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Karyotype Analysis in Ten Non-Tuberous Taxa of *Solanum* L.*

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All the taxa investigated possessed 2n=24 chromosomes. The karyotypes were symmetrical possessing median and sub-median constrictions. They are characterised by gross homogeneity in the chromosome morphology, yet each and every one of the species had a distinct karyotype of its own. Even the two varieties of *Solanum melongena* differed from one another in certain details of their karyotypes suggesting that karyotype analysis would not offer any scope for evaluation of phylogenetic relationships among the species studied. Morphological divergence of the species had no relation to the karyotypic differences. It was concluded that the study of chromosome morphology in *Solanum*, at best can have only a phyletic significance as a commentary upon the validity of conclusions based on evidence from external morphology and other cytogenetic data. It appeared that specialisation in this genus had been principally effected by structural alteration of chromosomes.

In the section *Leptostemonum* of the genus *Solanum* to which the species under investigation belong, the chromosome number is strikingly constant indicating that evolutionary processes are not operating to reduce or to increase the chromosome number to have phylogenetic specialization. But the study of karyotypes could bring out information on the nature of evolutionary processes at work and the trends of evolution in the species. In general an alternation in the karyotype suggests that more profound changes have taken place at the sub-microscopic level, although chromosomal changes and re-arrangements could take place which are not reflected in the morphology of the karyotype. In many groups virtually no help can be derieved from this source but in others it either confirms the classification based on gross morphology or suggests how a more natural classification might be achieved. The karyotypes of the species under study herein were analysed to understand the extent of differentiation that has taken place and to examine whether there are large differences which could be associated with morphological differentiation.

MATERIAL AND METHODS

The material involved in the present investigations consisted of ten taxa representing nine tuberiferous species of *Solanum* Linn. viz., (1) *S. melongena* Linn. which was represented by one cultivar. "Pusa purple long" and one wild variety, *S. melongena* var. *insanum* prain, (2) *S. incanum* Linn. (3) *S. xanthocarpum* Schrad. and Wendl. (4) *S. indicum*

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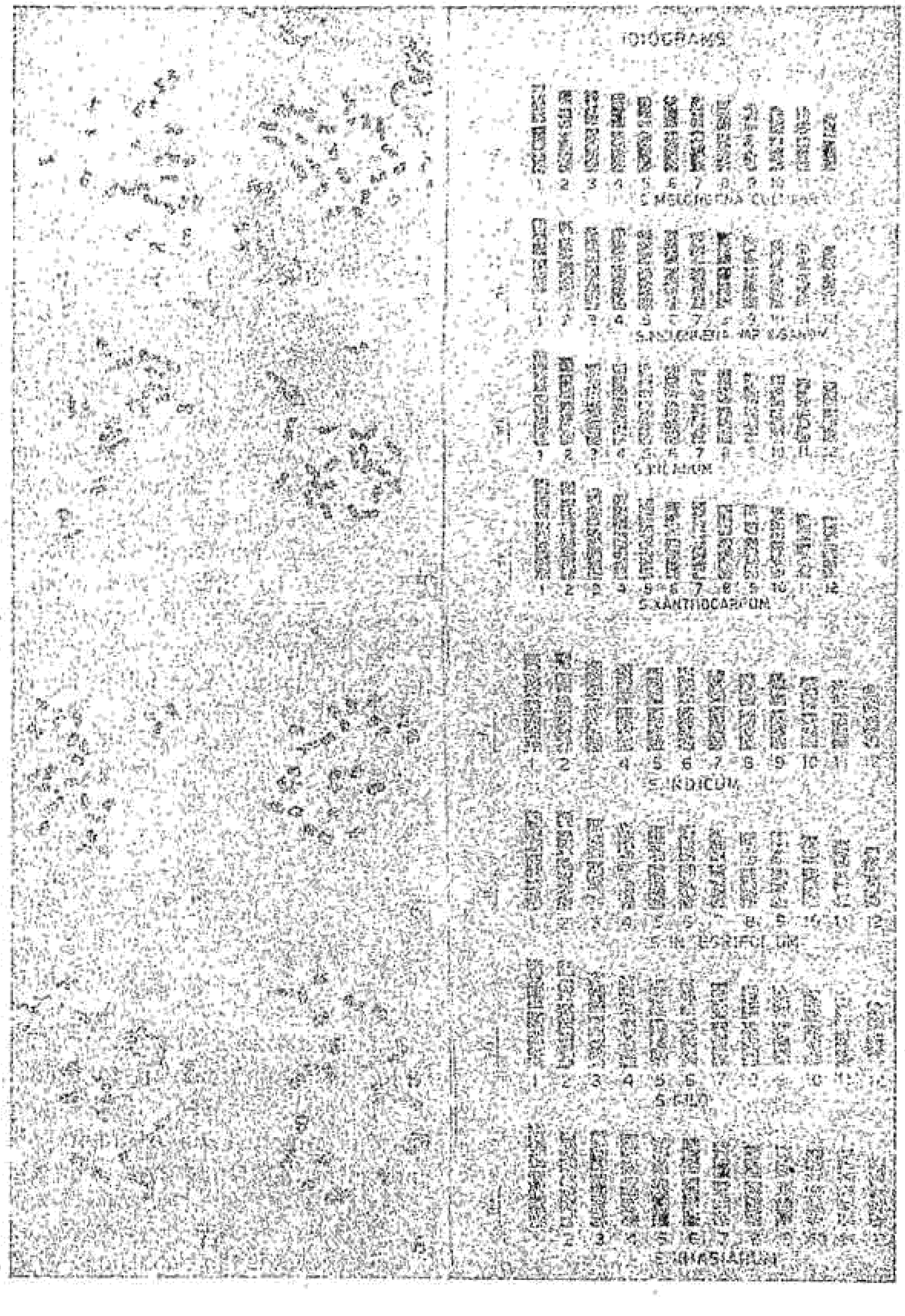
Linn. (5) *S. integrifolium* Poir (6) *S. gilo* Raddi (7) *S. khasianum* Clarke (8) *S.sisymbrifolium* Lam. and (9) *S. zuccagnianum* Dun.

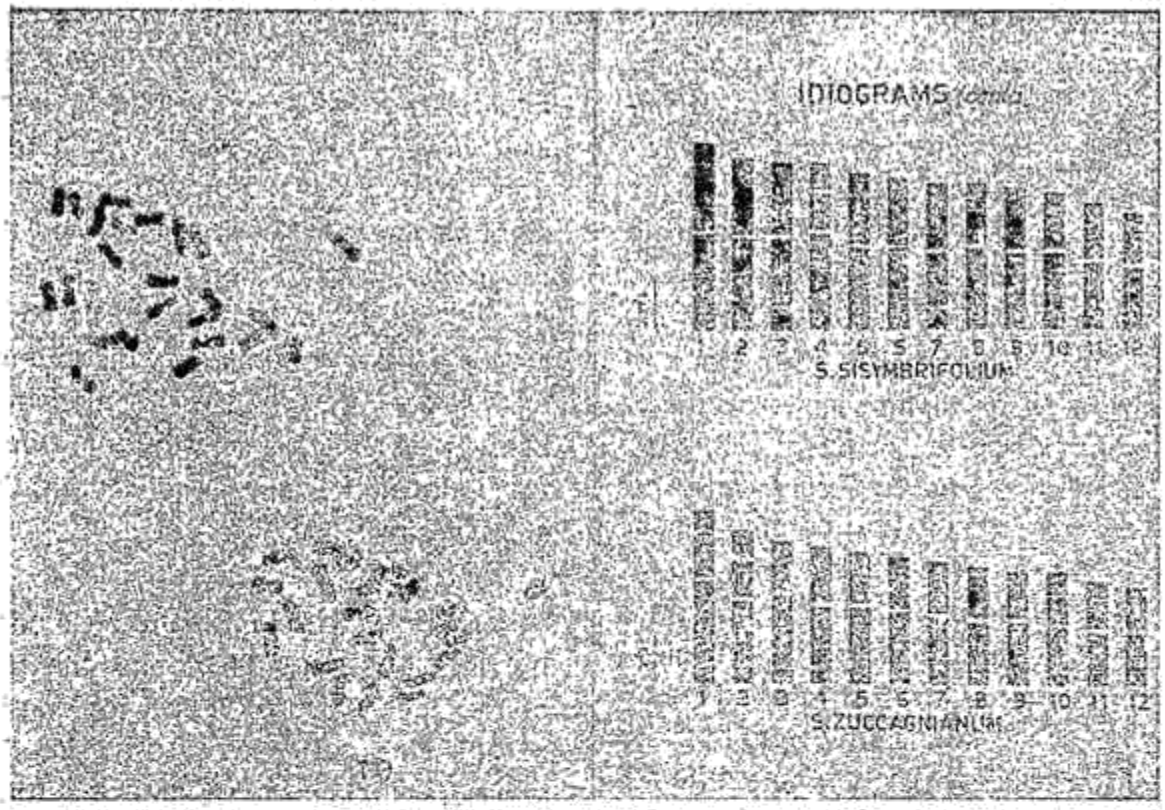
When the seedlings attained an age of 45 to 50 days in the garden pots, the root tips were excised between 7·30 and 8·00 a. m. and dropped in specimen tubes containing saturated solution of p-dichlorobenzene and kept there in for about 45 minutes to an hour. The root tips were washed several times in tap water, fixed immediately in acetic alcohol (1 : 3) and were kept in a refrigerator maintained at 10°C for about eight hours. The root tips were then washed with distilled water and finally transferred to 70 per cent alcohol. They were hydrolysed in normal Hydrocholoric acid for three minutes at 60°C, stained in basic fuchsin for half an hour and squashed in one per cent propionoorcein after washing them with distilled water. The slide was slightly warmed after putting a cover slip over the squash and pressed in the folds of a blotting paper. The cover slip was sealed with gum-mastic and the slides remained semi-permanent in this condition. All the observations, drawings and photographs were taken when the slides were fresh.

The chromosome plates were drawn with the aid of a camera lucida. The magnification of the chromosomes was computed with the help of a stage-micrometer and the chromosome lengths on the camera lucida drawings were measured with the help of a fine divider and converted into microns.

Long and short arms were measured independently. The gap caused by the constriction was not, however, measured. After the measurements were made, the chromosomes were paired according to the length of the chromosomal arms and the position of the primary constriction and the mean values of the long and short arms of the pair were added up, to represent each chromosome in the haploid complement of each species. The values of the chromosomes were then arranged in the order of descending length. For every species, an average of 10 plates was taken to study the karyotype. To draw the idiogram, the method suggested by Chennaveeraiah (1960) was followed. This consisted of arranging the chromosomes in order of decreasing length from left to right. The ends of the long arms were directed downwards lying on the same abscissa. A scale in microns was also given on the side of the ideogram. The constriction, whether primary or secondary, was shown by a uniform gap which in the idiogram does not add up to the length of the chromosome. The chromosomes were numbered from left to right in slanting arabic numbers. The idiograms were drawn first on a graph paper and then transferred to a drawing paper.

F per cent is the percentage of the short arm length over the total length


IDIOGRAMS
S. XANTHOCARPUM
S. INDICUM



of a chromosome as followed by Shindo and Kamemotoh (1963). Relative length is the percentage length of the individual chromosome over the total length of all chromosomes in a haploid complement as used by Levan and Hsu (1959). According to F per cent values, the chromosomes were classified into two groups: sub-median - 30 F per cent = 45 and median - 45 F per cent = 50.

RESULTS AND DISCUSSION

The chromosome number of all the species investigated was $2n = 24$. The karyotypes are illustrated in plate I. The ten taxa under investigation had fallen mainly into two categories — one having secondary constrictions on the short arms of one of the pairs of chromosomes and the other without secondary constrictions in the complement. *S. khasianum* alone represented the latter group while the rest of the species had fallen into the former group. The species were compared in respect of (1) long arm, (2) short-arm, (3) total length of the chromosome, (4) F per cent, (5) relative length of each chromosome and (6) total chromatin length of the haploid complement. Proximal and distal ends of the chromosomes bearing secondary constrictions were also considered in all the species except in *S. khasianum* which did not have secondary constriction. Analysis of variance was carried out for finding out the significance of the differences between the species with regard to the above characters.

The length of the chromosomes in the species studied varied from 1.42 to 3.56 microns. In general, *S. sisymbrifolium* was having the longest chromosomes while *S. integrifolium* was having the shortest chromosomes. The total chromatin length of the haploid complement varied from 23.12 microns in *S. integrifolium* to 34.31 microns in *S. sisymbrifolium*. The species occupied different ranks for different chromosomes with regard to F per cent and relative length of the chromosomes. The F per cent ranged between 35.47 and 47.61 and the relative lengths between 6 02 and 11.58 among the species. Chromosomes with median and sub-median constrictions only were noticed in all the species. The ten taxa differed from one another with regard to the position of the centromeres on their chromosomes. *S. melongena* cultivar, *S. melongena* var. *insanum* and *S. gilo* had two medianly constricted chromosomes and 10 sub-medianly constrictod chromosomes. But the chromosomes with median constrictions were not the same in these three species. *S. incanum* had five median and seven sub-median centrometeres. *S. xanthocarpum* possessed only sub-median constrictions on all chromosomes. *S. indicum* showed the maximum number of medianly constricted chromosomes. (8) In the haploid complement of *S. integrifolium* and *S. khasianum*, there was one median centromere but the chromosomes on which they occurred were different in these two species. *S. sisymbrifolium* had seven medianly constricted chromosomes and *S. zuccagnianum* had three.

Secondary constriction was not observed in *S khasianum*. Among the remaining species, all, except *S. sisymbrifolium*, had the secondary constriction on the short arm of the second chromosome. In *S. sisymbrifolium*, the secondary constriction was present on the short arm of the fourth chromosome. The proximal and distal ends of the short arms of the chromosomes bearing secondary constriction, were the longest in *S. sisymbrifolium* and the shortest in *S. indicum*.

There was a significant difference between *S. sisymbrifolium* and the rest of the species with regard to lengths of all chromosomes (except in the case of first chromosome) and total chromatin length of the haploid complement, *S. sisymbrifolium* having the highest total chromatin length and *S. integrifolium* having the lowest total chromatin length. All the karyotypes were symmetrical by possessing median and sub-median constrictions. The position of the primary and secondary constrictions varied in their minute details between different species. The number of median constrictions ranged from nil in *S. xanthocarpum* to eight in *S. indicum*. Though characterised by gross homogeneity in the chromosome morphology, each and every one of them had a distinct karyotype of its own.

The absence of secondary constriction in *S. Khasianum* distinguishes it from the rest of the species. Such

distinction is evident from its morphological deviation as well as its inability to cross with any of the other species also. In view of the postulate (Matsuura, 1938) that each chromosome is potentially nucleolus organising, its actual synthesis depending upon its 'Valency' in competition with other chromosomes, it is to be presumed that in *S. Khasianum*, a specific area in one of its chromosomes would have taken the nucleolar organising function. On the basis of the presence or absence of secondary constrictions, it is not possible to state as to which of the groups represent the primitive condition. It may apparently seem that species having secondary constrictions have possibly evolved from those without secondary constrictions as is evident from the work of Chakravorti (1951). On the other hand, one cannot preclude the possibility that the species with less number of secondary constrictions or absence of them may have been evolved from species with more number of secondary constrictions through loss of certain segments by amphiplasty during structural alterations.

Even the species having secondary constrictions could be assigned to two groups with respect to the position of the secondary constrictions on the chromosomes. Though in all these species the secondary constriction is situated on the short arm of the one of the chromosomes, in *S. sisymbrifolium* alone it is situated on the fourth chromosome while in the rest of the species it is located on second chromosome. Thus, the presence or absence of secondary constriction and its position on a particular chromosome have divided the 10 taxa into three groups: (1) Those without any secondary constrictions (*S. khasianum* group), (2) those with a secondary constriction on the short arm of the fourth chromosome (*S. sisymbrifolium* group) and those with a secondary constriction on the short arm of the second chromosome (group including the rest of the species).

Based on the length of each chromosome and the total chromatin length of the haploid complement, *S. sisymbrifolium* could be distinguished from the rest of the species. As postulated by Delaunay (1926), that there will be reduction in chromosome size with advancing evolution, *S. sisymbrifolium* should be considered as a most primitive of all the species and this view is supported by its perennial and gigantic nature when compared to the other species. Such phenomenon of reduction in size of the chromosomes with advancing evolution was also reported in *Crepis* by Babcock and Cemeron (1934). Even the rest of the species, wherein a gradation in total chromatin length in the haploid complement was seen, it should be assumed, are undergoing parallel evolution with different degrees of acceleration which is reflected in the chromosome lengths.

The taxa also differed with regard to the position of the centromeres on their chromosomes. Though all the karyotypes exhibited symmetry, the species differed in degree of symmetry. *S. indicum* had the maximum number of chromosomes with sub-median constrictions while *S. xanthocarpum* had only median constriction on all chromosomes. However, this degree of variation in symmetry in these species would not be a reliable criterion to derive conclusions on any phylogenetic relationship between the taxa since there is variation in the degree of symmetry even between the two varieties of S. *melongena*. The existence of such variation in the degree of symmetry between the different varieties of S. *melongena* is also evident from the work of Rai (1959) wherein the varieties were grouped according to the number of median and sub-median constrictions. According to Leven (1935), primitive types have median or sub-median constrictions, while with advancing evolution, the chromosomes become sub-terminally constricted, indicating an evolution from symmetry to assymmetry and it can be assumed that the evolutionary trend in the species studied is also to change the location of centromeres from median to sub-median positions thus, leading to more of asymmetry.

Thus, it is clear that karyotype analysis in the taxa studied would not offer any scope for evalution of phylogenetic relationships between the species. The presence of karyotype differences even between the varieties of the same species suggests that karyotype analysis may not be helpful in the delimitations of the taxa but would be helpful in assessing the evolutionary trends in this group of *Solanum* as a whole. At best, the study of chromosome morphology in *Solanum* can have only a phyletic significance as a commentary upon the validity of conclusions based upon evidence from external morphology and other cytogenetical data.

In view of the general constancy in the chromosome number, lack of evidence for large differences in the karyotypes between different taxa and existence of structural differences between the species (discussed elsewhere), it appears that specialisation in this genus has been principally effected by structural alteration of chromosomes. The continued accumulation of such structural changes has been possibly a principal contributory factor to the origin of new species. The meiotic behaviour in the parents, which shows distinct bivalent formation, suggests that homozygosity for these changes has been attained due to their self - fertilizing habit.

In *Solanum* wherein the chromosomes are too small, the analysis of pachytene chromosomes may be useful in unravelling still minor differenees existing between the taxa as is

evident in the studies of Gottschalk (1954) in respect of *Lycopersicon*.

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