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THE VASCULAR ANATOMY OF HEMITRIMEROUS SEEDLINGS OF PHASEOLUS VULGARIS

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INTRODUCTORY

In an earlier paper[1] we discussed the gross vascular anatomy of dimerous and trimerous seedlings of the garden bean. By *dimerous* seedlings we understand those of the normal type, characterized by two cotyledons and two primordial leaves, both sensibly opposite in insertion. By *trimerous* we mean those which have a whorl of three cotyledons and three primordial leaves. The cotyledons may be, and frequently are, more or less irregular in insertion. The primordial leaves are, in the seedlings considered, inserted in a regular whorl.

In addition to these two types of seedlings, those which are in a sense intermediate in superficial structure between the two types hitherto studied may occur. These are seedlings with a whorl of three cotyledons but with a normal pair of primordial leaves instead of three as in the case of trimerous seedlings. These we have called *hemitrimerous.* They are extremely rare in occurrence, but during the four years during which these studies have been under way a number sufficiently large to justify a brief discussion of their gross vascular anatomy has been secured.

Our purpose in this paper is to compare the anatomy of these hemitrimerous seedlings with the trimerous seedlings (in common with which they have three cotyledons) on the one hand and with dimerous seedlings (in common with which they have two primordial leaves) on the other.

For convenience of reference the three types will in some cases be designated by the number of cotyledons and primordial leaves: 2–2 = dimerous, 3–3 = trimerous, and 3–2 = hemitrimerous.

MATERIALS

The hemitrimerous plants and the trimerous and dimerous seedlings with which they are compared were largely secured in the series of germina-

[1] Harris, J. Arthur, Sinnott, E. W., Pennypacker, J. Y., and Durham, G. B. The vascular anatomy of dimerous and trimerous seedlings of *Phaseolus vulgaris.* Amer. Jour. Bot. 8: 63–102. 1921.

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tions which furnished the materials for our earlier discussion of dimerous and trimerous seedlings. The dimerous and hemitrimerous seedlings were derived from the same parent plants in lines 75, 93, and 98. In lines 29, 139, and 143 the germinations were made from mass seed instead of from the seed of individual parent plants. All of the seed, however, was grown in the same experimental field in 1917.

Since it has been shown in an earlier paper[2] that there is practically no correlation between the anatomical characters of the trimerous and dimerous seedlings from the same parent plant, we are fully justified in using random samples of hemitrimerous, trimerous, and dimerous seedlings for a comparison of their vascular characters.

A detailed account of the vascular topography of the dimerous and trimerous seedling is presented in a previous paper by the writers, but may be summarized very briefly here. Each primary polar bundle of the root bifurcates in the base of the hypocotyl to form a "primary double bundle," which gives rise to two distinct and well separated strands in the central region of the hypocotyl. In addition to these, there are usually present in the hypocotyl a number of "intercalary" bundles, arising either *de novo* or by splitting of some of the primary strands. At the cotyledonary node a rather complex vascular anastomosis takes place, from which the cotyledonary strands depart and out of which the vascular system of the epicotyl is organized.

Presentation and Analysis of Statistical Data

Base of Hypocotyl

The frequency distribution of the various types of vascular organization at the base of the hypocotyl is shown for all the available data in table 1. In this table the number of primary double bundles appears in parentheses, while the number of intercalary bundles follows the + sign.

Because of the relatively small numbers of hemitrimerous seedlings which can be obtained and because of the irregularity of the frequency distributions for bundle number, it has not seemed desirable in this paper to consider the frequency distributions of the numbers of bundles of the several types. Neither has it seemed desirable, on the basis of the relatively small series of hemitrimerous seedlings which can be obtained, to consider the relative variabilities of bundle number in the different regions of the three types of seedlings as we did in our discussion of variation in the dimerous and trimerous types. We have, therefore, limited ourselves to a comparison of mean bundle number, leaving the question of variability until larger series of countings can be obtained.

[2] Harris, J. Arthur, Sinnott, E. W., Pennypacker, J. Y., and Durham, G. B. Correlations between anatomical characters in the seedling of *Phaseolus vulgaris*. Amer. Jour. Bot. 8: 339–365. 1921.

TABLE I.

Base of Hypocotyl	Line 29			Line 75			Line 98			Line 139			Line 143		
	3–3	3–2	2–2	3–3	3–2	2–2	3–3	3–2	2–2	3–3	3–2	2–2	3–3	3–2	2–2
(4) + 0. .	—	1	83	—	—	101	—	—	117	—	2	270	2	3	291
(4) + 1. .	—	4	11	—	2	39	—	1	55	1	5	26	3	6	102
(4) + 2. .	1	2	1	—	1	14	—	1	32	—	—	6	—	—	5
(4) + 3. .	1	—	—	—	—	4	—	—	2	—	—	—	—	—	—
(4) + 4. .	1	—	—	—	—	2	—	—	—	—	—	—	—	—	—
(4) + 5. .	—	—	—	—	—	2	1	—	—	—	—	—	—	—	—
(4) + 6. .	—	—	—	1	—	1	—	—	—	—	—	—	—	—	—
(4) + 7. .	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—
(5) + 0. .	7	11	1	1	4	13	4	3	7	4	2	1	15	26	13
(5) + 1. .	6	7	3	8	7	9	6	5	8	4	11	2	31	20	7
(5) + 2. .	—	—	—	2	—	3	1	2	1	—	—	—	—	—	—
(5) + 3. .	—	—	—	—	—	1	—	2	1	—	—	—	—	—	—
(6) + 0. .	39	16	—	107	32	7	160	24	1	92	20	—	134	52	—
(6) + 1. .	—	1	—	12	6	2	10	2	1	5	2	—	25	6	1
(6) + 2. .	—	—	—	2	2	—	—	1	—	—	—	—	—	—	—
(6) + 4. .	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—
(7) + 0. .	1	—	—	7	2	1	1	1	—	—	—	—	5	1	1
(7) + 1. .	—	—	—	—	—	—	—	1	—	—	—	—	4	—	—
(7) + 2. .	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
(8) + 0. .	—	—	—	1	—	—	—	—	—	—	—	—	1	—	—
(8) + 1. .	—	—	—	—	—	—	—	—	1	—	—	—	1	—	—
	56	43	99	142	57	199	183	43	226	106	42	305	221	114	420

Table 2 shows the average number of primary double bundles, intercalary bundles, and total bundles in the three types of seedlings, and gives the differences and probable errors of differences in the means upon which we must depend for conclusions.

The entries in the first section of this table show that the average number of primary double bundles is relatively lower in the hemitrimerous than in the trimerous seedlings. It is also relatively higher than the number in the dimerous seedlings. The differences, while small, may reasonably be considered significant in comparison with their probable errors. The differences between the hemitrimerous and the dimerous class are much larger than those between the hemitrimerous and the trimerous.

Turning to the statistical constants for intercalary bundles set forth in the second section of table 2, we note that in four of the five cases the hemitrimerous seedlings have a larger number of intercalary bundles than the trimerous seedlings. These differences are small, but may be significant. In the one case in which the hemitrimerous seedlings have a smaller number of intercalary bundles than the trimerous plantlets the difference is only -0.01 ± 0.04. In two of the cases the hemitrimerous show a larger number of intercalary bundles than the dimerous seedlings, but in three lines the reverse is true. The differences are in general not so large in comparison with their probable errors as in the case of the comparison for number of primary double bundles.

Table 2. *Mean number of bundles at base of hypocotyl*

	f	Primary Double Bundles	Intercalary Bundles	Total Bundles
Line 29				
3–3	56	5.68 ± .05	.27 ± .07	5.95 ± .04
3–2	43	5.21 ± .08	.53 ± .12	5.74 ± .10
2–2	99	4.04 ± .01	.16 ± .03	4.20 ± .03
(3–2)–(3–3)		− 0.47 ± .09	+ .26 ± .14	− 0.21 ± .11
(3–2)–(2–2)		+ 1.17 ± .08	+ .37 ± .12	+ 1.54 ± .10
Line 75				
3–3	142	5.98 ± .02	.25 ± .04	6.23 ± .03
3–2	57	5.74 ± .05	.44 ± .07	6.18 ± .07
2–2	199	4.24 ± .03	.62 ± .05	4.85 ± .05
(3–2)–(3–3)		− 0.24 ± .05	+ .19 ± .08	− 0.05 ± .08
(3–2)–(2–2)		+ 1.50 ± .06	− .18 ± .09	+ 1.33 ± .09
Line 98				
3–3	183	5.93 ± .01	.13 ± .02	6.06 ± .02
3–2	43	5.67 ± .07	.53 ± .09	6.21 ± .08
2–2	226	4.11 ± .02	.62 ± .03	4.73 ± .04
(3–2)–(3–3)		− 0.26 ± .07	+ .40 ± .09	+ 0.15 ± .08
(3–2)–(2–2)		+ 1.56 ± .07	− .09 ± .09	+ 1.48 ± .09
Line 139				
3–3	106	5.91 ± .02	.09 ± .02	6.00 ± .02
3–2	42	5.36 ± .08	.43 ± .05	5.79 ± .06
2–2	305	4.01 ± .00	.13 ± .02	4.14 ± .02
(3–2)–(3–3)		− 0.55 ± .08	+ .34 ± .05	− 0.21 ± .06
(3–2)–(2–2)		+ 1.35 ± .08	+ .30 ± .05	+ 1.65 ± .06
Line 143				
3–3	221	5.81 ± .03	.29 ± .02	6.10 ± .03
3–2	114	5.45 ± .04	.28 ± .03	5.73 ± .04
2–2	420	4.06 ± .01	.29 ± .02	4.35 ± .02
(3–2)–(3–3)		− 0.36 ± .05	− .01 ± .04	− 0.37 ± .05
(3–2)–(2–2)		+ 1.39 ± .04	− .01 ± .04	+ 1.38 ± .04

We cannot, therefore, assert on the basis of the data now in hand whether dimerous, hemitrimerous, and trimerous seedlings differ in the number of intercalary bundles at the base of the hypocotyl. In so far as it goes the evidence *suggests* that the hemitrimerous seedlings have a larger number of intercalary bundles than the trimerous but a smaller number than the dimerous plantlets.

The means for total number of bundles (primary double bundles plus intercalary bundles) at the base of the hypocotyl set forth in the third section of table 2 show that in four of the five cases the mean number of bundles is lower in the hemitrimerous than in the trimerous seedlings. The differences are, however, very slight indeed and cannot in general be considered significant in comparison with their probable errors. The differences between the hemitrimerous and dimerous seedlings on the other hand are rather large and in every case are unquestionably significant.

Summarizing these results, we note that the hemitrimerous seedlings are conspicuously differentiated from the dimerous seedlings in the number of primary double bundles and in the total number of bundles. They are less conspicuously differentiated, if at all, in number of intercalary bundles. They are unquestionably differentiated from the trimerous seedlings by their lower number of primary double bundles and possibly by a higher number of intercalary bundles. They cannot be said to differ from the trimerous seedlings in the total number of bundles at the base of the hypocotyl.

Central Region of Hypocotyl

For the number of bundles in the central region of the hypocotyl we have the fundamental frequency distributions given in table 3. Considering the mean number of bundles in table 4, it appears that the number of bundles in the central region of the hypocotyl of hemitrimerous plants is slightly lower than that found in trimerous seedlings in four of the six lines available. The differences are, however, small and would not for the most part be considered significant in comparison with their probable errors. The bundle number of hemitrimerous plants is in every case distinctly higher than that of dimerous plants at this level, and these differences are conspicuous and unquestionably significant. Thus in hypocotyledonary structure the hemitrimerous seedling is very close indeed to the trimerous but perhaps shows a slight deficiency in bundle number.

This result is not surprising in view of the fact that so far as the cotyledonary node and lower portions of the axis are concerned the external form of hemitrimerous and trimerous seedlings is essentially identical.

Central Region of Epicotyl

If a differentiation between the hemitrimerous and trimerous seedlings obtains anywhere, one would expect to find it in the epicotyledonary region,

TABLE 3. *Distribution of number of bundles in central region of hypocotyl*

	8	9	10	11	12	13	14	15	16	17	18	20	24	Total
Line 29														
3–3.....	—	—	1	6	41	1	3	3	—	—	—	—	1	56
3–2.....	—	2	6	8	21	2	2	—	1	1	—	—	—	43
2–2.....	67	21	9	2	—	—	—	—	—	—	—	—	—	99
Line 75														
3–3.....	1	3	5	36	292	40	29	5	1	4	—	—	—	416
3–2.....	—	2	3	13	51	16	14	2	2	—	—	—	—	103
2–2.....	177	131	103	46	31	14	11	1	1	3	1	—	—	519
Line 93														
3–3.....	—	—	8	32	382	82	38	12	1	—	1	1	—	557
3–2.....	—	—	4	6	17	8	7	1	—	—	—	—	—	43
2–2.....	36	93	170	107	96	40	18	1	—	—	2	—	—	563
Line 98														
3–3.....	—	1	6	12	297	21	8	—	—	—	—	—	—	345
3–2.....	—	—	3	7	25	3	3	1	1	—	—	—	—	43
2–2.....	125	126	83	37	11	5	—	—	—	1	—	—	—	388
Line 139														
3–3.....	—	—	4	8	84	6	3	1	—	—	—	—	—	106
3–2.....	1	3	4	11	19	3	1	—	—	—	—	—	—	42
2–2.....	269	23	7	4	1	1	—	—	—	—	—	—	—	305
Line 143														
3–3.....	2	1	11	14	136	21	25	6	3	1	1	—	—	221
3–2.....	1	2	17	19	54	4	8	5	4	—	—	—	—	114
2–2.....	263	83	47	17	4	3	1	2	—	—	—	—	—	420

since the sole superficial difference between the two types of seedlings is found at the primordial node. The frequency distributions in table 5 show that the nodal number of bundles is in general lower in the hemitrimerous than in the trimerous seedlings. It also indicates that they are higher in the hemitrimerous than in the dimerous seedlings. The averages and their probable errors in the second section of table 4 show that in each of

TABLE 4. *Mean number of bundles in central regions of internodes*

Line	f	Central Region of Hypocotyl	Central Region of Epicotyl	Line	f	Central Region of Hypocotyl	Central Region of Epicotyl
Line 29				Line 98			
3–3.....	56	12.36±.16	14.75±.18	3–3....	345	12.03±.02	14.89±.04
3–2.....	43	11.74±.16	12.93±.17	3–2....	43	12.07±.12	13.72±.13
2–2.....	99	8.45±.05	12.05±.02	2–2....	388	9.24±.04	12.12±.01
(3–2)–(3–3).		− .62±.23	− 1.82±.25	(3–2)–(3–3)		+ .04±.12	− 1.17±.14
(3–2)–(2–2).		+ 3.29±.17	+ .88±.17	(3–2)–(2–2)		+ 2.83±.13	+ 1.60±.13
Line 75				Line 139			
3–3.....	416	12.19±.03	15.47±.04	3–3....	106	11.99±.05	15.24±.08
3–2.....	103	12.32±.08	13.85±.10	3–2....	42	11.36±.12	13.93±.18
2–2.....	519	9.52±.05	12.26±.02	2–2....	305	8.19±.02	12.10±.01
(3–2)–(3–3).		+ .13±.09	− 1.62±.11	(3–2)–(3–3)		− .63±.13	− 1.31±.20
(3–2)–(2–2).		+ 2.80±.09	+ 1.59±.10	(3–2)–(2–2)		+ 3.17±.12	+ 1.83±.18
Line 93				Line 143			
3–3.....	557	12.29±.03	15.65±.04	3–3....	221	12.29±.06	16.10±.08
3–2.....	43	12.26±.13	14.84±.18	3–2....	114	11.89±.10	13.68±.09
2–2.....	563	10.62±.04	12.19±.02	2–2....	420	8.66±.04	12.36±.02
(3–2)–(3–3).		− .03±.13	− .81±.18	(3–2)–(3–3)		− .40±.12	− 2.42±.12
(3–2)–(2–2).		+ 1.64±.14	+ 2.65±.18	(3–2)–(2–2)		+ 3.23±.11	+ 1.32±.09

TABLE 5. *Distribution of number of bundles in central region of epicotyl*

	10	11	12	13	14	15	16	17	18	19	20	21	22	Total
Line 29														
3–3.....	1	—	3	11	13	15	4	2	4	1	1	1	—	56
3–2.....	2	3	19	4	6	6	2	1	—	—	—	—	—	43
2–2.....	—	—	97	—	1	1	—	—	—	—	—	—	—	99
Line 75														
3–3.....	—	—	3	16	63	164	93	41	27	4	4	1	—	416
3–2.....	—	3	16	28	27	14	9	4	1	—	1	—	—	103
2–2.....	1	4	422	58	21	10	3	—	—	—	—	—	—	519
Line 93														
3–3.....	—	—	5	18	47	236	129	56	51	10	4	—	1	557
3–2.....	—	—	5	4	9	13	5	3	2	2	—	—	—	43
2–2.....	1	6	483	42	20	10	1	—	—	—	—	—	—	563
Line 98														
3–3.....	—	—	8	24	69	176	49	9	7	1	1	1	—	345
3–2.....	—	1	6	12	13	8	2	1	—	—	—	—	—	43
2–2.....	—	—	352	27	7	1	1	—	—	—	—	—	—	388
Line 139														
3–3.....	—	—	—	8	21	38	24	9	4	2	—	—	—	106
3–2.....	—	2	6	12	8	6	5	1	2	—	—	—	—	42
2–2.....	—	—	278	23	4	—	—	—	—	—	—	—	—	305
Line 143														
3–3.....	—	—	5	9	19	54	49	37	31	9	6	2	—	221
3–2.....	—	—	31	19	37	17	6	2	—	2	—	—	—	114
2–2.....	—	—	318	66	27	5	4	—	—	—	—	—	—	420

the six lines the average number of bundles in the epicotyl is significantly lower in the hemitrimerous than in the trimerous seedlings, and (probably) significantly higher in the hemitrimerous than in the dimerous seedlings.

In epicotyledonary structure the hemitrimerous seedlings occupy as a matter of fact almost exactly an intermediate position between the dimerous and the trimerous types.

Summary

The purpose of this paper is a comparison of the gross vascular anatomy of hemitrimerous seedlings of *Phaseolus vulgaris* with those which are trimerous and those which are dimerous. By dimerous seedlings we understand those with *two* cotyledons and *two* primordial leaves, by trimerous seedlings those with *three* cotyledons and *three* primordial leaves, and by hemitrimerous seedlings those with *three* cotyledons and *two* primordial leaves. The hemitrimerous is, therefore, intermediate in external form between the dimerous and the trimerous seedling. In the internal structure of the axis at the transition zone, which here occurs at the base of the hypocotyl, the hemitrimerous seedling is clearly differentiated from the trimerous type by a slightly smaller average number of primary double bundles, and possibly by a slightly larger number of intercalary bundles. The total number of bundles in the basal region of the axis of hemitrimerous seedlings is not sensibly different in hemitrimerous and trimerous plantlets. The hemitrimerous are conspicuously differentiated from the dimerous seedlings by a larger number of primary double bundles and a larger total number of bundles. On the basis of the data available they cannot be asserted to differ significantly from the dimerous plants in the number of intercalary bundles.

In the central region of the hypocotyl, the vascular anatomy of the hemitrimerous seedling conspicuously exceeds that of the dimerous in bundle number but agrees very closely indeed with that of the trimerous plantlet, although it may have a slightly lower average number of bundles.

In the central region of the epicotyl the mean number of bundles in the hemitrimerous seedling is, roughly speaking, intermediate between that of the trimerous and that of the dimerous types.

Recapitulating, it appears that in internal structure the hypocotyl of the hemitrimerous seedling is practically identical with that of the trimerous seedling with which it has in common a whorl of three cotyledons. The epicotyledonary internode in the hemitrimerous seedling, limited by a trimerous cotyledonary and a dimerous primordial node, is intermediate in anatomy between the trimerous type with three cotyledons and three primordial leaves and the dimerous type with two cotyledons and two primordial leaves.