



Cytogenetical Assessment of Apiaceae Lindl. From District Sirmaur, Himachal Pradesh, India

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DOI:10.5958/2455-7129.2018.00011.0

ABSTRACT

During the present study, population-based meiotic studies were carried out on 10 species of Family Apiaceae from selected localities of district Sirmaur of Himachal Pradesh in the Western Himalayas (India). New chromosome counts in *Heracleum canescens* ($2n=22$) and *Pleurospermum brunonis* ($2n=22$) have been reported for the first time on world-wide basis. Furthermore, meiotic course was noted to be normal in *Bupleurum lanceolatum*, *B. longicaule*, *Heracleum brunonis*, *Sanicula elata*, *Selinum tenuifolium*, *S. vaginatum* and *Vicatia conifolia*, it varied from normal to abnormal in the populations of *Bupleurum hamiltonii* and *Heracleum canescens* whereas it was invariably found to be abnormal in all the populations of *Pleurospermum brunonis*. These anomalous taxa were marked with meiotic abnormalities in the form of cytomixis, chromosomal stickiness, unoriented bivalents, formation of laggards and bridges resulting in abnormal microsporogenesis, and production of heterogeneous-sized fertile pollen grains along with reduced pollen fertility.

Key Words:

Apiaceae, Chromosome numbers, Meiotic course, Sirmaur.

INTRODUCTION

Sirmaur is the south-eastern district of Himachal Pradesh, forming distinct phyto-geographical pocket of the Western Himalayas. It has a total area of 2,825 km² with altitudinal variation from 400-3,630m. Sirmaur is predominantly mountainous having beautiful green forests and valleys, especially in Churdhar area, where the highest peaks remain snow covered for six months. Low denuded hill ranges of Shivalik represent the south-western part of the district.

The family Apiaceae Lindl. (Umbelliferae Juss.) comprises of 455 genera and 3,500 species in the world (Pimenov and Leonov 1993). In India, it is represented by 53 genera and 198 species (Aswal and Mehrotra 1994) of which 12 genera and 13 species have been known from district Sirmaur of H.P. (Kaur and Sharma 2004). It is cosmopolitan, being particularly abundant in the northern Hemisphere and is one of the best known families because of its characteristic inflorescences and fruits and the distinct chemistry, reflected in the odour, flavour, and even toxicity of many of its members (Heywood 1993). Most of the members are of economic relevance which includes carrot,

celery, coriander, and parsley belonging to the subfamily Apiioideae. These are annual, biennial or perennial, erect, rarely decumbent, mostly herbaceous aromatic plants with stems hollow; leaves alternate, rarely opposite or basal; petiole with sheathing at base; stipules absent (except in subfam. Hydrocotyloideae); a compound umbel, with flowers occurring in umbellate arranged radially and fruits schizocarpic. Three subfamilies (Apiioideae, Saniculoideae and Hydrocotyloideae) are traditionally recognized (Drude 1897–1898), with subfamily Apiioideae being the largest and taxonomically most complex (404 genera, 2,827–2,935 species, Pimenov and Leonov 1993). Many members of the family are known for their medicinal and ethnobotanical uses (Sher et al. 2011).

MATERIALS AND METHODS

For meiotic studies, flower buds were collected from different localities of the district Sirmaur of the Western Himalayas, India (Table 1). Smears of appropriately sized flower buds were made after fixing them in Carnoy's fixative, using

the standard acetocarmine technique. Pollen fertility was estimated by mounting mature pollen grains in a glycerol-acetocarmine (1:1) mixture. 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 the Nikon 80i Eclipse Digital Imaging System. Voucher specimens were deposited in the Herbarium, Department of Botany, Punjabi University, Patiala, Punjab.

RESULTS

Detailed cytological studies were carried out on 17 populations of 10 species and 6 genera belonging to family Apiaceae. The data regarding locality with altitude, accessions and meiotic chromosome numbers along with figure numbers of the presently worked out species are presented in Table 1. The results for each species with new/varied chromosome counts and abnormal meiotic courses are discussed below.

Table 1: Information on Taxa with accession number, habit, locality with altitude, meiotic chromosome numbers, ploidy level/meiotic course, pollen fertility, average pollen size and previous reports of the investigated members of Apiaceae from district Sirmaur of Western Himalayas, India.

FAMILY: Apiaceae Lindl.									
Sr. No.	Taxon	Accession Number	Habit	Locality with Altitude (m)	Meiotic Chromosome Number (2n)	Ploidy Level/Meiotic course	Pollen Fertility (%)	Pollen size (µm)	Previous reports+
1.	<i>Bupleurum hamiltonii</i> N.P. Balakr. (= <i>B. tenu</i> Buch.- Ham D. Don)								
	P-1	55674	Herb	Chapdhar, 2,400	16	2x/A	87.32	23.13×14.38-19.27×12.27	2n=16 Mehra & Dhawan 1971; Constance et al. 1976; Cauwet-Marc 1978, 1982; Ahmad & Koul 1980; Carbonnier & Farille 1980
	P-2	55675		Chadna, 2,300	16	2x/N	95.48	21.28×12.36	
2.	<i>B. lanceolatum</i> Wall. ex DC.								
		56771	Herb	Chapdhar, 2,400	16	2x/N	98.18	22.14×14.18	2n=16 Mehra & Dhawan 1971
3.	<i>B. longicaule</i> Wall. ex DC.								
	P-1	57357	Herb	Jamnala, 2,600	16	2x/N	96.16	24.45×21.27	2n=12 Alexeeva et al. 2000 2n=16 Ahmad & Koul 1980; Das & Mallick 1992; Pimenov et al. 2006
	P-2	57358		Chapdhar, 2,400	16	2x/N	95.73	17.27×13.46	
4.	<i>Heracleum brunonis</i> (de Candolle) C. B. Clarke								
		55199	Herb	Bhangyanimata, 2,800	22	2x/N	92.48	25.16×14.14	2n=22 Pimenov et al. 2006; Rani et al. 2011b 2n=33 Kumar & Singhal 2011
5.	<i>Ucaescens</i> Lindl.								
	P-1	56800	Herb	Jamnala, 2,600	22*	2x/A	86.12	24.34×12.26 20.32×12.11	-----
	P-2	56801		Chapdhar, 2,400	22*	2x/N	97.18	25.44×13.62	

<i>Pleurospermum brunonis</i> Benth. ex C.B. Clarke									
6.	P-1	56030	Herb	Tisri, 3,000	22*	2x/A	70.12	26.87×13.17 19.23 ×11.41	-----
	P-2	56762		Churdhar, 3,600	22*	2x/A	73.18	25.55×15.26 20.22 ×13.22	
<i>Sanicula elata</i> Buch.-Ham. Ex D. Don (= <i>S. europaea</i> L.)									
7.	P-1	56711	Herb	Jamnala, 2,600	16	2x/N	96.12	27.28×15.18	2n=16 Tischler 1931; Wanscher 1931; Hara & Kurosawa 1963; Kurosawa 1966; Bhattacharya 1967; Skalinska <i>et al.</i> 1968; Frey 1969; Schotsman 1970; 1980; Peev 1977; Queiros 1978; Silvestre 1978; Ahmad & Koul 1980; Strid 1980; Van Loon 1980; Strid & Semernko 1990; Wetsching & Leute 1991; Mesicek 1992 2n=32 Gadella 1977; Ahmad & Koul 1980; Morton 1993
	P-2	56712		Chapdhar, 2,400	16	2x/N	98.00	26.38×13.38	
<i>Selinum tenuifolium</i> Wall. ex DC.									
8.	P-1	56713	Herb	Sangrah, 2,200	22	2x/N	98.00	23.19×14.74	2n=22 Schulz-Gabel 1930; Sharma & Bhattacharya 1959; Sharma & Sarkar 1967-1968; Malla <i>et al.</i> 1974
	P-2	56714		Shamra, 1,500	22	2x/N	96.43	24.38×12.27	
<i>S. vaginatum</i> C.B. Clarke									
9.	P-1	57344	Herb	Jamnala, 2,600	22	2x/N	98.65	26.63×23.16	2n=22 Ahmad & Koul 1980; Das & Mallick 1993; Pimenov <i>et al.</i> 2006
	P-2	57345		Telangna, 2,800	22	2x/N	97.48	24.72×20.52	
<i>Vicatia conifolia</i> DC. (= <i>Cherophyllum gracillimum</i> Klotz.)									
10.	57340		Herb	Tisri, 3,000	22	2x/N	98.24	26.56×12.19	2n= 20 Khatoon & Ali 1993 2n= 22 Hore 1971, 1980; Retina & Pimenov 1977; Ahmad & Koul 1980; Pimenov <i>et al.</i> 2006

A= Abnormal, N=Normal

* Species cytologically worked out for the first time at world level.

Genus: *Bupleurum* L

At present, three species namely, *B. hamiltonii* N.P. Balakr., *B. lanceolatum* Wall. ex DC. and *B. longicaule* Wall. ex DC. have been cytologically worked out.

***B. hamiltonii* N.P. Balakr. (= *B. tenue* Buch.- Ham D. Don)**

Two populations of species have been studied from Chapdhar (2,400 m) and Chadna (2,300 m) showing chromosome count of $2n=16$ counted in PMCs at Diakinesis (Fig. 1). The present

chromosome count of $2n=16$ is in line with the previous reports from India (Ahmad and Koul 1980) and from outside India. Further, meiotic course in one accession is abnormal with the presence of cytomixis from Prophase-I to T-II, chromosomal stickiness at M-I, laggards and bridges resulting in abnormal microsporogenesis (Fig. 2-10, Table 2). All these abnormalities lead to the formation of fertile and sterile pollen grains. The pollen fertility is reduced to 87.32%, whereas, in other accession meiotic course is found to be normal with regular tetrad formation and high pollen fertility (95.48%).

Table 2: Data on abnormal meiotic course in one population of *Bupleurum hamiltonii* collected from Chapdhar (55674)

S. No.	Meiotic abnormalities	Frequency (%)
1.	PMCs involved in cytomixis at Meiosis-I & Meiosis-II	9.37 (9/96)/ 3.33 (3/90)
2.	No. of PMCs involved in cytomixis	2-4
3.	Chromosomal stickiness at M-I	4.38 (5/ 114)
4.	Bridges at A-I & T-I/ A-II & T-II	2.22(2/90)/ ----
5.	Laggards at A-I & T-I/ A-II & T-II	4.70 (4/85)/ 1.16 (1/86)
6.	Triads - WMN / WM	3.40(3/88)/ ----
7.	Tetrads - WMN / WM	87.50 (77/88)/ 6.81(6/88)
8.	Polyads	2.27 (2/88)

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

B. lanceolatum Wall. ex DC.

It is commonly distributed in the Himalayas from Western Pakistan, Kashmir (India) to Nepal and between the altitudinal range of 2,000-3,000m. The present chromosome count of $2n=16$ (Fig.11) is in conformity with the previous single report from the Utrakhhand in the Western Himalayas of India (Mehra and Dhawan 1971).

B. longicaule Wall. ex DC.

At present, two populations studied from Jamnala (2,600m) and Chapdhar (2,400m) depict chromosome count of $2n=16$ in the form of 8 bivalents at M-I (Fig. 12) in conformity with the previous reports from India. The species is also known to have another diploid cytotype with $2n=12$. Meiotic course is normal with regular tetrad formation and quite high pollen fertility (95-96%).

Cytological literature of the genus reveals that out of 180 taxonomically known species, 87 (48.34%) species are known for chromosome numbers varying as $2n=12,14,16,19,20,21,22,24,25,26,28,30,31,32,34,37,40,42,60,64$. *Bupleurum* is characterized by a basic

chromosome number of $x = 8$, a number that is rare in Apiaceae ($x = 11$). Cauwet-Marc et al. (1977) proposed the base number $x = 8$ as the primitive one in *Bupleurum*, and $x = 6, 7$ as derived characters. Overall, 6 species show intraspecific euploid series based on $x=6,7,8$ and 18 species are marked with aneuploid cytotypes. Out of 16 taxonomically known species from India, 12 species are cytologically investigated having as many as 11 species at diploid level ($2n=12, 14, 16$) and just one species as polyploid.

Genus: Heracleum L.

At present, two species, namely, *H. brunonis* (de Candolle) C. B. Clarke and *H. canescens* Lindl. have been cytologically worked out.

H. brunonis (de Candolle) C. B. Clarke

Presently studied accession depicts the meiotic chromosome count of $2n=22$ as confirmed from the presence of 11 bivalents at Diakinesis/M-I (Fig.13) which is in conformity with the previous reports from India (Pimenov et al. 2006). The species is also known to have $2n=33$ (Kumar and Singhal 2011). Meiotic course is normal resulting into regular microsporogenesis.

The pollen fertility is quite high (92.48%).

***H. canescens* Lindl.**

PMC shows 11 bivalents at M-I (Fig. 14) and 11:11 distribution of chromosome at A-I. The species is cytologically worked out for the first time on world-wide basis. The phenomenon of

cytomixis is seen involving transfer of chromatin material among 2-3 proximate PMCs. Some other abnormalities such as bridges and laggards at anaphases and telophases are also observed along with abnormal microsporogenesis (Fig. 15-17, Table 3). At the end, some heterogenous sized pollen grains are produced. The pollen fertility is 86-89%.

Table 3: Data on abnormal meiotic course in population of *Heracleum canescens*.

S. No. Meiotic abnormalities	Frequency (%)
1. PMCs involved in cytomixis at A-I & T-I / A-II & T-II	7.27 (8/110)/ -----
2. No. of PMCs involved in cytomixis at A-I & T-I / A-II & T-II	2-3
3. Chromosomal stickiness at M-I	3.05 (4/131)
4. Bridges at A-I & T-I/ A-II & T-II	6.25(6/96)/-----
5. Laggards at A-I & T-I/ A-II & T-II	5.00 (4/80)/----
6. Dyads- WMN / WM	2.22(2/90)/ ----
7. Triads - WMN / WM	4.44(4/90) /----
8. Tetrads - WMN / WM	86.66(78/90)/ 6.66(6/90)

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

As per cytological literature, the genus reveals that out of 70 taxonomically known species, 63 (90.00%) are cytologically known on world level ($2n=19, 22, 23, 24, 40, 42, 44, 46$) with 15.87% showing polyploidy. Out of 20 taxonomically known species from India, 12 species are chromosomally known, of which 6 (50.00%) are polyploids. *Heracleum* is characterized by a basic chromosome number of $x=10, 11$, where $x=11$ as primary basic number making euploid series in one species. Three species are marked with aneuploid cytotypes conforming to numerous such cases already reported, especially for specimens collected from the Hengduan Mountains in China.

Genus: *Pleurospermum* Hoffm.

At present, single species *P. brunonis* Benth. ex C.B. Clarke has been cytologically worked out. Two populations of *P. brunonis* Benth. ex C.B. Clarke was studied from Tisri (3,000m) and Churdhar (3,600m) show chromosomal report of $2n=22$, as counted from 11 bivalents at M-I

(Fig.18). The species is cytologically worked out for the first time on world-wide basis. Further, meiotic course is found to be abnormal with presence of cytomixis from Prophase-I to T-II (hyperploids and hypoploid cells also seen), chromosomal stickiness at M-I, laggards and bridges at A-I (Fig.19-21). All these anomalies result into abnormal microsporogenesis with the presence of triads, tetrads, with or without micronuclei (Tables 4-5) and low pollen fertility (70-73%).

Out of 50 taxonomically known species, 8 (16.00%) are cytologically known on world level ($2n=18, 22, 33, 44, 50$) with 12.50% showing polyploidy. As per cytological literature of the genus, it is characterised by basic numbers as $x=9, 11$ where 11 is the primary basic number making euploid series and $x=9$ is present in four different species. Out of 14 taxonomically known species from India, 3 (21.05%) species are cytologically worked out and all exist as diploids ($2n=18, 22$).

Table 4: Meiotic abnormalities in *Pleurospermum brunonis*.

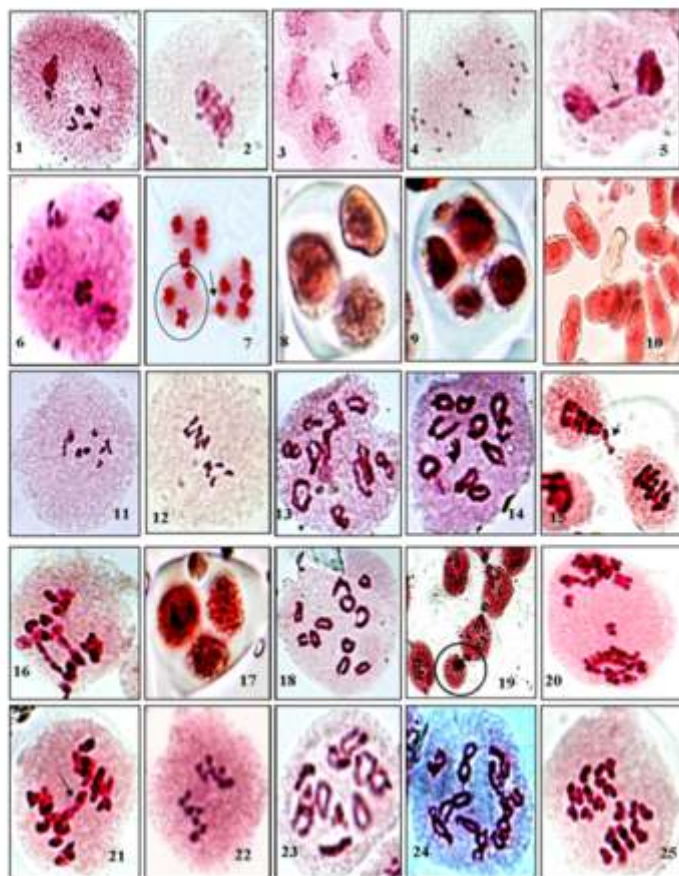
Accession Number	Cytomixis		Meiotic course showing PMCs with		
	% of PMCs involved Meiosis-I/ Meiosis-II	Number of PMCs involved	Chromosomal stickiness at M-I (%)	Bridges at Meiosis -I/ Meiosis-II (%)	Laggards at MeiosisI/ Meiosis-II (%)
56030	13.84 (18/130)/ 6.66 (6/90)	2-6	5.12 (6/ 117)	2.22(2/90)	9.30 (8/86)
56762	10.04 (13/125)/ 3.33 (3/90)	2-4	4.34 (5/ 115)	3.09(3/97)	3.03 (3/99) 4.65(4/86) 2.41 (3/124)

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

Table 5: Data on abnormal microsporogenesis in *Pleurospermum brunonis*.

Accession Number	Microsporogenesis (Values in %)				
	Triads		Tetrads		Polyads
	WMN	WM	WMN	WM	
56030	4.47(6/134)	1.49(2/134)	84.32 (113/134)	6.71(9/134)	2.98 (4/134)
56762	2.75(4/145)	-----	86.89 (126/145)	7.58(11/145)	2.75 (4/145)

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



Bupleurum hamiltonii: (Fig. 1: Diaskinesis showing 8II., Fig. 2: Chromatin stickiness at M-I., Fig. 3: Cytomixis., Fig. 4: Laggards at A-I., Fig. 5: Bridge at T-I., Fig. 6: Multipolarity at T-II, Fig. 7: Transfer of pole at T-II, Fig. 8: A triad., Fig. 9: A tetrad with micronuclei., Fig. 10: Fertile and sterile pollen grains.); *B. lanceolatum* Wall. ex DC. (Fig. 11: M-I showing 8II.); *B. longicaule* Wall. ex DC. (Fig. 12: Meiosis in PMC (2n=16) at M-I showing 8II.); *Heracleum brunonis* (de Candolle) C. B. Clarke (Fig. 13: M-I showing 11II.); *H. canescens* Lindl. (Fig. 14: M-I showing 11II., Fig. 15: Cytomixis at M-I., Fig. 16: Bridges at A-I., Fig. 17: A triad with micronucleus.); *Pleurosperm umbrunonis* Benth. ex C.B. Clarke (Fig. 18: M-I showing 11II., Fig. 19: Group of PMCs showing cytomixis., Fig. 20: Laggard at A-I., Fig. 21: Bridge at A-I.); *Sanicula elata* Buch.-Ham. Ex D.Don (Fig. 22: A-I showing 8:8 distribution of chromosomes.); *Selinum tenuifolium* Wall. ex DC. (Fig. 23: M-I showing 11II.); *S. vaginatum* C.B. Clarke (Fig. 24: M-I showing 11II.); *Vicatia conifolia* DC. (Fig. 25: A-I showing 11:11 distribution of chromosomes.).

Genus: *Sanicula* L.

Single species namely, *S. elata* Buch.-Ham. Ex D.Don has been cytologically investigated at present. During meiotic studies, the PMCs depict the presence of 8 bivalents at M-I and 8: 8 distribution of chromosomes at A-I. The present chromosome count of $2n=16$ (Fig. 22) is in agreement with the previous reports from India (Ahmad and Koul 1980) and from outside India. The species also occurs with $2n=32$ (Ahmad and Koul 1980; Morton 1993). Meiotic course is normal with regular microsporogenesis. The pollen fertility is quite high.

Out of 40 taxonomically known species, 28 (70.00%) species are cytologically known on world level ($2n=8, 16, 32, 48, 64$) with 7.14% showing polyploidy. From India, 2 (66.67%) species are cytologically worked out of which one species exists at diploid ($2n=16$) level and second one at tetraploid level. For this genus, one report of $2n=8$ (Hiroe 1954) has never been confirmed again, hence $x=4$ is to be considered with restraint and rather $x=8$ to be taken as primary basic number forming euploid series in two species at world level. Aneuploidy is also reported in two species.

Genus: *Selinum* L.

At present, two species *S. tenuifolium* Wall. ex DC. and *S. vaginatum* C.B. Clarke have been cytologically explored.

***S. tenuifolium* Wall. ex DC.**

Meiotic studies in the species reveal the chromosome count of $2n=22$ as confirmed from the presence of 11 bivalents at M-I (Fig. 23) and 11:11 distribution of chromosomes at A-I in conformity with the previous reports from India (Sharma and Sarkar 1967-1968). The course of meiosis is normal in both the populations. The pollen fertility is 96-98%.

***S. vaginatum* C.B. Clarke**

Meiotic studies have been performed on the two accessions showing chromosome number of $2n=22$, counted at Diakinesis/M-I (Fig. 24) in conformity with the previous reports from India.

The pollen fertility is almost cent per cent.

Selenium is characterized by a basic chromosome number of $x=11$. A perusal of literature shows that 8 species of the genus are taxonomically known and all are cytologically worked out. Out of 5 taxonomically known species from India, 3 (60.00%) species are cytologically investigated. The genus lacks aneuploidy and polyploidy.

Genus: *Vicatia* DC.

Presently, single species, namely, *V. conifolia* DC has been cytologically investigated. The chromosome count of $2n=22$ in the presently studied two accessions is confirmed from the presence of 11 bivalents at M-I and 11:11 distribution of chromosome at A-I (Fig. 25). It is in conformity with the earlier reports from India (Ahmad and Koul 1980; Pimenov et al. 2006) and from outside India. The species is also known to have $2n=20$ (Khatoon and Ali 1993). The meiotic course is normal resulting into almost cent per cent pollen fertility (96.24%).

Chromosome numbers literature of the genus reveals that all the 5 taxonomically known species are cytologically worked at world level ($2n=20, 22, 44$) with 20.20% showing polyploidy. Out of 5 taxonomically known species from India, one cytologically worked out species exists at tetraploid level. The basic chromosome number $x = 11$ makes euploid series in one species.

DISCUSSION

A significant contribution to the cytology of the family from outside India has been provided by some researchers such as Skalinska (1974) from Poland; Ferakova (1976) from Slovakia; Retina and Pimenov (1977) from middle Asia; Khatoon and Ali (1993) from Pakistan; Probatova (2004) from Sakhalin, Moneron and the Kurile Islands. Appreciable amount of work has been done on cytology of Indian members as well by Sharma and Sarkar (1967-1968) from the eastern Himalayas, Sinha and Sinha (1977) from Bihar and Subramanian (1986) from South India. From the western Himalayas, most of the species have not been able to get enough cytological attention except

for few reports available by Mehra and Dhawan (1971); Ahmad and Koul (1980) and Kumar and Singhal (2011) from area other than explored presently.

Perusals of cytological literature shows that the more common chromosome numbers in the family include $2n = 12, 14, 16, 18, 20, 22, 24, 26, 32, 36, 40, 44, 48, 64, 72$ based on $x = 6, 7, 8, 9, 10, 11$, with the frequency of $x = 8, 9, 10, 11$ being the most common on world-wide basis. It is noted that most of the genera are polybasic (*Bupleurum*, *Daucus*, *Pimpinella*, *Scandix* and *Sium*) followed by those which are dibasic (*Heracleum*, *Oenanthe*, *Pleurospermum*, *Vicatia*) and strictly monobasic one (*Chaerophyllum*) on world level. The polyploidy is overall low in these genera as evident from lowest of 6.06% in *Pimpinella* to highest of 25% in *Sium* on worldwide basis. In case of *Heracleum*, polyploidy is only 14.70% following the trend like other genera on world_wide basis, however on India basis, it exhibits quite high frequency of 50%.

The meiotic abnormalities have been recorded in some or all the populations of *Bupleurum hamiltonii*, *Heracleum canescens*, and *Pleurospermum brunonis*. In such populations, the meiotic abnormalities in the form of cytomixis, chromatin stickiness, bridges or laggards have been observed at different stages of meiosis. These meiotic abnormalities point out the existence of intraspecific genetic variability. The cytomixis in the form of chromatin transfer has been observed from early prophase to pollen grain formation in most of these populations. Cytomixis in these species results into the formation of PMCs with less or more chromosome number, enucleated PMCs, irregular microspore tetrads and pollen sterility (Jeelani et al. 2014). Previously, similar observations as a consequence of chromatin transfer had also been reported in other plants (Jeelani, et al. 2012; Rani et al. 2012; Jeelani et al. 2014). Chromatin stickiness linking few bivalents has been observed at metaphase-I Cytomixis and chromatin stickiness are well thought-out to be the result of genetic factors (Bellucci et al. 2003; Kumar et al. 2013) and environmental factors (Nirmala and Rao 1996) as well as genomic

environmental interface (Baptista-Giacomelli et al. 2000) and seems to be equally applicable to the presently studied populations. These meiotically abnormal populations show the presence of chromosomal laggards and bridges at anaphases and telophases. All this results into abnormal microsporogenesis leading to the formation of monads, diads, triads and polyads, along with micronuclei with the formation of varied sized fertile pollen grains and reduced pollen fertility.

ACKNOWLEDGMENTS

The authors are grateful to the University Grants Commission, New Delhi, under the DRS SAP III of UGC, FIST of the DST programs and the Rajiv Gandhi National Fellowship Scheme for providing financial assistance. We are very thankful to the Director of Botanical Surveys of India, Dehra Dun, for his help in identification of plant species.

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