

POLLEN MORPHOLOGICAL STUDIES IN *CAPSICUM*-II. INTERSPECIFIC HYBRIDS, INDUCED TETRAPLOIDS AND DESYNAPTIC MUTANTS

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Abstract

Detailed pollen morphology has been studied in eight F_1 interspecific hybrids, two induced autotetraploids and one desynaptic mutant. The pollen grains are prolate-spheroidal to subprolate, tricolporate to tetracolporate and psilate. The size of the grains showed variation at different ploidy levels. The variation in size and shape, apocolpial diameter, and mesocolpial diameter is higher in induced autotetraploids and desynaptic mutant, but intermediate in F_1 hybrids. Finally, the significance of pollen morphology in unravelling the evolutionary status of the above taxa *vis-a-vis* their parents has also been discussed.

Introduction

The importance of pollen morphology as an expression of the geographical distribution, genomal constitution, taxonomy and evolution of plants has been demonstrated in recent years. Palynology of species and varieties of the genus *Capsicum* has been studied and the interrelationships among them were deduced in part I. Information on the pollen morphology of species hybrids, induced polyploids and desynaptic mutants in angiospermic taxa is rather meagre. There are, however, a few reports on the pollen morphology of interspecific hybrids, viz., *Sonneratia* (Muller, 1969), *Hibiscus* (Nair, 1961), *Amaranthus* (see Nair, 1970; Pal & Khoshoo, 1966) and *Physalis* (Lydia Prasad *et al.*, 1984). Similarly a few reports on pollen morphology of polyploids, viz., Rice (Sampath & Ramathan 1951; Maurizio, 1956; Rangaswamy & Raman, 1973) and *Physalis* (Lydia Prasad *et al.*, 1984) have been made. Also the pollen morphology in induced mutants has been investigated in *Pimpinella* (Joshi & Raghuvanshi, 1967) and *Capsicum* (Raghuvanshi, 1976). Still there is no information available on the palynology of the interspecific hybrids, induced polyploids and desynaptic mutants in the genus *Capsicum*. The present study documents for the first time the pollen morphology of species hybrids, induced polyploids and mutants of *Capsicum* and its significance in our understanding of the interrelationships of these taxa.

Materials and Methods

The eight interspecific F_1 hybrids, viz., *C. annuum* var. *G3* \times *C. frutescens*, *C. annuum* var. *cerasiformis* \times *C. chinense* var. *mishme*, *C. annuum* var. *cerasiformis* \times *C. pendulum*, *C. frutescens* var. *tabasco* \times *C. annuum* var. *cerasiformis*, *C. chinense* \times *C. frutescens*, *C. chacoense* \times *C. annuum* var. *BOB*, *C. chacoense* \times *C. chinense* var. *mishme* were obtained through artificial hybridization. Autotetraploids were obtained in two cultivars of *C. annuum* through colchicine administered to the seedlings by the following methods: (i) 10 day old seedlings of *C.*

annuum var. *cerasiformis* were treated with aqueous solution of 0.3% colchicine by applying the chemical to the apical growing buds using a small cotton plug to keep the bud continuously wet for two days, (ii) the growing tips of three-week old seedlings of *C. annuum* var. *TNK* in the field at eight leaves stage were cut and 0.3% aqueous solution of colchicine in cotton swabs was applied to the cut end continuously for six hours. A induced desynaptic mutant was obtained through the seed treatment of 0.2% aqueous colchicine solution for 48 hours.

The fresh polliniferous material of interspecific hybrids, tetraploids and the desynaptic mutants were collected from the adult plants. Pollen preparations were made by revised acetolysis method of Erdtman (1969). Observations have been recorded with the help of light microscopy (Carl Zeiss binocular). The measurements are based on an average of fifty non-chlorinated grains randomly selected but excluding the deviating or abortive pollen. The terminology used is that of Faegri and Iverson (1964) and Murry and Eshbaugh (1971) and the descriptions of pollen are in accordance with Erdtman (1952, 1969).

Description of Pollen Grains

I. Interspecific hybrids:

1. *C. annuum* var. *G3* × *C. frutescens* var. *tabasco*: *Shape*: prolate-spheroidal to subprolate, semi-angular in polar view, *Size*: $23.73 \pm 1.46 \mu$ (P) × $20.44 \pm 0.11 \mu$ (E) PEI = $109.25 \pm 0.53 \mu$ and PAI = $15.33 \pm 0.43 \mu$ size varied from very small to larger pollen grains. *Structure*: Exine tectate $1.24 \pm 0.01 \mu$ thick, ectexine thicker than endexine. A general thickening noticeable near the apertures. In polar view equatorial diameter $20.57 \pm 0.9 \mu$, mesocolpial diameter $12.56 \pm 0.14 \mu$ and apocolpial diameter $3.13 \pm 0.09 \mu$ in equatorial view. *Apertures*: Tricolporate, angulaperturate, inaperturate grains also observed rarely. Margos distinct, os lalongate, constricted, extends half the width of the grain. Sometimes the apertures irregularly or obliquely placed, surface psilate (Pl. 1, Figs. 1-3; Table 1).

2. *C. annuum* var. *cerasiformis* ± *C. chinense* var. *mishme*: *Shape*: prolate-spheroidal, subtriangular in polar view, *Size*: $24.87 \pm 0.29 \mu$ (P) ± $22.48 \pm 0.29 \mu$ (E), PEI = $110.96 \pm 1.27 \mu$ and PAI = $17.09 \pm 0.74 \mu$. Size also varies from very small to large, aborted grains very irregular. *Structure*: Exine tectate $1.16 \pm 0.01 \mu$ thick, ectexine and endexine nearly of same thickness. In polar view equatorial diameter $20.57 \pm 0.33 \mu$, mesocolpial diameter $12.44 \pm 0.28 \mu$ and apocolpial diameter $3.83 \pm 0.17 \mu$ in equatorial view. *Apertures*: mostly tricolporate, either irregular or obliquely placed, angulaperturate, os lalongate, constricted os extends half the width of the grain, outer ends tapering to slightly rounded. Surface psilate (Pl. 1, Figs. 4-6; Table 1).

3. *C. annuum* var. *cerasiformis* × *C. pendulum*: *Shape*: prolate-spheroidal, subtriangular in polar view. *Size*: $25.53 \pm 0.25 \mu$ (P) × $22.68 \pm 0.18 \mu$ (E), PEI = $112.64 \pm 0.98 \mu$ and PAI = $13.38 \pm 0.67 \mu$, aborted grains irregular in sizes. *Structure*: Exine tectate $1.20 \pm 0.02 \mu$, thick, ectexine and endexine nearly equal in thickness. In polar view the equatorial diameter $22.36 \pm 0.21 \mu$, mesocolpial diameter $13.36 \pm 0.24 \mu$ and apocolpial diameter $4.12 \pm 0.14 \mu$ in equatorial view. *Apertures*: mostly tricolporate rarely tetracolporate, angulaperturate, in equatorial view furrows bordered by distinct margos, os lalongate, unstricted, extends half the width of the grain, outer ends tapering. Surface psilate (Pl. 1, Figs. 7-9; Table 1).

Table 1—Mean frequency of pollen parameters of the hybrids, induced autotetraploids and desynaptic mutant of *Capsicum* and their chromosome number

Taxa	2n	Polar diameter (P)	Equatorial diameter (E) (equatorial view)	Polar equatorial index P/E X 100	Equatorial diameter (polar view)	Apocolpial diameter	Mesocolpial diameter	Polar area index A/E X 100
<i>C. annuum</i> var. G3 X	24	23.73±1.46 (20.01—26.72)	20.44±0.11 (18.32—24.34)	109.25±0.53 (91.20—123.63)	20.57±0.09 (17.79—26.02)	3.13±0.09 (2.83—6.90)	12.56±0.14 (10.62—2.44)	15.33±0.43 (11.72—29.06)
<i>C. frutescens</i>								
<i>C. annuum</i> var. <i>cerasiformis</i> × <i>C. chinense</i> var. <i>mishme</i>	24	24.87±0.29 (21.06—28.47)	22.48±0.29 (17.35—26.46)	110.96±1.27 (94.44—137.12)	20.57±0.33 (16.55—24.51)	3.83±0.17 (0.00—5.34)	12.44±0.28 (9.03—15.84)	17.09±0.74 (11.95—24.60)
<i>C. annuum</i> var. <i>cerasiformis</i> × <i>C. pendulum</i>	24	25.53±0.25 (20.44—28.76)	22.68±0.18 (19.56—26.55)	113.64±0.98 (94.67—130.67)	22.36±0.21 (18.58—25.75)	4.12±0.14 (2.57—6.90)	13.36±0.24 (9.73—16.72)	18.38±0.67 (10.34—29.77)
<i>C. frutescens</i> var. <i>tabasco</i> × <i>C. annuum</i> var. <i>cerasiformis</i>	24	23.50±0.30 (19.20—26.64)	21.85±0.32 (17.70—26.81)	108.80±1.55 (88.34—124.01)	20.55±0.33 (15.13—23.45)	3.85±0.14 (2.48—5.49)	12.39±0.27 (8.58—18.58)	18.36±0.66 (12.03—38.41)
<i>C. chinense</i> var. <i>mishme</i> × <i>C. frutescens</i> var. <i>tabasco</i>	24	22.73±0.20 (20.88—28.41)	20.96±0.15 (18.85—24.16)	108.62±0.81 (96.33—124.78)	20.58±0.25 (13.72—27.88)	3.09±0.11 (1.77—5.04)	13.43±0.23 (8.78—16.46)	14.76±0.51 (8.77—23.73)
<i>C. chacoense</i> × <i>C. annuum</i> var. <i>BOB</i>	24	2.24±0.26 (17.79—25.66)	7.18±0.27 (15.66—24.07)	105.44±1.23 (91.53—120.72)	18.67±0.34 (10.53—24.78)	2.89±0.09 (1.06—4.51)	11.55±0.30 (8.32—19.38)	13.81±0.51 (8.47—23.38)
<i>C. chacoense</i> × <i>C. frutescens</i> var. <i>tabasco</i>	24	27.93±0.19 (24.69—29.91)	25.35±0.20 (22.12—27.43)	110.34±0.86 (98.72—125.62)	26.09±0.16 (24.34—29.20)	4.58±0.11 (3.09—6.28)	19.34±0.45 (13.09—23.98)	18.03±0.46 (11.72—24.21)
<i>C. chacoense</i> × <i>C. chinense</i> var. <i>mishme</i>	24	22.37±0.16 (19.38—23.98)	19.5±0.12 (17.70—12.33)	114.27±0.71 (104.57—125.99)	19.55±0.17 (15.84—21.33)	2.97±0.07 (1.86—3.81)	12.70±0.15 (10.62—15.33)	15.26±0.40 (10.01—22.99)
<i>C. annuum</i> var. <i>cerasiformis</i>	48	36.91±0.21 (34.07—39.39)	31.89±0.26 (26.28—35.40)	116.03±0.99 (98.41—134.02)	33.02±0.16 (30.80—35.13)	5.22±0.14 (2.74—6.99)	23.65±0.20 (18.58—25.75)	16.43±0.44 (8.10—25.18)
<i>C. annuum</i> var. <i>TNK</i>	48	38.19±0.31 (31.59—42.57)	31.67±0.21 (28.14—33.72)	121.35±1.15 (94.68—134.89)	32.94±0.32 (26.99—39.82)	5.60±0.11 (4.78—7.61)	22.46±0.24 (18.58—25.75)	19.01±0.34 (14.92—25.13)
<i>C. annuum</i> var. <i>cerasiformis</i> desynaptic mutant	24	23.42±0.22 (18.14—26.37)	20.00±0.21 (15.75—22.30)	117.57±1.34 (103.91—136.07)	20.08±0.24 (16.72—23.89)	2.17±0.19 (0.00—4.34)	13.61±0.14 (11.41—15.13)	10.83±0.97 (0.00—17.34)

4. *C. frutescens* var. *tabasco* × *C. annuum* var. *cerasiformis*: *Shape*: Prolate-spheroidal, subtriangular in polar view. *Size*: $23.50 \pm 0.30 \mu$ (P) × $21.85 \pm 0.32 \mu$, PEI = $108.80 \pm 1.55 \mu$ and PAI = $18.36 \pm 0.66 \mu$. *Structure*: Exine tectate $1.13 \pm 0.03 \mu$ thick, ektexine thicker than endexine. A general thickening present near the apertures. In polar view the equatorial diameter $20.55 \pm 0.33 \mu$, mesocolpial diameter $12.39 \pm 0.27 \mu$ and apocolpial diameter $3.85 \pm 0.14 \mu$ in equatorial view. *Apertures*: Tricolporate, angulaperturate, syncolporate, 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. 1, Figs. 10-12; Table 1).

5. *C. chinense* var. *mishme* × *C. frutescens* var. *tabasco*: *Shape*: Prolate-spheroidal to subprolate, semiangular in polar view. *Size*: $22.73 \pm 0.20 \mu$ (P) × $20.96 \pm 0.15 \mu$ (E) PEI = $108.62 \pm 0.81 \mu$ and PAI = $14.76 \pm 0.51 \mu$. *Structure*: Exine tectate $1.24 \pm 0.01 \mu$ thick, ektexine thicker than endexine. A general thickening present near the apertures. In polar view the equatorial diameter $20.58 \pm 0.25 \mu$, mesocolpial diameter $13.43 \pm 0.23 \mu$ and apocolpial diameter $3.09 \pm 0.11 \mu$ in equatorial view. *Apertures*: Mostly tricolporate occasionally tetracolporate, angulaperturate, inaperturate grains also observed. Margos distinct, os lalongate, constricted, extends half the width of the grain, outer ends slightly tapering to rounded. Rarely syncolporate condition was also observed. Surface psilate (Pl. 2, Figs. 13-15; Table 1).

6. *C. chacoense* × *C. annuum* var. *BOB*: *Shape*: Prolate spheroidal to subprolate, semiangular in polar view. *Size*: $22.24 \pm 0.26 \mu$ (P) × $21.18 \pm 0.27 \mu$ (E), PEI = $105.44 \pm 1.23 \mu$ and PAI = $13.81 \pm 0.51 \mu$. *Structure*: Exine tectate $1.26 \pm 0.03 \mu$ thick, ektexine and endexine nearly equal in thickness. A general thickening noticeable near the apertures. In polar view the equatorial diameter $18.67 \pm 0.34 \mu$, mesocolpial diameter $11.55 \pm 0.30 \mu$, and apocolpial diameter $2.89 \pm 0.09 \mu$ in equatorial view. *Apertures*: Tricolporate, occasionally tetracolporate, angulaperturate, rarely fossaperturate, occasionally inaperturate grains also observed. Os lalongate, deeply constricted, extends half the width of the grain, outer ends pointed to slightly rounded. Surface psilate (Pl. 2, Figs. 16-18; Table 1).

7. *C. chacoense* × *C. frutescens* var. *tabasco*: *Shape*: Prolate-spheroidal to subprolate, semiangular in polar view. *Size*: $27.93 \pm 0.19 \mu$ (P) × $25.35 \pm 0.20 \mu$ (E) PEI = $110.34 \pm 0.86 \mu$ and PAI = $18.03 \pm 0.46 \mu$. *Structure*: Exine tectate $1.43 \pm 0.09 \mu$ thick, ektexine thicker than endexine. A general thickening noticeable near the apertures. In polar view the equatorial diameter 26.09 ± 0.16 , mesocolpial diameter $19.34 \pm 0.45 \mu$ and apocolpial diameter $4.58 \pm 0.11 \mu$ in equatorial view. *Apertures*: Mostly tricolporate, occasionally tetracolporate, angulaperturate or fossaperturate, rarely syncolporate, margos indistinct, os lalongate, deeply constricted to non-constricted, extends three fourth width of the grain, outer ends pointed to slightly rounded. Surface psilate (Pl. 2, Figs. 19-21; Table 1).

8. *C. chacoense* × *C. chinense* var. *mishme*: *Shape*: Prolate-spheroidal to subprolate, angular to semiangular in polar view. *Size*: $22.37 \pm 0.16 \mu$ (P) × $19.55 \pm 0.12 \mu$ (E), PEI = $114.27 \pm 0.71 \mu$ and PAI = $15.26 \pm 0.40 \mu$. *Structure*: Exine tectate $1.08 \pm 0.03 \mu$ thick, ektexine and endexine nearly equal in thickness. A general thickening present near the apertures. In polar view, equatorial diameter $19.55 \pm 0.17 \mu$, mesocolpial diameter $12.70 \pm 0.15 \mu$, and apocolpial diameter $2.97 \pm 0.07 \mu$ in equatorial view. *Apertures*: Mostly tricolporate rarely tetracolporate, angulaperturate or fossaperturate, less frequently inaperturate grains also noticed. Margos distinct to indistinct, os lalongate, deeply constricted, extends half the width of the grain, outer ends pointed to slightly rounded. Surface psilate (Pl. 2, Figs. 22-24; Table 1).

II. Colchicine induced variants of *C. annuum*:

(a) Autotetraploids:

1. var. *TNK*: *Shape*: Subprolate, tri or quadrilobed, subtriangular in polar view. *Size*: $38.19 \pm 0.31 \mu$ (P) \times $31.67 \pm 0.21 \mu$ (E), PEI = $121.35 \pm 1.15 \mu$ and PAI = $19.01 \pm 0.34 \mu$. *Structure*: Exine tectate $1.140 \pm 0.02 \mu$ thick, ectexine and endexine equal in thickness. In polar view equatorial diameter $32.94 \pm 0.16 \mu$, mesocolpial diameter $22.46 \pm 0.24 \mu$ and apocolpial diameter $5.60 \pm 0.11 \mu$ in equatorial view. *Apertures*: Tricolporate to tetracolporate, angulaperturate, colpae bordered by distinct margos, os lalongate constricted to non-constricted, extends half the width of the grain, outer ends slightly rounded. Surface psilate (Pl. 3, Figs. 25-30; Table 1).

2. var. *cerasiformis*: *Shape*: Subprolate, tri or quadrilobed or hexalobed, semiangular in polar view. *Size*: $36.91 \pm 0.21 \mu$ (P) \times $31.89 \pm 0.26 \mu$ (E) PEI = $116.03 \pm 0.99 \mu$ and PAI = $16.43 \pm 0.44 \mu$. *Structure*: Exine tectate $1.32 \pm 0.02 \mu$ thick, ectexine thicker than endexine. A general thickening noticeable near the opertures. In polar view the equatorial diameter $33.02 \pm 0.16 \mu$, mesocolpial diameter $23.65 \pm 0.20 \mu$ and apocolpial diameter $5.22 \pm 0.14 \mu$ in equatorial view. *Apertures*: Tricolporate or tetracolporate, angulaperturate or fossaperturate, colpae bordered by distinct margos, os lalongate non-constricted, outer ends pointed, extends half the width of the grain. Surface psilate (Pl. 3, Figs. 31-33; Table 1).

(b) Desynaptic mutant of *C. annuum* var. *cerasiformis*: *Shape*: Subprolate, semiangular in polar view. *Size*: $23.42 \pm 0.22 \mu$ (P) \times $20.00 \pm 0.21 \mu$ (E), PEI = $117.57 \pm 1.34 \mu$ and PAI = $10.83 \pm 0.97 \mu$. *Structure*: Exine tectate $1.30 \pm 0.02 \mu$ thick, ectexine thicker than endexine. A general thickening present near the apertures. In polar view the equatorial diameter $20.08 \pm 0.24 \mu$ m, mesocolpial diameter $13.61 \pm 0.14 \mu$ and apocolpial diameter $2.17 \pm 0.19 \mu$. *Apertures*: Mostly tricolporate, occasionally tetracolporate, angulaperturate or fossaperturate, inaperturate grains also observed. Margos indistinct, os lalongate, deeply constricted, extends half the width of the grain, outer ends pointed to slightly rounded. Surface psilate (Pl. 3, Figs. 34-36; Table 1).

Discussion

The pollen morphology of the species and varieties of *Capsicum* which were involved in the hybridization programme is rather fairly homogeneous. Generally the pollen of *Capsicum* is subprolate or prolate-spheroidal in shape (Erdtman, 1952; Murry & Eshbaugh, 1971; Basak, 1967; Nair & Kapoor, 1974; Raghvanshi, 1976). The shape of pollen grains in species and varieties currently involved in the hybridization work was found to be subprolate to prolate-spheroidal and oblate spheroidal (Aniel Kumar, 1984). In polar view the shape markedly varies with species and ploidy and is considered to be valuable as was observed by Muller (1969) in *Sonneratia* species and hybrids and also in interspecific hybrids of *Physalis* (Lydia Prasad et al., 1984). The pollen grains in the eight interspecific F₁ hybrids of the present study showed irregular shapes due to reduced pollen fertility. Triangular and occasionally tetralobed grains were found in all the F₁ hybrids except in *C. annuum* var. *cerasiformis* \times *C. chinense* var. *mishme* hybrid. Shrunken, aberrant and inaperturate condition was found in two F₁ hybrids (*C. annuum* var. *cerasiformis* \times *C. chinense* var. *mishme* and *C. chacoense* \times *C. chinense* var. *mishme*). The shape of the pollen grains in the F₁ hybrids of *C. annuum* var. *cerasiformis* \times *C. chinense* var. *mishme*, *C. chinense* \times *C. frutescens* was found to be intermediate between the respective parents, while

in the remaining six F_1 hybrids (*C. annuum* var. *G3* × *C. frutescens* var. *tabasco*, *C. annuum* var. *cerasiformis* × *C. pendulum*, *C. frutescens* var. *tabasco* × *C. annuum* var. *cerasiformis*, *C. chacoense* × *C. frutescens* var. *tabasco* and *C. chacoense* × *C. chinense* var. *mishme*) they were generally prolate-spheroidal. In contrast, Muller (1969) has recorded the shape of the pollen grains in the F_1 hybrids of *Sonneratia alba* × *S. ovata* and *S. alba* × *S. cascolaris* as either dominant or recessive but never intermediate. He suggested that the shape subprolate is dominant over prolate-spheroidal type. Lydia Prasad *et al.* (1984) also encountered variation in pollen grains shape in the interspecific hybrids of *Physalis*.

Raw colchiloids *C. annuum* var. *cerasiformis* and *C. annuum* var. *TNK* generally suffer from low pollen production and reduced fertility compared to the corresponding diploid genotypes. Both tricolporate (30.00%) and tetracolporate (70.00%) grains were encountered in the two tetraploids. The shape of the pollen grains in them is subprolate, having a mean PEI of $121.35 \pm 1.15 \mu$ and $116.30 \pm 0.99 \mu$ respectively. Similar variation in pollen shapes was recorded in *Sisymbrium irio* complex (Nair & Sharma, 1966-67). Shrunken and aberrant grains not uncommon in newly synthesized polyploids were encountered in the two tetraploids of the present study and also in the induced autotetraploid *Physalis pubescens* (Lydia Prasad *et al.*, 1984).

Pollen grains of the desynaptic mutant were by and large subprolate; however, prolate-spheroidal and oblate-spheroidal grains were also recorded though in a low frequency thus exhibiting variation in pollen shapes. The occurrence of shrunken and aberrant grains in the interspecific hybrids, raw colchiloids and desynaptic mutant of the present study was attributed to the irregular meiosis and polyad formation. Similar variation in pollen shape was attributed to higher pollen sterility. Such variation in pollen shapes was reported in the induced mutants of *Pimpinella* (Joshi & Raghuvanshi, 1967) and *Capsicum* (Raghuvanshi, 1976).

Pollen size seems to be an important character in *Capsicum*. The size variation was more evident in all the eight F_1 hybrids of the present study showing micro and macro pollen grain formation. Similar micro and macro pollen grains were reported in the F_1 hybrid of *Amaranthus dubius* × *A. spinosus* (Pal & Khoshoo, 1966), and the variation in the sizes of the pollen has been attributed to the presence of lagging univalents resulting in fewer chromosomes or more chromosomes in the microspores. The variation encountered in pollen sizes of interspecific hybrids and mutants of the present investigation may be attributed to the occurrence of univalents and irregular meiosis in them.

Larger size of the pollen grains often provides a reliable index for the detection of autotetraploids in the experimental populations. In the present study the pollen grains in induced autotetraploids of *C. annuum* var. *cerasiformis* and *C. annuum* var. *TNK* were found to be larger than those of the diploid progenitors. A test for significance revealed that they were highly significantly different from each other (Table 2). Though there was no overall correlation between the chromosome number and pollen size it is presumed that the plants with lower chromosome number have smaller pollen and increase in the chromosome number of the same taxa is generally accompanied by larger pollen and with more defectives, more apertural numbers, and changes in aperture disposition etc. Such variations in the pollen size that accompanied an increase in chromosome number was also recorded in *Oryza* (Sampath & Ramanathan, 1951; Rangaswamy & Raman, 1973), *Plantago* (Basset & Crompton, 1968) and in *Physalis pubescens* (Lydia Prasad *et al.*, 1984). Variation in pollen size ranging from small to large was encountered in the desynaptic mutant of the present study and this is attributed to irregularities pre-

Table 2—Comparison of various pollen characters in the diploids and their corresponding tetraploids of *Capsicum* L. ('t' values)

Paired comparison	Polar diameter	Equatorial diameter	Polar equatorial index	Apocolpial diameter	Polar area index
<i>C. annuum</i> var. <i>cerasiformis</i> (diploid) and <i>C. annuum</i> var. <i>cerasiformis</i> (tetraploid)	44.30	28.21	4.28	4.68	4.95
<i>C. annuum</i> var. <i>TNK</i> (diploid) and <i>C. annuum</i> var. <i>TNK</i> (tetraploid)	36.98	19.66	11.39	6.19	0.87*

*=Not Significant at $p=0.05$.

vailing in the genome. Similar variation in the pollen sizes were also reported in taxa treated with chemicals and physical mutagens such as in *Pimpinella* (Joshi & Raghuvanshi, 1967) and *Capsicum* (Raghuvanshi, 1976) respectively. Therefore, the variation in the pollen sizes observed in interspecific hybrids, tetraploids and the desynaptic mutant of *Capsicum* is attributed to the unstable nature of the newly synthesized plants.

The pollen size was measured along the polar axis. Based upon sizes the pollen grains may be placed either in small (10-25 μ) or in medium (25-50 μ) classes (Erdtman, 1952; Murry & Eshbaugh, 1971). Accordingly six out of the eight F_1 hybrids fit into the small class whose mean ranges from 22.24 to 24.80 μ . The remaining two F_1 hybrids (*C. annuum* var. *cerasiformis* x *C. pendulum* and *C. chacoense* x *C. frutescens* var. *tabasco*) and the two tetraploids of *C. annuum* varieties *cerasiformis* and *TNK* and one desynaptic mutant come under medium class with mean ranges of 25.53 to 38.19 μ .

The relative size of the polar area based on polar area index (PAI) has been suggested by Faegri and Iversen (1954) and Murry and Eshbaugh (1971) as a quantitative character of diagnostic value. On the basis of the polar area index the following two classes are suggested pertaining to the taxa of the present study.

- (1) smaller polar area index (PAI) between 10-15 μ , eg: desynaptic mutant, *C. chacoense* x *C. annuum* var. BOB and *C. chinense* x *C. frutescens*.
- (2) Medium size polar area index (PAI) between 15-20 μ , eg: two induced autotetraploids of *C. annuum* varieties of *cerasiformis* and *TNK* and six interspecific hybrids, viz., *C. annuum* var. G3 x *C. frutescens*, *C. annuum* var. *cerasiformis* x *C. pendulum* and *C. chinense* var. *mishme*, *C. frutescens* var. *tobasco* x *C. annuum* var. *cerasiformis*, *C. chacoense* x *C. frutescens* var. *tobasco* and *C. chacoense* x *C. chinense* var. *mishme*.

In all the interspecific hybrids, two induced autotetraploids and one desynaptic mutant, the PAI was less than that of the corresponding parents due to syncolporate condition. Similar results were reported in the induced autotetraploid, interspecific hybrids and the mutants of *Physalis* (Lydia Prasad et al., 1984). Smaller PAI due to syncolporate condition was also observed in some species of *Capsicum* (Murry & Eshbaugh, 1971) and in the induced mutants of *C. annuum* (Raghuvanshi, 1976).

The higher number of apertures and the occasional inaperturate condition observed in the induced autotetraploids, desynaptic mutant and interspecific hybrids could be attri-

buted to the meiotic irregularities in the newly synthesized genome. The multiaperturate and occasional inaperturate condition was also reported in the interspecific hybrids, induced polyploids, and polyhaploid of *Physalis* (Lydia Prasad *et al.*, 1984) and polyhaploids of *Hordeum* (Rajendra *et al.*, 1978), *Solanum* species (Erdtman, 1952; Anderson & Gensel, 1976) and induced mutants of *Capsicum annuum* (Raghuvanshi, 1976). Injecting colchicine to the flower buds Dover (1972) was able to induce multiaperturate condition in *Triticum aestivum* containing alien addition chromosomes in the genomes.

The endoaperture (os) was found to be lalongate, deeply constricted to non-constricted nature and extending half to three fourths of the width in all the eight F₁ hybrids, two autotetraploids and the desynaptic mutant. Irregular os with tapering ends was recorded in 4 F₁ hybrids of the present study (*C. annuum* var. G3 x *C. frutescens*, *C. annuum* var. *cerasiformis* x *C. pendulum*, *C. chacoense* x *C. frutescens* var. *tabasco* and *C. chacoense* x *C. chinense* var. *mishme*). Irregular os with outer ends rounded was observed in the F₁ hybrids of *C. annuum* var. *cerasiformis* x *C. chinense* var. *mishme*, two autotetraploids of *C. annuum* and the desynaptic mutant. Circular os was observed in *C. frutescens* var. *tabasco* x *C. annuum* var. *cerasiformis* hybrid and bifurcated os was observed in *C. chinense* x *C. frutescens* and *C. chacoense* x *C. annuum* var. BOB hybrids. Irregular os formation could be attributed to the meiotic irregularities and higher pollen sterility present in the genome. Similar irregular os was also reported in interspecific hybrids and induced polyploids of *Physalis* (Lydia Prasad *et al.*, 1984), species hybrids of *Sonneratia* (Muller, 1969), induced mutants of *C. annuum* (Raghuvanshi, 1976) and in some species of *Solanum* (Sharma, 1974).

Analysis of variance was also employed in the eight F₁ hybrids for quantitative measurements utilising parameters such as polar diameter (P) ($F=79.93$, $P>0.01$), equatorial diameter (E) ($F=65.23$, $P>0.01$), polar equatorial index (PEI) ($F=6.70$, $P>0.01$), apocolpial diameter (A) ($F=27.48$, $P>0.01$), and polar area index (PAI) ($F=10.30$, $P>0.01$). The 'F' values indicated highly significant differences among them.

Inter-relationships

The inter-relationships between the five species of *Capsicum* have been explored through the crossability relationships and a cytogenetic analysis of the eight F₁ interspecific hybrids. Hybrids were obtained easily in the following combinations, viz., *C. frutescens* var. *tabasco* x *C. annuum* var. *cerasiformis*, *C. annuum* var. *cerasiformis* x *C. pendulum*, *C. annuum* var. *cerasiformis* x *C. chinense* var. *mishme*, *C. chacoense* x *C. annuum* var. BOB and *C. chinense* x *C. frutescens*. Cytogenetic studies revealed that the hybrids differ from each other at least in one or two translocations in their genomes. They are partly pollen fertile indicating that there are considerable homologies or homologies among the genomes of the respective parents and hence they are probably closely related to each other. The pollen morphological evidence deduced through the application of the two parameters (PEI and PAI) also supports the cytogenetical evidence.

Evolutionary significance

In general the plant morphologists agree that similarity in a large number of characters of different taxa indicate close relationships, whereas diversity among the characters shows distant relationship. In recent years a few palynologists like Erdtman (1952, 1961), Saad (1961), Nair (1965), Punt (1971), Sharma (1969) and Muller (1969) have attempted to trace the evolutionary significance of some pollen morphological characters. In the genus *Capsicum* it is difficult to express any definite opinion about the evolutionary sig-

nificance of pollen morphological characters. However, the present study highlights that some pollen characters showed evolutionary significance in species hybrids, induced autotetraploids and desynaptic mutant than in the respective parents.

- (1) *Shape*: Prolate-spheroidal grains are considered to be advanced over the subprolate, eg: All the eight F₁ interspecific hybrids.
- (2) Multiaperturate condition is an advanced character over tricolporate eg: induced autotetraploids of
C. annuum, desynaptic mutant and F₁ hybrids of
C. annuum var. *cerasiformis* x *C. pendulum*,
C. chinense x *C. frutescens*, *C. chacoense* x
C. annuum var. *BOB*.
- (3) Circular os is considered to be an advanced feature over bifurcated and tapering outer ends of the os,
eg: F₁ hybrid of *C. frutescens* var. *tobasco* x
C. annuum var. *cerasiformis*.
- (4) Bifurcated os is advanced than tapering outer ends of the os, eg: F₁ hybrids of
C. chinense x *C. frutescens* and *C. chacoense* x *C. annuum* var. *BOB*.

The utilization of the above pollen morphological characters for the purpose of interpreting the relative advancement and the primitiveness of the taxa revealed that the interspecific hybrids, induced autotetraploids and desynaptic mutant showed advanced features over the corresponding parental species and varieties.

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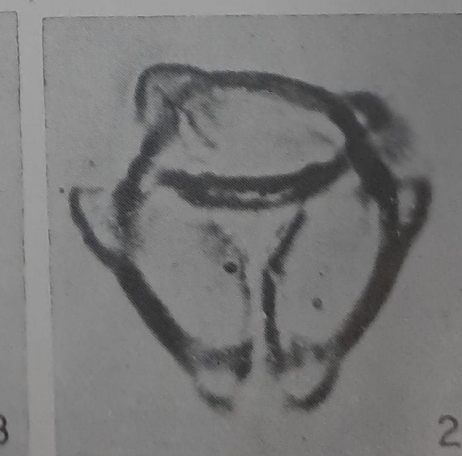
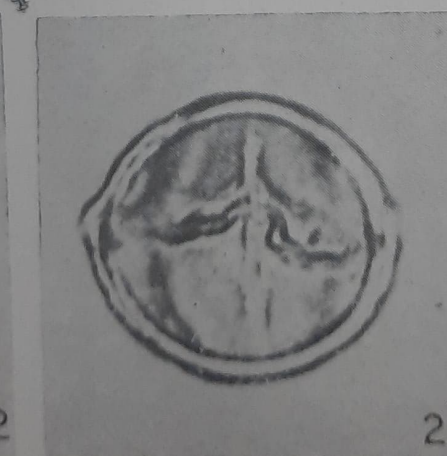
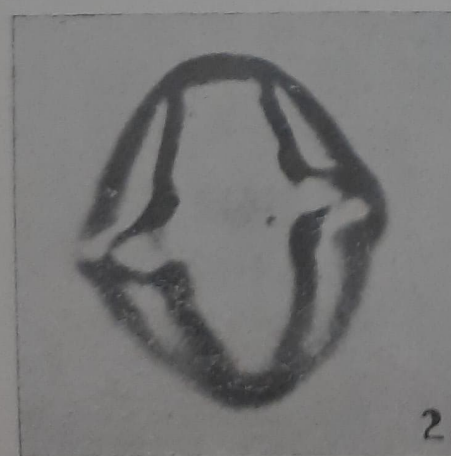
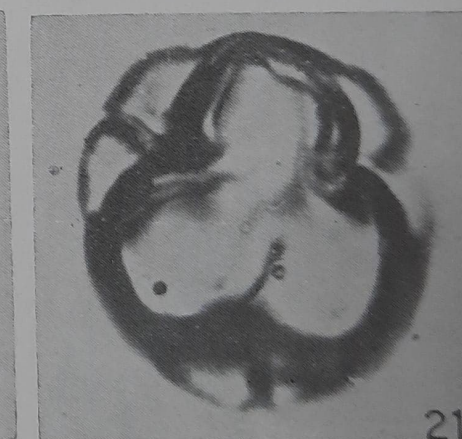
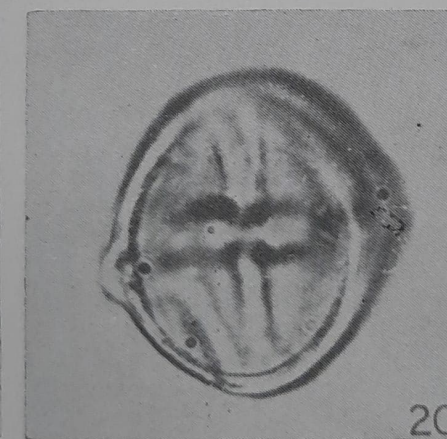
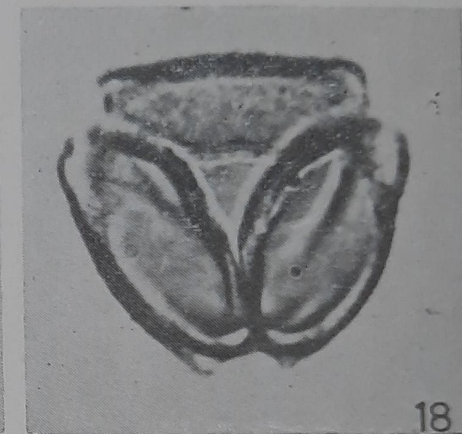
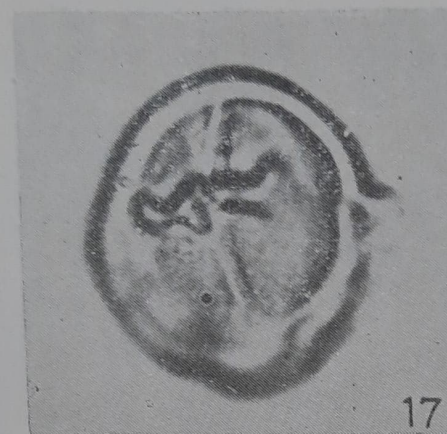
Explanation of Plates

(For all figures, magnification bar represents 10 μ)

PLATE 1

- 1-3. Pollen grains of *C. annuum* var. *G3* \times *C. frutescens* var. *tabasco*
 1. Equatorial view showing well separated colpae and mesocolpium.
 2. Equatorial view showing ill-defined Os.
 3. Polar view showing margos.
- 4-6. Pollen grains of *C. annuum* var. *cerasiformis* \times *C. chinense* var. *mishme*
 4. Equatorial view showing colpae.
 5. Equatorial view showing irregular, constricted Os.
 6. Polar view showing well developed margos.
- 7-9. Pollen grains of *C. annuum* var. *cerasiformis* \times *C. pendulum*
 7. Equatorial view showing colpae.
 8. Equatorial view showing nonconstricted Os.
 9. Polar view showing margos.
- 10-12. Pollen grains of *C. frutescens* var. *tabasco* \times *C. annuum* var. *cerasiformis*
 10. Equatorial view showing colpae.
 11. Equatorial view showing deeply constricted circular Os.
 12. Polar view showing syncolporate condition.





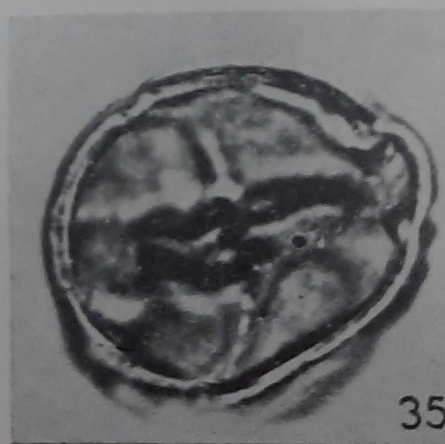
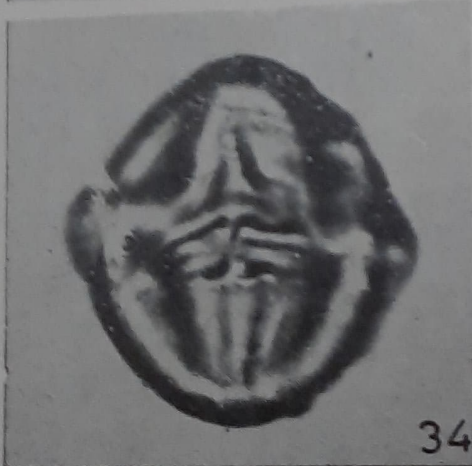
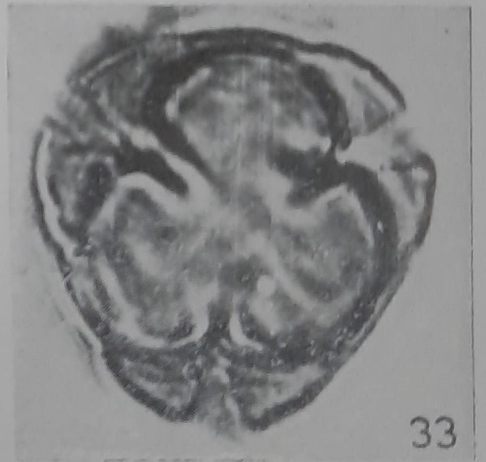
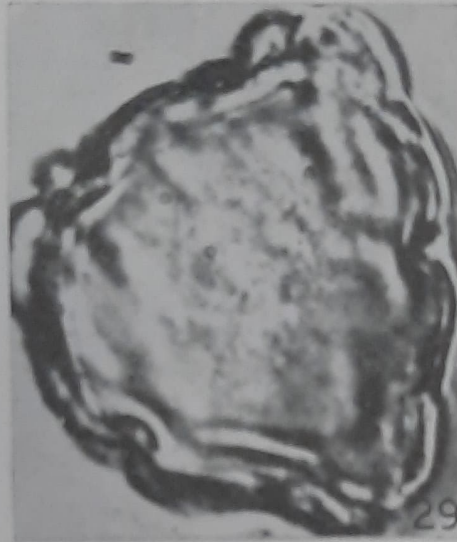
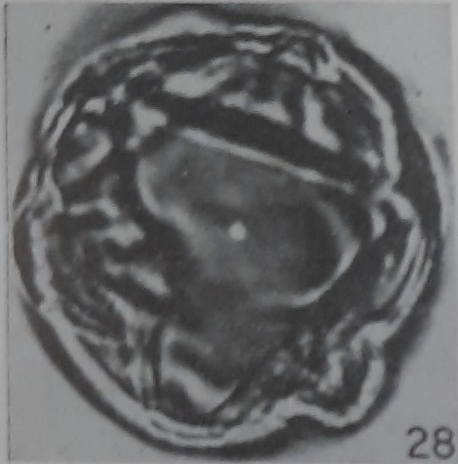
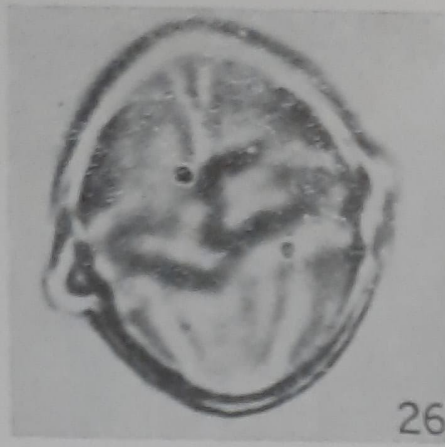


PLATE 2

13-15. Pollen grains *C. chinense* var. *mishme* × *C. frutescens* var. *tabasco*

13. Equatorial view showing well separated colpae.

14. Equatorial view showing irregular, bifurcated Os.

15. Polar view showing tetracolporate condition.

16.18. Pollen grains of *C. chacoense* × *C. annuum* var. *BOB*

16. Equatorial view showing well separated colpae.

17. Equatorial view showing irregular, constricted Os.

18. Polar view showing syncolporate condition.

19-21. Pollen grains of *C. chacoense* × *C. frutescens* var. *tabasco*

19. Equatorial view showing colpae.

20. Equatorial view showing constricted Os.

21. Polar view showing margos.

22-24. Pollen grains of *C. chacoense* × *C. chinense* var. *mishme*

22. Equatorial view showing colpae.

23. Equatorial view showing long narrow irregular Os.

24. Polar view showing syncolporate condition.

PLATE 3

25-30. Pollen grains of induced autotetraploid of *C. annuum* var. *TNK*

25. Equatorial view showing enlarged colpae.

26. Equatorial view showing irregular constricted Os.

27. Polar view showing distinct margos.

28. Polar view showing pores situated between the angles.

29. Polar view showing irregular shape.

30. Polar view showing tetracolporate condition.

31-33. Pollen grains of induced autotetraploid of *C. annuum* var. *cerasiformis*

31. Equatorial view showing colpae

32. Polar view showing pores situated between the angles.

33. Polar view showing well developed margos.

34-36. Pollen grains of induced desynaptic mutant of *C. annuum* var. *cerasiformis*

34. Equatorial view showing colpae.

35. Equatorial view showing irregular deeply constricted Os.

36. Polar view showing margos.