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On the Sex Expression of *Coptis japonica* MAKINO

By

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(With 3 Text-figures and Plate I)

Coptis japonica MAKINO is a perennial herb of *Ranunculaceae* which is widely distributed in middle and northern Japan. In spring, three or four flowers bloom at the top of the flower-stalk. Examining well, one can easily see that these flowers show remarkable ranges of variation in the number of their flower organs. Especially it is noteworthy that the number of stamens as well as carpels ranges from 0 to a multitude. In other words, this group of plants involves male, female and hermaphrodite individuals, therefore it can be said to be trioecious.

On the polyoecism of the plants of *Ranunculaceae* there is a number of reports. Especially, the gynodioecism of *Ranunculus* has been reported by several authors. But no papers have been published with respect to the trioecism of *Coptis japonica* MAKINO so far as the author is aware.

MARSDEN-JONES and TURRILL (1929) made some investigations on the sex inheritance of a gynodimorphic plant, *Ranunculus acris*. The types of sex expression were classified by them into five categories, namely male, female, normal, minus normal and abnormal. They made some breeding tests with these five types. But no conclusion has been drawn from their results on account of the paucity of the materials. SALISBURY reported frequently about the variation of the number of flower organs on various Ranunculaceous plants in his papers, but his materials were all hermaphrodite and he has never referred to the sex expression.

The present author attempted to study statistically the distribution of different types of sex expression in this group of plants, and to determine the genetical nature of these types by the way of crossing and selfing. To his great regret, the seeds secured by crossing and selfing could not be induced to germinate by any method of germinating tests, so that it was necessary to give up the attempt to get offspring, which had been the

principal object of the present study. Here, in consequence, only the results of the morphological study on the types of the sex expression of these plants will be reported.

The materials were collected by Dr. A. KIMURA of the Tôhoku Imperial University, at Mukôyama, Sendai, in 1931, and then planted in pots at the green house of the Botanical Institute, Faculty of Science, Hokkaido Imperial University, Sapporo.

As in early December 1932 some plants began to bloom, the author tried to count the number of stamens and carpels of each flower. In 1931, Prof. MATSUURA made some counting with the same materials and methods. Comparing his results with the author's, it can be easily recognized that the same individual reveals little difference in the number of stamens and carpels in the two years. Therefore it can be said that the type of the sex expression is fixed in each individual. Table I shows some instances of the comparison.

TABLE I

Some instances of the comparison of Prof. MATSUURA's and the author's results. The figures show the average number of three of four flowers on a plant.

	A Plant		B Plant		C Plant	
	Stamens	Carpels	Stamens	Carpels	Stamens	Carpels
1931	19.3	10.0	8.7	11.3	14.7	9.3
1932	15.7	10.3	8.7	10.7	14.0	10.3

	D Plant		E Plant		F Plant	
	Stamens	Carpels	Stamens	Carpels	Stamens	Carpels
1931	3.3	7.7	20.6	8.7	35.7	11.3
1932	5.2	11.5	26.7	9.0	31.5	11.5

In this way, the whole 230 plants were submitted to experiment till the end of February 1933. In consequence, they were classified preliminarily into four categories as described below according to their sex expressions:

1. female plants with flowers having no stamens,
2. male plants with flowers having no carpels,
3. abortive..... plants with flowers having both functionless stamens and carpels,
4. hermaphrodite... plants with flowers having both functional

stamens and carpels.

The female plant was recorded in only one case. The percentage to the total number is 0.43%. It bears three flowers having 4, 5 and 7 carpels respectively.

Thirteen male plants were found to make a percentage of 5.65%. The stamen number in each of 36 flowers fluctuates between 18 and 88 with the mean value of 55.239 ± 2.097 and the standard deviation of $\pm 18.657 \pm 1.504$. (These variation constants and others which follow are accompanied by the probable error). One plant having three flowers with traces of carpels whose numbers are 5, 7 and 8 respectively was observed.

The abortive plants differ apparently from others in appearance. The size of the flowers as well as their flower organs are somewhat small. The diameter of the corolla is about $2/3$ that of the normal one. The anther involves few pollen grains and the carpels few ovules. The number of both stamens and carpels is also small. The whole condition of the flowers appears less vigorous than others. By crossing and selfing they produced no seeds. The plants belonging to this category are 10 *in toto*. The percentage is 4.34%. The number of stamens ranges from 0 to 11 with 4.967 ± 0.320 as the mean, 6 as the mode and $\pm 2.0643 \pm 0.230$ as the standard deviation. The number of carpels fluctuates between 0 and 12 with 8.065 ± 0.260 as the mean, 8 as the mode and $\pm 2.152 \pm 0.187$ as the standard deviation.

The hermaphrodite plants occupy the greater part of the whole, namely 89.57%. They make a gradual arrangement between the approximately male plant and the approximately female. The most nearly male flower has 45 stamens and 8 carpels, and the most nearly female flower has 8 stamens and 18 carpels. The number of stamens in all hermaphrodite flowers ranges from 1 to 58, and that of carpels from 4 to 18. Their variation constants are shown in Table II. The variation for the number of stamens shows an asymmetrical and bimodal curve, while the variation curve for carpels is approximately normal. The correlation coefficient between the number of stamens and carpels is a negative one, namely -0.213 with the probable error of ± 0.025 .

Looking over the whole group of hermaphrodite plants at least three types of sex expression can be recognized. Temporarily, they were classified into three groups as follows:

1. minus normal . . . the carpels are comparatively in large number, while the stamens are small,
2. normal both stamens and carpels are of a tolerably large

number,

3. plus normalthe stamens are of a comparatviely large number, while the carpels are small.

However, the boundary between these types is not very distinct as a matter of course. The variation constants with respect to the number of stamens and carpels in each of the types are also shown in Table II.

TABLE II
Variation constants and correlation coefficients for the number of stamens and carpels in hermaphrodite flowers.

i) Stamens

	Mo	Mi	M±P.E.	σ ±P.E.	V±P.E.
Hermaphrodite	11	13	14.551±0.214	±8.020±0.151	55.116±1.320
M. normal	7	8	7.630±0.116	±2.700±0.082	35.386±1.198
Normal	16	15	15.551±0.161	±3.938±0.113	25.323±0.826
P. normal	28	26	26.905±0.410	±6.904±0.305	25.061±1.177

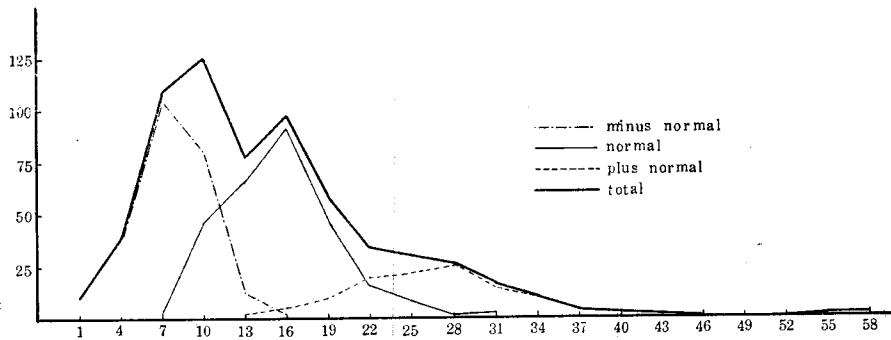
ii) Carpels

	Mo	Mi	M±P.E.	σ ±P.E.	V±P.E.
Hermaphrodite	10	11	10.743±0.052	±1.942±0.034	18.077±0.352
M. normal	11	11	11.424±0.076	±1.785±0.054	15.713±0.488
Normal	10	10	10.712±0.065	±1.614±0.046	15.076±0.444
P. normal	9	9	9.362±0.126	±2.006±0.088	21.421±1.132

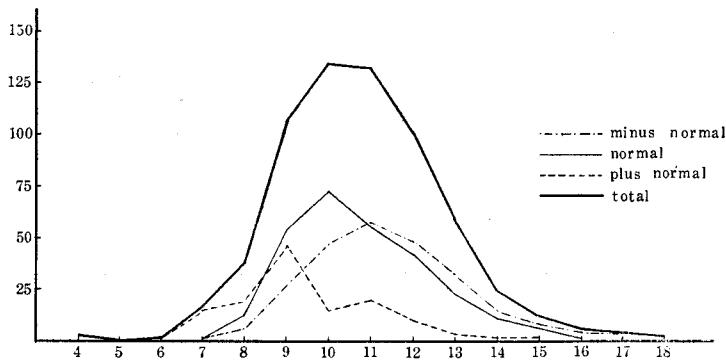
iii) Correlation Coefficients

	Correlation coefficients between stamens and carpels
Hermaphrodite	-0.213±0.025
M. normal	+0.015±0.043
Normal	+0.292±0.038
P. normal	+0.319±0.056

As already stated, the variation of the number of stamens in hermaphrodite flowers exhibits an asymmetrical and bimodal curve. It suggests to one that it is a combined form of more than two normal curve. In fact, it can be divided into three normal curves with the respective modes of 7, 16 and 28 corresponding to three groups of hermaphrodite flowers (Text-fig. 1). The normal curve of the carpels also proved to be a combined form of three normal curves with the modes of 9, 10 and 11 respectively (Text-fig. 2).



Text-fig. 1. Variation polygons for the number of stamens in hermaphrodite flowers (containing 206 flowers).



Text-fig. 2. Variation polygons for the number of carpels in hermaphrodite flowers (containing 206 flowers).

Moreover, the correlation coefficient between the number of stamens and carpels in each of these three types is always positive, while in whole hermaphrodite flowers the correlation is a negative one. This fact also suggests us that the negativity of the correlation in whole hermaphrodite flowers is only a seeming one.

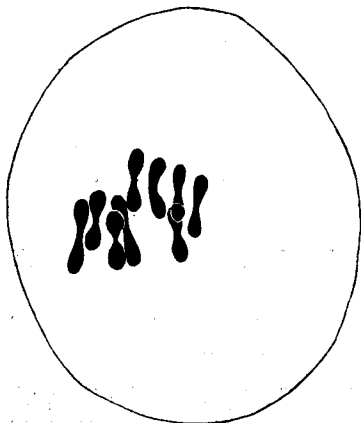
From these considerations it seems to be adequate to divide the whole hermaphrodite plants into three types. And one is allowed to suppose that in nature the plants of six types exist independently of each other, viz. female, male, minus normal, normal, plus normal and abortive (Table III). This assumption, however, should be confirmed by the breeding tests, but unfortunately they could not be carried out from the reason already related.

TABLE III

Classification according to the sex expression.

	Number of plants observed	%	Number of flowers counted	Average number of stamens per flower	Average number of carpels per flower
Female	1	0.43	3	0	5.3
Male	13	5.65	36	55.2	0
M. normal	83	36.09	248	7.6	11.4
Normal	87	37.83	274	15.6	10.7
P. normal	36	15.65	116	26.9	9.4
Abortive	10	4.34	31	5.0	8.1

The genetic factors relating the sex determination and the inheritance of sexuality in this plant are unknown. SOROKIN (1927) made some cytological investigations on the gynodioecious plant, *Ranunculus acris*. She said that the gynodioecism in this plant was associated with the unstable condition of the plant character, and was an indication of the unbalanced types of changes which had taken place in the chromosome complement of the nuclei. WHYTE (1929) stated that in *Ranunculus acris* there are no cytological differences between the plants of different sex expressions. NAKAJIMA (1933) reported on the somatic chromosome number of *Coptis japonica* MAKINO in his paper. According to his results the chromosome number of the male and the female plants is the same, namely $2n=18$. But, as he made no morphological description of the chromosomes, it is uncertain whether there is a heteromorphic pair of chromosomes or not.



Text-fig. 3. Side view of the first metaphase plate in the micro-sporogenesis of the normal plant. (Aceto-carmin preparation, magnification ca. $\times 2500$).

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The author has observed the meiosis of P.M.C. of the normal plant in aceto-carmin preparations. On the first metaphase plate 9 bivalents were counted, and there were found no figures showing the heteromorphic pair (Text-fig. 3). Presumably it may be concluded from these facts, that the sex determination in this plant is hardly explicable on the basis of cytological evidences.

In conclusion, the author wishes to

express his hearty thanks to Prof. H. MATSUURA, under whose guidance this work has been carried out, for his kind suggestions and criticism, and to Doctor A. KIMURA of the Tôhoku Imperial University for having supplied him the materials in the present studies.

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Explanation of Plate

All the photographs were taken by the aid of Zeiss Mikroplanar, with camera bellow at about 30 cm. Magnification ca. $\times 6 \times 4/5$.

- Fig. 1. Female flower with 7 carpels.
- Fig. 2. Male flower with 88 stamens.
- Fig. 3. Minus normal flower with 3 stamens and 13 carpels.
- Fig. 4. Normal flower with 15 stamens and 11 carpels.
- Fig. 5. Plus normal flower with 37 stamens and 11 carpels.
- Fig. 6. Side view of the plus normal flower with 25 stamens and 12 carpels.
- Fig. 7. Abortive flower with 3 functionless stamens and 9 functionless carpels.

