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**ORIGINAL ARTICLE**

## **An Anatomical Study of Vascular System of Spike: Dynamics of Central Vascular Bundles at Successive Internodes along the Rachis of Wheat**

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### **ABSTRACT**

The dynamics of central vascular bundles at successive internodes was investigated within a spike of wheat (*Triticum aestivum* L. var. *PBW-343*). Spikes were divided into three grain positions included proximal (spikelet number 1 to 5), middle (spikelet number 6 to 15), and distal (spikelet number 16 to 20) regions. The result indicated that the average size of central vascular bundles declined in an acropetal fashion and there was a net reduction to the tune of approximately 95 percent in its quantum by the time it entered the terminal internode as compared to the base of the ear. In the proximal segment, the net loss in total measurable area of central vascular bundles was approximately 17 percent and a comparison of this value in the middle segment of spike, revealed that the loss was approximately 70 percent which was about 50 percent higher than proximal segment. Similarly the reduction in distal position was approximately 14 percent. It appeared that there was a direct positive correlation between reductions in the size of central vascular bundle with the fertility of a spikelet as well as its grains capacity to grow. 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 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 objective of this present study was to establish the size 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.

### **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. Spikes were divided into three grain positions included proximal (spikelet number 1 to 5), middle (spikelet number 6 to 15), and distal (spikelet number 16 to 20) regions.

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The spikelets were numbered in ascending order with the most proximal one on peduncle side as number 1 with a sequential increase ending at number 20. 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°C M.P.). Subsequently, the embedded materials were kept in paraffin wax for 24 hours at 60°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  $\mu\text{m}$  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). Sizes of individual vascular bundles in different internodes of spike were determined according to Whingwiri *et al.* [11] by the distance in transverse section between the outer edges of the bundle sheath cells, adjacent to the two metaxylem vessels. The total vascular bundle size was the aggregate of individual vascular bundles sizes. In making sections, particular emphasis was given to (i) the upper part of the peduncle (position 0) to provide an estimate of the size of vascular bundles entering to the ear from the stem; (ii) rachis internode number 10, the region where large grains are formed; and (iii) rachis internode 17, the zone where small grains have been observed among distal spikelets.

## Results and discussion

Evaluation of the frequency distribution of the size of the central vascular bundles along the rachis reveal that the average size of central vascular bundles declined in an acropetal fashion and there was a net reduction to the tune of 94.9 percent in its quantum by the time it entered the terminal internode (internode 19) as compared to the base of the ear (position 0). The critical analysis of the decrement offered some unique revelations in the three different segments. It was revealable that in the first four internodes (supporting 5 spikelets: proximal) the net loss in total measurable area of central vascular bundles was 16.7 percent and a comparison of this

value from 5 to 14 (10 internodes: middle segment) revealed that the loss was 69.4 percent which was 52.7 percent higher than proximal segment. Similarly the reduction in distal position, supporting 16 to 19 internodes, was 13.9 percent.

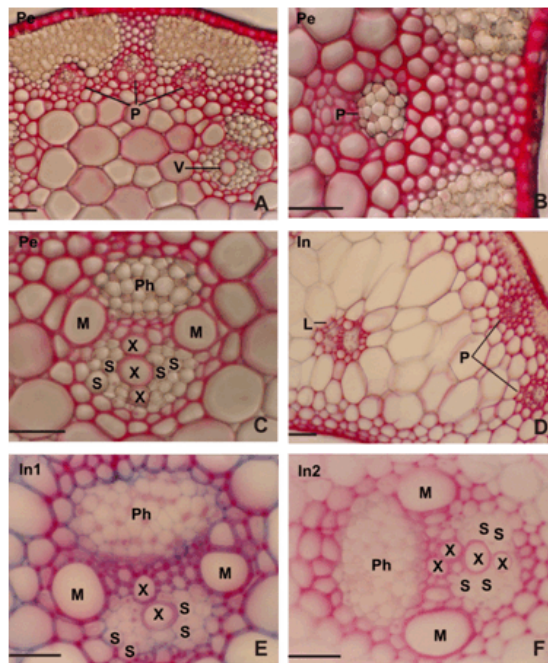
As is well known through the innumerable reports and findings, middle region of spike as compare with proximal and distal regions produces the maximum level of grain dry weight [2,3]. Hence, it appeared that there was a direct positive correlation between reductions in the size of central vascular bundle with the fertility of a spikelet as well as its grains capacity to grow.

The analysis of data further concludes that the total size of vascular systems became progressively smaller at successive internodes. In internodes where the number of central vascular bundles remained the same (i.e., internodes 1, 2 and 3 as well as 17), the percentage of decline within the two successive internodes was between 0.8 to 3.2 percents. The occasional significant lose of measurable dimensions of vascular bundle (e.g. in internodes 2 and 3) was by virtue of net reduction in their size since the number of vascular bundle remained same in them. However, in the internodes occupying, middle and distal segments of rachis, the percentage of reduction in total vascular bundles was relatively higher (between 4.6 to 9.5 percents in middle segment) which was due to disappearance of bundles. Presumably, these bundles have been diverted into the spikelet without branching what plant anatomists commonly call as traces phenomenon.

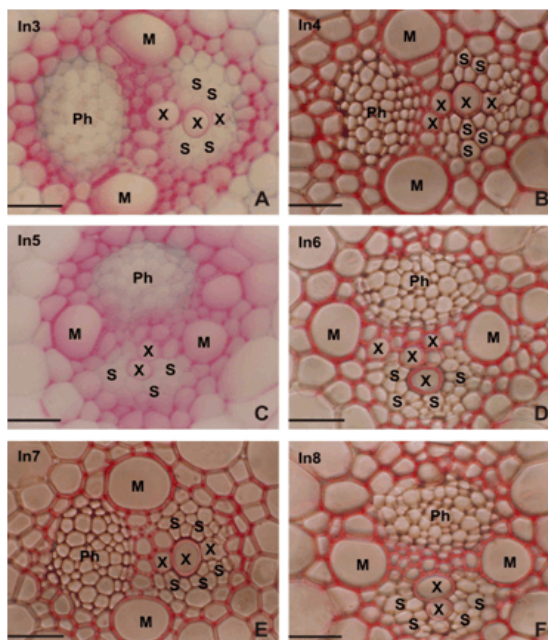
The scrutiny of the Figures 1,2,3 and 4 showing the transverse sections of lateral vascular bundles along the successive internodes in rachis (numbering 1 to 19) depicts that concurrently with the decline in vascular size, the number and cross-sectional surface area of xylem vessels and sieve tubes declined acropetally and the greatest reduction occurred in the middle segment of spike (between internode 5 to 14).

It appears that branching and dropping of vascular bundles along the rachis was accompanied by a reduction in total vascular size as well as cross-sectional surface area of xylem elements and sieve tubes in the bundle at successive internodes. Assimilates in the branching bundles would be channeled into two areas, one to the next rachis internode and the other to the specific spikelet where it has branched thus lessening the supply to the next spikelet. On the other hand, where dropping occurred there was diversion of entire bundles into spikelets and presumably an absolute supply of assimilates to the recipient spikelet.

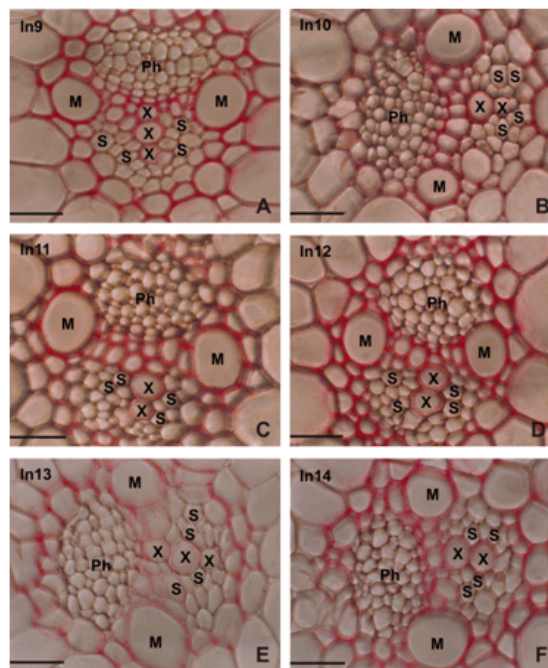
To sum up the above findings it is apparent that the disparity in the dimensions of vascular bundles at different segments of a spike could be a pivotal factor affecting the ultimate size as well as number of grains present along the rachis.



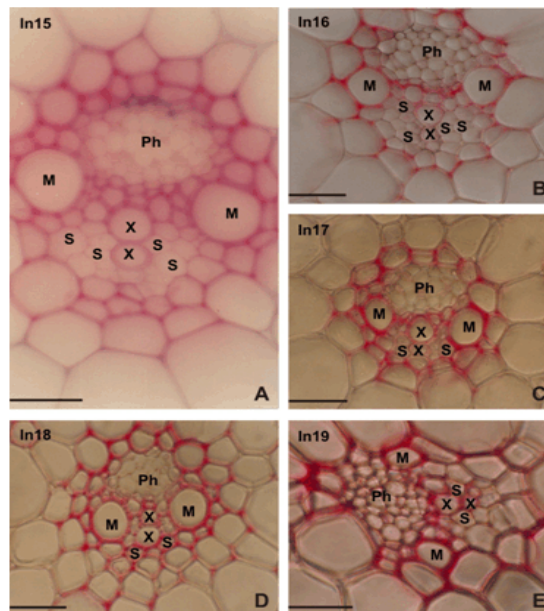
**Fig. 1:** Transverse sections of vascular bundles in the rachis internodes at different magnifications (peduncle, Internode1 (In1) and In2): A- Central vascular bundles (V) and peripheral vascular bundles (P) in peduncle (Pe); B- Transverse section of peripheral vascular bundle; C- Transverse section of one of central vascular bundle in peduncle; D- Lateral vascular bundles (L) and peripheral vascular bundle (P) of internode; E- Transverse section of lateral vascular bundle in internode 1 (In1); F- Transverse section of lateral vascular bundle in internode 2 (In2). (S, sieve tubes; Ph, phloem; M, metaxylem; X, xylem vessels). Scale bar = 50  $\mu$ m.



**Fig. 2:** Transverse sections of lateral vascular bundles in the rachis internodes (In3 – In8): A- Transverse section of lateral vascular bundle of internode 3 (In3); B- Transverse section of lateral vascular bundle of internode 4 (In4); C- Transverse section of lateral vascular bundle of internode 5 (In5); D- Transverse section of lateral vascular bundle of internode 6 (In6); E- Transverse section of lateral vascular bundle of internode 7 (In7); F- Transverse section of lateral vascular bundle of internode 8 (In8). (S, sieve tubes; Ph, phloem; M, metaxylem; X, xylem vessels). Scale bar = 50  $\mu$ m.



**Fig. 3:** Transverse sections of lateral vascular bundles in the rachis internodes (In9 – In14): A- Transverse section of lateral vascular bundle of internode 9 (In9); B- Transverse section of lateral vascular bundle of internode 10 (In10); C- Transverse section of lateral vascular bundle of internode 11 (In11); D- Transverse section of lateral vascular bundle of internode 12 (In12); E- Transverse section of lateral vascular bundle of internode 13 (In13); F- Transverse section of lateral vascular bundle of internode 14 (In14). (S, sieve tubes; Ph, phloem; M, metaxylem; X, xylem vessels). Scale bar = 50  $\mu$ m.



**Fig. 4:** Transverse sections of lateral vascular bundles in the rachis internodes (In15 - In19): A- Transverse section of lateral vascular bundle of internode 15 (In15); B- Transverse section of lateral vascular bundle of internode 16 (In16); C- Transverse section of lateral vascular bundle of internode 17 (In17); D- Transverse section of lateral vascular bundle of internode 18 (In18); E- Transverse section of lateral vascular bundle of internode 19 (In19). (S, sieve tubes; Ph, phloem; M, metaxylem; X, xylem vessels). Scale bar = 50  $\mu$ m

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