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Factors determining natural regeneration of yew (*Taxus baccata* L.) in the Kórnik Arboretum

Abstract: All yew plants in the Kórnik Arboretum have been plotted onto maps of individual sectors and analysed with respect to location category ("near trunk", "under canopy", "in the open"), size (assumed to reflect age), genus of tree associated with in the "near trunk" category and environmental factors characterising the respective Arboretum sectors. There is practically no regeneration "in the open" (0.2%), most of it 82.5% is "under canopy" and only 17.3% "near the trunk". It is assumed that thrushes (*Turdidae*) are primarily responsible for regeneration in the under canopy category (endozoochoria) and nuthatches (*Sitta europea* L.) in the near trunk category (synzoochoria). Under canopy regeneration exists in all size classes while near the trunk there is a distinct decline in the number of yew plants with increase in size (age) suggesting that conditions for further development there are less favourable. Nutchatches disperse yew seeds in the vicinity of mother plants, for cleaning them preferring trees to shrubs and particularly trees with smooth bark trunks (*Fagus, Carpinus*), however yew survival near the trunk is better under conifers. Thrushes disperse yew seed over wider areas. Survival of yews is best under loose canopies, in moderate shade, on drier well draining, low pH, soils.

Additional key words: endozoochoria, synzoochoria, *Sitta europea, Turdidae,* seed dispersal

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Introduction

In the Kórnik Arboretum natural regeneration of yew is observed as very abundant, whereas in many parts of Poland and in other countries it is almost impossible. This phenomenon has been of interest to biologists for quite some time. The study reported here has been performed in the Kórnik Arboretum (Old Arboretum) with the aim of identifying some causes of this special situation. Particularly it was considered of interest to compare the present state of yew regeneration with that observed in 1972 (Bartkowiak and Zieliński 1973). The earlier study covered only 5 sectors of the Arboretum, while the current one included them all. The author was particularly interested in identifying the role of birds in the dispersal and regeneration of yew. In the Kórnik Arboretum yew distribution is characterised by some specific features identifiable only after a full inventory of all currently growing yew plants.

The existing populations of this species are subjected to various environmental influences. Description of the conditions under which yews grow well and where they do not, may help in the identification of reasons why the species is declining in natural conditions and what should be done to promote it in parks, gardens and nature reserves. Yew decline has been described by many scientists (Boratyński et al. 1997, Bugała 1975, Gieruszyński 1961, Izdebski 1956, Kościelny and Król 1965, Król 1975, Mańka et al. 1968, Myczkowski 1961, Środoń 1975) and the overall trend is that many natural stands of the species disappear and the existing ones have few or no natural regeneration.

The following reasons for yew decline have been suggested:

- Excessive shade (shade is needed for natural regeneration to form but can cause dying off of older plants) (Fabijanowski 1951, Gieruszyński 1961, Izdebski 1956, Kościelny and Król 1965, 1970).
- Lowering of the water table, drought (Gieruszyński 1961, Izdebski 1956, Mańka et al. 1968, Wodziczko 1922).
- Thick layer of litter preventing growth (Izdebski 1956, Kościelny and Król 1965)
- Grazing by boar, deer and cattle (Boratyński et al. 1997, Fabijanowski 1951, Izdebski 1956, Kobendza 1949, Kościelny and Król 1970).
- Fungal infection by *Clindrocarpon radicicola* (Mańka et al. 1968).
- Peaty soils, without Ca and high pH (Izdebski 1956, Kościelny and Król 1970).
- Insufficient number of fructifying female specimens or mature specimens in general (Sokołowski 1921)
- Overheating of seedlings covered by litter (Gieruszyński 1961).
- Competition from other species, destruction by windfalls (Gieruszyński 1961).
- Cold winds, freezing during the winter (Kobendza 1949).
- Absence of a loose stand (Bartkowiak 1970)
- Open areas – yew does not grow without some shade (Fabijanowski 1951).
- Perhaps the localisation of yews in the Kórnik Arboretum will help to identify the conditions it requires for successful regeneration.
- Birds participate in the process of regeneration and dispersal of yew and depending on what bird species are involved the structure, abundance and localisation of the regeneration will be different. It would be interesting to establish which species of birds have the greatest influence on the formation of yew regeneration and how this influence operates. Thus the aim of the study was:
  1. To make an inventory of the yew population existing in the Kórnik Arboretum.
  2. To compare site conditions were regeneration is abundant with those where it is less so.
  3. To determine the role of birds in the distribution pattern and behaviour of yew populations.

Here only a summary of the results will be presented. The full report, with sector maps giving exact location of all the yews found, is available as a Masters thesis (Giertych 1998).

Methods employed

Thus, to start with, it was necessary to list all yew plants, mapping their exact localisation relative to other trees and permanent features. The obtained full documentation of all yew plants growing in the Arboretum will be of use for future comparative studies and analyses.

An inventory was made of yew plants in 22 sectors (out of 23, sector no. 1 is a commercial nursery) of the Kórnik Arboretum (Old Arboretum) of the Polish Academy of Sciences Institute of Dendrology. The area under study is 35 ha. Each yew plant found was plotted accurately onto a sector map. The yew plants were classified by height, which is an approximation to their age, and for mature individuals their sex was recorded. Some individuals were damaged by grazing or by grass cutting machinery – this was also recorded. Seven **size classes** were adopted:

0 – an unbranched seedling, lignified or not, with a height under 10 cm,
1/2 – a lignified, branching seedling up to 10 cm tall,
1 – a yew plant up to 1 m tall,
2 – a yew plant 1–2 m tall,
3 – a yew shrub 2–3 m tall,
4 – a small tree more than 3 m tall,
5 – a tall tree.

Three occurrence categories were scored:

- "near trunk" – yew plants within 10 cm from some "body" such as trunks of trees or shrubs other than yew, tree stumps or walls.
- "under canopy" – yew plants growing at distances greater than 10 cm from tree trunks, but still under canopies of trees (all yews growing under yews were included here).
- "in the open" – yews growing beyond crowns of trees or shrubs.

Within the "near trunk" category the "body" in question was described and when it was a tree trunk an attempt was made to identify the species. In the category "in the open" only very few yews (14 individuals) were found, thus this category was discarded for the purpose of numerical analyses. Sex was determined for the mature individuals.

All observations were made during the winter and early spring of 1994/95.

For 16 selected genera trees were counted which had at least one yew plant in the "near trunk" category. For these genera also the total number of trees growing in the Kórnik Arboretum were counted. On this basis a hypothetical population was considered consisting only of trees of the selected genera. The preference of yew regeneration under different genera was calculated as the proportion of trees with yews in the "near trunk" category and the mean number of yews in this category per tree of the given genus.

To study the effect of site differences ten environmental factors were selected based on literature suggestions about what affects yew regeneration. The 22 Arboretum sectors were classified depending on what was the dominant condition in them into 3–5 groups with respect to each factor and the sectors within each group were used as replicates to calculate the significance of differences between the groups in

terms of occurrence of yew plants of various categories ("near trunk" and "under canopy") and sizes (0, 1/2, 1 and >1) in a variance analysis. The >1 size class was not considered for the "under canopy" category because of the strong anthropogenic influences on these plants (cutting, planting, trimming). The factors considered were:

1) loose tree coverage (4 groups): 0–5% (Sectors: 14, 15, 17, 20, 23); 5–10% (Sectors: 4, 7, 8, 10, 16); 10–15% (Sectors: 2, 5, 11, 19, 22); 15–20% (Sectors: 3, 6, 9, 12, 13, 18, 21).
2) insolation (4 groups, visual estimates): full (Sectors: 14, 15, 17, 20, 23); strong (Sectors: 2, 4, 5, 7, 11); poor (Sectors: 3, 6, 8, 16, 19, 22); deep shade (Sectors: 9, 10, 12, 13, 18, 21).
3) area of sector that is open (4 groups): 0–20% (Sectors: 14, 15, 17, 20, 23); 20–40% (Sectors: 5, 7, 8, 9, 10); 40–60% (Sectors: 4, 11, 16, 21); 60–80% (Sectors: 2, 3, 6, 12, 13, 18, 19, 22).
4) abundance of mature fructifying female yew trees (5 groups): none or with scarcely fructifying trees (Sectors: 7, 8, 15, 17, 20, 21, 23); single trees (Sectors 4, 5, 6, 14, 16); single groups of trees (Sectors: 2, 9, 11, 22); trees in many parts of the sector (Sectors: 10, 12, 18); trees throughout the sector forming yew stands in places (Sectors: 3, 13, 19).
5) shrub coverage (3 groups): 0–20% (Sectors: 14, 15, 16, 20, 21, 23); 20–40% (Sectors: 5, 8, 9, 11, 13, 17, 18, 19); 40–60% (Sectors: 2, 3, 4, 6, 7, 10, 12, 22).
6) soil type (5 groups): anthropogenic (Sectors: 2, 3, 4, 7, 9, 10, 13); moorish (Sectors: 5, 6, 8, 11); gley podsols (Sectors: 12, 18, 21); bogs; (Sectors: 14, 15, 17, 20, 23); brown (Sectors: 16, 19, 22).
7) soil species (4 groups): sand (Sectors: 2, 3, 5, 6, 8, 9, 11, 12, 18, 21); clayey sand (Sectors: 4, 7, 10); silt (Sectors: 13, 16, 19, 22); peat (Sectors: 14, 15, 17, 20, 23).
8) pH level (3 groups): < 5.3 (Sectors: 12, 16, 18, 21); 5.3–6.7 (Sectors: 4, 7, 9, 10, 11, 13, 19, 22); > 6.7 (Sectors: 2, 3, 5, 6, 8, 14, 15, 17, 20, 23). Factors 6), 7) and 8) (based on soil map of the Arboretum made in 1958 by Kowalkowski and Prusinkiewicz (1959)
9) coverage by well decomposing litter (4 groups): 0,20% (Sectors: 2, 14, 15, 17, 20, 23); 20–40% (Sectors: 4, 7, 10, 21, 22); 40–60% (Sectors: 5, 6, 8, 11, 19); 60–80% (Sectors: 3, 9, 12, 13, 18).
10) soil moisture (4 groups, based on Bugała 1978): permanently waterlogged (Sectors: 14, 15, 17, 20, 23); periodically flooded, near ponds and water runs (Sectors: 2, 4, 5, 8, 10); higher placed but moist (Sectors: 3, 7, 9, 11, 21); moderately moist and sometimes dry (Sectors: 6, 12, 13, 16, 18, 19, 22).

The effect of birds was considered only in relation to the main two categories of occurrence. It was assumed that all yews found in the "near trunk" category were regenerated through synzoochoria, that is primarily thanks to the activity of nuthatch (*Sitta europea* L.) and that all of those found in the "under canopy" category regenerated through endozoochoria, mainly through various thrushes (*Turdidae*). Yews under yews were treated separately assuming they could have regenerated directly by falling of their mother trees.

Results

Table 1 gives a summary of the results obtained by sectors. Only 14 yews were found unassociated with trees and shrubs. These were not included in further calculations. There were 20 individuals seriously damaged by grazing or grass cutting, which it was not possible to classify into any size class and these were also excluded from calculations. All >1 size classes were combined into one for calculations. In the higher size classes flowering individuals gave the following male to female ratios for the whole arboretum: size 2–23:23, size 3–85:80, size 4–75:59, size 5 – 24:27. These do not differ significantly from the expected 1:1 ratio.

As can be seen (Table 1) in the "near trunk" category there is a decline in the number of plants with age (size class). In the "under canopy" this decline is much less obvious.

There were 822 "bodies", primarily tree trunks, with yew plants near them. The "near trunk" category included 712 yews near broadleaf trees, 390 near conifers, 77 near shrubs, 140 near stumps, 4 near walls or benches and 116 near trees or shrubs unidentified by genus. The identified genera with yew plants "near trunk" included 25 genera of broadleaves, 8 genera of conifers and 15 genera of shrubs.

The 972 yew plants (y) found in the "near trunk" category of 16 selected genera is shown in Table 2, which includes also the total number of trees of the given genus (t) and the number of trees of the genus with at least one yew plant under it (n). The genera are arranged descending depending on the proportion of trees with at least one yew plant near its trunk (n/t). This latter ratio is considered as an indication of bird (nuthatch) preference when choosing tree trunks to deposit yew seeds on. *Carpinus* and *Fagus* are obviously the most preferable. *Pinus* is last on the list. The number of yew plants growing near the trunks of a given genus relative to the number of trunks of the genus growing in the Arboretum (y/t) gives a very similar sequence of genera, with *Fagus* and *Carpinus* most preferable and *Pinus* at the end of the list. However the average number of yew plants growing near trunks of trees that have at least one yew plant near them (y/n) gives a very different sequence. Obviously conifers, including pine, provided they are visited by nuthatches, support more yews around them than do broadleaves and the lowest values are for *Fraxinus* and *Populus*.

Table 1. Number of yew plants in the Kórnik Arboretum, by sectors, location and size class

Sector	Where found												Total
	Near trunk				Under canopy				In the open				
	Size class												
	0	1/2	1	>1	0	1/2	1	>1	0	1/2	1	>1	
1	–	–	–	–	–	–	–	–	–	–	–	–	–
2	15	7	3	5	12	1	1	66	2	0	0	0	112
3	74	10	12	18	302	74	14	96	1	0	0	0	601
4	2	3	1	2	16	27	6	90	2	0	0	7	156
5	15	5	6	7	43	23	4	2	0	0	0	2	107
6	28	17	12	11	55	32	11	5	0	0	0	0	171
7	3	3	4	3	10	14	1	0	0	0	0	0	38
8	35	24	17	15	21	130	11	16	0	0	0	0	269
9	92	41	15	17	115	105	13	121	0	0	0	0	519
10	35	30	11	6	55	57	5	159	0	0	0	0	358
11	91	32	11	3	269	243	7	14	0	0	0	0	670
12	23	14	8	5	7	25	3	81	0	0	0	0	166
13	25	18	23	23	28	108	51	168	0	0	0	0	444
14	2	3	2	1	1	20	6	5	0	0	0	0	40
15	0	0	2	1	0	1	0	0	0	0	0	0	4
16	46	16	16	5	467	404	97	534	0	0	0	0	1585
17	3	12	3	3	9	32	5	20	0	0	0	0	87
18	64	50	40	23	113	212	71	509	0	0	0	0	1082
19	78	62	21	13	370	275	46	241	0	0	0	0	1106
20	6	5	3	3	10	8	3	12	0	0	0	0	50
21	7	19	20	8	15	172	153	166	0	0	0	0	560
22	2	2	1	1	2	8	23	84	0	0	0	0	123
23	5	7	2	2	0	17	18	18	0	0	0	0	69
Total	651	380	233	175	1920	1988	549	2407	5	0	0	9	8317
Total				1439				6864				14	8317

Table 3 gives the results of comparing groups of sectors differing in various environmental traits in terms of occurrence of yew regeneration. As can be seen in the "near trunk" category tree coverage, insolation and proportion of open area affect the number of yew plants found but only in the higher size categories. Shrub coverage was important for all size classes (these 4 traits are related factors). For the "under canopy" category only the proportion of open area gave a significant differentiation, and again not in the smallest size class. Availability of fructifying mother trees significantly differentiated sectors only for the "near trunk" category and only for the lowest and highest size classes. Yews "under canopy" were unaffected by this trait. Soil type was more important for the "under canopy" category, and for the "near trunk" category only for size class 1. Soil species had some limited effect on most size classes in both categories. pH is unimportant for the smaller size classes but increasingly so with increase in size, especially in the "under canopy" category. Decomposing litter affects all size classes but only in the "near trunk" category. The same is true though less strongly for soil moisture.

Finally a word is needed about changes since the previous study on yews in the Kórnik Arboretum (Bartkowiak and Zieliński 1973). Only a fragment of the Arboretum were studied then, covering 5 sectors. Comparing them with what was observed in 1994 (Table 4) it can be seen that the number of mature fructifying yew trees doubled. Four of these did not even exist in 1972. The number of bodies (walls, benches, trunks, stumps) near which yews regenerate increased by a third. Fig. 1 shows a map of the Arboretum fragment in question with yews growing in them in 1972 and 1994 plotted. As can be seen the number of bodies increased substantially. For example in the fragment of sector 18 shown there were no yews in 1972 and there are many now.

Discussion

Of the 8317 yew plants found in the Arboretum more than 3000 grow in sectors 16, 18 and 19 which

Table 2. Number of trees, trees with yews "near trunk" and no. of yews "near trunk" in a hypothetical population composed of selected genera of trees

Genus	No. trees	No. trees with yew	Yews no. near trees	Coefficients		
	t	n	y	n/t	y/t	y/n
Carpinus	160	74	115	0.463	0.719	1.554
Fagus	78	36	71	0.462	0.910	1.972
Ulmus	47	13	21	0.277	0.447	1.615
Quercus	193	51	85	0.264	0.440	1.667
Larix	52	12	28	0.231	0.538	2.333
Picea	359	73	171	0.203	0.476	2.342
Abies	258	49	114	0.190	0.442	2.327
Betula	158	29	42	0.184	0.266	1.448
Acer	394	68	133	0.173	0.338	1.956
Fraxinus	136	23	27	0.169	0.199	1.174
Alnus	130	21	26	0.162	0.200	1.238
Populus	64	10	12	0.156	0.188	1.200
Tilia	479	59	89	0.123	0.186	1.508
Robinia	81	8	11	0.099	0.136	1.375
Aesculus	105	9	15	0.086	0.143	1.667
Pinus	110	6	12	0.055	0.109	2.000
Total	2804	541	972	0.193	0.347	1.797

have old park trees, primarily hornbeams, limes, oaks, maples and beeches. These sectors are more dry than others being located higher. There is considerable shade in these sectors which favours regeneration. Sectors 14, 15, 17, 20 and 23 had decidedly the smallest number of yew plants. These sectors include waterlogged areas with grasses and other meadow plants, that hinder yew regeneration.

Regeneration appears in the Kórnik Arboretum in various places classified here as categories. These differ markedly. "Under canopy" 82,5% of yews were found, "near trunk" 17,3% and "in the open" only 0.2%.

While yews in the "near trunk" category are a very important feature of the Kórnik Arboretum, such location is not very favourable for regeneration of the species. Survival of these plants is low as can be seen from the decline in numbers with increase in size class (Table 1). This was already noticed earlier (Kościelny and Król 1970). The number of yew plants in the "under canopy" category is not only much greater but also the decline with size class is much less (Table 1). These plants develop from bird excrements including undigested seed. That endozoochoria is more important than synzoochoria was already noticed by Fabijanowski (1951) and Bartkowiak (1975). The actual location of these excrement droppings is purely accidental and thus regeneration may occur in any part of the Arboretum. However there is practically no regeneration in the open, where ground vegetation (grasses) predominate. Yews require some shade controlling the ground vegetation to develop, and thus it is in the "under canopy" category that we have most of the regeneration in all size classes. As an additional observation it may be mentioned that even in shade, under canopies, yews will not regenerate if the ground is covered by a mat of ivy (*Hedera helix* L.) or within dense ground vegetation of spring plants (*Crocus purpureus* Weston, *Galanthus nivalis* L., *Leucojum vernum* L. *Scilla verna* L.) that flower before leafing of canopies brings shade. These plants are very common in parts of the Arboretum.

The 33 genera of trees near the trunk of which yew plants were found is less than what was reported by Bartkowiak and Zieliński (1973). They speak of 50 genera. This discrepancy is perhaps a consequence of the fact that Bartkowiak, who new the Arboretum intimately and over all seasons, was better prepared to identify trees. On the other hand it is possible that when writing "50 trees" he meant also shrubs, which would better agree with my figure of 48 for both trees and shrubs. Their study did not analyse in detail the trees or shrubs near which yews grew, and the figure given was only an estimate (J. Zieliński, personal communication). On the map of the fragment of the Arboretum (Fig. 1) showing regeneration through synzoochoria only points are given without specifying what were the bodies near which the yews were found. The Bartkowiak and Zieliński (1973) report does not mention shrubs, and yet it is obvious that yews do regenerate under them.

Bartkowiak (1975) wrote that "in general yew seedlings are found near trunks of species that have fur-

Table 3. Influence of various environmental factors differentiating Arboretum sectors on yew regeneration as observed in 1994/95 * ,** ,*** = significance at 0.10, 0.05, 0.01 level

	Environmental factor	Where yews found	Size class	d.f. group/residual	F	Signif.
1.	Loose tree coverage	near trunk	0	3/18	2.41	
			1/2	3/18	1.45	
			1	3/18	4.21	**
			>1	3/18	6.74	***
		under canopy	0	3/18	0.93	
			1/2	3/18	1.07	
			1	3/18	1.16	
2.	Insolation	near trunk	0	3/18	2.28	
			1/2	3/18	2.85	*
			1	3/18	6.35	***
			>1	3/18	5.12	***
		under canopy	0	3/18	2.77	*
			1/2	3/18	1.88	
			1	3/18	2.12	
3.	Area that is open	near trunk	0	3/18	1.73	
			1/2	3/18	1.20	
			1	3/18	2.05	
			>1	3/18	3.54	**
		under canopy	0	3/18	1.83	
			1/2	3/18	3.39	**
			1	3/18	2.96	*
4.	Abundance of female yews	near trunk	0	4/17	2.99	**
			1/2	4/17	1.98	
			1	4/17	1.91	
			>1	4/17	3.04	**
		under canopy	0	4/17	1.77	
			1/2	4/17	0.41	
			1	4/17	0.18	
5.	Shrub coverage	near trunk	0	2/19	3.92	**
			1/2	2/19	5.86	**
			1	2/19	3.43	*
			>1	2/19	4.69	**
		under canopy	0	2/19	0.42	
			1/2	2/19	2.57	
			1	2/19	1.86	

rowed bark, at least near the ground. These include primarily limes, oaks, elms, ashes, pines and spruces". The present study does not support this. As can be seen from Table 2 trees most frequently having yew plants in the "near trunk" category are hornbeams and beeches. These are smooth-barked trees, thus the preference of nuthatches to use rough bark stems for seed cleaning is not confirmed. It appears that conifers, especially pines, are not visited as readily by nuthatches, but when they do leave yew seeds under them yew plants survive more readily. This is probably related to the site conditions existing there.

As Table 4 and Fig. 1 indicate between 1972 and 1994 there is a 33% increase in the number of "bodies" near which yews regenerate. This may indicate either an increase in the activity of birds or an increase in the availability of seeds. There is a doubling of the number of seed yielding yew plants over the same period in the portion of the Arboretum studied on both occasions. However what is most interesting is the change of location of the regenerating yews. In the fragment of sector 18 shown in fig. 1 there were no bodies with yews in 1972 and there are 16 now. Two of the yews near trunks are more than 1 m tall.

Table 3. cont.

	Environmental factor	Where yews found	Size class	d.f. group/residual	F	Signif.
6.	Soil type	near trunk	0	4/17	1.33	
			1/2	4/17	1.27	
			1	4/17	2.89	**
			>1	4/17	1.57	
		under canopy	0	4/17	2.75	*
			1/2	4/17	2.99	**
			1	4/17	3.75	**
7.	Soil species	near trunk	0	3/18	2.99	*
			1/2	3/18	1.56	
			1	3/18	2.98	*
			>1	3/18	3.11	*
		under canopy	0	3/18	2.48	*
			1/2	3/18	3.22	**
			1	3/18	1.66	
8.	pH level	near trunk	0	2/19	1.30	
			1/2	2/19	2.65	*
			1	2/19	4.47	**
			>1	2/19	0.39	
		under canopy	0	2/19	1.01	
			1/2	2/19	5.03	**
			1	2/19	10.40	***
9.	Decomposing litter coverage	near trunk	0	3/18	5.55	***
			1/2	3/18	2.94	*
			1	3/18	3.82	**
			>1	3/18	11.73	***
		under canopy	0	3/18	0.86	
			1/2	3/18	0.62	
			1	3/18	0.34	
10.	Soil moisture	near trunk	0	3/18	2.93	*
			1/2	3/18	1.65	
			1	3/18	3.23	**
			>1	3/18	2.79	*
		under canopy	0	3/18	2.22	
			1/2	3/18	2.19	
			1	3/18	1.69	

Table 4. Comparison of yew regeneration structure in 1972 and 1994

Sector no.	Mature, female seed yielding yews		Bodies near which yews grew < 10 cm away		Yews not seen in 1972, seed yielding in 1994
	1971	1994	1972	1994	
6	3	4	0	16	1
8	2	3	17	21	1
11	5	6	35	57	1
12	5	12	49	33	0
18	0	4	21	36	1
Total	15	29	122	163	4

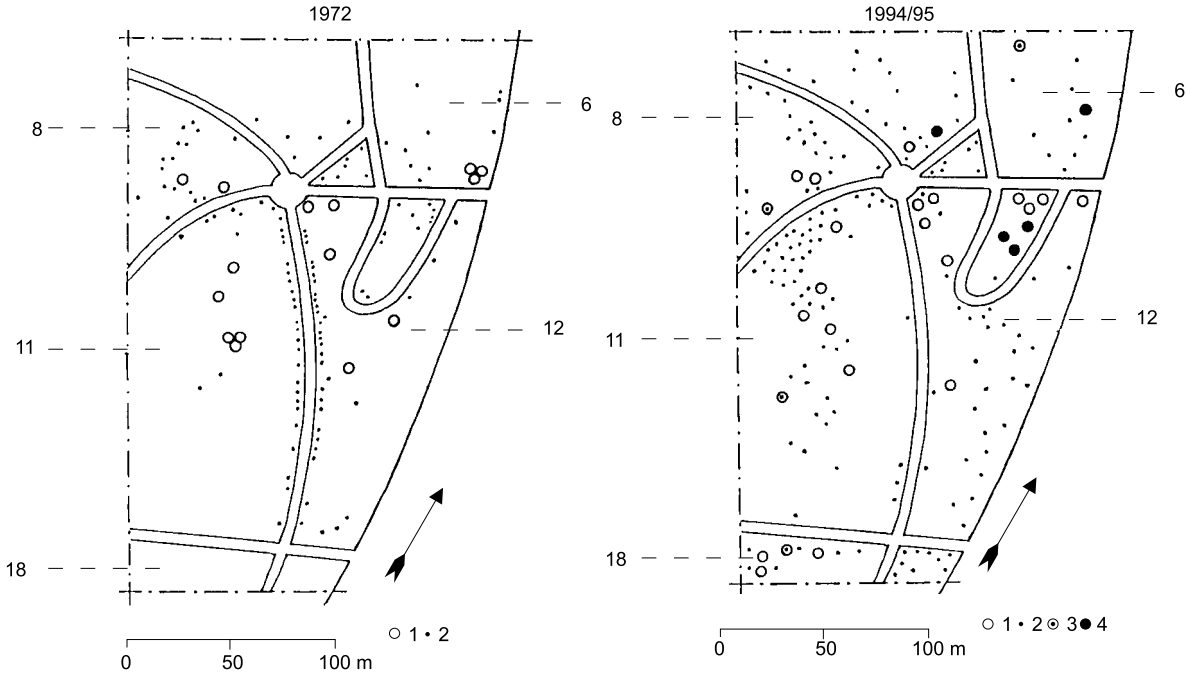

Fig. 1. Location of yew regeneration in a fragment of the Kórnik Arboretum as observed in 1972 (Bartkowiak and Zieliński 1973) and in 1994/95.

1. Bodies (trunks, stumps, walls etc.) close to which at least one yew plant grows; 2. Mature female yew trees fructifying in the year of study; 3. Mature female yew trees found in 1994/95 the occurrence of which, even as seedlings, was not reported in 1972; 4. Mature female yew trees found in 1994/95 which were reported in 1972 as juvenile. Nos. 6, 8, 11, 12 and 18 refer to Arboretum sectors

Also in this fragment of sector 18 there are now 4 mature seed bearing individuals which were not registered as such in 1972. In sector 11 in 1972 a large proportion of the "near trunk" yews grew near the Zamoyska Lime Alley trees, while in 1994/95 few of these trees had yews near their trunks. The decline of yew regeneration in the Zamoyska Lime Alley is understandable if one considers the behaviour of nuthatches. As Bartkowiak (1970) reports to consume or hide a yew seed the bird chooses trunk bases regardless of their diameters but necessarily with easy access to them, especially to the bark in the root collar against which the nuts are rubbed to deprive them of the arils, which the birds do not consume. Places where such cleaning of the nuts took place are easily visible from a distance as red stains on the bark. On the other hand it is known that old trees, particularly limes, when they loose their vitality for height growth, start producing sprouts that encircle the base of the trunk as a dense thicket. Because of this feature the trees in the lime alley have lost their attractiveness for nuthatches which moved to other trees in the Arboretum. The new bodies in sector 11 near which nuthatches have left seeds that produced seedlings are 11 spruces, 5 oaks, 4 birches, 4 beeches, 3 maples, 9 stumps and others. Thus the area over which the yews are regenerating has increased substantially and the concentration of them is not as great as in 1972. This is an indication of the dynamic with which yews develop in the Kórnik Arboretum.

For the environmental factors considered the following relations were noted.

As Bartkowiak (1970) observed yew regeneration through synzoochoria occurs primarily in loose stands. This was confirmed (Table 3, factor 1). Yews in the "near trunk" category regenerated significantly better under loose stands. However this is true only for the higher size classes which indicates that it is not necessarily the preferences of nuthatches, but that conditions for survival are better under loose stands. On the other hand the observation of Bartkowiak (1970) that regeneration through endozoochoria is more successful in more dense stands is not confirmed.

The opinion of many authors (Król and Kościelny 1965, 1970, Izdebski 1956, Fabijanowski 1951, Gieruszyński 1961) that direct insolation hinders yew regeneration is fully confirmed, not only by the absence of regeneration in the open, but also by the significantly lower number of larger yew plants "near trunk" in the more insolated sectors of the Arboretum, and of younger ones in the "under canopy" category (Table 3, factor 2). This result does not contradict the opinion that with age more light is needed. The deep shade in natural yew stands can hinder regeneration but in the conditions of an Arboretum,

where the trees are maintained at a loose spacing, such deep shade does not occur.

I know from observation that park birds prefer to fly among trees and shrubs feeling safer there. They avoid flying over open spaces, meadows, ponds and the like. Thus the presence of open areas was considered as a possible factor affecting regeneration. There are significant differences, in both categories of occurrence (Table 3 factor 3), but only in the higher age classes which suggests that it is not a question of bird preference but of better survival in partially shaded places.

Lack of seed could be a factor limiting regeneration (Conwetz 1892 after Mańka 1956, Sokołowski 1921). This proved true only for regeneration through synzoochoria (Table 3, factor 4). Nuthatches carry the seeds in the their beaks, so distance is important. Dispersal by endozoochoria is less dependent on distance from the mother trees. Digestion in thrushes takes about 45 min (Bartkowiak 1970), enough for the birds to reach any part of the Arboretum.

Needing access to stem bases nuthatches prefer trees to shrubs, and this is reflected in the significant differences in yew regeneration in the "near trunk" category between sectors depending on their shrub coverage (Table 3, factor 5). This factor is of no importance to thrushes and as expected no significant differences in the "under canopy" category.

Since young seedlings are rooted in decomposing litter only, type of soil is of little importance for them, but the occurrence of yews in the higher size classes is increasingly significantly affected by soil type (Table 3, factor 6). Survival of yew plants is best on brown earths and gley podsols and least on bogs. This confirms the opinion (Izdebski 1956, Kościelny and Król 1970) that yews require well drained soils.

Soil species is of lesser importance (Table 3, factor 7). Best yew regeneration was found in silty soils ("near trunk" also in clayey sand), while on peats it is less successful.

Soil pH increases in importance with age of yew plants (Table 3. factor 8). The lower the pH the better the regeneration. This agrees with the observation of Izdebski (1956) and Kościelny and Król (1970) that high pH can be a cause of yew decline.

The role of thick, compressed and non-decomposing litter in hindering yew regeneration has been suggested by Izdebski (1956), Król and Kościelny (1965, 1970). The present study indicates that this factor appears to be of importance only for the "near trunk" category (Table 3, factor 9) and therefore should not be associated with yew decline in general.

Also lack of soil moisture has been credited with importance in yew decline (Mańka et al. 1968, Izdebski, Gieruszyński 1961, Wodziczko 1922). Kościelny and Król (1970) disagree and their opinion is confirmed (Table 3, factor 10). Only yews in the "near trunk" category are affected and there is more regeneration in the drier sectors.

Conclusions

The natural regeneration of yew continues to expand in the Kórnik Arboretum. It is most abundant under canopies of trees.

Regeneration close to the trunk occurs but its survival is much poorer than further away, thus endozoochoria seems more important than synzoochoria in yew dispersal. Nuthatches prefer smooth barked trees (beech, hornbeam) for cleaning yew seeds, but survival of yew plants is better near trunks of conifers.

Survival of yews is best under loose canopies, in moderate shade, on drier well draining, low pH, soils.

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References

Bartkowiak S. 1970. Ornitochoria rodzimych i obcych gatunków drzew. Arboretum Kórnickie 15: 237–261.

Bartkowiak S. 1975. Rozsiewanie nasion przez ptaki. Chapter in „Cis pospolity" Ser. Nasze drzewa leśne (Ed. S. Białobok). PWN Warszawa–Poznań: 167–176.

Bartkowiak S., Zieliński J. 1973. Rola synzoochorii w naturalnym odnowieniu cisa (*Taxus baccata* L.) Arboretum Kórnickie 18: 265–272.

Boratyński A., Kmiecik M., Kosiński P., Kwiatkowski P., Szczęśniak E. 1997. Chronione i godne ochrony drzewa i krzewy polskiej części Sudetów, Pogórzy i Przedgórza Sudeckiego. *Taxus baccata* L. Arboretum Kórnickie 42: 111–147.

Bugała W.1975. Systematyka i zmienność. Chapter in „Cis pospolity" Ser. Nasze drzewa leśne (Ed. S. Białobok). PWN Warszawa–Poznań: 18–38.

Bugała W. 1978 Arboretum Kórnickie, Przewodnik. PWN Poznań.

Fabijanowski J. 1951. Cis. *Taxus baccata* L. Chrońmy Przyrodę Ojczystą 7 (3/4): 18–32.

Giertych P. 1998. Ocena udziału ptaków w pojawianiu się nalotu cisowego na przykładzie badań w Arboretum Kórnickim Instytutu Dendrologii PAN. MSc thesis, Faculty of Forestry, Kraków Agricultural Academy.

Gieruszyński T. 1961. Struktura i dynamika rozwojowa drzewostanów rezerwatu cisowego w Wierzchlesie. Ochrona Przyrody 27: 41–90.
Izdebski K. 1956. Drzewa i krzewy rezerwatu cisowego Wierzchlas i struktura biologiczna drzewostanu. Zeszyty Naukowe UMK w Toruniu, Biologia 1: 5–41.
Kobendza R. 1949. Cisy w Puszczy Boreckiej. Chrońmy Przyrodę Ojczystą (4): 68–69; (6): 44–47.
Kościelny S., Król S. 1965. Wstępne wyniki badań nad wpływem czynników warunkujących naturalne odnawianie się cisa. Rocznik Wyższej Szkoły Rolniczej, Poznań, 27: 102–107.
Kościelny S., Król S. 1970. Próby ustalenia czynników ekologicznych warunkujących naturalne odnowienie się cisa w rezerwatach. Poznańskie Towarzystwo Przyjaciół Nauk. Prace Komisji Nauk Rolniczych i Nauk Leśnych. 30: 79–105.
Kowalkowski A., Prusinkiewicz Z. 1959. Gleby Arboretum Kórnickiego. Arboretum Kórnickie 4: 233–276.
Król S. 1975. Zarys Ekologii. Chapter in „Cis pospolity" Ser. Nasze drzewa leśne (Ed. S. Białobok). PWN Warszawa–Poznań: 78–103.
Mańka K. Gierczak M., Prusinkiewicz Z. 1968. Zamieranie siewek cisa (*Taxus baccata* L.) w Wierzchlesie na tle zespołu saprofitycznych grzybów środowiska glebowego. Poznańskie Towarzystwo Przyjaciół Nauk. Prace Komisji Nauk Rolniczych i Nauk Leśnych. 25: 177–195.
Myczkowski S. 1961. Zespoły leśne rezerwatu cisowego „Wierzchlas". Ochrona Przyrody 27: 91–108.
Sokołowski J. 1921. Cis na ziemiach polskich i w krajach przyległych. Ochrona Przyrody 2: 4–22.
Środoń A.. 1975. Historia cisa na naszych ziemiach. Chapter in „Cis pospolity" Ser. Nasze drzewa leśne (Ed. S. Białobok). PWN Warszawa–Poznań: 7–17.
Wodziczko A. 1922. Sprawozdanie z wycieczki po Pomorzu odbytej w celach ochrony przyrody. Ochrona Przyrody 3: 61–70.

Streszczenie

Na planach sekcji Arboretum Kórnickiego zaznaczono wszystkie cisy, wyróżniając kategorię lokalizacji („przy pniu", „pod koroną", „na otwartej przestrzeni"), rozmiar cisa (związany z wiekiem), rodzaj drzewa dla kategorii „przy pniu" i czynniki środowiskowe różnicujące sekcje Arboretum. Praktycznie nie ma odnowienia „na otwartej przestrzeni" (0,2%), większość cisów rośnie „pod koronami" (82,5%), a tylko 17,3% „przy pniu". Zakłada się, że głównie drozdowate (*Turdidae*) są odpowiedzialne za odnowienie „pod koronami" (endozoochoria), a kowaliki (*Sitta europea* L.) „przy pniu" (synzoochoria). „Pod koronami" jest odnowienie we wszystkich klasach wielkości (wieku), a „przy pniu" obserwuje się wyraźny spadek liczebności wraz ze wzrostem siewek, co sugeruje, że warunki rozwoju są tam gorsze. Kowaliki roznoszą nasiona cisa w pobliżu drzew matecznych, a do ich czyszczenia preferują pnie drzew bardziej niż krzewów i to drzew o gładkiej korze (*Fagus, Carpinus*), cisy natomiast przeżywają lepiej „przy pniu" drzew iglastych. Drozdowate rozprowadzają nasiona na większym obszarze. Utrzymanie się odnowienia jest najskuteczniejsze pod luźnym zadrzewieniem, w niewielkim ocienieniu, na suchszych, przepuszczalnych glebach, o niskim pH.