The earliest mention of the cytology of the Rutaceae appeared in 1912, in a paper by Osawa who counted 8 chromosomes instead of 9 in Citrus sp. On the Simarubaceae, cytological work only on three genera, Ailanthus, Quassia and Picrasma is recorded. Extensive cytological work has been done on the genus Citrus, in the Rutaceae. The family Simarubaceae consists of 30 genera and about 200 species, the distribution of most of them is in the warmer parts of the world. The Rutaceae is rich in species. The study recorded here concerns the cytology of 10 species in 8 genera of the Rutaceae and 2 species in 2 genera of the Simarubaceae. The following description includes also geographical distribution of Xanthoxylum.

**Materials and methods**

Iron acetocarmine squash technique was the most satisfactory one for staining chromosomes. Flower buds were collected from plants growing in their natural condition and were fixed in 3 parts of absolute alcohol: 1 part glacial acetic acid and the freshly fixed material was placed immediately under a vacuum pump. Use of a trace of ferric acetate in the fixative was helpful in some cases. A small portion of the anther or the ovule was dissected out and heated to boiling in acetocarmine and then squashed when still hot. It was found that inverting the prepared slide over vapours of con. HNO₃ gave better differentiation of the chromosomes in some cases.

Microphotographs were taken from freshly squashed preparations on Ilford Rapid Process Panchromatic plates. The drawings were made with a Zeiss camera lucida.

A list of the plants of this investigation is given below indicating the localities from which they were obtained (Table 1).

As most of my material was obtained from the various botanic gardens in England except Quassia amara which was obtained from Bombay, India, it has not been possible to discover where each species was originally collected.

**Observations**

**Choisya ternata.** It is an ornamental plant with scented flowers. The chromosome count for Choisya ternata was obtained as \(n=27\) (Fig. 1).
species shows slightly irregular meiosis, the irregularities being manifested by a few lagging chromosomes at first metaphase. At second anaphase and second metaphase, the twenty-seven chromosomes are spherical (Fig. 2). No previous cytological work on *Choisya* is recorded.

*Correa backhousiana*. Pollen mother cells of this species show a regular meiosis and normal tetrad production. At first metaphase 16 bivalents are counted (Fig. 3), in agreement with the counts of three other species of *Correa* found by Smith-White (1954b). The chromosome number \( n = 16 \) is recorded here for the first time.

*Skimmia formanii*. This species is a hybrid of *S. japonica* × *S. reevesiana*. The chromosomes number for this species is determined as \( n = 16 \) (Fig. 4, 5). No cytological work on *Skimmia* is recorded so far. The pollen grains show considerable variability as regards their shape and size in this species.

*Ptelea trifoliata*. Original chromosome number for this species was found to be twenty one (Fig. 6) and is the first recorded count for the genus. Meiotic irregularities in the pollen mother cells were observed. Figs. 7, 8, 10 show the formation of univalents and trivalents at metaphase I. Certain round extranuclear bodies which occur regularly were observed at first and second telophase (Fig. 9). They stained to the same extent as the nucleoli with acetocarmine. Their exact function and nature is not known. They

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**Table 1**

<table>
<thead>
<tr>
<th>Genus</th>
<th>Classification</th>
<th>Locality</th>
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<tr>
<td><strong>RUTACEAE</strong></td>
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<tr>
<td><em>Xanthoxylum americanum</em></td>
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<td>Royal Botanic Gardens, Kew</td>
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<td></td>
<td>Subfamily Rutoideae</td>
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<tr>
<td><em>Xanthoxylum bungeii</em></td>
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<tr>
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<td>Chelsea Physic Gardens</td>
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<td></td>
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<td><em>Evodia danielli</em></td>
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<td><em>Evodia glolei</em></td>
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<td><strong>SIMARUBACEAE</strong></td>
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<td><em>Ailanthus altissima</em></td>
<td>Tribe Picrasmeae</td>
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<tr>
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<td>Bombay, India</td>
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<tr>
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</tbody>
</table>
are not found in the pollen grains. They may probably be bodies extruded from telophase nuclei.

An irregular wall formation occurs in *Ptelea* which gives rise to one binucleate and two uninucleate spores. The occurrence of polyploidy may be as a result of occurrence of lagging chromosomes which organise into micronuclei. The pollen grains arising in this way are non-functional. The plant may be a hybrid and is characterised by a high degree of sterility.


*Phellodendron sachalinense*. The chromosome number in the pollen mother cells of this plant is found to be forty (Fig. 13) and is the first recorded count for the genus. Pollen mother cells show regular meiosis. The species appears to be fully pollen fertile.

*Dictamnus albus var. caucasus*. This species shows n=36 (Fig. 11).
During meiosis irregularities in the form of laggards at first anaphase were observed and frequently chromosome bridges also (Figs. 12). This is in agreement with Bowden’s (1945) record of n=36 for Dictamnus albus.

Evodia. The chromosome number for Evodia daniellii was found as n=40 (Fig. 14), this count differing from that of Bowden (1945) who gives n=36 for material grown on Blandy Experimental Farm, University of Virginia. It is interesting to note the apparent existence of aneuploidy within the genus Evodia.

Evodia glocii. Evodia glocii has n=36 (Figs. 15) and is the first recorded count for the species. Univalents were observed at diakinesis and at metaphase I. Trivalents also occur in this plant (Fig. 17). Widespread degeneration of pollen grains takes place in this species.

Xanthoxylum. The mitotic chromosome number for Xanthoxylum
Americanum is $2n=136$. Walker (1942) records $2n=68$ for the same species obtained from E. N. America. *Xanthoxylum bungeii* has $2n=32$. The chromosomes are small and rod shaped. Both the species are apomictic.

*Xanthoxylum* consists of about nine species which are distributed in the mainly temperate regions of E. Asia and E. N. America. This genus does not occur in Europe nor is it recorded in Africa or South America. Asa Gray (1858) brought forward a list of a large number of genera which Eastern Asia has in common with E. N. America. It is quite possible, that in ancient times there was an interchange of forms between E. Asia and E. N. America and this has presumably taken place in high Northern latitudes. These considerations suggest an ancient continuity of territory between America and Asia presumably existing during the tertiary period.

In order to determine the age of the species of *Xanthoxylum*, some fossil remains of the plants were examined by the writer. The following three species are preserved as fossils.

1) *Zanthoxylum juglandinimum* was found at Oeningen in Switzerland.

2) *Zanthoxylon costatum* is preserved at the Isle of Wight, from the middle Oligocene period. The fossil remains of a seed and leaves of this plant have been preserved. From the perfect state of the seed, it is estimated that it has travelled only a little distance. This species is not completely identical with the living species of either *Xanthoxylum* or *Fagara*, a closely allied genus.

3) *Zanthoxylon spiraceaeolium Lesq.* (Schimper and Schenk, 1879–90) was represented in the Tertiary period in N. America. This particular species is now extinct in N. America. Presumably it was destroyed during
the Pleistocene glaciations. The genus therefore was formerly less restricted in its distribution and occurred in Europe.

Family Simarubaceae. The family Simarubaceae is closely allied to the Rutaceae morphologically, differing mainly in the absence of oil glands and in the marked tendency to unisexuality in the flowers.

Ailanthus altissima. The chromosome count for Ailanthus altissima shows that n=40 (Fig. 18) and is the first recorded count for the genus. In the pollen mother cells, small meiotic irregularities are observed. In Fig. 16 a lagging chromosome at second anaphase is shown. The anthers exhibit a considerable number of degenerated or defective pollen.

Quassia amara. In the pollen mother cell of Quassia amara, 18 chromosomes are counted (Fig. 19). This is in agreement with Janaki Ammals (1955) record of 2n=36 for the material obtained from Guiana.

Abnormal tetrad formation is observed in Quassia. Figs. 20, 21, 22, show formations of 5, 8 and 10 spores in a tetrad. The disturbance in the normal meiotic behaviour may have been due to susceptibility to environmental changes. Darlington (1937) has discussed several cases of abnormality in microspore formation. He attributed the phenomenon to the variable behaviour of dividing cells in which the normal relationship of the spindles to the chromosomes have been upset by failure of pairing.

Discussion

1) Chromosome size

Though both Dictamnus and Correa are herbs, considerable difference in absolute chromosome size exists in them. Those of Dictamnus are of the size 1–1.2 m in the pollen mother cell. Correa growing in the hot houses in London has fairly large chromosomes (1.5 m). Those of Choisya are the largest chromosomes observed (1.8 m). It should be noted however that medium sized chromosomes are characteristic of the family Rutaceae and are observed in most of the genera so far investigated.

It is now believed that differences in absolute size of the chromosomes have nothing to do with the size of the chromonema or gene string but are related to the coiling properties of the DNA and to the amount and distribution of certain chemical substances in the chromosomes.

It is also found that external factors control to some extent differences in chromosome size. Pierce (1937) in Viola records that lack of phosphorous in the nutrition of the plant causes considerable reduction in the size of the chromosomes. It has been found that species with larger chromosomes occupy cooler climates. In the Simarubaceae, Quassia growing in Bombay, has smaller chromosomes (0.85–1 m) when compared with those of Ailanthus (1.25 m) growing in the temperate zones. However the extent to which

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external factors can control absolute chromosome size in general needs further to be explored.

It is not possible to decide whether the reduction or increase in absolute chromosome size in the Rutaceae is phylogenetic, for there is no evidence on this point.

2) Chromosome numbers

There can be no doubt that the basic chromosome number in the Rutaceae is 9, since this number has already been found recorded in several sub-families and tribes. Modification of the primitive chromosome set has been either by a stepwise increase in the basic chromosome number or by polyplody. For example diploid chromosome numbers recorded in Xanthoxylum are as follows:

- X. clava-herculis (Fagara) -72(8×) Bowden, 1940
- X. piperitum -70. Nakajima, 1937
- X. americanum -68. Walker, 1942

My determinations are:

- X. americanum -136. Desai, 1956
- X. bungeii -32. Desai, 1956

In the present investigation, the chromosome number 2n=136 for X. americanum is the highest count recorded in the whole family; also aneuploid changes have been observed for the first time in Evodia.

Some authorities consider that the relative ages of species can be to some extent estimated by comparison of their chromosome numbers. Material of Xanthoxylum obtained from the British Isles has a higher chromosome number than that determined as 2n=68 by Walker (1942) for the same species in America. The former material has presumably originated from the latter. The doubling of the chromosome number may have been due to ecological causes and related to irregularities observed at meiosis (Desai 1956). Polyploids are most successful in habitats which are newly acquired. The few chromosome numbers published and those found by the Author show the present day Xanthoxyleae to be high polyploids.

3) Observations other than chromosome numbers

The irregularities in meiosis observed in some of the species are described earlier. Irregular tetrad formation occurs in Quassia. A tetrahedral arrangement of microspores in a tetrad is common to all the plants of the Rutaceae and the Simarubaceae under the present investigation. It was observed in all the plants except Skimmia that the stages of development of the mother cells were widely different in the anthers of one flower or even in the sporangia of one and the same anther. For instance, in one microsporangium the mother cells may be in the later stages of meiosis when in others of the same anther they may be yet in prophase.
Summary

1. Chromosome numbers have been determined for the first time for 10 species belonging to 8 genera of the two families, Rutaceae and Simarubaceae.
2. The process of meiosis has been studied in detail in the pollen mother cells of these plants and the irregularities during meiosis noted.
3. Formation of univalents and trivalents is observed in Ptelea and in Evodia globii.
4. Polyploidy is observed in Xanthoxylum and aneuploid changes in Evodia danielli.

Acknowledgements

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Literature cited