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MORPHOLOGICAL INVESTIGATIONS OF THE FOSSIL *CARPINUS*-NUTLETS FROM POLAND

Badania morfologiczne nad kopalnymi orzeszkami rodzaju *Carpinus* w Polsce

1. INTRODUCTION

The present paper is the third devoted by the writer to the genus *Carpinus*. The first, in which the morphology, anatomy, and variability of the nutlets of eight main recent species of *Carpinus* were discussed, was published in Vol. X of the Publications of the Geological Institute (J. Jentys-Szaferowa and M. Białobrzeska, 1953). It was intended to provide a basis for the determination of fossil materials. The second, published in Monographiae Botanicae (1958), gave a critical review of the history of the genus *Carpinus* in Europe, based on drawings or photographs of its involucres, reproduced in works on palaeobotany from the middle of the nineteenth century onwards. Both these papers formed an introduction to an elaboration of the history of the genus *Carpinus* in Poland based on fossil fruits.

On the basis of special studies, an attempt has been made to determine the similarities and differences of fossil fruits in successive geological epochs and elucidate the origin of the species *Carpinus betulus* now predominating in Europe.

As the writer anticipated in her treatise published in 1953, it was impossible to confine oneself to one method when elaborating fossil material. It was necessary not only to supplement the morphological investigations by anatomical examinations both of the pericarp and the perigone of the nuts, but to go further and apply the epidermal method. The transition from one method to another was influenced by the necessity of supplementation or foundation of the results obtained by new or more convincing proofs.

When describing the history of the hornbeams in Poland, I kept to the same train of thought as in my investigations. I shall therefore describe in this paper the biometric investigation on the shape of fossil nuts, in the next one the investigation on the anatomical structure of the perigone and the pericarp, and finally the investigations on the epidermis. I shall only attempt to draw conclusions as the history of the genus *Carpinus* in Poland on the basis of the research as a whole.

The fossil material of hornbeams on which I based my work consisted of numerous nutlets differing in age. The youngest came from the Holocene Age, so that these provided a sub-fossil material, frequently little damaged and completely unflattened, with a wellpreserved perigone. The oldest nutlets, flattened like black scales and apparently completely deprived of the perigone, came from the Lower Miocene. A total of 1664 fossil hornbeam nutlets were examined with reference to their morphology, about 250 nutlets with reference to their anatomy, and more than 200 nutlets with reference to the structure of the epidermis of the perigone and the layers under the epidermis seen from above.

The chief difficulty of the work, besides that involved in making preparations of the damaged brittle material, lay in the differentiation of the changes occasioned by the process of fossilization from the actual morphological and anatomical changes which occurred among the nutlets of the hornbeams growing in Poland during the last forty million years, more or less. In order to avoid the possibility of error as far as possible, I endeavoured to do as follows. After examining the recent materials, I investigated those of the subfossil materials which I was sure belonged to *Carpinus betulus*, a sole species now growing in Poland, and which in all likelihood did not differ from this in any detail. I then turned to the Pleistocene material, first from the younger and then from the older Interglacial Period, and in this way defined the changes which had occurred in the nutlets of the same species as a result of their becoming constatly flatter and of the increasing length of time which they had lain in the ground. This made it posssible for me to distinguish the specific characters which had remained unchanged during the period of fossilization. It was only on the basis of the changes on which fossilization had no influence that it was possible to judge the actual changes which had occurred among the nutlets of trees living in past geological epochs. In my opinion, this kind of procedure should be applied in all palaeobotanical investigations, including palynology, dealing with the deciphering of plant history or changes connected with evolution. The investigations were therefore made by working back from the youngest to the oldest materials. It was only on the basis of these results that I attempted to reconstruct the history of the hornbeam in Poland from its first appearance down to the present day.

My co-workers in these long and difficult investigations were my assistants, Miss M. Białobrzeska, M. A., and Miss J. Truchanowicz, M. A., who made measurements of morphological characters, statistical calculations, drawings and photographs under my direction. In the elaboration of the fossil materials it was necessary to show accuracy and a critical faculty, in order to reduce the source of error as far as possible. It was also often necessary to repeat measurements, or to make them on material prepared sometimes in one way and sometimes in another. As a result I obtained a numerical material on which I could safely rely. I made the anatomical and epidermal preparations myself, as well as the measurements of their characters.

The results of the biometrical examinations are given in Tables 6 — 12, while the localities from which the examined samples came are set out in Table 2 and marked on the map in Fig. 4. To all the Polish botanists who gave me their materials to elaborate, I offer cordial thanks.

2. CRITICAL REMARKS ON THE MATERIAL AND METHOD

The morphological investigations were based on measurements, as accurate as possible, of fossil hornbeam nutlets and a comparison of these with the recent species in order to determine their similarities and differences.

In order to draw conclusions on the essential differences which occurred in hornbeam nutlets in past geological epochs on the basis of measurements of characters, it was first necessary to find answers to a number of questions. The first two questions were fundamental, viz.,

1) Do the dimensions of fossil relics diminish as a result of agelong lying in the ground and loss of part of the organic material during fossilization?

2) Is fossilization accompanied by a change in shape?

The answer to these questions must be found at the very beginning, as if fossilization may bring about changes both in the dimensions and in the shape of plant relics, the conclusion which may be drawn from the morphological comparison of fossil with recent plants would be of no significance in the elucidation of their history and evolution.

Botanists and archaeologists investigating fossil corn from prehistoric hearths or historical finds know that these grains should be compared not with normal contemporary grains, but with carbonized contemporary grains. Carbonization is accompanied both by contraction, shown in a diminution of the length of the grain, often averaging over 30 per cent, and by a change in the length-breadth and breadth-thickness ratios (Matlakówna 1925, Moldenhaver 1948). The carbonized grains tend, as Hopf (1955) expressed it, to assume a shape very closely approximating a sphere. By charring grains of contemporary corn these workers acquired comparative material on the basis of which they determined the species and varieties of the corn grown by our prehistoric and historic ancestors.

In order to make sure that the hornbeam nutlets undergo changes in shape also as a result of carbonization, two samples of nutlets of *Carpinus betulus*, compared of 95 and 100 specimens, were measured with reference to length, breadth and thickness. These nutlets were then carbonized, by keeping for about two and a half hours on a heated asbestos mat, continually mixing so that they should burn equally. After cooling, their length, breadth and height were re-measured. Samples of nutlets differing in shape were deliberately chosen for the experiment. In one sample there were nutlets broader than they were long, with a mean length-breadth ratio of 0,90, while in the other were long, narrow nutlets, the length of which exceeded the breadth average 1.23 times. In both cases there ensued a marked diminution in the dimensions of the nutlets after charring. The changes in shape were not very great, as the figures given below very well illustrate.

Sample	Number of nutlets		Arithmetic means of characters				
			length	breadth	thickness	length: breadth	breadth: thickness
1	95	before charring	6.39±0.04	7.05±0.02	3.27±0.02	0.90±0.01	2.15±0.01
		after ,,	4.82±0.04	5.58±0.03	2.74±0.02	0.87±0.05	2.04±
		difference	25%	21%	16%	4%	5%
2	100	before charring	6.44±0.04	5.23±0.03	2.41±0.02	1.23±0.01	2.17±0.01
		after ,,	5.44±0.03	4.64±0.03	2.20±0.02	1.17±0.01	2.11±0.01
		difference	15%	11%	9%	5%	3%

In both cases, the length of the nutlets was markedly lessened, the breadth less so, and the thickness the least. As a result, this gave in the first case a broadening of the nutlets averaging ± 4 per cent and a thickening by ± 5 per cent, and in the second case a broadening by ± 5 per cent and a thickening by ± 3 per cent. From these data it is seen that in principle the nutlets of *Carpinus betulus* behave when charred similarly to corn grains; they not only contract, but tend to assume forms approaching a sphere, though in hard lignified hornbeam nutlets composed of thick-walled cells this is shown more weakly than in the thin-walled corn grains.

These results, when changes in shape might freely occur during carbonization, cannot be compared to the process of carbonization in the ground, which takes place under a monolateral pressure. Here then is no question of any increase in the thickness of the relic lying horizontally. The thickness is constantly being lessened, the more so the longer the relic remains under pressure of the layers of earth. In addition, palaeobotanists investigating plant relics not charred by fire, but carbonized as a result of a long-continued, slow process of oxidation, agree that the dimensions and shape of the outline of a relic lying horizontally in the earth do not undergo changes during fossilization. There are numerous proofs of this in the shape of wood, seeds or fruits, which have been preserved in some rock of sedimental origin in such a way that the impression of the relic was kept from the times when it was still fresh. The relic and the impression fit each other with the utmost accuracy, in spite of the sometimes complete carbonization of the relic and the subsequent flattening.

From this it may be assumed that the dimensions and shape of the outline of hornbeam nutlets found in the earth should be approximately the same as in life. It must be taken into account, however, that when fossil nutlets dry up after having been extracted from the earth, a shrinkage may ensue, which influences both the dimensions and the shape of the nutlets. It had therefore to be decided whether, when comparing fossil and recent materials, they should be measured dry or damp.

The fossil materials of hornbeam nutlets which I received for elaboration from Polish botanists, were preserved in two ways; one was to keep them in a dry state, and the other was to keep them in a mixture of glycerine and alcohol. It sometimes happened that the same material was given to me partly dry and partly damp, e. g. the Pliocene materials from Mizerna, which were brought from the terrain over a number of years and preserved partially dry and partially in a mixture of glycerine and alcohol; moreover, the time which particular materials had lain in the mixture sometimes differed by some years. I therefore selected two plates, containing hornbeam nutlets originating from the same level, but not preserved in glycerine for the same length of time, and measured 44 nutlets from the first and 42 from the second. Afterwards they were carefully rinsed from the mixture, cautiously dried, and again measured. The results of the measurements are as follows:

Sample	Number of nutlets	Method of measuring	Arithmetic means of nutlets		
			Length	Breadth	Length; breadth ratio
1	44	damp	4.97 ± 0.12	3.83 ± 0.09	1.29 ± 0.02
		dry	4.89 ± 0.11	3.74 ± 0.09	1.31 ± 0.02
	difference		1.6%	2.3%	1.5%
2	42	damp	5.98 ± 0.18	4.63 ± 0.17	1.31 ± 0.04
		dry	5.63 ± 0.16	4.42 ± 0.14	1.30 ± 0.04
	difference		5.8%	4,8%	0.8%

From these figures it follows that in both samples after drying there ensued a slight diminution in the dimensions of the nutlets. In the second sample, which had remained longer in glycerine, this diminution was greater than in the first. This had no essential effect on the change in the shape of the nutlets, since the differences between the arithmetic means of the length-breadth ratio, in view of the errors of 0.02 and 0.04, were without significance. Other investigations showed that comparatively young material (subfossil and from the Interglacial Riss--Würm) swelled more in a mixture of glycerine and alcohol than completely carbonized and markedly flattened Miocene nutlets. On account of this, I came to the conclusion that the measurements would be burdened with the least error if all the fossil nutlets were measured in the dry state. In this form they would be comparable with the Recent specimens, and the diminution of their dimensions in relation to those at the time of extraction from the earth should not exceed a few per cent on the average.

The next stage of the research was to establish the characters by means of which it would be possible to compare fossil and recent nutlets. As anticipated in the 1953 paper, there were seven of these characters, viz.,

1) Length of nutlet
2) Breadth of nutlet
3) Number of ribs,
4) Ratio of length to breadth
5) Position of the broadest part in percentage of length.
6) Basal angle
7) Apical angle

Among these characters, in the number of ribs, often not well preserved in the fossil material, was the greatest source of error.

Measurements of the fossil material were made on the contour of the nutlets under sevenfold magnification, as for the recent nutlets in the first part of the research. There was a difference between the method of drawing recent nutlets, described in the 1953 treatise, and that used for the fossils, i. e. the picture of the fossil nutlets was not transferred to paper by means of a microscope and an Abbe's drawing apparatus, but its shadow under sevenfold magnification was traced round, using a photographic enlargement apparatus. This was quicker and more accurate. As before, a similarly enlarged millimetre scale was used, on which the measurements were read with an accuracy of 0.125 mm.

Before making the measurements the material was carefully examined by means of a binocular microscope and sorted, selecting nutlets which had not been deformed while they lay in the ground, and flattened only along the shorter axis in transversal section, i. e. those in which only the thickness had been changed. The outline of such a nutlet could be compared with the outline of a recent nutlet. This, however, was not absolutely strict, as during the anatomical examinations it was ascertained that in some fossil nutlets the longer axis in transversal section became twisted; this was difficult to observe before sectioning (Plate I, A). The percentage of such nutlets was not large, however, so that it could not cause any distinct change in the arithmetic means in a larger number of measurements.

Another thing which had to be decided before morphological analysis of the fossil material was made had a biological aspect. The fossil nutlets on which my research was based had the character of local samples; each of these samples was composed of nutlets certainly originating from many trees and many generations, but growing in the vicinity of one locality (see Table 2). In order to evaluate and classify these local fossil samples, it was necessary to learn the characteristics of the local samples of recent *Carpinus betulus* nutlets and their relation to the characteristics possessed by this species over the whole of its present area in Europe. This refers to the morphological characteristics common to a number of specimens growing near one another. These features acquire particular importance if there are characters which correlate with one another and are characteristic of a given shape. They are intensified by the continual crossing of specimens growing near one another.

It was not easy to find an answer to this question, as in spite of much correspondence with botanists and foresters of various countries in Europe, I did not receive from any country a sample of nutlets which could adequately represent the variability of hornbeam nutlets in a given territory. The material which I received — although composed of a great number of nutlets — mostly came from only a few specimens. I had, however, asked for few nutlets, but from at least 50 specimens from a given territory. The nutlets were often mixed together without giving the number of trees from which they had come. The best sample was that sent through the courtesy of Professor Gaussen from a wood in the locality of Montech, in Southern France, north of Toulouse (Table I, no. 1, Tables 6—12, no. 4). This sample was composed of 200 nutlets collected from 20 trees (10 from each). Of these, 100 nutlets were measured (five from each tree) and compared with a sample of 100 nutlets from the whole range of *Carpinus betulus*. This comparison was carried out by taking the arithmetic means of a sample from the whole of Europe as a comparative unit, and each time calculating how much the arithmetic means of the local sample from Montech were greater or smaller than the means of the comparative unit. Thus the comparative unit was always the divisor. This comparison appeared as follows:

	M_1 (Europe)	M_2 (Montech)	M_2; M_1
1) Length of nutlet	6.06	5.85	0.96
2) Breadth of nutlet	5.34	5.02	0.94
3) Number of ribs	8.50	8.45	0.99
4) Ratio of length to breadth	1.14	1,16	1.01
5) Position of the broadest part in percentage of length	41.57	41.63	1.00
6) Basal angle	161.20	158.10	0.98
7) Apical angle	112.20	108.25	0.96

The figures obtained by division show how much the arithmetic means of the samples compared are greater or lesser than the means of the comparative unit. Graph I in Fig. 1 was plotted partly on the basis of these figures; the comparative unit (M_1) is given in the form of a straight line with the heading „1". Then the results of dividing M_2 by M_1, were marked on the graph at the appropriate points, and after joining them by dotted lines, an angular line A was obtained. The ratio of this to the straight vertical line was the ratio of the characters of the Montech sample to the sample from the whole of Europe. A detailed description of this graphic method and the range of its application may be found in the papers published by the author in 1949—1951, 1953 and 1959.

On the graph I. in Fig. 1 it is seen that a distinctive character of the nuts from near Toulouse (angular line „A") is that they are slightly smaller, relatively narrower (x), and have sharper apices (y) than the averages from Europe as a whole.

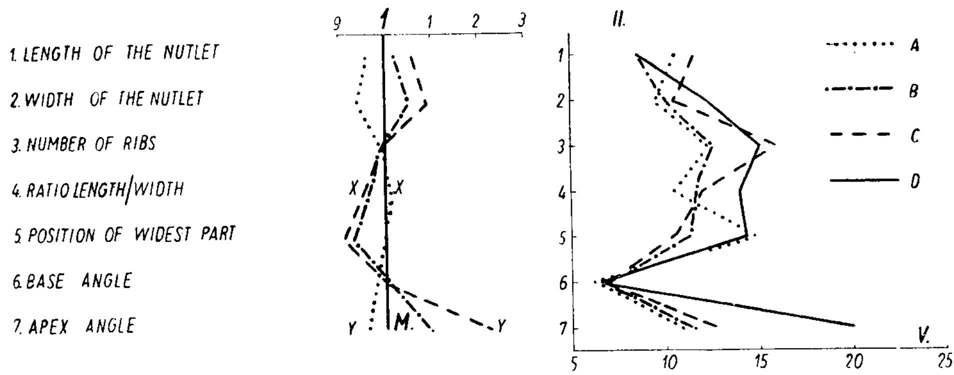


Fig. 1. I. The relation between the size and shape of local samples of *Carpinus betulus* (angular lines) and the sample from the whole of the European range of this species (vertical line) II. Curves of the coefficients of variability of the above four samples. A. Montech, near Toulouse. B. the Forest of Białowieża. C. The whole of Poland. D. The whole of Europe

Fig. 1. I. Stosunek wielkości i kształtu lokalnych prób *Carpinus betulus* (linie łamane) do próby z całego europejskiego zasięgu tego gatunku (linia pionowa). II. Wykres współczynników zmienności 4 powyższych prób. A. Montech k. Tuluzy, B. Puszcza Białowieska, C. Cała Polska, D. Cała Europa

In the same figure, an angular line marks the local sample „B", i. e. a sample of 80 nutlets gathered from forty trees in the Primeval-Forest of Białowieża in Poland (see Table 1, no. 2, and Tables 6—12, no. 3). This line is the converse of that of the shape of the nutlets from Montech. The hornbeams from Białowieża had slightly larger and comparatively broader (x) nutlets with blunter apices (y) than the averages from Europe as a whole. The angular line „C" denotes a sample of 400 nutlets from 40 trees from the whole of Poland (see Table 1, no. 10, and Tables 6—12, no. 2). The nuts in this sample are on the average still broader and with blunter apices than the local sample from Białowieża, which gives evidence that large, broad, blunt-ended nuts are characteristic of Poland as a whole. The accompanying graph of the coefficients of variability (Fig. 1 II) indicates that the general sample from Europe is distinctly more variable than the local samples compared with it in only two characters, i. e. the ratio of length to breadth and the apical angle. On the basis of these data it should be expected that the formation in certain localities of narrow and comparatively sharp nuts or broad, blunt nuts is a general, congenital characteristic of the genus *Carpinus betulus*.

The truth of this assumption was confirmed by the examination of such local samples as I had at my disposal, although (as already mentioned) these had not been very systematically collected.

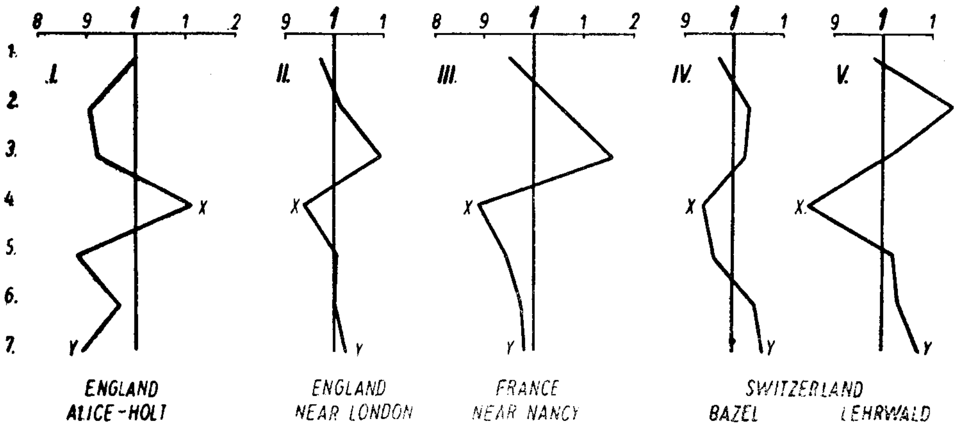


Fig. 2. The relation between recent local samples of C. *betulus* (angular lines) and a sample from Europe as a whole (vertical lines) (see Tab. 1)

Fig. 2. Stosunek współczesnych prób lokalnych C. *betulus* (linie łamane) do próby z całej Europy (linie pionowe) (patrz Tab. 1.)

Fig. 2 shows the comparative sizes and shapes of *Carpinus betulus* nutlets from five European local samples, marked in Table 1 as nos. 3 — 7. They are composed of 50 — 100 nutlets, but mostly come from an unknown number of trees. As in Fig. 1, the vertical line in the centre of each graph in Fig. 2 represents a sample of *Carpinus betulus* from the whole area in Europe (v. Table 1, no. 9), while the angular line corresponds to the local sample. From the four local samples it is seen that if „x", i. e. the length-breadth ratio, is found on the right side of the comparative unit (which means that the nuts are narrow), then „y", i. e. the apical angle, is found on the left, and vice versa. This regularity was absent only in graph no. III, i. e. the sample from Nancy. Here, however, the value of the arithmetic mean for characters no. 7 in the local sample was 109.30° ± 1.66, but 112.20 ± 1.87 for the comparative unit, i. e. the placing of the point „y" on the left or right side of the comparative unit lay within the field of error.

From Figs. 1 and 2 it is seen that the formation in some localities of comparatively broad nutlets with broad apices and in others of comparatively narrow sharp-ended nutlets is a general characteristic in

Table 1
Tabela 1

THE MEASUREMENTS OF RECENT NUTLETS OF CARPINUS BETULUS
POMIARY WSPÓŁCZESNYCH ORZESZKÓW CARPINUS BETULUS

No	Locality *Miejscowość*	Number of trees *Liczba drzew*	Number of nutlets *Liczba orzeszków*	Arithmetic means of characters *Średnie arytmetyczne cech*						
				Length *Długość*	Width *Szerokość*	Number of ribs *Liczba żeberek*	Ratio length/width *Stosunek dług./szer*	Position of widest part *Położenie najszerszej części*	Basal angle *Kąt podstawy*	Apical angle *Kąt wierzchołka*
1	France, near Touluse	20	100	5,85 ± 0,06	5,02 ± 0,05	8,45 ± 0,11	1,16 ± 0,01	41,63 ± 0,61	158,10 ± 1,04	108,25 ± 1,16
2	Poland, Białowieża Forest	40	80	6.20 ± 0,06	5,59 ± 0,06	8,40 ± 0,11	1.11 ± 0,01	39,13 ± 0.49	163,35 ± 1.33	123.20 ± 1.59
3	England, Alice Holt	?	100	6,09 ± 0,04	4,86 ± 0,03	7,79 ± 0,09	1,25 ± 0,01	36,74 ± 0,42	155,25 ± 1,03	88,30 ± 1,21
4	England, near London	?	100	5,81 ± 0.08	5.41 ± 0,06	9,24 ± 0,13	1,08 ± 0,02	41.45 ± 0.45	160,95 ± 1,05	115,10 ± 1,87
5	France, near Nancy	?	50	5,77 ± 0,04	4,61 ± 0,08	9,76 ± 0,13	1,02 ± 0,01	39.32 ± 0.44	156,70 ± 1.09	108,30 ± 1,66
6	Switzerland, near Basel	?	50	5,90 ± 0,05	5,44 ± 0.06	8,60 ± 0,13	1,07 ± 0.01	39,98 ± 0.68	165.60 ± 1,10	119,90 ± 1,60
7	Switzerland — Lehrwald	?	50	5,94 ± 0,05	6.05 ± 0,05	8,60 ± 0,12	0,97 ± 0,01	38.06 ± 0,52	165,70 ± 1,12	120.30 ± 1,56
8	Samples 1—7 added	?	530	5,94 ± 0,05	5,28 ± 0.05	8,69 ± 0,12	1,09 ± 0,01	39.47 ± 0,51	160,81 ± 1,08	111,92 ± 1,52
9	The whole of Europe	16	100	6.06 ± 0.05	5,34 ± 0,06	8,50 ± 0,13	1.14 ± 0.01	41,57 ± 0,59	161,20 ± 1,03	112,20 ± 1,87
10	The whole of Poland	40	400	6,44 ± 0.04	5,85 ± 0,03	8,48 ± 0,06	1,09 ± 0,01	38,24 ± 0,20	161,45 ± 0.57	138,40 ± 0,90

local samples of *Carpinus betulus* in Europe. Two types of nutlets of this description are shown in Fig. 3.

As for the remaining characters included in the measurements, these do not exhibit any close connection with the length-breadth ratio and the apical angle. In one sample there may be comparatively narrow

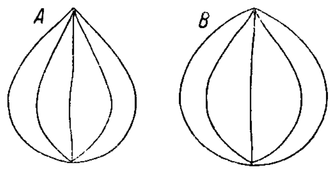


Fig. 3. Hornbeam nutlets drawn according to the arithmetic means. A. Local sample from Alice Holt. B. Local sample from Białowieża Primeval-Forest

Fig. 3. Orzeszki grabu narysowane według średnich arytmetycznych. A. próba lokalna z Alice Holt. B. próba lokalna z Puszczy Białowieskiej

nutlets with the broadest part set low (Fig. 2 graph I), and in another comparatively broad nutlets also having the broadest part set low (Fig. 1, graphs B and C), etc. The length of the nutlet and the basal angle are also unconnected with its greater or lesser breadth.

In Table 1, no. 8 are given the arithmetic means for the sum of seven local samples from Europe, and under them the arithmetic means of a sample of 100 nutlets from 16 trees (6 — 7 nutlets from each tree) from over the whole European range of *Carpinus betulus*. These figures approximate one another very closely, which shows that the sample from the whole European range of *Carpinus betulus* represents the population of this species well.

Bearing in mind these critical considerations, I set myself the task of basing the morphological investigations of fossil hornbeam nutlets on the following assumptions:

1) Fossil nutlets of the genus *Carpinus* are, when taken from the ground, comparable with recent nutlets as regards their dimensions and the shape of their contour.

2) After drying, fossil nutlets undergo an insignificant diminution in their dimensions, which is not accompanied by any change in shape. The difference in the dimensions of nutlets freshly collected from the earth and when dried is the smaller the greater the degree to which they are fossilized.

3) Fossil hornbeam nutlets originating from a single locality should be treated as local sample. Conclusions may be drawn as to the shape of nutlets of the genus *Carpinus* in any given geological epoch only on the basis of a number of local samples.

There still remained one question to be answered before beginning biometric investigations on the Polish fossil material. Should these materials be compared with the recent materials from the whole of Poland, or with samples from the whole of Europe? The answer to this will be given in the discussion of the measurements of Quaternary nutlets (see page 19).

3. BIOMETRIC INVESTIGATIONS OF NUTLETS FROM THE QUATERNARY

According to the assumptions discussed in the Introduction, investigations of the fossil materials were begun on the youngest, the Holocene. Then the Pleistocene materials were examined. In both these periods, as far as we know, no other species of the genus *Carpinus* grew in Poland except *Carpinus betulus*, which grows there today. The investigations of the fossil Holocene and Pleistocene nutlets of the species *Carpinus betulus* was to be the key facilitating the examination and comprehension of the older materials.

In Table 2 all the fossil nutlets included in the measurements are shown. Only those nutlets which had been selected for biometric investigations as neither damaged not distorted by fossilization are mentioned. Actually the material included in the investigation was larger, since many nutlets, slightly damaged or deformed in consequence of not lying quite horizontally in the ground, were used for anatomical or epidermal examinations.

In Table 2, besides the age and the numbers of the nutlets examined, are given the nature of the deposit in which they were found, the locality whence they came, and the names of the authors who elaborated the particular fossil flora. The full titles and places of publication are found in the list of references on pp. 34 — 36. The localities from which the fossil flora mentioned in Table 2 comes are marked on the map in Fig. 4.

The results of the measurements are given in Tables 6 — 12, at the end of the treatise.

In Fig. 5 is shown the relation between the shapes of Holocene and Pleistocene hornbeam nutlets from eight localities in Poland, i. e. the relation between the shape of eight fossil local samples and the arithmetic means of recent hornbeam nutlets from all over Europe. This corresponds to Figs. 1 and 2, in which are given the graphs of recent local samples of *Carpinus betulus*.

The first three samples in Fig. 5 come from subfossil materials from

Table 2
Tabela 2

FOSSIL MATERIALS
MATERIAŁY KOPALNE

Age *Wiek*		Number of nutlets *Liczba orzeszków*	Character of sediment *Charakter osadu*	Locality *Miejscowość*	Authors *Autorzy*
Holocene *Holocen*	Subfossil *Subfosylne*	28 130 50	peat, shell marl — silt	Roztoki Krzeszów Raków	Szafer, Jaroń (1935) Szafer (1939) Kozłowska (1923)
Pleistocene *Plejstocen*	Interglacial Riss — Würm *Interglacjał Riss — Würm*	50 19 190 120 150	shell marl peat, shell marl peat peat, clay silt	Rumlówka Nieciosy Samostrzelniki Rusinowo Dzbanki	Środoń (1950) Bremówna, Sobolewska (1950) Szafer (1926), Trela (1935) Stark, Firbas, Overbeck (1932) Piech (1929)
	Interglacial Mindel — Riss *Interglacjał Mindel — Riss*	7 7 5	peat silt, gytia peat	Olszewice Żydowszczyzna Ciechanki	Lilpop (1930), Sobolewska (1956), Trela (1930) Szafer 1926, Jaroń (1933) Bremówna (1953)
Pliocene *Pliocen*	upper *górny*	200	silt	Mizerna	Szafer (1954)
	lower *dolny*	300	silt	Krościenko	Szafer (1946—47)
Miocene *Miocen*	upper *górny*	160	silt	Domański Wierch	Szafer (1950)
	middle *środkowy*	225	silt	Gliwice	Szafer (1959)
	lower *dolny*	9	salt	Wieliczka	Zabłocki (1927—30)

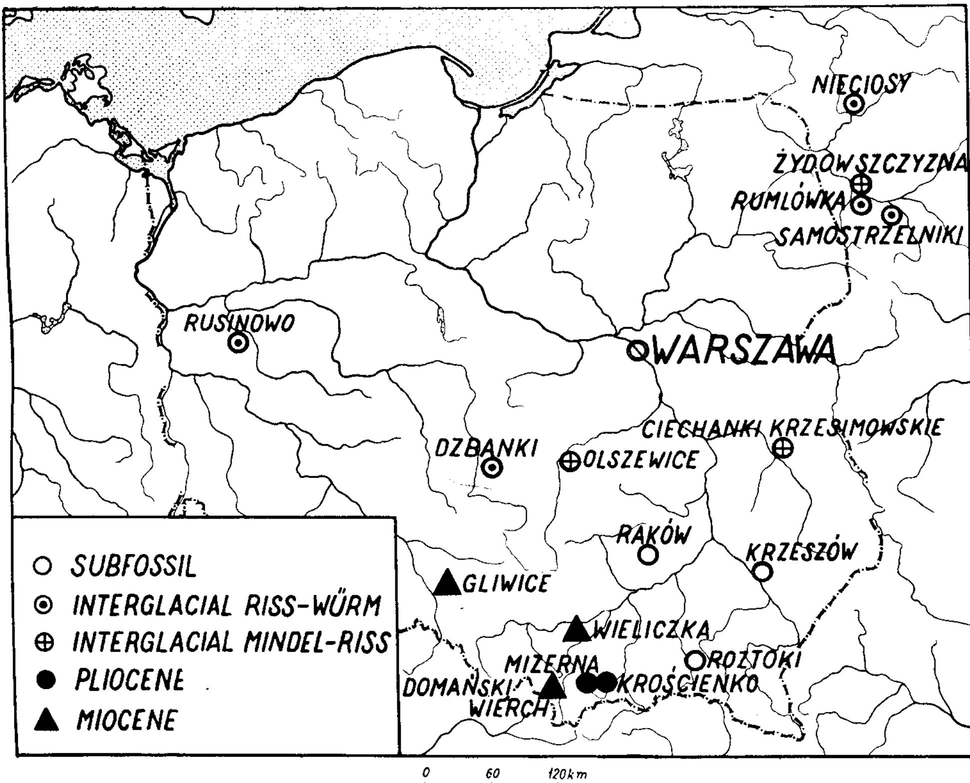


Fig. 4. A map of fossil floras with the hornbeam nutlets investigated

Fig. 4. Stanowiska flor kopalnych z badanymi orzeszkami grabu.

the optimum climatic period after the Ice Age and the next five from the Climatic optimum during the Riss-Würm Interglacial. The dating was confirmed by pollen analysis, carried out in the same localities from which the macrofossilia originated. The age of the subfossil nutlets should be reckoned as from four to five thousand years, and that of the Interglacial nutlets as about 80.000 years.

As might have been anticipated, the characters of the fossil local samples diverged from the comparative unit (straight vertical lines), which illustrated the average shape of the recent nutlet in the sample of *Carpinus betulus* from the whole of Europe. Among them there were samples of shorter and so smaller nutlets, and of longer and so larger nutlets (characters 1 and 2), with a greater or lesser average number of ribs (character 3), with broadest part situated higher or lower (5); in short, each sample had its own local features. The characteristic feature which they had in common was that if the length-breadth ratio in the nutlets was smaller than in the comparative unit, i. e. if they

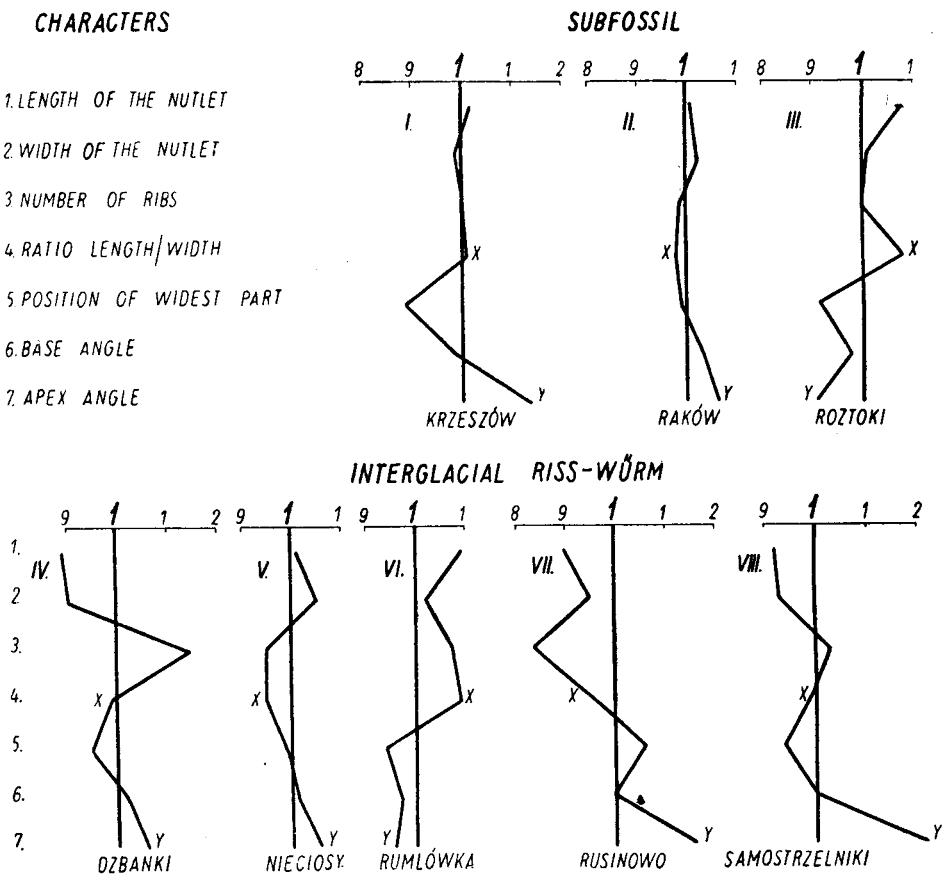


Fig. 5 The relation between the size and shape of fossil nutlets from the Quaternary (angular lines) and the recent sample of *Carpinus betulus* from over the whole range (vertical lines)

Fig. 5. Stosunek wielkości i kształtu kopalnych orzeszków z czwartorzędu (linie łamane) do współczesnej próby *Carpinus betulus* z całego zasięgu (linie pionowe)

were comparatively broad (the breadth went into the length fewer times), the figure illustrating the apical angle was larger (character 7). On the contrary, when the ratio of length to breadth was greater, this was accompanied by a decrease in the apical angle. These points are marked by the letters x y on each graph, as in Figs. 1 and 2. Only in the sample from Krzeszów (Graph I), in characters 4 and 7 there is an apparent disagreement. There are such small differences between the means from Krzeszów and those from Europe as a whole, however, that these lie within the limits of error. The mean from Krzeszów for character 4 is 1.15±0.01, and that from Europe is 1.14±0.01, i. e. in the

THE MEASURMENTS OF FOSSIL NUTLETS OF *CARPINUS* (SEE TABLE 4)
POMIARY KOPALNYCH ORZESZKÓW GRABU (PATRZ TABELA 4)

Age *Wiek*			Number of nutlets *Liczba orzeszków*	Arithmetic means of characters *Średnie arytmetyczne cech*						
				Length *Długość*	Width *Szerokość*	Number of ribs *Liczba żeberek*	Ratio length/width *Stosunek dług./szer.*	Position of widest part *Położenie najszerszej części*	Basal angle *Kąt podstawy*	Apical angle *Kąt wierzchołka*
Quaternary *Czwartorzęd*	Holocene *Holocen*	Recent: *Współczesne* Europe *Europa*	100	6,06 ± 0,05	5,34 ± 0,06	8,50 ± 0,13	1,14 ± 0,01	41,57 ± 0.59	161,20 ± 1,03	112.20 ± 1,87
		Poland *Polska*	400	6,44 ± 0,04	5,85 ± 0,03	8,48 ± 0,06	1,09 ± 0,01	38.24 ± 0,20	161,45 ± 0,57	138,40 ± 0,90
		Subfossil *Subfosylne*	208	6,13 ± 0,05	5,33 ± 0,05	7,96 ± 0,13	1,15 ± 0.01	38,24 ± 0.29	161,40 ± 0,72	122,75 ± 1,20
	Pleistocene *Plejstocen*	Intergl. Riss-Würm *Interglacjał Riss-Würm*	529	5,65 ± 0,03	4,96 ± 0.03	8,59 ± 0,09	1.14 ± 0,01	40.16 ± 0,23	160,15 ± 0,45	127,95 ± 0,81
Tertiary *Trzeciorzęd*	Pliocene *Pliocen*	Upper *Górny*	200	4,04 ± 0,19	3,52 ± 0,05	9,45 ± 0,12	1,25 ± 0,01	39,95 ± 0,27	157,55 ± 0,82	114,30 ± 1,36
		Lower *Dolny*	300	3,49 ± 0,04	2,96 ± 0,03	8,12 ± 0,23	1 19 ± 0,01	38,87 ± 0,23	161,40 ± 0,60	119,90 ± 0,99
	Miocene *Miocen*	Upper *Górny*	160	3,89 ± 0,04	2,86 ± 0,03	—	1,38 ± 0,01	36,14 ± 0.28	146,50 ± 0,95	100,30 ± 1,17
		Middle *Środkowy*	225	4,29 ± 0.04	3.09 ± 0,03	—	1,40 ± 0,01	35,93 ± 0,31	153,30 ± 0,70	87,70 ± 1,12

Table 4
Tabela 4

DIFFERENCES IN ARITHMETIC MEANS OF FOSSIL AND RECENT NUTLETS EXPRESSED IN PERCENTAGE (SEE TABLE 3)

RÓŻNICE MIĘDZY ŚREDNIMI ARYTMETYCZNYMI KOPALNYCH I WSPÓŁCZESNYCH ORZESZKÓW WYRAŻONE W PROCENTACH (PATRZ TABELA 3)

Age *Wiek*		Differences in arithmetic means of characters *Różnice w średnich arytmetycznych cech*													
		Length *Długość*		Width *Szerokość*		Number of ribs *Liczba żeberek*		Ratio length/width *Stosunek dług./szer.*		Position of widest part *Położenie najszerszej części*		Basal angle *Kąt podstawy*		Apical angle *Kąt wierzchołka*	
		—	+	—	+	—	+	—	+	—	+	—	+	—	+
Quaternary *Czwartorzęd*	Subfossil *Subfosylne*	—	1,15%	0,19%	—	6,35%	—	—	0,87%	8,01%	—	—	0,12%	—	9,40%
	Interglacial Riss-Würm *Interglacjał Riss-Würm*	6,76%	—	7,11%	—	—	1,05%	—	0%	3,39%	—	0,03%	—	—	14,03%
Tertiary *Trzeciorzęd*	Upper Pliocene *Górny Pliocen*	28,22%	—	34,08%	—	—	11,17%	—	9,64%	3,82%	—	2,26%	—	—	1,87%
	Lower Pliocene *Dolny Pliocen*	42,41%	—	44,57%	—	4,47%	—	—	4,38%	6,49%	—	—	0,12%	—	6,86%
	Upper Miocene *Górny Miocen*	35,81%	—	46,44%	—	—	—	—	21,05%	13,06%	—	9,11%	—	10,60%	—
	Middle Miocene *Środkowy Miocen*	29,21%	—	42,13%	—	—	—	—	22,80%	13,57%	—	4,90%	—	21,39%	—

first case the actual mean varies from 1.14 to 1.16, and in the second from 1.13 to 1.15. An increase in the number of measurements might here cause the transference of the point x from the right to the left side of the graph, and then the general picture would be normal. (cf. Fig. 2, III).

After analysing the shape of fossil nutlets shown in Fig. 5, I came to the conclusion that they had the same characteristic features as fruits of the species *Carpinus betulus* in Europe have today, i. e. the local samples had blunt and comparatively broad nutlets or narrower and more sharply-ended nutlets. I did not find any nutlets in which an increase in breadth was accompanied by a tapering of the apical angle, (i. e. in which these characters were associated with an inverse correlation), among samples of *Carpinus betulus* nutlets, whether living or fossil.

We now come to the detailed analysis of the characters of size and shape in subfossil and Pleistocene nutlets.

In Tables 6 — 12 are given the results of measurement of the eight Quaternary samples examined (nos 5 — 12). Calculated on this basis, the summary arithmetic means characteristic of the Holocene and Pleistocene are given in Table 3. Those the Holocene are less exact, since I had at my disposal only three samples, containing altogether 208 nutlets. The Riss-Würm Interglacial was better represented, as here I had five samples with a total number of 529 nutlets. Table 3 is the complement of Table 4; here are calculated the relation between the arithmetic means of the fossil nutlets from Table 3 and the sample of *Carpinus betulus* from the whole of Europe. The figures given here show if the fossil means are greater or smaller in percentage than those of recent *Carpinus betulus*. E. g. the figure 1.15 per cent under the heading „+", relating to the length of subfossil nutlets denotes that these were 1.15 per cent longer than recent nutlets, while the Interglacial nutlets were 6.76 per cent shorter than the recent and so were put under the heading „—". Figs 8 — 11 complement Tables 3 and 4.

A glance at Table 4 will make it clear that the differences in the dimensions of the subfossil and recent nutlets were without significance, as were also the differences in their length-breadth ratio. There were 6.35 per cent fewer ribs, but this is a normal phenomenon in fossil nutlets, as the ribs are often damaged and it is difficult to count them accurately. On the other hand, there was a slight difference in the location of the broadest part. In the Holocene, this lay on the average 8.01 per cent lower than in the *Carpinus betulus* of to day in Europe as a whole. There was also a slight difference in the apical angle, which was 9.40 per cent broader. If, however, we look at Table 3, where besides the sample from the whole of Europe there is given the mean of a recent sample from Poland, it is seen that the Polish subfossil nutlets were in some characters identical to the sample from Europe as a whole, in others to the sample from Poland, but in certain characters occupied an intermediate position. In short, during the Holocene climatic optimum in Poland there grew a *Carpinus betulus* similar to that which grows there today, but its nutlets were a little narrower and had sharper ends.

In the Riss-Würm Interglacial, the nutlets were smaller than in the Holocene, but on the other hand they approximated more closely in shape to the means for the whole of Europe than the subfossil nutlets; they occupied an intermediate position between the recent nutlets from Europe and Poland only as regards the apical angle (Figs. 8 — 11, I — III).

The decrease in the dimensions of the Interglacial nutlets does not give grounds for the statement that the species *Carpinus betulus* in the Riss-Würm Interglacial in Poland had smaller fruits, as this was material already partially carbonized, but not yet very much flattened, and so had undergone some shrinkage during drying. A decrease of about 7 per cent in the dimensions is thus comprehensible.

When considering the shape and size of the Interglacial nutlets, I omitted those of the Older Interglacial, i. e. of the period between the Mindel and Riss (v. Tables 6 — 12). This would, it is true, be the next step backwards which would assist in the determination of the degree of morphological changes evoked by the increasingly protracted lying of the nutlets in the earth, but the samples which I had of this period were so small that they were not fit for biometric investigations.

All the materials from the Mindel-Riss period elaborated by Polish botanists came from borings and contained little in the way of macro-relics, and I only had at my disposal 17 nutlets in a sufficiently good state of preservation for the measurement of their morphological characters. As seen from Table 6, their length was 4 — 6,5 mm, so that it exceeded the Modal values found in living *Carpinus betulus*. The smallest of them, however, was not smaller than the smallest found today, or than those found in the Riss-Würm Interglacial. As a whole, they were contained within the limits of variability of the nutlets of living *Carpinus betulus*.

Summarizing these observations, it may be said that:

1) In the Holocene and Pleistocene, the species *Carpinus betulus* then growing in Poland did not differ in the dimensions of its nutlets from the contemporary species.

2) In shape, these nutlets approximated more closely to the means

of recent nutlets from Europe as a whole than to the means from Poland, i. e. they were in general a little narrower and had sharper ends than those in Poland today.

3) In the Quaternary, *Carpinus betulus* had a local morphological variability similar to that found today.

Since the Quaternary Polish nutlets approximated more closely to the means from Europe as a whole than to the means from Poland, I decided to use a sample of 100 nutlets from over the whole European range as a comparative unit for all the fossil materials, i. e. the same comparative unit as that used for the determination of the characters of the Recent species of hornbeam in the first part of my work (1953).

4. THE NUTLETS FROM THE PLIOCENE

It was of fundamental importance for my further research to be quite certain that the dimensions of the nutlets of *Carpinus betulus*, and especially the length, had not undergone any changes during fossilization. Length was the character of which the measurements in the fossil material were fraught with the least error. All nutlets which had not lain horizontally but a little obliquely in the earth were so distorted that it was easy to eliminate them from the samples destined for biometric investigations. Again, what was more important, it followed from the measurements of recent hornbeam nutlets that the most definite morphological character for distinguishing the species *Carpinus betulus* from the other species living today was the length (1953). I hoped, therefore, that after measuring the nutlets from the Neogene it would at least be possible to separate the species *Carpinus betulus* from the other species of *Carpinus* described in Poland from this era (Z a b ł o c k i 1928, 1930, S z a f e r 1946 — 47). A graph of the length of the Recent nutlets, repeated from the 1953 treatise, is given in Fig. 6, I.

I considered the possibility of distinguishing the species *Carpinus betulus* from the mixture of fossil nutlets on the basis of length to be the most important result of the morphological investigations. After measuring the Pliocene materials from Mizerna and Krościenko (W. Szafer 1946 — 47, 1954), it proved that the hope based on Graph I in Fig. 6 was entirely without foundation, and that the results of the measurement of the Pliocene nutlets raised a new problem, which had to be solved.

If we look at Tables 3 and 4, and Figs. 6 and 8, we shall see that though there were no distinct differences in length between the recent *Carpinus betulus* nutlets and those of the youngest Interglacial, there

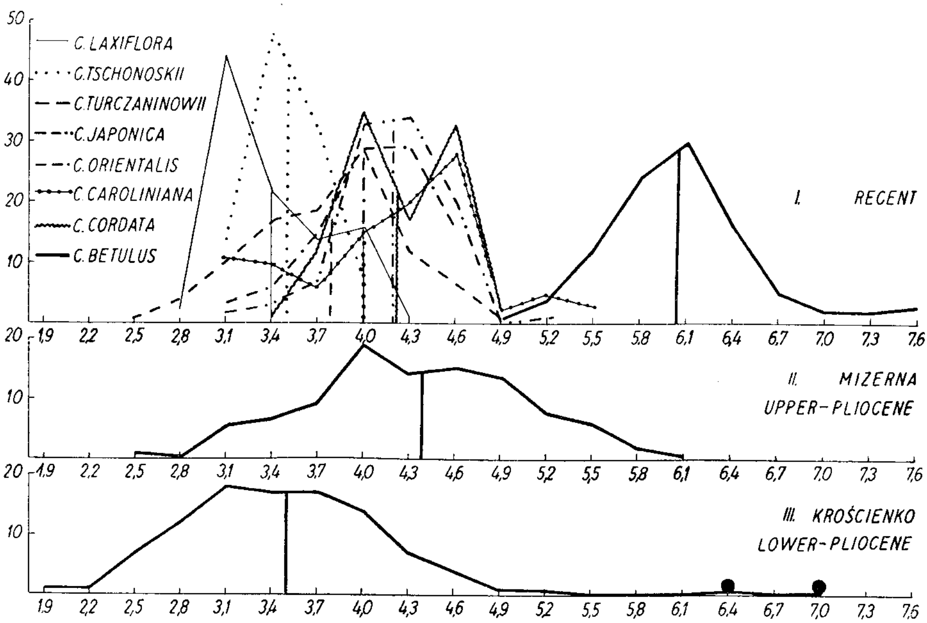


Fig. 6. Length of nutlets of the species of *Carpinus*. I. Recent II. From the Upper Pliocene at Mizerna. III. From the Lower Pliocene at Krościenko

Fig. 6. Długość orzeszków rodzaju *Carpinus* I. współczesnych, II. Z górnego pliocenu w Mizernej, III. z dolnego pliocenu w Krościenku

was a pronounced difference between the Interglacial nutlets and those of the Upper Pliocene. Here there occurred some sort of sudden change. The nutlets from the Upper Pliocene were 28.22 per cent shorter than the recent, and the nutlets from the Lower Pliocene found by W. Szafer at Krościenko (1946) were still shorter. The arithmetic mean of their length was over 42 per cent less than that of the recent *C. betulus* from Europe. This cannot be attributed to shrinkage of the fossil materials as a result of drying, since the Pliocene nutlets were markedly carbonized and flattened, and had not contracted to the same degree as the Interglacial nutlets. It is impossible to substract even 6 per cent as a result of drying from the values of 28 and 42 per cent.

Professor Szafer determined the nutlets from Mizerna as belonging solely to the species *Carpinus betulus*. At Krościenko, there were distinguished species affined to C. laxiflora, C. Tschonoskii and *C. Turczaninowii var. polyneura,* besides *Carpinus betulus foss.** As seen from

* W. Szafer described from Mizerna and Krościenko, besides the species mentioned above, a new microcarpous species „*Carpinus minima*”. After a detailed examination these fruits proved to be of a different structure than the fruits of the genus *Carpinus* and will be described by the author in another paper.

Fig. 6, I. *Carpinus laxiflora* has very small nutlets, and *Carpinus Turczaninowii var. polyneura* is a small-fruited variety of a species which even normally has not large fruits. A mixture of recent nutlets from *Carpinus betulus, C. laxiflora,* and *C. Turczaninowii var. polyneura* should therefore give a two-peaked curve of length. But neither for the nutlets from Mizerna nor from Krościenko do we see two-peaked length diagrams in Fig. 6. At first I could not understand this. It may be interpreted in various ways.

1) Both at Mizerna and at Krościenko there grew only the species *Carpinus betulus*, but the nutlets in consequence of lying in the earth for an increasingly long period contracted more and more. In this case all the previous deductions that the length of nutlets lying horizontally in the earth does not change during fossilization, are wrong. The possibility of a mixture of small-fruited and large-fruited species, however, would then have to be excluded, since all the nutlets would shrink in a similar fashion, and in the case of a mixture of types the two-peaked frequency diagram should continue to be kept.

2) In the Pliocene, the species *Carpinus betulus* did not grow at all at Mizerna and Krościenko, but only small-fruited hornbeams.

3) In the Upper Pliocene at Mizerna and in the Lower Pliocene at Krościenko, *Carpinus betulus* grew but differed from the contemporary in so far as it had not large but small fruits.

In order to answer these questions it was necessary in the first place to consider the fundamental matter, viz. to reach a conviction as to whether the species *Carpinus betulus* grew at all in the Pliocene. I endeavoured to find the answer to this in the results of statistical investigations.

Let us begin with the analysis of the samples from Mizerna and from Krościenko, making use of the data given in the Tables or the graphs plotted from these in Fig. 7 — 11. In Graphs I, II Fig. 7 the arithmetic means of the character of size and shape of a local sample from the Upper Pliocene deposits at Mizerna, near Czorsztyn and of a sample from the Lower Pliocene at Krościenko. (Tables 6 — 12, Nos 17 and 18) are compared with those of a sample representing the contemporary variability of hornbeam nutlets from the whole of Europe (Tables 6 — 12, No 1) and which serves as the comparative unit, represented as a vertical line in the centre of the graphs. The graphs are constructed in the same manner as in Figs. 1 and 2, described on p. 10. Something new is introduced here beside the continuous angular line which illustrates the given sample with regard to size and shape, i. e. a dotted angular line which illustrates the variability of the same sample as regards particular characters. This line was drawn on the basis of an adjustement, re-

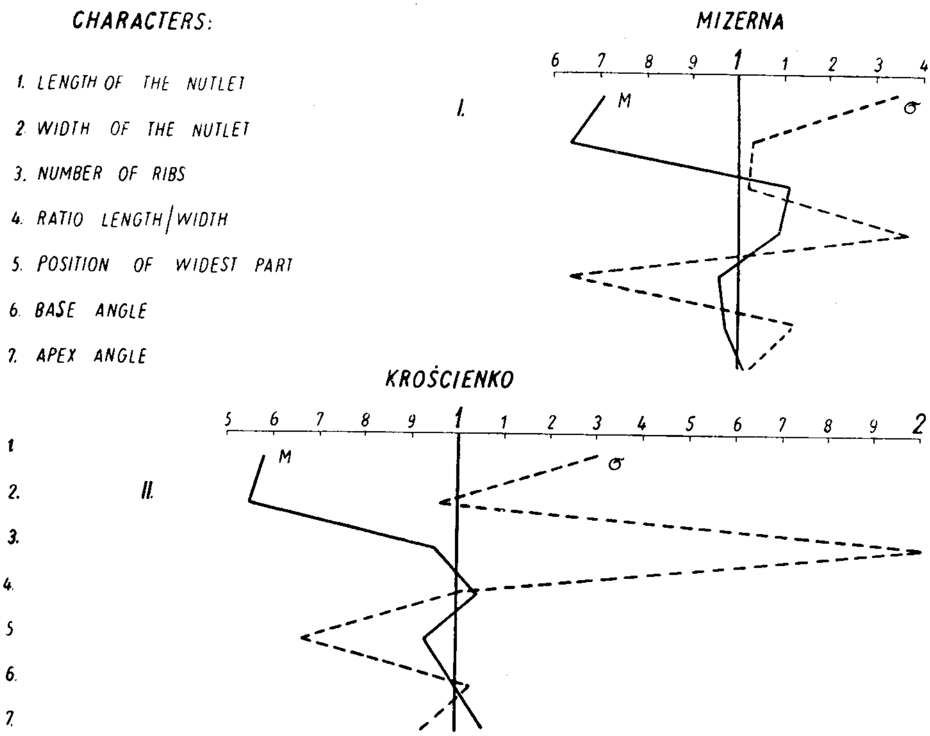


Fig. 7. The relation between the size and shape of Pliocene nutlets (angular lines) and Recent nutlets of *Carpinus betulus* (vertical lines). I. The Upper Pliocene at Mizerna. II. The Lower Pliocene at Krościenko

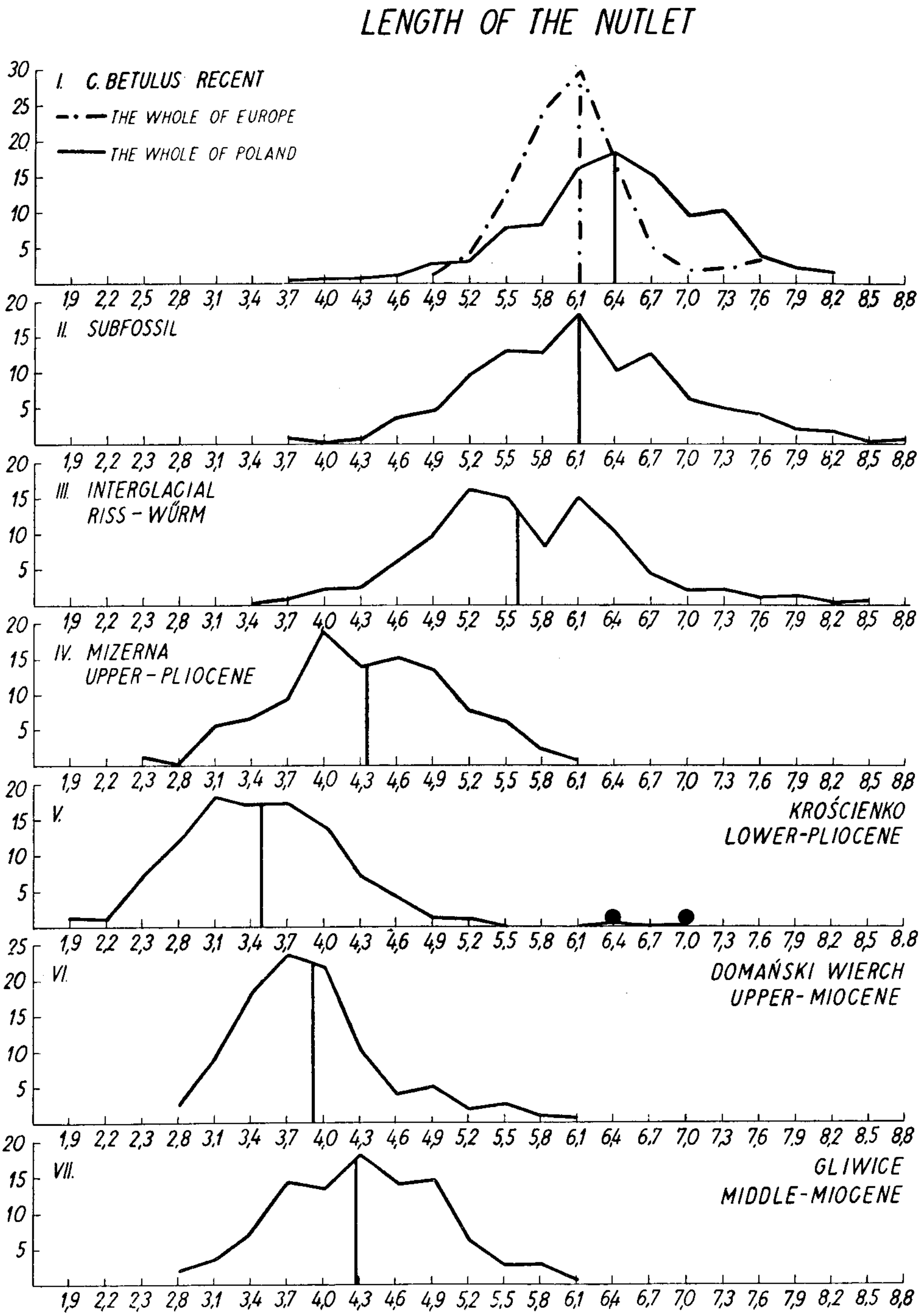
Fig. 7. Stosunek wielkości i kształtu orzeszków plioceńskich (linie łamane) do orzeszków współczesnych *Carpinus betulus*). I. pliocen górny w Mizernej, II. pliocen dolny z Krościenka

peated each time, of the standart deviation of the sample under examination to the standard deviation of the comparative unit ($\sigma_2 : \sigma_1$), similar to the adjustment on p. 10 of the value of the arithmetic means ($M_2 : M_1$). If the continuous and dotted angular lines coincide, the variability of both samples is the same. If the dotted angular line shifts to the right of the continuous angular line, the variability of the given character is greater in the sample compared than in the comparative unit, and vice-versa, if it is found on the left side the variability of the sample compared is smaller.

From graphs I and II in Fig. 7 it is seen that the nutlets from Mizerna and Krościenko were, as already mentioned, markedly smaller than the contemporary nutlets of *Carpinus betulus* (characters 1 and 2), while as regards the characters of size (4 — 7) there was no very evident difference between them. The Pliocene nutlets were comparatively narrower, since their breadth went into their length more times than in the recent nutlets (character 4). Although this was not accompanied by the apical sharpness so characteristic of the local samples of *Carpinus* (v. letters *x*, *y* in Figs. 1. 2 and 5), it cannot be said that it is impossible for these to be local samples of *Carpinus betulus*, since the differences between the sample compared and the comparative unit in character 7 from Mizerna and character 4 from Krościenko were so small that they lay within the limits of error. The local samples of the subfossil species *Carpinus betulus* and from the Later Riss-Würm Interglacial given in Fig. 5 sometimes differed much more in shape from the comparative unit than did the Pliocene samples from Mizerna and Krościenko, but none the less unmistakably belonged to *Carpinus betulus*.

In other Recent species of the genus *Carpinus*, which I examined morphologically and described in 1953, the shape of the fruits differed from the fossil nutlets from the Polish Pliocene. In two of them, *Carpinus cordata* and *C. japonica* the shape was so characteristic and different that it was immediately possible to exclude their presence at Mizerna and Krościenko. In five others, viz., *C. caroliniana, orientalis, laxiflora, Turczaninowii* and *Tschonoskii* each had its own characteristic feature. Some had sharp apices, others a large number of ribs, others were rather narrow in relation to their length. The nutlets from the Polish Pliocene could not have belonged to any of these species, nor yet could they be a mixture of several small-fruited species of the genus *Carpinus*, as then the apices of the mixture would not be so comparatively blunt and in this respect so little variable as in the samples from Mizerna and Krościenko. This possibility may therefore also be excluded. On the other hand, relying only on the shape of the nutlets, and so on characters 4 — 7, it would be possible to assume a mixture of the species *Carpinus betulus* and one or more small-fruited hornbeams, especially since the great variability in character 4 in the sample from Mizerna and in character 3 in the sample from Krościenko favours a mixture. This does not, however, explain why the difference in the dimensions of nutlets of the species *Carpinus betulus* and the small-fruited hornbeams here discussed suddenly disappeared during the Pliocene. (Fig. 6.)

In view of the impossibility of deciding from the characters taken into consideration whether the species *Carpinus betulus* grew in Poland during the Pliocene, my observations took another direction. I endeavoured to find some morphological feature of the species *C. betulus* which was not shared by the nutlets of other species, and which might be an indication that there were really nutlets of this species in the samples from the Pliocene.


LENGTH OF THE NUTLET
I. C. BETULUS RECENT
THE WHOLE OF EUROPE
THE WHOLE OF POLAND
II. SUBFOSSIL
III. INTERGLACIAL RISS - WÜRM
IV. MIZERNA UPPER - PLIOCENE
V. KROŚCIENKO LOWER-PLIOCENE
VI. DOMAŃSKI WIERCH UPPER- MIOCENE
VII. GLIWICE MIDDLE-MIOCENE

←

Fig. 8. Length of recent nutlets of *Carpinus betulus* (I) and of the fossil nutlets investigated (II — VII)
Fig. 8. Długość orzeszków *Carpinus betulus* (I) oraz zbadanych orzeszków kopalnych (II — VII)

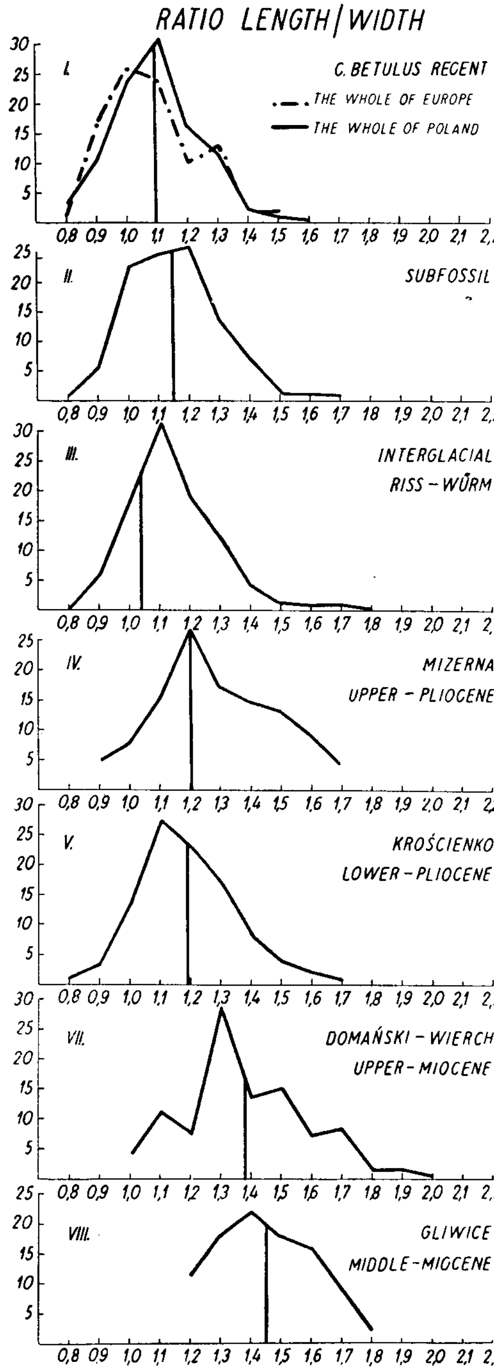
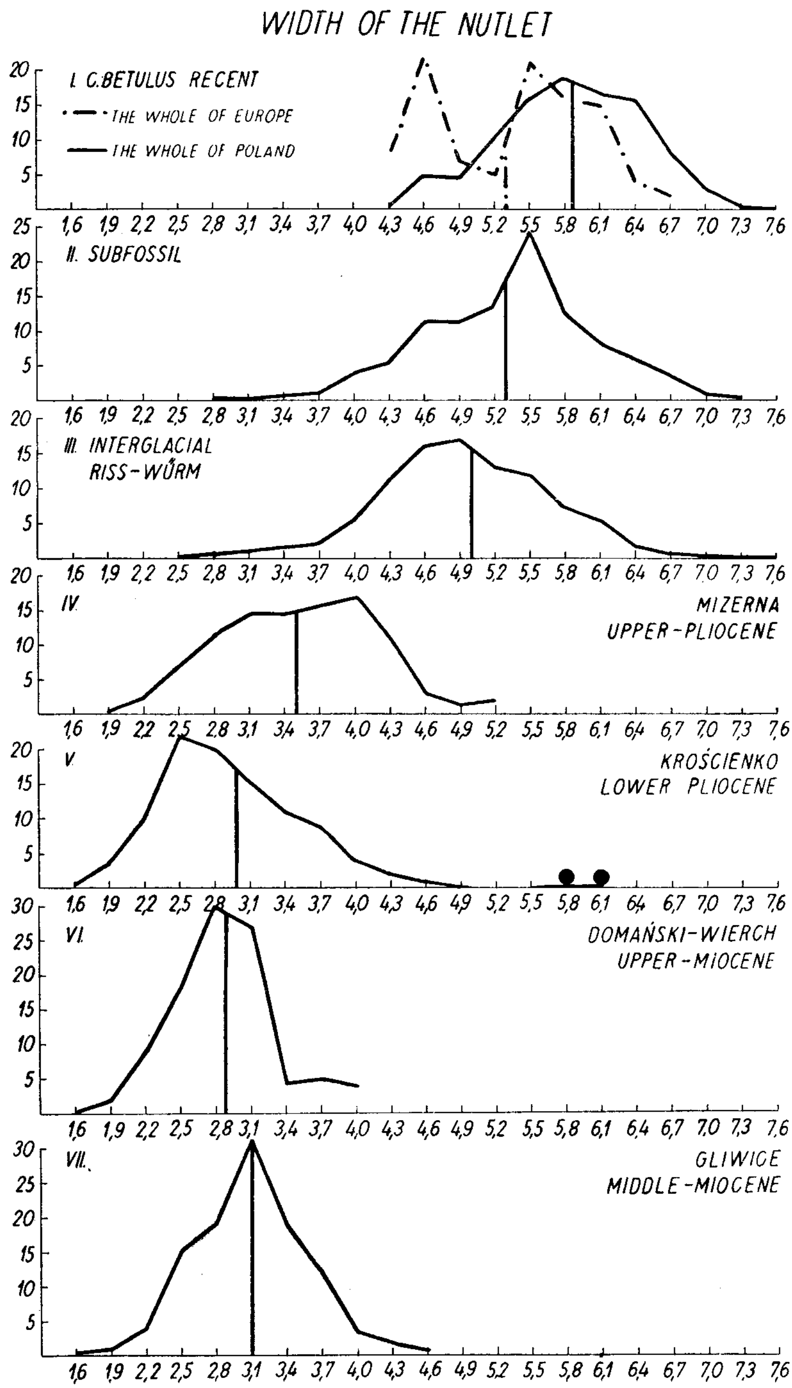


Fig. 9. The ratio of length to breadth in recent nutlets of *Carpinus betulus* (I) and in the fossil nutlets investigated (II — VII)
Fig. 9. Stosunek długości do szerokości współczesnych orzeszków *Carpinus betulus* (I) oraz zbadanych orzeszków kopalnych (II — VII)


WIDTH OF THE NUTLET
I. C.BETULUS RECENT
THE WHOLE OF EUROPE
THE WHOLE OF POLAND
II. SUBFOSSIL
III. INTERGLACIAL RISS-WÜRM
IV.
MIZERNA
UPPER-PLIOCENE
V.
KROŚCIENKO
LOWER PLIOCENE
VI.
DOMAŃSKI-WIERCH
UPPER-MIOCENE
VII.
GLIWICE
MIDDLE-MIOCENE
1,6 1,9 2,2 2,5 2,8 3,1 3,4 3,7 4,0 4,3 4,6 4,9 5,2 5,5 5,8 6,1 6,4 6,7 7,0 7,3 7,6

When analysing the results of measurements of recent hornbeams, I noticed that the species *C. betulus* has a large percentage of nutlets in which the length equals the breadth. Nutlets with a length-breadth ratio of 1.1 are most frequently met with in this species, while nutlets in which the length equals the breadth, and so with a length-breadth ratio of 1.0 amounted to 26 per cent in the samples of *Carpinus betulus* from Europe, and to 24 per cent in those from Poland, and so were about one-quarter. These figures are shown in Table 5.

In the local samples of *C. betulus* the percentage of nutlets of equal length and breadth depended on the type of nutlet. In a sample with narrow nutlets from Montech near Toulouse there were only 15 per cent, but in a sample with broad nutlets from Białowieża 25 per cent. As for other species of the recent genus *Carpinus*, nuts equal in length and breadth were found only in the species *C. caroliniana* (16 per cent), *C. Turczaninowii* (5 per cent), and *C. orientalis* (1 per cent).

I did not take into account the nutlets of *C. Tschonoskii*, as of this species I had only material from a single tree, cultivated in the Botanical Gardens at Kew and so not in its natural surroudings. These nutlets were very little variable, and the 12 per cent of nutlets in which the relation of length to breadth was 1 — 1.05 was a variability of the individual and not of the whole species.

In the remaining species all the nutlets were longer than broad, as may also be seen from Table 5.

Nutlets which were broader than long, with a length-breadth ratio of 0.8 or 0.9, were found only in *Carpinus betulus* and in a very small percentage in *C. caroliniana*, but in no other species. In Table 5 there are also given the percentages of pronouncedly narrow and long nutlets, with a length-breadth ratio of over 1.5. It follows from this that recent hornbeams may be divided as regards their nutlets into 3 groups:

1) *Carpinus betulus* and *C. caroliniana*, having a greater or smaller percentage of nutlets broader than they are long or markedly long and narrow.

2) *Carpinus Turczanowii*, *C. laxiflora* and possibly *C. Tschonoskii*, having no or at least very few markedly broad or markedly narrow nutlets.

3) *C. orientalis*, *C. cordata* and *C. japonica*, with a predominant percentage of nutlets narrow in relation to their length.

←

Fig. 10. Breadth of recent nutlets of *Carpinus betulus* (I) and of the fossil nutlets investigated (II — VII)

Fig. 10. Szerokość współczesnych orzeszków *Carpinus betulus* (I) oraz zbadanych orzeszków kopalnych (II — VII)

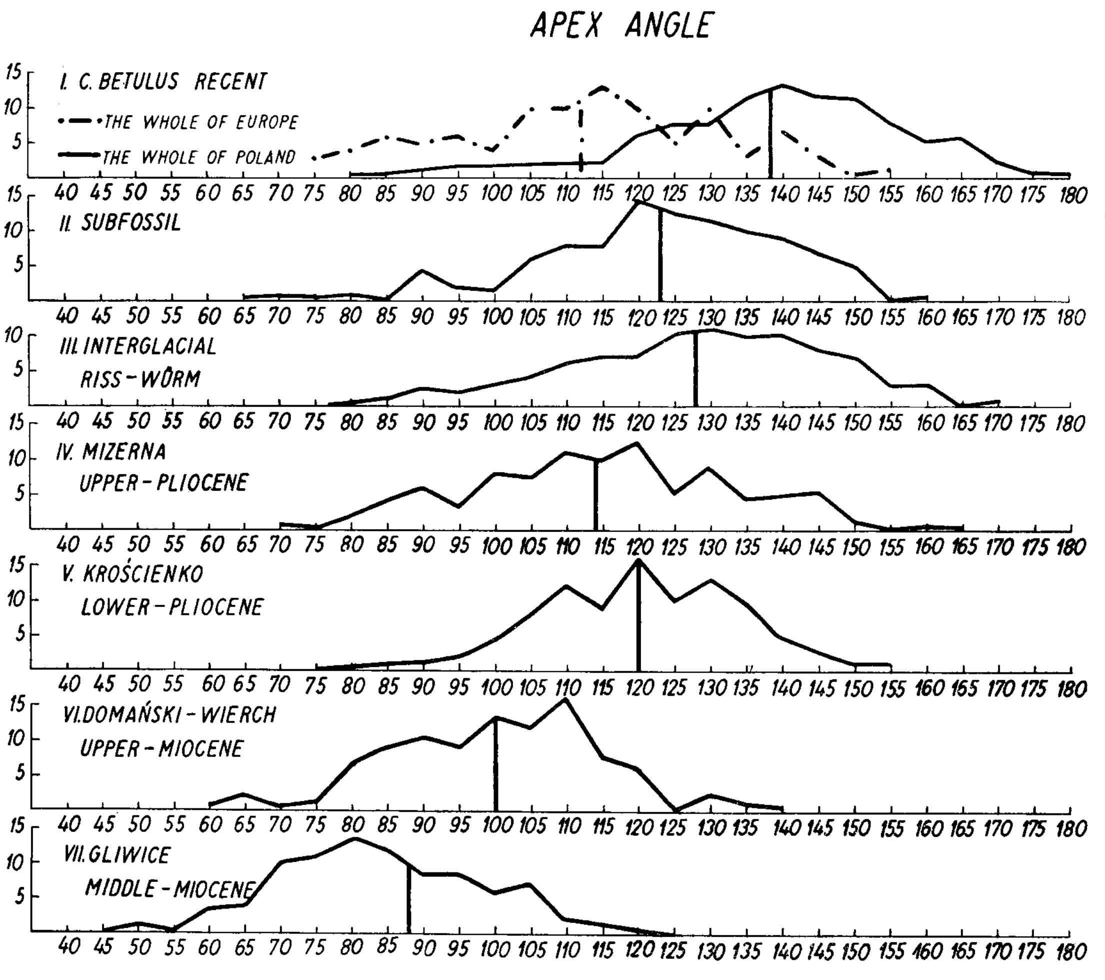


Fig. 11. The apical angle in recent nutlets of *Carpinus betulus* (I) and in the fossil nutlets investigated (II — VII)

Fig. 11. Kąt wierzchołka współczesnych orzeszków *Carpinus betulus* (I) oraz zbadanych orzeszków kopalnych (II — VII)

In the lower part of Table 5 I have put the percentages of markedly broad or markedly narrow nutlets found in the fossil samples. Each of these had the character of a local sample. The subfossil and Interglacial samples had a larger or smaller percentage of nutlets broader than they were long, or in which the breadth exceeded the length depending on whether the local sample contained a type of narrow nutlet or a type of broad nutlet. Beside these are given the percentages characteristic of the whole Holocene or Pleistocene era.

RATIO LENGTH/WIDTH
STOSUNEK DŁUGOŚCI DO SZEROKOŚCI

Recent nutlets / *Orzeszki współczesne*

No	Species and locality / *Gatunek i miejscowość*	Number of nutlets / *Liczba orzeszków*	0,8	0,9	1,0		1,4	1,5	1,6	1,7	1,8	1,9	2,0	2,1	2,2	2,3	0,8–0,9	1,5–2,3
1	Carpinus betulus. The whole of Europe / *Cała Europa*	100	—	9%	26%		13%	0%	1%	—	—	—	—	—	—	—	9%	1%
2	Carpinus betulus. The whole of Poland / *Cała Polska*	400	3%	11%	24%		2%	1%	0,2%	—	—	—	—	—	—	—	14%	1,5%
3	Carpinus betulus. Montech near Toulouse / *Montech k. Tuluzy*	100	—	1%	15%		3%	2%	2%	—	—	—	—	—	—	—	1%	4%
4	Carpinus betulus. Białowieża Forest / *Puszcza Białowieska*	80	—	11,5%	25%		—	2,5%	1,5%	—	—	—	—	—	—	—	11,5%	3%
5	Carpinus caroliniana	100	1%	2%	16%		12%	5%	1%	—	—	—	—	—	—	—	3%	6%
6	Carpinus Turczaninowii	100	—	—	5%		13%	1%	1%	—	—	—	—	—	—	—	—	2%
7	Carpinus Tschonoskii (Kew)	50	—	—	12%		—	—	—	—	—	—	—	—	—	—	—	—
8	Carpinus laxiflora	50	—	—	—		20%	—	—	—	—	—	—	—	—	—	—	—
9	Carpinus orientalis	100	—	—	1%		35%	28%	11%	2%	—	—	—	—	—	—	—	41%
10	Carpinus cordata	100	—	—	—		8%	24%	36%	19%	10%	1%	—	—	—	—	—	90%
11	Carpinus japonica	100	—	—	—		7%	3%	7%	20%	27%	25%	6%	2%	1%	1%	—	92%

Fossil nutlets / *Orzeszki kopalne*

No	Age / *Wiek*	Locality / *Miejscowość*	Number of nutlets / *Liczba orzeszków*	0,8	0,9	1,0		1,4	1,5	1,6	1,7	1,8	1,9	2,0	2,1	2,2	2,3	0,8–0,9	1,5–2,3
12	Holocene / *Holocen*	Roztoki	28	7%	—	—		10,7%	7%	—	3,5%	—	—	—	—	—	—	7%	10,5%
13	Holocene / *Holocen*	Krzeszów nad Sanem	130	—	6%	24%		8,4%	0,8%	1,5%	0,8%	—	—	—	—	—	—	6% }6,1%	3% }3,3%
14	Holocene / *Holocen*	Raków	50	—	6%	24%		—	—	—	—	—	—	—	—	—	—	6%	—
15	Interglaciale / *Interglacjał* Riss-Würm	Rumlówka	50	—	—	18%		14%	—	8%	2%	—	—	—	—	—	—	—	10%
16	Interglaciale / *Interglacjał* Riss-Würm	Nieciosy	19	—	15%	25%		—	—	—	—	—	—	—	—	—	—	15%	—
17	Interglaciale / *Interglacjał* Riss-Würm	Samostrzelniki	190	1%	7%	17%		3%	1,5%	—	0,5%	—	—	—	—	—	—	8% }6,5%	0,5% }3,8%
18	Interglaciale / *Interglacjał* Riss-Würm	Rusinowo	120	—	9%	17%		6%	3%	3%	2%	1%	—	—	—	—	—	9%	6%
19	Interglaciale / *Interglacjał* Riss-Würm	Dzbanki	150	—	3%	22%		1%	0,6%	—	—	—	—	—	—	—	—	3%	0,6%
20	Pliocene / *Pliocen*, upper / *górny*	Mizerna	200	—	5,5%	7,5%		14,5%	6,5%	4,5%	2%	—	—	—	—	—	—	5,5%	13%
21	Pliocene / *Pliocen*, lower / *dolny*	Krościenko	300	1%	3%	13%		8%	4%	2%	0,5%	—	—	—	—	—	—	4%	6,7%
22	Miocene / *Miocen*, upper / *górny*	Domański Wierch	160	—	—	4%		14%	15%	8%	8%	1,5%	1,5%	0,5%	—	—	—	—	34%
23	Miocene / *Miocen*, middl. / *środk.*	Gliwice	218	—	0,5%	1%		18%	18%	9%	6%	1,5%	1,5%	—	1,5%	0,5%	—	0,5%	38%

Let us now turn to the samples from the Pliocene. At Mizerna there were found 5.5 per cent, i. e. 11 nutlets broader than they were long. At Krościeńko there were 4 per cent, or also 11 nutlets photograph (see B in Plate I). Their dimensions differed; at Mizerna they were from 2.5 mm to 4.6 mm, and at Krościenko from 1.9 to 4 mm long. From Table 5, it would have to be assumed that all these nutlets belonged to the type *C. betulus* or perhaps *C. caroliniana.* In any case almost the whole of the sample from Mizerna and the greater part of the sample from Krościenko were composed of nutlets of *C. betulus* or *C. caroliniana* with a small admixture of other species, since only in this case would it be possible to find so high a percentage of nutlets broader than their length. *C. caroliniana* has already been excluded, as although the nutlets in the samples from Mizerna and Krościenko were more closely approximated to this species than to *C. betulus* in their dimensions, yet their shape was different. There remained therefore only one possibility, that mentioned in point 3 on page 21, viz., that in the Pliocene in Poland there grew a hornbeam with fruits exactly the same in shape as the recent *Carpinus betulus,* but much smaller.

It must now be considered which of the recent species of hornbeam might have been mixed with *C. betulus* in the Pliocene. It should be remembered that samples from Mizerna and Krościenko are fossil local samples. If we were to take up the attitude that a small-fruited species of the type *C. betulus* grew there, this could have had the same biological characteristics as the recent species *C. betulus,* i. e. in some places there should grow hornbeams with comparatively broad and blunt nutlets, and in others with narrow, sharp-ended nutlets. At Mizerna a fairly high percentage of broad nutlets, i. e. with a length-breadth ratio of 0.8 — 0.9 would give ewidence rather of the first type. In this case since up to 13 per cent of the nutlets were 1.5 — 2.3 times longer than their breadth we must accept an admixture of some species with long and narrow nutlets.

The percentage of particularly narrow nuts was smaller at Mizerna than at Krościenko, for it was only 6.5 per cent. The percentage of very broad nutlets was also comparatively small, 4 per cent. Here the admixtures might be suspected as belonging to the second group of nutlets, given on page 27, i. e. those hornbeams of which the nuts are neither markedly broad nor markedly narrow. This would agree with the determination of Professor Szafer, who presumed from the external appearance of the nutlets that the species *C. Tschonoskii* and *C. laxiflora* grew at Krościenko besides *C. betulus.*

When discussing the Pliocene hornbeams from Krościenko, only the

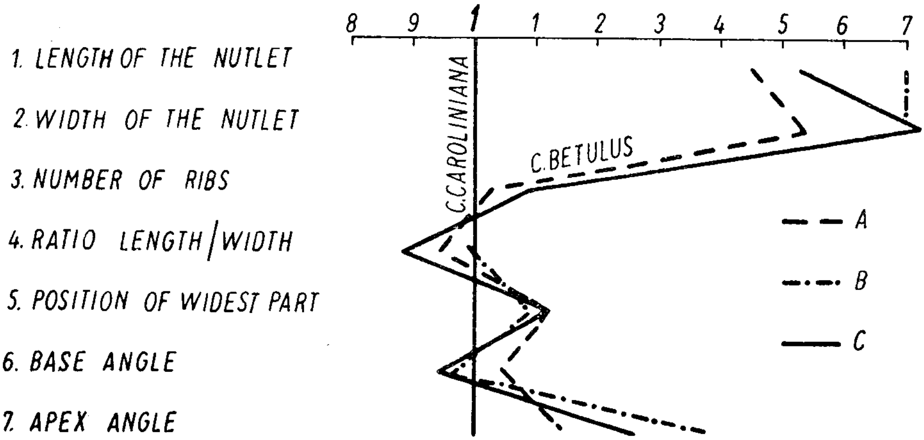


Fig. 12. The relation of size and shape in: A. a sample of *Carpinus betulus* from over the whole range, B. and C. two large nutlets found at Krościenko (v. Figs. 8 and 10 V) (angular lines), to *C. caroliniana* (vertical line)

Fig. 12. Stosunek wielkości i kształtu: A — próby *C. betulus* z całego zasięgu, B. i C — dwóch dużych orzeszków znalezionych w Krościenku (patrz ryc. 8 i 10. V.) (linie łamane) do *C. caroliniana* (linia pionowa)

population of nutlets which vary in length from 1.9 to 5.5 mm was taken into consideration, and for the time being two very much larger nutlets found amongst the others were passed over. One of them was 6.4 mm long and 6 mm broad, and the other 7.1 mm long and 5.9 mm broad (v. Tables 6,7). Both these nutlets were distant by more than three times the value of the standard deviation from the arithmetic means given for Krościenko in Tables 6 and 7, and so according to the law of three sigmas they did not belong to the population just mentioned. They have been marked on Graph III, Fig. 6. by means of large dots. During the measurements of the other characters these nutlets disappeared, as they did not differ in any way from the rest of the population except in their dimensions (Figs. 8 — 11 and Tables 6 — 12). These two nutlets, compared with the arithmetic means of another species, i.e. *Carpinus caroliniana,* had a line of shape exactly similar to that of *C. betulus*. I deliberately chose a species resembling *C. betulus* as closely as possible as regards shape as a unit of comparison in order to gain greater certainty that these two nutlets distinctly had the shape of those of *C. betulus* (Fig. 12, Plate I. F_4 — F_5).

The determination of the specific provenance of single specimens on the basis of other „line of shape" has already been tested in systematics. It was applied for the first time in Part III of my paper on the analysis of *Betula alba* L. on the basis of leaf-measurements (Jentys-Szaferowa 1951). In spite of the individual difference in shape between the two nutlets under discussion, of which one was only slightly longer than its breadth, and the second 1.2 times longer, their lines of shape, considered as the expression of the combination of characters distinguishing them, are exactly similar to that of *C. betulus* as compared with *C. caroliniana,* although (as already mentioned) these two species have approximately similar shape. Details relating to the shapes of Recent nutlets of these two species of hornbeam were given in the 1953 treatise.

The finding at Krościenko of two hornbeam nutlets from the Pliocene, not differing from the recent either in measurements or in shape, introduced a new problem into the history of the genus *Carpinus* in Poland. These nutlets were undoubtedly of the same age as the rest of the material found. The mode of flattening and the whole external appearance testified to this. One of the nutlets even had the perigone completely destroyed, so that it was not possible to count its ribs. There was therefore no question of their having got into the Pliocene loam as a result of contamination by recent material.

One of these fruits was of the same length as the *Carpinus betulus* nutlets most often found in Poland today, and the most often found in one of the local Interglacial samples (Rusinowo); the second was still larger, and both undoubtedly belonged to a population similar to the recent. In any case, if my evidence is correct that the small-fruited hornbeams from Mizerna and Krościenko, morphologically similar to the species *Carpinus betulus,* really belonged to this type, it would have to be assumed either that two species of hornbeam with fruits morphologically similar but differing in dimensions grew in the neighbourhood of Krościenko during the Pliocene, or that there grew only one species, but having small-fruited and large-fruited forms. This question will be discussed in detail in the following papers.

Summarizing the evidence given, it may be stated that:

1) In the Polish Pliocene there grew at Mizerna near Czorsztyn and at Krościenko on the Dunajec hornbeams with fruits exactly similar to those of the recent species *C. betulus,* but much smaller.

2) Besides the species mentioned, there existed as early as the Pliocene a hornbeam which did not differ either in dimensions or in shape of fruits from the recent species *C. betulus.*

3) Besides those two already mentioned there appeared in the Pliocene at Mizerna and Krościenko a small percentage of other species of the genus *Carpinus,* which do not grow in Poland today.

5. THE NUTLETS FROM THE MIOCENE

In order to characterize the nutlets found from the Polish Miocene, we must turn back to Tables 3 and 4, for the data relating to the samples of hornbeams from the Upper Miocene found on Domański Wierch in the dale of Nowy Targ, about 20 km from Mizerna (v. map in Fig. 4). This flora has not yet been elaborated, but the materials have already been collected and deposited in the Palaeobotanical Laboratory of the Botanical Institute, Polish Academy of Sciences. The second Miocene sample comes from the Upper Miocene at Gliwice, in Silesia, and has been elaborated by Professor W. Szafer. The report is in the press (Publications of the Geological Institute). Besides these, a few Miocene nutlets have been found by J. Zabłocki in the salt strata at Wieliczka (v. Plate I G — J).

In Tables 3 and 4 and in graphs VI and VII in Fig. 8 it may be seen that the length of the Miocene nutlets is distinctly greater than that of those from the Lower Pliocene at Krościenko. This is a further confirmation of what was written on page 7, that the time which the nutlets have lain in the earth has no effect on their dimensions.

The Miocene differ from the Pliocene nutlets not only in their dimensions, but also, and especially, in that they are markedly narrower in relation to their length and have pronouncedly sharp apices (Figs. 9 —

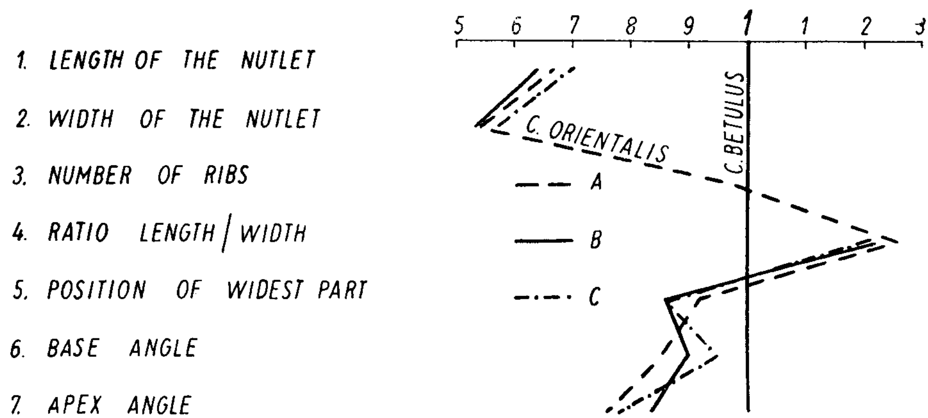


Fig. 13. The relation of size and shape in nutlets of C. *orientalis* (angular line A) and in two Miocene samples (angular lines B and C), to a sample of recent C. *betulus* (vertical line)

Fig. 13. Stosunek wielkości i kształtu orzeszków C. *orientalis* (linia łamana A) oraz z prób mioceńskich (linie łamane B i C) do próby współczesnego C. *betulus* (Linia pionowa)

— 11, graphs VI and VII). Both in dimensions and in shape, the Miocene nutlets are very similar to the contemporary species *Carpinus orientalis*, as is clearly seen in Fig. 13. J. Zabłocki, when elaborating the Miocene flora from Wieliczka also called attention to the similarity of the hornbeam nutlets found there to *C. orientalis* and described them under the name of *C. polonica Zabłocki.*

In the treatise: „The genus *Carpinus* in Europe in Palaebotanical Literature" (1958), I observed that so far no involucres of *Carpinus orientalis* from the Miocene have been found north of the Sudetic and Carpathian ranges. In the Miocene flora from Sośnica (Goeppert 1855, Krausel 1920), the findings of involucres of the genus *Carpinus* contained only the type *C. betulus* with a small admixture of the type *C. caroliniana*. The abundant appearance of the type *C. orientalis* in the Upper Miocene at Gliwice, in the Middle Miocene on Domański Wierch, and in the still older flora from Wieliczka, would throw an entirely new light on the history of the genus *Carpinus* in Europe. For this reason, I shall for the time being refrain from expressing my own opinion on the specific provenance of the nutlets from the Polish Miocene, returning to this question in the general discussion after carrying out anatomical and epidermal investigations.

6. SUMMARY OF THE INVESTIGATIONS ON THE MORPHOLOGY OF THE FOSSIL NUTLETS

As a result of biometric investigations on the fossil nutlets of the genus *Carpinus* in Poland, the following conclusions have been reached:

1) In the climatic optimum of the Holocene and Pleistocene, the species *Carpinus betulus* lived in Poland. The only difference between its fruits and those of the hornbeam now growing in Poland is that its nutlets were slightly narrower and more tapering.

2) In the Pliocene there lived in Poland a hornbeam with fruits of the type of *Carpinus betulus*, but much smaller than the recent. In their dimensions they approximated those of the present American species *C. caroliniana*. Together with this there grew, during the Polish Pliocene, a species which did not differ in any particular as regards the fruits from the recent *Carpinus betulus*. This species, however, appeared only sporadically. Besides these, there was an admixture of certain species associated with a warmer climate, which no longer grow in Poland. It was impossible to decide on the basis of their morfological appearence only — to which living species they correspond.

3) The hornbeams growing in Poland during the Miocene had nutlets

a little longer than the Lower Pliocene fruits, narrow and sharpended. These were very similar morphologically to the species *C. orientalis*. Their specific appurtenance cannot be determined without the investigations on their anatomy and on their epidermis, which will be described in the author's following papers.

LITERATURE CITED

Arnold C. A., 1947, An Introduction to paleobotany. New York and London, 1 — 433.

Bremówna M., Sobolewska M., 1950, Wyniki badań botanicznych osadów interglacjalnych w dorzeczu Niemna. (The results of botanical investigations of interglacial deposits in the Niemen Basis). Acta Geol. Polon. 1 (4) : 335 — — 364. Warszawa.

Bremówna M., 1953, Flora interglacjalna z Ciechanek Krzesimowskich (Interglacial flora from Ciechanki Krzesimowskie by Łączna). Acta Geol. Polon. 3 : 475 — 480, Warszawa.

Goeppert H. R., 1855, Die Tertiäre Flora von Schossnitz in Schlesien, 1 — 52, Görlitz.

Hopf M., 1955, Formveränderungen von Getreidekörnern beim Verkohlen. Ber. Deutsch Bot. Gesel. 68 (4) : 191 — 193, Stuttgart.

Jaroń Br., 1933, Analiza pyłkowa interglacjału z Żydowszczyzny koło Grodna. (Pollenanalytische Untersuchung des Interglazials von Żydowszczyzna bei Grodno in Polen. Roczn. Pol. Tow. Geolog. 9 : 147 — 183, Kraków.

Jentys-Szaferowa J., 1952, Analysis of the collective species *Betula alba* L. on the basis of leaves measurements. Part III. Determination on the basis of a single leaf. Bul. Acad. Pol. Sc. 1951 1 — 40, Cracovie.

Jentys-Szaferowa J., Białobrzeska M., 1953, Owoce rodzajów *Carpinus* i *Ostrya* (Fruits of the Genera *Carpinus* and *Ostrya*). Prace Inst. Geol. 10 : 5 — 35, Warszawa.

Jentys-Szaferowa J., 1958, Importance of Quaternary Materials for Research on the Historical Evolution of Plants. Ver. Geobot. Inst. Rübel, 34 : 67 — 73, Zürich.

Jentys-Szaferowa J., 1958, The Genus *Carpinus* in Europe in the Paleobotanical Literature (Rodzaj *Carpinus* w europejskiej literaturze paleobotanicznej). Monogr. Bot. 7 : 3 — 59, Warszawa.

Jentys-Szaferowa J., 1959, The Biometrical Method in Investigations of the Historical Evolution of Plants, Proceed. Int. Bot. Congr. 2 : 181, Montreal.

Jentys-Szaferowa J., 1959, A Graphical Method of Comparing the Shapes of Plants, Rev. Pol. Acad. Sc. 4 (1) : 9 — 38, Warszawa.

Jentys-Szaferowa J., 1959, Graficzeskoj metod sprawnienija form rastienii, Żurnał Pol. Akad. Nauk, 4 (1) : 9 — 38, Warszawa.

Jentys-Szaferowa J., 1959, Graficzna metoda porównywania kształtów roślinnych, Nauka Pol. 7 (3) : 79 — 110, Warszawa.

Kozłowska A., 1923, Flora międzylodowcowa z pod Rakowa (La flore interglaciaire des environs de Raków) Acta Soc. Bot. Pol. 1 (4) : 213 — 233, Warszawa.

Kräusel R., 1920, Die Pflanzen des Schlesichen Tertiärs. Jahrb. K. preuss. geol. Landesanst. 1917, 38 (2) : 1 — 338, Berlin.

Kräusel R., 1920, Nachträge zur Tertiärflora Schlesiens, I. ibidem 1918, 39 (1). — Berlin.

Kräusel R., 1921, Nachträge zur Tertiärflora Schlesiens, III. Über einige originale Goepperts und neuere Funde, ibidem 1919, 40 (1) : 363 — 433, Berlin.

Matlakówna M., 1925, Średniowieczne szczątki roślinne ze Żmudzi oraz niektóre zagadnienia pochodzenia zbóż. (Mittelalterliche Pflanzenreste aus Samogitien und einige Bemerkungen über die Abstammung der Getreidearten), Acta Soc. Bot. Pol. 3 (2) : 1 — 46, Warszawa.

Moldenhaver K., 1948, Główne zboża występujące w wykopaliskach Biskupina (Wielkopolska), The Prinzipal Cereals in the Biskupin Findings of the Early Iron-Age. Rocz. Nauk Roln. 51 : 306 — 312, Poznań.

Passendorfer E., Lilpop J. i Trela J. 1930, — O utworach interglacjalnych w Olszewicach pod Tomaszowem Mazowieckim (The interglacial formations in Olszewice near Tomaszów in central Poland). Sprawozd. Kom. Fizjogr. PAU 64 : 49 — 86, Kraków.

Piech K., 1929, Flora warstw międzylodowcowych okolicy Szczercowa, Dzbanek Kościuszkowskich i niektórych innych miejscowości w dorzeczu środkowej Warty (Badania nad dyluwium woj. Łódzkiego). Roczn. Pol. Tow. Geolog. 6 : 14 — 20, Kraków (1930).

Sobolewska M., 1956, Wyniki analizy pyłkowej osadów interglacjalnych z Olszewic. (Pollen analysis of the interglacial deposits of Olszewice on the Wieprz River. Pylcewoj analiz mieżlednikowych obrazowanij iz Olszewic na riekie Wieprz). Biul. Inst. Geolog. 100 : 271 — 289, Warszawa.

Stark P., Firbas F., Overbeck F., 1932, Die Vegetationsentwicklung des Interglazials von Rinnersdorf in der östlichen Mark-Brandenburg. Abh. Naturw. Ver. 28 : 105 — 130, Bremen.

Szafer Wł., 1926, O florze i klimacie okresu międzylodowcowego pod Grodnem (Über den Charakter der Flora und des Klimas der letzten Interglazialzeit bei Grodno in Polen). Sprawozdania Komisji Fizjograficznej PAU. 60 : 1 — 40, Kraków.

Szafer Wł., Jaroń Br., 1935, Plejstoceńskie jezioro pod Jasłem (Pleistocene Lake near Jasło in Poland). „Starunia" PAU. 8 : 1 — 20, Kraków.

Szafer Wł., 1939, Nowe znalezienia flory pleistoceńskiej w Polsce. — (Neue Fundorte der pleistocäne Flora in Polen). Biul. Inst. Geolog. 9 : 1 — 3, Warszawa.

Szafer Wł., 1946, 1947, Flora plioceńska z Krościenka n. Dunajcem I., II. (The Pliocene Flora of Krościenko in Poland I., II). Rozpr. Wydz. Mat. Przyr. PAU. 72 (1) : 1 — 162, (2) : 1 — 213, Kraków.

Szafer Wł., 1950, Domański Wierch. Przewodnik do wycieczki na Podhale XXII Zjazdu Polskiego Towarzystwa Geologicznego w r. 1949. (Guide d'excursion en Podhale de la XXII Réunion de la Société Géologique en 1949). Roczn. Polsk. Tow. Geol. 19 : 505 — 508, Kraków.

Szafer Wł., 1954, Plioceńska Flora okolic Czorsztyna i jej stosunek do Plejstocenu. (Pliocene Flora from the Vicinity of Czorsztyn (West Carpathians) and its Relationship to the Pleistocene). Prace Inst. Geol. 11 : 1 — 238, Warszawa.

Szafer Wł., Mioceńska Flora ze Starych Gliwic na Śląsku. (The Miocene Flora from Stare Gliwice in Silesia). Ibidem (in print)

Środoń A., 1950, Rozwój roślinności pod Grodnem w czasie ostatniego interglacjału. (The development of vegetation in the Grodno area during the last interglacial period) (Masovien II), Acta Geolog. polon. 1 : 365 — 400, Warszawa.

Trela J. 1930, Analiza pyłkowa utworów międzylodowcowych w Olszewicach (Pollen analysis of the interglacial formations in Olszewice) 64 : 77 — 86.

Trela J., 1935, Interglaciał w Samostrzelnikach pod Grodnem (Interglazial in Samostrzelniki bei Grodno in Polen) „Starunia" 9 : 1 — 8, Kraków.

Walton J., 1936, On the factors which Influence the External. Form of Fossil Plants, Royal. Soc. Lond., Biol. Sc., 226 (535) : 219 — 237, London.

Zabłocki J., 1927, Tertiäre Flora des Salzlagers von Wieliczka Erster Teil. Acta Soc. Bot. Pol. 5 (1) : 174 — 208, Warszawa.

Zabłocki J., 1930, Tertiäre Flora des Salzlagers von Wieliczka (Zweiter Teil.). Acta Soc. Bot. Pol. 7 (1) : 139 — 163, Warszawa.

Zabłocki J., 1930, Flora kopalna Wieliczki na tle ogólnych zagadnień Paleobotaniki Trzeciorzędu. (Die Fossile Flora von Wieliczka und die Allgemeinen Probleme der Paleobotanik des Tertiärs). Acta Soc. Bot. Pol. 7 (2) : 215 — 240, Warszawa.

STRESZCZENIE

1. WSTĘP

Morfologiczne badania nad kopalnymi orzeszkami rodzaju *Carpinus* są pierwszą częścią historii rodzaju *Carpinus* w Polsce, opartej na badaniach owoców kopalnych, a obejmującej okres od miocenu po dzień dzisiejszy. W drugiej części, którą ogłoszę niebawem, opiszę badania anatomiczne nad tym samym materiałem, zaś w trzeciej badania nad skórką perigonu orzeszków. Część ta obejmie zarówno materiały kopalne, jak i współczesne, w rozprawie z r. 1953 nie była bowiem uwzględniona budowa epidermy orzeszków u dziś żyjących gatunków grabu. W każdej z tych części będę się starała wyjaśnić historię rodzaju *Carpinus* w Polsce opierając się na innej metodzie. Dopiero po tak szczegółowej analizie kopalnych orzeszków postaram się wyciągnąć wnioski ogólne, wiążąc je z wynikami badań nad historią rodzaju *Carpinus* w Europie opisaną w r. 1958.

Aby odróżnić zmiany wywołane fosylizacją od istotnych zmian morfologicznych i anatomicznych, jakie zachodziły w orzeszkach rodzaju *Carpinus* w miarę następujących po sobie epok geologicznych, przeprowadzałam wszystkie moje badania idąc od materiałów najmłodszych do najstarszych. Po zbadaniu orzeszków współczesnych *Carpinus betulus* badałam przeto materiały holoceńskie, co do których miałam pewność, że należały do tego samego gatunku. Następnie analizowałam materiały z młodszego, potem ze starszego interglacjału, określając zmiany, jakie występowały na owocach *C. betulus* wskutek coraz dłuższego leżenia w ziemi. Dało to możność wyodrębnienia cech gatunkowych, które pozostały w czasie fosylizacji nie zmienione. Dopiero na podstawie zmian w tych cechach można było orzekać o istotnych zmianach kształtu lub budowy orzeszków grabu i próbować odtworzyć jego historię i ewolucję na terenie Europy środkowej.

2. KRYTYCZNE UWAGI O MATERIALE I METODZIE

Przystępując do tak trudnego zadania, jakim była próba uchwycenia zmian w orzeszkach kopalnych w czasie ubiegłych epok geologicznych, musiałam zastosować jak najdalej idący krytycyzm zarówno w stosunku do materiałów wybranych do badań, jak i w stosunku do metod, aby zmniejszyć o ile się tylko dało źródło błędów. Zasadnicze znaczenie miało znalezienie odpowiedzi na dwa pytania, a mianowicie: 1) czy wskutek długotrwałego leżenia w ziemi zmieniają się rozmiary szczątków kopalnych, oraz 2) czy fosylizacji towarzyszy zmiana kształtu?

Botanicy i archeologowie badający zboża kopalne wiedzą, że należy je porównywać nie z współczesnymi normalnymi, ale ze zwęglonymi ziarniakami zbóż. Zwęgleniu towarzyszy bowiem zmiana rozmiarów i kształtu (Matlakówna 1925, Moldenhaver 1948, Hopf 1955). Podobnie zachowują się spalone orzeszki grabu (patrz tabela na s. 6). Zjawiska tego, kiedy mogła nastąpić swobodna zmiana kształtu, nie można jednak porównywać do procesów zwęglenia, które odbywają się w ziemi przy coraz większym ucisku narastających warstw. Paleobotanicy są zgodni co do tego, że w powyższych warunkach ulega stałemu zmniejszeniu jedynie grubość szczątka (Walton 1936, Arnold 1947). Toteż rozmiary i kształt obrysu poziomo leżących w ziemi orzeszków grabu powinny być zbliżone do obrysu, jaki miały one w stanie żywym. Po wysuszeniu mogą się ich rozmiary zmniejszyć, ale nie więcej, niż o kilka procent. Różnice w wymiarach kopalnych orzeszków grabu, mierzonych w stanie suchym i mokrym zawiera tabela na s. 8. Wpływ na zwiększenie rozmiarów kopalnych owoców ma również długotrwałe przechowywanie w glicerynie.

Po zrobieniu szeregu doświadczeń doszłam do wniosku, że moje pomiary będą obciążone najmniejszym błędem, jeżeli wszystkie orzeszki kopalne będą mierzone w stanie suchym.

Kształt orzeszków kopalnych określałam na podstawie szczegółowych pomiarów następujących cech: (porównaj Szaferowa i Białobrzeska 1953)

1. Długość orzeszków
2. Szerokość orzeszków
3. Liczba żeberek
4. Stosunek długości do szerokości orzeszków
5. Położenie najszerszej części w %% długości
6. Kąt podstawy
7. Kąt wierzchołka

Liczby 1 — 7 zamieszczone pionowo na fig. 1, 2, 5, 7, 12 i 13 oznaczają zawsze powyższe cechy w tej samej kolejności. Pomiary wykonywano na obrysach orzeszków siedmiokrotnie powiększonych. Otrzymywano je obrysowując cień orzeszków, rzucony na papier za pośrednictwem aparatu do powiększeń fotograficznych.

Dalsza rzecz, nad którą trzeba było się zastanowić, miała aspekt biologiczny. Chodziło o to, że orzeszki kopalne, na których oparłam swoje badania, miały charakter prób lokalnych. Każda z nich była złożona z okazów pochodzących niechybnie z wielu drzew i z wielu pokoleń, ale z lasów rosnących stosunkowo niedaleko od miejsca znalezienia flory kopalnej. Sposób zachowania większości materiałów świadczył bowiem o bliskim transporcie. Dla oceny i klasyfikacji tych lokalnych prób kopalnych trzeba poznać właściwości prób lokalnych współczesnych orzeszków *Carpinus betulus* oraz ich stosunek do próby tegoż gatunku z całego zasięgu.

W rezultacie badań opisanych na s. 10 — 12 i popartych tabelą 1 oraz fig. 1, 2 i 3 doszłam do wniosku, że gatunek *Carpinus betulus* ma na całym obszarze swego zasięgu tę właściwość, że w jednych terenach występują okazy o owocach wąskich i stosunkowo ostro zakończonych, zaś w innych o owocach stosunkowo szerokich i tępych. Opis zastosowanej tu metody graficznej porównywania kształtów można znaleźć w moich rozprawach z r. 1953 i 1959.

Biorąc pod uwagę powyższe krytyczne rozważania, postanowiłam oprzeć badania morfologiczne kopalnych orzeszków grabu na następujących założeniach:

1. Kopalne orzeszki rodzaju *Carpinus* są w chwili wydobycia z ziemi porównywalne ze współczesnymi pod względem rozmiarów oraz kształtu swego obrysu.

2. Po wysuszeniu ulegają kopalne orzeszki nieznacznemu zmniejszeniu rozmiarów, któremu nie towarzyszy zmiana kształtów.

3. Kopalne orzeszki grabów pochodzące z jednej miejscowości należy traktować jako próbę lokalną. Dopiero na podstawie szeregu prób lokalnych można wnioskować o kształcie orzeszków, jakie miały gatunki grabu w danej epoce geologicznej.

3. BADANIA BIOMETRYCZNE NAD ORZESZKAMI Z CZWARTORZĘDU

Badania nad kształtem i zmiennością orzeszków z czwartorzędu oparłam na szeregu prób orzeszków współczesnych gatunku *Carpinus betulus*, na trzech próbach orzeszków subfosylnych oraz na 5 próbach pochodzących z interglacjału eemskiego.

Analiza biometyczna tych prób oraz ich porównanie jest opisane na s. 15 — 17 i poparte tabelami 2 — 4 oraz fig. 4 i 5. Szczegółowe wyniki pomiarów znajdują się na tabelach 6 — 12.

Na podstawie przeprowadzonych badań biometrycznych stwierdziłam, że:

1. W optimum klimatycznym holocenu i w plejstocenie rósł w Polsce gatunek *Carpinus betulus* nie różniący się od współczesnego rozmiarami orzeszków.

2. Średni kształt powyższych orzeszków był bardziej zbliżony do współczesnych orzeszków z próby z całej Europy niż do próby z całej Polski, to znaczy były one stosunkowo węższe i ostrzej zakończone, niż dziś żyjące w Polsce.

3. *Carpinus betulus* żyjący w wymienionych epokach geologicznych miał taką samą lokalną zmienność morfologiczną orzeszków, co dzisiejszy.

4. ORZESZKI Z PLIOCENU

Z pomiarów wykonanych w r. 1953 wynikło, że najpewniejszą cechą morfologiczną, na podstawie której można odróżnić orzeszki gatunku *C. betulus* od innych współczesnych gatunków grabu, była ich długość. Miałam przeto nadzieję, że po wykonaniu pomiarów orzeszków z pliocenu będzie można przynajmniej oddzielić gatunek *Carpinus betulus* od innych gatunków grabów kopalnych, opisanych z tego okresu w Polsce. W przypadku mieszaniny powinnam była bowiem otrzymać dwuwierzchołkową krzywą długości. Jak widać z fig. 6 krzywe długości orzeszków z Mizernej i z Krościenka nie tylko nie są dwuwierzchołkowe, ale nie dają nawet podstawy do twierdzenia, że w tych okresach rósł w Polsce gatunek typu *betulus*. Linie kształtu orzeszków znalezionych w Mizernej i w Krościenku świadczą jednak wyraźnie o podobieństwie morfologicznym orzeszków plioceńskich do orzeszków *betulus* (fig. 7). Orzeszki kopalne były mniejsze (cechy 1 i 2), ale różniły się mniej od średnich *C. betulus* z całego zasięgu (linia prosta), niż niektóre współczesne próby lokalne tego gatunku (porównaj fig. 1 i 2). Podobieństwo orzeszków plioceńskich do współczesnego *C. betulus* widać również na fig. 9 i 11.

Wielka zmienność owocków z Mizernej w cesze 4 tj. w stosunku długości do szerokości orzeszka oraz owocków z Krościenka w cesze 3, tj. w liczbie żeberek (fig. 7) świadczy, że mamy tam prawdopodobnie do czynienia nie z 1 gatunkiem, ale z mieszaniną grabu typu *C. betulus* z jakimś innym grabem małoowockowym. W takim jednak razie trzeba jednak przyjąć, że plioceński grab typu *C. betulus* miał znacznie mniejsze orzeszki niż dzisiejszy.

Aby potwierdzić przypuszczenie, że plioceński drobnoowocowy grab należy rzeczywiście do typu *C. betulus,* szukałam u tego gatunku jakiejś właściwości morfologicznej, której nie mają inne graby. Właściwość tę znalazłam w cesze 4, tj. w stosunku długości do szerokości orzeszków. Pokazało się, że jedynie u gatunku *C. betulus* spotykamy duży procent (do 26%) orzeszków równie szerokich jak długich oraz orzeszki szersze od swej długości (tabela 5). Pomiędzy innymi współczesnymi gatunkami jedynie *C. caroliniana* ma w małym stopniu tę właściwość, u innych gatunków nie spotkałam nigdy orzeszków szerszych niż długich (por. Szaferowa i Białobrzeska 1953).

Graby subfosylne i interglacjalne były pod względem tej właściwości zupełnie podobne do współczesnego *C. betulus* (tabela 5, nr 12 — 19). Co do orzeszków z pliocenu, to 5,5% orzeszków szerszych od długości w próbie Mizernej oraz 4% z próby w Krościenku świadczą o tym, że próby te nie należały w 100% do gatunku *C. betulus,* ale że znajdował się w nich, szczególnie w próbie z Krościenka pewien procent innych gatunków grabu. Niemniej procent typu *C. betulus* musiał tam być wysoki. Istotna różnica między orzeszkami z pliocenu a współczesnymi leżała tylko w rozmiarach.

Wynik opisanego wyżej rozumowania zgadza się w zupełności z wyrażonym poprzednio przypuszczeniem.

Między małymi owocami grabów z Krościenka znalazłam dwa orzeszki różniące się wyraźnie wielkością (fig. 6, 8 i 10). Były one zarówno pod względem rozmiarów jak kształtu zupełnie podobne do owoców współczesnego *Carpinus betulus.* (fig. 12). Były jednak one w porównaniu z resztą próby z Krościenka tak duże, że opierając się na prawie 3 sigma trudno było je zaliczyć do tej samej populacji co resztę materiału z Krościenka. Natomiast zmieściłyby się one w populacji grabów z Mizernej. Świadczy to o tym, że oprócz grabów typu *C. betulus* o drobnych owocach rosły w polskim pliocenie graby o owocach takich samych jak dziś. W pliocenie dolnym występowały one prawdopodobnie sporadycznie. W pliocenie górnym nie stwierdziłam ich obecności.

W interglacjale Riss-Würm nie było już formy drobnoowockowej, widocznie graby te były mniej odporne i wyginęły, została jedynie forma o dużych owocach, która żyje u nas do dziś.

W rezultacie badań nad orzeszkami z pliocenu można stwierdzić że:

1. W polskim pliocenie rósł grab typu *C. betulus*, ale o mniejszych niż dziś owocach.

2. Obok wymienionego występował w małej ilości grab o owocach identycznych, jak współczesny *C. betulus*.

3. Poza powyższymi żyły w Polsce w pliocenie w małej domieszce inne gatunki rodzaju *Carpinus*, które nie rosną tam dzisiaj.

Badając orzeszki rodzaju *Carpinus* z pliocenu nie uwzględniłam drobnych owocków opisanych przez W. Szafera jako „*Carpinus minima*" (Szafer 1946, 1954). Jak już pisałam w r. 1958 (s. 5) mają one inną budowę anatomiczną, niż orzeszki rodzaju *Carpinus*. Owoce „*Carpinus minima* Szafer" opiszę szczegółowo w osobnej rozprawie.

5. ORZESZKI Z MIOCENU

Orzeszki mioceńskie znalezione w Polsce były dłuższe, niż owocki z dolnego pliocenu (tabela 3 i 4 oraz fig. 8). Były też znacznie węższe i miały bardziej ostre wierzchołki (fig. 9 i 11). Były one podobne zarówno wielkością jak i kształtem do orzeszków współczesnego gatunku *C. orientalis* (fig. 13). Ponieważ jednak w Polsce znaleziono dotychczas liczne mioceńskie okrywy typu *C. betulus*, nie znaleziono zaś zupełnie okryw typu *C. orientalis* (J. Szaferowa 1958), przeto wstrzymuję się na razie od wyrażenia zdania co do przynależności gatunkowej orzeszków grabu z polskiego miocenu, zostawiając rozstrzygnięcie sprawy do czasu otrzymania wyników badań nad budową anatomiczną owoców oraz nad charakterem ich epidermy.

CONTENTS

Plate 1

A_1 — A_2 A fruit of *Carpinus betulus*-type from the Upper Pliocene at Mizerna. On the cross-section of this fruit one can see that it was compressed parallel to the long axis

B A fruit of *Carpinus betulus*-type from the Upper Pliocene from Mizerna — broader than long

C — H The scale of the variability of length of fossil *Carpinus*-fruits from Poland. From each geological epoch there were chosen: the shortest, the mean and the longest fruit

C_1 — C_3 Subfossil fruits of Carpinus betulus

D_1 — D_3 Fruits of *Carpinus betulus* from the Interglacial Riss-Würm

E_1 — E_3 Fruits of *Carpinus species* from the Upper Pliocene at Mizerna

F_1 — F_3 Fruits of *Carpinus species* from the Lower Pliocene at Krościenko: the shortest, the mean and the longest fruit, belonging to the continuous variability of the sample (see Table 6)

F_4 — F_5 Two big fruits of the type *Carpinus betulus* found in the Lower Pliocene at Krościenko (see Table 6)

G_1 — G_3 Fruits of *Carpinus species* from the Upper Miocene at Domański Wierch

H_1 — H_3 Fruits of *Carpinus species* from the Middle Miocene at Gliwice

J_1 — J_5 Fruits of *Carpinus polonica* Zabłocki from the Lower Miocene at Wieliczka

Tablica 1

A_1 — A_2 Orzeszek typu *Carpinus betulus* z górnego pliocenu w Mizernej. Na przekroju widać, że orzeszek został spłaszczony wzdłuż swojej długiej osi

B Orzeszek typu *Carpinus betulus* z górnego pliocenu w Mizernej szerszy od swej długości

C — H Skala zmienności długości kopalnych orzeszków grabu w Polsce. Z każdej epoki geologicznej wybrano najkrótszy, średni i najdłuższy orzeszek

C_1 — C_3 Subfosylne orzeszki *Carpinus betulus*

D_1 — D_3 Orzeszki *Carpinus betulus* z interglacjału Riss-Würm

E_1 — E_3 Orzeszki rodzaju *Carpinus* z górnego pliocenu w Mizernej

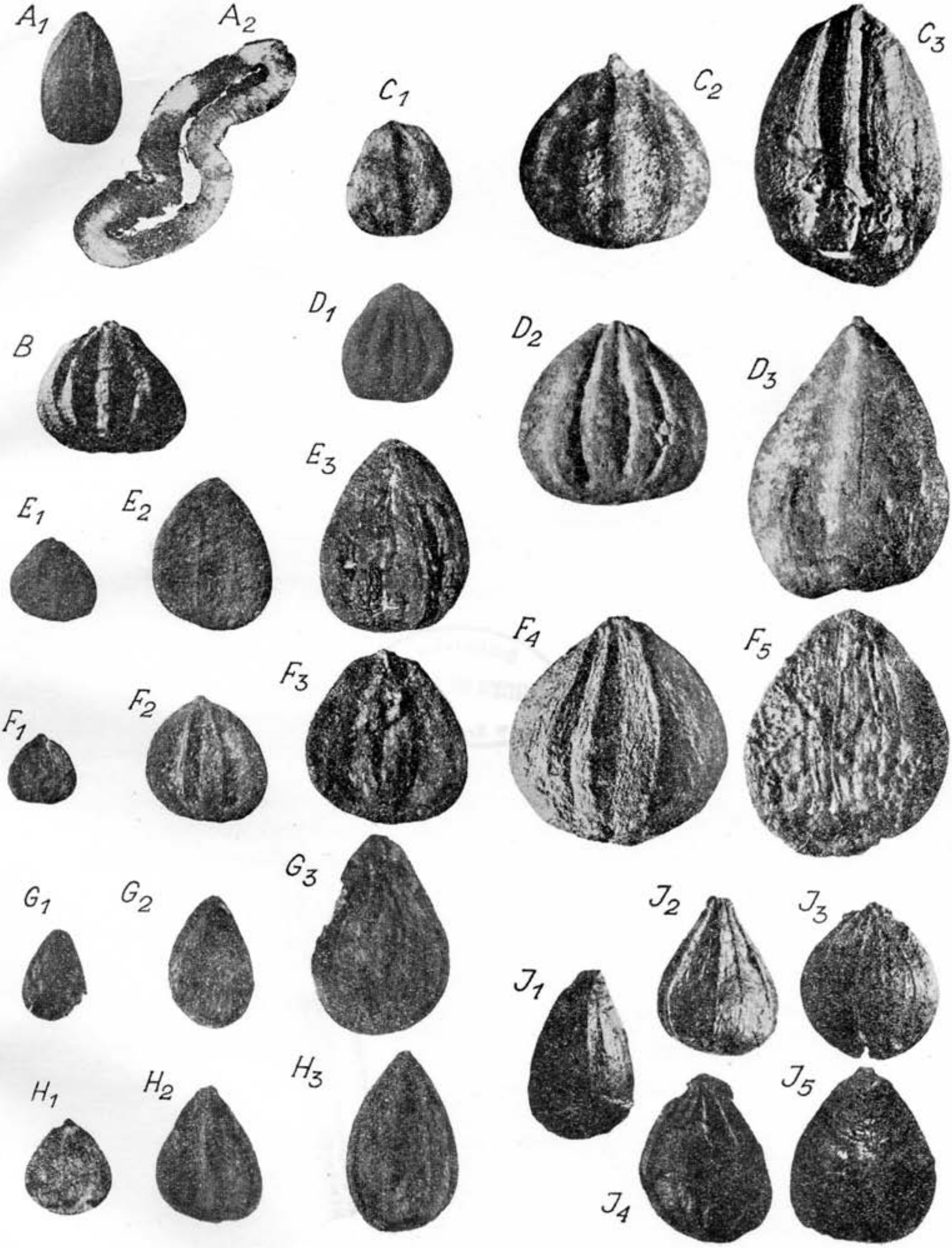
F_1 — F_3 Orzeszki rodzaju *Carpinus* z dolnego miocenu w Krościenku, najmniejszy, średni i największy, należące do zmienności ciągłej w danej próbie (patrz tabela 6)

F_4 — F_5 Dwa duże orzeszki typu *Carpinus betulus*, znalezione w dolnym pliocenie w Krościenku (patrz tabela 6)

G_1 — G_3 Orzeszki rodzaju *Carpinus* z górnego miocenu na Domańskim Wierchu

H_1 — H_3 Orzeszki rodzaju *Carpinus* z środkowego miocenu w Gliwicach

J_1 — J_5 Orzeszki *Carpinus polonica* Zabłocki, znalezione w dolnym miocenie w Wieliczce


A1
A2
C1
C2
C3
B
D1
D2
D3
E1
E2
E3
F1
F2
F3
F4
F5
G1
G2
G3
H1
H2
H3
J1
J2
J3
J4
J5

1. LENGTH OF NUTLETS
DŁUGOŚĆ ORZESZKÓW

Age *Wiek*		No	Locality *Miejscowość*	Number of nutlets *Liczba orzeszków*	1,9	2,2	2,5	2,8	3,1	3,4	3,7	4,0	4,3	4,6	4,9	5,2	5,5	5,8	6,1	6,4	6,7	7,0	7,3	7,6	7,9	8,2	8,5	8,8	min – max	M ± m	σ	v
Holocene *Holocen*	Recent *Współczesne*	1	Carpinus betulus: The whole of Europe *Cała Europa*	100											1	4	13	24	30	16	5	2	2	3					5,00 – 7,75	6,06 ± 0,05	0,51	8,40
		2	Carpinus betulus: The whole of Poland *Cała Polska*	400							1	1	1	3	10	13	30	31	63	72	62	39	45	15	8	6			3,80 – 8,30	6,44 ± 0,04	0,75	11,64
		3	Carpinus betulus: Białowieża Forest *Puszcza Białowieska*	80												2	11	11	25	15	7	5	2	1	1				5,12 – 8,00	6,20 ± 0,06	0,53	8,54
		4	Carpinus betulus: Montech near Toulouse *Montech k. Tuluzy*	100										2	6	14	18	18	20	9	5	4	3	1					4,75 – 7,62	5,85 ± 0,06	0,62	10,59
	Subfossil *Subfosyl.*	5	Roztoki	28										1	1	2	1	0	6	2	4	4	1	4	1	1			4,75 – 8,25	6,55 ± 0,17	0,90	13,74
		6	Krzeszów	130							1	0	1	4	8	14	20	17	15	13	16	5	7	4	2	2	0	1	3,70 – 8,70	6,19 ± 0,05	0,51	9,69
		7	Raków	50										2	0	3	5	8	16	5	5	3	2	0	1				4,62 – 7,87	6,11 ± 0,09	0,64	10,47
Plejstocene *Plejstocen*	Riss-Würm	8	Rumlówka	50												1	2	3	8	12	9	6	2	2	4	0	1		5,12 – 8,50	6,63 ± 0,09	0,68	10,25
		9	Nieciosy	19											1	0	4	1	7	3	0	1	1	0	1				5,00 — 8,00	6,14 ± 0,15	0,68	11,07
		10	Samostrzelniki	190								6	7	13	30	28	25	12	32	20	6	1	5	3	1	1			3,90 – 8,10	5,57 ± 0,06	0,83	14,90
		11	Rusinowo	120							3	4	4	11	8	18	17	14	16	16	3	2	3	1					3,80 – 7,60	5,55 ± 0,07	0,82	14,70
		12	Dzbanki	150						1	2	1	2	9	16	41	33	15	18	7	3	1	0	0	1				3,40 – 8,00	5,42 ± 0,05	0,63	11,43
	Mindel-Riss	13	Olszewice	7											2	1	1	2	0	1									4,80 – 6,50	5,51 —	—	—
		14	Żydowszczyzna	7								3	0	3	1														4,00 – 4,90	4,30 —	—	—
		15	Ciechanki	5								1	1	0	2	0	0	0	1										4,00 – 6,00	4,84 —	—	—
Pliocene *Pliocen*	upper *górny*	16	Mizerna (The well) *(Studnia)*	19				2	3	2	1	2	2	1	3	3													2,90 – 5,20	4,04 ± 0,19	0,84	20,79
		17	Mizerna (The main layer) *(Główny pokład)*	200			2	0	11	14	19	39	25	29	28	17	10	5	1										2,40 – 6,00	4,35 ± 0,05	0,69	15,86
	lower *dolny*	18	Krościenko	300	2	3	20	35	55	51	50	42	22	13	3	2	0	0	0	1	0	1							1,80 – 7,10	3,49 ± 0,04	0,66	18,91
Miocene *Miocen*	upper *górny*	19	Domański Wierch	160				4	14	29	38	35	16	7	8	3	4	1	1										2,80 – 6,00	3,89 ± 0,04	0,62	19,93
	middl. *środk.*	20	Gliwice	225				5	8	16	33	31	41	32	33	13	6	6	1										2,80 – 6,20	4,29 ± 0,04	0,67	15,60
		21	Wieliczka	4									1	2	1														4,40 – 4,90	4,67 —	—	—

Table 7
Tabela 7

2. WIDTH OF NUTLETS
SZEROKOŚĆ ORZESZKÓW

Age *Wiek*		No	Locality *Miejscowość*	Number of nutlets *Liczba orzeszków*	1,6	1,9	2,2	2,5	2,8	3,1	3,4	3,7	4,0	4,3	4,6	4,9	5,2	5,5	5,8	6,1	6,4	6,7	7,0	7,3	7,6	min – max	M ± m	σ	v
Holocene *Holocen*	Recent *Współczesne*	1	*Carpinus betulus*: The whole of Europe *Cała Europa*	100										8	22	7	5	21	16	15	4	2				4,25 – 6,75	5,34 ± 0,06	0,65	12,17
		2	The whole of Poland *Cała Polska*	400						1	0	0	0	1	19	18	41	64	76	69	64	32	12	2	1	3,20 – 7,60	5,85 ± 0,03	0,62	10,59
		3	Białowieża Forest *Puszcza Białowieska*	80										3	5	8	6	19	16	16	3	3	1			4,25 – 7,12	5,59 ± 0,06	0,58	10,37
		4	Montech near Toulouse *Montech k. Tuluzy*	100									2	6	28	20	19	13	8	4						4,00 – 6,25	5,02 ± 0,05	0,48	9,56
	Subfossil *Subfosyl.*	5	Roztoki	28							1	0	2	0	1	7	2	4	2	4	3	1	1			3,50 – 6,87	5,41 ± 0,16	0,85	15,71
		6	Krzeszów	130					1	0	0	2	4	10	16	13	18	31	17	6	6	5	0	1		2,80 – 7,20	5,27 ± 0,06	0,73	13,85
		7	Raków	50									2	1	6	3	7	14	6	6	3	1	1			4,00 – 6,87	5,45 ± 0,09	0,65	11,92
Pleistocene *Plejstocen*	Riss-Würm	8	Rumlówka	50									2	0	8	9	3	8	10	7	2	0	1			4,00 – 7,00	5,38 ± 0,09	0,65	11,89
		9	Nieciosy	19											1	3	2	5	1	5	1	1				4,60 – 6,75	5,61 ± 0,12	0,57	9,98
		10	Samostrzelniki	190						1	3	5	9	26	31	37	26	24	12	8	5	1	1	0	1	3,10 – 7,50	4,96 ± 0,05	0,71	14,31
		11	Rusinowo	120				1	2	3	5	6	9	12	17	15	18	14	8	8	1	1				2,50 – 6,80	5,09 ± 0,07	0,85	16,69
		12	Dzbanki	150				1	1	0	1	1	11	22	34	30	23	14	9	3						2,60 – 6,00	4,81 ± 0,05	0,58	12,05
	Mindel-Riss	13	Olszewice	7										4	1	0	0	1	1							4,20 – 5,70	4,72 –	—	—
		14	Żydowszczyzna	6							1	1	2	0	2											3,50 – 4,75	4,09 –	—	—
		15	Ciechanki	4								1	0	1	0	1	0	0	0	1						3,75 – 6,00	4,75 –	—	—
Pliocene *Pliocen*	upper *górny*	16	Mizerna (The well) *(Studnia)*	19			1	3	3	3	5	2	2													2,30 – 4,10	3,14 ± 0,11	0,51	16,21
		17	Mizerna (The main layer) *(Główny pokład)*	200		1	5	14	23	29	29	31	34	21	6	3	4									2,00 – 5,30	3,52 ± 0,05	0,67	19,03
	lower *dolny*	18	Krościenko	300	1	11	30	66	60	46	35	27	12	6	4	0	0	0	1	1						1,70 – 6,00	2,96 ± 0,03	0,63	21,28
Miocene *Miocen*	upper *górny*	19	Domański Wierch	160	1	3	15	29	48	43	7	8	6													1,70 – 4,10	2,86 ± 0,03	0,45	15,73
	middl. *środk.*	20	Gliwice	218	1	2	8	31	39	62	38	24	7	4	2											1,70 – 4,50	3,09 ± 0,03	0,50	16,18
		21	Wieliczka	4					1	0	0	2	1													2,90 – 4,00	3,57 –	—	—

Table 8
Tabela 8

3. NUMBER OF RIBS
LICZBA ŻEBEREK

Age *Wiek*		No	Locality *Miejscowość*	Number of nutlets *Liczba orzeszków*	3	4	5	6	7	8	9	10	11	12	13	14	15	16	min – max	M ± m	σ	v
Holocene *Holocen*	Recent *Współczesny*	1	Carpinus betulus: The whole of Europe *Cała Europa*	100			1	3	17	31	28	14	4	2					5 – 12	8,50 ± 0,13	1,28	10,05
		2	The whole of Poland *Cała Polska*	400		2	11	7	50	137	116	53	16	7	1				4 – 13	8,48 ± 0,06	1,37	16,15
		3	Białowieża Forest *Puszcza Białowieska*	80				3	9	37	17	12	2						6 – 11	8,40 ± 0,11	1,07	12,60
		4	Montech near Toulouse *Montech k. Tuluzy*	100				20	36	27	13	4							6 – 10	8,45 ± 0,11	1,07	12,66
	Subfossil *Subfosyl.*	5	Roztoki	30					6	11	6	6	1						7 – 11	8,50 ± 0,20	1,12	13,17
		6	Krzeszów	42		1	6	10	7	9	7	2							4 – 10	7,09 ± 0,33	2.17	30,69
		7	Raków	45					9	18	11	4	3						7 – 11	8,42 ± 0,16	1,10	13,06
Pleistocene *Plejstocen*	Riss-Würm	8	Rumlówka	50					3	12	21	11	3						7 – 11	8,98 ± 0,14	0,97	10,69
		9	Nieciosy	19				1	4	9	3	2							6 – 10	8,05 ± 0,22	1,00	12,42
		10	Samostrzelniki	66					11	16	22	15	2						7 – 11	8,74 ± 0,12	1,04	11,89
		11	Rusinowo	65			6	12	26	7	11	3							5 – 10	7,21 ± 0,16	1,31	18,60
		12	Dzbanki	65				1	0	8	20	21	10	4	1				6 – 13	9,76 ± 0,14	1,16	11,88
	Mindel-Riss	13	Olszewice	3					1	1	1								7 – 9	8,00 —	—	—
		14	Żydowszczyzna	—			—	—	—	—	—	—	—						—	—	—	—
		15	Ciechanki	—			—	—	—	—	—	—	—						—	—	—	—
Pliocene *Pliocen*	upper *górny*	16	Mizerna (The well) *(Studnia)*	—			—	—	—	—	—	—	—						—	—	—	—
		17	Mizerna (The main layer) *(Główny pokład)*	104					9	16	33	28	12	7	1				7 – 13	9,45 ± 0,12	1,31	13,80
	lower *dolny*	18	Krościenko	116	1	0	0	1	9	33	38	19	10	4	0	0	0	1	3 – 16	8,12 ± 0,23	2,57	31,65
Miocene *Miocen*	upper *górny*	19	Domański Wierch	—								—							—	—	—	—
	middl. *środk.*	20	Gliwice	—								—							—	—	—	—
		21	Wieliczka	—								—							—	—	—	—

4. LENGTH/WIDTH RATIO OF NUTLET
STOSUNEK DŁUGOŚCI DO SZEROKOŚCI

Age *Wiek*		No	Locality *Miejscowość*	Number of nutlets *Liczba orzeszków*	0,8	0,9	1,0	1,1	1,2	1,3	1,4	1,5	1,6	1,7	1,8	1,9	2,0	2,1	2,2	min — max	M ± m	σ	*v*
Holocene *Holocen*	Recent *Współczesne*	1	Carpinus betulus: The whole of Europe *Cała Europa*	100		9	26	22	18	11	13	0	1							0,86 — 1,61	1,14 ± 0,01	0,16	14,03
		2	Carpinus betulus: The whole of Poland *Cała Polska*	400	11	45	95	126	64	45	9	4	1							0,78 — 1,63	1,09 ± 0,01	0,13	11,92
		3	Carpinus betulus: Białowieża Forest *Puszcza Białowieska*	80		9	20	27	15	6	0	2	1							0,85 — 1,56	1,10 ± 0,01	0,14	12,72
		4	Carpinus betulus: Montech near Toulouse *Montech k. Tuluzy*	100		1	15	41	23	13	3	2	2							0,95 — 1,61	1,16 ± 0,01	0,13	11,20
	Subfossil *Subfosyl.*	5	Roztoki	28	2	0	0	4	12	4	3	2	0	1						0,82 — 1,75	1,16 ± 0,04	0,25	21,55
		6	Krzeszów	130		8	32	31	27	17	11	1	2	1						0 88 — 1,66	1,15 ± 0,01	0,17	14,78
		7	Raków	50		3	13	15	13	6										0,90 — 1,33	1,11 ± 0,01	0,11	9,90
Pleistocene *Plejstocen*	Riss-Würm	8	Rumlówka	50			9	9	9	11	7	1	3	1						0,96 — 1,68	1,24 ± 0,03	0,18	14,51
		9	Nieciosy	19		3	5	7	2	2										0,88 - 1,30	1,07 ± 0,02	0,12	11,21
		10	Samostrzelniki	190	2	13	33	70	39	23	6	3	0	1						0,80 — 1,69	1,13 ± 0,01	0,14	12,38
		11	Rusinowo	120		11	21	32	22	17	7	4	3	2	1					0,89 — 1,82	1,17 ± 0,01	0,19	16,23
		12	Dzbanki	150		5	34	55	34	19	2	1								0,89 — 1,46	1,13 ± 0,01	0,11	9,72
	Mindel-Riss	13	Olszewice	7			1	2	3	1										1,01 — 1,30	1,17 —	—	—
		14	Żydowszczyzna	6			1	3	1	1										0,96 — 1,28	1,09 —	—	—
		15	Ciechanki	4	1	0	1	1	1											0,83 — 1,20	1,01 —	—	—
Pliocene *Pliocen*	upper *górny*	16	Mizerna (The well) *(Studnia)*	19	1	1	1	2	3	3	1	4	0	2	1					0,82 — 1,82	1,31 ± 0,06	0,27	20,61
		17	Mizerna (The main layer) *(Główny pokład)*	200		11	15	31	54	34	29	13	9	4						0,86 — 1,75	1,25 ± 0,01	0,22	17,60
	lower *dolny*	18	Krościenko	300	3	8	38	82	70	52	25	13	7	2						0,84 — 1,73	1,19 ± 0,01	0,16	13,48
Miocene *Miocen*	upper *górny*	19	Domański Wierch	160			6	18	12	46	22	24	14	13	2	2	1			1,00 — 2,00	1,38 ± 0,01	0,20	14,49
	middl. *środk.*	20	Gliwice	218		1	3	18	28	46	39	40	19	14	3	3	0	3	1	0,90 — 2,17	1,40 ± 0,01	0,21	15,00
		21	Wieliczka	4				1	1	1	0	0	1							1.15 — 1,62	1,32 —	—	—

5. POSITION OF WIDEST PART
POŁOŻENIE NAJSZERSZEJ CZĘŚCI

Age *Wiek*		No	Locality *Miejscowość*	Number of nutlets *Liczba orzeszków*	23	26	29	32	35	38	41	44	47	50	53	56	59	62	65	min — max	M ± m	σ	v
Holocene *Holocen*	Recent *Współczesne*	1	*Carpinus betulus*: The whole of Europe *Cała Europa*	100			1	2	15	27	19	12	10	7	3	3	1			29,4 — 58,8	41,57 ± 0,59	5,93	14,26
		2	The whole of Poland *Cała Polska*	400			2	8	33	89	114	98	47	9						26,2 — 48,3	38,24 ± 0,20	3,94	10,30
		3	Białowieża Forest *Puszcza Białowieska*	80				6	11	17	23	15	5	3						30,7 — 51,1	39,13 ± 0,49	4,39	11,21
		4	Montech near Toulouse *Montech k. Tuluzy*	100			1	6	10	22	24	17	7	5	4	3	0	0	1	29,4 — 64,9	41,63 ± 0,61	6,15	14,77
	Subfossil *Subfosyl.*	5	Roztoki	28			1	5	6	2	8	5	0	0	1					30,5 — 51,6	38,42 ± 1,00	5,32	13,84
		6	Krzeszów	130		1	1	18	36	43	26	4	0	1						27,0 — 50,0	37,04 ± 0,31	3,55	9,55
		7	Raków	50				1	3	13	12	15	6							32,0 — 48,0	41,30 ± 0,51	3,61	8,74
Pleistocene *Plejstocen*	Riss-Würm	8	Rumlówka	50				3	11	15	11	7	2	1						31,2 — 48,8	39,08 ± 0,57	4,02	10,28
		9	Nieciosy	19				1	2	3	5	5	3							32,1 — 48,0	41,15 ± 0,96	4,20	10,20
		10	Samostrzelniki	190			2	27	39	46	42	20	10	2	1	0	1			28,3 — 59,1	38,51 ± 0,34	4,77	12,38
		11	Rusinowo	120			1	1	3	3	37	33	26	14	1	0	1			30,1 — 58,3	44,00 ± 0,39	4,26	9,70
		12	Dzbanki	150		1	1	6	22	49	43	17	8	2	0	1				25,0 — 55,1	39,47 ± 0,34	4,17	10,56
	Mindel-Riss	13	Olszewice	7							1	3	1	2						39,5 — 50,7	45,82 —	—	—
		14	Żydowszczyzna	6																			
		15	Ciechanki	4																			
Pliocene *Pliocen*	upper *górny*	16	Mizerna (The well) *(Studnia)*	19					3	4	8	3	1							34,0 — 48,5	40,34 ± 0,83	3,63	9,02
		17	Mizerna (The main layer) *(Główny pokład)*	200			2	6	31	47	61	40	13							29,0 — 48,4	39,95 ± 0,27	3,86	9,66
	lower *dolny*	18	Krościenko	300			11	16	42	101	75	44	11							29,0 — 48,3	38,87 ± 0,23	4,00	10,29
Miocene *Miocen*	upper *górny*	19	Domański Wierch	160			6	31	49	55	13	4	0	0	2					27,7 — 52,7	36,14 ± 0,28	3,76	10,40
	middl. *środk.*	20	Gliwice	218	2	4	12	52	51	55	23	13	5	1						22,0 — 50,0	35,93 ± 0,31	4,57	12,71
		21	Wieliczka	4					2	1	1										37,5 —	—	—

6. BASAL ANGLE
KĄT PODSTAWY

Age *Wiek*		No	Locality *Miejscowość*	Number of nutlets *Liczba orzeszków*	110	115	120	125	130	135	140	145	150	155	160	165	170	175	180	min — max	M ± m	σ	v
Holocene *Holocen*	Recent *Współczesne*	1	*Carpinus betulus* The whole of Europe *Cała Europa*	100						2	3	7	7	11	22	22	15	4	7	134 — 180	161,20 ± 1,03	10,29	6,38
		2	*Carpinus betulus* The whole of Poland *Cała Polska*	400	1	1	1	0	5	5	12	18	28	51	76	82	63	29	28	108 — 180	161,45 ± 0,57	11,39	7,05
		3	*Carpinus betulus* Białowieża — Forest *Puszcza Białowieska*	80				1	1	0	3	4	2	13	9	12	17	10	8	123 — 180	163,35 ± 1,33	11,97	7,32
		4	*Carpinus betulus* Montech near Toulouse *Montech k. Tuluzy*	100					1	4	4	7	10	16	20	21	14	0	3	129 — 180	158,10 ± 1,04	10,37	6,55
	Subfossil *Subfosyl.*	5	Roztoki	28			1	0	0	0	0	3	3	6	4	4	5	2		122 — 174	158,35 ± 2,15	11,29	7,13
		6	Krzeszów	130						3	4	9	11	24	19	26	22	5	7	135 — 180	160,30 ± 0,84	9,64	6,01
		7	Raków	50								1	3	1	9	15	13	3	5	146 — 180	166,00 ± 1,12	7,87	4,74
Pleistocene *Plejstocen*	Riss — Würm	8	Rumlówka	50		1	0	0	3	1	2	1	9	8	7	11	3	1	3	116 — 180	156,30 ± 1,89	13,27	8,48
		9	Nieciosy	19								1	1	2	5	4	4	1	1	145 — 180	163,15 ± 1,50	6,55	4,01
		10	Samostrzelniki	190			1	0	0	1	7	7	22	22	43	40	27	9	11	119 — 180	160,95 ± 0,78	10,17	6,31
		11	Rusinowo	120							4	2	11	13	29	31	20	6	4	140 — 180	162,00 ± 0,78	8,51	5,25
		12	Dzbanki	150					3	3	7	9	14	26	29	29	22	3	5	128 — 180	158,65 ± 0,95	11,74	7,39
	Mindel-Riss	13	Olszewice	7							2	0	0	1	1	1	2			141 — 169	157,42 —	—	—
		14	Żydowszczyzna	—																			
		15	Ciechanki	—																			
Pliocene *Pliocen*	upper *górny*	16	Mizerna (The well) *(Studnia)*	19									3	5	2	5	2	0	2	149 — 180	161,55 ± 2,05	8,93	5,52
		17	Mizerna (The main layer) *(Główny pokład)*	200				1	2	8	9	17	30	29	36	29	21	6	12	124 — 180	157,55 ± 0,82	11,61	7,36
	lower *dolny*	18	Krościenko	300			1	1	1	5	9	9	21	44	73	56	42	12	26	119 — 180	161,40 ± 0,60	10,66	6,60
Miocene *Miocen*	upper *górny*	19	Domański Wierch	160	1	1	1	3	17	12	21	28	33	16	10	10	5	0	2	110 — 180	146,50 ± 0,95	12,08	8,24
	middl. *środk.*	20	Gliwice	218		1	0	1	4	4	17	20	63	34	36	26	8	1	3	115 — 180	153,30 ± 0,70	10,35	6,76
		21	Wieliczka	4								1	1	0	2					146 — 160	153,50 —	—	—

7. APICAL ANGLE
KĄT WIERZCHOŁKA

Age *Wiek*		No	Locality *Miejscowość*	Number of nutlets *Liczba orzeszków*	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155	160	165	170	175	180	min ÷ max	M ± m	σ	v
Holocene *Holocen*	Recent *Współczesne*	1	*Carpinus betulus* — The whole of Europe *Cała Europa*	100								3	4	6	5	6	4	10	10	13	10	5	10	3	7	3	0	1						75 — 153	112,20 ± 1,87	18,70	16,66
		2	The whole of Poland *Cała Polska*	400									2	2	3	6	6	7	9	10	23	30	30	45	52	46	45	31	19	23	8	1	2	80 — 180	138,40 ± 0,90	18,00	13,00
		3	Białowieża — Forest *Puszcza Białowieska*	80										1	1	1	4	9	8	9	5	11	13	9	4	3	2							85 — 150	123,30 ± 1,59	14,24	11,54
		4	Montech near Toulouse *Montech k. Tuluzy*	100									1	3	3	10	16	16	19	8	12	5	6	1										79 — 135	108,25 ± 1,16	11,61	10,72
	Subfossil *Subfosyl.*	5	Roztoki	26						1	1	1	2	0	3	2	1	7	0	1	4	1	0	1	0	1								63 — 144	102,50 ± 3,67	18,70	17,26
		6	Krzeszów	130							1	0	0	0	2	0	0	2	8	8	22	19	17	17	13	12	8	0	1					70 — 159	128,45 ± 1,19	13,62	10,59
		7	Raków	50											4	2	2	3	8	7	3	5	6	2	5	1	2							89 — 152	118,80 ± 2,24	15,71	13,22
Pleistocene *Plejstocen*	Riss-Würm	8	Rumlówka	50							1	2	2	4	6	6	1	3	7	3	1	5	4	3	2									72 — 140	106,20 ± 1,34	9,37	8,81
		9	Nieciosy	19														3	3	2	4	4	1	0	1	1								103 — 146	119,45 ± 2,49	10,89	9,11
		10	Samostrzelniki	190										1	0	1	0	2	7	7	11	20	19	23	26	25	21	11	12	1	3			87 — 170	137,20 ± 1,08	14,91	10,86
		11	Rusinowo	120										1	3	1	5	3	5	11	9	14	13	9	12	12	15	3	2	0	2			85 — 170	130,05 ± 1,65	18,03	13,86
		12	Dzbanki	150											5	4	10	12	10	15	12	13	23	20	13	6	4	2	1					88 — 158	122,85 ± 1,29	15,81	12,86
	Mindel-Riss	13	Olszewice	7																		2	1	1	1	1	0	1						126 — 156	137,57 —	—	—
		14	Żydowszczyzna	—																																	
		15	Ciechanki	—																																	
Pliocene *Pliocen*	upper *górny*	16	Mizerna (The well) *(Studnia)*	19						1	3	0	1	1	0	1	1	0	3	2	1	0	1	0	2	1	0	1						63 — 156	106,55 ± 6,51	27,35	25,66
		17	Mizerna (The main layer) *(Główny pokład)*	200							1	6	4	8	12	7	16	15	22	20	25	11	18	9	10	11	3	0	1	1				72 — 164	114,30 ± 1,36	19,35	16,92
	lower *dolny*	18	Krościenko	300					1	0	0	0	1	5	4	7	14	26	37	28	47	31	38	30	16	8	5	2						59 — 153	119,90 ± 0,99	17,30	14,42
Miocene *Miocen*	upper *górny*	19	Domański Wierch	160					1	3	1	2	11	15	17	14	22	19	26	12	10	0	4	2	1									58 — 140	100,30 ± 1,17	14,83	14,78
	middl. *środk.*	20	Gliwice	218	1	0	3	1	8	11	11	23	24	30	27	19	19	14	15	5	4	1	0	0	1	1								42 — 145	87,70 ± 1,12	16,58	18,90
		21	Wieliczka	4						1	0	0	0	0	1	0	1	0	0	0	0	0	1											64 — 131	96,25 —	—	—

ERRATA

Page 6, line 15;	read thickness instead of height				
— 8, — 4;	— Length:breadth	—	—	Length;breadth
— 10, — 20;	— M_2: M_1	—	—	M_2; M_1
— 17, — 20;	— Those for the	—	—	Those the
— 17, — 23;	— Table 4	—	—	Table 3
— 17, — 24;	— Table 3	—	—	Table 4
— 30, — 20;	— of the	—	—	of other
— 32, — 9;	— Middle Miocene	—	—	Upper Miocene