Biosystematics of *Adiantum lunulatum* Burm. Complex in India with Special Reference to W. Himalayan Taxa

P. N. Mehra and S. P. Khullar

Department of Botany, Panjab University, Chandigarh-160014, India

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Adiantum lunulatum Burm. is one of the most common and widely distributed amongst the Indian ferns. In the Himalayan foot-hills, as well as elsewhere, it grows on slopes and walls in moist shady localities upto an altitude of 1,500 m. In the earlier literature on Indian ferns it was known as *A. philippense* L. Verma (1962) advocated the adoption of the name *A. lunulatum* over *A. philippense* instead.

Cytology has revealed this fern to be a great species complex in India (refer Table 1; Fig. 1). From the E. Himalayas four types have been reported, viz. diploid sexual, diploid apomict, triploid apomict and tetraploid sexual (Mehra and Verma 1963). From S. India too, such types have also been reported (Abraham *et al.* 1962, P. Methew in Fabbri 1965). The triploid apomict is the more widespread polyploid type and formerly only this type was recorded from the W. Himalayas (Mehra 1938, 1944). In the present extensive survey of the W. Himalayan population of *A. lunulatum*, besides the triploid apomict a diploid apomict has also been detected. In this communication it is intended to discuss the biosystematics of this complex.

In view of the great cytological variation in this complex a little digression upon the taxonomy of the taxa constituting it is essential.

Taxonomy

From the E. Himalayas 4 taxa of this complex have been reported: diploid sexual, diploid apomict, triploid apomict and tetraploid sexual. The diploid sexual has been named as a separate species *A. teestae* by Verma (1964). About the tetraploid and diploid sexual, Mehra and Verma (1963) mention that these two are close to each other. The diploid apomict is also very similar. But the triploid apomict differs in many respects. In view of this it is desirable to split the E. Himalayan element into two groups, the '*teestae*' group comprising the diploid sexual, diploid apomict and tetraploid sexual (Figs. 6-8) and the '*lunulatum*' group consisting of the triploid apomict (Fig. 5). The triploid from the E. Himalayas, in spite of morphological variation, conforms to *A. lunulatum* Burm. These E. Himalayan samples were compared by Dr. R. E. Holttum (Kew) who expressed the view that these specimens 'come nearest' to Burmann's type. The '*teestae*' group is characterised by small herbaceous fronds (4-18 cm), pinnae small (0.4-1.0 × 0.6 cm), basal angle between 90-150°, but never more than 180° (cf. Verma 1964). The '*lunulatum*' group is characterised by larger fronds and pinnae as compared to the

'teestae' group.

The S. Indian material (= *A. philippense*: Figs. 2, 3) agrees in overall morphology with the triploid *lunulatum* and hence would come under the '*lunulatum*' group. The W. Himalayan samples (Fig. 4) too fall in the '*lunulatum*' group. The '*teestae*' group appears to be restricted to the E. Himalayas alone.

In view of the great diversity in morphology and also the occurrence of different types within the groups ('*lunulatum*' and '*teestae*'), it is desirable, as stated above, to

Fig. 1. Map of India showing the distribution of the various polyploid types of *Adiantum lunulatum* and *A. teestae*. *A. teestae*: ◡- 2xS, ◡- 2xA, ◡- 4xS. *A. lunulatum*: ○- 2xS, ●- 2xA, ▲- 3xA, ◻- 4xS. S: sexual; A: apomict.

split *A. lunulatum* into two different species, *A. lunulatum* Burm. (s.s.) comprising the S. Indian diploid sexual, diploid apomict, tetraploid sexual, the cosmopolitan triploid, as well as the W. Himalayan diploid apomict (Figs. 2-5, 9, 10). The E.

Figs. 2-4. *Adiantum lunulatum*. 2, diploid sexual (S. India). 3, tetraploid sexual (S. India). 4, diploid apomict (W. Himalayas). All $\times 1/4$.

Himalayan diploid sexual, diploid apomict and the tetraploid sexual would comprise the 'teestae' group, characterised by small size of the individuals and pinnae (Figs. 6-8, 11). It may, however, be pointed out that these differences (small size, etc.)

are not due to the environment as the triploid apomict, which also grows in the E. Himalayas under similar environmental conditions, is similar in morphology to the triploid occurring elsewhere in India. It is only the diploid sexual, diploid apomict and tetraploid sexual of the E. Himalayas that are morphologically distinct from their counterparts growing elsewhere in the country. The distribution pattern of the new segregated two complexes is given in Table 1.

Table 1. Distribution of the various polyploid types in
Adiantum lunulatum Complex

Cytotype	Location	Author
A. <i>A. lunulatum</i> sensu stricto		
Diploid sexual	S. India (Trivandrum)	Abraham <i>et al.</i> (1962)
Diploid apomict	S. India	Mathew in Fabbri (1965)
	Kalka (W. Himalayas)	Present report
Triploid apomict	W. Bengal	Roy and Sinha (1958)
	Darjeeling	Verma (1964)
	Sikkim	Verma (1964)
	Dehra Dun	Mehra (1938, 1944)
	Mussoorie	Mehra and Verma (1960)
	Nainital	Verma and Loyal (1960)
	Kumaon hills	Present report
	Simla hills	Present report
	Mt. Abu	Mehra and Verma (1960)
	S. India	Abraham <i>et al.</i> (1962)
	Bombay	Mehra and Verma (1960)
	Ceylon	Manton and Sledge (1954)
	Japan	Mitui (1968)
	S. Africa	Manton and Sledge (1954)
	W. Africa	Manton (1959)
Tetraploid sexual	S. India (Permmade and Ponmudi)	Abraham <i>et al.</i> (1962)
B. <i>A. teestae</i> Verma		
Diploid sexual	Darjeeling (E. Himalayas)	Verma (1964)
Diploid apomict	Darjeeling (E. Himalayas)	Verma (1964)
Tetraploid sexual	Darjeeling	Verma (1964)

W. Himalayan cytotypes

Morphology

Triploid apomict: The triploid is by far the most common cytotype. Fig. 5 reveals to some extent the variation that exists in this taxon. The frond size varies from 15–45 cm in population growing under similar environmental conditions. A lot of variation in size and shape of the pinnae also exists. However, there is no correlation between the size of pinnae and that of the plant. Large fronds with small pinnae are not uncommon. Fig. 10 (natural size) depicts the size, shape and lobing patterns that exist in the pinnae. The size varies from 1.0–4.5 cm long and 0.8–1.5 cm broad. The pinnae may be lobed, both the large as well as the small ones, or more or less entire.

Diploid apomict: Like the previous taxon the diploid apomict also shows a fair degree of variation in size of both the frond and the pinnae, as also the shape of the pinnae (Fig. 9b, c). The frond size varies from 15–30 cm. The size of the pinnae is 1.5–3.0 cm long and 0.8–1.5 cm broad. The pinnae may be lobed or entire.

Figs. 5–8. 5, *A. lunulatum* triploid apomict (W. Himalayas). 6–8, *A. teestae*. 6, diploid sexual. 7, diploid apomict. 8, tetraploid sexual. All $\times 1/4$.

Table 2 gives a comparison of certain characters of the two cytotypes which reveals a great deal of overall morphological similarity. The size range overlaps in the two, so that without attempting the cytology of the species, it is difficult to distinguish between them. In microscopic characters, however, the diploid apomict

possesses smaller dimensions of stomata and spores.

Cytology

Diploid apomict: The diploid apomict in the W. Himalayas has so far been located only at one place, i. e. Kalka. Prior to this only triploids were reported from this region. Spore mother cells obtained from the 8-celled sporangia revealed the presence of 60 bivalents (Fig. 12). Such sporangia released 32 seemingly viable spores. An extensive study was helpful in obtaining a few spore-mother-cells

Figs. 9-11. Pinnae. 9, 10, *Adiantum lunulatum*. 9, (a) diploid sexual, (b, c) diploid apomict, (d) tetraploid sexual. 10, triploid apomict. 11, *A. teestae*. (a) diploid sexual, (b) diploid apomict, (c) tetraploid sexual. All $\times 1$.

Table 2. Comparison of diploid apomict and triploid apomict types of *Adiantum lunulatum* Burm. in the W. Himalayas

	Diploid apomict	Triploid apomict
Frond size	15-30 cm	15-45 cm
Pinnae size	1.5-3.0 cm long 0.8-1.5 cm broad	1.0-4.5 cm long 0.8-1.5 cm broad
Stomata range (length $\times$ breadth)	25.0-31.25 $\times$ 18.8-25.0 μ	31.25-34.47 $\times$ 21.87-28.13 μ
Spores (range)	34.38-40.92 μ	43.74-46.88 μ

Fig. 12-13. *Adiantum lunulatum*. 12, diploid apomict 'n'=60. $\times 1600$. 13a, diakinesis in a spore mother cell from the 16-celled sporangium in the diploid apomict showing $29_{II}+2_I$ (explanatory diagram Fig. 13b). $\times 1600$.

belonging to the 16-celled (normal) sporangia. A study of these revealed $29_{II}+2_I$ (Fig. 13a, b).

Triploid apomict: This is the most common cytotype and ranges in its occur-

rence from the Kumaon hills in the East (in the W. Himalayas) to Simla hills in the West. Dividing spore-mother-cells obtained from the 8-celled sporangia revealed 90 bivalents (Fig. 14), and each such sporangium released 32 spores, pointing to the apogamous nature of the individuals. Mehra (1944) had earlier shown that there is a premeiotic failure of mitosis at 8-celled stage of the sporangium development,

Figs. 14–16. *Adiantum lunulatum*. 14, triploid apomict 'n'=90. $\times 1300$. 15a– 16a, diakinesis in spore mother cells from the 16-celled sporangium in the triploid apomict showing $1_{III} + 30_{II} + 27_I$ (explanatory diagrams Figs. 15b and 16b). $\times 1700$.

thus doubling the chromosome number in the ensuing mother cells and setting a stage for the formation of autobivalents.

A few cells belonging to the 16-celled sporangia were also obtained. An analysis of these revealed the following chromosomal associations:

$1_{III} + 30_{II} + 27_I$ which approximately comes to $X_I + X_{II}$ where $X = 30$ (Figs. 15a, b; 16a, b).

Ghatak (1960) reported approximately $30_{II} + 30_I$ in the 16-celled sporangia, and the same has been corroborated by the investigations of Roy and Sinha (1961).

Cytogenetics

Diploid apomict: The study of the chromosome analysis of spore-mother-cells pertaining to the 16-celled sporangia, is of paramount importance in throwing light on the cytogenetics of the apogamous species.

In *Adiantum lunulatum* diploid apomict, a few cells belonging to the 16-celled sporangia revealed at metaphase I, $29_{II} + 2_I$ as stated above. The occurrence of a large number of paired bivalents is quite significant.

Table 3. Comparison of diploid sexual (S. India)* and diploid apomict (W. Himalayas)

	Diploid sexual	Diploid apomict
Frond size	30 cm	15–30 cm
Pinnæ size	2.5 cm long and 1.3 cm broad	1.0–3.0 cm long and 0.8–1.5 cm broad
Stomatal size (range)	26.0–29.25 × 19.50–22.75 μ	25.0–31.25 × 18.81–25.0 μ

* Only one frond could be studied. The S. Indian samples were obtained through the kind courtesy of Prof. A. Abraham, Kerala University, Trivandrum (India).

Manton (1950) suggested two possibilities for the origin of apomixis in case of diploid apomict *Pteris cretica* L.

i) As a hybrid between two related species with somewhat complete homology between chromosomes.

ii) As an apomictic form of a formerly sexual species in which, in the absence of sexual behaviour and consequent natural selection, translocations and effects of chromosomal changes subsequently accumulated.

In the case of *Pteris cretica* L. diploid apomict, analysis of the 16-celled sporangia revealed $26_{II} + 6_I$ (Verma and Khullar 1965). This led the authors to suggest that possibly in the case of *Pteris cretica*, apomixis has originated in a previously sexual species. Manton (1950) had earlier ruled out such a possibility because a sexual form of *P. cretica* aff., now discovered by Walker (1962) from Ternate, was then not known to exist.

In the present case the situation is not very much different. The large number of paired bivalents show a great deal of similarity of genomes. A diploid sexual of the species (*A. lunulatum*) occurs in S. India which is very much similar to the diploid apomict of the W. Himalayas (cf. Table 3).

In view of the occurrence of a diploid sexual with similar morphological charac-

ters as the diploid apomict, supported by evidence provided by the chromosomal analysis, it is inferred that the diploid apomict *A. lunulatum* has arisen from the diploid sexual *A. lunulatum* Burm. It is to be noted that both the diploid sexual and diploid apomict forms occur in S. India. Although so far the diploid sexual has not yet been located in the W. Himalayas, its presence here could be suspected. The genetic set up of the diploid apomict (following Mehra 1961) could be symbolically represented as AA' and the sexual form as AA. A' is formed as a result of some sort of cryptic alteration in A genome.

It may be recalled that in case of *A. lunulatum* (s.s.) a whole series, diploid sexual, diploid apomict, triploid apomict and tetraploid sexual exist, with little external morphological variation (cf. Figs. 2-5, 9-10).

Triploid apomict: Some cells belonging to the 16-celled sporangia in the triploid apomict were also observed. An analysis of these revealed the following chromosomal associations as stated above:

$$1_{III} + 30_{II} + 27_I$$

These figures are not much different from what Ghatak (1960) and Roy and Sinha (1961) have stated, i.e. $(30_{II} + 30_I)$.

The constitution of the triploid could be represented symbolically as AA'B, where the species BB is less closely related to AA'. Normally a condition of X pairs + X univalents (AAB) is supposed to occur when a diploid apomict (AB) or a tetraploid (AABB) has back-crossed with one of its parents (Mehra 1961). But in the present context this cytological condition seems to have resulted when a diploid apomict AA' became hybridised with a different but related species BB resulting in the triploid with AA'B genomic constitution. However, the taxon with BB genome has so far not been located.

Summary

A diploid apomict, in addition to the already known triploid apomict is described from the W. Himalayas in the widely ranging species *Adiantum lunulatum* Burm. On the basis of morphological evidence it is suggested that the whole complex be split up into two, viz., *A. lunulatum* (s.s.) comprising the universally known triploid apomict, the diploid and tetraploid sexual from S. India and the diploid apomict from W. Himalayas and S. India. The other species, *A. teestae* Verma would comprise of the E. Himalayan diploid sexual and diploid apomict forms together with the tetraploid sexual. Chromosomal associations in the 16-spore mother-celled sporangia have been analysed and on this evidence the origin of the two polyploid types in *Adiantum lunulatum* is discussed. It is argued that the diploid apomict *A. lunulatum* (sensu stricto) probably originated in a previously sexual taxon. Genetically speaking, the diploid apomict is AA', while the triploid is AA'B in constitution but still possessing approximately X pairs + X univalents.

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