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CYTOLOGICAL STUDIES OF BRASSICACEAE BURN. (CRUCIFERAE JUSS.) FROM WESTERN HIMALAYAS



Cytological studies have been carried out on 12 species of Brassicaceae Burn. on population basis from different geographical areas of Kashmir and Himachal Pradesh in the Western Himalayas. Variable chromosome reports for *Barbarea intermedia* ($n = 16$), *Cardamine loxostemonoides* ($n = 8$), *Nasturtium officinale* ($n = 8$), *Sisymbrium orientale* ($n = 14$) on world-wide basis have been added to the previous reports of these species. The chromosome numbers in seven species as *Barbarea intermedia* ($n = 8$), *B. vulgaris* ($n = 8$), *Capsella bursa-pastoris* ($n = 8$), *Descuriania sophia* ($n = 10$), *Rorippa islandica* ($n = 8$), *Sisymbrium strictum* ($n = 7$) and *Thlaspi alpestre* ($n = 7$) have been worked out for the first time from India. The meiotic course in the populations of seven species such as *Barbarea intermedia*, *Capsella bursa-pastoris*, *Coronopus didymus*, *Descuriania sophia*, *Nasturtium officinale*, *Sisymbrium orientale* and *S. strictum* varies from normal to abnormal while all the populations of two species *Barbarea vulgaris* and *Sisymbrium irio* show abnormal meiotic course. Meiotic abnormalities are in the form of cytomixis, chromosomal stickiness, unoriented bivalents, inter-bivalent connections, formation of laggards and bridges, all resulting into abnormal microsporogenesis. Heterogenous sized fertile pollen grains and reduced reproductive potentialities have invariably been observed in all the meiotically abnormal populations. However, the meiotic course in all the populations of *Cardamine loxostemonoides*, *Rorippa islandica* and *Thlaspi alpestre* is found to be normal with high pollen fertility.

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Introduction. The family Brassicaceae includes 332 genera and 3,709 species [1] widely distributed throughout the world but abundant in north temperate zone with Mediterranean as major centre. In Indian subcontinent, 61 genera and 168 species [2] are taxonomically known which are mostly found in temperate and alpine Himalayas. Starting with the first comprehensive cytological studies [3–5], at present more than 9,000 chromosomal counts are known for 232 (68.6 %) genera and 1,558 (42.0 %) species of the family all over the world [1]. The chromosome numbers in the family vary from $n = 4$ in *Stenoptalum nutans* from Australia to $n = 128$ in *Cardamine concatenate* and *C. diphylla* from eastern North America [1]. From the Indian subcontinent, the chromosomal counts are known for nearly half the number of species of the family i.e. 90 species belonging to 41 genera. It is noted that cytological evaluation of Brassicaceae has got poor attention from Western Himalayas, in general, and for the present studied areas in particular. As the family is well documented with natural allopolyploidy, dysploid aneuploid series and mixoploidy coupled with economic importance, making it very good collection of plant material to be studied further from cytological perspective. To make additions to the chromosomal database and to study the genetic diversity at intra- and interspecific levels, concerning lesser known angiospermic families, from newer here as areas the present meiotic studies on the aforesaid taxa of Brassicaceae have been carried out.

Materials and methods. For meiotic studies, flower buds were collected from different localities of selected areas of Western Himalayas (Table 1). Smears of appropriate sized flower buds were made after fixing in Carnoy's fixative, using standard acetocarmine technique. Pollen fertility was estimated by mounting mature pollen grains in glycerol-acetocarmine (1:1) mixture or 1 % aniline blue. Well-filled pollen grains with stained nuclei were taken as apparently fertile, while shrivelled and unstained pollen grains were counted as sterile. Photomicrographs of pollen mother cells and pollen grains were made from freshly prepared slides using Nikon 80i eclipse Digital Imaging System. Voucher specimens are deposited in the Herbarium, Department of Botany, Punjabi University, Patiala (PUN).

Results. Detailed meiotic studies have been carried out on 29 populations belonging to 12

Table 1
Data showing location, altitude, accession number, present chromosome number, ploidy level, meiotic course and pollen fertility in different taxa of family *Brassicaceae* Burn. from Western Himalayas

| Taxa | Locality/Altitude (m)/ Accession Number | Present Chromosome Number (<i>n</i>)/ Figure Number | Ploidy level | Meiotic course**/ Pollen fertility, (%) |
|--|--|--|-----------------|---|
| <i>Barbarea intermedia</i> Boreau | Ferozpur Nallah Distt. Baramulla (Kashmir)/2,400 /54270 | 8 (Fig. 1, <i>a</i>) | 2x | A/64.42 |
| | Triund, Distt. Kangra N/(H.P.*/3,000/52744 | 16 (Fig. 1, <i>b</i>) | 4x | N/96.50 |
| <i>B. vulgaris</i> R.Br. | Chhota-Bhangal, Distt. Kangra (H.P.)/2,300/52796 | 8 (Fig. 1, <i>c</i>) | 2x | A/60.78 |
| <i>Cardimine loxostemonoides</i> O.E. | Ferozpur Nallah, Distt. Baramulla (Kashmir)/2,200/52473 | 8 (Fig. 1, <i>d</i>) | 2x | N/97.55 |
| | Ratnipora, Distt. Pulwama (Kashmir)/ 1,750/52472 | 8 | 2x | N/83.87 |
| <i>Capsella bursa-pastoris</i> (L.) Medik | Lower Munda, Distt. Anantnag (Kashmir)/ 2,300/54193 | 16 (Fig. 1, <i>e</i>) | 4x | A/69.01 |
| | Ratnipora, Distt. Pulwama (Kashmir)/1,750/54192 | 16 | 4x | A/62.42 |
| | Chhota-Bhangal, Distt. Kangra (H.P.)/2,300/52722 | 8 (Fig. 1, <i>f</i>) | 2x | A/60.00 |
| | Salai, Distt. Kangra (H.P.)/1,600/52733 | 16 | 4x | N/97.98 |
| | Shillai, Distt. Sirmaur (H.P.)/1,800/52653 | 16 | 4x | N/98.65 |
| <i>Coronopus didymus</i> (L.) Smith | Triund, Distt. Kangra (H.P.)/3,000/52703 | 16 (Fig.1, <i>g</i>) | 4x | A/65.78 |
| | Dharmkot, Distt. Kangra (H.P.)/2,800/ 52677 | 16 | 4x | N/94.54 |
| <i>Descurainia sophia</i> Webb ex Prantl. | Yusmarg, Distt. Budgam (Kashmir)/2,600/54202 | 10 (Fig. 1, <i>h</i>) | 2x | A/63.45 |
| | Pehalgam, Distt. Anantnag (Kashmir)/ 2,300/54201 | 10 | 2x | N/88.78 |
| <i>Nasturtium officinale</i> R.Br. | Ferozpur Nallah, Distt. Baramulla (Kashmir)/2,100/54205 | 8 | 2x | N/92.65 |
| | Ranhear, Distt. Kangra (H.P.)/800/52736 | 8 (Fig. 1, <i>i</i>) | 2x | A/65.50 |
| | Nahan, Distt. Sirmaur (H.P.)/900/55242 | 8 | 2x | A/61.45 |
| <i>Rorippa islandica</i> (Oeder) Berbas | Keller, Distt. Shopian (Kashmir)/2,000/ 54827 | 8 (Fig. 1, <i>j</i>) | 2x | N/92.00 |
| <i>Sisymbrium irio</i> L. | Aharbal, Distt. Kulgam (Kashmir)/2,100/ 54271 | 14 (Fig. 1, <i>k</i>) | 4x | A/63.47 |
| | Saketi, Distt. Sirmaur (H.P.)/800/55241 | 7 (Fig. 1, <i>l</i>) | 2x | A/60.87 |
| | Renukaji, Distt. Sirmaur (H.P.)/650/54234 | 14 | 4x | A/66.94 |
| <i>S. orientale</i> L. | Keller, Distt. Shopian (Kashmir)/2,200/ 54235 | 14 (Fig 1, <i>m</i>) | 4x | A/65.76 |
| | Chhota-Bhangal, Distt. Kangra (H.P.)/ 2,300/52741 | 8 | 2x | N/96.45 |
| | Triund, Distt. Kangra (H.P.)/3,000/52740 | 8 | 2x | A/62.00 |
| | Churdhar, Distt. Sirmaur (H.P.)/3,630/ 54206 | 8 | 2x | A/60.50 |

Continuation of table 1

| Taxa | Locality/Altitude (m)/ Accession Number | Present Chromosome Number (n)/Figure Number | Ploidy level | Meiotic course**/ Pollen fertility, (%) |
|----------------------------|--|---|-----------------|---|
| <i>S. strictum</i> L. | Batnoor Tral, Distt. Pulwama (Kashmir)/2,300/ 52475 | 7 (Fig 1, n) | 2x | A/69.78 |
| | Chhota-Bangal, Distt. Kangra (H.P.)/2,300/ 52704 | 7 | 2x | A/65.75 |
| | Nauradhar, Distt. Sirmaur (H.P.)/1,800/54209 | 7 | 2x | N/96.98 |
| <i>Thlaspi alpestre</i> L. | Baragran Distt. Kangra (H.P.)/3,000/52742 | 7 (Fig. 1, o) | 2x | N/93.50 |

* H.P. = Himachal Pradesh, ** N = Normal, ** A = Abnormal.

Data on cytomixis, meiotic course and pollen size in different

| Taxa/Accessions | Cytomixis | | Meiotic | |
|--------------------------------|--|----------------------------|--------------------------------------|--|
| | % age of PMCs involved Meiosis-I/Meiosis-II | Number of PMCs involved | Chromosomal stickiness at M-I (%) | |
| <i>Barbarea intermedia</i> | | | | |
| 54270 | 13.86(14/101)/5.71(6/105) | 2-3 | 6.06(6/99) | |
| 52796 | -/- | - | 1.98(2/101) | |
| <i>B. vulgaris</i> | | | | |
| 52796 | 9.73(11/113)/8.04(7.87) | 2-3 | - | |
| <i>Capsella bursa-pastoris</i> | | | | |
| 54193 | 20.83(25/120)/15.38(20/130) | 2-6 | 13.91(16/115) | |
| 54192 | 7.14(7/98)/4.08(4/98) | 2-3 | 5.55(4/72) | |
| 52722 | -/- | - | - | |
| <i>Coronopus didymus</i> | | | | |
| 52703 | 5.21(6/115)/6.83(8/117) | 2-3 | 3.38(4/118) | |
| <i>Descurainia sophia</i> | | | | |
| 54202 | 5.21(6/115)/6.42(7/109) | 2-3 | 3.73(4/107) | |
| <i>Nasturtium officinale</i> | | | | |
| 55736 | -/- | - | - | |
| 55242 | 7.33(8/109)/5.08(6/118) | 2-3 | 1.81(2/110) | |
| <i>Sisymbrium irio</i> | | | | |
| 54271 | -/- | - | 4.65(6/129) | |
| 55241 | 5.94(6/101) | 2-3 | - | |
| 54234 | -/- | - | - | |
| <i>S. orientale</i> | | | | |
| 54489 | 6.95(8/115)/5.00(6/120) | 2-3 | 6.15(8/130) | |
| 52740 | -/- | - | 2.04(2/98) | |
| <i>S. strictum</i> | | | | |
| 52475 | 11.53(15/130)/8.00(10/125) | 2-3 | 3.05(4/131) | |
| 52704 | 12.87(17/132)/12.59(16/127) | 2-3 | 5.45(6/110) | |

Figures in parenthesis denote observed number of abnormal PMCs in the numerator and total number of PMCs

species of 9 genera of the family Brassicaceae from different localities with altitudinal range of 800–3,000 m from two districts of Himachal Pradesh and 2,000–2,600 m from six districts of Kashmir. The data regarding locality with altitude, accession number, present chromosome numbers with figure numbers, ploidy level, nature of meiotic course and pollen fertility of the presently worked out populations has been presented in Table 1.

Two populations of *Barbarea intermedia*, one each from Kashmir and Himachal Pradesh shows intraspecific variability in the form of $2x$ ($n = 8$) and $4x$ ($n = 16$) cytotypes, res-

pectively. Single population of *B. vulgaris* collected from Himachal Pradesh and two populations of *Cardamine loxostemonoides* collected from Kashmir represent $2x$ cytotypes, all exhibiting $n = 8$. *Capsella bursa-pastoris* is another species depicting intraspecific variability as one population from Himachal Pradesh shows $2x$ cytotype ($n = 8$) whereas two populations from Kashmir and two populations from Himachal Pradesh show $4x$ cytotype ($n = 16$) pointing wide spread occurrence of tetraploids of this species in the Western Himalayas.

Both the populations of *Coronopus didymus*, studied from Himachal Pradesh have the tet-

Table 2

species of *Brassicaceae* Burn. from Western Himalayas

| course showing PMCs with | | | Size (μm) of fertile pollen grains (Range) |
|----------------------------------|---|---|---|
| Unoriented bivalents at M-I (%) | Bridges at Meiosis-I/Meiosis-II (%) | Laggards at Meiosis-I/ Meiosis-II (%) | |
| 6.45(6/93) 3.48(4/115) | 7.23(11/152)/8.92(10/112) 14.28(15/105)/9.52(10/105) | 8.86(7/79)/11.22(11/98) 11.76(12/102)/8.84(10/113) | 15.08×13.00–15.16×13.08 |
| – | 8.84(10/113)/7.50(9/120) | 9.23(12/130)/– | 19.96×18.47–16.45×16.20 |
| 12.50(15/120) – 5.55(4/72) | 13.04(15/115)/10.00(12/120) 9.67(6/62)/12.90(8/62) 10.00(5/50)/8.00(4/50) | 14.61(19/130)/15.00(18/120) 11.29(7/62)/8.06(5/62) 11.11(6/54)/9.25(5/54) | 18.18×17.05–17.24×17.10 |
| 2.63(3/114) | 4.80(6/125)/4.13(5/121) | 6.25(8/128)/5.88(7/119) | 14.17×13.35–16.25×15.45 |
| 1.85(2/108) | 6.25(7/112)/1.53(2/130) | 4.87(6/123)/1.73(2/115) | 18.83×17.24–16.95×16.05 |
| – 1.76(2/113) | 4.16(4/96)/5.21(6/115) 4.87(6/123)/– | 5.04(6/119)/3.60(4/111) 6.95(8/115)/– | 15.78×14.00–15.17×13.14 |
| 6.40(8/125) – – | 6.95(8/115)/5.00(6/120) 6.36(7/110)/6.08(7/115) 6.83(8/117)/– | 7.20(9/125)/5.60(7/125) 8.00(10/125)/9.91(12/121) 5.21(6/115)/6.66(8/120) | 16.78×14.00–15.26×13.87 |
| 5.08(6/118) 4.04(4/99) | 6.89(8/116)/3.36(4/119) 7.47(8/107)/5.12(6/117) | 6.66(8/120)/7.69(9/117) 13.60(17/125)/12.30(16/130) | 18.78×16.00–15.05×17.90 |
| 4.65(6/129) 3.14(4/127) | 5.98(7/117)/5.21(6/115) 4.95(6/121)/4.20(5/119) | 9.30(12/129)/7.63(10/131) 5.00(6/120)/5.78(7/111) | 16.75×15.90–14.56×13.26 |

observed in denominator.

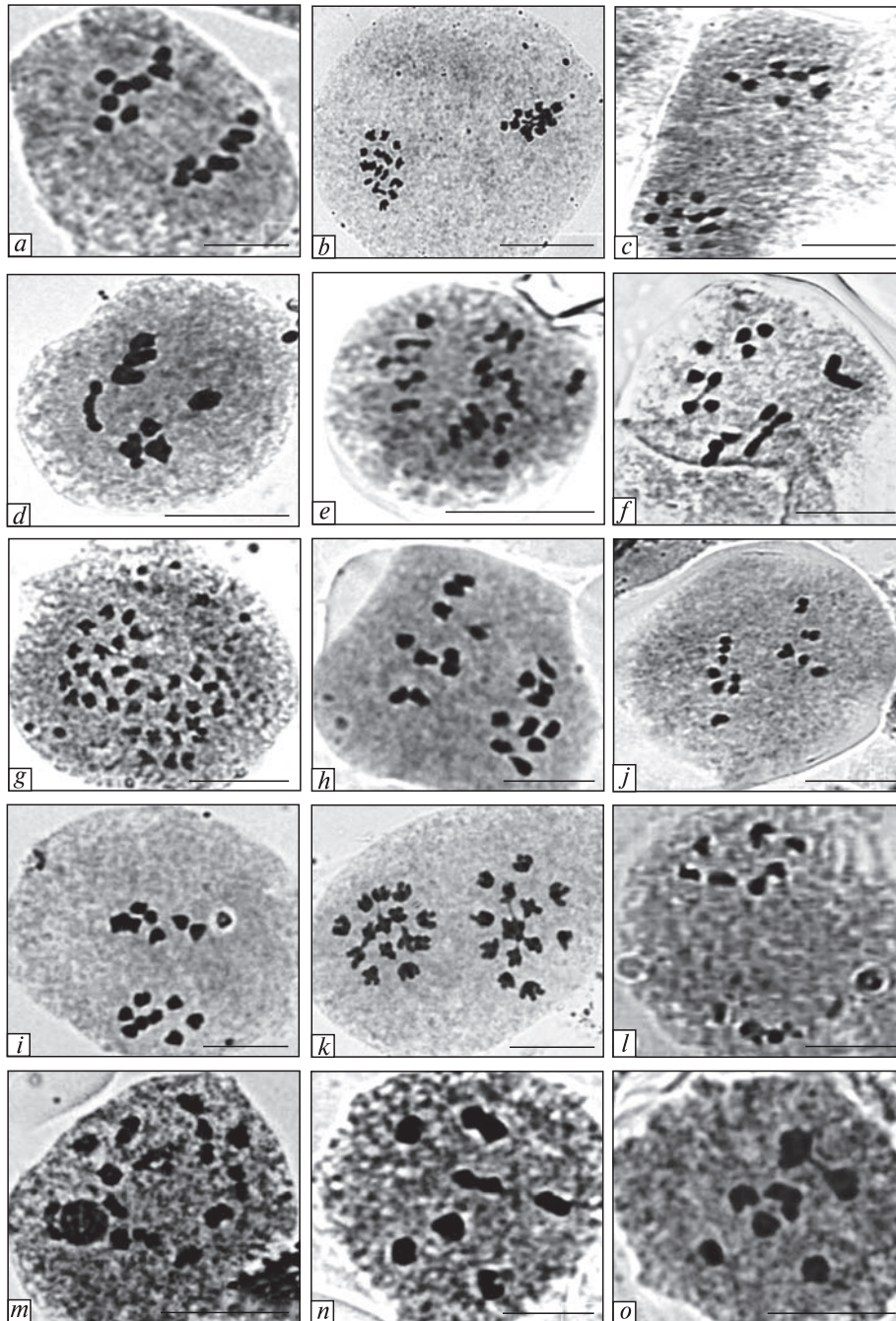


Fig. 1. *Barbarea intermedia* (a) – PMC at A-I ($n = 8$); *B. intermedia* (b) – PMC at A-I ($n = 16$); *B. vulgaris* (c) – PMC at A-I ($n = 8$); *Cardimine loxostemonoides* (d) – PMC at M-I ($n = 8$); *Capsella bursa-pastoris* (e) – PMC at M-I ($n = 16$); *Capsella bursa-pastoris* (f) – PMC at M-I ($n = 8$); *Coronopus didymus* (g) – PMC at M-II ($n = 16$); *Descuriania sophia* (h) – PMC at A-I ($n = 10$); *Nasturtium officinale* (i) – PMC at A-I ($n = 8$); *Rorippa islandica* (j) – PMC at A-I ($n = 8$); *Sisymbrium irio* (k) – PMC at M-II ($n = 14$); *S. irio* (l) – PMC at A-I ($n = 7$); *S. orientale* (m) – PMC at Diakinesis ($n = 14$); *S. strictum* (n) – PMC at M-I ($n = 7$), *Thlaspi alpestre* (o) – PMC at M-I ($n = 7$). Bar = 10 μm

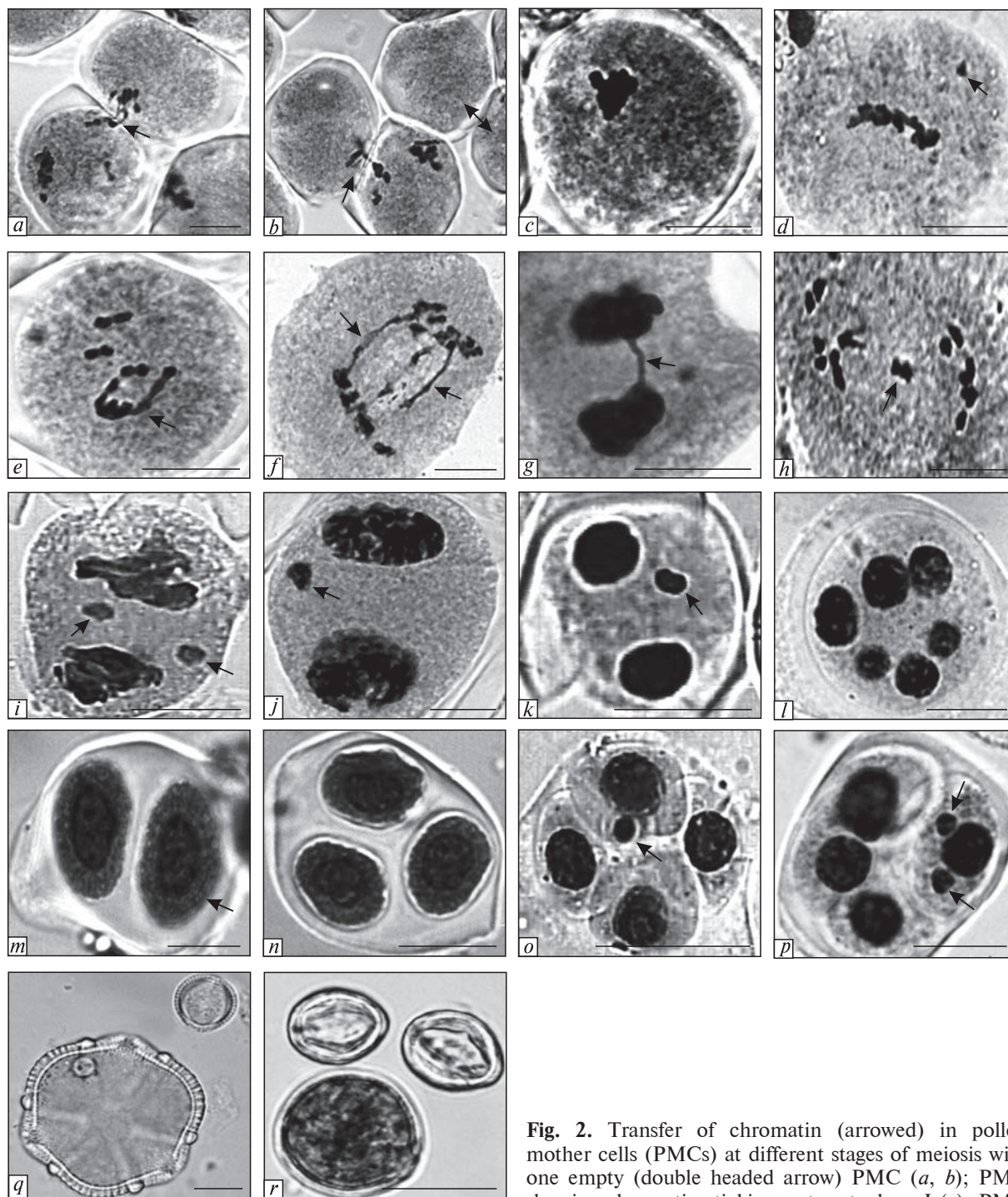


Fig. 2. Transfer of chromatin (arrowed) in pollen mother cells (PMCs) at different stages of meiosis with one empty (double headed arrow) PMC (*a, b*); PMC showing unoriented bivalent at M-I (*d*); PMC showing chromatin stickiness at metaphase I (*c*); PMC showing inter-bivalent connections at M-I (*e*); PMC with multiple bridges (arrowed) at anaphase I (*f*); PMC showing bridge (arrowed) at telophase I (*g*); PMC with laggards (arrowed) at anaphase I (*h*); PMCs showing laggards (arrowed) at telophase I (*i-k*); PMC with six poles at telophase II (*l*); Diad (*m*); Triad (*n*); Tetrad with micronuclei (arrowed) (*o, p*); Fertile pollen grains differing in size (*q*); Fertile and sterile pollen grains (*r*). Bar = 10 μ m

raploid cytotypes ($n = 16$). Two populations of *Descurainia sophia* have been collected from Kashmir exhibiting meiotic chromosome number $n = 10$ and diploid status based on $x = 10$. In case of *Nasturtium officinale*, one population from Kashmir and two populations from different parts of Himachal Pradesh, all depict $2x$ cytotypes with $n = 8$. Likewise *Rorippa islandica* based on single population studied from Kashmir is also $2x$ ($n = 8$). For *Sisymbrium irio* one population from district Kangra of Himachal Pradesh is reported to be $2x$ ($n = 7$) whereas two other populations, one from Kashmir and other from district Sirmour of Himachal Pradesh on the contrary are noted to be $4x$ ($n = 14$). *S. orientale* makes interesting case where three populations studied from Himachal Pradesh represent only $2x$ ($n = 8$), but a single population studied from Kashmir is found to be $4x$ based on $x = 7$. In case of *S. strictum*, one population from Kashmir and two from Himachal Pradesh as well as for *Thalspi alpestre*, a single population from Himachal Pradesh, all unequivocally represent $2x$ cytotypes strictly with $n = 7$.

The meiotic abnormalities have been recorded in some populations of *Barbarea intermedia*, *Capsella bursa-pastoris*, *Coronopus didymus*, *Descurainia sophia*, *Nasturtium officinale*, *Sisymbrium orientale* and *S. strictum* and in all the populations of *Barbarea vulgaris* and *Sisymbrium irio*. In such populations, the meiotic abnormalities in the form of cytomixis, chromatin stickiness, unoriented bivalents, inter-bivalent connections, bridges, laggards or multipolar spindle have been observed at different stages of meiosis (Table 2; Fig. 2, *g–k*). Regarding cytomixis, the chromatin transfer from early prophase to pollen grain formation has been observed in most of these populations, with the highest percentage recorded in one population of *Capsella bursa-pastoris* involving 2–6 PMCs (Table 2). Cytomixis in these species results into the production of hypo- and hyperploid PMCs and even empty PMCs (Fig. 2, *b*). Chromatin stickiness involving few bivalents or whole complement is seen from prophase-I to metaphase-I (Fig. 2, *c*). The unoriented bivalents at metaphase-I (Fig. 2, *d*) have also been observed with highest frequency noted in one population of *Capsella bursa-pastoris* (Table

2). Interbivalent connections have been observed at M-I in one of the populations of *Capsella bursa-pastoris* from Chotta Bhangal (Fig. 2, *e*). These meiotically abnormal populations quite frequently show the presence of chromosomal laggards and bridges at anaphases and telophases (Fig. 2, *f–k*). Instead of regular spindle formation, abnormal split spindles and three poles per PMC at T-I and even six poles at T-II (Fig. 2, *l*) have been seen in significant number of PMCs in *Capsella bursa-pastoris*, *Descurainia sophia*, *Nasturtium officinale* and *Sisym-*

Data on abnormal

| Taxa/Accessions | Monads | |
|--------------------------------|--------------|-------------|
| | WMN | WM |
| | | |
| <i>Barbarea intermedia</i> | | |
| 54270 | 2.06(2/97) | 1.03(1/97) |
| 52796 | 5.60(6/107) | – |
| <i>Barbarea vulgaris</i> | | |
| 52796 | 2.00(2/100) | 2.00(2/100) |
| <i>Capsella bursa-pastoris</i> | | |
| 54193 | 1.98(2/101) | 0.99(1/101) |
| 54192 | 4.76(6/126) | 2.38(3/126) |
| 52722 | 4.31(6/139) | 0.71(1/139) |
| <i>Coronopus didymus</i> | | |
| 52703 | 1.96 (2/102) | 0.98(1/102) |
| <i>Descurainia Sophia</i> | | |
| 54202 | 1.04(1/96) | 1.04(1/96) |
| <i>Nasturtium officinale</i> | | |
| 55136 | – | – |
| 55242 | 1.90(2/105) | 0.95(1/105) |
| <i>Sisymbrium irio</i> | | |
| 54271 | 0.86(1/115) | 1.73(2/115) |
| 54241 | – | – |
| 54234 | 1.96(2/102) | 0.98(1/102) |
| <i>S. orientale</i> | | |
| 54489 | 0.98(1/102) | – |
| 52740 | 0.97(1/103) | – |
| <i>S. strictum</i> | | |
| 52475 | 1.83(2/109) | 0.91(1/109) |
| 52704 | 2.88(3/104) | 1.92(2/104) |

Indication. WMN = without micronuclei; WM = with number of PMCs observed in denominator.

brium orientale. This results into abnormal microsporogenesis leading to the formation of monads, diads, triads or polyads, along with micronuclei (Fig. 2, *m-p*; Table 3) and leads to the formation of heterogeneous sized fertile pollen grains with reduced pollen fertility (Fig. 2, *q, r*). The pollen fertility in the populations with normal meiosis has been recorded to be nearly cent per cent.

Discussion. As evident from the great amount of variation reported in chromosome numbers of Brassicaceae in literature on world-wide basis, it is clear that family Brassicaceae represents range

of genera depicting mono-, di- and polybasic nature. Some authors have suggested the base numbers to be considered from $x = 4-13$, considering even some higher numbers as 32, 42, etc. to be taken as base numbers, the later most probably represent single and isolated gametic number report for any species of the genus [1]. On the other hand some authors have reported only $x = 5-8$ as primary base numbers [6]. Both the statements reveal unanimously that $x = 8$ is the most popular base number. Analysis of overall chromosome number data proves that x

Table 3
microsporogenesis in different species of *Brassicaceae* Burn. from different areas of Western Himalayas

| Microsporogenesis, % | | | | | |
|----------------------|-------------|---------------|-------------|---------------|------------------|
| Diads | | Triads | | Tetrads | |
| WMN | WM | WMN | WM | WMN | WM |
| 7.21(7/97) | 2.06(2/97) | 4.12(4/97) | 2.06(2/97) | 69.07(67/97) | 12.37(12/97) |
| 1.86(2/107) | 1.86(2/107) | 6.54(7/107) | 0.93(1/107) | 65.42(70/107) | 17.75(19/107) |
| 4.00(4/100) | 2.00(2/100) | 5.00(5/100) | 2.00(2/100) | 62.00(62/100) | 21.00(21.00/100) |
| 1.98(2/101) | 0.99(1/101) | 0.99(1/101) | 3.96(4/101) | 67.32(68/101) | 21.78(22/101) |
| 6.34(8/126) | 3.17(4/126) | 5.55(7/126) | 3.17(4/126) | 57.14(72/126) | 17.46(22/126) |
| 1.43(2/139) | 5.03(7/139) | 11.51(16/139) | 6.47(9/139) | 52.51(73/139) | 17.98(25/139) |
| 1.96(2/102) | 2.94(3/102) | 1.96(2/102) | 0.98(1/102) | 67.64(69/102) | 21.56(22/102) |
| 1.04(1/96) | 1.04(1/96) | 2.08(2/96) | 2.08(2/96) | 69.79(67/96) | 21.87(21/96) |
| 1.94(2/103) | – | 3.88(4/103) | – | 75.72(78/103) | 18.44(19/103) |
| 2.85(3/105) | 0.95(1/105) | 1.90(2/105) | 1.90(2/105) | 68.57(72/105) | 20.95(22/105) |
| 1.73(2/115) | 2.60(3/115) | – | 1.73(2/115) | 67.82(78/115) | 21.73(25/115) |
| 3.19(3/94) | 1.06(1/94) | 1.06(1/94) | 2.12(2/94) | 71.27(67/94) | 21.27(20/94) |
| 2.94(3/102) | 1.96(2/102) | 1.96(2/102) | 0.98(1/102) | 67.64(69/102) | 21.56(22/102) |
| – | 0.98(1/102) | 3.92(4/102) | – | 70.58(72/102) | 23.52 (24/102) |
| 0.97(1/103) | – | 1.94(2/103) | 0.97(1/103) | 72.81(75/103) | 22.33(23/103) |
| 1.83(2/109) | 1.83(2/109) | 3.66(4/109) | 2.75(3/109) | 64.22(70/109) | 22.93(25/109) |
| 0.96(1/104) | 1.92(2/104) | 0.96(1/104) | 1.92(2/104) | 65.38(68/104) | 25.00(26/104) |

micronuclei. Figures in parenthesis denote observed number of abnormal PMCs in the numerator and total num-

= 8 is represented nearly by 20 % of taxa in the family followed by $x = 7$ being present in 19.13 % taxa [1]. Another frequent base number $x = 10$ is found in 10.24 % taxa and seems to be secondarily derived base number. The same holds true for Indian representatives in general and presently investigated taxa from Western Himalayas in particular.

The meiotic chromosome numbers for *Barbarea intermedia* ($n = 8$), *B. vulgaris* ($n = 8$), *Descuriania sophia* ($n = 10$), *Rorippa islandica* ($n = 8$), *Sisymbrium strictum* ($n = 7$) and *Thlaspi alpestre* ($n = 7$) have been worked out for first time from India confirming the same chromosome number for these species from outside India. But at the same time other interspecific cytotypes are also known in literature on world-wide basis for some of these species to be taken into account such as *Barbarea vulgaris* $2n = 14$ [7], *Descuriania sophia* $2n = 14, 28, 56$ [5, 8, 9], *Rorippa islandica* $2n = 32$ [10]. Out of the four species where new and varied cytotypes have been reported for the first time, *Barbarea intermedia* ($n = 16$) and *Sisymbrium orientale* ($n = 14$) make an addition of tetraploid cytotypes on world-wide basis. In case of *Cardamine loxostemonoides* present diploid report ($n = 8$) against tetraploid cytotype $2n = 32$ [11] and for *Nasturtium officinale* also present diploid report ($n = 8$) against another diploid cytotype with $2n = 14$ [12], tetraploid ($2n = 32$) and octaploid ($2n = 64$) cytotypes [5] are recorded on world-wide basis. The diploid cytotype ($n = 8$) in *Capsella bursa-pastoris* is reported for the first time from India and confirms the previous reports of $2n = 32$ [13–15] from outside India. *Sisymbrium irio* is another species with presently worked out diploid and tetraploid cytotypes like those of *Barbarea intermedia* and *Capsella bursa-pastoris*. Although *Sisymbrium irio* is one species with high amount of intraspecific variability existing in the form of $2n = 14, 21, 28, 42, 56$ numbers showing diploid to octaploid cytotypes collected from the same region of India [16] but in spite of wide screening at present only diploid and tetraploid cytotypes could be found. In *Coronopus didymus* present tetraploid chromosome number count of $n = 16$ is in line with the earlier report of $2n = 32$ from India [17] and from outside India [4,

5, 18]. From this entire account one thing emerges out that there exists a lot of variation of chromosome numbers in the species of the family Brassicaceae. Allopolyploidy coupled with hybridization resulting from different base number seems to be major evolutionary factor for generating higher chromosome numbered taxa as postulated earlier [19]. The phenomenon of mixoploidy has also been described for certain members of Brassicaceae [20], and explained that mostly gamete formation in such plants is not affected and show behaviour of normal diploids, but sometimes as an aberration some of the aneuploid and polyploidy cells may enter the germline to give rise to dysploid and polyploidy plants especially in apomicts and spontaneous hybrids.

The meiotic abnormalities are considered to be resulting from genetic [21–23] and environmental factors [24] as well as genomic-environmental interaction [25]. Chromatin transfer, production of hypo- and hyperploid PMCs and meiotic irregularities in anaphase segregation of chromosomes may be the possible mechanisms for the formation of large sized pollen grains and low pollen fertility as has been earlier reported in several angiospermic plants [26–29]. All these factors seem to be equally applicable in the presently investigated populations with meiotic irregularities in the form of cytomixis, chromosomal stickiness, unoriented bivalents, interbivalent connections, laggards and bridges. The occurrence of sufficient variation of chromosome numbers as well as change of meiotic behavior at intra- and interspecific level of these 12 species calls for further need of the extensive cytological exploration at population basis of members of Brassicaceae from different phytogeographical areas of India to complete the data bases for Indian Brassicaceae.

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ЦИТОЛОГИЧЕСКОЕ ИЗУЧЕНИЕ
СЕМЕЙСТВА BRASSICACEAE BURN.
(CRUCIFERAE JUSS.) ИЗ ЗАПАДНЫХ ГИМАЛАЕВ

Цитологические исследования проведены на 12 видах семейства Brassicaceae Burn. из популяций различных географических зон Западных Гималаев. Определены хромосомные числа для *Barbareaea intermedia* ($n = 16$), *Cardamine loxostemonoides* ($n = 8$), *Nasturtium officinale* ($n = 8$), *Sisymbrium orientale* ($n = 14$) и добавлены к известным сведениям об этих видах. Хромосомные числа семи видов, *Barbareaea intermedia* ($n = 8$), *B. vulgaris* ($n = 8$), *Capsella bursa-pastoris* ($n = 8$), *Descuriania sophia* ($n = 10$), *Rorippa islandica* ($n = 8$), *Sisymbrium strictum* ($n = 7$) и *Thlaspi alpestre* ($n = 7$), были определены впервые в Индии. Течение мейоза в популяциях семи видов (*Barbareaea intermedia*, *Capsella bursa-pastoris*, *Coronopus didymus*, *Descuriania sophia*, *Nasturtium officinale*, *Sisymbrium orientale* и *S. strictum*) изменяется от нормального до аномального, в то время как в популяциях *Barbareaea vulgaris* и *Sisymbrium irio* наблюдается аномальный ход мейоза. Мейотические аномалии проявляются в виде цитомиксиса, слипшихся хромосом, дезориентированных бивалентов, межбивалентных соединений, формирования отставших хромосом и мостов, что в целом приводит к нарушениям микроспорогенеза. Гетерогенные по размеру фертильные пыльцевые зерна и сниженный репродукционный потенциал наблюдались во всех мейотически аномальных популяциях. В то же время ход мейоза во всех популяциях *Cardamine loxostemonoides*, *Rorippa islandica* и *Thlaspi alpestre* был нормальным и сопровождался высокой фертильностью пыльцы.

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ЦИТОЛОГІЧНЕ ВИВЧЕННЯ СІМЕЙСТВА
BRASSICACEAE BURN. (CRUCIFERAE JUSS.) ІЗ
ЗАХІДНИХ ГІМАЛАЇВ

Цитологічні дослідження проведені на 12 видах родини Brassicaceae Burn. з популяцій різних географічних зон Західних Гімалаїв. Визначені хромосомні числа для *Barbareaea intermedia* ($n = 16$), *Cardamine loxostemonoides* ($n = 8$), *Nasturtium officinale* ($n = 8$), *Sisymbrium orientale* ($n = 14$) і додані до відомостей про ці види. Хромосомні числа семи видів, *Barbareaea intermedia* ($n = 8$), *B. vulgaris* ($n = 8$), *Capsella bursa-pastoris* ($n = 8$), *Descuriania sophia* ($n = 10$), *Rorippa islandica* ($n = 8$), *Sisymbrium strictum* ($n = 7$) та *Thlaspi alpestre* ($n = 7$), були визначені вперше

в Індії. Проходження мейозу в популяціях семи видів (*Barbareaea intermedia*, *Capsella bursa-pastoris*, *Coronopus didymus*, *Descuriania sophia*, *Nasturtium officinale*, *Sisymbrium orientale* і *S. strictum*) змінюється від нормального до аномального, тоді як в популяціях *Barbareaea vulgaris* і *Sisymbrium irio* спостерігається аномальний хід мейозу. Мейотичні аномалії проявляються у вигляді цитоміксису, злиплених хромосом, дезорієнтованих бивалентів, міжбивалентних сполук, формуванні відсталих хромосом і мостів, що в цілому призводить до порушень микроспорогенезу. Гетерогенні за розміром фертильні пилокві зерна та знижений репродукційний потенціал спостерігалися в усіх мейотично аномальних популяціях. В той же час хід мейозу в усіх популяціях *Cardamine loxostemonoides*, *Rorippa islandica* і *Thlaspi alpestre* був нормальним і супроводжувався високою фертильністю пилку.

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