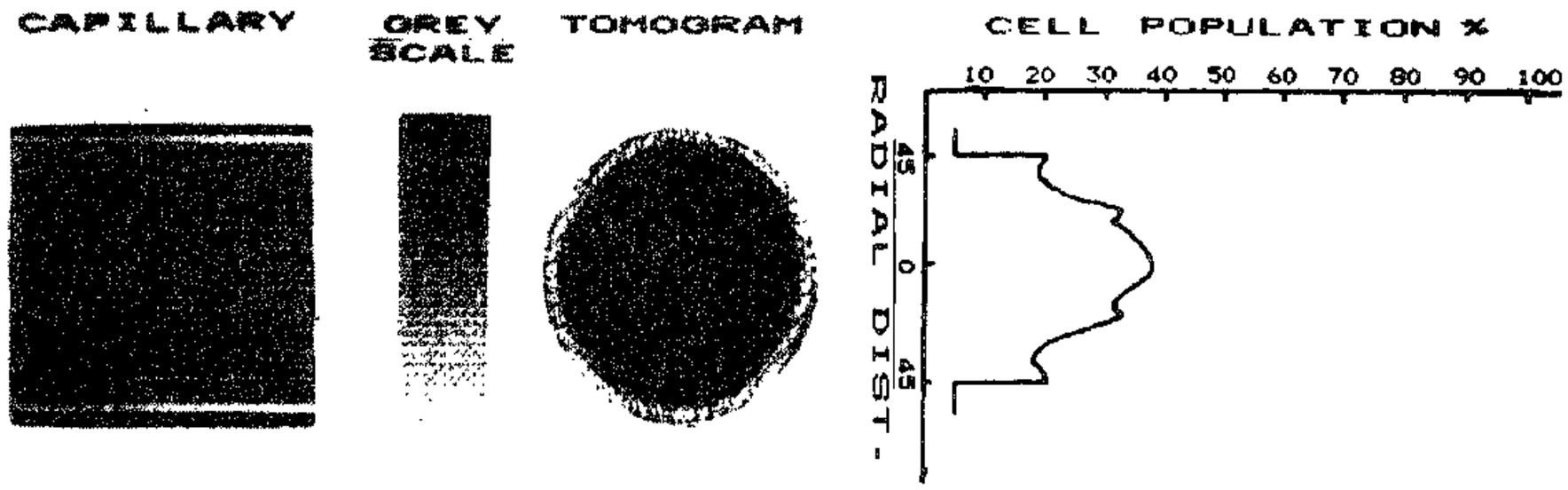

Figure 3. Axial and cross-sectional views of the capillary with blood of haematocrit 10%. The cell population shows an increase at the axis.

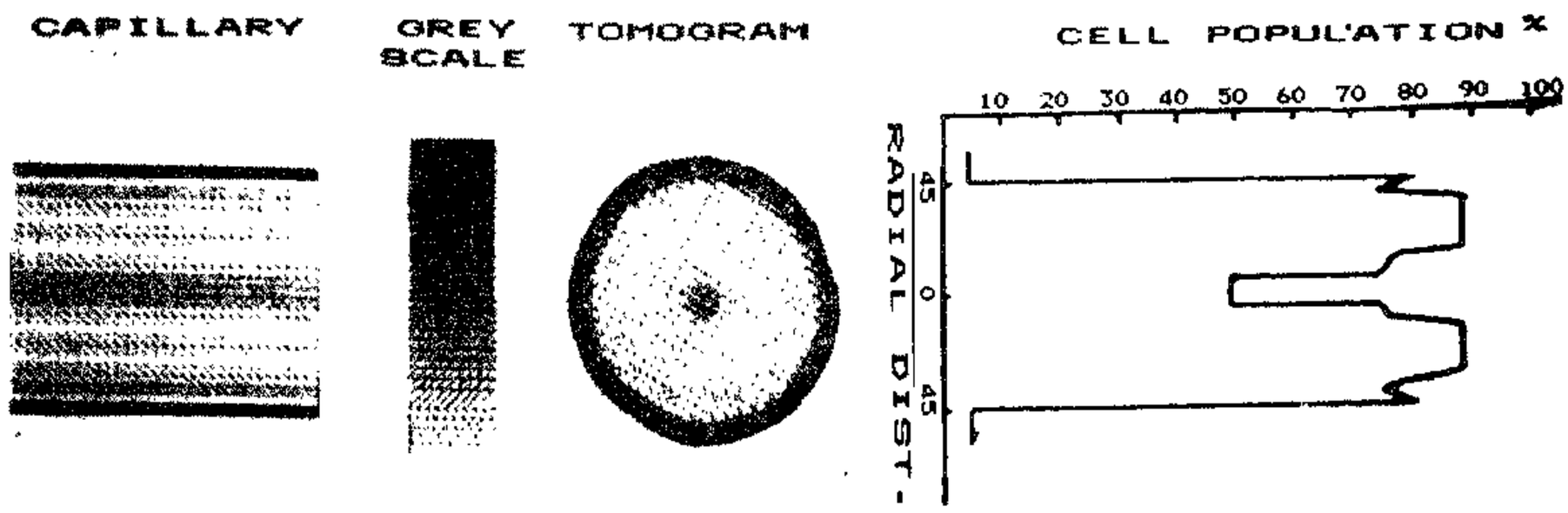

Figure 4. Axial and cross-sectional views of the capillary with blood of haematocrit 60% along with grey scale. The cell population decreases at the centre compared to regions between the axis and the tube wall.

at haematocrit 60%. By a similar procedure the distribution of erythrocytes at various hematocrits was obtained and cell population in the central region determined. Figure 5 shows the variation of cell population at the axial region of the tube. Initially it increases at the axis compared to the other region, followed by a decrease with increasing haematocrit.

The present observations show that at low haematocrit the cells tend to move inward which is similar to that of the action of Magnus force acting on the spheres leading to axial drift thus reducing their concentration close to the wall[2]. The minimum distance to which the suspension could move away from the wall is 1.301 times the radius of the sphere[3]. The validity of the same phenomenon for erythrocytes which are discoid or flattened disk shows that the hydrodynamic lift to the erythrocytes is more than Magnus force[4].

The velocity away from the wall region is well defined and is maximum at the centre. Each layer consists of cells that form a necklace around the core region. The thickness of this layer is equal to that of the diameter of the particles[5,6]. Due to axial drift an increasing number of cells form annular laminae of varying cell population. The maximum velocity leads to maximum concentration at the centre of the tube. These cells move faster than the surrounding plasma thus explaining the Fahraeus effect[7] which states that the

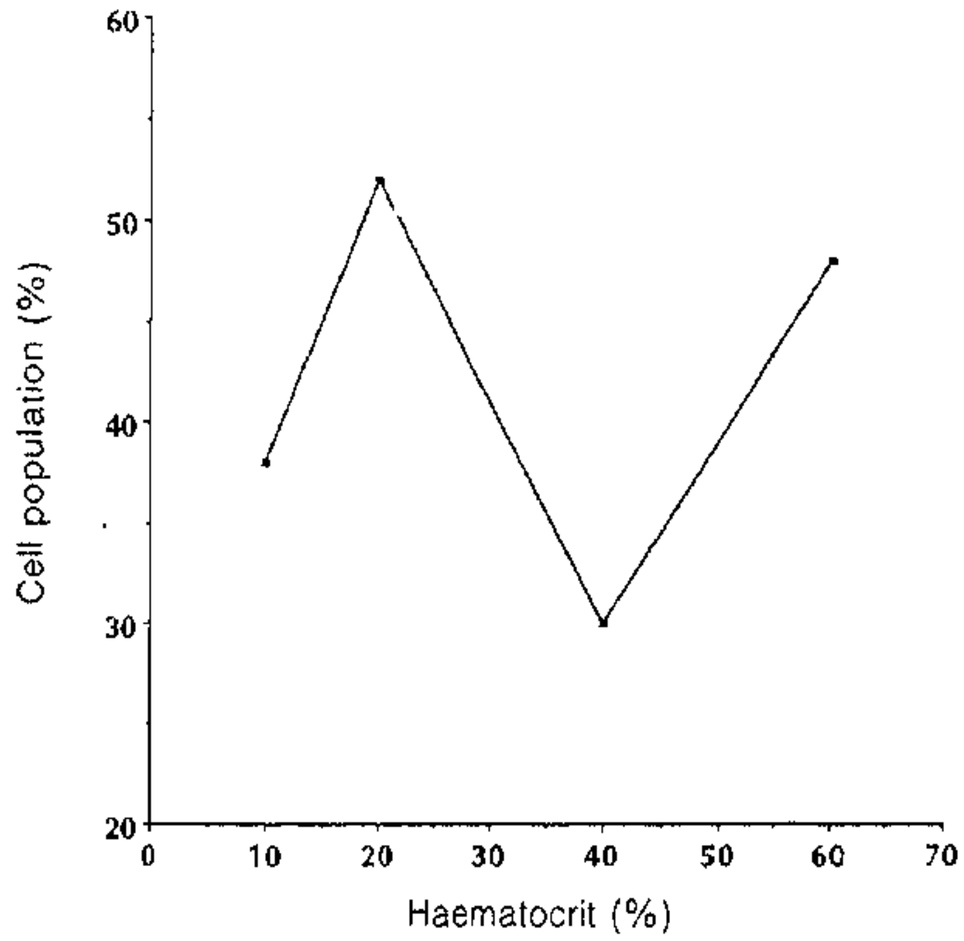

Figure 5. Variation of the cell population at the axis of the tube with blood of varying haematocrits under steady flow conditions.

capillary cell concentration is less than that of the feed reservoir. The velocities associated with these cells are smaller than that of Poiseuille's flow[8].

For solid spheres at high population the outwardly directed dispersive pressure also increases and a subtle balance between the two forces determines the ultimate

radius concentration pattern[9]. The inertial effect causes individual neutral density, rigid spheres flowing down a tube to migrate towards an annulus, an effect which is known as the Segre and the Silberberg effect. This migration becomes increasingly obvious as the flow rate rises and the tube length increases[10].

Unlike sphere suspensions, the plasma layer in blood flow is quite variable. Occasionally cells move near the wall to touch it[8]. With the increase of haematocrit the cell–cell interaction increases, leading to the formation of aggregates which rotate as a whole. At equilibrium these form an average size and an elongated shape. With the increase in Reynolds number the cells not only show axial migration but also move outward from the tube axis[10], thus giving rise to tubular pinch effect[9].

This phenomenon could be explained assuming that at low concentration the cells tend to migrate toward the centre forming the laminae of varying concentration and a disorderly packed core of cells. With the increase of cell concentration the number of cells at the centre remains almost the same, whereas the annular laminae attain uniform concentration of cells which even extends towards the wall thus decreasing the width of the plasma layer[11]. With further increase of concentration the disorderly packing at the centre does not increase significantly compared to that of the laminae region leading to further reduction of plasma layer[9,10].

In conclusion, the flow of erythrocytes in a capillary of 90 μm diameter exhibits phenomena similar to those observed in solid suspensions. The mechanisms responsible for these could be similar but of different magnitudes due to the deformable nature of erythrocytes. Contrary to earlier observations, these phenomena could occur even at the same flow velocity.

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Methods to enhance solid mutation frequency in *Colocasia*

K. Vasudevan and J. S. Jos
Central Tuber Crops Research Institute, Trivandrum 695 017, India

Though successful induction of mutation in *Colocasia* through gamma irradiation has already been achieved, the mutation frequency has remained low and an attempt has been made in the present study to enhance the frequency by adopting different techniques. The side tubers were subjected to 1 kR gamma treatment and planted as 1) whole tubers, 2) tuber pieces of 4–5 g, 3) tuber pieces keeping the identity of top, middle and base and 4) tubers collected from MV1 generation and retreated (recurrent irradiation). In addition to sprouting, observations on morphological characteristics were recorded on 45th day after planting. The tubers harvested from such MV1 plant were planted as MV2 progeny clones. Mutations were screened from MV2 generation for various leaf and plant characters. In general population raised from sliced materials showed greater growth reduction and also recorded a maximum Chimera frequency of 34.2%. The solid mutants were also greater in the population raised from the middle and the base.

MUTATIONS are induced in vegetatively propagated crops following gamma-ray treatments; however their recovery and isolation pose problems. In some crops adventitious bud techniques and tissue culture are cited[1] as successful methods to obtain homohistant (solid mutant, i.e. nonchimeral mutated plants). Vasudevan *et al.*[2] reported comparatively low mutation frequency in *Colocasia*. However, Vasudevan and Jos[3], and Vasudevan *et al.*[4] have shown that it is possible to attain higher frequency of homohistant in *Colocasia* with suitable methods.

The frequency of mutations induced by 1 kR γ-ray treatment (taro, accession no. C 9, locally known as 'Thamarakhannan' in *Colocasia esculenta* Curtz), was determined by: (i) 50 mature or well-developed side tubers planted as whole tubers along with the control following γ-ray treatment, (ii) 15 γ-irradiated side tubers cut into pieces weighing about 3 grams, and 50 pieces planted in the field along with control, (iii) the irradiated tubers made into slices and planted keeping the identity of top, middle and basal pieces, and (iv) 15 side tubers randomly collected from MV1 generation retreated (recurrent irradiation) with 1 kR γ-rays and planted in the field along with the control after cutting into 50 slices. The above materials were planted in the field in two replications at 30 × 30 cm spacing.

In addition to sprouting, observations on morphological characteristics were recorded on the 45th day after planting . The tubers harvested from each MV1 plant were planted as MV2 progeny clones. Mutations were screened from MV2 generation for various leaf and plant characters.

Table 1. Sprouting, growth parameters, chimeral and solid mutation frequency in whole tuber, sliced tuber and recurrent irradiated population of *Colocasia esculenta* variety C.9 following 1 kR γ-ray treatment.

Treatment	Number of tubers/ slices	Sprouting (% of control)	Height (cm)	Leaf length (cm)	Leaf width (cm)	Sheath length (cm)	Weight of tuber (g)	Chimeral frequency (%)	Solid mutation frequency (%)
Whole tuber									
Control	50	100	21.5	12.2	7.2	10.5	163.0	0	0
Irradiated	50	87	14.5	8.0	6.8	7.1	132.0	13.0	7.6
Tuber pieces									
Control	50	100	18.8	9.8	6.5	8.6	121.0	0	—
Irradiated	50	80	12.5	7.2	5.4	6.2	104.0	26.7	16.5
Tuber slices									
Control	50	100	17.9	10.1	6.7	8.5	157.0	0	0
Irradiated Top	25	88	13.4	7.4	5.6	6.7	128.0	18.5	9.3
Middle + basal	50	70	11.5	6.8	5.0	6.1	107.0	34.2	17.7
Recurrent treatments									
Control	50	100	18.7	13.0	9.6	10.2	141.0	0	0
Irradiated + Irradiated	50	64	6.8	4.6	2.9	3.4	111.0	31.7	17.8
CD	—	—	1.17	0.25	0.92	0.42	8.4	—	—

Delay and reduction in sprouting were observed in irradiated populations, which was more pronounced in the sliced materials (Table 1). Morphological characteristics recorded in the MV1 generation showed a significant difference between treatments as against control. Moreover, the maximum growth reduction in terms of plant height (6.8 cm), leaf length (4.6 cm), leaf width (2.9 cm), and sheath length (3.4 cm) was recorded in the recurrent irradiated population as against 18.7 cm, 13.0 cm, 9.6 cm and 10.2 cm, respectively, for these traits in control. It is also interesting to note that the growth reduction, an index of physiological injury in MV1, was greater in the populations raised from the middle and basal pieces compared to the top pieces (Table 1). In general, the population raised from sliced materials displayed greater growth reduction compared to those raised from whole tuber following irradiation.

The effect of γ irradiation, expressed in terms of leaf chimeral frequency, was also greater in the population from sliced tubers, the maximum being recorded (34.2%) in the population raised from middle and basal pieces of irradiated tubers. Screening of mutations also revealed that the treated population raised from sliced tubers recorded higher frequency of mutations compared to the one raised from whole tuber treatment with 1 kR γ irradiation. Moreover, solid mutants were also more in the population raised from slices, and the maximum frequency (17.7%) was in the population raised from middle and basal pieces of the tuber, while the whole tubers as well as pieces produced more chimeral plants with various sector sizes. The higher frequency of solid mutants in the population raised from slices indicates that after slicing, each piece gets a chance to form a bud, which otherwise may remain dormant because of apical dormance. The development of such a bud with the expression of the mutation in the growing tissues increases the chance of recovering solid mutants. The situation is very different in the population raised from whole tubers where the terminal buds become the main shoot and the side shoots develop from the preformed eye which may carry only a few initial cells. However, the mutant cell may not have an equal chance to form a sprout along with the unaffected ones. The recovery of solid mutants, with lower frequency and the formation of chimeral sprouts are mainly due to the above pattern of growth and development. Hence the study reveals that the mutation frequency can also significantly be enhanced in *Colocasia* (C 9) by irradiating well-developed side tuber with 1 kR γ-rays and using small slices weighing about 4–5 g for planting.

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Serological relationship of rice tungro spherical virus and bacilliform virus components associated with rice tungro disease

M. D. Mishra, F. R. Niazi and R. K. Jain
Division of Mycology and Plant Pathology, Indian Agricultural Research Institute, New Delhi 110 012, India

Immunosorbent electron microscopy revealed a degree of serological relationship between rice tungro spherical virus and bacilliform virus indicating the existence of some common epitopes on the capsid protein of the two particles.

ETIOLOGICAL studies on rice tungro disease led to the discovery of association of two morphologically and serologically distinct rice tungro spherical virus (RTSV) and bacilliform virus (RTBV)[1,2]. However, a recent publication[3] pointed out certain similarities in the biological and intrinsic structural properties of these two viruses. It was, therefore, considered worthwhile to reexamine serological relationship of these particles.

RTSV particles with and without RTBV particles respectively were purified following Mishra *et al.*[4] and the modified Saito's procedure[5] standardized in this laboratory (Niazi *et al.* unpublished). For preparing the antisera separately of RTSV with and without RTBV, rabbits were immunized separately with purified preparations by three intravenous injections followed by two intramuscular injections at weekly intervals. For intramuscular injections, antigen was mixed with equal volume of Freund's incomplete adjuvant. Rabbits were bled one week after the last injection for obtaining the antisera.

To study the serological relationship, combined immunosorbent electron microscopy (ISEM) and decoration technique[6] was followed and various combinations of coating, trapping and decoration were tested (Table 1).

The present studies indicate that S+B antibodies trapped both S+B antigens in the ratio of 5:3 from clarified diseased sap, while S antibodies not only trapped S antigens but also B antigens from clarified diseased sap and purified preparations of S+B antigens in the ratio of 7:1 (Figure 1*a*). In further experimenta-

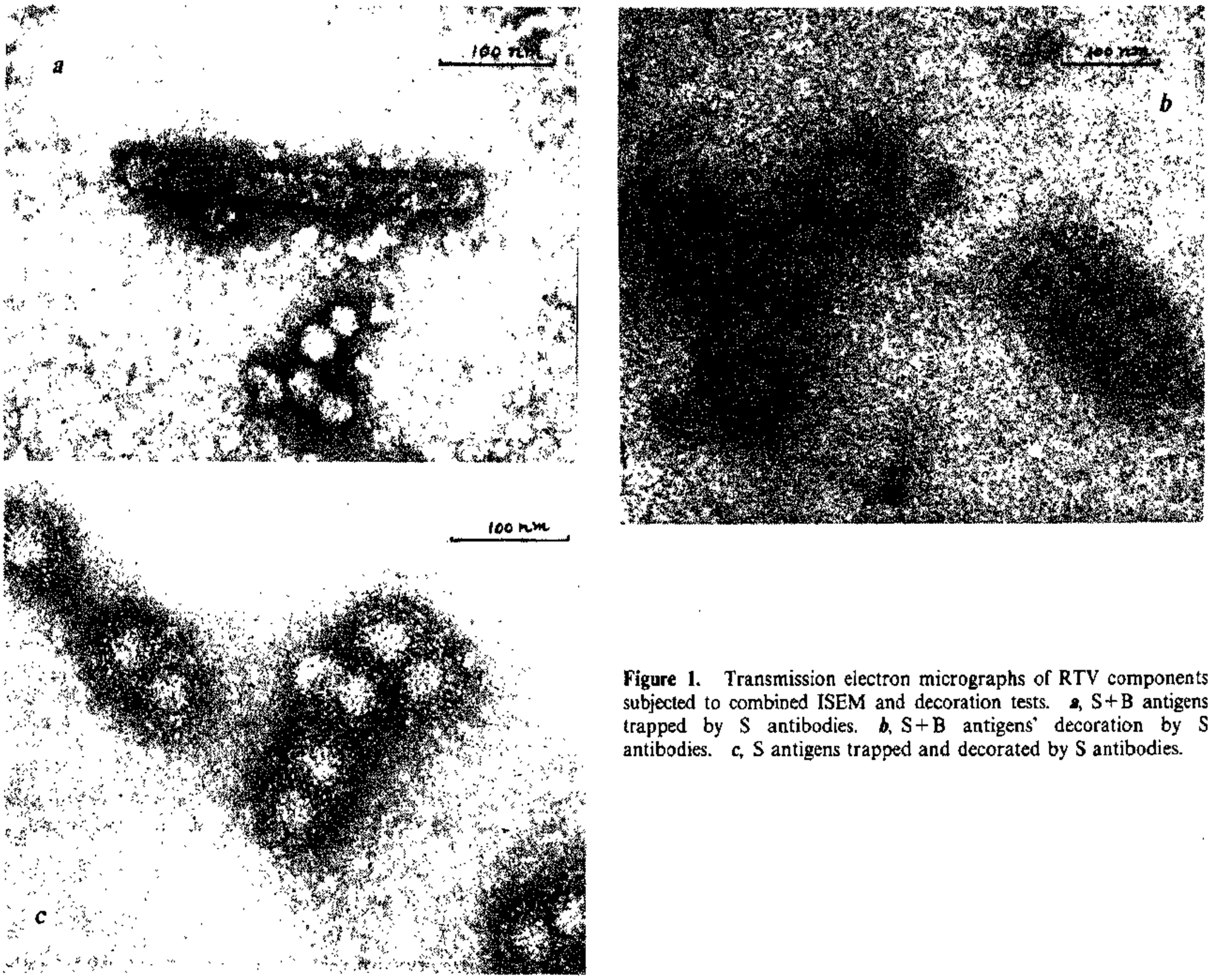

Figure 1. Transmission electron micrographs of RTV components subjected to combined ISEM and decoration tests. *a*, S+B antigens trapped by S antibodies. *b*, S+B antigens' decoration by S antibodies. *c*, S antigens trapped and decorated by S antibodies.