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Matsubayashi, Motokazu

Mori, Toshito

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KOBE UNIVERSITY

STUDIES ON THE SPECIES DIFFERENTIATION IN THE SECTION TUBERARIUM OF SOLANUM*

VII. Morphological Analysis of the Tetra- and the Pentaploid F_1 Hybrids from *S. demissum* × *S. chacoense*

Motokazu MATSUBAYASHI and Toshito MORI

In tuber-bearing *Solanum*, since OPPENHEIMER (1933) had found the tetraploid hybrids in the cross *S. chacoense* (2x) × *S. tuberosum* (4x), it has been reported by several earlier workers that crosses between species which differ in chromosome numbers from each other sometimes give rise to, besides normal F_1 hybrids, hybrids with an additional set of chromosomes. The present authors also, from the cross *S. demissum* (6x) × *S. chacoense* (2x) made in 1954, have obtained pentaploid hybrids in addition to tetraploid ones, with such an unexpected high frequency as the ratio of the former to the latter is 3 to 4. A similar occurrence of pentaploid plants has been found by PRAKKEN and SWAMINATHAN (1952) in the same cross, and by DODDS (1950) and BAINS and HOWARD (1950) in the crosses between *S. demissum* and each of *S. rybinii* (2x) and *S. garciae* (2x).

In order to research how did such pentaploid hybrids occur. it has to be elucidated that which the parent species is responsible for the source of an additional chromosome set in the hybrids. Thus, morphological analysis of both the tetra- and the pentaploid hybrids was attempted by the present authors, in comparison with the parents. The results are given in this paper.

MATERIALS AND METHODS

The materials examined in this study are as follows:

S. demissum LINDL. (2n=72); Nr. R 49/82, series Demissa.

S. chacoense BITT. (2n=24); Nr. R 49/82, series Commersoniana.

Tetraploid F_1 hybrids (2n=48) from *S. demissum* × *S. chacoense*.

Pentaploid F_1 hybrids (2n=60) from the same cross.

The former two species had been supplied from the Max-Planck-Institut für Züchtungsforschung in 1953 and since then have been maintained at the experimental field of this laboratory. Both of the latters were obtained from the cross made in 1954. In the cross, 10 flowers of *S. demissum* pollinated with *S. chacoense* set 20 full-filled seeds, from which 4 tetraploid and 3 pentaploid hybrid seedlings arose. The resulting hybrids as well as their parents grew under similar conditions.

All the morphological characters were observed and measured at the earlier stage of flowering in each of the present materials. For measurements, the methods described in a previous paper (KAWAKAMI & MATSUBAYASHI, 1954) were correspondingly applied.

RESULTS

1. Flower

Corolla : Corollas of the pentaploid hybrids were larger in some degree than those of the tetraploid ones in diameter, being similar to *S. chacoense* (Tab. 1 and Fig. 1-a). Corolla shape was availably represented with "flower index" that is a ratio of B to A in the corolla (KAWAKAMI & MATSUBAYASHI, 1954). Thus, this was classified and named as follows:

Flower index	Corolla shape
<40%	stellate
50%	sub-stellate
60%	intermediate
70%	sub-rotate
>80%	rotate

On the basis of this classification. it was decided that corolla shapes of *S. demissum*, the tetraploid hybrids, the pentaploid hybrids and *S. chacoense* are rotate, intermediate, sub-stellate and stellate respectively (Tab. 1 and Fig. 1-a).

In corolla color (upper surface), while the tetraploids were pale purple, the pentaploids were purplish white or almost white, the former showing a similarity to *S. demissum* and the latter to *S. chacoense*.

Pistil : Like *S. demissum*, the tetraploids had simple stigmas but the pentaploids showed notched stigmas which are characteristic of *S. chaeoense*

* Contributions from the Laboratory of Plant Breeding, Hyogo Agricultural College, No. **34.**

TABLE 1. Flower characters of the hybrids examined and their parents

	Corolla			Pistil		Anther			Calyx		
	Size (mm)	Index	Color	Length (mm)	Stigma	Length (mm)	Breadth (mm)	Color	Size (mm)	Index	Color
S. demissum	23.4	80.0	Purple	8.8	Entire	4.0	1.2	Deep orange	10.4	25.5	Purplish green
Tetraploid F_1 hybrids	23.1	77.5	Pale Purple	8.7	Entire	4.0	1.3	Orange	7.3	31.4	Purplish green
Pentaploid F_1 hybrids	24.7	61.0	Purplish white	8.5	Notched	4.8	1.4	Yellow	6.3	62.1	Green
S. chacoense	25.2	33.9	White	9.0	Notched	5.4	1.5	Yellow	7.0	64.9	Green

TABLE 2. Leaf characters of the hybrids examined and their parents

	Compound leaf		Terminal leaflet			Number per leaf of		Pubescence	Size of stomata	
	Length (cm)	Breadth (cm)	Length (mm)	Breadth (mm)	Index	Leaflets	Interjected leaflets		Length (μ)	Breadth (μ)
S. demissum	20.8	9.0	48.1	26.4	54.9	7.8	3.5	All over with thick hairs	39.6	28.5
Tetraploid F_1 hybrids	21.8	9.8	49.9	29.2	58.5	8.5	3.8	Sparsely hairy	33.8	21.3
Pentaploid F_1 hybrids	23.4	12.6	55.6	43.3	77.9	7.2	1.2	Glabrous or glabrescent	34.6	23.0
S. chacoense	24.9	15.6	50.7	33.6	66.3	10.9	0.5	Glabrous	28.6	20.2

TABLE 3. Growth rate of the hybrids examined and their parents at the earlier atage of flowering

	Plant height (cm)	Plant width (cm)	Height/Width (×100)
S. demissum	31.4	40.3	77.9
Tetraploid F_1 hybrids	28.6	38.5	74.3
Pentaploid F_1 hybrids	25.2	35.8	70.4
S. chacoense	38.5	46.4	82.6

(Fig. 1-c). In length of style there was little difference among the present materials, but in ovary shape the pentaploids were more similar than the tetraploids to *S. chacoense* (Tab. 1 and Fig. 1-c).

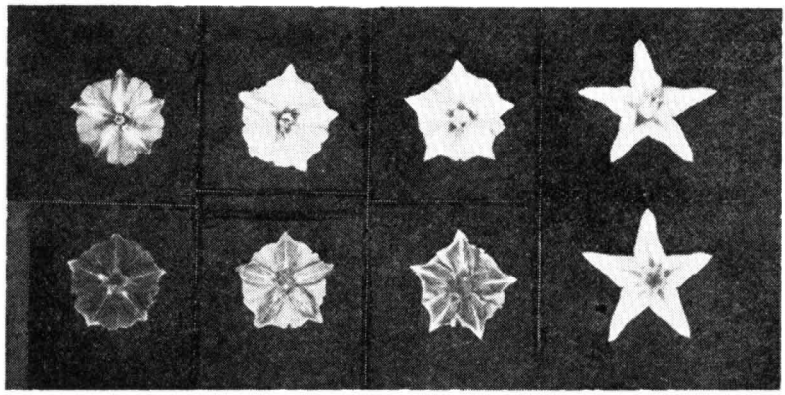
Anther : Both of *S. chacoense* and the pentaploids, as seen in Table 1 and Figure 1-d, differed from the two others by the former's larger anthers with spindle form. Also, anther color of the former two was yellow, whereas that of the others was orange. The pentaploid hybrids, thus, showed a marked resemblance to *S. chacoense* in the anther characters.

Calyx : In size and color of the calyces. *S. demissum* was distinguished easily from the other materials by that the this species only possesses larger and purplish green-colored ones. Between the two hybrid plants, however, there was no difference in these characters. The calyces of *S. chacoense* were hairless, but those of both the hybrids were more or less hairy, being similar to *S. demissum*. Calyx shape was represented with "calyx index" that was calculated in the same method as in the flower index mentioned above. From this index, it was known that the tetraploids show a resemblance to *S. demissum* and the pentaploids to *S. chacoense* in their calyx shapes. These features are shown in Table 1 and Figure 1-b.

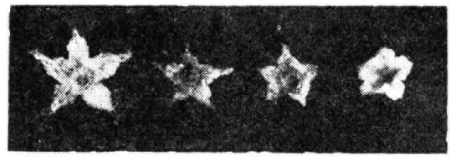
2. Leaf

Leaf size: The pentaploids had larger compound leaves than the tetraploids in both length and breadth, especially the latter. In this respect, the pentaploids were similar to *S. chacoense* and the tetraploids to *S. demissum* respectively (Tab. 2).

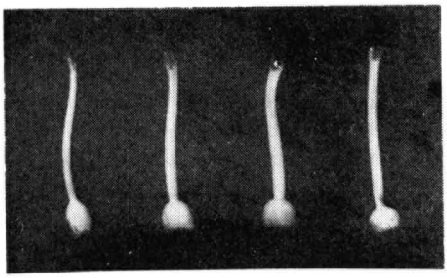
Leaflet : As shown in Table 2 and Figure 2, *S. demissum* was clearly characterized by the terminal leaflets much larger than the laterals, and the tetraploids also showed such an appearance in some degree. The others had not the terminal leaflets differing from the laterals. The pentaploids as well as *S. chacoense*, however, showed a higher value in breadth of the terminal leaflets, being different from the others. Accordingly, "leaf index" represented with a ratio of breadth to length was higher in both the pentaploids and *S. chacoense*



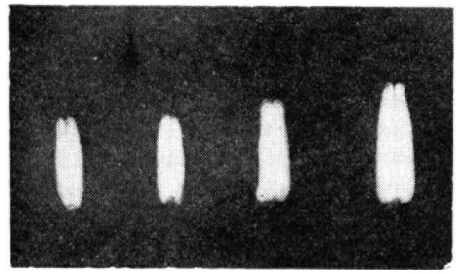
a. Corollas (×1/1.5)



b. Calyces (×1.25)



c. Pistils (×2.7)



d. Anthers (×3)

FIG. 1. Floral parts of the F_1 hybrids and their parents; *S. demissum*, tetraploid hybrid, pentaploid hybrid and *S. chacoense*, from left to right.

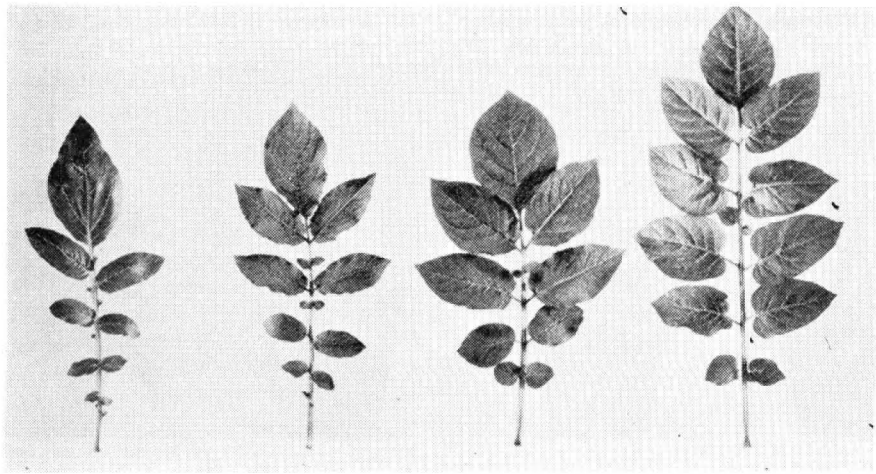


FIG. 2. Leaves of the F_1 hybrids and their parents; *S. demissum*, tetraploid hybrid, pentaploid hybrid and *S. chacoense*, from left to right (×1/4.7).

than in the others. In the number of leaflets per leaf, there was not almost difference among the materials concerned, except for *S chacoense* which has about 10 leaflets.

Interjected leaflet : The number of interjected leaflets per leaf was 3 to 4 for *S. demissum* and 0 to 2 for *S. chacoense*. The pentaploids had fewer pairs of those than in the tetraploids, showing 1.8 in a mean number (Tab. 2).

Pubescence : The leaves of *S. demissum* and the tetraploids were covered with thick and long hairs, but those of the pentaploids were glabrous or often slightly hairy, indicating they to be similar to *S. chacoense* with quite glabrous leaves.

Stoma : The stomatal sizes varied regularily in different materials concerned, in proportion to their various levels of ploidy (Tab. 2). So far as this character is concerned, consequently, similarity of both the hybrids to the parents was contrary to that of the other characters.

3. Stem

The tetraploids were greenish purple and the pentaploids were purplish green in stem color. Since *S. demissum* and *S. chacoense* have purple and green stems respectively, the stem color of the pentaploids appears to be similar more than in the tetraploids to *S. chacoense*.

In pubescence. the stems showed the same feature as in the leaves, namely the pentaploids were glabrous or glabrescent, as compared with the tetraploids being hairy sparsely.

4. Growth habit

For comparing the growth rate of the present materials, their heights and widths were measured at the earlier stage of flowering and their growth habits were indicated with a proportion of the height to the width. Table 3 shows the results. Both of the hybrids, especially the pentaploids, were smaller and slower growing than the parent species (Fig. 3).

DISCUSSION

As mentioned in the foregoing pages, from the results of morphological analysis in the two types of F_1 hybrids and their parent species, it was clearly found that the pentaploid hybrids show much more morphological resemblance than the tetraploid ones to *S. chacoense*. The pentaploids were particularly similar to *S. chacoense* in stigma shape, anther length, calyx index, calyx color, leaf type. leaf index and pubescence. Such an aspect, for the sake of comparison, is given as a diagram in Figure 4. In this diagram, the characters examined, apart from those which are not only intermediate between those of both the parents but also common to both the hybrids, are got together and arranged in order on the basis of their morphological similarities to each of the parents.

According to it, while the tetraploids have the characters similar to *S. chacoense* no more than 7% of the characters listed there, the pentaploids have those amounting to 76.5%.

Prakken and Swaminathan (1952) also have pointed out that the tetraploid hybrids are more different than the triploid ones from *S. tuberosum* in the direction of *S. chacoense* in all characters. by comparing the morphology of the two types of hybrids from *S. tuberosum* (4x) × *S. chacoense* (2x) with that of their parents.

These facts, *i.e.* the phenotypical effects. as the above-mentioned workers have suggested, may certainly be due to the presence of doubled chromosome sets from *S. chacoense*. The earlier workers, in fact, have noted, although few, the formation of pollen dyads in *S. chacoense* (Oppenheimer, 1933 and Prakken & Swaminathan, 1952). One of the



Fig. 3. Plants of the F_1 hybrids and their parents, at the earlier stage of flowering; *S. demissum*, tetraploid hybrid, pentaploid hybrid and *S. chacoense*, from left to right (×1/12).

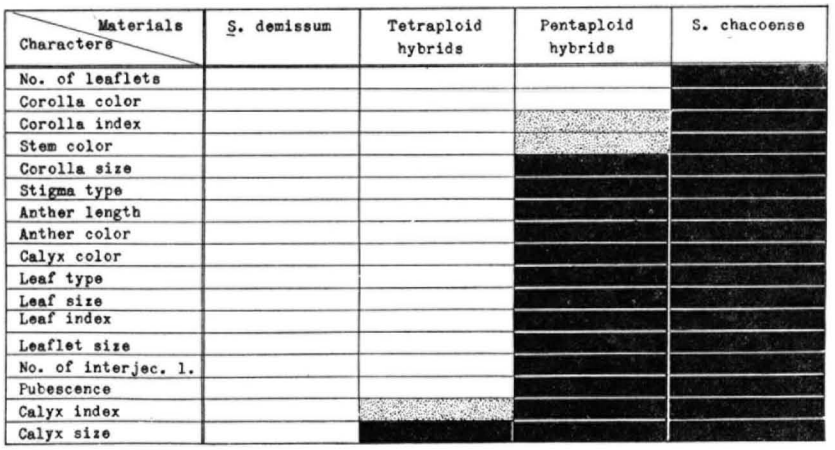


Fig. 4. Diagram showing morphological similarity of both the hybrids to the parents; ☐, ⁞⁞⁞ and ■ show characters of *demissum*-, intermediate- and *chacoense*-types respectively.

present authors also has observed a higher frequency of restitution nuclei in the same species than in any of the diploid species examined (MATSUBAYASHI, 1957).

Thus, it is highly probable from the morphological evidences given above that the pentaploid hybrids were produced by fertilizing normal female gametes from *S. demissum* with unreduced male gametes from *S. chacoense* in the cross between them.

SUMMARY

Morphological analysis was made in both of the tetra- and the pentaploid F_1 hybrids from *S. demissum* ($6x$)×*S. chacoense* ($2x$), in comparison with their parent species.

The pentaploid hybrids were found to have much more resemblance than in the other hybrids to the male parent *S. chacoense* in many characters examined. From the available data, it was concluded that such a morphological feature of the pentaploid hybrids is probably owing to the presence of doubled chromosome sets of *S. chacoense*. and considered that this may be due to the functioning of unreduced male gametes from the same species.

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