Root-shoot Transition of Ranunculus Septentrionalis Poir

Ronald Maurice Duehr

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ROOT-SHOOT TRANSITION OF RANUNCULUS

SEPTENTRIONALIS POIR.

BY

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A thesis submitted in partial fulfillment of the requirements for the degree Master of Science, Department of Botany, South Dakota State College of Agriculture and Mechanic Arts

March, 1963
ROOT-SHOOT TRANSITION OF RANUNCULUS

SEPTENTRIONALIS POIR.

This thesis is approved as a creditable, independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser

Head of the Major Department
ACKNOWLEDGMENTS

The writer wishes to express his appreciation to Dr. Ward L. Miller under whose direction this study was made, for his kindly criticisms and helpful suggestions during the course of the study.

Thanks are also due Mr. G. A. Myers for fully examining the sections and for giving help on doubtful points of technique and interpretation.

Sincere appreciation is also due the author's wife, Linda, for her patience and sacrifices during this study.
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INTRODUCTION

Review of the Literature

The study of transition is not new among botanists. The first anatomical studies of the transition were worked on over a century ago. There remain, however, many economically important plants for which the transition has not been worked out. Cheadle (3) states:

A knowledge of vascular tissues is immensely important to an understanding not only of the activities of vascular plants in their present environments, but also how they must have survived and prospered through the ages. There is no attainable limit to what may be learned or to how it may be put to use.

By 1915 enough work had been done on the transition in plants so that Worsdell (26) had this to say:

The object of botanical investigation, in whatever department, should be to determine, as far as possible, the interrelationship of the various facts which are accumulated, and arrange them accordingly; and not merely, as has for so long been the custom, to pile them in a chaotic heap.

In the second French edition of his 'Traité de Botanique', M. Van Tieghem has described three types of transition from a shoot to a root-structure in the primary axis of Angiospermous seedlings (1891, p. 782). Tracing the transition downwards from shoot to root, Sargent (17) summarized the types as follows:

1. The number of xylem and phloem-bundles in the upper part of the hypocotyl is the same as the number of such bundles in the stele of the primary root. The transition takes place by the branching of each internal xylem-group to right and left of the phloem-group external to it. The protoxylem of each branch turns outwards during the process. The phloem-groups remain in situ, and each is now divided from the next by a pair of xylem-branches with external protoxylem. Each pair fuses into a single group, and the root-stele is complete.
2. The number of xylem and phloem-groups in the upper part of the hypocotyl is twice that of the corresponding bundles in the stele of the primary root. The transition takes place by the fusion of the phloem-groups in pairs. The xylem-groups also approach each other in pairs, the protoxylem of each group becoming external during the process. Thus each pair of centrifugal xylem-groups becomes a single group of centripetal xylem.

3. The number of xylem and phloem-groups in the upper part of the hypocotyl is the same as that characteristic of the primary root-stele. The transition takes place by the branching of each phloem-group to the right and left of the xylem-group within it. At the same time the xylem-groups rearrange their elements so that those of the protoxylem become external. Thus each centripetal xylem-group is divided from the next by a pair of phloem-branches. When a new phloem-group has been constituted from each pair of branches, the root-stele is complete.

Sargent (17) summarizes a fourth type as follows:

The characteristic feature of this transition is that two bundles only enter the hypocotyl which passes into a root with tetrarch symmetry from the beginning. In the second type described by M. Van Tieghem (l.c.) the number of phloem or xylem-bundles entering the hypocotyl from above is twice that of the corresponding bundles in the primary root. This is a common structure among Dicotyledons, as in many Cruciferae, but as yet it has not been found among Monocotyledons. The fourth scheme is the converse of this. The stem-bundles entering the hypocotyl are only half as numerous as those forming the primary root.

Internal phloem offers additional problems in the interpretation of the transition. Artschwager (1), Thiel (21), Winter (25), Whiting (24), Scott and Brebner (18), Holroyd (10), and King (12) have worked on plants with this characteristic.

Other workers on transition in this century are Buxton (2), Drabble (6), Hill and De Fraine (8), Cochran and Cowart (4), Hoffman (9), Jones (11), Miller and Wetmore (14), Phillips (16), Sinnott (20), Thomas (23), Compton (5), Speith (21), and Miller (15).
Scott and Sharsmith (19) in 1933 approached the transition
phenomenon with a physiological interpretation. They state:

In *Ricinus communis* the opposing streams of food and
water conduction determine the paths of xylem and phloem
differentiation, and may therefore be considered as the prin-
cipal factors in the causal anatomy of the transition zone.

Not all of the literature on transition has gone unchallenged
through the decades. Thiel's (21) findings in 1932 on potato did
not agree with Artschwager (1), who did his work in 1918.

The transition region in the past has been described from a
psychological point of view rather than from a logical point of view.
The psychological interpretation is the root to hypocotyl to
cotyledon-shoot series. A logical interpretation would be from the
cotyledonary node upward into the shoot, and from the cotyledonary
node downward into the root. This would be logical because the tis-
sues mature in both directions (up and down) from the cotyledonary
node. In this paper the psychological interpretation will be followed.

**Purpose of the Study**

The writer has found no work on the transition for the genus
*Ranunculus*. The purpose of this paper is to trace the exarch primary
xylem of the root, through the successive steps, to the endarch con-
dition of the shoot, and to trace also the shift from radially
arranged bundles of the root to collaterally arranged bundles in the
shoot for *Ranunculus septentrionalis* Poir., the swamp buttercup.
METHODS AND MATERIALS

Slide Preparation

The plants of the swamp buttercup, *Ranunculus septentrionalis* Poir., were grown in the greenhouse. The seedlings used for sectioning were approximately 9.6 millimeters in length from the root tip to the shoot tip. At this size there was complete maturation of the metaxylem between the protoxylem poles and no secondary thickening had taken place.

The material was killed and fixed in FAA (5% formalin, 5% acetic acid, and 90% of 50% ethyl alcohol). The material was then dehydrated with alcohol, cleared in xylol and infiltrated with paraffin according to the usual laboratory methods. The sections were cut to a thickness of ten microns and stained with safranin and fast green.

Serial sections were made of the hypocotyledonary portion of the axis, beginning at a level that was clearly root-like in character, and continuing upward into the bases of the first foliage leaves where a typical stem structure was established.

Photographic Technique

The photographs were taken with an A. O. Spencer Microphotographic camera and stand using a Bausch and Lomb microscope and microscope illuminator. The high-power photographs were exposed for one second with a magnification of 537.5 times. Low-power photographs were exposed for one-fifth second with a magnification of 125 times.
INTERPRETATIONS

There are two loci of xylary differentiation in the root, resulting in a diarch type of stele. The endodermis is one cell thick and recognized by the tangentially elongated cells with Casparian strips present on the radial walls. The pericycle is also one cell thick and lies immediately inside the endodermis. The two protoxylem groups lie against the pericycle and metaxylem occupies the area between the protoxylem poles. The root has the usual radial arrangement of xylem and phloem with the two phloem groups lying alternate with the xylem wings. The intervening parenchyma of the stele consists of only a few scattered cells (Figures I and XI-A).

At a point where the hypocotyl begins, the first evidence of transition is noticed. The primary xylem differentiates into two distinct strands. This is made evident by the apparent radial splitting of each strand and differentiation of the two strands in oppositely directed curves (Figures II and XI-B). The metaxylem differentiates tangentially, approaching more closely the periphery of the stele at successively higher levels in the hypocotyl (Figures III and XI-C and XI-D).

The protoxylem maintains its original position out against the pericycle until the lower level of the cotyledonary node is reached (Figures III and XI-C). Above this level, the protoxylem is differentiated further and further inward from the pericycle, attaining a mesarch position, the protoxylem being flanked on two sides by metaxylem (Figures IV and XI-D). This centripetal differentiation
continues, and at the cotyledonary plate the protoxylem groups are almost endarch (Figures V and XI-B).

At the cotyledonary node the primary xylem leaves the stele rather abruptly, at almost right angles to the long axis of the stele, and crosses the cortex (Figure VI). In the bases of the cotyledons the collateral bundles have endarch protoxylem and thus the transition of the xylem is complete (Figure XI-F).

Low in the hypocotyl the first xylem elements of the first foliar trace differentiate along the flank of the diarch plate. At this level the xylem cells of the foliar trace are all primary in origin, and lie alternate with the cotyledons (Figures IV and XI-B).

The trace of the first leaf of the epicotyl is collateral and has endarch protoxylem. Thus, there is no transition in the first foliar trace from the hypocotyl (Figures IV and XI-B) to the epicotyl (Figures X and XI-F).

While the primary xylem is undergoing transition by reorientation, changes are also taking place in the phloem. Each phloem group expands somewhat circumferentially (Figures VII and XI-C) and trifurcates (Figures VIII and XI-D), two strands traversing the axis radially and one remaining vertical. The phloem groups traversing the axis vertically supply the first foliage leaves with phloem. Progressive differentiation of procambium into primary phloem then follows two divergent paths for each original phloem group. The two strands traversing the axis radially, of any one group, diverge from each other and approach opposite xylem poles. Thus, a strand of phloem tissue from one of the original phloem groups approaches a
similar strand from the other group, the two meeting and merging together at a position centrifugal to the xylem poles (Figure XI-E).

At the cotyledonary plate the phloem leaves the stele abruptly alongside the xylem trace and crosses the cortex to the base of a cotyledon (Figure IX). In the base of each cotyledon, where the xylem is endarch, the phloem differentiates on the abaxial side of the primary xylem; thus the collateral bundle is established (Figure XI-F).
The transition region of *Ranunculus septentrionalis* Poir., agrees basically with that of *Beta vulgaris* L., which was described by E. A. Lyle (13) and used by K. Esau (7) to describe a basic type in her book, *Plant Anatomy*.

The transition region in the seedling of *Ranunculus septentrionalis* Poir., takes place in a relatively short distance of the main axis. This distance is approximately 0.320 millimeters. The cotyledonary traces depart from the stele very abruptly, the departure being completed in 0.230 millimeters.

Although the trace for the first foliage leaf begins 0.060 millimeters below the beginning of the cotyledonary trace it remains unaltered, the protoxylem being endarch throughout its length.

The traces for the rest of the foliage leaves arise from procambium tissue of the unelongated epicotyl. The epicotyl remains unelongated until floral initiation.
SUMMARY AND CONCLUSIONS

1. Seedlings approximately 9.6 millimeters were used for the serial sections, because at that size there was complete maturation of the metaxylem without secondary thickening having taken place.

2. The transition begins in the lower hypocotyl where the primary xylem and phloem have a radial arrangement.

3. At the cotyledonary node the protoxylem is almost endarch as the cotyledonary traces depart abruptly from the main stele and cross the cortex.

4. The primary phloem trifurcates just below the cotyledonary node. Two strands of each original group, traversing the axis radially, supply the cotyledons with phloem, and the one strand remaining vertical supplies the first foliage leaf with phloem.

5. In the base of the cotyledon the transition is complete, as the protoxylem is completely endarch and the bundle is collateral.

6. The primary xylem is endarch throughout the foliar trace, which differentiates against the diarch plate just below the cotyledonary plate.
Figure I. Transverse section of the root, showing diarch structure

Figure II. Transverse section of the lower hypocotyl, showing some differentiation of xylem along oppositely directed curves
Figure III. Transverse section of the hypocotyl, showing protoxylem in its original root-position out against the pericycle

Figure IV. Transverse section of the hypocotyl, showing protoxylem in the mesarch position and the trace for the first foliar leaf of the epicotyl
Figure V. Transverse section of the cotyledonary plate, showing the protoxylem being almost endarch

Figure VI. Transverse section of the cotyledonary plate, showing the primary xylem crossing the cortex
Figure VII. Transverse section of the hypocotyl, showing the phloem expanding circumferentially.

Figure VIII. Transverse section of the hypocotyl, showing trifurcation of the phloem.
Figure IX. Transverse section of the cotyledonary plate, showing the primary phloem crossing the cortex.

Figure X. Transverse section of the epicotyl, showing the first foliar leaf trace.
Figure II. Diagram of the vascular transition of *Ranunculus septentrionalis* Poir.
LITERATURE CITED


