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in *Cucumis* and *Citrullus*

J. T. ROSA

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## THE INHERITANCE OF FLOWER TYPES IN CUCUMIS AND CITRULLUS

J. T. ROSA<sup>1</sup>

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### SEX FORMS IN FRUIT-PRODUCING FLOWERS

The horticultural varieties of melons and cucumbers, belonging to the genus *Cucumis*, and of watermelons, belonging to *Citrullus*, may be divided into two groups according to the arrangement of the sex organs. In one, the andromonoecious group, the plants bear staminate and hermaphrodite flowers. The former are borne in clusters of five in the axils of the main axis and of the lateral branches, while the latter occur singly on the two basal nodes of lateral branches of the first and second order (Rosa,<sup>(8), (9)</sup>). In the second, or monoecious group, the plants bear staminate and pistillate flowers, the location of the pistillate being the same as that of the hermaphrodite flowers in group 1. Monoecism generally is said by systematists to be the typical condition in *Cucumis* and *Citrullus*. However, the occurrence of hermaphrodite flowers in cantaloupe melons has been reported comparatively recently by Munson,<sup>(6)</sup> and Blinn,<sup>(1)</sup> and in watermelons by Rosa.<sup>(9)</sup> A typical hermaphrodite flower of the cantaloupe melon is illustrated in figure 1.

In cultivated varieties of melons (*Cucumis melo*) of the present day, the andromonoecious group greatly predominates in number. All of the varieties of English and American netted melons (*C. melo* var. *reticulatus*) which were grown at Davis in 1923, 1924 and 1925 were found to have hermaphroditic flowers. About 300 different varieties of this group came under observation. In 1925, however, the Snake melon (*C. melo* var. *flexosus*) and three European varieties

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of netted melon, Sucrin de Tours, Heinemann's Freiland, and Japan White, were found to be producing pistillate flowers. In 1926, 84 varieties of melons from various European and Asiatic sources were grown at Davis, and of these 76 were andromonoecious, 7 were monoecious, and in 1 some plants belonged to one group, some to the other. In 1927, 63 new foreign varieties were tested; 56 were andromonoecious, 5 were monoecious and 2 were mixed.

*Cucumis cocomon*, of which several varieties were grown, is andromonoecious. *C. utilissima* and *C. mormodica* are monoecious. The three foregoing cross readily with *C. melo* and should be considered merely as botanical varieties of that species, according to the delimitations established by Naudin. *Cucumis anguria*, the West Indian Gherkin, is monoecious; attempts to cross it with *C. melo* and with *C. sativus* failed.

In the cucumber (*Cucumis sativus*), conditions are different from those in melons. Of about 50 American and European varieties which have been tested, all are monoecious except one, the Lemon cucumber, which has hermaphroditic flowers.

In watermelons and citron melons (*Citrullus vulgaris*) the monoecious condition predominates. Of about 60 varieties which have been tested at Davis, only a few have been found to possess hermaphroditic flowers. These include the Black Seeded Angelino, Black Seeded Chilian, Snowball, Winter King, and a Kalihari citron melon.

The monoecious condition in the plant kingdom in some instances appears to be unstable, the exact forms of sex expression tending to be altered by environmental conditions. Thus, Higgins and Holt<sup>(4)</sup> report a variety of forms of sexual expression in the papaya (*Papaya carica*); and Schaffner<sup>(11)</sup> produced apparent cases of sex reversal in *Arisaema*, through manipulation of moisture and nutrition. It is also of especial interest that Durham<sup>(2)</sup> found hermaphroditic flowers in certain inbred lines of the summer squash, *Cucurbita pepo*, which has always been considered as strictly monoecious. Moreover, the hermaphroditism observed by Durham in squash appears to have been, at least in some cases, of a transitory nature, as some of the plants returned to the monoecious condition in the latter part of the season.

In contrast to the instances mentioned above, sexual forms in *Cucumis* and *Citrullus* appear to be remarkably constant. The basis for this statement is found in the writer's pollination records for 1924-1927. During the course of breeding work with melons, cucumbers and watermelons, the sex conditions in the flowers employed have been recorded. In the cucumbers and watermelons, out of several

hundred flowers of each that have been examined, no case of hermaphroditic flowers on monoecious varieties or plants has been found. However, in the andromonoecious varieties of watermelon, some variations do occur. Thus, hermaphroditic flowers are found occasionally, especially toward the end of the flowering period, with only one or two stamens instead of three. But the missing stamens are usually represented by more or less well-developed staminodia.

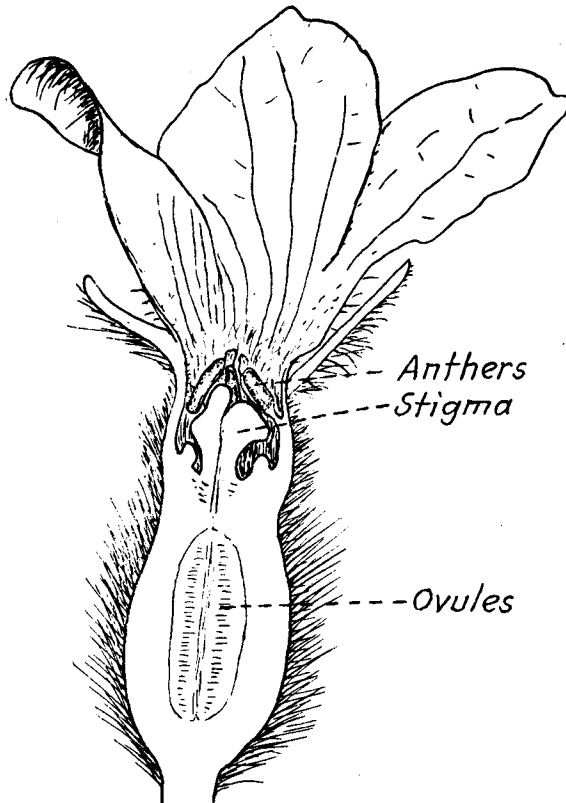


Fig. 1. Longitudinal section of hermaphroditic flower, Salmon Tint melon. The stamens are attached near the base of the corolla tube.

On the andromonoecious plants of some varieties of *Cucumis melo*, occasional pistillate flowers have been found. Table 1 gives a summary of the observations on flowers of cantaloupes and related varieties of melons. Nearly half of the flowers recorded were in inbred lines of the variety Salmon Tint, the others being in miscellaneous varieties of *C. melo* which have been used in the breeding work.

TABLE 1  
SEXUAL FORMS OF FLOWERS OBSERVED IN *Cucumis melo*.

Year	Andromonoecious plants		Monoecious plants	
	Hermaphroditic flowers	Pistillate flowers	Hermaphroditic flowers	Pistillate flowers
1924	200	0	0	0
1925	542	1	0	30
1926	955	6	0	60
1927	1090	8	0	158
<b>Total.....</b>	<b>2787</b>	<b>15</b>	<b>0</b>	<b>248</b>

In monoecious melon plants no case of reversal to the prevailing pistillate condition has been observed, though it is not possible to say that such reversal never occurs, as the number of flowers observed is not very large. With the andromonoecious varieties, however, 15 instances of reversal in 2,802 flowers, or 1 in 187, were found. As an average plant may produce about 60 hermaphroditic flowers during its chief flowering period, this indicates that about one plant in three may produce a single flower of aberrant sex form. The production of the aberrant forms has not been observed to be correlated with any particular environmental conditions, nor to any certain stage of plant development. The seed from pistillate flowers borne on andromonoecious plants, when pollinated by staminate flowers of the same plant, give rise in the following generation to andromonoecious plants, with flowers and fruit like the prevailing type of the parent. No explanation of the occurrence of the rare pistillate flowers is available, other than the supposition that they result from some circumstance in the ontogeny of the flower, which leads to the omission of the stamens. They may be the result of a somatic mutation, which does not affect the cell layers from which the ovules arise, hence are not transmitted to progeny.

An interesting fact is that the fruits which develop from pistillate flowers on prevailing andromonoecious plants, are different from those arising from hermaphroditic flowers on the same plant. These differences are in part shown in figure 2. The fruit from the pistillate flower is larger, longer, has a much lower ratio of width to length, and shows the longitudinal sutures much more plainly, than fruits from

hermaphroditic flowers. In the Salmon Tint variety, five fruits known to have come from pistillate flowers have been observed, and they all consistently showed the differences in form just mentioned. As individual fruit measurements have been made on many fruits of inbred lines of Salmon Tint, it is possible to determine the frequency of occurrence of pistillate flowers in that variety by inspection of the fruit measurement records. In 1926 and 1927, 6,400 fruits were measured, and 16 showed the abnormal shape characteristics of fruit from pistillate flowers. In this variety, then, the frequency of pistillate flowers appears to be about 1 in 400, of those that actually produce fruit.

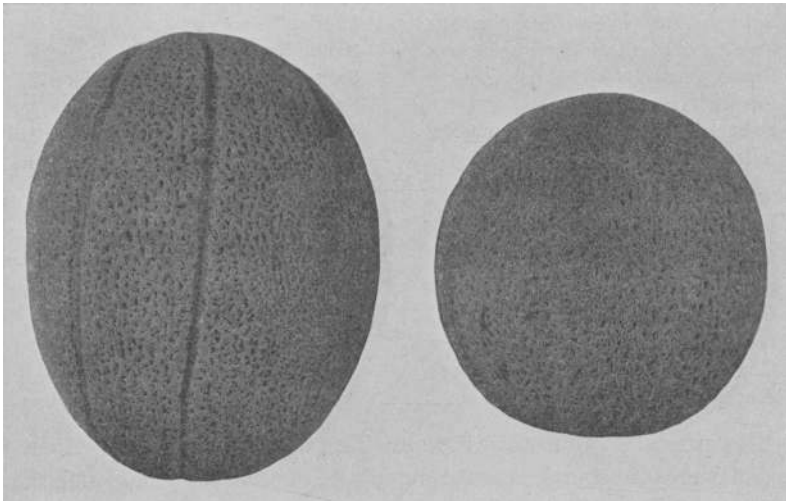


Fig. 2. Two fruits from the same plant of Salmon Tint melon. The one on the left came from a pistillate flower, the one on the right from an hermaphroditic flower. The latter fruit represents the normal for fruits of this particular inbred line.

Since the forms of sexual expression in melons, cucumbers and watermelons are subject to comparatively little fortuitous variation, it was considered of interest to investigate further the basis for the distinction of the two types which have been described. This is of importance not only in connection with other studies on the genetics of these genera, but because of the bearing on the general problems of evolution and of inheritance of sex expression in plants. Monoecious species have hitherto received rather little attention in studies on inheritance of sex.

## INHERITANCE OF SEX FORMS

The selfing of andromonoecious varieties of melons in 1924, (a) with pollen from anthers in hermaphroditic flowers, and (b) with pollen from staminate flowers on the same plant, gave identical results in the progeny, i.e., the production of andromonoecious plants like the parent.

In 1925, a number of crosses were made between varieties of the two contrasted types of sex expression. The following is a list of the crosses which have been followed through the  $F_2$  generation:

Melon:	Ovule parent	Pollen parent
	Salmon Tint ( <i>andromonoecious</i> ) ×	Freiland ( <i>monoecious</i> )
	Salmon Tint ( <i>andromonoecious</i> ) ×	Snake ( <i>monoecious</i> )
	Snake ( <i>monoecious</i> ) ×	Salmon Tint ( <i>andromonoecious</i> )
	Serpent ( <i>monoecious</i> ) ×	Salmon Tint ( <i>andromonoecious</i> )
	Salmon Tint ( <i>andromonoecious</i> ) ×	Waldemar Gratscheff ( <i>monoecious</i> )
	Salmon Tint ( <i>andromonoecious</i> ) ×	Sucrin de Tours ( <i>monoecious</i> )
Cucumber:		
	Lemon ( <i>andromonoecious</i> ) ×	Chicago Pickle ( <i>monoecious</i> )
	Lemon ( <i>andromonoecious</i> ) ×	Long Green ( <i>monoecious</i> )
Watermelon:		
	Conquerer ( <i>monoecious</i> ) ×	Angeleno ( <i>andromonoecious</i> )
	Klondyke ( <i>monoecious</i> ) ×	Angeleno ( <i>andromonoecious</i> )
	Green Seeded Citron ( <i>monoecious</i> ) ×	Angeleno ( <i>andromonoecious</i> )
	Angeleno ( <i>andromonoecious</i> ) ×	Green Seeded Citron ( <i>monoecious</i> )

The parental plants of Salmon Tint and Klondyke used in the crosses were of second generation inbred lines. The parental plants of the other varieties were all from commercial stocks. That these parental plants were all homozygous for their respective sex forms was proved by growing progenies from selfed seeds of them in the following two years.

The  $F_1$  generation of these crosses was grown in 1926. In all cases the monoecious form appeared to be completely dominant, the fruit-producing flowers being always pistillate. Back crosses were made to the presumably recessive hermaphroditic-flowered parents.

*Results with Melons in the  $F_2$  Generation.*—The  $F_2$  progenies were grown in 1927. During the middle portion of the flowering season, the pistillate flowers on the  $F_2$  plants were examined by two men working independently. Their observations checked with each other in every case. Table 2 shows the distribution of sex forms which was found in the melon crosses.



TABLE 2

PHENOTYPES OCCURRING IN F<sub>2</sub> OF CROSSES BETWEEN MONOECIOUS AND ANDROMONOECIOUS VARIETIES OF MELONS (*Cucumis melo*)

Cross	Number of plants	Plants with pistillate flowers	Plants with hermaphroditic flowers
Salmon Tint x Freiland.....	74	56	18
Salmon Tint x Snake.....	39	30	9
Snake x Salmon Tint.....	135	109	36
Serpent x Salmon Tint.....	39	29	10
<b>Total</b> .....	<b>287</b>	<b>224</b>	<b>73</b>
<i>Calculated, 3 : 1 ratio</i> .....		<i>222.75</i>	<i>74.25</i>

In the F<sub>2</sub> generation in the melon crosses there is a remarkably close approximation to a Mendelian mono-hybrid ratio, of three pistillate plants to one hermaphroditic-flowered. Accordingly, it may be concluded that hermaphroditism in melons depends upon a single recessive factor.

*Results with Cucumbers.*—The F<sub>1</sub> plants in the cucumber crosses always show the pistillate condition to be completely dominant. Only one small F<sub>2</sub> progeny was grown; this gave 11 plants bearing pistillate to 5 with hermaphroditic flowers. It is probable that in the cucumbers, as in melons, the hermaphroditic condition depends upon a single recessive factor.

*Results with Watermelons in the F<sub>2</sub> Generation.*—As with the other species, the F<sub>1</sub> plants of the watermelon crosses bore pistillate flowers. In the F<sub>2</sub> generation, segregation occurred as shown in table 3. The distinction between the phenotypes was not so clear cut as in melons and cucumbers, however. The stamens in the hermaphroditic flowers were not always equally well developed, but as mentioned previously, this condition is also found in the parental andromonoecious varieties. In some of the pistillate F<sub>2</sub> plants, small staminodia were observed occasionally. There was, however, no difficulty in classifying the plants.

Although only 113 plants were grown in F<sub>2</sub>, the results are a nearly perfect 3:1 ratio, indicating that in watermelons also, the primary difference between pistillate and hermaphroditic flowers depends upon a single factor, hermaphroditism being recessive. However, it is possible, in watermelons, that this character may be more

sensitive to nutritional or environmental conditions, than it is in melons and cucumbers, as the stamens of hermaphroditic flowers are not always equally developed.

TABLE 3  
PHENOTYPES OCCURRING IN F<sub>2</sub> OF CROSSES BETWEEN MONOECIOUS AND  
ANDROMONOECIOUS VARIETIES OF WATERMELONS (*Citrullus vulgaris*)

Cross	Number of plants	Plants with pistillate flowers	Plants with hermaphroditic flowers
Conqueror x Angeleno.....	33	23	10
Klondyke x Snowball.....	35	26	9
Klondyke x Angeleno.....	45	35	10
<b>Total</b> .....	<b>113</b>	<b>84</b>	<b>29</b>
<i>Calculated, 3 : 1 ratio</i> .....		<i>84.75</i>	<i>28.25</i>

*Results with the Back-crosses.*—The F<sub>1</sub> hybrids were back-crossed to their recessive hermaphroditic-flowered parental variety. Table 4 shows the sex expression observed in the sesqui-hybrids.

TABLE 4  
SEX EXPRESSION OF PLANTS FROM BACK-CROSSING F<sub>1</sub> PLANTS TO THEIR  
ANDROMONOECIOUS PARENT

Parentage		Number of plants	Plants with pistillate flowers	Plants with hermaphroditic flowers
Melons:	Salmon Tint x $\frac{\text{Salmon Tint}}{\text{Freiland}}$ .....	40	23	17
	Salmon Tint x $\frac{\text{Salmon Tint}}{\text{Snake}}$ .....	38	16	22
	<b>Total</b> .....	<b>78</b>	<b>39</b>	<b>39</b>
Watermelons:	Angeleno x $\frac{\text{Angeleno}}{\text{Citron}}$ .....	33	18	15
	$\frac{\text{Angeleno}}{\text{Citron}}$ x Angeleno.....	27	13	14
	<b>Total</b> .....	<b>60</b>	<b>31</b>	<b>29</b>

It is seen that the back-crosses with melons (*Cucumis melo*) happened to produce exactly the expected 1:1 ratio of pistillate and hermaphroditic plants. In the watermelons, the observed results likewise approach closely to the 1:1 ratio.

*Discussion of Results on Sex Form.*—The evidence both from  $F_2$  progenies and from the back-crosses are in agreement, in indicating that the differentiation of pistillate and hermaphroditic flowers in *Cucumis* and *Citrullus* depends upon a single genetic factor, hermaphroditism being recessive. Moreover, the factor concerned in sex differentiation in this case must be borne both by micro- and macrogametes, since reciprocal crosses and back-crosses give concordant results.

The question may now be raised concerning the probable origin of the two forms of flowers in the Cucurbitaceae. Though the occurrence of hermaphroditic flowers has generally been overlooked by systematists, this form is probably not of recent origin. Thus, Spallanzani,<sup>(12)</sup> in the 18th century, found that some varieties produced fruit with viable seeds when the flowers were carefully isolated against the introduction of foreign pollen. And Sagaret<sup>(10)</sup> in 1824 found that the cantaloupe, Boul' de Siam, set fruit with viable seeds when the flowers were covered with bell jars. These writers suspected that the seeds they obtained were of parthenogenetic origin, but it is more likely that they resulted from the self fertilization of hermaphroditic flowers. Numerous tests by the present writer for parthenogenesis in various species of Cucurbitaceae have all given negative results. Phenospermic seeds occasionally are produced when pollen is not applied, or when incompatible pollen of another species is used.

From the evolutionary point of view, it is generally considered that the various plant families are advancing along parallel lines toward the dioecious condition (Yampolsky<sup>(14)</sup>). On this basis, the andromonoecious condition, with its hermaphroditic flowers, would be more primitive than the strictly monoecious form. The monoecious form in the Cucurbitaceae probably has arisen from the andromonoecious, the change involving only the mutation of a single gene. It is of some interest that this change would involve a dominant mutation. Moreover, it has been shown in this paper, that there is some tendency for the production of occasional pistillate flowers on hermaphroditic plants, though the reverse has never been observed. This change in sex form, however, appears not to be hereditary in the cases which have been studied by the writer.

## ASSOCIATION OF FRUIT SHAPE WITH SEX FORM OF THE FLOWER

In examining the flowers of  $F_2$  and back-cross progenies, it was noticed that pistillate flowers usually had a long ovary, while hermaphroditic flowers had shorter ovaries, tending more nearly to the round form. When the fruit came to maturity, the same general relation in fruit shape was observed. This observation also applies in general to the parental varieties of melons, cucumbers and water-melons. In two of the melon crosses the individual fruits from  $F_2$  plants were measured. Dividing the equatorial by the polar diameter gives an index for fruit shape,  $\frac{ED}{PD}$ , which is less than 1 for oblong fruits and more than 1 for oblate fruits. In cross 8 the factor for fruit shape was based on measurement of five or more fruits from each plant; in cross 13 only one representative fruit of each plant was measured. Table 5 gives the average of the fruit shape ratios for the pistillate and hermaphroditic plants in these crosses.

TABLE 5  
AVERAGE FRUIT SHAPE RATIOS,  $\frac{ED}{PD}$ , FOR PISTILLATE- AND HERMAPHRODITIC-  
FLOWERED PLANTS IN THE  $F_2$  GENERATION OF MELON CROSSES

Cross	Pistillate-flowered plants		Hermaphroditic-flowered plants	
	Number of plants	Average of shape ratios	Number of plants	Average of shape ratios
8. Salmon Tint x Freiland.....	53	.628±.005	14	.783±.014
13. Snake x Salmon Tint....	69	.291±.005	26	.371±.008

The shape ratios for the parental varieties used in these crosses were as follows: Salmon Tint, .941; Freiland, .625; and Snake, .105. It is clear from table 5 that the fruit shape differs in the  $F_2$  phenotypes, the fruits developing from hermaphroditic flowers being the thicker in proportion to their length. The difference between the means of the shape ratios for the two types is about 10 times its probable error in both crosses. It cannot be said with certainty that this fact is due to linkage of a genetic factor for fruit shape with the factor for sex-expression. The association may be due to

the action of a single factor, one character being the result of the other. However, the association of these characters was the same in the  $F_2$  phenotypes as it was in the parental varieties. It may be recalled, also, that fruit arising from the occasional pistillate flowers in varieties normally hermaphroditic-flowered, show a similar deviation in fruit shape from the normal for the variety.

### CARPEL NUMBER IN THE FLOWERS AND THE FRUITS

The members of the genus *Cucumis* are generally considered to be trimerous both as to the gynoeceium and the androeceium. Naudin<sup>(7)</sup> considered the cucumber, *C. sativus*, to represent the basic condition for the androeceium of the Cucurbitaceae—two stamens each with two thecae, and one with a single theca. The same arrangement is found also in most varieties of *Cucumis melo* and *Citrullus vulgaris*. This condition has been referred to by some writers as “two and a half” stamens. It is usually accompanied by a tri-carpellate ovary surmounted by a three-lobed stigma. Vuillemin,<sup>(13)</sup> however, argues that both androeceium and gynoeceium were originally hexamerous, each consisting of two trimerous whorls; by abortion of one member of one whorl, these organs became pentamerous, and by the suppression of one entire whorl, trimerous. Heimlich,<sup>(3)</sup> in his study of the staminate flower in cucumber, could find no evidence of aborted vascular bundles supposed to supply missing stamens, and because of this, concluded that the double stamens are the complete normal type, while the single stamen is a half or reduced form. Then the androeceium would be trimerous, as the gynoeceium certainly appears to be, in the cucumber.

The writer found two varieties of melons, the Golden Beauty Casaba (*Cucumis melo* var. *inordorus* Naud.) and Pomegranate (*C. dudaim* L. or *C. melo* var. *odoratissimus* Naud.) which are pentamerous both as to androeceium and gynoeceium. There are five single stamens (like the half stamen of other *Cucumi*) in both the staminate and hermaphroditic flowers, and there are five separate locules in the ovarian cavity. These characteristics have remained constant in inbred lines of the Casaba, to the fourth inbred generation. A cross-section of the Casaba fruit showing the five carpels is presented in figure 3, and one of a cantaloupe melon showing the ordinary tri-carpellate condition, in figure 4.

It has also been observed that all varieties of melons, except those that are perfectly smooth on the surface, like Honey Dew, or those in which the surface is broken by numerous fine corrugations, as in Snake, show ten distinct lobes to the fruit, with longitudinal sutures between them. This is illustrated in extreme degree in figure 5. These lobes correspond to the ten parts of the calyx and corolla, two alternating whorls of five parts each. The outer part of the melon fruit then consists of receptacle fused with and enclosing the pericarp. It seems to the writer that the flowers of *Cucumis* and of *Citrullus* were originally pentamerous throughout. This stage of evolutionary

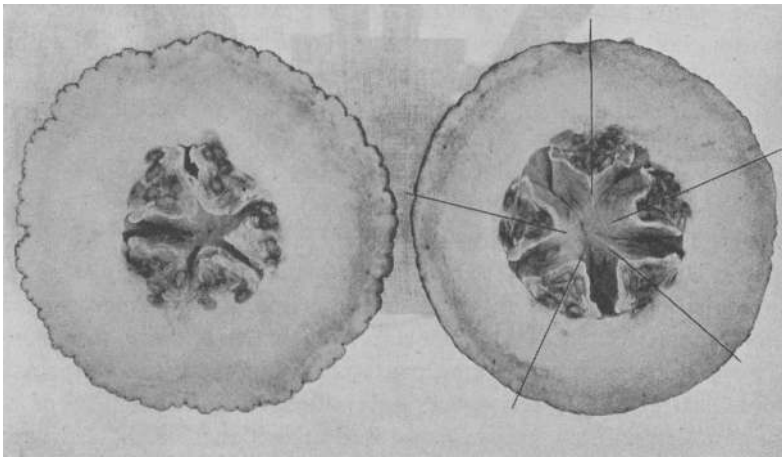


Fig. 3. Cross sections of fruit from two inbred lines of Casaba melon, showing the five carpels. The inked lines on the fruit at the right indicate the division between the carpels.

development is represented today by the two varieties mentioned above. But most present-day varieties of melons present a trimerous gynoeceium. In the ovary, two carpels have been eliminated, either by union or by abortion, resulting in the tri-carpellate condition, now found in most melons, all cucumbers and nearly always in watermelons. Both cantaloupe melons and watermelons occasionally produce fruits with four carpels, however. This is most common in watermelons in varieties which have hermaphroditic flowers and which therefore may be presumed to be nearer the primitive type. But the evolution of the androecium has not advanced so far, and now generally presents a pseudo-trimerous condition, with one single and two double stamens.

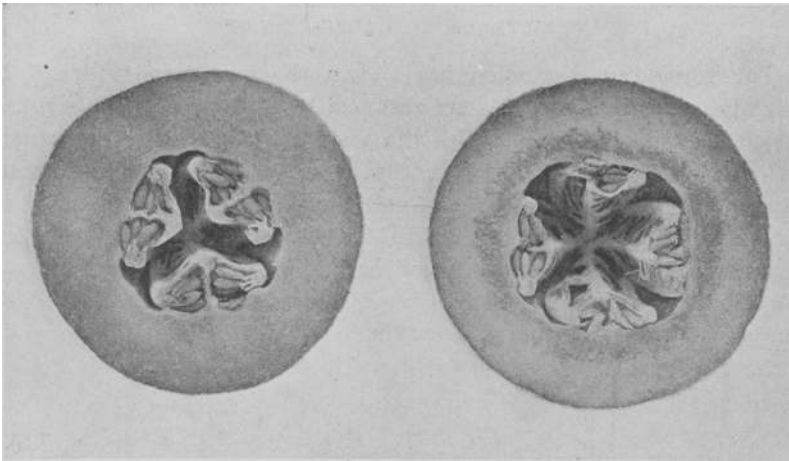


Fig. 4. Cross sections of fruit of the Salmon Tint melon. The one on the left shows the usual tri-carpellate condition found in this variety. At the right is one of the four-carpellate fruits which occasionally occurs.

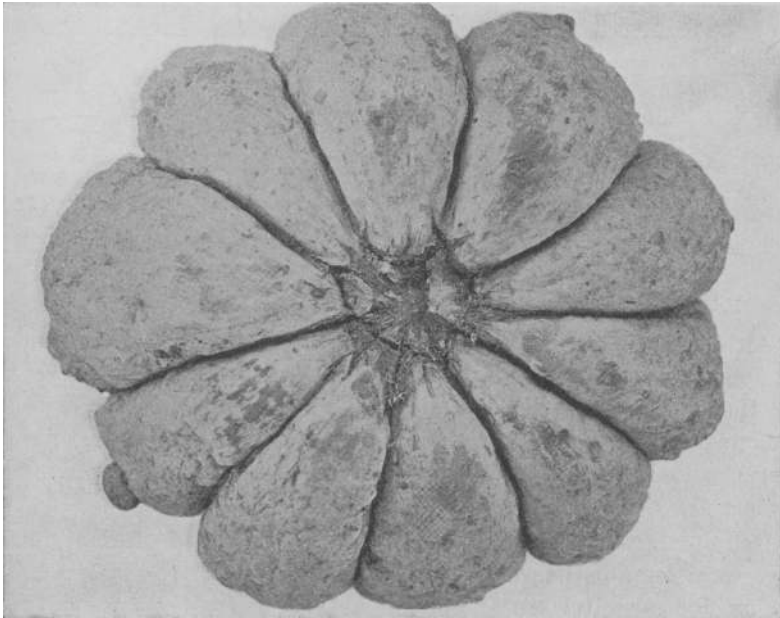


Fig. 5. A cantaloupe melon viewed from the stem end. It shows the ten lobes of the fused receptacle, separated by deep sutures. Most other varieties of *Cucumis melo* show the same condition, though the lobes are usually not so prominent.

## INHERITANCE OF CARPEL NUMBER

The foregoing discussion has shown the evolutionary trend by which tri-carpellate varieties are assumed to have arisen from a primitive five-carpellate form. With the view of determining the genetic basis for the distinction between these two forms, crosses were made between the pentamerous Casaba and the tri-carpellate Salmon Tint, Persian and Hoodoo varieties. In these crosses, as well as several others which will not be discussed here, the tri-carpellate form was completely dominant in the  $F_1$  generation, as was also the pairing of four of the stamens, the pseudo-trimerous androecium. The results in the  $F_2$  populations are given in table 6.

TABLE 6

DISTRIBUTION OF CARPEL NUMBER IN THE  $F_2$  GENERATION OF CROSSES BETWEEN TRI-CARPELLATE AND FIVE-CARPELLATE VARIETIES OF *Cucumis melo*

Cross	Plants with tri-carpellate fruit	Plants with five-carpellate fruit
Casaba x Hoodoo.....	35	14
Casaba x Salmon Tint .....	27	10
Salmon Tint x Casaba.....	25	14
Casaba x Persian.....	24	11
<b>Total</b> .....	<b>111</b>	<b>49</b>
<i>Calculated 3 : 1 ratio</i> .....	<i>120</i>	<i>40</i>

$$\text{Deviation} = 9 \pm 3.69; \frac{D}{E} = 2.4; \text{probability per } 100 = 10.55.$$

Although this is not as close an approximation to the theoretical 3:1 ratio as was obtained in the crosses involving sexual forms, yet the fact that such a deviation as the one occurring here may be expected to occur once in every ten trials under the laws of chance, justifies the inference that in this case also a single gene difference is involved. Further tests, however, are desirable.

Definite segregation for carpel number occurred in  $F_2$ , though there were some intermediate forms. Thus some of the plants classified as five-carpellate in table 6, had a few fruit with only four carpels. And many of the plants classified as having tri-carpellate fruit bore some with four carpels. Figure 6 shows a five-carpellate fruit of an  $F_2$  plant of the cross Casaba  $\times$  Persian, in which is observed



a tendency of four placentae to unite in pairs, leaving the fifth free. The number of stamens in the  $F_2$  plants was found generally to agree with the number of carpels.

Seed were taken from three tri-carpellate and from three five-carpellate  $F_2$  plants of the Casaba  $\times$  Hoodoo cross. Two of the former and all of the latter, bred true, while one of the tri-carpellate segregated again in the  $F_3$  generation.

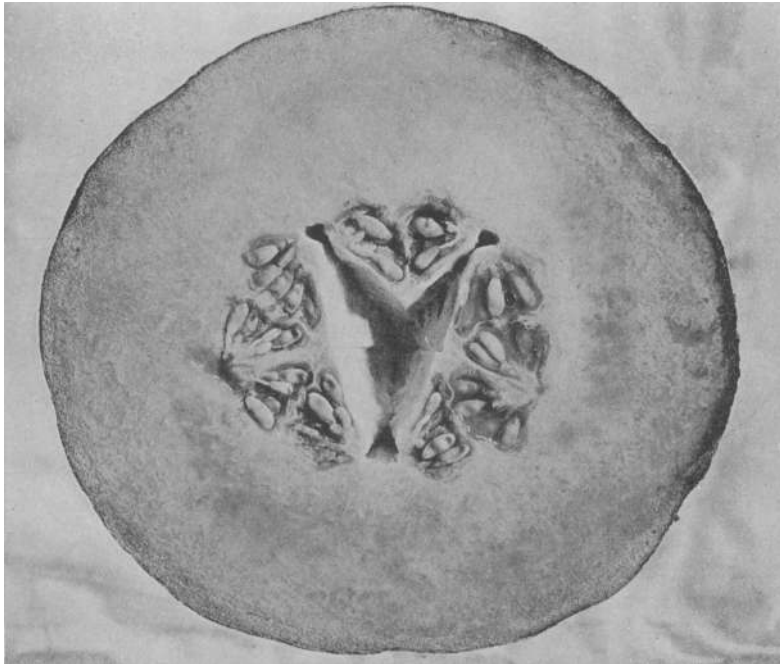


Fig. 6. Cross section of five-carpellate fruit from an  $F_2$  segregate of the cross Casaba  $\times$  Persian, showing a tendency of four carpels to pair in two's.

Jones and Raynor,<sup>(5)</sup> studying carpel number in crosses between bi- and tri-carpellate varieties of *Bryonia*, found more complicated conditions to exist. They assumed, however, that there were two factors,  $G_1$  and  $G_2$ , for the bi-carpellate ovary, the constitution of the tri-carpellate being  $g_1 g_2$ . The evidence on the behavior of this character in melons indicates that in this plant, probably only one genetic factor is involved in determining carpel number. It is interesting, moreover, that the five-carpellate form, which seems to be the most primitive from the phylogenetic point of view, is recessive. In this case, as in the study of sex forms, evolution by dominant mutations is suggested.

## ASSOCIATION OF FRUIT SHAPE WITH CARPEL NUMBER

The fruits from some  $F_2$  progenies of the melon crosses were measured and the average ratio for fruit shape was calculated, using five or more fruits from each plant. The results are given in table 7.

TABLE 7  
AVERAGE FRUIT SHAPE RATIOS  $\frac{ED}{PD}$  FOR PLANTS BEARING MOSTLY TRI-CARPELLATE AND MOSTLY FIVE-CARPELLATE FRUITS

Cross	Tri-carpellate plants		Five-carpellate plants	
	Number of plants	Average of fruit shape ratios	Number of plants	Average of fruit shape ratios
Casaba x Salmon Tint.....	27	.924±.013	10	1.021±.019
Salmon Tint x Casaba.....	23	.938±.015	14	1.020±.014
Casaba x Persian.....	23	.904±.011	11	1.027±.016

It is seen that there is a definite association between carpel number of the fruits, and their shape. The five-carpellate phenotypes have fruits that are in general round or slightly oblate. The tri-carpellate fruits are oblong or oval. The difference in mean fruit-shape ratio is four to six times the probable error. The relation found in the Casaba x Persian cross is the opposite of that existing in the shape of the parental varieties. Carpel number, therefore, will require consideration in genetics studies on fruit shape. Similar results, both as to the dominance of low carpel number, and the association of carpel number and shape, have been obtained by the writer with tomato fruits.

## SUMMARY AND CONCLUSIONS

It is shown that the cultivated varieties of *Cucumis melo* are preponderantly andromonoecious, relatively few varieties being monoecious. The opposite distribution exists in the varieties of *Cucumis sativus* and *Citrullus vulgaris*.

The varieties of these three species were found to be constant in the sex arrangements of the carpellate flowers, except that in a number of andromonoecious varieties of *Cucumis melo*, about one flower in 186 was transformed to the pistillate condition. The association of

elongated fruit shape with sex of pistillate flowers, permits of estimating that this "sex reversal" occurred in about one in 400 flowers that produced fruit, in inbred lines of the Salmon Tint variety.

The results of crossing monoecious  $\times$  andromonoecious varieties, and *vice versa*, indicate that the monoecious condition depends upon a single dominant factor in all three species. Very close approximation to a ratio of 3 monoecious to 1 andromonoecious plants was obtained in  $F_2$ , with a 1:1 ratio in the backcrosses to the recessive parental variety.

It is suggested that hermaphroditic flowers are the more primitive type from the evolutionary point of view, and that the pistillate form has arisen from them by dominant gene mutation.

The flowers of *Cucumis* and *Citrullus* are considered to have been originally pentamerous throughout. The tri-carpellate ovary, which is now the prevailing type in most varieties, probably arose from the five-carpellate form, two carpels having been eliminated. In the evolution of the androecium, the pentamerous condition as now represented in Casaba melons, with five single stamens, preceded the pseudo-trimerous condition (two double and one single stamen), which accompanies the tri-carpellate ovary.

Crosses of tri-carpellate with five-carpellate varieties show that the latter, probably the more primitive form, is recessive, and the segregation in  $F_2$  can probably be explained on a single major factor difference. The reduction of carpel number, with corresponding fusion of stamens, suggests evolution by means of dominant mutations.

An association of sex conditions, in the carpellate flowers, with shape of the resultant fruit, was found. In  $F_2$  progenies, fruits from hermaphroditic-flowered plants were more nearly globose than those of pistillate-flowered plants. A similar association of shape with carpel number was observed, five-carpellate fruit of  $F_2$  phenotypes being globose or oblate, while tri-carpellate were oval or oblong.

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The titles of the Technical Papers of the California Agricultural Experiment Station, Nos. 1 to 20, which HILGARDIA replaces, and copies of which may be had on application to the Publication Secretary, Agricultural Experiment Station, Berkeley, are as follows:

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