Acta Biologica Szeged. *21* (1—4), pp. 35—40 (1975)

INFLUENCE OF HISTOLOGICAL FACTORS ON STALK STRENGTH IN MAIZE

L. KÁLMÁN, J. NÉMETH, Á. KOROM, and I. MARÓTI

Cereal Research Institute, Szeged and *Department of Botany, Attila József University, Szeged*

(Received September 12, 1974)

Abstract

For 10 maize genotypes, the percentage of broken stalks two weeks after harvesting, and crushing strength of 5 cm sections of the second internode were determined and crushing strength was compared with histological structure.

The primary determinant of mechanical stalk strength appeared to be, beyond the rind thickness, the thickness of the sheath of the vascular bundles at the periphery of the stalk. The number of vascular bundles did not differ, except in the peripheral zone, where more were present in weak-stalked types.

In the last few years the increased stalk-breaking in maize, that caused considerable yield loss in Hungary was considered to be result of monoculture, mechanized harvesting, application of large amounts of nitrogen fertilizer (above 160 kg/ha), and higher plant population.

Research workers searching for the causes of stalk-breaking usually discuss the problem from the point of view of their own special field of research, emphasizing the overhelming importance of one of the factors possible that may be important.

The fungi reported by SZÉCSI (1973), *Fusarium roseum* var. *graminearum* and *Fusarium roseum* var. *culmorum* were the cause of root-and stalk-rot in corn in Hungary.

KOEHLER et al. (1925), FOLEY (1960), and WILCOXSON (1962) observed that many broken stalks were not badly rotted, yet rotted stalks still stood upright. NELSON (1958) suggested distinguishing between two types of stalk-breaking, i.e., caused by susceptibility to fungi on the one hand, and caused by the poor mechancal strength of stalk tissue on the other.

In order to estimate stalk strength, and often stalk-rot too, for many years only a single method was used, namely a percentage of broken stalks — broken above the ear — of a given genotype. This method provides a measure of the gross character, but provides little information concerning the relative importance of component factors, and it is seriously dependent upon environmental factors.

ZUBER and GROGAN (1961) introduced a mechanical method applicable for quantitative measuring. This crushing-strength measurement provides reliable information in regard to stalk strength of individual plants, because crushing-strength is significantly correlated with standing upright and rind thickness and weight of 5 cm sections of second and third internodes.

The question is raised whether existence of various types showing a wide range of stalk quality may be explained on the basis of the fine structure of stalk.

Inbred lines differing in lodging behaviour were studied by HUNTER and DALBEY (1937) in the field and in the laboratory. Correlations between anatomical structure and field behaviour were found. Strong-stalked lines possessed thick layers of deeply stained sclerenchyma, both around the vascular elements and in the subepidermis, and had angular cells with small intercellular spaces.

McROSTIE and MACLACHLAN (1942) noted that strong-stalked corn had much lignification beyond the rind and a large number of vascular bundles within the lignified area. MAGEE (1948) reported that strong-stalked types had a low bundle number per square millimeter in the rind, a high percentage of sheath per bundle, a large stalk diameter, and a wide lignified zone. FOCKE and KUHFUSS (1961) concluded that resistance to lodging appeared to be associated with an increase in stalk lignification both in the peripheral tissues and in the vascular bundles.

BOOTHROYD (1962) concluded that stalk strength was not associated with the histological aspects considered which include the percentage of sclerenchyma sheath fibres per vascular bundle and per unit area of the rind. NELSON (1958) established that genetical improvement of stalk strength had not been accompanied by the change in number of vascular bundles, neither in the rind nor in the pith. According to CHANG and LOESCH (1972) the genotypic correlation between field lodging and bundle number in pith was essentially nil.

In the present work we studied the relationship between mechanical stalk strength and morphological components of the stalk.

Materials and Methods

Five strong-stalked single crosses (A223×B14, EPI×W79A, Bc5[1]×GK4[2], A90×153R Fv2×153R) and five weak-stalked single crosses (A619×A632, A223×Kb6[3], Kb6×K71[4], Exp.29 F7×GK1) were chosen on the basis of previously observed stalk lodging responses. The hybrids were planted in a simple randomized block design with four replications. The spacing in the case of hybrids belonging to the early—maturity hybrids were planted in rows 70 cm apart and 25 cm between plants within rows whereas the later—maturing hybrids were spaced 70 cm between and 30 cm within rows.

1) Line released to cooperators by Zagreb.
2) Lines used by the Cereal Research Institute of Szeged
3) Lines used by the Institute for Irrigation in Szarvas, Hungary
4) Lines used formerly by the University of Agricultural Sciences of Keszthely, Hungary.

The percentage of stalk-breakage was recorded two weeks post harvesting (which occurred when grain moisture was 28 per cent). Stalks samples were taken from the second internode above soil level and dried at 40 °C for seven days. For the determination of mechanical stalk strength, five cm sections were cut from each internode.

Crushing strength was measured with an oil hydraulic press, while rind thickness was evaluated with a micrometer according to the method introduced by ZUBER and GROGAN (1961).

Six stalk sections of each hybrid were used for the histological study and the six observations were averaged. The stalks one centimeter thick were sawed from the center of each internode. Sections were boiled in distilled water for 8—10 hours and sectioned with a freezing microtome. After a histochemical staining (malachit green, toluidin blue) the sections were covered in gelatin paraffin. Besides micro—photographs some sections were photographed by projecting their image onto film with an enlarger.

Results and Discussion

Our measurements showed that the types resistant to stalk-breaking belonged to the interval 131—190 kilopounds, and the weak-stalked types belonged to the interval 50—115 kilopounds (Table 1).

Table 1. Percentage of stalk breakage and crushing strength and rind thickness of the second internode of the strong- and weak-stalked genotypes

Genotypes	Percentage of stalk breakage two weeks after harvesting (H_2O % at harvest = 28	Crushing strength (kp)	Rind thickness (mm)
A223×B14	1.3	151	1.634
EP1×W79A	5.3	190	1.235
Bc5×GK4	5.7	131	1,267
A90×153R	6.2	175	1.428
Fv2×153R	6.6	150	1.065
A619×A632	25.0	94	1.392
A223×Kb6	57.1	50	1.079
Kb6×K71	64.0	115	1.116
Exp.29*	65.8	54	1.097
F7×GK1	84.0	79	0.925
SzD%		41	0.151

* closed pedigree

According to data obtained out of the literature and our earlier results, there is a significant correlation between mechanical strength and rind thickness (ZUBER and GROGAN, 1961).

The "rind" represents a peripheral part of the stalk section which may be separated from the pith even mechanically after drying. It is a darker cylindrical ring.

The area of rind of the second internodes was estimated at 17—24 p. c. The area of rind in the case of strong-stalked genotypes was somewhat larger than in the case of weak-stalked ones. But the mechanical strength of the stalk can not be explained merely by thickness of the rind.

As a result of our investigations we concluded that the fine structure of the rind has an important role in making the stalk strong. Probably stalk strength is dependent on the proportion of lignified tissue elements.

If a stalk section is magnified a few times, it is clear that the collaterally closed vascular bundles are closer together near the periphery than in the central parenchymatic ground tissue which consits of larger cells with relatively thin walls. Distribution of the vascular bundles was counted in 0,5 mm broad zones from the epidermis to pith, and density was recorded in a columnal diagram (Fig. 1). The number

of vascular bundles in the first zone was higher in the case of the weak-stalked genotypes than in the strong-stalked ones. The density of vascular bundles in the second, third, and fourth zones was nearly the same.

Being merely 40 – 60 μ thick, even in the lower internodes, the hypodermal parenchyma is presumably of little importance in strengthening the stalk. The sclerified parenchyma is more important among the strengthening tissues. The rind consists mostly of this tissue and it may be regarded as a transitional zone between ground parenchyma and hypodermal sclerenchyma. The sclerified parenchyma was, on an average, 0,2 – 0,3 mm larger in the strong-stalked genotypes than in the weak-stalked ones. The peripheral zone consisting of smaller cells and intercellular spaces is important not only in strengthening the stalk but also in the transport of metabolites as well.

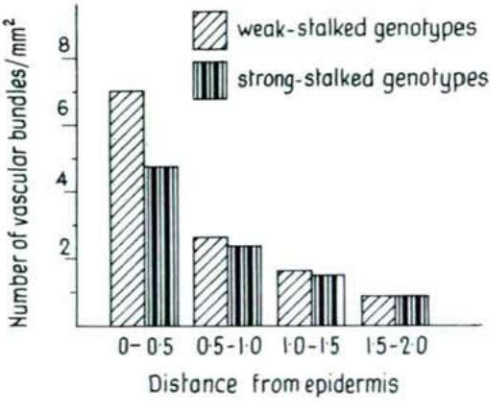

Fig. 1. Distribution of vascular bundles in different zones between rind and pith in the weak- and strong-stalked genotype

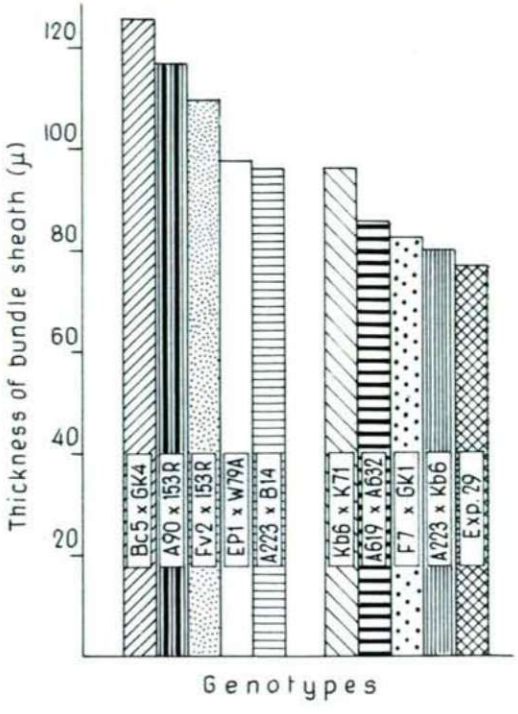

Fig. 2. The avarage thickness of bundle sheaths in the 2 mm zone from epidermis of weak- and strong-stalked genotypes

During the ripening period, when most of the cells in the pith die off because of Fusarium infection, the water transport in the plant is hardly disturbed, as the 50—60 p. c. of vascular bundles located in the rind (Table 2) continue to function.

Table 2. Percentage of the rind area of the cross section of 2. internode and the percentage of the vascular bundles in the rind and pith of the 2. internode at the different hybrids

Combinations	Percentage of the rind area of the cross section of 2. internode	Percentage of the vascular bundles in the rind and pith of the 2. internode
A223×B14	23.9	53—47
EP1×W79A	20.8	46—54
Bc5×GK4	20.6	55—45
A90×153R	23.3	54—46
Fv2×153R	21.2	54—46
A619×A632	23.1	60—40
A223×Kb6	18.9	42—58
Kb6×K71	18.9	54—46
Exp.29	19.3	50—50
F7×GK1	17.2	54—46

The third strengthening tissue is the bundle sheath. This sheath, consisting of fibres of procambial origin, can continue to thicken as a result of sclerification of parenchyma cells. The thickness of bundle sheaths was, on an avarage, 20—30 μ thicker in the strong-stalked genotypes than in the weak-stalked ones (Figs. 2, 3).

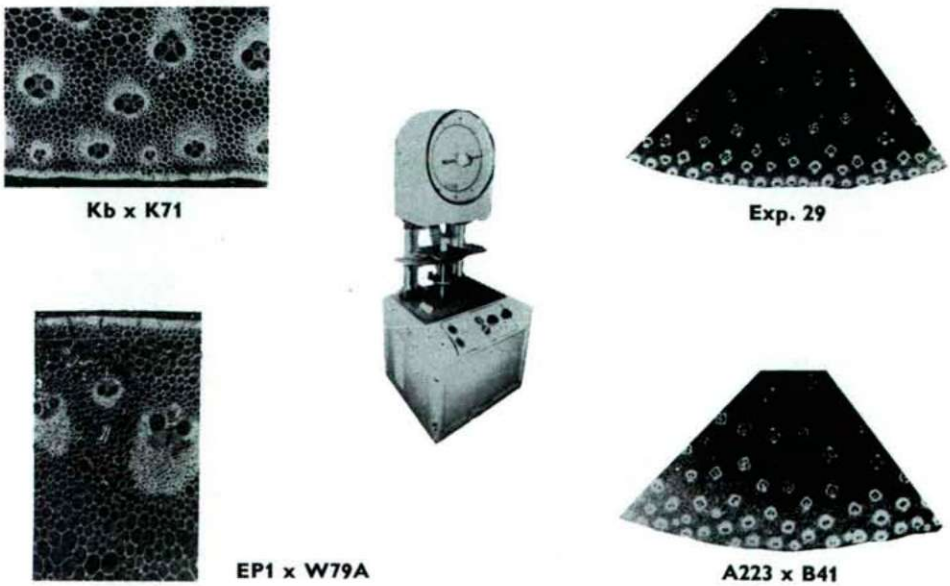

Fig. 3. Cross sections of stalk of strong — and weak — stalked hybrids and the hydraulic press.

Literature

BOOTHROYD, C. W. (1962): Histological structure of corn stalks in relation to field resistance to stalk rot. Phytopathology *52*, 726 (Abstr.)

CHANG, HUI-SHONG, and LOESCH, P. J. JR. (1972): Genetic variation of four anatomical traits and their association with stalk-quality traits in maize (*Zea mays* L.). — Crop Science *12*, 271—274.

FOCKE, R. and KUHFUSS, K. H. (1961): Beobachtungen über Umbruchschaden bei Mais unter Einwirkung von Erdraupenfrass. — Nachr. Bl. Dtsch. Pfl. Sch. Dienst, Berlin *15*, 184—187.

FOLEY, D. C. (1960): The response of corn to inoculation with Diplodia zeae and Gibberella zeae. — Phytopathology *50*, 10 (Abstr.).

HUNTER, J. W. and DALBEY, N. E. (1937): A histological study of stalk-breaking in maize. — American Journal of Botany *24*, 492—494.

KOEHLER, B. G., DUNGAN, H. and HOLBERT, J. R. (1925): Factors infuencing lodging in corn. III. — Agr. Exp. Sta. Bull. 354.

MAGEE, J. A. (1948): Histological structure of the stem of *Zeae mays* in relation to stiffness of stalk. — Iowa State Coll. J. Sci. *9*, 489—503.

MC ROSTIE, G. P. and MACLACHLAN, J. D. (1942): Hybrid corn studies. — J. Sci. Agr. *22*, 307—313.

NELSON, C. E. (1958): Lodging of field corn as affected by cultivation, plant population, nitrogen fertilizer, and irrigation treatment. — U. S. Dept. Agr. Production Res. Rept. No. 16.

NELSON, S. W. (1968): Observed and expected response of yield and stalk strength to full-sib family selection in a population of maize. Ph. D. Thesis. — North Carolina State University (Libr. Congress Card Mic. 68—17. 567; Univ. Microfilms, Ann Arbor, Mich, Diss. Abstr. *29*, 4534-B).

SZÉCSI, Á. (1973): *Fusarium roseum* var. *graminearum* és *F. roseum* var. *culmorum* izolátumok celluláz aktivitása talajkultúrában. — Növénytermelés *22*, 103—106.

WILCOXSON, R. D. (1962): Stalk rot in relation to yield of corn. — Phytopathology *52*, 416—4188.

ZUBER, M. S. and GROGAN, C. O. (1961): A new technique for measur.ng stalk strength in corn. Crop Sci. 1:380.

Address of the authors:
Dr. L. KÁLMÁN
Dr. J. NÉMETH
Dr. Á. KOROM
Cereal Research Institute
H-6726 Szeged,
Dr. I. MARÓTI
Department of Botany, A. J. University
H-6701 Szeged, P. O. Box 428,
Hungary