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Ecology, Phytogeography and Perennation of Bryophytes in Rajasthan (India)

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Abstract: ***Present investigation deals with the study of bryophytes in relation to soil and climatic condition, broadly speaking three bryoecological zones. These zones are arid and semi arid, the plateau and the southern region having different climatic condition and vegetation. Biotic and biotic factors play an important role in the occurrence and distribution of bryophyte vegetation in the state. The availability of water, amount of moisture in the air, temperature, light, elevation, nature of soil and its availability to retain moisture and biotic factors control the distribution of bryophyte species. Sixty four bryophyte species have been collected from different parts and various localities of this state out of which geographically 43 occur in the Western Himalayas, 34 in Eastern Himalayas and 32 in South India. Further it was reported that plants perennate in adverse climatic condition by the formation of gemmae, tubers, meristematic rolling apical apices and some other vegetative parts of the plants.***

Keywords: Ecology, phytogeography, perennation, bryophytes, bryoecological zones

1. Introduction

Rajasthan is the second largest state of India, located between the latitude $23^0$3' N to $30^0$12'N and longitudes $69^0$30'E to $78^0$17'E spread over an area of 3, 42,274 sq. km. The climate of Rajasthan shows great variations in changes of temperature precipitation, humidity and wind conditions. The diurnal fluctuation in temperature is the most important characteristic feature of the climate of this state. The north-western part of the soil lacks vegetation or vegetation with important ecological adaptations. The change of temperature from day to night is sudden and very high i.e. 3.4^0C to 20^0C in January and 30^0C to 50 ^{0}C in May and June.

This climatic condition is extremely unsatisfactory for the vegetation in general and bryophytes in particular. The xerothermic index of Rajasthan does not afford much attention on the bryophytes. Legris and Viart (1959), recorded very useful information on the xerothermic of this state. However Bapna (1962, 1975, 1980) Deora and Chaudhary (1995, 1996) Chaudhary and Deora (1996, 2001) made a good contribution to study the bryophytes of this region. Bapna and Vyas (1962) studied preliminary accounts of hepataceae of Mt. Abu with their ecological aspects. Mahabale amd Kharadi (1946) while describing the ecological features of the vegetation of Mt. Abu mentioned some liverwort species but overall a comprehensive study of this state particularly to bryophytes ecology, phytogeography and perennation in drought condition is an important area.

Keeping this in mind present authors ventured to undertake this work to collect bryophytes from various parts of Rajasthan from different ecological conditions and further to divide entire state in different bryoecological zones with phytogrographical aspects.

2. Materials and Methods

An extensive and intensive field survey was made by visiting various places of Rajasthan in different seasons to collect bryophytes. All the specimens were labeled, numbered and properly processed for further study. The voucher specimens were deposited in the bryology laboratory department of botany B.N. (P.G.) College, Udaipur (Rajasthan)

3. Results and Discussion

The state of Rajasthan is spread in a rhomboidal shape. The whole area of this state can be divided into following three bryoecological divisions with their distinct climatic conditions resulting into different form of vegetation (Table-1).

Table 1: Average Temperature, Rainfall and Humidity in Bryoecological zones

Bryoecological zones	*Altitudes*	*Temperature ^{0}C Jan June*	*Rainfall*	*Relative Humidity %*
1. Arid and Semi-arid	200-400m	Max 27.85 45.91 Min 3.01 20.64	5.1 to 11.6	54.76
2. The Plateau region	400-700m	Max 25.64 44.67 Min 3.58 20.10	18.3 to 23.5	55.45
3.Southern Region	700-1558m	Max 27.68 41.11 Min 4.38 18.05	25.1 to 61.27	66.02

I. The Arid and Semi-arid Region

The western part of Rajasthan comprising nearly 60% of the total area of this state is mostly sandy and 200-400 meters above MSL. The area today comprises the modern administrative districts of Bikaner, Barmer, ,,Ganganagar, Jaisalmer, Jhunjhunu, Jaipur, Jodhpur, Churu, Pali and Sikar. Due to low rainfall and high temperature the vegetation is very poor, represented mainly by xeric forms. This well defined region is practically devoid of bryophyte vegetation which occurs on most sand dunes of near water sources during the rainy season. This area remain dry for a long period and among this exceptionally few species

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growing near water reservoirs' are *Riccia disolor, R.tuberculata*; *Marchantia polymorpha, Plagiochasma appendiculata*; *Funaria hygrometrica, Hyophila, involuta* and *Brachymenium exile* etc.

II. The Plateau Region

This area extends around Aravalli ranges and is about 257-486 meters above MSL. The is region contrast with the arid and semi arid areas, the soil in the valleys being frequently black; loam, alluvium, and comparatively more fertile. The districts of Beawar, Ajmer, Jaipur, Alwar, Sawai Madhopur, Bhilwara, Chittorgarh, and Kota are situated within this region. The area consists of disssected broadly hilly belts. Numerous outlying hills and mounts, 400 meters to 800 meters high are found with wide valleys. Here a few species of liverworts and mosses are found in crevices of rocks or on moist soil or in humid areas. A few common species are *Riccia discolor*, *R..plana*, *R.crystallina*; *Plagiochasma appendiculata*, *Fissidens sylvaticus*, *Semibarbula orientalis*, *Hyophila involuia* and *Gymnistomiella vernicosa* etc.

III. Southern Region

This region may be described as a fairly well defined zone which is dominated by the Aravalli ranges. There are a series of hills (600 to 1201. M.alt) intersected by many small streams that cut deep valleys. This region includes mainly Mt. Abu, Sirohi, Kumbhalgarh, Dungarpur, Parasramji, Udaipur, and Banswara. The area is botanically the most important part of the Rajasthan, here the climate is more humid and environmental conditions are quite favorable for the growth of natural vegetation. The soil was collected from various localities where the bryophytes grow. It was found to be calcareous in texture and rich in calcium carbonate, potassium, phosphates and nitrates were also present and well suited for the normal growth of bryophytes. Soil water-content at ordinary temperature varied from 22% to 30%. Most of the part of this region is covered with forest. Many plants uncommon in adjoining areas are found here. High humidity and low temperature favour the growth of bryophytes. Besides the rich angiosperm flora important liverworts and mosses of this zone are *Fossombronia himalayensis, Pellia epiphylla, Asteralla, blumeana*; *A angusta*; *Plagiochasma appendiculata, P. articulata, Targionea hypophijlla, Cyathodium barodae, C.tuberosum*; *Riccia melanospora, R. discolor, R.aravalliensis, R.gangetica, R.plana, R.fluitans, R.crystallina, R.frosti, Anthoceros erectus, A.subtilis, Phaeoceros himalayensis, Notothylus indica, Notothylus levieri* etc. Common mosses are *Bryum dichotomum, B.recurrulum, Timmiella anomala, Mnium species, Entodon prorepens, E.myrus, Fissidens diversifolius, F.sylvaticus, Funaria hygrometrica, F.nutans Gymnostomiella vernicosa, Philonotis mollis, anomobryum auratum, Fabronia minuta, Dlaphnodon procumbence* and *Wijkia tanytricha* etc.

4. Habitat and Factors:

The occurrence and distribution of moss vegetation is highly affected by the variation in climate. The most important factors which affect the distribution of bryophytes are discussed below.

1. Moisture

Moisture content of the soil and of the atmosphere is an important factor that controls the occurrence and distribution of bryophytes. The relative humidity has a profound effect on the distribution of the bryophytes, The highest relative humidity at Mount Abu (63.51%) is positively correlated with the richest moss flora. As we proceed to the West and North west or extreme North, the relative humidity decreases over most of the areas. This is hardly adequate to support forest, as well as moss vegetation. Correlated with the absence of forest, we find that the moss flora are almost lacking in the region.

Most of the mosses in the surveyed areas grow on moist soil near water or shady places or on old walls of houses or on tree trunks which dry out gradually. Prolonged droughts so common in this region, result in the reduction of their number and may lead even to the extinction of certain species.

A study of Rajasthan mosses in their existing environments suggests that most of the species have to face critical conditions to survive. The biotic influence of man might have led to the total disappearance of some while many other are barely surviving. The majority of mosses prefer constantly moist places while some are able to withstand extreme habitats. For example *Hyophila rosea* grow near water current whereas *Fabronia minuta* grow on tree trunk, *Entodon prorepens* is found growing on exposed rocks.

2. Temperature and Light

The effect of temperature on the distribution of mosses is difficult to assess as it affect relative humidity of atmosphere and moisture of soil. However, in general the incidence of mosses is high in environment with relatively low temperature variation whereas, eurythermal areas have poor flora. This is evident from the following data:

Table 2: Distribution of Bryophytes in Rajasthan

S. No.	*Ecological region*	*Temperature Fluctuation (^0C)*	*No. of species*
1	Southern	15-20	42
2	The plateau	25-30	15
3	Arid and semi-arid	30-35	07

Ecologically, light affects temperature, as well as moisture condition of a habitat. This is illustrated by a study of North west areas at Mount Abu. They are comparatively more shaded whereas, the Eastern areas are exposed to light; the former localities are rich in bryophyte vegetation and the latter rather poor showing only some xeric forms. This is probably due to the fact that where light intensity is higher, majority of the species are excluded as in the north of Mount Abu (Achalgarh, Gurushikar) which is open to direct sun light. It was observed that plants receiving long photoperiod show more rapid development of sex organs than those in shady places. It was also observed that most of the light preferring types are annuals and usually lack asexual means of reproduction.

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3. **Soil**
The nature of the soil and its ability to retain moisture play an important role in the distribution of various species. It was observed that in arid and semi-arid areas where soil is generally sandy there is absence of bryophyte vegeation, whereas in the compact water retaining substrata, such as sandy loam, loam and clay found in the southern region mosses grow in profusion. In this state most of the species grow on alkaline soil with pH of 7.5 to 8, yet some occur on slightly acidic soils with pH 6.7. It seems that pH is not an important factor in the distribution of bryophytes, at least in Rajasthan. It was observed that plants growing on walls show luxuriant growth in comparison to those growing on moist soil or rocks. This suggests that the species might exhibit a preference for calcium.
4. **Elevation**
It was observed that as we move towards the highest peak of Mount Abu (Gurusikhar 1201 M Alt.) the vegetation gradually decreases. At Gurusikhar no moss plants are found growing whereas, at an altitude of 750 to 1120 m, comparatively rich vegetation is found growing. It shows that differences in elevation clearly influence the distribution of bryophytes. It was observed that most of species are restricted to the Southern area with an altitude of 700-1500 m above MSL. Only a few occur in the plateau region with an elevation of 400-600 meters whereas, the poorest region is the arid and semi-arid zone with 200-300 m altitude. In distribution pattern, it is usually found that most of the northern species occur at the summit of the highest elevation points and most of the southern species are restricted to the regions of low elevation. The distribution of mosses also follows the same pattern generally. However, this is not so in this area. This is due to the dry conditions prevailing over the greater part of the state.
5. **Biotic Factors**
Man and his hungry herds of grazing animals have contributed a great deal in accentuating the arid conditions in Rajasthan. The influence of man upon the vegetation has been very adverse. Vast area of forest were used for the fire wood and other domestic purpose as a result of which the vegetation has been practically decimated. Herds of grazing animals kept by nomadic tribes graze the vegetation wherever it exists. Such intense and continuous biotic interference in Rajasthan have destroyed vast stretches of trees vegetation where only grasses grow in autumn. The destroyed stretches of vegetation are still subjected to continuous or even increasing pressure of grazing and are therefore, leading towards denudation and destruction. Therefore, the bryophytes are also affected by such critical situation and sparse vegetation. Further at Mt. Abu the luxuriant growth to Lantana is having deteriorating effect on the growth of bryophytes. Most of the species are vanishing from the area which was collected in the past few years due to thick vegetation of Lantana camara. Eva Clausen (1952) has also shown that the relative humidity has a profound effect on the distribution of bryophytes. Their ability to withstand desiccation is an important factor in their distribution. Mahabale and Chavan (1954) have also reached a similar conclusion on the geographical distribution of liverwort in Gujarat.

5. Phytogeography

Most of the parts of Rajasthan remain dry for a long period. With a few exceptions, climatic conditions are quite unfavorable for the growth and existence of bryophytes. Only those species which have a wide range of tolerance can survive. 64 species have so far been identified from this state. Out of this 36 grow in West Himalayas, 24 in South India and 27 in East Himalayas (Table-1)

The bryophyte flora of Rajasthan particularly of the Southern area is composed mainly of ubiquitous species which occur in the East, North West and South. This may be due to the disposition of the Aravalli ranges, many species growing in this area are common to North as well as South and thus from a connecting link between the Northern and Southern elements. Table-II shows the distribution of the various species in Ajmer, Alwar, Banswaran, Chittorgarh, Ganganagar, Jaipur and Jodhpur districts.

Mosses: Elements, Affinities and Analysis
An analysis of the affinities with the neighboring flora reveals the following pattern, that is 36 species common with the Western Himalayas, 27 species common with Eastern Himalayas but only about 24 species with South India.

1. **Genera found in West Himalayas and also represented in Rajasthan are-**

Fissidens Anoectangium Barbula
Bryocerythrophyllum Hydrogonium Hyophila
Timiella Weissia Funaria
Physcomitrium Gymnostomiella Anomobryum
Brachymenium Bryum Semibarbula
Febronia Levierella Philonotis
Pseudobarbella Entodon

2. **Genera found in South India and also represented in Rajasthan are-**

Fissidens Anoectangium Hydrogonium
Hyophila Timmiella Weissia
Funaria Gymnostomiella Anomobryum
Brachymenium Bryum Philonotis
*Leviere*ll*a*

3. **Genera common to Western Himalayas, South India and Rajasthan are:**
Fissidens Anoectangium Hydrogonium
Hyophila Timmiella Weissia
Funaria Gymnostomiella Anomobryum
*Brachymenium Bryum Philonotis Leviere*ll*a*

4. **The following species collected from elsewhere in Rajasthan are absent Mount Abu:**
Fissidens bryoides F.sylvaticus Hyophila comosa
H. rosea Mnium species

5. **Moss speices found in Rajasthan, common with Western Himalayas are:**
Trematon sabulosus Fissidens bryoids F. curvato-involutus
F. diversifolius F. sylvaticus Anoectangium stracheyanum

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Barbula constricta B.vinealis Brycerythrophyllum recurvirostrum
Hydrogonium arcuatum H. Conseguinecm H. involuta
H. rosea Tortula muralis Semibarbula orientalis
Funaria hygrometrica F. Nutans Physcomitrium japonicum
Anomobryum auratum B. exile Gymnostomiella vernicosa
Bryum argenteum B. capillare B. paradoxum
B. cellulare B. plumosm Philonotis revolute
Fabronia minuta Entodon myurus Psudobarbella compressiramea
Levierella febroniacea E. prorepens Diaphanodon procumbens

6. **Moss species found in Rajastna and common with South India are:**

Fissidens curvato-involutus F. diversifolius Anoectangium stracheyanum
Hydrogonium arcuatum H. consegineum Hyophila comosa
H. involuta H. rosea Semibarbula orientalis
Timmiella anomala B. exile Weissia contraversa
Funaria hygrometrica Bryum argenteum Gymnostomiella vernicosa
Anomubryum auratum B. capillare Brachymenium acuminatum
B. cellulare B. paradoxum B. plumosum
B. recurvulum Philonotis mollis Wijkia tanytricha

7. **Moss species found in Rajasthan and common with Western Himalayas, Eastern Himalayas and South India are-**

Fissidens curvato- involutus H. consanguineum Anoectangium stracheyanum
Semibarbula orientalis Hyophila involuta Funaria hygrometrica
Gymnostomiella vernicosa B. exile Brachymenium acuminatum
Bryum cellulare B. plumosum

8. **The following rare species have been collected only from Mt. Abu in Rajasthan:**

Entodon prorepens E. myurus Funaria nutans
Fissidens diversifolius Wijkia tanytricha

9. **Species collected from Mt. Abu and one more locality are-**

Barbula constricta Brachymenium exile Fissidens curvato-involutus
Semibarbula orientails Hyophila involuta Hydrogonium consenguineum
Fabronia minuta

The above analytical outline reveals that the moss elements follow the same general trend in floral dispersal throughout as those in higher plants. The present study, as mentioned earlier suggests that moss flora of Rajasthan is not very different from that of Western Himalayas or South India. Further, the present study reveals that Aravalli range might have provided a suitable path for the migration of these species.

6. Perennation

Rajasthan remains dry for a considerable part of the year. Most of the species appear just after the first showers of rains and complete their life cycle within a short period of one to three months. Most of the species get dried up before completing their life cycle due to high temperature and low rainfall. The species found in arid and semi-arid regions or in the plains of Rajasthan are annuals and depend entirely on the spores for propagation and survival as the temperature during summer is quite high and plants get completely dried up. It was observed that on the approach of favorable conditions, the plant parts e.g. stem, rhizoids and leaves revive their growth with the first showers of rain and multiply through regeneration. Each plant part is giving one or more apical shoots while the older portion dies.

In plants growing under xeric condition after a few days of drought, the leaves become enrolled and scattered on the soil or on the rocks along with their stem portions. Such plants readily revive and resume their growth after a shower of rain (in any season). It was observed that sterile plants were in great abundance as compared to fertile one.

In species like *Physomitrium japonicum* underground gemmae are formed for perennation during unfavorable period. These develop on the rhizoids and are red in colour. During the unfavourable conditions, the parent plant dies but gemmae remain in the resting stage thoughout the seasons, In favourable conditions, new gametophyte sprout from these resting gemmae However, no underground gemmae have been observed in other species of mosses.

Gemmae formation has also been observed in *Semibarbula orientalis* and Hyophila rosea. In *Semibarbula orientalis* gemmae develop on the apex of shoot and in axil of leaves of middle portion of stem but in *Hyophila rosea* these multicellular vegetative bodies occur only in axil of leaves. During the unfavorable conditions plants completely get dried and these gemmae were scattered on the substratum. In favorable conditions these gemmae revive and give rise to new moss plant.

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