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Anthropochory in xerothermic grasslands in the light of experimental data

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Abstract

The degree and character of epianthropochory was analyzed on the basis of the number and affiliation to particular species of diaspores (Table 2, Fig. 2) catching on clothes and shoes of humans moving freely in the grassland (Fig. 1).
It has been noted that diaspores of various species which fructified during the experiments (Table 1, Table 2) may be carried on clothes. The extent of anthropochory depends on the structural relationships of the environment, especially on the exuberance of the vegetation (Fig. 2).

I. PROBLEM AND NOTIONS. SUBJECT AND OBJECT OF INVESTIGATION

Xerothermic grassland has for a long time been one of the favorite areas for ecological investigations (see Ellenberg 1963 and the literature quoted by him, Krausch 1962). Investigations on the biology of florescence and dissemination (see Quantin 1935; Molinier, Muller 1938; Medwecka-Kornaś 1949, 1950; Preis 1939; Füllekrug 1969) on the one hand, and inquiry into the relationship between the distribution and origins of grassland and the process of their colonization (Firbas 1949, 1952; Krausch 1966; Kornaś 1959; Kozłowska 1928; Medwecka-Kornaś 1960), on the other, are among the most interesting investigations performed on xerothermic grassland. A problem which belongs to both types of investigations, namely anthropochory has not been, to the author's knowledge, investigated on xerothermic grassland. All considerations on the origin of xerothermic grassland and its relationship with the settlement of man and past and present migrations of plants ("steppe" plants) must involve the question of anthropochory. The distribution of xerothermic species outside their natural habitats, for instance on railway and highway embankments, on dikes, dams, walls of excavations and gravel-pits etc. cannot be explained otherwise than by anthropochory; of course anemochory and zoochory also participate in the distribution.

The following fact convinced me of the role of man in the dissemination of xerothermic plants. When conducting field phytosociological investigations in xerothermic grassland of the Bielsk Plain, I noticed that every day I came home with enormous quantities of seeds and fruits attached to my clothes or hidden in their folds, cuffs, shoes etc. Analysis of one days "yield" attached to my trousers and their cuffs gave the following data: 771 diaspores belonging to 27 species of vascular plants. Among them were: 55 mericarpia of *Galium boreale*, 59 of *G. verum*, 6 of *G. erectum*, 130 of *Pimpinella saxifraga*, 33 of *Seseli annuum*, 86 pods (with perigonia) of *Trifolium montanum*, 112fruits of *Hieracium umbellatum*, 23 of *Rumex thyrsiflorus*, 109 fruits (with perigonia) of *Rumex acetosa*, 24 seeds of *Helianthemum ovatum* etc.

Anthropochory, that is the dissemination of plants by the intermediary of man, is partly a form of zoochory, and partly a distinct phenomenon (Ridley 1930; van der Pijl 1969). Its distinctness is related to the activity and methods of locomotion which are peculiar to man.

Unintended and unaware dissemination of plants by man, similarly to zoochory proper, may happen by means of the outer parts of the body and clothing (epizoochory, epianthropochory) or as a result of eating fruit and the passage of diaspores through the alimentary tract, this mainly occurs with fleshy fruits containing hard seeds (endozoochory, endoanthropochory).

Such are the direct methods of dissemination of diaspores by man as a biological organism. Indirect methods involve the use of mechanical systems of communication created by man. Their role in dissemination of various types of diaspores is steadily increasing. The railway has been analyzed in this respect (Kreh 1960), and so have ships. This phenomenon is a sort of "mechanochory", which I have called mechanoanthropochory to stress its relation to man.

R. Je. Lewina (1957) calls this phenomenon agestochory (see also Kornaś 1964). The same authoress also distinguishes ergasjochory in relation to weeds and speirochory, that is the distribution of diaspores with material for planting. I think that the last way could be applied in a wider sense, that is as any dissemination with agricultural crops.

Anthropochory, similarly to other means of plant dissemination (zoochory, anemochory, hydrochory, autochory) consists of the following stages: a) taking diaspores from plants on which they were formed, b) their transport and their, c) dissemination. Each of these stages plays a part in determining the efficiency of anthropochory. Other factors — biocenotic and habitat conditions on the site to which the diaspores are transported, and their ability to germinate and develop have an influence on the reproduction of the species. From the point of view of the biology of dissemination and the ecology of reproduction the causes, mechanism and effectiveness of antropochory may be distinguished.

The purpose of the present work was to investigate experimentally the first phase of anthropochory. Of particular interest were the problems: which species, formally constituents xerothermic grassland, may be disseminated by man, what is the degree of anthropochory and to what extent does it depend on the content and structure of the plant communities of xerothermic grassland.

The method used in these investigations is called an "dissimulation experiment" (Faliński mscr. b). It should resemble as much as possible the natural interaction between man and a biocenosis of a given type. In our case this meant obtaining diaspores from a xerothermic grassland by catching them onto the clothes of a man moving on a slope in a natural way, without taking very large or very small steps and not dragging his feet. The man wear normal clothes and shoes. This imitated the movements of a shepherd, a tourist or a chance passer-by, in any case a man not concerned with the problem of anthropochory.

Some limitations which had to be introduced in the experiment were necessary to ensure reproducible results and make it possible to obtain quantitative data. Particulars will be given in the following chapter.

II. MATERIAL AND METHODS

The field experiments were performed in xerothermic grassland temporarily identified with the association *Phleo-Veronicetum* Br-Bl. 1963 (see Braun-Blanquet 1963; Braun-Blanquet, Moor 1938 and Passarge 1964). This grassland represents a north-east European, poorer form of the order *Festucetalia valesiacae* (class *Festuco-Brometea*).

This kind of grassland grows on the slopes and summits of kame hills in the region of the central Polish glaciation near the village Haćki, district Bielsk Podlaski, on the denuded Bielsk Plain (macroregion: North Podlasie Lowland, subprovince: Podlasie — White Russian Lowlands). A closer characterization of these xerothermic grasslands is given in the work of Faliński (mscr. a).

The experiments were performed on 15 constant areas, each was a 5-meter square, with one edge parallel to the slope. The inclination of particular surfaces was 0 to 40°, and their exposure varied (see Table 1). The floristic composition and structure of each association was described separately on each experimental area in the form of a phytosociological record made during the period of optimal development of the plants (June 1969), and presented in Table 1. Nine of these areas (No. 4-14) represent typical variants of the association, three are a dry variant with *Sedum acre* (No. 1–3), and one a humid variant similar to a ryegrass meadow (*Arrhenatheretum elatioris*, No. 15).

The investigations on anthropochory were performed at the end of the period of maximal fruiting and dissemination, which occurs in August and September on this grassland. In 1969 the investigations were performed on sunny days, with almost no wind, after a considerable period of good weather (Sept. 25–26). As dissemination depends to some degree on the temperature and humidity of the air, the experiments were performed when microclimatic conditions were fairly stable, that is between 10:15 A.M. and 3:45 P.M. Central European time. The

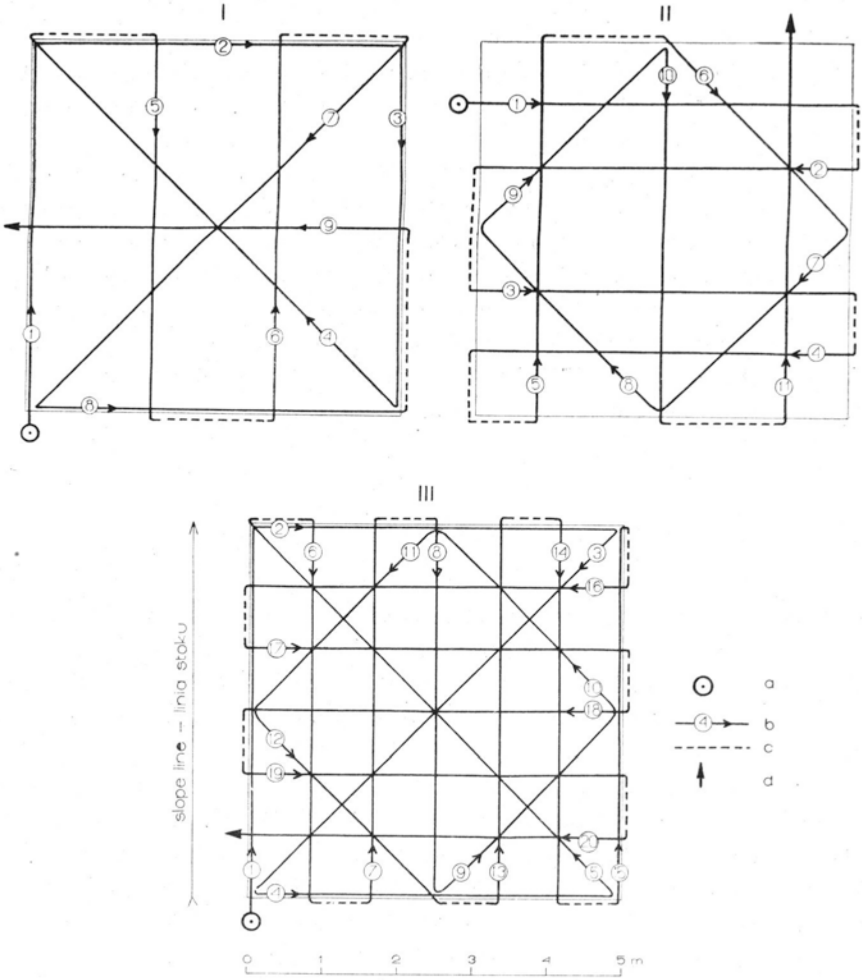

Fig. 1. Investigation of epianthropochory "by walking" on the experimental area according to a fixed itinerary

I — first trial, II — second (supplementary) trial, each approx. 50 m per 25 square meters, III — combined trial, with an itinerary of approx. 100 m per 25 square meters, *a* — entry into area, *b* — itinerary and its direction, *c* — isolates ("sterile") passage on a carpet outside the area, *d* — exit and receipt of material.

temperature and relative humidity registered on a thermohygrograph placed 20 cm from the ground were respectively 12.5–17.0°C, and 74–78%.

The investigations were repeated the following year on 5 areas (No. 3, 5, 9, 13 and 14) for the sake of comparison, on the same date (Sept. 26, 1970) by the same method. The weather was different — the second sunny, but windy day after a long period of rain. Air temperature was 9–11°C, and relative humidity 83–88%.

The boundaries of each area were marked off by connecting posts in the four corners with string. Points of the walk were markes on the string by placing coloured ribbons every 0.83 m. One man moved on such an area according to a strictly

Table 1

Vegetation of the study areas

variant		A							B						C
No of study area	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
No of record	2857	2856	2858	2854	2853	2859	2875	2872	2852	2868	2864	2861	2851	2855	2870
Slope aspect	SW	SES	NWW	NEN	.	NEN	NWN	NWN	SWW	E	NE	NES	NWW	NEN	NWW
Slope degrees	36	38	38	20	.	40	40	19	10	12	18	28	28	21	30
Cover c %	100	100	100	50	100	100	100	100	100	100	100	100	100	100	100
d%	.	.	30	+	+	30	+	10	+	10	10	10	10	10	20
Plot area m^2	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Number of spp. of vasc. plants	26	15	48	51	43	59	48	41	55	40	42	52	64	57	38
Number of spp. of bryophyta	.	.	2	3	3	10	2	3	2	4	3	3	3	3	3
Festucetalia valesiacae:															
● ⊙ Achillea collina	1.2	1.2	+.2	+.2	1.2	+.2	+	.	+.2	.	+	+.2	+.2	1.2	+.2
⊙ Achillea pannonica	+.2	1.2	1.2	+.2	1.2	+.2	+	/+/	+.2	/+/	+	/+/	+.2	+.2	.
Bromus inermis	2.3	.	+	/+/	.	+	.	.	+	/+.2/	.	/+.2/	.	1.3	.
● ⊙ Scabiosa ochloreuca	.	.	+	.	.	.	1.2	1.2	/+.2/	+	.	+.2	.	/+/	.
Viola rupestris	.	.	.	+	.	.	+.2	+	.	+	.	+.2	.	+.2	
Festuco – Brometea:															
● ⊙ Medicago falcata	4.4	3.3	3.4	.	1.2	3.4	4.5	5.5	4.4	4.5	4.5	3.4	1.2	3.5	1.2
⊙ Phleum phleoides	+	+.2	1.2	1.2	+.2	+.2	1.2	1.2	+.2	+.2	1.2	+.2	+.2	+.2	.
● ⊙ Artemisia campestris	1.1	+.2	+.2	.	.	+.2	+.2	/+/	+.2	1.2	+.2	+.2	.	+	.
● ⊙ Dianthus carthusianorum	/+/	.	1.2	+	+.2	+	+.2	+.2	+.2	1.2	/+/	+	/+.2/	+	.
⊙ Poa compressa	1.2	1.2	+	.	.	.	/+.2/	.	+	+.2	.	.	.	/+.2/	.
● ⊙ Centaurea rhenana	2.2	2.2	1.1	.	/1.2/	.	.	.	+	.	.	1.1	/+/	.	.
● ⊙ Pimpinella saxifraga	.	.	1.2	1.2	1.2	+.2	1.2	+	1.2	1.2	+.2	1.2	1.2	+.2	2.2
● ⊙ Galium erectum	.	.	2.2	.	1.2	2.3	+.2	1.2	+.2	1.2	+	1.2	1.2	+.2	+.2
● ⊙ Plantago media	.	.	1.2	1.2	1.2	1.2	+.2	+.2	1.2	.	1.2	+.2	1.2	+.2	1.2
● ⊙ Seseli annuum /loc./	.	.	/+/	+.2	+.2	+.2	/1.1/	1.1	1.2	+	+	+.2	+.2	+	+
Camptothecium lutescens	.	.	2.3	+.2	+.2	2.3	+	+.2	1.3	1.2	1.2	1.2	1.3	1.3	.
Thuidium abietinum	.	.	2.3	+.2	+.2	.	+.2	+.2	1.3	+.2	+.2	+.2	+.2	1.3	.
● ⊙ Centaurea scabiosa	.	.	1.2	1.1	/+/	1.2	.	/1.1/	2.2	2.2	/1.2/	1.2	1.2	2.2	.
⊙ Veronica spicata	.	.	+	/+.2/	.	.	1.2	+.2	1.2	+.2	+.2	+	/+.2/	/+.2/	+
● ⊙ Filipendula hexapetala	.	.	2.2	+.2	1.2	+.2	1.1	/+/	2.3	.	+	.	3.4	.	1.1
● ⊙ Helianthemum ovatum	.	.	1.2	1.2	+	1.2	.	1.2	+.2	1.2	.	+.2	1.2	1.3	.
⊙ Polygala comosa	.	.	+.2	+.2	+.2	+	.	.	+.2	.	+	+.2	+.2	+.2	.
● ⊙ Ranunculus steveni /loc./	.	.	.	+	+.2	1.2	.	1.1	+.2	.	+.2	+	1.2	1.2	.
⊙ Campanula glomerata	.	.	.	/+/	.	+.2	.	.	.	.	+	+.2	+.2	/1.2/	1.2
⊙ Prunella grandiflora	.	.	.	+.2	/1.2/	.	.	.	+.2	.	.	.	+.2	.	.
⊙ Ranunculus bulbosus	.	.	.	+	.	.	.	.	+.2	.	.	.	+	.	.
⊙ Carex caryophyllea	.	.	.	.	.	.	1.2	.	.	+.2	.	.	+	.	.
● ⊙ Veronica teucrium /loc./	/+/	.	2.2	.	.	.	.	.	.	.	.	.	.	.	.
Allium oleraceum	.	.	.	.	.	.	.	/+/	.	.	.	.	.	+.2	.
Brachypodium pinnatum	.	.	.	.	.	.	.	.	.	.	.	.	+.2	/+/	.
⊙ Gentiana cruciata	.	.	.	.	.	.	.	.	.	.	.	.	/+.2	2.2/	.
Ajuga genevensis	.	.	.	.	.	+.2	.	.	.	.	.	.	.	.	.
D – Var.:															
⊙ Calamintha acinos	1.2	1.2	+.2	.	.	.	.	.	/+/	.	.	.	.	.	.
⊙ Sedum acre	1.3	2.3	+.2	.	.	.	.	.	.	.	.	.	.	.	.
⊙ Arenaria serpyllifolia	+.2	1.3	+	.	.	.	.	.	.	.	.	.	.	.	.
Veronica verna	+.2	+.2	+	.	.	.	.	.	.	.	.	.	.	.	.
Accompanying:															
Taraxacum officinale	+	.	+	/+/	.	+	+	.	+.2	.	1.2	/+/	+	+	+
Festuca rubra	1.2	.	+.2	.	.	+.2	1.2	+	+.2	.	+.2	+	+.2	.	.
● ⊙ Galium boreale	.	.	2.2	+.2	+.2	+.2	+.2	+.2	+.2	+.2	2.3	4.5	2.2	2.3	2.2
● ⊙ Galium verum	.	.	1.2	+.2	1.2	2.2	+.2	1.2	1.2	+.2	1.2	1.2	1.2	+	+.2
● ⊙ Trifolium montanum	.	.	+	2.3	3.4	1.2	/+/	+.2	1.2	1.2	/+.2/	1.2	2.3	2.3	.
⊙ Thymus pulegioides	.	.	2.3	.	+.3	+.2	+.2	+	+.2	+.2	.	.	+.2	1.2	1.2
● ⊙ Knautia arvensis	.	.	+	.	.	+	1.2	1.1	1.2	1.1	+	+	/+/	+	.
⊙ Briza media	.	.	+	+.2	+.2	.	+	+	+.2	.	/+/	.	+.2/	+	+
⊙ Hypochoeris maculata	.	.	+	.	1.2	+	.	1.2	1.2	+	.	+	1.2	1.2	.
Trisetum flavescens	.	.	+	+	.	+	+.2	1.2	.	.	3.4	1.2	+	.	1.2
● ⊙ Phleum pratense	.	.	+.2	.	.	+.2	+.2	+	+.2	.	+.2	.	+	.	+.2
⊙ Lotus corniculatus	.	.	/+/	+.2	+.2	+.2	.	.	.	.	/+/	.	1.2	.	+
⊙ Tragopogon orientalis	.	.	+	+	.	+	.	.	/+.2/	1.2	.	/+.2/	+	+.2	.
Stellaria graminea	.	.	+	+	.	+	.	.	+	.	.	+.2	+	+	.
Festuca pratensis	.	.	+	+	+	+	.	.	.	+	2.3	+.2	.	.	.
⊙ Hieracium pilosella	.	.	+.2	+.2	+.2	+	+	.	+	.	.	.	+	.	.
Ranunculus polyanthemos	.	.	+	1.2	+	+.2	+	.	+	.	.	.	.	.	+
● ⊙ Centaurea jacea	.	.	+	.	.	1.2	1.2	.	+	.	+.2	.	1.2	.	3.4
⊙ Leontodon hispidus	.	.	+	.	.	+	+	+.2	.	.	+	+	.	.	+.2
⊙ Veronica chamaedrys	.	.	.	+	.	+.2	+.2	+	+	.	+	+	+.2	+	+.2
● ⊙ Trifolium alpestre	.	.	.	1.3	+	1.2	.	.	1.2	+.2	.	+	2.3	+.2	+.2
Betula verrucosa c	.	.	.	+	+	+	.	+	.	+	+	+	r	+	.
⊙ Vicia cracca	.	.	.	+	.	+.2	.	.	.	/+.2/	+	+.2	+	+	+.2
Agrostis vulgaris	.	.	.	.	1.3	+	+	/+/	.	+	+	.	+	.	+
● ⊙ Hypericum perforatum	.	.	.	.	/+/	+	1.2	.	/+/	.	/+/	+	+	.	.
⊙ Anemone silvestris	.	.	.	.	.	/+/	.	1.2	/1.2/	2.2	.	+	+	3.4	.
⊙ Senecio jacobea	.	.	.	+	+	+	/+/	.	/+/	.	+	.	.	.	.
● ⊙ Campanula rapunculus	.	.	.	+	.	1.2	.	.	+	.	.	/+/	1.2	+	.
Thuidium philiberti	.	.	.	+.2	+	1.2	.	.	.	.	.	.	+.2	+.2	+.2
Juniperus communis	.	.	.	.	+	+	+	+	.	1.1	.	.	.	+	.
⊙ Chrysanthemum leucanthemum	.	.	.	.	+	+	.	.	+	.	.	.	+	+	+
⊙ Achillea millefolium	.	.	.	.	.	+	+	.	.	+	+	+	.	.	+
● ⊙ Rumex acetosa	.	.	.	.	.	+	+	.	.	.	1.2	+	/+/	.	1.2
● ⊙ Berteroa incana	+.2	2.2	+	.	.	.	.	.	.	+.2	.	/+/	.	.	.
⊙ Helichrysum arenarium	+	.	/+/	.	.	.	+	.	/+.2/	.	.	.	.	+	.
Agropyron repens	+.2	.	+	.	.	.	.	.	.	.	+.2	+.2	.	+	.
Cerastium vulgatum	+	.	.	.	+.2	+	.	.	+	.	.	.	+	.	.
Anthoxanthum odoratum	.	.	.	+.2	+	.	.	.	+.2	.	+	.	1.3	.	.
● ⊙ Hieracium umbellatum	.	.	.	+.2	.	1.2	.	.	.	2.2	.	.	+.2	+	.
● ⊙ Plantago lanceolata	.	.	.	.	.	.	+	+	.	.	.	.	+	+	+
⊙ Cichorium intybus	.	.	+	.	.	+.2	.	.	+	.	.	.	+	.	.
⊙ Potentilla argentea	.	.	.	.	+	.	+	.	+.2	+	.	.	.	.	.
Rhytidiadelphus squarrosus	.	.	.	.	.	+.2	.	1.2	.	.	+.2	.	.	.	2.2
● ⊙ Rumex thyrsiflorus	.	.	.	.	.	.	/1.2/	.	.	.	1.2	+.2	.	.	+
Viola hirta	.	.	.	.	.	.	+	+.2	.	.	.	.	+	.	+

Accidental species:

3 x: ● ⊙ Convolvulus arvensis 1/+.2, 2/+.2, 12/+; ⊙ Trifolium pratense 4/+, 5/+, 7/+.2; ⊙ Luzula campestris 4/+, 5/+, 15/+; ⊙ Primula officinalis 4/+, 6/1.2, 11/+.2, Saxifraga granulata 4/+, 6/1.2, 11/+; ⊙ Peucedanum oreoselinum 4/+, 8/+, 9/+; ⊙ Solidago virga-aurea 4/+, 10/+, 15/+; Fragaria moschata 4/+.3, 13/1.2, 15/+.2; Trifolium medium 5/+, 8/+, 10/+.2; ● ⊙ Genista tinctoria 5/+, 9/+.2; 13/1.2;, Pirus communis 9/+. 10/+, 12/+; Poa pratensis 12/+, 13/+, 14/+.

2 x: Crepis sp. 1/1.2, 2/1.1; Bromus mollis 1/+, 8/+; ⊙ Capsella bursa-pastoris 1/+, 12/+; ⊙ Silene otites 1/+, 12/1.2; ⊙ Carum carvi 4/+, 13/+; Linum catharticum 4/+, 13/+; ⊙ Cynosurus cristatus 4/+, 13/+.2; Carex glauca 4/+.2, 14/1.2; ⊙ Campanula persicifolia 4/+.2/ 15/+; Equisetum pratense 6/+, 8/+; Carex contigua 9/+, 13/+.2; Tragopogon maior 12/+, 14/+.2; Pimpinella saxifraga fo. 10/+, 15/+.

1 x: Study area no 1: Tragopogon pratensis +, ⊙ Melilotus albus +, Bryum caespiticum +.2, Ceratodon purpureus +.2; no 2: ⊙ Camelina microcarpa 1.2; no 3: Veronica dilleni +; no 4: Plantago maior +; no 5: ⊙ Trifolium repens +, Sieglingia decumbens +; no 6: Sorbus aucuparia c r, Urtica dioica +.2, Myosotis sp. +, ⊙ Tanacetum vulgare +, Thuidium delicatulum +.2, Rhytidiadelphus triquetrus +.2, Mnium marginatum +.2, Mnium undulatum +.2, Eurhynchium swartzii +.2, Barbula fallax +, Lophocolea bidentata +.2; no 7: ⊙ Daucus carota +, Frangula alnus c +, ⊙ Trifolium arvense +, Larix sp. cult. c +; no 8: Malus silvestris c +, Rhamnus cathartica c +; no 9: ⊙ Verbascum thapsiforme /+,2/; no 10: Sedum maximum +.2, Quercus sessilis c +; no 12: Carex hirta +.2, Lycopsis arvensis +, Brachythecium albicans +,2; no 13: Scorzonera humilis +, Carex pilulifera +, Rosa sp. +.2, Picea excelsa cult. c r; no 14: Calamagrostis epigeios +, Lathyrus pratensis +; no 15: Geum urbanum +, Alnus glutinosa cult. b 1.1, Calliergon cuspidatum +.2

⊙ Species fructified during the researches
● Species which diaspores were collected during the researches

A – dry variant with Sedum acre, B – typic variant, C – humid variant similar to a ryegrass meadow

Study results on the epianthropochary in the xerothermic grasslands

Dissemination units	Units express the number of collected diaspores	No of study area	1	2	3		4	5		6	7	8	9		10	11	12	13		14		15	1–15	3,5,9,13,14	
		Year	1969	1969	1969	1970	1969	1969	1970	1969	1969	1969	1969	1970	1969	1969	1969	1969	1970	1969	1970	1969	1969	1969	1970
		Number of species	1	4	6	10	4	6	4	10	7	7	10	6	7	10	7	15	9	11	8	9	30	22	19
		Number of diaspores	15	43	18	86	39	46	55	64	102	107	214	110	247	265	343	363	97	404	112	662	2932	1045	460
mericarpium, schizocarpium	mericarpium	Pimpinella saxifraga	.	.	3	55	29	34	9	10	11	2	11	18	9	41	2	69	32	10	9	37	268	127	123
mericarpium	mericarpium	Galium boreale	.	.	3	3	.	.	.	.	5	4	6	.	4	162	307	16	1	256	22	567	1330	281	26
mericarpium	mericarpium	Galium verum	.	.	.	1	.	.	.	2	21	29	28	6	.	17	5	8	2	2	.	8	120	38	9
legumen, semen	semen	Medicago falcata	.	.	.	1	.	2	.	12	45	54	.	.	3	2	22	9	.	32	1	.	181	43	2
mericarpium, schizocarpium	mericarpium	Seseli annuum	.	.	3	.	.	4	8	.	.	.	53	20	.	27	5	8	1	1	1	.	101	69	30
legumen cum perigon.	legumen cum perigon.	Trifolium montanum	.	.	.	.	7	1	1	16	.	.	5	.	1	.	.	153	.	71	47	.	254	230	48
mericarpium	mericarpium	Galium erectum	.	.	.	.	.	.	.	1	4	12	.	.	1	4	.	.	.	1	.	.	23	1	.
semen	semen	Plantago media	.	.	.	1	.	1	.	.	.	4	30	.	.	.	.	8	39	.	.	.	43	39	40
legumen cum perigon	legumen cum perigon	Trifolium alpestre	.	.	.	.	2	.	.	4	.	.	2	.	.	.	.	9	4	.	.	2	19	11	4
achaenium, anthodium	achaenium	Hieracium umbellatum	.	.	.	.	.	.	.	3	.	.	.	.	226	.	.	1	.	3	.	1	244	14	.
achaenium, anthodium	achaenium	Centaurea scabiosa	.	.	1	.	.	.	.	1	.	.	1	.	.	.	.	.	.	1	.	.	4	3	.
anthodium, achaenium	achaenium	Achillea collina /+ A.pannonica/	.	.	.	10	.	4	37	.	.	.	62	49	.	.	.	.	3	.	.	.	66	66	99
anthodium, achaenium	achaenium	Centaurea jacea	.	.	.	.	.	.	.	2	.	.	.	.	.	1	.	3	.	.	.	30	36	3	.
anthodium, achaenium	achaenium	Artemisia campestris	15	.	3	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	19	3	.
semen, silicula	semen	Berteroa incana	.	34	.	4	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	37	.	4
fructus	fructus	Filipendula hexapetala	.	.	.	3	.	.	.	.	.	.	.	16	.	.	.	46	.	.	.	.	46	46	19
fructus cum perig., semen	semen	Helianthemum ovatum	.	.	.	.	1	.	.	.	.	.	16	.	.	.	.	.	.	26	29	.	43	42	29
achaenium cum calic.	achaenium	Scabiosa ochroleuca	.	.	.	.	.	.	.	.	2	2	.	.	.	.	.	.	.	.	2	.	4	.	2
capsula, semen	semen	Plantago lanceolata	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	2	.	.	.	14	16	2	1
anthodium, achaenium	achaenium	Centaurea rhenana	.	4	.	6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	.	6
semen	semen	Dianthus carthusianorum	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	5	.	.
semen, capsula	semen	Campanula rapunculus	.	.	.	.	.	.	.	13	.	.	.	.	.	.	.	17	13	.	.	.	30	17	13
spicula	spicula	Phleum pratense	.	.	.	.	.	.	.	.	14	.	.	.	.	6	.	.	.	.	.	.	20	.	.
achaenium cum calic.	achaenium cum calic.	Knautia arvensis	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	1	.	.	.	.	4	1	.
achaenium	achaenium	Ranunculus steveni	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	2	1	.
semen	semen	Convolvulus arvensis	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.
semen	semen	Veronica teucrium	.	.	5	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	5	2
fructus cum perigon.	fructus	Rumex acetosa	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	2	.	.
fructus	fructus	Rumex thyrsiflorus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1	.	.
legumen, semen	semen	Genista tinctoria	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	3	3	.
semen	semen	Hypericum perforatum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	2
achaenium	achaenium	Compositae indet.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1

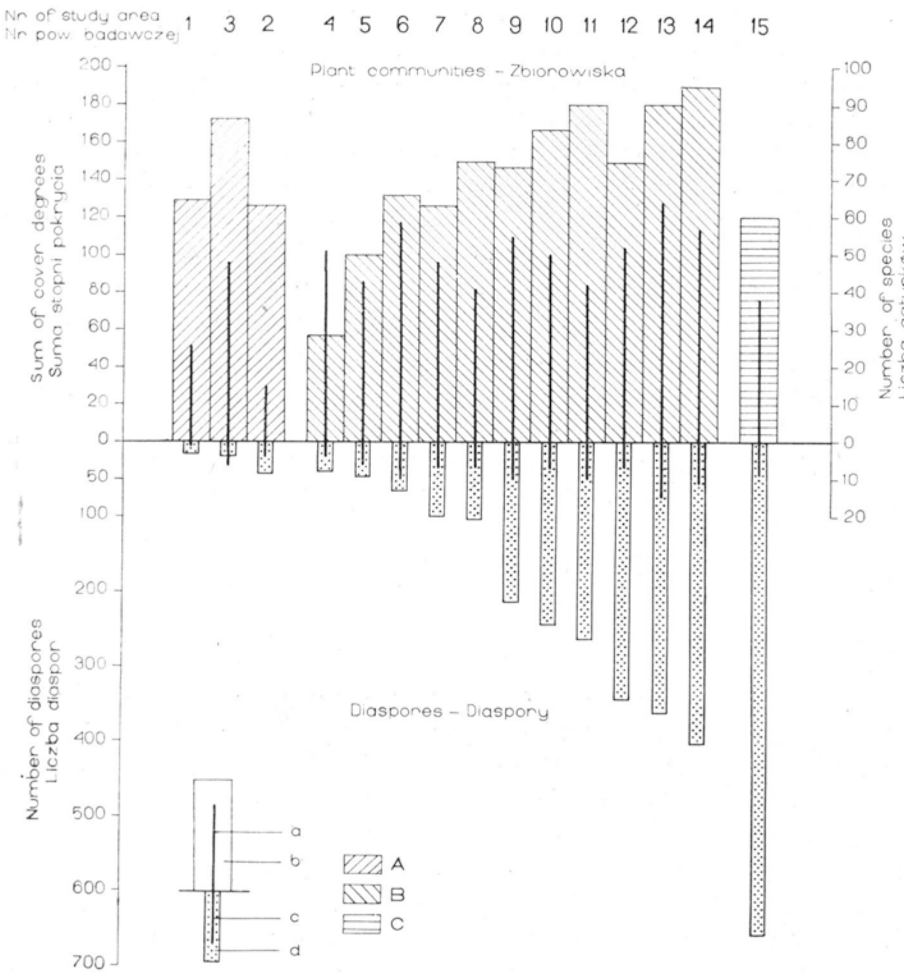

Fig. 2. Number of diaspores and amount of species the diaspores of which were collected versus some structural characteristics of xerothermic grasslands on the investigated areas.

A — dry variant with *Sedum acre*, *B* — typical variant, *C* — a more humid variant, resenbling a meadow *a* — number of species of vascular plants on the area, *b* — sum of degrees of covering, as and index of vegetation exuberance, *c* — number of species the diaspores of whick were collected, *d* — number of collected diaspores

fixed itinerary, walking as naturally as possible (Fig. 1). The clothes were as typical as possible — laced shoes, cotton socks, and denim trousers with cuffs. The material was collected in 2 subsequent samplings (Figs. 1/I and 1/II), each about 50 m long, thus the complete itinerary was about 100 m long. Repeated passage on the same segment (when necessary for the continuity of the itinerary) were performed on the outer side of the area, walking carefully of a oilcloth carpet (Fig. 1 c.).

After each passage all diaspores were collected from the shoes and clothing, and the material was labelled and packed.

After removing small animals Arachnoidea, ladybirds and molluscs and parts of plants which were not seeds from the samples the material was sorted. The diaspores were assigned to their proper taxonomic species on the basis of previously collected diaspores from near the test area, and partly by means of tables prepared on this basis. In Table 2 and Fig. 2 the number of diaspores of particular species collected in on the two samplings on each area are given. If a species had more than one form of dissemination (e.g. *Medicago falcata* has full pods, empty pods and free seeds), the number of the more common type is given (see Table 2).

Supplementary investigations were performed on the behaviour of diaspores of all mentioned species in respect to an electrified body. A semi-transparent polystyrene circle 50.6 mm in diametre (about 20 square centimetrs) electrified by rubbing with a piece of cloth was used. This circle was moved near to glass (unelectrified) plate on which diaspores were placed, and the number of diaspores caught by the electrified block and the time necessary for their attachment were counted. Only some of these data will be used here. A detailed analysis will appear separately.

III. RESULTS

1. In 1969, 2932 diaspores of 30 species were collected on 15 experimental areas. In 1970, 460 diaspores (Table 2) belonging to 19 species were collected on five areas. In the preceding year 1045 diaspores of 22 species were collected on the same 5 areas (Fig. 3). Species whose diaspores were collected during the investigations represent 22.72% of all species of vascular plants occurring on the 15 areas (132 species), and 38.46% of all species which fructified during the time of the investigations in 1969 (78 species; see Table 1).

2. The diaspores represent on particular areas 1–15 species (3.8–26.7%), and 15–662 diaspores were collected from each area.

3. Diaspores morphologically adapted to epizoochory are the most numerous. In 1969, 1330 diaspores of *Galium boreale* made up 45.35% of all those collected. There are, however, many diaspores having no distinguishable adaptation to epizoochory (Table 2), e.g. the almost smooth mericarpia of *Pimpinella saxifraga* (268 diaspores = 9.14%) the smooth seeds of *Medicago falcata* (181 diaspores = 6.17%), and pods with dry perigonia of *Trifolium montanum* and *T. alpestre* (273 diaspores = 9.31%).

4. Diaspores of the 32 species examined are distinctly drawn to an electrified body (polystyrene plate). the achenes of *Scabiosa ochloreuca* are the most weakly attracted. The electrified plate also attracts diaspores, such as the pod (with perigonium) *Melilotus alba* (weight — 2 mg) or *Anthyllis vulneraria* (approx. weight 7 mg), and even entire capsules of *Campanula rapunculus* (weight 20 mg, dimensions 10 by 8 mm).

5. No clear correlation was found between the number of species occurring on the surface and the number of species whose diaspores were collected in the

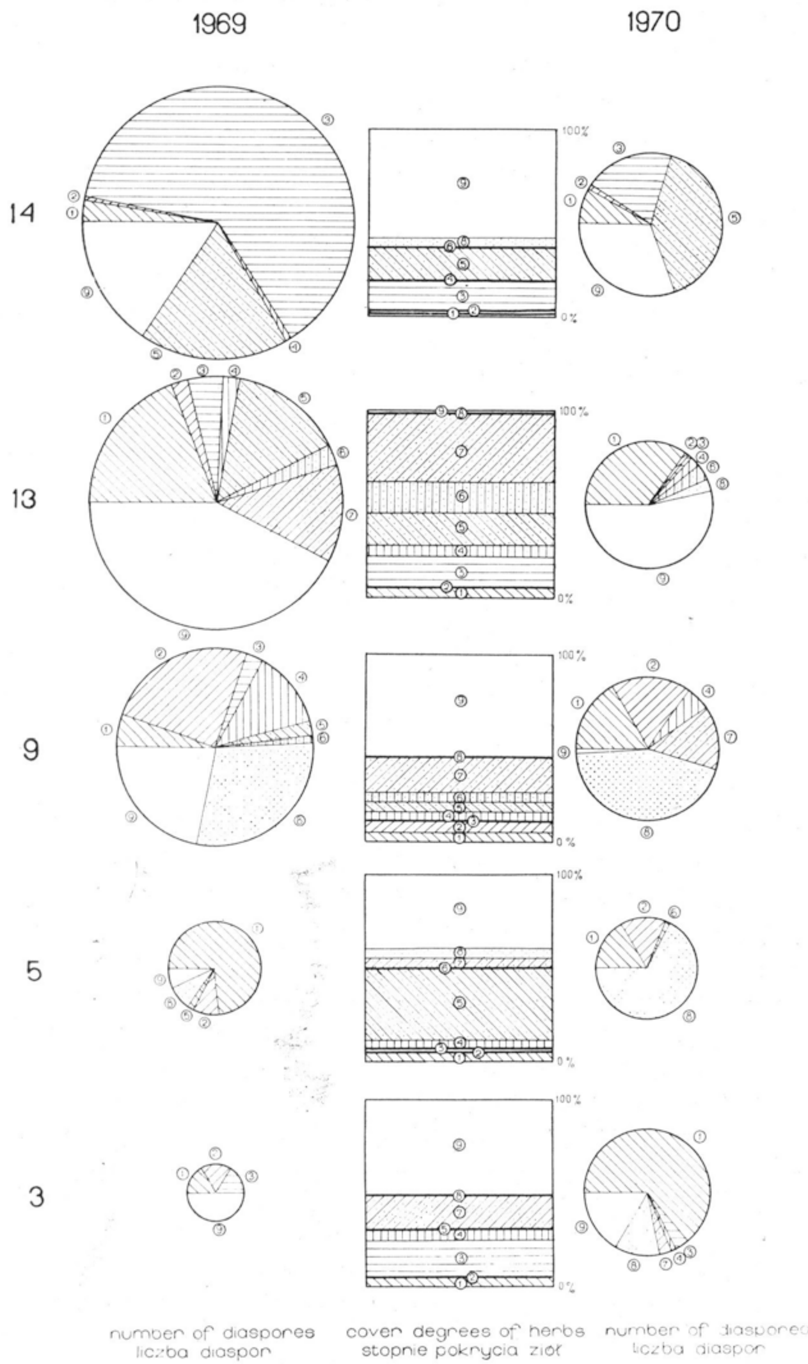

Fig. 3. Comparison of amount of diaspores from particular species collected by the "method of walking" on five areas in the years 1969 and 1970.

1 — Pimpinella saxifraga, 2 — Seseli annuum, 3 — Galium boreale, 4 — Galium verum, 5 — Trifolium montanum, 6 — Trifolium alpestre, 7 — Filipendula hexapetala, 8 — Achillea collina (+A. pannonica), 9 — remaining species samples, and neither between the number of diaspores collected and the total number of species present.

6. The phytosociological differentiation of grassland is expressed in the following way: samples collected in the drier variant (with *Sedum acre*) give on the average eight times less diaspores than those collected in the typical variant, regardless of the number of species present. (More samples from the drier variant are, however, necessary to obtain a statistical confirmation).

7. A significant correlation (correlation coefficient $r=0.92$) has been found for the typical variant between the number of diaspores collected on a surface and the index of undergrowth abundance, expressed as the sum of degrees of covering by particular species; the degrees are converted to what is called the mean value of coverage (Braun-Blanquet 1951).

IV. DISCUSSION

In the discussion we should try to find answers to at least the following questions:

1. Why are not all the species occurring on a given area represented in the samples collected?

The following factors determine the fact that some of the species are not represented in the samples: during the period when the experiments were performed some of them had already passed through the stage of dissemination (Table 1), and some other species (e.g. *Thymus pulegioides*, *Polygala comosa*, *Hieracium pilosella*) were to low to reach the clothing. The latter reason can also be an explanation for the smaller amount of species represented in the samples collected from the drier variant (with *Sedum acre*). We may assume that walking caused the dispersal of seeds from small plants onto the ground, but this could not be observed directly. Plants with very tall stems disseminated some of their ballistic diaspores as a result of walking on the grassland (Medwecka-Kornaś 1949, 1950), but they did not form a part of the samples, probably because they either did not reach the adhesive surface or else rebounded from it. Similarly, tall plants having diaspores adapted to anemochory, released numerous seeds with pappus, of which only a few reached the adhesive surface. Finally, the diaspores of some species which were present at the beginning of the itinerary may have become attached to the clothing, but fell off before the material was collected. Some species, represented on the surface by few individuals, did not have a chance of attaching their diaspores, which is in agreement with the laws of probability.

2. What does the number of diaspores collected depend on?

The factors which may be taken into consideration may be divided into three groups: a) factors extraneous in respect to the phytocenosis, b) biocenotic (phytocenotic) factors, that is factors depending on the phytocenosis, c) morphological traits and biology of the species.

The extraneous factors are the microclimatic conditions during the investigations and during the period preceding them, the angle of inclination of the slope on which the test area was marked off, whether the area was penetrated by man and cattle in the period preceding the investigations, and also the properties of the adhesive surface.

Phytocenotic factors interesting from the point of view of anthropochory are: the floristic composition of the plant community, number of species, cover and density of species, the horizontal and vertical structure of the community, its phenological state, and that of its components, and to some extent the abundance of fructification, which is on the borderline between phytocenotic and morphological and biological factors. The morphological and biological factors include the manner of occurrence of individuals (singly, in tufts or patches), the fraction of fructifying individuals, the placement of diaspores on shoots, the role played by the mother plant in the liberation of diaspores, and finally the physical properties of the diaspores themselves.

The action of each of these factors could be described separately, but to explain interactions between them experiments must be performed. To determine the extent and effectiveness of anthropochory the over-all effect of all these factors appears to be the most important, but the mechanism of anthropochory cannot be explained without considering each of them separately. This, however, would be beyond the scope of this work.

3. What properties of diaspores have a decisive effect on epianthropochory?

This question is one of the classical problems of the biology of dissemination. Let us limit ourselves to stating; that all factors favouring epizoochory proper, such as morphological adaptation in the form of hooks, sticky or rough surface of diaspores, waviness of the surface as a result of the drying of diaspores, wrinkling of the surface of the dry perigonium attached to the fruit etc. also favour epianthropochory. Because of the differentiated surface of our clothing we carry more seeds than do animals on their skins. This especially concerns diaspores having typical adaptation to anemochory. The calicular pappus of most plants of the family *Compositae*, especially pinnate pappus attaches extremely well to all fabrics.

Seperate attention should be devoted to the electric properties of the diaspores surface as it seems to play some part in catching and transferring diaspores on the outer parts of the body and clothing of man and the coat of animals. During field investigations it was noted that the so-called ballistic diaspores and others, not having any distinct adaptation to epizoochory remained after coming into contact for a moment on the clothing, and then fell. In many cases the period was long enough for the diaspore to fall onto a fold of clothing or get caught in the warp of the fabric.

This fact can be explained clearly if we consider that the diaspores of herbaceous plants, including almost all species occurring in xerothermic grassland, are small enough to be attracted by electrified bodies.

Laboratory investigations have confirmed this observation. The clothes worn nowadays are made of materials containing at least some artificial fibres, or specially processed natural fibres, both having well-known and often undesirable electric properties. Probably epiantropochory will increase, with the tendency to produce more artificial fibres.

4. Was the method used appropriate?

Several objections may be advanced as regards the method used. In particular, if it was used only once during a vegetative season, the results will only be fragmentary. A more complete result could be obtained if the experiments were repeated on the surfaces a couples, or even a dozen times during the year, and the surfaces were protected against other forms of penetration. Such an increase of the number of surfaces, and especially their selection on the basis of homogeneity could influence the accuracy of the research.

Nevertheless our method gives some insight into the extent of epianthropochory, and it has helped particularly in finding that man may carry on his clothing not only diaspores having specially adapted to epizoochory, but also some others under special conditions. Our method may be used to measure potential epianthropochory. Actual epianthropochory is influenced by so many factors that not all of them can be taken into consideration in our investigations. Research on potential epianthropochory, especially using a perfected method, may allow us to draw important conclusions. Some of them may serve to solve such questions as the migration and dissemination of xerothermic plants, and the formation of xerothermic grassland in places which did not initially have favourable conditions.

V. CONCLUSIONS

1. It was found that a man moving freely on xerothermic grassland collects diaspores of a large number of species on his shoes and clothing, and may then transport them for considerable distances. This phenomenon is of the character of epianthropochory, and is in a sense analogous to epizoochory.

2. Not only diaspores having morphological adaptation to epizoochory were found to be carried on man's clothing and shoes. There were also other diaspores having such traits as a sticky or wrinkled surface, the presence of calycine pappus or dry perigonia.

3. Diaspores were found to become easily electrified in contact with electrified bodies, such as clothing containing synthetic fibres, or specially processed natural ones. This has some bearing on the dissemination of species in grassland.

4. The extent of epianthropochory was found to depend on the structure of the plant association, and in particular on the exuberance of the vegetation.

5. The method used allows a careful analysis of the first stage of epianthropochory (the catching of diaspores and, partly, their transport). Observations on epianthropochory may be utilised in studies on the migrations and dissemination of "steppe" plants, and also in investigations on the genesis of secondary xerothermic grassland.

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Antropochoria w murawach kserotermicznych w świetle badań eksperymentalnych

Streszczenie

Antropochoria, jako szczególna postać zoochorii została bliżej zbadana w murawach kserotermicznych porastających pagórki kemowe. Murawy te należą do zespołu *Phleo-Veronicetum* (rząd *Festucetalia valesiacae*, klasa *Festuco-Brometea*, tab. 1). Badania przeprowadzono na 15 stałych powierzchniach badawczych. Analizowano rozmiary i charakter epiantropochorii na podstawie liczby diaspor i składu gatunkowego diaspor (tab. 2, ryc. 2) przyczepiających się do odzieży i obuwia człowieka poruszającego się w sposób swobodny po murawach (ryc. 1). Stwierdzono, że diaspory znacznej liczby gatunków, które owocowały w czasie badań na powierzchniach (tab. 1, tab. 2) mogą być przenoszone na odzieży człowieka. Rozmiary antropochorii zależą między innymi od stosunków strukturalnych zbiorowiska, a zwłaszcza od bujności roślinności (ryc. 2). Na przyczepianie się diaspor do odzieży człowieka i skóry zwierząt może wpływać łatwość elektryzowania się diaspor, jako ciał o małej przeważnie masie i małych rozmiarach.