Shrubs Jap. ed. 1, I, p. 420, f. 218 (1922).—KUDO, Rep. Veg. N. Saghal. p. 219 (1924) (f. *latifolia* NAKAI).

Sambucus latipinna var. *coreana* NAKAI, l.c. p. 11 (1921) pro parte; l.c. p. 421 (1922) pro parte.

Sambucus racemosa var. *pubens* f. *pubescens* KUDO, Medic. Pl. Hokkaido pl. 88 (1922).

Sambucus racemosa subsp. *euracemosa* var. *typica* subvar. *pubescens* WOLF in Mitt. Deuts. Dendr. Ges. XXXIII, p. 27 (1923) pro parte.

Sambucus Miquelii NAKAI ex KOMAROV et KLOB.—ALISOVA, Key Pl. Far East. Reg. USSR. II, p. 962 (1932).

Nom. Jap. *Yezo-niwatoko*.

Hab. in the lower part of Mt. Apoi, etc. Fl. Jun.

Dist. Honshu, Yezo, S. Kuriles, Saghalien, Korea, Manchuria, Ussuri, Amur, Ochotsk and E. Siberia.

(To be continued.)

On the Distribution and Construction of the Resin Canal in *Rhus succedanea*.¹⁾

By

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With 13 Text-figures.

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I. Introduction.

The resin canals in *Rhus* of *Anacardiaceae* hitherto have been studied by many botanists: ENGLER^{2), 4)} (1881, 1896) described the anatomy of the resin canals in the young branches of some species of *Rhus*, and then SOLEREDER⁵⁾ (1899) described the distribution of the resin canals of *Rhus viminalis*, *Rh. semialata* and *Rh. glauca* in his work on the systematic anatomy of dicotyledons. MCNAIR³⁾ (1918) investigated the distribution and construction of the resin canal in the stem of *Rhus diversiloba*. All these literatures treated namely the resin canals in *Rhus* which grow in foreign countries, but rather briefly, with the exception of MCNAIR's description.

1) Contributions from the Botanical Laboratory, Kyushu Imperial University, No. 66.

The anatomical investigations of *Rhus* which grow in Japan were done by MEYER¹⁾ (1879), MÖBIUS⁶⁾ (1899), INUI⁷⁾ (1900), TABATA⁸⁾ (1907), TAKAHASHI¹⁰⁾ (1921) and MOLISCH¹¹⁾ (1931). MEYER discussed the wax in the fruit of *Rhus succedanea* in his treatise on Japanese wax. MÖBIUS and TAKAHASHI stated in detail the origin, construction and distribution of the resin canal in *Rhus vernicifera* and INUI described very briefly the character of the resin canal in other related species in addition to *Rhus vernicifera*. TABATA stated the microchemical research of the fruit and the seedling of *Rhus succedanea*, and MOLISCH expressed the protein crystal of latex in the resin canal of *Rhus vernicifera* and *Rh. silvestris* in his treatise on microchemical investigation of *Anacardiaceae*.

Judging from the above mentioned literature, the detailed anatomical investigation of the resin canal in *Rhus* in Japan is almost limited to *Rhus vernicifera* at present, therefore I will now describe my investigation of the resin canal in six species of *Rhus* in Japan. In the first place I have studied the anatomy of *Rhus succedanea* in detail, and published the results of the research in a series of papers (12, 13, 14, 15, 16) in Japanese. This paper is to describe the principal points of the contents of those papers. I wish on this opportunity to express my gratitude to Prof. KOKETSU, who has kindly assisted me in my work.

II. Materials and Methods.

The distribution and construction of secretory organs in the plants are sometimes different according to the difference of the organs of the plant body or of the oldness of the organs, so I have observed the resin canal of each organ of *Rhus succedanea* in different stages of its development. I used namely buds, seeds and the very young fruit as material, in order to investigate the first developed stage of the resin canal, and also the young organs after sprouting or germination to probe the somewhat grown stage. Further I used materials from the young roots and stems forming the cork layer after a year to the very old ones which made a remarkable development in cork layer. Most of the materials used were preserved in formalin. Microtom sections were prepared sometimes from flowers and very young fruit.

III. The Result of Studies.

(a) Stem.

The stem of a seedling not long after germination has one resin canal in each phloem of the vascular bundles, 4 resin canals in all (Fig. 1); vascular bundles in the younger portion of the stem of seedlings, which are about a month old after germination, occur in many fragmental bund-

Fig. 1. Cross section of a young stem germinated from the seed. Fig. 2. Cross section of a young stem sprouted from the bud. Fig. 3. Cross section of an old stem. Fig. 4. Longitudinal section of the node of a young stem sprouted. Fig. 5. An anastomose of the resin canals in the pitch. Fig. 6. Cross section of the petiole of a cotyledon. Fig. 7. Cross section of the midrib of a well developed leaf. Fig. 8. Cross section of a small lateral root (2 mm. in diam.) of an old root. Fig. 9. Horizontal section of a petal. Fig. 10. Cross section of the mesocarp of a young fruit. Fig. 11. A group of the special cells in the mesocarp of a very young fruit. Fig. 12. The early stage of a resin canal built schizogenously in the mesocarp of a very young fruit. Fig. 13. The later stage of a resin canal enlarged lysigenously and its parenchyma sheath observed in the mesocarp of a somewhat developed fruit.

at, Assimilation tissue. bt(1), Primary portion of the bast. bt(2), Secondary

les, but the number of the resin canals is often more than that in the older portion, where the vascular bundle forms a circle surrounding the pith. Such an unusual occurrence is but only a passing phenomenon in the course of the development. That is to say, I think that the resin canal, even in the same tissue, has a tendency to grow more rapidly in the younger portion of a tissue in which its vigorous growth is usually seen. The number of the resin canals in the phloem increases according as the stem of the seedling grows, but we find a few resin canal in the pith only after the lapse of one year.

The very young stem which has sprouted from a bud has a great many vascular bundles which are arranged in a ring in cross section. Each phloem is bordered by a crescent-shaped group of well developed sclerenchymatous bast fibres which separate the phloem from the parenchymatous outer cortex. These fibrous bundles are almost in contact with others at their margins, and thus constitute another ring around the phloem ring. We can find no resin canal in the cortex, but a large one is to be seen in the phloem of each vascular bundle (Fig. 2). Though the resin canals in the phloem of the stem of *Schinus molle* of *Anacardiaceae* anastomose according to TRÉCUL, the resin canals in *Rhus succedanea* run parallel to the vascular bundles without anastomosis, and with blind ends. After a lapse of nearly a month after sprouting the smaller resin canals are sometimes to be found in the inner side of the primary one, but occasionally also close to the cambium.

We can also see many resin canals in the periphery of the pith of very young stems sprouted from the buds. They are scattered in a ring at the cross section, and we often find among them some remarkably large ones. These canals in the pith sometimes make a net-work in the node of the young stem (Figs. 4, 5), especially often in the winter bud. While both epithel cells of the resin canal and its circumferential cells are thin in the pith, the latter cells of the resin canal in the neighbourhood of the xylem are thickened to some degree. SOLEREDER⁵⁾ has noticed that the steam of *Anacardium*, *Dobinea* and *Thyrodium* of *Anacardiaceae* has the resin canal in the cortex as well as in the bast, but *Rhus succedanea* has the resin canal nowhere else than the bast and the pith.

After a year, we can find no difference of the structure between the stem which has sprouted from the bud and the one which has germinated from the seed. The stem which has passed 3-5 years has the irregular

portion of the bast. ck, Cork. ex, Cortex. ep, Epidermis. epi, Epithel cell. fe, Layer of the flat cells. gb, Group of the sclerenchymatous bast fibre. p, Pith. pc, Parenchymatous cell. ph, Phloem. ps, Parenchyma sheath. rc, Resin canal. sc, Stone cells. te, Trichome. vb, Vascular bundle. x, Xylem.

groups of the sclerenchymatous bast fibres in the primary portion of the bast and the resin canals are situated in the tissue on their inner side. The number of the resin canals found in the primary portion of the bast in the old stem is relatively less than those in the young stem and the shape in the cross section becomes flat in some degree, but in the secondary portion of the bast we can see many small resin canals which are round shaped. The resin canal in the phloem of the stem of *Rhus succedanea* is relatively numerous in the young stem and is situated at the inner side of the crescent shaped group of bast fibres and its distribution is rather regular, but no sooner than the cork layer is formed in the cortex, a number of the resin canals in the outer portion of the bast begins to diminish and also those secondarily formed resin canals which are distributed irregularly in that portion are scarcely able to be distinguished from the primary ones.

The group of the sclerenchymatous bast fibres is to be found no more in the old stem where the resin canals are oval shaped in the cross section, and measure sometimes nearly 0.2 mm. in long diameter (tangential direction), and nearly 0.06 mm. in short diameter (radial direction). The membrane of these cells found in the neighbourhood of each resin canal increase somewhat its thickness. Though the resin canals in the secondary portion of the bast are few in number at first, their number increases as the years wear on and a great many small resin canals are to be found scattered irregularly in the old stem (Fig. 3). If we cut off stems or leaves, we find after a while the bark of trees becomes black all over, on account of latex which has oozed out from the cut. After a microscopical inspection, their latex is oozed mostly from the resin canals in the secondary portion of the bast. The resin canals in this portion are smaller than the ones in the primary portion and are circular shaped in the cross section, but the greater part of the canals afterwards become elliptical. These resin canals are not surrounded by so many small neighbouring cells as those in the primary portion. The resin canals found in the old stem, as those in the young stem, also run parallel to the vascular bundles.

According to JADIN,⁵⁾ the genus *Corynocarpus* of *Anacardiaceae* has the resin canals neither in the phloem nor in the pith, and the genus *Julianea* has no resin canals in the phloem, but in the pith; and according to ENGLER²⁾, *Rhus Toxicodendron* has the resin canals in the phloem, but not in the pith. Thus after the literature, some species of *Anacardiaceae* have the resin canals in the pith, while some others have no resin canals in it. ENGLER²⁾ denoted that many trees of the genus *Rhus* which grow in the tropical districts have the resin canals in the pith, but on the contrary, those of the subtropical districts have no resin canals in the

pith. As I stated before, although the resin canal of *Rhus succedanea* is scarcely to be found in the pith of the stem of the seedlings, the stem which has sprouted from buds has the resin canals in its pith soon after sprouting.

The resin canals in the pith of the old stem are less in number, but larger in size than those of the young stem. The largest one measures nearly 0.27 mm. in diameter in cross section, and most of them becomes flat. The length of the canals measures nearly 1 mm. in the shortest and 6 mm. or more in the longest. The resin canals in the pith of the old stem sometimes form a net-work even in the internodes. The neighbouring cells to the epithel cells increase somewhat the thickness of their cell membrane. The epithel is surrounded by many smaller cells, as in the case of the phloem, by a single layer of small cells, or directly by usual cells of large size.

(b) Leaf.

In the petiole of the cotyledon after germination, there are only 2 resin canals (Fig. 6), but we find 4 resin canals in the petiole and midrib of the common leaves of seedlings. The number of the resin canals in the midrib diminishes to only one at its distal portion. In the lateral veins and veinlets, we find also only one resin canal each.

On the contrary, the well developed leaves sprouted from buds have a great many resin canals in the pulvinus and the internode of the common petiole, but the resin canals diminish in number as the common petiole comes to its distal end. At this end of the common petiole, 8 vascular bundles arrange themselves almost symmetrically in many cases, and as a rule each one take a large resin canal.

The petiole of the leaflets has 4 large vascular bundles and some small ones, and these are arranged in the shape of a ring. The resin canals in the phloem of both the right and the left one among the 4 large vascular bundles are somewhat larger than those in the phloem of both the upper and the lower one as a rule. In this petiole we often find, at the upperside in the tissue of the cortex, the cross section of 2 veinlets, each of which has one resin canal. Though 4 resin canals are found also in the midrib of the leaflets (Fig. 7), these diminish into only one at the end of it, and also in the lateral vein and veinlet only one resin canal is ordinarily to be found, and the lower side of the canal is surrounded by a group of the bast fibres which is nearly crescent shaped. All of these resin canals found in the phloem run parallel to vascular bundles.

There are resin canals in the pith of the common petiole and also in that of the petiole and lateral veins of the leaflets, namely in the pulvinus of the common petiole, they are especially numerous and are arranged

similar to that of the stem. But a few of them are found in the distal portion of the midrib and in the lateral vein.

(c) Root.

SOLEREDER⁵⁾ expressed that the root of *Anacardiaceae* has the resin canal in the phloem. According to my investigation, the youngest root of the seedling of *Rhus succedanea* has 4 vascular bundles in the cross section and the phloem portion has one resin canal. These resin canals run together with the vascular bundles up to the end of the root having no anastomosis. The somewhat developed main root, which has already lateral root has yet only 4 large resin canals, without any secondary one, and its lateral roots also have 4 resin canals, running parallel to the vascular bundles as in the main root. The 3-4 years old root has 4-6 resin canals which lie at a nearly equal distance from each other in the outer side of the bast, but we see 10-20 small resin canals which are arranged almost circularly in one or sometimes two rows in the inner portion of the bast. Those 4-6 large resin canals in the outer portion are to be found even near the end of the root. There are also 4-6 resin canals in the outer portion of the bast of the smaller lateral root (Fig. 8). Each resin canal tapers gradually off to a point, as it comes to the end of the root. It has been observed that large and small resin canals are distributed irregularly in the outer and inner portion of the bast in the old root, 6-10 mm. in diam., of a plant which has grown about 50 years.

The resin canals in the stem and leaf of this plant are accompanied by a group of the sclerenchymatous bast fibres as a rule, but it is not the case in the root. The construction of the resin canal in the root is similar to that in the stem, and its shape is circular or elliptical in cross section, and the epithel of a canal consists of the small cells which are similar to neighbouring cells.

(d) Flower.

There are some smaller vascular bundles in addition to 4-5 large ones in the flower stalk. Each phloem of these vascular bundles is accompanied by one resin canal. The sepal and petal have a large vascular bundle as the midrib, in the phloem of which we see a somewhat large resin canal. Although this resin canal is large in diameter at the base, it becomes smaller and smaller, according as it comes the upper part. We find also one resin canal in the phloem of each lateral vascular bundle which branches off on both sides of it. Further we often see 1-2 smaller vascular bundles running up from the base of the petal on the right and left sides of the large middle one. In the phloem of these bundles we find one small resin canal each (Fig. 9).

The pistillate flower of this plant has 5 short stamens with a rudi-

mental anther, but the male flower has 5 long stamens with longitudinally cracked anther containing a great deal of pollens. A very young stamen has resin canals neither in the filament nor in the anther, but the well developed filament has one resin canal in its axis, running parallel to the vascular bundles. The pistil in the male flower is very small, and very young pistil has no resin canal, not only in its ovary wall but also in the ovules. On the contrary the pistillate flower has a large ovary, the wall of which has a great number of the resin canals accompanied by the vascular bundles, even in the stage of a bud, but has no resin canals in the ovules. These resin canals are at first arranged in a circle, and according to the development of the ovary, they increase in number, and are often arranged somewhat irregularly. We find some resin canals in the style of the well developed pistil, but never in the stigma.

(e) Fruit.

There are plenty of large and small resin canals accompanied by vascular bundles in the mesocarp, and they run parallel with one another from the base of the fruit to the style rest. The course of the development of resin canals is observed distinctly in the tissues of the mesocarp of a very young fruit, namely the groups of special cells are found in the inner part of the mesocarp, and among the special cells of each group occurs a small schizogenous space. This is the first stage of the resin canal (Figs. 11, 12). The resin canal gradually increases in number with the development of the fruit, and as a rule, larger ones are found in the outer part of the mesocarp; and the resin canals in developed fruits are arranged in 2-3 rows or somewhat irregularly in the cross section of the widest part of the mesocarp. However, at the narrowest part smaller resin canals are arranged in rows. In very young fruit the resin canal has no parenchyma sheath, which is built gradually according as the fruit becomes bigger and bigger, and the vascular bundles, in many cases, are arranged in a circle at the outer portion of this parenchyma sheath (Fig. 10). The thickness of this sheath measures 0.2 mm. or more in the cross section of the ripe fruit. On account of the enlargement of the cells in the parenchyma sheath according to the development of the fruit, the shape of the resin canal changes to an elliptical or an irregular form in the cross section.

ENGLER⁴ described that *Anacardiaceae* has schizogenous resin canals, while SIECK³ mentioned them as schizolysigenous. But according to my investigation of the fruit of *Rhus succedanea*, the resin canal occurs schizogenously in the beginning, and it becomes lysigenous in the later stage; namely it must be a schizolysigenous resin canal (Figs. 12, 13).

The cotyledon of *Rhus succedanea* has two layers of palisade tissue.

and there are 5–13 resin canals close by it in the cross section. The hypocotyl and the radicle have 4 resin canals which run parallel to the vascular bundles. *Pittosporum Tobira* of the family *Pittosporaceae* has the resin canals in the bast, but no resin canal in the seed. However, *Rhus succedanea* has it not only in the bast but also in the seed. Tracing further the ovules of *Rhus succedanea* I could find no resin canals in it at all. This must be an interesting fact in the comparative anatomy.

IV. Overlooking Consideration.

Putting together the above mentioned results of investigation, the system of resin canals in *Rhus succedanea* is as follows:

The resin canal in *Rhus succedanea* is found in the phloem and the pith. The first stage of its development is clearly observed in the mesocarp of the fruit. The groups of special cells in the mesocarp of very young fruit form schizogenously a very small resin canal, and it grows larger and larger lysigenously, according as the fruit develops. It must therefore be a schizolysigenous resin canal, as SIECK³⁾ stated about the resin canals of *Anacardiaceae*. The resin canal of this plant may be divided into two kinds from the difference of the period of its development. One is built in the earliest stage as it in the embryo and the winter bud, while the other begins to appear later in the inner part of the bast. This distinction is clear in very young branches which have sprouted from a bud; the first built resin canals are large and situated in the outer part of the phloem, while the later grown ones are smaller than the former, and are situated in the inner portion of the phloem, but the resin canals of these two kinds are no more distinctly identifiable, as soon as the cork layer develops. According as the stem of this plant develops, the smaller resin canals are built in the secondary portion of the bast; their number is very numerous, and the secretive function of resin in old stems is mainly done by the resin canals in this portion.

Botanist's opinions are divided about the question whether *Anacardiaceae* has the resin canal in the pith, or not. ENGLER²⁾ described that many trees of the genus *Rhus* which grow in the tropical districts have the resin canal in the pith, and on the contrary, those in the subtropical districts have none in it. After my investigation, though the resin canal is observed scarcely in the pith of the seedling of *Rhus succedanea*, the very young branches sprouted from the bud have early the resin canal in their pith. Though the resin canals in the phloem run parallel to the vascular bundles, those in the pith sometimes form anastomosis. This fact is found in the longitudinal sections of a winter bud. The resin canals in the pith are situated mostly in its peripheral portion, and their diameter

in the cross section is sometimes several times larger than the ones in the phloem. The resin canals in both the phloem and the pith are generally surrounded by many smaller cells, and each one in the phloem has a group of the sclerenchymatous bast fibres near the outside of those smaller cells, with the exception of roots, flowers and fruit. The resin canal found in the well developed fruits has a sheath which consists of many large parenchymatous cells, and the vascular bundles are scattered at the periphery of it; this is a point which is not observed in the phloem of the stem.

V. Summary.

1. The stem of a seedling has only 4 resin canals in the phloem but none in the pith. On the contrary, the very young stem which has sprouted from the bud has a great many resin canals in both the phloem and the pith. Those in the phloem run parallel to the vascular bundles in any part, ending blindly. The resin canals in the pith sometimes make a net work, especially when they appear in buds. The number of the resin canals in the outer portion of the bast of old stems diminishes gradually and their shape is somewhat oval in the cross section, and the neighbouring cells of their epithel increase the thickness of the cell membrane in some degree. On the other hand, many smaller resin canals which are almost circularly formed in the cross section appear in the secondary portion of the bast.

2. There are only 2 resin canals in the petiole of the cotyledon, but 4 in the petiole of the leaflets of the seedling, and only one in the lateral veins and veinlets. The petiole and midrib of a well developed leaf has 4 large resin canals and additional smaller ones, but only one in the distal portion of the midrib, in the lateral veins and veinlets.

3. There are 4 resin canals in the very young root. The 3–4 years old root has 4–6 resin canals in the primary portion of the bast, and moreover 10–20 resin canals in its secondary portion which are arranged almost circularly in one or two rows. The resin canals in the primary and the secondary portion in the bast of the very old main root are however distributed irregularly and in different sizes in the cross section.

4. The sepals and petals have a large vascular bundle as a midrib running towards the distal portion from the base, which is accompanied by a large resin canal in its phloem. In each of the vascular bundle, branching off from it on both sides, we find also a resin canal.

5. There are a great number of small and large resin canals in the mesocarp of the fruit, which run parallel with one another from the base of the fruit stalk to the style rest. They increase their number with the development of the fruit. The first stage of the resin canal may be clearly

observed in the mesocarp of fruits. The groups of special cells in the mesocarp of a very young fruit forms at first schizogenously a very small resin canal, which becomes larger and larger lysigenously according as the fruit develops. These resin canals in this part are surrounded by a parenchyma sheath as the fruit develops by and by, and vascular bundles are arranged in a circle around this sheath.

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Literature Cited.

- 1) MEYER, A., Ueber den Japantalg. Arch. d. Pharm. Zeits. d. d. Apoth. Vereins. **215**, p. 97, 1879.
- 2) ENGLER, A., Ueber die morphologischen Verhältnisse und die geographische Verbreitung der Gattung *Rhus*, sowie der mit verwandten lebenden und ausgestorbenen Anacardiaceae. ENGLER's Bot. Jahrb. **1**, p. 386, 1881.
- 3) SIECK, W., Die schizolysigenen Sekretbehälter. Jahrb. wiss. Bot. **27**, p. 197, 1895.
- 4) ENGLER, A., Natürliche Pflanzenfamilien, III Theil, 5 Abteilung, p. 143, Berlin, 1896.
- 5) SOLEREDER, H., Systematische Anatomie der Dicotyledonen. p. 279, Stuttgart, 1899.
- 6) MÖBIUS, M., Eine morphologische anatomische Studie. Der Japanische Lackbaum, *Rhus vernicifera*. Frankfurt, 1899.
- 7) INUI, T., Ueber den Gummiharzgang des Lackbaum und seiner verwandten Arten. Bot. Centrbl. **83**, p. 352, 1900.
- 8) TABATA, S., Ueber die Früchte und Keimpflanzen von *Rhus succedanea*. Jour. Sci. Coll. Tokyo, **23**, p. 1, 1907.
- 9) MCNAIR, J., Secretory canals of *Rhus diversiloba*. Bot. Gaz., **65**, p. 368, 1918.
- 10) TAKAHASHI, K., Study on the resin canal of *Rhus vernicifera*. (In Japanese), Forest Exp. Gaz., No. 22, 1921.
- 11) MOLISCH, H., Beiträge zur Mikrochemie der Pflanzen. Ueber Eiweisskristalle in den Sekretgängen der Anacardiaceen. Ber. Deut. Bot. Ges., **49**, p. 324, 1931.
- 12) HARADA, M., Anatomical study on the leaves of *Rhus succedanea*, especially on the distribution of the resin canal. (In Japanese), Jour. Soci. Fores. Tokyo, **14**, No. 4, p. 238, 1932.
- 13) HARADA, M., Study on the development and construction of the fruit of *Rhus succedanea*. (In Japanese), Jour. Soci. Fores. Tokyo, **15**, No. 6, p. 398, 1933.
- 14) HARADA, M., Study on the development of the stem of *Rhus succedanea*, especially on the resin canal. (In Japanese), Jour. Soci. Fores. Tokyo, **17**, No. 5, p. 323, 1935.
- 15) HARADA, M., Anatomical study on the root of *Rhus succedanea*, especially on the resin canal. (In Japanese), Jour. Soci. Fores. Tokyo, **17**, No. 7, p. 499, 1935.
- 16) HARADA, M., Anatomical study on the flower of *Rhus succedanea*, especially on the resin canal. (In Japanese), Jour. Soci. Fores. Tokyo, **17**, No. 12, p. 562, 1935.