging to native species of dendroflora occur in 39% of mid-field clumps and 57% of water-edge hedgerows. The age of the oldest individuals of pedunculate oak (*Quercus robur*), ash (*Fraxinus excelsior*), and black poplar (*Populus nigra*) was determined at about 380, 200 and 190 years respectively. The oldest oaks were growing in water-edge hedgerows, and ash and black poplar trees in mid-field clumps (Orłowski and Nowak, unpublished manuscript). These data indicate a relatively long time of existence of those woodlots, which, especially in the case of riparian woodlots and mid-field clumps, suggests that they are hundreds years old. It is possible that the water-edge hedgerows which are localized along natural watercourses may constitute a remnant of riparian forests. The avenues were the most degraded group of the studied woodlots, mainly due to improper tree felling and shrub clearing (Orłowski 2003). All woodlots were divided, with respect to shape and localization, into two groups:

1. Linear woodlots, along linear elements of landscape:

a) Avenues (n = 34) – rows of trees on one or both sides of paved and unpaved roads (total length = 13870 m; average length = 407.94 m, minimum = 50 m, maximum = 2600 m, SD = 504.77 m). Average density of avenues per 1 km^2 of the area studied was 0.78 and average total lenght – 253.1 m. The avenues covered 14% of all roadsides within the study area (Orłowski 2004a). Part of the avenues was characterized by the presence of a spontaneous bushy vegetation. In general the tree layer was of anthropogenic origin.

b) Water-edge hedgerows (n = 75) – rows of trees on one or both sides of small watercourses and irrigation ditches, of average width from 3 to 6 meters (total length = 29410 m; average length = 392.13 m, minimum = 25 m, maximum = 1925 m, SD = 402.83 m). Average density of water-edge hedgerows per 1 km^2 of studied area was 1.37 and average total lenght – 536.7 m. In total the water-edge hedgerows covered 43% of the sideline of all watercourses and irrigation ditches (Orłowski 2004a). They were characterized by the presence of spontaneous shrubby vegetation, which, as in the case of avenues, was removed as part of agro-irrigation treatments.

2. Patch woodlots – mid-field clumps termed also as forest islands (n = 74) – in the form of compact patches (of overall area = 70.77 ha; average = 0.96 ha, minimum = 0.025 ha, maximum = 15.08 ha, SD = 2.23 ha). Average clump density per 1 km^2 was 1.35 and average total area – 1.29 ha. Some woodlots were subject to forest management. The bush layer was of natural character.

2.3. Field study

In order to become familiar with terrain topography and localization of the woodlots, the exploration was carried out in late autumn and in winter of 1999/2000. Field study on species composition of the respective woodlots was conducted since late September 2000 to April 2001. On each visit the controlled objects were marked on a 1:12 500 map and the found species of trees and shrubs were recorded. The controls of avenues and water-edge hedgerows were done by walking along them. Small mid-field clumps were checked by walking across the middle of a woodlot. In larger clumps the checks were done along parallel transects 100 m apart. Additionally, all clumps were checked along their boundaries. Size determination of the studied objects was done with the help of: cadastral dates and maps (1:5000), topographic maps (1:25 000 and 1:10 000), aerial photographs or by direct measurements in the field. Analysis of aerial photographs was done using the Arc-Explorer computer program (operating in Windows).

The following species were included in the group of woody species: ivy (*Hedera helix*) and travelerr's joy *Clematis vitalba* [according to Seneta and Dolatowski 2000], additionally two species of genus *Reynourtia* – Japanese knotweed (*R. japonica*) and giant knotweed (*R. sachalinesis*), and hop (*Humulus lupulus*). In the case of blackberries (*Rubus* spp.), currants (*Ribes* spp.) and poplar hybrids (*Populus* sp.), due to difficulties with identifications only the genus could be determined.

2.4. Statistical analysis

Statistical analysis of the collected material was done by using the Statistica 5 software and Excel 2000. To normalize the distributions, a logarithmic transformation was carried out of the following data: mid-field clump area, length of riparian woodlots, length of avenues, number of woody species in clumps and riparian woodlots. The normality of the above variables was checked with the Kołmogorow-Smirnov test (confidence level $P < 0.05$ was assumed as threshold). Differences in frequency of occurrence of the respective woody species were tested with the χ^2 (2 × 2) test. The differences in the average number of woody species were tested with the variance analysis (ANOVA). The dependence between the number of woody species and area or length of a woodlot was determined using the Pearson correlation coefficient.

3. RESULTS

In general, in the three types of woodlots 77 woody plant species (65 in clumps, 62 in water-edge hedgerows and 43 in avenues) were found. The highest average number of species was found in mid-field clumps (11.8 species in a woodlot on average), the lowest in avenues (average = 7.9). In spite of the statistically proven difference in the average number of species between the three types of woodlots (Fig. 2), there were no differences in average values between clumps and water-edge hedgerows (Mann-Whitney's test, U = 2305, Z = –1.44, $P = 0.14$). Distinct differences appeared in the average values in the case of avenues (avenues *vs.* mid-field clumps, Mann-Whitney's test, U = 779, Z = –3.16, $P = 0.0015$; avenues *vs.* water-edge hedgerows, Mann-Whitney's test, U = 948, Z = –2.13, $P = 0.03$).

To most common species (frequency over 50%) in all three types of woodlots belonged: elder (*Sambucus nigra*), single-neck hawthorn (*Crataegus monogyna*), blackberries (*Rubus* sp.) and blackthorn (*Prunus spinosa*). In the water-edge hedgerows the most abundant were species associated with wet habitats (Table 1). As characteristic for water-edge hedgerows (frequency over 50% in that type of woodlots only) can be regarded the following: black alder (*Alnus glutinosa*), white willow (*Salix alba*) and grey willow (*S. cinerea*) (Table 1). In clumps, markedly more frequent were 20 species. In avenues

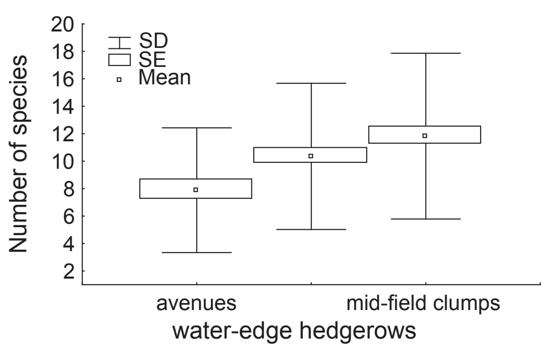

Fig. 2. Average number of woody species, ± 1 standard deviation (SD) and ±1 standard error (SE) in three types of mid-field woodlots of Wrocław Plain. Differences in average values are statistically significant (ANOVA, $F_{2,18} = 6.03$, $P < 0.0029$).

Table 1. Frequency (%) of occurrence of woody species in three types of mid-field woodlots (significant preferences in bold); χ^2 test and significance levels based on comparison between different types of mid-field woodlots – 1 – water-edge hedgerows, 2 – mid-field clumps, 3 – avenues. Levels of significance are: n.s. – $P > 0.05$, * – $P < 0.05$, ** – $P < 0.01$ and *** – $P < 0.001$

Taxa (dispersal mode)[1]	Status in Poland[2]	Frequency (%)			*P*-values		
		Water-edge hedgerows n = 76	Mid-field clumps n = 74	Avenues n = 34	1 *vs.* 2	1 *vs.* 3	2 *vs.* 3
Ribes uva-crispa (A)	–		**5**		*	-	n.s.
Sambucus nigra (A)	+	62	**79**	64	*	n.s	n.s.
Sambucus racemosa (A)	+		1		n.s.	-	n.s.
Hedera helix (A)	+		**5**		*	-	n.s.
Betula verrucosa (W)	+	14	22	12	n.s.	n.s.	n.s.
Betula pubescens (W)	+		1		n.s.	-	n.s.
Fagus sylvatica (A)	+		3		n.s.	-	n.s.
Humulus lupulus (A)	+	**21**	**38**	12	*	n.s.	**
Prunus padus (A)	+	**26**	**40**	6	n.s.	*	***
Prunus serotina (A)	–	1	1		n.s.	n.s.	n.s.
Prunus avium (A)	+	13	20	23	n.s.	n.s.	n.s.
Quercus rubra (A)	–		**5**		*	-	n.s.
Quercus robur (A)	+	21	**49**	12	***	n.s.	***
Cornus alba (A)	–	14	16	9	n.s.	n.s.	n.s.
Cornus sanguinea (A)	+	3	1	3	n.s.	n.s.	n.s.
Crataegus oxyacantha (A)	+	1			n.s.	n.s.	-
Crataegus monogyna (A)	+	69	**81**	59	n.s.	n.s.	*
Crataegus coccinea (A)		1		3	n.s.	n.s.	n.s.
Carpinus betulus (W)	+	1	**8**	3	*	n.s.	n.s.
Pyrus communis (A)	+	24	15	30	n.s.	n.s.	n.s.
Malus domestica (A)	+	43	36	44	n.s.	n.s.	n.s.
Sorbus aucuparia (A)	+	1	1		n.s.	n.s.	n.s
Fraxinus excelsior (W)	+	51	60	50	n.s.	n.s.	n.s.
Rubus spp. (A)	+	58	63	59	n.s.	n.s.	n.s.
Viburnum opulus (A)	+	5	9		n.s.	n.s.	n.s.
Aesculus hippocastanum (A)	–	1	3	**9**	n.s.	*	n.s.
Acer pseudoplatanus (W)	+	1	**9**	6	*	n.s.	n.s.
Acer negundo (W)	–	1	3	3	n.s.	n.s.	n.s.
Acer campestris (W)	+	1	3		n.s.	n.s.	n.s.
Acer saccharinum (W)	–		1		n.s.	-	n.s.
Acer platanoides (W)	+	1	**8**	6	*	n.s.	n.s
Frangula alnus (A)	+	1	5	3	n.s.	n.s.	n.s
Corylus avellana (A)	+	5	7	3	n.s.	n.s.	n.s
Ligustrum vulgare (A)	–	12	12	6	n.s.	n.s.	n.s
Syringa vulgaris (A)	–	1		**6**	n.s.	n.s.	*
Tilia cordata (W)	+	4	**20**	**27**	**	***	n.s.
Tilia platyphyllos (W)	+	1	1	6	n.s.	n.s.	n.s.
Rubus idaeus (A)	+	1	**9**		*	n.s.	n.s.
Morus alba (A)	–		3		n.s.	n.s.	n.s.
Mespilus germanica (W)	–		1		n.s.	-	n.s.
Alnus glutinosa (O)	–	**58**	12	12	***	***	n.s.
Alnus incana (O)	+	5	1		n.s.	n.s.	n.s.
Juglans regia (A)	+	1		3	n.s.	n.s.	n.s.
Ribes sp. (A)	+		**11**		**	-	*
Clematis vitalba (W)	–	3			n.s.	n.s.	-
Robinia pseudoacacia (A)	–	16	15	**50**	n.s.	***	***
Rosa canina (A)	+	57	48	**68**	n.s.	n.s.	*
Rosa rugosa (A)	–	1			n.s.	n.s.	-
Pinus strobus (W)	–		1		n.s.	-	n.s.
Pinus silvestris (W)	+		3		n.s.	-	n.s.
Lonicera tatarica (A)	–	1			n.s.	n.s.	-
Ramnhus cathartica (A)	+	10	**32**	06	**	n.s.	**
Prunus domestica (A)	+	4	**15**	3	*	n.s.	n.s.
Prunus syriaca (A)	–		1		n.s.	-	n.s.
Prunus spinosa (A)	+	63	**70**	50	n.s.	n.s.	*
Symphoricarpos albus (A)	–	3	8		n.s.	n.s.	n.s.
Picea pungens (W)	–	1	3	6	n.s.	n.s.	n.s.
Picea abies (W)	+	8	**20**	3	*	n.s.	*
Populus sp. (W)	–	11	11	12	n.s.	n.s.	n.s.
Populus alba (W)	+	**16**	11		n.s.	*	*
Populus nigra (W)	+	**42**	32	21	n.s.	*	n.s.
Populus tremula (W)	+	8	**15**		n.s.	n.s.	*
Populus nigra 'Italica' (W)	–	1	1		n.s.	n.s.	n.s.
Euonymus europaea (A)	+	7	11	6	n.s.	n.s.	n.s.
Ulmus scabra (W)	+		**10**		**	-	*
Ulmus campestris (W)	+	5	8		n.s.	n.s.	n.s.
Ulmus laevis (W)	+	32	39	35	n.s.	n.s.	n.s.
Salix alba (W)	+	**68**	**40**	18	**	***	*
Salix caprea (W)	+	**5**			*	n.s.	-
Salix fragilis (W)	+	**45**	32	21	n.s.	*	n.s.
Salix purpurea (W)	+	3			n.s.	n.s.	-
Salix cinerea (W)	+	**60**	15	9	***	***	n.s.
Salix viminalis (W)	+	14	7	3	n.s.	n.s.	n.s.
Parthenocissus quinquefolia (A)	–		3		n.s.	-	-
Prunus mahaleb (A)	–	1		3	n.s.	n.s.	n.s.
Reynourtia japonica (O)	–	**7**			*	n.s.	-
Reynourtia sachalinensis (O)	–	1			n.s.	n.s.	-

[1] (A) – animal dispersed, (W) – wind dispersed, (O) – water dispersed

[2] (+) – native, (–) – exotic

Table 2. Total number of species with regard to the ways of dispersal and origin in the respective woodlot types. Differences in number of species between the respective woodlots are not significant statistically (χ^2 test, $P > 0.05$)

Number of species	Type of woodlot		
	Water-edge hedgerows	Mid-field clumps	Avenues
Animal dispersed	33	35	25
Wind dispersed	25	28	17
Water dispersed	4	2	1
Total number of woody species	62	65	43
of that number:			
Native species	43	48	32
Exotic species	19	17	11

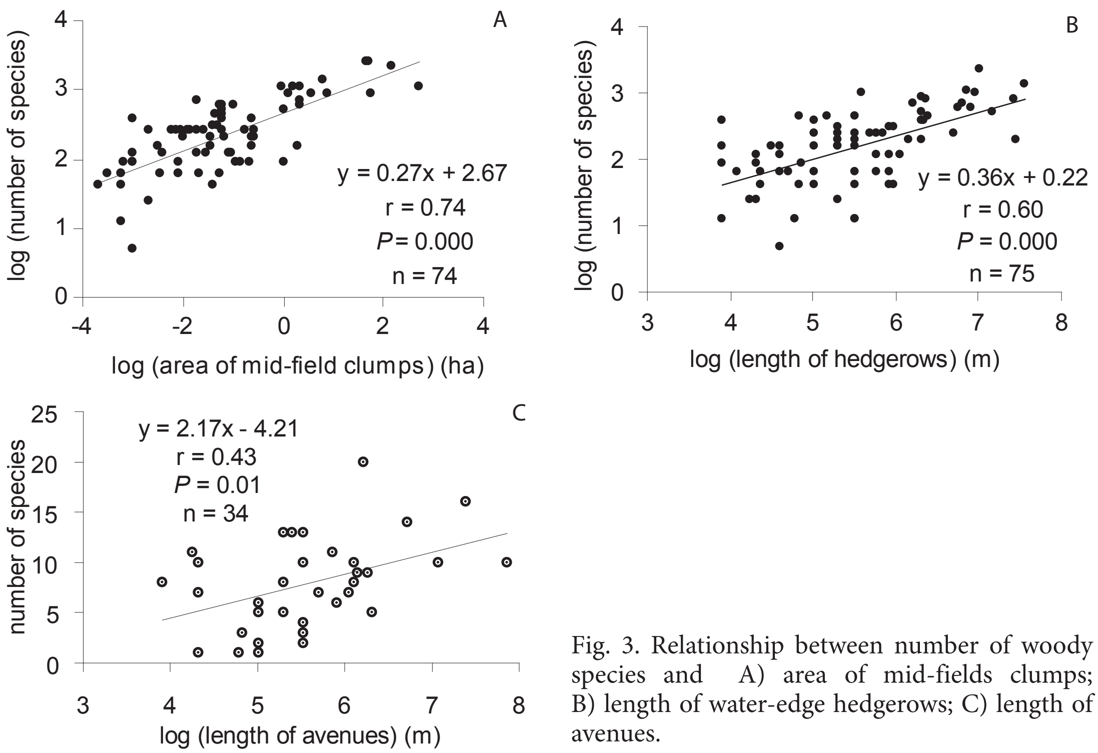

Fig. 3. Relationship between number of woody species and A) area of mid-fields clumps; B) length of water-edge hedgerows; C) length of avenues.

particulary common were small-leaved lime (*Tilia cordata*), black locust (*Robinia pseudoacacia*) and wild rose (*Rosa canina*). For 21 species statistically significant differences in occurrence frequency between water-edge hedgerows and clumps were documented. Ten species differed in frequency of occurrence between water-edge hedgerows and avenues. Differences between clumps and avenues were shown for 15 species.

The share of species of foreign origin in three types of woodlots remained on similar level, and was 31% in water-edge hedgerows, 27% in mid-field clumps and 26% in avenues (Table 2).

No significant differences were found between frequencies of occurrence in the respective types of woodlots of species dispersed by wind, animals and water, and of native and foreign origin (Table 2).

For the three types of woodlot studied a high statistically significant correlations were found between the size of woodlot (length for water-edge hedgerows and avenues, and area for mid-field woodlots) and number of woody species (Fig. 3). That was most conspicuous in the case of mid-field clumps.

4. DISCUSSION AND CONCLUSIONS

Mid-field woodlots of Wrocław Plain were characterized by a high share of photophilous species, characteristic for the regenerative stage of forest (single-neck hawthorn, blackthorn, elder). Currently, in agricultural areas of western and central Europe these species constitute the main component of hedgerows (Moonen and Marshall 2001). For instance in England and Wales the most frequent species found in 1597 hedgerows were: single-neck hawthorn (94%), blackthorn (69%), roses (*Rosa* spp.) (60%), elder (48%) and ash (47%) (Anonymus 2000). In Sweden, the most abundant species in hedgerows were: roses (*Rosa* spp.) (64%), pedunculate oak (64%), spindle (*Euonymus europaea*) (59%), elder (58%), ash (55%) and hawthorn (*Crataegus* spp.) (54%) (Sarlöv Herlin and Fry 2000).

Among the three types of mid-field woodlot studied in Wrocław Plain the largest numbers of woody species were characteristic for forest islands. This, probably, reflected the more diverse habitat conditions within them. Some woodlots had the characteristic photophilous ecotone plant associations well developed (e.g. with *Humulus lupulus*), while their interiors remained strongly shadowed. This is also confirmed by the high correlation coefficient between size of a mid-field woodlot and number of species.

Hoonnay and co-authors (1998) have distinguished two main groups of variables, the so-called internal and external variables that determine floristic diversity of forest islands. According to them the internal variables include: the area of wooded patch, habitat diversity within the woodland, duration of isolation, origin, kind and length of forest management of the woodlot and environmental factors (among others, structure, kind and nutrient content in the soil). The external variables refer to the character of the landscape around a woodland and degree of its isolation (Honnay *et al.* 1998, 1999). In spite of so many variables affecting the floristic diversity of forest islands, that relation, based on the classical theory of islands (between island area and number of species – MacArthur and Wilson 1967) describes the situation found in Wrocław Plain. In the Finland, Estonia and Lithuania it has been shown that the area of a forest island was positively correlated with the number of tree and shrub species (Mikk and Mander 1995), however, to a lesser degree than in Wrocław Plain. No effect, however, was found of the degree of woodlot isolation on the number of species (Mikk and Mander 1995). In Belgium in 234 isolated forest patches (of average size 136 ha) the size of patch remained in close correlation with the overall number of herbaceous plant species, but it affected to a lesser degree the number of tree and shrub species, which occurrence depended more on the differentiated site conditions (Honnay *et al.* 1999).

The main variables determining the floristic richness of hedgerows include: the width, area, tree height, complexity of vertical structure (storey structure), distance from the nearest forest patch and frequency of agro-irrigation treatments. The length of hedgerows is considered in few papers as the only factor (Moonen and Marshall 2001, de Blois *et al.* 2002, Boutin *et al.* 2002). In the Wrocław Plain area the number of woody species in linear woodlots remained in close relation with their length. It could be due to increased habitat diversity and increased probability of species occurrence with increasing length of woodlot. For example, in an agricultural area of Quebec (this area, like Wrocław Plain, is also situated in temperate zone) the average length of three types of hedgerows (in spontaneous development, artificially introduced and dominated by herbaceous plants) (n = 44) was between 520 and 718 meters, while the largest number of woody species was found in natural woodlots with well developed tree layer (Boutin *et al.* 2002). The average length of hedgerows in Canada was greater than in the Wrocław Plain area (520 m in Canada *vs.* 392

in Wrocław Plain) (Boutin *et al.* 2002, the present work). In England and Wales in 1597 hedgerows (average length 154.9 m) the average number of woody species was over two times lower than in the Wrocław Plain (England and Wales – 5.8 *vs.* 10.3 – Wrocław Plain) (Anonymus 2000, the present work).

The clear differences in the average number of species between avenues and water-edge hedgerows (7.9 *vs.* 10.3) found in Wrocław Plain reflect the markedly better habitat condition, and are also due to less drastic agro-irrigation treatments that eliminate vegetation along watercourses more than along roadsides.

The results of studies conducted in Canada and Sweden have confirmed a higher share of species dispersed by animals in hedgerows compared to bushy plant associations in forest ecotone. It is also assumed that species dispersed by wind are among the most frequent in forest ecotone (Fritz and Merriam 1994, Sarlöv Herlin and Fry 2000). Equally significant factors influencing the presence of animal-dispersed species in hedgerows are their width, vegetation composition and number of connections with other habitats (Sarlöv Herlin and Fry 2000). For example, in hedgerows located near woodlands higher frequencies of hazel (*Corylus avellana*), bird cherry (*Prunus padus*) and guelder rose (*Viburnum opulus*) were found (Grime *et al.* 1988). The lack of differences in frequency of the species of different dispersal modes in woodlots of Wrocław Plain as compared with other areas, may result from different landscape structure, age of woodlots and level of anthropogenic pressure. In the case of Wrocław Plain such a situation may be the result of a centuries-long adaptation of the woodlots to the habitat conditions that have always been under human pressure.

The results of the present work indicate an essential role of small watercourses and irrigation ditches as refuges for species associated with wetland habitats (willows, poplars). The populations of these species have been strongly reduced in many regions with much transformed landscape. For instance, in the British Isles the black poplar has become an endangered species, which total population there is estimated at barely two thousand individuals (Spencer 1994).

From the point of view of protection of biological diversity on agricultural areas it seems advantageous to preserve the differentiated structure and species composition of woodlots. It means that besides those with well developed tree layer, both linear and patch-like, there should be some woodlots with shrubby associations dominate. For example they can be of crucial importance for the small passerines species (whitethroat, *Sylvia communis*, barred warbler, *Sylvia nisoria*, marsh warbler, *Acrocephalus palustris*), which occur only in woodlots devoid of trees but with well developed shrub layer (Orłowski 2004b). Allowing spontaneous development of bushy associations, e.g. of blackthorn, hawthorn, willows or blackberry, along the slopes of irrigation ditches and roadsides is a natural way of inhibiting the invasion of floristically foreign elements (e.g. knotweeds, *Reynourtia* spp. and a series of expansive species of herbaceous plants, e.g. tansy, *Tanacetum vulgare* and goldenrods, *Solidago* spp.).

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5. SUMMARY

The paper presents the results of studies devoted to woody species composition in three types of mid-field woodlots (N = 183), located on the area of 5480 ha in the intensively managed agricultural landscape of Wrocław Plain (Lower Silesia, south-western Poland, Fig. 1). All woodlots were divided, with respect to shape and localization, into two groups:

1. Linear woodlots, along linear elements of landscape: a) avenues (n = 34) – rows of trees on one or both sides of paved and unpaveded roads (average length ± SD = 407.94 ± 504.77 m); b) water-edge hedgerows (n = 75) – rows of trees

on one or both sides of small watercourses and irrigation ditches, of average width from 3 to 6 meters (average length ± SD = 392.13 ± 402.83 m).

2. Patch woodlots – mid-field clumps termed also as forest islands (n = 74) – in the form of compact patches (average area ± SD = 0.96 ± 2.23 ha).

In general, in the three types of woodlots 77 woody plant species were found (Table 1). The highest average number of species was found in mid-field clumps – 11.8, the lowest in avenues – 7.9 (Fig. 2). This, probably, reflected the more diverse habitat conditions within the mid-field clumps. The clear differences in the average number of species between avenues and water-edge hedgerows found, reflect the markedly better habitat condition, and are also due to less drastic agro-irrigation treatments that eliminate vegetation along watercourses more than along roadsides.

To the most common species (50% frequency in all the woodlots) belonged: elder (*Sambucus nigra*), single-neck hawthorn (*Crataegus monogyna*), blackberry (*Rubus* spp.) and blackthorn (*Prunus spinosa*). For 21 species, statistically significant differences between frequency of occurrence in water-edge hedgerows and clumps were found. Ten species differed in frequency of occurrence between water-edge hedgerows and avenues. Differences between clumps and avenues were documented for 15 species (Table 1).

No significant differences were found in the occurrence of species dispersed by wind, animals and water, and between native species and those of foreign origin, in the respective types of woodlots (Table 2). Such situation may be the result of a centuries-long adaptation of the studied woodlots to the habitat conditions that have always been under human pressure.

For the three types of woodlots studied, high statistically significant correlations were found between the size of woodlots (length for water-edge hedgerows and avenues, and area for mid-field clumps) and the number of recorded woody species (Fig. 3). In the case of the mid-field clumps that relation is based on the classical islands theory. In linear woodlots it could be due to increased habitat diversity and increased probability of species occurrence with increasing length of woodlot.

The results of the present work indicate an essential role of small watercourses and irrigation ditches as refuges for species associated with wetland habitats (willows – *Salix* spp., poplars – *Populus* spp.), which populations have been strongly reduced in many regions with much transformed landscape. From the point of view of protection of biological diversity on agricultural areas it seems advantageous to preserve the differentiated structure and species composition of woodlots.

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