

ANATOMICAL TRAITS OF SEVEN CORN-INBRED LINES INCLUDING TWO WITH GENE BROWN MIDRIB

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ABSTRACT

Anatomical investigations of the stem in seven *Zea mays* L. inbred lines were performed on specimens bred in the Experimental Institute of Breeding and Plant Acclimatization in Smolice. Two of the lines (bm₁ and bm₂) including the gene brown midrib were characterized by a higher digestibility. The remaining five lines (S215, S335, S336, S336A and S339) were selective inbred lines used as components in hybrid breeding at the Institute in Smolice.

The investigated lines were compared in respect to 50 anatomical traits of the stem. The comparisons were performed by means of the Wrocław dendrite method. The lines formed three distinct groups according to the degree of similarity. The first group consisted of two lines with the gene brown midrib (bm₁ and bm₂), the second of four lines (S215, S336, S336A and S339), and the third of line S335. The inclusion of both the lines with gene bm into one group was based on similarity regarding the set of traits of parenchyma, particularly of the peripheral part of the stem, as well as metaxylem and metaphloem traits. However, these lines differed considerably in respect to epidermis traits. It was peculiar that the stomata of the *Amaryllis* type occurred in one of the lines (S339).

Each line made a specific mosaic of traits. The sets of traits characterizing the particular lines were specific in such a degree that they could be used, like a fingerprint, for their identification.

KEY WORDS: corn, stem anatomy, epidermis, sclerenchyma, parenchyma, vascular bundles, brown midrib, xeromorphy.

INTRODUCTION

Corn is a plant originating from Middle America of tropical and subtropical climate. As a result of cultivation it has been adopted to a considerably wider spectrum of climatic conditions. Forms of great morphological and physiological diversity and of various agricultural properties (Bennet 1987; Kuperman 1962; Poething 1944) were obtained. For farming purposes forms of corn were selected as grain-producing or digestible as a whole plant. The lines and hybrids with the gene brown midrib (bm) show a particularly high digestibility (Hunter 1985; Muller et al. 1971). These forms, apart from traits of significantly higher digestibility, are characterized by lowered rigidity of stems and susceptibility to lodging. So stem rigidity and their mechanical hardness depend mainly on the degree of sclerification; the lower the degree of sclerification, the higher the digestibility (Engels and Cone 1985; Struik 1985), but lower the resistance against breaking and stem lodging (Garber and Olson 1919; Hunter and Dalbey 1937).

The increasing degree of sclerification is recognized as an index of adaptation of the plant to xerothermal conditions (Stalfelt 1956; Shields 1950). Corn is by nature a xerophytic plant. It is characterized by photosynthesis of C4 type. This

type of photosynthesis represents the plants adaptation to desert and semidesert conditions of low air humidity and high light intensity (Good and Bell 1985).

The aim of the present work was to recognize the occurrence of sets of anatomical stem traits in two lines with gene bm and five lines of a more xeric character, which constitute the breeding material for formation of corn hybrids.

We analysed the general features of the stem i.e., vascular bundles, the sclerenchyma, the epidermis and the parenchyma. The basic aim was to answer the question, whether all the analysed traits occurring in lines bm₁ and bm₂ are less xeric than in the remaining five lines of corn.

MATERIAL AND METHODS

Plants of seven inbred lines of corn: bm₁, bm₂, S215, S335, S336, S336A and S339, developed in the Plant Breeding and Acclimatization Institute – Experimental Station in Smolice were analysed. A brief characterization of the lines is presented in Table 1. According to the five-degree scale of morphological classification by Kuperman (1962), all the seven lines belong to one of the five distinguished classes. Samples for analysis taken from second internode over the

TABLE 1. Characteristics of seven investigated inbred lines of corn.

No.	Line sign	Origin/Breeding number	Plant height – cm	Date of 50% silking
1	bm ₁	398642.2.1.1 bm synt Gbm	165	15.07
2	bm ₂	398641.1.1.1 bm synt. Gbm	165	26-28.07
3	S215	Synt. fl. Nr 24890-2	220	25.07
4	S335	Mol1 × CM7 Nr 35940	130	18.07
5	S336	Iodent × 1193 Ph3950	160	26.07
6	S336A	Iodent × 1193 Ph3950	160	30.07
7	S339	B73 × F2 ²	160	18.07

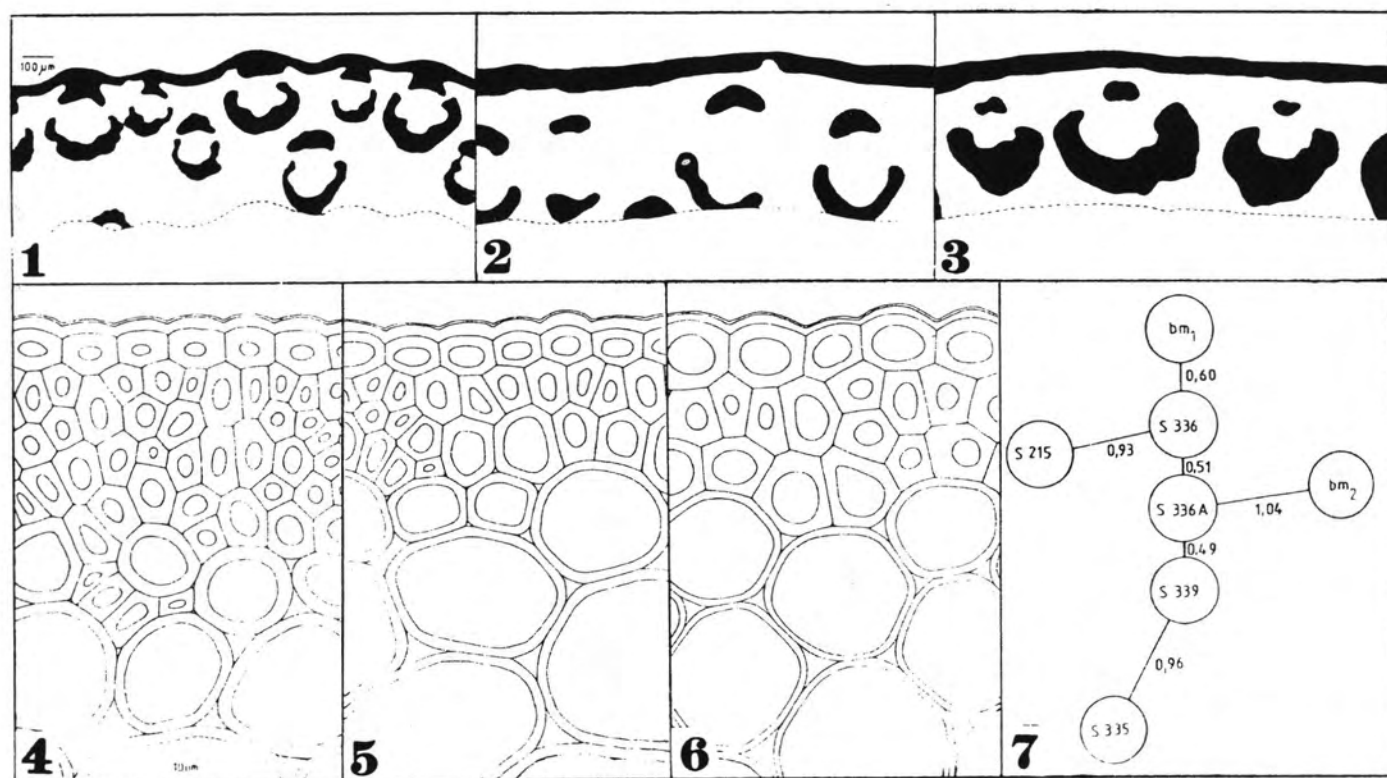
ear, were collected in the latter period of corn vegetation (September 16, 1993) and fixed in 70% ethanol. Manual sections of the collected samples were subjected to reactions with zink chloride and iodine, phloroglucine with hydrochloric acid and Sudan IV. Tissue macerates were prepared using hydrogen peroxide (H₂O₂) at temperature of 40°C. The number of stomata was determined on celloidic prints. Measurements of surfaces covered with sclerenchyma and vascular bundles were performed on drawings by planimeter. The surface covered by cell walls in the peripheral, sclerenchymatic stem ring was determined by the "scanning" method, a microscope with an ocular equipped with a grid.

Figures presenting the distribution of sclerenchyma in the peripheral part of the stem were performed using a reader – Documator (Zeiss). The rest of figures was prepared using a microscope – Amplival (Zeiss), with a drawing socket MNR2 (PZO). For comparative analysis the dendritic method, according to the Wrocław taxonomy (Perkal 1967), was used. The analysed lines were compared in respect to 50 anatomical traits (see list of traits in Fig. 26).

RESULTS

Distribution of vascular bundles and sclerenchyma

On cross-sections of the corn stem one can distinguish: the peripheral, including the epidermis, densely packed vascular bundles surrounded by lignified sclerenchyma fibres and thick-walled parenchyma, and the central part of more loosely distributed vascular bundles surrounded by thin-walled parenchyma cells, with a small amount of sclerenchyma. The peripheral part of the stem covered from 15.9% (S215) to 22.7% (bm₂) of the cross-section surface of the stem. The number of vascular bundles in stem ranged from 180 (bm₁) to 252 (S335). According to the number of bundles per surface unit, differences were found between the lines. The highest density was recorded in line bm₂ (4 bundles per 1 mm²), and the lowest in line S215 (1.5 bundle per 1 mm²). The peripheral part of the stem contained from 50 to 65% of bundles. The density of bundles in the peripheral part ranged from 2.9 per mm² (S339) to 6.5 per mm² (bm₁), and in the central part from 0.8 per mm² (S339 and S336) to 1.8 per mm² (bm₂).



Figs 1, 2, 3. Distribution of sclerenchyma in the peripheral part of the stem in three corn lines: 1 – bm₂, 2 – S339, 3 – S215.

Figs 4, 5, 6. Anatomical structure of the peripheral part of the stem in three corn lines: 4 – S336A, 5 – bm₁, 6 – S335.

Fig. 7. Dendrite illustrating the degree of similarity between seven lines of corn determined on grounds of five traits of sclerenchyma fibers.

The lines differed distinctly in shape and size of bundles and in number and way of distribution of subepidermal and circum-bundle sclerenchyma. The lines bm_1 , bm_2 and S336A (Fig. 1) showed bundles distinctly smaller in size, circular in cross-section, and of similar distribution of sclerenchyma as in the remaining lines. Distinctly radially elongated bundles and the accompanying strands of sclerenchyma were found in lines S336, S339 and S335 (Fig. 2). Among the analysed lines particularly distinct was the line S215, of very massive sclerenchymatic sheaths, broadened in the tangential stem axis (Fig. 3).

Significant differences between the lines were connected with the structure of the peripheral part of the stem. The surface covered by sclerenchyma in that part of the stem ranged from 25.9% (bm_1) to 41.2% (S215). Line bm_2 , in contrast to the remaining lines, showed phloem fibers of bundles closest to the stem surface, bound with the subepidermal sclerenchyma ring. Thereby formed were sclerenchyma ribs appearing as a fine relief on the stem surface. It seems, that such a distribution of sclerenchyma may protect the stem against breaking.

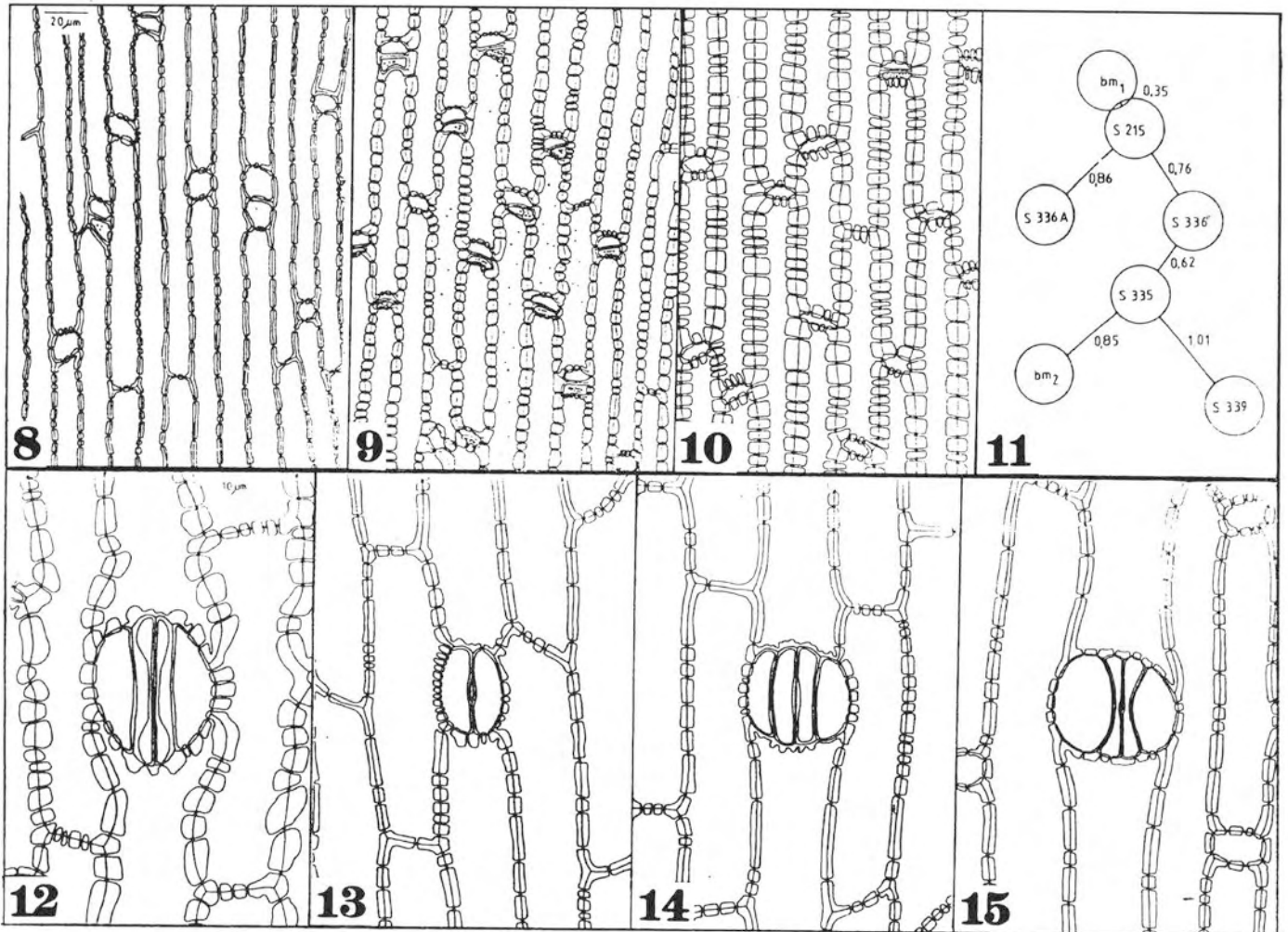
The results of measurements of the surface covered by cell walls in the external stem ring, including the epidermis, and the layers of sclerenchymatic fibers and the thick-walled parenchyma localized under it, allowed to ascertain that the investigated lines differentiate into two groups. The first group, of finer stem construction, consisted of lines bm_1 , bm_2

and S335, and the second one of the remaining four lines (S215, S336, S336A and S339). The surface covered by cell walls was in the first group 43% to 44% and in the second 68% to 72% (Figs 4, 5, 6).

Sclerenchyma fibers

The average length of sclerenchyma fibers of the investigated lines ranged between 813 μm (S339) and 1089 μm (S215). The variation range of fiber diameter fluctuated between 10.5 μm (bm_2) and 17.2 μm (S335). The lines differed distinctly in thickness of sclerenchyma fiber walls. The thickest walls (4.3 μm) were characteristic for fibers of line S215, and the thinnest (1.9 μm) for bm_2 . It seems that lines bm_1 and bm_2 differ distinctly in respect to sclerenchyma-fiber thickness. The cell walls of lines bm_1 were more than twice as thick as in bm_2 .

The degree of similarity between the lines determined on the basis of average differences with regard to five sclerenchyma-fiber traits (length, diameter, wall thickness, surface of cross-section and the percentage share of walls in cross-section) shows that the smallest differences occur between lines S336A and S339, S336, whereas the greatest differences occur between bm_1 and S335 (Fig. 7). According to the analysed set of sclerenchyma-fiber traits, the lines bm_1 and bm_2 reveal a considerable degree of separation.



Figs 8, 9, 10. Surficial picture of stem epidermis of three corn lines: 8 – bm_2 , 9 – bm_1 , 10 – S336A.

Fig. 11. Dendrite illustrating the degree of similarity between seven corn lines determined on grounds of 13 epidermis traits.

Figs 12-15. Stomata of two corn lines: 12 – stomatal apparatus typical for grasses and corn, as exemplified by line bm_1 ; 13-15 – atypical for grasses and corn stomatal apparatuses in line S339.

Epidermis

The epidermis of the corn stem is a heterogeneous tissue. Its basic components are the ordinary epidermal cells, elongated along the stem axis. Further components are the stomata cells, guard cells, modified ordinary cells adjacent to stomata, siliceous cells and cork cells (Figs 8 to 15).

In the epidermis of the corn stem there frequently occur alternate strands of cells with and without stomata. The ordinary epidermal cells in areas with stomata were somewhat broader and shorter than the respective cells in areas devoid of stomata.

The analysed lines differed considerably in number of the distinguished types of cells, their sizes and thickness of cell-walls. The average length of ordinary epidermal cells fluctuated between 86.2 μm (S339) and 187.3 μm (bm_2). The variation range of width of ordinary epidermal cells was between 14.2 μm (bm_2) and 21.9 μm (S336). Line bm_2 showed the longest, and at the same time the narrowest ordinary epidermal cells. The thickness of the external wall of ordinary epidermal cells ranged from 5.1 μm (S339) to 8.5 μm (bm_1). Anticlinal walls were the thinnest in line bm_2 (1.9 μm), and the thickest in S336A (4.0 μm).

The ordinary epidermal cells had numerous simple pits in walls contacting them with subepidermal cells. The pits occurred in greatest number in line S339 (6200 pits per mm^2), in lowest number in bm_2 (1500 pits per mm^2).

Four inbred lines: bm_1 , bm_2 , S215 and S335 had undulated anticlinal walls of the ordinary epidermis cells. The undulation was more intense within the strands of cells with stomata. The remaining lines had straight anticlinal epidermis walls. The external surface of epidermal cells showed a relief specific for the particular lines. Line bm_1 showed a very characteristic shape of the epidermis surface, with a strongly undulated system of cavities and protrusions. The undulation of surface walls was considerably more intense than in anticlinal walls.

The cell walls of ordinary epidermal cells of six lines showed a strong double refraction in polarized light, with the exception of the cells of line S339. The epidermis cells of line S339 have probably an anisotropic system of cellulose fibrils, while in the remaining lines the system of fibrils is isotropic.

The lines differed considerably in respect to size of stomata and the way of their morphology and density. Six lines showed stomata developed in a way characteristic for grasses (Fig. 12). In these lines the size of stomata showed a relatively small range – from 44.8 μm (S215) to 53.4 μm (S336). As a surprise came the occurrence of stomata of the *Amaryllis* type (a type characteristic for most of Angiosperms), and of intermediate forms between this type and the type characteristic for the Poaceae (Figs 13-15) in the line S339. The stomata of line S339 were considerably smaller (34.8 μm) than in the remaining lines. In line S339 a part of the cells, predestined for transformation into stomata, formed complexes of non-functional cells. These lines differed also considerably in shape of subsidiary cells. These cells, contrary to guard cells and ordinary epidermal cells, have thin cell walls. The number of stomata ranged between 2.5 per mm^2 (S336) and 13.6 per mm^2 (bm_1).

For all the seven lines characteristic was the occurrence of short cells – cork and silica cells in the stem epidermis. These cells occurred in a considerably higher frequency than the stomata. The number of short cells ranged in the analysed lines from 66 per mm^2 (S339) to 576 per mm^2 (S215). The cork and silica cells are much shorter than the ordinary

epidermal cells (Figs 8-10). The lines differed considerably in the relation between the length of short cells and ordinary epidermal cells. The greatest differences were observed between cell lines S215 and S339. In line S215 the ordinary cells were 24 times, and in line S339 only 7 times longer than the short cells.

The analysed lines were divided into three groups in respect to silica bodies content in silica cells. A considerable amount of silica bodies was accumulated by lines S336, S336A and bm_1 . The lines bm_2 , S215 and S335 accumulated usually 1-3 silica bodies. In line S339 no silica bodies were recorded.

The inbred lines differed in number of siliceous cells among short cells. Lines of highest number of short cells – S215 and bm_1 , contained at the same time the highest percentage of silica cells (46% and 43%). The line S339 of lowest number of short cells had only about 4% of cells similar in structure to silica cells, but without silica bodies. Short cells occurred singly, in twos or threes. The lowest number of short cells occurring singly showed line bm_1 (6.4%), and the highest number – line S339 (92.3%). Silica cells accompanied, as a rule, cork cells, and only rarely occurred singly.

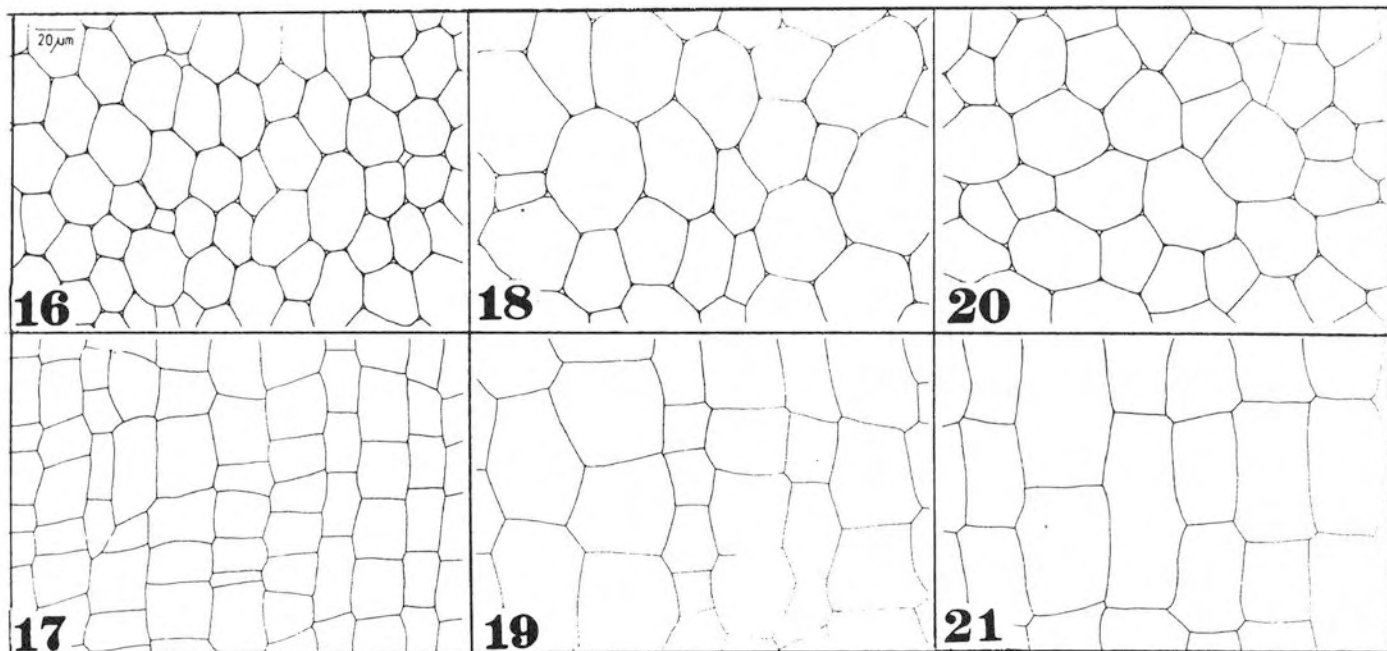
From comparisons of the seven lines, in respect to all the analysed epidermis traits, it results that the lowest degree of similarity occurs between lines bm_1 and S339, and the highest between bm_1 and S215 (Fig. 11).

Parenchyma

In the investigated lines the extravascular parenchyma tissue was clearly differentiated into a peripheral and central part. The differences concerned mainly the wall thickness and the size of cells. The walls of the peripheral part of the stem were considerably thicker than in the central part. The cell volume in the central part was on average 7.6 times as big as in the peripheral part. The greatest differences were recorded in line bm_1 (15.8 times), and the lowest in S336 (5.3 times). The differences between peripheral and central parenchyma concerned also cell shape. The length of parenchyma cells in the peripheral part was on average 3.5 times their width, and in the central part – 1.7 times. The investigated lines differed considerably in respect to height and diameter of parenchyma cells. The average diameter of parenchyma cells in the peripheral part ranged from 30 μm (bm_1) to 57 μm (S339), and in the central part from 53 μm (bm_2) to 78 μm (S339). The mean height of parenchyma cells in the peripheral part ranged from 100 μm (S339) to 217 μm (S335), and in the central part from 73.2 μm (S215) to 175.3 μm (S335).

The analysis of the degree of similarity, based on five traits of extravascular parenchyma cells, indicates that the investigated lines form one set of groups of highest similarity when parenchyma of the peripheral part of the stem is taken into account, and others when the parenchyma of the central part of the stem is considered (Figs 22, 23). In respect to traits of parenchyma cells of the peripheral part of the stem the lines are divided into three groups (Fig. 22). The lines bm_1 and bm_2 formed an almost identical pair, (distance 0.08). The second group was formed by four lines: S215, S336, S336A and S339. In this set line S336 took an intermediate position. Line S335 formed the third group of lowest degree of similarity in relation to the remaining lines.

In respect of traits of parenchyma cells of the central part of the stem the lines formed two groups (Fig. 23). The first one consisted of bm_1 , bm_2 , S336 and S215 (Figs 16 and 17), and the second of S335, S336A and S339 (Figs 18-21). The first group of high similarity consisted of the lines bm_1 and S336. The degree of similarity of lines bm_1 and bm_2 was, in



Figs 16-21. Parenchyma cells of the central part of the stem in three corn lines: 16, 17 – bm_2 ; 18, 19 – S335; 20, 21 – S336A; Figs 16, 18, 20 – cross-sections; Figs 17, 19, 21 – longitudinal sections.

respect to parenchyma traits of the central part of the stem, considerably lower than in respect to traits of this tissue in the peripheral zone.

Metaxylem and metaphloem

A characteristic trait of most of the stem bundles in corn is the presence in metaxylem of two vessels distinguished by size. The average diameter of these vessels ranged in the investigated lines from 48.4 μm (bm_2) to 79.1 μm (S336A). The cross-section surface of metaxylem vessels in line S336A was about 2.7 times that of bm_2 . The line with the greatest surface of vessels per 1 mm^2 of the stem was line S336A (18.666 $\mu m^2/mm^2$), which is, at the same time characterized by the greatest vessel diameter. This suggests that among the investigated lines this one shows the most effective water conduction. The lines of smallest vessel surface per 1 mm^2 of of the stem were: bm_1 (9.161 $\mu m^2/mm^2$) and S339 (9.520 $\mu m^2/mm^2$).

Sieve-tube members of corn metaphloem are specialized. They are characterized by simple sieve plates situated perpendicularly to the long axis of the stem. The average surface of cross-section of sieve-tube members ranged from 155 μm^2

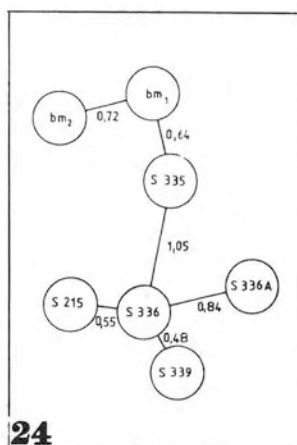


Fig. 24. Dendrite illustrating the degree of similarity between seven corn lines in respect to seven traits of metaxylem and metaphloem.

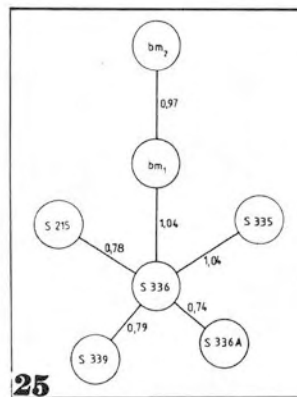
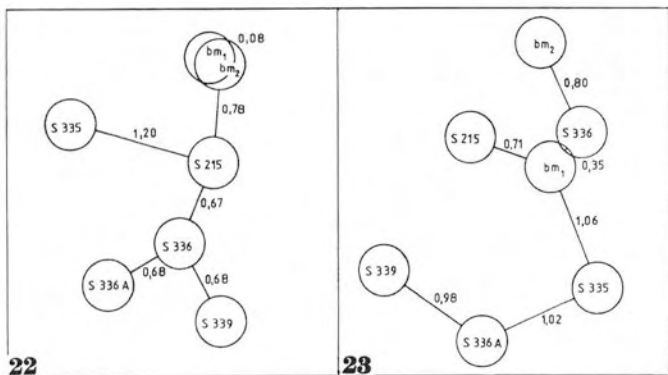


Fig. 25. Dendrite illustrating the degree of similarity between seven corn lines in respect to 50 anatomical traits of the stem.



Figs 22, 23. Dendrites illustrating the degree of similarity between seven corn lines in respect to five traits of the extravascular-parenchyma cells; 22 – peripheral part of the stem; 23 – central part of the stem.

(bm_1) to 351 μm^2 (S336A). Line bm_2 showed sieve-tube sizes similar to those in bm_1 .

The analysed lines differed considerably in respect to size of vascular bundles and their components, phloem and xylem. The differences in bundle size were also associated with their position in the stem. The surface covered by metaphloem in bundles of the peripheral part of the stem was on average about half of that in bundles of the central part. The line with the smallest surface of metaphloem in vascular bundles of the

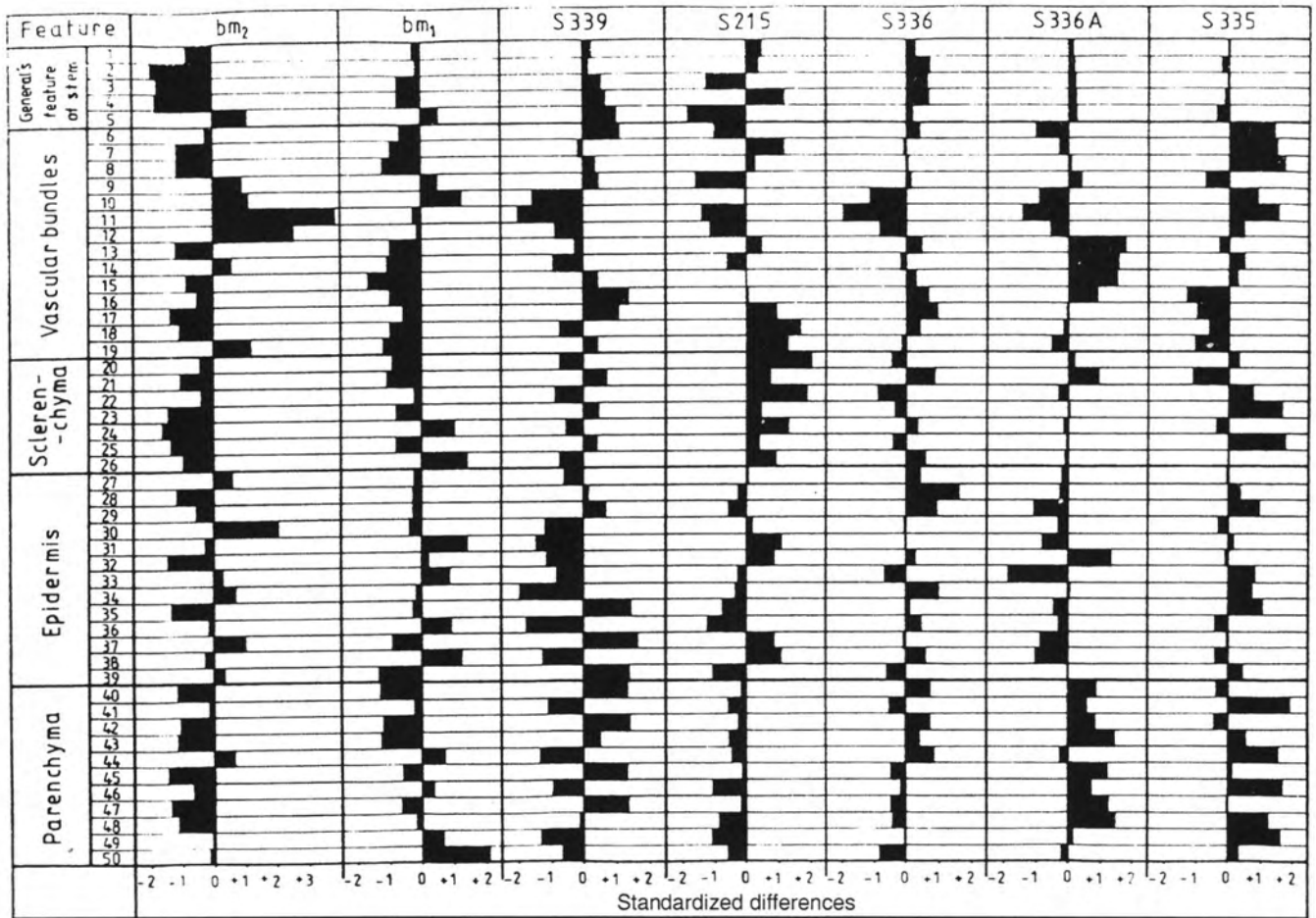


Fig. 26. Diagram of standardized differences (ξ) of 50 anatomical traits of the stem in seven corn inbred lines; $\xi = \frac{(x - \bar{x})}{s}$; x – mean value of trait for single line; \bar{x} – mean value of trait for seven lines; s – standard deviation.

List of investigated traits

General features of the stem:

1. Stem diameter.
2. Surface of cross-section of the peripheral part of the stem (P1).
3. Surface of cross-section of the central part of the stem (P2).
4. Surface of the whole cross-section of the stem (P1+P2).
5. Percentage of P1 from (P1+P2).

Vascular bundles:

6. Number of vascular bundles in the peripheral part of the stem (P1).
7. Number of vascular bundles in the central part of the stem (P2).
8. Number of vascular bundles in the whole cross-section of the stem (P1+P2).
9. Percentage of vascular bundles of P1 from (P1+P2).
10. Number of vascular bundles per 1 mm² of P1.
11. Number of vascular bundles per 1 mm² of P2.
12. Number of vascular bundles per 1 mm² of P1+P2.
13. Surface of cross-section of metaxylem vessels.
14. Surface of metaxylem vessels per 1 mm² of cross-section of the stem.
15. Surface of cross-section of sieve-tube members.
16. Surface of metaphloem in bundles of the peripheral part of the stem.
17. Surface of metaphloem in bundles of the central part of the stem.
18. Total metaphloem surface in cross-section of the stem.
19. Surface of metaphloem per 1 mm² of the stem (P1+P2).

Sclerenchyma:

20. Surface covered by sclerenchyma in the outer 0.5 mm of the stem ring.
21. Surface covered by cell walls in the outer 80 μ m of the stem ring.
22. Length of sclerenchymatic fibers.
23. Diameter of cross-section of sclerenchymatic fibers.
24. Thickness of cell walls of sclerenchymatic fibers.
25. Surface of cross-section of sclerenchymatic fibers.
26. Percentage of cross-section of sclerenchymatic fibers covered by cell wall.

Epidermis:

27. Length of ordinary epidermal cells.
28. Tangential breadth of ordinary epidermal cells.
29. Height of anticlinal walls of ordinary epidermal cells.
30. Length-breadth relation in ordinary epidermal cells.
31. Thickness of outer epidermal-cell walls.
32. Thickness of anticlinal walls of epidermal cells.
33. Number of stomata per 1 mm² of surface.
34. Size of stomata.
35. Number of pits per 1 mm² of surface in ordinary epidermal cells and subepidermal cells.
36. Number of cork cells and silica cells per 1 mm².
37. Size of cork and silica cells (along the stem axis).
38. Percentage of silica cells among short cells.
39. Percentage of short cells occurring singly.

Parenchyma:

40. Diameter of parenchyma cells in the peripheral part of the stem.
41. Height of parenchyma cells in the peripheral part of the stem.
42. Surface of cross-section in parenchyma cells in the peripheral part of the stem.
43. Volume of parenchyma cells in the peripheral part of the stem.
44. Relation of height to diameter in parenchyma cells of the peripheral part of the stem.
45. Diameter of parenchyma cells in the central part of the stem.
46. Height of parenchyma cells in the central part of the stem.
47. Surface of cross-section of parenchyma cells in the central part of the stem.
48. Volume of parenchyma cells in the central part of the stem.
49. Relation of height to diameter in parenchyma cells of the central part of the stem.
50. Relation of volume of parenchyma cells in the central part of the stem to volume of parenchyma cells in the peripheral part of the stem.

peripheral part of the stem was line S335 ($2.578 \mu\text{m}^2$), and with the largest one – line S339 ($7.922 \mu\text{m}^2$). The line of smallest metaphloem surfaces in bundles of the central part of the stem was bm_2 ($6.021 \mu\text{m}^2$), and with the largest ones – line S339 ($13.416 \mu\text{m}^2$). The variation range of lines in respect to metaphloem surface per 1 mm^2 of stem was from $11.600 \mu\text{m}^2$ (bm_1), to $19.300 \mu\text{m}^2$ (S215).

According to metaxylem and metaphloem traits, the investigated lines formed two groups. To the first belonged bm_1 , bm_2 and S335, and to the second S336, S339, S215 and S336A (Fig. 24).

General characteristics

Considering all the fifty traits, the lines could be divided into three groups (Fig. 25). The first group is constituted by lines bm_1 and bm_2 , the second by S336, S336A, S215 and S339, and the third one by line S335. The inbred line S336 takes an intermediate position among all the investigated lines. It results from comparison of seven inbred lines analysed in respect to standardized differences of the traits that each of the lines represents a specific combination (Fig. 26). The sets of traits characterizing the particular lines are in such a degree specific that they form a sort of a fingerprint and may serve for their identification.

The greatest anatomical differences occurred between lines bm_2 and S335. In line bm_2 thirty six from all the fifty traits showed numerical values lower than the average of seven lines, whereas line S335 had twenty nine traits of values higher than the average.

On the grounds of standardized means of fifty traits, the lines could be arranged in a linear system (Fig. 27). According to this arrangement four lines: S339, S215, S336 and S336A are very close to each other. The range of differences between lines taking extreme positions in this group, S339 and S336A, was significantly smaller (0.52) than between these lines and bm_1 and bm_2 on the one hand, and S335 on the other. The four lines with average standardized values of very close traits showed, however, large differences in respect to numerical values of particular traits and their combinations (Fig. 26).

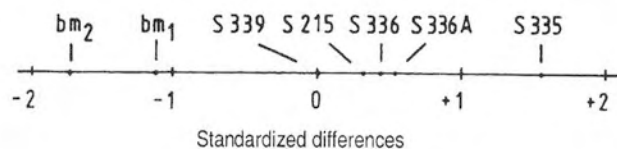


Fig. 27. Linear arrangement of seven corn inbred lines based on means (\bar{x}), standardized differences ($\bar{\xi}$); $\bar{x} = \frac{\sum \xi}{n}$, $\sum \xi$ – sum of standardized differences of 50 anatomical traits; n – number of traits (50).

DISCUSSION AND CONCLUSIONS

The increasing numerical values of the bulk of analysed anatomical traits of the stem are clearly associated with the increase in xerism. Among such traits are mainly those, which lead to the increase in the degree of sclerification, improvement of waterflow and its control. The analysis of the investigated lines in this respect shows that inbred lines with gene brown midrib show in general the lowest degree of xerism among the seven analysed lines. However, in respect to some of these traits, these lines were the best in adaptation to xerophytic conditions. In line bm_2 to such traits belonged: the highest number of bundles per surface unit of stem cross-section,

and the longest, but at the same time the narrowest ordinary epidermal cells. In turn line bm_1 is represented by in the following series of xeric traits: highest number of stomata per surface unit, high content of silica bodies in silica cells, highest number of cork and silica cells and the thickest external walls of epidermis cells.

The obtained results indicate that each of the analysed lines is a composition of xero-, and mesophytic traits. Thus, it may be expected that as a result of crossing between properly selected lines, in filial generations may appear some recombinants with traits much more mesophytic and xerophytic than in the presently analysed forms.

The degree of resistance to lodging and mechanical injuries is mainly associated with xeric traits, and above all with the amount and properties of the sclerenchyma. Easily lodging forms of corn and other plants have distinctly less sclerenchyma than forms resistant to lodging (Garber and Olson 1919; Hunter and Dalbey 1937; Murdy 1960). Garber and Olson (1919) found a positive correlation between wall thickness of the sclerenchyma and resistance to lodging, and lack of correlation between length of sclerenchyma fibers and lodging. The analysed lines differed considerably in a series of traits regarding the sclerenchyma, such as: transverse measures of fibers, cell-wall thickness, degree of lignification, length of fibers and spatial distribution of this tissue. Most probably each of these traits has its share in the mechanical properties of the stem. The resistance of the stem to lodging and breaking is most probably affected also by shape of the cross-section of the stem. It seems that in this aspect the occurrence of the finely ribbed structure of the stem in line bm_2 is also important. This may possibly compensate the reduced amount of sclerenchyma in this line. Spatz et al. (1993) and Spatz and Speck (1994) in their studies on resistance of cereal plant stems to mechanical injuries mentioned the significant, influence of parenchyma turgor on this resistance. The extravascular, thin-walled parenchyma in corn occurs in the central part of the stem. The investigated lines differed distinctly in size of these parenchyma cells. Parenchyma of cells small and elongated longwise the stem axis, has most probably higher mechanical values than parenchyma of large isodiametric cells. The type of parenchyma occurring in lines with bm gene, and particularly in line bm_2 , is probably another compensation for the limited amount of sclerenchyma in this line.

The parenchyma in the peripheral part of the corn stem undergoes sclerification to a different degree. In forms of particularly rigid stems, apart of hypodermal and circumbundle sclerenchyma fibers, a strong sclerified cylinder of parenchyma develops (Magee 1948). In the analysed lines this parenchyma differed not only in degree of sclerification, but also in size and shape of the cells. Lines bm were characterized by exceptionally narrow and long cells. This is probably another trait compensating the reduced amount of sclerenchyma in these inbred lines.

A significant influence on mechanical properties of the stem is probably exerted also by the epidermis. The lines differed widely in cell composition, size of cells and thickness of the epidermal-cell walls. Considerable differences in respect to epidermis structure occurred between lines bm_1 and bm_2 . The epidermis structure of line bm_2 indicates its distinctly greater mechanical resistance in comparison with line bm_1 .

His peculiar that in stem epidermis of one of the lines (S339) occur stomata of the Amaryllis type, a type characteristic for all Angiospermae. The unusual for Poaceae occurrence of stomata of kidney-shaped cells has been previously observed in corn by Warneke (1912). The stomata described

by him occurred on the internal surface of leaf sheaths. These stomata differed somewhat from those in line S339. They showed guard cells arranged perpendicularly to the stoma axis. The appearance of Amaryllis-type stomata in corn points to the way of evolution of stomata of the Graminae type.

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CECHY ANATOMICZNE 7 LINII WSOBNYCH KUKURYDZY W TYM DWÓCH Z GENEM BROWN MIDRIB

STRESZCZENIE

Wykonano badania anatomiczne łodygi 7 linii wsobnych kukurydzy wyhodowanych w Zakładzie Doświadczalnym Hodowli i Aklimatyzacji Roślin w Smolicach. Dwie spośród tych linii (bm₁ i bm₂), zawierające gen brown midrib odznaczały się podwyższoną strawnością. Pozostałe 5 linii (S215, S335, S336, S336A i S339) stanowiły elitarnie linie wsobne będące komponentami w hodowli mieszańców w Zakładzie w Smolicach.

Badane linie porównano pod względem 50 anatomicznych cech łodygi. Porównań dokonano przy pomocy metody dendrytu wrocławskiego. Pod względem stopnia podobieństwa badane linie utworzyły trzy odrębne grupy. Jedną grupę stanowiły dwie linie z genem brown midrib (bm₁ i bm₂), drugą – cztery linie (S215, S336, S336A i S339) a trzecią – linia S335. O zaszeregowaniu obu linii z genem bm do jednej grupy zdecydowało podobieństwo pod względem zespołu cech dotyczących miękiszu, szczególnie peryferyjnej części łodygi, oraz metaksylemu i metafloemu. Linie te różniły się natomiast znacznie pod względem cech skórki. Osobliwością jednej z linii (S339) było występowanie aparatów szparkowych typu Amaryllis.

Każda z badanych linii stanowiła charakterystyczną mozaikę cech. Zestawy cech charakteryzujące poszczególne linie były tak dalece specyficzne, że można je uznać za odpowiednik odcisku palca, mogący służyć do ich identyfikacji.

SŁOWA KLUCZOWE; kukurydza, anatomia łodygi, skórka, sklerenchma, miękisz, wiązki przewodzące, brown midrib, kseromorfizm.