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Anatomical Characteristics of the Uppermost Internode of Winter Wheat Genotypes Differing in Stem Length

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Abstract. Twenty one winter wheat (*Triticum aestivum* L.) genotypes classified as (1) short, (2) medium or (3) tall were grown in field trials. The following parameters have been measured on the main stem: stem length, peduncle length, dry mass and conducting system parameters including number of vascular bundles and their total and phloem area on peduncle cross section, ear yield and its components. Regardless of differences in peduncle length among the genotypes groups differing in stem length, the peduncle relative length varied only between 36 and 38 % of the total stem length. Nearly identical was also the peduncle specific dry mass reaching 7.4 to 7.6 mg (dry mass) per cm (peduncle length).

The highest number of vascular bundles as well as the largest bundle and phloem area per peduncle cross section were found in the group of short cultivars. There was a positive correlation between the anatomical parameters and kernel number or dry mass per spike. The relationships need not be valid with each genotype because the final ear productivity is subjected to climatic variation well after anthesis when the formation of the stem anatomy has been by far accomplished.

The introduction of dwarfing genes Rht 1 and Rht 2 from the cultivar Norin 10 allowed selection of short wheat cultivars. The reduction of stem length has been also connected with an increasing yield potential which is very often correlated with a higher number of kernels per canopy area and a higher harvest index (Bremner and Davidson 1978). It may be deduced that the dwarfing genes induced changes of the dry matter distribution among the individual plant organs. Brooking and Kirby (1981) and Fischer and Stockman (1986) brought evidence that an increase in kernel number has been connected with an increase in spike dry mass at anthesis. Assimilate made available due to the stem growth inhibition can be efficiently used for a better ear growth. After anthesis, when stem growth does no more proceed, the rate of assimilate transport into the spike may be reduced by the capacity of the conducting tissue.

In this paper, the short, medium and tall cultivars have been used for analyses of the relationship between the stem and peduncle length, their anatomical parameters and ear yield.

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MATERIAL AND METHODS

Twenty one cultivars and lines of winter wheat (*Triticum aestivum* L.) divided into short, medium-stemmed and tall ones were sown in a field experiment in Praha-Ruzyně using a seed rate of 4.5 millions of viable seeds ha^{-1}. The three groups comprised the following genotypes:

1. Short genotypes: Bu-17, Maris Fundin, Maris Marksman, Sava, Super Zlatná.
2. Medium-stemmed genotypes: Amika, Caribo, Kormorán, Margin, Maris Huntsman, NA-4, Slavia, UH-1072, Weihenstephan 378.
3. Tall genotypes: Chlumecká 12, Fakir, Iljichovka, Kavkaz, Mironovskaja, Mironovskaja 10, Zora.

All the short genotypes hold the dwarfing gene (Šíp and Škorpík 1987).

At maturity, 10 plants were sampled from each of the 3 field replicates of each genotype. Only the main stem was further used for the measurements of the stem length, peduncle length and dry mass. Number of kernels per ear and one kernel mass were also determined. For anatomical analyses, a 2 cm long peduncle segment was cut off about 1 cm below the ear, put into boiling water for one hour and then into glycerol for at least one week. Hand made cross sections were investigated using a stereomicroscope WILD M5A with a camera and monitor. On the cross sections, the number of large vascular bundles was counted directly on the monitor. The picture of the bundle was then redrawn from the monitor onto a transparency and using a planimeter the total bundle and phloem area was determined. Finaly, the bundle and phloem areas per peduncle cross section have been calculated.

RESULTS AND DISCUSSION

The stem length of the short cultivar group (73 cm) was by 36 % smaller than the average of the long cultivar group. The peduncle length was 27, 33 and 43 cm in the average of short, medium stemmed and tall cultivars, respectively. Hence, the relative peduncle length was nearly identical for all the three groups, namely 0.36 to 0.38 of the total stem length. There was a similar proportionality in the peduncle dry mass of 205, 245 and 317 mg of short, medium and tall cultivars, respectively, resulting in a specific peduncle dry mass of 7.4 to 7.6 mg (peduncle dry mass) cm^{-1} (peduncle length) and indicating practically no difference among the three groups.

The highest number of vascular bundles as well as the largest vascular bundle and phloem areas on peduncle cross section were found in the group of short cultivars (Table 1). On the other hand, the lowest values of the investigated anatomical parameters were found in the tall variety group. Its bundle and phloem areas were smaller by 17 and 11 %, respectively. Contrary to these results, Kozdoj (1987) evaluating short and tall spring wheat cultivars found

TABLE 1

Capacity of transport system in the peduncle of winter wheat genotypes summed up into three groups according to their stem length.

Group of genotypes	Vascular bundles [No.]	Bundle area on peduncle cross section [μm²]	Phloem area on peduncle cross section [μm²]
Short	22.5	299 598	37 927
Medium	20.8	257 698	35 295
Tall	19.7	248 933	33 664
$LSD_{0.05}$	0.5	10 178	1 577

that the decrease in stem length was connected with a decrease in the number of vascular bundles while the total cross section area of bundles or phloem per internode did not decrease.

There was a positive correlation between the number of vascular bundles and their area (r = 0.583) or phloem area (r = 0.612) per the whole peduncle cross section. However, no significant correlation was found between the size of one bundle or its phloem and the number of bundles per peduncle.

Significant correlations were also found between the number of kernels per ear and vascular bundle number (r = 0.637), bundle area (r = 0.648) and phloem area (r = 0.739). Slightly smaller values were obtained when calculting the correlation coefficients between the ear yield and bundle area (r = 0.510) or phloem area (r = 0.577).

It may be seen, that the short genotype group has both the highest transport capacity and ear productivity (Table 2) which was expressed mainly by the significantly higher number of kernels per ear.

TABLE 2

Kernel yield and its components in the main stem of winter wheat genotypes summed up into three groups according to their stem length.

Group of genotypes	Number of kernels per ear	Kernel mass [mg]	Kernel yield per ear [g]
Short	40.9	40.0	1.63
Medium	36.4	45.4	1.59
Tall	33.3	45.9	1.53
$LSD_{0.05}$	2.0	1.5	0.99

Positive correlations between yield and stem structures have also been reported in the literature. Nátr (1964) found a higher number of vascular bundles in highly yielding and lodging resistant winter wheat cultivars as compared with low yielding and lodging nonresistant cultivars. The ear productivities of di-, tetra-, and hexaploid wheat cultivars were also positively correlated with phloem cross section areas (Evans *et al.* 1970). A higher kernel mass per ear in a sample of soviet wheat cultivars was also accompanied by a higher bundle and phloem area as demonstrated by Pushkarenko (1984). Using cultivars with different ear productivity, we were able to demonstrate that the highest sink capacity was closely correlated with a high capacity of the stem transport system (Nátrová 1987).

Results reported in this paper indicate, that the group of short cultivars has not only a highest ear productivity but also the highest transport capacity of the peduncle when compared with the average of medium and especially tall cultivars group. However, the ear production could be considerably modified by variation of external conditions even by the end of the whole growing season while the formation of the stem anatomy is nearly completed by the end of anthesis. Furthermore, limiting effects of the conducting system on ear productivity are likely to occur only when both high rate of photosynthesis and long life span of leaves and kernel filling have been assured. An appropriate stem anatomy is unambigously an important prerequisite for a high ear productivity. But such a prerequisite although very important cannot be considered as the only decisive condition. The anatomical structure enables certain rates of physiological processes the realisation of which however depends on the interaction between the genotype under consideration and its environmental conditions.

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