Research Article

Meiotic Studies in Some Species of Tribe Cichorieae (Asteraceae) from Western Himalayas

Raghbir Chand Gupta,1 Henna Goyal,1 Vijay Singh,1 and Rajesh Kumar Goel2

1 Department of Botany, Punjabi University, Patiala 147002, India
2 Department of Pharmaceutical Sciences and Drug Research, Punjabi University, Patiala 147002, India

Correspondence should be addressed to Vijay Singh; vijaykataria05@rediffmail.com

Received 28 August 2014; Accepted 16 October 2014; Published 13 November 2014

Academic Editor: Jennifer A. Tate

Copyright © 2014 Raghbir Chand Gupta et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

The present paper deals with meiotic studies in 15 species belonging to 6 genera of the tribe Cichorieae from various localities of Western Himalayas. The chromosome number has been reported for the first time in Hieracium crocatum (2n = 10) and Lactuca lessertiana (2n = 2x = 16). Further, intraspecific variability has been reported for the first time in H. umbellatum (2n = 2x = 10 and 2n = 6x = 54), Tragopogon dubius (2n = 2x = 14 and 2n = 4x = 28), and T. gracilis (2n = 2x = 14). The chromosome report of 2n = 2x = 10 in Youngia tenuifolia is made for the first time in India. Maximum numbers of the populations show laggards, chromosome stickiness, and cytomixis from early prophase to telophase-II, leading to the formation of aneuploid cells or meiocytes with double chromosome number. Such meiotic abnormalities produce unreduced pollen grains and the reduced pollen viability.

1. Introduction

The tribe Cichorieae (also known as Lactuceae) encompasses 95 genera and ca. 2500 species, primarily in temperate to subtropical zones of the Northern Hemisphere [1]. Members of the tribe are characterized by very important uniform characteristics, such as homogamous ligulate capitula and the presence of milky latex.

The presently investigated species are also known to have medicinal uses, such as Hieracium crocatum to cure gastric troubles, Lactuca dolichophylla to cure constipation, L. macrorhiza used as an ingredient to cure stomach ache, L. serriola to treat ailments of the urinary tract, and Taraxacum officinale used as diuretic and laxative [2–4].

Chromosome studies are valuable determinants in studying evolution. Many workers have studied the cytology of Indian Asteraceae, including members of tribe Cichorieae. Cytological studies on the family from Lahaul-Spiti area, an ecologically very fragile cold desert area of Western Himalayas, are almost lacking. As an attempt to fill this lacuna, the present investigations have been undertaken.

2. Materials and Methods

2.1. Plant Material. Exploratory surveys were made during the years from 2009 to 2013 in selected localities (Table 1) of Himachal Pradesh (Kullu and Lahaul-Spiti Districts). The cytologically worked-out plants were identified using regional floras and compared with the specimens deposited at the Herbarium of Botanical Survey of India, Northern Circle, Dehra Dun. The voucher specimens (Table 1) were deposited in the Herbarium, Department of Botany, Punjabi University, Patiala (PUN).

2.2. Meiotic Studies. For meiotic chromosome counts, unopened floral buds of suitable sizes were fixed in a freshly prepared Carnoy’s fixative (mixture of alcohol, chloroform, and glacial acetic acid in a volume ratio 6 : 3 : 1) for 24 h. These were subsequently transferred to 70% alcohol and stored in refrigerator at 4°C until used for meiotic analysis. Meiocytes were prepared by squashing the developing anthers and stained with acetocarmine (1%). Chromosome number was determined at diakinesis/M-I/II/A-I/II from freshly prepared slides with light microscope Olympus. 500–600 pollen...
Table I: The table showing details on taxon, geographical coordination, accession number, average plant height, flowering-fruiting period, chromosome number (2n), ploidal level (x), and pollen fertility of tribe Cichorieae (Asteraceae) from Western Himalayas.

| Taxon                        | Locality with altitude (m) and geographical coordinates | Accession number (PUP*) | Average plant height (cm) | Flowering-fruiting period | Chromosome number (2n) | Ploidal level (x) | Pollen fertility (%) |
|------------------------------|----------------------------------------------------------|--------------------------|----------------------------|---------------------------|------------------------|-------------------|----------------------|
| Hieracium crocatum Bunge ex Ledeb. | Trilokinath, Lahaul (H.P.), 2760 32°42'0" N, 76°41'0" E | 52760                     | 42 ± 6.4                   | June–September            | 10‡                    | 2x                | 88.4                 |
| H. umbellatum L. H. umbellatum L. (P1) | Jispa, Spiti (H.P.), 3142 32°38'0" N, 77°10'0" E | 52763                     | 42 ± 2.3                   | June–September            | 10‡                    | 2x                | 91.0                 |
|                             | Keylong, Lahaul (H.P.), 3080 32°3'48" N, 77°14'8" E | 52774                     | 46 ± 72                    | June–September            | 54‡                    | 6x                | 82.1                 |
| L. dissecta D. Don. L. dissecta D. Don. | Hadimba, Temple, Manali, 2438 32°14'32" N, 77°11'14" E | 58562                     | 16 ± 4.3                   | June–September            | 16                     | 2x                | 88.1                 |
| L. dolichophylla Kitamura L. dolichophylla Kitamura | Sissu, Lahaul (H.P.), 3130 32°29'0" N, 77°7'0" E | 57504                     | 20 ± 5.2                   | June–September            | 16                     | 2x                | 79.2                 |
| L. lessertiana C. B. Clarke L. lessertiana C. B. Clarke | Batal, Spiti (H.P.), 3890 32°27'28" N, 77°37'10" E | 52776                     | 32 ± 7.2                   | June–September            | 16‡                    | 2x                | 70.2                 |
| L. macrohiza (Royle) Hook. f. L. macrohiza (Royle) Hook. f. | Chotadhara, Spiti (H.P.) 3800 | 57510                     | 25 ± 4.6                   | June–September            | 16                     | 2x                | 71.3                 |
| L. sativa L. L. sativa L. | Hadimba, Temple, Manali, 2438 32°14'32" N, 77°11'14" E | 58534                     | 55 ± 2.4                   | March–November            | 18                     | 2x                | 87.0                 |
| L. seriola L. L. seriola L. | Jispa, Spiti (H.P.), 3200 32°38'0" N, 77°10'0" E | 58535                     | 55 ± 2.5                   | April–October             | 18                     | 2x                | 76.0                 |
| Prenanthes brunoniana C. B. Clarke Prenanthes brunoniana C. B. Clarke | Tandi, Keylong (H.P.), 2573 32°34'40" N, 77°13'6" E | 52764                     | 80 ± 13.1                  | June–August               | 16                     | 2x                | 90.1                 |
| Taraxacum officinale L. Taraxacum officinale L. (P1) | Marhi, Manali (H.P.), 3330 32°20'56" N, 77°13'4" E | 52587                     | 27.1 ± 3.2                 | March–November            | 16                     | 2x                | 86.2                 |
|                             | Keylong, Lahaul (H.P.), 3080 32°3'48" N, 77°14'8" E | 52693                     | 8.3 ± 7.9                  | 32                        | 4x                     | 73.6               |                      |
|                             | Kibber, Spiti (H.P.), 4205 32°19'54" N, 78°0'32" E | 57491                     | 17.2 ± 1.6                 | 24                        | 3x                     | 56.3               |                      |
| Tropogonon dubius Scop. Tropogonon dubius Scop. (P1) | Keylong, Lahaul (H.P.), 3080 32°3'48" N, 77°14'8" E | 57503                     | 50 ± 2.5                   | June–September            | 14‡                    | 2x                | 83.0                 |
|                             | Lossar, Spiti (H.P.), 4079 32°24'49" N, 77°49'11" E | 57505                     | 35 ± 7.3                   | June–September            | 28‡                    | 4x                | 90.3                 |
| T. gracilis D. Don T. gracilis D. Don | Koksar, Lahaul (H.P.), 3160 32°41'37" N, 77°23'54" E | 52768                     | 25.2 ± 4.9                 | June–September            | 14‡                    | 2x                | 79.2                 |
| Youngia glauca Edgew. Youngia glauca Edgew. | Zingzingbar, Lahaul (H.P.), 4270 32°47'30" N, 77°59'28" E | 52773                     | 73 ± 5.3                   | July–August               | 14                     | 2x                | 83.0                 |
| Y. japonica (L.) DC. Y. japonica (L.) DC. | Hadimba, Temple, Manali, 2438 32°14'32" N, 77°11'14" E | 57500                     | 42 ± 4.7                   | June–September            | 16                     | 2x                | 78.2                 |
| Y. tenuifolia (Wild.) Bab. Y. tenuifolia (Wild.) Bab. | Jispa, Spiti (H.P.), 3200 32°38'0" N, 77°10'0" E | 52771                     | 15 ± 4.2                   | June–September            | 10†                    | 2x                | 87.2                 |

*Herbarium, Punjabi University, Patiala. ‡First ever chromosomal report. §First cytotype report from India.
mother cells were analyzed for meiotic behaviour at different stages, metaphase-I/II (M-I/II), anaphase-I/II (A-I/II), and telophase-I/II (T-I/II).

2.3. Pollen Grain Analysis. Pollen fertility was estimated through stainability tests using glycerol-acetocarmine (1:1) mixture and aniline blue (1%). Up to 450–800 pollen grains were examined for pollen fertility and size frequencies. Well-filled pollen grains with stained nuclei were taken as apparently fertile while shriveled and unstained pollens were counted as sterile.

2.4. Photomicrographs. Photomicrographs from the freshly prepared desirable slides having clear chromosome counts, dyads, triads, tetrads, and pollen grains were taken with a digital imaging system of Leica QWin.

3. Results

3.1. Chromosome Number

Hieracium crocatum Bunge ex. Ledeb. The present species revealed the diploid cytotype (2n = 10, Figure 1(a)), which is a first ever chromosome report for the species.
Both the cytotypes, 2n = 10 (Figure 1(b)) and 2n = 54 (Figure 1(c)), are the new records from the world, although the species is already known to have 2n = 18 [5] and 2n = 27 [6] from outside India. Polyploid cytotypes show some enlargement in vegetative and floral characters (Table 2).

Lactuca dissecta D. Don. The present report (2n = 16, Figure 1(d)) is in line with many previous reports from India [7–10] and abroad [11].

L. lessertiana (Wall. ex DC) C. B. Clarke. The present chromosome report of 2n = 16 (Figure 1(e)) is in line with many previous reports from India [7, 8, 10, 12].

L. sativa L. Meiotic analysis of the species reveals the diploid cytotype (2n = 18, Figure 1(h)), which is in conformity with the previous works of Chatterjee and Sharma [14] and Gupta and Gill [15].

L. serriola L. The present chromosome report (2n = 18, Figure 1(i)) is confirmed by many workers from India [7, 12, 15, 16].

Prenanthes brunoniana C. B. Clarke. The present chromosome report of 2n = 16 (Figure 1(j)) is in conformity to only previous report from Garhwal, Uttarakhand, by Shetty [8].

Taraxacum officinale L. The present meiotic investigation revealed three cytotypes, 2n = 2x = 16 (Figure 1(k)), 2n = 3x = 24 (Figure 1(l)), and 2n = 4x = 32 (Figure 1(m)). Both diploid and tetraploid cytotypes are common and are reported by many workers [17]. Gupta et al. [13], besides tritidal cytotype, also reported some other cytotypes, that is, 2n = 26, 27, 32, 38, and 40. Morphologically, the tetraploids do not show any robust and gigas effect due to polyplody Table (2), but they certainly show a lot of variation in shape of leaves.

Tragopogon dubius Scop. Both the cytotypes, 2n = 14 (Figure 1(n)) and 2n = 28 (Figure 1(o)), are varied cytotypes at world level. The species is reported earlier with 2n = 24 by Koul and Gohil [18] and Mehta and Ramanandan [12] from Kashmir Himalayas. From outside India, the species is known to have 2n = 12, 24, and 36 [5]. Morphologically, tetraploid cytotype does not show any gigas effect as compared to diploid (Table 2).

T. gracilis D. Don. The present chromosome report (2n = 14, Figure 1(p)) is a varied chromosome count for the species at world level. Earlier, Mehta and Ramanandan [12] reported diploid cytotype with 2n = 12 from the Western Himalayas.
### Table 2: Morphological comparison of different cytotypes of tribe Cichorieae from Western Himalayas.

| Taxon/voucher data | Chromosome number (2n) | Leaf size (mean ± SD) | Shape of leaf | Flower colour | Average number of capitula/plant | Stomatal size (μm) (mean ± SD) | Pollen size (μm) (mean ± SD) | Stomatal index (%) |
|--------------------|------------------------|-----------------------|----------------|----------------|-------------------------------|--------------------------------|--------------------------------|---------------------|
| **Hieracium umbellatum** |                        |                       |                |                |                               |                                |                                |                     |
| PI—52763           | 10                     | 4.0 ± 0.2 × 1.0 ± 0.3 | Entire         | Yellow         | 17                            | 23.21 ± 0.4 × 31.54 ± 2.4      | 16.75 ± 0.7 × 20.1 ± 1.2      | 33.33               |
| P2—52774           | 54                     | 7.0 ± 1.2 × 1.5 ± 0.5 | Serrate-toothed| Yellow         | 22                            | 29.80 ± 2.1 × 34.26 ± 1.7      | 15.0 ± 0.56 × 20.0 ± 0.9      | 23.07               |
| **Taraxacum officinale** |                      |                       |                |                |                               |                                |                                |                     |
| PI—52687           | 16                     | 20.0 ± 0.6 × 1.9 ± 0.9| Yellow         | 3              | 17.6 ± 0.4 × 14.5 ± 0.9        | 18.75 ± 0.4 × 20.62 ± 0.8      | 28.57               |
| P2—52693           | 32                     | 5.9 ± 1.2 × 2.6 ± 0.6 | Yellow         | 4              | 18.75 ± 0.3 × 20.1 ± 0.4       | 18.98 ± 1.4 × 19.75 ± 1.6      | 23.07               |
| P3—57491           | 24                     | 6.9 ± 0.6 × 1.9 ± 0.7 | Purple         | 6              | 18.30 ± 1.3 × 18.98 ± 2.8      | 18.75 ± 2.4 × 23.0 ± 2.5       | 30.0                |
| **Tragopogon dubius** |                        |                       |                |                |                               |                                |                                |                     |
| PI—57503           | 14                     | 15 ± 0.5 × 0.6 ± 0.3  | Linear         | Yellow         | 23                            | 22.19 ± 0.5 × 27.54 ± 0.7      | 23.0 ± 1.3 × 12.0 ± 0.8       | 28.5                |
| P2—57505           | 28                     | 15 ± 0.5 × 0.9 ± 0.3  | Linear lanceolate | Yellow    | 17                            | 18.36 ± 1.2 × 15.25 ± 0.8      | 22.75 ± 0.7 × 20.11 ± 1.4     | 16.66               |

*SD: standard deviation.*
### Table 3: Data on cytomixis and meiotic course in the studied populations of tribe Cichorieae from Western Himalayas.

| Accession number | Cytomixis | Meiotic course |
|------------------|-----------|---------------|
|                  | PMCs involved (%) | Number of PMCs involved (%) | PMCs with chromosomal stickiness at M-I (%) | PMCs with unoriented bivalents at M-I (%) | PMCs with bridges (at A-I, II/T-I, II) (%) | PMCs with laggards (at A-I, II/T-I, II) (%) |
| 52760            | 0.8 (10/125) | 1-2 | 3.10 (4/129) | 7.20 (9/125) | 10.08 (12/114) | 10.56 (13/123) |
| 52763            | 3.96 (8/126) | 1-2 | 5.50 (6/109) | 2.30 (3/130) | 4.31 (6/139) | 1.55 (2/129) |
| 52774            | 11.71 (13/111) | 2-4 | 11.57 (14/121) | 13.79 (16/118) | 26.95 (38/141) | 10.44 (14/134) |
| 52764            | 2.4 (3/125) | 1-2 | 4.0 (5/125) | —/— | 4.0 (5/125) | —/— |
| 58562            | 5.4 (6/111) | 1-2 | 3.17 (4/126) | 2.70 (3/111) | —/— | —/— |
| 57504            | —/— | 0 | 0.82 (1/121) | 1.80 (2/111) | 4.50 (5/111) | 0.82 (1/121) |
| 52776            | —/— | 0 | 1.66 (2/120) | —/— | —/— | —/— |
| 57510            | 2.77 (4/144) | 1-2 | 3.47 (5/144) | 2.0 (3/144) | —/— | —/— |
| 58534            | —/— | 0 | —/— | —/— | —/— | —/— |
| 58535            | 1.0 (1/97) | 1-2 | 11.34 (11/97) | 6.1 (6/97) | 7.21 (7/97) | 2.06 (2/97) |
| 52687            | 4.35 (5/144) | 2-3 | 5.50 (6/109) | 8.39 (11/131) | 3.84 (8/130) | 10.08 (12/114) |
| 52693            | 1.78 (2/112) | 1-2 | 7.20 (9/125) | —/— | 3.10 (4/129) | 3.84 (8/130) |
| 57491            | 29.91 (35/117) | 2-6 | 16.28 (21/129) | 13.79 (16/116) | 12.5 (17/136) | 10.44 (14/134) |
| 57503            | 2.43 (3/123) | 1-2 | 2.30 (3/130) | —/— | —/— | —/— |
| 57505            | 1.72 (2/160) | 1-2 | 1.37 (2/145) | 2.38 (3/126) | 1.16 (2/125) | 3.25 (4/123) |
| 52768            | —/— | 0 | —/— | —/— | —/— | —/— |
| 59773            | 2.77 (4/144) | 1-2 | 3.53 (4/144) | 1.76 (2/113) | 5.30 (6/113) | 1.76 (2/113) |
| 57500            | —/— | 0 | —/— | —/— | —/— | —/— |
| 57771            | 1.61 (2/124) | 1-2 | 1.62 (2/123) | —/— | —/— | —/— |

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

### Table 4: Data on abnormal microsporogenesis on different accession of tribe Cichorieae from Western Himalayas.

| Taxon/accession numbers | Monads WM (%) | Dyads WM (%) | Triads WM (%) | Tetrads WM (%) |
|-------------------------|---------------|--------------|---------------|---------------|
|                         | WMN (%)       | WMN (%)      | WMN (%)       | WMN (%)       |
| 58533                   | —/—           | 0.97 (1/103) | 2.91 (3/103) | 96.11 (99/103) |
| 52760                   | 2.75 (3/109)  | 2.75 (3/109) | 2.75 (3/103) | 90.82 (99/109) |
| 52763                   | —/—           | 1.80 (2/111) | 2.70 (3/111) | 90.09 (100/111) |
| 52774                   | 1.5 (2/130)   | 2.30 (3/130) | 3.60 (4/111) | 86.15 (112/130) |
| 52764                   | —/—           | 1.6 (2/120)  | —/—           | 98.3 (118/120) |
| 58562                   | —/—           | —/—          | —/—           | 100 (123/123) |
| 57504                   | 0.95 (1/105)  | 1.90 (2/105) | 1.90 (2/105) | 92.38 (97/105) |
| 52776                   | —/—           | 1.66 (2/121) | 4.13 (5/121) | 95.04 (115/121) |
| 57503                   | 0.80 (1/124)  | 1.61 (2/124) | 4.03 (5/124) | 91.93 (114/124) |
| 58534                   | 1.05 (1/95)   | —/—          | —/—           | 99.2 (139/140) |
| 58535                   | 1.72 (2/116)  | 4.31 (5/116) | 5.17 (6/116) | 81.89 (95/116) |
| 52687                   | 1.5 (2/130)   | 0.76 (1/130) | 0.82 (1/121) | 87.60 (106/121) |
| 52593                   | —/—           | 0.8 (1/125)  | 0.8 (1/125)  | 92.17 (106/115) |
| 57491                   | 2.29 (2/87)   | 4.59 (4/87)  | 2.29 (2/87)  | 72.41 (63/87) |
| 57503                   | —/—           | —/—          | —/—           | 100 (121/121) |
| 57505                   | —/—           | 0.8 (1/125)  | 1.6 (2/125)  | 96.8 (123/125) |
| 52768                   | 1.66 (2/121)  | 4.13 (5/121) | 4.13 (5/121) | 87.60 (106/121) |
| 52773                   | 0.86 (1/115)  | 2.60 (3/115) | 2.60 (3/115) | 92.17 (106/115) |
| 57500                   | 1.66 (2/121)  | 0.82 (1/121) | 0.82 (1/121) | 82.64 (100/121) |
| 52771                   | —/—           | 3.10 (4/129) | 0.75 (1/129) | 80.60 (104/117) |

Figures in parenthesis denote observed number of abnormal PMCs in the numerator and total number of PMCs observed in the denominator.
Figure 2: (a-b) PMC showing transfer of chromatin material in *Taraxacum officinale* and *Hieracium umbellatum*, respectively. (c) PMC at metaphase-I showing chromatin stickiness in tetraploid cytotype of *T. officinale*. (d) PMC showing late disjunction at anaphase-1 (arrowed). (e) PMC at telophase-II showing chromatin bridges (arrowed). (f) PMC at anaphase-I showing chromatin laggards (arrowed) in triploid cytotype of *T. officinale*. (g) Monad. (h) Diad with micronuclei. (i) Triad with micronucleus. (j) Tetrad with micronucleus. (k) Heterogeneous sized fertile and sterile (arrowed) pollen grains. (Scale: 10 𝜇m, IV: quadrivalent, II: bivalent, I: univalent.)

the genus varies in the range of $2n = 10–48$ and is polybasic on $x = 5, 8, 9,$ and $17$, of which $x = 9$ is the most dominant number.

*Prenanthes* L. Twenty-two species in the genus are known cytotaxonomically, including 1 from India. The most common base number is $x = 8$ represented with 19 species, including diploids (16 species) and tetraploids (3 species). However, the intraspecific polyploids are not available in the genus. Besides, $x = 9$ is also present in 3 species that are diploid. Hence, the genus is proposed to be dibasic on $x = 8$ and 9.

*Taraxacum* L. The genus is very complex, reinforcing the reason of having 347 cytologically (including 10 species from India) worked-out species. The chromosome numbers vary in the range of $2n = 8–64$, the most common of which is $2n = 3x = 24$ (230 spp.) on $x = 8$, followed by diploid (47 spp.) on the same base number. Genus is reported to have a series of base numbers on $x = 4, 6, 8, 9$, and 11, but only $x = 8$
is known to have well-developed polyploid races \((2x-6x)\). Intraspecific polyploidy is also known to occur in \(x = 9\) and 11 (1 species each).

**Tragopogon L.** 75 species in the genus are cytologically known, with chromosome number in the range of \(2n = 12–36\), almost all based on \(x = 6\). The overall polyploidy in the genus is 26.6% (20 spp.), out of which 14 species show intraspecific polyploidy. The variable chromosome number of \(2n = 14\) is found in 4 species (including the present data) and \(2n = 28\) in only one species (from the present data).

**Youngia L.** A total of 35 species are taxonomically known, cytology is reported for only 14 species (including 5 from India), with 9 species showing polyploid cytotypes (3x, 4x, and 6x). The chromosomes numbers reported so far are \(2n = 10, 15, 16, 20, 24, 32,\) and 42, out of which \(2n = 10 (43.7\%)\) is the most common followed by \(2n = 16 (31.2\%).\) The genus is polyploidic \((x = 5, 7, 8)\), of which \(x = 5\) is most common.

**4.2. Meiotic Abnormality.** The phenomenon of inter-PMC migration of chromatin/chromosome between/among the contiguous meiocytes through cytotomic channels is termed as cyt oxmis (coined by Gates [26]). However, the phenomenon has been reported for only 1st species (including 5 from India), and subsequently in angiosperms by Koernicke [28]. Since that time, cytomixis has been reported in a large number of plants [29]. Transfer of chromatin or chromosomes may take place through such inter-PMC cytomitic channels [30–32]. Some workers reported cyt oxis to be more prevalent in polyploids than their diploid counterparts [33, 34]. Occasionally, either hyploid meiocytes [35–37] or enucleated meiocytes or meiocytes with a hyperploid number of chromosomes have been reported [30, 37–39]. It is very much clear that the enucleated meiocytes die, but hypo- and hyperploid meiocytes could lead to the formation of gametes with variable chromosome number and size. Cyt oxmis is considered as a process of evolutionary significance because it results in change in gametic chromosome numbers [30, 40]. Chromosome stickiness also results in the formation of fragmented chromatin. This chromatin stickiness, late or non-disjuncting bivalents, and chromosomal laggards seem to be responsible for chromosomal bridges [41]. All these meiotic abnormalities consequently affect the process of microsporogenesis, leading to the formation of monads, dyads, triads, or polyads with or without micronuclei, which ultimately produce heterogeneous sized (large and small) fertile pollen grains and reduced pollen fertility. The size difference may be due to the formation of unreduced gametes \((2n)\), which may produce plants with higher ploidal level through polyplidization (for review, see [42–45]).

As observed in the presently investigated data, the chromatin rearrangement due to meiotic abnormalities is considered the base of inter- or intraspecific diversity. Further, it provides a catalogue for studying different evolutionary trends such as breeding system or polyploidy and hybridization.

**Conflict of Interests**

The authors declare that there is no conflict of interests regarding the publication of this paper.

**Acknowledgments**

The authors are grateful to the University Grants Commission of New Delhi (DRS SAP III) and I.P.L.S. (DBT) for providing financial assistance. The authors are highly thankful to the Head, Department of Botany, Punjabi University, Patiala, for providing necessary lab facilities during the work.

**References**

[1] Z. Shi, X. J. Ge, N. Kilian et al., “Cichorieae,” in Flora of China, Z. Y. Wu, P. H. Raven, and D. Y. Hong, Eds., vol. 20–21 of Asteraceae, pp. 195–353, Science Press, Beijing, China, Missouri Botanical Garden Press, St. Louis, Mo, USA, 2011.

[2] M. Howard, Traditional Folk Remedies, Ebury Press, London, UK, 1987.

[3] B. A. Clare, R. S. Conroy, and K. Spelman, “The diuretic effect in human subjects of an extract of Taraxacum officinale folium over a single day,” Journal of Alternative and Complementary Medicine, vol. 15, no. 8, pp. 929–934, 2009.

[4] K. N. Singh, “Traditional knowledge on ethnobotanical uses of plant biodiversity: a detailed study from the Indian western Himalaya,” Biodiversity: Research and Conservation, vol. 28, pp. 63–67, 2012.

[5] E. A. Nazarova, “Chromosome numbers in the Caucasian representatives of the families Asteraceae, Brassicaceae, Fabaceae, Limoniacaeae,” Botanicheskii Zhurnal, vol. 69, pp. 972–975, 1984 (Russian).

[6] S. A. Volkova and E. V. Boyko, “Chromosome numbers in some species of Asteraceae from the southern part of the Soviet Far East,” Botanicheskii Zhurnal, vol. 71, p. 1693, 1986.

[7] P. N. Mehra, B. S. Gill, J. K. Mehta, and S. S. Sidhu, “Cytological investigations on the Indian Compositae. I. North-Indian taxa,” Caryologia, vol. 18, pp. 35–68, 1965.

[8] B. V. Shetty, “IOPB chromosome number reports XIV,” in Taxon, vol. 16, pp. 552–571, 1967.

[9] R. C. Gupta, Himshikha, P. Kumar, and R. S. Dhaliwal, “Cytological studies in some plants from cold deserts of India, Lahaul and Spiti (Himachal Pradesh),” Chromosome Botany, vol. 4, no. 1, pp. 5–11, 2009.

[10] S. Bala and R. C. Gupta, “IAPT/IOPB chromosome data 12,” in Taxon, K. Marhold, Ed., vol. 60, pp. 1784–1786, 2011.

[11] Z. A. Razaq, A. A. Vahidy, and S. I. Ali, “Chromosome numbers in Compositae from Pakistan,” Annals of the Missouri Botanical Garden, vol. 81, no. 4, pp. 800–808, 1994.

[12] P. N. Mehra and P. Remanandand, “IOPB chromosome number reports XXII,” Taxon, vol. 18, pp. 433–442, 1969.

[13] R. C. Gupta, B. S. Gill, and R. K. Garg, “Chromosomal conspec-itus of Western Himalayan Compositae,” Aspects of Plant Sciences, vol. 11, pp. 427–437, 1989.

[14] T. Chatterjee and A. K. Sharma, “Cytotaxonomy of cichorieae,” Genetic, vol. 10, no. 1, pp. 577–590, 1969.

[15] R. C. Gupta and B. S. Gill, “Cytology of family Compositae of Punjab plains,” Proceedings of the National Academy of Sciences, India, Section B, vol. 49, pp. 359–370, 1983.

[16] A. K. Koul, A. Wakhlu, and J. L. Karihaloo, “Chromosome numbers of some flowering plants of Jammu (Western Himalayas) II,” Chromosome Information Service (CIS) 20, 1976.

[17] B. S. Gill and R. C. Gupta, “Cytological investigations on the North-West Himalayan Taraxacum officinale complex (Com-positae),” in Recent Researches in Plant Sciences, S. S. Bir, Ed., pp. 292–301, Kalyani Publishers, New Delhi, India, 1979.
[18] A. K. Koul and P. N. Gohil, “Cytotaxonomical conspectus of the flora of Kashmir, I. Chromosome numbers of some common plants,” Phyton, vol. 15, pp. 57–66, 1973.

[19] D. Kaur, V. K. Singhal, and K. Marhold, “IAPT/IOPB chromosome data 13,” Taxon, vol. 61, pp. 889–902, 2013.

[20] R. C. Gupta, V. Kataria, and A. Mehra, “Cytomorphological studies in some gamopetalous species of Western Himalaya: an attempt to add new or varied cytotypes,” Chromosome Botany, vol. 7, pp. 59–65, 2012.

[21] N. V. Stepanov, “Chromosome numbers of some higher plants taxa of the flora of Krasnoyarsk region,” Botanicheskii Zhurnal, vol. 79, pp. 135–139, 1994.

[22] E. G. Rudyka, “Chromosome numbers in vascular plants from the southern part of the Russian Far East,” Botanicheskii Zhurnal (Moscow & Leningrad), vol. 80, pp. 87–90, 1995.

[23] B. L. Turner, W. L. Ellis, and R. M. King, “Chromosome numbers in the Compositae IV,” American Journal of Botany, vol. 48, no. 3, pp. 216–223, 1961.

[24] G. L. Stebbins, J. K. Jenkins, and M. S. Walters, Chromosomes and Phylogeny in the Compositae. Tribe Cichorieae, vol. 16, University of California Publications in Botany, Berkeley, Calif, USA, 1953.

[25] A. S. Tomb, K. L. Chambers, D. W. Kyhos, A. M. Powell, and P. H. Raven, “Chromosome numbers in the Compositae. XIV. Lactuceae,” The American Journal of Botany, vol. 65, pp. 717–722, 1978.

[26] R. R. Gates, “Pollen formation in oenothera gigas,” Annals of Botany, vol. 25, no. 4, pp. 909–940, 1911.

[27] W. Arnoldy, “Beiträge zur Morphologie der Gymnospermen. IV. Was sind die “Keimbläschchen” oder Hofmeisters-Körperchen” in der Eizelle der Abietineen?” Flora, vol. 87, pp. 194–204, 1900.

[28] M. Koernicke, Über ortsveränderung von Zellkernen S B Niederein Ges Natur-U Heilkunde Bonn A, 1901.

[29] V. K. Singhal and P. Kumar, “Impact of cytomixis on meiosis, pollen viability and pollen size in wild populations of Himalayan poppy (Meconopsis aculeata Royle),” Journal of Biosciences, vol. 33, no. 3, pp. 371–380, 2008.

[30] E. Falistocco, N. Tosti, and M. Falcinelli, “Cytomixis in pollen mother cells of diploid Dactylis, one of the origins of 2n gametes,” Journal of Heredity, vol. 86, no. 6, pp. 448–453, 1995.

[31] S. R. Mursalimov and E. V. Deineko, “An ultrastructural study of cytomixis in tobacco pollen mother cells,” Protoplasma, vol. 248, no. 4, pp. 717–724, 2011.

[32] E. A. Kravets, “Nature, significance, and cytological consequences of cytomixis,” Cytology and Genetics, vol. 46, no. 3, pp. 188–195, 2012.

[33] S. Y. A. Semyarkhina and M. S. Kuptsou, “Cytomixis in various forms of sugar beet,” Vestsi AN BSSR Ser Biyal, no. 4, pp. 43–47, 1974.

[34] V. K. Singhal, B. S. Gill, and R. S. Dhaliwal, “Status of chromosomal diversity in the hardwood tree species of Punjab state,” Journal Cytology and Genetics, vol. 8, pp. 67–83, 2007.

[35] M. Ashraf and R. N. Gohil, “Cytology of legumes of Kashmir Himalaya. V. Cytomixis and chromosome migration in Astragalus subuliformis DC,” Nucleus, vol. 37, pp. 19–122, 1994.

[36] T. Morikawa and J. M. Leggett, “Cytological and morphological variations in wild populations of Avena canariensis from the Canary Islands,” Genes & Genetic Systems, vol. 71, no. 1, pp. 15–21, 1996.

[37] M. Sheidai, S. Jafari, P. Taleban, and M. Keshavarzi, “Cytomixis and unreduced pollen grain formation in alopecurus L. and catbrosa beauv. (Poaceae),” Cytologia, vol. 74, no. 1, pp. 31–41, 2009.

[38] M. Bellucci, C. Roscini, and A. Mariani, “Cytomixis in pollen mother cells of Medicago sativa L,” Journal of Heredity, vol. 94, no. 6, pp. 512–516, 2003.

[39] P. Kumar, V. K. Singhal, and D. Kaur, “Impaired male meiosis due to irregular synopsis coupled with cytomixis in a new diploid cytotype of Dianthus angulatus (Caryophyllaceae) from Indian cold deserts,” Folia Geobotanica, vol. 47, no. 1, pp. 59–68, 2012.

[40] Y. Liu, R.-K. Hui, R.-N. Deng, J.-J. Wang, M. Wang, and Z.-Y. Li, “Abnormal male meiosis explains pollen sterility in the polyploid medicinal plant Pinellia ternata (Araceae),” Genetics and Molecular Research, vol. 11, no. 1, pp. 112–120, 2012.

[41] S. Kumar, S. M. Jeelani, S. Rani, R. C. Gupta, and S. Kumari, “Cytology of five species of subfamily Papaveroideae from the Western Himalayas,” Protoplasma, vol. 250, no. 1, pp. 307–316, 2013.

[42] R. Villeux, “Diploid and polyploid gametes in crop plants: mechanisms of formation and utilization in plant breeding,” in Plant Breeding Reviews, J. Janick, Ed., p. 442, AVI Publishing Co. Wesport, Connecticut, Conn, USA, 1985.

[43] F. Bretagnolle and J. D. Thomson, “Gametes with the somatic chromosome number: mechanisms of their formation and role in the evolution of autopolyploid plants,” New Phytologist, vol. 129, no. 1, pp. 1–22, 1995.

[44] F. Fatemeh, M. Sheidai, and M. Asadi, “Cytological study of the genus Arenaria L. (Caryophyllaceae),” Caryologia, vol. 63, no. 2, pp. 149–156, 2010.

[45] S. M. Jeelani, S. Rani, S. Kumar, S. Kumari, and R. C. Gupta, “Meiotic studies in some members of Caryophyllaceae juss. from the western Himalayas,” Acta Biologica Cracoviensis Series Botanica, vol. 53, no. 1, pp. 86–95, 2011.