Zhi-Cen Lou*, Xuan Wang**, Masayuki Mikage*** & Tsuneo Namba**: Pharmacognostical studies on the Chinese crude drug Da-huang IV****, On the abnormal vascular system and coil-like vessel in the rhizomes of certain Rheum spp.

Da-huang (大黃, rhubarb) is a well-known Chinese drug and it has long been used in both Chinese and Western medicine. The Da-huang specified in the Chinese Pharmacopoeia (1985) consists of the dried rhizomes and roots of Rheum palmatum L., R. tanguticum Maxim. ex Balf., and R. officinale Bail. All these species have abnormal vascular bundles in the pith of their rhizomes, the cross sections of these medullary vascular bundles are generally called star-spots or stellate spots. And the presence of star-spots has been used as an important diagnostic criterion for evaluation of the official Da-huang.

The presence of star-spots in the rhizome of Rheum spp. was first described by Solereder (1899), although he did not use this term. He reported that the medullary vascular bundles with central phloem and peripheral xylem were found in the mature rhizomes of R. officinale, R. emodi Wall., R. rhaponticum L. and R. palmatum. Metcalfe & Chalk (1950) has quoted Solereder’s description of the medullary vascular system in the pith of R. officinale, but did not mention any other species of Rheum. Trease (1961) and Wallis (1967) have mentioned the presence of star-spots in the rhizomes of Chinese Da-huang derived from R. palmatum and R. officinale as well as the English rhapontic rhubarb derived from R. rhaponticum. According to Tschirch (1899), rhizomes of the

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palmatum type are distinguished by the relatively small size of the star-spots and also the fact that they form a continuous ring, while R. officinale has larger star-spots which are more irregularly distributed. But Li & Zhang (1983) reported that the arrangement of the star-spots depended upon the parts of the rhizome being sectioned and was not related to the species of Da-huang. In addition to these reports, we found the occasional presence of very peculiar type of vessels, accompanied by abnormal vascular bundle system, which we named coil-like vessels.

In this report, to examine the abnormal vascular bundle system and coil-like vessels in the rhizomes of Rheum species morphologically and histologically in detail, the rhizomes of R. palmatum, R. tanguticum, R. officinale and R. emodi are studied through the usual sections and serial sections cut both transversely and longitudinally.


After washing the rhizome fixed in FAA, the transverse slices of about 1.5 cm thick were taken serially from the top to the lower end of the rhizome, and examined macroscopically. Suitable pieces were then selected and sectioned by means of freezing microtomy to obtain serial sections of 15–30 μm in thickness for microscopical examination. The sections under 15 μm in thickness are not suitable for the observation of coil-like vessels. Longitudinal sections were made in radial and tangential directions in a similar way. The macerated preparations were made by digesting the material with 5% potassium hydroxide solution. The first report of this study (Lou et al., 1988) should be referred to details.

**Observations** General structure of the rhizome, abnormal vascular bundle system and leaf trace of Rheum palmatum, R. tanguticum and R. officinale are described below.

The outermost layer is thick periderm of dark brown colour. When new periderms are formed in the deeper layers, the cortical tissue and a part of phloem will be cut out and die. In the secondary phloem many small leaf
traces of reddish brown colour and some big ones running radially are found. The ground tissue of the secondary phloem consists of parenchyma cells with many large intercellular spaces similar to those in the pith. The normal vascular bundles are collateral and arranged in a large circle. The vessel elements are few in number, occurring solitary or in groups of 2 to 5, and giving no reaction for lignin. The pith is very large, in which the anastomosing abnormal vascular bundles are characteristically recognized. Many clustered crystals of calcium oxalate and starch grains are contained in parenchyma cells. The starch grains are of single and compound of 2-5.

The morphology of abnormal vascular bundle system of the three species are fundamentally the same. In the pith region, the abnormal vascular bundles extend either in a vertical or horizontal direction, anastomosing here and there. On the contact point of the bundles, some cells and vessels curve more or less and the vessels are sometimes arranged irregularly (Fig. 1). At the upper part of the rhizome, in the transverse section (Fig. 2-A, B), it exhibits a number of abnormal vascular bundles, i.e. star-spots, arranged into 1 to 3 rings (Fig. 2-A, B) at the periphery of the pith. Inside this ring, in the central region of the pith, there are some vascular bundles running horizontally or obliquely to connect with the star-spots ring, and a number of vascular bundles go still further from the star-spots ring outward through the normal vascular cylinder to unite with the leaf traces. This structure remains practically the same in the middle portion of the rhizome (Fig. 2-C) except that the star-spots and the rings also decrease in number and the spots become larger in size. In the lower part of the rhizome (Fig. 2-D), the star-spots become fewer in number, larger in size, irregular in shape, and the star-spots ring becomes indistinct. In some cases, 2 or 3 star-spots unite into a big one. This result agrees well with Li & Zhang's report (1983) that the arrangement of the star-spots depended upon the parts of the rhizome being sectioned and was not related to the species, but they did not mention the changing pattern of the arrangement of abnormal vascular bundles in a rhizome and of the size of star-spot.

Observing the radial longitudinal sections of the rhizome (Fig. 3), it exhibits the abnormal vascular bundles running longitudinally and forming a tube-like structure at the periphery of the pith. This bundle often branches out horizontally to both outward and inward, especially in the upper and middle parts of the rhizome; the outward bundles join with the leaf traces and the inward ones
Fig. 1. Star-spots in the tangential longitudinal sections of the rhizomes of Rheum tanguticum, showing the division and combination of star-spots. (c, cambium; mr, medullary ray; v, vessel)
Fig. 2. Transversely cut surfaces of the rhizome of *Rheum officinale* at different portions from upper to lower (see Fig. 3), showing the distribution of star-spots. The material shown here is 7 cm long and 4.8 cm in diameter at the middle point. (bu, bud; c, cambium; k, cork; lft, leaf trace; ss, star-spot; vbm, medullary vascular bundle)
traverse in the pith. In the pith, besides horizontally running bundles, there are also a number of star-spots that are the cross sections of the medullary bundles running perpendicularly to the cut surface.

The pith can be divided into three parts, viz. the star-spots ring, the inner and outer parts of the star-spots ring. In the tangential longitudinal section cut through the star-spots ring (Fig. 4-E), there are numerous vascular bundles running longitudinally through the parenchymatous pith and connect each other into a net-like structure, with a few bundles cut transversely in the form of star-spots. In the sections cut through the inner or outer parts of the star-spots ring (Fig. 4-F), many vascular bundles cut transversely or somewhat obliquely in the form of star-spots, either centric or eccentric, are recognized.

These abnormal vascular bundles never connect with root traces.

The abnormal vascular bundle in the normal xylem, which is the leaf trace originated from medullary vascular bundle, can be seen in the form of eccentric star-spot in the tangential longitudinal section (Fig. 4-D), i.e. most vessels are situated at the upper side in the spot. The type of structure of the leaf trace in the secondary phloem is almost the same. Besides this type of leaf traces,
Fig. 4. Tangential longitudinal sections at different positions of the rhizome of *Rheum palmatum*, showing dead leaf traces at the periphery of secondary phloem (A), near the terminal of dead leaf trace (B-1), parenchyma cells arranged in spiral in the phloem (B-2), coil-like vessels in the xylem (C), transversely cut surface of the eccentric abnormal vascular bundle at the periphery of pith (D), the section cut through the star-spots ring (E), and transversely cut surfaces of centric and eccentric abnormal vascular bundles, namely star-spots, in the pith (F). (c, cambium; k, cork; mc, medullary cell; pph, phloem parenchyma; pxy, xylem parenchyma; s, sieve tube; v, vessel; vcl, coil-like vessel)

many small vascular bundles running horizontally are seen in the secondary phloem. In the superficial tangential longitudinal sections cut through the periderm zone (Fig. 4-A), there are observed many scattered dark brown round spots with diameters of about 1 mm. This bundle consists of several decaying
Fig. 5. Coil-like vessels in the xylem of abnormal vascular bundles of *Rheum emodi*. A, transversa view; B, oblique (longitudinal) views; C, isolated vessel segment.
vessels and a little parenchyma surrounded by the layers of cork cells (Fig. 4-B1). And sometimes, the same type of vascular bundles appear in the xylem and periphery of the pith. This structure may be the healing tissue of the dead primitive leaf traces.

A very peculiar type of vessels, which we named "coil-like vessel", is found present in the rhizomes of *R. palmatum*, *R. tanguticum*, *R. officinale* and *R. emodi*, accompanied with the abnormal vascular bundles including the leaf traces in the normal xylem (Fig. 5). They can be observed clearly either in transverse or longitudinal sections of the rhizome. The vessel looks like a coil of snake in transverse view (Fig. 5-A), or like a coiled tube, or when cut through longitudinally, a number of short curved tubes arranged in parallel in the longitudinal view of the abnormal vascular bundles (Fig. 5-B). The isolated vessel elements are very short, curved tube-like, subspherical or ovoid in shape, often with a short tail at one end (Fig. 5-C). The walls of these vessels are similar to those of the normal vessels, being reticulately thickened and cellullosic, giving no reaction for lignin. The perforation is simple, large and round, and sometimes situated at the middle of the vessel element. The end segment of a coil-like vessel is usually subspherical in shape and connects to a normal vessel.

In the secondary phloem no coil-like vessel is seen, but it is apparent that some parenchyma cells are arranged in spiral with cell walls having the power of affecting polarized light (Fig. 4-B2). And in the normal xylem zone, the parenchyma cells arranged in spiral in the secondary phloem are replaced by coil-like vessels (Fig. 4-C).

**Discussions** From the results of this study and the previous reports, the abnormal vascular bundle system in the rhizomes of *Rheum palmatum*, *R. tanguticum* and *R. officinale* may be summarized and elucidated morphologically as follows: In the periphery of the pith, some columnar vascular bundles extend vertically arranged into one to three concentric circles (star-spots ring), and the inside of the ring is traversed by a complete network of anastomosing vascular bundles arranged in transverse zones, following closely upon one another and corresponding to the nodes; these bundles connect with the bundles in the star-spots ring and some are running outwards through the star-spots ring and normal vascular bundle ring to unite with the leaf traces. This type of bundle, when cut transversely, exhibits the form of a star-spot which consists of a
central strand of primary phloem surrounded by the phloem, xylem and radiate rays produced by a tertiary cambium ring. In addition, the abnormal vascular bundles produce coil-like vessels along the strand. These structures are typically observed in the upper half of the rhizome, and in the lower part of the rhizome the star-spots become fewer in number, larger in size, irregular in shape, and the star-spots ring becomes indistinct.

The abnormal vascular system described above is found not only in the rhizomes of *R. palmatum*, *R. tanguticum* and *R. officinale*, but also in the rhizome of *R. emodi* from Xizang (Tibet).

The occurrence of the abnormal vascular bundles in the rhizome of *R. emodi* was first reported by Solereder (1899). However, Youngken (1946) reported that the star-spot was absent from the rhizomes of authentic *R. emodi* from Kashmir, Darjeeling, Nepal, Dera Afghanistan, etc., and he observed that there were some internal variations in his materials. In addition, Li & Zhang (1983) reported that the star-spot was absent from the rhizomes of unofficial Da-huang including those of *R. emodi*. And this time, we (Wang et al. 1988) discerned it in the rhizome of the species from Xizang (Tibet), but fewer in number. Youngken, furthermore, observed some internal variations in his materials, and he pointed to their probable hybrid origin. Considering all these conflicting reports, further study on the rhizome of *R. emodi* is deemed necessary.

The occurrence of coil-like vessels in plants is indeed a peculiar phenomenon, and it may be related to the special requirement of the rapid increase in size of the pith and excessive shortness of the internodes of the tuberous rhizome of a hemicryptophyte to which the *Rheum* spp. mentioned here belong. In any case, the growth process of the abnormal vascular bundle system, coil-like vessel and leaf trace ought to be studied from young stage of the rhizome.

References


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[]「帝釈峡の自然」刊行会：帝釈峡の自然 561 pp. 1988. 同刊行会（広島県比婆郡東城町帝釈 小田村一朗）。植物関係としては、イチジクと石灰岩植物、開花期、種子植物、シダ植物、コケ類、地衣類、キノコ類、ケイ藻、植物プランクトンの調査報告と、糸管束植物文献目録がある。

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