Cytology of North-West Indian Trees

I. Zizyphus jujuba and Z. rotundifolia

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Introduction

The Jujube *(Zizyphus jujuba)* commonly called as *Ber* in the Punjab, is one of the most common wild fruit trees in India in general, and the Punjab in particular. Mostly the wild plants bear small and poor quality fruit. However, there are several superior varieties which sell very cheap, being within the reach of poor people. On account of this it is aptly called as "the poorman's fruit". Jujube is so popular among this class of people that it is intimately connected with folklore, particularly of the people of the Punjab.

Botanically Jujube belongs to the genus *Zizyphus* (family *Rhamnaceae).* The generic name is in fact derived from "Zizouf" which is the Arabic name of the fruit of *Zizyphus lotus* Lam. (Bailey, 1947). *Zizyphus* is rather omall woody genus (shruhs and medium-sized trees) containing about 40 species (Rendle, 1959) distributed throughout, tropical, subtropical and temperate regions of both the hemispheres. Out of these the edible fruits are yielded by only a few species notably *Z. jujuba* Lam.; *Z. sativa* Gaertn.; and *Z. lotus* Lam. (Bailey, 1947).

In India Jujube is grown and/or is cultivated throughout the plains up to an altitude of about 2,000 meters. In the Punjab it is grown in Rohtak, Hissar, Gurgaon, Panipat, Patiala, Sangrur, Bhatinda, Jind and Mahendergarh. It grows in arid situations often even on sand mounds and can withstand both severe heat as well as frost. This it is able to do by being a very deep feeder and by its xerophytic characteristics which restrict water loss from aerial parts particularly in the leaves. The upper surface of leaves is shiny and reflects the incident light. These are but a few features which enable it to grow in habitats which are ordinarily inhospitable to plants in general, and fruit trees in particular. It is a matter of common observation that therc are thick groves of Jujube in places which are unfit for any cultivation on account of the poor quality of soil and want of irrigation facilities. An added advantage is the presence of spines near the leaf bases which prevent to a fair extent grazing by ordinary farm animals.

The fruit ripens and is ready for consumption in February and March and this coincides with the slack season for all other fruits in the market. Furthermore, Jujube is heavy yielder and on average 5,000—30,000 fruits are set per plant.

The fruit has good food value. Besides containing vitamins A and B, Jujube is one of the rich sources of vitamin C. According to Singh (1957) average calorific value per 100 grams of fruit pulp is about 55 and per ounce is 16.

The fruit is consumed mostly in fresh state but sun-dried fruit is frequently liked by the countrymen in the Punjab plains, where Jujube is often the only locally available fruit. In Southern Europe it is used as a table dessert and after processing with sugar or honey it is comparable to good quality Persian dates. Chinese use dried and processed Jujube and the fruits is called "Chinese Date" (Hayes, 1945; Bailey, 1947).

A remarkable feature of Jujube is that it is resistant to fungous and physiological diseases. However, fruits, leaves and bark are attacked by a few insect pests which can be conveniently controlled by insecticides.

Jujube and fruit of some other species of *Zizyphus* are extensively used in the indigenous system of medicine throughout its distributional range for several ailments (Kritikar and Basu, 1933).

The tree is used extensively as a host for rearing lac insects *(Laccifer lacca)* in India (Schery, 1958). In addition timber is moderately durable in open, and durable under cover. It is used for constructional. and several other purpoces, being in good demand where other timber is either scarce or expensive (Pearson and Brown, 1932). Wood of Jujube has high calorific value and makes excellent charcoal. Since the branches are thorny these are extensively used by farmers for fencing their fields. The bark is used for dying and tanning purposes. The leaves are used as fodder in the Punjab and Rajasthan.

From the foregoing account it is clear that Jujube is a plant with diverse uses and, what is more important, it grows in habitats that are ordinarily inhospitoble to other plants. Apart from some fragmentary work, *Zizyphus* in general and Jujube in particular have been altogether neglected so far. The taxonomy of the entire genus is extremely confused. As yet no one is certain about the taxonomic identity of common cultivated types, some call them *Z. jujuba* Lam. while others call them *Z. jujuba* Mill., still others regard them *Z. sativa* Gaertn., *Z. vulgaris* Lam., *Z. mauritiana* Ham. (Hayes, 1945) and so on.

Keeping in view the above important features and the lack of any systematic knowledge on its taxonomy, morphology and cytogenetics, a programme of study has been started on the genus in general and Jujube in particular. As a first step a survey of 37 varieties of Jujube (*Z. jujuba* Lam.) and some selections of *Z. rotundifolia* Lam. (syn: *Z. nummularia* Wight. and Arn.) has been made. The survey is a yet preliminary and as a first step a morphological, cytological and chemical evaluation of the material has been attempted. Such a study assumes importance because of the fact that the genus is no where as important as in China and India. Furthermore, a study of the genus from this area is important because according to De Candolle (vide Watt, 1893) and Vavilov (1949-50) North-Western India falls within the centre of origin of the Jujube.

It is therefore essential to make a thorough survery of the material growing in this area where Jujube has been grown since the Sanskritic times (Watt, 1893) and where there is a good degree of varietal diversity. Such a study when complete, is likely to throw light on the origin of the cultivated types and would help in chalking out a programme for producing improved types. In the present

communication an account of the cytological findings will be presented.

Material

The material of *Z. jujuba* and *Z. rotundifolia* was collected chiefly from Amritsar and Ambala districts of the Punjab, from both wild and cultivated plants. However, most of the material of Jujube came from the Punjab Government Fruit Research Station, Bahadurgarh (Patiala), where nearly 40 varieties of cultivated Jujube have been gathered. These have been grafted on the wild root-stock. These varieties have been collected from various places in India and *Table 1* gives the original source of each variety. The material gathered at the station therefore can be treated as a fairly representative sample of the Indian varieties of Jujube. The Research Station has embarked on a programme of improvement and propagation by bud grafting of the Jujube under an Indian Council of Agricultural Research scheme

Pressed voucher specimens along with preserved fruits have been deposited in the Herbarium of the Panjab University Botany Department, Chandigarh-3.

Table 1. — Original Source of the material.

Serial No.	Plant No.	Variety	Original Source of the material
Z. jujuba LAM.			
1.	30/1	Banarsi	U. P.
2.	29/1	Banarsi Pewandi	U. P.
3.	24/5	Chuhara	Hariana (Panjab)
4.	2/4	Dandan	Hansi and Jind
5.	26/13	Desi Alwar	Ahmedabad
6.	21/1	Golar	Hariana
7.	19/12	Gorva	Village Talod, Distt. Sabarkantha (Bombay)
8.	1/1	Kaithali	Kaithal, Jind
9.	17/1	Kalagola	Hariana
10.	19/5	Katha Bombay	Village Talod, Distt. Sabarkantha (Bombay)
11.	31/1	Kathaphool	Phool (Bhatinda)
12.	22/4	Laddu	Hariana
13.	22/1	Mirchia	Nasirpur (Patiala)
14.	2/8	Nalaghari	Nalagarh
15.	26/1	Narikele	West Bengal
16.	13/1	Nazuk	Hariana
17.	1/16	Noki	Jind
18.	20/1	Pathani	Jhajjar
19.	31/7	Phool	Phool (Bhatinda)
20.	14/1	Sandhura Narnaul	Hariana
21.	1/4	Sandhura Sanor	Sanaur (Patiala)
22.	28/8	Sanor/2	Sanaur (Patiala)
23.	29/8	Sanor/3	Sanaur (Patiala)
24.	30/7	Sanor/4	Sanaur (Patiala)
25.	33/1	Sanor/6	Sanaur (Patiala)
26.	12/1	Seo	Rohtak
27.	23/1	Sufeda	Hariana
28.	28/1	—	U. P.
29.	—	Umran	Hansi, Jind
30.	1/10	Willaiti	Sanaur (Patiala)
31.	4/2	Z. G. 2	Panjab Government Fruit Nursery Garden, Jullundur.
32.	3/1	Z. G. 3	— do —
33.	—	Wild (Root stock)	Bahadurgarh (Patiala)
34.	—	Hoshiarpur/1	Hoshiarpur
35.	—	Kalianwali	Village Kaleghanupur (Amritsar)
36.	25/1	Ilaichi	Hariana
37.	—	Mithianwali	Village Gulab Garh Distt. Bhatinda
Z. rotundifolia LAM.			
38.	—	Z. R./1	P. U. Campus, Chandigarh
39.	—	Z. R./2	— do —
40.	—	Z. R./3	— do —
41.	—	Z. R./4	Village Kaleghanupur (Amritsar)
42.	—	Z. R./5	Khalsa College, Amritsar.

Material

Methods

Zizyphus is a very difficult cytological material and in the beginning a number of trials had to be made in order to obtain reliable cytological preparations.

For meiotic studies young flower buds were fixed in Marks' fixative (MARKS, 1952). Four hundred milligrams of Ferric hydroxide were dissolved by gentle heating (70° C) in 100 cc. of Propionic acid and the acid solution obtained was used in Cornoy's fixative in place of Acetic acid. The buds were left in the fixative for 36 to 48 hours. Thereafter the buds of appropriate size were squashed in 1% Propiono-carmine.

Somatic chromosome number was determined from actively growing root-tips obtained from freshly germinated seeds. Such root-tips were pretreated with 0.002 mol. solution of 8-Hydroxyquinoline for 2—3 hours at 18° C. These tips were then fixed in Farmer's solution for 3—5 hours. After which these were transferred to 1% Aceto-orcein and were left overnight. Next day these were macerated in Aceto-orcein—N. Hcl mixture (9:1) and then squashed in 1% Aceto-orcein..

Studies were made from temporary slides which were thereafter made permanent in the usual manner. While making permanent, much of the clarity was lost due to shrinkage of cells and staining of cytoplasm. All diagrams were drawn at an uniform magnification × 2500.

Zizyphus jujuba

In most of the varieties course of meiosis was followed from diakinesis to anaphase II. Pollen sterility was also calculated by taking the stainable pollen as fertile *(Table 2)*. Unless otherwise mentioned the course of meiosis was apparently normal. Only important points will be mentioned below:

1) Banarsi (30/1):

Diakinesis was studied in two pollen mother cells. In one cell there were observed 3 quadrivalents + 18 bivalents *(Fig. 1)* while in the other there was present a single quadrivalent + 22 bivalents *(Fig. 2)*. On average therefore there are 2 quadrivalents and 20 bivalents. Pollen sterility was 19.42%

2) Banarsi Pewandi (29/1):

At diakinesis 3 quadrivalents + 18 bivalents were clearly discernible *(Fig. 3)*. Pollen sterility was 14.38%.

3) Chuhara (24/5):

Chromosome counts were made in two cells at metaphase I. In one of the cells there were counted 4 quadrivalents + 16 bivalents *(Fig. 4)* and in another were 2 quadrivalents + 20 bivalents *(Fig. 5)*. Therefore there were 3 quadrivalents and 18 bivalents per cell. Pollen sterility was 13.72%.

4) Dandan (2/4):

Two cells were studied one was at diakinesis and contained 2 quadrivalents + 19 bivalents + 2 univalents *(Fig.*

6). The other was at metaphase I and possessed 2 quadrivalents + 20 bivalents *(Fig. 7)*. Pollen sterility was 14.74%.

5) Desi Alwar (26/13):

Only one cell at diakinesis was available which contained one quadrivalent + 22 bivalents *(Fig. 8)*. Pollen sterility was 18.8%.

6) Golar (21/1):

No analysable cells at diakinesis and metaphase I were available. This was due to the presence of unanalysable associations of bivalents and chromosomes. However, some cells were observed at a stage comparable to anaphase I. One of these showed one bivalent + 46 univalents *(Fig. 9)*. Varying number of (1—6) lagging univalents were observed at telophase I *(Figs. 10—12)*. Pollen sterility was 33.1% which is significantly higher than other varieties.

7) Gorva (19/12):

Cells at diakinesis and metaphase I were not available. However, normal anaphases with 24:24 disjunction were observed *(Figs. 13,14)*. Pollen sterility was 19.83%.

8) Kaithali (1/1):

In all 5 cells were examined. Two were at diakinesis containing 3 quadrivalents + 18 bivalents *(Fig. 15)* and 22 bivalents + 4 univalents *(Fig. 16)*. The two cells at metaphase I showed 5 quadrivalents + 14 bivalents *(Fig. 17)* and 3 quadrivalents + 18 bivalents. Therefore at metaphase I 4 quadrivalents + 16 bivalents were present per cell. Anaphase I was normal with 24:24 disjunction *(Fig. 18)*. Further course of meiosis was normal with 13.7% pollen sterility.

9) Kalagola (17/1):

Chromosome counts were made from 2 cells at diakinesis. These contained 5 quadrivalents + 14 bivalents each *(Fig. 19)*. Pollen sterility was 7.60%.

10) Katha Bombay (19/5):

At diakinesis there were 4 quadrivalents + 16 bivalents *(Fig. 20)*. Anaphase I was quite normal *(Fig. 21)*. Pollen sterility was 14.53%.

11) Kathaphool (31/1):

Meiosis was normal. At metaphase I 6 quadrivalents + 12 bivalents were found *(Fig. 22)*. At anaphase I 24:24 disjunction was observed *(Fig. 23)*. Pollen sterility was 16.87%.

12) Laddu (22/4):

A single cell at metaphase I was analysable. There were present 2 quadrivalents + 19 bivalents + 2 univalents *(Fig. 24)*. Pollen sterility was 17.07%.

13) Mirchia (22/1):

Chromosome number was determined from two cells at metaphase I. One cell revealed 8 quadrivalents + 8 bivalents *(Fig. 25)* and the other cell had 5 quadrivalents + 14 bivalents *(Fig. 26)*. There was very high quadrivalent frequency in one cell. In the other cell though the frequency was low but bivalents were so close as to appear disjoined quadrivalents. There were mean 6.5 quadrivalents + 11 bivalents per cell. Pollen sterility could not be determined due to lack of proper material.

14) Nalaghari (2/8):

Only one cell at diakinesis was obtained showing 3 quadrivalents + 18 bivalents *(Fig. 28)*. Pollen sterility was 18.69%.

15) Narikele (26/1):

Only one cell was available for study. This was at anaphase I showing 25:23 disjunction *(Fig. 27)*. This conforms the gametic number to be 24. Although this is not normal disjunction, yet from low pollen sterility (12.5%) one can infer that there are no serious abnormalities involved

16) Nazuk (13/1):

Metaphase I and anaphase I was studied in this variety. At metaphase I there were observed 3 quadrivalents + 17 bivalents + 2 univalents *(Fig. 29)*. In the other two cells at meta-anaphase there were present 12 bivalents + 24 univalents *(Fig. 30)* and one quadrivalent + 3 bivalents + 38 univalents *(Fig. 31)*. Pollen sterility was 16.23%.

17) Noki (1/16):

A single cell at metaphase I showed clearly 5 quadrivalents + 14 bivalents *(Fig. 32)*. Pollen sterility was 18.9%.

18) Pathani (20/1):

Cytological observations were recorded from two cells at diakinesis which contained 4 quadrivalents + 16 bivalents *(Fig. 33)* and one quadrivalent + 22 bivalents respectively. There were mean 2.5 quadrivalents + 19 bivalents. Pollen sterility was rather high being 27.37%.

19) Phool (31/7):

The two cells at metaphase I contained 5 quadrivalents + 14 bivalents *(Fig. 34)* and 4 quadrivalents + 16 bivalents. On average there were 4.5 quadrivalents + 15 bivalents. Pollen sterility was 13.4%.

20) Sandhura Narnaul (14/1):

Three cells were available at diakinesis which contained 4 quadrivalents + 16 bivalents *(Fig. 35)*, 3 quadrivalents + 18 bivalents *(Fig. 36)* and 2 quadrivalents + 20 bivalents *(Fig. 37)* respectively. This gives on average association of 3 quadrivalents + 18 bivalents. Three more cells were found at metaphase I, two of which contained 3 quadrivalents + 18 bivalents *(Fig. 38)* and one had 2 quadrivalents + 20 bivalents *(Fig. 39)*. A noteworthy feature is that in addition to the normal complement of chromosomes, in 5 (out of 6 cells) there was found a small chromosomal body (probably a supernumerary or B chromosome). At anaphase there was normal disjunction *(Fig. 40)* and the probable supernumerary chromosome was seen in a process of division. At telophase more often there was a pair of laggards. Probably the laggards were due to the divided supernumerary chromosome *(Fig. 41)*. Another interesting point is that the nucleoli were persistent at anaphase and these were often four in number but these were lacking in two cells studied at metaphase I. Pollen sterility was 28.50%.

21) Sandhura Sanor (1/4):

Chromosome counts were made at anaphase I showing 24 chromosomes at one of the poles *(Fig. 42)*. Pollen sterility was 25.20%.

22) Sanor/2 (28/8):

Due to clumping, good diakinesis or methaphase plates could not be obtained. One cell was at meta-anaphase in which a tentative analysis showed 18 bivalents + 12 univalents *(Fig. 43)*. At telophase I there were present laggards *(Fig. 44)*. Due to lack of material pollen sterility could not be determined.

23) Sanor/3 (29/8):

One cell at metaphase I showed 7 quadrivalents + 9 bivalents + 2 univalents *(Fig. 45)*. Anaphase I was normal with 24:24 disjunction *(Fig. 46)*. Pollen sterility was 28.10%.

24) Sanor/4 (30/7):

Two cells were examined at metaphase I which contained 4 quadrivalents + 15 bivalents + 2 univalents *(Figs. 47)*, and 2 quadrivalents + 20 bivalents *(Fig. 48)*. One of the cells showed close grouping of bivalents, possibly due to secondary associations. On average there were 3.5

quadrivalents + 16.5 bivalents + one univalent. Pollen sterility was 35.46%.

25) Sanor/6 (33/1):

At methaphase I there were recorded 4 quadrivalents + 16 bivalents in one cell *(Fig. 49)*. Pollen sterility was 20.27%.

26) Seo (12/1):

Four cells were examined at diakinesis. One of these contained 4 quadrivalents + 16 bivalents *(Fig. 50)*, another had 3 quadrivalents + 18 bivalents, and the remaining two had 2 quadrivalents + 20 bivalents each *(Fig. 51)*. There were, therefore, 2.75 quadrivalents + 18.5 bivalents per cell. Pollen sterility was 14.04%.

27) Sufeda (23/1):

One cell at metaphase I showed 4 quadrivalents + 15 bivalents + 2 univalents *(Fig. 52)*. Pollen sterility was 12.80%.

28) 28/1:

Two cells at metaphase I showed 3 quadrivalents + 18 bivalents *(Fig. 53)* and 2 quadrivalents + 20 bivalents respectively. The mean frequency of quadrivalents was 2.5 and of bivalents 19. A cell showed 48 chromosomes and in all probability it represents anaphase I in which the two groups have come to lie close because of squashing *(Fig. 54)*. Pollen sterility was 22.58%.

29) Umran:

Three cells could be analysed, two of these were at diakinesis and contained one quadrivalent + 22 bivalents and one quadrivalent + 21 bivalents + 2 univalents *(Fig. 55)*. Only one cell at metaphase I was available which contained 3 quadrivalents + 18 bivalents *(Fig. 56)*. Pollen sterility was 13.54%.

30) Willaiti (1/10):

At metaphase I there were observed 5 quadrivalents + 14 bivalents *(Fig. 57)* and 4 quadrivalents + 13 bivalents + 6 univalents *(Fig. 58)* in one cell each. On average there were 4.5 quadrivalents + 13.5 bivalents + 3 univalents. Pollen sterility was 19.68%.

31) Z. G. 2 (4/2):

At diakinesis were observed 5 quadrivalents + 14 bivalents in one cell *(Fig. 59)*. Pollen sterility was 14.63%.

32) Z. G. 3 (3/1):

One cell at diakinesis revealed 2 quadrivalents + 20 bivalents *(Fig. 60)*. Pollen sterility was 11.20%.

Table 2. — Summary of the cytological observations.

Variety	Haploid Chromosome number	Mean association at diakinesis (D) or metaphase I (M)				Pollen sterility (percentage)
		IVs	IIIs	IIs	Is	
Z. jujuba						
Banarsi	24	2	—	20	— (D)	19.42
Banarsi Pewandi	24	3	—	18	— (D)	14.38
Chuhara	24	3	—	18	— (M)	13.72
Dandan	24	2	—	20	— (M)	14.74
Desi Alwar	24	1	—	22	— (D)	18.80
Golar	24	—	—	1	46 (M-A)	33.10
Gorva	24	—	—	—	—	19.83
Kaithali	24	4	—	16	— (M)	13.70
Kalagola	24	5	—	14	— (D)	7.60
Katha Bombay	24	4	—	16	— (D)	14.53
Kathaphool	24	6	—	12	— (M)	16.87
Laddu	24	2	—	19	2 (M)	17.07
Mirchia	24	6.5	—	11	— (M)	—
Nalaghari	24	3	—	18	— (D)	18.69
Narikele	24	—	—	—	—	12.50
Nazuk	24	3	—	17	2 (M)	16.23
Noki	24	5	—	14	— (M)	18.90
Pathani	24	2.5	—	19	— (D)	27.37
Phool	24	4.5	—	15	— (M)	13.40
Sandhura Narnaul	24 + 1 B	3	—	18	— (M)	28.50
Sandhura Sanor	24	—	—	—	—	25.20
Sanor/2	24	—	—	18	12 (M-A)	—
Sanor/3	24	7	—	9	2 (M)	28.1
Sanor/4	24	3.5	—	16.5	1 (M)	35.46
Sanor/6	24	4	—	16	— (M)	20.27
Seo	24	2.75	—	18.5	— (D)	14.04
Sufeda	24	4	—	15	2 (M)	12.80
28/1	24	2.5	—	19	— (M)	22.58
Umran	24	3	—	18	— (M)	13 54
Willaiti	24	4.5	—	13.5	3 (M)	19.68
Z. G. 2	24	5	—	14	— (D)	14.63
Z. G. 3	24	2	—	20	— (D)	11.20
Wild (Root stock)	24	3	—	16	4 (D)	—
Hoshiarpur/1	2n = 48	—	—	—	—	—
Kalianwali	2n = 60	0.285	0.85	10.43	35.43	—
Ilaichi	n = 48	9	—	30	— (M)	90.50
Mithianwali	2n = 96	—	—	—	—	—
Z. rotundifolia						
Z. R./1	24	3	—	18	— (D)	8.6
Z. R./2	24	3	—	18	— (D)	7.4
Z. R./3	24	—	—	24	— (D)	—
Z. R./4	36	1.5	—	33	— (D)	50.25
Z. R./5	36	—	—	36	— (D)	—

33) Wild (Root stock):

Very few division figures were available out of which only one at diakinesis was worth analysis. It contained 3 quadrivalents + 16 bivalents + 4 univalents *(Fig. 61).*

34) Hoshiarpur/1:

Mitotic number of chromosomes was counted at metaphase in root-tip which revealed 48 chromosomes *(Fig. 62).* Detailed karyotypic studies were not possible, because of the small size and the fuzzy outline of the chromosomes. Improved techniques are being used.

35) Kalianwali:

This type was studied from a solitary tree growing in village Kaleghanupur near Amritsar. A meiotic analysis showed that there are varying numbers of quadrivalents, trivalents, bivalents and univalents in this type. An analysis of 7 cells is tabulated below giving 2n = 60, a new somatic chromosome number in the Jujubes:

IVs	IIIs	IIs	Is	Figure Nr.
1	1	12	29	*63*
1	—	11	34	*64*
—	3	4	43	*65*
—	2	12	30	*66*
—	—	15	30	*67*
—	—	10	40	*68*
—	—	9	42	*69*
Mean No. 0.285	0.85	10.43	35.43	

Anaphase I is also abnormal and two cells could be analysed which confirmed the number 2n = 60. There were 12—17 univalents in the equatorial zone *(Figs 70, 71).* Telophase I was abnormal and there were noted 9—22 laggards *(Figs. 72—74).* Pollen sterility could not be determined. Fruit yield is also unknown.

36) Ilaichi (25/1):

One cell at diakinesis and 2 at metaphase I were analysed. At diakinesis there were observed as many as 11 quadrivalents + 26 bivalents *(Fig. 75).* The two cells at metaphase I contained 11 quadrivalents + 26 bivalents *(Fig. 76)* and 7 quadrivalents + 34 bivalents *(Fig. 77)* respectively. On average there were 9 quadrivalents + 30 bivalents per cell. Further course of meiosis could not be traced due to paucity of the material at right stage. However, the high sterility (90.50%) and variable size in pollen is indicative of its being abnormal. Moreover, no seeds were found in the fruits.

37) Mithianwali:

Mitotic number was determined which showed 96 chromosomes *(Fig. 78).* Karyotype could not be analysed.

Zizyphus rotundifolia

38—40) Z. R./1—3:

Three selections were examined from Panjab University Campus, Chandigarh. A cell in each at diakinesis showed 3 quadrivalents + 18 bivalents *(Fig. 79),* 3 quadrivalents + 18 bivalents *(Fig. 80),* and 24 bivalents *(Fig. 81)* respectively in the three selections. The three varieties taken together have mean 2 quadrivalents + 20 bivalents. Pollen sterility is also very low being 7.4—8.6%.

41—42) Z. R./4—5:

Two selections were examined at Amritsar and revealed 2 quadrivalents + 32 bivalents *(Fig. 82),* one quadrivalent + 34 bivalents *(Fig. 83),* and 36 bivalents *(Fig. 84)* in three cells examined at diakinesis. Mean number was one quadrivalent + 34 bivalents. Pollen sterility determined in one selection was rather high being nearly 50.25%.

Concluding Remarks

Basic number

A perusal of all the work done on the cytology of the genus *Zizyphus (Table 3)* reveals that only 6 species have been cytologically worked out so far. This table reveals that three reports are discordant. Two of these namely n = 10 and 20 on *Z. oenoplia* and *Z. jujuba* by SRINIVASACHAR (1940) are based on sectioned material and the determinations were made by him incidental to the embryological studies. All the subsequent work on these species make it abundantly clear that SRINIVASACHAR's findings are not reliable. This leaves the report of 2n = 26 for *Z. sativa* by CHIARUGI (1930). Again all the subsequent work on this species has shown that the exact number is 2n = 24. Therefore, it is logical to conclude at present that the genus *Zizyphus* is monobasic with only x = 12 and not tribasic (x = 10, 12, 13) as assumed by DARLINGTON and WYLIE (1955).

Grade of polyploidy

With the above conclusion in mind it is obvious from the present data *(Table 3)* that *Z. lotus* and *Z. sativa* (Chinese

Table 3. — Summary of the chromosome numbers of the genus *Zizyphus* (cf. DARLINGTON and WYLIE, 1955, and CAVE *et al.*, 1955—1961).

Species	Chromosome number		Authority
	n	2n	
Z. jujuba: Indian Jujube	12	—	MORINAGA *et al.*, 1929.
	20	—	SRINIVASACHAR, 1940.
	24	—	SRINIVASAN, 1952.
	24	—	Present work.
	—	60	Present work.
	36	—	SRINIVASAN, 1952.
	48	96	Present work and SRINIVASAN, 1952.
Z. lotus	12	—	REESE, 1957.
Z. mauritiana	24	—	SRINIVASAN, 1952.
Z. oenoplia	10	—	SRINIVASACHAR, 1940.
	24	—	SRINIVASAN, 1952.
Z. rotundifolia	24	—	Present work.
	36	—	Present work and SRINIVASAN, 1952.
Z. sativa as *vulgaris* and *jujuba*, MILL. — Chinese jujube	12	—	MORINAGA *et al.*, 1929.
	—	26	CHIARUGI, 1930.
3 varieties	12	—	BOWDEN, 1945.

Jujube) are at diploid level, *Z. mauritiana* and *Z. oenoplia* at the tetraploid level, *Z. rotundifolia* is both tetraploid and hexaploid, and *Z. jujuba* (Indian Jujube) contains an array of forms ranging from an old and solitary report of diploid number (MORINAGA *et al*, 1929), to tetra-, penta-, hexa- and octoploid types. Out of these tetraploidy is the most predominant. Taking both wild and cultivated species together, the grade of polyploidy ranges from 2 x to 8 x, which is significant in that the *Zizyphus* is a woody genus and such genera ordinarily contain low incidence of polyploidy (STEBBINS, 1938, 1950; DARLINGTON, 1956; KHOSHOO, 1959). One factor which may have aided the preservation of polyploidy in the genus is the strong capacity to sprout repeatedly from the root-crown. However, if woody genera (shrubs and trees) important to man for fruit and flower are taken separately, we find quite a high incidence of polyploidy in such types. This as is also true of Indian Jujube, is due to man's direct interest in them. Outside the cultivated types like *Z. jujuba* and *Z. mauritiana*, polyploidy is only shown by the weedy shrubs like *Z. rotundifolia* and *Z. oenoplia*. Possibly the weedy tendencies may be responsible for the establishment of polyploid races in these species.

Type of polyploidy

The present work has shown that at the tetraploid level ($2n = 48$) in *Z. jujuba* the maximum number of quadrivalents seen was from 8 (var. *Mirchia)* to a minimum of 1 in each cell. The average per cell varies from 7 to 1 *(Table 2)*. There is no critical account of meiosis available for *Z. oenoplia* and *Z. mauritiana* which are both tetraploid. In the tetraploid types of *Z. rotundifolia,* quadrivalents were found in two selections, while the third has 24 perfect bivalents *(Table 2)*. Coupled with the presence of quadrivalents there are secondary associations (also recorded by SRINIVASAN, 1952). Furthermore, the seedling progeny of the cultivated tetraploid types are never uniform and in this region cultivators do not prefer to raise seedling Jujubes. In short, the tetraploids show two important properties, namely formation of a reasonable number of multivalents and exhibit segregation in their progeny. Both these are the important attributes of segmental allo-polyploids. Such a conclusion fits very well with the sterility (16—35% in pollen) found in the various tetraploid types. Obviously, such type of polyploidy gives rise to some inviable combinations as a result of recombination between partially homologous chromosomes of the parents.

The solitary case of pentaploid Jujube found in Amritsar district is indeed the result of hybridization. On average there are 3 basic sets (i. e. 36 chromosomes) which remain unpaired (actually 35.43 univalents), and the two remaining sets are variously associated in quadrivalents, trivalents and bivalents (cf. *Table 2)*. It is not safe to say anything more than this at this stage.

Nothing definite is known about the meiosis in hexaploid Jujubes, but the hexaploids in *Z. rotundifolia* possess low quadrivalent frequency and in one selection there were all bivalents.

In the octoploid type (var. *Ilaichi)* the maximum number of quadrivalents found was 11 and on average the number was 9 *(Table 2)*.

From the foregoing account it is clear that quadrivalents and also a measure of secondary associations are characteristics of all the polyploid types and it is reasonable to assume that the higher polyploids may be straight autoploids of the lower types, and as such combine the characters of auto-, allo, segmental alloploids. It is of interest to point out that most of the polyploid types are neither free from multivalents nor from pollen sterility *(Table 2)*.

Origin of Polyploidy

In woody species in general barriers to hybrid inviability and sterility are more poorly developed than in herbs (STEBBINS, 1950, 1958). Although direct studies of this type have not been made on *Zizyphus,* yet from the indirect evidence (from meiosis of the tetraploids) it appears to be quite true of this genus as well. Furthermore, in the allied genus *Ceanothus* ($x = 12$) it has been clearly shown that the species differentiation is at the ecospecific level (STEBBINS, 1950; NOBS, 1951). Coupled with this there is the entomophilous mode of pollination because of the nectariferous disk. This would result in rampant hybridization. The hybrids are likely to be reasonably fertile and once polyploids arise from such hybrids, they are going to be segmental alloploid in nature, as is also clear from the meiotic and breeding studies. If the ensuing polyploids are of value, they are sure to be maintained in cultivation because of the propagation by grafts, which has been in operation since very early times in this species.

The natural cases of polyploids in species like *Z. oenoplia* and in particular *Z. rotundifolia* show reduced multivalent formation and sterility (cf. *Table 2)*. There are also individual plants in these with total bivalent formation. All these types seem to be apparently more diploidized and harmonious, although R. Z./4 (6 x) selection of *Z. rotundifolia* did show 50% pollen sterility. It appears that in wild plants natural selection favours higher fertility.

The pollen sterility does not appear to be a disadvantage in the cultivated types, because even in *Ilaichi* (8 x) with about 91% pollen sterility there was abundant fruit formation. However, the fruit had a very small and thin stone and it is often called "seedless Jujube". SRINIVASAN (1952) also found one seedless octoploid individual. The other octoploid type *(Mithianwali)* is, however, seeded. The very low pollen fertility means that the fruit formation is the result of parthenocarpic development and may be pollen from neighbouring trees (brought due to entomophilous mode of pollination) is able to induce fruit formation accompanied by total seed sterility. Again this is also true in the tetraploid varieties where meiosis is abnormal and gives rise to pollen which though stainable is variable in size. The cultivated types obviously have not undergone selection for higher fertility because in them size and quality of the fruit is the only consideration. It does not matter if a particular type has low pollen fertility as long as there is parthenocarpic fruit formation.

Indian and Chinese Jujubes

As has been pointed out earlier that taxonomically the entire genus is in a mess. This is particularly true of the cultivated types. Cultivation of Jujubes has been in vogue primarily in China and India. In China, Jujube has been grown for the last 4,000 years and there are at least 400 varieties in cultivation there (HAYES, 1945). In India, we have been able to find reference to Jujube in Yajurveda Samhita, written not later than 1,000 B. C. (cf. MACDONELL and KEITH, 1958). This means the fruit is known since about 3,000 years in India. Furthermore, fruits are used in the religions rites by SANATANIST BRAHMINS in North India, in particular in Kashmir. There is no estimate of the number of the Indian varieties. There is also a reference to it in Puranas in which it is said that Jujube abounded near

Badarica Srama (Badrinath) and "The devotees and sages of those times lived upon its fruit" (DEB, 1829). At any rate it is clear that Jujubes have been in cultivation since ancient times both in India and China. In contrast to the Indian Jujubes, the Chinese Jujubes have not been studied cytologically. Only a few varieties have been worked out *(Table 3)* and if the work of MORINAGA *et al.* (1929) and BOWDEN (1945) gives an idea about the prevailing situation in the Chinese Jujubes, then these may be at diploid level. On the other hand the present data show (barring an old solitary report of diploidy by MORINAGA *et al.*, 1929) that the Indian jujubes are predominantly tetraploid, with some penta-, hexa- and octoploid types. That diploids are not common in India, is also clear from the total absence of triploid types. These facts if substantiated by further work (more so on Chinese types) have important implications on the origin and differentiation of jujubes vis-a-vis the theories of origin of jujube proposed by DE CANDOLLE (vide WATT, 1893), VAVILOV (1949-50) and BAILEY (1947). Therefore a discussion on the place of origin and subsequent spread of jujubes should wait till more is known about their taxonomy, morphology and cytology.

Taxonomical difficulties

So far there has not been any serious and broad-based attempt to work on the taxonomy of the genus in particular of the cultivated types, which have been described under a variety of names as pointed out in the introductory part of this paper. The writers do not propose to discuss the taxonomy of the cultivated types here, but want to bring out that the Indian jujubes are indeed a heterogeneous assemblage, possessing all types of leaves and fruits from orbicular to elliptical; the apices of fruits from obtuse to acuminate and from tree to shrubby habit. Part of this polymorphicity is initially brought about by entomophilly. The writers have seen on several occasions same pollinators visiting shrubby species like *Z. rotundifolia* and wild trees of *Z. jujuba* growing together in waste places outside the villages. Furthermore, in field it sometimes becomes difficult to decide about the taxonomic identity of shrubby types. Such types are not uncommon and share characters of both *Z. jujuba* and *Z. rotundifolia*. There are distinct intergrading types. More often it is difficult to diagnose these intergrading types taxonomically. In the present work the varieties like *Golar* (mean association $1_{II} + 46_{Is}$) and *Sanor/2* (mean association $(18_{IIs} + 12_{Is})$ with high pollen sterility appear to be hybrids. The pentaploid is yet another hybrid type.

Next to natural hybridization, segmental allo-polyploidy is the other major cause for the taxonomic difficulties. This type of polyploidy throws segregates which would connect the parents. Though cultivators avoid raising orchards from seedling trees, yet if a few such plants get established in nature, they would be enough to throw good number of segregates throughout their long life time. Both entomophilly and the segmental alloploidy in them eliminate the taxonomic differences between the parents by producing intergrading types. In any future taxonomic attempts these factors will have to be taken into consideration.

Economic properties

For economic evaluation of a particular variety the following characters have been utilized for the present:

(I) Total fruit weight.

(II) Percentage of pulp.

(III) Percentage of sugar.

(IV) Percentage of citric acid.

To this should be added the yield of a variety. However, at present we have no critical data on this aspect.

Each variety was scored for the above four characters and combined values obtained show that the best varieties are: *Nalaghari, Umran, Phool, Kaithali, Banarsi, Noki* and *Ilaichi*. Out of these the first six are tetraploids, while the last is octoploid. Though the fruit weight in *Ilaichi* (8 x) is low (average 3.52 gm), yet the major portion of it contains the pulp (96.65%). Furthermore, fruit is seedless and has the highest sugar percentage (21.41) recorded for the Indian types. What it has lost by way of weight, it has made up in seedlessness and high percentage of pulp and sugar and low acidity. Same is also true of another octoploid type, *Mithianwali*. However, the most pupular types in Punjab are *Umran* and *Kaithali* in particular the former. *Umran* in some cases has a fruit roughly $1^1/_4$ times the size of an average egg.

Summary

A cytological study of 37 varieties belonging to *Zizyphus jujuba* and 5 selections belonging to *Z. rotundifolia* has been made.

Chromosome counts have been made in the 42 varieties. In case of *Z. jujuba* 34 varieties are tetraploid, one is pentaploid, while the remaining two are octoploid. In *Z. rotundifolia* tetraploid and hexaploid types have been recorded.

The present data along with the previous work done have been discussed and conclusions have been drawn with regard to the basic number of the genus, grade and incidence of polyploidy, origin and type of polyploidy, comparison between Indian and Chinese jujubes, the causes of taxonomical difficulties, and the economic properties of the important varieties.

Zusammenfassung

Titel der Arbeit: *Über die Zytologie nordwest-indischer Bäume. I.* —

37 Varietäten von *Zizyphus jujuba* und 5 Auslesen aus *Z. rotundifolia* sind zytologisch untersucht worden.

Bei diesen 42 Varietäten sind die Chromosomen gezählt worden. Bei *Z. jujuba* sind 34 Varietäten tetraploid, eine ist pentaploid, während die restlichen 2 oktoploid sind. Bei *Z. rotundifolia* sind tetraploide und hexaploide Typen gefunden worden.

Die jetzt vorhandenen Daten wurden diskutiert und Schlußfolgerungen auf die Chromosomen-Grundzahl der Gattung gezogen. Ferner wurden Grad und Auswirkung, Entstehung und Typ der Polyploidie besprochen, die indischen und chinesischen Jujuben verglichen, Gründe für taxonomische Schwierigkeiten diskutiert und auf ökonomisch wesentliche Eigenschaften der wichtigen Varietäten hingewiesen.

Résumé

Titre de l'article: *Cytologie des arbres du Nord-Est de l'Inde. I.*

Une étude cytologique de 37 variétés de *Zizyphus jujuba* et 5 sélections de *Z. rotundifolia* a été faite.

On a compté les chromosomes dans les 42 variétés. Chez *Z. jujuba* 34 variétés sont tétraploïdes, une est penta-

ploïde, les deux autres octoploïdes. Chez *Z. rotundifolia* on a trouvé des types tétraploïdes et hexaploïdes.

Ces données, ainsi que celles obtenues auparavant, ont été discutées et des conclusions ont été tirées en ce qui concerne le nombre de base du genre, la nature et le taux de la polyploïdie, son origine et son type, la comparaison entre les jujubiers de l'Inde et de la Chine, les causes de difficultés taxonomiques, et les caractéristiques économiques des variétés importantes.

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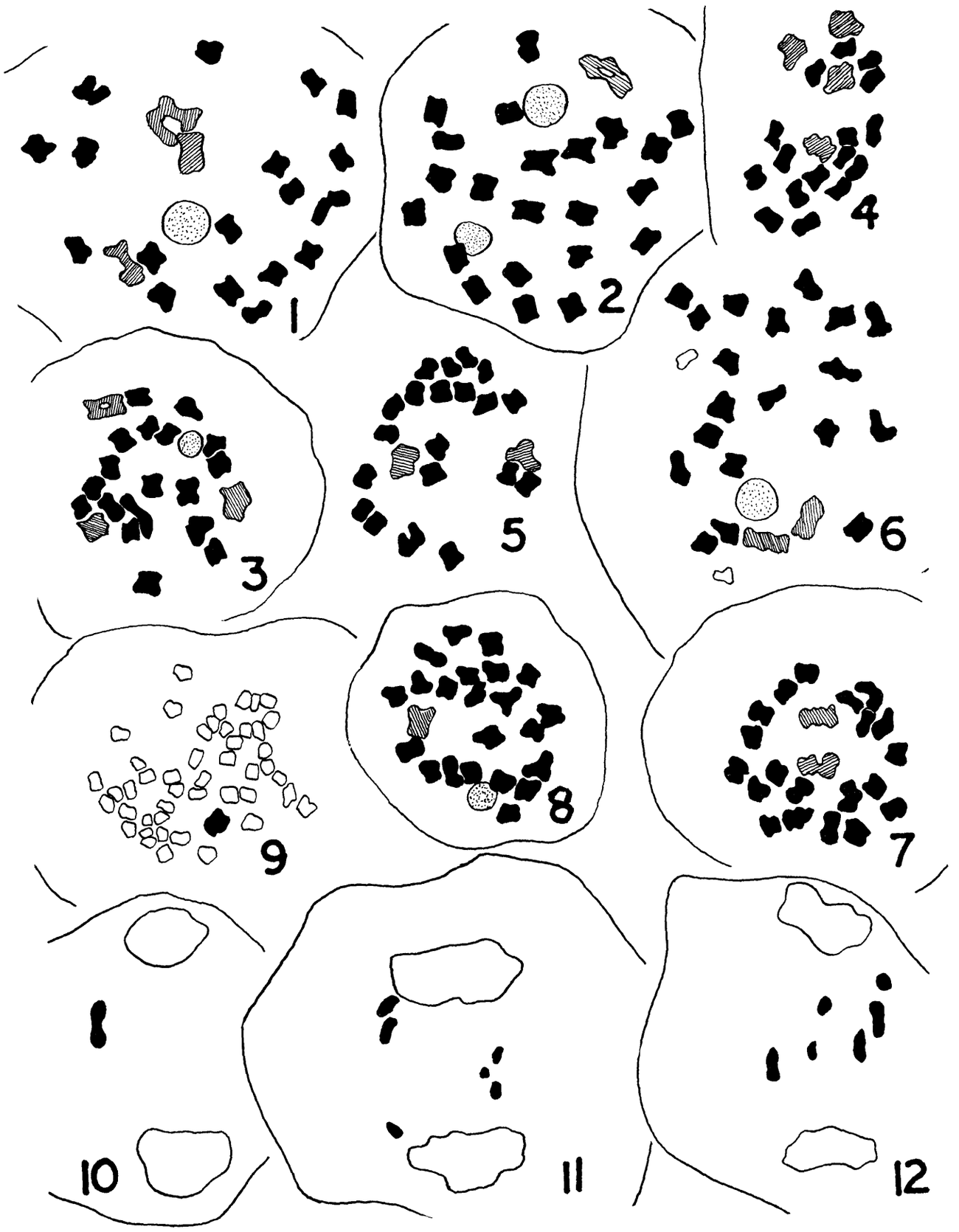
Explanation to the following Figures 1—84

Figs. 1—78. — *Z. jujuba.* — *Figs. 1—2.* — Banarsi: Diakinesis showing 3 quadrivalents + 18 bivalents, and 1 quadrivalent + 22 bivalents. — *Fig. 3.* — Banarsi Pewandi: Diakinesis with 3 quadrivalents + 18 bivalents. — *Figs. 4—5.* — Chuhara: Metaphase I showing 4 quadrivalents + 16 bivalents, and 2 quadrivalents + 20 bivalents. — *Figs. 6—7.* — Dandan: Diakinesis indicating 2 quadrivalents + 19 bivalents + 2 univalents, and metaphase I with 2 quadrivalents + 20 bivalents. — *Fig. 8.* — Desi Alwar: Diakinesis containing one quadrivalent + 22 bivalents. — *Fig. 9.* — Golar: Meta-anaphase with 1 bivalent + 46 univalents. — *Figs. 10—12.* — Golar: Telophase I showing 1 bivalent, 6 chromosomes, and 6 chromosomes, respectively as laggards. — *Figs. 13—14.* — Gorva: Anaphase I showing 24:24 disjunction. — *Figs. 15—16.* — Kaithali: Diakinesis with 3 quadrivalents + 18 bivalents and 22 bivalents + 4 univalents. — *Fig. 17.* — Kaithali: Metaphase I revealing 5 quadrivalents + 14 bivalents. — *Fig. 18.* — Kaithali: Anaphase I with 24:24 disjunction. — *Fig. 19.* — Kalagola: Diakinesis having 5 quadrivalents + 14 bivalents in each. — *Figs. 20—21.* — Katha Bombay: Diakinesis containing 4 quadrivalents + 16 bivalents, and anaphase I with 24 chromosomes at each pole. — *Figs. 22—23.* — Kathaphool: Metaphase I showing 6 quadrivalents + 12 bivalents, and anaphase I with 24:24 disjunction. — *Fig. 24.* — Laddu: Metaphase I with 2 quadrivalents + 19 bivalents + 2 univalents. — *Figs. 25—26.* — Mirchia: Metaphase I revealing 8 quadrivalents + 8 bivalents, and 5 quadrivalents + 14 bivalents. — *Fig. 27.* — Narikele: Anaphase I with 25:23 disjunction. — *Fig. 28.* — Nalaghari: Diakinesis showing 3 quadrivalents + 18 bivalents. — *Fig. 29.* — Nazuk: Metaphase I containing 3 quadrivalents + 17 bivalents + 2 univalents. — *Figs. 30—31.* — Nazuk: Meta-anaphase I showing 12 bivalents + 24 univalents, and one quadrivalent + 3 bivalents + 38 univalents. — *Fig. 32.* — Noki: Metaphase I with 5 quadrivalents + 14 bivalents. — *Fig. 33.* — Pathani: Diakinesis showing 4 quadrivalents + 16 bivalents. — *Fig. 34.* — Phool: Metaphase I containing 4 quadrivalents + 16 bivalents. — *Figs. 35—37.* — Sandhura Narnaul: Diakinesis with 4 quadrivalents + 16 bivalents + 1 B chromosome; 3 quadrivalents + 18 bivalents + 1 B chromosome, and 2 quadrivalents + 20 bivalents + 1 B chromosome. — *Figs. 38—39.* — Sandhura Narnaul: Metaphase I containing 3 quadrivalents + 18 bivalents + 1 B chromosome; 3 quadrivalents + 18 bivalents, and 2 quadrivalents + 20 bivalents and 1 B chromosome. — *Fig. 40.* — Sandhura Narnaul: Anaphase I with 24:24 and B chromosome dividing. — *Fig. 41.* — Sandhura Narnaul: Telophase I showing a pair of lagging chromosomes. — *Fig. 42.* — Sandhura Sanor: Anaphase I with 24 chromosomes at one pole. — *Fig. 43.* — Sanor/2: Meta-anaphase with 18 bivalents + 12 univalents. — *Fig. 44.* — Sanor/2: Telophase I showing lagging chromosomes. — *Fig. 45.* — Sanor/3: Metaphase I showing 7 quadrivalents + 9 bivalents + 2 univalents. — *Fig. 46.* — Sanor/3: Anaphase I with 24:24 disjunction. — *Figs. 47—48.* — Sanor/4: Metaphase I containing 4 quadrivalents + 15 bivalents + 2 univalents, and 2 quadrivalents + 20 bivalents. — *Fig. 49.* — Sanor/6: Metaphase with 4 quadrivalents + 16 bivalents. — *Fig. 50.* — Seo: Diakinesis revealing 4 quadrivalents + 16 bivalents. — *Fig. 51.* — Seo: Diakinesis with 2 quadrivalents + 20 bivalents. — *Fig. 52.* — Sufeda: Metaphase I showing 4 quadrivalents + 15 bivalents + 2 univalents. — *Fig. 53.* — 28/1: Metaphase I containing 3 quadrivalents + 18 bivalents. — *Fig. 54.* — 28/1: Anaphase I with 48 chromosomes. — *Fig. 55.* — Umran: Diakinesis having one quadrivalent + 21 bivalents + 2 univalents. — *Fig. 56.* — Umran: Metaphase I containing 3 quadrivalents + 18 bivalents. — *Figs. 57—58.* — Willaiti: Metaphase I with 5 quadrivalents + 14 bivalents, and 4 quadrivalents + 13 bivalents + 6 univalents. — *Fig. 59.* — Z. G. 2: Diakinesis revealing 5 quadrivalents + 14 bivalents. — *Fig. 60.* — Z. G. 3: Diakinesis with 2 quadrivalents + 20 bivalents. — *Fig. 61.* — Wild (root stock): Diakinesis showing 3 quadrivalents + 16 bivalents + 4 univalents. — *Fig. 62.* — Hoshiarpur/1: Mitotic metaphase with 48 chromosomes. — *Fig. 63.* — Kalianwali: Metaphase I with one quadrivalent + one trivalent + 12 bivalents + 29 univalents. — *Fig. 64.* — Kalianwali: Metaphase I with one quadrivalent + 11 bivalents + 34 univalents. — *Fig. 65.* — Kalianwali: Metaphase revealing 3 trivalents + 4 bivalents + 43 univalents. — *Fig. 66.* — Kalianwali: Metaphase I showing two trivalents + 12 bivalents + 30 univalents. — *Fig. 67.* — Kalianwali: Metaphase I with 15 bivalents + 30 univalents. — *Fig. 68.* — Kalianwali: Metaphase I having 10 bivalents + 40 univalents. — *Fig. 69.* — Kalianwali: Metaphase I containing 9 bivalents + 42 univalents. — *Figs. 70—71.* — Kalianwali: Anaphase I showing 12 and 17 chromosomes in the equatorial zone. — *Figs. 72—74.* — Kalianwali: Telophase I showing 9—22 laggards. — *Fig. 75.* — Ilaichi: Diakinesis with 11 quadrivalents + 26 bivalents. — *Figs. 76—77.* — Ilaichi: Metaphase I containing 11 quadrivalents + 26 bivalents, and 7 quadrivalents + 34 bivalents. — *Fig. 78.* — Mithianwali: A cell from root-tip showing 96 chromosomes. — *Figs. 79—84.* — Z. *rotundifolia.* — *Fig. 79.* — Z. R./1: Diakinesis containing 3 quadrivalents + 18 bivalents. — *Fig. 80.* — Z. R./2: Diakinesis showing 3 quadrivalents + 18 bivalents. — *Fig. 81.* — Z. R./3: Diakinesis with 24 bivalents. — *Fig. 82.* — Z. R./4: Diakinesis with 2 quadrivalents + 32 bivalents. — *Figs. 83—84.* — Z. R./5: Diakinesis showing one quadrivalent + 34 bivalents, and 36 bivalents.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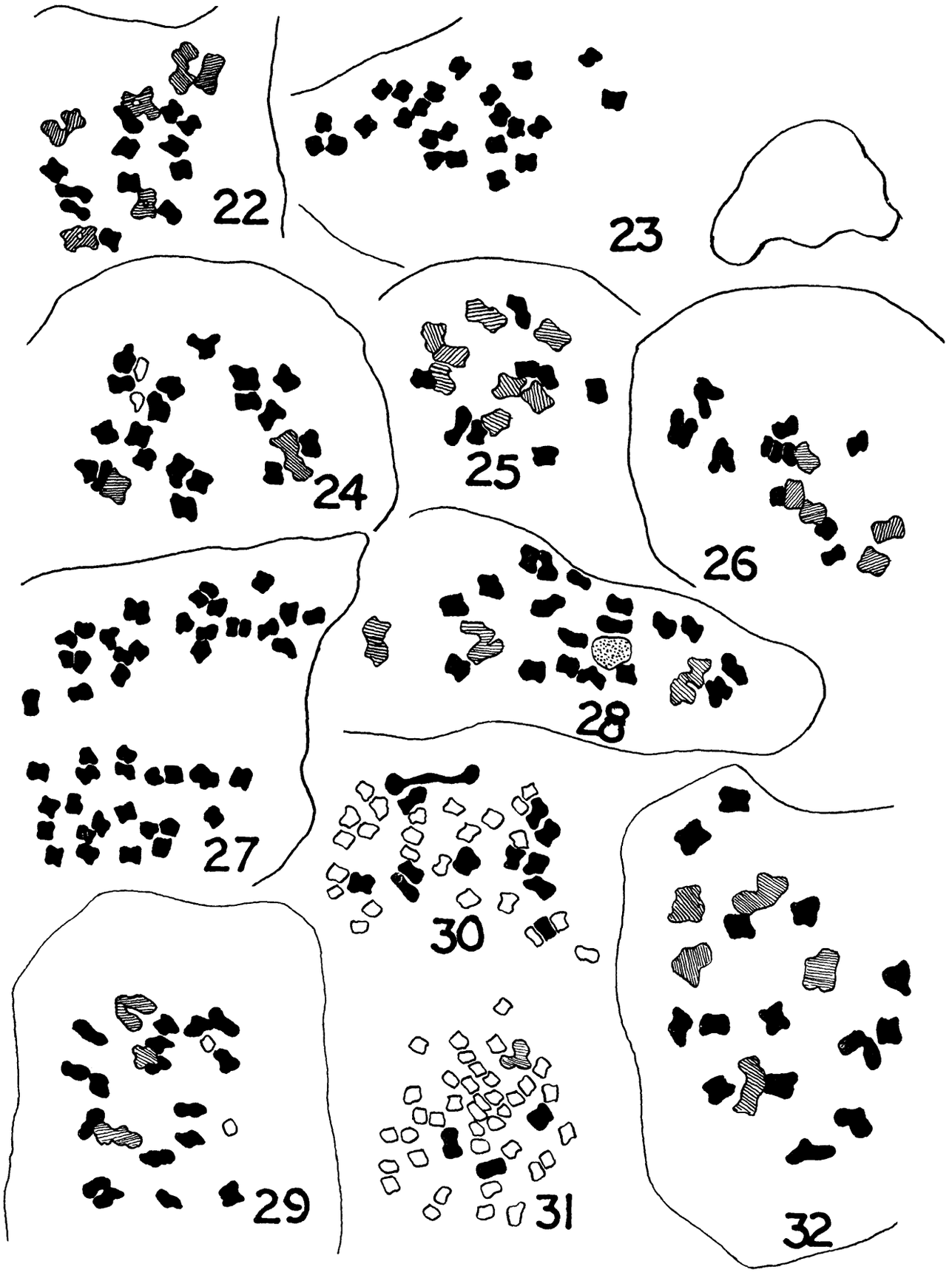
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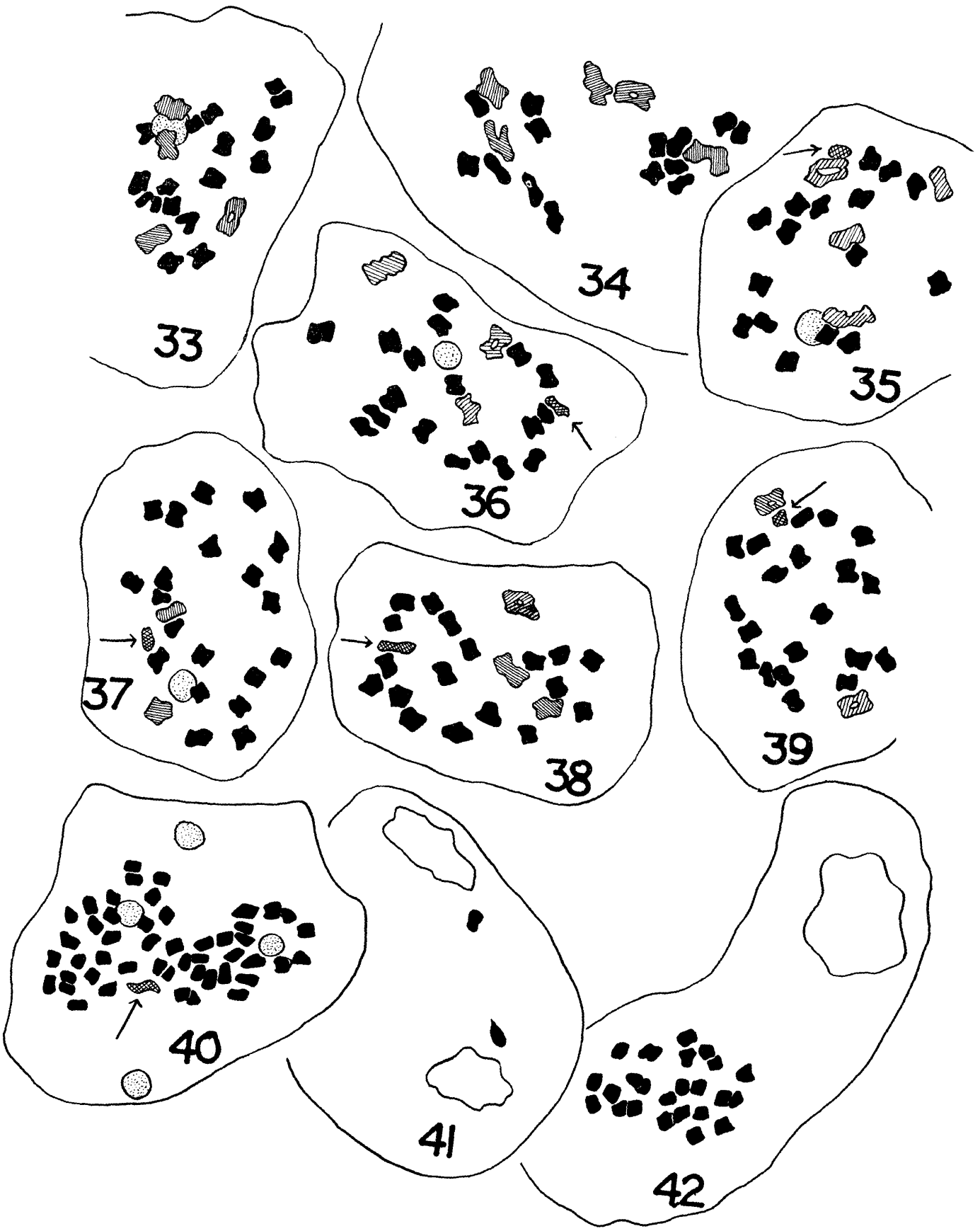
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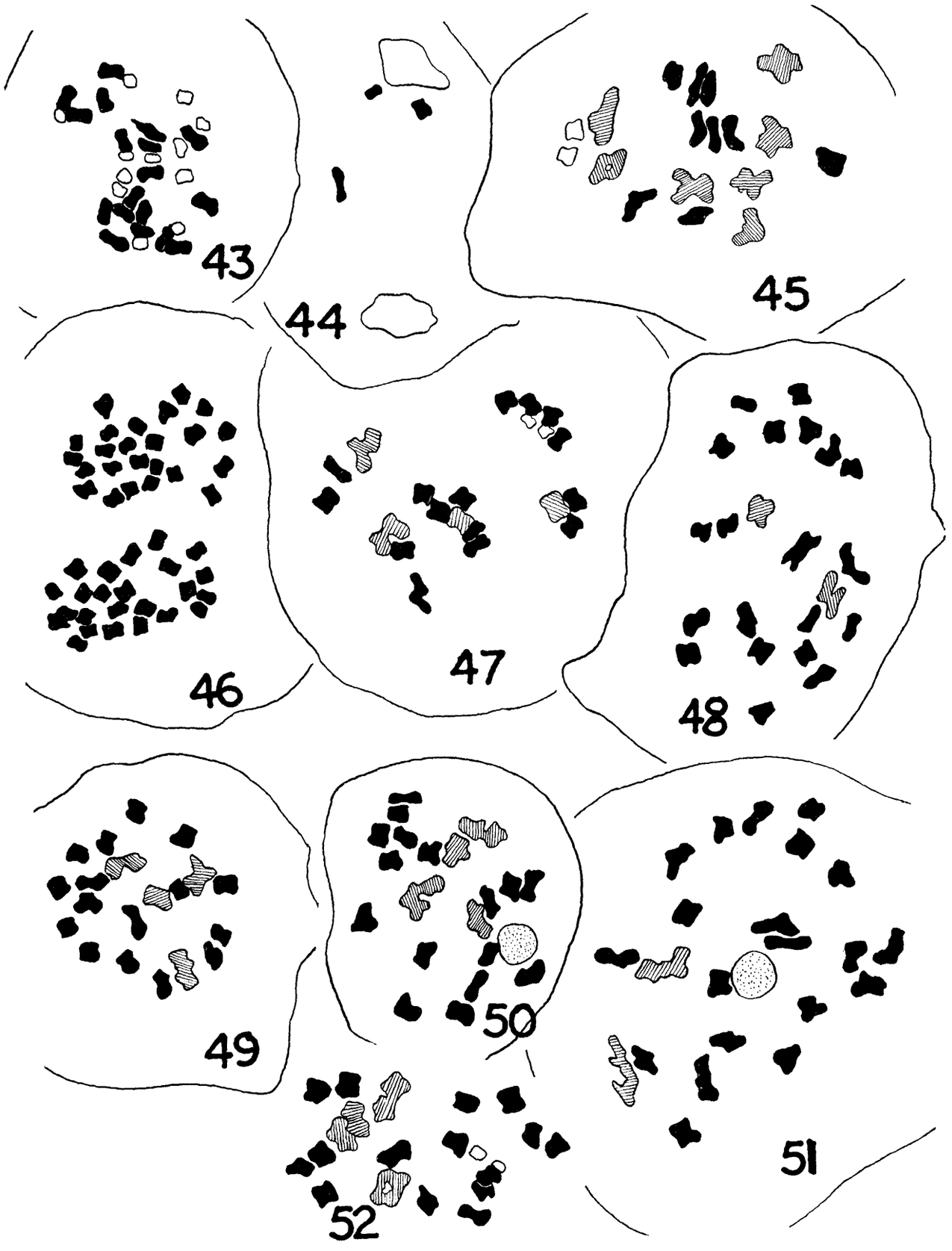
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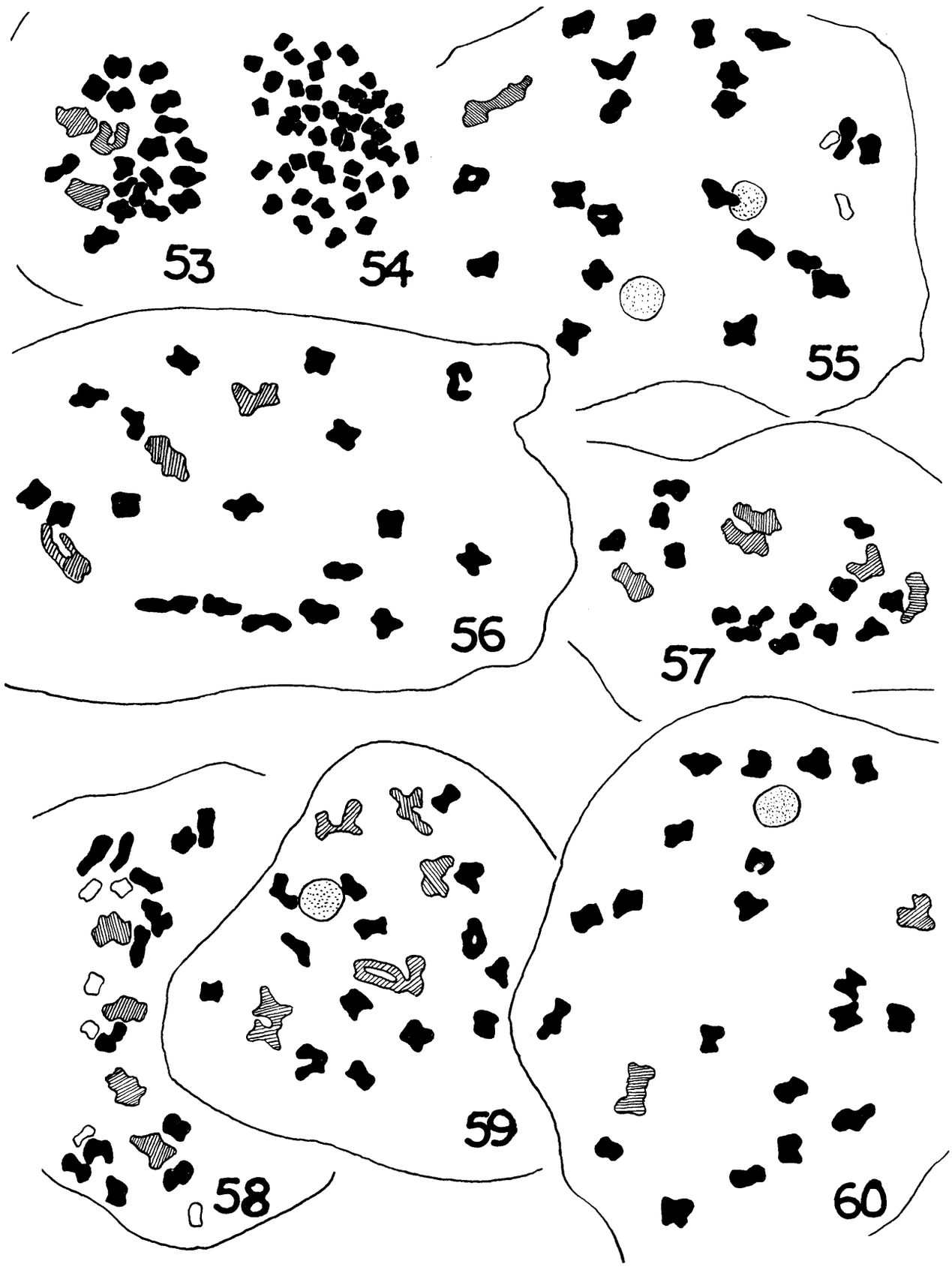
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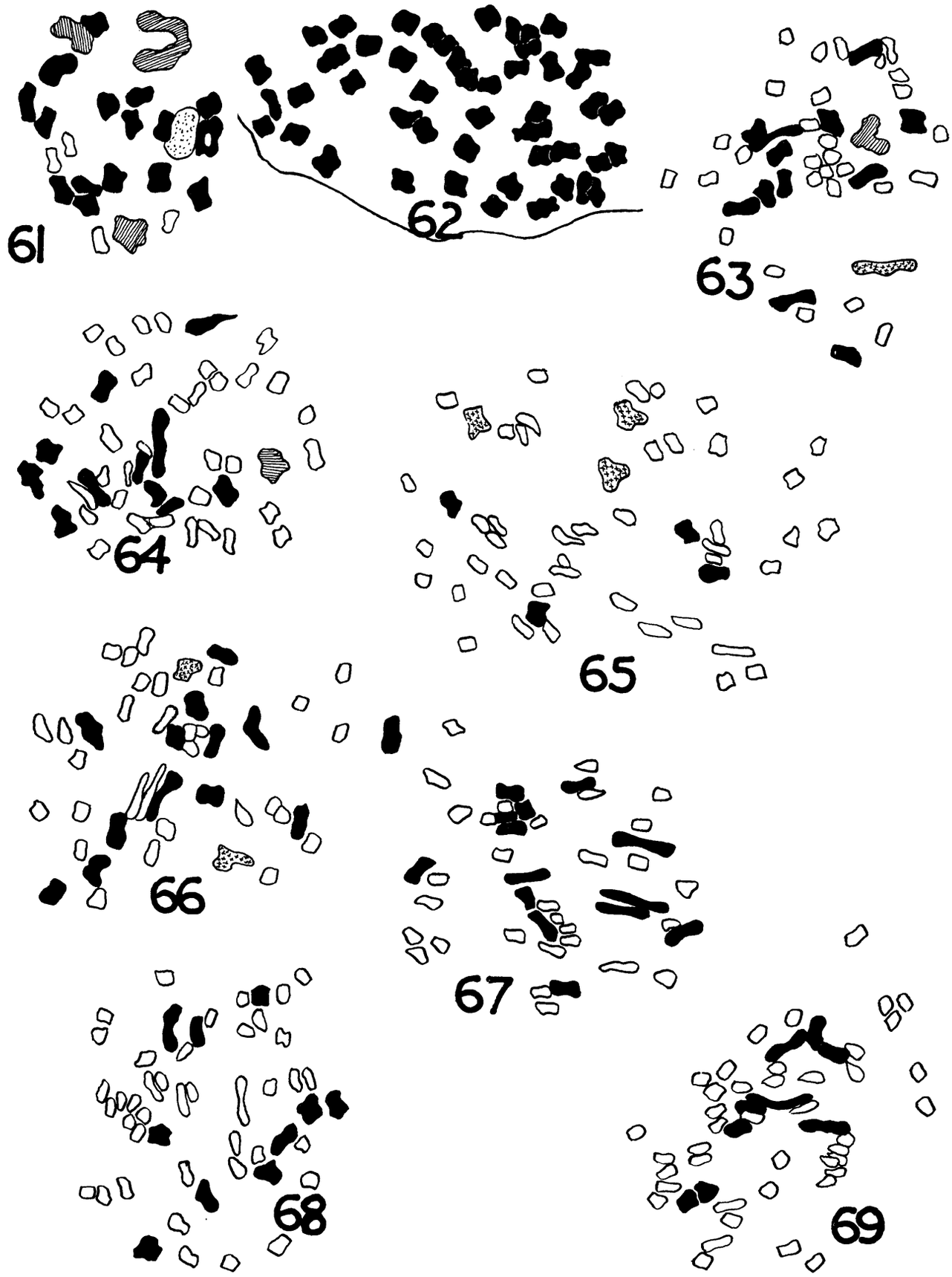
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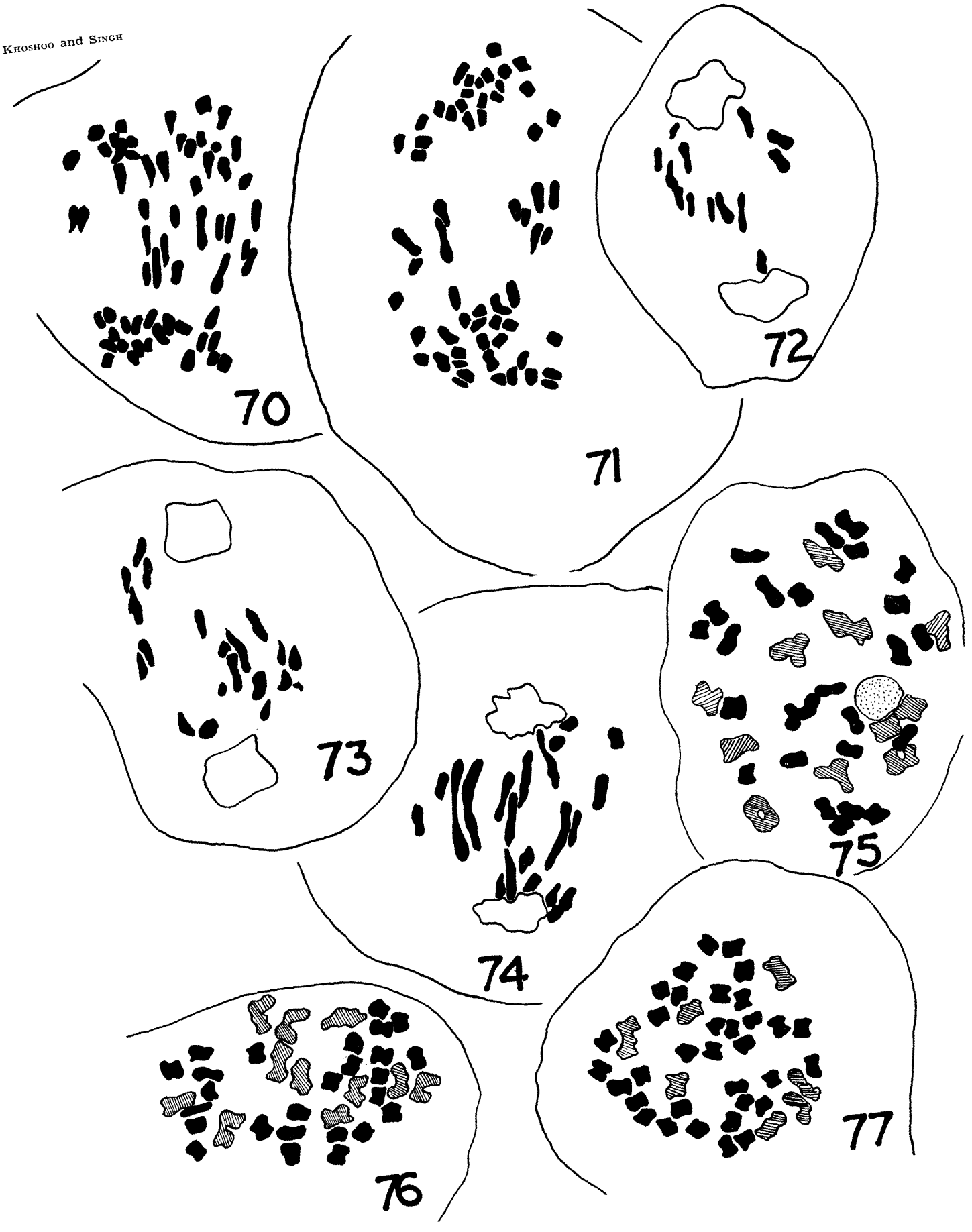
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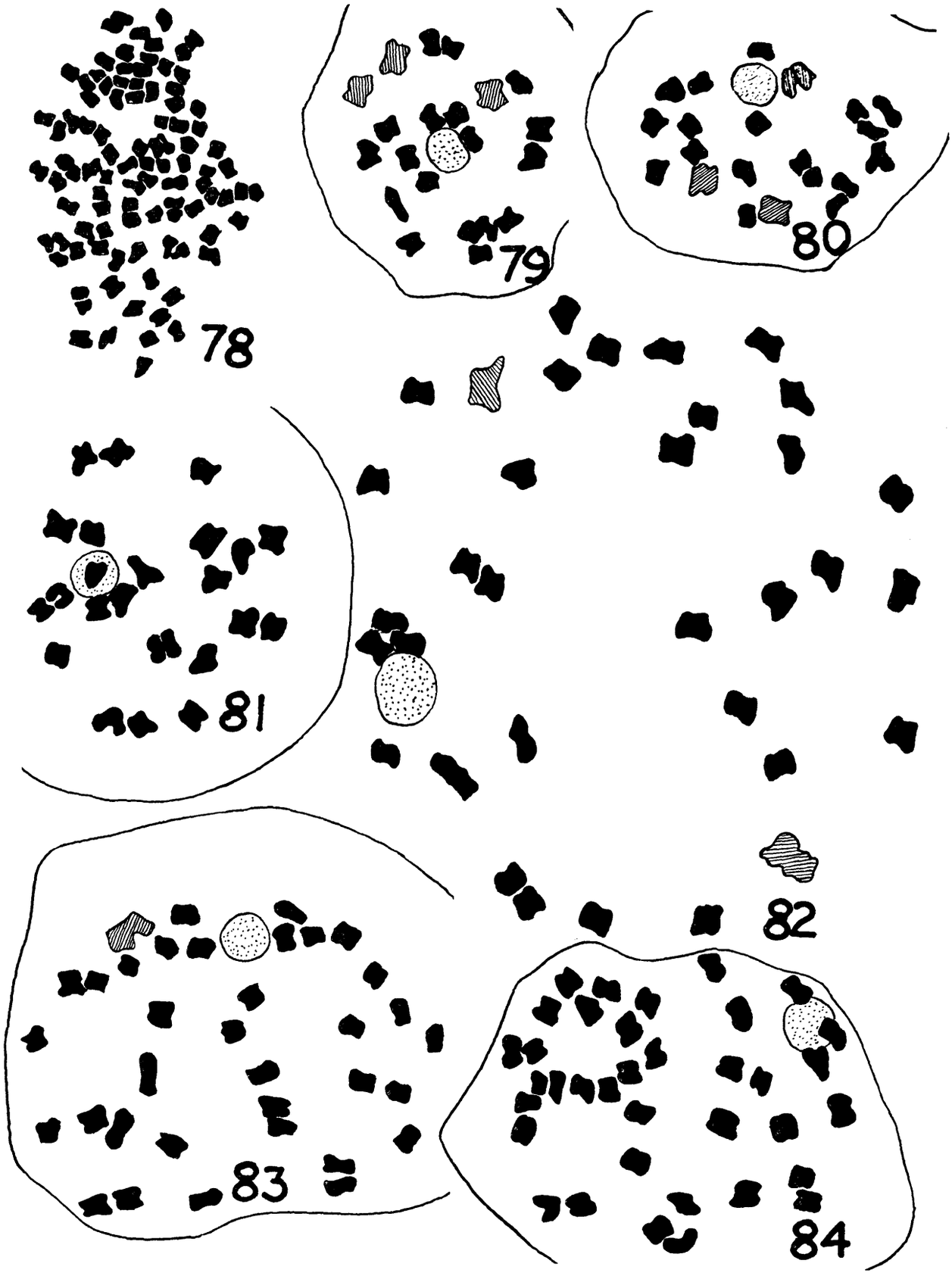
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