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Secondary dispersal of seeds by the Magpie *Pica pica* L. in agricultural landscape

Wtórna dyspersja nasion z udziałem sroki *Pica pica* L. w krajobrazie rolniczym

SUMMARY

The aim of the study was to broaden the knowledge about the role played by the Magpie (*Pica pica* L.) in the secondary dispersal of seeds with help of nest material, which takes place in the agricultural landscape with the distinct dominance of arable fields. We also tried to assess which plant life-history traits can be helpful in the dispersal mediated by the Magpie. Six nests were collected after the breeding season; the mud (soil) layer was separated from the nests and the seed pool present there was studied with the use of the seedling emergence method. The number of seedlings detected in the study nests varied between 23 and 126 per 1000 g of soil dry weight, the total number of recorded taxa was 41 (the number of species in subsequent nests varied between 10 and 24). All recorded species can be divided into four ecological groups, which point to the source of the nest material: weeds, ruderal species, species connected with field roads, and grassland and meadow species. Among them, weeds are the best represented group. We think that the secondary dispersal by the Magpie is most beneficial for weeds with no adaptation for dispersal, with a persistent seed bank and a low seed weight.

STRESZCZENIE

Celem badań było rozszerzenie wiedzy na temat znaczenia sroki *Pica pica* L. we wtórnym rozprzestrzenianiu się nasion wraz z materiałem gniazdowym w rolniczym krajobrazie Wyżyny Lubelskiej. Podjęłyśmy również próbę oceny, które z cech historii życiowej roślin mogą być pomocne w efektywnej dyspersji z udziałem sroki. Zasoby nasion zgromadzone w warstwie gleby gniazd oceniłyśmy za pomocą metody wschodu siewek. Stwierdziłyśmy obecność 41 taksonów, łącznie we wszystkich gniazdach; liczba siewek w pojedynczym gnieździe była zróżnicowana: od 23 do 126 na 1000 g suchej masy gleby. Wszystkie stwierdzone taksony zostały zaklasyfikowane do 4 grup ekologicznych, są to: chwasty upraw, gatunki ruderalne, gatunki zbiorowisk dywanowych oraz gatunki charakterystyczne dla łąk i muraw. Stwierdziłyśmy, że największymi beneficjentami wtórnego przenoszenia diaspor z udziałem sroki są chwasty o lekkich i trwałych nasionach, pozbawionych jakichkolwiek adaptacji do dyspersji.

Keywords: secondary seed dispersal, long-distance dispersal (LDD), agricultural landscape, nest material, Magpie, life-history traits

INTRODUCTION

Fragmented and dynamic agricultural landscape can be described by the ‘matrix-patch-network’ model. Small areas favourable for living organisms (i.e. patches, like forest or grassland islands, small water bodies) are surrounded there by unfavourable environment called the matrix (e.g. arable fields) and connected by linear structures named the network – roads and road sides, balks, hedgerows, streams and ditches (4, 19, 20). Agricultural landscape determines the biological diversity of Europe because a large part of the Continent is dominated by human-land use. Recently, it has undergone two parallel processes: homogenisation and fragmentation (17). They lessened the number of patches and the connectivity among suitable habitats, and they lowered the probability of their colonisation and recolonisation – the processes depending on the dispersal of organisms (27). Therefore, the long-distance dispersal (LDD) becomes crucial for the persistence of species in a dynamic fragmented landscape (26, 34). In the case of plant seeds, the LDD can be generated by an unusual behaviour of a standard dispersal vector (e.g. extreme wind conditions), by a non-standard vector, or by multiple subsequent dispersal vectors (12, 24, 25, 26, 30). Sometimes, when a number of subsequent dispersal vectors are involved, we can call it a ‘secondary dispersal’ – the process by which seeds that are already on the ground are moved to another location. It is often mediated by animals (35). Non-standard means of dispersal seem to be extremely important in the case of weeds. Most of them had evolved no dispersal mechanisms (or they are barochorous) and they rely on dispersal by humans (2).

The goal of our study was to evaluate the role of the Magpie *Pica pica* L. in the secondary seed dispersal with nest material in agricultural landscape. This process can be called both a secondary dispersal and the dispersal by the non-standard vector, and we knew that this bird species could gather a high number of seeds in the nest (6, 7). The Magpie builds its multilayered nests between late January and early March. The external layer is built of sticks and it surrounds the clay or mud layer and the inner lining. The material is usually collected within the territory of a pair of Magpies, which is approximately 5–7 ha large (3). The nest is used only once, but the mud layer can persist untouched for more than a year (16). The benefits of the dispersal by Magpie are not only the translocation of seeds incorporated in the mud layer but also the 'secondary releasing' of seeds higher above the ground. This process enables them to receive longer flight times and reach longer distances, especially when the seeds are light (30).

We wanted to broaden our knowledge about this way of seed dispersal in agricultural landscape with a distinct dominance of arable fields. We also tried to assess which plant life-history traits can be helpful in the dispersal mediated by the Magpie. The knowledge of the birds' behaviour and the observations of the fate of nests made us formulate the following starting hypothesis: the secondary dispersal by the Magpie is the most beneficial for weeds with no adaptation for dispersal, a persistent seed bank and a low seed weight.

STUDY SITE AND METHODS

The study area was Snopków, a village in the close vicinity of Lublin. It is located on the border of the protected landscape area 'Dolina Ciemiegi', on the Naleczów Plateau in the north-western part of the Lublin Upland (south-east Poland). The substratum of the Lublin Upland consists of a thick loess layer founded on upper Cretaceous layers (18, 36). Because of soil fertility, the area has been almost entirely adapted for farming, deforested and densely populated. The region is characteristic of the extensive type of the farming system, the area of arable fields is small, and there exists a relatively dense network of linear landscape elements like field roads, balks and hedgerows. Abandoned fields and meadows are also significant landscape elements there. The importance of linear landscape structures in the maintenance of the seed pool diversity of different species important to this agroecosystem was underlined earlier (5).

Six nests of the Magpie were collected after the breeding season (three of them in 2008 and three in 2009) in the close vicinity of the village. All nest sites were located close to each other: the distance between the two furthest nests was approximately 1500 meters. The main criterion for the nest selection was the similarity of the closest surrounding, which was dominated by arable fields (cereals or root crops). The nest layers were separated, described and weighted (Table 1). The mud layer (the term soil layer will be also used) was put into plastic boxes and kept moist in cold frames for the whole vegetative season (i.e. six months). All the emerging seedlings were counted and identified. The number of seedlings was calculated for 1000 g of soil dry weight.

All landscape elements (i.e. arable fields, meadows and grasslands, abandonments, wastelands, roads, balks and hedgerows) were identified within a 100-m radius of the nests in July 2009. All species with their abundance were

Table 1. Characteristics of nests and their surrounding

Nest	Dry weight (g)		Tree or shrub species where the nest was localized	Nest surrounding
	Soil	Inner layers		
1	1319	53	*Betula pendula* Roth	arable fields, significant share of meadows, hedgerows and wastelands
2	2102	68	*Syringa vulgaris* L.	dominance of arable fields, wide field road in the vicinity
3	2937	90	*Prunus spinosa* L.	dominance of arable fields, field roads in the close vicinity
4	2323	72	*Prunus spinosa* L.	arable fields, significant share of meadows and hedgerows
5	1102	49	*Prunus spinosa* L.	dominance of arable fields
6	3809	109	*Prunus spinosa* L.	dominance of arable fields

recorded in representative landscape elements around each nest. The following abundance scale was used: 0.5 – sporadic species, 1 – cover less than 10%, 2 – 11–20%, 3 – 21–30%, …, 10 – 90–100%. The total vegetation cover was also noted.

To analyse seed bank data and vegetation data the Canoco 4.5 software was used. Seed bank data were standardised to make them comparable with the vegetation data in the following way: 0.5 – sporadic species, with only one seed recorded or with the share smaller than 1%, 1 – share up to 10%, 2 – share between 10 and 20%, …, 10 – share between 90 and 100%. The Detrended Correspondence Analysis (DCA) was conducted (31). All statistics (the Spearman rank correlation, Kruskall-Wallis test, Wald-Wolfowitz runs test and χ^2 test) were calculated with the use of Statistica PL.

The main source for species life-history traits (dispersal mode, seed bank type and seed weight) was Grime et al. (11). When there was no data for the species in Grime et al. (11) the type of the seed bank was assessed with the use of the data from the Thompson et al. database (32). The term 'persistent' was used both for a short-term and a long-term persistent seed bank type (classification according to Bakker et al. [1]). Seed weight categories are according to Grime et al. (11), seed weight of *Cerastium arvense*, *Conyza canadensis*, *Galinsoga parviflora*, *Lamium amplexicaule*, *Melilotus* sp., *Oxalis fontana*, *Solidago gigantea* and *Chenopodium glaucum* was according to the data base (http://people.ucalgary.ca/~smvam26osi/UK_Peru_data.htm); *Galinsoga ciliata* according to Milberg et al. (21).

RESULTS

SEED POOL STRUCTURE AND SOURCE OF NEST MATERIAL

The number of seedlings detected in the mud layer of the study nests varied between 23 and 126 per 1000 g of soil dry weight (Table 2). The nests with the most numerous seed pool were dominated by one species only: in nests 4 and 6 it was *Poa pratensis*, in nest 5 – *Chenopodium glaucum.* The total number of recorded taxa was 41 (the number of species in subsequent nests varied between 10 and 24), most of them were represented by single seeds in the nests. All recorded species can be divided into four ecological groups: species connected with field roads, weeds, ruderal species, and grassland and meadow species (Table 3). Weeds are the best represented group: 18 species were recorded, and they constitute more than a half of the total number of seeds in three nests. Although the share of the ecological groups is highly variable, leading to the lack of significant differences among mean values of percent share in different groups of species (Kruskall-Wallis test, H=4.58; *P*=0.2049), the share of grassland and meadow species is significantly lower than all the other groups taken together (Wald-Wolfowitz runs test, Z=2.72; *P*=0.0064).

The comparison between the species structure of the nests' seed pool and the vegetation of the landscape elements present in their vicinity helped us point out the main source of the soil material which was incorporated into the nest structure. The first step of the analysis was the exclusion of the data from hedgerows. Their species structure was totally different from the other analysed landscape elements (arable fields, abandoned fields, field roads and their neighbourhood, balks, wastelands, meadows and grasslands) and also from the nests. The Detrended Correspondence Analysis (DCA) showed that the main source of the soil found in the nests was probably field roads, wastelands and arable fields (Fig. 1). These landscape habitats are characteristic of the lowest values of the plant cover, and in consequence the highest availability of soil material (Table 4). The source of the soil also determines the main group of plant species potentially benefiting from the secondary dispersal by the Magpie: weeds, ruderal species and those connected with field roads.

SECONDARY DISPERSAL VERSUS LIFE-HISTORY TRAITS

The most distinct feature of the seed pool of the nests is the significant share of the species with no dispersal adaptation (mean value for all nests – 57%), which are the main beneficiaries of the secondary dispersal. This share reaches respectively 79 and 84% in nests 5 and 6, which are surrounded almost exclusively by arable fields. The best represented species from this group, which are simultaneously the stable element of the nests, are: *Chenopodium*

Table 2. Structure of the seed bank of the Magpie nests. Number of seeds per 1000 g of soil dry weight); nomenclature according to Mirek et al. (22)

Taxa	Nest					
	1	2	3	4	5	6
Species connected with field roads						
Lolium perenne L.		2		11		1
Matricaria maritima L. subsp. *inodora* (L.) Dostal				1		
Plantago major L.	10	1	4	17	2	1
Poa annua L.	4					
Polygonum aviculare L.			1	5	1	1
Weeds						
Amaranthus retroflexus L.		1		1		1
Chenopodium album L.		1	2	4	7	15
Chenopodium glaucum L.					47	
Echinochoa crus-galli (L.) P. Beauv.			9			
Galeopsis tetrahit L.						1
Galinsoga ciliata (Raf.) S. F. Blake						1
Galinsoga parviflora Cav.	2		1			2
Galium aparine L.			1			
Gnaphalium uliginosum L.				1	5	5
Lamium amplexicaule L.			1			
Myosotis arvensis (L.) Hill				1		1
Oxalis fontana Bunge			2			
Polygonum lapathifolium L. subs. *pallidum* (With.) Fr.	1		1	1		1
Polygonum minus Huds.			1			
Setaria pumila (Poir.) Roem. & Schult.	1	1	5			
Setaria viridis (L.) P. Beauv.	1		1	11		35
Stellaria media (L.) Vill.		1		1		3
Veronica polita Fr.			1			
Ruderal species						
Anthriscus sylvestris (L.) Hoffm.				1		
Artemisia vulgaris L.	2	4		1		3

Cont. Tab. 2

Taxa	Nest					
	1	2	3	4	5	6
Capsella bursa-pastoris (L.) Medik.				1		4
Cerastium arvense L.				1		
Conyza canadensis (L.) Cronquist	1	5	1	1		1
Convolvulus arvensis L.				1		
Melandrium album (Mill.) Garcke						1
Melilotus sp.					1	
Rumex obtusifolius L.	1		1			
Solidago gigantea Aiton				8	5	
Urtica dioica L.	3	2	2	2	1	1
Meadow and grassland species						
Achillea millefolium L.				1		
Daucus carota L.				2		
Hypericum perforatum L.		1		1		1
Poa pratensis L. and other *Poaceae*		3		41	7	47
Taraxacum officinale F. H. Wigg.		1		3	1	
Other taxa						
Epilobium sp.					1	
Rubus sp.					2	
Total number of seedlings	26	23	34	118	80	126
Number of taxa	10	12	16	24	12	20

Table 3. Percent share (%) of ecological groups of species in the seed pool of the nests

Ecological group	Nest						Mean value
	1	2	3	4	5	6	
Species connected with field roads	54	13	15	29	4	2	19
Weeds	19	17	73	17	74	52	42
Ruderal species	27	48	12	14	9	8	20
Grassland and meadow species	–	22	–	40	10	38	18
Other taxa	–	–	–	–	3	–	<1

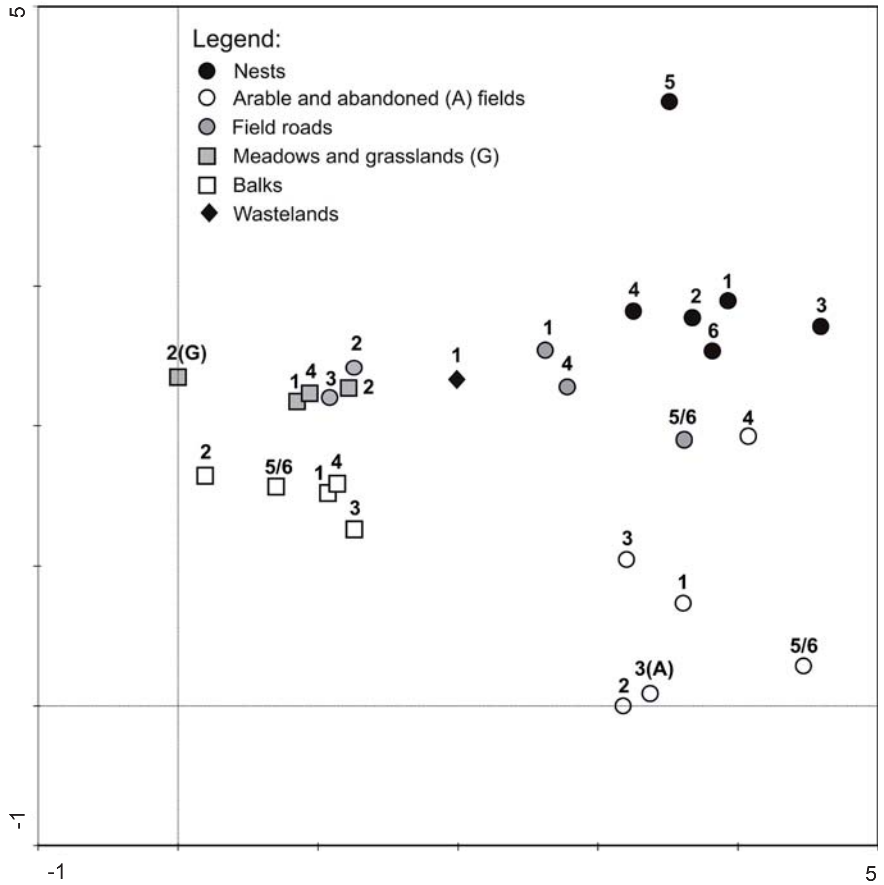

Fig. 1. Results of the DCA analysis: species composition of seed banks found in the nests and the vegetation cover of landscape elements in the vicinity of nests (radius – 100 m). Symbols indicate different types of landscape elements, numbers – subsequent nests and their surroundings. Hedgerows were excluded from the analysis

Table 4. Spearman rank correlations between the features of nests and the landscape elements, with axes in the DCA; correlation of the share of ruderal species with both axes was not significant (NS)

Variable	Correlation with axis 1	Correlation with axis 2
Vegetation cover	-0.686 $P<0.001$	NS
Share of species connected with field roads	0.488 $P<0.01$	0.539 $P<0.01$
Share of weeds	0.688 $P<0.0001$	-0.395 $P<0.05$
Share of meadow and grassland species	-0.867 $P<0.0001$	NS

album, *Ch. glaucum, Setaria pumila*, *S. viridis, Lolium perenne*, *Polygonum aviculare*, *P. lapathifolium* subsp. *pallidum* and *Poa pratensis*. The remaining species present in the mud layer of the nests represent three types of dispersal mode: anomochory (mean value – 24%, 12 species with different adaptations to wind dispersal); epizoochory (18%, 6 species) and endozoochory – *Rubus* sp., present only in nest 3, constituting 3% of its total seed pool (Table 5). The most numerous wind-dispersed diaspores represent the Asteraceae family: *Artemisia vulgaris*, *Conyza canadensis*, *Galinsoga ciliata*, *G. parviflora*, *Gnaphalium uliginosum* and *Solidago gigantea*. The most common epizoochorous species is *Plantago major* – with dispersules adhesive through the secretion of mucillage (characteristics according to Grime et al. [11]). Most of the species found in the nests create persistent seed banks (28 species), the mean share of this group in the total seed pool is 63%; 13 species have transient seeds; in the case of three taxa (*Epilobium* sp., *Oxalis fontana* and *Melandrium album*) we did not find any information about the type of the seed bank (Table 5). Abandoned nests can persist on trees or bushes for a few years trapping diaspores inside and the persistence of seeds is an important life-history trait in the analysed way of dispersal. Seed weight of species present in the study nests is low: in the case of the majority of species it does not exceed 1 mg (Table 5).

We also checked the correlation between selected life-history traits of recorded species (Table 6). The dispersal mode and seed weight are combined:

Table 5. Percent share (%) of seeds of species with different life-history traits in the study nests

Life-history trait		Nest						Mean value
		1	2	3	4	5	6	
Dispersal mode	anemochory	31	57	11	16	16	14	24
	epizochory	42	4	43	17	3	2	18
	endozoochory	–	–	–	–	3	–	0.5
	none	27	39	43	67	79	84	57
Seed bank type	transient	15	30	28	65	16	69	37
	persistent	85	70	72	35	84	31	63
Seed weight (mg)	<0.20	31	52	11	14	15	13	23
	0.21–0.50	54	26	20	53	70	43	44
	0.51–1.00	4	4	9	14	1	29	10
	1.01–2.00	4	13	11	17	11	13	12
	>2.00	8	4	46	3	3	2	11

Table 6. Association between selected life-history traits, d.f. – degree of freedom, NS – non significant

	Seed bank type	Dispersal mode
Dispersal mode	d.f. = 3 χ^2=3.008; NS	
Seed weight	d.f. = 5 χ^2=3.373; NS	d.f. = 15 χ^2=28.681; P<0.05

anemochorous seeds and those with no dispersal adaptations are lighter than other seeds. All wind-dispersed seeds and 60% of those without any distinct dispersal mode found in the nests are lighter than 1 mg. No connection between the type of the seed bank and the dispersal mode or seed weight was found, but this fact can be easily explained. Seventy percent of species with no dispersal mode create persistent seed bank, but this type of the bank is also the most common in the case of the species exhibiting dispersal adaptations (67% of all anemochorous, epizoochorous and endozoochorous species taken together). The majority of transient and persistent seeds are light (almost 70% in both groups), but it must be remembered that only the species with the persistent seed bank can be the beneficiaries of the dispersal with the nest material.

DISCUSSION

The role of birds in the functioning of different ecological systems has been recently fully appreciated. They are a significant mobile link in both natural and human-dominated ecosystems and they connect different habitats in space and time. One of the most underlined functions of birds is their being an effective vector in seed dispersal, especially in the LDD. They are also called 'ecosystem engineers' and nest construction is an example of this function (29). Building of nests is often connected with the creation of the suitable environment for many species, e.g. in the case of the White Stork *Ciconia ciconia* (15), and also with the dispersal of plant diaspores, which are frequently incorporated into the structure of the nest. It must be emphasised that the mechanism of seed dispersal with the nest material has been described very rarely.

Seeds can be placed by birds in nests intentionally or not. Dean et al. (8) analysed nests of 31 bird species from semiarid karoo shrubland and they found seeds of 55 plant species there. The authors claimed that cottony covering of seeds is an adaptation to this dispersal mechanism. Seeds present in the nests of the Magpie were transported by birds unintentionally with the soil used to build one of the nest layers. It is an example of the secondary dispersal mediated by several (at least two) subsequent vectors and transported seeds do not exhibit any specific adaptation to being dispersed by the bird, as it was in the case of some particular species of karoo shrubland described by Dean et al. (8). We are only able to indicate the groups of plant species with a higher probability of being dispersed in this way: weeds, ruderal species and those connected with field roads. All of them are connected with the habitats characterised by low plant cover, where the bare soil is highly accessible to birds. This regularity was also found in the case of Magpies' nests situated in the agricultural landscape with a higher share of meadows (7).

The LDD is thought to be involved, among others, in the spread of invasive species (10, 23, 24, 28, 34). Some seeds of invasive or potentially invasive species, e.g. *Diplotaxis tenuifolia* (L.) DC. and *Erucastrum gallicum* (Willd.) O. E. Schultz, had been found earlier in the nest material of the Magpie (7). We also found seeds of some alien species which constitute a serious threat to the local flora. The most numerous were *Amaranthus retroflexus*, *Conyza canadensis* and *Solidago gigantea*. Sánchez et al. (28) studied the pellets of waders and observed that their role as dispersers of alien plants must be taken into consideration. We think that also the Magpie and probably the other birds of agricultural landscape must also be taken into consideration as potential non-standard vectors involved in the spreading of alien plant species.

The process of dispersal interacts with plant life-history traits and habitat availability, that is usually connected with the level of disturbances (13). Only effective dispersal events are important in many ecological processes, and a mere translocation of seeds, even for long distances, is not sufficient. Only the dispersal followed by a successful establishment can be called effective, and one of the main questions asked in the studies of the LDD is which internal (morphological, physiological and behavioural) factors determine the success of the LDD (23). We singled out the following life-history traits which can be crucial for the successful establishment of seeds transported by the Magpie with the nest material: a persistent seed bank and a low seed weight. Thompson et al. (33) point out that the persistence of seeds is highly correlated with the level of habitat disturbances; the value of the longevity index is the highest in the case of species connected with arable fields and wastelands. These groups of species are best represented in the studied nests and they seem to be the main beneficiaries of the analysed mechanism of secondary dispersal. It was noticed that persistent seeds are small and compact, which helps in their incorporation into the soil, where mainly persistent seeds were found. Short-lived diaspores are usually bigger, elongated or flattened (9, 33). We did not find any connection between seed persistence and seed size, although the majority of seeds found in the nests were small and persistent. However, we also found species creating the persistent seed bank, despite their having relatively bigger seeds, e.g. *Convolvulus arvensis* – the species with the biggest seeds among all found diaspores, or *Galeopsis tetrahit* and *Polygonum lapathifolium*. It is well known in the literature that in the case of weed seeds the connection between low seed mass and persistence is not the rule. It is explained that there is no correlation between the size and shape of the seeds and the possibility of their transportation down the soil (33). The probability of the movement down of the soil profile is higher because of the human activity like ploughing.

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REFERENCES

1. Bakker J. P., Bakker E. S., Rosén E., Verweij G. L., Bekker R. M. 1996. Soil seed bank composition along a gradient from dry alvar grassland to *Juniperus* shrubland. J. Veg. Sci. 7, 165–176.
2. Benvenuti S. 2007. Weed seed movement and dispersal strategies in the agricultural environment. Weed Biol. Manag. 7, 141–157.
3. Birkhead T. R. 1991. The magpies. The ecology of Black-billed and Yellow-billed Magpies. T. & A. D. Poyser Ltd, London.
4. Corbit M., Marks P. L., Gardescu S. 1999. Hedgerows as habitat corridors for forest herbs in central New York, USA. J. Ecol. 87, 220–232.
5. Czarnecka J. 2006. Roadsides as plant diversity refuges in agricultural landscape. Ecol. Quest. 7, 37–46.
6. Czarnecka J., Kitowski I. 2007. Nests of White Stork (*Ciconia ciconia*) and Black-billed Magpie (*Pica pica*) as places of accumulation of plant diasporas. [In:] Botanika w Polsce – sukcesy, problemy, perspektywy. Streszczenia referatów i plakatów. E. Kępczyńska, J. Kępczyński (eds), Wyd. Oficyna IN PLUS, Szczecin, 61 (in Polish).
7. Czarnecka J., Kitowski I. 2008. The potential role of nests of black-billed magpie *Pica pica* L. in accumulation and dispersal of seeds in agricultural landscape. Pol. J. Ecol. 56, 673–682.
8. Dean W. R., Milton S. J., Siegfried W. R. 1990. Dispersal of seeds as nest material by birds in semiarid karoo shrubland. Ecology 7, 1299–1306.
9. Fenner M., Thompson K. 2005. The Ecology of Seeds. Cambridge University Press, Cambridge.
10. Guerrero A. M., Tye A. 2009. Darwin's Finches as seed predators and dispersers. The Wilson J. Ornithol. 121, 752–764.
11. Grime J. P., Hodgson J. G., Hunt R. 1996. Comparative Plant Ecology. A Functional Approach to Common British Species. Chapman & Hall, London.
12. Higgins S. I., Nathan R., Cain M. L. 2003. Are long distance dispersal events in plants usually caused by non-standard means of dispersal? Ecology 84, 1945–1956.
13. Higgins S. I., Richardson D. M. 1999. Predicting plant migration rates in changing world: the role of long-distance dispersal. Am. Nat. 153, 464–475.
14. http://people.ucalgary.ca/~smvamosi/UK_Peru_data.htm
15. Indykiewicz P. 2006. House Sparrow *Passer domesticus*, Starling *Sturnus vulgaris*, Tree Sparrow *Passer montanus* and other residents of nests of the White Stork *Ciconia ciconia*. [In:] P. Tryjanowski, T. H., Sparks, L. Jerzak (eds), The White Stork in Poland: Studies in Biology, Ecology and Conservation. Bogucki Sci. Publ., Poznań, 225–235.
16. Jerzak L. 2005. Magpie *Pica pica* in Poland – current state of knowledge. [In:] L. Jerzak, B. P. Kavanagh, P. Tryjanowski (eds), Ptaki krukowate Polski [Corvids of Poland]. Bogucki Sci. Publ., Poznań, 541–556.

17. Jongman R. H. G. 2002. Homogenisation and fragmentation of European landscape: ecological consequences and solutions. Lands. Urb. Plan. 58, 211–221.
18. Kondracki J. 2002. Geografia regionalna Polski [Regional geography of Poland]. Wyd. Nauk. PWN, Warszawa.
19. Le Coeur D., Baundry J., Burel F., Thenail C. 2002. Why and how we should study field boundary biodiversity in an agrarian landscape context. Agric. Ecosyst. Environ. 89, 23–40.
20. Marshall E. J. P. 2002. Introducing field margin ecology in Europe. Agric. Ecosyst. Environ. 89, 1–4.
21. Milberg P., Andersson L., Thompson K. 2000. Large-seeded species are less dependent on light for germination than small seeded ones. Seed Sci. Res. 10, 99–104.
22. Mirek Z., Piękoś-Mirkowa H., Zając A., Zając M. 2002. Flowering plants and pteridophytes of Poland. A checklist. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.
23. Nathan R., Cronin J. T., Strand A. E., Cain M. L. 2003. Methods for estimating long-distance dispersal. Oikos 103, 261–273.
24. Nathan R., Schurr F. M., Spiegel O., Steinitz O., Trakhtenbrot A., Tsoar A., 2008. Mechanisms of long-distance seed dispersal. Trends Ecol. Evol. 23, 638–647.
25. Nogales M., Padilla D. P., Nieves C., Illera J. C., Traveset A. 2007. Secondary seed dispersal systems, frugivorous lizards and predatory birds in insular volcanic badlands. J. Ecol. 95, 1394–1403.
26. Ozinga W. A., Bekker R. M., Schaminée J. H., van Groenendael J. M. 2004. Dispersal potential in plant communities depends on environmental conditions. J. Ecol. 92, 767–777.
27. Poschold P., Bonn S. 1998. Changing dispersal processes in the central European landscape since the last ice age: an explanation for the actual decrease of plant species richness in different habitats. Acta Bot. Neerl. 47, 27–44.
28. Sánchez M. J., Green A. J., Castellanos E. M. 2006. Internal transport of seeds by migratory waders in the Odiel marshes, south-west Spain: consequences for long-distance dispersal. J. Avian Biol. 37, 201–206.
29. Sekercioglu C. H. 2006. Increasing awareness of avian ecological function. Trends Ecol. Evol. 21, 464–471.
30. Soons M. B., Bullock J. M. 2008. Non-random seed abscission, long-distance wind dispersal and plant migration rates. J. Ecol. 96, 581–590.
31. Ter Braak C. J. F., Šmilauer P. 2002. CANOCO Reference manual and CanoDraw for Windows User's guide: Software for Canonical Community Ordination (version 4.5). Microcomputer Power, Ithaca, NY, USA.
32. Thompson K., Bakker J. P., Bekker R. M. 1997. The Soil Seed Banks of North West Europe: Methodology, Density and Longevity. University Press, Cambridge.
33. Thompson K., Bakker J. P., Bekker R. M., Hodgson J. G. 1998. Ecological correlates of seed persistence in soil in the NW European flora. J. Ecol. 86, 163–169.
34. Trakhtenbrot A., Nathan R., Perry G., Richardson D. M. 2005. The importance of long-distance dispersal in biodiversity conservation. Diversity Distrib. 11, 173–181.
35. Wang B. C., Smith T. B. 2002. Closing the seed dispersal loop. Trends Ecol. Evol. 17, 379–385.
36. Wilgat T. 1992. System obszarów chronionych województwa lubelskiego [System of protected areas of the Lublin Region]. Wyd. UMCS, Lublin.