Advances in Environmental Biology, 5(7): 1433-1437, 2011
ISSN 1995-0756

This is a refereed journal and all articles are professionally screened and reviewed

ORIGINAL ARTICLE

An Anatomical Study of Vascular System of Spike: Distribution of Central and Peripheral Vascular Bundles along the Rachis of Wheat

Davood Eradatmand Asli and Alireza Houshmandfar

Department of Agronomy and Plant Breeding, Islamic Azad University, Saveh Branch, Saveh, Iran.

Davood Eradatmand Asli and Alireza Houshmandfar: An Anatomical Study of Vascular System of Spike: Distribution of Central and Peripheral Vascular Bundles along the Rachis of Wheat

ABSTRACT

The distribution of central and peripheral vascular bundles was investigated within a spike of wheat (*Triticum aestivum* L. var. *PBW-343*). The results divulged that the distribution of the central and peripheral vascular bundles in their rachises was different from that of the main stem of the plant. The total number of central and peripheral vascular bundles declined acropetally from the peduncle till it attained minimum values at the internode below the terminal spikelet. Two lateral vascular bundles were branching in every node (spikelet) along the rachis as compared to central vascular bundles which showed dropping in the whole of rachis except in first three nodes or occasionally elsewhere, where only branching operated. The number of central vascular bundles deduction in proximal vascular bundles was at a rate of less than one bundle per spikelet, whereas in middle segment of spike the rate of decline appeared to increase on an average of 1.3 vascular bundles in each spikelet. However the declension in distal segment of spike was less than the middle segment at the rate of one bundle per spikelet which was more than proximal segment. From the foregoing, it may be hypothesized that wherever the vascular bundle in rachis branched (as in proximal or distal), it was associated with a poor grain number as well as in the poor fertility of the spikelet and was, associated with a lower capacity of the individual grains to grow (1000 grain weight) as compared to dropping (prevalent in middle segment of the ear) which was linkable with higher fertility as well as better precipitation of photosynthetase by individual grains. To sum up the above findings it is apparent that the disparity in the dimensions of vascular bundles at different segments of a spike could be a pivotal factor affecting the ultimate size as well as number of grains present along the rachis.

Key words: Partitioning of assimilates; spikelet; grain weight; *Triticum aestivum* L.

Introduction

One of the key factors which directly affects the grain yield in wheat is the partitioning of assimilates between grains and vegetative biomass [1,4,8,10]. Frequently, the efficiency of the vascular system for mobilizing the assimilates to the growing grains has been pointed out as prime factor which could limit the grain yield [9]. However, little information is available about the ways and means used by the vascular systems for the translocation of assimilates from the peduncle to the grains which are strikingly variable in their capacity in accumulating food. The objectives of this present study were to establish the number and distribution of the vascular bundles in the different parts of rachis divisible into proximal, middle and distal segments through which food was supplied to individual differentially growing grains in aforementioned positions of spike and correlate the same with their innate natures.

Corresponding Author

Davood Eradatmand Asli, Department of Agronomy and Plant Breeding, Islamic Azad University, Saveh Branch, Saveh, Iran.
Email: asli@iau-saveh.ac.ir

Materials and methods

The investigations were conducted with a common bread wheat (*Triticum aestivum* L. var. *PBW-343*), which was sown in circular earthenware pots (50x30x30 cm) containing 35 kg of soil mixed with farmyard manure (4:1). Eight seeds per pot were sown and after 15 days, seedlings were thinned to two. Hoagland's nutrient solution [5] was supplied to the pots. For study of vascular bundles of rachis tagged ears were collected and spikelets removed from the rachis at maturity. Rachis internodes were fixed in formalin, acetic acid and ethyl alcohol (formalin 5 ml, acetic acid 5 ml, 50 percent ethyl alcohol 90 ml in the ratio of 1:1:9). After 3 days, the material was transferred to 70 percent alcohol until use. The internodes of spike were dehydrated in tertiary butyl alcohol (TBA) according to the procedures described by Johansen [6] with some modifications. After dehydration, materials were kept for another 24 hours in TBA before embedding in paraffin wax (58 – 60^{o}C M.P.). Subsequently, the embedded materials were kept in paraffin wax for 24 hours at 60^{o}C and were used for cutting sections. The serial sections were done by rotary microtome (Spencer 820, American Optical Company, USA) at the thickness of 8-12 µm and stretched on plate and processed for staining. The staining was executed with safranin and fast green combination according to the procedures described by Purvis *et al.* [7] with some modifications. Staining samples mounted in D.P.X. and kept in oven for 24 hours to dry and thereafter photographed with a photomicrography microscope (Olympus Camera). The numbers of central and peripheral vascular bundles as well as the number of xylem elements and of sieve tubes in lateral bundles were counted under a light microscope (Olympus, Japan).

Results and discussion

Figure 1 reveals a step wise description of the out-lines of anatomical studies of the rachis which supported the vital spikelets e.g. Figure 1A (right) shows an ear whereas 1A (left), produced after the removal of the spikelets gives an overview of the rachis. A closer morphological look of Figure 1A projects that the main axis is semicircular at the initiation of any internode, and as it ascends takes a spindle shape which culminates into a node in a semicircular form to restart into a fresh internode (Figure 1B). The microscopic view of the internode (Figure 1C) reflects that all vascular bundles are embedded in the parenchyma with the larger ones (V) being arranged in a circle or ellipse, while the smaller peripheral (P) are located close to chlorophyllous bands. In the internodes, the two largest bundles (L) were usually at the 2/3rd end of the long axis of the ellipse, and are termed as lateral bundles (Figure 1C).

A closer scrutiny of Figure 1 D and E discloses that all the vascular bundles of the peduncle do not continue into the rachis and that the number of bundles entering each node depends on the specific position of the node in the rachis e.g. the number of central vascular bundles in the peduncle was found to be 25 while at the internode number 1 the same got truncated to 22 but at internode 9 it further declined to 15. This is in contrast to the situation in the stem where the number of bundles is the same after every leaf node. It appears that the distribution of the vascular system in the rachis is different from that of stem.

Figures 1 (C, E and D), 2, 3 and 4 show the distribution of the central and peripheral vascular bundles in individual internodes of different segments (i.e., proximal, middle and distal) running through the rachis of ear of wheat. As apparent from the Figures, the total number of central and peripheral vascular bundles declined acropetally from the peduncle to the rachis till it attained minimum values of 4 and 12 respectively at the internode below the terminal spikelet. The pattern of decline, however, varied with the type of bundles.

Furthermore, a positive linear relationship was established between the mean number of spikelets per ear and the number of central vascular bundles at the base of the rachis (internode 1). The total number of central vascular bundles at the base of the rachis less two is related to the total number of spikelets present on the ear. This relationship was valid for all ten replications which were examined. The 1:1 relationship suggested there was a constant number of bundles supplying each spikelet and further, a single bundle tends to belong to each spikelet while the rest as a constant number served some unknown purposes. A scrutiny of data shows that the number of central vascular bundles declined at an approximate rate of one bundle per internode along the rachis specifically from internode 3 onwards. Up to internode three the number of central vascular bundles remained at 22. Since the basal five spikelets, being supported by four internodes have been designated as proximal segment of the ear [3] it may be assumed that the declension in the number of central vascular bundles in this zone was to the tune of only two vascular bundles or to say an average 0.4 of a vascular bundle per spikelet. Hence the number of deduction in proximal vascular bundles was at a rate of less than one bundle per spikelet, whereas between internode 5 and 14 (middle segment of spike) the rate of decline appeared to increase (1,1,1,2,2,2,1,1,1 and 1 vascular bundle disappearing in internodes 5,6,7,8,9,10,11,12,13 as well as 14 respectively) on an average of 1.3 vascular bundle in each spikelet.

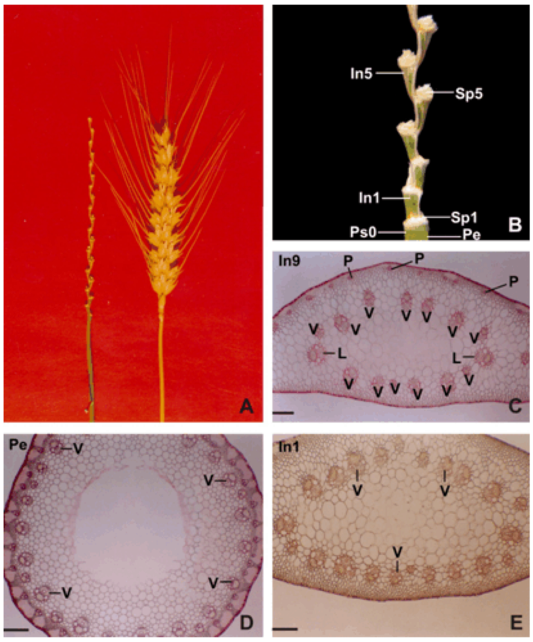

Fig. 1: A- Mature wheat ear showing arrangement of spikelets along the rachis (right) and spikelets removed (left); B- Lower portion of rachis magnified to show peduncle (Pe), position 0 (Ps0), internode 1 (In1), internode 5 (In5), spikelet 1 (Sp1) and spikelet 5 (Sp5); C- Transverse section of rachis internode 9 showing the centeral (V), lateral (L) and peripheral (P) vascular bundles; D- Upper region of the peduncle of a 20 spikelet ear (V,central bundles); E- Transverse section of internode 1 of a 20 spikelet ear showing the number of central vascular bundles (V). Scale bar = 200 µm.

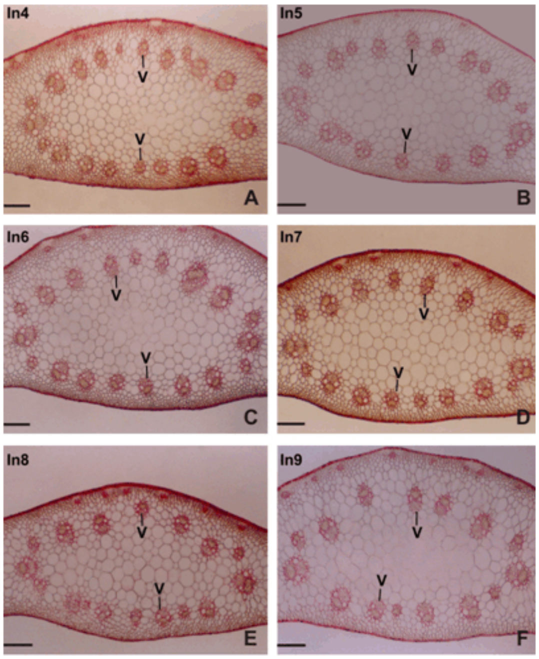

Fig. 2: Transverse sections of vascular bundles of rachis internodes (In4 - In9) in different segments of spike: A- Internode number 4 with 21 central vascular bundles (V); B- Internode number 5 with 20 central vascular bundles (V); C- Internode number 6 with 19 central vascular bundles (V); D- Internode number 7 with 18 central vascular bundles (V); E- Internode number 8 with 17 central vascular bundles (V); F- Internode number 9 with 15 central vascular bundles (V). Scale bar = 200 µm.

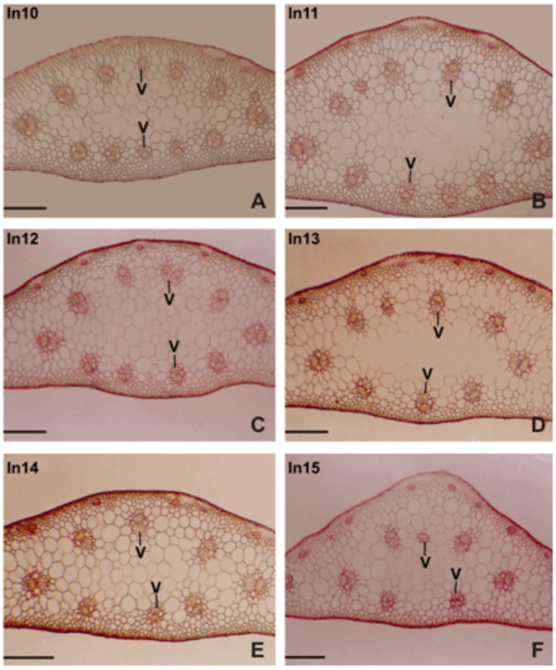

Fig. 3: Transverse sections of vascular bundles of rachis internodes (In10 – In15) in different segments of spike: A- Internode number 10 with 13 central vascular bundles (V); B- Internode number 11 with 11 central vascular bundles (V); C- Internode number 12 with 10 central vascular bundles (V); D- Internode number 13 with 8 central vascular bundles (V); E- Internode number 14 with 8 central vascular bundles (V); F- Internode number 15 with 7 central vascular bundles (V). Scale bar = 200 µm.

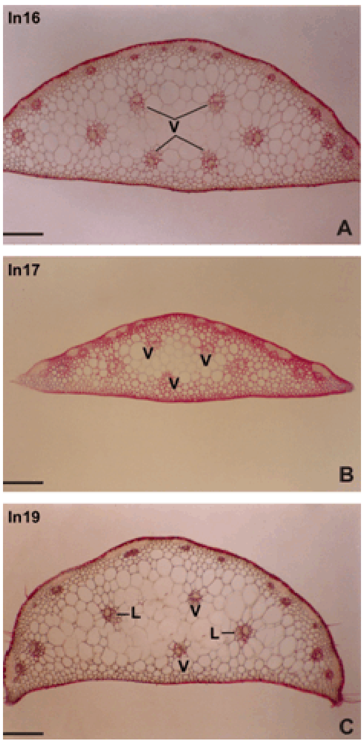

Fig. 4: Transverse sections of vascular bundles of rachis internodes (In16 – In19) in different segments of spike: A- Internode number 16 with 6 central vascular bundles (V); B- Internode number 17 with 5 central vascular bundles (V); C- Internode number 19 with 2 central vascular bundles (V) and 2 lateral vascular bundles (L). Scale bar = 200 µm.

However the declension of vascular bundles between internode 15 and 19 was less than middle segment at the rate of one bundle per spikelet (1,1,0,1 and 2 vascular bundles in internodes 15,16,17,18 and 19 respectively) which was more than proximal segment (Figures 1 E, 2, 3 and 4). As is well known through the innumerable reports and findings, middle region of spike as compare with proximal and distal regions produces the maximum level of grain dry weight [2].

Furthermore, of the four central vascular bundles, traversing through the terminal spikelets the function of two is baffling and are usually referred as lateral bundles and contribute the base number of bundles available to each spikelet in an ear. These lateral or surplus bundles branch at every node of spike. The branching assures their constant number at every internode and hence does not follow the acropetal decrease in their number along the rachis as was the case of central bundles. The supply by these lateral bundles is through branching network as compared to central bundles which may be designated as dropping. Going by this nomenclature it may be surmised that lateral vascular bundles were branching in every node (spikelet) along the rachis exclusively in the first three nodes as well as node number 18 as compared to the case of central vascular bundles which was dropping in the whole of rachis except in first three nodes as well as node number 18 where only branching operated.

Peripheral bundles were relatively more in the basal internodes. Their number fell from 38 (at the base of the ear) to 27 at internode 5 (start of middle segment of rachis) and to 15 at internode 15 (first spikelet of distal segment of spike). These bundles were immediately adjacent to photosynthesizing chlorophyllous parenchymatous cells, in the outer extremities of the rachis and presumably functioned to transport nascently synthesized assimilates into the tissues of the rachis. The minimum number of recorded peripheral bundles was 12 noticeable at internode below the terminal spikelet (Figure 4C).

From the foregoing, it may be hypothesized that wherever the vascular bundle branched (as in proximal or distal), it was associated with a poor grain number thereby resulting in a poor fertility of the spikelet and was also, associated with a lower capacity of the individual grains to grow (1000 grain weight) as compared to dropping (prevalent in middle segment of the ear) which was associated with higher fertility as well as better precipitation of photosynthetase by individual grains. To sum up the above findings it is apparent that the disparity in the dimensions of vascular bundles at different segments of a spike could be a pivotal factor affecting the ultimate size as well as number of grains present along the rachis.

References

1. Abeledo, L.G., D.F. Calderini, G.A. Slafer, 2002. Physiological changes associated with genetic improvement of grain yield in barley. In: G.A. Slafer, J.L. Molina-Cano, R. Savin, J.L. Araus, eds. Barley science: recent advances from molecular biology to agronomy of yield and quality. New York: Food Product Press, pp: 361-386.
2. Aufhammer, W., P. Zinsmaier, F. Bangerth, 1986. Variation of dry matter accumulation at definite positions within wheat ears and levels of indole-3yl acetic acid (IAA). Plant Growth Regulation, 4: 305-310.
3. Bangerth, F., W. Aufhammer, O. Baum, 1985. IAA level and dry matter accumulation at different positions within a wheat ear. Physiol Plant, 63: 121-125.
4. Foulkes, M.J., G.A. Slafer, W.J. Davies, P.M. Berry, R. Sylvester-Bradley, P. Martre, D.F. Claderini, S. Griffiths, M.P. Reynolds, 2010. Raising yield potential of wheat. III. Optimizing partitioning to grain while maintaining lodging resistance. Journal of Experimental Botany 1-18.
5. Hoagland, D.R., D.I. Arnon, 1939. The water culture method for growing plants without soil. Calif. Agri. Expt. Stn. Cir. 12: 347-352.
6. Johansen, D.A., 1940. Plant microtechnique. McGraw-Hill, New York, pp: 273-277.
7. Purvis, M.J., D.C. Collier, D. Walls, 1966. Laboratory techniques in botany. 2nd edn. Butterworths, London, pp: 287.
8. Shearman, V.J., R. Sylvester-Bradley, M.J. Foulkes, 2005. Physiological processes associated with wheat yield progress in the UK. Crop Science, 45: 175-185.
9. Simmons, S.R., D.N. Moss, 1978. Nitrogen and dry matter accumulation by kernels formed at specific florets in spikelets of spring wheat. Crop Sci., 18: 139-143.
10. Reynolds, M.P., M.J. Foulkes, G.A. Slafer, P.M. Berry, M.A.J. Parry, J.W. Snape, W.J. Angus, 2009. Raising yield potential in wheat. Journal of Experimental Botany 60: 1899-1918.