POLLEN MORPHOLOGICAL STUDIES IN *CAPSICUM* I. SPECIES AND VARIETIES

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Abstract

Pollen morphological study of eleven taxa of the genus *Capsicum* comprising five species, viz., *C. frutescens* L., *C. chinense* Jacq., *C. pendulum* Willd., *C. chacoense* Hunz., and seven varieties of *C. annuum* (*Cerasiformis, longum* 1068, *BOB, TNK, G3* (cultivated), *glabriusculum* and *antigua* (wild varieties) has been done. Pollen grains are tricolporate, angulaperturate and psilate. Detailed qualitative and quantitative study of the various palynological characters has enabled meaningful separation of species and varieties. The polar equatorial index (PEI) and polar area index (PAI) were calculated for each taxon and compared among themselves. *C. frutescens* shows relationship with the two wild varieties of *C. annuum*, viz., *glabriusculum* and *antigua* in its PEI suggesting that the two wild varieties may be assigned subspecific rank under *C. frutescens*, when PAI was employed relationship with *C. chacoense* and *C. annuum* var. *cerasifomis* came to light. Palynology clearly reveals that all the species involved in the present investigation are quite distinct from each other. The cytogenetic findings on the species and species hybrids of the present study support the findings of the palynological study.

Introduction

The recent trend among taxonomists is to adopt modern methods for the classification of plants taking evidences from various disciplines, such as anatomy, cytology, genetics, biochemistry, palynology etc., which would throw adequate light on the natural affinities among them. The genus *Capsicum* has a wide range of species (27) and a large number of varieties. Species differentiation and delimitation of the genus *Capsicum* still appears to be uncertain. Though palynology of some members of *Capsicum* has been studied by quite a few workers (Kessler, 1930 ; Erdtmans, 1952; Nair & Kapoor 1974; Basak, 1967; Murry & Eshbaugh, 1971; Rao & Shukla, 1975 and Raghuvanshi, 1976) these studies were either scanty or of a fragmentary nature. The present paper, therefore, deals with various aspects of pollen morphology of eleven taxa of the genus *Capsicum* for evaluating their inter-relationships.

Material and Methods

Genetic stocks of *C. frutescens* L., *C. chienense* Jacq., *C. pendulum* Willd., *C. chacoense* Hunz and cultivars of *C. annuum* L., viz., *Cerasiformis*, *longum* 1068, *G3*, *BOB*, *TNK* and wild varieties of *glabriusculum* and *antigua* obtained from various sources were maintained for several generations at the Andhra University, Botany Experimental Farm, Waltair. Fresh polliniferous material from the just opened flowers of buds which were about to open was collected from the above eleven taxa and was subjected to acetolysis treatment of Erdtman (1969). The methodology employed by us is similar to that of Clausen (1962), Stone (1963), Lewis (1965), Skavarla and Turner (1966), Punt (1968), Reitsma (1969), Muller (1969), Murry and Eshbaugh (1971) and Raghuvanshi (1976).

The observations were based on the study of both chlorinated and non-chlorinated grains. However, measurements were taken from fifty non-chlorinated grains per sample randomly selected but excluding the deviating or abortive grains. Various parameters such as polar diameter (P), equatorial diameter (E) and apocolpial diameter (A) at equatorial view and mesocolpial diameter (M) and equatorial diameter (E) at polar view were measured with Carl-Zeiss moving scale eye-piece micrometer and later converted into μm. The size was measured along both polar and equatorial axis. The apocolpial diameter was measured as the distance between the apices of the two colpi; polar equatorial index (PEI) was calculated by using the formula $PEI = P/E \times 100$ (Erdtman, 1952, 69) and polar area index (PAI) by using the formula $PAI = A/E \times 100$ (Faegri & Iverson, 1964; Murry & Eshbaugh, 1971). The range, mean, standard deviation, standard error, the analysis of variance and 't' tests were employed for comparisons of various categories of species following the procedures adopted by Snedecor and Cocharn (1967) and Kapur (1971).

The terminology employed is that of Faegri and Iverson (1964) and the pollen descriptions encompasing shape classes, size and apertural positions are based upon Erdtman's (1952, 1969) classification.

Description of Pollen Grains

1. *C. frutescens* var. *tabasco* L. *Shape:* Subprolate, triangular in polar view. *Size:* 24.33 ± 0.32 μm (P) $\times$ 21.06 ± 0.30 μm (E); $P/E \times 100 = 115.32 \pm 1.30$ μm and $PAI = 27.98 \pm 1.00$ μm; *Structure*: Exine tectate 1.17 ± 0.01 μm thickness. Ektexine thicker than the endexine. A general thickening noticeable near the apertures. In polar view the equatorial diameter 23.07 ± 0.21 μm, mesocolpial diameter 14.69 ± 0.30 μm and apocolpial diameter was 5.84 ± 0.22 cm in equatorial view. *Apertures:* Tricolporate, rarely tetracolporate, angulaperturate, os lalongate, extends half width of the grain, and appears to be deeply constricted, lateral ends slightly pointed surface psilate (Pl. 1, Figs. 1-3, Table 1).

2. *C. chinense* var. *mishme* Jacq. *Shape:* Oblate-spheroidal, Subtriangular, in polar view. *Size:* 25.69 ± 0.22 μ (P) $\times$ 26.53 ± 0.21 μ (E) $PEI = 96.75 \pm 0.86$ μ and $PAI = 17.30 \pm 0.33$ μ. *Structure*: Exine tectate, 1.13 ± 0.02 μ thick. Ektexine thicker than endexine. Indistinct margos present. In polar view equatorial diameter 25.59 ± 0.17 μ, apocolpial diameter 4.58 ± 0.08 μ and mesocolpial diameter 21.87 ± 0.21 μ. *Apertures*: Tricolporate, anguloperturate, os lalongate, extends half the width of the grain and appears to be deeply constricted, outer ends rounded. Surface psilate (Figs. 4-6, Table 1).

3. *C. pendulum*: *Shape:* prolate-spheroidal, sub-triangular in polar view. *Size:* 24.77 ± 0.15 μ (P) $\times 23.53 \pm 0.21$ μ (E) $PEI = 105.60 \pm 0.93$ μ and $PAI = 17.96 \pm 0.43$ μ. *Structure:* Exine tectate 1.15 ± 0.01 μ thick, Ektexine and endexine nearly equal in thickness, slightly thickened margos present near the apertures. In polar view equatorial diameter 24.62 ± 0.22 μ, apocolpial diameter 4.21 ± 0.09 μ and mesocolpial diameter 15.63 ± 0.38 μ. *Apertures:* Tricolporate, angulaperturate, colpae distinct bordered by margos, os lalongate, deeply constricted, extends half the width of the grain, outer ends slightly rounded. Surface psilate (Pl. 1, Figs. 7-9, Table 1).

4. *C. chacoense:* Shape prolate spheroidal, triangular in polar view. *Size:* 27.54 ± 0.22 μ (P) $\times 25.22 \pm 0.24$ μ (E) $PEI = 109.45 \pm 0.80$ μ and $PAI = 20.21 \pm 0.39$ μ. *Structure:* Exine tectate 1.18 ± 0.02 μ thick, distinct margos present near the aperture. In polar view, equatorial diameter 26.13 ± 0.24 μ, apocolpial diameter 5.10 ± 0.11 μ and meso-

Table 1—Mean frequency of pollen parameters of the species and varieties of *Capsicum* L. and their chromosome number

Taxa	2n	Polar diameter p (in Microns)	Equatorial diameter (equatorial view) (in Microns)	Polar equatorial index P/E X 100	Equatorial diameter (Polar view)	Apocolpial diameter	Mesocolpial diameter	Polar area index A/E X 100
C. annuum var. *cerasiformis*	24	23.53± 0.22 (20.01—26.72)	21.45± 0.26 (18.32—24.34)	110.18± 0.95 (91.20—123.63)	22.86± 0.25 (17.79—26.02)	4.37±0.14 (2.83—6.90)	16.05 ± 0.31 (10.62—20.44)	20.51± 0.70 (11.72—29.06)
C. annuum var. *longum* 1068	24	23.45± 0.15 (21.06—26.28)	22.79± 0.17 (20.44—2.39)	103.11± 0.71 (96.04—114.61)	21.03± 0.21 (18.58—24.07)	4.19±0.12 (2.82—5.49)	12.85 ± 0.17 (10.71—16.37)	18.15± 0.55 (10.87—25.63)
C. annuum var. *BOB*	24	23.27± 0.31 (19.38—26.64)	23.49± 0.33 (15.52—26.99)	99.53± 1.30 (86.34—121.33)	21.08 ± 0.17 (18.58—23.09)	4.14±0.14 (2.48—6.55)	12.51± 0.19 (10.62—15.40)	17.61± 0.53 (9.12—26.06)
C. annuum var. *TNK*	24	23.06± 0.27 (19.38—25.84)	23.70± 0.36 (18.58—27.17)	98.21± 1.68 (80.99—127.27)	22.63± 0.30 (17.69—28.94)	4.35 œ0.17 (2.03—8.23)	13.90± 0.32 (10.71—21.33)	18.37± 0.65 (8.22—27.48)
C. annuum var. *G3*	24	25.08± 0.17 (20.97—27.70)	23.86± 0.21 (19.20—26.72)	106.07± 1.01 (93.41— 29.06)	23.62 ± 0.20 (19.47—25.93)	4.43± 0.14 (1.95—6.72)	15.05±0.14 (10.53—19.38)	18.67± 0.58 (7.81—29.06)
C. annuum var. *glabriusculum*	24	29.19± 0.45 (23.72—33.80)	23.17± 0.22 (20.35—25.75)	125.93± 1.51 (92.45—146.09)	24.03± 0.70 (20.35—26.37)	1.89±0.26 (0.00—5.40)	15.68± 0.32 (11.41—21.24)	8.17± 1.12 (0.00—21.63)
C. annuum var. *antigua*	24	18.18± 0.26 (14.51—21.68)	15.52± 0.29 (9.29—21.06)	118.09 ± 2.78 (69.03—190.53)	15.64± 0.21 (13.18—19.20)	2.26±0.24 (0.00—4.51)	9.14± 0.25 (6.02—15.04)	14.60± 1.59 (0.09—38.11)
C. frutescens var. *tabasco*	24	24.33± 0.32 (19.47—31.06)	21.06± 0.30 (18.49—25.75)	115.32± 1.30 (92.58—141.24)	23.07± 0.21 (20.44—25.75)	5.84±0.22 (3.54—9.73)	14.69± 0.30 (10.53—19.47)	27.98± 1.00 (16.53—42.30)
C. chinense var. *mishme*	24	25.68± 0.22 (20.97—27.88)	26.53± 0.21 (21.59—28.58)	96.75± 0.86 (91.22—110.66)	25.59± 0.17 (23.80—28.49)	4.58±0.08 (3.36—5.58)	21.87± 0.21 (18.69—25.08)	17.30± 0.33 (12.29—20.97)
C. pendulum	24	24.77± 0.15 (22.03—27.52)	23.53± 0.21 (18.41—25.40)	105.60+ 0.93 (94.31—133.62)	24.62± 0.22 (20.27—27.52)	4.21±0.09 (3.27—6.28)	15.63± 0.38 (11.50—22.00)	17.96± 0.43 (11.89—28.51)
C. chacoense	24	27.54± 0.22 (24.34—32.21)	25.22± 0.24 (22.92—30.09)	109.45± 0.80 (92.20—121.15)	26.13± 0.24 (23.27—30.17)	5.10±0.11 (3.45—6.64)	18.81± 0.47 (11.06—25.66)	20.21± 0.29 (14.88—26.66)

colpial diameter 18.81$\pm$0.47 μ. *Apertures:* Tricolporate, angula aperturate, or lalongate, deeply constricted extends half the width of the grain, outer ends slightly rounded. Surface psilate (Pl. 1, Figs. 10-12, Table 1).

5. *C. annuum* var. *cerasiformis:* Shape prolate-spheroidal, triangular in polar view. *Size*: 23.53$\pm$0.22 μ (P) x 21.45$\pm$0.26 (E), PEI=110.18$\pm$0.95 μ and PAI=20.51$\pm$0.70 μ. *Structure*: Exine tectate, 1.35$\pm$0.01 μ in thickness. Ektexine and endexine nearly equal in thickness. A general thickening noticeable near the apertures. In polar view equatorial diameter 22.86$\pm$0.25 μ, apocolpial diameter 4.37$\pm$0.14 μ and mesocolpial diameter 16.05$\pm$0.31 μ. *Apertures:* Tricolporate, angulaperturate, colpae bordered by distinct margos. Os lalongate deeply constricted, extends half the width of the grain, outer ends tapering. Surface psilate (Figs. 13-15, Table 1).

6. *C. annuum* var. *longum* 1068: Shape prolate spheroidal, subtriangular in polar view. *Size*· 23.45$\pm$0.15 μ (P)$\times$22.79$\pm$0117 (E) PEI=103.11$\pm$0.77 μ and PAI=18.15 $\pm$0.55 μ. *Structure*: Exine tectate, 1.19$\pm$0.02 μ thick, Ektexine and endexine nearly equal in thickness. A general thickening present near the apertures. In polar view equatorial diameter 21.03$\pm$0.21 μ, apocolpial diameter 4.19$\pm$0.12 μ and mesocolpial diameter 12.85$\pm$0.17 μ. *Apertures*: Tricolporate, angulaperturate, indistinct margos. Os lalongate, deeply constricted, extends half the width of the grain, outer ends tapering (pointed) surface psilate (Pl. 2, Figs. 16-18, Table 1).

7. *C. annuum* var. *BOB:* Shape suboblate,semiangular in polar view. *Size:* 23.27$\pm$0.31 μ (P)$\times$23.49$\pm$0.33 μ (E), PEI=99.53$\pm$1.30 μ and PAI=17.61$\pm$0.53 μ. *Structure*: Exine tectate, 1.06$\pm$0.01 μ in thickness, Ektexine and endexine nearly equal in thickness. A general thickening noticeable near the apertures. In polar view equatorial diameter 21.08$\pm$0.17 μ, apocolpial diameter 4.14$\pm$0.14 μ and mesocopial diameter 12.5$\pm$0.19 μ. *Apertures:* Tricolporate, angulaperturate, colpae bordered by distinct margos. Os lalongate, deeply constricted, extends half the width of the grain, outer ends slightly rounded. Surface psilate (Pl. 2, Figs. 19-21, Table 1).

8. *C. annuum* var. *TNK*: Shape oblate-spheroidal, subtriangular in polar view. *Size:* 23.06$\pm$0.27 μ (P)$\times$23.70$\pm$0.36 μ (E), PEI= 98.21$\pm$1.68 μ and PAI=18.37$\pm$0.65 μ. *Structure:* Exine tectate 1.31$\pm$0.09 μ thick, ektexine and endexine nearly equal in thickness. A general thickening present near the apertures. In polar view, equatorial diameter 22.63$\pm$0.30 μ, apocolpial diameter 4.35$\pm$0.17 μ and mesocolpial diameter 13.90$\pm$0.32 μ. *Apertures*: Tricolporate, angulaperturate, colpae bordered by distinct margos, os lalongate, deeply constricted, extends more than half the width of the grain; outer ends slightly rounded. Surface psilate (Pl. 2, Figs. 22-24, Table 1).

9. *C. annuum* var. *G3*: Shape prolate-spheroidal, subtriangular in polar view. *Size:* 25.08$\pm$0.17 μ (P)$\times$23.86$\pm$0.21 μ (E), PEI=106.07$\pm$1.01 μ and PAI=23.62$\pm$0.20 μ. *Structure*: Exine tectate, 1.04$\pm$0.03 μ thick, ektexine thicker than the endexine. A general thickening present near the apertures. In polar view, equatorial diameter 23.86$\pm$0.21 μ, apocolpial diameter 4.43$\pm$0.14 μ. *Apertures:* Tricolporate, angulaperturate, colpae bordered by distinct margos, os lalongate deeply constricted, extends more than half the width of the grain, lateral ends slightly pointed. Surface psilate (Pl. 1, Figs. 25-27, Table 1).

10. *C. annum* var. *glabriusculum:* Shape subprolate, triangular in polar view. *Size:* 29.19$\pm$0.45 μ (P) x 23.17$\pm$0.22 (E), PEI=125.93$\pm$1.51 μ and PAI—8.17$\pm$1.12 μ. *Structure*: Exine tectate, 1.29$\pm$0.01 μ in thickness, ektexine thicker than the endexine. A general thickening noticeable near the apertures. In polar view the equatorial diameter 24.03$\pm$0.20 μ, apocolpial diameter 1.89$\pm$0.26 μ in equatorial view, and mesocolpial

diameter 15.68±0.32 μ. *Apertures:* Tricolporate, rarely tetracolporate, angulaperturate, colpae bordered by distinct margos. Os lalongate deeply constricted extends half the width of the grain, surface psilate (Pl. 3, Figs. 28-30, Table 1).

11. *C. annuum* var. *antigua:* Shape subprolate, triangular in polar view. *Size:* 18.10±0.26 μ (P) × 15.52±0.29 μ (E), PEI=118.09±2.78 μ and PAI=14.60±1.59 μ. *Structure:* Exine tectate 1.12±0.01 μ thick, ektexine thicker than the endexine. A general thickening noticeable near the apertures. In polar view equatorial diameter 15.64±0.21 μ, mesocolpial diameter 9.14±0.25 μ and apocolpial diameter 2.26±0.24 μ in equatorial view. *Apertures:* Tricolporate, angulaperturate, colpae bordered by distinct margos, os lalongate deeply constricted, extends half the width of the grain, otuer ends slightly rounded. Surface psilate (Pl. 3, Figs. 31-33, Table 1).

Taxonomical considerations and evolutionary significance

The present study reveals that pollen morphology of the species and varieties of *Capsicum* by and large is homogeneous; however, in respect of certain features they differ which facilitates categorising them as distinct species and varieties. The shape of the pollen grain is determined using the polar equatorial index. The pollen grains of *Capsicum* are generally subprolate to prolate-spheroidal (Erdtman, 1952; Basak, 1967; Murry & Eshbaugh, 1971; Nair & Kapoor, 1974; Rao & Shukla, 1975; Raghuvanshi, 1976). But in *Capsicum baccatum*, *C. cardenasii* and *C. chacoense* the pollen grains are prolate (Murry & Eshbaugh, 1971). However in the present study three types of pollen grains are recorded, viz., subprolate (*C. frutescens*, *C. annuum* varieties *glabriusculum* and *antigua*) having a mean PEI of 115.32±1.30 μm, 125.93±1.51 μm and 118.09±2.78 μm respectively). Prolate-spheroidal (*C. pendulum*, *C. chacoense* and *C. annuum* cultivars, viz., *cerasiformis*, *longum* 1068, *G3* having a mean PEI of 105.60±0.93, 109.45±0.80, 110.18±0.95, 103.11±0.77 and 106.07±1.01 μm respectively) and oblate spheroidal (*C. chinense*, *C. annuum* cultivars *BOB* and *TNK* having a mean PEI of 96.75±0.86, 99.53±1.30 and 98.21±1.68 μm respectively). Basing on the pollen morphological characters, Basak (1967) described the pollen types in *Capsicum* as 'Solanum type'. The size, shape, besides the structure of the wall, aperture and os are considered to be of diagnostic value and are given due importance in the classification of pollen grains. In polar view the shape markedly varies with the species and is considered to be valuable. Muller (1969) has also applied this criterion in his studies on *Sonneratia* species and hybrids. In polar view the pollen grains are uniformly triangular to subtriangular and angulaperturate in all the 11 taxa of the present study. In the two wild varieties of *C. annuum*, viz., var. *glabriusculum* and var. *antigua* the pollen grains are mostly irregular due to reduced fertility, a feature also met with by Raghuvanshi (1976) in his wild varieties of *C. annuum*.

Structural and sculptural characters visible with light microscope show slight variations between the species and varieties of *Capsicum*. In all the 11 taxa the exine is tectate and 1.04-1.35 μ thick. Ektexine is thicker than the endexine in six taxa (*C. frutescens*, *C. chinense*, *C. annuum* varieties *G3*, *glabriusculum* and *antigua*) while in the remaining five, ektexine and endexine are more or less of the same thickness. In all taxa a general thickening of the ektexine near the apertures was noticed except in *C. chinense*. This may be due to the furrows completely bordered by margos. Similar findings were recorded by Murry and Eshbaugh (1971) in the Solaninae complex.

Pollen size is considered to be an important diagnostic character in *Capsicum* as evidenced by significant differences between the species and varieties of the present study.

The size was measured along the polar axis. Based upon the size, the pollen grains are classified into two types; small (10-25 μ) and medium (25-50 μ) classes (Erdtman, 1952; Murry & Eshbaugh, 1971; Lydia Prasad *et al.*, 1984). Accordingly the pollen grains of *C. frutescens*, *C. pendulum*, *C. annuum* varieties, viz., *Cerasiformis longum* 1068, *BOB*, *TNK* and *antigua* belong to the small class (mean range varied from 18.18 to 24.77 μ) while *C. chinense*, *C. chacoense*, *C. annuum* var. *G3* and var. *glabriusculum* belong to the medium class (mean range varied from 25 to 29.19 μ).

The relative size of the polar area based on polar area index (PAI) has been suggested as an important tool for the purpose of species separation (Faegri & Iverson 1964; Murry & Eshbaugh 1971, and Lydia Prasad *et al.*, 1984). Based on the polar area index Murry & Eshbaugh, (1971); established discrete size classes for the genera of the Solaninae complex and *Capsicum*. According to them *C. baccatum*, *C. cardenasii*, *C. chacoense* and *C. eximurum*, whose PAI varied between 20.71 and 27.08 were placed under medium class. Higher polar area index was reported in *C. pubescens* (Murry & Eshbaugh, 1971) and in *C. microcarpum* (Raghuvanshi, 1976). For members of *Capsicum* of the present study the following classes depending upon PAI are suggested. (1) small polar area index (PAI) between 0-10 μ (*C. annuum* var. *glabriusculum*). (2) intermediate PAI between 11-20 μ (*C. chinense*, *C. pendulum*, *C. chacoense* and six varieties of *C. annuum*, viz., *cerasiformis*, *longum* 1068, *BOB*, *TNK*, *G3* and *antigua* (3) larger PAI (i. e. more than 20 μ eg. *C. frutescens*).

The endoaperture (os) is found to be lalongate in all the species and varieties of the present study and the differences lie only in its constricted or non-constricted nature; os extended half or three fourth of the width of the grain. In seven taxa (*C. frutescens*, *C. annuum* varieties, viz., *cerasiformis*, *longum* 1068, *BOB*, *TNK*, *G3* and *glabriusculum*), Os is constricted and lateral ends tappering to pointed and circular, os was observed in the remaining four taxa (*C. chinense*, *C. pendulum*, *C. chacoense* and *C. annuum* var. *antigua*) of the present investigation. Among the constricted or non-constricted, Os, only the tapering or pointed ends were reported in some species of *Capsicum* by Murry and Eshbaugh (1971) and by Raghuvanshi (1976) in some species and varieties of *Capsicum*. However, in the present study both tapering and circular type of os were met with.

Analysis of variance was applied to test the various categories of quantitative measurements for each species and the varieties. The 'F' values indicate highly significant differences showing that the characters are reliable for separating the species and varieties (Table 2). Applying the same statistical test Murry and Eshbaugh (1971) found that the 'F' values were highly significant, delimiting *C. baccatum* from *C. pubescens* in respect of equatorial diameter. They stated that the need for more characters be taken into consideration for species delimitation. In the present study the same statistical test was applied to all the five species and varieties of *C. annuum*. These studies revealed that there are enough differences between the five species prompting them to be recognised as distinct species. Similarly significant differences were noticed between the varieties of *C. annuum*.

Inter-relationships among 11 taxa have been studied employing the PEI and PAI. When PEI and PAI were taken together similarity was observed between *C. chinense*, *C. pendulum*, *C. chacoense* and five cultivars of *C. annuum*, viz., *cerasiformis*, *longum* 1068, *BOB*, *TNK* and *G3*. However, when PEI alone was employed as a parameter marked similarity was noticed between *C. frutescens* and two wild varieties of *C. annuum*, viz., *glabriusculum* and *antigua*. This view point was further augmented by the evidence obtained from crossability relationships between *C. frutescens* and wild varieties of *C. annuum* which yielded rather highly fertile hybrids indicating closer relationship among them (R. C. Panda unpublished). When PAI alone was taken *C. frutescens* showed similarity with *C. annuum*

Table 2—Analysis of variance for various quantitative characters of the pollen grains in species and varieties of *Capsicum*

Source	df	Polar diameter			Equatorial diameter			Polar equatorial index			Apocolpial diameter			Polar area index		
		S.S.	M.S.	'F' value	S.S.	M.S.	'F' value	S.S.	M.S.	'F' value	S.S.	M.S.	'F' value	S.S.	M.S.	'F' value
For all species																
Total	249	1143.50			1867.08			21415.6			319.57			8366.23		
Between the species	4	471.03	117.76	42.82*	1115.00	278.75	90.80*	9565.3	2391.33	49.44*	88.16	22.04	22.45*	3617.83	904.46	49.48*
Within the species	245	672.47	2.75		752.08	3.07		11850.3	48.37		231.41	0.94		4478.40	18.28	
For all varieties																
Total	349	4476.54			3905.91			7754.10			913.24			18803.68		
Between the varieties	6	3156.42	526.07	136.64*	2640.33	440.06	119.26*	30990.77	5165.13	424.07*	358.78	59.80	36.91*	5054.35	842.39	21.02*
Within the varieties	343	1320.12	3.85		1265.58	3.69		44176.33	12.18		554.46	1.62		13749.33	40.09	

* 'F' value significant at 1% leve

var. *glabriusculum* and *C. chacoense*. However, when PEI and PAI were taken together all the cultivated varieties of *C. annuum* resemble each other more closely, but differ from that of wild varieties. This view is also supported by the fact that highly fertile hybrids with heterotic vigour were obtained between the cultivars of *C. annuum* while the hybrids between the wild and cultivated varieties of *C. annuum* yielded partially sterile hybrids. Similar studies were also made in the species of *Physalis* (Lydia Prasad *et al.*, 1984) to deduce relationships among them.

For the purpose of demarcating the various species in *Capsicum*, two parameters such as PAI and PEI were employed. Significant differences have been recorded between the five species thus implying the distinctness of each species (Table 3). Cytogenetic analysis of these five species also suggest them to be distinct species, further supporting the palynological evidence (Aniel Kumar, 1984). However, when other parameters were employed the differences were insignificant among them. Similar differences were noticed between the varieties of *C. annuum*, when the above two parameters (PEI and PAI) were employed suggesting that these are distinct varieties.

Table 3—Comparisons of polar equatorial index and polar area index in the species of *Capsicum* L.

Species compared		Polar equatorial index 't' values	Polar area index 't' values
C. annuum	—*C. frutescens*	3.42	8.83
C. annuum	—*C. chinense*	7.18	0.82
C. annuum	—*C. pendulum*	1.84	1.50
C. annuum	—*C. chacoense*	0.44	4.00
C. frutescens	—*C. chinense*	11.92	10.14
C. frutescens	—*C. pendulum*	6.09	9.19
C. frutescens	—*C. chacoense*	3.85	7.22
C. chinense	—*C. pendulum*	8.85	1.22
C. chinense	—*C. chacoense*	10.77	5.68
C. pendulum	—*C. chacoense*	3.13	3.86

Table value 1.98 at 0.05.

The study of the pollen of *Capsicum* highlights that features such as size, apocolpial diameter, endoaperture and PAI are useful in assessing and evaluating the taxonomic relationships between the species. Such studies have prompted the authors to postulate that probably the two wild varieties of *C. annuum*, viz., *glabriusculum* and *antigua* may be elevated and assigned a subspecies rank under *C. frutescens*. It is pertinent to note that exomorphological and cytological findings also indicate considerable differences between the wild varieties of *C. annuum* and the cultivated varieties of this taxon.

Acknowledgements

Thanks are given to Mr K. Prakasha Rao for his help in photography work; to the C. S. I. R. and U. G. C. (New Delhi) for financial assistance to OAK and RCP respectively.

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Explanation of Plates

Plate 1

(For all figures magnification bar represents 10 μ.)

1-3. Pollen grains of *C. frutescens* var. *tabasco*.

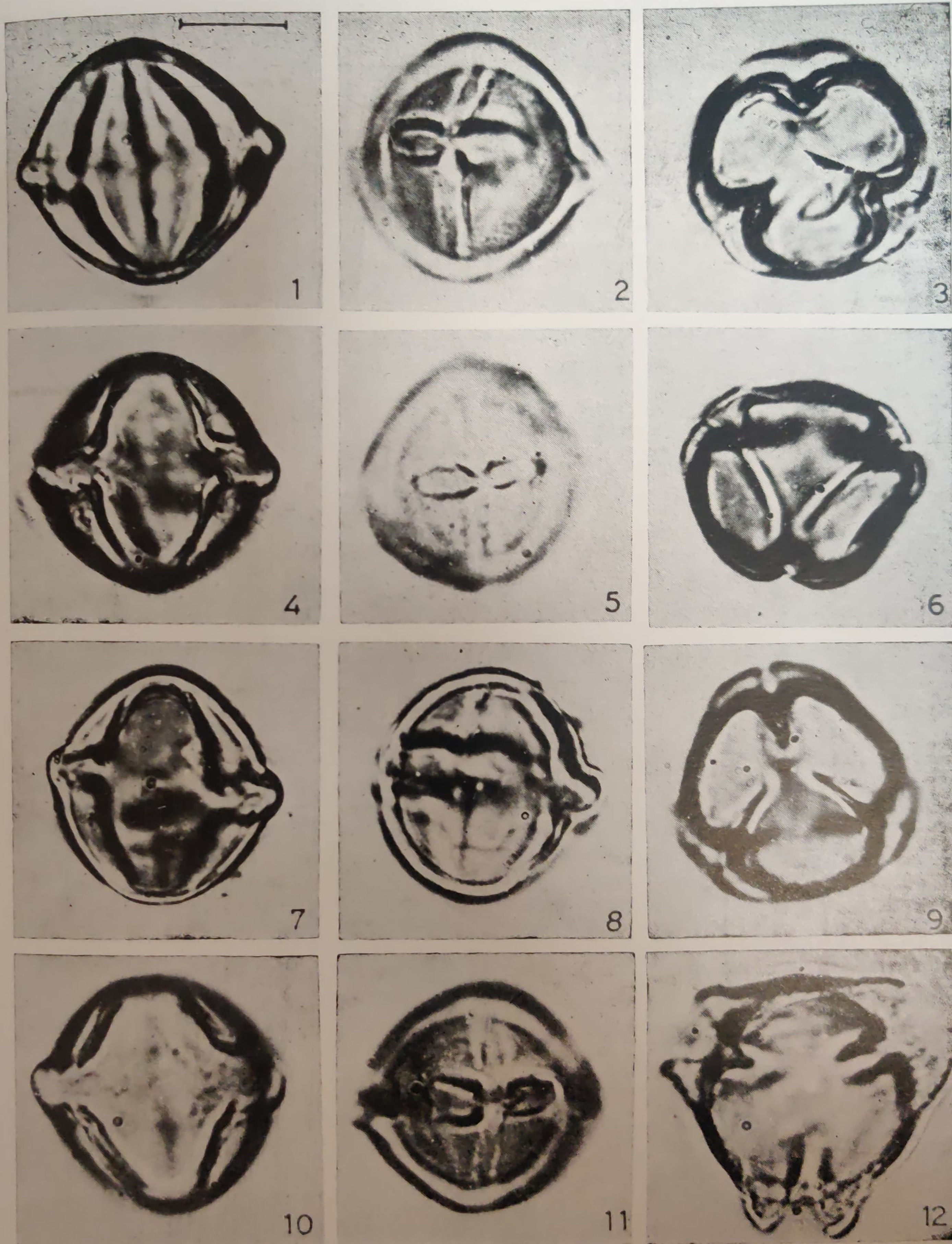
1. Equatorial view showing "Mesocolpium" bounded by two adjacent colpae
2. Equatorial view showing deeply constricted os
3. Polar view showing tricolporate condition

4-6. Pollen grains of *C. chinense* var. *mishme*

4. Equatorial view showing colpae
5. Equatorial view showing deeply constricted os
6. Polar view showing well developed margos

7-9, 7-9: Pollen grains of *C. pendulum*

7. Equatorial view showing colpae
8. Equatorial view showing constricted os
9. Polar view showing well developed margos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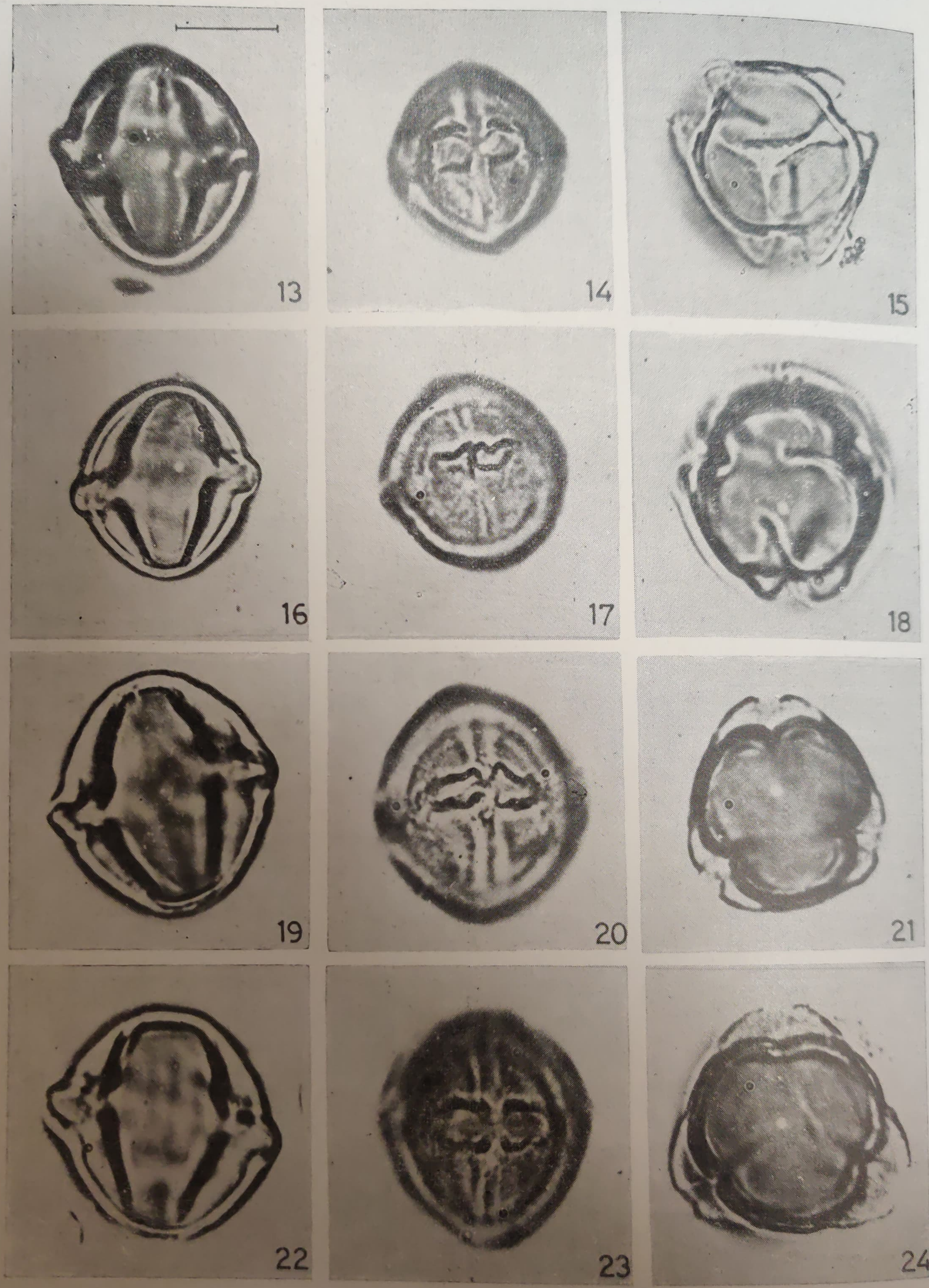
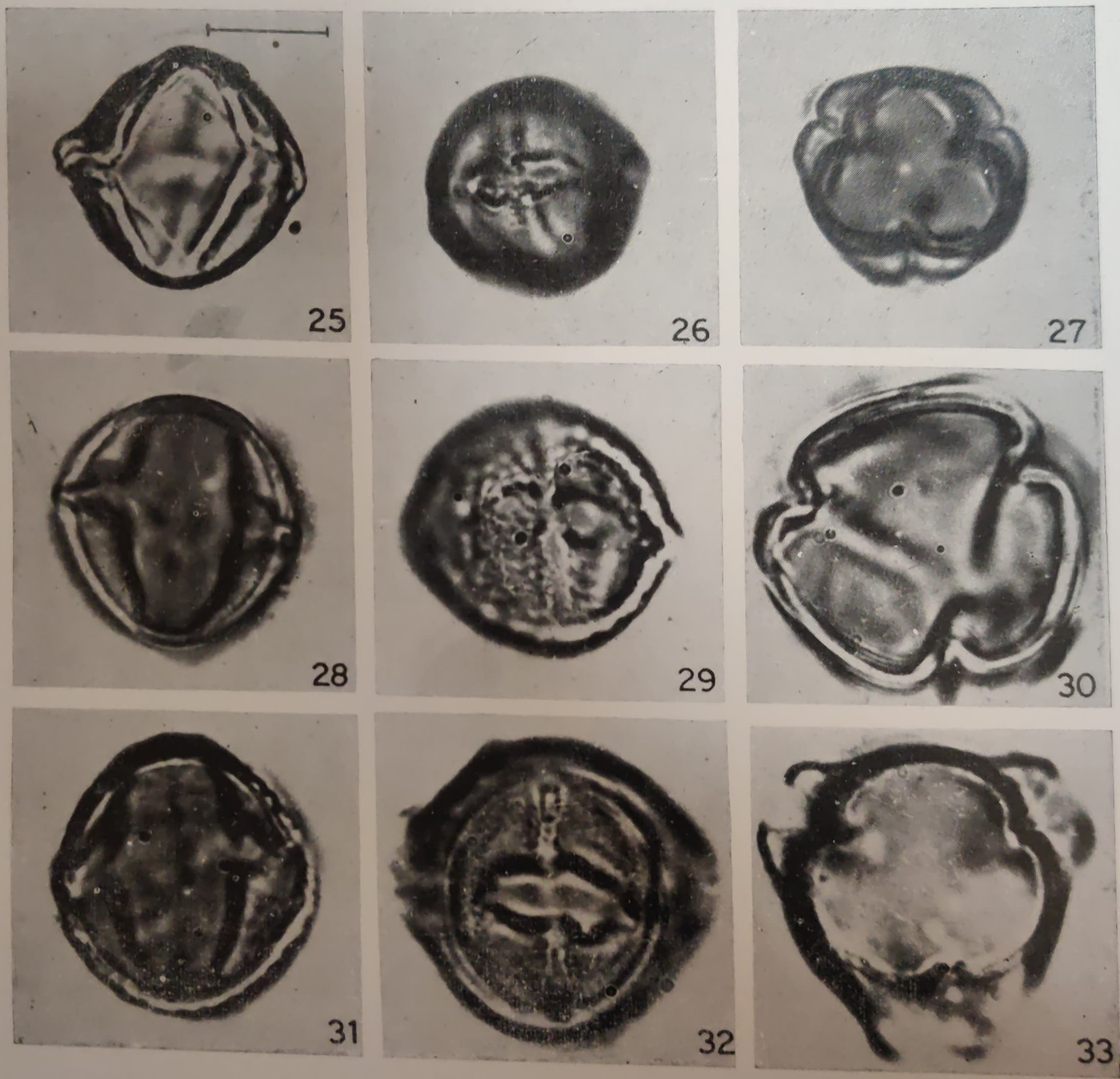


Kumar *et al.*—Plate 2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10-12. Pollen grains of *C. chacoense*

10. Equatorial view showing colpae
11. Equatorial view showing deeply constricted os
12. Polar view showing well developed margos

Plate 2

(For all figures magnification bar represents 10 μ,)

13-15. Pollen grains of *C. annum* var. *cerasiformum*

13. Equatorial view showing colpae
14. Equatorial view showing constricted os
15. Polar view showing tricolporate condition

16-18. Pollen grains of *C. annumum* var. *longum* 1068.

16. Equatorial view showing colpae
17. Equatorial view showing constricted os
18. Polar view showing tricolporate condition with margos

19-21. Pollen grains of *C. annumum* var. *BOB*

19. Equatorial view showing well separated colpae
20. Equatorial view showing constricted os
21. Polar view showing ill-defined margos

22-24. Pollen grains of *C. annuum* var. *TNK*

22. Equatorial view showing colpae
23. Equatorial view showing deeply constricted os
24. Polar view showing margos

Plate 3

(For all figures magnification bar represents 10 μ.)

25-27. Pollen grains of *C. annuum* var. *G3*

25. Equatorial view showing syncolporate condition
26. Equatorial view showing constricted os
27. Polar view showing tricolporate condition with margos

28-30. Pollen grains of *C. annuum* var. *glabriusculum*

28. Equatorial view showing colpae
29. Equatorial view showing constricte dos
30. Polar view showing well developed margos

31-33. Pollen grains of *C. annuum* var. *antigua*

31. Equatorial view showing colpae
32. Equatorial view showing deeply constricted circular os
33. Polar view showing margos