Internal stem features of spring wheat varieties as factors determinig resistance to lodging

E.V. Ageeva[1]*, I.N. Leonova[2], E.A. Salina[2], I.E. Likhenko[1]

[1] Siberian Research Institute for Plant Industry and Breeding – Branch of the Institute of Cytology and Genetics, SB RAS, Krasnoobsk, Novosibirsk region, Russia
[2] Institute of Cytology and Genetics, SB RAS, Novosibirsk, Russia

DOI 10.18699/ICG-PlantGen2019-09

* e-mail: elenakolomeec@mail.ru

Abstract: Using the anatomical method, the study of the main parameters of the internal stem structure of Russian spring bread wheat varieties was performed in order to assess their impact on resistance to lodging. An increase in the number of parenchyma vascular bundles from top to bottom was established. The decrease in the diameter of the vascular bundles is compensated for by an increase in their number. The diameter of vascular bundles in the internodes had a slight effect on resistance to lodging. The relationship between the numbers of bundles and stem diameter in both interstices was traced. Resistance to lodging correlated with the number of vascular bundles and the length of the internode EN1 and EN2. The number of vascular bundles, stem diameter and thickness of the primary cortex contribute to a high productivity of the ear. The study of anatomo-morphological traits allowed us to identify the cultivars 'Novosibirskaya 31', 'Velut' and 'Bel', which may be of interest for breeding for resistance to lodging.

Key words: resistance to lodging; stem; vascular bundles; parenchyma; internode; wheat.

1. Introduction

Resistance to lodging is one of the important characteristics of modern varieties of bread wheat. Lodging results in a decline in yield and grain quality, and hampers mechanical harvesting. Resistance to lodging in plants is determined by anatomo-morphological, physiological, and chemical parameters of stems (Packa et al., 2015). Anatomical characters usually include the length and diameter of the stem, the number and diameter of the vascular bundles, and the thickness of the primary cortex. However, now there is no consensus as to which parameters make the main contribution to lodging resistance. The aim of our study was to investigate the anatomo-morphological parameters of the stem in Russian varieties of bread wheat.

2. Materials and methods

Plant material incudes 11 Russian spring wheat varieties presented in Table 1. Plants were grown on the experimental field of Siberian Research Institute for Plant Industry and Breeding – Branch of the Institute of Cytology and Genetics SB RAS in 2018. For analysis of the stem anatomical structure, a technique developed at the All-Russian Research Institute of Grain Crops named after I.G. Kalinichenko (2009) for assessment of the conductive system of the ear's internode was used. Estimation of the internodes was carried out on the base of the method proposed by Lazarevich S.V. (1999), that is, from the internode under the ear to the internodes of the lower part of the stem. The internode under the ear was denoted 'EN1' (entre-noeud), the second from the top, 'EN2' and etc. Particular attention in the study of the internal structures of the stem of spring bread wheat in internodes EN1 and EN2 in the varieties was given to the stem diameter, the thickness of the primary cortex, the number and diameter of the vascular parenchyma bundles. Resistance to lodging was scored by a five-point standard technique. For statistical processing, an ANOVA method were used (Dospekhov, 1985). Principal coordinate analysis of the total number of the traits was done with the use of the MRAN software Snedecor 5. The factor analysis was carried out using STATISTICA 8.

3. Results and discussion

The varieties 'Saratovskaya 29' and 'Novosibirskaya 18' were the most prone to lodging. Slightly sopping stems were observed in the 'Novosibirskaya 29', 'Chernyava 13' and 'Novosibirskaya 31' genotypes. The remaining samples of the set do not lodge. The number of bundles in EN1 among the studied samples varied from 14 to 24, but in EN2, from 16 to 33 (see Table 1). On average, an increase in their number from internode EN1 to internode EN2 was eight bundles. The varieties 'Bel' and 'Velut' stood out for these characters, in which 24 and 21 bundles were formed in the internode under the ear, but in the next internode, 33 and 29, respectively. The diameter of the vascular bundle in the upper internode did not exceed 260 μm, and in some genotypes it was below 225 μm. The decrease in the diameter of vascular bundles in EN1 was compensated for by the increase in their number in 'Novosibirskaya 18' (224 μm, 18 bundles), 'Obskaya 2' (215 μm, 19 bundles), 'Trizo' (228 μm, 18 bundles) and 'Bel' (228 μm, 24 bundles); in EN 2 in 'Novosibirskaya 29' (268 μm, 26 bundles), 'Chernyava 13' (270 μm, 28 bundles), 'Novosibirskaya 18' (262 μm, 28 bundles) and 'Velut' (239 μm, 29 bundles).

The varieties 'Bel' (176 and 239 μm in EN1 and EN2, respectively), 'Velut' (217 and 239 μm) and 'Novosibirskaya 31' (219 and 237 μm) were distinguished by the thickness of the primary cortex. The diameter of the internode under the ear was more than 3 mm. The largest diameter of EN1 was in 'Bel' (4.82 mm), 'Chernyava 13' (4.04 mm), and 'Novosibirskaya 31' (4.07 mm). The diameter of EN2 varied from 4.63 to 7.63 mm, which was 2.36 mm larger than the aver-

Table 1
Morphological stem indicators of spring bread wheat, 2018

	The internode under the ear (EN1)				The second upper internode (EN2)			
Variety	Number of bundles, pcs	Diameter of bundles, μm	Diameter of stem, mm	Thickness of the primary cortex, μm	Number of bundles, pcs	Diameter of bundles, μm	Diameter of stem, mm	Thickness of the primary cortex, μm
Novosibirskaya 15	14	259	3.22	164	25	275	5.81	205
Novosibirskaya 29	16	234	3.60	128	26	268	5.29	188
Bel	24	228	4.82	176	33	250	7.63	239
Chernyava 13	18	237	4.04	160	28	270	6.12	213
Saratovskaya 29	14	220	3.18	147	16	254	4.63	184
Obskaya 2	19	215	3.91	136	28	248	6.42	164
Novosibirskaya 18	18	224	3.61	169	28	262	6.01	206
Trizo	18	228	3.60	176	23	258	5.32	199
Novosibirskaya 31	23	245	4.07	219	25	280	6.42	237
Novosibirskaya 16	16	234	3.76	127	28	271	6.18	198
Velut	21	249	3.81	217	29	265	6.16	239
Mean	18	234	3.83	169	26	261	6.17	205
$LSD_{0,05}$*	1.4	9	0.2	10	2.4	8	0.6	12

* Least Significant Difference

Table 2
Results of factor analysis of anatomo-morphological features

Features	PC1*	PC2	PC3
The numbers of bundles of parenchyma EN1, pc.	**–0.899**	0.170	–0.328
The diameter of bundles of parenchyma EN1 , **μ**m	0.308	**–0.870**	0.336
The diameter stem EN1, mm	**–0.862**	0.407	–0.076
The thickness of the primary cortex EN1, **μ**m	**0.619**	–0.504	–0.467
The numbers bundles of parenchyma EN2, pc.	**–0.801**	0.264	0.347
The diameter bundles of parenchyma EN2, **μ**m	0.081	**–0.864**	0.194
The diameter stem EN2, mm	**–0.901**	0.289	0.145
The thickness of the primary cortex EN2, **μ**m	**0.804**	–0.451	–0.268
Resistance to lodging	0.469	0.080	**0.718**

* PC, principal component

age diameter of the upper internode among the samples. The variety ‘Bel’ was characterized by the thickest stem from the whole set, the diameter of EN2 was 7.63 mm. The thinnest stem was in ‘Saratovskaya 29’, 4.63 mm.

In terms of all the features studied, the varieties ‘Velut’ (71.0), ‘Novosibirskaya 31’ (67.3) and ‘Bel’ (67.0) had the largest number of weighted ranks. The correlation analysis reflected the presence of significant correlations between the length of the stem and the length of the upper internode (r = 0.91). A positive correlation of the average degree (r = 0.59–0.37) was noted between the number of vascular parenchyma bundles and resistance to lodging. The correlation between the stem diameter in EN1, EN2 and resistance to lodging did not exceed 0.21.

Estimation of the obtained data by the principal component analysis established that the first three components account for 93.65 % of the total variance. Of these, 52.26 % is explained by the first component, 28.87 %, by the second, and 11.52 %, by the third. The first component is related to the main parameters of the stem in the internodes studied: the number of vascular bundles of the parenchyma, the diameter of the internode and the thickness of the primary cortex (Table 2).

The relationship between the number of bundles and stem diameter in both internodes was established. At the same time, a decrease in the indices of these features results in an increase in the thickness of the primary cortex.

The leading role in the first component belonged to the stem diameter in EN2 (–0.901) and the number of vascular parenchyma bundles in EN1 (–0.899). A number of authors claim that stem diameter and number of vascular bundles are related to the productivity of the ear (Skripka, 2012; Zakharov et al., 2014).

The second component is related to the diameter of the vascular bundles of the parenchyma in the internodes studied. The analysis of this factor showed that it has a significant negative correlation with the diameter of the vascular bundles in EN1 and EN2. It can be assumed that the selection of plants with a smaller diameter of the bundles of the parenchyma layer may be effective.

The greatest load of the third component is observed in resistance to lodging, in the thickness of the primary cortex in the upper internodes and in the number of vascular bundles in EN2, a significant positive relationship was noted only with resistance to lodging (0.718). The feature of resistance to lodging is positively correlated with the number of bundles of parenchyma in EN2 and with the diameter of the bundles in EN1, while an increase in the thickness of the primary cortex and the number of bundles in the upper internode have a negative effect on the resistance to lodging.

Anatomo-morphological features have been identified, which correlate with wheat resistance to lodging (number of vascular bundles, length of internodes EN1 and EN2) and can cause the implementation of high ear productivity (number of vascular bundles, stem diameter and thickness of the primary cortex). It was found that the varieties 'Novosibirskaya 31', 'Velut' and 'Bel' are characterized by the most optimal combination of parameters such as stem diameter, number of vascular bundles and resistance to lodging which allows us to recommend them for breeding.

References

Packa D., Wiwart M, Suchowiska E., Bienkowska T. Morpho-anatomical traits of two lowest internodes related to lodging resistance in selected genotypes of *Triticum*. *Int. Agrophys*. 2015;29:475–483. DOI 10.1515/intag-2015-0053.

Ionova E.V. The method to assess the level of development of the conductive system of the ear's internode of winter wheat with different water availability. *Grain Economy Russia*. 2009;4:18–22 (in Russian).

Lazarevich S.V. The evolution of the anatomical structure of the stem of wheat. Minsk: Bel. ed. partnership "Hut", 1999. 295.

Dospehov B.A. The technique of field experience. Moscow: Agropromizdat, 1985;244–268.

Skripka L.F. Features of the anatomical structure of the stem of winter wheat against the background of making complex compost. *Ecological Bulletin of the North Caucasus*. 2012;3:79–87.

Zakharov V.G., Syukov V.V., Yakovleva O.D. Conjugation of anatomo-morphological features with resistance to lodging of spring soft wheat in the conditions of the Middle Volga region. *Vavilov J. Genet. Breed*. 2014;18(3):506–510 (in Russian).

Acknowledgments. Russian Science Foundation (project 16-16-00011-P) supported this work. Plant cultivation was carried out in the framework of the IC&G budget project No. 0324-2019-0039.

Conflict of interest. The authors declare no conflict of interest.