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Evaluation of Resistance to Lodging of Buckwheat Varieties on the Basis of Anatomical Features.

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ABSTRACT

Lodging crops is one of the reasons for shortage of crops and reducing its quality. For common buckwheat, the tendency to lodging is one of the factors limiting the production of this valuable crop. At the moment, the main area under buckwheat in Russia is taken by the varieties created on the basis of new morphobiotypes: restrictedly branching, determinant, with the physiological determination of growth. The present study aims at evaluating the resistance to lodging varieties, from different modern selections of buckwheat in Russia. We used the method of anatomical studies. It was found that the capacity of growth of woody tissues (sclerenchyma and wood) in the stem of buckwheat can serve as an indicator of resistance to lodging. Quality varietal differences in the anatomical features have not been found. The varieties significantly differed in area of lignified tissues in cross sections of the stem; this feature manifests itself in different varieties, regardless of their affiliation to a particular morphobiotype. It was concluded that in the process of selection of significant increase in thickening lignified tissues of buckwheat varieties did not happen. In addition, the positive correlation of mean strength between the area of woody tissues and the stem thickness and root maintenance of plants.

Keywords: lodging, common buckwheat, varieties, anatomical structure of the stem.

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INTRODUCTION

One of the reasons for the shortfall in the harvest of field crops is the lodging of crops. Every year there is lodging of crops by 30-60% of all cultivated areas [1]. With intensive early lodging, about 60% of the harvest is lost [2]. Lodging of plants leads to the increased growth of weeds, in raw years there is the probability of germination of grain on the root. Such cropping is difficult, it can be accompanied by significant crop damage and its quality decrease.

Resistance of field crops to lodging depends on the growing conditions: air temperature, intensity and spectral composition of light, humidity and soil. The high dense stand, the level of mineral nutrition and moisture supply contribute to lodging of plants [3]. Also, the resistance of plants to lodging is determined by their morphology. There is a correlation between lodging resistance and stem length. The most resistant are the short stature varieties. The leading shoot in the varieties that are resistant to lodging is characterized by short internodes, developed mechanical and vascular tissue, high cellulose content and high lignification of tissues [3]. Natural phenomena are often the direct cause of lodging: strong wind, cloudburst.

The crop lodging control consists in applying the correct agricultural engineering on the one hand. The selection of resistant varieties and hybrids of plants as the most economical and environmentally friendly method plays an important role on the other hand [2].

When estimating the resistance to lodging of varieties and selection material in the field, visual measuring in scores is the most commonly used method [4]. As an alternative to visual measuring of lodging the photogrammetric method is offered, which allows to objectively assess the extent of lodging in terms of quantity [5]. The use of laboratory methods requires relatively small samples of the test material, at the same time they are more time-consuming. Morphological methods are based on measuring the diameter of stem, the height of plant, the length of internodes, the strength of stalk, the mass of stalk and root segments, etc. [4, 6]. The anatomical method allows to trace the formation of the structures being respondent to stalk strength. The indicators of resistance to lodging cereal crops are the thickness of straw, the power of sclerenchyma ring and the number of vascular conducting bundles [7].

Lodging is one of the factors limiting the production of buckwheat [8, 9, 10, 11]. The main reason for low resistance of buckwheat to lodging lies in its architectonics. Poorly developed root system and mechanical stalk tissues often do not provide an adequate backing-up to the long branched stalk with lots of mesophyllous leaves. Usually lodging happens in the second half of vegetation when the plants of buckwheat have the shoots already developed. Stem and root lodging of plants occur in the crops of buckwheat [12]. Increasing doses of nitrogen fertilizers and seeding rate significantly heightens the risk of buckwheat lodging by reducing the content of lignin and related enzymes in the lower part of the stem [11].

For cereals and grains, including buckwheat, the method of prediction of lodging, comprising selection of approbation bundle in the phase of earing (budding) and estimated probability of lodging on the ratio of the minimum and maximum diameter of the 2nd internode from the bottom has been proposed [13]. The original method of selecting plants that are resistant to buckwheat lodging on the color of the root system, the indicator of root maintenance and content of rutin in roots has been also provided [14].

The anatomical structure of the buckwheat stem is a detailed description in a number of works [15, 16, 17, 18, etc.]. Alekseyeva and Pausheva [19] are among the first who study the anatomy of the buckwheat stem from the point of view of lodging. Total estimation of the varieties of buckwheat on lodging resistance has been carried out by Z. I. Ugnivenko [20]. As the anatomical features of resistance, the width of the ring of wood and cortex, the diameter of the central cavity have been defined.

In recent decades, a series of new varieties of buckwheat on the basis of naturally occurring mutations have been found in Russia, such as limited branching, determinate feature, physiological determination of growth. These varieties together with traditional indeterminate varieties occupy the main areas under buckwheat in the country [21]. The aim of this study was to evaluate the resistance to lodging on the anatomical characteristics of the varieties, representing different modern areas of selection of buckwheat in Russia.

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RESEARCH METHODS

We have studied the anatomical structure of the stem of common buckwheat of 6 diploid varieties: Bogatyr (the selection of the Shatilovskaya Agricultiral Experimental Station) Chishminskaya (the selection of the Bashkir Agricultural Research Institute), Ballada and Demeter (the selections of the All-Russian Research Institute of Legumes and Groats Crops) Saulyk and TVS (the selections of the Tatar Research Institute of Agriculture). The varieties are modern selections in Russia: Bogatyr (the first selected variety of buckwheat) and Chishminskaya – the traditional indeterminate morphobiotype, Ballada – the limited branching, Demeter – the determinate morphobiotype, Saulyk and TVS – the forms with physiological determination of growth.

The collection of material was carried out in the collection buckwheat nursery, which was placed on the selection crop rotation of the TatRIA (near the village of Bolshye Kabany of the Laishevo region of Tatarstan of the Russian Federation). The seeding technique is solid drilling, seeding rate – 2,0 million seeds / ha.

To study the anatomy of stalks of the plants in the budding stage, the pieces of the main stalk of different heights from the middle part of internodes were selected and fixed in 70% ethanol. Ten plants from each variety were analyzed. In the laboratory, the material was run through a series of alcohols and brought to the wax. Permanent preparations of cross sections of the stem were made from it. The thickness of sections was 14 microns. Coloration of preparations was fulfilled with gemalaun by Delafield. To find out what structures lignify, a reaction to lignification using phloroglucinol and hydrochloric acid was carried out additionally [22, 23].

The analysis of the anatomical structure of the stem was carried out using a light microscope AC-12. With 105-fold magnification of the microscope, from preparations there were made pictures of peripheral parts of the stem at the level of the hypocotyl using Canon 1100D camera. Based on the photos made with the help of MapInfo Professional program, the area of lignified tissues was calculated. The program allows to accurately estimate the area of curvilinear figures. The scale of ocular micrometer was used to define the scale of drawing. Using stage micrometer, it was determined that the division value of the ocular micrometer was 12,5 microns. The sample size for each plant accounted for 30 values.

Also at the stage of picking maturity for three years by morphological characteristics of resistance to lodging was being determined: plant height, stem thickness in the 2nd internode, etc. (the sample consisted of 35 plants of each variety in each year).

Data processing was performed using the software package of statistical and biometrics and genetic analyses in plant cultivation and selection AGROS [24]. The significance of differences between mean values was determined by Student's ratio at 95% significance level [25].

RESULTS AND DISCUSSION

The structure of the buckwheat stem of the studied varieties is not substantially different from the descriptions in the literature. During budding the buckwheat stem on a cross section in the upper part (the 5th internode from the bottom of the stem) has a rounded or slightly flattened shape; the section edge is wavy (Figure 1). Under the single-layered epidermic tissue there is an angular collenchyma. Its thickness reaches 4-5 layers of cells. Collenchyma thickness is uneven, it is especially well developed in the edges of the stem. Under collenchyma there are several layers of cells forming the parenchyma of the cortex, which rarely meets druses of calcium oxalate. Starch sheath among the other cells of parenchyma cortex is not clearly distinguished. The conduction system has a fascicular structure. The collateral bundles are arranged in a circle, the large interchange the small. In large bundles cambium cells are clearly visible, as well as several large vessels of metaxylem with thickened cell envelopes. The mechanical elements are absent in the xylem. Small bundles formed by interfascicular cambium consist of the elements of phloem and parenchyma. A significant part of the section is taken by the marrow, consisting of large multifaceted parenchyma cells.

On the sections through the third internode of the stem from the bottom there is a gradual increase in the size of vascular bundles. The parenchyma cells in the marrow of the stem begin to break down.

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On the sections through the hypocotyl it is seen that the conduction tissues of the stem have acquired an annular structure (Figure 2). Outwards from the phloem, 8-10 sclerenchyma bundles containing 10-50 extraxilaria fibers are well marked. Inside the wood is lined with a thin layer of parenchyma marrow. In the section center there is a quite large central cavity by this time.

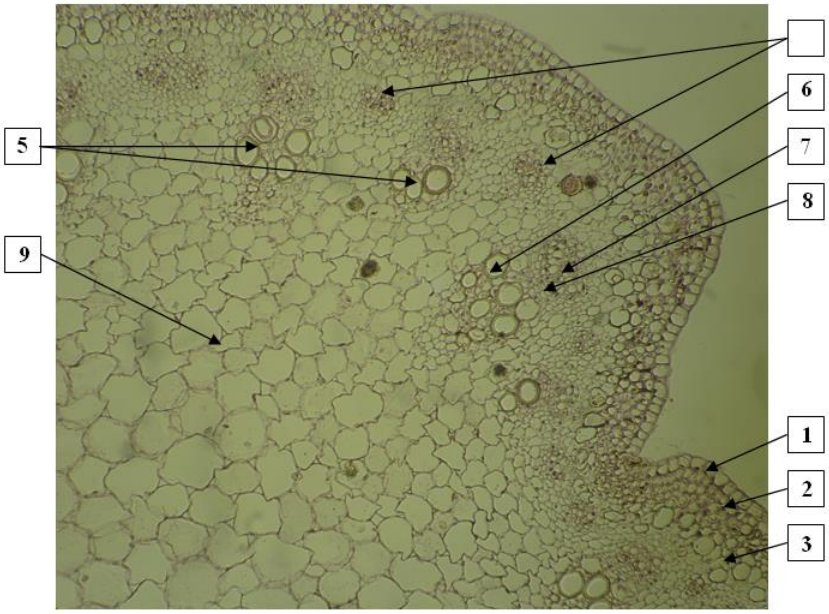

Figure1. The part of a cross section through the 5th internode from the bottom: 1 - epidermis, 2 - collenchyma, 3 - parenchyma of the cortex, 4 - small conducting bundles, 5 - large conducting bundles, 6 - cambium, 7 - phloem, 8 - xylem, 9 - parenchyma of the marrow.

Thus, the stem structure of the studied samples of common buckwheat is typical of dicotyledonous plants [26]. Quality varietal differences in the anatomical features are not found.

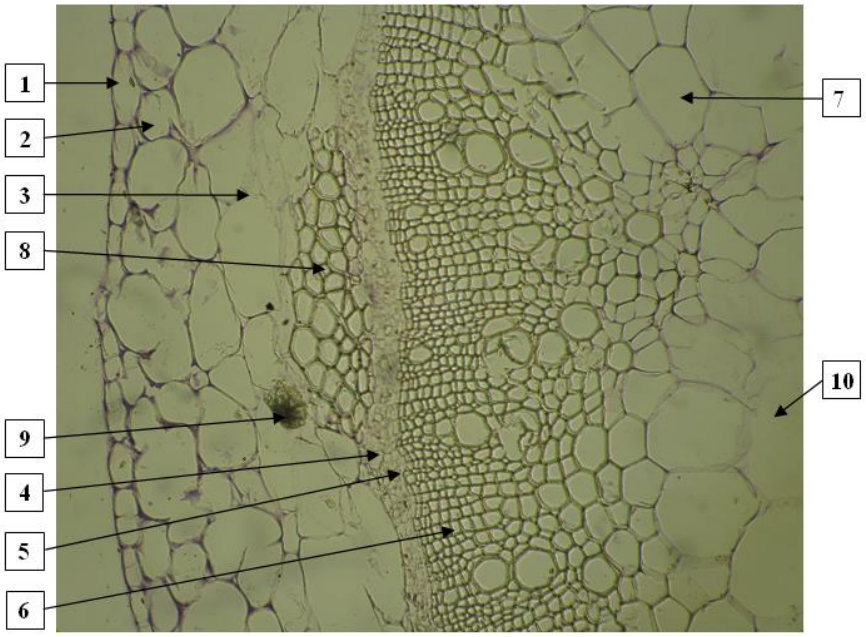

Figure 2. The part of a cross section through the hypocotyl: 1 - epidermis, 2 - collenchyma, 3 - parenchyma of the cortex, 4 - phloem, 5 - cambium, 6 - wood, 7 - parenchyma of the core, 8 - sclerenchyma bundle, 9 - druses of calcium oxalate, 10 – central cavity.

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In the second half of buckwheat vegetation, when the plants of buckwheat are gaining a significant biomass, the risk of lodging increases, resistant functions in the stem are performed by tissues the cell walls of which are lignified. The deposition of lignin in the cell walls makes them particularly stiff [26]. The data obtained suggest that the lignin content in the stem tissue is closely related to lodging resistance in buckwheat [11, 27].

The reaction to lignification has shown that the stem of buckwheat in the budding phase there occurs lignification of sclerenchyma cell walls and wood, i. e. the capacity of development of these tissues can be an indicator of resistance to lodging.

The evaluation of the area of the lignified tissues in sections through the stem has shown that the varieties differ significantly on the basis of this feature (Table 1). The maximum characteristic values are in Saulyk and Bogatyr varieties, the minimum – in the variety of Chishminskaya. The remaining varieties have intermediate values of the area of lignified tissues. Thus, this feature manifests itself in different varieties, regardless of their affiliation to a particular morphobiotype.

Table 1. The Area of Lignified Tissues in the Sections through the Stem of the Varieties of Buckwheat.

Variety	The area of Lignified Tissues, micron^2	
	Mean	Error of mean
Bogatyr	525593,5 d	8419,4
Chishminskaya	406753,5 a	8852,3
Ballada	464497,9 bc	10769,0
Demeter	485619,3 c	7860,5
Saulyk	542663,3 d	14985,2
TVS	457595,9 b	9083,8

Note: hereinafter the values, accompanied by the same letters, differ insignificantly.

According to the morphological characteristics of resistance to lodging, significant differences between the varieties were identified by the height of plants, the length of three basal internodes, the relation of the thickness of the stem in its upper part to the thickness of the stem in its lower part (diminution of the stem). The best results in terms of lodging were revealed resistance according to the following characteristics: the height of the stem – in TVS, the length of the lower internodes – in TVS, Ballada and Saulyk, diminution of the stem taper – in Demeter (Table 2). Varietal differences in the thickness of the stem in the 2nd internode and root maintenance of the plants turned out to be insignificant. The correlation analysis between the area of lignified tissues on the cross sections and the studied morphological characters in buckwheat varieties has been carried out. No significant interrelationships have been found. A positive correlation between the area of average force of lignified tissues with the stem thickness (r = 0,38) and root maintenance of the plants (r = 0,59) has been identified.

Table 2. Morphological Features of Buckwheat Varieties, Characterizing Their Resistance to Lodging.

Characteristics	Variety					
	Bogatyr	Chishminskaya	Ballada	Demeter	Saulyk	TVS
The height of plants, sm	97,2 e	88,9 cd	84,1 c	80,4 bc	74,3 b	57,7 a
The length of three lower internodes, sm	40,4 bc	37,6 b	33,8 a	35,1 ba	33,7 a	30,7 a
The thickness of the 2-nd internode, sm	0,54 a	0,52 a	0,53 a	0,56 a	0,52 a	0,58 a
Relation of the length of the7-th internode to the thickness of the 2-nd internode of the stem	0,40 bc	0,36 ab	0,45 c	0,31 a	0,35 ab	0,40bc
Relation of the mass of root to the mass of elevated organs (root maintenance)	0,07 a	0,06 a	0,07 a	0,08 a	0,08 a	0,08 a

SUMMARY

- Thickening of lignifying tissues (sclerenchyma and wood) in the stem of buckwheat can serve as an indicator of resistance to lodging.
- The structure of the stem in the studied buckwheat varieties is typical of dicotyledonous plants. Quality varietal differences in the anatomical features have not been found.
- Varietal differences in size of the lignified tissues on the cross sections of the stem are significant, the maximum values of the parameter are characteristic features of the varieties of Bogatyr and Saulyk, the minimum – the variety of Chishminskaya.
- A positive correlation of average force between the area of lignified tissues with the thickness of the stem and root maintenance of the plants.

CONCLUSION

The present study has shown that, despite the significant morphological differences of the varieties representing modern trends of selection of buckwheat in Russia from the point of view of the anatomical structure of the stem, they all have a similar structure. Significant thickening in development of the lignified tissues in the process of selection did not occur since the area of the lignified tissues in the cross sections of the stem turned out to be the maximum, including the first selection buckwheat variety of Bogatyr.

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