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Botanical analysis of a bundle of flax (*Linum usitatissimum* L.) from an early medieval site in northern Poland; a contribution to the history of flax cultivation and its field weeds

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Abstract. A bundle of flax (*Linum usitatissimum* L.) radiocarbon dated to 1210±70 uncal B.P. (830±90 cal A.D.) was analysed for its macrofossil content. Apart from stems, capsules and seeds of flax, a large number of diaspores (fruits and seeds) from other plants was identified. Field weeds were the most numerous taxa present, among them three flax field weeds, *Spergula maxima, Camelina alyssum* and *Cuscuta epilinum*. Development of the specific flax weed community is discussed. Indicator values are used to characterize the edaphic conditions of this early medieval flax field. The field weeds spectrum also suggests that this flax was sown as a summer crop after an earlier crop of millet.

Key words: Archaeobotany – *Linum usitatissimum* L. – Flax weeds – Early Middle Ages – Northern Poland

Introduction

Fossil records which can be regarded as palaeobiocenoses (*sensu* Willerding 1979), the combination of plants found in the original community as it grew, are relatively rare from archaeological sites. The majority of the botanical materials of this category are represented by samples of charred cereal grains (for example Wieserowa 1967; Karg 1995) and only exceptionally by uncarbonized material (for example remnants of *Juncetum gerardi*, Behre 1976). This latter type of palaeobotanical data is certainly most informative for reconstructing past plant communities.

In 1995 an early medieval settlement in Wrześnica (northern Poland) was excavated by Włodzimierz Rączkowski of the University of Poznań. He found a whole bundle of uncarbonized flax preserved by alluvial deposits. The result of botanical examination of this particular find, which according to the present author represents the palaeobiocenosis of a field of flax, is a subject of the present paper.

Remains of cultivated flax (*Linum usitatissimum* L.) are known from numerous sites in Poland (Wasylikowa et al. 1991) where, as in most of the rest of Europe, its cultivation started as early as the Neolithic (Zohary and Hopf 1988). Usually there are records of single seeds or fragments of capsules dispersed in culture layers. Only occasionally were greater accumulations of seeds found (Alsleben 1995), capsules and shives, the remnants of flax stems after separation of the fibres (Klichowska 1961, 1969) or even flax stems (Moldenhawer and Hulewicz 1961). Except for the latest published data from Wolin (Alsleben 1995), none of the above finds were analysed for flax weeds. Large accumulations of flax remains, together with the rich segetal flora, have been described, however, from many archaeological sites in other countries, especially in Germany (for example Behre 1976, 1977, 1983, 1991).

The history of flax cultivation is directly linked with development of specific flax weeds (Hjelmqvist 1950) and, in recent years, their subsequent disappearance from Poland (Kornaś 1961; Mirek 1976) as well as from other areas of Europe (Oberdorfer 1957; Mirek 1997). The main aim of this paper is to present a picture of an early medieval field of flax with its weed flora as reflected in the archaeobotanical material, as a contribution to the discussion of the history of segetal vegetation.

The site

The site of Wrześnica is situated in northern Poland in the Baltic coastal zone in its widest sense (Fig. 1). The early medieval fortified settlement was established on a small clearly defined sandbank in the curve of a palaeomeander in a river valley, close to the present right bank of the river Wieprza. Today, the site is surrounded by low-lying palaeomeanders covered mostly by mires. The nearest mineral edge of the river valley terraces is about 150 m from the site. The settlement developed during the period from the 9th to the 11th century A.D. Its fortified phase ended due to a fire at the beginning of the 10th century; afterwards the settlement was partly reconstructed and continued its activity as an open settlement (Rączkowski and Sikorski 1996).

The bundle of flax was found, covered by river mud, in the archaeological trench dug about 2.5 m outside the rampart of the settlement, on the riverside, between

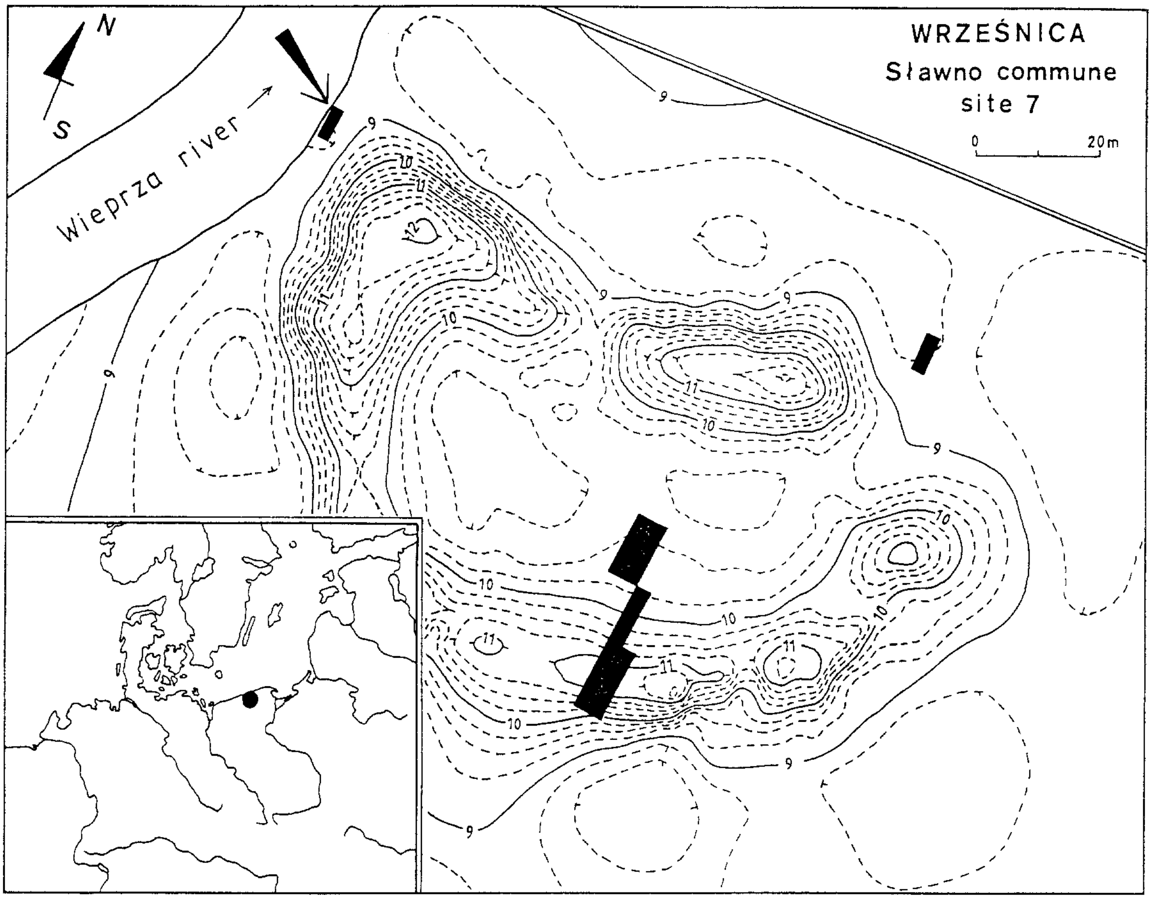

Fig. 1. Location of the archaeological site in Wrześnica (according to Rączkowski and Sikorski 1996). The place where the bundle of flax was found is indicated by an arrow

early medieval wooden structures protecting the river bank (Fig. 2). The object was well defined, with visible stems going in one direction without signs of disturbance or contamination.

Material and methods

The whole bundle (ca. 3570 cm³ in volume) was collected as a monolith during the excavation. Preserved in a fresh state, the whole sample was then cleaned by removing the 0.5 cm thick outer layer, and wet sieved in a laboratory on meshes of 2.0, 1.0, 0.5 and 0.2 mm. The total content of botanical material was analysed using a Carl Zeiss Jena Stemi Sv-11 stereoscopic microscope. The botanical nomenclature follows *Vascular Plants of Poland - a check list* (Mirek et al. 1995) except for *Spergula arvensis* which, according to Kulpa (1958) and Kowal (1966), has been divided into minor species on the basis of seed dimensions and morphology. The classification of particular species to habitat groups is based on their occurrence in present-day plant communities in Poland (Matuszkiewicz 1982), while ecological indices of edaphic factors follow the Polish version (Zarzycki 1984) of indicator values (Table 1), with some supplements from Ellenberg et al. (1992). The comparisons and conclusions about flax weeds are based on 157 phytosociological records collected in the period between 1950-1970 in different parts of Poland (Kornaś 1961; Faliński 1966; Szotkowski 1970; Warcholińska 1974), including northern regions (Nowiński 1964, 1965).

Results

Dating

A sample of the flax stems was radiocarbon dated in the Radiocarbon Laboratory of the Silesian Technical University in Gliwice. Its age was determined as 1210 ± 70 uncal B.P. (830 ± 90 cal A.D. analysed interval ± sigma, confidence level 68.10% [764-893 A.D.]) (Gd-7945). The date is in agreement with the archaeological chronology of the settlement (Rączkowski and Sikorski 1996).

Sample composition

The sample was composed mainly of plant remains and fine and medium grained mineral material of fluvial origin. The small number of animal remains (35) was represented by unidentified fragments of insects and cocoons.

The plant material was very well preserved and uncarbonized with the exception of an insignificant (in relation to the sample volume) number of fine wood charcoal fragments (Table 2). The sample consisted mainly of a huge number of compressed flax stems. Only single unidentified vegetative fragments of other plants were found. The very good state of preservation of the fossil material, the undisturbed arrangement of the flax

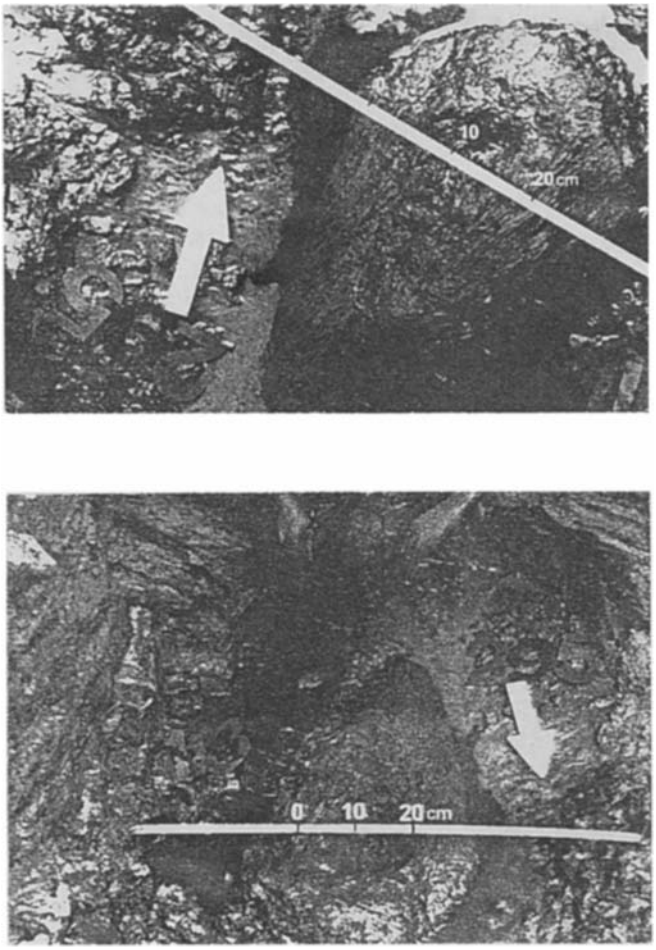

Fig. 2. The bundle of flax in situ (photo W. Raczkowski)

stems forming the bundle and the insignificant admixture of fragments of other plants and animals suggest that this bundle was covered by fluvial deposit during a short period (a single flooding episode?).

Plant remains

The sample contained uncarbonized stems, capsules and seeds of flax, as well as diaspores (fruits and seeds) of other plants. The even base of the bundle and total absence of root systems suggest that this flax was collected using a sickle. The upper parts of the stems were also absent, probably as result of threshing or because they had disintegrated, being thinner and more delicate. The remaining sections of stems were straight, single or sparsely branched, 26-28 cm long. Generally only their central part (the central cylinder) was preserved, which is rather typical of fossil material (Körber-Grohne 1967); fragments of epidermis and fibres are scarce. It has been estimated that this sample contained not less than about 800 specimens of flax plants.

The capsules of flax were mostly in fragments (they constituted ca. 152 complete specimens). The complete and almost complete specimens (n= 20) have an average length of ca. 7.49 mm (min. 6.5 mm, max. 8.0 mm). 1460 free linseeds have been counted, however a number of other specimens still remain enclosed in capsules. The seeds (n=50) are large, 4.2 mm in average length (min. 3.9 mm, max. 4.6 mm) and 2.25 mm in average breadth (min.1.92 mm, max. 2.6 mm). The above dimensions are close to the data from several early medieval sites in northern Germany, such as Elisenhof (Behre 1976), Haithabu (Behre 1983) or Niens (Behre 1991).

Apart from remnants of flax, more then 1400 diaspores representing 92 plant taxa, 76 of which have been identified to species or subspecies level, were found in this material (Table 2).

Table 1. The 5-grade scale of edaphic indices according to Zarzycki (1984)

Index value	W soil moisture	Tr soil trophy	R soil reaction	D soil dispersion	H soil humus
1	very dry	extremely oligotrophic	extremely acid pH<3.5	rocks	no humus
2	dry	oligotrophic	very acid pH ca 3.5-4.5	scree, gravel	very poor in humus
3	neither dry nor moist (*frisch*)	mesotrophic	acid pH ca 4.6-5.5	sand	mineral and humus soils
4	moist	eutrophic	moderately to weakly acid pH 5.6-6.5	sandy-clayey or clayey-sandy soils	peaty soils with minerogenic matter
5	wet	extremely eutrophic	neutral and basic pH >6.6	heavy clay and silt	organic

Table 2. Plant macrofossil taxa. Habitat groups: **1**. cultivated fields, **2**. ruderal habitats, **3**. meadows and pastures, **4**. different riverside zones, **5**. forests and forest edges; affiliation of particular taxa to the habitat groups presented in Fig. 6 is indicated by shading; ecological index numbers (for species classified as probably growing in the flax field) according. to Zarzycki (1984), with some supplements according to Ellenberg et al. (1992): W = soil moisture, Tr = soil trophy (nutrient status), R = soil reaction (pH), D = soil dispersion, H = soil humus content; species occurring in sub-recent flax fields are marked by an asterisk (*)

Taxon name	Number of diaspores	Habitat groups	Index numbers W	Tr	R	D	H
**Agrostemma githago* L.	9	**1**	3	3-4	4-5	4-3	3
Alisma plantago-aquatica L.	1	**4**	-	-	-	-	-
Alnus glutinosa (L.) Gaertn.	19	**4**, 5	-	-	-	-	-
Batrachium sp.	3	**4**	-	-	-	-	-
Betula sect. *albae*	2	**5**	-	-	-	-	-
Bidens cernua L.	1	**4**	-	-	-	-	-
Bidens tripartita L.	2	1, 3, **4**	-	-	-	-	-
**Camelina alyssum* (Mill.) Thell.	12s+5 fr siliqu.	**1**	3	3	4	4	3
**Camelina microcarpa* Andrz.	22	**1**, 2	2-3	3	4	2-4	2
**Camelina sativa/alyssum*	5fr siliquae	**1**	-	-	-	-	-
**Capsella bursa pastoris* (L.) Medik.	5	**1**, 2	3	4	4	4	2-3
Carex elata All.	4	3, **4**	-	-	-	-	-
Carex leporina L.	12	3, **4**	-	-	-	-	-
Carex nigra Reichard	1	3, **4**	-	-	-	-	-
Carex cf. *paniculata* L.	1	3, **4**	-	-	-	-	-
Carex pseudocyperus L.	1	**4**	-	-	-	-	-
Carex rostrata Stokes	6	**4**	-	-	-	-	-
Carex vesicaria L.	1	**4**	-	-	-	-	-
Carex sp.	7	-	-	-	-	-	-
Caryophyllaceae indet.	10	-	-	-	-	-	-
**Cerastium holosteoides* Fr.em.Hyl.	7	**1**, 2, 3	3-4	3-4	3-5	4-5	3
Cereals indet.	21 spik. forks	**1**	-	-	-	-	-
Chelidonium majus L.	1	**2**, 4	-	-	-	-	-
**Chenopodium album* L.	27	**1**, 2, 4	3	4-5	3-5	4-5	3
Chenopodium sp.	4	-	-	-	-	-	-
**Cirsium arvense* (L.) Scop.	1	**1**, 2	2-3	3-4	3-5	4-5	3
**Cuscuta epilinum* Weihe ex Boenn.	1	**1**	-	-	-	-	-
**Echinochloa crus-galli* (L.) P. Beauv.	204	**1**	4-3	4	3	4	3
Eleocharis cf. *palustris* (L.) Roem.& Schult.	3	**4**	-	-	-	-	-
Eleocharis cf. *uniglumis* (Link) Schult.	1	**4**	-	-	-	-	-
Epilobium sp.	1	-	-	-	-	-	-
**Fallopia convolvulus* (L.) Á. Löve	5	**1**	2-4	3-4	4-5	4-5	3
Filipendula ulmaria (L.) Maxim.	1	3, **4**	-	-	-	-	-
Fragaria vesca L.	3	**5**	-	-	-	-	-
**Galeopsis ladanum* L.	2	**1**, 2	2-3	3	5-3	2-3	2
**Galeopsis tetrahit/bifida*	18	**1**, 2	3-4	3-4	4	4	3
**Galium* cf. *aparine* L.	1	**1**,2,4	4	4-5	3-5	4-5	3
**Galium spurium* L.	7	**1**	2-3	4	4-5	4-5	3
Glyceria maxima (Hartm.) Holmb.	7	**4**	-	-	-	-	-
Gramineae indet.	3	-	-	-	-	-	-
Juncus effusus L.	15s+5 capsules	3, **4**	-	-	-	-	-
Labiatae indet.	11	-	-	-	-	-	-
Lamium album L.	2	**2**	-	-	-	-	-
**Lapsana communis* L.s.s.	2	**1**, 2, 4	3	4	4-5	4	3
**Leontodon autumnalis* L.	5	**1**, 2, 3	3	4	4	4	3
**Linaria vulgaris* Mill.	1	**1**, 2	2-3	3-4	4-5	2-4	2
Linum catharticum L.	1	**3**	-	-	-	-	-

Taxon name	Number of diaspores	Habitat groups	Index numbers W	Tr	R	D	H
Linum usitatissimum L.	>1460 seeds ca. 152 capsules >800 stems	-	-	-	-	-	-
Luzula pilosa (L.) Willd	1	**5**	-	-	-	-	-
Lychnis flos-cuculi L.	2	**3**	-	-	-	-	-
Malus sp.	4	? **5**	-	-	-	-	-
**Mentha* cf. *arvensis* L.	2	1, 3, **4**	4	4-3	3-5	4-5	3
Myosotis palustris (L.) L. em Rchb.	1	3, **4**	-	-	-	-	-
Myosotis sp.	1	-	-	-	-	-	-
Myosoton aquaticum (L.) Moench.	1	**4**	-	-	-	-	-
**Panicum miliaceum* L.	130	**1**	-	-	-	-	-
Pedicularis palustris L.	1	**4**	-	-	-	-	-
Picris hieracioides L.	1	**2**, 3	-	-	-	-	-
**Plantago major* L.	6	**1**, 2, 4	4-5	3	3	4	4
**Polygonum aviculare* L.	5	**1**, 2	3	4-3	4-5	4-5	2-3
**Polygonum hydropiper* L.	43	**1**, 2, 4	4-5	4	2-4	4-5	3
**Polygonum lapathifolium* subsp. *lapathifolium*	33	**1**, 2	4-5	4	4-5	4	3
**Polygonum lapathifolium* subsp. *pallidum* (With.) Fr.	64	**1**, 4	3-4	4	4-5	4	3
Potentilla argentea L.s.s.	1	**5**	-	-	-	-	-
**Potentilla erecta* (L.) Räusch.	8	**1**, 3, 5	3-4	2-3	2-4	4-3	2-4
**Prunella vulgaris* L.	9	**1**, 2, 3, 5	3-4	4	4	4	3
Ranunculus acris L.s.s.	14	**3**	-	-	-	-	-
**Ranunculus repens* L.	13	**1**, 2, 3	4-3	4	4-5	4-5	3
Ranunculus sardous Crantz	6	3, **4**	-	-	-	-	-
Ranunculus sceleratus L.	1	**4**	-	-	-	-	-
Ranunculus sp.	5	-	-	-	-	-	-
Rubus idaeus L.	4	**5**	-	-	-	-	-
**Rumex acetosella* L.	44	**1**, 3	2	2	2-3	3-4	2
**Rumex obtusifolius* L.	5	**1**, 4	3-4	4-5	3-5	4-5	3
Scirpus sylvaticus L.	40	3, **4**					
**Scleranthus annuus* L.	1	**1**	1-3	2-3	2-3	3	2
**Setaria pumila* (Poir.) Roem.& Schult.	53	**1**	3	3	3	3-4	2-3
**Setaria viridis/verticillata*	9	**1**	3	3	3	3-4	2-3
* *Solanum nigrum* L. em. Mill.	12	**1**, 2	3	4	4	4-5	3
**Sonchus asper* (L.) Hill	67	**1**	3	4	5	4-5	3
Sorbus aucuparia L. em. Hedl.	2	**5**	-	-	-	-	-
Sorbus cf. *torminalis* (L.) Crantz	4	**5**	-	-	-	-	-
**Spergula maxima* (Weihe) O. Schwarz	72	**1**	3	3	-	-	-
**Spergula sativa* Boenn.	13	**1**	-	-	-	-	-
**Spergula vulgaris* Boenn.	17	**1**	3-4	3-4	2-3	3-4	2
**Stellaria graminea* L.	1	**1**, 3	3	4	4	4	3
**Stellaria media* (L.) Vill.	12	**1**, 2	3-4	4-5	5-3	4-5	3
Triglochin maritimum L.	1	3, **4**	-	-	-	-	-
Urtica dioica L.	183	2, **4**	-	-	-	-	-
Vaccinium myrtillus L.	1	**5**	-	-	-	-	-
Vaccinium vitis-idaea L.	2	**5**	-	-	-	-	-
**Vicia hirsuta* (L.) S. F. Gray	1	**1**, 2	3	3	3-4	4-3	3
**Viola arvensis/tricolor*	10	**1**, 2	2-3	2-4	3-4	3-5	2-3
Coenococcum geophilum	12	-	-	-	-	-	-
Varia indet.	12	-	-	-	-	-	-
charcoal <0.5, 0.5-1.0, >1.0cm	62, 53, 13	-	-	-	-	-	-
animal remains	35	-	-	-	-	-	-

Notes on the identification of the most important weed species

Camelina. Two species of *Camelina* were recognized in this material. The identification is based mainly on the length of seeds and thickness of siliquae which, according to the thorough taxonomic work by Mirek (1981), generally appear to be the best taxonomic characters separating particular species.

Camelina microcarpa Andrz. - 22 seeds (Fig. 3C,D). Seeds oval in outline, round at the base, narrowed at the top. The narrow, cylindrical radicle separated from the cotyledon by distinct furrows. Surface densely tuberculate. Seeds (n=20) 1.04 mm in average length (min. 0.88 mm, max. 1.2 mm), 0.57 mm in average breadth (min. 0.50 mm, max. 0.65 mm).

Camelina alyssum (Mill.) Thell. - 12 seeds, 5 valves of siliquae (Fig. 3A,B). Seeds oval, irregular in outline. The radicle not so clearly separated from the cotyledon as in the previous species. Surface tuberculate, some specimens without an outer layer. Dimensions (n=8): 2.48 mm in average length (min. 2.4 mm, max. 2.52 mm), 1.2 mm in average breadth (min. 1.0 mm, max. 1.3 mm). Siliquae light yellow-brown or light brown in colour, elongate-pyriform or depressed pyriform in outline, valves reticulately-veined. The dimensions (length x breadth x thickness) of the three complete specimens are as follows: 1. 6.9 x 4.5 x 5.0 mm, 2. 7.7 x 4.3 x 4.5 mm, 3. 9.0 x 4.8 x 5.0 mm.

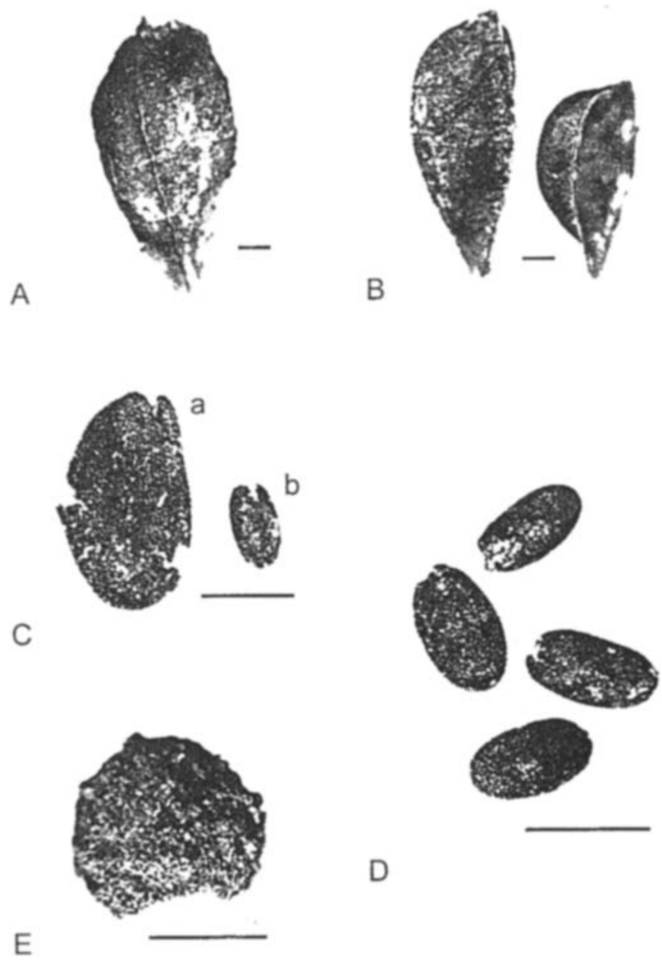

Fig. 3. Plant remains of the most important weeds. **A** *Camelina alyssum*, valve of siliqua (frontal view); **B** *Camelina alyssum*, valves of siliquae (lateral view); **C** seeds of **a** *Camelina alyssum*) and b *Camelina microcarpa*; **D** *Camelina microcarpa*, seeds; **E** *Cuscuta epilinum*, fragment of a seed. Each scale bar equals 1 mm

Camelina sativa/alyssum - 3 complete valves and 2 fragments of siliquae similar in shape and in reticulate surface pattern to those identified as *C. alyssum*. However, according to the data presented by Mirek (1976), their dimensions are closer to those characteristic of *C. sativa* (5.2 x 4.1 x 4.0 mm and 6.2 x 4.0 x 4.2 mm) or unidentifiable because of deformation or fragmentation of the specimens.

Cuscuta epilinum Weihe ex Boenn. - 1 large (ca. 1/3) fragment of a seed completely preserved along the long axis, 1.6 mm in diameter (Fig. 3E). This large dimension, slightly exceeding values typical for this species (1.0-1.5 mm, according to Kulpa (1958)) results from deformation of the specimen. The thick wall surface is covered by deep irregular spongy structures formed from epidermis cells, yellow-greyish in colour. In this case the other species of *Cuscuta* can be easily excluded on the basis of the large seed size and the structure of its surface. According to the reference collection as well as the key published by Kulpa (1958) the seed surfaces of other species is also rough but more delicate (not spongy).

Spergula arvensis. Generally, in archaeobotanical studies, seeds of *S. arvensis* are rarely identified to the finest level, because the most important diagnostic characters, such as the presence and formation of the wing and of club-hairs (papillae), cannot usually be observed on fossil material. However the very well preserved material from this site and their detailed comparison with the reference collection enabled separation of three minor species of *S. arvensis* according to the criteria presented by Kulpa (1958) and Kowal (1966). The main characters which were analysed include seed diameter, distinctness of small warts forming a reticulate (stelliform) pattern on seed surface and presence of club-hairs or their remnants. The comparison of modern reference material and fossil seeds shows that the pale club-hairs (papillae) have short, black, resistant bases, which usually are preserved in fossil material in the form of small, acute, irregular processes.

Spergula maxima Weihe - 72 seeds (Fig. 4A,B). Seeds round in outline or deformed, lenticular. Surface in places covered by more or less scattered, irregular small processes which are the remnants of tough bases of club-hairs. In some specimens single hairs preserved. Warts almost indistinct; wings absent. Seed average diameter (n=15) 1.87 mm (min. 1.6 mm, max. 2.1 mm). The presence of *S. linicola* Boreau, which has seeds of similar dimensions but without papillae, has been excluded.

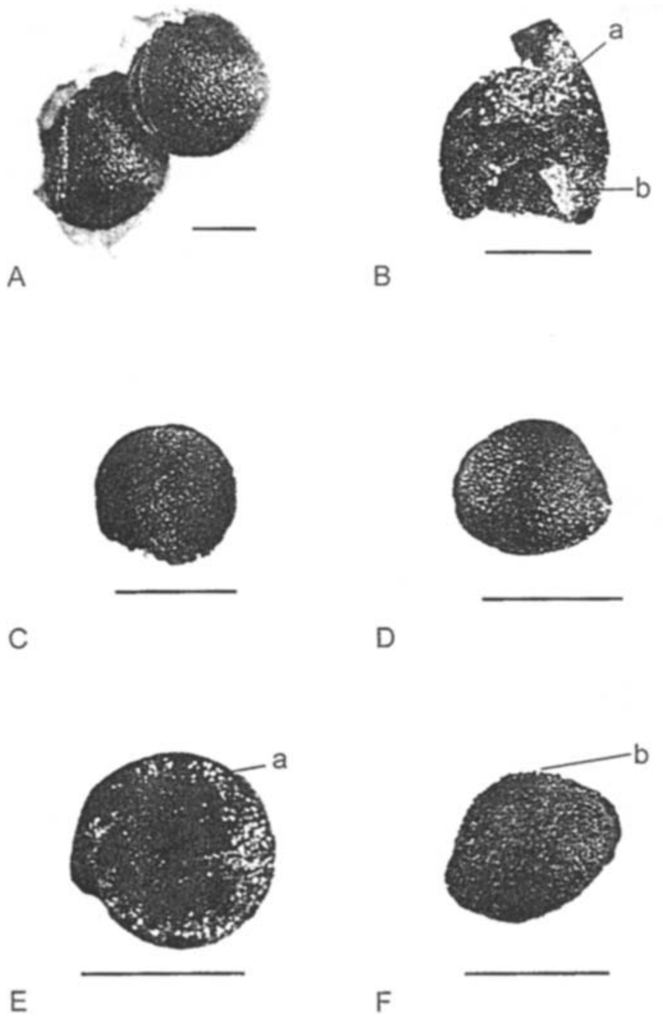

Fig. 4. **A** *Spergula maxima*, two seeds with remnants of a capsule; **B** *Spergula maxima*, broken seed with **a** club-hairs and **b** remnants of capsule; **C-D** *Spergula sativa*, seeds; **E-F** *Spergula vulgaris*, seeds **a** club-hairs, **b** hair bases. Each scale bar equals 1 mm

Spergula sativa Boenn. - 14.5 seeds (Fig. 4C,D). Seeds round, lenticular, some specimens deformed. Surface glabrous, covered with rather distinct flattened warts. The epidermal cells form a reticulum-like pattern. Papillae as well as processes absent. Some specimens with remnants of a narrow wing. Seed average diameter (n=14) 1.14 mm (min. 0.98 mm, max. 1.23 mm).

Spergula vulgaris Boenn. - 12.5 seeds (Fig. 4E,F). Seeds round in outline or deformed, lenticular. Reticulum-like pattern difficult to observe or indistinct, processes or papillae scattered over surface of seeds. Wings absent. Seed average diameter (n=10) 1.18 mm (min. 1.1 mm, max. 1.25 mm).

Ecological analysis

The fossil material mostly represents five widely-defined groups of habitats as indicated in Table 2. The most numerous in the number of species (Fig. 5A) as well as the number of diaspores (Fig. 5B) are the remains of field weeds (1). Fruits and seeds of plants typical of habitats connected with different riverside zones form the second group (4). Plants from ruderal habitats (2), meadows and pastures (3) as well as from woodland (5) are represented by a relatively low number of species and (with some exceptions) very low numbers of specimens.

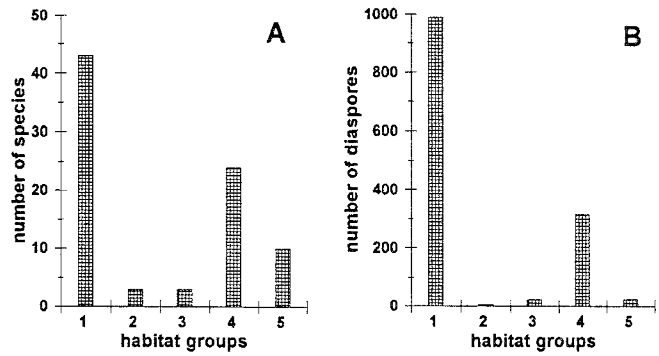

Fig. 5. **A** Frequency of species and **B** their diaspores according to habitat groups. For explanation, see Table 2

Flax field. Cerealia indet., *Panicum miliaceum* and *Spergula sativa,* which in this case probably infested the flax field, as well as 40 species of weeds noticed in cultivated flax in Poland (Kornaś 1961; Nowiński 1964, 1965; Faliński 1966; Szotkowski 1970; Warcholińska 1974), have been classified to this group. It has been assumed that all of these weed remains came from the same field as the fossil flax, which means that they are treated as remnants of the same plant community.

Three species of specialised weeds (speirochores) typical of flax fields and characteristic of *Spergulo-Lolietum remoti* subrecent association, *Camelina alyssum*, *Cuscuta epilinum* and *Spergula maxima,* are of special interest in this material. *Galium spurium, Camelina microcarpa* and *Spergula vulgaris* are also frequently mentioned among species typical of this association. Other species, indicated in Table 2 by an asterisk, find their optimum conditions in different segetal communities, in ruderal habitats or in other types of vegetation. The most prominent group represents the Panico-Setarion alliance of field weed communities developing in root crops and millet on rather poor or moderately rich sandy-clayey soils. The important feature of these communities is the constant presence of acidophilous species from sandy habitats (Matuszkiewicz 1982). In this material, this type of vegetation is represented by *Echinochloa crus-galli, Setaria pumila, S. viridis/verticillata* (probably *S. viridis* as this species is much more common in Poland), *Polygonum lapathifolium* subsp. *pallidum, Stellaria media, Spergula vulgaris, Rumex acetosella* and *Scleranthus annuus.* The next group of species which formed a weed community in the cultivated flax in Wrześnica is linked mostly with winter cereals and includes among others *Agrostemma githago*, *Fallopia convolvulus, Vicia hirsuta* and *Galeopsis ladanum.* The next, rather large, group unites nitrophilous species common in different field weed communities and in ruderal habitats such as, for example, *Chenopodium album, Polygonum aviculare, P. lapathifolium* subsp. *lapathifolium, P. hydropiper, Sonchus asper, Ranunculus repens* and *Viola arvensis/tricolor*. The latter group, which could be the most questionable, includes a few species which have been mentioned as "sporadic species" among the flax field weeds such as *Solanum nigrum, Linaria vulgaris, Prunella vulgaris* and *Potentilla erecta* (Szotkowski 1970).

The great number of field weed species enables an attempt to be made to characterize the edaphic conditions of this particular flax field. The ecological index numbers worked out from the Polish data (Zarzycki 1984) with some supplements from Ellenberg et al. (1992) are the basis for this reconstruction (Fig. 6).

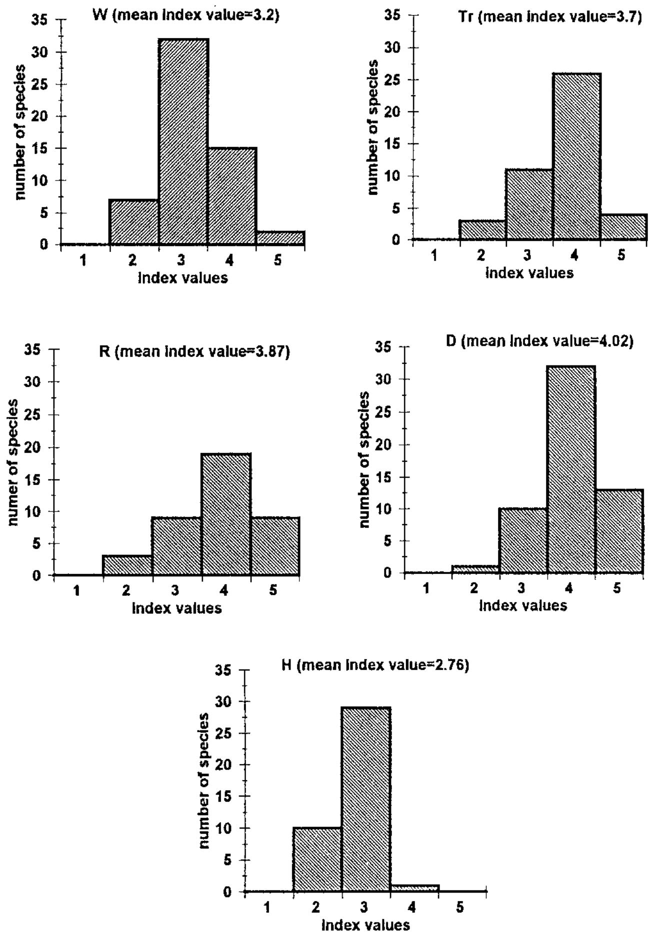

Fig. 6. Edaphic index values for soil moisture (**W**), trophy (**Tr**), reaction (**R**), dispersion (**D**) and humus content (**H**) for flax field weeds; calculation according to values shown in Table 2. Species which are characterized by the range of two index values are classified to both positions, while those with larger tolerance of particular edaphic factors (indifferent) have been excluded

Among the segetal weeds from Wrześnica, species associated with soils that are neither dry nor moist, (*frisch* in German, a widely used term), clearly dominate. *Agrostemma githago, Setaria pumila, Setaria viridis, Sonchus asper, Polygonum aviculare* should be mentioned among these. Only two species, *Rumex acetosella* and *Scleranthus annuus* are typical of drier soils, while *Mentha arvensis, Polygonum lapathifolium* subsp. *lapathifolium* and *P. hydropiper* are characteristic of rather damp habitats or they indicate that the soil could be periodically flooded. The cultivation took place on mesotrophic/eutrophic sandy-clayey soil that was moderately acid and relatively rich in organic matter and humus as emphasized by the presence of *Echinochloa crus-galli, Setaria pumila, S. viridis, Lapsana communis, Leontodon autumnalis* as well as *Chenopodium album* and *Stellaria media*. The above soil conditions correspond fully with the edaphic requirements of flax (Herse 1982).

These weeds are almost all therophytes (Oberdorfer 1983), which are annual plants realizing their full life cycle between one ploughing and the next (Fig. 7); among these, summer annuals are the most important, indicating that this flax was sown as a summer crop.

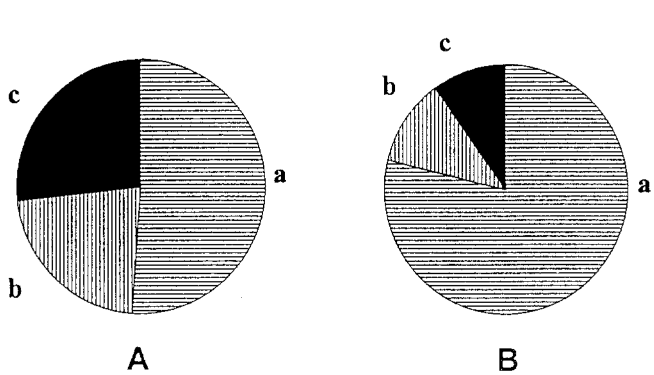

Fig. 7. Life-forms in the group of flax field weeds as shown by proportion of **A** species and **B** their diaspores; **a** therophytes (summer weeds), **b** therophytes (summer/winter weeds), **c** perennials

Ruderal habitats. Only *Lamium album, Chelidonium majus* and *Picris hieracioides* have been classified to this group (Fig. 5). It is clear, however, that diaspores from several nitrophilous species regarded in this paper as segetal weeds, especially *Chenopodium album, Stellaria media, Solanum nigrum* or plants of riverine thickets such as *Urtica dioica* could, at least partly, come from various ruderal habitats (see Table 2), which were certainly present in and around the settlement.

Meadows and pastures. Vegetation arising directly from animal husbandry practices is poorly represented in this material. However, the presence of *Ranunculus acris, Linum catharticum* and *Lychnis flos-cuculi* indicates that wet meadows were present in the Wieprza valley, in the neighbourhood of the settlement. It is also probable that some of diaspores from species classified as typical of riverside vegetation (see Table 2) could have come from wet meadows.

Riverside. A relatively large number of species represent ecologically-differentiated riverside zones (Table 2). They include the water plants *Alisma plantago-aquatica* and *Batrachium* sp., and land plants forming vegetation belts in fens along river margins. Sedges - *Carex rostrata, C. pseudocyperus, C. vesicaria, C. elata*, and other species such as *Scirpus sylvaticus, Juncus effusus, Eleocharis* cf. *palustris, Triglochin maritimum, Glyceria maxima* and plants of riverine thickets such as *Alnus glutinosa, Urtica dioica* or *Bidens cernua* should also be mentioned here. The good representation of the riverside vegetation results directly from the location of the site. A number of diaspores of such species as *Urtica dioica, Carex* spp. and others could be transported in the course of flooding.

Forests and forest edges. A small number of species represents various forest communities, forest edges and glades. Most of them produce edible fleshy fruits, the remains of which could probably be linked with the immediate vicinity of the settlement (such as *Fragaria vesca, Malus* sp., *Rubus idaeus, Sorbus aucuparia*, and *Vaccinium* spp.).

Discussion and conclusions

The floristic composition of the archaeobotanical material discussed in this paper confirms the preliminary suggestion that it represents a palaeobiocenosis of a flax field, insignificantly contaminated by diaspores from other plant communities. From the ecological point of view, the spectrum of field weeds presents a consistent picture of the edaphic conditions of the soil on which this flax was growing and the life forms indicating summer cultivation. This picture would not change significantly even if a more rigid selection of species was applied to the group of flax weeds.

Judging from the situation in which the bundle of flax from Wrześnica was found, perhaps retted at the river bank, the flax was used for fibre. It had been grown in optimal edaphic conditions as indicated by ecological characters of the weed flora accompanying the flax remains, and further confirmed by the relatively large capsules and seeds. Also, the favourable climatic conditions, as shown by the large number of Panicoideae among the weed diaspores, were unquestionably of considerable significance.

The great number of field weed species found together with the fossil flax is certainly a result of the harvesting method. The flax was probably cut with a sickle, close to the ground as indicated by the presence of small herbs such as *Scleranthus annuus, Stellaria media* or *Prunella vulgaris.* This prevented the cleaning of the crop of weeds, in contrast to what was usually done when harvesting by uprooting. The ethnographic sources (Sobisiak 1968), as well as agricultural manuals (Herse 1982), indicate that flax cultivated for fibre was collected mainly by pulling it up, which first enabled retention of the entire length of the fibres and secondly made it to remove some weeds while harvesting. It is difficult to say why the flax from Wrześnica was cut off, but maybe flax was harvested using a sickle in some areas, especially those with more compact and cohesive clayey soils. It is possible that on the clayey sandy soils in Wrześnica cutting was the most effective method of harvesting flax, particularly in dry years. The above suggestions about the flax harvesting method which have been deduced from the weed spectrum supports the previous conclusion based on the shape of the bundle and absence of roots in the material. However, it is not impossible that the roots were cut off after harvesting.

The large amount of *Panicum miliaceum* and weeds characteristic of the Panico-Setarion alliance (such as *Echinochloa crus-galli, Setaria pumila, S. viridis/verticillata*) typical of segetal communities in millet cultivation suggests that millet could have been the crop grown previously on the flax field. This supposition is not directly supported by historical or recent ethnographical data. It is known from such sources that flax was sown mainly after different root crops, oat or winter cereals, and that the best yields were usually obtained on fallow or virgin land (Schilling and Müller 1951; Sobisiak 1968). In some European regions mixed cultivation of root crops and flax was popular, while in America summer wheat and flax were sown together (Schilling and Müller 1951). It seems however, that in the fossil material each of the above cases should be distinguished by the specific spectrum of weed species: enriched by diaspores from the presumed previous crop, plants typical of fallows or virgin land, respectively. In the material discussed, only millet fulfils such a condition.

In the material studied, the group of species of Panicoideae is also indicative of a climate warmer than that of today. According to the present data, the above weeds, which are relatively thermophilous, are rare or do not grow in the region because of the unfavourable climatic conditions (Wójcik 1973). Also, millet cultivation has recently been not recommended in this area because of its higher warmth requirements (Herse 1982).

Comparing the data obtained in Wrześnica with the lists of taxa accompanying some other early medieval finds of *Linum usitatissimum* (for example Behre 1976, 1983, 1991; Pals and van Dierendonck 1988; Alsleben 1995; Cappers 1995) and earlier quoted recent phytosociological records from different sites in Poland, it is evident that all these flax fields were infested mainly by summer and winter/summer annual weeds, which indicates summer cultivation. The list of species is usually large, both in ancient and recent weed spectra. It varies according to soil conditions and probably also to the previous crop. The large number of Panicoideae, which is characteristic of the material from Wrześnica, was also observed in the subrecent linseed contamination in samples, particularly those which came from warmer areas in the south-east of Poland and with more primitive agriculture (Sajdel 1937).

Among the flax field weeds, the most interesting is the group of the obligate speirochores, (weeds which are completely dependent on dispersal of their seeds with crop seeds sown by humans). Due to the very strong selection in the form of grain cleaning and the removal of weeds from the growing crop, they have adapted their morphology and biology to that of cultivated species (Rothmaler 1946; Hjelmqvist 1950; Kornaś 1972) and in this way they became a real pest in flax fields. In many areas at the beginning of this century, flax fields were so badly infested by these weeds that the yield dropped below the profitable limit. In Poland *Cuscuta epilinum, Spergula maxima, Camelina alyssum* and *Lolium remotum* belonged to these specific linicolous weeds, which distinguished the *Spergulo-Lolietum remoti* association (Kornaś 1961). In the reports from more than 60 years ago on the contamination of linseed with weeds in different regions of Poland (Sajdel 1937) all these species are quoted as present at the highest frequencies and with a large number of diaspores. In remote areas with rather primitive agriculture they constituted the main contamination in linseed. According to the data from Kornaś (1972), in some samples from Gorce (western Carpathians), *Lolium remotum, Camelina alyssum* and *Cuscuta epilinum* constituted together 35-99% of the total weed diaspores as late as 1952. In one of these samples *Cuscuta epilinum* alone comprised 90% of the linseed contamination!

The spectrum of flax field weeds obtained from the fossil material presented in this paper suggests that during the early medieval period the obligate speirochores (mentioned above) were not so common in fields of flax as they were in later times. In Wrześnica *Spergula maxima* was the most numerous, *Camelina alyssum* and *Cuscuta epilinum* were rather rare, while *Lolium remotum* was absent or scarce. This seems to be in agreement with archaeobotanical records from other sites. *Spergula maxima* probably belongs to those most frequently occurring in comparison to other species of this group. It appears in fossil flax finds (such as Lange 1978; Pals and van Dierendonck 1988; Alsleben 1995) or dispersed in culture layers (for example Wasylikowa 1978; Latałowa 1992; Latałowa and Badura 1996); its earliest record is probably that from Hetzdorf dated to the late La Tène (Lange 1978). Its presence in archaeobotanical materials is clearly underestimated, because most authors do not separate this species from *S. arvensis*. However, in several papers seed dimensions presented for *S. arvensis* are, at least in part, within the range of *S. maxima* (for example Behre 1983), which suggests that this specialised weed of flax (or even *S. linicola*?) was more common than usually thought. *Cuscuta epilinum* is known from several sites in Europe dated from the Neolithic to Medieval times (Willerding 1986), where it occurs mostly as single specimens or in small numbers. The accumulation of pollen (*Cuscuta europaea*-type, which includes *C. epilinum*) and seeds of this species has only been described from Noord Holland, the Netherlands (Pals and van Dierendonck 1988). *Camelina alyssum* has mainly been reported from several sites in Denmark (Jensen 1985) where it has appeared since the pre-Roman Iron Age; it has also been found in early medieval deposits in Germany (Elisenhof, Behre 1976). A review of archaeobotanical biliographies suggests that *Lolium remotum* belongs to the most rare of these species, which is confirmed by the information on this plant given by Willerding (1986), indicating only three sites dated from the Bronze Age to medieval times; recently it has been found in the early medieval cultural layers in Wolin (Alsleben 1995). These data, even if not complete, certainly show that prehistoric flax fields were only slightly infested by obligate speirochores. The association of specific flax weeds probably started to develop rather early in prehistory, but its form as known from subrecent records only developed fully in modern times. A similar conclusion has previously been drawn by E. Lange (1978) on the basis of archaeobotanical material from Germany.

The last, definitive stage in the history of flax weeds took place in recent decades. The recent extinction of "linicolous plants" is a well known phenomenon described from Poland (for example Kornaś 1961; Szotkowski 1970; Mirek 1976) and from other European regions (for example Tüxen 1950; Oberdorfer 1957; Mirek 1997). In Poland this process took place mainly in the 1950s and 1960s, 10-20 years later than in most of central and western Europe (Mirek 1976). The obligatory purchase of certified linseed by contract growers, improved methods of mechanical seed cleaning and the chemical control of weeds have all been mentioned among the causes of the disappearance of linicolous weeds (Kornaś 1961; Warcholińska 1974; Mirek 1976).

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