ACTA PALAEOBOTANICA
XVIII (2): 17—34, 1977

IRENA GLUZA

REMAINS OF THE GENUS *BROMUS* FROM A NEOLITHIC SITE IN KRAKÓW

Szczątki rodzaju *Bromus* ze stanowiska neolitycznego w Krakowie

ABSTRACT. A fairly large number of *Bromus arvensis* caryopses and rather fewer *B. racemosus* and *B. sterilis* were recovered from carbonized material of the Lengyel culture (C-14: 5150 B.P.). Observations on the morphology of modern naked grains of *B. racemosus*, *B. commutatus*, *B. secalinus*, *B. mollis* and *B. arvensis* were carried out. Graphs have been presented for length, breadth, thickness, as well as for indices of length/breadth, thickness/breadth, and thickness/length ratios providing a picture of size and shape variation of caryopses.

INTRODUCTION

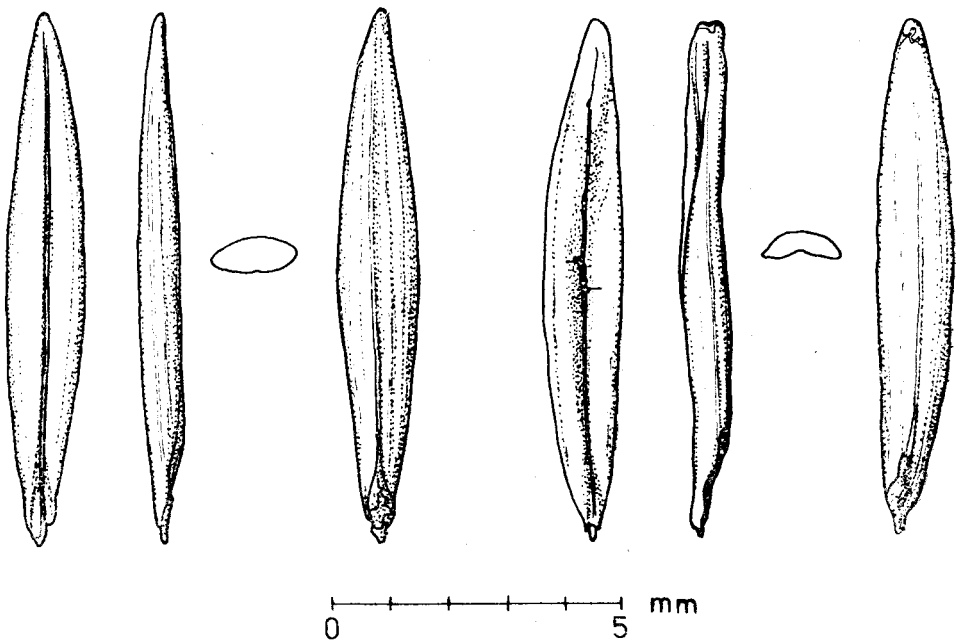
The *Bromus* grains discussed in this paper originate from the Neolithic pit 416, excavated on the Kraków — Nowa Huta site, stand 62 Mogiła, are 134 (Gluza 1971). The chronology of this site was determined, on the basis of pottery, as the middle phase of the Lengyel culture and the C-14 dating of carbonized grains gave the result of 5150±180 B.P. (3200 B.C., Gd — 164). The fill of the pit was composed of brown soil with an admixture of dispersed lumps of baked clay and potsherds. Carbonized remains of cereals, with weed seeds and fruits, formed a layer at the sloping bottom of the pit. The layer was found at the depth of 170—180 cm in the south and 180—190 cm in the north part of the pit. From each part of the pit, two kilograms of the carbonized material were analysed. In both samples, the naked caryopses of *Bromus* occurred the most abundantly (95 cm³), together with the remains of *Triticum dicoccum*, *T. monococcum* and *Hordeum vulgare*. From the volume of 2000 *Bromus* grains measuring 8 cm³, their approximative number was estimated at about 24 000. As such a large number of caryopses was found for the first time in excavations from the territory of Poland, more attention was given to them. A considerable differentiation of dimension and shape enabled the distinction of three species

(Pl. I). The identification of *B. sterilis*, occurring in small quantity, was not difficult. The remaining large number of grains (env. 95 cm³) seemed, on cursory examination, to be a homogenous morphological type, differing from the grains of *B. secalinus*. They were first described as *Bromus* sp. (Gluza 1971). Reexamination of the whole material brought to light two types of caryopses which have been identified as *B. arvensis* and *B. racemosus*.

MORPHOLOGICAL CHARACTERISTICS OF FOSSIL MATERIAL

Bromus sterilis L.

26 well preserved or slightly damaged grains and 75 halves belong to this species. They are long, narrow-lanceolate, gradually tapering towards both ends (Text-fig. 1). The ventral side usually is shaped like a long and deep groove, with a ridge-like thickening at the bottom. The furrow of some grains is shallowed

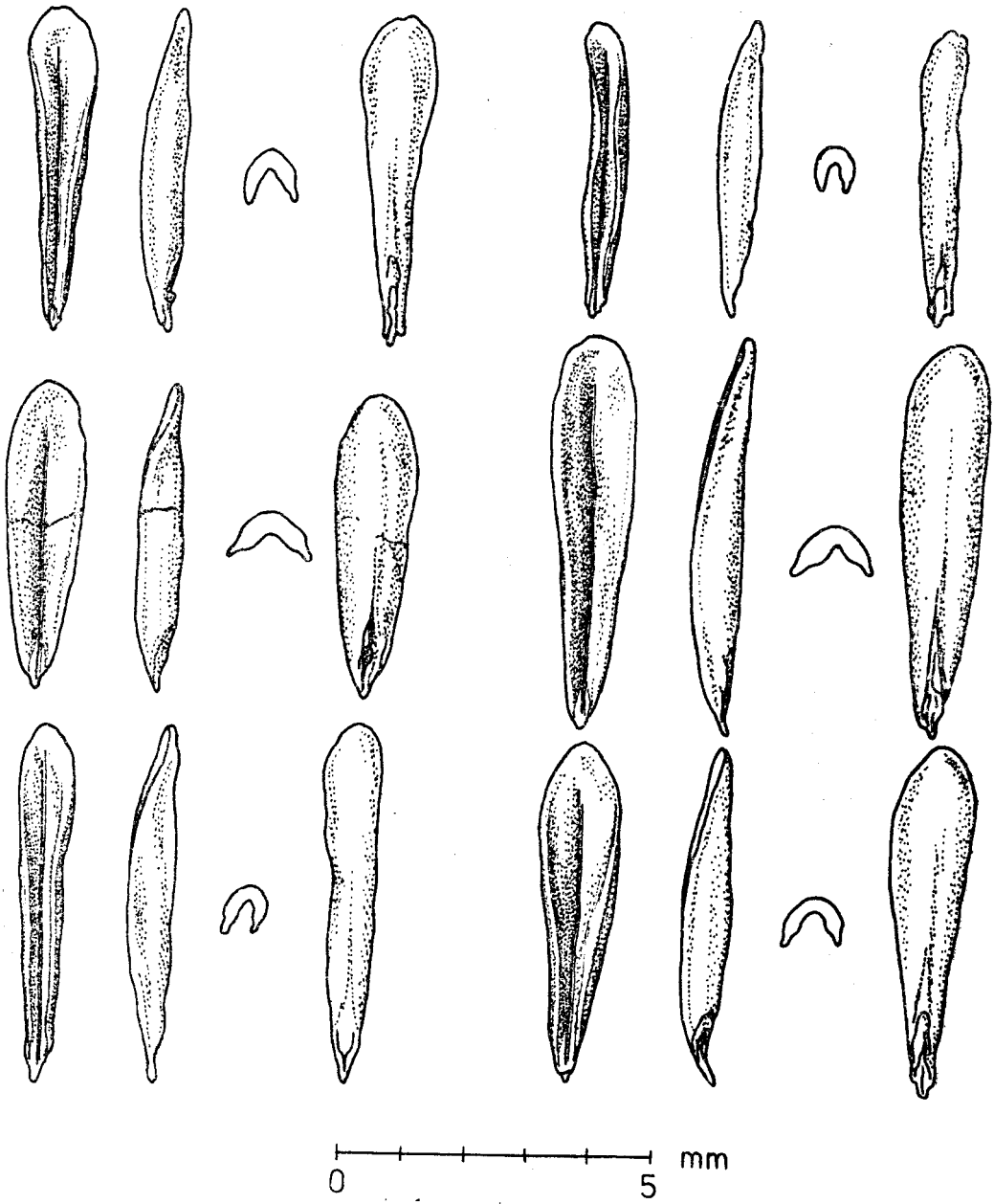


Text-fig. 1. Neolithic grains of *Bromus sterilis*

Ryc. 1. Neolityczne ziarniaki *Bromus sterilis*

in varying degrees in the upper part in consequence of puffing due to carbonization. A few specimens are of cylindrical shape with rounded lateral sides and convex ventral side. The slightly convex dorsal side has imprints of the lemma nervation. The imprint of the lemma central nerve, running from

the apex of the pointed embryo to the upper end of grain, is distinctly marked, 2 or 3 imprints of lateral nerves are faintly visible. Dimensions of 16 grains: length — 8·18 (6·80—9·00), breadth — 1·26 (1·10—1·45), thickness — 0·72 (0·65—1·00) mm.

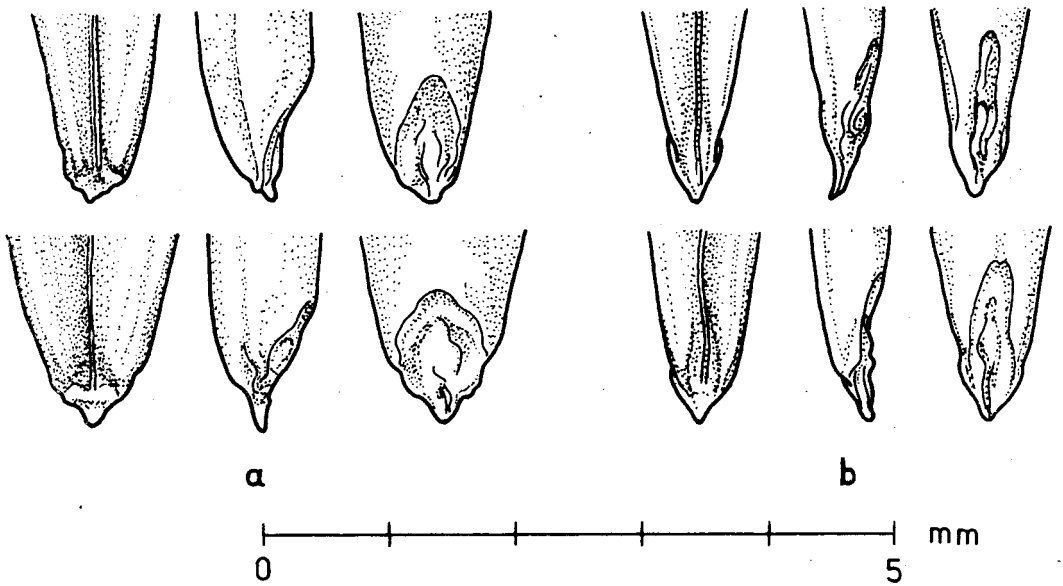


Text-fig. 2. Neolithic grains of *Bromus arvensis*

Ryc. 2. Neolityczne ziarniaki *Bromus arvensis*

Bromus arvensis L.

The majority of grains (about 3/4 of the total volume) are narrow and slender, broadest in the upper part and growing narrower towards the base (Text-fig. 2). The ventral side is narrowly V-shaped in the lower part, its edges diverge gradually towards the apex. From the ventral side the upper end of the grain is spatulate-flattened. The ridge-like thickening of furrow does not reach the



Text-fig. 3. Basal parts of Neolithic grains of *Bromus racemosus* (a) and *B. arvensis* (b) from ventral, lateral and dorsal sides. The difference in the shape of embryo is shown

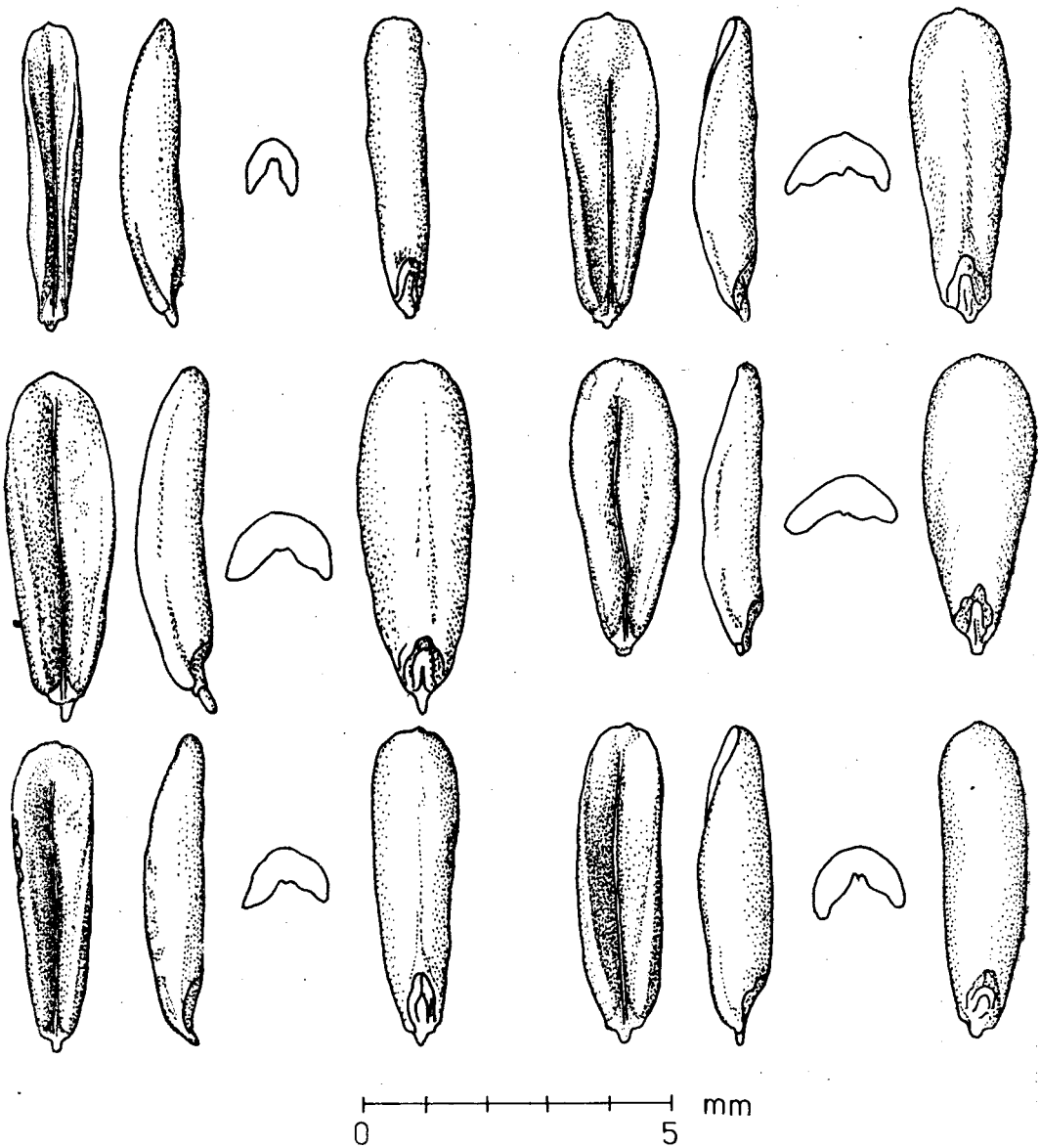
Ryc. 3. Nasadowe części neolitycznych ziaren *Bromus racemosus* (a) i *B. arvensis* (b) z brzusznej, bocznej i grzbietowej strony. Zaznaczono różnice w kształcie zarodka

apex of the caryopses. Grains are thickest in the middle tapering towards both ends. Along the lateral sides of the lower part a shallow groove, a trace of palea adherent to the pericarp, is visible (Kowal 1969). The dorsal side is convex, smooth, without distinct imprints of lemma nervation. The upper end of the grain viewed from the dorsal side is narrowly or broadly rounded, the base strongly narrowed, the apex of the narrow embryo is acute (Text-fig. 3b).

Bromus racemosus L.

The remaining grains (about 1/4 of total volume) are distinctly thicker and broader than those of *B. arvensis* type (Text-fig. 4). The maximum thickness is found in the middle, the maximum breadth in the middle or in the upper part of the caryopses. Furrow edges are evenly divergent along the whole length

of grain, or compressed at the base and divergent in the upper part. The ridge-like thickening of the furrow does not reach the apex. The apex of grains is rounded or blunt, in a few cases slightly curved to the ventral side. The dorsal

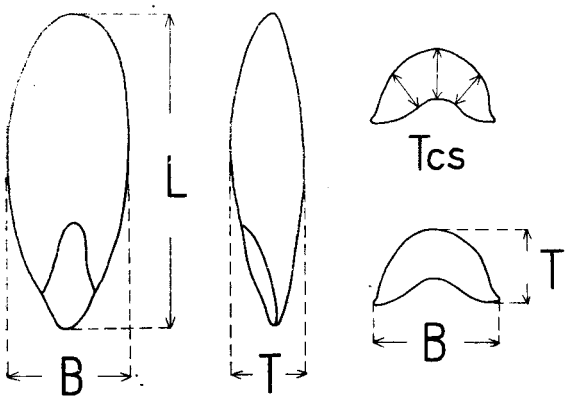


Text-fig. 4. Neolithic grains of *Bromus racemosus*
Ryc. 4. Neolityczne ziarniaki *Bromus racemosus*

side is convex, rounded or roof-like. The base of grains is broad, the embryo shorter than in the previous type, with a more or less rounded apex (Text-fig. 3a).

MEASUREMENTS OF FOSSIL GRAINS

For both species length, breadth and thickness of 80 caryopses have been measured as indicated in Text-fig. 5. Also the indices used in the studies of cereals $\frac{\text{length} \times 100}{\text{breadth}}$ (L:B) and $\frac{\text{thickness} \times 100}{\text{breadth}}$ (T:B) as well as an additional index $\frac{\text{thickness} \times 100}{\text{length}}$ (T:L) were calculated (Table 1, Text-figs. 6, 7). The



Text-fig. 5. The way of measuring of length (L), breadth (B) and thickness (T) for fossil and extant caryopses of the genus *Bromus*. Tcs — thickness of caryopsis in cross-section
(see page 23)

Ryc. 5. Sposób pomiaru długości (L), szerokości (B) i grubości (T) kopalnych i współczesnych ziarniaków rodzaju *Bromus*. Tcs — grubość ziarniaka w przekroju poprzecznym (por. str. 23)

caryopses of both species are almost equal in length, but they differ in breadth and thickness. Differences in shape are better expressed in graphs for L:B and T:L indices. The T:B ratio does not show any differentiation.

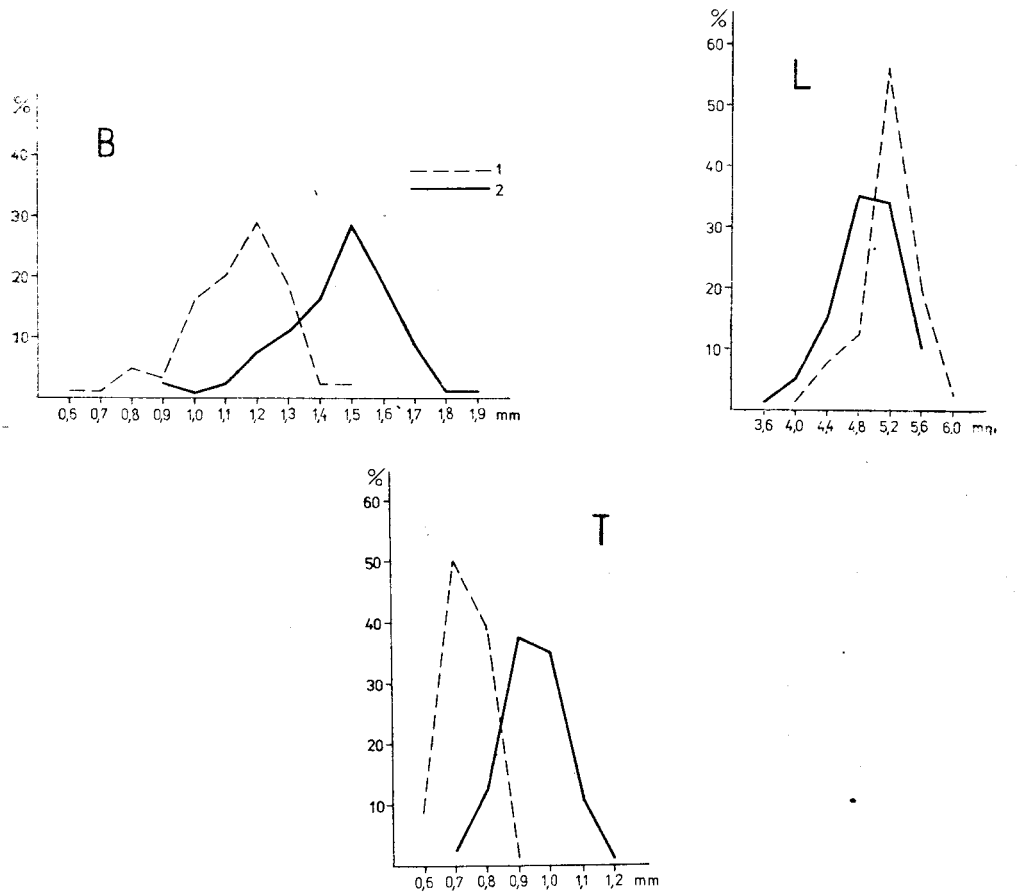
The thickness of caryopses has been measured as for cereal grains, that is the maximum transverse measure of a caryopsis viewed from the lateral side.

Table 1
Tabela 1

Dimension and index values for *B. arvensis* and *B. racemosus* caryopses from Neolithic site Kraków — Nowa Huta, stand 62 Mogiła, pit 416
Wymiary i wartości wskaźników dla ziarniaków *B. arvensis* i *B. racemosus* z neolitycznego stanowiska Kraków — Nowa Huta, stan. 62 Mogiła, jama 416

Species Gatunek		Length Długość	Breadth Szerokość	Thickness Grubość	$\frac{L \cdot 100}{B}$	$\frac{T \cdot 100}{B}$	$\frac{T \cdot 100}{L}$
Bromus arvensis	min.	4·20	0·60	0·60	363	48	11·4
n = 80	aver.	5·24	1·15	0·75	461	66	14·3
	max.	6·00	1·50	0·90	700	108	16·9
Bromus racemosus	min.	3·75	0·90	0·70	251	44	14·5
n = 80	aver.	4·97	1·47	0·96	342	66	19·3
	max.	5·60	1·90	1·20	550	105	23·7

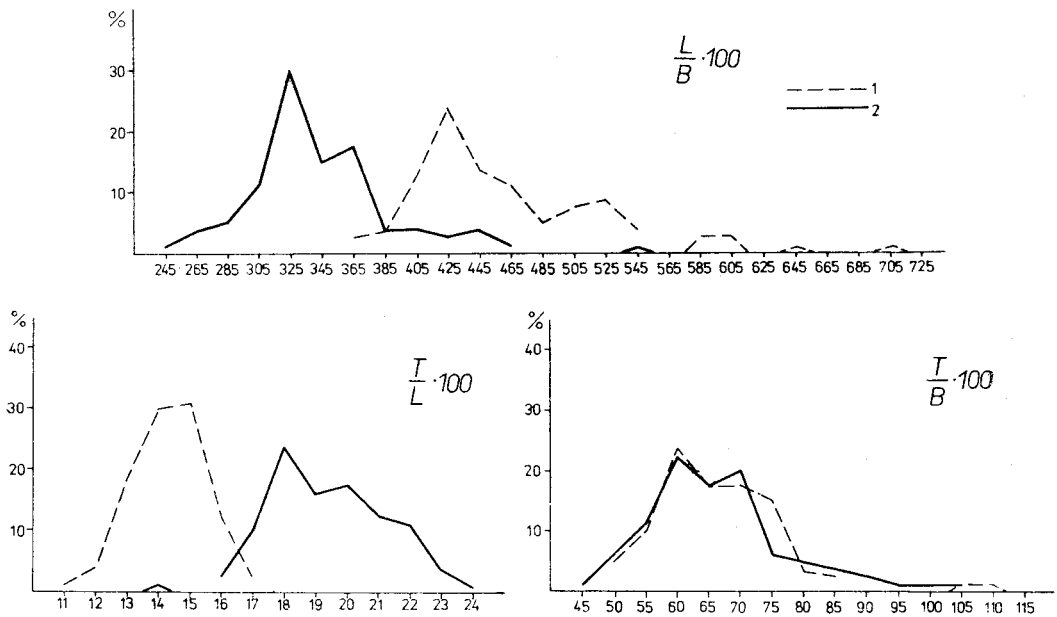
This dimension depends partly on the degree of divergence of the lateral sides of the furrow and does not reflect an important feature such as the distance between the seed-coat of the ventral and dorsal sides, which can be defined as the thickness of caryopsis in cross-sections (Tcs). This feature is illustrated by



Text-fig. 6. Frequency polygons for the length (L), breadth (B) and thickness (T) of the Neolithic grains of *Bromus arvensis* (1) and *B. racemosus* (2)

Ryc. 6. Wieloboki zmienności dla długości (L), szerokości (B) i grubości (T) neolitycznych ziarniaków *Bromus arvensis* (1) i *B. racemosus* (2)

the series of cross-sections (Text-fig. 8). For this, 80 basal half-grains were taken at random from the sample containing both species. At the distance of 2·5 mm from basal end of grain the outline of outer walls and inner damages were drawn using a low power microscope. The degree of damage was various. Some grains had fissures between the starch cells of the endosperm. Partial detachment of seed-coat from the endosperm was noticed most frequently. Only a few grains showed no marked deformations.



Text-fig. 7. Frequency polygons for the indices lenght/breadth, thickness/breadth and thickness/length for Neolithic grains of *Bromus arvensis* (1) and *B. racemosus* (2). L. — lenght, B — breadth, T — thickness

Ryc. 7. Wieloboki zmienności wskaźników stosunku długości do szerokości, grubości do szerokości i grubości do długości dla neolitycznych ziarniaków *Bromus arvensis* (1) i *B. racemosus* (2). L — długość, B — szerokość, T — grubość

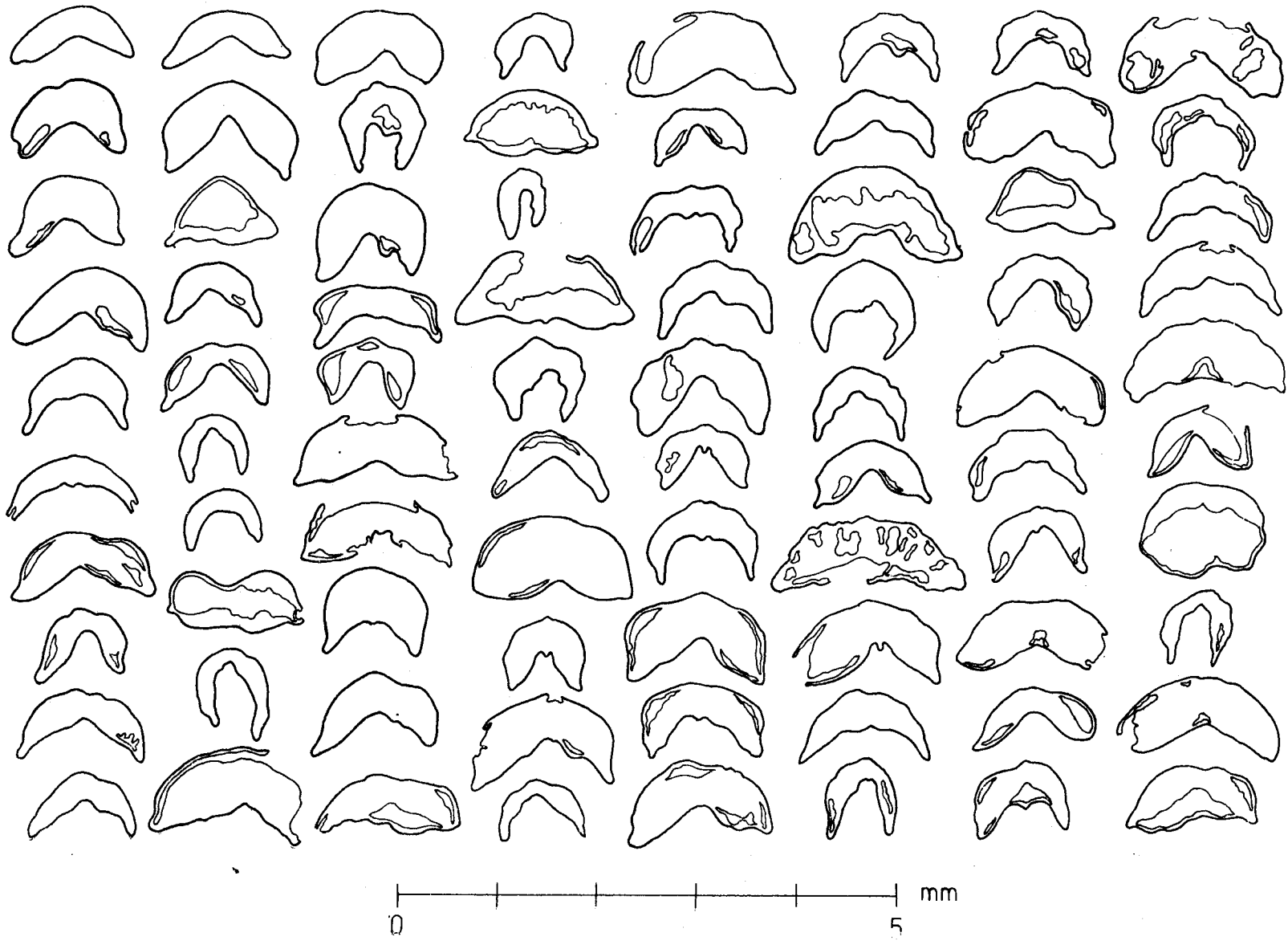
Text-fig. 8 enables the comparison between the thickness of grains in cross-section, their breadth and the degree of divergence of the lateral sides of the furrow. The picture obtained confirmed the distinction of two types of grains in the material. Grains of thinner cross-section belong to *B. arvensis*, while those with a thicker cross-section may be assigned to *B. racemosus*. Such comparisons are valid only for grains recovered from one site, probably carbonized in identical conditions.

COMPARISON WITH MODERN MATERIAL

The Neolithic material of *Bromus arvensis* and *B. racemosus* has been compared with caryopses of all *Bromus* species at present occurring in Poland. Caryopses of *B. arvensis* L., *B. commutatus* Schrad., *B. secalinus* L., *B. racemo-*

Text-fig. 8. Comparison of cross-sections of Neolithic grains of *Bromus arvensis* and *B. racemosus*

Ryc. 8. Porównanie przekrojów poprzecznych neolitycznych ziarniaków *Bromus arvensis* i *B. racemosus*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sus L., and *B. mollis* L. (*B. hordaceus* auct.) which appear to be nearest fossil specimens, were studied more closely.

The distinction of contemporary grains of these species is principally based on the characteristics of hulled caryopsis (Kowal & Rudnicka-Sternowa 1969; Kulpa 1974; Brouwer & Stählin 1955; Scholz 1970). The determination on the basis of naked grains is more difficult and in the case of single, less typical grains, often even impossible. When classifying contemporary material, anatomical features of caryopses are used, but changes due to carbonization do not allow the use of this method for fossil grains, and only morphological characteristics can be considered in their determination. Hence observations were carried out on the morphology of grains in ripening panicles and a clear dependence of naked grain shape on hulled caryopsis characteristics and on its position in the multifloral spikelet was noticed.

The *B. arvensis* spikelets are narrowly ovate. Mature, hulled caryopses have a narrow, V-shaped furrow, the lateral sides compressed at the base and divergent towards the apex. In consequence, flowers are separated in maturity and rachilla is evident.

The *B. mollis* spikelets are ovate. Hulled caryopses of elliptic-obovate outline are compressed in a spikelet, overlapping until the end of ripening time. Short rachilla internodes adhere to the ventral side of caryopses and are hidden in mature spikelet. The lateral sides of grains are not compressed, the thickness of grains is much smaller than their breadth.

For three remaining species (*B. secalinus*, *B. racemosus* and *B. commutatus*), flowers closely overlap in a spikelet only in early stages of grain development. Towards the end of ripening, a separation of flowers takes place, due to inrolling of the margins of the lemma and caryopsis. This change results in the increase of grain thickness. The most marked inrolling occurs in grains of *B. secalinus* which gives them a cylindrical shape, similar to cereals. Grains are narrowly oblong, with a deep, narrow furrow. The thickness of grains is almost equal to their breadth.

The lateral sides of *B. racemosus* and *B. commutatus* grains are less inrolled. *B. racemosus* grains are mostly narrowly oblong. They differ from *B. secalinus* grains in their smaller size, thinner cross-section (Tcs dimension in Text-fig. 5) and stronger divergence of lateral sides. *B. commutatus* caryopses are bigger and more slender than those of *B. racemosus*. Their ventral side is groove-like, but divergence of lateral sides and the thickness in cross-section vary. The majority of contemporary caryopses are lateraly compressed at the base with margins gradually diverging towards the apex. Specimens also occur with lateral sides divergent evenly (but more markedly than in *B. secalinus*) along the whole furrow. The thickness of *B. racemosus* and *B. commutatus* grains is smaller than their breadth, but considerably greater than the breadth of *B. mollis* grains. The lower caryopses of *B. racemosus* and *B. commutatus*, remaining longer in spikelets, are laterally more compressed than the upper grains which

fall-off earlier. In consequence of the prolongation of ripening time, the lower grains of spikelets are similar in shape to *B. secalinus*.

In order to obtain comparative data for size and shape variation of grains, specimens of extant *Bromus* species were collected by the author on the territories close to the Neolithic site. All mature caryopses of at least one panicles were measured (Table 2).

Table 2
Tabela 2

Dimensions and index values for extant caryopses of *B. racemosus*, *B. secalinus*, *B. commutatus*, *B. mollis* and *B. arvensis*
Wymiary i wartości wskaźników dla współczesnych ziarniaków *B. racemosus*, *B. secalinus*, *B. commutatus*, *B. mollis* i *B. arvensis*

Species Gatunek		Length Długość	Breadth Szerokość	Thickness Grubość	L·100 / B	T·100 / B	T·100 / L
B. racemosus L.	min.	5·35	1·30	1·00	278·0	66·6	16·3
n = 60	aver.	5·96	1·57	1·22	379·8	77·5	20·4
	max.	6·25	1·85	1·45	425·0	89·2	24·1
B. secalinus L.	min.	5·25	1·17	0·80	275·5	43·8	12·4
(a) n = 90	aver.	6·71	1·60	1·57	418·7	98·9	23·3
	max.	7·25	2·30	1·85	564·0	124·0	26·4
B. secalinus L.	min.	5·90	1·30	1·30	320·0	76·4	20·4
(b) n = 50	aver.	6·51	1·68	1·64	392·1	96·3	25·2
	max.	6·90	2·00	1·90	511·5	119·2	29·9
B. commutatus	min.	6·50	1·15	0·95	328·8	53·3	14·1
Schrad.	aver.	6·88	1·55	1·21	448·4	78·9	17·6
(a) n = 50	max.	7·20	2·25	1·45	586·9	100·0	20·0
B. commutatus	min.	5·80	1·27	0·90	360·0	63·1	14·2
Schrad.	aver.	6·69	1·65	1·21	409·3	73·5	18·0
(b) n = 50	max.	7·20	2·00	1·40	500·0	96·4	20·7
B. mollis L.	min.	5·30	1·45	0·60	326·1	30·7	8·9
(a) n = 50	aver.	6·60	1·86	0·83	354·9	44·3	12·6
	max.	6·90	2·10	1·00	393·3	56·6	15·0
B. mollis L.	min.	4·60	1·25	0·72	282·8	45·9	14·2
(b) n = 50	aver.	5·15	1·64	0·86	315·1	52·4	16·6
	max.	5·60	1·85	1·00	353·8	64·0	19·1
B. arvensis L.	min.	4·90	0·80	0·70	360·7	62·9	12·1
n = 35	aver.	5·88	1·11	0·96	540·9	87·9	16·4
	max.	6·45	1·40	1·25	725·0	115·0	21·1

List of material:

1. *Bromus racemosus* L. — Kraków, Nowa Huta, humid meadow midway between Plac Centralny and the Vistula, VI. 1975, 60 grains from two panicles were measured;
2. *Bromus secalinus* L. — (a) Buczkowice, Bielsko-Biała voivodenship, in rye field, VII. 1973, 90 grains from one panicle; (b) Kraków, Nowa Huta-Pleszów, in wheat field, VII. 1973, 50 grains from two panicles;
3. *Bromus commutatus* Schrad. — (a) Kraków, meadow by Piastowska Street, VII, 1973, 50 grains from two whole panicles; (b) Kraków, Dzierżyński Street, near the fence of a vegetable garden, VII. 1973, 50 grains from one panicle;
4. *Bromus mollis* L. (*B. hordaceus* auct.) — (a) Kraków, Nowa Huta-Pleszów, meadow, VII. 1974, a form of long and narrow caryopses, 50 grains from one panicle; (b) Kraków, a plot of grass on Tokarski Street, VII. 1974, a form of short and broad caryopses, 50 grains from one panicle;
5. *Bromus arvensis* L. — Kraków, Nowa Huta-Pleszów, the road-side, VII. 1973, 35 caryopses from two panicles.

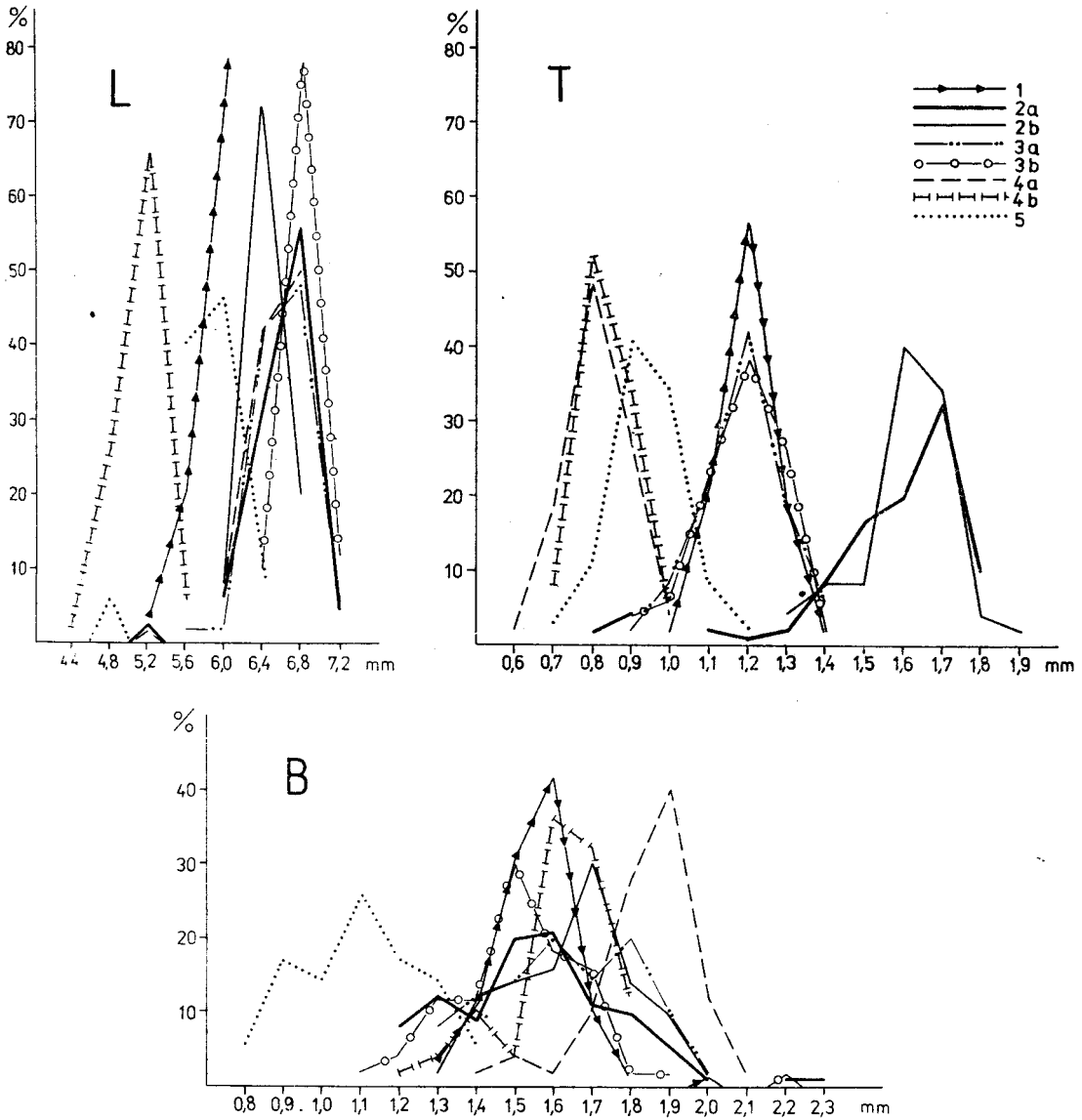
The length of modern grains does not show enough differentiation to allow distinction of fossil grains beyond doubt. Neolithic grains of *B. racemosus* and *B. arvensis* are shorter than the majority of contemporary grains, but the curves of their length overlap as in graphs for present-day grains (Text-fig. 9).

The breadth of modern caryopses enables the determination of *B. arvensis* as that with the narrowest grains, measuring 0·8—1·4 mm. The breadth of fossil specimens of this species is almost identical. In the case of *B. racemosus*, which belongs to the group of species with broader grains, the breadth of fossil and contemporary specimens is also almost the same. *B. secalinus* differs clearly, by the thickness of caryopses, from other species. *B. commutatus* and *B. racemosus* are of transitional type, the grains of *B. mollis* and *B. arvensis* are the thinnest. The mutual relations between the curves for *B. arvensis* and *B. racemosus* in the Neolithic and the extant material are similar, but absolute values for fossil grains are smaller.

The L:B index (Text-fig. 10) for recent specimens distinctly separates *B. arvensis* (the narrowest grains) from *B. mollis* (the broadest grains) and *B. racemosus*. The curves for *B. secalinus* and *B. commutatus* take an intermediate position and overlap the curves of the previous species. This index for Neolithic grains shifts towards lower values, which is probably caused by the shortening of grains during carbonization. In *B. arvensis*, this feature shows great variability. The absence of clear culmination in the curve for extant material might result from an insufficient number of measurement (35). However, the curve for fossil material, based on 80 measurement, also shows a large range of variation in this index as compared with others.

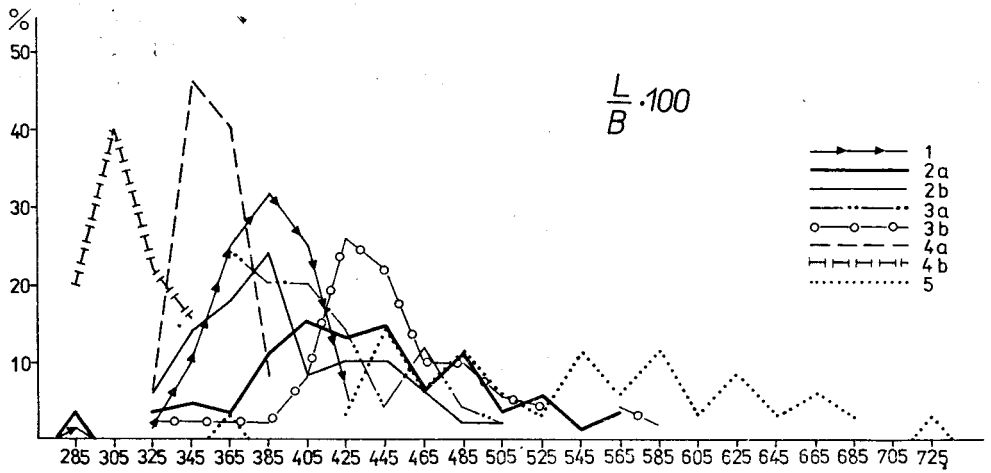
The ratio between the thickness and the breadth for contemporary grains allows a clear distinction between *B. secalinus* and *B. mollis*. The remaining

species constitute a transitional group and do not differ from each other distinctly. The curves of both Neolithic species overlap and shift towards index values lower than those of modern specimens. This is due to the decrease of grain



Text-fig. 9. Frequency polygons for the length (L), breadth (B) and thickness (T) for extant specimens of *Bromus racemosus* (1), *B. secalinus* (2a and 2b), *B. commutatus* (3a and 3b), *B. mollis* (4a and 4b), *B. arvensis* (5). 1—5 localities listed on page 28

Ryc. 9. Wieloboki zmienności dla długości (L), szerokości (B) i grubości (T) współczesnych ziarniaków *Bromus racemosus* (1), *B. secalinus* (2a i 2b), *B. commutatus* (3a i 3b), *B. mollis* (4a i 4b) i *B. arvensis* (5). 1—5 stanowiska zestawione na str. 28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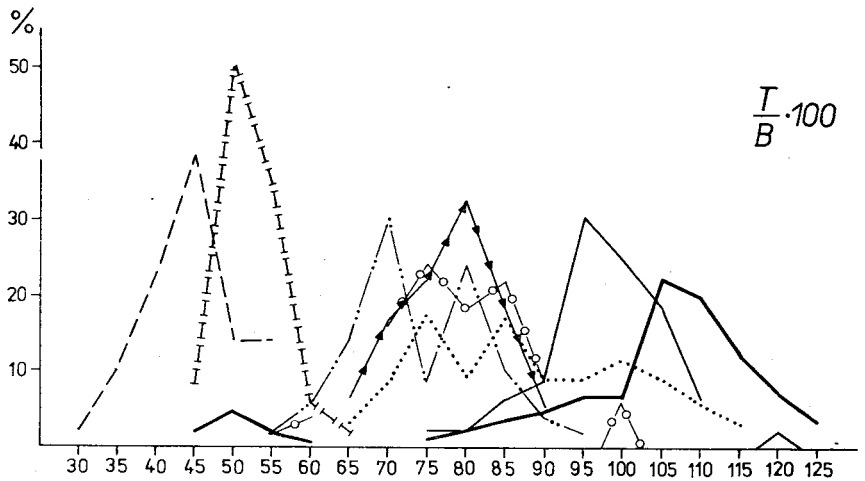
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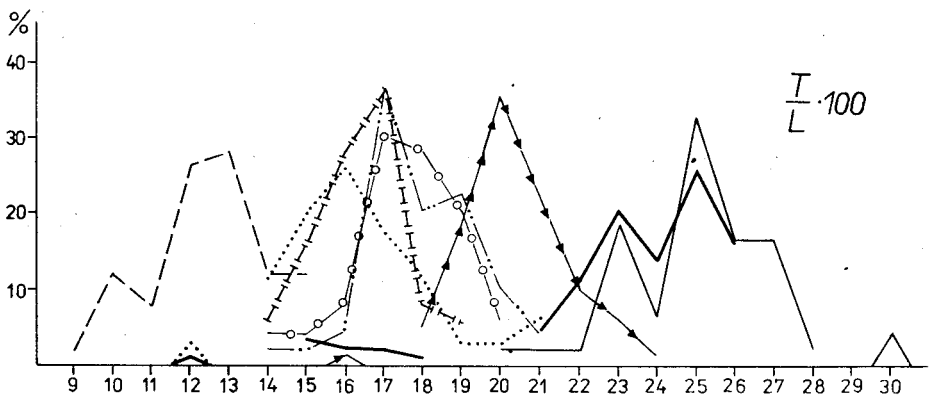
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thickness as a result of divergence of the lateral sides of furrow, caused by carbonization.

The ratio between the thickness and the length for contemporary specimens distinctly separates *B. secalinus* caryopses, the thickest, from the remaining species. Grains of *B. racemosus* are most similar to those of *B. secalinus*. *B. arvensis*, *B. commutatus* and, to some extent, *B. mollis* constitute a group with similar index values. This feature clearly differentiates the caryopses of extant *B. arvensis* and *B. racemosus*. The values of the T:L index for fossil and present-day grains of both species are similar. Probably this feature does not change due to carbonization as much as the other indices.

The measurement of contemporary material shows that present-day grains of *B. arvensis* and *B. racemosus* differ from each other in breadth and thickness as well as in the L:B and T:L indices. These differences are also visible in graphs of charred Neolithic grains from Nowa Huta and they confirm the identification of both species.

Grains of contemporary *B. racemosus* are often confused with *B. commutatus* caryopses. Characteristics given in H. Scholz's key (Scholz 1970) are of great help in the determination of hulled grains. Measurements presented in this paper, show that naked grains of both species differ in length and thickness/length index. Such features as the thickness, the breadth and thickness/breadth index point to the similarity of *B. racemosus* and *B. commutatus* grains. Grains of *B. secalinus* are thicker than those of *B. racemosus* and *B. commutatus*, their thickness/length and thickness/breadth indices are higher.

Archaeological Museum, ul. Senacka 3, 31-002 Kraków
Muzeum Archeologiczne

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←

Text-fig. 10. Frequency polygons for the indices length/breadth, thickness/ breadth and thickness/length for the extant specimens of *Bromus racemosus* (1), *B. secalinus* (2a and 2b), *B. commutatus* (3a and 3b), *B. mollis* (4a and 4b) and *B. arvensis* (5). L — length, B — breadth, T — thickness. 1—5 localities listed on page 28

Ryc. 10. Wieloboki zmienności wskaźników stosunku długości do szerokości, grubości do szerokości i grubości do długości dla współczesnych ziarniaków *Bromus racemosus* (1), *B. secalinus* (2a i 2b), *B. commutatus* (3a i 3b), *B. mollis* (4a i 4b) i *B. arvensis* (5). 1—5 stanowiska zestawione na str. 28

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STRESZCZENIE

SZCZĄTKI RODZAJU *BROMUS* ZE STANOWISKA NEOLITYCZNEGO W KRAKOWIE

W zwęglonym materiale kultury lendzielskiej (C-14: 3200 B.C.) stwierdzono występowanie dużej ilości ziarniaków *Bromus arvensis* oraz w mniejszej liczbie *B. racemosus* i *B. sterilis*. Przeprowadzono obserwacje nad morfologią współczesnych nagich ziarniaków *B. racemosus*, *B. commutatus*, *B. secalinus*, *B. mollis* i *B. arvensis*. Przedstawiono dla nich wieloboki zmienności dla długości, szerokości, grubości, wskaźników stosunku długości do szerokości, grubości do szerokości i długości do grubości, obrazujące wielkość i kształt ziarniaków. Z pomiaru materiału współczesnego wynika, że dzisiejsze ziarniaki *B. arvensis* i *B. racemosus* różnią się między sobą szerokością i grubością oraz stosunkiem długości do szerokości i grubości do długości. Różnice te są także widoczne na wykresach zwęglonych ziarniaków neolitycznych z Nowej Huty i potwierdzają oznaczenie tych dwu gatunków.

Współczesne ziarna *B. racemosus* są często mylone z ziarniakami *B. commutatus*. Dla oznaczenia ich ziaren oplewionych bardzo przydatne są cechy podane w kluczu Scholza (1970). Jak wynika z pomiarów ziaren współczesnych przedstawionych w obecnej pracy, nagie ziarna obu gatunków różnią się długością i stosunkiem grubości do długości. Natomiast takie cechy jak grubość, szerokość i stosunek grubości do szerokości wskazują na podobieństwo ziaren *B. racemosus* i *B. commutatus*. Ziarna *B. secalinus* są grubsze niż ziarna *B. racemosus* i *B. commutatus* oraz mają wyższy stosunek grubości do długości i grubości do szerokości.

PLATE

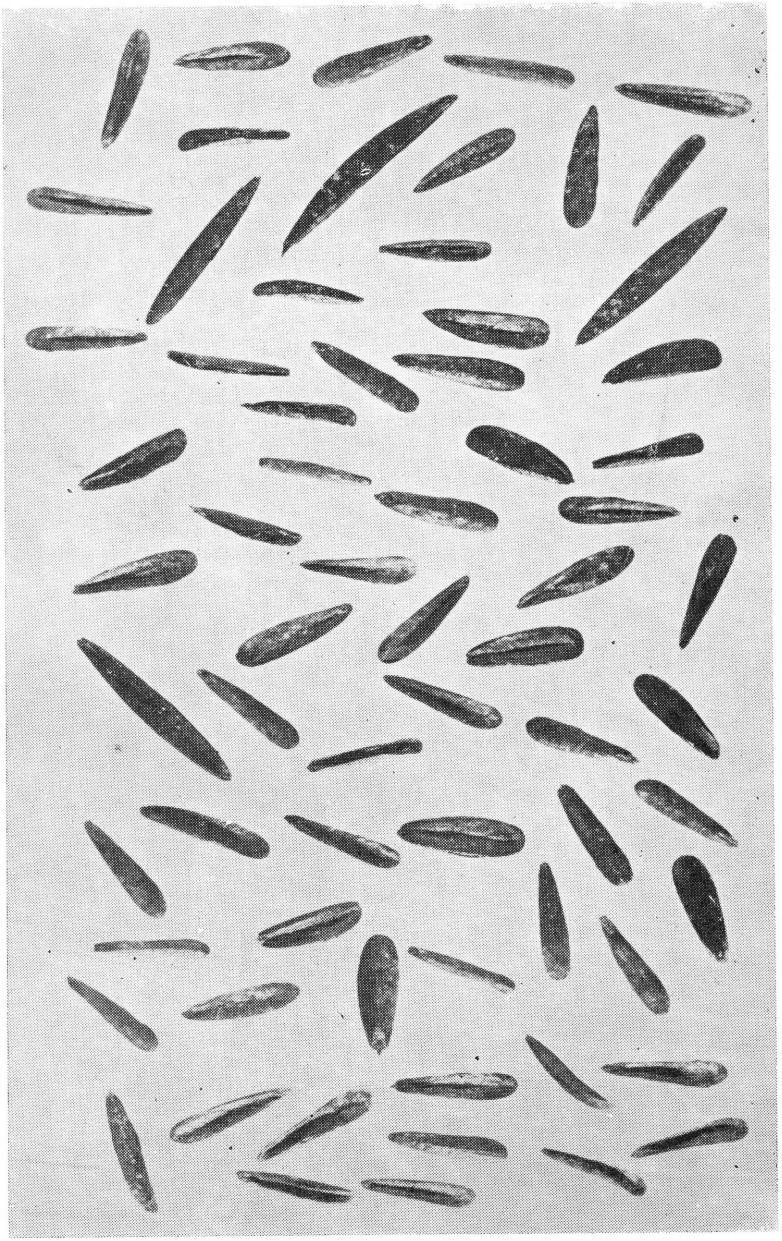
TABLICA

Plate I

Carbonized grains of *Bromus sterilis*, *B. arvensis* and *B. racemosus* from the Neolithic site Kraków — Nowa Huta, Mogiła 62

Tablica I

Zwęglone ziarniaki *Bromus sterilis*, *B. arvensis* i *B. racemosus* z neolitycznego stanowiska Kraków — Nowa Huta, Mogiła 62



I. Gluza
Acta Palaeobotanica XVIII/2