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STUDIES ON THE FLORA OF THE RAJASTHAN DESERT—A REVIEW

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INTRODUCTION

The Rajasthan part of the Indian desert, commonly known as the Rajasthan desert, covers a total area of about 1,96,000 sq. km between latitudes of 24° 40′ and 30° 12′ north and longitude of 69° 30′ and 75° 55′ east and occupies nearly three fifth of the total area of the state. It includes the districts of Ganganagar, Bikaner, Jaisalmer, Barmer, Jodhpur, Churu and parts of Nagaur (96%), Jalor (88%), Jhunjunu (69%), Sikar (65%), Pali (48%) and Ajmer (9%), districts (Krishnan, 1968 a, b). The eastern limit of this region is marked by the Aravalli ranges tending in north-easterly direction. These ranges divide the regions of western Rajasthan characterised by desertic and sub-desertic climate from the comparatively more damp and fertile regions on the south-east.

Western Rajasthan, believed to be under sea during the Jurassic, Cretaceous and Eocene period must have uplifted into dryland sometime in the upper Tertiary (Krishnan, 1952). The advent of arid conditions is believed to be mainly due to climatic oscillations which took place after the last phase of glaciation during the Pleistocene period.

Many historians and archaeologists have pointed out that the Rajasthan desert was once a centre of flourishing civilisation. Though the original cause of desert can be traced to geological events, its deterioration since 600 A.D. is attributed largely to human activities. The use of trees for firewood and other domestic purposes increased beyond their recuperative power. Heads of goat and sheep moved about by the nomadic tribes chewed up vegetation wherever it existed or appeared (Hora, 1952). Gupta (1968) classified the anthropogenic influences and concluded that if not man made, Rajasthan desert is certainly a man-maintained desert.

The greater part of the Rajasthan desert is covered with wind blown sand and alluvium. The solid geology is practically concealed with the exception of hilly outcrops which account for only 13,209 sq. km. Of these, the Kailana-Jodhpur-Mandore plateau is an extensive plateau rising abruptly from the plains and is composed of Vindyan sand-stone. The Jalor hills are mostly of lower Vindyan series consisting of Malani Volcanics, Jalor granite and other basic rocks. The Barmer hills are chiefly of volcanic origin consisting of Malani rhyolites, the notable ones being the two parallel ranges, each about 24 km, situated in Siwana Tahsil. There are a few rocky elevated ridges and hillocks in Jaisalmer district also. The Jaisalmer plateau and outliers are highly fossiliferous and are made up of sand-stone.

In Nagaur, Bap, Phalodi, Jodhpur, Jaisalmer, Pali Jalor and Bikaner areas extensive rocky plains are present. There are also some other minor rocky plains strewn with stony materials adjacent to the hills.

A spectacular feature of the Rajasthan desert is the occurrence of sand dunes which vary in height from a few metres to about 80 metres. About 58% of western Rajasthan is covered with sand dunes of different types, magnitude and orientation, and the large

sized dunes are concentrated in western parts, in the districts of Barmer, Jaisalmer and Bikaner.

In the northern part of the desert, in Ganganagar district, the Ghaggar alluvial plain is situated.

The only river of significance in western Rajasthan is the Luni, an ephemeral river carrying water during the short monsoon period. There are also some fresh water lakes, like Balsamand and Kailana (Jodhpur), Gajner (Bikaner) etc.

Saline depressions (Playas) or lakes are scattered throughout western Rajasthan, the well known ones being Sambhar lake, Pachpadra, Lunkaransar and Didwana. In addition, there are many less known local saline tracts like those at Kaparda, Sujangarh, Tal Chappar, Parihara, Sargot, Mitha ka rann, Kharia rann, Pokran, That, Lawan, Khutani, Khanodwala, Kharowala, Phalodi, Mansar and Kodamdesar. The northern tip of the Rann of Kutch butts into Barmer and Jalor districts.

The Rajasthan desert is characterised by low erratic rainfall, high solar radiation, extreme variations in diurnal and seasonal temperature with high summer temperature, low humidity of the atmosphere for the greater part of the year, high evaporation rates, desiccating winds and dust storms during summer, sandy and unretentive character of soil, low water table, general soil and water salinity and poor vegetative cover. The entire western Indian arid and semi-arid zone forms a typical belt of low rainfall with the rainfall in western Rajasthan decreasing rapidly from the Aravalli range towards west and west-north-west. The mean annual rainfall ranges from about 100 mm in the north-western sector of Jaisalmer district to about 450 mm in Sikar district. The failure of monsoon rains in this region is quite frequent, causing severe famine. Another characteristic feature is the great extremes of temperature with cold winters and very hot summers. In winter the temperature falls at many places below freezing point and frost occurs. On the other hand, heat during the summers is very intense and scorching with the mean maximum temperature in May ranging between 40-42°C over most parts of western Rajasthan. As a consequence of high temperature, coupled with the low rainfall, evaporation far exceeds precipitation, with the result there is very little moisture to support vegetation.

VEGETATION TYPES AND FLORAL COMPOSITION

As might be expected from its geographical position and limited rainfall, the flora of western Rajasthan is not rich. The vegetation is sparse and the number of species limited. The area under forest is negligible, being only 0.69 per cent.

Three ecological zones can be recognised in western Rajasthan (Sarup, 1952). They are :

1. To the south and south-east of the region near Aravalli hills, but not strictly in the desert.

2. Semi-arid region about 160 km parallel to the first region.

3. The arid region to the extreme west of the region. Here the vegetation is very poor.

Blatter and Hallberg (1918-21) termed the vegetation types of W. Rajasthan as "formations" which are exclusively controlled by edaphic factors. The five habitats distinguished by them are : (1) Aquatic, (2) Sand, (3) Gravel, (4) Rock and (5) Ruderal. Biswas and Rolla (1953), taking into consideration the edaphic factors against the general poor rainfall, classified the desert vegetation as (1)

Sand community (Psammophytic), (2) Gravel community and (3) Rock community. Bharadwaj (1961) distinguished three primary and three secondary land forms in western Rajasthan. Based on physiographic factors, Mulay and Joshi (1964) recognised four main ecosystems in Rajasthan, namely : (1) Rocky areas, (2) Aquatic and marshy areas, (3) Saline areas and (4) Sandy plains and dune areas. Similar classification has been adopted by Saxena (1972) who showed that there are seven ecosystems in W. Rajasthan *viz.* (1) Hills and rock outcrops, (2) Piedmont slopes, (3) Alluvial plains, (4) Saline flats and depressions, (5) Graded river beds, (6) Sand dunes and (7) Aquatic areas. These have further been sub-divided by him, depending upon the features of the environment and the vegetation. In a recent publication (Saxena, 1977), he recognised six formations in the Indian desert, namely (1) the mixed xeromorphic thorn forest, (2) the mixed xeromorphic woodland, (3) the mixed xeromorphic riverine thorn forest, (4) the lithophytic scrub desert, (5) the psammophytic scrub desert and (6) the halophytic scrub desert.

Champion (1936) recognised the following four principal types of vegetation from Rajasthan : (1) Northern desert thorn forest, (2) Northern *Acacia* scrub forest (500-1000 mm rainfall) (3) Northern *Euphorbia* scrub and (4) Inland dune scrub. Following Champion's (*l. c.*) system of classification, Mathur (1960) enumerated seven types from Rajasthan, of which one type, namely Tropical thorn forest is from W. Rajasthan. Based on the recent classification of Champion and Seth (1968) in their Revised Survey of Forest Types of India, the following types of vegetation can be recognised from W. Rajasthan (under the sub-group 6B—Northern tropical thorn forests) : (1) Desert thorn forest (6 B/C 1), (2) *Ziziphus* scrub (6 B/DS 1), (3) Tropical *Euphorbia* scrub (6 B/DS 2), (4) *Euphorbia* scrub (6/E 1), (5) *Acacia senegal* forest (6/E 2), (6) *Salvadora* scrub (6/E 4), (7) *Cassia auriculata* scrub (6/E 4/DS 1) and (8) Desert dune scrub (6/1S 1).

The total Angiosperm flora of the western Rajasthan, including both indigenous and naturalised plants, comprises of about 774 species and 48 varieties, belonging to 384 genera under 90 families. The following table (Table 1) gives the number of families, genera and species under Dicotyledons, Monocotyledons and Gymnosperms.

Table 1. *Statistical synopsis of the Flora*

	Families		Genera		Species	
	No.	%	No.	%	No.	%
Dicotyledons	76	83.52	301	78.20	588	75.87
Monocotyledons	14	15.38	83	21.55	186	24.00
Gymnosperms	1	1.10	1	0.25	1	0.13
	91	100.00	385	100.00	775	100.00

The families with 16 or more species are as follows :

1. Poaceae (Gramineae)	125 spp.	(56 genera)
2. Fabaceae (Papilionaceae)	80 spp.	(30 genera)
3. Asteraceae (Compositae)	49 spp.	(35 genera)
4. Convolvulaceae	38 spp.	(9 genera)
5. Cyperaceae	32 spp.	(6 genera)
6. Malvaceae	29 spp.	(9 genera)
7. Acanthaceae	26 spp.	(14 genera)

8.	Euphorbiaceae	24 spp.	(7 genera)
9.	Boraginaceae	22 spp.	(9 genera)
10.	Cucurbitaceae	21 spp.	(11 genera)
11.	Amaranthaceae	19 spp.	(9 genera)
12.	Scrophulariaceae	16 spp.	(13 genera)
13.	Solanaceae	16 spp.	(6 genera)
14.	Tiliaceae	16 spp.	(3 genera)

The following families have 8 or more genera :

1.	Poaceae (Gramineae)	56 genera	(125 spp.)
2.	Asteraceae (Compositae)	35 genera	(49 spp.)
3.	Fabaceae (Papilionaceae)	30 genera	(80 spp.)
4.	Acanthaceae	14 genera	(26 spp.)
5.	Scrophulariaceae	13 genera	(16 spp.)
6.	Cucurbitaceae	11 genera	(21 spp.)
7.	Asclepiadaceae	10 genera	(11 spp.)
8.	Convolvulaceae	9 genera	(38 spp.)
9.	Malvaceae	9 genera	(29 spp.)
10.	Boraginaceae	9 genera	(22 spp.)
11.	Amaranthaceae	9 genera	(19 spp.)
12.	Caryophyllaceae	8 genera	(8 spp.)

The genera with 6 or more species are as follows : *Ipomoea* L. (17 spp.), *Cyperus* L. (17 spp.), *Indigofera* L. (14 spp.), *Heliotropium* L. (14 spp.), *Tephrosia* Pers. (12 spp.), *Euphorbia* L. (12 spp.), *Eragrostis P.* Beauv. (12 spp.), *Aristida* L. (11 spp.), *Convolvulus* L. (9 spp.), *Corchorus* L. (8 spp.), *Alysicarpus* Neck. ex Desv. (8 spp.), *Amaranthus* L. (8 spp.), *Sida* L. (7 spp.), *Cassia* L. (7 spp.), *Fimbristylis* Vahl (7 spp.), *Abutilon* Mill. (6 spp.), *Hibiscus* L. (6 spp.), *Ziziphus* Mill. (6 spp.), *Solanum* L. (6 spp.), *Chloris* Sw. (6 spp.), *Digitaria* Heist. ex Fab. (6 spp.) and *Sporobolus* R. Br. (6 spp.).

If the Fabaccae *s. l.* (Leguminosae) are taken as one family they comprise 41 genera and 104 species. Even then Poaceae (Gramineae) occupy the first place, the second and third positions being occupied by Fabaceae *s. l.* (Leguminosae) and Asteraceae (Compositae) respectively.

Except for Poaceae (Gramineae) and Cyperaceae (157 spp.), the Monocotyledons are poorly represented. The remaining 29 species belong to 12 different families. The ratio of species belonging to Monocotyledons to Dicotyledons is 1 : 3.1, of genera 1 : 3.6 and of families 1 : 5.4. Only one species of Gymnosperm, namely *Ephedra foliata* Boiss. is found in this area.

The ratio of the total number of genera to species is 1 : 2.01 which is rather low in comparison to the corresponding ratio for the whole of India which is estimated to be about 1 : 7, but it is more or less comparable to the ratio for North Gujarat—1 : 1.83 (Saxton, 1922), Delhi State—1 : 1.63 (Maheshwari, 1963) and Indus Plain Region—1 : 2.2 (Maheshwari, *l. c.*).

A comparison of ten dominant families in W. Rajasthan with those in the whole of Rajasthan State, North Gujarat, Delhi State, Indus Plain Region and India shows that while Orchidaceae takes the first position in the Flora of India, Poaceae (Gramineae) tops the list in all the other cases. There is a general resemblance between the flora of W. Rajasthan and that of Delhi State and N. Gujarat as far as the dominant families are concerned, the first and second positions being occupied by Poaceae (Gramineae) and Fabaceae *s. l.* (Leguminosae) respectively. Cyperaceae, however, are more dominant in N. Gujarat when compared to W. Rajasthan.

HISTORY OF FLORISTIC SURVEYS AND RESEARCH IN ALLIED FIELDS

The first known record of the plants of Rajasthan dates back to the year 1852 when Allen published a book on "The views and flowers from Gujarat and Rajputana" which, however, is of little botanical significance. In

their Introductory Essay in "Flora Indica" Hooker and Thomson (1855) observed that the vegetation of Rajwara which included Marwar (Jodhpur, Bikaner, Jaisalmer and Barmer), Mewar (Pali and Udaipur), Jaipur, Kotha and Gwalior is not known in detail. They also remarked that the flora of the desert of Jaisalmer resembles that of southern Punjab.

King (1869) gave some information on the famine plants of Marwar and in 1879 published "The Sketch of the Flora of Rajputana" which was the first scientific account on the flora of this region. Brandis toured in the forests of Rajasthan during the years 1869-70 and incorporated his observations in the "Forest Flora of North West and Central India" (Brandis, 1874). An anonymous publication entitled "Introductory note to Jodhpur and Jaisalmer trees and plants" is believed to have been published by Miss Macadam, presumably in the year 1890. Adams (1899) in his book "The Western Raputana States" listed about 50 species of plants.

The first comprehensive account on the plants of Rajasthan desert was by Blatter and Hallberg (1918-21) who visited the districts of Jodhpur, Jaisalmer and Barmer accompanied by T. S. Sabnis and D. B. Bulsara and published a series of papers under two parts—Part I containing a list of plants with the description of new species, while Part II deals with the ecological side of the flora and is accompanied by meteorological notes. They remarked that "the Indian Desert is perhaps the least known part of the plains of India" and that "the vast deserts of N. Africa, Arabia, Central Asia, and even the New World have attracted the attention of many botanists, but the Indian Desert has been sadly neglected" Now, however, western Rajasthan is perhaps one of the best botanically explored regions in India, thanks to the interest shown by the various universities in Rajasthan, the Central Arid Zone Research Institute, Jodhpur, and the Botanical Survey of India.

Biswas (1952), Biswas and Rolla (1953), Sarup (1957 a), Mathuda (1958), Puri and Jain (1960, 1962 a), Joshi (1961), Vyas (1971) and Nathawat (1971) have dealt with the vegetation of Rajasthan, some of them very briefly. An account of the vegetation and flora of Jodhpur division has been given by Rolla and Kanodia (1962-63). Kanodia and Gupta (1969) dealt with the sand dune flora of western Rajasthan. Ramachandra Rao (1941) published a list of some plants from Rajasthan, S. W. Punjab, Sind, Baluchistan and Kathiawar. Sankhala (1951) enumerated the plants of N. W. Rajasthan. Sarup listed plants of Jodhpur and its neighbourhood (Sarup, 1951, 1954), Bikaner and its neighbourhood (Sarup, 1957 b) and Jaisalmer and its neighbourhood (Sarup, 1958 a). The vegetation in Ladnun in Nagaur district and Kailana in Jodhpur district were studied by Tandon (1958) and Bhimaya *et al.* (1964) respectively. Singh *et al.* (1976-77) gave an account of the plants of Luni development block in Jodhpur district. Many contributions have been made towards the flora of the semi-arid parts of Jhunjhunu district, particularly Pilani, Chirawa, Jhunjhunu and Mandrela and their neighbourhood (Mulay and Ratnam, 1950; Bakshi, 1954; Nair, 1956, 1961; Nair and Nathawat, 1956; Nair and Joshi, 1957; Joshi, 1956 a, 1958). Sharma, B. M. (1962, 1965) studied the composition of the plant communities of Churu, while Dhillon and Bajwa (1972) enumerated the plants of Ganganagar district.

In many of the publications mentioned above, reference to aquatic vegetation or plants has been made. Sarup (1957 c, 1958 c), however, made a special study of the hydrophytes of western Rajasthan.

Sarup (1957 d, 1958 d, e) also made a study of the halophytes of the Indian desert. Saxena

and Gupta (1973) dealt with the vegetation of Pachpadra salt basin.

Bhandari has published several papers, mostly relating to new plant records from western Rajasthan and also on the identity and nomenclature of desert plants (Bhandari 1954, 1962, 1963 a, b, 1964, 1965 a, b, 1967, 1971). New records for western Rajasthan have also been published by Nair and Deshpande (1960), Jain and Kotwal (1960), Raizada and Jain (1961), Jain (1963), Bhandari and Singh (1964), Hingorani and Gaur (1965), Verma *et al.* (1965), Majumdar *et al.* (1969), Majumdar (1969) and Dhillon and Bhandari (1974). Bhandari and Verdcourt (1972) dealt with the identity and nomenclature of two species of *Rhynchosia* described by Blatter and Hallberg (*l. c.*) from western Rajasthan. Majumdar (1971) also gave the correct names for 13 taxa reported from Rajasthan. A new species of *Tribulus*, namely *Tribulus rajasthanensis* Bhandari and Sharma (1977) has recently been published. A taxonomic study of *Indigofera* L. in Rajasthan was undertaken by Nair and Koshy (1963).

The pioneering work of Hooker and Thomson (*l. c.*) of dividing India into floristic provinces was continued further by Clarke (1898) who included Rajputana in his subsubarea "India Deserta", which coincides roughly with the "Indus Plain Region" of Hooker (1906), Calder (1937) and Chatterjee (1939). Agharkar (1952) regarded the flora of Rajputana desert as a mixture of western (Arabian-African), eastern (Indo-Malayan) and general (Indian and widely distributed) elements. He also observed that they are found in varying proportions in different parts, the western types being more common in the west, and the eastern types being found near the foot of the Aravallis. Blatter and Hallberg (*l. c.*) and Biswas and Rolla (*l. c.*) found the eastern elements to be about one-seventh of the western and pointed out that the Indo-Malayan and western Botanical regions meet in western Rajputana desert. They, thus, supported Drude's (1890, 1913) contention that the line of demarcation between the Indo-Malayan and "Perso-Arabian" flora ranges from the Gulf of Cambay northwards along the Aravallis. Meher-Homji (1970), Meher-Homji and Bharucha (1975) and Legris and Meher-Homji (1975) analysed the floristic elements according to vegetation types and concluded that the demarcation corresponds in general with that of Drude (*l. c*). A brief account of the pattern of plant distribution in Rajasthan was given by Mulay (1960). Bharucha and Meher-Homji (1965) conducted investigations on the floristic elements of the semi-arid zones of India. Meher-Homji (1965 a) showed that the strength of the north African steppe (Sudano-Deccanian) element in the northern semi-arid zone is two times higher when compared with that in the entire southern semi-arid zone including the Deccan. Sharma, S. (1965) also dealt with some phytogeographic aspects of Rajasthan. Bhandari and Sharma (1977) gave an account of the biogeography of the Indian desert. Majumdar (1975) gave a brief account of the origin, nature and economic aspects of the Rajasthan flora.

The first flora providing keys to the identification along with short descriptions for the species found in western Rajasthan was published by Puri *et al.* (1964). This has been critically reviewed by Gupta and Bhandari (1965). Very recently, Bhandari (1978) published the "Flora of the Indian Desert" which, however, covers only the districts of Jodhpur, Jaisalmer and Barmer.

The study of grasses of arid and semi-arid regions of western Rajasthan, particularly with reference to the ecology of grasslands and other applied aspects, for obvious reasons, received considerable attention, the notable contributions being those by Dabadghao and

his associates (Dabadghao, 1957 a, b, 1958 a, b, 1960; Dabadghao and Shankarnarayan, 1973). The other papers dealing with the ecology, improvement and types of grasslands, as also the impact of grazing on vegetation cover are by Mathuda (1957), Shah (1957), Satyanarayan (1958 a), Prakash (1958), Prakash and Nanda (1961), Aggarwal (1961), Das *et al.* (1963, 1965), Prakash and Ahuja (1964), Shankarnarayan and Satyanarayan (1964), Das and Bhimaya (1964), Bhimaya *et al.* (1965, 1969), Gupta and Saxena (1966, 1969, 1970, 1971 c, 1972 a, b), Bhimaya (1967), Bhimaya and Ahuja (1967, 1968, 1969), Kaul (1968), Pandeya (1968), Nanda and Gupta (1968), Kaul and Chakravarty (1968 a, b), Chakravarty (1968), Nanda (1969), Gupta (1971) etc. A short account of the annual and perennial grasses of the Rajasthan desert has been given by Chakravarty (1964). Gupta (1966 a) gave a general account of the distribution of grasses in various habitats and described the characteristics of some grass species for soil conservation in the arid regions of north-west India. An account of the grasses of the rangelands in arid Rajasthan with an enumeration of grasses found there has been presented by Gupta and Sharma (1971). A comprehensive account of range ecology and development in the Thar Desert has been given by Gupta (1975 a). Grasses found in certain areas of Jhunjhunu district have been enumerated by Ramachandran (1950) and Joshi and Sharma (1964, 1966), Kanodia and Nanda (1968) dealt with the genus *Aristida* in western Rajasthan. A new species of *Lasiurus* was described from western Rajasthan by Satyanarayan and Shankarnarayan (1964). Bor's (1973) book includes information on the taxonomy of grasses from Rajasthan also.

The weeds found in western Rajasthan have been mentioned by Blatter and Hallberg (*l. c.*). Sharma, B. M. (1959, 1961) and Satyanarayan and Saxena (1966), however, have made a special study of the weeds. Chopra and Handa (1960) and Gupta *et al.* (1966) gave an account of the medicinal plants of arid zone. King (1869), Gupta and Kanodia (1968) and Bhandari (1974) dealt with the vegetable products used as food during scarcity and famine periods.

Vernacular names of useful plants of north-west Indian arid regions, along with their uses have been given by Gupta and Dutta (1967). Gupta and Saxena (1968 a) and Gupta (1970) undertook a resource survey of two species of *Salvadora* (for non-edible oil) and gummiferous Acacias respectively, in western Rajasthan. Singh and Shetty (1976, 1977) dealt with the natural plant resources of western Rajasthan.

There are a number of publications dealing with the synecological and phytosociological characteristics of the Rajasthan desert. The biological spectrum of the Indian desert flora was studied by Das and Sarup (1951). Bharucha (1951, 1955 a, 1975), Puri (1952), Ratnam and Joshi (1952), Sarup (1952, 1953, 1955), Vyas (1955), Joshi (1956 b), Sarup and Vyas (1957, 1958), Sarup and Bhandari (1957), Ratnam and Ramdeo (1958), Sarup and Puri (1960 a, b), Rolla and Kanodia (1962), Satyanarayan (1958 b, 1963, 1964), Sen (1965, 1966), Shankarnarayan *et al.* (1965), Meher-Homji (1965 b), Gupta and Saxena (1965, 1968 b, 1971 a, b), Satyanarayan *et al.* (1966), Satyanarayan and Gaur (1967, 1968), Gaur and Satyanarayan (1967), Joshi and Bansal (1968), Cherian and Bole (1971), Saxena (1972), Sharma, B.M. (1972), Gupta and Sharma (1973) and Prakash and Gupta (1976) have dealt with some ecological aspects of desert areas of western Rajasthan. Gupta (1975 b) gave an account of the "Plant life in the Thar" Bharucha (1955 b) reviewed the work on plant ecological research in the arid and semi-arid regions of Afghanistan, India and Pakistan. Sarup (1958 b) and Sarup and Bhandari (1958)

reviewed the work on plant ecology of the Indian desert. Gupta (1966 b) published a bibliography on the ecology (synecology and phytosociology) of arid and semi-arid regions of India. Recently, Joshi and Gupta (1973) reviewed the work done on the ecology of the arid and semi-arid zones in India bringing forth the varied aspects of the inter-relationship of vegetation and the environment. A vegetation map of Rajasthan has also been published (Gaussen *et al.*, 1972).

The ecological studies of the Rajasthan desert soils were undertaken by Bharucha (1960). The vegetation in relation to soil has been studied by Krishnaswamy and Gupta (1952), Sarup and Dutt (1954), Ramdeo (1955), Verma (1964) and Sharma B. M. (1967, 1968). Air-photo analysis of plant communities in relation to edaphic factors in the arid zone of western Rajasthan was described by Gupta and Abichandani (1968).

The climate of the dry zones and its influence on the vegetation has been given in considerable detail by Raheja (1965), Shanbagh (1958) and Waheed Khan (1959). Meher-Homji (1977) dealt with the bio-climatic and vegetational aspects of the arid zones of India.

Badhwar *et al.* (1948), Nair (1954), Bhimaya *et al.* (1964) and Mulay and Joshi (1964) gave suggestions on the choice of species for afforestation of the arid and semi-arid regions. Provenance trial in relation to tree introduction in arid lands was undertaken by Kaul (1965). Puri and Jain (1962 b) dealt with the botanical aspects of dry zone afforestation in India. Banerjee (1952), Sen (1962), Bhimaya and Kaul (1962), Kaul and Ganguli (1964), Joshi (1973), Seth and Kaul (1973), Bora (1973), Muthana and Gyan Chand (1973), Shukla (1973) and Verma (1975) have discussed about the different aspects of dry zone afforestation in Rajasthan.

Jain (1972) in his "Floral composition of Rajasthan—A review" gave a brief history of botanical exploration in Rajasthan, a synopsis of the floral composition and vegetation, and a comprehensive bibliography. Recently, Gupta and Prakash (1975) have edited a book entitled "Environmental analysis of the Thar Desert"

That the Rajputana desert has attracted a lot of attention in recent years is evident from the number of symposia organised, namely (1) Symposium on Rajputana Desert organised by the Council of the National Institute of Sciences of India at New Delhi in 1952, proceedings of which have been published in the *Bull. nat. Inst. Sci. India* 1, 1952. It has been reviewed by Chapline (1953), (2) Symposium on Problems of Indian Arid Zone organised jointly by the Ministry of Education, Government of India and U N E S C O in 1964 at the Central Arid Zone Research Institute, Jodhpur, (3) Symposium on Natural Resources of Rajasthan sponsored jointly by the University of Jodhpur and the University Grants Commission and held at Jodhpur in 1968, (4) Symposium on Arid Zone held at Jodhpur in 1968 under the auspices of 21st International Geographic Congress, India in collaboration with the I C A R and the Central Arid Zone Research Institute, Jodhpur, (5) Winter School on the Development of Rajasthan Desert held at Jodhpur in 1973 and organised by the Indian National Science Academy in collaboration with the Central Arid Zone Research Institute, Jodhpur, (6) Workshop on the Problems of the Deserts in India organised by the Geological Survey of India at Jaipur in 1975 and (7) Conference on Desert Technology held in 1976 at Jodhpur by the Indian Society of Desert Technology.

Botanical exploration in western Rajasthan by Botanical Survey of India :

After the reorganisation of the Botanical Survey of India in 1954, botanical explorations

were undertaken in some selected localities of western Rajasthan by the Western Circle, Poona between the years 1957-1960, particularly in the districts of Barmer, Jaisalmer, Jodhpur and Bikaner. Some collections have been made from Ganganagar and Pali districts also. In 1964 botanical collections from Jaisalmer and Jodhpur were made by the Central Circle, Allahabad.

The Arid Zone Circle of the Botanical Survey of India was set up in 1972 at Jodhpur for studying the flora of the regions in N. W. India which are by and large arid or semi-arid. After its setting up intensive botanical explorations have been undertaken in the districts of Barmer, Jaisalmer, Bikaner, Ganganagar, Churu, Pali and Jodhpur, covering almost the entire district in each case. Botanical explorations in Jalor district have also been partly completed.

A check-list of plants recorded from Rajasthan state, based on the available information, namely published literature and the collections in the various herbaria in India is being prepared, giving important synonyms. references and distribution. This will form a precursor to the writing of the flora of categories :

PROSPECTS OF FUTURE STUDIES

Taking into consideration the published literature, Jain (1972) grouped the districts of western Rajasthan under the following categories :

1. Fairly well explored	:	Jodhpur and Jhunjhunu districts.
2. Under explored	:	Barmer, Jaisalmer, Bikaner, Sikar and Churu districts.
3. Almost unexplored	:	Jalor, Pali, Nagaur and Ganganagar districts.

On the basis of the publications and the botanical explorations undertaken in recent years, particularly by the Botanical Survey of India, the districts in western Rajasthan can be reclassified as follows :

1. Well explored	:	Jodhpur, Pali Barmer, Jaisalmer, Bikaner, Ganganagar and Churu districts.
2. Fairly well explored	:	Jhunjhunu and Jalor districts.
3. Under explored	:	Sikar district.
4. Almost unexplored	:	Nagaur district.

Jain (1972) had suggested the undertaking of monographic works on small families or genera pertaining to Rajasthan, and has also emphasised that importance should be given to genera which are economically important or are more common. Monographic studies of this nature have been published only for the genus *Indigofera* L. (Nair and Koshy, *l. c.*) and also for the genus *Aristida* L. (Kanodia and Nanda, *l. c.*). Recently, however, revision of the genus *Cassia* L. in Rajasthan (V. Singh, in press) and the genus *Eragrostis* P. Beauv. in Rajasthan (G. P. Roy, in press) have been undertaken at the arid Zone Circle of the Botanical Survey of India, Jodhpur.

The Rajasthan Canal Project and its likely impact on the desert ecosystem :

Prior to the construction of the Gang canal, the construction of which was taken up due to the ceaseless efforts of Maharaja Ganga Singh, the ruler of Bikaner state, and which was formally opened in October, 1927 the entire district of Ganganagar was a typical desert. The vegetation was scanty with the tree species poorly represented. It was thinly populated and little crop was cultivated. Drinking water was the most precious commodity. The construction of

the Gang canal and the other canals which came into being later, like the Bhakra canal and the Rajasthan canal system, has resulted in the transformation of a vast inhospitable stretch of arid land into a fertile land. Ganganagar district has now become a "Granary of Rajasthan" famed for its agricultural produce and fruits. There was a phenomenal increase in the population in the last fifty years. Previously, except for a few green tracts in the present tahsils of Hanumangarh, Suratgarh and Bhadara, no forest existed in Ganganagar district. After the advent of the Gang canal appreciable increase in the number of trees and plantations has taken place, particularly along the banks of the canal. The common trees planted along the canal are *Acacia nilotica* (L.) Willd. ex Del. subsp. *indica* (Benth.) Brenan, *Allbizia lebbeck* Benth., *Dalbergia sissoo* Roxb., *Eucalyptus* spp., *Ficus* spp. etc. Further, a large number of marshy and aquatic plants and, wherever the soil is saline, some halophytes are encountered. There has also been a considerable increase in the weed flora. New plants from the hilly areas of Punjab have spread downwards and have established themselves along the banks of the canal or are found as seasonal weeds in irrigated areas (Dhillon and Bhandari, 1974).

A major event which is bound to have a profound influence on the ecosystem of the north-western part of the Rajasthan Desert is the construction of the Rajasthan canal. Its construction work was started in 1958 and on completion it will be one of the world's largest irrigation projects (Sain, 1976). It is estimated to cost 4060 million rupees for the entire project. The canal has its origin in the Harike Barrage at the confluence of the rivers Satlej and Beas in the Punjab. It runs as a feeder for 204 km of which 169 km is in Punjab and Haryana and the rest is in the Ganganagar district of Rajasthan. The main canal, when completed, will be 445 km long with 7000 km of distribution system. Work on the first phase of the project, namely 189 km length of the main canal and 3000 km length of distribution system, has been completed. The area to be served by this canal falls mainly in the districts of Ganganagar, Bikaner and Jaisalmer.

The gross service area of the Rajasthan canal project will be over 2 million hectares of which the cultivable command area will be 1.3 million hectares (Sain, *l. c.*; Kapoor & Rajvanshi, 1977). A vast tract of wasteland in N. W. Rajasthan will thus be transformed into a prosperous green belt humming with economic activity.

The flora of this region will positively undergo a major transformation with the increased irrigation facilities. The transformation brought about by the Gang canal in Ganganagar district will be repeated—on a larger scale. Trees species alien to this region will be planted extensively. A large number of plants—particularly the weeds will be introduced by the canal water from Punjab. The cultivation of the land also will result in a tremendous increase in weed flora. Natural vegetation will be destroyed in the irrigated area by the farmers and some characteristic desert plants are likely to get eliminated from the canal command area. There is thus a paramount need for intensive floristic and ecological studies in and around the canal command area for understanding the impact of the Rajasthan Canal on the flora of this region.

REFERENCES

ADAMS, A The Western Rajputana States. London. 1899.

AGGARWAL, S. C. Grassland communities of dry tropical forests. *Indian Forester* 87 : 309-315. 1961.

AGHARKAR, S. P. Plant ecology of the Rajputana desert. *Bull. nat. Inst. Sci. India* 1 : 246-247. 1952.

ALLEN, G. L. The Views and Flowers from Gujarat and Rajputana. New Delhi. 1852.

BADHWAR, R. L., A. C. DEY AND A. L. GRIFFITH The afforestation of dry and arid areas. *Indian Forester Bull.* 133. 1948.

BAKSHI, T. S. The vegetation of Pilani and its neighbourhood. *J. Bombay nat. Hist. Soc.* 52 : 484-514. 1954.

BANERJEE, J. The role of vegetation in desert control. *Bull. nat. Inst. Sci. India* 1 : 277-283. 1952.

BHANDARI, M. M. On the occurrence of *Ephedra* in the Indian desert. *J. Bombay nat. Hist. Soc.* 52 : 10-13. 1954.

——New plant records for north-west Indian desert. *Proc. Indian Sci. Cong.* Pt. III, 307-308. 1962.

——Notes on Indian desert plants. I. New records for north-west Indian desert. *Proc. Rajasthan Acad. Sci.* 10 : 40-50. 1963 a.

——Idem. II. On the identity and nomenclature of *Talinum portulacifolium* (Forsk.) Asch. & Sch. *Ann. Arid Zone* 1 : 176-179. 1963. b.

——Idem. III. Critical notes on some recently reported new records. *Ibid.* 2 : 181-184. 1964.

——Idem. IV. New names and combinations. *Bull bot. Surv. India* 6 : 327-328. 1964.

——On *Coccinia grandis* (L.) Voigt. *Ann. Arid Zone* 4 : 227-229. 1965 b.

——Flora of the Indian desert. VI. Additions, corrections and some nomenclatural notes. *Ibid.* 6 : 200-210. 1967.

——*Caralluma edulis* (Edgew.) Benth. & Hook. A new record for India. *J. Bombay nat. Hist. Soc.* 68 : 296-297. 1971.

——Famine foods in the Rajasthan desert. *Econ. Bot.* 28 : 73-81. 1974.

——Famine—food of the Rajasthan desert. In Roonwal, M. L. (Ed.), *The Natural Resources of Rajasthan* 1 : 289-302. Jodhpur. 1977.

——Flora of the Indian Desert. Jodhpur. 1978.

——AND S. C. SHARMA. Biogeography of the Indian desert. *Trans. Indian Soc. Desert Tech. & Univ.. Cent. Desert Stud.* 2 : 80-90. 1977.

——AND V. S. SHARMA. A new *Tribulus* (Zygophyllaceae) from India. *Bot. Not.* 129 : 367-369. 1977.

——AND D. SINGH. *Dactyliandra* (Hook. f.) Hook. f. : A Cucurbitaceous genus new to the Indian flora. *Kew Bull.* 19 : 133-138. 1964.

——AND B. VERDCOURT. Notes on Indian desert plants V. On the identity and nomenclature of two supposed new species of *Rhynchosia* described by Blatter and Hallberg. *Bull. bot. Surv. India* 12 : 108-112. 1970.

BHARADWAJ, O. P. The arid zone of India. In a History of Land Use in Arid Regions (Ed. L. Dudley Stamp). *Arid Zone Res.* XVII, 143-13. UNESCO, Paris. 1961.

BHARUCHA, F. R. Ecological problems of the Rajasthan desert. *8th Silv. Conf.*, Dehra Dun. 1951.

——The structure and physiological feature of the Rajasthan desert. *Arid Zone Res.* Ser. V, 34-35. 1955 a.

——Afghanistan, India and Pakistan. *Ibid.* VI, 19-39. 1955 b.

——Ecological studies of the Rajasthan desert soils. *Proc. nat. Inst. Sci. India* 26 B : 233-256. 1960.

——Plant associations of W. Rajasthan. In Gupta, R. K. and I. Prakash (Ed.). *Environmental Analysis of the Thar Desert* 274-297. Dehra Dun. 1975.

——AND V. M. MEHER-HOMJI. On the floral elements of the semi-arid zones of India and their ecological significance. *New Phytol.* 64 : 330-342. 1965.

BHIMAYA, C. P. Production potentials of rangelands of the arid zone of India. *Biological Productivity of Lands, Lakes and Seas.* Govt. of India, Ministry of Education, New Delhi. 1967.

——AND L. D. AHUJA. Development of Sewan grassland in arid parts of western Rajasthan. *Indian Fmg.* 17 : 26-28. 1967.

——AND —— Preliminary studies of vegetation in rangelands of western Rajasthan through stock maps (Vegetational maps). *Proc. Symp. Recent. Adv. Trop. Ecol.* Pt. II, 383-389. Varanasi. 1968.

——AND —— Criteria for determining condition class of rangelands in western Rajasthan. *Ann. Arid Zone* 8 : 73-79. 1969.

——, —— AND N. S. VANGANI. Evaluation of rangelands by stockmaps. *Agric. Res.* 5 : 233. 1965.

——, A. K. CHAKRAVARTY, R. B. DAS AND G. N. BHATI. Grazing studies in the arid and semi-arid zones of Rajasthan. III. Growth of different kinds of livestock in natural pasture at Pali. Impact

of grazing on vegetative cover and determination of animal equivalent. *Indian J. Anim. Sci.* 39 : 416-428. 1969.

BHIMAYA, C. P. A CHERIAN AND Y. SATYANARAYAN. Preliminary studies on the vegetation of Kailana, Rajasthan. *Indian Forester* 90 : 667-675. 1964.

——AND R. N. KAUL. Some afforestation problems and research needs in relation to erosion control in arid and semi-arid parts of Rajasthan. *Proc. All-India Dry Zone Afforestation Study Tour and Symp.* 336-352. 1962.

——, ——, B. N. GANGULI, I. S. TYAGI, M. D. CHOUDHURY AND R. SUBBAYYAN. Species suitable for afforestation of different arid habitats of Rajasthan. *Ann. Arid Zone* 2 : 162-168. 1964.

BISWAS, K. Desert vegetation. *Bull. nat. Inst. Sci. India* 1 : 247. 1952.

——AND S. R. ROLLA. Rajputana desert vegetation. *Proc. nat. Inst. Sci. India* 19 B : 411-421. 1953.

BLATTER, E. AND F. HALLBERG. The flora of the Indian desert (Jodhpur and Jaisalmer). *J. Bombay nat. Hist. Soc.* 26 : 218-246, 525-551, 811-818, 968-987; 27 : 40-47, 270-279, 506-519. 1918-1921.

BOR, N. L. The Grasses of Burma, Ceylon, India and Pakistan (Excluding Bambuseae) (Reprinted ed.). Koenigstein—Ts. W. Germany. 1973.

BORA, G. K. Afforestation in the Rajasthan desert. *Winter School on the Development of Rajasthan Desert* 23-24. (Abstr.). Jodhpur, 1973.

BRANDIS, D. The Forest Flora of Northwest and Central India. London. 1874.

CALDER, C. C. An outline of the vegetation of India. In *An Outline of the Field Sciences of India* 71-91. Indian Science Congress Association, Calcutta. 1937.

CHAKRAVARTY, A. K. Selection of grasses & legumes for arid zone pasture. *Proc. Symp. Prob. Arid Zone, Jodhpur.* 211-215. 1964.

——Grasslands of the Indian Arid Zone. *Symp. Arid Zone,* Jodhpur. Mimeo. pp. 14. 1968.

CHAMPION, H. G. A preliminary survey of forest types of India and Burma. *Indian Forester Rec. (n. s.) Silva* 1-286. 1936.

——AND S. K. SETH. A Revised Survey of Forest Types of India. Delhi. 1968.

CHAPLINE, W. R. The Rajputana Desert. *Curr. Sci.* 22 : 161-164. 1953.

CHATTERJEE, D. Studies on the endemic flora of India and Burma. *J. Roy. Asiat. Soc. Bengal (Science)* 5 : 19-67. 1939.

CHERIAN, A. AND P. V. BOLE. Ecological changes in a protected grassland in arid zones. *Proc. School on Plant Ecol.* 89-98. New Delhi 1971.

CHOPRA, I. C. AND K. L. HANDA. Medicinal plants of the arid zones. I. *Arid Zone Res.* Ser. XIII. 11-53. 1960.

CLARKE, C. B. The subareas of British India, illustrated by the detailed distribution of the Cyperaceae in that empire. *J. Linn. Soc. Lond. (Bot.)* 34 : 1-146. 1898.

DABADGHAO, P. M. Ecology of grasslands in arid and semi-arid tracts of India and the principle of their management. *UNESCO Symp. on Soil Erosion and its Control in Arid and Semi-arid zones.* 133-139. Karachi. 1957 a.

——Grassland Survey of India. New Delhi. 1957 b.

——Grasslands and grassland problems in west Rajasthan. *Proc. II Seminar Soil Cons.* 139-149. 1958 a.

——Ecology of grasslands in the arid and semi-arid tracts of India and the principles of their management. Jodhpur. 1958 b.

——Types of grass cover in India and their management. *Proc. 8th Internat. Grassl. Cong.* Edinburgh. 226-230. 1960.

——AND K. A. SHANKARNARAYAN. The Grass Cover of India. New Delhi. 1973.

DAS, R. B. AND C. P. BHIMAYA. Ecology of grasslands of western Rajasthan. *Proc. Symp. Prob. Indian Arid Zone. Jodhpur.* 222-226. 1964.

——, ——, G. N. BHATI AND Y. RAMACHANDRAN. Grazing studies on a rocky rangeland. *J. Soil and Water Cons. India* 13 : 33-47. 1965.

——, P. M. DABADGHAO, S. P. MARWAHA AND R. DEB ROY. Grazing capacity studies in grasslands of western Rajasthan. *Ann. Arid Zone* 2 : 14-25. 1963.

—— AND S. SARUP. The biological spectrum of the Indian desert flora. *Univ. Rajputana Stud. (Biol. Sci.)* 36-42. 1951.

DHILLON, K. B. S. AND P. S. BAJWA. A contribution to the botany of Ganganagar district, North Rajasthan. *Bull. bot. Surv. India* 11 : 234-244. 1969.

DHILLON, K. B. S. AND M. M. BHANDARI. Some plant records for Rajasthan. *J. Bombay nat. Hist. Soc.* 70 : 577-582. 1973 (1974).

DRUDE, O. Handbuch der Pflanzengeographie. Sttutgarat. 1890.

—— Die Oekologie der pflanzen. *Die Wissenschaft* 50. Brunswick. 1913.

GAUR, Y. D. AND Y. SATYANARAYAN. Phytosociological studies of the monsoon vegetation of rocky habitat. *Indian Forester* 93 : 806-814. 1967.

GAUSSEN, H., V. M. MEHER-HOMJI, P. LEGRIS, F. BLASCO, A. DELACOURT, R. K. GUPTA AND F. P. TROY. International map of the vegetation and of environmental conditions. Sheet Rajasthan with notice. I. C. A. R., New Delhi. *Inst. Fr. Podichery Trav. Sect. Sci. Tech. Hors Serie* No. 12. 1972.

GUPTA, R. K. Soil conservation in the arid regions of north-west India — An ecological perspective. *J. Agric. Trop. Bot. Appl.* 13 : 544-564. 1966 a.

——Bibliography on the ecology (Synecology and phytosociology) of arid and semi-arid regions of India. *Experta Bot.* 7 : 178-190. 1966 b.

——Anthropogenic influence on the vegetation of western Rajasthan. *Vegetatio* 16 : 79-94. 1968.

——Resource survey of gummiferous Acacias in western Rajasthan. *Trop. Ecol.* 11 : 148-161. 1970.

——Ecology of pastoral areas in the arid zone of Rajasthan. *Ann. Arid Zone* 10 : 136-157. 1971.

——Range ecology and development. In Gupta R. K. and I. Prakash (Ed.), *Environmental Analysis of the Thar Desert* 322-360. Dehra Dun. 1975 a.

——Plant life in the Thar. *Ibid.* 202-236. 1975 b.

——AND C. T. ABICHANDANI. Air-photo analysis of plant communities in relation to edaphic factors in the arid zone of western Rajasthan. *Proc. Symp. Recent Adv. Trop. Ecol.* Pt. I, 57-66. Varanasi. 1968.

——AND M. M. BHANDARI. Book review (Flora of Rajasthan by G. S. Puri *et al.*). *Ann. Arid Zone* 4 : 235-237. 1965.

——AND B. K. DUTTA. Vernacular names of the useful plants of north-west Indian arid regions. *J. Agric. Trop. Bot. Appl.* 14 : 402-452. 1967.

——, Y. D. GAUR, S. P. MALHOTRA AND B. K. DUTTA. Medicinal plants of the Indian arid zone. *Ibid.* 13 : 247-288. 1966.

—— AND K. C. KANODIA. Plants used during scarcity and famine periods in the dry regions of India. *Ibid.* 15 : 265-285. 1968.

—— AND I. PRAKASH (Ed.). Environmental Analysis of the Thar Desert. Dehra Dun. 1975.

—— AND S. K. SAXENA. Plant communities of sand dunes. *Agric. Res. Journ.* 5 : 231-232. 1965.

—— AND —— Habitat, grassland types and forage potential of Jalore district in western Rajasthan. *Ann. Arid Zone* 5 : 189-203. 1966.

—— AND —— Resource survey of *Salvadora oleoides* Decne. and *S. persica* Linn. for non-edible oil in western Rajasthan. *Trop. Ecol.* 9 : 140-152. 1968 a.

—— AND —— Ecological studies on the prospects of developing some agro-industries in western Rajasthan. *Symp. nat. Resources of Rajasthan,* Abst. a—13. Jodhpur. 1968 b.

—— AND —— Ecological studies on the prospects of developing some agro-industries in Western Rajasthan. *The Natural Resources of Rajasthan.* 1 : 199-211. 1977.

—— AND —— Grassland types and their ecological succession in western Rajasthan. *Workshop on Forage Utilization.* I. G. F R. I. Jhansi. 1969.

—— AND —— Some ecological aspects of improvement and management of Sewan (*Lasiurus sindicus*) rangelands. *Ann. Arid Zone* 9 : 193-208. 1970.

—— AND —— Integrated ecological surveys for agricultural development in the arid zones of India. 1. Chohtan Community Development Block in Barmer district of Rajasthan. *Ibid.* 10 : 85-98. 1971 a.

—— AND —— Ecology of Jalore district in western Rajasthan. *J. Indian bot. Soc.* 50 : 237-246. 1971 b.

—— AND —— Ecological studies on the protected and overgrazed rangelands in the arid zone of W Rajasthan. *Ibid.* 50 : 289-300. 1971 c.

—— AND —— Distribution and growth of *Sehima nervosum* (Rottl.) Stapf in western Rajasthan. *Indian J. Agric. Res.* 6 : 151-158. 1972 a.

——AND —— Potential grassland types and their ecological succession in Rajasthan desert. *Ann. Arid Zone* 11 : 198-218. 1972 b.

—— AND S. K. SHARMA. Grasses of the rangelands in arid Rajasthan. *J. Agric. Trop. Bot. Appl.* 18 : 50-99. 1971.

—— AND —— Phytosociological changes in an enclosed area of old alluvial flats of Jodhpur in the Indian arid zone during a period of five years.. *J. Indian bot. Soc.* 52 : 99-108. 1973.

HINGORANI, G. R. AND R. C. GAUR. Short note on occurrence of *Heliotropium curassavicum* L. in Rajasthan. *Indian Forester* 91 : 293. 1965.

HOOKER, J. D. A sketch of the Flora of British India. *Reprinted from the third edition of the Imperial Gazetteer.* Oxford. 1906.

——. AND T. THOMSON. Flora Indica : Being a systematic account of the plants of British India, together with observations on the structure and affinities of their natural orders and genera. London. 1855.

HORA, S. L. The Rajputana desert. Its value in India's national economy. *Bull. nat. Inst. Sci. India* 1 : 1-11. 1952.

JAIN, S. K. Invasion of plants in arid regions of India. *Proc. nat. Acad. Sci. India* 33 B : 58-60. 1963.

—— Floral composition of Rajasthan—A review. *Bull. bot. Surv. India* 12 : 176-187. 1970.

—— Floral composition of Rajasthan : A review. *The Natural Resources of Rajasthan.* 1 : 47-64. 1977.

—— AND N. K. KOTWAL. A note on some little known plants from Rajasthan. *Sci. & Cult.* 26 : 191-192. 1960.

JOSHI, M. C. A preliminary survey of the sand dune vegetation of Pilani and its neighbourhood. *Symp. Vanamahotsava,* Abstr. 7-8. Agra. 1956 a.

—— Grasslands and range resources studies of Shekhawati area, Rajasthan. *The Natural Resources of Rajasthan.* 1 : 93-104. 1977.

—— Plant ecology of Bikaner and its adjacent areas in comparison with rest of western Rajasthan. *J. Indian bot. Soc.* 35 : 495-511. 1956 b.

—— A preliminary survey of the sand-dune vegetation of Pilani and its neighbourhood. *Ibid.* 37 : 309-327. 1958.

—— The Rajasthan desert, its vegetation and its problems. *Souvenir All India Agric. Econ. Conf. 21st session* 26-39 Pilani. 1961.

—— Afforestation and its requirements in the Shekhawati area of Rajasthan. *Winter School on the Development of Rajasthan Desert* 20 (Abstr.). Jodhpur. 1973.

——AND M. B. L. BANSAL. Physiographic, ecologic and floristic studies of certain areas in Jhunjhunu district, Rajasthan. *Proc. Symp. Recent Adv. Trop. Ecol.* Pt. II 438-450. Varanasi. 1968.

——AND R. K. GUPTA. Ecology of arid and semi-arid zones in India. *Progress of Plant Ecology in India* 1 : 111-153. New Delhi. 1973.

——AND C. B. S. R. SARMA. Study of grasses and sedges of certain areas in Jhunjhunu district, Rajasthan. *Proc. Symp. Prob. Indian Arid Zone* 217-221. Jodhpur. 1964.

——AND —— Grasses of certain areas in Jhunjhunu district. Rajasthan. *Indian Forester* 92 : 570-575. 1966.

KANODIA, K. C. AND P. C. NANDA. The genus *Aristida* in western Rajasthan. *Ibid.* 94 : 296-302. 1968.

——AND R. K. GUPTA. Sand dune flora of western Rajasthan. *J. Bombay nat. Hist. Soc.* 65 : 681-695. 1968 (1969).

KAPOOR, A. S. AND B. S. RAJVANSHI. The Rajasthan canal project. In Jaiswal, P.L. *et al.* (Ed.), *Desertification and its control.* 121-129. I.C.A.R. New Delhi. 1977.

KAUL, O. N. Grassland improvement in dry and arid tracts of Rajasthan. *Symp. nat. Resources of Rajasthan* Abstr. a-5. Jodhpur. 1968.

—— Grassland improvement in dry and arid tracts of Rajasthan. *The Natural Resources of Rajasthan* 1 : 79-91. 1977.

KAUL, R. N. An approach to provenance trial in relation to tree introduction in arid lands. *Ann. Arid Zone* 4 : 164-171. 1965.

——AND A. K. CHAKRAVARTY. Range development in western Rajasthan. *Ibid.* 7 : 258-264. 1968 a.

—— AND ——Range development in Western Rajasthan. *The Natural Resources of Rajasthan* 1 : 135-136 (Abstr.). 1977.

——AND —— Idem. *Symp. nat. Resources of Rajasthan* Abstr. a-7. Jodhpur. 1968 b.

——AND B. N. GANGULI. Afforestation studies in the arid zone of India. *Proc. Symp. Prob. Indian Arid Zone* 183-186. Jodhpur. 1964.

KING, G. Notes on the famine foods of Marwar. *Proc. Asiat. Soc. Bengal* 38 : 116-122. 1869.

——Sketch of the Flora of Rajputana. *Indian Forester* 4 : 226-236. 1879.

KRISHNAN, A. Delineation of different climatic zones in Rajasthan and their variability. *Indian J. Geogr.* 3 : 33-40. 1968 a.

——Distribution of arid areas in India. *Symp. Arid Zone,* Mimeo. pp. 15. Jodhpur. 1968 b.

KRISHNAN, M. S. Geological history of Rajasthan and its relation to present dry condition. *Bull. nat. Inst. Sci. India* 1 : 19-31. 1952.

KRISHNASWAMY, V. S. AND R. S. GUPTA. Rajputana desert, its vegetation and its soils. *Indian Forester* 78 : 595-601. 1952.

LEGRIS, P. AND V. M. MEHER-HOMJI. Bioclimatology and vegetation of the Rajasthan desert. *Workshop Prob. Deserts in India* 27-28 (Abstr.). Jaipur. 1975.

MACADAM, MISS. Introductory Note to Jodhpur and Jaisalmer Trees and Plants. 1890.

MAHESHWARI, J. K. The Flora of Delhi. New Delhi. 1963.

—— Studies on the alien flora of Rajasthan. *The Natural Resources of Rajasthan* 1 : 35-46. 1977.

MAJUMDAR, R. B. Notes on the flora of Rajasthan —II. Additions to the flora of N. W. Rajasthan. *Bull. bot. Soc. Beng.* 23 : 35-40. 1969.

——Notes on Rajasthan flora—III. *Ibid.* 25 : 75-76. 1971.

—— Origin, nature and economic aspects of Rajasthan flora. *Ibid.* 29 : 135-140. 1975.

——, S. K. MURTI AND J. N. SRIVASTAVA. Notes on Rajasthan flora I. *J. bot. Soc. Beng. J. Sen Mem.* Vol. 461-468. 1969.

MATHUDA, G. S. Grazing problem and control of the Rajasthan desert. *Indian Forester* 83 : 603-605. 1957.

—Impressions of a tour in Rajasthan. *Ibid.* 84 : 417-423. 1958.

MATHUR, C. M. Forest types of Rajasthan, *Ibid.* 86 : 734-739. 1960.

MEHER-HOMJI, V. M. On the "Sudano-Deccanian" floral element. *J. Bombay nat. Hist. Soc.* 62 : 15-18. 1965 a.

——A contribution to the study of plant succession and climax vegetation with special reference to the dry parts of north-west and south-east India. *Trop. Ecol.* 6 : 152-164. 1965 b.

——Some phytogeographic aspects of Rajasthan, India. *Vegetatio* 21 : 299-320. 1970.

——The arid zones of India : Bioclimatic and vegetational aspects. In Jaiswal P. L. *et al.* (Ed.), *Desertification and as control.* I. C. A. R., 160-175. New Delhi. 1977.

——AND F. R. BHARUCHA. Phytogeography of the Thar region. In Gupta R. K. and I. Prakash (Ed.), *Environmental Analysis of the Thar Desert* 237-273. Dehra Dun. 1975.

MULAY, B. N. Patterns of plant distribution in Rajasthan. *Mem. Indian bot. Soc.* 3 : 9-12. 1960.

——AND M. C. JOSHI. A study of the problems of Rajasthan desert. *Proc. Symp. Prob. Indian Arid Zone* 43-47. Jodhpur. 1964.

——AND B. V. RATNAM. Study of vegetation found rourd about Pilani and its neighbourhood. *Proc. Indian Sci. Cong.* Pt. III, 64-65. 1950.

MUTHANA, K. D. AND GYAN CHAND. Studies on arid zone afforestation. *Winter School on the Development of Rajasthan Desert* 24-25 (Abstr.) Jodhpur. 1973.

NAIR, N. C. A study of the vegetation and the choice of species in the afforestation of Rajasthan. *Proc. nat. Acad. Sci. India* 24 B : 164-176. 1954.

——Flora of Chirawa. *Proc. Rajasthan Acad. Sci.* 6 : 49-64. 1956.

——Vegetation of Jhunjhunu, Mandrela and the neighbouring places. *J. Bombay nat. Hist. Soc.* 58 : 433-440. 1961.

——AND M. B. DESHPANDE. A note on the occurrence of *Acanthospermum hispidum* DC. in Rajasthan. *J. Bombay nat. Hist. Soc.* 57 : 441-442. 1960.

——AND T. T. KOSHY. A taxonomic study of the genus *Indigofera* Linnaeus in Rajasthan. *Ibid.* 60 : 326-336. 1963.

——AND G. S. NATHAWAT. Vegetation of Pilani and its neighbourhood. *Ibid.* 54 : 91-106. 1956.

——AND M. C. JOSHI. Sand-dune vegetation of Pilani and its neighbourhood. *J. Indian bot. Soc.* 36 : 599. 1957.

NANDA, P. C. Ecological basis of classification for improvement of grassland in Indian arid zone. *Symp. Planning for Draught Areas* 19 (Abstr.). *Nat. Inst. Sci. India* 1969.

——AND K. M. GUPTA. Grasses and grasslands, their distribution in Rajasthan. *Symp. nat. Resources of Rajasthan,* Abstr. a-9. Jodhpur. 1968.

—— AND —— Grasses and grasslands : Their distribution and utilization in Rajasthan. *The Natural Resources of Rajasthan* 1 : 137-150. 1977.

NATHAWAT, G. S. Some aspects of the vegetation of Rajasthan. *Proc. School on Plant Ecol.* (Ed. R. Misra and R. R. Das), 54-65. New Delhi. 1971.

PANDEYA, S. C. Range resource of Rajasthan : a resume. *Symp. nat. Resources of Rajasthan,* Abstr. a-6. Jodhpur. 1968.

PANDEYA S. C. Range resources of Rajasthan : A review. *The Natural Resources of Rajasthan* 1 ; 105-134. 1977.

PRAKASH, I. AND R. K. GUPTA. An ecological exploration of an extremely arid tract of Rajasthan. *Indian J. Ecol.* 3 : 11-21. 1976.

PRAKASH, M. Trees and grasslands in Rajputana desert. *Indian Forester* 84 : 384. 1958.

——AND L. D. AHUJA. Studies on different range condition class grasslands in western Rajasthan. *Ann. Arid Zone* 3 : 91-98. 1964.

——AND P. C. NANDA. Ecological distribution of natural fodder grasses in western Rajasthan. *Indian Forester* 87 : 10-19. 1961.

PURI, G. S. The present position of the plant ecology of the deserts of Rajasthan and Saurashtra. *Bull. nat. Inst. Sci. India* 1 : 233-240. 1952.

——AND S. K. JAIN. Trees and grasslands in Rajasthan. *Indian Forester* 86 : 85-86. 1960.

——AND —— Botanical exploration in western India. *Trop. Ecol.* 3 : 49-69. 1962 a.

——AND —— Botanical aspects of dry zone afforestation in India. *Proc. All-India Dry Zone Afforestation Study Tour and Symp.* 268-273. 1962 b.

——, ——, S. K. MUKERJEE, S. SARUP AND N. N. KOTWAL. Flora of Rajasthan. *Rec. bot. Surv. India* 19 : 1-159. 1964.

RAHEJA, P. C. Influence of climatic changes on the vegetation of arid zone in India. *Ann. Arid Zone* 4 : 64-73. 1965.

RAIZADA, M. B. AND S. K. JAIN. First record of the genus *Dignathia* from India. *Indian Forester* 87 : 426-428. 1961.

RAMACHANDRAN, K. R. Common grasses found round about Pilani. *Proc. Indian Sci. Cong.* Pt. II, 65-66. 1950.

RAMACHANDRA RAO, Y. A list of some of the more common plants of the desert areas of Sind, Baluchistan, Rajputana, Kathiawar and South-West Punjab with their local names as far as possible. *I. C. A. R. Misc. Bull.* No. 43 : 1-45. Delhi. 1941.

RAMDEO, K. D. Plant life in relation to soil in Jodhpur and its neighbourhood *Univ. Rajasthan. Stud. (Biol. Sci.)* 31-38. 1955.

RAO, H. S. AND M. P. SHIVA. The role of non-timber forest products in Rajasthan's economy. *The Natural Resources of Rajasthan* 1 : 165-180. 1977.

RATNAM, B. V. AND M. C. JOSHI. An ecological study of the vegetation near about a temporary pond in Pilani. *Proc. Rajasthan Acad. Sci.* 3 : 45-59. 1952.

——AND K. D. RAMDEO. An ecological note on sewage farm vegetation at Jodhpur. *Univ. Rajasthan Stud. (Biol. Sci.)* 3 : 47-54. 1958.

ROLLA, S. R. AND K. C. KANODIA. Studies on ecology and vegetation of interior parts of Barmer and Jaisalmer districts in Rajasthan. *Proc. Indian Sci. Cong.* Pt. III, 321-322. 1962.

——AND —— Studies on the vegetation and flora of Jodhpur division, Rajasthan State. *Ann. Arid Zone* 1 : 16-46 ; 2 : 35-60. 1962-63. (See also 2 : 189. 1964).

SAIN, K. Role of Rajasthan canal in the development, utilisation and stabilisation of Rajasthan desert. *Trans. Indian Soc. Desert Tech. and Univ. Cent. Desert Stud.* 1 : 151-157. 1976.

SANKHALA, K. S. Enumeration of the flowering plants of north-western Rajasthan. *Univ. Rajputana Stud. (Biol. Sci.)* 1 : 43-56. 1951.

SARUP, S. A list of some common plants of Jodhpur and its neighbourhood. *Ibid.* 1 : 29-35, 1951.

——Plant ecology of Jodhpur and its neighbourhood. A contribution to the ecology of north-western Rajasthan. *Bull. nat. Inst. Sci. India* 1 : 223-232. 1952.

——Plant ecology of the north-west Rajasthan. *Proc. Internat. Symp. Desert Res. Jerusalem.* Special Publ. Res. Council, Israel 2 : 335-345 1953.

——A List of Some Common Plants of Jodhpur and its Neighbourhood. 1-25. Jaipur. 1954.

——On some problems in the immobilisation of the Indian desert. *Jaswant Coll. Mag.* 26 : 1-19. 1955.

——A brief note on vegetation of Rajasthan. *Dungar Coll. Mag.* 18 : 1-8. 1957 a.

——A List of Common Plants of Bikaner and its Neighbourhood. 1-12. Jaipur. 1957 b.

——Studies in the hydrophytes of Jodhpur. *J. Indian bot. Soc.* 36 : 597. 1957 c.

——The halophytes of the Indian desert. *Ibid.* 36 : 598. 1957 d.

——A List of Some Common Plants of Jaisalmer and its Neighbourhood. 1-16. Jaipur. 1958 a.

——Progress of desert ecology in India during 1950-56. *Univ. Rajasthan Stud. (Biol. Sci.)* 3 : 55-60, 1958 b.

SARUP, S. Hydrophytes of Jodhpur *Ibid.* 3 : 61-70 1958 c.

——Halophytes of Indian desert. *Ibid.* 3 : 71-76. 1958 d.

——The halophytes of the Indian desert. *Dungar Coll. Mag.* 23 : 1. 1958 e.

——AND M. M. BHANDARI. Plant ecology of the Indian desert in retrospect and prospect. *J. Indian bot. Soc.* 36 : 598-599. 1957.

——AND —— Idem. *Univ. Rajasthan Stud.* (*Biol. Sci.*) 3 : 98-124. 1958.

——AND K. DUTT. Soil in relation to vegetation of Jodhpur. *Proc. Indian Sci. Cong.* Pt. III, 162. 1954.

——AND G. S. PURI. Studies on vegetation of Arid Zone of India II. The distribution of some desert plants in various habitats in Rajasthan state. *Univ. Rajasthan Stud.* (*Biol. Sci.*) 4 : 87-88. 1960 a.

——AND —— The vegetation types of the Indian desert. *Ibid.* 4 : 57-85. 1960 b.

——AND L. N. VYAS. Ecological studies on vegetation of Jodhpur Tahsil. *J. Indian bot. Soc.* 36 : 589-590. 1957.

——AND —— Idem. *Univ. Rajasthan Stud.* (*Biol. Sci.*) 3 : 77-97. 1958.

SATYANARAYAN, Y. Treelands or grasslands in the Rajputana desert? A plea for grasslands. *Indian Forester* 84 : 549-553. 1958. a.

——Indigenous species in the stabilisation of sand dunes of Rajasthan desert. *J. Soil and Water Cons. India* 7 : 47-51. 1958 b.

——Ecology of the central Luni basin, Rajasthan. *Ann. Arid Zone* 2 : 82-97. 1963.

——Habitats and plant communities of the Indian desert. *Proc. Symp. Prob. Indian Arid Zone* 59-67. Jodhpur. 1964.

——AND Y. D. GAUR. Phytosociological variations in floristic composition of vegetation in the arid zone. I. Monsoonal vegetation of the alluvial plains. *Ann. Arid Zone* 6 : 178-199. 1967.

——AND —— Phytosociological changes of monsoon vegetation in semi-rocky habitats. *J. Indian bot. Soc.* 47 : 371-381. 1968.

——AND S. K. SAXENA. An account of weeds of Central Research Farm, Jodhpur, Rajasthan. *J. Bombay nat. Hist. Soc.* 63 : 344-353. 1966.

——, —— AND Y. D. GAUR. Studies on dune ecology. 1. Vegetation of stabilised dunes. *Trop. Ecol.* 7 ; 163-170. 1966.

——AND K. A. SHANKARNARAYAN. A new species of *Lasiurus* from western Rajasthan. *J. Bombay nat. Hist. Soc.* 60 : 763-766. 1963 (1964).

SAXENA, S. K. The concept of eco-system as exemplified by the vegetation of western Rajasthan. *Vegetatio* 24 : 215-227. 1972.

——Vegetation and its succession in the Indian desert. In Jaiswal, P. L. *et al.* (Ed.), *Desertification and its control* 176-192. I. C. A. R., New Delhi. 1977.

——AND R. K. GUPTA. Vegetation of Pachpadra salt basin in western Rajasthan. *J. Bombay nat. Hist. Soc.* 70 : 104-127. 1973.

SAXTON, W. T. Additional notes on plants of northern Gujarat. *Rec. bot. Surv. India* 9 : 251-262. 1922.

SEN, D. N. Ecology of Indian desert. *Proc. Indian Sci. Cong.* Pt. III, 418. 1965.

——Ecology of Indian desert. I. On the phytosociology of the vegetation of Jodhpur. *Trop. Ecol.* 7 : 136-152. 1966.

SEN, N. N. Dry zone afforestation in Rajasthan. *Proc. All-India Dry Zone Afforestation Study Tour and Symp.* 323-335. 1962.

SETH, S. K. AND O. N. KAUL. Technique of dry zone afforestation with special reference to limiting factors of climate and soil. *Winter School on the Development of Rajasthan Desert* 21-22. (Abstr.). Jodhpur. 1973.

SHAH, S. A. Treelands and grasslands in Rajputana desert. *Indian Forester* 83 : 488-491. 1957.

SHANDAGH, G. Y. A new method for the classification of the climates of arid and semi-arid regions. *Proc. nat. Inst. Sci. India* 24 : 150-158. 1958.

SHANKARNARAYAN, K. A., A. CHERIAN AND Y. D. GAUR. Ecology of dune vegetation at Osian (Rajasthan). *J. Indian bot. Soc.* 44 : 37-50. 1965.

——AND Y. SATYANARAYAN. Grazing resources of Rajasthan. I. Grassland types of the alluvial plains. *Indian Forester* 90 : 436-441. 1964.

SHARMA, B. M. Ecological studies of weeds and their role in immobilisation of the desert. *Proc. Indian Sci. Cong.* Pt. III, 301. 1959.

——Ecological studies of weeds of Jaswant College compound, Jodhpur. *Proc. nat. Acad. Sci. India* 31 B ; 427-437. 1961.

SHARMA. B. M. Studies on vegetation of arid zone of India. VIII. Composition of some scrub communities of Churu, Rajasthan. Ibid. 32 B : 157-168. 1962.

——Composition and structure of plant communities of Churu, Rajasthan. *Trop. Ecol.* 6 : 106-123. 1965.

——Carbon/nitrogen status of soil under some plant communities of Churu, Rajasthan. *Indian Forester* 93 : 552-557. 1967.

——Ecological studies of desert soils of Churu, Rajasthan (India) : pH status. *J. Soil and Water Cons. India* 16 : 1-5. 1968.

——Phytosociological studies on the vegetation of sand dunes of Sikar, Rajasthan. *Indian Forester* 98 : 220-233. 1972.

SHARMA, S. Some facts about the phytogeography of Rajasthan. *Univ. Rajasthan Stud. Bot.* 1-8. 1965.

SHUKLA, M. L. Afforestation of Rajasthan desert. *Winter School on the Development of Rajasthan Desert* 25-27. (Abstr.). Jodhpur. 1973.

SINGH, S., S. K. SAXENA AND A. S. KOLARKAR. Integrated natural resources survey of Luni development block, western Rajasthan (India). *Indian J. Geogr.* 11-12 : 1-10. 1976-77.

SINGH, V. AND B. V. SHETTY. A survey of natural plant resources of Rajasthan desert. *First Indian Conf. Desert Tech.* Pt. II and III, 34-35 (Abstr.). Indian Soc. Desert Tech., Jodhpur. 1976.

——AND —— Idem. *Trans. Indian Soc. Desert Tech. and Univ. Cent. Desert Stud.* 2 : 296-305. 1977.

SRIVASTAVA, T. N. Forest resources of Rajasthan *The Natural Resources of Rajasthan* 1 : 151-164. 1977.

TANDON, S. K. The vegetation of Ladnun (Jodhpur) 17-26. Jaipur. 1958.

VERMA, D. M. A study of vegetation and soil properties in an enclosed area at Kailana (Jodhpur). *Trop. Ecol.* 5 : 52-59. 1964.

——, B. M. WADHWA AND O. P. MISRA. Some additions to the flora of Rajasthan. *Proc. nat. Acad. Sci. India* 35 : 163-170. 1965.

VERMA, S. K. Forestry and afforestation practices. In Gupta, R. K. and I. Prakash (Ed.), *Environmental Analysis of the Thar Desert* 298-321. Dehra Dun. 1975.

VYAS, L. N. Plant ecology of Jodhpur Tahsil. *Univ Rajasthan Stud. (Biol. Sci.)* 2 : 39-46. 1955.

——Vegetation of Rajasthan. *Proc. School Plant. Ecol.* (Ed. R. Misra & R. R. Das), 43-53. New Delhi. 1971.

WAHEED KHAN, M. A. Climate of the dry zones. *Indian Forester* 85 : 139-181. 1959.