Meiotic Studies in Some Polypetalous Species from District Kangra (Himachal Pradesh), India

Savita Rani*, Raghbir Chand Gupta and Santosh Kumari

Department of Botany, Punjabi University Patiala 147 002

Received November 25, 2011; accepted February 5, 2012

Summary At present, meiotic studies have been carried out on a population basis covering 23 species belonging to 13 genera and 10 families of Polypetalae from District Kangra of Himachal Pradesh. New reports in the form of varied chromosome numbers have been marked for the first time on a world-wide basis for 13 species, namely *Bupleurum lanceolatum* (*n*=16), *Impatiens bicolor* (*n*=8), *I. racemosa* (*n*=7), *Medicago polymorpha* (*n*=16), *Fumaria indica* (*n*=8), *Geranium lucidum* (*n*=13), *G. ocellatum* (*n*=13), *Hypericum elodeoides* (*n*=8), *H. japonicum* (*n*=16), *Malva verticillata* (*n*=21), *Epilobium roseum* (*n*=9), *Geum roylei* (*n*=14), *Rosa macrophylla* (*n*=14) and *Triumfetta pilosa* (*n*=16). Six species, namely *Boenninghausenia albiflora* (*n*=10), *Circaea alpina* (*n*=11), *E. palustre* (*n*=18), *Rosa brunonii* (*n*=7) and *R. indica* (*n*=7), have been cytologically worked out for the first time from India, along with additional cytotypes for 3 Indian materials, namely *Abutilon indicum* (*n*=7), *E. cylindricum* (*n*=9) and *Oxalis corniculata* (*n*=7). Amongst these species, the course of meiosis varies from normal to abnormal in different populations of *Malva neglecta*, *Rosa brunonii* and *R. indica* whereas all the studied accessions of *Bupleurum lanceolatum*, *Geum roylei*, *Impatiens sulcata*, *Oxalis corniculata* and *Rosa macrophylla* have been found to be abnormal. The meiotic abnormalities include various phenomenon such as cytomixis, chromatin stickiness, unoriented bivalents, laggards, chromatin bridges and multipolarity at different stages of meiosis along with abnormal microsprogenesis ultimately leading to reduced pollen fertility and formation of heterogenous sized pollen grains.

Key words Chromosome numbers, District Kangra, Himachal Pradesh, Meiosis, Polypetalous species.

District Kangra is located on the south-western end of the Himachal Pradesh, a hilly state in the Western Himalayas. The geographical area of the district of Kangra is 5,739 sq. km and lies on the 31°45'0" to 32°28'05" N latitude and 75°35'34" to 77°04'46" E longitude. Its area extends from the low hill sub-tropical zone of altitude range (400–650 m) in Shiwaliks to the high hill wet sub-temperate zone (above 3000 m) in Dhauladhar and Pir Punjal through the mid hill sub-humid zone (651–1800 m) in Palampur and Dharamshala. The wide range of altitude, topography and climatic conditions have endowed the district of Kangra with rich and diversified flora. In the Kangra district, subclass Polypetalae is represented by 52 families and 140 genera and nearly 225 species including a large number of cultivated plants (Chowdhery and Wadhwa 1984). The economic importance of this group of plants is already well recognized (Kapur 1985, Sharma and Maheshwari 2005, Uniyal et al. 2006). A perusal of literature shows that for the district Kangra, no attempts have been made to assess the genetic diversity of the vast diverse flora of the area except for a few chromosome number reports by Bir and Kumari 1981, Jeelani et al. 2010, 2011, Kumar et al. 2011. To study the genetic diversity in a better way at the intraspecific level and to further enrich the

*Corresponding author, e-mail: savitarana3@gmail.com
DOI: 10.1508/cytologia.77.197
### Table 1  Information regarding name of plant, its accession number, species, habit, locality with longitude and altitude, meiotic number, ploidy level, meiotic course, pollen fertility and average pollen grain size of the investigated members of Polypetaleae from District Kangra (H.P.) India

<table>
<thead>
<tr>
<th>Taxon*</th>
<th>Accession number (PUN)</th>
<th>Locality along with latitude and longitude/altitude (m)</th>
<th>Meiotic chromosome number</th>
<th>Ploidy level/meiotic course**</th>
<th>Pollen fertility (%)</th>
<th>Average pollen grain size (μm)***</th>
</tr>
</thead>
<tbody>
<tr>
<td>Family: Apiaceae Lindl.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Bupleurum lanceolatum</em> Wall. ex DC.</td>
<td>56163</td>
<td>Bara-gran, 32°02’N 76°50’E/3,000</td>
<td>n=16</td>
<td>4x/A</td>
<td>67.21</td>
<td>23.56×18.78–21.34×17.67</td>
</tr>
<tr>
<td>Family: Balsaminaceae DC.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Impatiens bicolor</em> Royle (=I. amorphata Edgew.; I. niamaicensis Gilg.)</td>
<td>55944</td>
<td>Triund, 32°16’N 76°22’E/3,000</td>
<td>n=8</td>
<td>2x/N</td>
<td>95.70</td>
<td>31.09×19.50</td>
</tr>
<tr>
<td>Family: Fabaceae Lindl.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Bupleurum lanceolatum</em></td>
<td>55943</td>
<td>Multin, 32°04’N 76°55’E/2,400</td>
<td>n=7</td>
<td>2x/N</td>
<td>97.76</td>
<td>31.66×18.00</td>
</tr>
<tr>
<td>Family: Hypericaceae Juss.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Medicago polymorpha</em> L.</td>
<td>55892</td>
<td>Rehlu, 32°13’N 76°10’E/900</td>
<td>n=16</td>
<td>4x/N</td>
<td>98.90</td>
<td>21.11×19.90</td>
</tr>
<tr>
<td>Family: Fumariaceae Marquis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Fumaria indica</em> (Hausskn.) Pugsley</td>
<td>55123</td>
<td>Dehra, 31°52’N 76°12’E/550</td>
<td>n=8</td>
<td>2x/N</td>
<td>82.78</td>
<td>35.78×32.87</td>
</tr>
<tr>
<td>Family: Geraniaceae Juss.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Geranium lucidum</em> L. (=G. camaraense C. Huang)</td>
<td>52735</td>
<td>Chota-bhangal, 32°02’N 76°50’E/2,300</td>
<td>n=13</td>
<td>2x/N</td>
<td>87.89</td>
<td>51.59×45.90</td>
</tr>
<tr>
<td>Family: Hypericaceae Juss.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Hypericum elodeoides</em> Choisy</td>
<td>52711</td>
<td>Triund, 32°16’N 76°22’E/3,000</td>
<td>n=13</td>
<td>2x/N</td>
<td>79.89</td>
<td>51.09×45.00</td>
</tr>
<tr>
<td>Family: Malvaceae Juss.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Abutilon indicum</em> (L.) Sweet (=A. albicum (Willd.) Sweet)</td>
<td>55148</td>
<td>Triund, 32°16’N 76°22’E/3,000</td>
<td>n=13</td>
<td>2x/N</td>
<td>88.76</td>
<td>53.67×51.65</td>
</tr>
<tr>
<td>Family: Onagraceae Juss.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Circaea alpina</em> L. (=Carlostephania minor Bubani)</td>
<td>55950</td>
<td>Renhear, 32°13’N 76°10’E/850</td>
<td>n=7</td>
<td>2x/N</td>
<td>81.76</td>
<td>37.89×40.76</td>
</tr>
<tr>
<td>Family: Oxalidaceae R. Br.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Oxalis corniculata</em> L.</td>
<td>56380</td>
<td>Dal-Lake, 32°20’N 76°18’E/3,800</td>
<td>n=11</td>
<td>2x/N</td>
<td>91.89</td>
<td>51.78×42.78</td>
</tr>
<tr>
<td>Family: Onagraceae Juss.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>E. cylindrica</em> D. Don. (=E. beaverdianum H. Lév.)</td>
<td>56381</td>
<td>Triund, 32°16’N 76°22’E/3,000</td>
<td>n=11</td>
<td>2x/N</td>
<td>90.11</td>
<td>51.08×42.70</td>
</tr>
<tr>
<td>Family: Onagraceae Juss.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>E. palustris</em> L.</td>
<td>54287</td>
<td>Chota-bhangal, 32°02’N 76°50’E/2,300</td>
<td>n=9</td>
<td>2x/N</td>
<td>87.27</td>
<td>29.55×25.59</td>
</tr>
<tr>
<td>Family: Oxalidaceae R. Br.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>E. roseum</em> Schreb.</td>
<td>54288</td>
<td>Bara-gran, 32°02’N 76°50’E/3,000</td>
<td>n=9</td>
<td>2x/N</td>
<td>92.29</td>
<td>29.23×25.12</td>
</tr>
<tr>
<td>Family: Onagraceae Juss.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>E. palustris</em> L.</td>
<td>55912</td>
<td>Bara-bhangal, 32°14’N 76°50’E/3,800</td>
<td>n=9</td>
<td>2x/N</td>
<td>93.60</td>
<td>28.13×24.34</td>
</tr>
<tr>
<td>Family: Onagraceae Juss.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Oxalis corniculata</em> L.</td>
<td>56380</td>
<td>Multin, 32°04’N 76°55’E/2,400</td>
<td>n=18</td>
<td>4x/N</td>
<td>89.23</td>
<td>26.87×24.78</td>
</tr>
<tr>
<td>Family: Oxalidaceae R. Br.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Oxalis corniculata</em> L.</td>
<td>55913</td>
<td>Lohadhari, 32°02’N 76°50’E/2,600</td>
<td>n=9</td>
<td>2x/N</td>
<td>90.29</td>
<td>25.47×24.78</td>
</tr>
<tr>
<td>Family: Onagraceae Juss.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Oxalis corniculata</em> L.</td>
<td>56365</td>
<td>Ranhear, 32°13’N 76°10’E/850</td>
<td>n=7</td>
<td>2x/A</td>
<td>65.34</td>
<td>33.80×34.06–32.56×33.82</td>
</tr>
</tbody>
</table>
chromosomal database, the present meiotic studies have been carried out on 190 polypetalous species including 48 species with new or varied chromosome numbers reports. The results on 23 such species have already been published (Rani et al. 2011), whereas the results for the other 25 species are discussed in this paper.

Materials and methods

For meiotic studies, flower buds were collected from different localities of the district of Kangra (Table 1). Smears of appropriate sized flower buds were made after fixing in the Carnoy’s fixative, using standard acetocarmine techniques. Pollen fertility was estimated by mounting mature pollen grains in glycerol-acetocarmine mixture at a ratio of 1:1. 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 a Nikon 80i eclipse Digital Imaging System. Voucher specimens are deposited in the Herbarium, Department of Botany, Punjabi University, Patiala (PUN).

Results and discussion

The present paper deals with meiotic studies on 23 species of Polypetalae from the district of Kangra with new/varied chromosome counts. The data regarding locality with altitude, accession number, present chromosome number, ploidy level, nature of meiotic course and pollen fertility of these species are given in Table 1. Previous chromosome reports have been consulted from chromosome number compilations by Fedorov (1974), Kumar and Subramaniam (1986), Index to Plant

<table>
<thead>
<tr>
<th>Taxon*</th>
<th>Accession number (PUN)</th>
<th>Locality along with latitude and longitude/altitude (m)</th>
<th>Meiotic chromosome number</th>
<th>Ploidy level/ meiotic course**</th>
<th>Pollen fertility (%)</th>
<th>Average pollen grain size (μm)***</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Families, Genera and Species, all are arranged alphabetically for convenience. **A=Abnormal, N=Normal ***Range of larger and smaller sized pollen grains counted in case of meiotically abnormal taxa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Family: Rosaceae Juss. | Geum roylei Wall. (=G. urbanum L.) | 55125 Triund, 32°16’N 76°22’E/3,000 | n=14 4x/A | 65.78 | 20.60–16.52–16.78–12.98 |
|-----------------------|-----------------------------------|--------------------------------------|---------------------------|---------------------|---------------------|----------------------------------|
| Rosa brunonii Lindl. (=R. clavigera H. Lév.) | 56313 Triund, 32°16’N 76°22’E/3,000 | n=7 2x/N | 70.67 | 20.15–19.89 |
| R. indica L. (=R. cymosa Tratt.) | 56314 Dharmkot, 32°15’N 76°20’E/2,800 | n=7 2x/A | 59.90 | 21.21–20.67–18.89–18.02 |
| R. macrophylla Lindl. | 55909 Boh, 32°17’N 76°10’E/1,900 | n=14 4x/A | 61.23 | 19.43–19.00–16.89–16.00 |
| Family: Rutaceae Juss. | Boenninghausenia albiflora Rchb. | 54340 Chota-bhangal, 32°02’N 76°50’E/2,300 | n=10 2x/N | 65.78 | 10.11–10.00 |
| Family: Tiliaceae Juss. | Triumfetta pilosa Roth | 55134 Bhanala, 32°12’N 76°10’E/800 | n=16 4x/N | 96.87 | 40.77–25.02 |
| | 55901 Ranhear, 32°13’N 76°10’E/850 | n=16 4x/A | 59.87 | 40.38–25.78–43.78–27.87 |
Chromosome Numbers from 1968 onwards, available from various journals, proceeding volumes and the web. Further, in case of any plant species having the same chromosome number reported by multiple authors, a few of the latest references have been cited in the text.

**Apiaceae**

*Bupleurum lanceolatum* Wall. ex DC.

The single accession worked out in the present paper reveals \( n=16 \) (Fig. 1) adding tetraploid cytotype for the species on a world-wide basis. The species is earlier known to have \( 2n=16 \), a single report that also comes from India (Mehra and Dhawan 1971).

**Balsaminaceae**

*Impatiens bicolor* Royle (=*I. amphorata* Edgew.)

Out of the 2 populations worked out at in the present report, one shows \( n=8 \) (Fig. 2) and the other \( n=7 \) (Fig. 3). The chromosomal count of \( n=7 \) is in conformity with earlier reports from India (Khoshoo 1966) and from the Netherlands (Tischler 1935–1936), whereas the chromosome report of \( n=8 \) adds a new cytotype on a world-wide basis. The species also exhibits tetraploid (\( 2n=32 \)) based on its third base number \( x=8 \), from Uganda (Zinov’eva-Stahevitch and Grant 1984).

---

**Figs. 1–12.**

I. racemosa DC.

The single accession of the species reveals $n=7$ (Fig. 4) which is a new cytotype for the species on a world-wide basis. Previously, the species is known to have chromosomal reports of $2n=18$ from India (Chatterjee and Sharma, 1970), South East Asia (Shimizu et al., 1984), Nepal and Yunan (Akiyama et al., 1996), Yunan and China (Sugiura et al. 1997) and $2n=20$ from Nepal (Malla et al. 1977).

I. sulcata Wall. (= I. gigantea Edgew.)

The chromosome report of $n=7$ (Fig. 5) is a new report for the species on a world-wide basis, which previously had earlier chromosome reports of $2n=16$ from Kashmir in India (Jeelani et al. 2010); $2n=18$ from Nepal (Akiyama et al. 1992); and $2n=20$, again from India (Khoshoo 1966).

Fabaceae

Medicago polymorpha L.

The single accession shows $n=16$ (Fig. 6) which is the first tetraploid report for the species on a world-wide basis. The species is already known to have a more common number, $2n=14$, from India (Kumari and Bir 1990), New Mexico (Luque et al. 1988) and Mediterranean region (Runemark 2006) along with $2n=16$ from India (Kumari and Bir 1990), Israel (Diaz Lifante et al. 1992) and Egypt (Mohamed 1997).

Fumariaceae

Fumaria indica (Hausskn.) Pugsley

Both populations exhibit $n=8$ (Fig. 7). This is a new diploid cytotype for this species on a world-wide basis. Earlier the species was identified as having another diploid with $2n=22$ from India (Rai 1939) and a hexaploid with a common number $2n=48$ from India (Sidhu and Bir 1983) and from outside of India (Lidén 1986).

Geraniaceae

Geranium lucidum L. (=G. camaense C. Huang)

Both the populations reveal $n=13$ (Fig. 8) which adds a new diploid cytotype for the species on a global level. The species is already known to be polybasic having diploids and polyploids, namely $2n=20$ from Morocco (Galland 1988); $2n=28$ from India (Kaur et al. 2010); $2n=40$, common number from Bulgaria (Petrova and Stanimirova 2003); $2n=42$ from Morocco (Galland 1988); $2n=46$ (Strid and Anderson 1985) and $2n=60$ (Aryavand 1983) from outside of India.

G. ocellatum Cambess. (=G. mascatense Boiss.)

Both the populations investigated in the present report reveal $n=13$ (Fig. 9) which is reported for the first time. Earlier the species is known to have only tetraploid cytotypes with $2n=56$ from West African mountains (Morton 1993).

Hypericaceae

Hypericum elodeoides Choisy

The single accession reveals $n=8$ (Fig. 10) which adds a new diploid cytotype for the species on a world-wide basis. Earlier, was identified at having another diploid cytotypes, namely $2n=18$ from India (Gupta et al. 2009); and tetraploid, namely $2n=32$ from India (Sandhu and Mann 1989)
and for outside of India (Sugiura 1944).

H. japonicum Thunb.

Both the populations of the species reveal \( n = 16 \) (Fig. 11) which is first report of tetraploid cytotype on a global level. Earlier the species is known to have had a single report of \( 2n = 16 \) from New Zealand (de Lange et al. 2004).

Malvaceae

Abutilon indicum (L.) Sweet (= A. albidum (Willd.) Sweet)

Both the populations of the species reveal \( n = 7 \) (Fig. 12) which is a chromosomal report for this species that varies from previous reports at the Indian level and is in conformity with earlier reports from outside of India as \( 2n = 14 \) (Fryxell and Stelly 1993). Earlier reports for the species are of \( 2n = 28 \) (Carr 1985); \( 2n = 36 \) (Podlech 1986); hexaploids predominant as \( 2n = 42 \) from India (Munirajappa and Krishnappa 1993) and Pakistan (Afaq-Husain et al. 1988); and octaploids as \( 2n = 72 \) (Krishnappa and Munirajappa 1982) from India.

M. verticillata L.

Both the populations show \( n = 21 \) (Fig. 13), adding a new hexaploid cytotype for the species on a world-wide basis. The species is earlier known to have polyploids at the higher levels reaching up to 18× level as evident from chromosome reports of \( 2n = ca. 76 \) from East Africa (Hedberg and
Hedberg 1977); $2n=ca. 84$ from Asia (Skovsted 1941) and $2n=ca. 126$ from North America (Gervais 1979).

Onagraceae

Circaea alpina L. (=Carlostephania minor Bubani)

Both the populations show $n=11$ (Fig. 14) which is the first report for the species from India and is in conformity with previous reports from Russia (Kochjarová 1992; Stepanov 1994) and other countries.

E. cylindricum D. Don. (=E. beauverdianum H. Lév.)

All the 3 accessions reveal $n=9$ (Fig. 15) which varies from earlier reports for the species in India. The species has earlier been reported to have $2n=36$ from India (Kumar and Singhal 2011) and China (Chen et al. 1992).

E. palustre L.

The single accession of the species depicts $n=18$ (Fig. 16) which is the first report for Indian material and is in accordance with the earlier tetraploid reports of $2n=36$ from Russia (Stepanov 1994) and Czech (Javurková and Jarolímová 1992).

E. roseum Schreb.

The single accession of the species shows $n=9$ (Fig. 17) which adds a new diploid cytotype for the species on a global level. The species has previously been reported as having $2n=36$ from India (Chatterjee et al. 1989) and Sweden (Lovkvist and Hultgard 1999).)

Oxalidaceae

Oxalis corniculata L.

The meiotic studies reveal $n=7$ for the species (Fig. 18) which varies from earlier reports for Indian material but is in conformity with earlier reports of $2n=14$ from outside India (Naranjo et al. 1982). The species is also known to exhibit cytotypes with different base numbers as evident from $2n=24$ (Sarkar et al. 1982), $2n=44$ (Roy et al. 1988) and $2n=48$ (Sharma and Chatterjee 1960) from India.

Rosaceae

Geum roylei Wall. (=G. urbanum L.)

The species exhibits $n=14$ (Fig. 19) at various stages of meiosis and adds a new tetraploid cytotype for the species on a world-wide basis. Earlier the species was reported as having triploid $2n=21$ from Belarus (Dmitrieva 2000) along with hexaploids quite common as $2n=42$ from India (Kaur et al. 2010) and outside India from Belarus (Dmitrieva 2000) and Bulgaria (Baltisberger 2006).

Rosa brunonii Lindl. (=R. clavigera H. Lév.)

Both the populations show $n=7$ (Fig. 20) which is reported for the first time in India and conforms to previous reports from outside India (Lewis and Basye 1961).

R. indica L. (=R. cymosa Tratt.)

The 2 populations reveal $n=7$ (Fig. 21) which is the first cytological report for the species from
India and is in conformity with the earlier reports from outside India (Reimann-philipp 1974).

**R. macrophylla Lindl.**

The single accession of the species depicts \( n = 14 \) (Fig. 22) which is the first report of tetraploid cytotype from India and is in accordance with \( 2n = 28 \) from The Turkish Himalayas (Hurst 1928) and East Asia (Krahulcovarholub and Holub 1998). The species also exhibits diploid cytotypes as \( 2n = 14 \) from India (Sandhu and Mann 1989) from West China (Täckholm 1922) and Turkest-Himalyas (Hurst 1928).

**Rutaceae**

**Boenninghausenia albi flora Rchb.**

The 2 populations worked out in the present report show \( n = 10 \) (Fig. 23) which is the first report for the species from India and is in conformity with the earlier reports from outside India (Guerra 1985). The species also has another cytotype as \( 2n = 18 \) from outside India (Khatoon and Ali 1993).

**Tiliaceae**

**Triumfetta pilosa Roth**

The single accession of the species shows \( n = 16 \) (Fig. 24) which is the first chromosome report of tetraploid cytotype, as the species has previously been subject to a single other report which gave \( 2n = 64 \) from South India (Krishnappa and Munirajappa 1980).

**Table 2.** Data on abnormal meiotic course in meiotically abnormal species from the district of Kangra

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Accession number</th>
<th>%age of PMCs involved meiosis-I/meiosis-II</th>
<th>Number of PMCs involved</th>
<th>Chromosomal stickiness at M-I (%age)</th>
<th>Unoriented bivalents at M-I (%age)</th>
<th>Bridges at meiosis-I/meiosis-II (%age)</th>
<th>Laggards at meiosis-I/meiosis-II (%age)</th>
<th>Multipolarity at T-II (%age)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Bupleurum lanceolatum</em></td>
<td>56163</td>
<td>8.33 (10/120)/7.07 (7/99)</td>
<td>2–6</td>
<td>4.00 (4/100)/17.47 (18/103)</td>
<td>5.88 (6/102)/—</td>
<td>2.86 (2/70)/—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td><em>Impatiens sulcata</em></td>
<td>55139</td>
<td>—/-</td>
<td>——</td>
<td>2.00 (2/100)/2.06 (2/97)</td>
<td>2.85 (3/105)/2.66 (2/75)</td>
<td>——</td>
<td>1.81 (2/110)/0.90 (1/110)</td>
<td>1.98 (2/101)</td>
</tr>
<tr>
<td><em>R. macrophylla</em></td>
<td>55909</td>
<td>2.70 (2/74)/—</td>
<td>2–3</td>
<td>4.54 (5/110)/4.04 (4/99)</td>
<td>5.55 (4/72)/—</td>
<td>5.21 (6/115)/1.98 (2/101)</td>
<td>6.66 (8/120)</td>
<td>—</td>
</tr>
<tr>
<td><em>Triumfetta pilosa</em></td>
<td>55901</td>
<td>—/—</td>
<td>——</td>
<td>2.38 (2/84)/—</td>
<td>1.98 (2/101)/2.48 (3/121)</td>
<td>6.12 (6/98)/—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>
Meiotic abnormalities have been recorded in some populations of *Malva neglecta*, *Rosa brunonii* and *R. indica* and in all the populations of *Bupleurum lanceolatum*, *Geum roylei*, *Impatiens sulcata*, *Oxalis corniculata* and *Rosa macrophylla*. In such populations, meiotic abnormalities in the form of cytomixis (Figs. 25, 36, 41), chromatin stickiness (Figs. 32, 44), unoriented bivalents (Figs. 29, 46), bridges, laggards (Figs. 26, 30, 33, 37, 39, 42, 45, 47) or multipolarity (Figs. 34, 48) have been observed at different stages of meiosis (Table 2). Cytomixis in the form of chromatin transfer has been observed from early prophase to pollen grain formation in most of these populations (Figs. 25, 36, 41). Chromatin stickiness involving a few bivalents has been observed at metaphase-I (Figs. 32, 44). Cytomixis and chromatin stickiness are considered to be the result of genetic factors (Ghaafari 2006; Fadaei et al. 2010; Jeelani et al. 2011) and environmental factors (Nirmala and Rao 1996) as well as genomic-environmental interaction (Baptista-Giacomelli et al., 2000) and seems to be equally applicable to the presently investigated populations. These meiotically abnormal populations show the presence of chromosomal laggards and bridges at anaphases and telophases. All this results in abnormal microsporogenesis leading to the formation of monads, diads, triads and polyads, along with micronuclei (Figs. 27, 31, 40, 43; Table 3) with the formation of heterogeneous sized fertile pollen grains and reduced pollen fertility (Fig. 28, 35, 38; Table 1). Large sized pollen grains have been observed to be in the range of 6–7% in each such population. Occurrences of giant pollen grains, possibly unreduced 2n pollen grains, have earlier been reported in several species (Vorsa and Bingham 1979, Bertagnolle and Thomson 1995, Sheidai et al. 2008, Fadaei et al. 2010). Unreduced gametes are known to produce higher polyploidy levels through polyploidization (Villeux 1985).

| Taxa                        | Accessions | Monads | | | | | | | | Diads | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
Acknowledgements

The authors are grateful to the University Grants Commission, New Delhi for providing financial assistance under the DRS SAP III of UGC as well as to the Department of Science and Technology, New Delhi for FIST programmes to this department. We are also highly thankful to the Director and other staff of Herbarium of Botanical Survey of India, Dehradun for their help in the identification of the plant species.

References


Jeelani, S. M., Rani, S., Kumar, S., Gupta, R. C. and Kumari, S. 2010. Cytomorphological diversity in some species of...
Imperatia Linn. (Balsaminaceae) from Western Himalayas (India). Cytologia 75: 379–389.
— and —. 1982. IOPB chromosome number reports LXXVI. Taxon 31: 582–583.
Mehra, P. N. and Dhawan, H. 1971. IOPB chromosome number reports XXXIV. Taxon 20: 792.
Naranjo, C. A., Mola, L. M., Poggio, L. and De Romero M. 1982. Estudios citotaxonómicos y evolutivos en especies herba-