SYSTEMATICS AND ECOLOGY OF BERBERIDACEAE IN UTTARAKHAND STATE

THESIS

SUBMITTED TO THE

FOREST RESEARCH INSTITUTE UNIVERSITY

DEHRA DUN, UTTARAKHAND

for

THE AWARD OF THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN FORESTRY

(FOREST BOTANY)

By

Umeshkumar L. Tiwari

Wildlife Institute of India,

Chandrabani, Dehradun,

Uttarakhand, India

2011

DEDICATED TO

MY

GRANDFATHER

AND PARENTS

DECLARATION

I hereby declare that the thesis entitled **"Systematics and Ecology of Berberidaceae in Uttarakhand state"** submitted to Forest Research Institute (University), Dehra Dun, for the award of the degree of Doctor of philosophy in Forest botany, in record of original research work done by me under the supervision of Dr. G. S. Rawat and Co-supervision of Dr. B. S. Adhikari, Wildlife Institute of India, Dehra Dun, and it has not formed the basis for the award of any other degree or diploma. I also declare that the thesis embodies my own work, observations and analysis and this work contributes towards advancement of knowledge in subject.

Umesh Tiwari

(Umeshkumar L. Tiwari)

Date: 27.12.2011

Place: W.I.I., Dehra Dun

Candidate

Countersigned:

G S Rawat

(Dr. G. S. Rawat)

Supervisor

B S Adhikari

(Dr. B. S. Adhikari)

Co-Supervisor

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

Dr. G. S. Rawat, *F.N.A.Sc.*,
Professor, Department of Habitat Ecology,

CERTIFICATE

This is to certify that the thesis entitled **"Systematics and Ecology of Berberidaceae in Uttarakhand State."** Submitted to Forest Research Institute (University), Dehra Dun, for the award of the degree of Doctor of Philosophy in Forest Botany, is a record of bonafide research work carried out by Shri Umeshkumar L. Tiwari under my guidance and supervision. No part of this thesis has been submitted for any other degree and it fulfils all the requirements laid down in the ordinance of Forest Research Institute (University) Dehra Dun for this purpose.

Place: W.I.I., Dehra Dun
Dated: 10·XII·11

(Dr. G. S. Rawat)
Supervisor

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Dr. B. S. Adhikari, Scientist 'E',

Department of Habitat Ecology

CERTIFICATE

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Place: W.I.I., Dehra Dun

Dated: 22.12.2011

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To,

✓ Sh. Umesh Kumar Lalchand Tiwari
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Sub: -Registration for Doctor of Philosophy Degree in Forestry.

Dear Sir/Madam,

In response to your application dated 29.02.08 for enrolment as Research Scholar for the Degree of Doctor of Philosophy in Forestry in this Institute, it is to inform you that the following decisions have been taken:-

1. You have been registered for Doctor of Philosophy w.e.f. **01.03.2008 to 28.02.2013** as an **Internal Research Scholar.**

2. Your registration number is: **- 0803/WII/E-2129/R-1052/7A-245.**
(For all further correspondence please quote your registration number.)

3. The Topic for research approved by the F.R.I University **"Systematics and Ecology of Berberidaceae in Uttarakhand State.".**

4. Name of Discipline: **Forest Botany**
(As per clause 3.3 of the Ph.D. Ordinance)

5. (i) Name of Supervisor: - **Dr. G.S. Rawat**

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Registrar
F.R.I. University

Encl: 1. **Fee receipt No.6147 dated 14.07.2008 for Rs.16,000/-**
2. **Format of progress report**

Copy to:

1. Dr. G.S. Rawat, Professor/Supervisor, WII, 18 Chandrabani, Dehradun-248001 (Uttarakhand) for information.
2. Dr. K.Sankar, Nodal Officer, WII, 18 Chanderbani, Dehradun-248001 for information.

(T.C. Nautiyal)
Registrar
F.R.I. University

FOREST RESEARCH INSTITUTE

UNIVERSITY

DEHRA DUN

This is to certify that **Mr. Umeshkumar L. Tiwari** enrolment no. **0803/WII/E-2129/R-1052/7A-245** carried out research work under Dr. G. S. Rawat (supervisor) and Dr. B. S. Adhikari (Co-Supervisor) of Wildlife Institute of India, Centre of Forest Research Institute (University). The topic of the research registered with FRI University was **"Systematics and Ecology of Berberidaceae in Uttarakhand State."** The scholar presented his work in the pre-thesis submission seminar held on 9th December 2011 and the RAC found the work to be satisfactory and approves the work to be presented in the form of thesis for the evaluation by examiners for "Award of Ph.D. Degree" by FRI University.

Supervisor

Head of Division

Expert Member

Expert Member

Expert Member

Expert Member

Expert Member

Chairman RAC

CERTIFICATE OF ATTENDANCE

This is to certify that **Mr. Umeshkumar L. Tiwari**, a Ph.D. Candidate registered with Forest Research Institute (University) **[Reg. No. 0803/WII/E-2129/R-1052/7A-245]** whose thesis is entitled "Systematics and Ecology of Berberidaceae in Uttarakhand state" under the supervision of Dr. G. S. Rawat, and co-supervision of Dr. B. S. Adhikari, Wildlife Institute of India, has achieved over 75 % attendance during the entire course of his Ph.D. work at Wildlife Institute of India, Dehradun, as per the Ph.D. Ordinance of the Forest Research Institute (University).

Dr. K. Sankar
Nodal Officer
RAC, FRI-DU (WII Centre)
Wildlife Institute of India
Dehra Dun

Dr. G. S. Rawat
(Supervisor)
Wildlife Institute of India
Dehra Dun

Date: 13/12/11
Place: W.I.I., Dehra Dun

भारतीय वन्यजीव संस्थान
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Y. V. Jhala, Ph.D.
Scientist 'G'
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Wildlife Institute of India

CERTIFICATE

This is to certify that **Mr. Umeshkumar L. Tiwari**, a Ph.D. scholar of the Forest Research Institute (University) at WII-Center **[Reg. No. 0803/WII/E-2129/R-1052/7A-245]** has done the required course-work and training in theory and applications of statistical analysis as stipulated in the Ph.D. ordinance of the Forest Research Institute (University).

Mr. U. Tiwari has attended courses on Univariate and Multivariate statistical methods. He has shown competence with use of various software's likes SPSS, Biodiversity Pro, EstimateS and PCORD.

Y Jhala.

Date: 9th Dec 2011

(Y.V. Jhala)

Place: W.I.I., Dehradun

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Scientist 'F' & Nodal Officer
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CERTIFICATE

This is to certify that **Mr. Umeshkumar L. Tiwari**, a Ph.D. scholar of the Forest Research Institute (University) at WII-Centre **[Reg. No. 0803/WII/E-2129/R-1052/7A-245]** has pursued more than 100 hours of course-work and training in various computer applications as stipulated in the Ph.D. Ordinance of the Forest Research Institute (University).

The candidate is also hereby certified that he has adequate knowledge of the following computer applications:

Fundamentals of computers

Operating Systems (Microsoft Windows 98/XP, Window Vista)

Word processor (Microsoft WORD 2007)

Spreadsheet program (Microsoft EXCEL 2007)

Presentation graphics (Microsoft POWERPOINT 2007)

Database software (Microsoft ACCESS 2003)

Fundamentals of programming

Internet basics & terminology

(Qamar Qureshi)

Date: 19th Dec 2011
Place: W.I.I., Dehra Dun

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ACKNOWLEDGEMENTS

"Prayer has been made to mother earth that She blesses us with the knowledge required to exploit the treasures of the nature but without disturbing the environmental balance."

~Atharva Veda

I had born in Jaunpur district of the North Indian state of Uttar Pradesh and brought up in Mumbai state of Maharashtra. During my graduation, I was very much impressed by Mr. Sushil Shinde who knows many plant names, their uses and other information's. That time I was thinking to do graduation with chemistry but his efforts and interest in subject has change my mind and I took Botany for graduation and decided to do Master of Science in plant taxonomy. I believe that there is a subtle magnetism in Nature, which, if we unconsciously yield to it, will direct us aright. I never had any other desire so strong, and so like covetousness, as that.... I might be master at last of a small house and a large garden, with very moderate conveniences joined to them, and there dedicate the remainder of my life to the culture of them and the study of nature. I am very much fantasy to Himalaya and its beauty, I believe that Himalaya has its own charm and beauty, and it is sustaining half of Indian subcontinent. The present study on the 'Systematic and Ecology of Berberidaceae in Uttarakhand state' has involved great efforts and infinite hours of trekking, observations, samplings and continuous work on computers. Not all these activities could have been possible without the generous help and support from a large number of individuals.

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Special thanks to Dr. Tana Mewada, my fiancé, she had boosted me time to time and encouraged for to do some good work which can help the environments and society and also grateful to her parents for their love and encouragements.

I am ever indebted to my younger brother Mr. Ravikumar Tiwari, as he have helped me a lot throughout my life, encouraged and boosted my moral throughout my work. I am also grateful to his wife Ruchi, as she had made good atmosphere in house with her views and support to all. Thanks to my uncles and aunties Mr. Fulchand Tiwari, Vijaysankar Tiwari, Ramaji and Keshari and love which I am getting from my cousin brothers and sisters Sanjay, Nagendra, Sunil, Vinay, Anay, Vikash, Reshma, Ragni, Jyoti and Kiran.

Most sincere and hearty thanks to my parents who have always been a source of love, encouragements, help, guidance and everything. My parents also had accompanied me a few days on my fieldwork. My Great Grand Father, Who died on January 2009 at the age of 108 years, but his inspiration and hard work teaches me a lot, I am happy that his blessing is always with me.....

Umeshkumar L. Tiwari

ABBREVIATIONS

BOTANICAL TERMS

TYPIFICATION

Type: Type is a term used alone, or forming part of a compound term to indicate a particular taxonomic group, especially a genus or species, chosen as the representative example in characterizing the larger taxonomic group to which it belongs.
Syntype: A syntype is any of two or more specimens simultaneously selected by an author as types in the original paper describing a new species or subspecies when a holotype was not designated.
Holotype: Also called type specimens or just type. A holotype is the single physical specimen of an organism selected by the original author of a species to be the standard-bearer for the new name which defines the characteristics of the whole species, or the illustration used as the basis for naming the species when no type has been selected.
Lectotype: A lectotype is a biological specimen or illustration later selected (usually from among the isotype(s), syntype(s), or paratype(s)) to serve as definitive type example of a species or subspecies when the original author of the name did not designate a holotype.
Isotype: An isotype is a biological specimen duplicate of the holotype collected in the same place and at the same time (in the type locality).
Neotype: A substitute specimen selected if the holotype was destroyed or otherwise lost.

HERBARIUM ACRONYMS

K: Royal Botanic Gardens, Kew, U. K.
BM: The Natural History Museum, London, U. K.
CJB: Conservatoire et Jardin botaniques de la Ville de Genève, Switzerland. GENEVA.
WU: Botanisches Museum der K. K. Universitaet, Vienna.
DD: Forest Research Institute, Indian Council of Forestry Research and Education, Dehra Dun, Uttarakhand, INDIA.
BSD: Botanical Survey of India, Northern Circle, Dehra Dun, Uttarakhand, INDIA
CAL: Botanical Survey of India, Kolkata, Uttarakhand, INDIA
LWG: National Botanic Garden, Lucknow, Uttar Pradesh, INDIA
WII: Wildlife Institute of India, Dehra Dun, Uttarakhand, INDIA.

BOTANICAL LATIN IN CITATIONS AND PUBLICATION ABBREVIATION FOR LITERATURES

s.n.	*sine no.*	Sine numero without a number (voucher number)
sine loc.		Sine locality without locality
et		and
f.	*filius*	son
auct.	*auctorum*	of various authors

p.p.	*pro parte* in parts
e.g.	*exempli gratia* for example
nom. inval.	*nomen invalidum* name invalid
nom. illeg.	*nomen illegitimum* illegitimate name
sp.	*species* species
nom. nud.	*nomen nudum* new name
l.c.	*loco citato* at the place cited
nom. superfl.	*nomen superfluum* name superfluous when published
nom. cons.	*nomen conservandum* name conserved in ICBN
typ. cons.	*typus conservandum* type material is conserved
a.s.l.	above sea level
i.e.	that is
ex	obtained from
var.	varietiy
et al.	and others
Suppl.	Supplementary
Fl. Brit. Ind.	Flora of British India
Syst. Nat.	Regni Vegetabilis Systema Naturale, Sive Ordines, Genera et Species Plantarum Secundum Methodi Naturalis Normas Digestarum et Descriptarum
Fl. Upper Gang. Pl.	Flora of the Upper Gangetic Plain and of the adjacent Siwalik and Sub Himalayan tracts, Calcutta
J. Linn. Soc. Bot.	Journal of Linnaean Society of Botany, London
Rec. Bot. Surv. India	Records of Botanical Survey of India
J. Asiat. Soc. Beng.	Journal of Asiatic Society of Bengal, Calcutta
Gard. Illus.	Gardening Illustrated
For. Fl. Punj.	A forest flora for the Punjab with Hazara and Delhi. Cornell University.
J. Bot. Lond.	Journal of Botany, London
Fl. Sim.	Flora Simlensis
Bot. Reg.	Edward's Botanical Register
Bot. Mag.	Curtis' Botanical Magazines
Sp. Pl.	Species Plantarum
Gen. Plan.	Genera Plantarum
Fl. W. Pak.	Flora of West Pakistan
Bull. Herb. Boiss.	Bulletin de l'Herbier Boissier. Geneve & Bale.
Ind. For.	The Indian Forester
Indian J. For.	Indian Journal of Forestry
Nor. J. Bot.	Nordic Journal of Botany
Trans. Linn. Soc. London	Transactions of the Linnean Society of London. Botany.
Repert. Spec. Nov.	Repertorium Specierum Novarum Regni Vegetabilis.
Regni Veg.	Centralblatt für Sammlung und Veroffentlichung von Einzeldiagnosen neuer Pflanzen. Berlin

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SYSTEMATICS AND ECOLOGY OF BERBERIDACEAE IN UTTARAKHAND STATE

SUMMARY

1. The family Berberidaceae [A.L. de Jussieu (1789)] is a heterogeneous assemblage of primitive angiosperms comprising ca 17 genera and 650 species in the world, which are distributed mostly in the northern hemisphere. In India, the family is represented by three genera and 68 species. Largest among them is the genus *Berberis* having about 55 species. Majority (>95%) of them are distributed in the Himalayan region and few others are found in other hilly regions of Central and South India viz., Pachmarhi hills, Nilgiris, and Chhota Nagpur. Although there is low generic and species diversity in this group, there seems to be very high infra-species and ecotypic variation. Such a variation has led to taxonomic complications. A few species are exploited commercially for their valuable medicinal properties. However, owing to morphological convergence, several species are used as adulterants and used interchangeably by the herbal industries. Several species have been collected only once and there is hardly any information on their population status and ecology. Keeping this information gap, a study on the "Systematics and Ecology of Berberidaceae in Uttarakhand State" was undertaken during 2008 – 2011 with the basic aim to enhance the current knowledge on the Taxonomy and Ecology of Berberidaceae in the state.

2. Major objectives of the study were as follows:

- To study the infra-specific taxonomic variation within the family Berberidaceae found in Uttarakhand.
- To study the autecology of endemic *Berberis* species along the gradient of altitude in the state.
- To assess the availability and extraction pattern of medicinally important *Berberis* species in the state, and
- To suggest conservation measures for the threatened and endemic species in the state.

3. Extensive surveys of Berberidaceae members were conducted in various districts of Uttarakhand state [53,483 km^2; 28° 43' to 31° 28' N and 77 °34' to 81 °03'] covering an altitudinal gradient of 1000 – 4000 m asl and different vegetation types. The state has a much wider altitudinal range (300 to 7817 m asl) and varied eco-climatic zones. Intensive study of medicinal and endemic *Berberis* populations was conducted in select localities within Garhwal and Kumaon sub-regions. Detailed description of the study area including physical features, geology, soil, vegetation types and land use practices have been given in Chapter 2.

4. Study on the Systematics of Berberidaceae in the state involved initial consultation of literature and Herbarium specimens housed in the national herbaria so as to ascertain the known range of distribution and type localities for all the species reported from Western Himalaya. Following this exercise, detailed field surveys were conducted during early spring and summer when most of *Berberis* species flower. Standard field and herbarium techniques (Jain & Rao 1974) were followed and all the species were studied in detail for their morphological variation and compared with the earlier collections. A total of 32 taxa were compared based on 37 taxonomic characters and cluster analysis was done to find out their morphological affinities and relatedness. Populations of medicinal and endemic species were studied following standard phytosociological methods and aut-ecological parameters such as phenology, mi cro-habitat features such as soil and canopy cover, aspect, degree of slope, population trends along altitudinal and anthropogenic pressure gradients were recorded following conventional methods. For each endemic species localities were recorded using GPS. For the intensive study area meteorological data viz., temperature and precipitation were extrapolated from MODIS LST images for the years 2008, 2009 and 2010.

5. Detailed taxonomic keys for the identification of species in the field, systematic treatment including latest nomenclature, synonymy, morphological variation and distribution have been given in Chapter 3. Prior to this study, 33 taxa of Berberidaceae were known to occur in the state of Uttarakhand. Based on present investigation it can be said that there

are at least 36 taxa within present boundaries of the state. The study resulted in the discovery of a new species to science (*Berberis rawatii* Tiwari & Adhikari Nordic Journal of Botany 29: 184-188. 2011) and 2 species new records for Uttarakhand state. Populations of two endemic species, *B. lambertii* and *B. ahrendtii* have been located and collected after a gap of 100 years. Earlier description of *B. lambertii* was based on vegetative characters and for the first time in this study it has described in greater detail using floral characters.

6. Twelve taxa that were reported by previous workers could not be located in the field despite best efforts. Possibility of local extinction or misidentification by earlier workers cannot be ruled out. Three species, viz., *B. glaucocarpa, B. coriaria, and B. affinis* are closely allied to *B. aristata* and seem to have been separated based on superficial characters and it is extremely difficult to separate them in the field. Further genetic and taxonomic evaluation is likely to result in merger of these species into one taxon. Cluster analysis based on 37 characters revealed that the species of *Berberis* could be grouped in 6 distinct clusters. These groups have been further characterized morphologically.

7. Chapter 4 deals with autecology of endemic *Berberis* species in Uttarakhand. The main questions addressed in this chapter include (i) which are the crucial habitats for the endemic species of *Berberis*? (ii) which are the climatic factors affecting their distribution? (iii) what are their population structure and status? With the help of previous literature and extensive field survey four endemic *Berberis* species were collected from field and developmental morphology and flowering phenology of three endemic *Berberis* species were studied. Phenological records were maintained from early March 2008, shortly after snowmelt at 2300 m, until mid-November 2011, in three sampling sites in between 2200-3000m altitudes. The study reveals that the percentage of mature plants was higher than sapling/seedlings populations at all the sites. Largest seedling and sapling of *B. osmastonii* and *B. rawatii* were observed in Muniyalikhet (Chamoli district) and Kalamuni (Pithoragarh district). *Berberis lambertii* grows in soil rich in Calcium, Magnesium and humus organic matter. *B. osmastonii* and *B. rawatii* preferred skeletal (gravelly) soil on steep grassy slopes. Detailed phonological cycles for all the endemic

species have been described. It was found that *B. lambertii* has less than 120 individuals in two populations, while *B. osmastonii* has more than two populations and over 2000 individuals. Only 355 individuals of *B. rawatii* have been located so far.

8. Chapter 5 deals with population status and extraction pattern of medicinally important *Berberis* species in the state of Uttarakhand. Various transects and strata have been compared in terms of density, frequency and abundance of medicinally important species. In order to see the variation among the habitats occupied by the *Berberis* species, Principal Component Analysis and Canonical Correspondence Analysis was used in order to see the effect of environmental variables on the distribution of species. For the extraction pattern, records of Uttarakhand Forest Department and Forest Development Corporation were consulted to know the quantity of *Berberis* species harvested from various forest Divisions in the state. The collection centers (Mandis) were visited to ascertain the prevalent market rates at which *Berberis* stem and roots (dry weight) were sold. Three different climatic zones were identified, and interviewed locals in villages to find out use pattern of *Berberis* species in the State. In order to establish the relationship between volume of wood and weight and predict the harvestable biomass per plant samples of stem base and roots (30 cm above and below basal part of stem) were collected and representing different girth classes. Fresh weight of roots and stem were determined in field using spring balance. The samples of known weight were then oven-dried at 60°C till constant weight gained to obtain dry weight. Using fresh/ dry weight ratio, the dry weight of each of sample was estimated.

9. Over all 205 transects were laid in 14 different habitat types, each transect have 20 points but some time inaccessible to area due to which plot numbers are varying, overall 3882 plots were laid in different parts of state and in each plot abiotic and biotic factors were recorded. Shannon and Simpson diversity index give that maximum diverse habitat type is Kharsu Mixed Forest (KMF H'= 2.5 and D= 8) and the lowest diversitywere found in Pine forest (PF H'= 0.6 and D= 1.8). Species richness is higher in Kharsu Mixed Forest (KMF=12.4) and minimum is in Pine Forest (PF=2). At lower elevation range (600 -1500 m a.s.l.) only one or two species of *Berberis* were present. Maximum

numbers of *Berberis* species were encountered between elevation range 2501-3500 m in South and South-East facing aspect. PCA gives 5 clusters- Cluster one *i.e.*, Kharsu Mixed Forest, in this species like *Berberis glaucocarpa*, *B. pachyacantha* and *B. kunawurensis* are present. Species like *B. umbellata* and *B. jaeschkeana* are mainly found in between Bugyal and KMF. Cluster two is mainly mixed of 12 different habitat types where most of the species of *Berberis* are present, like *B. coriaria, B. asiatica, B. lycium, B. chitria* and *B. aristata*. A distinct habitat type (blue pine forest in the rain-shadow zone in Malari) was segregated as cluster 3 that represented the habitat of *B. pseudumbellata* Cluster four had *Berberis kumaonensis*, found in moist alpine meadows and temperate grassy slopes in Greater Himalaya. *Berberis rawatii*, *B. osmastonii*, *B. conccina* var. *brevivora* and *B. lambertii* preferred temperate grassy slopes. To analyze *Berberis* species distribution across the different habitats and to correlate the environmental factors, analysis was performed using the data from 182 plots where species were present and 11 variables using canonical correspondence analysis. Monte Carlo test results for Species – Environment Correlations shows (r= 0.947 and 0.879; p= 0.010), correlation was found to be highly significant. Out of 11 variables used, 8 showed high inter-set correlation, namely canopy cover, elevation, summer, winter and monsoon temperatures and precipitation.

10. It was found that medicinal species *i.e., B. aristata, B. asiatica* and *B. lycium* are patchily distributed in the state. *B. asiatica* and *B. lycium* had wider altitudinal range (500 to 2600 m) while *B. aristata* was confined to a narrow altitudinal zone (2200 to 3500 m). Regeneration status of *Berberis asiatica* was best in Banj-Burans Mixed forest and High altitude mixed forest and *Berberis aristata* was best in Kharsu Mixed forest. Regeneration of *Berberis lycium* was best in open canopy cover and temperate grassy slopes. The official records of State Forest Department and interviews with the local people revealed that the demand of *Berberis* species in the market fluctuates considerably. During the study period *B. asiatica* and *B. lycium* were extracted only from two localities in limited quantity to the tune of 100 – 150 kg. This translates to 37- 40 adult individuals of *B. asiatica*. Being a perennial species, these levels of harvest once in

4-5 years can be considered sustainable, provided habitats are protected. It was found that in some parts of the state *B. asiatica* was extracted heavily for fuel wood.

11. Chapter 6 deals with conservation measures for medicinal and rare endemic species of *Berberis* in the state. Various factors affecting populations of these taxa have been discussed. Based on endemism, population status and potential demand for commercial purpose, the following species need to be given highest priority for conservation in the state: *B. ahrendtii, B. lambertii, B. apiculata, B. rawatii, B. osmastonii, B. asiatica, B. lycium* and *B. aristata*. Distribution maps of medicinal species for various Forest Divisions of Garhwal region have been prepared. Based on these maps areas for conservation and development of each species have been suggested. The populations of rare endemic species have been located and a few sites for their long term monitoring. Considering the low population size, it is recommended that its RDB status of *B. lambertii* may be changed from Vulnerable to Endandered category of the IUCN.

For conclusion of study, floristic studies are one of the basic underlies in exposing the natural resources of an area. The regional and local floral studies in our country are used in preserving the nature, detecting the biological diversity and forming nature management plans. Therefore, this study was carried out in the studies of Berberidaceae family in Uttarakhand. Study is crucial for species distribution and conservation management and contributing to the ecologically sustainable management of natural resources. Uttarakhand is considered of high conservation value owing to its floral and faunal characteristics. This study also important for endemic *Berberis* species in state and arrange the endemic plants according to IUCN Red Data threat Categories. Their conservation is needed and these species need special mention in forest management plans, according to endemic species distribution it can be said that currently these species are threatened categories in land use systems. Forming biotopes, in which the endemic species exist, along with buffer zones around them and offering that to the policy makers in a landscape management model will provide success in maintaining endemic species.

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Chapter 1:

Introduction

CHAPTER 1.0
INTRODUCTION

So long as this land will have mountains, forests and pastures, that long will the Earth survive, sustaining us and the coming generations. - *Devistotra. A Hindu Shastra*

1.1 Berberidaceae: General Introduction

The family Berberidaceae was first established by A. L. Jussieu de (1789) as 'Berberides' and was considered one of the most primitive Angiosperms having a high number of disjunct or discontinuous genera. Berberidaceae is a heterogeneous assemblage of angiosperms comprising *ca* 17 genera and 650 species in the world which are distributed mostly in the northern hemisphere (Chamberlain and Hu 1975; Landrum 1999). Berberidaceae is characterized by shrubs or perennial herbs with reddish brown to pale branches, armed or unarmed. Several classification systems have been proposed for the extensive character variation in habit, floral morphology and fruit type. Of these, *Berberis* is the largest genus having *ca* 450 species in the world and Mahonia have *ca* 100 species (Ahrendt 1961). Chapman (1936) on the basis of carpellary anatomy proposed that Berberidaceae and Ranunculaceae arose by parallel evolution from a Proranalian complex. Taxonomically, *Berberis* is difficult genus due to extremely high morphological variation, probably affected by environment and hybridization. Overlapping characters, especially in leaves, stems, and flowers and berry size makes field identification often difficult. Leaf texture and serrations vary from season to season and with the age of the plant in some of the species. Ahrendt (1961) gave a comprehensive account of the genus but he compared mostly herbarium specimens and a few living ones grown at Royal Botanic Garden, Kew and other places. However, some of the species, described by him, are based on single specimen.

Berberis species (commonly known as 'barberry') have been attracting botanists, naturalists and ecologists since time immemorial due to their incredible range of diversity in shape, size and colour of leaves and fruits. They have been very closely associated with human beings since ancient times. Barberry is also recognized as a prominent constituent of herbal

medicines for more than 2600 years. Powder of barberry was used for Rhinoplasty by Shusruta (Muley 2002). In Indian Materia Medica (Nadkarni 1954), *Phalatrikadivati* (*Triphala, Musta, Indrayana* and *Daruharidra*) is most acceptable form of medicine for the treatment of several ailments including diabetes. About 40 named alkaloids have been identified in about eight genera of Berberidaceae (Willaman and Schubert 1961). *Berberis* species are known for their medicinal properties in various parts of the world, since time immemorial. In ancient India, 2600 years ago there are records of some species of *Berberis* used for medicinal purposes (Nadkarni 1954). In India *Berberis* have been used in indigenous system of medicines since *Vedic* period. *Rasont* (also called Rsaunt or Rasanjana) is a crude, concentrated extract prepared from the roots and stem bark of several species of the genus *Berberis* L. (Chatterjee 1949; Rajasekaran and Kumar 2009).

Berberis vulgaris, a common garden bush native to Europe and the British Isles is naturalized in North America, and has a history as old as human race. Native Americans believed that it worked as a supernatural power or as preventive or remedy of illness (Arayne et al. 2007). It is a deciduous shrub having yellow flowers and scarlet berries. Twenty two alkaloids have been reported from roots, stems, leaves and fruits of this plant, which are of medicinal importance. Berberine, one of the alkaloids, is the most widely used drug in Homeopathic system of medicine to cure kidney stones. In ancient times, Egyptian pharaohs and queens took Barberry with fennel seed to ward off the plague. In Egypt, it is still used to cure fevers associated with pestilence. In Italy, Barberry is called "Holy Thorn" for it is what they believe was wrapped in Christ's thorns he wore around his skull. Early physicians thought the yellow wood of common Barberry could most likely be used to cure jaundice. They believed this on the basis of a theory called the doctrine of signatures, which held that a plant's appearance or other characteristics were a sign of the type of disease or injury it would cure. Native American Indians used this herb in cases of general debility and to improve the appetite. The colonists used the root as a bitter tonic. In traditional folk medicine, Barberry is used to treat diarrhea, reduce fever, improve appetite and increase energy (Foster and Tyler 1999).

Because of its ornamental and medicinal values, barberry is still widely propagated and sold by nurseries for landscaping purposes in several parts of the USA. Barberry is shade

tolerant, drought resistant, and adjustable to an assortment of open and wooded habitats, wetlands and interrupted areas.

1.2 Berberidaceae in India

In India, the family is represented by three genera and 68 species. Largest among them is genus *Berberis* which has 55 species. Majority (>95%) of them are distributed in the Himalayan region. Only four species are found away from the Himalayan region *i.e.*, Nilgiri hills, chhota Nagpur and Pachmarhi hills of Madhya Pradesh (Rao et al. 1998a). Most of the members of Berberidaceae are found in secondary scrub vegetation. Traditionally foresters and ecologists have identified *Berberis* species as indicators of habitat degradation in the temperate region due to their thorny stem and unpalatable shoots (Personal communication). However a large number of native birds and mammals are known to depend on *Berberis* fruits. *Berberis asiatica*, one of the most common species in the middle hills of western Himalaya was known to be the alternate host of dreaded wheat rust *i.e.*, *Puccinia graminis tritici*. Hence, during the early phase of green revolution there was a movement to eradicate *Berberis* spp. from the Himalayan region. Similarly, several species of *Berberis* have been eradicated from the Himalayan region in order to reclaim the hill slopes for agriculture or to extract valuable drug 'Berberidine' from the roots and stems of this plant.

1.3 Present Study

The state of Uttarakhand is reported to have 22 species of *Berberis* (Rao et al. 1998a and b). Including all varieties and sub-species, about 29 distinct taxa are found in the state. At the same time several species have a number of eco-types and provenances. But this number is likely to be more, given the topographic and altitudinal variation in the state. Of these, seven species are endemic to state. According to the Red Data Book of Indian plants (Nayar and Sastry 1987 - 88) *Berberis lambertii* is Vulnerable, *B. affinis* and *B. osmastonii* are Rare. All these three species are endemic to a few pockets.

It has been observed that several species of Himalayan *Berberis* are used to extract raw drug by the herbal industries. Often, more common species are used as adulterants. For the conservation and management of this valuable resource it would be extremely important to address the questions such as (i) How many distinct species and sub-species of *Berberis* are found in the state and what is their conservation status ? (ii) Which are the factors determining their distribution and regeneration ? (iii) Which species are in highest demand from the herbal industries ? and, where are they collected from ? and in what quantity and season ? (iv) Are the current practices of harvesting sustainable way ? and (v) Which are the crucial habitats for the endemic species of *Berberis*?

It would be pertinent to establish taxonomic relationships among various taxa based on cladistics and relate various species with the successional trends in order to understand their biology and evolutionary ecology (Meacham 1980). Therefore, this study was conducted in the state of Uttarakhand, which lies in the core area of distribution for the Himalayan Berberidaceae.

1.4 Diversity and Distribution

Bentham and Hooker (1862) treat the family Berberidaceae *sensu lato* including Nandinaceae, Lardizabalaceae and Podophyllaceae in the order Ranales. Nandinaceae do not occur in India, though *Nandia demestica* Thumb., a native of China and Japan is often cultivated in Assam gardens and elsewhere for bright red berries. Lardizabalaceae and Podophyllaceae are treated as separate families. In India, Berberidaceae is represented by 3 genera (*Berberis*, *Mahonia* and *Epimedium*) and 68 species (Rao and Hajra 1993). Genus *Berberis* is represented by eight sections and 14 subsections. Section Tinctoriae is represented by 4 subsections with 14 species, section Angulosae is represented by four subsections with 13 species, section Wallichianae is represented by 6 subsections with 10 species and section Vulgaris and Section Ulicinae are represented by single species each, and 13 species of *Mahonia* are found in India (Rao and Hajra 1993; Rao et al. 1998a and b). Berberidaceae is represented by two genera *Berberis* and *Mahonia* in the state of

Uttarakhand. The family is represented by 4 sections of genus *Berberis* (22 species) and *Mahonia* (4 species). Six taxa of genus *Berberis* and one species of *Mahonia* are endemic to the state of Uttarakhand. Further, 14 taxa of *Berberis* are common with Nepal and 20 taxa are common with Western Himalaya.

1.5 Objectives

1. To study the infra-specific taxonomic variation within the family Berberidaceae found in Uttarakhand,
2. To study the Autecology of endemic *Berberis* spp. along the gradient of altitude in the state,
3. To assess the availability and extraction pattern of medicinally important *Berberis* spp. in the state and,
4. To suggest conservation strategies for the family Berberidaceae in the state.

1.6 Scope of Study

This is the first comprehensive account on taxonomy and ecology of Berberidaceae members in the state of Uttarakhand. It provides detailed information on the distribution of each species in the state and highlights the *Berberis* rich hotspots with endemic and threatened species in the state where, *ex-situ* conservation may be initiated. The study provides information on the distribution of Berberidaceae in different habitat types in the forested regions of the state and influence of different environmental factors on them. Detailed information has been given on the medicinal use of Berberidaceae in the study area.

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Chapter 2: Study Area

CHAPTER 2.0
STUDY AREA

"The Himalaya is a great devatatma, a great spiritual presence, stretching from the west to the east sea like a measuring rod to gauge the world's greatness." - Kalidasa.

2.1 General

The state of Uttarakhand situated in the northern part of India, shares an international boundary with China in the North and with Nepal in East. This nascent state has an area of 5.35 million ha (53,483 km^2) which accounts for nearly 15.5 percent of the total geographical area of Western Himalaya and 1.63 percent of the total land area of India (Figure 2.1). It lies between Latitudes 28° 43'N and 31° 28'N and Longitudes 77° 34'E and 81° 03'E. About 19% of the geographical area is under permanent snow, glaciers and steep slopes (Anonymous 2009). It is known as *Dev bhumi i.e.*, the land of the Gods. Historically, Uttarakhand has been the abode of a large number of saints and sages for centuries and during the course of their meditations they developed the science of Ayurveda. One of the greatest Ayurvedic texts, Charaka Samhita holds this region in high esteem and describes it as the best habitat of herbal wealth. It has two distinct traditional politico-cultural regions known as Garhwal and Kumaon. The state comprises 13 districts namely Chamoli, Pauri, Tehri, Uttarkashi, Dehradun, Haridwar and Rudraprayag in Garhwal and Nainital, Almora, Pithoragarh, Udham Singh Nagar, Champawat and Bageshwar in Kumaon. According to the Census 2001, the total population of the state is estimated to be 8.47 million. Major occupation is agriculture although the net cultivated area is only 14.07%, of which 22.4% falls in Udham Singh Nagar and Haridwar Districts.

2.2 Topography

Uttarakhand shows a great physical diversities and its climate is exceedingly diversified. The altitude varies from 300 m a.s.l. to 7817 m. The topography of Uttarakhand is varied, ranging from flat alluvial plains in the southern periphery to deep valleys, high peaks, and highly fragile cold deserts in the North. The region contains glaciers, high passes, meadows

and catchments of various rivers such as Yamuna, Ganga, Saryu and Sharada. The river Ganga is fed by several tributaries *viz.*, Alaknanda, Bhagirathai, Mandakini, Pindar and

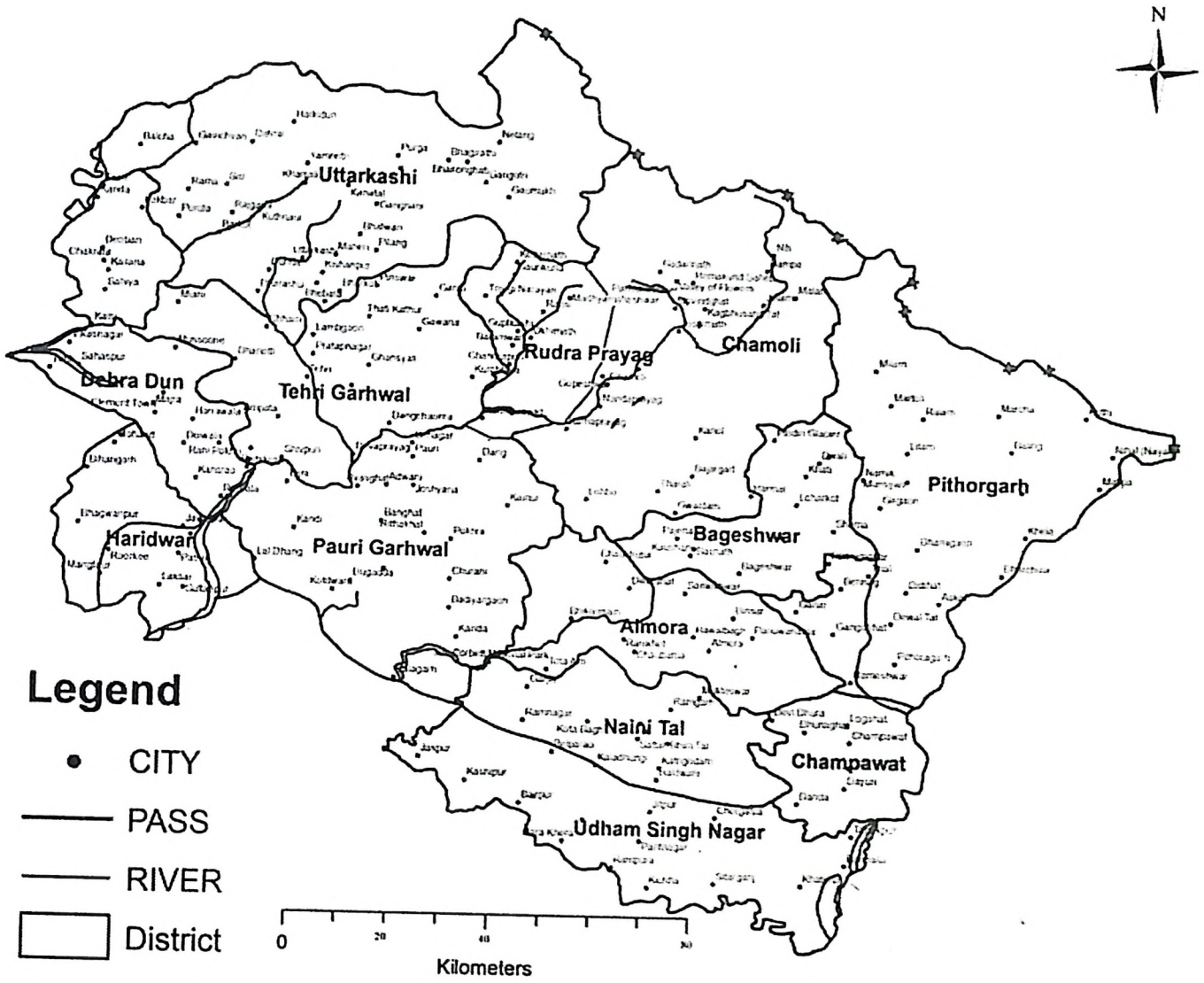

Figure 2.1 Uttarakhand State

Vishnu Ganga of the region (Figure 2.1). The prominent peaks are Nanda Devi, Kamet, Dunagiri, Satopanth, Bandar Poochh, Swarg Rohani, Badrinath, Chaukhmba, Kedarnath, Panchachuli, Nandakot, Gangotri, Neelkanth, Trisul etc. The upper high altitude region is referred to as the border areas with Tibet. The main passes in this region are Lipu Lekh, Darma, Kungari-Bingrih, Mana, Niti, while Gangotri, Pindari, Kaphni, Ralam and Milam are some major glaciers of the region.

2.3 Geology and Soil

The 2400 km long arcuate belt of Himalayan Mountains extending from Kashmir to Assam is conventionally divided into five zones that are broadly parallel to Himalayan trend. These zones are from South to North (Gansser 1964).

From Gangetic plain to extreme North up to Indian boundary, the Himalaya is divided into several geo-physical divisions - the Outer Himalaya consisting of the Tarai, Bhabar, Duns and Siwaliks, Lesser Himalaya have fertile river valleys, the Greater Himalaya a zone of high snow peaks, glacier and Trans Himalaya across the Himalaya (Valdiya 1988).

a) The Outer Himalaya: These are made up of sandstone, mudstone and sub-ordinate conglomerates of the Middle Miocene to early Pleistocene age. The Lower Siwalik consists of fine-grained calcareous sub grawacks and sub-litharenites alternating with dominate horizons of maroon mudstone of predominant coarse-grained sub-litharenite and subordinate Para conglomerate with maroon mudstone and sandstone deposited largely by braided rivers.

b) The Lesser Himalaya: It is made up of three litho tectonic units i) Autochthonous succession of the Precambrian strata forming the larger part of the inner belt. ii) Late Precambrian to early Paleozoic sedimentary rock formation, forming the Karol Nape, includes slates, phylites, sandstone and limestone. iii) The Precambrian metamorphic injected granite bodies.

Metamorphism: Most of the geologists working on Himalaya present, it as a simple product of continental collision.

Tertiary Granitoids of Uttarakhand Himalaya: The Higher Himalaya tourmaline-granite intrusions are exposed near Badrinath and Kedarnath. The leucocratic Badrinath granite is muscovite-biotitetourmaline granite to aplitic that cut across NE-SW striking flat anticline of high grade rocks just south of the Badrinath village (Sharma 1983). The continuity of the

Badrinath granite has been traced westward in Gangotri area and northward into the Arwa valley (Auden 1933).

c) The Greater Himalaya: It is made up of high grade metamorphic the Vaikrita group of Precambrian age. It is instructed extensively by mid tertiary granite.

d) The Trans Himalaya: The Trans Himalaya fault separates the Trans Himalaya from the great Himalaya. The rock formation, being shattered mylonotized otherwise complexly folded.

In Uttarakhand there is a wide variation in the soil type, which can be characterized into following groups – *Alpine zone (above 3000m)* - the soils are of glacial origin with naked rocks and meadows. These soils are mostly granites sandy loam in nature. *Cool temperate (2500-3000m)* - brown deciduous forest soils and grey coniferous forest soils usually predominate. *Warm temperate and subtropical zone (900-1800m)* - Brown forest soils varying from loam to clayey loam are fairly widespread. *Tropical zone (<900 m)* - is characterized by alluvial soils mixed with boulders, gravel and pebbles in the Shivalik valleys, Duns and Bhabar regions.

2.4 Climate

The climatic condition of Uttarakhand is very diverse due to great variations in altitudes, slopes, aspects and vegetation. Because of prevailing climatic conditions the year may be divided into three seasons *i.e.*, the winter (November – February), January being the coldest, when temperature goes down frequently to freezing point. Occasional rains and snowfalls particularly at higher elevations, experienced during January and February. The summer (April - June), May and June are the hottest months especially at lower elevations and valleys. The monsoon (July – September), characterized by heavy rains and high humidity with slight variation in temperature. The monsoon usually strikes at different places between second to fourth week of June and lasts up to the end of September. The heaviest precipitation occurs during July and August. The transitional periods between rainy season

and winter season and winter season and summer season are recognized as autumn (October-November) and as spring (February to March), respectively. In summer and rainy seasons, the foothills and broad valleys are quite warm, whereas chilling and severe winter and moderate to cool summer season characterize higher elevations. Normal annual rainfall ranges from100 cm to 250 cm. In the mountainous areas, the mean temperature falls by as much as 5.5°C for every 1000 m of elevation (Barry 1992) but large variations may occur due to location, time of the day and the season *etc.*

2.5 Eco-climatic Zones

The state is divisible into following eco-climatic zones *viz.*, subtropical, warm temperate, cool temperate, alpine and nival be divided into three physiographic regions *viz.*, the Himalayas, the Shivaliks and the plains. The state has a temperate climate except for the plain areas that have a subtropical type of climate. The high altitude regions of Uttarakhand Himalaya can be divided into three main climatic zones (Shah and Jain 1988).

The alpine zone: This area can be divided into two sub-groups (1) *dry alpine* the interior Himalayan ranges nearing Tibet border at an altitude of about 3200 m to 4000 m elevation with very low annual precipitation and (2) *wet alpine zone* that is spread from an altitude of 3000 m to 4000 m characterized by high annual precipitation. Both the regions are rich in *Berberis* species.

The temperate zone: Commencing from 1000 m to 2700 m elevation, it also consist of two climatic zones – (1) the *Dry temperate* and (2) *Wet temperate* region. Pine forests characterize the dry temperate forest with shrubs growing as undergrowth or forms separate patches in the upper ranges. The wet temperate region is dominated by mixed broad leafed and coniferous species. Many of the *Berberis* species and medicinal importance species are found in wet temperate region.

The Sub-tropical zone: This is the region existing in the valleys of the temperate zone. This zone has rich bio diversity of the state. (Action Plan: HRDI and Uttarakhand FD, 2002 unpublished).

2.6 General Vegetation

The forest vegetation of Uttarakhand exhibits a great deal of variation. This may be largely attributed to the variation in topography and climatic conditions that prevail from subtropical to alpine zones (Plate 2.1 and 2.2). The total forest cover of the state is approximately 24,495 km^2, which is 45.08 % of the total geographical area (Anonymous 2009) (Figure 2.2). A brief description of some major forest types and their characteristics are described below:

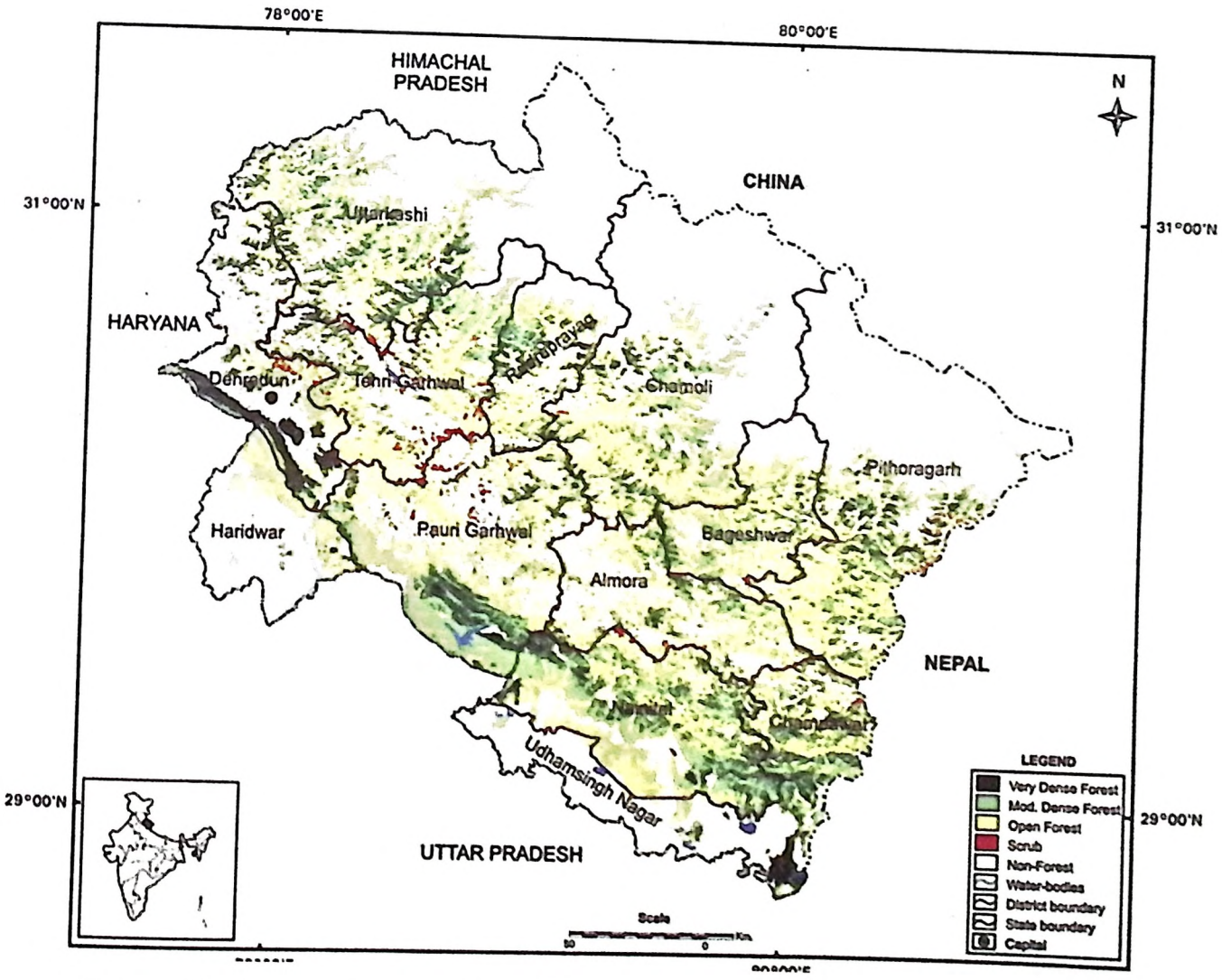

Figure 2.2 Forest cover map of Uttarakhand (Source: FSI report, 2003)

2.6.1 Subtropical Forest (<1500 m)

The various types of forests occurring in subtropical zone are as follows.

(i). Deciduous Riverine Forests: This type of forest is largely composed of Shisham (*Dalbergia sissoo*) and Khair (*Acacia catechu*) and both the species are usually form early stage of riverine succession in Himalayan foot hills. When these colonizers grow together, usually Shisham grows faster than Khair leading to the formation of two-storyed forests. The under story vegetation may be sparse or may be characterized by common grasses such as *Aristidia cyanantha*, *Saccharum bengalense*, *S. spontaneum* together with some other species of grasses. As the forests grow mature, these grasses are gradually replaced by a dense growth of *Pogostemon benghalense*, *Adhatoda zeylanica* and *Murraya koenigii* and tree species are replaced by *Holoptelea integrifolia* (Kanju). These forests gradually but surely change to the miscellaneous forest species in which Khair and Kanju may form a small proportions.

(ii). Deciduous Miscellaneous Forests of the Bhabar: The riverine types of forests slowly undergo changes and lead to formation of deciduous type of forests consisting of very different species. Such changes result in the composition of forests leading to the changes in the land. In such forests, no single tree species forms pure stand and thus it is completely mixed. Some of the common trees of this forest are: *Bombax ceiba*, *Haldinia cordifolia*, *Lagerstroemia parviflora, Holarrhena pubescens*, *Lannea coromendelica*, *Cassia fistula*, *Garuga pinnata*, *Catunaregam spinosa* and *Ziziphus xylopyra*. The transitional stages between the true riverain and the miscellaneous forests is often noticed where *Holoptelea integrifolia*, *Haldinia cordifolia*, *Moringa oleifera*, *Wrightia arborea etc.* are the first to appear. Some typical shrubs of the miscellaneous forests are: *Ziziphus mauritiana*, *Helicteres isora, Urena lobata, Sida cordata* together with some evergreen shrubs like *Mallotus philippensis*, *Clerodendrum viscosum, Dendrocalamus strictus* and *Adhatoda zeylanica*.

Carissa opaca, *Rhus parviflora* and *Woodfordia fruticosa*. The other species of trees include *Drypteris roxburghii*, *Ougenia oojeinensis*, *Lannea coromandelica*, *Bauhinia variegata*, *Mallotus philippensis*, *Sapium insigne*, *Sterculia villosa*, *Engelhardtia spicata* and *Glochidion velutinum*. Some common shrubs forming the undergrowth of these forests includes *Indigofera cassioides*, *Rhus parviflora*, *Woodfordia fruticosa*, *Murraya koenigii*, *Adhatoda zeylanica*, *Colebrookea oppositifolia*, *Carissa opaca* and *Nyctanthes arbor-tritis*.

2.6.2 Temperate Forests (1500 - 2500m)

Following major categories of forests can be seen within warm temperate belt:

(i). Chirpine Forests: A Chirpine (*Pinus roxburghii*) forest is generally occurring between the altitudes 1000 m and 2000m, though this species extends occasionally below and above these altitudes (Plate 2.1 C). The growth of Chirpine on steep rocky slopes is poor and in extreme conditions it can be replaced by low level scrub and other broadleaved species. Chirpine can establish easily on themselves on dry southern aspects where xerophytic conditions fire is prevalent. The ground vegetation in Chirpine forest is usually covered with few grasses and shrubs, which are fire resistant. Some of the commonest species associated with Chirpine are: *Lyonia ovalifolia, Pyracantha crenulata*, *Glochidion velutinum*, *Euphorbia royleana* is very often abundant on dry rocky grounds. *Rhus parviflora* and *Woodfordia fruticosa* often form an undergrowth of varying extent. *Indigofera cassioides, Lespedeza stenocarpa*, *Rubus ellipticus*, *R. niveus*, *Berberis lycium*, *Leptodermis lanceolata*, *Aechymanthera gossypina*, *Myrsine africana* and *Inula cappa* and others are often abundant shrub species.

(ii). Banj Oak Forests: Banj Oak (*Quercus leucotrichophora*) forests are generally found between 1500 m and 2400 m and occupy the moist ravines running down as low as 1000 m (Plate 2.1 B). The common associates of Banj Oak are: *Rhododendron arboreum*, *Lyonia ovalifolia*, *Neolitsea umbrosa*, *Ilex dipyrena*, *Carpinus viminea*, *Quercus lanata*, *Q. glauca*, *Euonymus pendulus*, *Betula alnoides*, *Pyrus pashia*, *Myrica esculenta*, *Populus ciliata* and *Alnus nepalensis*. Some of the common associates among shrubs are: *Berberis chitria*, *B.*

asiatica, *Desmodium elegans*, *Indigofera heterantha*, *Rubus niveus*, *Boenninghausenia albiflora*, *Myrsine africana*, *Deutzia staminea*, *Plectranthus japonicus*, *Pteracanthus alatus*, *Goldfussia dalhousiana*, *Pseudaechymanthera glutinosa* and *Sinarundinaria falcata*.

2.6.3 Cool Temperate Forest (2500 - 3000m)

(i). Tilonj Oak Forests: Tilonj Oak (*Quercus floribunda*) forests usually occur between Banj Oak and Kharshu Oak forests between the altitudes from 2100m - 2700 m. It attains its maximum development on deep moist soils and especially where subsoil is limestone. Telunj Oak is definitely more mesophytic than Banj Oak forests. Telunjoak forests are usually found in areas away from habitation and have last biotic damage. Telunjoak is less fire resistant than Banj Oak. These forests have luxuriant growth and have greater mixture of secondary species in the top storey mainly of deciduous trees with a well marked evergreen second storey. Some of the common tree species associated with Telunj Oak are: *Quercus leucotrichophora*, *Q. semecarpifolia*, *Betula alnoides*, *Carpinus viminea*, *Acer caesium*, *Ilex dipyrena*, *Euonymus pendulus*, *Persea duthiei*, *Aesculus indica*, *Abies pindrow*, *Ulmus wallichiana*, *Rhododendron arboreum etc.*, while common shrubs found in such forests are: *Rhamnus purpurea*, *Lindera pulcherrima*, *Lyonia ovalifolia*, *Myrsine semiserrata*, *Boenninghausenia albiflora*, *Sarcoccoca saligna*, *Lonicera quinquelocularis*, *Viburnum cotinifolium* and *Eurya acuminata etc.*

(ii) Temperate Deciduous Forests: These forests usually found from 2000 - 2750m in moist soil especially in depressions on northern aspects along hill streams. This type of forest is composed of deciduous tree species having large girths, though usually branched and occur singly or in a big group of varying extent. The undergrowth is usually poor due to close canopy but wherever canopy is broken, small trees, shrubs, and Himalayan bamboos come up. The predominant tree species forming moist temperate deciduous forests include *Aesculus indica*, *Ulmus wallichiana*, *Betula alnoides*, *Acer caesium*, *A. cappadocicum*, *Carpinus viminea*, *Juglans regia*, *Fraxinus micrantha*, *Corylus jacquemontii*, *Cornus macrophylla*, *Taxus wallichiana*, *Prunus undulata*, *Prunus nepaulensis*, *Euonymus fimbriatus etc.*, while shrubby layer is represented by *Viburnum foetens*, *Rubus nepalensis*,

Berberis spp., *Spiraea* spp., *Strobilanthus wallichii*, *Thamnocalamus spathiflorus*, *T. falconeri*, *Cardiocrinum giganteum*. Among the climbers *Parthenocissus semicordata* and *Clematis connata* are most frequent.

(iii). Kharshu Oak Forests: Kharshu Oak (*Quercus semecarpifolia*) is a dominant species of this forest and occurs between the altitudes 2500 m - 3300m (Plate 2.2 D). This Oak forms a dense crop with some admixture of other species but at some places it forms pure crop of its own. Its second storey, it is often absent but dense patches of Himalayan bamboos represent a marked features in many places, though sometimes absent in other aspects. There is generally a ground of mostly deciduous shrubs with a varying amount of grasses, ferns, and herbaceous flora. Scattered trees of Silver Fir and Spruce are found in these forests. At higher elevations, it merges with sub-Alpine forests of Silver Fir, Rhododendron, Birch, but often it directly merges into Alpine meadows. Some common tree associates of Kharshu Oak are: *Betula utilis*, *Quercus floribunda, Acer caesium*, *Abies pindrow*, *Meliosma simplicifolia*, *Rhododendron arboreum* and *Sorbus foliolosa,* while *Rosa sericea*, *R. macrophylla*, *Viburnum foetens*, *Cotoneaster acuminatus*, *Strobilanthus wallichii*, *Ribes glaciale* and, *Salix denticulata* are among the dominant shrubs.

(iv). Temperate Grassy Slopes: These types of habitat are found in between 2200 - 3000m. At higher elevations, it merges into the sub Alpine forests of Kharsu mixed forest (Plate 2.1 D and 2.2 C). Some common associated species of Temperate Grassy slopes are *Rhododendron arboreum*, *Cotoneaster acuminata*, *Strobilanthus wallichii*, *Berberis chitria*, *Berberis lycium* and *Plectranthus japonicus etc.*

2.6.4 Sub-alpine Forest (3000-3500m)

Dominant associations in the Sub-alpine forests are described below:

(i). Kharshu Oak and Fir Mixed Forests: The distributional range of this forest lies between 2600 m -3400 m particularly on the northern aspects and sheltered localities (Plate 2.2 A). The drier parts in these forests tend to be occupied by pure Kharshu Oak forests

characterized by early melting of snow. Typically, two story forests with the Silver Fir standing singly or in stripes and groups over Kharshu Oak forests and other deciduous and evergreen trees.

Himalayan Bamboos are found throughout within these forests. Climbers are relatively less but there is a vigorous and gregarious growth of mosses. Some common tree associates are: *Quercus floribunda*, *Pyrus lanata*, *Rhododendron arboreum*, *R. barbatum*, *Sorbus foliolosa etc.*, while *Rosa macrophylla*, *Viburnum foetens, Berberis* spp., *Strobilanthus wallichii*, *Smilax vaginata* are among the shrub species. *Parthenocissus semicordata* and *Hedera nepalensis* among the climbers found in such forests.

(ii). Birch/Fir Forests: This type contains an irregular forest with Fir (*Abies spectabilis*), Birch (*Betula utilis*) and Rhododendrons (*Rhododendron arboreum* and *Rhododendron campanulatum*) in varying percentages as main constituents of the forests and occurs between 3000 m – 3300 m (Plate 2.2 A). Kharshu Oak also extends up to this forest along with Himalayan Bamboos. The common tree species often associated with this forest are: *Quercus semecarpifolia*, *R. barbatum*, *Pyrus* spp, *Prunus padus, Acer caesium, Juglans regia, Taxus baccata etc.*, while *Cotoneaster acuminata*, *Rosa sericea*, *Ribes glaciale*, *R. himalense*, *Lonicera* spp., *Rhododendron campanulatum, R. lepidaum, Gaultheria trichophylla* are common shrubs. Climbers (*Smilax vaginata*) are very sparse.

2.6.5 Alpine Vegetation (>3500m)

The types of vegetation occurring in this zone are briefly described under the following heads.

(i). Alpine Scrubs: There is a gradual transition from sub-Alpine forest to scrub above the Birch and Fir forests. The bushy growth of plants is prevalent throughout the area and patches are discontinuous because of broken terrain. The terrain is often steep and strewn with boulders and is frequently intersected by rocky slopes. Lower limit begins from 3200 m and upper limit can be extended beyond 4000 m a.s.l. Except *Rhododendron campanulatum*

and *Sorbus foliolosa* most of the species in alpine scrub are dwarf, hardly attaining 1 m in height. Some common shrub species are: *Rhododendron lepidotum*, *Gaultheria trichophylla*, *Juniperus communis*, *J. wallichiana*, *Berberis jaeschkeana*, *Lonicera* spp. and *Salix* spp. *etc.* Besides, some woody species like *Berberis*, *Caragana*, *Cotoneaster*, *Juniperus*, *Lonicera*, *Myricaria*, *Rhododendron*, *Rosa*, *Salix etc.* occurs in isolated patches.

(ii). Alpine Meadows: The alpine meadows are generally known as *Bugyals* in Uttarakhand. Several graceful, cushioned and hairy herbs grow in great profusion, which are well known for their beautiful and attractive flowers. All the plants growing above alpine scrubland and are collectively known as '*Bug*' from which the word *Bugyal* has been derived. Some of the common genera grow frequently in alpine meadows are: *Aconitum* spp., *Allium*, *Aster*, *Astragalus*, *Corydalis*, *Delphinium*, *Draba*, *Epilobium*, *Euphorbia*, *Gentiana*, *Geranium*, *Impatiens*, *Nepeta*, *Pedicularis*, *Polygonum*, *Potentilla*, *Primula*, *Ranunculus*, *Saussurea*, *Saxifragra*, *Sedum*, *Senecio*, *Stellaria*, *Swertia*, *Tanacetum* along with a large number of grasses and sedges.

2.7 Endemic Plants

The geographical positions, physiographic and geological history of Uttarakhand state have together contributed to considerably higher endemism in relatively younger mountain system. The Western Himalaya is one of the three major geomorphological divisions considered as mega centers of endemic plants with Garhwal- Kumaon Himalaya recognized as one of the 25 microcenters for endemic plants (Nayar 1996). About 5725 species of flowering plants are endemic to India represented under 147 genera and 47 families (Nayar 1996). Among the endemic species, *ca* 3471 are found in Himalaya and 84 species are endemic to Uttarakhand state (Uniyal et al. 2007). The genus *Berberis* has maximum representation of endemic species.

2.8 Local Communities and Land Use Practices

Uttarakhand resembles other parts of the Himalaya where various ethnic groups live in harmony. Leading chiefly an agrarian-pastoral way of life, the people of the state make their living from the hilly land, the best they can. Some, like the Bhotia traders, migrate far and wide, though the ancient trade routes with Tibet have been closed since 1950. Great fairs that bring all the peoples together are held throughout both, Garhwal and Kumaon. Most of the local people are heterodox Hindus and Buddhists, while Sikh migrants from West Punjab have settled in the lowlands since 1947. A few Muslim groups are native to the area too, although most have come recently. The Muslim Gujjar herders also migrate to the hills.

Jaunsari: The people of Jaunsar-Bawar (Upper Dehra Dun district) and Rawain (present day Uttarkashi) are distinct from their Garhwali neighbors in their style of dress and unique cultural practices. As a collection of smaller tribes, Jaunsari society is caste stratified with the indigenous Koltas as the main service caste and Khasa Brahmins and Rajputs as the main cultivators. The Jaunsari are well known to be one of the few polyandrous societies in the world, although this practice is receding into history. Marriage and sexual mores also tend to be more liberal, with women enjoying greater freedom to choose and divorce. Jaunsaris are also famous for their colorful clothes and festivals.

Bhotia: Bhotias traditionally lived in the high Himalayan region, close to the Tibetan border. The term Bhotia comes from "Bo" which is the native Tibetan word for Tibet. In the winter, they migrate to southern climes, although recently, many have begun settling permanently in the mid-Himalayas. Bhotias are subdivided into three main categories: The Jadhs of Uttarkashi, the Marchas (once mainly traders) and Tolchas (farmers) of Chamoli, and the Shaukas of Pithoragarh (near Dharchula). Apart from cultural differences, the Bhotia groups resemble one another in their distinctive Tibetan-like physical appearance. Furthermore, the Jadhs are followers of Buddhism and the Shaukas hold to their own Hindu-Buddhist faith, although both rely on Lamas to conduct ceremonies and rituals. The central Marcha / Tolcha groups are the most Hinduized, sharing Rajput septs (family names) with their Garhwali neighbors. Since the closing of the Tibetan frontier in the 1950s and the militarization of the

border, the traditional Bhotia trade routes have also been closed, leading to social and economic dislocation.

Buksha: The Bukshas are inhabitants of the Terai, although their locality falls in the western fringes of Nainital (now Udham Singh Nagar) and borders that of the Tharus. Bukshas worship Hindu Gods. A Seyana (literally, "Wise One") administers to their medical/spirit needs.

Tharu: The Tharus are a tribal Tibetan-related people that originally inhabited the eastern zone of the Terai, along the border with Nepal. They are subdivided into many sub-tribes, although a majority of them live in Nainital (now Udham Singh Nagar). As agriculturalists, Tharus tend to have large families that live communally, and it is traditional for brothers to live under one roof. Tharus observe ancient beliefs and like others in the hills, subscribe to shamanism, but also worship Hindu Gods. Tharu women, in claiming their descent from Rajput Ranis of Chittor, enjoy a high position in their society, as they tend to play a dominant role in family affairs.

Raji: The Rajis, also know as Vanrawats (forest lords) are few in number and live in the forest. They inhabit the woods around Askot in southern Pithoragarh, and hold to a tradition of saluting no one except the Askot Raja. They once practiced shifting cultivation until it was banned by the forest department. Although their agriculture was never well developed, they subsisted on the products of the forests, from edible roots to fruits to the crafting of wooden utensils to trade for other commodities.

The state has approximately 64% geographical area under the category of forests. This is well above national land use policy that prescribes at least 33% forest area for the country as a whole. The net sown area for food grain production in the state comes to about 12.42%. Uttarkashi recorded maximum forest area (726,290 ha). All the districts of Uttarakhand have more than 50% of forest land in their respective reporting area. Nainital is the only district which shows a significant amount of net sown area (204,317 ha) mainly concentrated in Tarai region of the district.

Plate- 2.1 Habitat Types

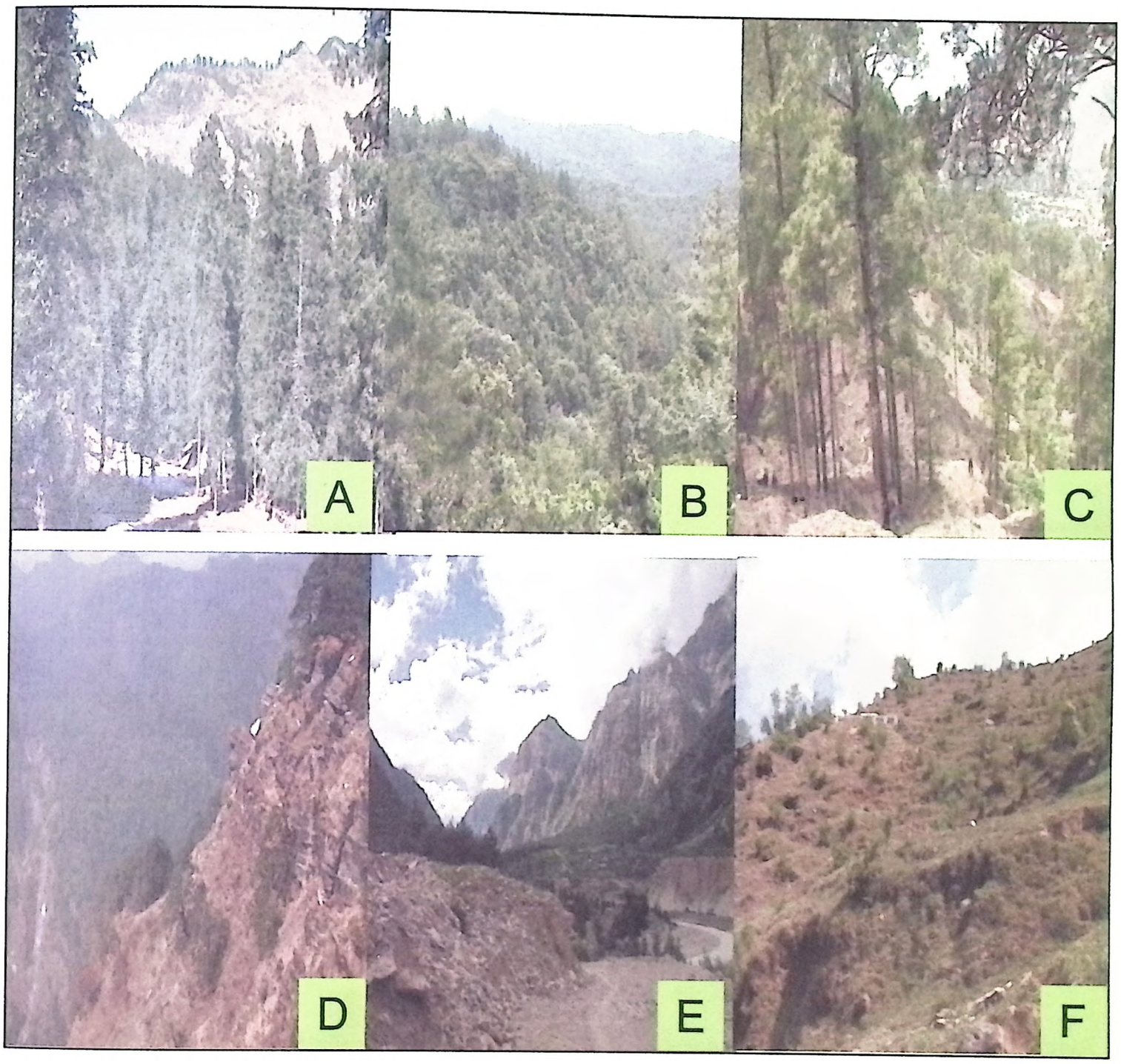

Plate 2.1: **A**- Deodar forest near Deovan, Chakrata; **B**- Banj mixed forest near Chawrangikhal; **C**: Chir forest near Rudraprayag; **D**- Temperate grassy slope at Humidhura, near Munsiyari; **E**- Fir forest near Garbyang; **F**- Open scrub land at temperate zone, Namik.

Plate- 2.2 Habitat Types

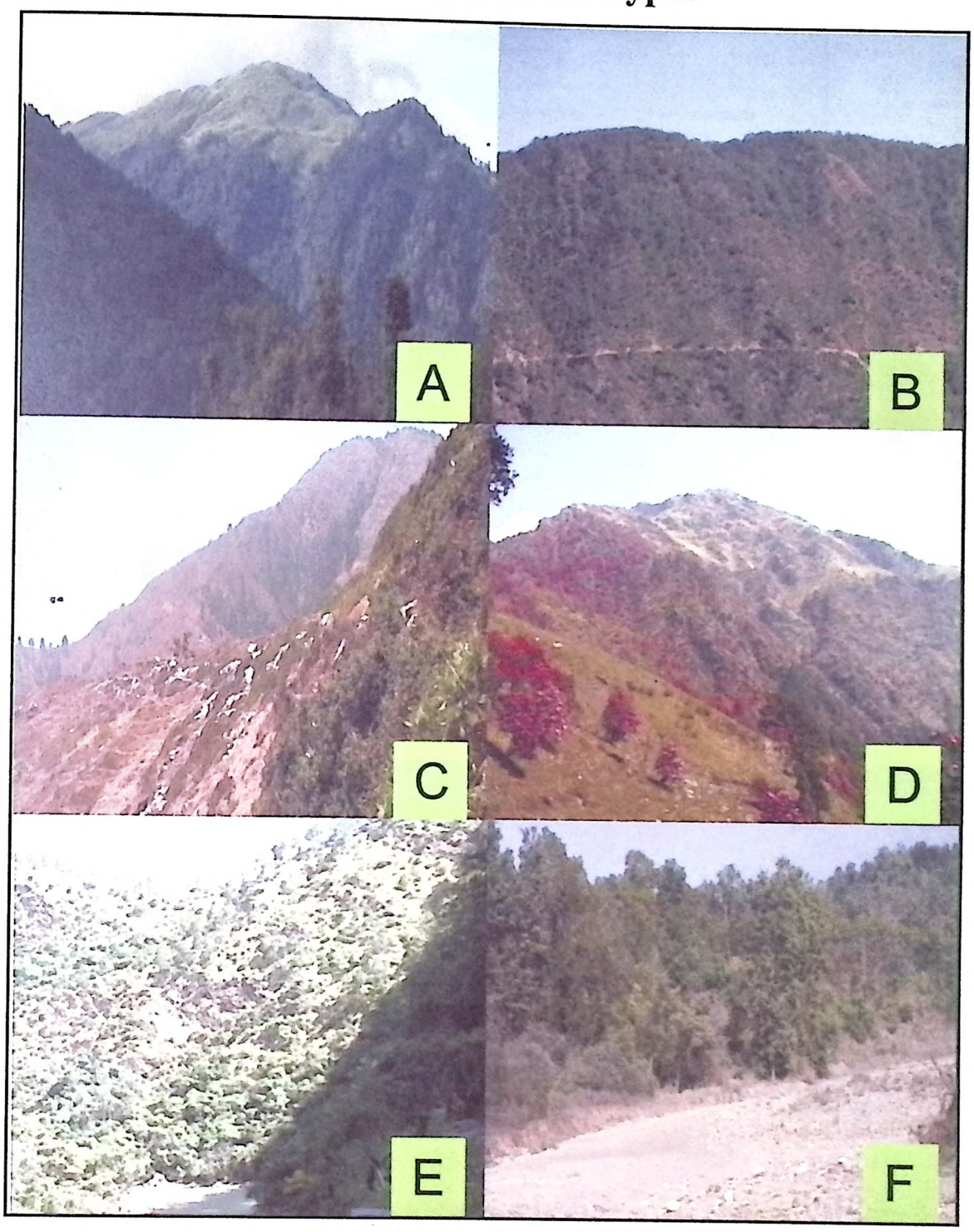

Plate 2.2: **A**- Kharsu oak forest below Pawali kantha; **B**- Banj Oak forest near Kandikhal; **C**: Temperate scrub land near Muniyalikhet; **D**- Subalpine Kharsu-Buras mixed forest at Khuliya Top near Munsiyari; **E**- Lower Mixed forest near Narayanbagad, Pinder valley; **F**- Sal forest Shyampur, Haridwar.

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Chapter 3: Systematics Studies

CHAPTER 3.0
SYSTEMATICS STUDIES

When solving problems, dig at the roots instead of just hacking at the leaves.

-Anthony J. D'Angelo

3.1 Morphological Diversity of Berberidaceae

The family exhibits great morphological variability, particularly in its habit and habitats, size, shape, types of inflorescence, relative length of sepals and petals. The state of Uttarakhand is representing two genera from Berberidaceae *i.e.*, *Berberis* and *Mahonia*. A general description of the plant morphology in the family is given below:

3.1.1 The Stem: In *Mahonia* the stem is generally scaly and green at first turning to brownish grey at maturity. In *Berberis*, the young shoots of the current year are generally greenish, often flushed with slight reddish tinge on the sun facing side. At the maturity, most of the *Berberis* stem turn ashy grey. In *Berberis* species the stem are either terete or sulcate (Figure 3.1 A and B). *Mahonia* stems are spineless while *Berberis* species invariably bear trident spines. Spines may be occasionally single or absent.

3.1.2 The Leaves: *Simple or compound: Berberis* and *Mahonia* bear simple and compound leaves respectively. In *Mahonia,* the number of leaflets comprising the pinnate leaf is an easily recognizable diagnostic character. *Berberis* leaves are arranged in fascicles or whorls, each of which is attached at a node and protected by the spines. The whorl of *Berberis* leaves is said to derive from pinnate leaf, in which the leaflet, internodes and rachis have been eliminated (Ahrendt 1961). Similarly, further metamorphosis of these simple leaves has been regarded as producing, first the foliaceous spine, then the palmate spines, then the manifold, and finally the trifid group of spines, sometimes called spine leaves (Figure 3.1 C-H). Thus, the number of leaves, or the number of leaves and spines taken together in each whorl at a *Berberis* stem node corresponds to the number of leaflets in the pinnate leaf of a *Mahonia* (Figure 3.1 G).

Leaf persistence: All Mahonias are evergreen. However, in case of *Berberis,* leaf persistence (evergreen or deciduous) had been used as a primary taxonomic character. Ahrendt (1961) stated that the sub-sections Asiaticae and Tinctoriae, *e.g.*, *Berberis lycium, B. asiatica, B. floribunda* and *B. umbellata* remain evergreen in mid winters. *B. concinna* and *B. kumaonensis* amongst the deciduous species of sub-section Angulosae.

Texture of leaves: Evergreen leaves are more or less coriaceous. Sometimes they are markedly thick and rigid with a distinct hypoderm, but sometimes it may be indistinct. Alternatively, they may be without hypoderm, marked by thin texture, and more flexible. *Mahonia* with more or less thick leaves has distinct hypoderm and form a natural group. In *Berberis* this character occurs in a number of American species, but otherwise only in some species of the Section Wallichianae. Schneider (1905) used this character for diagnostic purposes and divided the Wallichianae, in his key, into three parts characterized by the hypoderm being distinct, indistinct or absent.

Leaf base: (a) In Mahonias, the base of the leaflets is often sub-cordate (slightly overlapping the rachis) or truncate (lying along the rachis) *e.g.*, *M. napaulensis* (Figure 3.1 J). (b) Evergreen species of *Berberis* with, on occasion, a short decurrent petiole, up to 3 - 4 mm long *e.g.*, *B. pachyacantha* and *B. petiolaris* var. *garhwalana* (Figure 3.1 E). (c) Deciduous of *Berberis* mostly has sessile or very shortly petiolate leaves or at times decurrent petiole. *e.g.*, *B. lambertii*, *B. jaeschkeana* and *B. kumaonensis etc.*

Leaf margins: The margins of *Berberis* leaves and *Mahonia* leaflets are often spinose-toothed, and may classified in three groups.

(a) Margins quite entire, or at least typically so *e.g.*, *B. osmastonii*, *B lambertii* and *B. rawatii* (Figure 3.1 C), (b) Margins sparsely or remotely toothed *e.g.*, *B. asiatica*, *B. lycium*, *B. kumaonensis* and *Mahonia napaulensis* (Figure 3.1 D, F, G, H, I and J), (c) Margins densely spinose; *i.e.* the teeth numbering 1-50 (-100) according to size of leaf *e.g.*, *B. pachyacantha* and *B. petiolaris* var. *garhwalana*. (Figure 3.1 E).

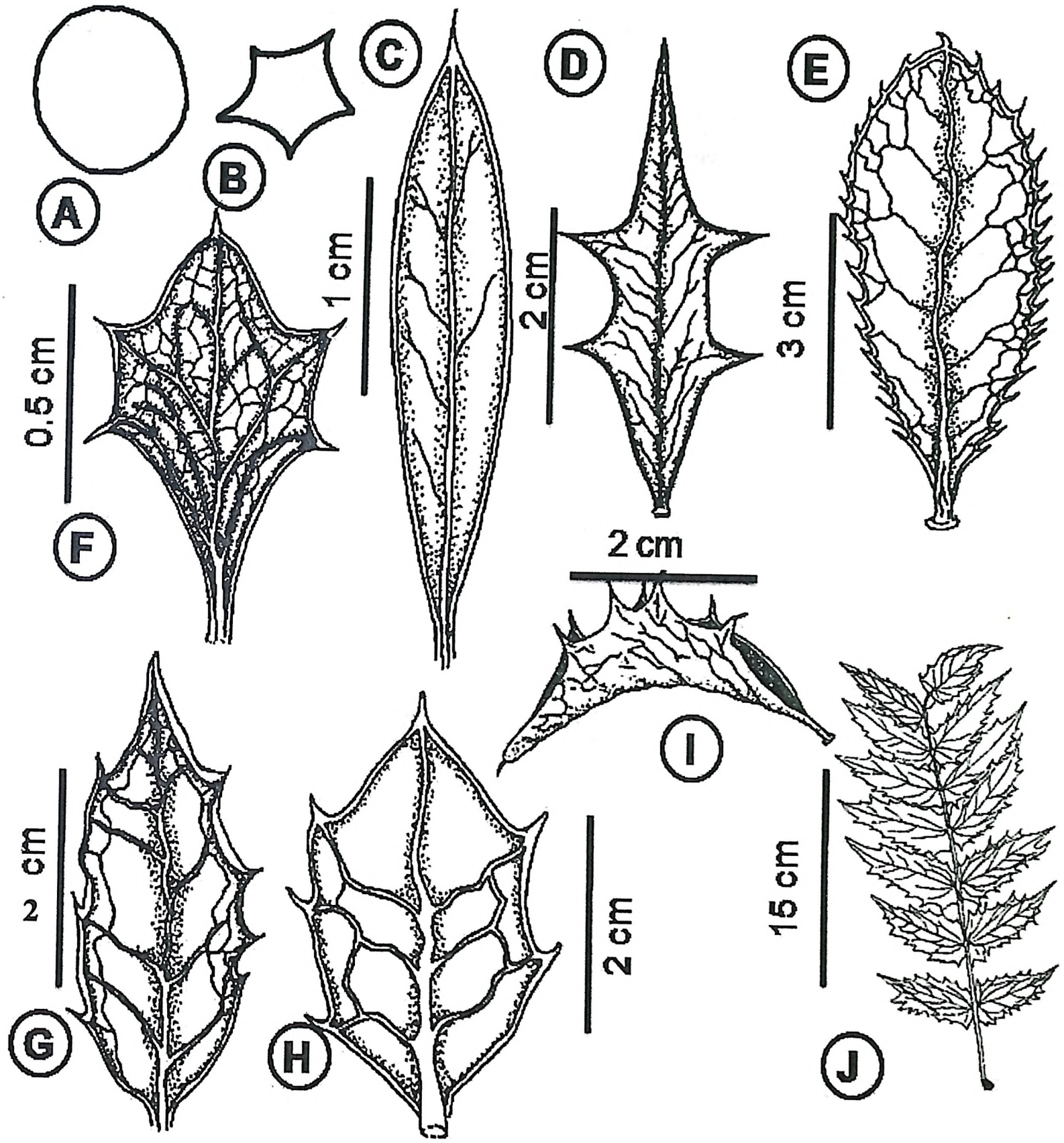

Figure 3.1. Stem – Terete (**A**) or Sulcate (**B**); Leaves: Simple – 1. Margins quite entire (**C**: *B. rawatii*); 2. Margins sparsely toothed (**D, F, G, H and I**); 3. Margins densely spinose (**E**: *B. pachyacantha* and *B. petiolaris* var. *garhwalana*); Leaves: Compound: Margin densely spinulose (**J:** *Mahonia napaulensis*).

3.1.3 Inflorescence: The following forms may be distinguished: **(a)** *Flowers solitary*: When the apical or axillary buds form single flower *e.g. Berberis kumaonensis* and *Berberis osmastonii.* (Figure 3.2 I and F), **(b)** *Flowers fascicled*: This is special types of cymose corymb. The flowers are very much clustering together *e.g. Berberis rawatii.* (Figure 3.2 J), **(c)** *Inflorescence umbellate*: The perfect umbel rarely occurs, but there is often a sub-umbellate form in which the pedicels spring from a short length of the stem, leaving a distinct peduncle below (Sects. Angulosae, some Tinctoriae, *etc.*) *e.g. Berberis umbellata.* (Figure 3.2 E), **(d)** *Inflorescence racemose - pseudumbellate*: Here the rachis from which the flowers spring is longer, the number of flowers increased, and the lower pedicels lengthened. The flowers having become pendulous, the inflorescence tends towards a raceme while still retaining the appearance of an umbel-like form *e.g.*, *Berberis pseudumbellata* (Figure 3.2 A and H), **(e)** *Inflorescence racemose*: The formal raceme, sometimes slightly compound below *e.g.*, *Berberis coriaria*, *Berberis glaucocarpa*, *Berberis ahrendtii etc.* (Figure 3.2 C, G and K), **(f)** *Inflorescence paniculate*: This appears in the Asiatic deciduous Sect. Polyanthae an interesting, distinct form is presented by *B. chitria* and *B. koehneana,* where the inflorescence is paniculate in its branching (Fig 3.2 D), **(g)** *Fascicled group of narrow slender racemes*: exhibited by *Mahonia* spp. 3-20 racemes in the inflorescence (Figure 3.2 L).

3.1.4 The Flower:

The flowers consist of prophylls (or bracteoles), sepals, petals, stamens and ovary (Figure 3.3 A i to iv).

Bracts: The bracts of the flowers in *Berberis* found at the base of the pedicels. They are mostly reddish, triangular, and vary from 1 to 4 mm in length. In certain species the bracts are of diagnostic value, where they are as long as or even slightly longer than pedicels. This character appears in certain species of the Sect. Polyanthae (with paniculate inflorescence) *e.g.*, *B. kunawurensis* on account of their short pedicels, have spike-like racemes which possess a prickly appearance in bud due to the protruding points of the bracts. The bracts at the bases of the pedicels to the flowers

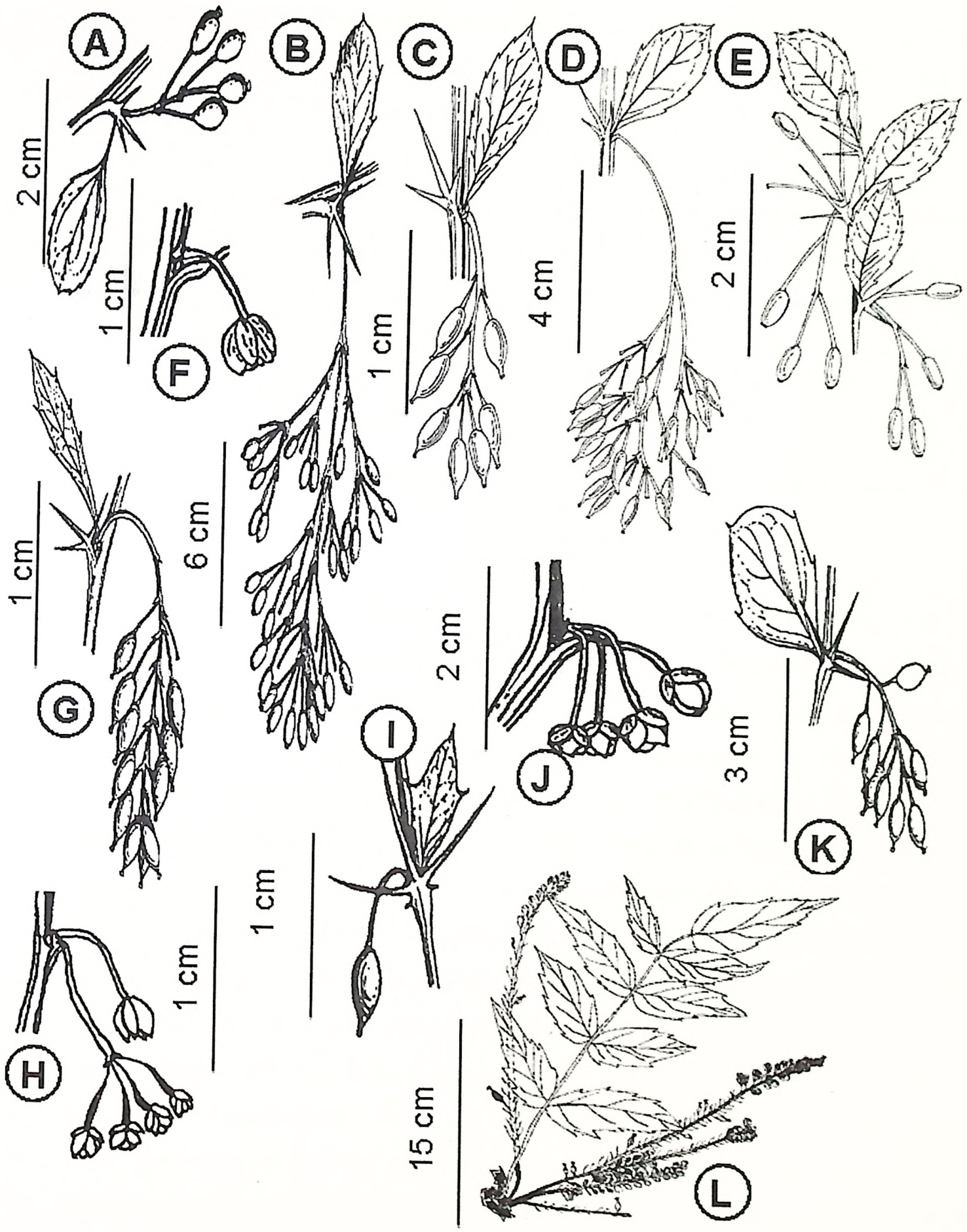

Figure 3.2. Inflorescence – 1. Racemose (**C**: *B. coriaria*; **G**: *B. ahrendtii* and **K**: *Berberis glaucocarpa*); 2. Umbellate and Subumbellate (**A** and **H**: *B. pseudumbellata*; **E**: *B. umbellata*); 3. Loosely corymbose paniculate (**B**: *B. koehneana* and **D**: *B. chitria*); 4. Solitary (**F**: *B. osmastonii* and **I**: *B. kumaonensis*); 5. Facicled (**J**: *B. rawatii*); 6. Facicled racemes (*Mahonia napaulensis*).

of *Mahonia* may be divided into two categories *viz.,* **(a)** Bracts distinctly longer than the pedicels, *i.e.* 3-5mm (*e.g.*, *Mahonia jaunsarensis*). **(b)** Bracts about as long as the pedicel, *i.e.* 2x1.25 cm (*e.g.*, *Mahonia napaulensis*).

Flower size: Three sizes, partly concurrent with other characters may be recognized. (a) Flowers abnormally small, 3-5 mm across., with the longest component with 2-3 mm long, (b) Flowers of normal size, 7-12 mm across, with the longest component with 4-6 mm long, (c) Flowers abnormally large 1.4-2 cm across, with the longest component 7-10 mm long.

Flower colour: In all the Asiatic species of *Berberis* and generally in the *Mahonia* is pure yellow coloured.

Bracteoles or Prophylls: At the apices of the pedicels in *Berberis*, 1-2 or occasionally 3 bracteoles are appressed to the calyx. The bracteoles are lanceolate or shortly triangular, and acute or acuminate, generally reddish, greenish or partly yellow. Most species possess bracteolate flowers. Sometimes the bracteoles are purely yellow and sepaloid in nature, though still very small and prophylloid in form. When this is so the flowers appear quite yellow beneath, the first sight as if they were without bracteoles, and may be called pseudobracteolate. There are, finally, a certain species with genuinely ebracteolate flowers, a character generally associated with the large-flowered species of the *Angulosae,* but found elsewhere as well. Ebracteolate flowers present, when viewed from below, or in bud, a clean, unbroken, yellow aspect, and the outer components are either (a) small sepals (*e.g.*, *B. concinna*) (Ahrendt 1961) which are larger, as well as different in shape from, pseudoprophylls, or (b) large sepals, often almost as large as the inner ones (*e.g.*, *B. kumaonensis, B. osmastonii* and *B. rawatii).* When, however, the flowers are truly bracteolate, the yellow appearance from below is broken by the green or red colour of the prophylls, which is often ornamental when the flower is in bud, and the prophylls are prominent (Figure 3.3 B i and ii). Bracteoles or Prophylls are absent in the Species of *Mahonia* found in Uttarakhand.

Confusion between bracteoles and outer sepals: In case of *Berberis* species, different authors or even the same author at different times, have indiscriminately and interchangeably used term bracteoles for outer sepals leading to confusion. Sometimes outer sepals were referred as prophylls. If, the generally small outer sepals of *Mahonia*, classed as prophylls, the majority of them would grouped under *Berberis*. Some botanists might consider this a reason for regarding the outer components of the *Mahonia* flowers as prophylls. However, although some outer sepals are somewhat prophylloid in nature, it is generally possible, after experience in examining the flowers, to make a satisfactory distinction. Whereas, the prophylls are nearly always 1 or 2 in number, and triangular and acuminate, the small outer sepals in a whorl of three, are ovate, and acute (Figure 3.3 B i).

3.1.5 Sepals: The sepals are generally in two whorls, of three each. In a number of species, there are three such series, each of three sepals. In most species of *Berberis* the inner sepals are longer than the petals, and it is then generally found that the outer are between one-half and two-thirds as long as the inner sepals. The sepals of the outer may be distinctly smaller than those of the two equal inner whorls, as in *B. concinna* (Ahrendt 1961). Then again, the median sepals may be intermediate in size between those of the outer and inner whorls, so that the three whorls form a regular gradation in size, *e.g.*, in *B. kumaonensis.* The outer sepals are generally ovate and acute or sub-acute, and the inner sepals obovate and rounded (Figure 3.3 B ii). In rare and extreme example both outer and inner sepals may be very acute or even sub-acuminate. In a number of *Mahonia* species, there are three such series, each of three sepals, as Takeda (1917) has pointed out, almost invariably in three whorls.

3.1.6 Petals: The petals are longer than the outer sepals, generally obovate and rounded, and emarginated. (Figure 3.3 B ii and vii). However, there are exceptions in certain species. The bases of the petals may be either clawed, cuneate and truncate (Figure 3.3 B iii and iv). Those that are clawed may be slightly, broadly, narrowly or conspicuously so. This feature, though recorded wherever possible, and generally constant within a species, has not used in diagnosis of species. At the base, there are always present two glands, which easily distinguish the petals from the sepals.

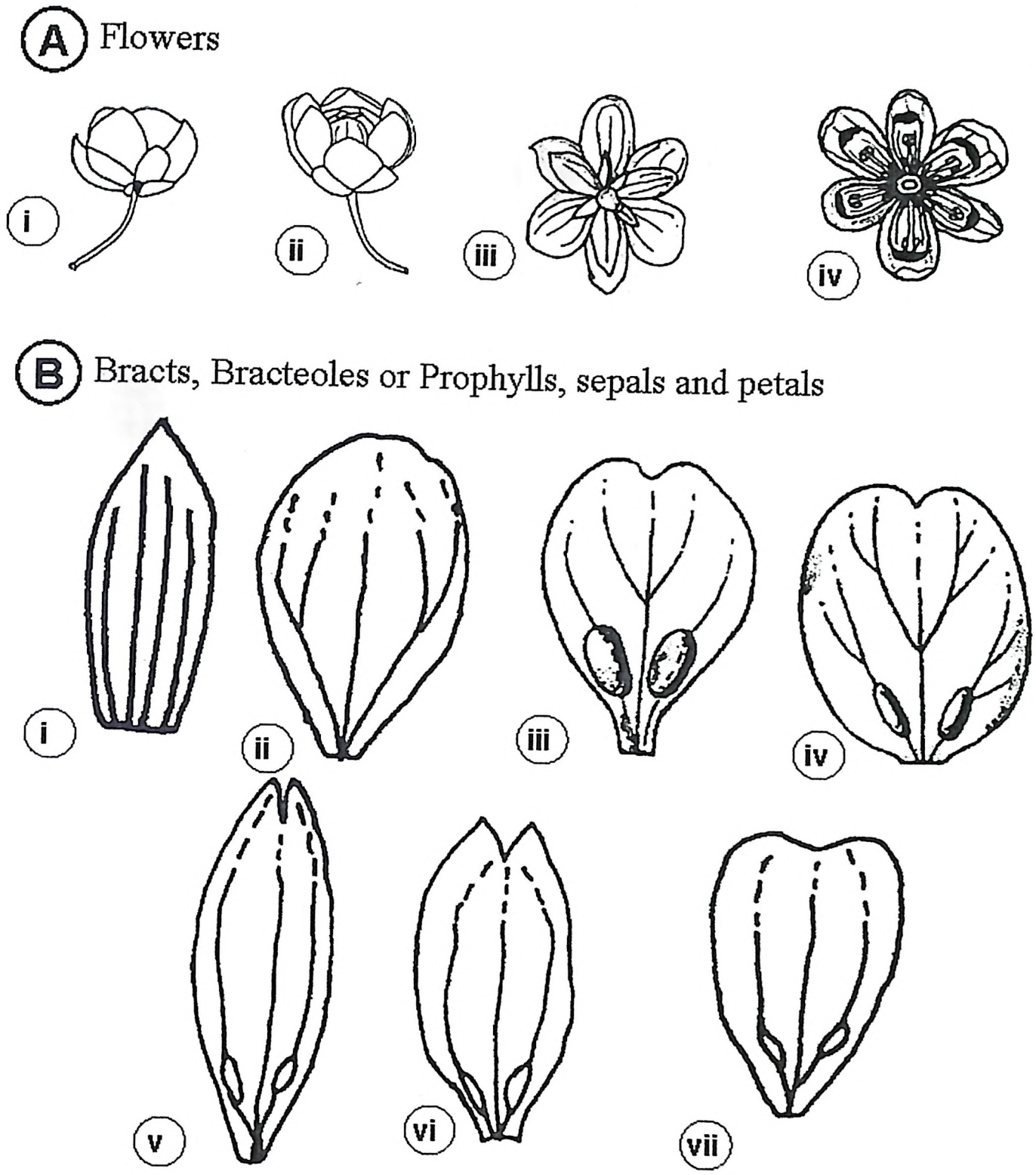

Figure 3.3. **A:** Flower:- (i- side view close of flower; ii- front view close of flower; iii- back view of open flower and iv- top view of flower); **B**: Floral parts:- (i- ovate acute apex or triangular acuminate; ii- rounded entire apex; iii- Petal- clawed base; iv- petal- truncate or cuneate base with oblong-elliptic glands; v- ovate, acute narrowly incised apex with lanceolate glands; vi- ovate elliptic, acutely emarginated acute lobes narrowly lanceolate glands; vii- obtusely emarginated obtuse lobes).

The apex of the petals may be entire or emarginate. The form of the emarginate apex varies that may be acutely emarginated (Figure 3.3 B vi), shallowly retuse (Figure 3.3 B iv), or

narrowly incised (Figure 3.3 B v). In each case the surrounding protecting lobes of the petal may be either acute (apex biapiculate) or obtuse (Figure 3.3 B iii to vii). In the genus *Mahonia,* the emarginate petal is even more predominant, there being recorded two species with entire petals (Figure 3.3 B ii).

The glands are either sub-concolorous (at most a slightly deeper yellow than the petals), or more or less conspicuously discolorous (orange). The shape of the glands varies from narrowly lanceolate, through normal oblong or elliptic, to orbicular shapes (Figure 3.3 B iii-vii). Their length (0-3 - 1.5 mm) is from one-tenth to one-fifth the length of the petals. In extreme examples they are contiguous and centrally placed or widely separated and actually on the margin of the petal. Generally, they are moderately separated and non-marginal. They may be either within the basal claw, if this exists, or above it, but are always within the basal third of the petal. The glands and basal character of the claw, though constant, have rarely used as a specific discriminating character.

In earlier literature on Berberidaceae (*e.g.*, Hooker 1875; Schneider 1905 and Takeda 1917), it has been stated that the petals of *Mahonia* have no glands, and this was cited as one of the bases of discrimination between the genera *Berberis* and *Mahonia.* This is far from accurate. The origin of the misconception appears to be that, in many species, the glands are very indistinct and therefore apt to overlook. However; Many species, have quite distinct, and some conspicuous, glands, as in *Berberis*.

3.1.7 Androecium

The stamens and the petals attached separately on thalamus. The stamens are generally about two-thirds as long as the petals and their length used rarely in specific discrimination. In the Asiatic sections, Asiaticae and Tinctoriae the stamens are somewhat swollen, in a slight, gentle curve, below the anthers (Figure 3.4 A- i to iv). The stamens of *Mahonia* may be classified in the same way as those of *Berberis*.

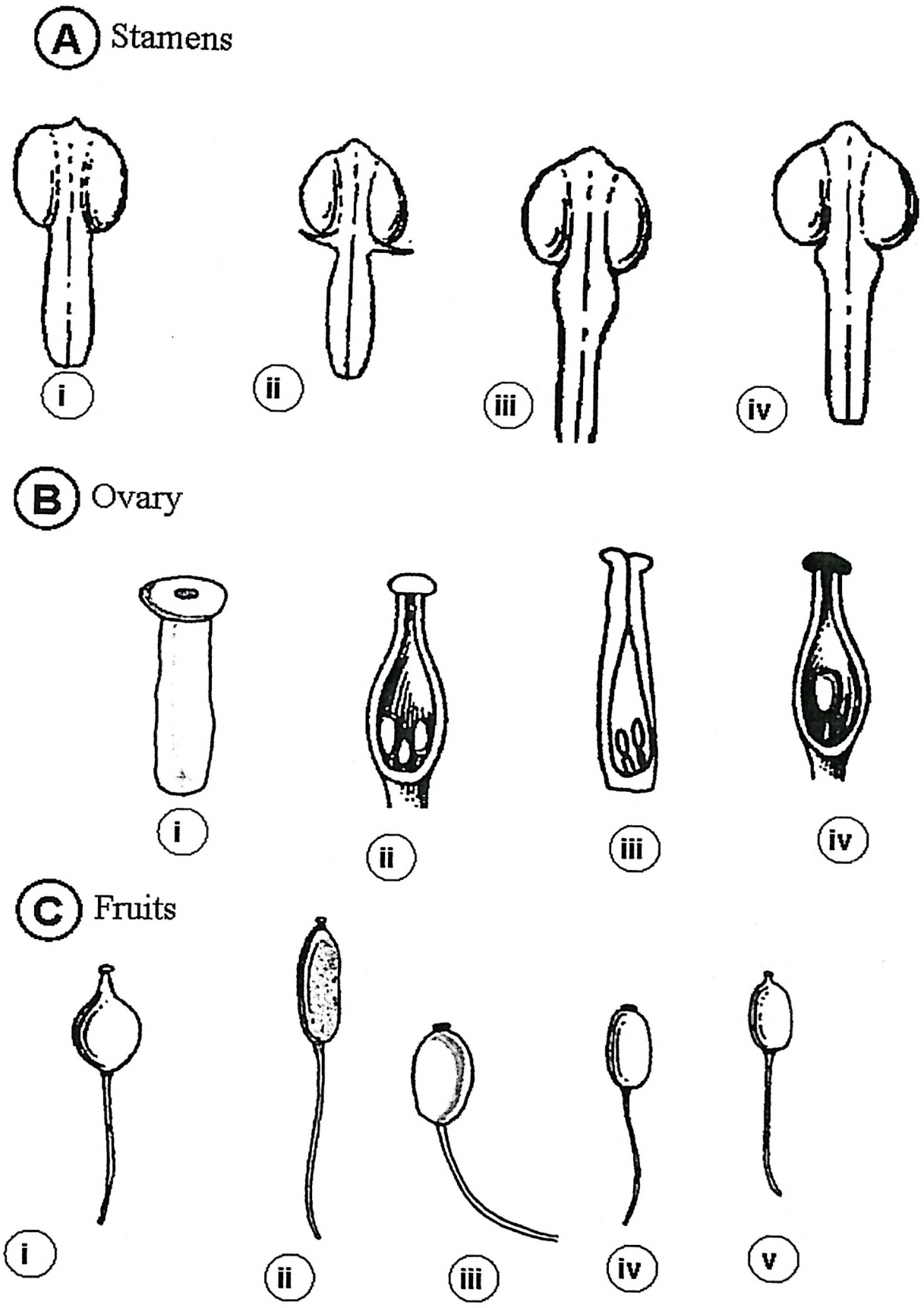

Figure 3.4. **A: Stamens**-shortly apiculate, edentate (i- *B. osmastonii*); conspicuously lanceolate, dentate (ii- *B. chitria*); slightly swollen, not dentate (iii- *M. napaulensis*); apex slightly apiculate, shortly dentate (iv- *B. aristata*); **B: Ovary**-oblong, estylose (i- *B. conccina* var. *breviora*); L.S. of ovary six ovules subsessile (ii); four ovules with disc shaped stigma (iii- *B. aristata*); solitary ovules with stalk (iv); **C: Fruit-** globose with long style (i- *B. osmastonii* and *B. rawatii*); elliptic narrowly oblong with distinct short style (ii- *B. chitria*); ovoid, estylose (iii- *B. pachyacantha*); oblong, estylose (iv- *B. kunawurensis*); berries ovoid with short style (v- *B. asiatica, B. lycium* and *B. aristata*).

3.1.8 Gynoecium

The ovary contains 1-8 (-15), or occasionally, more ovules. While the number of ovules is not actually constant in the species (Figure 3.4 B ii to iv). The style, which may absent from or present on the ovary, is persistent, and more easily discernible in the berry. Three types may distinguished: **(a)** Style, absent or so short, indefinite and indistinct that it may disregarded *e.g. Berberis umbellata* and *B. kunawurensis* (Figure 3.4 C iii and iv). **(b)** Style, distinct but not more than 0-5-0.75 (1) mm long *e.g. Berberis asiatica, B.aristata, B. chitria* (Figure 3.4 C ii and v) **(c)** Style elongated (1) 1-3 (5) mm long. Styles that are 2-5 mm. long when fully extended do not occur in the Asiatic species which, however, include a few in which the style is as much as 1.5mm long, *e.g. B. osmastonii* (Figure 3.4 C i).

3.1.9 Fruit

The following colour variations may be recognized. (a) Species with red, dark red or reddish purple berries (b) Species with black berries, with or without bloom. In *Mahonia* all the species appear to have black fruit (mostly pruinose). Red berries are predominantly epruinose, but there are a few species where red berries are covered with bloom, *e.g. B. umbellata, B. aristata* and *B. jaeschkeana.* Some of the *Berberis* species show a conspicuous white bloom, *e.g. B. asiatica, B. lycium*. In *Mahonia*, berries, almost all black, are also predominantly heavily pruinose.

Seeds: The seeds are from 1.5 to about **7** mm (mostly about 3 4 mm) long. With reference to their colour, the seeds may be either (a) dark, *i.e.*, dark red, red-purple or black, or (b) pale, *i.e.*, pale yellow, yellow-brown, or occasionally pale reddish yellow.

3.2 Review of Literature

The family Berberidaceae was first established by A. L. de Jussieu (1789) as 'Berberides' and was considered one of the most primitive groups of Angiosperms. A revision of the genus *Berberis* was done by Schneider (1905 and 1908), who recorded 13 new species and

one variety from Indian region. Fedde (1902) published first monographic work on Genus *Mahonia*. This was followed by a detailed work genus *Mahonia* by Takeda (1917), who reported 44 species from of old world and Ahrendt (1942-45) had published a monograph of section *Wallichianae* in which he recognized 71 species in eight subsections, Ahrendt (1945) surveyed the *Berberis* spp. from Bhutan, Assam, South Tibet, Upper Burma and North West Yunnan, and later Ahrendt (1961) published a detailed world revision of species of *Berberis* and *Mahonia*.

In a more recent study, Chamberlain and Hu (1975) revised section *Wallichianae* and treated 11 species, including one new species *Berberis victoriana* from Indian region. Jafari (1975), in *Flora of West Pakistan* included only one species of *Mahonia* and 15 species of *Berberis* from Kashmir region. Landrum (1999) while doing work on 'Revision of *Berberis* (Berberidaceae) in Chile and Adjacent Southern Argentina, had reported 22 species of *Berberis* were identified from continental Chile, the Juan Fernandez Islands, and adjacent southern Argentina and none of the species are common with Asian species.

Hooker (1875), for the first time compiled the taxonomic information available until then for Berberidaceae in India. He had vast field knowledge and deep understanding of Indian Berberidaceae as he spent several years in North-eastern India. He included six genera and 17 species under this family in his monumental work 'Flora of British India'. However, this treatment considered too general and subsequent workers split up these species into 17 taxa and added many more taxa which are new.

Chatterjee (1953) included 68 species of *Berberis*, 11 species of *Mahonia*, one species of *Epimedium* and 2 species of *Podophyllum* in this family from India. While Ahrendt (1961) reported 52 species of *Berberis* and 11 species of *Mahonia* from Indian region. Several other floristic work done in different parts of India, Collett (1902) while doing flora of Simla district, had reported five species of *Berberis* and one species of *Podophyllum*. Kachroo et al. (1977) while doing flora of Ladakh, had reported two species of *Berberis* and one species of *Podophyllum*. Rao and Hajra (1993) while treating the family for the *Flora of India* included 54 species of *Berberis*, one species of *Epimedium* and 13 species of *Mahonia* from

the Indian region. Aswal and Mehrotra (1994) recorded four species of *Berberis* from Lahul-spiti district of Himachal Pradesh. A recent work carried out by Rao et al. (1998 a and b) reported 55 species of *Berberis* in India. Among all the Himalayan states, Uttarakhand has the highest number of species (29 including sub-species). The number of *Berberis* species (including sub-species) in Pakistan, Jammu and Kashmir, Himachal Pradesh and Sikkim are 24, 25, 23 and 16 respectively (Jafari 1975, Rao et al. 1998 a and b).

There has not been any systematic study on Berberidaceae in Uttarakhand. General collection of plants including Berberidaceae, mentioned in various treatises. Collection of Strachey and Winterbottom that was revised by Duthie (1903-1929) recorded two species of *Holboellia* and 11 species of *Berberis*, Osmaston (1927) reported 13 species of *Berberis*, one species of *Mahonia* and two species of *Holboellia* in his Forest Flora of Kumaon. Naithani (1984) had reported 11 species of *Berberis* and one species of *Mahonia* from Chamoli District of Uttarakhand. While enumerating the plant wealth of Nanda Devi Biosphere Reserve (Hajara 1983, Hajra and Balodi 1995 and Samant 1999) had reported seven species of *Berberis* from the vicinity. In flora of Garhwal by Gaur (1999) had reported six species of *Berberis* and one species of *Mahonia* from the Pauri district in state. Rana et al. (2003) while dealing with flora of Tons valley had reported eight species of *Berberis* and one species of *Mahonia*. Kala and Rawat (2004) while doing work near by Valley of Flower national Park they had reported 4 species *Berberis*. 29 taxa of *Berberis* and 4 species of *Mahonia* are reported from Uttarakhand by Uniyal et al. (2007). Recently, *Berberis rawatii* sp. nov. has been described by Tiwari and Adhikari (2011) from Uttarakhand.

All these taxonomic works in Uttarakhand give a brief account on the occurrence, altitudinal range, habitat and phenology of Berberidaceae. However, most of these works either are on past collections or on based on short surveys. Hence, this study was undertaken with a view to bring out a comprehensive account on taxonomy of Berberidaceae of Uttarakhand.

3.3 Methodology

Systematic survey and collection of Berberidaceae members was conducted in different seasons in different forested areas of the study area following Jain and Rao (1977). Morphological studies was done by collecting fresh samples and studying Herbarium specimens at various Herbaria such as, KEW (K), National history Museum (BM), Vienna (W), WII, CAL, LKW, BSD and DD. Doubtful species, sub species and varieties were thoroughly studied to differentiate them from each other. An attempt made to simplify the taxonomy of the family Berberidaceae. User-friendly taxonomic keys were prepared based on vegetative as well as floral characters to aid field identification for various users including non-botanists. Cluster analysis was used to analyses and see clusters from more similar (in some sense or another) to each other's than to those in other clusters of species (Sibon 1973).

3.4 Results

3.4.1 Systematics Treatment of Berberidaceae in Uttarakhand

The detailed description starts with the classification of the family, followed by author citation and subsequent publications. This is follows description of the family and its distribution followed by type species, then key to Berberidaceae genera in Uttarakhand. The genus *Berberis* follows later start with author citations and subsequent publications, followed by generic description and distribution across the world. This is followed by key description of *Berberis* in Uttarakhand. Species description follows this, which starts with updated names with authors citations followed by its usage by subsequent authors in various practice, followed by basionyms if any then homotipic synonyms and hetrotipic synonyms. These are followed by information of type if known by the author and then the detailed description followed by flowering and fruiting period, distribution in world, India and state, ecology, additional specimen examined and taxonomic notes. During the herbaria, work only those type specimens are studied which are deposited in India especially at **CAL** (Howrah) and **DD** (Forest Research Institute, Dehra Dun) and **BSD** (Botanical Survey of

India, Dehra Dun). Type specimens are studied and collected which are preserved outside India or in India, either the copy of the protologue was acquired from BM, K and W or they have been quoted from standard references. Taxonomic noted deals with some critical notes and variation studied in species, which seems to be considerable taxonomically. Ecological notes gives in a small description of the habitat in which the species usually found growing in wild condition. Distribution of the species gives the distribution in Uttarakhand, India, world and endemic if they are. Author citations of books and journals have been used following Kew's website (**www.rbgkew.org.uk**) and **www.ipni.org** and following Brummitt and Powell (1992).

3.4.2 Systematic Position

Berberidaceae is the primitive group of plants belonging to the order Ranunculaes of Angiosperms.

Kingdom : Plantae
Division : Magnoliophyta
Class : Magnoliopsida
Order : Ranunculales
Family : Berberidaceae

BERBERIDACEAE JUSS., nom. cons.

Gen. Pl.: 286, 1789 (Berberides); Hook. f., Fl. Brit. India: 1: 107-113, 1875 (Berberideae); Sharma et al., Flora of India, 1: 351-413, 1993. Type: *Berberis* L.

Shrubs, evergreen or deciduous, sometimes rhizomatous or tuberous. Stems with or without spines. Leaves alternate, simple, or 1–3 × pinnately or 2–3 × ternately compound; stipules present or absent; venation pinnate or palmate. Inflorescences terminal or axillary racemes, spikes, umbels, cymes, or panicles, or flowers fascicled or solitary. Flowers pedicellate or sessile, bisexual, radially symmetric; bracteoles or bracts present or absent. Perianth usually 2- or 3- merous, rarely absent. Sepals 6-9, often petaloid, distinct, in 2 or 3 whorls. Petals 6, distinct, flat, hooded, pouched; nectar present. Stamens 6, opposite petals; anthers 2- celled,

dehiscing by valves or longitudinal silts. Ovary superior, apparently 1- carpellate; ovules numerous, rarely solitary; placentation marginal or appearing basal; style present or absent, sometimes persistent in fruit as a beak. Fruit a berry. Seeds 1 to 8, sometimes arillate; endosperm copious, fleshy or horny.

Table 3.1 Classification of Berberidaceae of Uttarakhand following Ahrendt (1961)

Family	Sections	Sub-sections	Species
Berberidaceae	Tinctoriae	Chitriae	*Berberis affinis*
			Berberis aristata
			Berberis chitria
			Berberis coriaria var. *coriaria*
			Berberis coriaria var. *patula*
			Berberis floribunda
			Berberis macracantha
		Eutinctorie	*Berberis petiolaris* var. *extensa*
			Berberis petiolaris var. *garhwalana*
		Umbellatae	*Berberis umbellata*
	Asiaticae		*Berberis ahrendtii*
			Berberis asiatica
			Berberis glaucocarpa
			Berberis lycium var. *lycium*
			Berberis lycium var. *simlensis*
			Berberis lycium var. *subfacicularis*
			Berberis lycium var. *subvirescens*
	Angulosae	Euangulosae	*Berberis concinna* var. *breviora*
			Berberis kumaonensis
		Jaeschkeane	*Berberis apiculata*
			Berberis hamiltoniana
			Berberis jaeschkeana var. *jaeschkeana*
			Berberis jaeschkeana var. *usteriana*
			Berberis lambertii
			Berberis osmastonii
	Vulgares		*Berberis pachyacantha* var. *pachyacantha*
			Berberis pachyacantha var. *zebeliana*
	Polyanthae		*Berberis koehneana*
			Berberis kunawurensis
	Hetropodae	Creticae	*Berberis cretica*
			Berberis rawatii
		Pseudoumbellatae	*Berberis pseudoumbellata*
	Longibracteatae	Acanthifoliae	*Mahonia acanthifolia*
			Mahonia borealis
			Mahonia jaunsarensis
		Napaulenses	*Mahonia napaulensis*

Seventeen genera and *ca* 650 species distributed mainly in the north temperate zone and on subtropical mountains. In India it is represented by 3 genera and 68 species, and 10 sections. In Uttarakhand family is represented by 7 sections (Table 3.1).

3.4.2.1 Key to the Berberidaceae Genera of Uttarakhand

1. Stem usually spiny; leaves simple; sepals usually in two series or whorls.....1. *Berberis*
1. Stem unarmed; leaves imparipinnate; sepals usually in three series.....2. *Mahonia*

3.4.2.2 Description of Berberidaceae Species

1. BERBERIS L.

Sp. Pl. 330. 1753; Gen. Pl. ed. 5:153. 1754; Gen. Pl.: 286, 1789; Boiss., Fl. Orient. 1:102. 1867; Schneid in Bull. Herb. Boiss. Ser. 28, 5:33. 48, 133-148, 391-403, 449-464, 655-670 and 800-812. 1905; Ahrendt in J. Linn. Soc. Bot. 57: 1-410. 1961; Fedtschenko in Kom., Fl. U.S.S.R. 7: 553. 1937; Chatterjee in Rec. Bot. Surv. India 16(2): 1-86. 1953; Parker, For. Punjab ed. 3: 1 i. 1918; Jafari in Nasir and Ali, Fl. W. Pakistan 87: 4-31. 1975; Grierson and Long in Fl. Bhutan 1(2): 322-327. 1984; Chamberlain and Hu in Notes Roy. Bot. Gard. Edinburgh 42(3): 529-557. 1985; Rao and Hajra in Sharma et al. Fl. India 1: 352. 405. 1993; Rao et al. in Rheedea 8(1): 1-66 and 8(2): 109-143, 1998.

Shrubs, often evergreen and armed, gregarious or sporadic; wood yellow; stem or branches red-brown or pale or whitish, sulcate to almost smooth. Leaves simple, but usually show a joint where blade meets petiole in fascicles or whorls, usually obovate to oblong-elliptic, often crowded, margin denticulate-spinulose to entire, petiolate to sessile. Inflorescence short on lateral branches, umbellate, fascicled or panicled, narely 1 or few flowered, often deflexed or hanging. Bracteoles often present 3. Flowers yellow to orange 3-merous, pedicellate. Perianth segments usually in 3 whorls; outer. 2 whorls forming the sepals; inner whorl forming the petals, each beset with 2 basal glands. Stamens 6 or 3 usually shorter than

petals, sensitive; anther-locules opening by recurved valves. Ovary simple; stigma peltate, sessile or on a short style; ovules few, basal, erect. Berry few-seeded.

About *ca* 500 species distributed in north temperate regions, a few in the south Hemisphere; 55 species in India. Many species of the genus are grown as ornamental shrubs and used for medicinal purposes.

Key to Species *Berberis* in Uttarakhand

1. Inflorescence simple racemose.....2
1. Inflorescence paniculate.....11
1. Inflorescence subumbellate or umbellate.....13
1. Flower solitary.....20
1. Inflorescence fascicled or sub-fascicled.....22
2. Fruit estylose .....**B. pachyacantha**
2. Fruit stylose.....3
3. Petal apex entire.....4
3. Petal apex emarginate.....9
4. Prophylls present.....5
4. Prophylls absent.....6
5. Leaves obovate, entire margin, sessile.....**B. ahrendtii**
5. Leaves obovate-elliptic, spinulose margin, petiolate.....**B. glaucocarpa**
6. Leaves membranous.....**B. petiolaris** var. **extensa**
6. Leaves subcoriaceous.....7
7. Style less than 1 mm long.....**B. floribunda**
7. Style more than 1mm or equal.....8
8. Flower less than 10 mm in diameter .....**B. affinis**
8. Flower more than 10 mm in diameter.....**B. aristata**
9. Fruit red.....**B. coriaria**
9. Fruit purplish blue.....10
10. Style less than 0.5 mm or equal.....**B. macracantha**
10. Style equal or more than 1 mm long.....**B. lycium**
11. Inflorescence 1-4 cm long.....**B. kunawurensis**
11. Inflorescence 7-27 cm long.....12
12. Flower bract 1.5 mm, prophylls absent, petal apex incised.....**B. koehneana**
12. Flower bract 4 mm, prophylls present, petal apex entire.....**B. chitria**
13. Fruit stylose 1 mm long.....**B. petiolaris** var. **garhwalana**
13. Fruit style 0.2 mm long or estylose.....14

14. 8-15 flowers in an inflorescence.....**B. apiculata**
14. 3-7 flowers in an inflorescence.....15
15. Leaves linear-lanceolate, narrow.....**B. lambertii**
15. Leaves oblong, obovate to elliptic, spatulate.....16
16. Fruit bluish purple.....**B. pseudoumbellata**
16. Fruit red.....17
17. Petals apex emarginate, Leaves entire..... **B. jaeschkeana** var. **usteriana**
17. Petals apex entire, Leaves spinulose.....18
18. Prophylls absent, 3 whorls of sepals, infl. subumbellate.....
.....**B. jaeschkeana** var. **jaeschkeana**
18. Prophylls present, 2 whorls of sepals, infl. umbellate.....19
19. Leaves closely reticulate, margin spinulose, apex subacute.....**B. umbellata**
19. Leaves entire or rarely spiny, apex obtuse.....**B. hamiltoniana**
20. Leaves linear-oblong narrowly elliptic with entire margin.....**B. osmastonii**
20. Leaves oblong-obovate, spinose.....21
21. Two whorls of sepals, prophylls present, style straight.....**B. conccina** var. **brevior**
21. Three whorls of sepals, prophylls present, and style bent.....**B. kumaonensis**
22. Inflorescence subfascicled, flowers many, leaves margin spinulose.....**B. asiatica**
22. Inflorescence fascicled, flower 3-7, leaves margin entire.....23
23. Prophylls present.....**B. rawatii**
23. Prophylls absent.....**B. cretica**

Berberis affinis G. Don, Gen. Syst. 1:115. 1831; Chatterjee in Rec. Bot. Surv. India 16(2): 19. 1953; Ahrendt in J. Linn. Soc. Bot. 57: 100. 1961; Banerjee in Sharma et al. Fl. India 1:380. 1993; Rao et al. Rheedea 8(1) 23. 1998. Type: Not traced.

Berberis floribunda Wall. ex G. Don var. *affinis* Ahrendt in J. Bot. Lond. 80 (Suppl): 89. 1942. (Figure 3.5A).

Stem glabrous, terete or subangled, pale yellow; internodes upto 5 cm long; spines 1-3, upto 5 mm long, absent or very weak. Leaves 4-7 x 1-2 cm, oblanceolate, attenuate and shortly petioled at base, narrowly acuminate at apex, entire, soft spinulose at apex. Inflorescence racemose, 10-25- fid, upto 7.5 cm long, includes peduncle 1-2 cm long. Pedicels 6-8 mm long; bracts 2-3.5 mm, linear. Flowers 8-9 mm in diameter. Berries 9-11 mm in diameter, linear, ovoid, stylose; style 1 mm long.

Flowering and fruiting: March-July.

Distribution: INDIA: Uttarakhand: Kumaon- Namik and Dwali (Endemic) (Rao et al 1998a)..

Habitat: It is found in Kharsu .Oak and Kharsu Mixed forest at cool temperarte zone in the State, 2300-3000 m in W. Himalaya (Rao et al. 1998a).

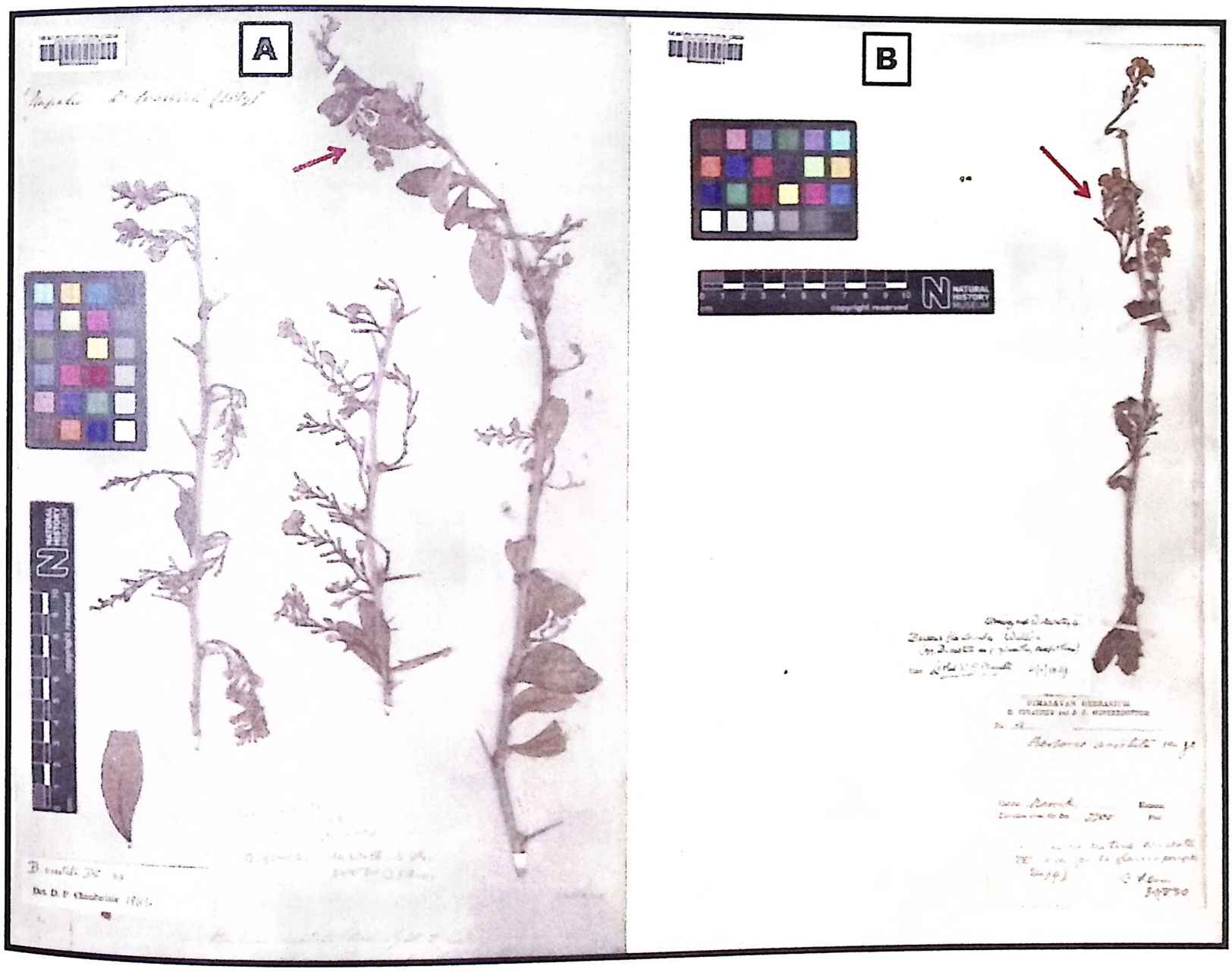

Figure 3.5. *Berberis affinis*: **A:** 1819, *Wallich s.n.* (BM); **B:** *Strachey* and *Winterbottom 4* (BM)

Specimens examined: Kumaon. Lithi 3150 m, March 1920, *W. J. Lambert 21739* (DD); Bageshwar: Dwali, 2700 m, July 1920, W. J. *Lambert s.n.* (DD); Namik, 2310 m, 17.1.1844, *Strachey and Winterbottom 4* (BM) (Figure 3.5 B).

Taxonomic Notes: This species has been reported from Dwali to Namik, nearly one hundred years ago from 2200-2800 m altitude, but never recollected by the subsequent workers since then. Don (1831) had described this species based on Wallich catalogue and given as *B. floribunda* '?'. This statement creates confusion while Ahrendt (1942) made new varieties of *B. floribunda* var. *affinis* (Figure 3.5A); but subsequent authors had merged these varieties in *Berberis affinis* (Ahrendt 1961; Sharma et al. 1993; Rao et al. 1998a). Ahrendt (1961), had said that this species have glabrous, terete stem, petals entire, leaves narrow (1:4) and spine solitary. However, the type locality was visited several times for collection of this species but it was not located but *B. aristata* was quite frequent in Namik, Lithi and Phurkia near Dwali. I have doubt about the existence of this species in state and further research is needed. This species has been included in the present work based on existing literatures. Specimen collected by *Strachey and Winterbottom 4* (BM) from Namik, look like *B. aristata* and it is corrected by Ahrendt as *B. floribunda* and then Rao et al. (1998a) mention this specimen as *B. affinis*, but I am sure this specimen and around Namik village *Berberis aristata* is present. The entire specimens, which are kept in Indian Herbaria of *B. affinis*, are *B. aristata*.

Berberis ahrendtii Rao and Uniyal, Ind. J. For. 8(4): 334. 1985; Uniyal and Rao in Sharma et al., Fl. India 1: 369. 1993; Rao et al., Rheedea 8(1): 62-63. 1998. Type: Cultivated: Fl. June, 1939; Fr. 27 Sept., 1939 (BM) (Figure 3.6)

Berberis lycioides Stapf in Bot. Mag. 151: 1902. 1926; Ahrendt in J. Linn. Soc. Bot. 57: 89. 1961, non. Lowe, 1856, nee Linden and Planch, 1883.

Shrub up to 3.5 m tall; stem pale yellow, glabrous, terete, internodes 3-5 cm long, spines, 1-2 cm long, solitary. Leaves 1.5-7 x 0.5-1.8 cm, narrowly obovate, apex subacute or mucronate, base attenuate, sessile, entire or slightly spinulose, finely reticulate, epapillose. Inflorescence racemose, 10-20 flowers, dense, drooping, sometimes compound below; peduncles 1-2 cm long; flowers 12-14 mm across; pedicel 7-10 mm long; bracts 2-3 mm. Sepal in 3 whorls; outer sepals 2.5 x 1.5 mm, ovate, acute; median ones 5x2.5 mm; inner ones ca 7.5-8 x 4.5-5 mm. Petal 6-5 x 4 mm, obovate-elliptic, entire, shorter than the inner

sepals; marginal glands 6.5 x 4 mm. Stamens 5 mm long produced, apiculate. Berries 11 x 6 mm, oblong-ovoid, pruinose, grey-white; style 1-1.25 mm long.

Flowering and fruiting: April-October.

Habitat: Open canopy in Kharsu Mixed and Banj Oak forests near Pangarbassa and Bairangana village in Chamoli district.

Altitude range: 1500–2700 m. Critically Endangered (Rao et al. 1998a).

Distribution: Chamoli (Endemic).

Specimens examined: Bairangana, Chamoli, 1620 m, 10.5.2009, *UKT 0988* (WII); Pangarbassa, Chamoli, 2680 m, 10.5.2009, *UKT 0989* (WII); Pangarbassa, Chamoli, 2680 m, 6.7.2009, *UKT 1068* (WII).

Additional specimens examined: **CAL**: Chamoli, Sept. 1864, *Brandis 3275*.

Taxonomic Notes: Rao and Uniyal (1985) proposed a new name, *Berberis lycioides* Stapf. 1926, as this name is a later homonym of *B. lycioides* Linden and Planch, 1883. During study duration, I have found two different populations of species in state. One population near Bairangana village with three individuals and second population near Pangarbassa on way to Tungnath in Chamoli district with two individuals. With only five individuals of this species in wild, it needs to be prioritized for conservation. Specimen that was kept in Calcutta by Brandis looks very close to *B. lycium*. The only difference is Petal emarginate in *B. lycium* and entire in *B. ahrendtii*. This species was collected after a gap of 147 years.

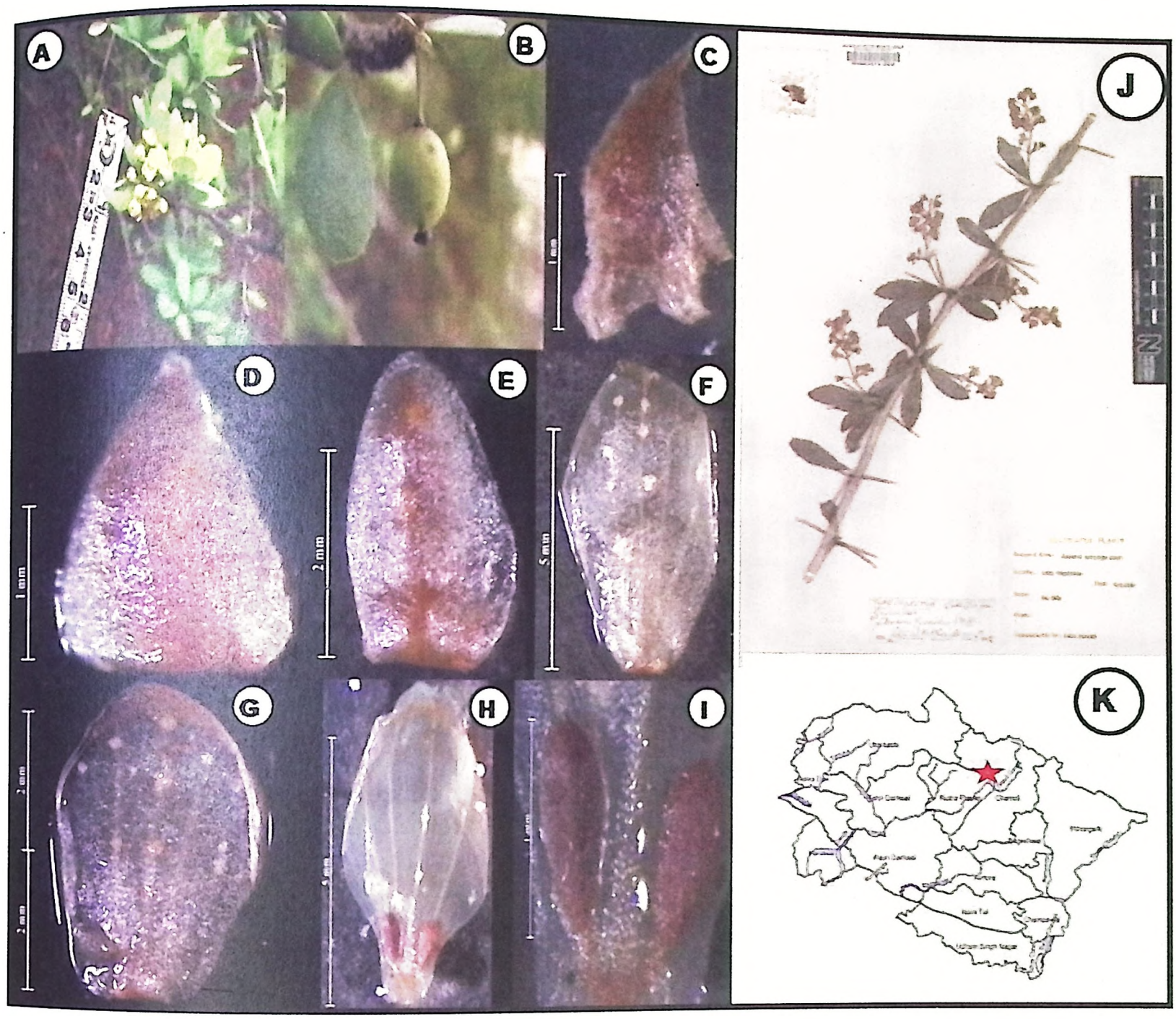

Figure 3.6: *Berberis ahrendtii* (*UKT-1068*) - **A:** Plant with inflorescence; **B:** Fruit; **C:** Bract; **D:** Prophylls; **E:** Outer sepal; **F:** Middle sepal; **G:** Inner sepal; **H:** Petals and **I:** glands on petal; **J**: Type - BM; **K**: Red star indicates distribution in the state.

Berberis apiculata (Ahrendt) Ahrendt, J. Linn. Soc. Bot. 57: 135. 1961; Nayar and Sastry, Red Data Book of Indian Plants 2: 75. 1988; Das Gupta in Sharma et al., Fl. India 1:360. f. 54: 1993; Rao et al., Rheedea 8(2): 122-123. 1998b. Type: *Ludlow and Sherriff 7356* (BM). (Figure 3.7)

Berberis usteriana (Schneid.) R. Parker var. *apiculata* Ahrendt, J. Asiat. Soc. Beng. 11:3.1945.

Shrub 1.5-1.7 m tall; stems subterete, gland-dotted, yellow, glabrous, densely leafy; internodes 5-10 mm long; spines 8-15 mm long, 3-fid. Leaves 20-30 x 6-7 mm, upto 10 from each node, narrowly obovate, apex rounded or mucronate, attenuate at base; margins with 2-3 spinose serrations, lustrous above, paler beneath, openly veined. Inflorescence subumbellate, 5-8 flowers, 25-40 mm long; peduncles very short or absent. Flowers yellow; pedicels 3-9 mm long; bracts 2.2-2.5 x 1 mm, lanceolate, acute, puberulous along margins. Prophyll 3-3.5 x 1-1.5 mm, ovate, obtuse. Outer sepal 5-6 x 2.5-3 mm, elliptic, obtuse; inner sepal 8 x 5-5.5 mm, obovate, obtuse. Petal 6.5 x 3.7 mm, subacute to subobtuse, entire, base clawed, with separate, oblanceolate glands; stamens 5 mm, produced, conspicuously apiculate; ovules 5-7, stigma stipitate. Berries 8-10 x 5 mm, red, oblong-obovoid, epruinose, very shortly stylose.

Flowering and fruiting: June- Sept.

Distribution: INDIA: Himachal Pradesh, Uttarakhand, West Bengal; BHUTAN (Rare).

Habitat: On the banks of streams and open dry places on hill slopes 2200-2500 m. near Gangori village on way to Harki-Dun in Tins valley.

Specimens examined: Gangori, On way to Har-ki-Dun, Uttarkashi, 2280 m, 8.7.2010, *UKT 0210* (WII).

Additional specimens examined: West Bengal: 22.4.1996, *s.l. 224* (CAL).

Figure 3.7. *Berberis apiculata* (*UKT-0210*) – **A:** Holotype *Ludlow and Sherriff 7356* (BM); **B:** Plant with Fruits; **C:** close up of Inflorescence; **D:** Desected flowers parts; **E:** Prophyll; **F:** Outer sepal; **G:** Inner sepal; **H:** Petal with glands and **I:** Fruit.

Taxonomic Notes: Previously this species was reported from Himachal Pradesh and West Bengal (Rao et al. 1998b), as its distribution shows this species should occur in Uttarakhand. Type of *Berberis apiculata* Ahrendt, *Ludlow and Sherriff 7356* (BM) looked quite similar to *B. jaeschkeana* but for some minor differences in number of flower (Rao et al. 1998b). This species is a new record for the state. This species is also listed in IUCN red listed plant as critically rare.

Berberis aristata DC, Syst. Nat: 2: 8. 1821; Hook. f. and Thoms. in Fl. Indica 1:222, 1855, p.p.; Ahrendt in J. Bot. Lond. 80 (Suppl.) 91. 1942; et in J. Linn. Soc. Bot. 57: 101. 1961; Chaterjee in Rec. Bot. Surv. India 16(2): 20. 1953; Grierson and Long, Fl. Bhutan 1(2): 326, 1984; Banerjee in Sharma et al., Fl. India 1:381. 1993; Rao et al. Rheedea 8(1) 24-27. 1998. (Figure 3.9 and 3.10)

B. sikkimensis (Schneid.) Ahrendt in J. Bot. Lond. 80 (Suppl.): 85. 1942; Sealy in Bot. Mag. 168, N. S., t. 173. 1957; Ahrendt in J. Linn. Soc. Bot. 57:99. 1961; Banerjee in Sharma et al., Fl. India 1:383. 1993. Type: CAL: Larhoery, 9000 ft, 27 Aug. 1849, *Hooker and Thomson s.n.* (K). (Figure 3.8)

B. chitria Lindl. var. *sikkimensis* Schneid. in Fedde, Report. Spec. Nov. 46: 248. 1939.

B. micrantha (Hook. f. and Thorns.) Ahrendt in Gard. Illus. 64: 426. 1944; et in J. Linn. Soc. Bot. 57: 96, 1961; Rao and Naithani in Sharma et al., FI. India 1: 383. 1993. Type: Bhutan: 1838. *Griffith 17-14* (K).

B. aristata var. *micrantha* Hook. f. and Thoms. in Hook, f., Fl. Brit. India 1:1 10. 1875, p.p.

B. ceratophylla G. Don, Sys. Gard. 1: 115. 1831; Ahrendt in J. Asial. Soc. Beng. (Sci.) (3) 11, 1945.

Shrub 1-3 m, deciduous, stems grooved glabrous, pale yellow, terete; internode 3-6 cm long; spines fairly stout, 1-3 cm, solitary towards apex of stems, 2-3-fid at base. Leave 2-8 x 0.7-3 cm, obovate to obovate-elliptic, mucronate, at apex subacute to acute, base cuneate, coriaceous, shortly petiolate, petiole 3-4 mm long, margins entire or with a few spinous teeth near apex, prominently veined. Racemes 8-25-fid., 4-10 cm long, including peduncle 1-5 cm long. Pedicels 5-10 mm long; bracts 3 x 0.8 mm. Flowers 11-14 mm in diameter; outer sepal 1.5-3 x 1 mm, ovate; median sepal 5-6 x 2-3 mm, narrowly ovate to elliptic, inner sepals 5-8

x 3-5 mm, obovate. Petal 6-7 x 3-4 mm, obovate to oblong-obovate, entire or sometime retuse, base cuneate; glands 1.2 x 0.4 mm, non marginal. Stamen 4.5-5.5 mm, shortly apiculate. Ovules 4-5. Berries 7-11 x 6-7 mm, ovoid to oblong-ovoid, slightly pruinose purplish blue, stylose; style 1 mm long.

Figure 3.8: *Berberis aristata*: Matia Nepal (BM).

Flowering and fruiting: May-October

Distribution: INDIA: Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Madhya Pradesh and Tamil Nadu. CHINA, NEPAL and BHUTAN.

Specimens examined: Phoolchattii, Yamuna Valley, 2287 m, 13.5.2008, *UKT 0005, 0006, 0007* and *0008* (WII); Phoolchattii, Yamuna Valley, 2286 m, 15.5.2008, *UKT 0088, 0091 and 0095* (WII); Datmir, on way to Har-ki-Dun, 2380 m, 3.6.2008, *UKT 0188, 0192, 0194, 0200, 00203 and 0206* (WII); Jakhol, Tons valley, 1918 m, 11.4.2009, *UKT 0918* and *0919* (WII);

Jankichattii, Yamuna Valley, 2538 m, 13.4.2009, *UKT 0923* (WII); 9.5.2009, Chopta, on way to Tungnath, 2750 m, *0983 UKT* (WII); Namik, Ramganga (E) valley, 2220 m, 13.4.2010, *UKT 2047 and 2048* (WII).

Additional specimens examined: Manumanganga valley, 2000 m. 28.4.1968, *C. M. Arora 37860* (BSD); Nagtibba, 2600 m, 27.7.1964, *U.C. Bhattacharya 33743* (BSD); Sanchatti, 2000 m, 12.6.1961, *M. A. Rao 15676* (BSD); Bhairoghati, 3000 m, July 1988, *B. D. Naithani 70787* (BSD); Hanumanchatii, 2400 m; 27.6.1957, *Y. K. Sarin and M. A. Rao 2828* (BSD); Near Beeph village on way to Yamnotri, 2500 m, 16.6.1961, *M. A. Rao 15768*

(BSD); Phoolchattii (on way to Yamnotri), 13.6.1961, *M. A. Rao 15686* (BSD); Chamoli: Bhyunder valley, 2400 m, 1.10.1962, *U. C. Bhatt 24234* (BSD); near Okhimath, 4.6.1978, *A. S. Rao 58441* (BSD); Pauri: Buwakhal, 1650 m, 26.5.1980, *A.A. Ansari and Ghana Nand 69059* (BSD); Trijuginarain, 2250 m, 7.11.1914, *A. E. Osmaston 623* (DD); Mussoorie, 20.6.1870, *s.l 16992* (CAL); June, 1869, *G. King s.n.* (CAL); Yamnotri, Phoolchatti, 13.6.1961, *Stainton Sykes and Williams 15686* (CAL); Mussoorie, 21.5.1900, M.A. Rao (CAL); 10.9.1885, Duthie 3811 (CAL); Mussoorie, 2.8.1963, *H. Santapau 28549* (CAL); Tehri Garhwal, Shanchattii, 12.6.1961, *H. Santapau 15663* (CAL); Furkia-Dwali, 3000-3500 m, 25.9.1957, *T. A. Rao 4608* (BSD); Ranikhet, 1680 m, 1.10.1963, *B. M. Wadhwa 57263* (BSD); Pithoragarh, Byans-Budhikali Valley, 25.5.1913, *I. H. Lyall* 58 (DD); Pithoragarh, 15.9.1900, *Inayat 24217* (CAL); Sirkha, 18.6.1969, *T. A. Rao 939* (CAL).

Taxonomic Notes: De Candolle described this species from specimen in Herb. Lambert collected by Buchnan-Hamilton from Nepal, which deposited by Buchnan under the name *B. chitria*. In description, De Candolle says "rami teretes, pallide grisci. Spinae simplices conicae grisae,.....racemi follis paullo longiores, 2-3 pollicares, patuli, sat racemes *B. vulgaries* similies". Judging by this statement there can be no doubt as this species to be true *B. aristata*. Ker (in Bot. Reg. 9: t 729. 1823) had given De Candolle's diagnosis but the plant figured is *B. chitria*. Hamilton sensu Don (Prodr. Fl. Nep. 204. 1825) too did not separate *B. aristata* and *B. chitria*. Lindley (1823), well distinguished the two species but understood *B. chitria* for *B. aristata*, and used for the latter the name *B. floribunda*. According to Don (1831) *B. chitria* was introduced into cultivation in 1820, and probably Wallich or another collector of his time introduced *B. aristata*. Hamilton collected both species, and deposited them under the name *B. chitria*. *Berberis coriaria* Royle (apud Lindley in Bot. Reg. xxvi. t. 46. 1841) seems to be nothing but it look alike *B. aristata*. This plant was raised in the gardens of the London Horticultural Society from seeds sent by Royle (1835), collected probably somewhere on the northwestern Himalayas. Unfortunately, I have not found any herbarium material from this region agreeing with Lindley's description and picture and mentioned by Kanjilal. He had included *Berberis coriaria* in Forest Flora. (rep. 1969) and Collet in Flora Simlensis (1902), and by Brandis (1906) in Indian Trees, but I do not agree to these authors those who had supported *B. coriaria* as species and not to

Berberis aristata DC. from Uttarakhand Himalaya. Due to lack of type specimen of *B. aristata* this complex was not solved.

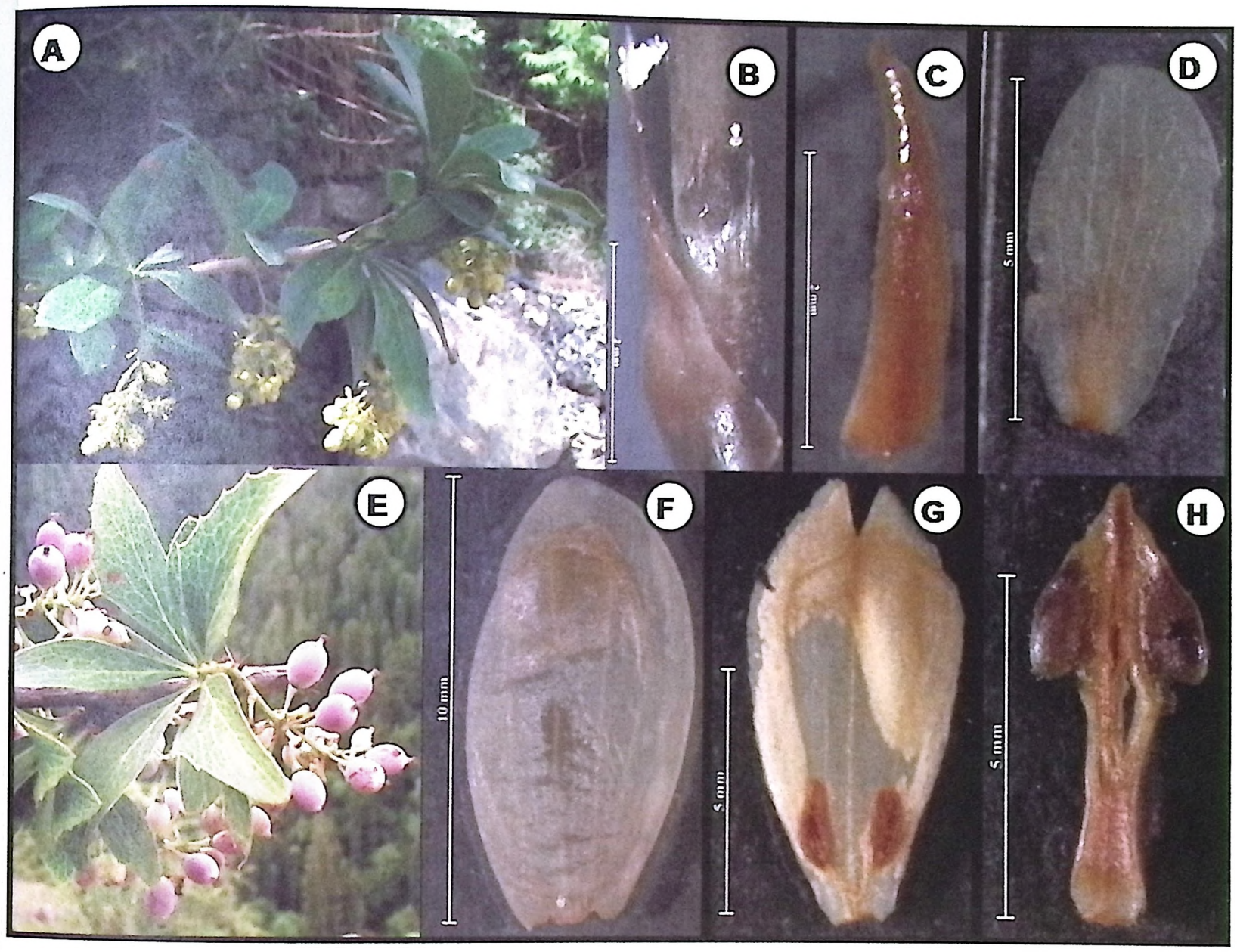

Figure 3.9. *Berberis aristata* (*UKT-0095*) – **A:** Twig with leaves and inflorescence; **B:** Bract; **C:** Outer sepal; **D:** Middle sepal; **E:** Twig with leaves and fruits; **F:** Inner sepal; **G:** Petal and **H:** Stamen.

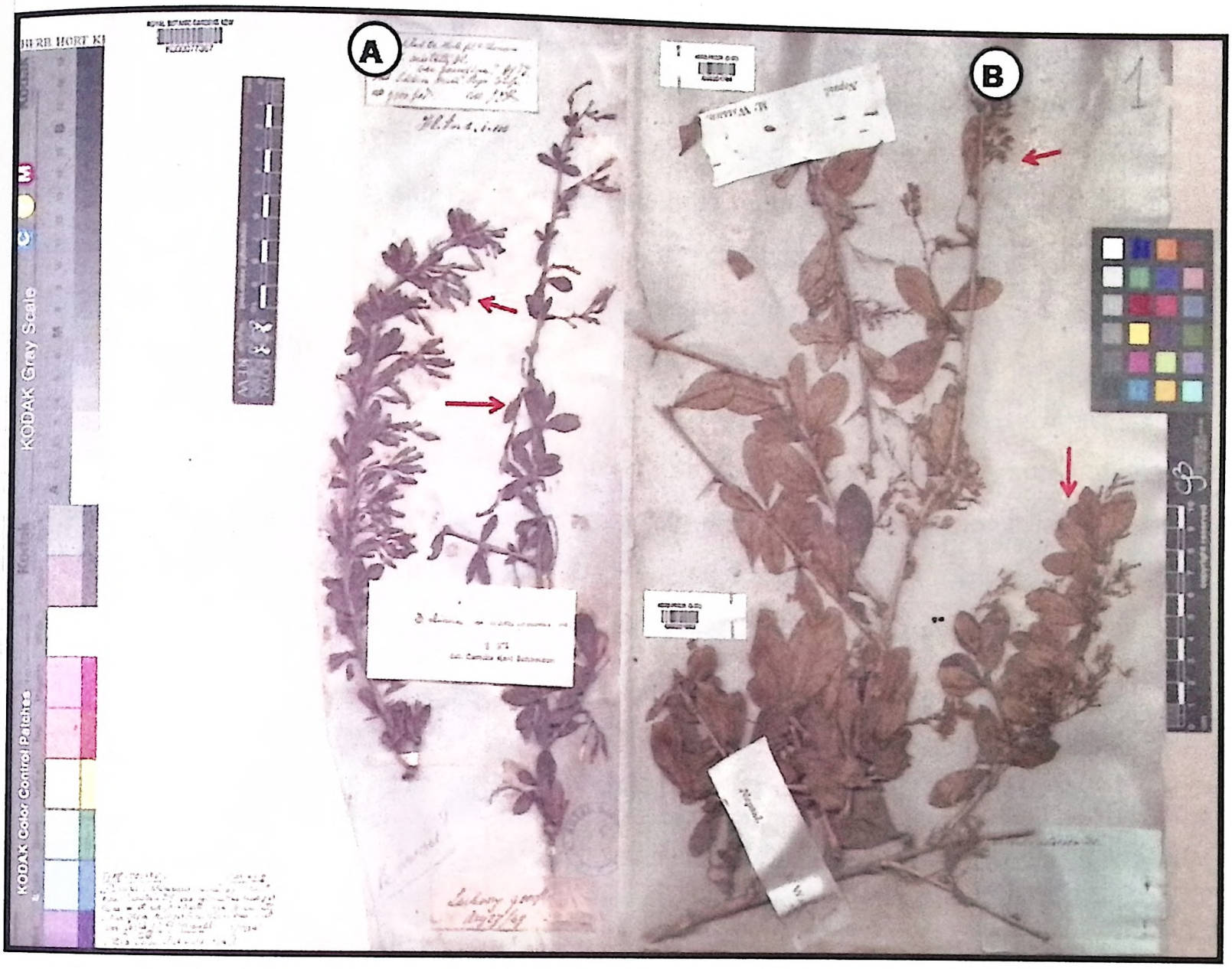

Figure 3.10. **A:** Red arrow indicates the leaf and inflorescence type, *B. sikkimensis Hooker s.n.* (K); **B:** *B. aristata*: Red arrow indicates the leaf and inflorescence type, 1820, *Wallich s.n.* (CJB).

Berberis asiatica Roxb. ex DC., Syst. Nat. 2:13. 1821, non Griffith, 1847; Hook. f. and Thoms., in Hook. f., Fl. Brit. Ind. 1:1 10. 1875; Duthie, Fl. Upper Gang. Pl. 1:32. 1903; Haines, Bot. Bihar and Orissa 1:20. 1921; Chatterjee in Rec. Bot. Surv. India 16(2): 13. 1953; Ahrendt in J. Linn. Soc. Bot. 57:86. 1961; Uniyal and Rao in Sharma et al. Fl. India 1:370. 1993; Rao et al., Rheedea 8(1) 52-54. 1998. Type: *Wallich s.n.* (CJB) (Figure 3.11 and 3.12)

Vernacular Name: Kilmora, Kasmod.

Shrub up to 3 m tall; stems yellowish, young ones sulcate, and puberulous, mature stem terete, glabrous; internodes upto 4 cm long; spines 3-fid, 0.9-3 cm long, central spine longer than the lateral ones. Leaves 1.1-7.5 x 0.8-3.5 cm, obovate, oblong-obovate or elliptic, apex mucronate, base attenuate, shortly petiolate; petiole 1-5 mm long, thickly coriaceous, entire or distinctly 2-6-spinose along margins, upper surface distinctly reticulate, lower surface papillose but reticulations less distinct. Inflorescence fascicled, racemose or umbellete-racemose, 15-25 flowers; pedicels 0.5-2.5 cm long, glabrous, reddish; bract 2.5-3 x 2-2.5 mm. Outer sepal 2-4 x 2-3 mm, broadly ovate; inner sepal 6-8 x 4-5 mm obovate. Petal 7-8 x 5.5-6 mm, obovate, emarginate; glands obovate. Stamens 3.5-5 mm long, truncate; anthers 2-3 mm long; filaments 1.5-2 mm long. Ovary ellipsoid; ovules 2-5. Berries 8-10 x 7 mm, oblong-ovoid to ellipsoid, pruinose, young ones green or pinkish green mature one pinkish, turning reddish and finally dark purple or black, slylose; style 0.5-1.5 mm long.

Distribution: INDIA: Himachal Pradesh, Uttarakhand, West Bengal, Arunachal Pradesh, Meghalaya, Bihar, Madhya Pradesh; AFGHANISTAN; NEPAL; BHUTAN; CHINA.

Habitat: Sub-Himalayan ranges, hillsides and valleys, sometimes associated with *Quercus* and *Rhododendron*; 900-2500 m.

Specimens examined: Kolhukhet, On way to Mussoorie, 1200 m, 1.6.2008, *UKT 0170* (WII); Jharipani, On way to Mussoorie, 1450 m, 1.6.2008, *UKT 0171* (WII); Mussoorie, 1680 m, 1.6.2008, *UKT 0172* (WII); Gonchar, Chamoli, 1008 m, 15.5.2009, *UKT 1000* (WII); Debal, Chamoli, 1080 m, 16.5.2009, *UKT 1001* (WII); Nandprayag, Chamoli, 1320 m, 18.5.2009, *UKT 1002* (WII); Kosi-katarmal, Almora 1230 m, 08.3.2010, *UKT 1910* (WII); Almora 1510 m, 08.3.2010, *UKT 1916* (WII); Kosi-katarmal, Almora 1260 m, 08.3.2010, *UKT 1925* (WII); Gonchar, Chamoli, 1081 m, 11.3.2010, *UKT 2007* (WII); Gonchar, Chamoli, 1082 m, 11.3.2010, *UKT 2010* (WII); Muniyalikhet, Pinder Valley, Chamoli, 2204 m, 14.4.2009, *UKT 2026* (WII).

Figure 3.11: *Berberis asiatica*: Syntype: Nepal, 1821, *Wallich s.n* (CJB), Geneva

Additional specimens examined: Dehradun. 900 m, 12.3.1957, *Y. K. Sarin and T. A. Rao 1928* (BSD); Sahastradhara, 29.1.1964, S. K. *Malhotra 30793, 31218* (BSD); Mussoorie, Barlowganj, 1500 m, 27. 12. 1956 *Y.K.Sarin 1485* (BSD); Lansdowne, 1500 m, 25.2.1960, *J. N. Vohra 11199* (BSD); Nagdeo area, 1800 m, *R. P. Srivastava 57012* (BSD); Khirsu 2100 m 25. 2. 1980, *A. A. Ansari and Charianad 69081* (BSD); Ranichauri. 2000 m, 28.2.1979, *A. K. Goel 65801* (BSD); Tharali, 900-1800 m. 22.3.1914, *Daulat Singh, II* (BSD); Lobha, 1650 m, 23.3.1914, *A. E. Osmaston 261* (BSD); Emeli Forest, 1800 m, 6.4.1913, *A. E. Osmaston 125* (BSD); Mussoorie. 10.2.1900, *P. W. Makinnone s.n.* (CAL). Kumaon: Naini-Saini, 1560 m, 16.4.1992; *T. Husain 21336* (LWG); Naini Saini, Bhangali Bunga Jungle, 1950 m, 18.4.1992, *T. Husain 212337* (LWG); On way to Kanalichina, Dhwaj, 1950 m, 19.4.1992, *T. Husain 212339, 212340* (LWG): On way to Kanalichina 1800 m, 19.4.1992, *T. Husain 212341, 212342* (LWG); Chandak, 1950 m, 20 4.1992, *T. Husain 212346, 212347* (LWG); On way from Tejam to Sungdum, 1980 m, 24.4.1992, *T. Husain 212361* (LWG); Tejam, 1980 m, 24.4.1992, *T. Husain 212362* (LWG); Sobla, 1980 m, 25.4.1992, *T. Husain 212364* (LWG); On way from Sobla to Narayan Ashram, 2100 m, 26.4.1992, *T. Husain 212365* (LWG); Narayan Ashram, 2100 m, 27.4.1992, *T. Husain 212366* (LWG); Bhatkot, 1680 m,

4.5.1992, *T. Husain 212369, 212370, 212371, 212372, 212372* (LWG); Mushtmanu, 1950 m, 5.5.1992, *T. Husain 212374, 212375, 212376* (LWG); Suvakot, near Wadda, 1650 m, 6.5.1992, *T. Husain 212377, 212378, 212379, 212380, 212381, 212382* (LWG); Almora Dist.: Ranikhet Chaubatia, 2.10.1912, *J. D. Hooker 39034* (CAL); Jageshwar, 1980 m, 7.5.1992, *T. Husain* 212384 (LWG); Nainital Dist, Jeolikot, 1250 m, *T. Husain and B. Datt* 211443 (LWG); Naukuchia Tal, 16.3.1961, *s.l. 14199* (BSD).

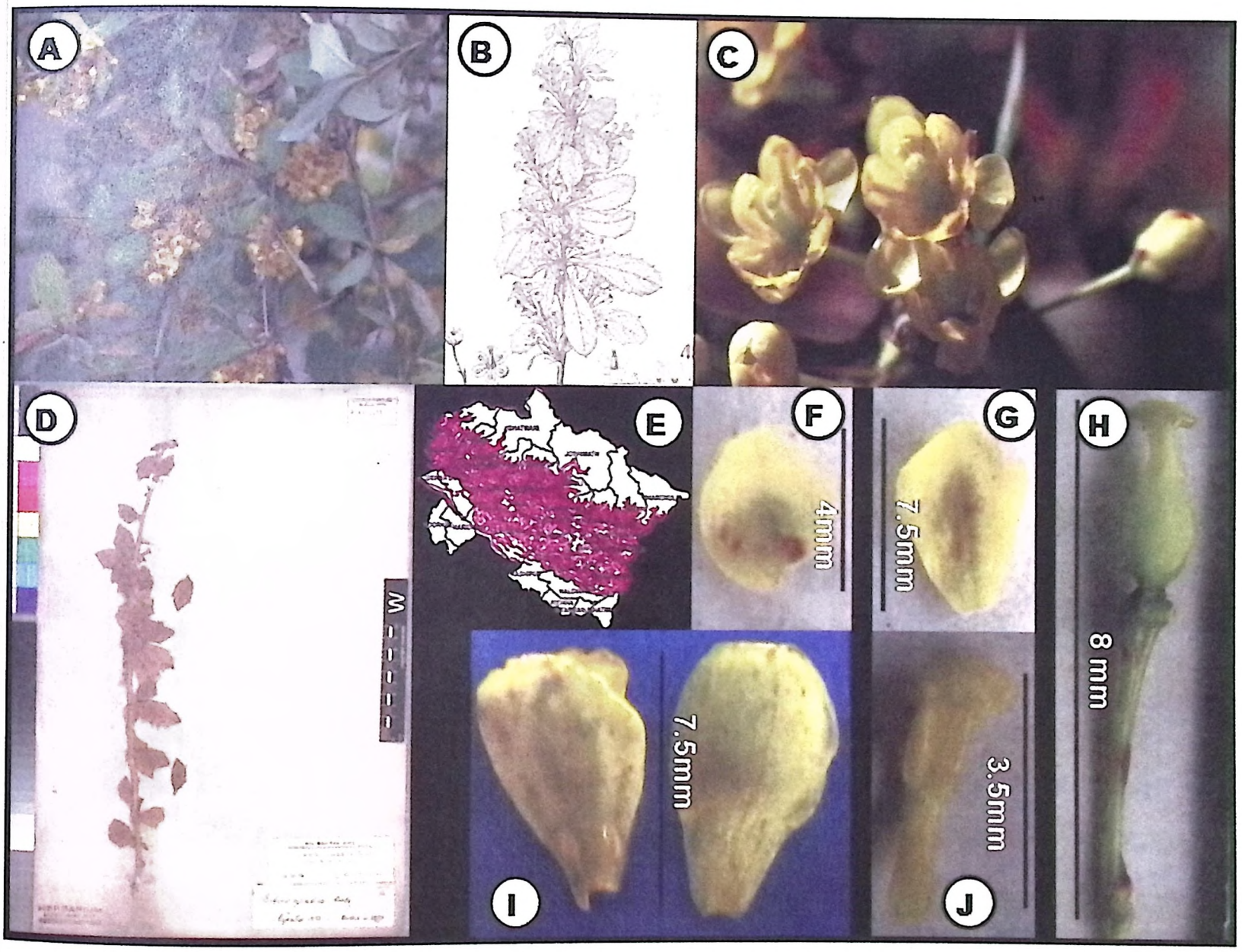

Figure 3.12. *Berberis asiatica* (*UKT-0170*) - **A:** Twig with leaves and inflorescence; **B:** Illustration by Tarpin and Lessert, 1823; **C:** Close up of Inflorescence; **D:** Type specimen: Nepal, 1820, *Wallich 1477* (W); **E:** Pink colour in map shows distribution in Uttarakhand; **F:** Outer sepal; **G:** Inner sepal; **H:** Fruit; **I:** Petals and **J:** Stamen.

Taxonomic Notes: This species has wide distribution in India from North to Central India from West to Eastern Himalaya. Leaves thickly coriaceous, spinulose margin, venation is quit prominent on both the surface of leaves, Subfasciculate inflorescence and blue berries are important character for identification of the species. This species is very much common and widely distributed in Uttarakhand. Condolle et al. (1823) illustrated it for the first time in Icones Selectae Plantarum vol 2.

Berberis chitria Lindl., Bot. Reg. 9:t. 729. 1823; Chatterjee in Rec. Bot. Surv. India 16(2): 18. 1953; Parker, For. Fl. Punj. 12. 1918 (partly); Ahrendt in J. Linn. Soc. Bot. 57: 97. f. 15 1961; Jafari in Nasir and Ali, Fl. W. Pak. 87: 14. f. 4, A-B. 1975; Banerjee in Sharma et al. Fl. India 1:381, 1993; Rao et al. in Rheedea 8(1): 18-21. 1998. (Figure 3.13, 3.14 and 3.15)

B. chitria Lindl. var. *occidentalis* Ahrendt in J. Bot. Lond. 80 (suppl.): 85. 1942; et in J. Linn. Soc. Bot. 57: 38. 1961.

Shrub 2-4 in tall; stems terete or angled; shoots pubescent, dark reddish-brown, mature puberulous or subglabrous; internodes 3-5 cm long; spines 3-fid, rarely 1-fid, 1-2 cm long, stout. Leaves 4.5-10 x 2-3 cm, obovate or elliptic, subsessile, apex mucronate, base cuneate, both surfaces papillose, and with elevated venation, dull green above, usually 3-9 spinulose at the margin. Inflorescence 8-20 flowered, loosely corymbose paniculate, with flowers formally in groups of three; 5-13 cm long, including peduncle 1.5-6 cm, drooping, glabrous; bracts 1.5-3 mm long. Flowers yellow, 12-18 mm across, pedicels 8-15 mm long, drooping. Outer sepal 6-7 x 5-6 mm, obovate; inner sepal 9-10 x 7.5-9 mm, obovate. Petal broadly elliptic, 8-9 x 6-7 mm, apex subacutcly emarginate with rounded lobes; base cuneate with oblong-elliptic glands, 1.2 x 0.6 mm. Stamen 7 mm, subapiculate at apex. Ovule 4-5, with longer stipes. Berries 10-12 x 14-6 mm, dark red-brown or red, narrowly ovoid or oblong-ellipsoid, epruinose, excluding 1-1.5 mm long style.

Flowering and fruiting: May-September

Distribution: INDIA: Jammu and Kashmir, Himachal Pradesh, Uttarakhand; NEPAL.

Habitat: This species is common at an elevation of 1500-3000 m in W. Himalaya.

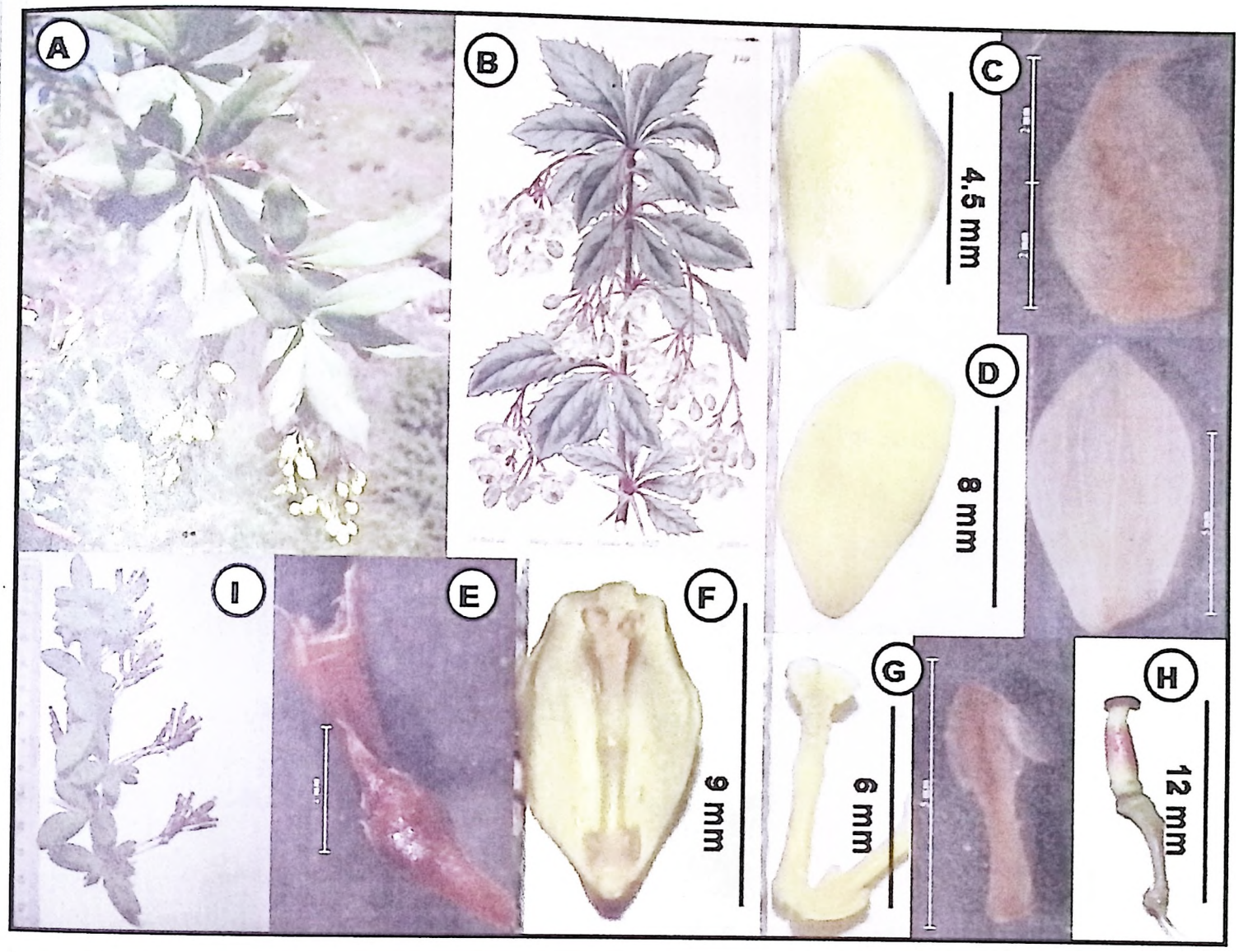

Figure 3.13. *Berberis chitria* Lindl.: (*UKT-0101*) - **A:** Habit; **B:** Type illustration by Lindley, 1823; **C:** Outer sepals; **D:** Inner sepals; **E:** Bract; **F:** Petals; **G:** Stamens and **H:** Immature Fruit and **I:** Twig with inflorescence and fruits.

Specimens examined: Phoolchattii, Yamuna Valley, 2288 m, 13.5.2008, *UKT 0004* (WII); Hanumanchattii, Yamuna Valley, 2200 m, 14.5.2008, *UKT 0015* (WII); On way to Yamnotri temple, 2510 m, 14.5.2008, *UKT 0050* (WII); On way to Yamnotri temple, 2718 m, 15.5.2008, *UKT 0101* (WII); Godar, Yamuna valley, 1910 m, 16.5.2008, *UKT 0127* (WII); Godar, Yamuna valley, 1720 m, 17.5.2008, *UKT 0144* (WII); Bhatiya, Yamuna valley, 2185 m, 18.5.2008, *UKT 0146* (WII); Tiya, Yamuna valley, 2120 m, 18.5.2008, *UKT 0149* (WII); Badiyar, Yamuna valley, 1829 m, 29.5.2008, *UKT 0153* (WII); Badiyar, Yamuna valley, 1820 m, 29.5.2008, *UKT 0158* (WII); Badiyar, Yamuna valley, 1855 m, 18.5.2008, *UKT 0163* (WII); Taluka, Tons valley, 2336 m, 3.6.2008, *UKT 0183* (WII);

Hanumanchattii, Yamuna valley, 2310 m, 28.6.2008, *UKT 0370* (WII); Deota, Tons valley, 2089 m, 14.7.2008, *UKT 0400* (WII); Gadugad, Tons valley, 1953 m, 14.7.2008, *UKT 0405* (WII); Kalamuni, Pithoragarh, 2780 m, 11.4.2010, *UKT 2040* (WII).

Additional specimens examined: Mussoorie, 1875 m, May 1879, *Gamble 1014* (K); Kathayan, 2100 m, May 1890, Gamble 23794 (K); Deota, May 1892; 2800 m, *Duthie 23662* (K); Mussoorie, Mossy fall, 12.8.1978, *G. Panigrahi and B. M. Wadhwa 64933* (BSD); Tehri-Garhwal, Magra, 1800 m, 31.5.1978, *A.K.Goel 63941* (BSD); Garhwal, Anusuryia Devi, 2700 m, 24.5.1971, *B. D. Naithani 44003* (BSD); Chamoli, Diwalikhal, 2000 m, 18.9.1985, *H. J. Chowdhury 73167* (BSD); Pauri Dist., Bubakhet, 1750m, 5.6.1975, *B. S. Aswal 55422* (BSD); Tehri Dist., Nagtibba, 3200 m, 3.6.1978, *A. K. Goel 64033* (BSD); Chamoli, 20.6.1979, *B. D. Naithani 68040* (BSD); *A. E. Osmaston 211* (BSD); Kedarnath Valley, 2400-3000m, *Sadanand s.n.* (BSD); Molla kaliphat, 2250 in, 23.10.1914. *Hira Singh 278* (BSD); Jaunsai-Deoban, 2400 m, *N. L. Bor 13069* (BSD); Uttarkashi; below Dodital, 25.6.1956, *K. C. Sahni 24796* (BSD); Near- Biph, Yamuna Forest Division, 2400 m, 31.5.1960, *K.C. Sahani 26373* (BSD); Chamoli: Dougalbitta, 2500m, 7.9.1988, *R. S. Hole s.n.* (BSD); Badiyar, 2460 m, 28.5.1936, *C. E. Parkinson 23636* (BSD); Mussoorie, 1950 m, June 1898, *Duthie s.n.* (BSD); Mussoorie, 4.5.1959, *M. B. Raizada s.n.* (BSD): Mussoorie, on Mossey fall, 1620 m, 24.5.1960, *H.O. Saxena 613* (BSD); Mussoorie, Camel's back, June 1933, *C. E. Parkinson 16* (BSD); Amritganga valley, 29.6.1971, *B. D. Naithani 44063* (CAL); Sitapur, 21.5.1972, *B.D. Naithani 47914* (CAL); Bahri Udyar, Baicha, 6.8.1972, *M. Arora 49638* (CAL); Dalia top, 5.8. 1972, *C. M. Arora 49606* (CAL); Deoban, *Ashar Hasain 6* (CAL); Bakriudyardt, 8.8.1972, *C. M. Arora 49724* (CAL); Tehri Garhwal, Chutter, 9.6.1972, *B. D. Naithani 48214 (CAL)*; Mandakini valley, Batwalchari 900 m, 18.4.1973, *B. N. Mehrotra 3917* (LWG); Jaunsar, Lokar, 2225 m, 1891, *J. S. Gamble 22800* (CAL); Tehri Garhwal, between Semidiardiard and Aura, May 1879, 1500-1800 m, *Duthie 1014* (CAL); Kumaon: Kumaon, 1821, *Wallich 1474 (2) A* (K); Nainital, 2300 m, *Strachey and Winterbottom 2, pro parte* (K); Nainital, April 1884, *Hooker and Thomson 716* (K); Daffia top, 2500 m, 5.8.1972, *C. M. Arora 49606* (BSD); Rathi, 2500 m, 29.4.1962, *U. C. Bhatt 21307* (BSD); Askote, 1800, 3.5.1972, *U. C. Bhatt 21372* (BSD); Almora Dist.

Taxonomic Notes: History of the description of this species is interesting; Lindley (1823) coined this name in preference to *B. aristata* DC. and stated that it is based on samples in the Lambertian Herbarium collected by Dr. Hamilton in Nepal, I think name of *B. aristata* and *B. chitria* was therefore based on the same type materials. De Candolle had preferred the original name for this species in the 'Regni Vegtabilis Systema Generale' (De Candolle 1821). Lindley deliberately rejected the latter's published name in the favors of the name *B. chitra* used in MS by Buchanan-Hamilton, of De Candolle's plant, but while doing this the spelling become altered to Chitria, with which epithet was associated a summary of De Candolle latin diagnosis and plate clearly illustrating very different plant. Thus, by combination of error, providing species a name new, which was not clearly published. Since then, it has been used and accepted on most occasions. It is figured as *B. aristata* in Bot. Mag. t. 2549 (Sims 1825) and Exotic flora by W. Hooker (1825) (Figure 3.15), where he tried to restore the De Candolle's *B aristata* but figure given by them looks like *B. chitria*.

Figure 3.14. *Berberis chitria* Lindl.: **A:** Red arrow indicates the leaf and inflorescence type, *Duthie 19860* (WU); **B:** Red arrow indicates the leaf and inflorescence type, *Buchnnan s.n.* (K).

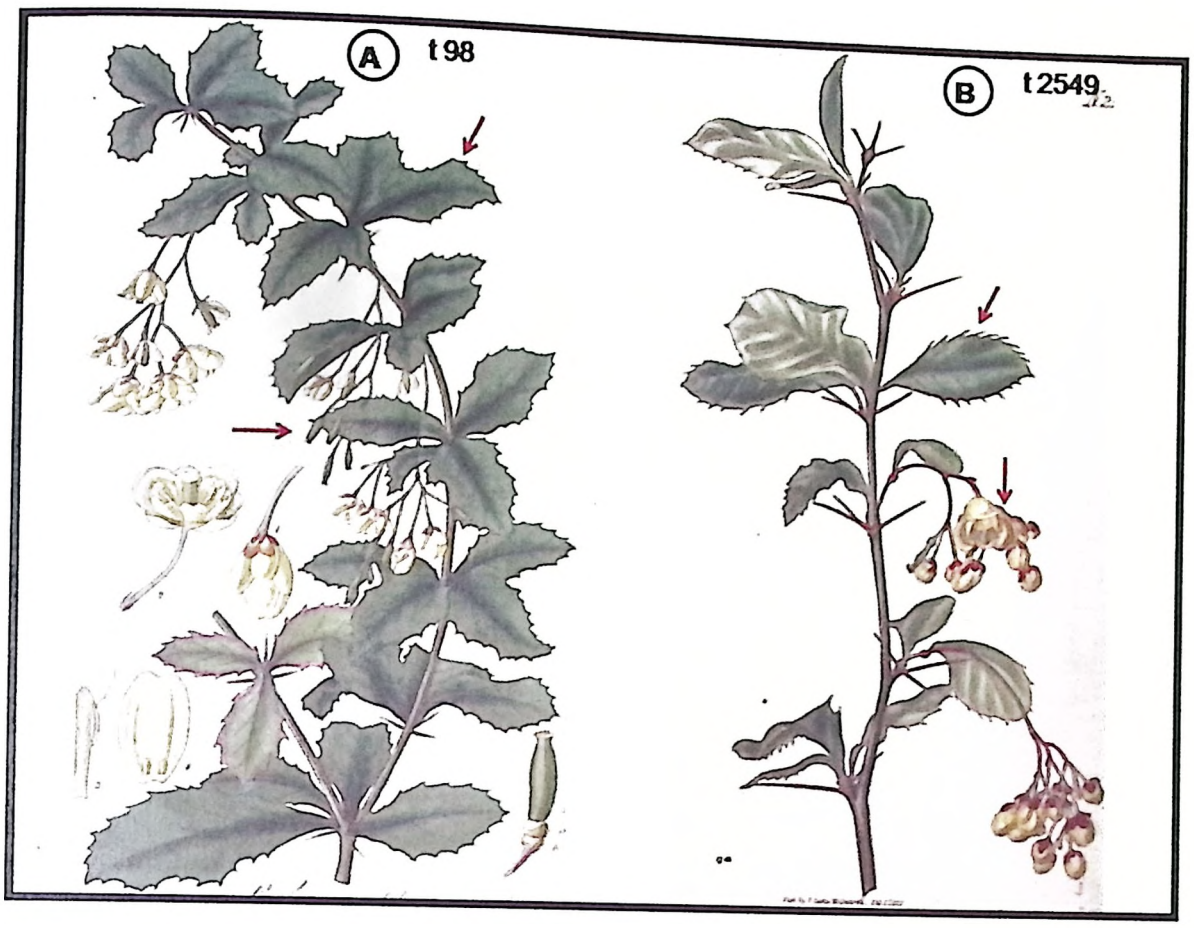

Figure 3.15. *Berberis chitria* Lindl.: **A:** Source: William J. Hooker in Exotic Flora t 98; **B:** Source: Sims in Botanical Magzine t. 2549.

In Flora of British India (Hooker 1975), had given Lindley's *B. chitria* as a synonym. Schneider (1905) noted that differences and said '*B. aristata* DC. inflorescence composities et a *B. chitria* ramis grinis angularis glabris. Sp. nov. videter' and segregated both as separate species. However, both taxa are currently accepted as species.

Berberis concinna* var. *brevior Ahrendt, J. Asiat. Soc. Beng. (Sci.) 11:3. 1945, et in J. Linn. Soc. Bot. 57: 1 19. 1961; Chatterjee, Rec. Bot. Surv. India 16 (2): 26. 1953; Sur in Sharma et al. Fl. India 1:356. 1993; Rao et al. Rheedea 8(2): 112. 1998. Type: Nepal: Namlang, 9000 ft, 28,Oct. 1931, K.N. Sharma E269 (holo - BM). (Figure 3.16A)

Shrub up to 2 m tall; stems glabrous stout, very sulcate; internodes 1-2.5 cm long; spines 1-1.5 cm long, 3-fid, sulcate. Leave 1-3 x 0.5 - 1.4 cm, suborbicular or obovate, apex ending into a spine, base cuneate, coriaceous, margins 3-7 strongly spinose - dentate, whitish pruinose below, densely finely papillose. Flowers solitary; pedicels 5-10 mm long. Prophyll 2-2.5 x 1.5-2 mm, oblong - triangular, acuminate. Outer sepal 4-6 x 3-4 mm, oblong - ovate, subacute; median and inner sepal 9-10 x 6-7 mm, obovate. Petal 6.5 x 4-5 mm, obovate,

apex acutely emarginate with 2 rounded lobes at apex. Stamen 4-4.5 mm long, truncate. Ovules 6-8. Berries 10-11 x 7-8 mm. ellipsoid, red, estylose.

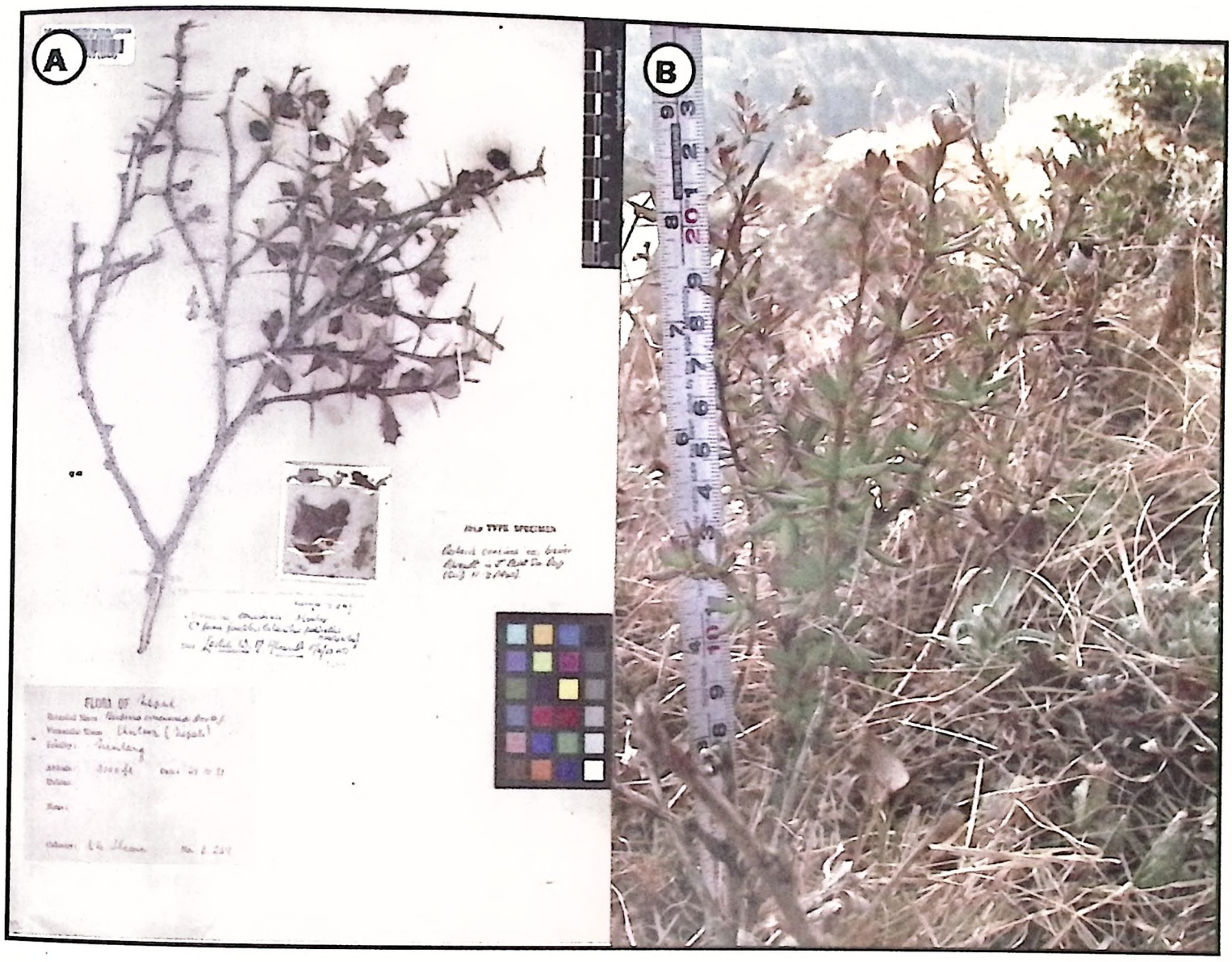

Figure 3.16. *Berberis concinna* var. *brevior* Ahrendt: **A:** Namlang, 9000 ft, 28,Oct. 1931, K.N. Sharma E269 (holo - BM); **B:** Habitat of *Berberis concinna* var. *brevior*.

Flowering and fruiting: June - October

Distribution: INDIA: Uttarakhand; NEPAL.

Habitat: Rocky crevices, 3000 - 4500 m (Rao et al. 1998b).

Additional specimens examined: Garhwal, 4.9.1885, *Duthie 1816* (CAL)

Taxonomic Notes: I had visited many places in state, but I had collected this species from betulidhar. It was in vegetative stage and several time i had visited but not get in flowering conditions. So i am not sure about presence of species in state. On the basis of past literature I am including this in my work.

Berberis coriaria Royle ex Lindl., Bot. Reg. 27: t. 46. 1841; Ahrendt in J. Bot. Loud. (Suppl.): 89. 1942; et in J. Linn. Soc. Bot. 57: 102. f. 16. 1961; Chatterjee in Rec. Bot. Surv. India 16(2): 20.·1953; Banerjee in Sharma et al., Fl. India 1:382; 1993; Rao et al., Rheedea 8(1) 21-22. 1998. (Figure 3.17 and 3.18A)

Key to the varieties

1. Racemes dense, rigid, 4-5 cm; pedicels 3-5 mm; bracts dentate; leaves slightly subcoriaceous.....*B. coriaria* var. *coriaria*

1. Racemes lax, 5-8 cm; pedicels 6-12 mm; bracts entire; leaves thickly coriaceous..... *B. coriaria* var. *patula*

B. coriaria var. coriaria

Type: Not traced.

Shrub *ca* 2.5-3 m tall; stems glabrous, angled, mature yellow; internodes 2.2-3 cm long; spines 3-fid, 10-17 mm long, stout, central one longer than the laterals. Leave 5-8 at each node, 19-34 x 6-10 mm, elliptic or obovate-oblong, apex acute or mucronate, cuneate, subsessile, margins entire; veins raised on the upper surface, subcoriaceous. Inflorescences 5-20- fid., racemose dense, with 1-2 additional flowers at the base; peduncle 40-50 mm long. Flowers 10-15 mm in diam., pedicel 3-5 mm, bract dentate. Sepal in two whorls; outer sepals 6-7 x 3-4 mm, oblong to obovate, subacute; inner sepal 7.5-8.5 x 4-6.5 mm; obovate, subacute. Petal 6-7 x 3-5 mm, oblong, emarginated, base clawed with a pair of glands, conspicuously 3-veined. Anther 2 mm long, apiculate; filament 2 mm long. Ovules 4-5. Berries bright red, epruinose, oblong, stylose; style 1-1.5 mm long, ash coloured.

Flowering and fruiting: May - October

Distribution: INDIA: Himachal Pradesh, Uttarakhand; NEPAL.

Habitat: Distribution range between 2200-3000 m in the Himalayas (Rao et al. 1998a).

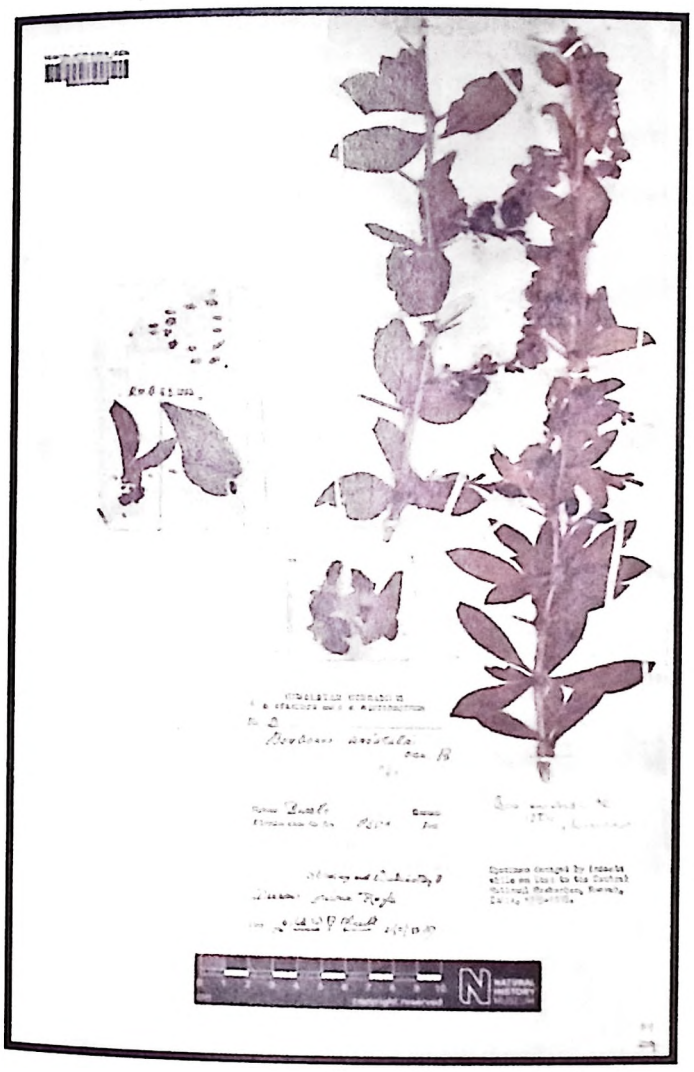

Figure 3.17: *B. coriaria*: Dwali, 8000 ft, *Strachey and Winterbottom 3* (BM)

Specimens examined : Garhwal: Uttarkashi Dist., near yamnotri, 3000m, 7.6.1992, *B. Datt and B. Lal 212279* (LWG); Ananlgang Valley, 3000 m, 11.10.1970, *B. D. Naithani 42141* (BSD); Tehri, way to Kushkalayni 2700-2800 m, 24.9.1994, *M. V. Vishwanathan 54917* (BSD); Near Wan, 2200 m, 1.5.1967, *U. C. Bhattacharyya 37222* (BSD); Tehri Garhwal, way to Ghuthu, 2500 m, 8.6.1972, *B. D. Naithani 48205* (BSD); Jaunsar, May 1894, *F. W. Forster 17019* (CAL); Tehri Garhwal 20.5.1893, *Duthie 17165* (CAL); Jaunsar Bodiyar, May, 1892, J.S.Gamble 27822 (CAL); Deoban, May, 1892, *J. S. Gamble 27822* CAL); Deoban, May, 1892, *J. S. Gamble 23802* (CAL); Jaunsar, Badiyar, April, 1892, *J. S. Gamble 93822* (CAL); Kumaon: 1835. Royal s.n. (K) seed only; Dwali, *Strachey and Winterbottom 3* (K); *Hooker and Thomson s.n.* (K); Almora-Dhakuri, 3000 m, July 1920, *Lambert s.n.* (K); Pithoragarh, Chaudans, 13.7.1886, *J. F. Duthie 5310* (DD); Nainital, Kalingot, 2400 m, 28.5.1914, *Hira Singh 184* (DD).

Taxonomic Notes: This species has been included on the authority of Rao et al. (1998a) and Ahrendt (1961) who had reported this species from Deoban, Dehradun and many places from state but its occurrence in state is doubtful. Lindley (1841) has described this species with figure and made quite clear formal nature of the racemes with short and stout pedicel, large flowers and red fruits and very emarginated petals. I am incapable to distinguish from *B. aristata*, not possessing any authentic specimen of this species. It would appear, however, from the specific character in the *Illustrations of the Botany of the Himalaya* that its pendulous racemes, short pedicel, and large flowers are not sufficient characters to point out the differences. The conception of Hooker and Thomson's *B. aristata* var. *floribunda*, which seems to contain a number of different forms, must be primarily identified with *B. glaucocarpa* Stapf (which has similar racemes) since the authors refer explicitly to "regularly racemose" as its best characters and also describe the fruit as shortly oblong, very glaucous and red epruinose. During consultation of different herbaria exist in India and other part of world found that all the specimens who are mounted as *B. coriaria* has same range of racemose inflorescence, entire petals and purpulish blue pruinose ovoid fruit. Ahrendt (1942) stated that fasciculate and corymbose flowers on specimens of *Strachey and Winterbottom 3* (BM), and the citation from Garhwal, may be taken as referring to *B. petiolaris* var. *garhwalana*, for the type of *B. coriaria* seems to be restricted to Kumaon. As Ahrendt (1942 and 1961) made the variety but as the character and figure drawn by Royal's look quite similar to *B. lycium* but the only difference is the red epruinose fruit, that fruit look artificial and this type of fruits are not found in any *Berberis* species or Tons valley area from where this species was described. I had collected lot of specimens from Tons valley, Yamuna valley, Bhagirathi valley, Balganga, Bhilangana valley, Mandakini, Alaknandda valley, Dhauliganga, Pushpavati valley, Pinder valley, Ramganga (E) valley, Dharma and Byans valley, but this species look quite similar to *B. aristata* DC description (Figure 3.19A).

Berberis coriaria* var. *patula Ahrendt, J. Bot. Lond. 80 (Suppl.): 91. 1942; et in J. Linn. Soc. Bot. 57 (369): 102. 1961; Banerjee in Sharma et al., Fl. India 1:382. 1993; Rao et al. Rheedea 8(1) 22-23. 1998. Type: The Wisley, fl. 19 May 1939; fr. 10 Nov. 1938 (Type BM) (Figure 3.18B)

Shrub *ca* 2.5-3 m tall; stems glabrous, angled, mature yellow; internodes 2.2-3 cm long; spines 3-fid, 10-17 mm long, stout, central one longer than the laterals. Leave 5-8 at each node, 1.9-3.4 x 6-10 mm, elliptic or obovatc-oblong, apex acute or mucronate, cuneate, subsessile, margins entire; veins raised on the upper surface, coriaceous. Inflorescence 5-20 flowers, racemose lax, with 1-2 additional flowers at the base; peduncle 40-80 mm long. Flower 1-1.5 cm in diam., pedicels 6-12 mm; bract entire. Sepal in two whorls; outer sepal 6-7 x 3-4 mm, oblong to obovate, subacute; inner sepal 7.5-8.5 x 4-6.5 mm; obovate, subacute. Petal 6-7 x 3-5 mm, oblong, emarginated, base clawed with a pair of glands, conspicuously 3-veined. Anther 2 mm long, apiculate; filament 2 mm long. Ovules 4-5. Berries bright red, epruinose, oblong ovoid, stylose; style 1-1.5 mm long, ash coloured.

Distribution: INDIA: Himalayas. Uttarakhand (Endemic) (Rao et al. 1998).

Specimens examined: Deota, 2780 m, 20. 5. 1898, *Duthie s.n.* (BM); Uttarkashi Dist., near Naradchattii on way to Yamnotri, 2300 m, 8.6.1992, *B. Datt and B. Lal 212275* (LWG); Uttarkashi Dist. Near Yamnotri, 3000 m, 7.6.1992, *B. Datt and B. Lal 212279B* (LWG); Harkidun, June, 1893, *J. S. Gamble 24329* (CAL); Badiyar, April, 1892, *J. S. Gamble 23549* (CAL); Sosa, 13.7.1886, *J. F. Duthie 5310* (CAL); Nainital, 2350 m, *Strachey and Winterbottom 2* pro parte (BM).

Taxonomic Notes: This variety has been included on the authority of Rao et al. (1998a) and Ahrendt (1961) who had reported this species from Uttarkashi on way to Yamnotri and from Sosa (Kumaon) in state but its occurrence in state is doubtful. The type speciemen were grown in Wisley Garden and Ahrendt collected and deposited in BM. While describing this varietiy, Ahrendt (1942) had mention that this species looks like *B. aristata* and only the diffrence in sulcate stems, and large fruit, pedicel laxiflorus and 6-12 mm long. The type specimen of *Berberis aristata* is not available and how can it be compaire with *B. aristata*. The specimen collected by Duthie's from Deota is also looks like *B. aristata* which is kept in BM, but named as *Berberis coriaria*. While compairing the other specimen kept in Indian herbaria and other then India, their characters are quite similar to *B. aristata*. Type specimen of *B. coriaria* var. *patula* is quite similar to *B. lycium* kept at BM (Figure 3.18B).

Ahrendt (1942 and 1961) while solving the problem he had added one more variety. I am quite sure this variety is not existing and it should be merge with *B. aristata*.

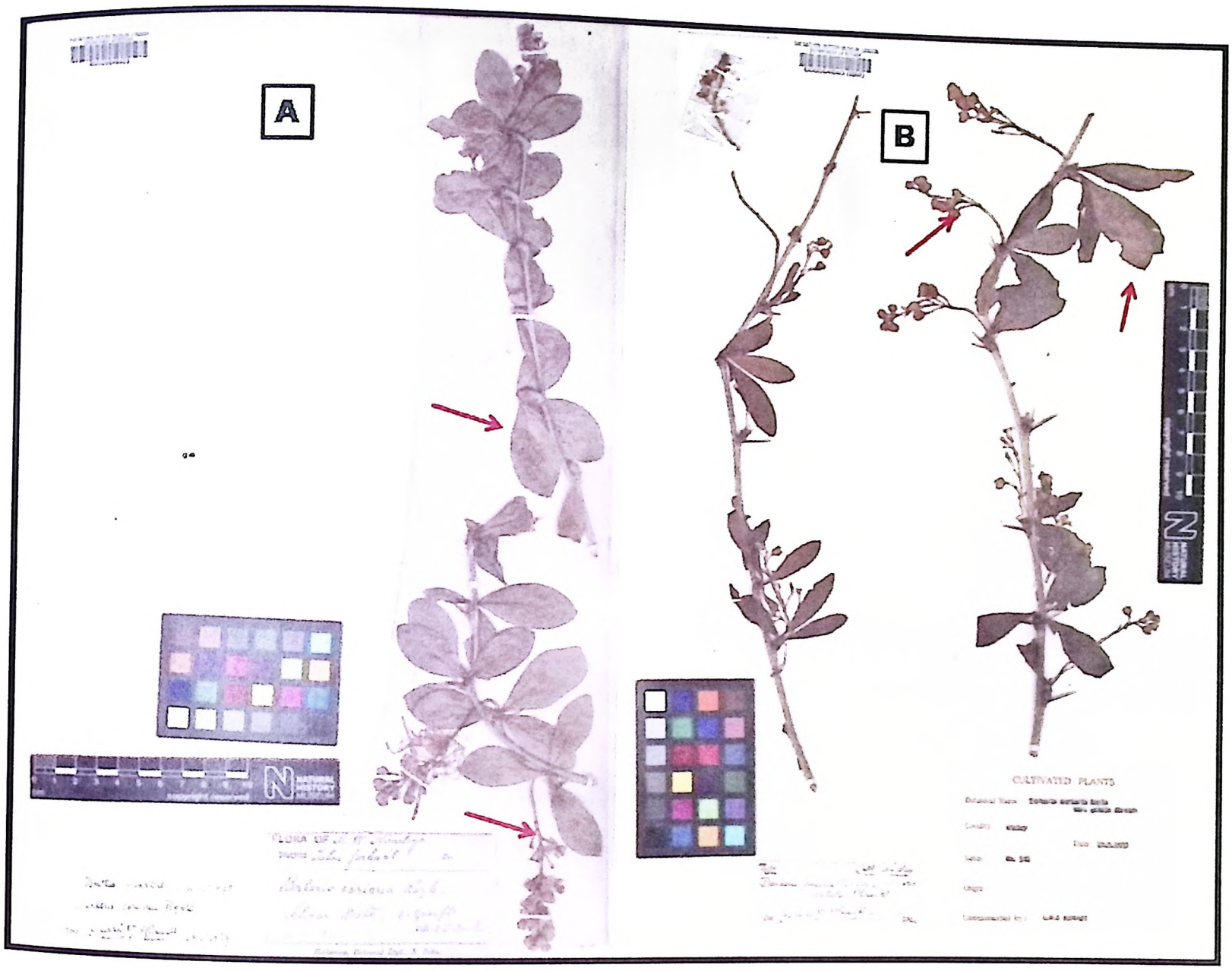

Figure 3.18. *Berberis coriaria* **A:** Deota, 1898, *Duthie s.n.* (BM) and **B:** The Wisley, 1939 (BM).

Berberis cretica L., Sp. Pl. 331. 1753; Ahrendt in J. Linn. Soc. Bot. 57: 225. 1961; Rao and Kumar in Sharma et al., FL India 1: 375. 1993; Rao et al., Rheedea 8(2): 134. 1998.

B. vulgaris var. *cretica* (L.) Hook.f. and Thoms, in Fl. Brit. India 1: 109. 1875.

Shrub 1-2 m high; stems glabrous, stout, sulcate, mature lustrous; spines yellow to orange. Leave 10-17 x 4-7 mm, obovate, apex acute to subacute, base cuneate, sessile, entire, both surfaces openly reticulate with distinct lateral veins. Inflorescence fascicled, 3-6 flowers, 6-

10 mm long; pedicel 2-5 mm long. Outer sepal 4 x 2.5 mm, elliptic; inner sepal 4-4.5 x 3 mm, obovate. Petal 4-4.7 x 3 mm, obovate, entire; glands 3, orange, oblanceolate, submarginal. Stamen 3.5-4.5 mm. Ovule 2. Berries 6-7 x 4-5 mm, ellipsoid, red, black or dark blue at maturity, epruinose or slightly pruinose, shortly stylose.

Flowering and fruiting: May - July.

Distribution: INDIA: Uttarakhand (Garhwal), Himachal Pradesh; CYPRUS; CRETE; GREECE. (Rao et al.1998b)

Habitat: Not identified.

Specimens examined: NIL

Taxonomic Notes: I have doubt about the distribution of species in Indian subcontinent. This species is mainly distributed in Greece and Crete. None of the Indian herbaria has a single authentic specimen collected from India region. This species is recorded in several literatures but no one has mentioned the specimen or any past collections. This species has been included on the authority of Rao et al. (1998b) and Ahrendt (1961) who had reported this species in state.

Berberis floribunda Wall. ex G. Don, Gen. Syst. 1:115. 1831; Chatterjee in Rec. Bot. Surv. India 16(2): 19. 1953; Ahrendt in J. Linn. Soc. Bot. 57:101. 1961; Benerjee in Sharma et al., Fl. India 1:381. 1983; Rao et al., Rheedea 8(1) 23-24. 1998. Type: *Wallich 1474* (4A, 5B) (K) (Figure 3.19)

B. umbellata Lindl. in Bot. Reg. 30: t. 44, 1844 (non Wall, ex G.Don, 1831); Hook . f. and Thom., in Hook, f., Fl. Brit. India 1: 1 10. 1875.

Shrub; stem glabrous, pale yellow, terete or subterete, sparsely and distinctly verruculose; nodes swollen; internodes 2.5-4 cm long; spines 4-10 mm long, absent or solitary,

rarely up to 3 at the base. Leave 3-5.2 x 1.5-2.3 cm, five at each node, unequal, obovate, lanceolate to elliptic, attenuate at base, entire or rarely with a few spinules along margins, subacute to obtuse at apex, distinctly reticulate on both surfaces, papillose on both the surfaces. Inflorescence racemose, 10- 25-fld; mostly sessile. Pedicel *ca* 6 mm long; bracts 1-2 mm long acuminate. Outer sepal 2.5 x 1.5 mm, oblong - ovate, subacute; median sepal 4x3 mm, elliptic; inner sepal 6 x 4.5 mm, obovate oblong - elliptic. Petal entire, clawed at base, glandular. Stamen 3-4 mm long, truncate or rounded - truncate. Ovule 4-5. Berries 6.5 - 7.5 x 4.5-5 mm, broadly oblong - ellipsoid, dark red, finally almost purple, pruinose blue, stylose; style 0.5 mm long.

Flowering and fruiting: May - September

Distribution: INDIA: Uttarakhand and Himachal Pradesh; NEPAL

Habitat: Himalayas, 2700-3500 m.

Specimens examined: Chamoli Bhyunder valley, 2700 m, 23.9.1963, *U. C. Bhattacharyya 29650* (BSD); Thini gaon, Muktinath, 24. 6. 1954. *Stainton, Skyes and Williams 1378* (CAL).

Figure 3.19: *Berberis floribunda*: *Wallich 1474* (4A, 5B) (K)

Taxonomic Notes: Don (1831) had described this species on the basis of Wallich manuscript, shrub of 10 ft height, 3 partite spine, unequal, leaves obovate-lanceolate, ovate-oblong, tapering much to the base, ending in mucronate at the apex, paler beneath, spine-ciliated; racemes many flowered, loose solitary, pendulous; fruit oblong. Hooker and Thomson (1855) mentioned that species has racemose disposition of the flowers is its best

character, but on some of the *Strachey and Winterbottom*'s and *Wallich*'s specimens both fasciculate and corymbose and racemose flower have offend seen on the same specimen. Lindley (1844) mention new name *Berberis umbellata* in Botanical Register but later this name becomes synoname for this species. Schneider (1905) merged *B. floribunda* in *Berberis aristata*. The pedicels of the flower are very short. The only type specimen (Figure 3.19) which is kept at 'K' look different which was collected from Nepal, but the specimen which were kept in Uttarakhand are not similar to the *B. floribunda*, all the specimen which is hosted in the Indian herbaria look very much similar to *Berberis aristata*. Specimen collected by *U. C. Bhattacharyya 29650* (BSD) looks like *B. aristata* and according to me; this species is not found in the Uttarakhand state.

Berberis glaucocarpa Stapf, Bot. Mag. 101, sub. t. 9102. 1926; Ahrendt in J. Bot. Lond. 80 (Suppl.): 101. 1943; *et* in J. Linn. Soc. Bot. 57: 90 f. 26 1961; Chatterjee in Rec. Bot. Surv. India 16 (2): 14. 1953; Jafari in Nasir and Ali, Fl. W. Pak. 87:13 .f. 3, C. 1975; Uniyal and Rao in Sharma et al., Fl. India 1:371. 1993; Rao et al., Rheedea 8(1) 57-58. 1998. Type: Jaunsar: Hills between Tons and Giri rivers, 8000 ft., May 1875, *Brandis 746* (holo - **K**). (Figure 3.20)

Berberis coriaria auct. non Royle; Brandis ex Gamble, Man. Indian Timb. ed. 1:14. 1881; Collett, Fl. Siml. 22. 1902.

Berberis aristata auct. non DC; Parker, For. Fl. Punj. with Hazara and Delhi 15. 1918.

Shrub 3-4 m tall; stems pale yellow, terete, glabrous, very minutely vemiculose; internode 2.5-4 cm long; spines solitary or 3-fid, 5-16 mm long. Leaves 1.5 - 8 x 0.7 - 2.5 cm, obovate - elliptic, apex mucronate, base tapering, sessile or very shortly petioled, usually 4-8 spinose - dentate at margin, pale, and venation clear on both surfaces. Inflorescence racemose, 15-25 flowers, 2-4 cm long, rigid, rarely slightly compound. Flower 10-12 mm across, pale yellow; pedicel 5-10 mm long in fruit, stout. Prophyll *ca* 1 mm long. Outer sepal *ca* 2 mm long, ovate; middle one 4 mm long; inner sepal 6 mm long, obovate. Petal 7 x 4.5 mm, obovate,

apex retuse, base clawed; glands 2. Stamen 5.5 mm long, apices subapiculate. Berries 6-9 x 6-8 mm, oblong - globose, black, pruinose white; style 1 mm long; seeds 3-4. Flowering and fruiting: April – September.

Distribution: INDIA: Jammu and Kashmir, Himachal Pradesh, Uttarakhand; PAKISTAN; NEPAL.

Habitat: In open shrubby places; 2100-3000 m (Rao et al. 1998a).

Specimens examined: Jankichattii, Yamuna valley, 2285 m, 15.4.2009, *UKT 0929* (WII); Jankichattii, Yamuna valley, 2285 m, 15.4.2009, *UKT 0930* (WII); Deoban, Chakrata, 2590 m, 27.4.2009, *UKT 0963* (WII).

Additional specimens examined: Gangi, 3000 m, 1 1.8.1978, *A. K. Goel 64382* (BSD); Jaunsar, Mundali, 2100-2400m, 4.6.1894, *Duthie 21090* (DD); Tehri, 2400 m, May, 1891, J. S. Gamble 22772 (DD); Junsar- Badiyar, 2100 m, May, 1892, *Gamble 93892* (DD); Deoban, 2400 m, 22'9.1958, *K. C. Sahni 26743* (DD); Deota, Tehri Garhwal, 2550 m, May, 1896, *Gamble 25762* (DD); Jaunsar, Mundali, 2340 m, April, 1894, *J. F. Duthie s.n.* (CAL); Deota, Tehri Garhwal, 2550 m, *Gamble s.n.* (CAL); Uttarkashi, Sukhi slopes, 14.9.1991, *B. S. Aswal 18318* (LWG); Uttarkashi, Jhala, 14.9.1991, *B. S. Aswal 18321* (LWG); Gangi, *A. K. Goel 64382* (LWG). Kumaon: Phurkia - Dwali, 2500 - 3000 m, 25.9.1957, *T. A. Rao 4608* (BSD).

Taxonomic Notes: Ahrendt (1961) distinguished *Berberis glaucocarpa* from *B. aristata* mainly because of their distribution as he has clearly remarked "He had not seen any herbarium specimens from east Tehri and the references to Kumaon (Collett 1902) and from Nepal (Parker 1918)", may be introduce confusion with *B. coriaria* and *B. aristata*. Ahrendt (1961) and subsequently Uniyal and Rao (1993) have distinguished *Berberis* section Tinctoriae from section Asiaticae based on colour of fruit whereas in the description of *B. aristata* they have mentioned berries as pruinose blue. Rao et al. (1998a) mention that, all the specimens from Kumaon and the other parts of the state for the segregation *B.*

glaucocarpa from *B. aristata* and *B. coriaria* are difficult and a clear-cut picture would only emerge after the study of type specimens of all the 3 taxa, but type specimen of *Berberis*

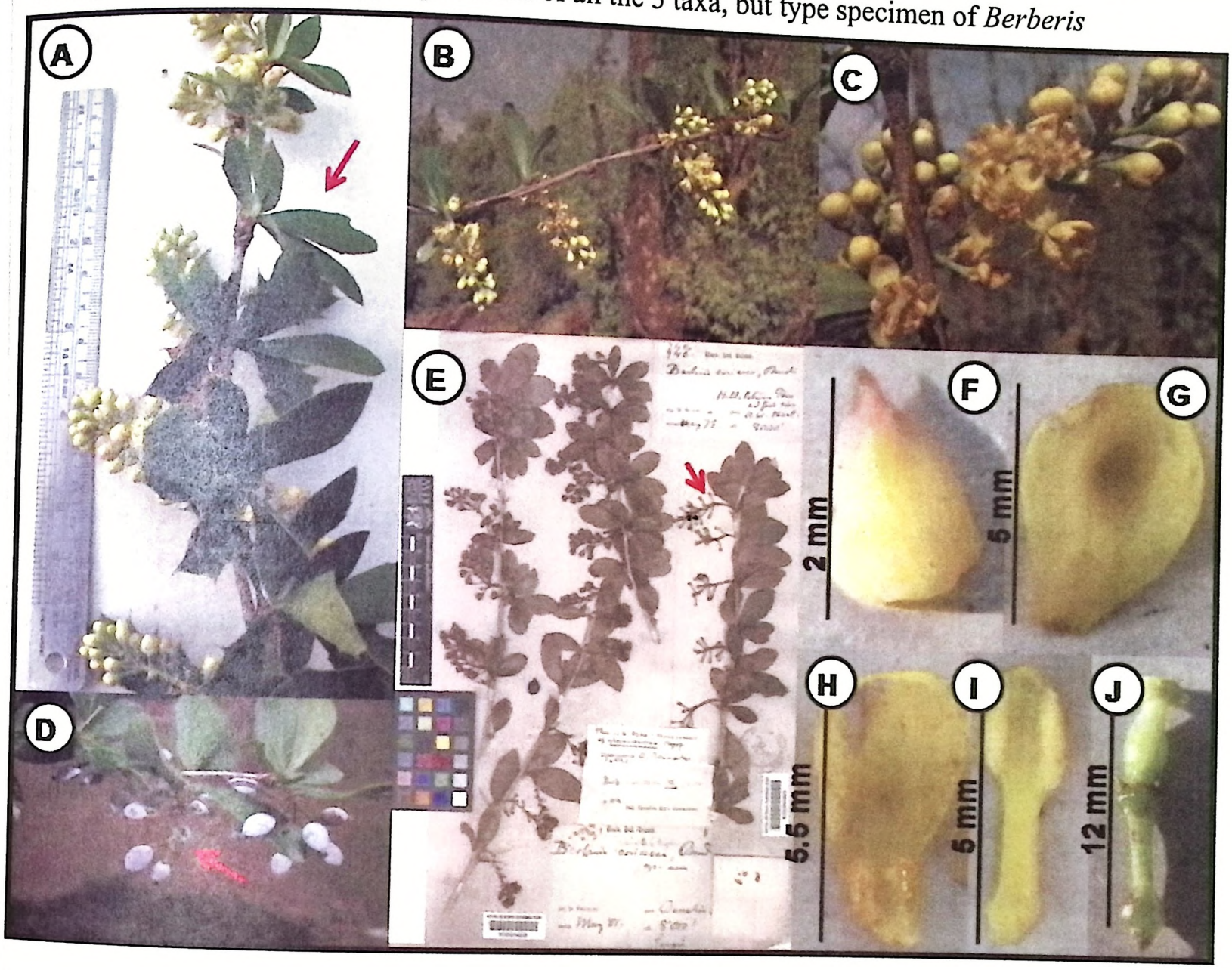

Figure 3.20: *Berberis glaucocarpa* (*UKT-0929*) – **A and B:** Twig with leaves and inflorescence; **C:** Close up of Inflorescence; **D:** Twig with fruit; **E:** Type specimen, North West Himalaya, 1876, *Brandis 746* (K); **F:** Outer sepal; **G:** Inner sepal; **H:** Petal; **I:** Stamen and **J:** Immature Fruit.

aristata and *Berberis coriaria* could not be traced and it is hard to discriminate these species from each others. As mention by Rao et al. (1998a) the stout nature of the pedicel and the rigid inflorescence in *B. glaucocarpa* may be good character for distinguishing this species from the other two, I disagree with this statement because the specimen which are kept in the Indian herbaria or other then India are quite similar to each other in terms of the leaf size, shape and flowering pattern. As mention by Stapf (1926) that this species has bluish purple fruit and specimen, which are kept at KEW (*Brandis 746* -K), appeared and match

with the description of *B. aristata* DC. Because of fruit colour (which is taxonomically not a good character) it should not treated as distinct species. I had collected several specimens from state and all the specimens, which are collected in altitudinal range between 2200 to 3600 m in state looks similar to each other except few leaves variation in size and shape, but flower parts, are almost similar to each other. This species cannot be segregated from *B. aristata* and it should be merged.

Berberis hamiltoniana Ahrendt, Gard. Illustr. 64: 426. 1944; Chatterjee, Rec. Bot. Surv. India 16(2): 20. 1953; Ahrendt, J. Linn. Soc. Bot. 57: 137. 1961; Das Gupta in Sharma et al., Fl. India 1:360, f. 55. 1993. Rao et al. Rheedea 8(2): 118-121. 1998. (Figure 3.21)

Shrubs 1.5-2.5 m tall; stems glabrous, sulcate, terete in older parts, angled towards the apex; internodes 1-1.5 cm long; spines 7-10 mm long, 3-fid, central spine slightly longer than the lateral ones. Leaves 2-3.5 x 0.6-1.3 cm, 4-9 from a single node, obovate, apex obtuse and spiny, entire or sometime spiny along margins, sub-lustrous, yellowish green on dorsal surface, below grey, pruinose, revolute along margins, prominently reticulate. Inflorescence umbellate - subracemose, sometimes fascicled, 5-10 flowers, 2.3 cm long; peduncles 0.3-2 cm long; pedicels 5-10 mm long; bract 1.5-2.5 mm long, lanceolate, acuminate. Prophylls 1.5-2 mm. Sepals 6.5 x 3.4 mm, elliptic, concave. Petals 5 x 4 mm, obovate, entire, cuneate at base; nector-glands non-marginal, separate, suboblong. Stamens 4-5 mm long, sometimes produced and subtruncate or obtuse at apex. Ovary oblong, estylose; ovules 3-5. Berries 9-10 x 6 mm, very bright red, dry, estylose.

Flowering and fruiting: June-October.

Distribution: INDIA: Uttarakhand, Himachal Pradesh; NEPAL; CHINA (Tibet).

Habitat: Stony hillsides, dry slopes, along the boulders on river banks of Kali in Pithoragarh district; 2875-4500 m.

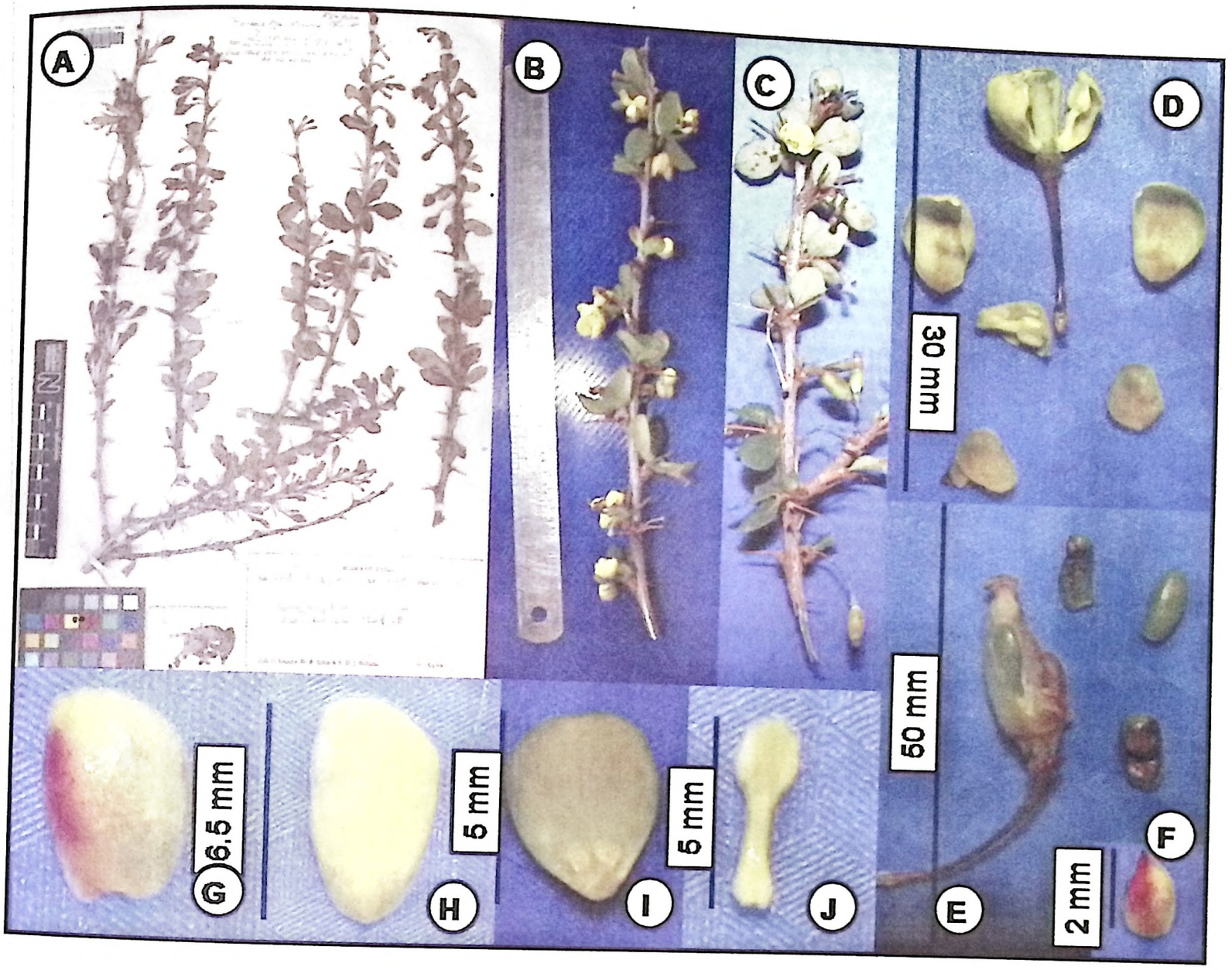

Figure: 3.21. *Berberis hamiltoniana* (*UKT-2097*) - **A:** Polunin, Sykes and Williams *5460*(BM); 1000 ft., Chutta, South East of Jumla, Nepal, 28 /9 / 1952. **B and C:** Twig with leaves and inflorescence; **D:** Dissected flowers parts; **E:** Fruit and seeds; **F:** Prophyll; **G:** Outer sepal; **H:** Inner sepal; **I:** Petal and **J:** Stamen.

Specimens examined: *UKT-2097, 2100, 2104, 2105* and *2108* Garbyang, Kalapani, Gunji and Siti from Byans Kali valley, Pithoragarh 7/07/2010, at 3000-3400 m a.s.l.

Additional specimen examined: Himachal Pradesh: Kalpa, Chini, Bashahar, 2875 m, 3.6.1962, *N. C. Nair 22386* (BSD); *Stainton E00112241*(E), 1954; Polunin, Sykes and Williams *5460*(BM); 1000 ft., Chutta, South East of Jumla, Nepal, 28 /9 / 1952 (Figure 3.21A).

Taxonomic Notes: Previously this species is reported from Himachal Pradesh (Rao et al.

1998b) and from Nepal (Ahrendt 1961). During this study I had collected this species from Kali river I had collected from Kali valley in between Budhi to Gunji village. This species is a new record for state of Uttarakhand.

Berberis jaeschkeana Schneid., Bull. Herb. Boiss. (2)5: 399. 1905; Parker, For. Fl. Punj. Hazara and Delhi 14. 1918; Chatterjee, Rec. Bot. Surv. India 16(2): 29. 1953; Ahrendt, J. Linn. Soc. Lond. 57: 138. 1961; Jafari in Nasir and Ali, Fl. W. Pakistan 87: 16. 1975; Das Gupta in Sharma et al., Fl. India 1:363, f. 56. 1993; Rao et al., Rheedea 8(2): 118-121. 1998. (Figure 3.22)

Key to varieties (after Ahrendt, 1961)

1. Stems puberulous; petals entire.....*B. jaeschkeana* var. *jaeschkeana*
1. Stems glabrous; petals emarginate.....*B. jaeschkeana* var. *usteriana*

B. jaeschkeana var. jaeschkeana

Type: Kashmir: *Falconer 97* (holo - K).

Shrub 1-2 m tall, deciduous, stem stout, angled, initially slightly reddish, yellow-brown at maturity; internode 5-20 mm long; spines 3-fid, 5-15 mm long, central one longer than the laterals, concolorous sulcate; hairy, scattered throughout. Leaves 10-35 x 5-10 mm, 3-5 at each node, obovoid-oblong, oblong-elliptic or narrowly obovoid-oblong, apex mucronate or sometimes rounded, base attenuate, mostly with margins 2-5 spinose; spines 10-15 mm long; slightly grey pruinose, beneath, green above, both surfaces openly veined and reticulate, sessile or subsessile. Inflorescence 3-5 flowers, umbellate or subumbellate, 10-40 mm long, glabrous. Flower 8-10 mm across, yellow; pedicel 9-13 mm long, glabrous; bract 2-3 x 1 mm, minutely puberulous; outer and middle sepal 4-7 mm long, obovate-elliptic, subacute, entire, inner sepals 8-9 x 7-8 mm, obovate, concave, and entire. Petal 6-7 x 5-6 mm, obovate, base clawed, conspicuously veined, glands 2 mm long. Stamen slightly produced, truncate; anther 2 mm long; filament 3 mm long. Ovules 4-6. Berries 8-10 x 5 mm, red, oblong-bvoid, epruinose, very shortly stylose.

Flowering and fruiting: May-August.

Distribution: Uttarakhand: Harki Dun, Yanmanotri, Gangotri, Kandara, Gidara and Dayara, Kushkalyani, Bedani-Ali, Bhuna, Bagachi Bugyals, Bhilangana valley above 2800 m, Tungnath. Jammu and Kashmir, Himachal Pradesh, China; Pakistan; Nepal.

Habitat: Forming dense patches on rocky or sandy slopes among boulders at an altitude of 2200-5200 m in the state.

Specimens examined: On way to Yamnotri temple, 3018 m, 14.5.2008, *UKT 0060* (WII); On way to Yamnotri temple, 3140 m, 15.5.2008, *UKT 0115* (WII); Osala, On way to Har-ki-Dun, Uttarkashi, 2655 m, 3.6.2008, *UKT 0212* (WII); On way to Har-ki-Dun, Uttarkashi, 2708 m, 3.6.2008, *UKT 0216* (WII); On way to Har-ki-Dun, Uttarkashi, 2800 m, 3.6.2008, *UKT 0220* (WII); Har-ki-Dun, Uttarkashi, 3200 m, 3.6.2008, *UKT 0226 and 0228* (WII); Har-ki-Dun, Uttarkashi, 3200 m, 4.6.2008, *UKT 0232, 0238, 0242, 0249 and 0253* (WII); On way to Yamnotri temple, 2673 m, 27.6.2008, *UKT 0345* (WII); On way to Yamnotri temple, 2594 m, 27.6.2008, *UKT 0355 and 0360* (WII); On way to Yamnotri temple, 2673 m, 27.6.2008, *UKT 0365* (WII); Chopta, On way to Tunganath temple, Chamoli, 2988 m, 9.5.2009, *UKT 0980* (WII); Chopta, On way to Tunganath temple, Chamoli, 2980 m, 9.5.2009, *UKT 0982 and 0284* (WII); Chopta, On way to Tunganath temple, Chamoli, 3000 m, 9.5.2009, *UKT 0985*(WII); Kandara Bugyal, Uttarkashi, 3650 m, 1.7.2010, *UKT 2084* (WII); Kalapani, Kali valley, Pithoragarh, 3574 m, 8.7.2010, *UKT 2101* (WII); Nabhidhang, Kali valley, Pithoragarh, 3981 m, 8.7.2010, *UKT 2102*(WII).

Additional specimens examined: Chamoli- Tungnath, *B. D. Naithani 44154* (LWG, BSD); Bhyundar valley, *U. C. Bhattacharyya 66357* (LWG); Mandakini Valley, Kedarnath to Garurchattii, 30.5.1972, *Mehrotra and Party 3337* (LWG). Mana Vasundhara, 3000-3500 m, 9.10.1959, *M. A. Rau 10467* (BSD); Mana, 3200 m, 11.10.59, *M. A. Rau 10515* (BSD); Chamoli, Niti proper, 8.9.1975, *B. D. Naithani 56117* (BSD); Chamoli, Duggalbhitta, 2200 m, 13.5.1985, *R. R. Rao 76241* (BSD); On way to Hemkund, 4000 m, 19.6.1969, *U. C.*

Bhattacharyya 39067 (BSD); Tehri-Garhwal, Panwali, 3200 m, 2.6.1972, *B. D. Naithani 48126* (BSD, CAL); On way to Kedarnath, 11.10.1965; 3200 m, *N. C. Nair 35875* (BSD);

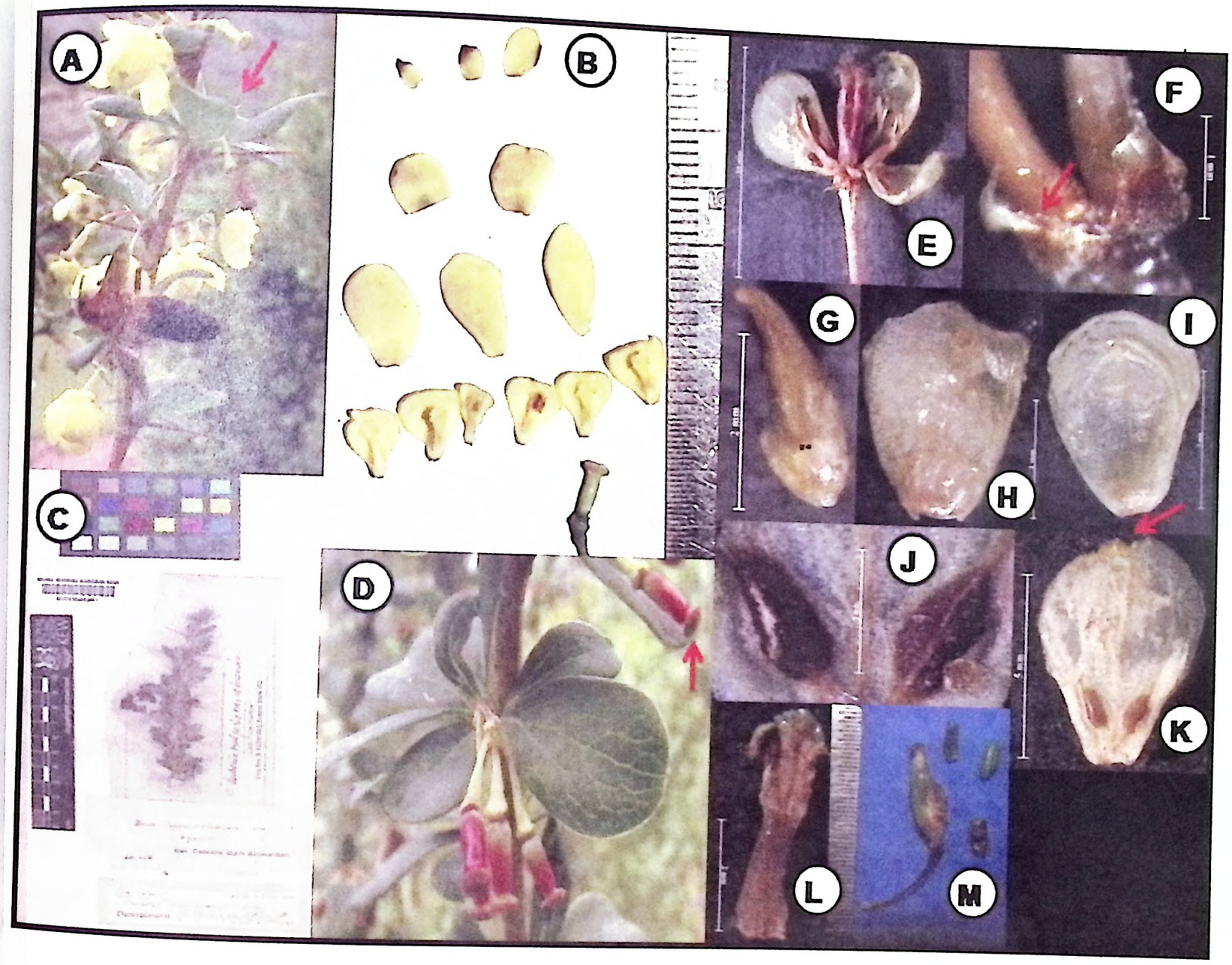

Figure 3.22. *Berberis jaeschkeana* var. *jaeschkeana* (*UKT-0115*) – **A:** Plant with inflorescence; **B:** Dissected flower parts; **C:** Holotype – *Falconer 97*(K); **D:** Plant with Fruits; **E:** Close up of flower; **F:** Bracts; **G:** Outer sepal; **H:** Middle sepal; **I:** Inner sepal; **J:** Glands; **K:** Petal; **L:** Stamen and **M:** Fruit and seeds.

Way to Dunagiri above-Kaga, 3200 m, 18.8.1974, *B. D. Naithani 53975* (BSD); Jaunsar, May 1892, *J. S. Gamble 9378* (CAL); Tehri-Garhwal, June, 1893, *J. S. Gamble 24467* (CAL); Kedarnath valley, *Soda Nand s.n.* (DD); Bogdwar/Martoli, 3000-4500 m, 14.7.1958, *T. A. Rao 6817* (BSD); Shelang glacier, 5000 m, 16.6.1958, *T. A. Rao 6918* (BSD); Pithoragarh - On way to Beirphoo, June, 85, *C. L. Malhotra and B. Balodi 77589* (BSD); Milam glacier, 4000-5200 m, 18.6.1958, *T. A. Rao 6983* (BSD); Hunthor (Milam village) *C.*

L. Malhotra and B. Balodi 77643 (BSD); Garbyang, 14.6.1960, *T. A. Rao 11887* (*CAL*); Ralam glacier, 4000 m, 30.6.2004, *G. S. Rawat 14236* (WII); Mana, 3400 m, 29.7.2004, *G. S. Rawat 14673* (WII); Above Bhudhi, Kali valley, 2800 m, 2.6.2004, *G. S. Rawat 14008* (WII).

Taxonomic Notes: Leaves in this species are distinctly grey pruinose, a character which could be easily observed in the field. A common species rather in state at an altitude of 2800 -3900 m.

Berberis jaeschkeana* var. *usteriana Schneid., Bull. Herb. Boiss. 2(5): 399. 1905; Ahrendt, J. Linn. Soc. Bot. 57: 139.1961; Jafari in Nasir and Ali, Fl. W. Pakistan 87: 18, 1975; Das Gupta in Sharma et al., Fl. India 1: 364. 1993; Rao et al., Rheedea 8(2): 121. 1998. Type: Kumaon: Chelab, Byans, *Duthie 5307* (holo - K) (Figure 3.23).

B. usteriana (Schneid.) Parker, Ind. For. 50: 399. 1924.

Deciduous shrub 1-2 m tall, stem stout, angled, initially slightly reddish, yellow-brown at maturity; internodes 5-20 mm long; spines 3-fid, 5-15 mm long, central one longer than the laterals, concolorous sulcate; hairs mullicellular, arising in multiples from lenticel-like black dots, scattered throughout. Leaves 10-35 x 5-10 mm, 3-5 at each node, obovoid-oblong, oblong-elliptic or narrowly obovoid-oblong, apex mucronate or sometimes rounded, base attenuate, mostly with margins 2-5 spinose; spines 10-15 mm long; slightly grey pruinose, beneath, green above, both surfaces openly veined and reticulate, sessile or subsessile. Inflorescence 3-5 flowers, umbellate or subumbellate, 10-40 mm long, glabrous. Flower 8-10 mm across, yellow; pedicel 9-13 mm long, glabrous; bract 2-3 x 1 mm, minutely puberulous; outer and middle sepal 4-7 mm long, obovate-elliptic, subacute, entire, inner sepal 8-9 x 7-8 mm, obovate, concave, and entire. Petal 6-7 x 5-6 mm, obovate, base clawed, conspicuously veined, glands 2 mm long. Stamen slightly produced, truncate; anther 2 mm long; filament 3 mm long. Ovule 4-6. Berries 8-10 x 5 mm, red, oblong-bvoid, epruinose, very shortly stylose.

Flowering and fruiting: June - September.

Distribution: INDIA: Jammu and Kashmir, Himachal Pradesh, Uttarakhand; NEPAL.

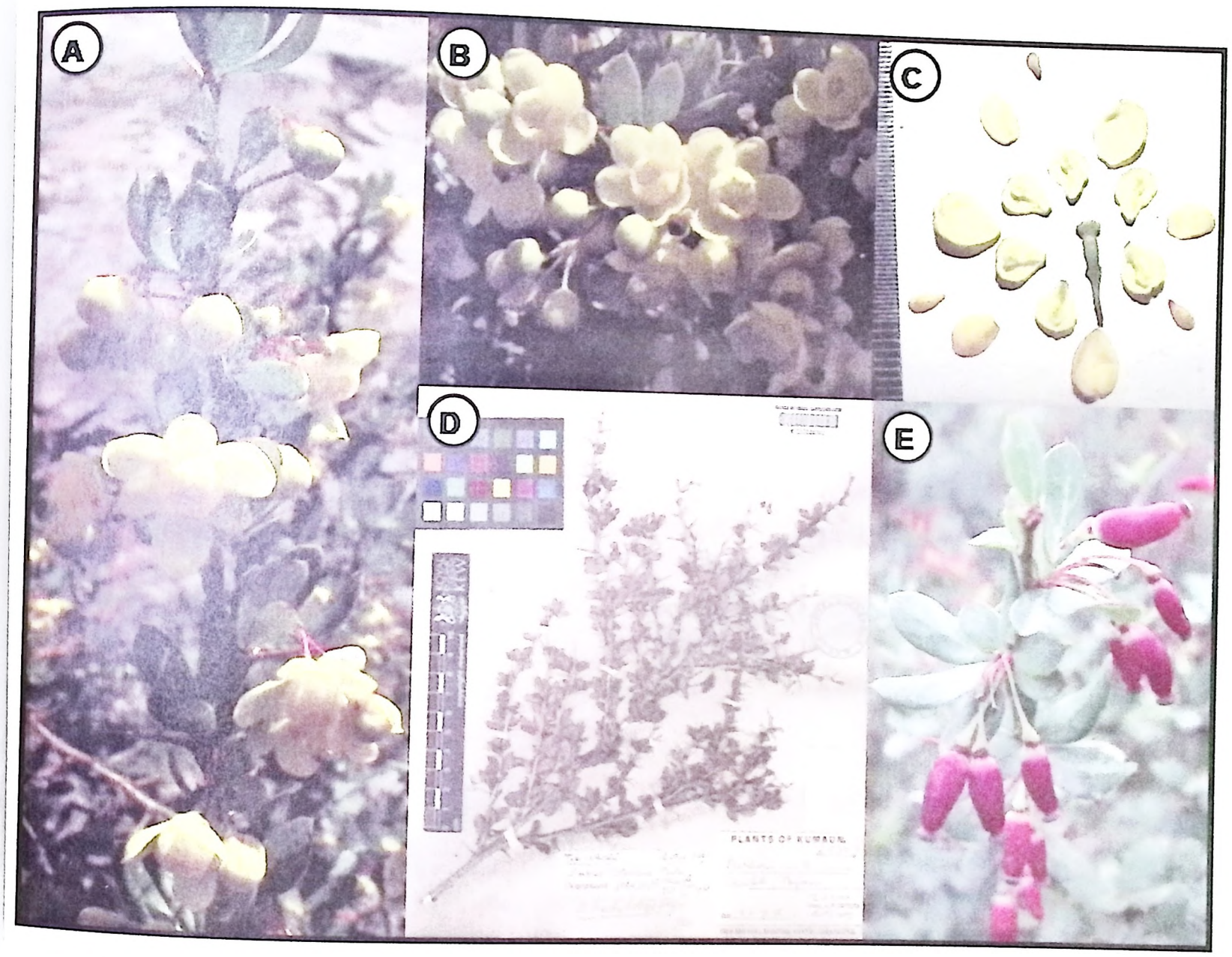

Figure 3.23. *Berberis jaeschkeana* var. *usteriana* (*UKT-2099*) – **A:** Plant with inflorescence; **B:** Close up of Inforescence Plant with Fruits; **C:** Desected flowers parts; **D:** Holotype –*Duthie 5307* (K) and **E:** Plant with fruits.

Habitat: This species grow in open canopy cover and in alpine medows in Kali river valley in easten Kumaon at an altitude of 2850-4500 m.

Specimens examined: Above Budhi village, Kali valley, Pithoragarh, 2949 m, 7.7.2010, *UKT 2094* (WII); Above Chiyalack, Kali valley, Pithoragarh, 3305 m, 7.7.2010, *UKT 2096*

(WII); Garbyang village, Kali valley, Pithoragarh, 3125 m, 7.7.2010, *UKT 2097*(WII); Changaru, Kali valley, Nepal, 3125 m, 7.7.2010, *UKT 2099* (WII); Gunji village, Kali valley, Pithoragarh, 3175 m, 8.7.2010, *UKT 2100* (WII); Kalapani, Kali valley, Pithoragarh, 3574 m, 8.7.2010, *UKT 2104* (WII); Kalapani, Kali valley, Pithoragarh, 3456 m, 8.7.2010, *UKT 2105* (WII); Gunji village, Kali valley, Pithoragarh, 3175 m, 8.7.2010, *UKT 2106* (WII); Siti, Kali valley, Pithoragarh, 3260 m, 9.7.2010, *UKT 2107* (WII); Siti, Kali valley, Pithoragarh, 3150 m, 9.7.2010, *UKT 2108*(WII).

Additional specimens examined: Kumaon: Almora, Garbyang, 3090 m, 13.7.1923, *R. N. Parker 2078* (DD); Byans, 19.7.11886, *J. F. Duthie 5308* (DD); Byans, Budhi 28 50m, 13.7.1923, *R. N. Parker 2077* (DD).

Taxonomic Notes: This variety differs from the type variety by the dwarf nature and typical stout nature of stem, glabrous stem, subumbellate some time fascicled inflorescene and shoots and red epruinose berries. This variety is very close to *B. hamiltoniana* the only difference it has prophyll 3 as 2 in *B. hamiltoniana*.

Berberis koehneana Schneid., Bull. Herb. Boiss. 2(5): 814. 1905; Chatterjee, Rec. Bot. Surv. India 16(2): 32. 1953; Ahrendt, J. Linn. Soc. Bot. 57: 210.f. 48. 1961; Uniyal and Rao in Sharma et al., Fl. India 1:378. 1993; Rao et al., Rheedea 8(2): 129-131. 1998. Type: India: Uttarakhand. Kumaon, Budhi, Byans, 8-9000 ft., *Duthie 5309* (WU) (Figure 3.24).

Shrub up to 2.5 m tall; young shoots red-brown, subsulcate; internodes 15-30 mm long; spine 10-20 mm long; 1-3-fid. Leave 10-40 x 4-18 mm, obovate to oblong-oblanceolate, apex mucronate, base cuneate, subsessile, entire or few spinulose on margins, greyish beneath, papillose. Inflorescence paniculate, many-flowers, 80-170 mm long, branches up to 80 mm long; pedicel 2-7 mm long; bract ca 1.5 mm long. Sepals in 3 whorls; outer sepal 3x2 mm, ovate; median sepal 4.5x4 mm, oblong-ovate; inner sepal 7x4.5 mm, obovate. Petal 5-6 x 3-4 mm, apex incised; glands obovate. Berries 6-8 x 3-4 mm, bright red, epruinose, oblong.

Flowring and fruiting: May – November.

Distribution: INDIA: Uttarakhand; NEPAL.

Habitat: This species grow in *Abies* spp. and *Pinus wallichiana* forest in easten Kumaon along the Kali river valley from Bhudhi village to Gunji at an altitude from 2800 to 3300 m.

Specimens examined: Budhi Village, Kali valley, Pithoragarh, 2650 m, 6.7.2010, *UKT 2092* (WII); Budhi Village, Kali valley, Pithoragarh, 2780 m, 6.7.2010, *UKT 2093* (WII); Above Budhi Village, Kali valley, Pithoragarh, 2949 m, 7.7.2010, *UKT 2095* (WII).

Additional specimens examined: Kumaon, Pithoragarh, Budhi-Byans 2550 m, 12 July, 1923, *Parker 2047* (DD).

Taxonomic Notes: Ahrendt (1961) separates *Berberis koehneana* var. *auramea* from var. *koehneana* by yellow stems. These yellow stem plants have been described from Nepal (Uniyal and Rao 1993). However, this species has lot of variation in leaf and inflorescence. As species growing in shade places have large obovate leaf and big paniculate inflorscence, but which grow in open places have narrow leaf some time spinulose or entire with mucronate apex, inflorescence short peducled but paniculate or some time subumballete inflorescence. I have lot of ambiguity between segregation of this species and *Berberis jaeschkeana* var. *usteriana*, when this species grow in open. Nevertheless, this species has prophylls and three whorls of sepal that is not present in *B. jaeschkeana* var. *usteriana*.

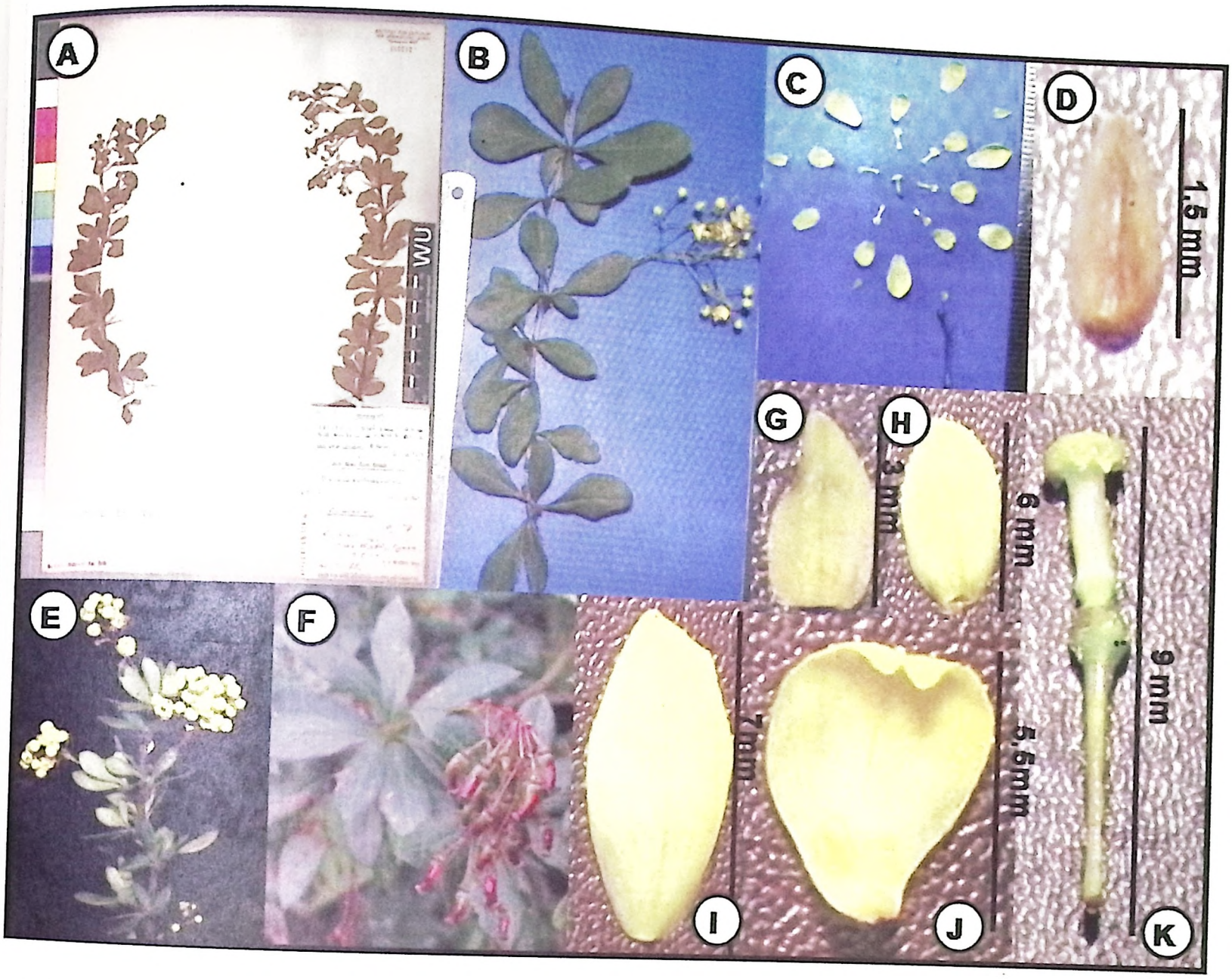

Figure 3.24. *Berberis koehneana* (*UKT-2092*) – **A:** Holotype – *Duthie 5309* (W); **B:** Plant with inflorescence; **C:** Desected flower; **D:** Prophyll; **E:** Plants with inflorescence; **F:** Plant with Fruits; **G:** Outer sepal; **H:** Middle sepal; **I:** Inner sepal; **J**: Petal with glands and **K**: Immature fruit.

Berberis kumaonensis Schneid., Bull. Herb. Boissser ser. 2, 5: 397. 1905; Chatterjee, Rec. Bot. Surv. India 16(2): 25. 1953; Ahrendt, J. Linn.Soc. Bot. 57: 120, f. 31. 1961; Sur in Sharma et al. Fl. India 1: 356. 1993 ; Rao et al. Rheedea 8(2): 112-113. 1998. Type: Kumaon: Rocks near Garbyang, Kali valley, 13000 ft., 15 sept. 1894, *Duthie 2697* (K and CJB) (Figure 3.25).

Suberect or prostrate compact shrub; stems glabrous; shoots slightly reddish; internode 5-20 mm long; spines 12-25 mm long, 3-fid, sulcate. Leaves 9-20 x 4-9 mm, obovate, apex acuminate or ending into a spine, base cuneate, glabrous on both surfaces, coriaceous;

margins 1-2 spinose serrate. Flower solitary; pedicel 5-9 mm long; prophylls 2 x 1.5 mm, triangular, acuminate. Outer sepal 7-7.5 x 3.5-4 mm, ovate, acute; median sepal 8-10 x 5-6 mm, oblong - obovate. Petal 5.5 mm long, obtuse, acutely emarginate, lobes subobtuse. Stamen 4.5 mm long, produced, apiculate. Ovule 6-8. Berries 1-1.3 x 6-7 mm, ovoid, red, attenuate and bent with short thick style at apex.

Flowering and fruiting: June - November.

Distribution: INDIA: Uttarakhand- Chopta, Bagachi and Garbyang; NEPAL.

Habitat: This species grow in open canopy cover at an altitude of 2500-4500 m in state.

Specimens examined: Chopta on way to Tunganath temple, Chamoli, 2900 m, 5.7.2009, *UKT 0978* (WII); Chopta, On way to Tunganath temple, Chamoli, 2902 m, 6.7.2009, *UKT 1065* (WII); Chopta, On way to Tunganath temple, Chamoli, 2902 m, 6.7.2009, *UKT 1066* (WII); Muniyali khet, Pinder valley, Chamoli, 2980 m, 25.7.2009, *UKT 1109* (WII); Garbyang Village, Kali valley, Pithoragarh, 3125 m, 7.7.2010, *UKT 2098* (WII).

Additional specimens examined: Garhwal; Dasoli, 3300m, July 1915, *A. E. Osmaston 701* (DD); Sub Tal, 2750 m, 3.6.1918, *A.E. Osmaston 947* (DD); Almora, Dhakuri, 3000 m, 15.7.1920, *W. J. Lambert s.n.* (DD); On way to Pindari Glacier, Dhakuri Mountain, 2850 m, 19.5.1950, *D. D. Awasthi 761* (LWG); Rankadhar, 3100 m, 28.9 1963, *U. C. Bhattacharyya 30922* (BSD, LWG); Tunganath 3000 m, 17.10.1970, *B. D. Naithani 42199* (BSD); Kumaon: Pithoragarh, On way to Bogdiar, 2500m, *s.l. 77707* (BSD); Dhauliganga valley, Tuktung, 3210 m, 20.7.1923, *R. N. Parker 2102* (DD); Lithi, 2750 - 3300 m, *W. J. Lambert s.n.* (DD); Way to Tungnath, 17.10.1970, *B. D. Naithani 42199* (CAL).

Figure 3.25. *Berberis kumaonensis* (*UKT-0978*) - **A:** Habit; **B:** Type- *Duthie 2697* (CJB); **C:** Plant with inflorescence and fruits; **D:** Close up of Flower; **E:** Illustration; **F:** Prophyll; **G:** Outer sepal; **H:** Inner sepal; **I:** Petal with glands; **J**: Stamen and **K**: Fruit.

Taxonomic Notes: This species was described by Schneider (1905) based on Duthie's collection from Garbyang, Kali Valley. This species has obovate leaf with 2-3 spinules on margin and single flower at an axis with bluish purple ovoid fruit.

Berberis kunawurensis Royle, Illust. Bot. Himal. 1 (2): 64. 1834; Parker, For. Fl. Punjab with Hazara and Delhi 13. 1918; Chatterjee, Rec. Bot. Surv. India 16 (2): 32. 1953; Ahrendt, J. Linn. Soc. Bot. 57: 211. 1961; Jafari in Nasir and Ali, Fl. W. Pakistan 87: 22. 1975; Uniyal and Rao in Sharma et. al. Fl. India 1: 379. 1993; Rao et al. Rheedea 8(2): 131-133. 1998. Type: Punjab: Kunawur, 1834, *Royle s.n.* (K). (Figure 3.26)

Berberis edgeworthiana Schneid., Bull. Herb. Boissier (2) 8: 263. 1908; Parker, For Fl. Punj. With Hazara and Delhi 14. 1918; Ahrendt in J. Linn. Soc. Bot. 57: 211. 1961. Type: N.W. Himalaya, 8000-11000 ft, 1844, *Edgeworth 65* (K).

Berberis brachybotrys Edgeworth in Trans. Linn. Soc. Lond. 20. 29. 1846, non C. Gay, 1845.

Berberis vulgaris L. var. *brachybotrys* Hook. f. and Thorns, in Hook, f., Fl. Brit. Ind. 1: 109. 1875.

Shrub, 1-1.5 m tall; young shoots red, minutely puberulous, mature stems sulcate, black tuberculate, multicellular hairs arising from tubercles, brown or yellowish-red; internodes 10-15 mm long; spines 3-fid, 5-15 mm long, central spine slightly longer than the lateral ones, sulcate, slender. Leaves 1-3 x 5-10 mm, narrowly obovate, lanceolate or elliptic, apex mucronate, base attenuate, 3-8 spinose (spines 10-12 mm long), scarcely reticulate, openly veined, papillose beneath, papillae inconspicuous. Inflorescence paniculate, 4-25 flowers; panicle 10-50 mm long; bracts 2 mm long. Flower 5-8 mm across; pedicel 5 mm long; outer sepal 2-2.5 mm long; inner sepal 5-7 x 4-5 mm, obovate; petal 4.5-5 x 3 mm, subequal, apex deeply and narrowly incised; glands oblong, 0.7 x 0.4 mm. Stamen obtuse, produced, 3 mm long. Ovule 2. Berries bright orange-red, estylose or very shortly styled.

Flowering and fruiting: May - September.

Distribution: INDIA: Uttarakhand, Jammu and Kashmir, Himachal Pradesh; PAKISTAN.

Specimens examined: Sukhi village, Uttarkashi, 2700 m, 30.6.2010 , *UKT 2082* (WII); Sukhi village, Uttarkashi, 2700 m, 1.7.2010 , *UKT 2083* (WII).

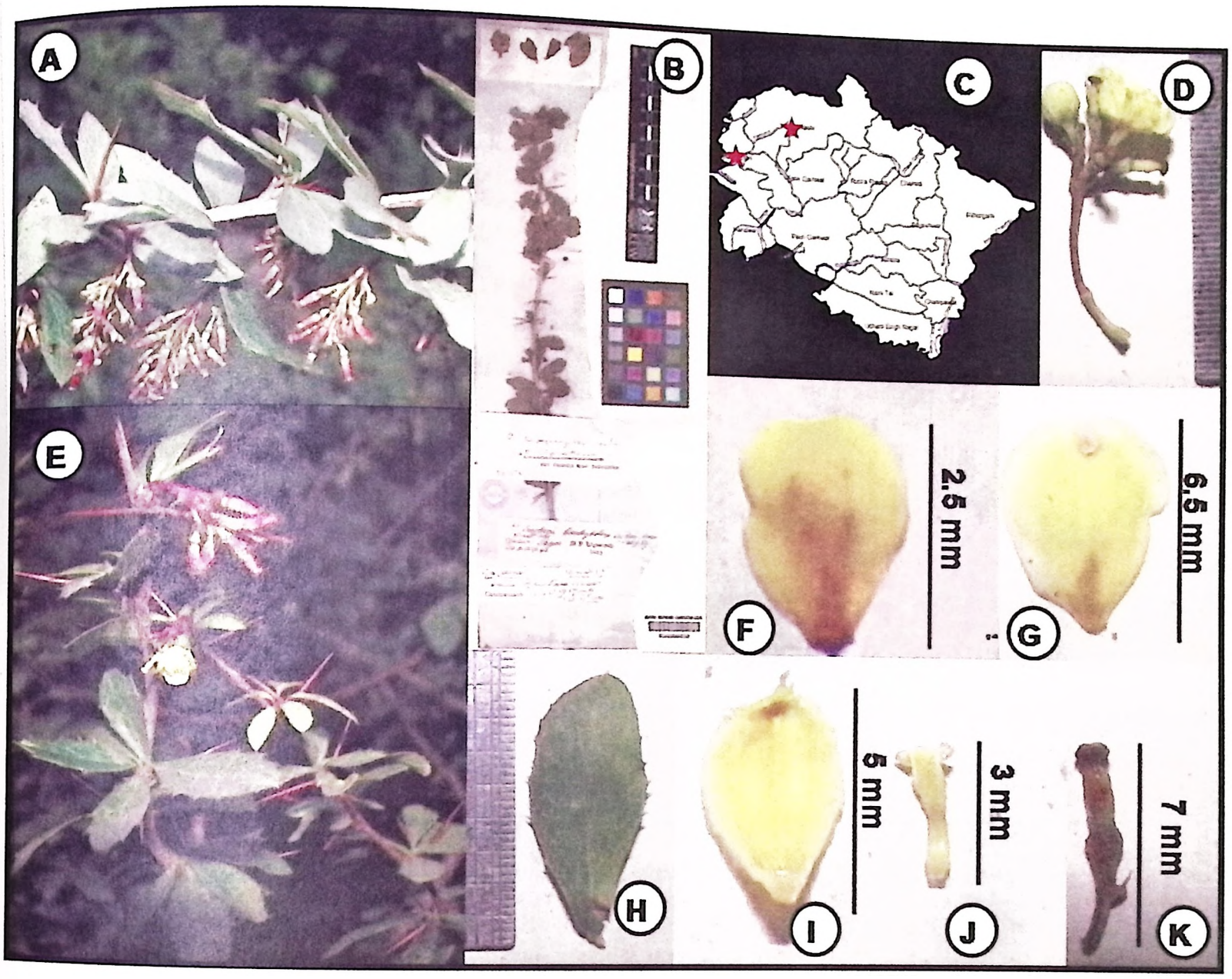

Figure 3.26. *Berberis kunawurensis* (*UKT-2082*) - **A:** Plant with Fruits; **B:** Type - *Royle s.n.* (K); **C:** Red star indicates distribution in the state; **D:** Inflorescence; **E:** Plants with inflorescence; **F:** Outer sepal; **G:** Inner sepal; **H:** Leaf; **I:** Petal with glands; **J**: Stamens and **K**: Bract and immature fruit.

Additional specimens examined: Chhakrata, 2200 m, 27.6.1961, *U. C. Bhattacharrya* 14886 (BSD); Jaunsar; Mundali, 2400 m, June 1895, *J. S. Gamble 25342* (BSD, CAL) Deoban, 2700 m, 1.6.1897, Duthie 19850 (BSD); Deoban Kunain, 2550 m, 5.6.1936, *C. E. Parkinson 7063* (BSD); Buder, 2700 m, 28.5.1936, *C. E. Parkinson 7011* (BSD); Uttarkashi, Above Sukhi, 17.6.1883, *J. F. Duthie 598* (CAL); Pithorgarh, Garbyang Byans, 3090 m, 26.5.1913, *Lyall 33* (CAL).

Taxonomic Notes: Rao et al. (1998b) say that leaves are inconspicuously papillose on the lower surface, a character that has escaped attention of Ahrendt (1961) and other workers, I

also agree to this character. I had visited several times from Deoban to Mundali area in search of but this species, I was not succeeding to collect it. I think that area has *Berberis aristata*, *B. chitria* and *B. jaeschkeana.*

Berberis lambertii Parker, Bull. Misc. Inf. Kew 1921: 367. 1921; Chatterjee. Rec. Bot. Surv. India 16(2): 29. 1953; Ahrendt, J. Linn. Soc. Bot. 57: 135. 1961; Nayar and Sastry, Red Data book of Indian Plants 1: 98. 1987; Gupta in Sharma et al. Fl. India 1: 364. 1993; Rao et al. Rheedea 8(2): 116-117. 1998. Type: Kumaon: Almora, Lambert *s.n.* (holo - K) (Figure 3.27).

Small shrub up to 1 m tall; stems glabrous, angled and finely sulcate, pale yellow; internodes up to 0.5-1.5 cm long; spines 4-5 cm long, 1-3-fid. Leaves 12-28 x 2-7 mm, oblanceolate, apex mucronate, base attenuate, sessile, entire, revolute with few lateral veins above; below much paler, whitish. Inflorescence pseudumbellate- subracemose, 4-7 flowers, 2.5-5.5 cm long; pedicel 5-10 mm long in fruits, glabrous, bract 1.5-2 mm. Sepal in 2 whorls; outer sepal, 2-3 mm, ovate with acute apex, reddish ting; inner sepal 3-3.5 x 1.5-2 mm. Petal 3.5-4 x 2-2.5 mm, obovate-elliptic, entire, longer than the inner sepal; gland 0.6 x 0.1 mm. Stamen 2.5-3 mm long produced, apiculate. Ovules 3-6. Berries 1-1.2 x 0.5-0.7 cm, red, ovoid, oblong, estylose.

Flowering and fruiting: August - October.

Habitat: This species is found in state only in two locality near its type locality, one patch is found in *Quercus semicarpifolia* open forest at kalamuni and second patch found in Temperate grassy slope on way to Humidhura from Betulidhar at an altitude of 2700–2900 m. Critically Endangered.

Distribution: INDIA: Uttarakhand (N.W. Himalaya): Pithoragarh: On way to Humdhura and Kalamuni, 2500-2800 m., (Endemic)

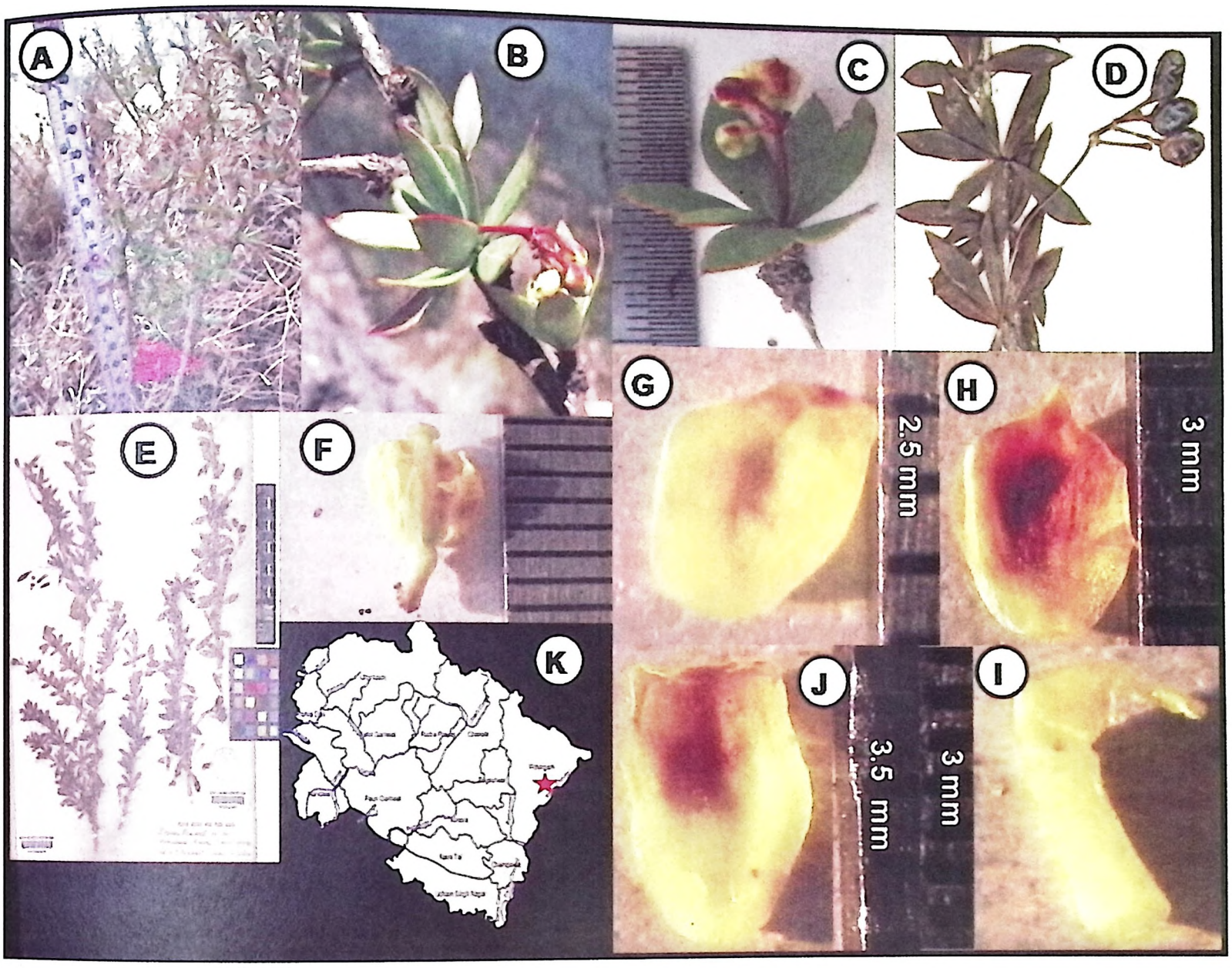

Figure 3.27. *Berberis lambertii* (*UKT-2112*) - **A:** Habit; **B:** Plant with inflorescence; **C:** Inflorescence twig; **D:** fruit; **E:** Type - Almora, *Lambert s.n.* (K); **F:** Flower; **G:** Outer sepal; **H:** Inner sepal; **I:** Stamen; **J**: Petal with glands and **K**: Red star indicates distribution in the state.

Specimen examines: Humidhura, Pithoragarh, 2802 m, 11.4.2010, *UKT 2035* (WII); Kalamuni, Pithoragarh, 2788 m, 11.4.2010, *UKT 2044* (WII); Humidhura, Pithoragarh, 2840 m, 12.7.2010, *UKT 2111* (WII); Kalamuni, Pithoragarh, 2760 m, 11.4.2010, *UKT 2112* (WII); Humidhura, Almora, 9000ft, *20.10.1920, W.J. Lambert 22394* (DD).

Taxonomic Notes: This species has not been fully described, no old literature has floral characters and here it is first time described with full characters. This species was also collected after a gap of 90 years, as this species was first collected by Lambert in 1920 and then no other worker had collected this species from state. W. J. Lambert considered it as a rare species, this species resembles *B. osmastonii* Dunn, but the leaves are rather larger, not so rigid or so and

white beneath and in *B. osmastonii*, they are densely papillose beneath (Parker, 1921). This species is listed in the Red data book of Indian Plants as Vulnerable. Ahrendt (1961) had mentioned the locality of this species "between Humidhura and Ratapani". I have seen this species at two locality one from Betulidhar to Humidhura their 37 individuals and 81 at Kalamuni top.

Berberis lycium Royle, Trans. Linn. Soc. Lond. 17:94.1834; Hook. f. and Thom. in Hook. Fl. Brit. India I: 1:10. 1875 (partly); Hook. f. in Bot. Mag. 1:15: t. 7075. 1889; Collett. Fl. Siml. 22. 1902; Chatterjee in Rec. Bot. Surv. India 16(2): 13. 1953; Parker. For. Fl. Panjb. 14. 1918 (partly); Ahrendt in J. Linn. Soc. Bot. 57:87. 1961; Jafari in Nasir and Ali, Fl W. Pak. 87: 10. 1975; Uniyal and Rao in Sharma et al. Fl. India I: 372-373. 1993; Rao et al. Rheedea 8(1) 58-59. 1998. Type: Kashmir: Royle *s.n.* (K) (Figure 3.28 A-B and E-P).

Key to the varieties of *Berberis lycium*

1. Stem sulcate
   2. Leaves whitish below.....*B. lycium* var. *lycium*
   2. Leaves dull green below.....*B. lycium* var. *subvirescens*
1. Stems terete.
   3. Inflorescence subfascicled.....*B. lycium* var. *subfascicularis*
   3. Inflorescence racemose.....*B. lycium* var. *Simlensis*

Shrub upto 4 m high; stems terete or sulcate, ash grey, pale, glabrous or pubescent; internodes 1.5-3.5 cm long; spines 3-fid, 5-20 mm long, subterete. Leave 2-7 x 0.5-1.2 cm, obovate or oblanceolate, attenuate at base, acute-mucronate at apex, entire or 2-4 spinulose along margins, papillose, greyish or whitish below. Inflorescence racemose, 10-25 flowers, 3-6 cm long, rarely shorter and subfascicled. Flower 6-8 mm across, usually pale-yellow; pedicel upto 2 cm long, slender, thin, glabrous; bract 2-2.5 mm long. Prophyll 1 mm long, ovate. Sepal in three whorls; outer one 2 x 1 mm, ovate, obtuse; median one 3.5-3.75 x 2-2.5 mm, ovate, obtuse; inner one 4.5-5 x 3 mm, obovate. Petal 4 x 2-2.5 mm, obovate, emarginate, with lanceolate basal glands. Stamen 2.5-3.25 mm, apiculate; anther 1.25 mm

long; filament 1.25-1.5 mm long. Ovule usually 4, shortly stipitate. Berries 7-9 x 5 mm, ovoid to ellipsoid, blue or black with heavy grey white bloom, stylose; style 1 mm long.

Flowering and fruiting: February - April.

Distribution: INDIA: Uttarakhand, Jammu and Kashmir, Himachal Pradesh, Madhya Pradesh, Tamil Nadu; PAKISTAN, NEPAL.

Habitat: This species is very much common in Garhwal Himalaya distributed all over in the state in open hill sides at an altitude between 600 - 2700 m.

Specimens examined: Nainbag, Tehri Garhwal, 850 m, 12.5.2008, *UKT 0001* (WII); Barkot, Uttarkashi, 1449 m, 12.5.2003, *UKT 0003* (WII); Biyali, Uttarkashi, 2050 m, 13.5.2008, *UKT 0001* (WII); Deota, Uttarkashi, 1366 m, 14.7.2008, *UKT 0377* (WII); Wazri, Uttarkashi, 2002 m, 15.4.2009, *UKT 0936* (WII); Kuthnor, Uttarkashi, 1800 m, 15.4.2009, *UKT 0937* (WII); Gopeshwar, Chamoli, 1548 m, 14.4.2010, *UKT 2065* (WII); Mandal, Chamoli, 1520 m, 15.4.2010, *UKT 2067* (WII).

Additional specimens examined: Sahashradhara, 24.5.1963, *S. K. Malhotra* 27672 (BSD); Robers Caves, 24.4.1964, *C. R. Bahu 35232* (BSD); Raipur, 1000 m, *U. C. Battacharrya 14816* (BSD); Bhuderwala, 17.8.1962, *J. N. Vohra 379* (CAL); Mussoorie, 1869, *G. King s.n.* (CAL); Sahashradhara, 600 m, 30.6.1960, *R. K. Issar s.n.* (DD); Chakrata, 2190 m, 27.5.1953, *M. B. Raizada 23614* (DD); Chakrata, 2600 m. 18.4.1957. *M. A. Rau 2225* (BSD); Chakrata 20.1.1968, *O. P. Misra 38105* (BSD), Agastyamuni, 21.4.1963, *C. L. Malhotra 26834* (BSD); Nandprayag, 23.6.1959. *M. A. Rau 10398* (BSD); Mandal, 1650 m. 21.5.1971. *B. D. Naithani 43941* (BSD); Khirsu, 1700 m. I7.4.1977. A. S. Rao 56469 (BSD); Khirsu Garden, 1800 m. 4.5.1976, *R. P. Srivastava 57033* (BSD); Nagdev, 1800 m, 22.4.1976, *R. P. Srivastava 57012* (BSD); Mussoorie: 1600 m, 2.4.1966, *C. L. Malhotra 36803* (BSD); Mall Road, 1950 m, 19.12.1956, *T. A. Rao 1331* (BSD); Sukhi to Jhala, 2400-2600 m, *J. F. Duthie 599* (DD); Jaunsar, Kotikansar, 1800 m, 1.6.1936, *C. E. Parkinson 7041* (DD); Uttarkashi, 1020 m, 24.5.1956, *K. C. Sahni 24774* (DD); NIM, 1.6.1992, *B. Datt*

and B. Lal 212235 (LWG); Bhagori, 1200 m, 30.5.1992, *B. Datt and B. Lal 212233* (LWG); Kalyani, 1550 m, 30.5.1992, *B. Datt and B. Lal 212226, 212227, 212231* (LWG); Barkot, 1200 m, 6.6.1992, *B. Datt and B. Lal 212273* (LWG).

Taxonomic Notes: This species is a variable and widespread distribution in Western Himalaya, which has benefitted from human disturbances. Other authors have subdivided this species into various entities, but after field and herbarium studies, I found that it could not rectify any subspecific division satisfactorily. There are many leaf shape, inflorescence type and number of flowers variations depending upon the environmental condition where this species is growing. More humid areas leaves tend to be broader and entire and with shorter spines. This species has quite distinct distribution in Western part of Himalaya; it has wide distribution from Kashmir to Garhwal but not very much common in Kumaon. This species is primarily use for making *Rasout*. Jafari (1975) has remarked this species as a very variable species said to have replaced *Berberis ceratophylla* Don in Kashmir and Western Himalaya and itself to be replaced by *B. parkeriana* Schneid. in the bordering areas of Kashmir and Pakistan. In drier areas, leaves tend to be narrower and toothed with larger spines. The plants of Kashmir and Shimla regions by Ahrendt (1945 and 1961) had been grouped into three varieties *viz.,* var. *subfascicularis*, var. *simlensis* and var. *subvirescens*, but I think these characters are not consistent, so recognizing even a single variety at this point seems unwarranted. Hence, I think all the varieties should be merged with *Berberis lycium*.

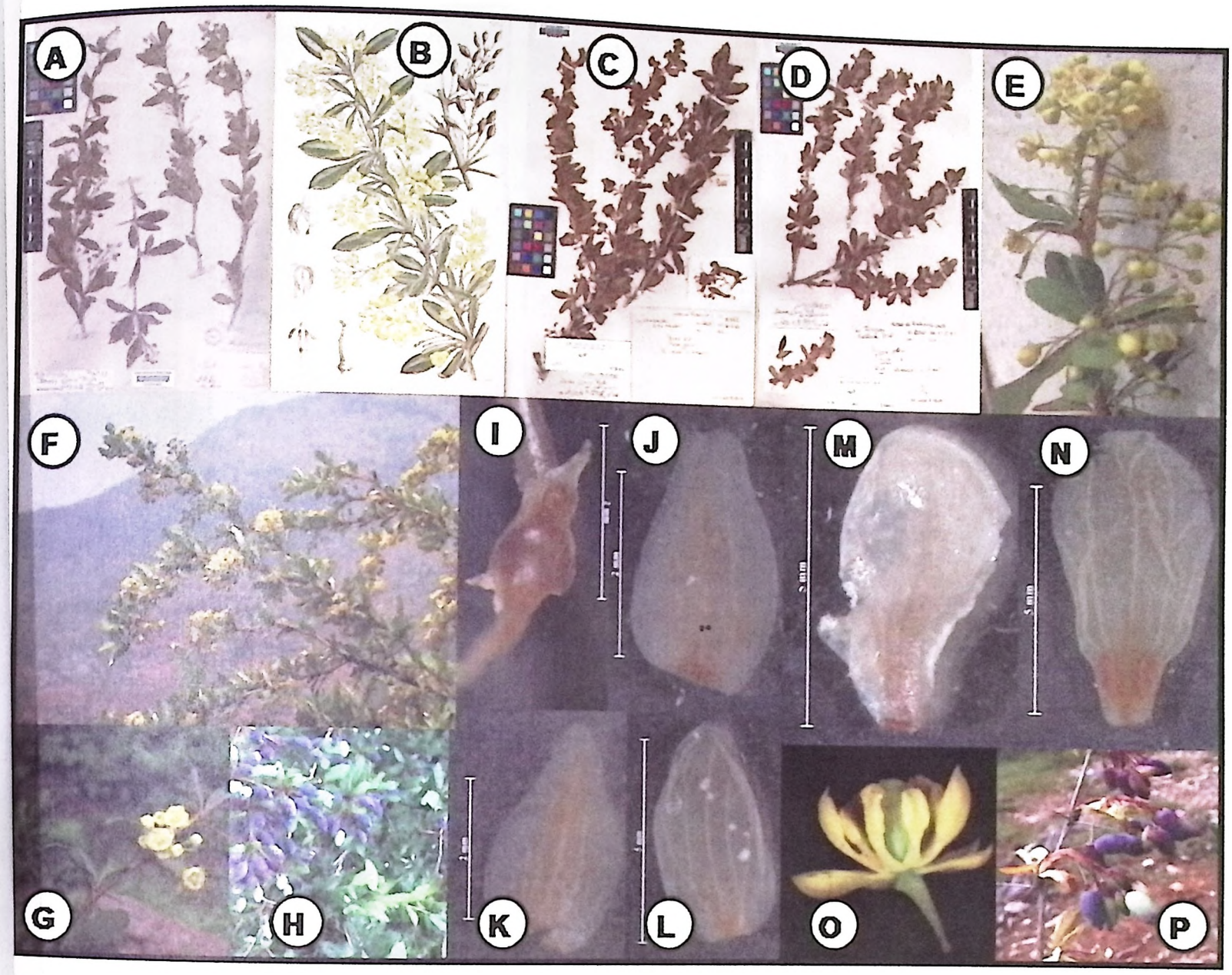

Figure 3.28. *Berberis lycium* (*UKT-0377*) - **A:** Type specimen *Royal s.n.* (K); **B:** Illustration in Botanical magazine 1844; **C:** Type specimen *B. lycium* var. *subvirescens*, *Ludlow and Sheriff 8095* (BM); **D:** Type specimen *B. lycium* var. *subfascicularis*, *Ludlow and Sheriff 9105* (BM); **E, F and G:** Twig and Habit with inflorescence; **H and P:** Fruits; **I:** Bract; **J:** Prophyll; **K:** Outer sepal; **L**: Middle sepal; **M**: Inner sepal; **N:** Petal and **O:** Close up of Flower.

Berberis lycium var. *simlensis* Ahrendt, J. Asiat. Soc. Bong. (Sci.) 11:1. 1945; et in J. Linn. Soc. Bot. 57:88.1961; Uniyal and Rao in Sharma et al. Fl. India 1:373. 1993; Rao et al. Kheedea 8(1): 61-62. 1998. Type: Punjab Himalaya: Simla. 7000 ft., July 1885, *Collett 234* (holo- K) (Figure 3.29).

Shrub upto 4 m high; stems terete, ash grey, pale, glabrous or pubescent; internode 1.5-3.5 cm long; spines 3-fid, 5-20 mm long, subterete. Leave 2-7 x 0.5-1.2 cm, obovate or oblanceolate, attenuate at base, acute-mucronate at apex, entire or 2-4 spinulose

along margins, papillose, greyish or whitish below. Inflorescence subfacicled, 10-25 flowers, 3.-6 cm long, rarely shorter and subfascicled. Flower 6-8 mm across, usually pale-yellow; pedicel upto 2 cm long, slender, thin, glabrous; bract 2-2.5 mm long. Prophyll 1 mm long, ovate. Sepals in 3 whorls; outer one 2 x 1 mm, ovate, obtuse; median ones3.5-3.75 x 2-2.5 mm, ovate, obtuse; inner one 4.5-5 x 3 mm, obovate. Petal 4 x 2-2.5 mm, obovate, emarginate, with lanceolate basal glands. Stamen 2.5-3.25 mm, apiculate; anthers 1.25 mm long; filament 1.25-1.5 mm long. Ovule usually 4, shortly stipitate. Berries 7-9 x 5 mm, ovoid to ellipsoid, blue or black with heavy grey white bloom, stylose; style 1 mm long.

Flowering and fruiting: March-July.

Distribution: INDIA: Uttarakhand, Jammu and Kashmir and Himachal Pradesh.

Habitat: 1200-2100m in exposed drier place (Rao et al. 1998a)

Specimens examined: Barkot, 1200 m, 6.6.1992, *B. Datt and B. Lal 212274* (LWG); Kalyani, 1550 m, 30.5.1992, *B. Datt and B. Lal 212225* (LWG); Kuthnor vill., 9.6.1992, *B. Datt and B. Lal* 210588 (LWG).

Taxonomic Notes: Uniyal and Rao (1993) had mentioned that this variety may be distinguished from all the other varieties of the group mainly by the pubescent nature of the stem, but this is not true as all the other varieties of *Berberis lycium* also have pubescent stem either while young or mature, a view also expressed by Uniyal and Rao (1993).

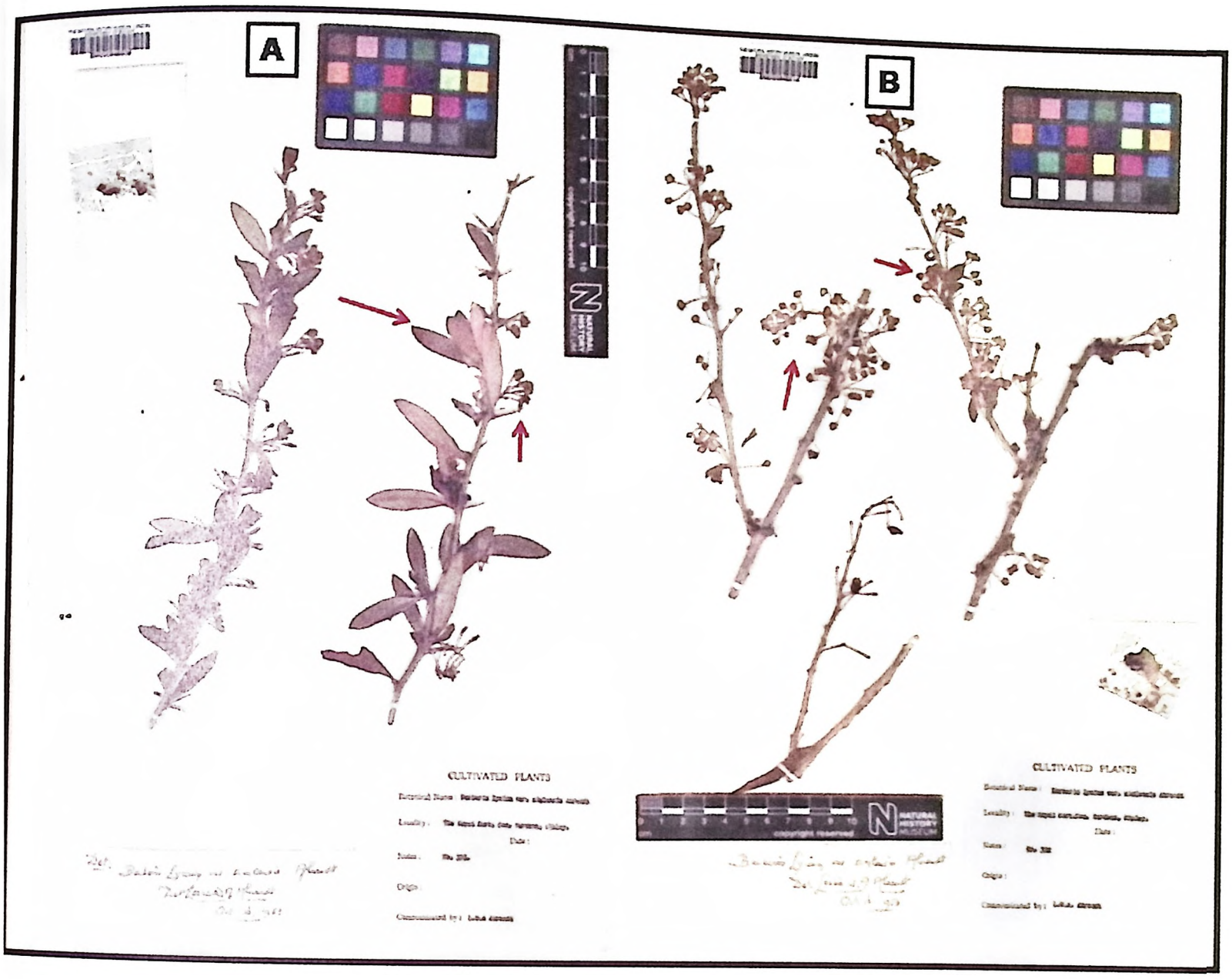

Figure 3.29. **A:** *Berberis lycium* var. *simlensis*, Ahrendt no. 391, From Wisley Garden (BM); **B:** *Berberis lycium* var. *simlensis*, Ahrendt no. 391, From Wisley Garden (BM). (Figure 3.28 D)

Berberis lycium* var. *subfascicularis Ahrendt, J. Linn. Soc. Bot. 57:88. 1961; Uniyal and Rao in Sharma et al. Fl. India 1:374. 1993; Rao et al. Rheedea 8(1): 61. 1998. Type: Kashmir, Kistwar Dist., Tsingana, 6500 ft, *Ludlow and Sherriff 9105* (Holotype - BM) (Figure 3.28 D)

Shrub upto 4 m high; stems terete, ash grey, pale, glabrous or pubescent; nternodes 1.5-3.5 cm long; spines 3-fid, 5-20 mm long, subtercte. Leaves 2-7 x 0.5-1.2 cm, obovate or oblanceolate, attenuate at base, acute-mucronate at apex, entire or 2-4 spinulose along margins, papillose, greyish or whitish below. Inflorescence subfascicled, 10-25 lowers, 3.-6 cm long, rarely shorter and subfascicled. Flower 6-8 mm across, usually pale-

yellow; pedicels upto 2 cm long, slender, thin, glabrous; bracts 2-2.5 mm long. Prophylls 1 mm long, ovate. Sepal in 3 whorls; outer one 2 x 1 mm, ovate, obtuse; median one 3.5-3.75 x 2-2.5 mm, ovate, obtuse; inner ones 4.5-5 x 3 mm, obovale. Petal 4 x 2-2.5 mm, obovate, emarginate, with lanceolate basal glands. Stamen 2.5-3.25 mm, apiculate; anther 1.25 mm long; filament 1.25-1.5 mm long. Ovule usually 4, shortly stipitate. Berries 7-9 x 5 mm, ovoid to ellipsoid, blue or black with heavy grey white bloom, stylose; style 1 mm long.

Flowering and fruiting: August - October.

Distribution: INDIA: Jammu and Kashmir, Himachal Pradesh and Uttarakhand.

Habitat: 1500 - 2500 m; Common in drier exposed places and in forest clearings (Rao et al. 1998a).

Specimens examined: Uttarkashi Dist., Bhankoli village, 2000 m, 30.5.1992, *B. Datt and B. Lal 212229, 212228* (LWG); Uttarkashi Dist., Kalyani, 1550 m, 30.5.1992, *B. Datt and B. Lal 212230* (LWG).

Taxonomic Notes: According to Rao et al. (1998a) say, apart from other varieties of *Berberis lycium* this variety has quite distinct character to segregate from others. Leaves are soft and darkgreen on upper and paler at beneath, inflorescence subfascicled.

Berberis lycium* var. *subvirescens Ahrendt, J. Linn. Soc. Bot. 57: 88. 1961; Uniyal and Rao in Sharma et al., Fl. India 1:374. 1993; Rao et al. Rheedea 8(1): 62. 1998. Type: Kashmir: Gandarbal, Sind valley, 5200 ft., 31 May, 1940, *Ludlow and Sherriff 8095* (holo- BM) (Figure 3.28 C).

Shrub upto 4 m high; stems terete, ash grey, pale, glabrous or pubescent; internodes 1.5-3.5 cm long; spines 3-fid, 5-20 mm long, subtercte. Leaves 2-7 x 0.5-1.2 cm, obovate or oblanceolate, attenuate at base, acute-mucronate at apex, entire or 2-4 spinulose along margins, papillose, greyish or whitish below. Inflorescence subfacicled, 10-25

flowers, 3.-6 cm long, rarely shorter and subfascicled. Flower 6-8 mm across, usually pale-yellow; pedicel upto 2 cm long, slender, thin, glabrous; bract 2-2.5 mm long. Prophylls 1 mm long, ovate. Sepal in 3 whorls; outer one 2 x 1 mm, ovate, obtuse; median one 3.5-3.75 x 2-2.5 mm, ovate, obtuse; inner ones 4.5-5 x 3 mm, obovale. Petal 4 x 2-2.5 mm, obovate, emarginate, with lanceolate basal glands. Stamen 2.5-3.25 mm, apiculate; anther 1.25 mm long; filament 1.25-1.5 mm long. Ovule usually 4, shortly stipitate. Berries 7-9 x 5 mm, ovoid to ellipsoid, blue or black with heavy grey white bloom, stylose; style 1 mm long.

Flowering and fruiting: April - June

Distribution: INDIA: Uttarakhand, Jammu and Kashmir and Himachal Pradesh.

Habitat: 1500 – 1700 m, common in village area on bank of streams (Rao et al. 1998a).

Specimens examined: Uttarkashi Dist., Kuthnor, 9.6.1992, *B. Datt and B. Lal 210588* (LWG); Kalyani, 1550 m,30.5.1992, *B. Datt and B. Lal 212232* (LWG).

Taxonomic Notes: Ahrendt (1961) and subsequently Uniyal and Rao (1993) stated that this variety is endemic to Jammu and Kashmir but Rao et al. (1998a) recorded this species from Uttarakhand Himalaya especially Uttarkashi District of Garhwal.

Berberis macracantha Schrader, Linnaea 12: 366. 1838; Schneid. in Mitt. Dtsch. Dendr. Ges. 14: 176. 1907; et in J. Arn. Arb. 4: 200. 1923; Ahrendt in J. Linn. Soc. Bot. 57: 101. 1961; Rao et al. Rheedea 8(1) 27. 1998.

Shrub 1.5-2 m in height, evergreen; stem stout, sulcate, pale yellow, slightly angular; young shoots purplish; internodes 1.5-3.5 cm long; spines 1.5-3.5 cm long, 3-fid, sulcate, fairly stout. Leaves usually 6, evergreen, 2-4.5 x 1-2 cm, obovate-elliptic, obtuse, mucronate, base attenuate, margins entire or with 5-15 spinose serrations (spines 0.5-1.5 mm), below dull green, above bright green. Inflorescence racemose, loose, 8-25 flowers; peduncle 1-1.5 cm long, glabrous, pale purplish. Pedicle about 5 mm long, glabrous. Flower

not seen. Ovule 2-4. Berries 8-12 x 5-6 mm, dark red, ellipsoid to ovoid stylose; style short upto 0.5 mm long, slightly pruinose.

Flowering and Fruiting: October (Rao et al. 1998a)

Distribution: INDIA: Uttarakhand.

Specimens examined: Uttarakhand; Chamoli Dist., Tungnath, 2700 m, 17.10.1992, *T. Husain and B. Datt 210593* (LWG). (Rao et al. 1998a).

Taxonomic Notes: Rao et al. (1998a) say that this species was collected from Tungnath (Chamoli) at an altitude of 2700 m seems to be a hybrid between *B. chitria* and *B. vulgaris*, which is growing in natural conditions very luxuriantly. This species forms a first report in India by Rao et al. (1998a). *Berberis vulgaris* is not found in India and so how it can be hybridize in between *B. chitria* and *B. vulgaris*. I have visited several time to Tunganath and adjacent area but failed to collect this species. In NBRI herbarium specimen of this species is missing and they are also not sure about this species in India. I am including this species based on Rao et al. (1998a).

Berberis osmastonii Dunn, Kew Bull. 1920: 335. 1920; Ahrendt, J. Roy. Hort. Soc. 74: 406. f. 146. 1949; Chatterjee, Rec. Bot. Surv. India 16(2): 9. 1953, et in J. Linn. Soc. Bot. 57:41. 1961; Das Gupta in Sharma et al. Fl. India 1: 365. f. 57, 1993; Rao et al. Rheedea 8(2): 117-118. 1998. Type: Garhwal 9000 ft, 12.5.1915, *Osmaston 225* (K). (Figure 3.30)

Vernacular Name: Tai ka Kannta.

Subprostrate shrub, about 20 cm tall; stems terete or subterete; shoots pubescent; mature stems yellow, lustrous, glabrous; internodes 5-10 mm long; spines 3-fid, 10-20 mm long. Leaves 10-20 x 2-3 mm, linear-oblong, or very narrowly elliptic, margins entire; enervate; lustrous above; pruinose white below, papillose. Flower solitary; pedicel 3-3 mm long; bract 1 mm long. Prophylls 3 x 0.4 mm, linear-lanccolate, acuminate. Outer sepal 3.5 x 1 mm,

oblong-lanceolate; inner sepal 7 x 3.5 mm, narrowly obovate. Petal 6 x 2.5 mm, similar, entire; base slightly clawed, attenuate. Stamen 5 mm long, apiculate. Ovule 6-8. Berries 10 x 6 mm, ovoid, stylose; style 1.5 mm long.

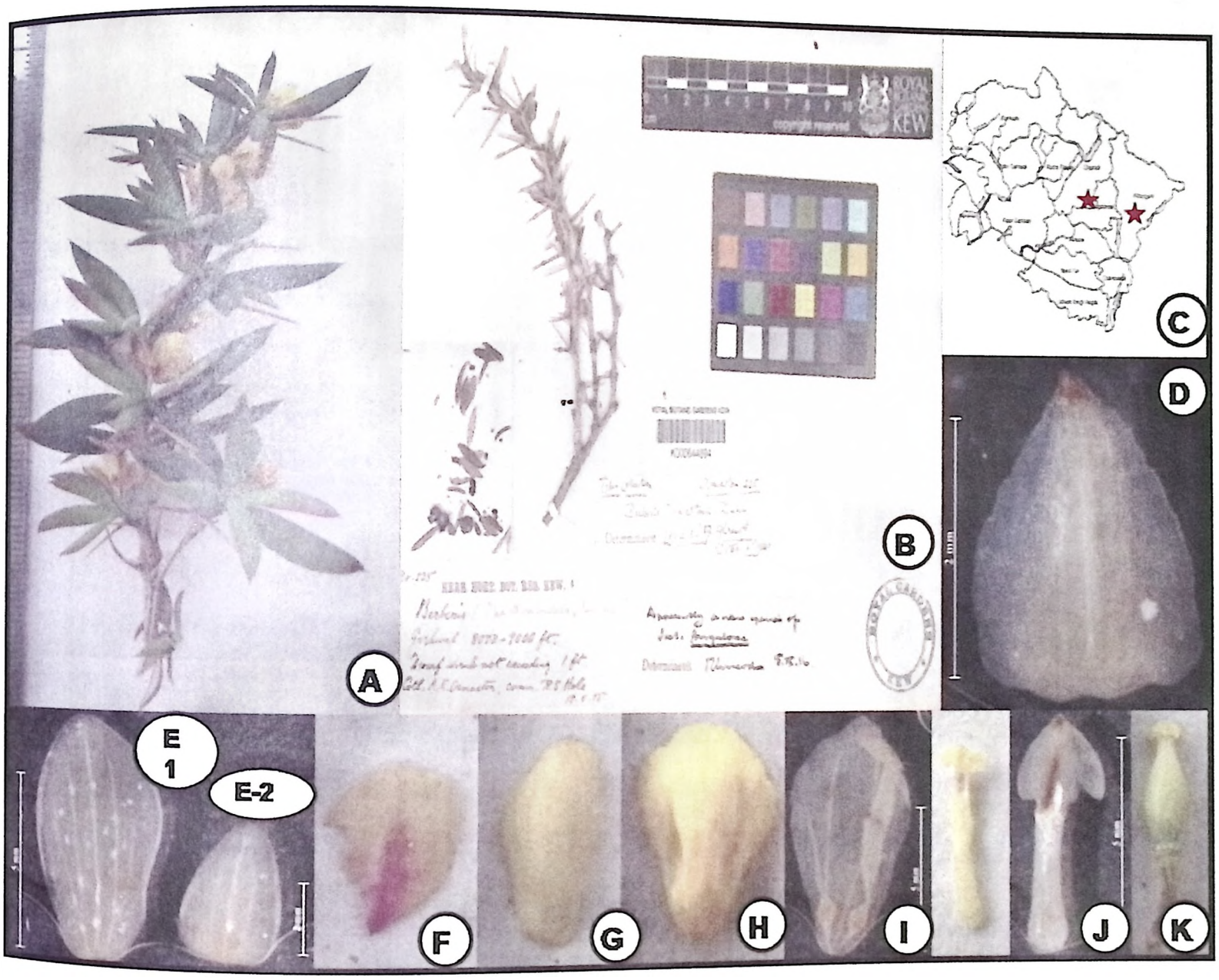

Figure 3.30. *Berberis osmastonii* (*UKT-0986*) – **A:** Plant with inflorescence; **B:** Type- *Osmaston 225* (K); **C:** Red star indicates distribution in the state; **D:** Prophylls; **E1** and **G:** Inner sepal; **E-2** and **F:** Outer sepal; **H** and **I:** Petal and glands; **J**: Stamens and **K**: fruit.

Flowering and fruiting: April - May

Distribution: INDIA: Uttarakhand- Muniyali khet, Betulidhar and Kalamuni (Endemic)

Habitat: A bare rocky slope 1700-3000 m, this species is found only at two places in state, not critically rare but due to anthropogenic pressure, the population is declining.
Specimens examined: Muniyalikhet, Pindar Valley, Chamoli, 2170 m, 10.5.2009, *UKT 0986* (WII); Muniyalikhet, Pinder Valley, Chamoli, 2250 m, 10.5.2009, *UKT 0987* (WII); Samkot, Pithoragarh, 2358 m, 9.4.2010, *UKT 2032* (WII); Humidhura, Pithoragarh, 2806 m, 9.4.2010, *UKT 2033* (WII); Kalamuni, Pithoragarh, 2720 m, 11.4.2010, *UKT 2046* (WII); Muniyalikhet, Pinder Valley, Chamoli, 2310 m, 14.4.2009, *UKT 2050* (WII).

Additional specimens examined: Garhwal- Kheta village, 1700 m, 14.5.1970, *C. M. Arora 41448* (BSD); Kheta, Pindarvalley, 2800 m, 14.5.1892, *A. E. Osmaston 1494* (DD); Kheta, 2640 m, 15.5.1918, *A. E. Osmaston 919* (DD).

Taxonomic Notes: This species is endemic to state and very much clear with its characters to identify.

Berberis pachyacantha Bien. ex Koehne, Deutshe Dend. 170. 1893; Parker, For. Fl. Punjab, Hazara and Delhi 12. 1918; Chatterjee, Rec. Bot. Surv. India 16(2): 31. 1953; Ahrendt, J. Linn. Soc. Bot. 57: 191. 1961; Jafari in Nasir and Ali, Fl. W. Pakistan 87: 21. f.5, A. 1975; Singh and Kachroo, For. Fl. Srinagar 164, 1976; Uniyal and Rao in Sharma et al. Fl. India 1:391. 1993; Rao et al. Rheedea 8(2): 127-129. 1998. (Figure 3.31)

Key to subspecies

1. Stems usually dark-red to pale brownish; flowers 7-9 mm across; pedicels usually 10-15 mm long..... *Berberis pachyacantha* subsp. *pachyacantha*
1. Stems usually pale; flowers 5-6 mm across; pedicels usually 4-8 mm long.....*Berberis pachyacantha* subsp. *zebeliana*

Berberis pachyacantha* subsp. *pachyacantha

Shrub 2-3 m tall, deciduous; stems dark-red, yellow or pale-brownish, subterete; internode 20-40 mm long; spines 5-12 mm long, solitary or 3-fid. Leaves 22-60 x 10-20 mm, oblong-obovate or obovate-elliptic, apex shortly mucronate, below pruinose, many spinulose on margin; petiole 10-12 mm long. Inflorescence racemose, 15-30 flowers; peduncle 10-15 mm long, sulcate. Flower 7-9 mm across; pedicels 10-15 mm long. Sepal in 2 whorls; outer sepal 4 x 2 mm, ovate-obtuse; inner sepal 5-6 x 3.5-4 mm, obovate. Petal 4-4.5 x 3 mm, acutely emarginate. Ovary oblong, 1-2-ovuled, Berries 8-11 x 4-7 mm, oblong-ovoid, red, epruinose, estylose.

Flowering and fruiting: April - August

Distribution: Uttarakhand: Yamuna Valley, Maggu, Bagachi, Above Wan, Above Durmi, Pawali kantha, on way to Shatratal, Near Dwali. Jammu and Kashmir, Himachal Pradesh, Uttarakhand; Pakistan and Iran.

Habitat: Moist shady localities at 2000-3300 m altitude.

Specimen examined: On way to Yamnotri temple, 2810 m, 14.5.2008, *UKT 0053* (WII); On way to Yamnotri temple, 2812 m, 14.5.2008, *UKT 0055* (WII); On way to Yamnotri temple, 3016 m, 14.5.2008, *UKT 0062* (WII); On way to Yamnotri temple, 3018 m, 14.5.2008, *UKT 0063* (WII); Ranachatii, Yamuna valley, 2558 m, 21.6.2008, *UKT 0316* (WII); Ranachatii, Yamuna valley, 2500 m, 21.6.2008, *UKT 0318* (WII); On way to Yamanotri, Yamuna valley, 2648 m, 24.6.2008, *UKT 0335* (WII); Bhyndar valley, Chamoli, 3006 m, 01.07.2009, *UKT 1042* (WII).

Additional specimens examined: Tehri Garhwal, Nag Tibba, 3000 m, 3.6.1978, *A. K. Goel 64051* (BSD); Tehri Dist., Gangotri-Kedarganga, 3246, 20.09.1967, *B. D. Naithani 37387* (BSD).

Taxonomic Notes: According to Jafari (1975) this species differs from *Berberis petiolaris* Wall. ex. G. Don, primarily by the estylose berries and thinner leaves. Petals emarginate in *Berberis pachyacantha* and entire in *Berberis petiolaris.*

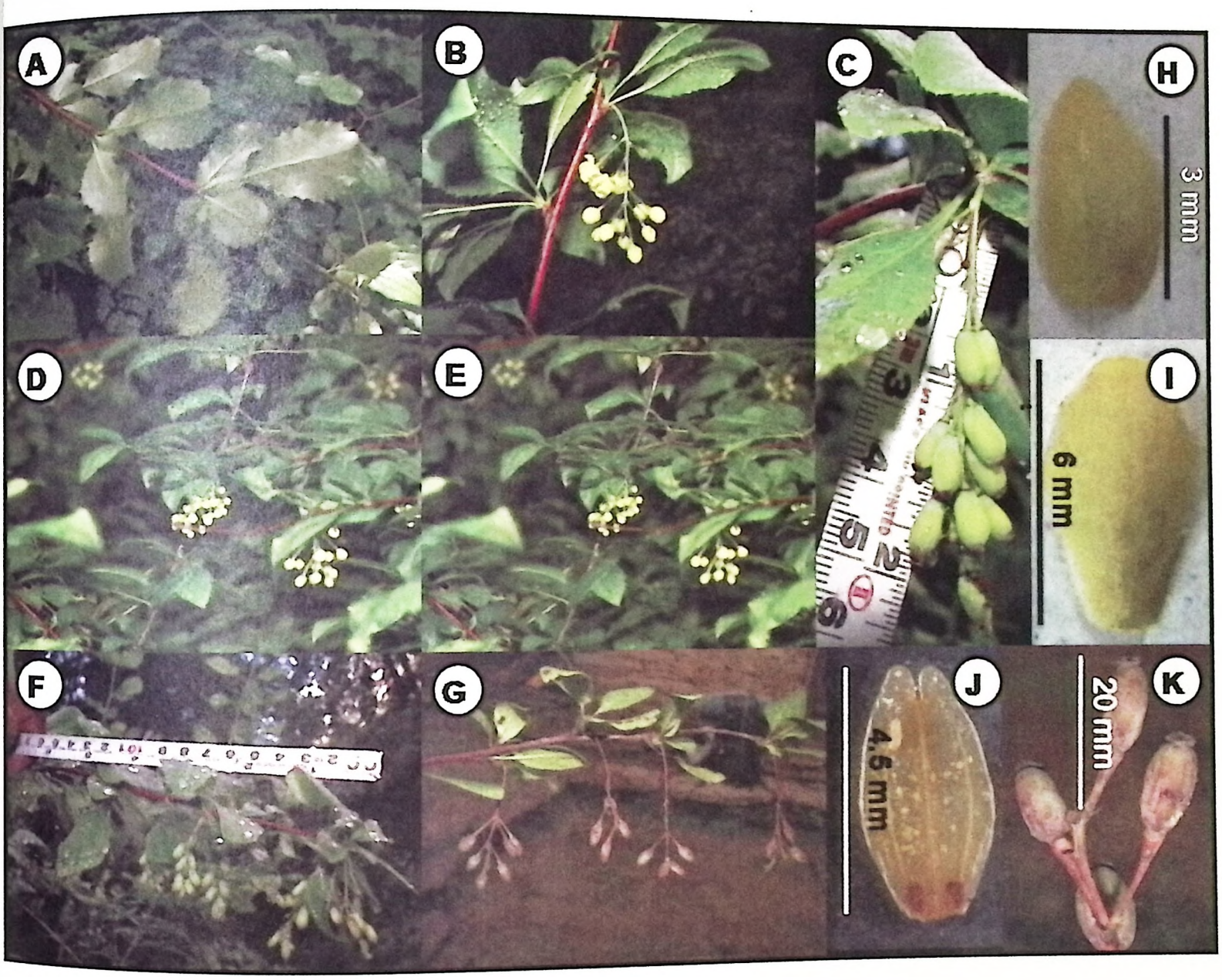

Figure 3.31. *Berberis pachyacantha* (*UKT-0055*) - **A:** Leaves; **B, D and E:** Plant with inflorescence; **C, F and G:** Plant with fruits; **H:** Outer sepal; **I:** Inner sepal; **J:** Petal with glands and **K:** Bract and mature fruit.

Berberis pachyacantha* subsp. *zebeliana (Schneid.) Jafari in Nasir and Ali, Fl. W. Pakistan 87:21.f.5, B. 1975; Uniyal and Rao in Sharma et al. Fl. India 1:392. 1993; Rao et al. Rheedea 8(2): 129. 1998. Type: India: Kashmir, *Falconer 95* (K).

B. zebeliana Schneid. in Bull. Herb. Boiss. 2(5):667. 1905; Chatterjee in Rec. Bot. Surv. India 16(2):31. 1953; Ahrendt in J. Linn. Soc. Bot. 57:184. 1961.

Shrub 2-3 m tall, deciduous; stems dark-red, yellow or pale-brownish, subterete; internodes 20-40 mm long; spines 5-12 mm long, solitary or 3-fid. Leaves 22-60 x 10-20 mm, oblong-obovate or obovaterelliptic, apex shortly mucronate, below pruinose, many spinulose on margin, petioled; petiole 1-12 mm long. Inflorescence racemose, 15-30-fld; peduncle 10-15 mm long, sulcate. Flower 7-9 mm across; pedicels 10-15 mm long. Sepal in 2 whorls; outer sepal 3x2 mm, ovate-obtuse; inner sepal 5-6 x 3.5-4 mm, obovate. Petal 4-4.5 x 3 mm, acutely emarginate. Ovary oblong, 1-2-ovuled, Berries 8-11 x 4-7 mm, oblong-ovoid, red, epruinose, estylose.

Flowering and fruiting: April - October

Distribution: INDIA: Uttarakhand, Jammu and Kashmir, Himachal Pradesh, Meghalaya; PAKISTAN; IRAN.

Habitat: Dry open places; 2100 m (Rao et al. 1998b)

Specimens examined: NIL

Taxonomic Notes: According to Jafari (1975) this taxon differs from type subspecies by smaller flowers on shorter pedicels (4-8 mm long), petals 3x2 mm; spines 1-3fid, 5-10 mm long, sometimes absent. But my observation differ from Jafari's, I don't know how this variety was reported from Uttarakhand state and the character which are used by Schneider (1905) is also very minor and it should be a ecotypic variation in the population of *Berberis pachyacantha*. I am including this subspecies on authority of Rao et al. (1998b) and Uniyal et al. (2007).

Berberis petiolaris Wall., ex G. Don, Gen. Syst. 1: 116. 1831; Ahrendt in J. Bot. Lond. 80 (suppl.): 82. 1942; et in J. Linn. Soc. Bot. 57: 94. 1961; Chatterjee in Rec. Bot. Surv. India 16(2): 16. 1953; Rao and Naithani in Sharma et. al. Fl. India 1: 385. 1993. Type: Nepal: 1818, *Wallich 1475*, part (BM).

Note: *B. petiolaris* var. *petiolaris* has not been discussed in this work, as it is a Nepalese species.

Key to the varieties

1. Inflorescence 8-15 flowered; glands on petals 1.25 mm long .....*B. petiolaris* var. *extensa*

1. Infloresence 3-7 flowered, sub-umbellate; glands on petals 2 mm long.....*B. petiolaris* var. *garhwalana*

Berberis petiolaris* var. *extensa Ahrendt ex Rao, Husain *et* B. Datt in Bot. Bull. Acad. Sin. 35: 229-232. 1994; Rao and Naithani in Sharma et al., Fl. India 1: 385. 1993; Rao et al., in Rheedea 8(1): 11. 1998. Type: Nepal: Sialgarhi, Bhauahabisa, Khola, 3000 m, 19.5.1952, *Polunin, Sykes and Williams 2066* (holo-BM) (Figure 3.32A).

Large evergreen shrub; stems glabrous, terete, sublustrous, mature stems deep red, red-brown or purplish-brown; internode 30-50 mm long; spines often absent, occasionally solitary, 3-13 mm. Leaves 15-60 x 7-30 mm, obovate, ovate or obovate- oblong, apex acute or mucronate, base attenuate, membranous, spinous-serrate, nerves raised on both sides, light green on both surfaces; petiolate; petiole 5-20 mm. Inflorescence racemose, 12-14 flowers; occasionally with 1-2 flowers from the base of the inflorescence, bract 1.5-3 mm long, uni or biserrate on both sides. Flowers yellow; pedicel 7-17 mm long, glabrous, sulcate, uniform throughout; outer sepal 4-5 x 2-2.5 mm, ovate; inner sepal 6.5-7 x 4.5-5 mm, obovate, entire; petal 6.5 -8 x 4-5 mm, obovate, entire, base clawed with a pair of lanceolate glands, conspicuously veined; glands 1.25 mm long, ovate. Stamen 5.5 mm long, winged, with two prominent sacs at the top; style 1-1.5 mm long.
Flowering and fruiting: May-June.

Distribution: INDIA: Uttarakhand; NEPAL (Rao et al. 1998a; Uniyal et al. 2007)

Specimens examined: Tehri Garhwal, Tali, *A. K. Goel 66624* (LWG, BSD) (Figure 3.33B).

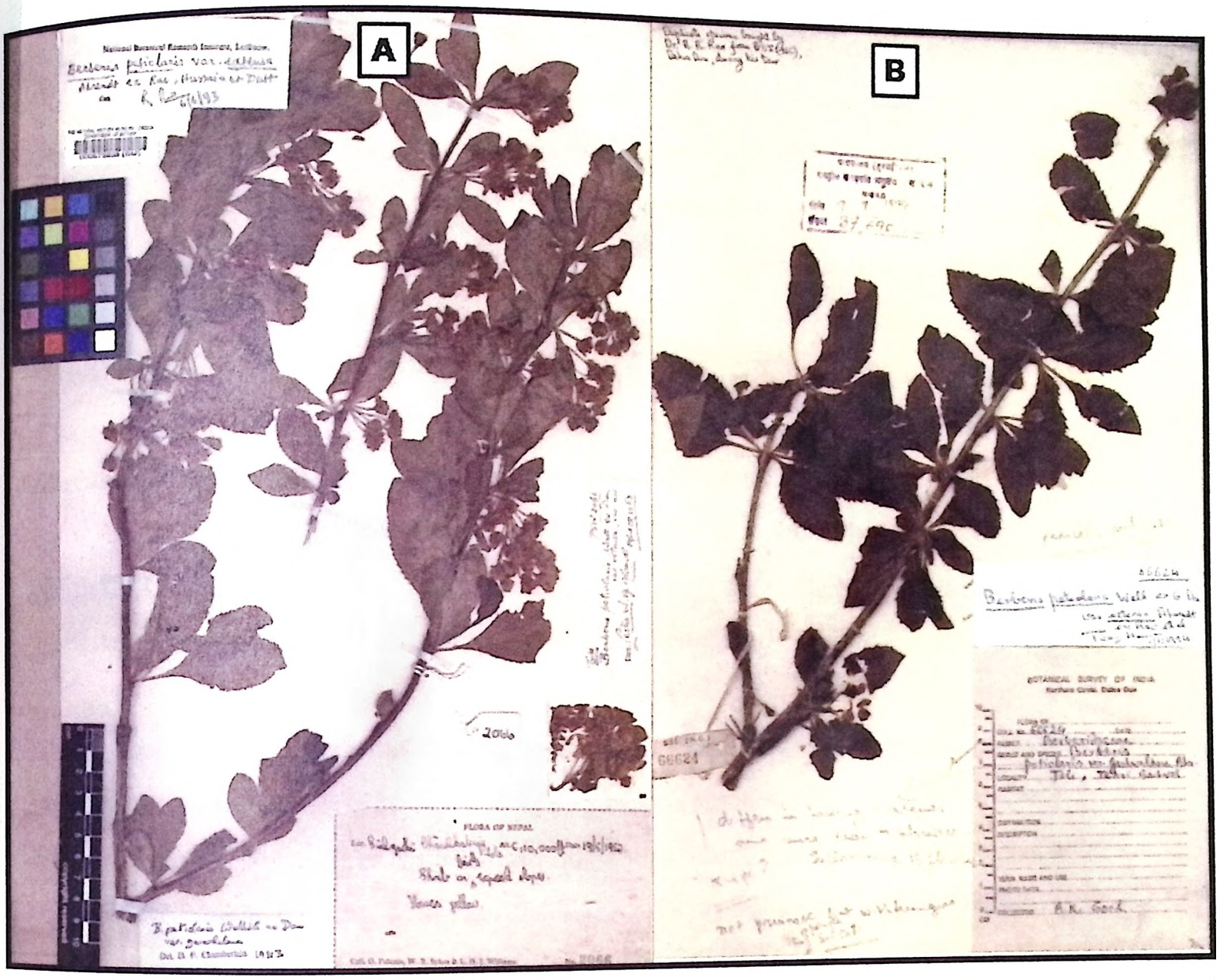

Figure 3.32. *Berberis petiolaris* var. *extensa*-**A:** *Polunin Skyes and Williams 2066* (BM); **B:** *A. K. Goel 66624* (LWG).

Taxonomic Notes: Rao et al. (1994) describe a variety of *B. petiolaris* var. *extensa* on basis of a specimen that is hosted in BM (*Polunin Skyes and Williams 2066*). They have distinguished this variety from var. *garhwalana* in having mostly evergreen leaves, uniform pedicels, racemose inflorescence, 12-14 flowered, bracts entire in var. *garhwalana* and serrate in var. *extensa*. Glands lanceolate and 2 mm in var. *garhwalana* and ovate and 1.2 mm long in var. *extensa*. Where as they have examined Indian specimen hosted in BSD and LWG from Tali by *A. K. Goel 66624* (Figure 3.32B). This specimen looks like *B. pachyacantha*. I have doubt on the existence of these varieties in India or Uttarakhand. As I had visited these areas, several times to collect this specimen from field but there are only three species of *Berberis* present in area, namely *B. jaeschkeana*, *B. umbellata* and *B.*

pachyacantha. Specimen, which was collected, by *Polunin Skyes and Williams 2066-* (BM) (Figure 3.32A) mounted as *Berberis petiolaris* var. *garhwalana*. I have doubt about its identity and it looks like *Berberis pachyacantha*. As early stage of flowering of *B. pachyacantha* has small style but as fruit mature it become estylose. I have collected several specimens of *Berberis pachyacantha* from different place in state and the entire specimens have same trends. I am including this subspecies on authority of Rao et al. (1998a) and Uniyal et al. (2007).

Berberis petiolaris* var. *garhwalana Ahrendt, J. Bot. Lond. Soc. (Suppl.): 82. 1942; *et* in J. Linn. Soc. Bot. 57:94. 1961; Chatterjee in Rec. Bot. Surv. India 16(2): 15. 1953, Rao and Naithani in Sharma et al. Fl. India 1: 385. 1993; Rao et al. in Rheedea 8(1): 11. 1998. Type: Garhwal: Tunghasi, 8000 fl., *Strachey and Winterbottom 5* (holo -BM) (Figure 3.33).

Large shrub; stems glabrous, terete, sublustrous, mature stems deep red, red-brown or purplish-brown; internode 30-50 mm; spines often absent, occasionally solitary or 3-fid, 3-13 mm long. Leaves 15-70 x 15-30 mm, obovate, ovate or obovate-oblong, apex acute or mucronate, base attenuate, petiolate; petiole 0.5-2 cm; light green on both sides, spinous-serrate, nerves raised on both surfaces, margins with c. 14 spinose, distict. Inflorescence racemose umbel, 3-7 flowers; peduncle 7-15 mm long; bract 2.5-3 mm long. Flowers yellow; outer sepal 3.5-5 x 2-2.5 mm, ovate; inner sepal 6.5-7 x 4.5-5 mm, obovate; petal 6.5-8 x 4-5 mm, obovate, entire, base clawed with a pair of lanceolate glands, conspicuously veined; gland 1.25 mm long. Stamen 5.5 mm, not produced; style 1-1.5 mm long. Berries ellipsoid or oblong, 7.5 x 3.5 cm. excluding style, 0.5 mm.

Flowering and fruiting: May-June.

Distribution: INDIA: Uttarakhand (Endemic)

Habitat: 2400-3000 m altitude.

Specimen examined: Uttarkashi, Near Yamanotri, 300m, 7.6.1992, *B. Datt and B. Lal* 212280 (LWG).

Taxonomic Notes: Don (1831) described a species *Berberis petiolaris* based on Wallich manuscript. This taxa has simple spine, leaves obovate, or obovate-oblong, spiny ciliated, on long petiole, membranous; racemes solitary, short loose, erect, or rather pendulus; flower large. In his decription, he did not mention the floral characters and not designated the type specimen. Ahrendt (1942) while distingusing the varieties of the *B. petiolaris* mentions that this species is often confused with *B. pachyacantha*, which has deciduous closely spinulose leaves, many flowered racemes, petals emarginated and shorter than the inner sepal and estylose berries, while this varieties has umbel inflorescence with 3-7 flowered, rairly 4-5 spinulose, style 0.5 mm long. But on the specimen collected by *Strachey and Winterbottom 5* (Type- BM), Schneider mentions that this is a form of *B. pachyacantha*, but Ahrendt in 1939 designated this species as type specimen of *Berberis petiolaris* var. *garhwalana* and published in 1942. However, I think this specimen look like *Berberis pachyacantha.* Yes, I agree that some of the inflorescence look like umbel but as the leves have 10-12 spinules at their margin and the fruit is absent (Type specimen of *B. petiolaris* and *B. petiolaris* var. *garhwalana* in (Figure 3.32). Rao et al. (1998a) mention that their specimens show racemose subumbellate inflorescence with 13 flowers and 4 cm long pedicel and Ahrendt (1961) gives pedicel as 7-15 mm. Ahrendt (1961) while distinguishing the varieties of *Berberis petiolaris* mentions that the inflorescence in the var. *garhwalana* has umbel with 3-7 flowers and peduncles 7-15 mm long whereas specimen studied (*Datt and Lal 212280*) revealed that the infloresence is racemose subumbellate with up to 13 flowers and up to 4 cm long peduncles but in their key they had distinguished the variety on basis of 3-7 flowers. The basic diffrence in distinguish of these two species are style present and absent and type and other specimen kept in Indian herbaria and abroad dosen't have any floral parts. Hence, I think this variety should merge under *Berberis pachyacantha.* I am including this subspecies on authority of Rao et al. (1998a) and Uniyal et al. (2007).

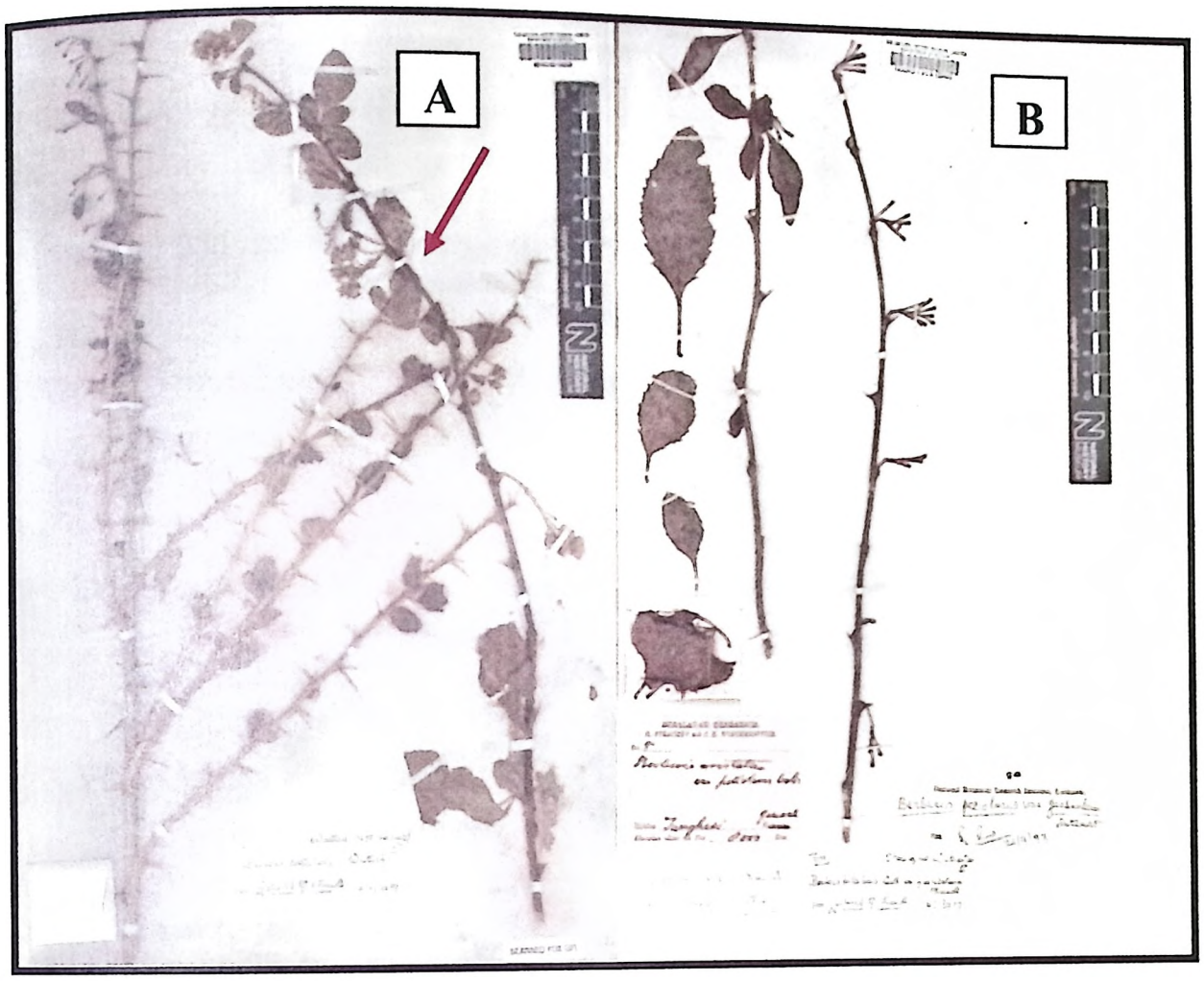

Figure 3.33. Type specimens of **A:** *Berberis petiolaris* Don (*Wallich 1475*p.p. in BM); **B:** *B. petiolaris* var. *garhwalana* Ahrendt, (*Strachey and Winterbottom 5* (BM).

Berberis pseudumbellata Parker, Kew Bull. 1921: 118.1921; Chatterjee, Rec. Bot. Surv. India 16 (2): 22. 1953; Ahrendt, J. Linn. Soc. Bot. 57: 226. 1961; Jafari in Nasir and Ali, Fl. W. Pakistan 87: 25. f. 7 B-C. 1975; Rao and Kumar in Sharma et al. Fl. India 1: 376. 1993; Rao et al. Rheedea 8(2): 137-139. 1998. Type: India: Himachal Pradesh, Chamba, Ravi valley, Ulansa, 7300 ft, 17.7.1920, *Parker s.n.* (K). (Figure 3.34)

Shrub 2-3 m tall, deciduous; stems sulcate, angled or subterete, dark-red to brownish or yellowish; internode up to 25 mm long; spine 1-3-fid, 6-15 mm long. Leaves 15-35 x 6-20 mm, oblong-obovate, apex rounded or mucronate, narrowed below, entire or 2-8 spinose at margins, veins raised on the lower surface; petiole ca 1 mm long. Inflorescence umbellate to subumbellate, 3-10 flowers; peduncle 5-10 mm long, sulcate. Flower 10 mm in diam; pedicel upto 15 mm long, stout; outer sepal 2.75 x 1.75 mm, ovate; inner sepal 5x3 mm,

obovate. Petal 5-6 x 3.5-4 mm, obovate, somewhat clawed; glands submarginal. Stamens 4 mm long, truncate. Stylose 0.5-1 mm long. Berries conspicuously pruinose.

Flowering and fruiting: May- October.

Distribution: Uttarakhand: Malari, Nelong; INDIA: Jammu and Kashmir and Himachal Pradesh; PAKISTAN.

Habitat: In *Cedrus deodara* and *Pinus wallichiana* forest; 3100-3300 m.

Specimens examined: Chamoli Dist., Malari, ca 3118 m, 3.07.2009, *UKT-1055* (WII); Chamoli Dist., Malari, ca 3110 m, 3.07.2009, *UKT-1056* (WII).

Additional specimens examined: Malari, *ca* 3000 m, 31 Aug. 1975, *B.D. Naithani 55931* (BSD); Nelang, 3000 m, July 1988, *B. D. Naithani 66492* (BSD); Nelong, 3500 m, 6.8.2004, *G. S. Rawat 14769* (WII); Nelong, 3500 m, 6.8.2004, *S. chandola 281* (WII); Malari, 3300 m, 25.7.2004, *G. S. Rawat 14645* (WII).

Taxonomic Notes: This species is present in two places in state viz., Nilong and Malari. It is typically a Trans-Himalayan species. I have visited twice to collect this species but I missed to collect in flowering condition, hence, floral character has been adopted from Rao et al. (1998b).

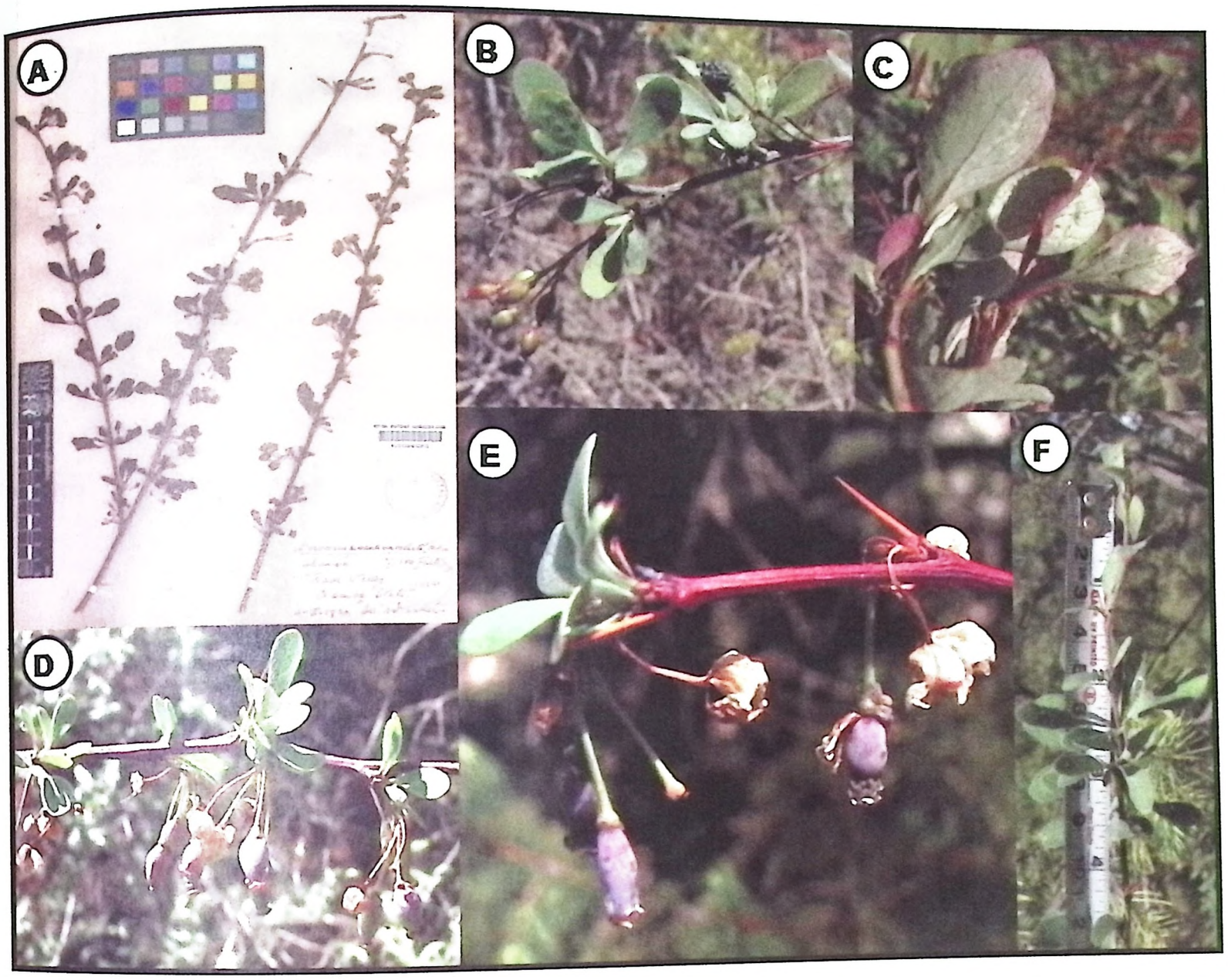

Figure 3.34. *Berberis pseudumbellata* (*UKT-1056*) – **A:** Type – *Royal s.n.* (K); **B:** Plant with Fruits; **C** and **F:** Leaves and **D** and **E:** Inflorescence.

Berberis rawatii U. L. Tiwari and B. S. Adhikari, Nord. Jour. Bot. vol 29 (2): 184-188. 2011. (Figure 3.35)

Berberis rawatii similis in foliis integris, inflorescentiis fasciculatis, stylis conspicuis et baccis nigris, sed praesentia petiolorum et prophyllorum, qui in his desunt, foliorum laminis supra et fructibus pruinosis, epruinosi in his, glandis elongato-ovatis, qui in his oblanceolatis, ovulis 3, in his 2, differt. Type: India, Uttarakhand, Muniyalikhet, Pindar valley, 2340m a.s.l., 16 April 2009, Umeshkumar L. Tiwari *UKT-935* (holotype-WII).

Shrub 30-45cm tall; stem glabrous, sulcate, grey, internodes 15-20 mm long; spines 3-fid, yellow colour, 6-7 mm long. Leaves 20-35 x 5-8 mm, narrowly oblong-elliptic, apex mucronate with spine on the tip, base attenuate, and margin entire, rigid, dull green above, pruinose below with few veins elevated, petiole 0.4-0.5 mm. Older leaves have 2-3 spinose-serrulate. Inflorescence fascicled, 3-7 flowers. Pedicels 9-10 mm. Prophylls 1-2.5 x 1-1.5 mm., acute apex, obovate, yellow with pink tinge. Outer sepals 5-6 x 2-2.5 mm., ovate, yellow. Inner sepals 5-6 x 2-2.5 mm., ovate, yellow. Petals 4-5 x 2-2.5 mm., obovate, entire, apiculate apex, yellow. Glands elongated-ovate, 0.5-0.6 mm. Stamens 4-4.5 mm., truncate apex. Filaments 3-3.5 mm., Ovules 3. Berries black, conspicuously pruinose, globose-obovoid, 6-7 x 2-2.5 mm., including style 0.7-1 mm. Seed pale red, ovoid.

Distribution: Muniyalikhet, Pindar Valley (Chamoli), Samkot and Munsiyari (Pithoragarh), Uttarakhand, India.

Flowering and fruiting: April – May.

Habitat: On open south-west facing dry grassy slopes in association with *Berberis asiatica* and *Berberis osmastonii.*

Conservation status: This species falls under Endangered EN B1a.b(v) category following IUCN (2003). The geographical range of this species is extremely narrow and population is fragmented. The geographical extent of habitat (limestone formations) in which this species grows in both the districts is less than 10 km^2. In all less than 500 individuals were counted in its entire range. The species requires immediate in-situ conservation, which may include protection of habitat.

Specimens examined: Muniyalikhet, Pindar Valley (30° 03' 22.5'-N, 079° 44' 31.3'-E, 2810m asl., SW-facing aspect, 34° slope), Chamoli, 14 April 2010, Umeshkumar Tiwari *UKT-2055* (DD), On way to Samkot (30° 00' 30.5'-N, 080° 10' 45.4'-E, 2343m asl., SW-facing aspect, 34° slope), Pithoragarh, 9 May 2010, Umeshkumar Tiwari *UKT-2053*; Shaheed Trilok Singh Pangtey Govt. Intermediate College , Munsiyari, (30° 03.704'-N, 080°

14.448'-E, 2282m asl., NE-facing aspect, 20° slope) Pithoragarh, 22 May 2010, Umeshkumar Tiwari *UKT-2521*.

Figure 3.35. **A.** Illustration of *Berberis rawatii*. 1. Twig; 2. Prophylls; 3. Outer sepals; 4. Inner sepal; 5. Petals; 6. Glands; 7. Stamen; 8. L. S. of fruit. 9. Seeds. **B.** Photographs of *Berberis rawatii*. 1: Twig; 2: Inflorescence; 3: Flower; 4: Prophylls; 5: Outer sepals; 6: Inner sepal; 7: Petals; 8: Stamen; 9: Immature fruit; 10: L.S. of fruit; 11: Glands on Petal. [**A-B**: Umeshkumar L.Tiwari *UKT-935*(Holotype-WII)].

Etymology: The species has been named after the well-known plant taxonomist and ecologist, Dr. G. S. Rawat at wildlife Institute of India.

Taxonomic Notes: This taxon falls in the Section Heteropodae of genus *Berberis* with *Berberis cretica* as its closest ally. *B. cretica* is reported from Crete, Cyprus and Greece (Linnaeus, 1753; Ahrendt, 1961; Strid, 1986 and Strid and Tan, 2002). However, it's occurrence in Indian sub-region is doubtful as evident from subsequent literature. *Berberis vulgaris* var. *cretica* which is said to be distributed from Garhwal to Baltistan (Hooker, 1875), but this variety has now been merged with *B. cretica* (Rao and Hajra, 1993; Rao et

al., 1998). *Berberis cretica* in having entire leaves, fascicled inflorescence, conspicuous style and black berries; but differs in the presence of petiole which is absent in *Berberis cretica*; dorsal surface of leaf pruinose which is epruinose in *B. cretica*; presence of elongated-ovate gland which is oblanceolate in latter; presence of prophylls which is absent in latter; ovules three which is two in latter and pruinose fruit which is epruinose in latter.

Berberis umbellata Wall, ex G. Don, Gen. Syst. 1:116. 1831; Hook. f. and Thoms. in Hook, f., Fl. Brit. India 1:1 10. 1875; Chatterjee in Rec. Bot. Surv. India 16(2): 21. 1953; Ahrendt in J. Linn. Soc. Bot. 57:104. 17. 1961; Sur in Sharma et al. Fl. India 1:389. 1993; Rao et al. Rheedea 8(1) 29-30. 1998. Type: Nepal: 1818, *Wallich 1475*, in p.p. (Figure 3.36)

Vernacular Name: Kilmora, Kasmod

Stem with young shoots deep red, sulcate; mature red-brown, smooth; spines mostly 3-fid, 7-17 mm long, sometimes absent, central spine longer than the laterals. Leaves 1.5-4.5 x 0.6-1.6 cm, obovate or elliptic-obovate, subacute to mucronate, shortly cuneate to decurrent at base, 5-20 spinulose and subserrulate along margins, thinly coriaceous, slightly lustrous above, below grey, densely papillose. Inflorescence subumbellate or fascicled, 3-6 flowers, rarely 10 flowers, 1.5-3.5 cm long, including 1-15 cm long peduncle; pedicels 0.5-2 cm long; bracts 2x1.8 mm, ovate, acute. Flowers yellow. Sepal 6, in 2 series. Outer sepal 3, 3.5-4.5 x 2.5-3 mm, ovate, acute; inner sepal 3, 5-6 x 4-5 mm, obovate, entire; petal 4.5 x 2.5-3 mm, ovate, emarginate with acute lobes, gland 1x0.4 mm. Stamens 6. Ovary simple; ovules stipitate. Berries 8-12 x 4-6 mm, bright red, oblong - ellipsoid, pruinose. Seeds dark brown.

Flowering and fruiting: May-August.

Distribution: INDIA: Uttarakhand and Himachal Pradesh; NEPAL, BHUTAN.

Habitat: 2850-4000 m in subalpine and alpine meadows.

Specimen examined: On way to Yamnotri temple, 3210 m, 14.5.2008, *UKT 0072 and 0110* (WII); On way to Yamnotri temple, 3230 m, 14.5.2008, *UKT 0076* (WII); On way to Yamnotri temple, 3235 m, 14.5.2008, *UKT 0079* (WII); On way to Yamnotri temple, 3230 m, 14.5.2008, *UKT 0082 and 0083* (WII); On way to Yamnotri temple, 3210 m, 15.5.2008, *UKT 0110* (WII); On way to Yamnotri temple, 3240 m, 15.5.2008, *UKT 0118* (WII); Bigradi, Uttarkashi, 2180 m, 14.6.2008, *UKT 0290, 0293 and 0296* (WII); Yamanotri, Uttarkashi, 3153 m, 24.6.2008, *UKT 0322, 0330 and 0340* (WII); Jhala, Uttarkashi, 2700 m, 2.7.2010, *UKT 2086* (WII); Kushkalyani, Uttarkashi, 3350 m, 3.7.2010, *UKT 2087* (WII).

Additional specimens examined: Uttarkashi, Bhojbasa-Chirbasa, 3400m, 5.9.1983, *U. C. Bhattacharyya 74943* (BSD); Bhojbasa, 3700 m, 4.9.1983, *U. C. Bhattacharyya 74834* (BSD); Pawali kantha, 3100 m, *B. D. Naithani 48183* (BSD); Badrinath, 3500 m, *M. A. Rao 3884* (BSD); Kumaon: Phurkia-Dwali, 3000-3500 m, 25.9.1957, *T. A. Rao 4604* (BSD).

Taxonomic Notes: As by Don (1831) this species has 3 parted spines, leaves obovate-oblong, mucronate, entire, glaucous beneath; pendulous racemose, erect, bearing at the top several umbellate pedicels which rise from the same centre. Main characters for the identification of this species are leaves which are thick and subcoriaceous, venation is prominent on both the surface of the leaf, flowers are subumbellate on a long peduncle, some time one flower come out from the axis from the base and forming the umbellate or subumbellate inflorescence.

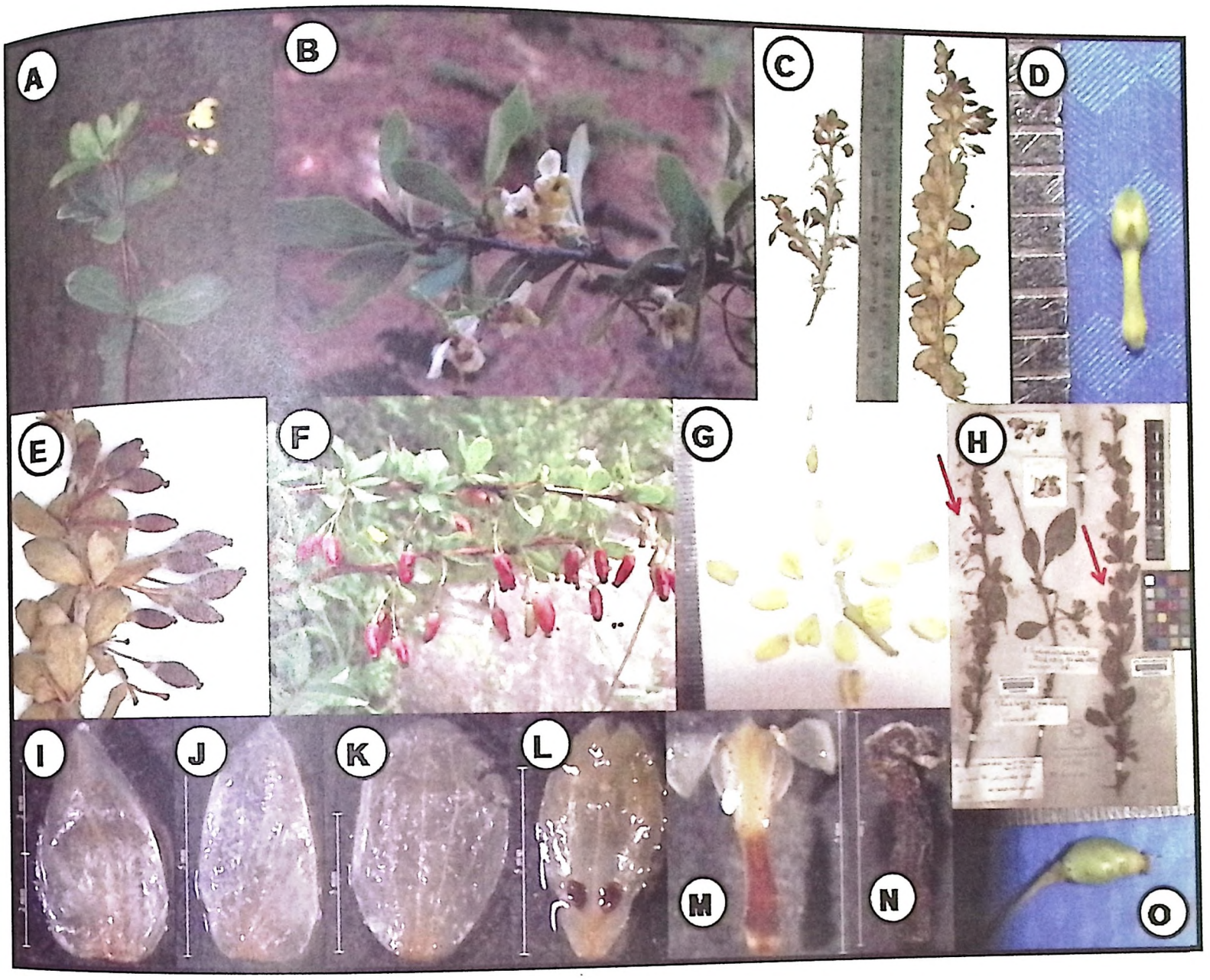

Figure 3.36. *Berberis umbellata* (*UKT-0079*) – **A** and **B:** Twig with leaves and inflorescence; **C**, **E** and **F:** specimen with fruits; **D:** Stamen; **G:** Dessected flower; **H:** Red arrow indicates the type specimen *Wallich 1475* (K); **I:** Outer sepal; **J:** Middle sepal; **K:** Inner sepal; **L:** Petal; **M** and **N:** Stamen and **O:** Fruit.

MAHONIA Nuttall,

Gen. N. Amer. Pl. 1: 211. 1818, nom. cons.; Hook. f. and Thomson 1: 109, 1875; Ahrendt in J. Linn. Soc. Bot. 57: 296-357. 1961; Parker, For. Punjab ed. 3: i. 1958; Bakshi in Sharma et al. Fl. India 1: 406-413. 1993.

Erect Shrubs, evergreen, 0.3–8 m tall. Spines absent. Leaves alternate, imparipinnate, sessile or petiolate; petiole to 14 cm; leaflets 3–41; lateral leaflets usually sessile; terminal leaflet sessile or petiolulate; margins of leaflets entire, variously toothed, or with coarse or fine

serrations. Inflorescence terminal, of (1) 3–18 fascicled simple or branched racemes or panicles, 3–35 cm, subtended by leaflet like bracts. Pedicel 1.5–24 mm, subtending bract shorter or longer than pedicel. Flowers yellow, with three whorls of sepals and 1 whorl of petals, with or without glands at base of petals. Anther connective not prolonged, apiculate or conspicuously prolonged. Ovary ellipsoid; ovules 1–7; styles absent or to 3 mm, persistent on mature fruit. Fruit berries, bluish or black, often glaucous. Seeds 1–7.

Distributed in Himalaya, China to Japan, Taiwan, Thailand, Philippines and N. and C. America; ca 70 species, 13 in India 4 in Uttarakhand.

Key to genus *Mahonia* in Uttarakhand

1. Racemes 5-10 cm. long fascicled 5-8; pedicels longer than, or subequal to bract; leaves to 28- 32 cm. long.....2
1. Racemes 15-30 cm. long fascicled 8-15; pedicels longer than, or subequal to bract; leaves to 28-30 cm. long.....3
2. Bracts only half as long as pedicels.....*M. jaunsarensis*
2. Bracts subequal to pedicels.....*M. borealis*
3. Style less than 1mm long; leaflets lustrous above.....*M. napaulensis*
3. Style 1 mm long; leaflets fairly broad, dull above.....*M. acanthifolia*

Mahonia acanthifolia G. Don, Gen. Syst. 1, 118, 1831; Takeda, Not. Roy. Bot. Gard. Edinb. 24(30): 219-220, 1917; Chatterjee, Rec. Bot. Surv. India, 16 (2): 39. 1953; Ahrendt, J. Linn. Soc. Bot. 57: 309. 1961; Bakshi in Sharma et al. Fl. India 1: 407. 1993. Nepal: 1821, *Wallich 1480* (Type, K); Pundoah, 1820, *Wallich 1480C* (K). (Figure 3.37)

Leaves 48 x 12 cm, oblong-lanceolate, with 8-11 pairs of obliquely set leaflets, overlapping at apical half, contiguous by the middle, separate below, the lowest pair (1-2 x 1-2 cm) set 15 mm. above the base. Leaflets fairly thick, rigid; above dull light green, becoming darker, slightly lustrous, with age, slightly veined; broadly to narrowly oblong-ovate; their length increasing from 4.5 to 6.5 cm, passing from base to middle, then slightly decreasing from 6.5 to 5.5 cm, on continuing to the apex; their breadth continuously decreasing from 3.5 to 2 cm; the terminal leaflet being larger, 6.5-7.5 x 3 - 5·4 cm, with a petiole c. 1.5 cm; bases of

lateral leaflets truncate; margin 2-4 spinose (1-2 mm)-serrate (4-6 mm), distant 1.5-3 cm. Inflorescence 15-23 cm long, fascicled 3-4; rachis 2.5-4 mm thick; bracts of the inflorescence 2-5-3 x 1.2-1.5 cm. Pedicel 4-6 mm; floral bract 2-3.5 mm. Outer sepal 1.5 x 1.5 mm, broadly ovate. Median sepal 4-5 x 3 mm, ovate, obtuse. Inner sepal 7 x 3 mm, oblong-elliptic. Petal 6 x 3 mm, oblong-elliptic, narrowly incised; glands distinct. Stamen 3.5 mm, apex distinctly conical-apiculate. Ovule 3-4. Berries oblong, pruinose blue, 10-12 x 5-7 mm, excluding style 1-1.5 mm.

Flowering and fruiting: October- November.

Habitat: Not Known

Distribution: Kumaon- Uttarakhand (Uniyal et al. 2007), Sikkim, Arunachal Pradesh, Megalaya; NEPAL.

Specimens examined: Kumaon- *Blinkworth, s.n.;* Darjeeling, Thio gapsek kum, 7000-8000 ft., fl. *Hooker 41* (K), May, 6000 ft., *Drummond 14814* (K), a specimen with leaflets thinner and more dentate; Darjeeling, Oct. 1874, *Gamble 1032* (K), and Mar. 1877, *Gamble 403SB* (K); 1880, *Gamble 8561* (K); Assam: Naga Hills, Japvo, 8000 ft., on precipitous densely forested slopes, not rare, 24 Nov. 1949, *Kingdon-Ward 19088* (BM).

Taxonomic Notes: This species is recorded in Uttarakhand flora based on Blinkworth's collection from Kumaon but this collection looks like *Mahonia napaulensis* DC. I have not seen any of the *Mahonia* species, which look like *M. acanthifolia* in state. This species is mainly distributed in Eastern Himalaya. Flora of India Bakshi (1993) had mention that this species has leaflets broader 1:1, racemes 14 cm long and 3-4 fascicled. In eastern Kumaon near Ratapani and Didihat forest in Pithoragarh district all, the species looks as *M. napaulensis*. I am sure *M. acanthifolia* is not present in the state. Description of species is based on Ahrendt 1961.

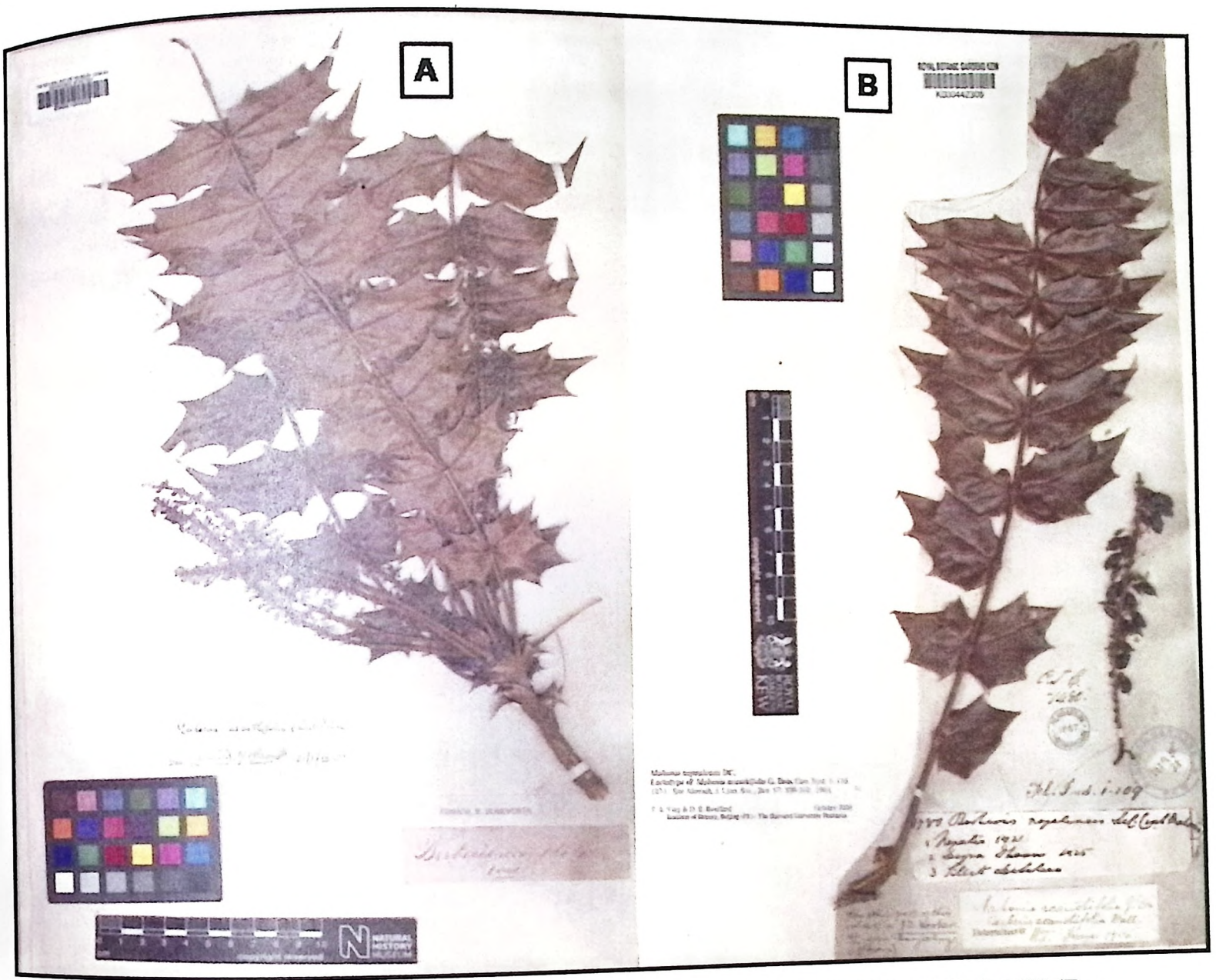

Figure 3.37. *Mahonia acanthifolia* – **A:** Kumaon- *Blinkworth, s.n.;* **B:** Nepal: 1821, *Wallich 1480* (Type-K).

Mahonia borealis Takeda, Notes R. Bot. Gard. Edinb. 24(30): 221. 1917; Chatterjee, Rec. Bot. Surv. India, 16 (2): 41, 1953; Ahrendt, J. Linn. Soc. Bot. 57: 307-308. 1961; Bakshi in Sharma et al. Fl. India 1: 408. 1993. Type: Royle, *s.n.*; Tehri: 7000 ft., Mussoorie, 1892. (Figure 3.38)

Leaves 40 x 15 cm, oblong-oblanceolate, 6- 9 pairs of usually separate leaflets, though they are contiguous or slightly overlapping by the apex; their internodes decreasing along the rachis from 7 to 3 cm. Leaflets thin, ranging from narrowly oblong-ovate to oblong-oblanceolate; their size, both length and breadth, increasing continuously from base to apex 10 x 1.73 cm; the smaller ovate basal pair measure 3 x 1.7 cm, and are set 5-10 mm. up the rachis; bases broadly rounded or truncate; margins 4-8 spinose, distant 7-12 mm; apical cusp

13-20 x 2-6 mm, not very conspicuous; above dull grey-green, with indistinct open sub-elevated reticulation; below with elevated branched venation, and fine close reticulation. Inflorescence 5-20 cm, fascicled 4-9, with thick rachis and inflorescence bracts 10 x 7 mm. Pedicel thick, 3-4 mm; floral bract 3-5 mm. Outer sepal 5 x 2.5 mm, ovate, acute. Median sepal 7 x 2.5- 3 mm, oblong-ovate, subacute. Inner sepals 8.5 x 3-3-5 mm, oblong-obovate. Petal 5-6 x 3-3-5 mm, oblong; apex acutely emarginate with obtuse lobes; glands distinct. Stamen slightly swollen below the anthers, but scarcely subdentate; apex produced, apiculate. Ovule 3-4. Berries 5-8 x 5 mm, globose, to ovoid, pruinose blue, excluding style 1-2 mm.

Flowering and fruiting: February- April.

Habitat: Not Known.

Distribution: Mussoorie, Chakrata, Ghesh, Bhilangana and Kalamuni-Uttarakhand, Himachal Pradesh (Takeda 1917). NEPAL.

Specimens examined: *Stewart s.n.* (K); Kumaon: 7000 ft., *Strachey and Winterbottom 1* (K).

Taxonomic Notes: This species is recorded in Uttarakhand based on *Royle s.n.* (K) from Mussoorie in 1892 and it is type specimen of *M. borealis*, which is described by Takeda (1917). Takeda has mention that this species is characterised by the oblong leaflets of rather thin texture with prominent veinlets, large bracts, short pedicels, and subglobose fruits. Its distribution is confined to the north-western parts of India. He says that, he has seen a plant of a similar appearance to this species but differing in the possession of larger leaflets and longer pedicels (5-8 mm. in length). The racemes are also longer (over 20 cm.) and more numerous in the fascicle. As neither flowers nor ripe fruits are present in the specimens, a closer examination has been impossible.

Figure 3.38: *Mahonia borealis* – Royle, *s.n.*; Tehri: 7000 ft., Mussoorie, 1892 (Type- K).

Collection looks like *Mahonia napaulensis* DC. from Mussoorie hills. In eastern Kumaon near Ratapani, Didihat forest and in Ramganga (E) valley towards Namik village all looks as *M. napaulensis*. I am sure *M. borialis* is not a good described species and this species should be amalgamation with *M. napaulensis*. Description of species was based on Ahrendt 1961.

Mahonia jaunsarensis Ahrendt, J. Linn. Soc. Bot. 57: 310. 1961; Rao and Agrawal, Ind. Jour. For. 4(3): 243-244. 1981; Bakshi in Sharma et al. Fl. India 1: 409. 1993. Type: Chakrata, 7000 ft., fl. 9 Apr. 1897, *Rich 3 (B 33)* (K). (Figure 3.39)

Local name: Khoru

Leaves 28 x 13 cm, obovate, with 5-7 pairs of leaflets mostly separate, but sometimes subcontiguous towards the apex of the leaf; their internodes gradually decreasing from 5 to 3.5 cm on passing from base to apex of rachis which is 2 mm thick; the small basal pair measuring 12 x 8 mm, and set only 5-7 mm above the base. Leaflets broadly ovate to broadly lanceolate, their length increasing from 3.5 to 7 cm from base to apex, while their breadth remains constant at 3.5 cm; bases broadly cuneate, rounded, or subtruncate; margins 3-5-spinose, distant 1-2 cm; apical cusp inconspicuous; terminal leaflet 9-2 x 4 cm, with petiole 1-5-2 cm; above slightly lustrous; both sides sub-elevated subreticulate. Inflorescence 7-14 cm long, fascicled five; bract of the inflorescence c. 1-5 cm long. Pedicel 5-7 mm; floral bracts 2-3.5 mm. Outer sepal 3-5 x 2 mm, ovate-lanceolate, subacute, uni-nerved; median sepal 3, 6-7 x 2-4 mm, lanceolate, obtuse, 3- nerved; inner sepal 3, 7-8 x 4-5 mm, obovate to oblanceolate, obtuse, 3- nerved. Petal 6, 6-7 x 3.5-4 mm, oblong-elliptic, emarginated or narrowly incised, truncate-cuneate, 3 nerved; glands2, distinct. Stamen 6, 4-5 mm, distal half brown, apiculate; filament 1.5 mm, swollen distally. Pistil 1, 5 mm, 0.7 mm long style, bluish black. Fruit berries, pruinose blue, ovoid, ellipsoid, 9 x 4 mm long.

Flowering and fruiting: February- April.

Habitat: Inside Banj Oak forest in state in moist valley, a large shrub common in moist places, and under oak forests near Chakrata.

Distribution: Chakrata, Uttarakhand (Endemic).

Specimens examined: Chakrata, 1878 m, 8/03/2009; *UKT-0495* (WII); Chakrata, 1910 m, 9/03/2009; *UKT-0498* (WII).

Additional specimens examined: Jaunsar, 6000 ft., Jadi forest, *Nand 73* (O); Chakrata, *Marshall, s.n.* (O).

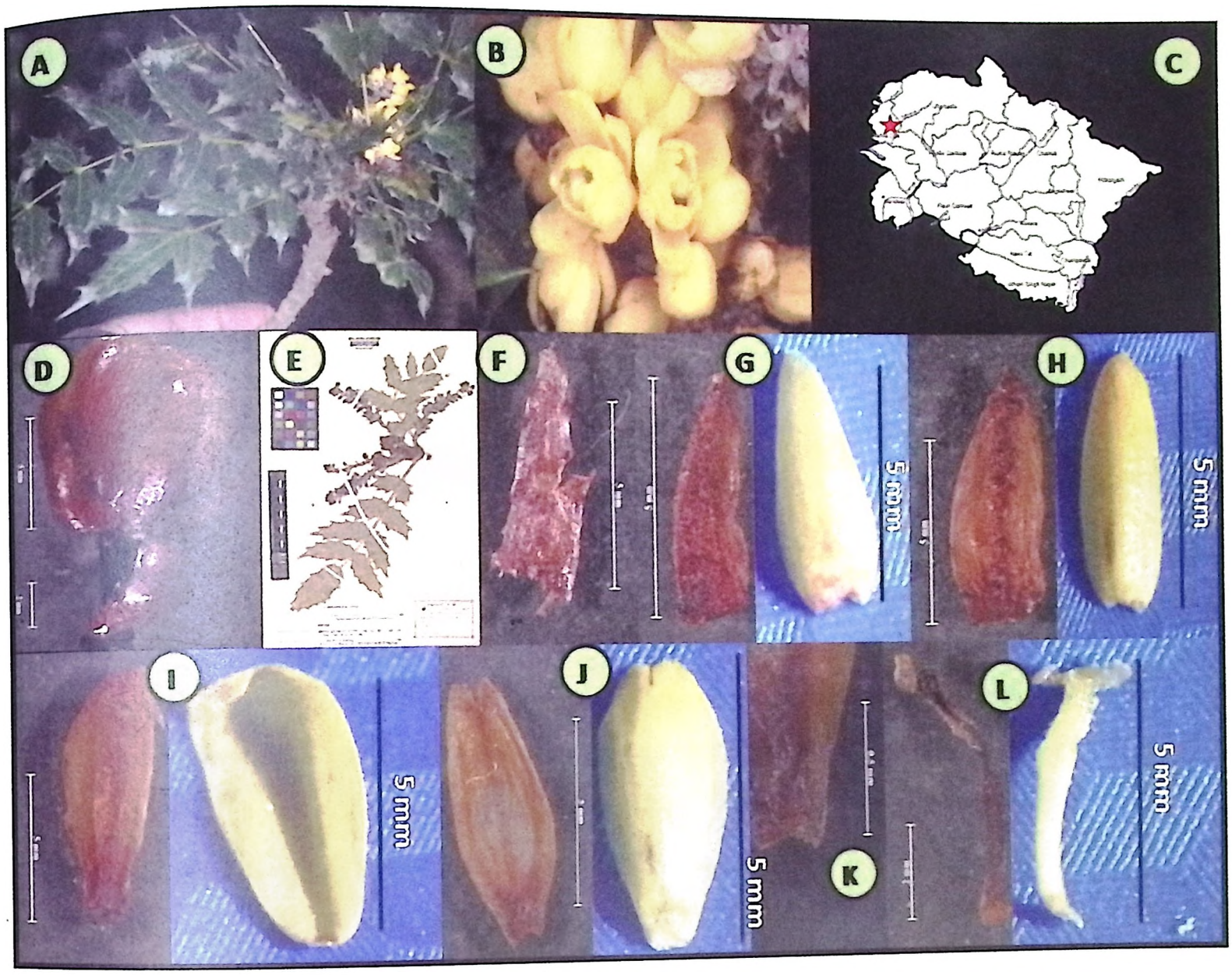

Figure 3.39. *Mahonia jaunsarensis* (*UKT-498*) – **A:** Plant with inflorescence; **B:** Inflorescence; **C:** Red star indicates species distribution in the state; **D:** Flower with bract; **E:** Type – *Rich 3* (K); **F:** Bracts; **G:** Outer sepals; **H**: Median sepals; **I**: Inner sepals; **J:** Petals; **K:** Gland; **L:** Stamens.

Taxonomic Notes: This is an endemic species to Uttarakhand, described by Ahrendt (1961), based on *Rich 3 (B 33)* (K) from Chakrata and it is type specimen of *M. jaunsarensis.* Ahrendt had not described full character that was later described by Rao and Agarwal (1981). I think this species is good species, because it has good characters to distinguished from *M. napaulensis* like racemes 5-10 cm. long fascicled 5-8; bract of flower is half or equal to pedicel of flower.

Mahonia napaulensis DC., Syst. 2: 21. 1821; Takeda, Not. Roy. Bot. Gard. Edinb. 24(30): 216. 1917; Chatterjee, Rec. Bot. Surv. India, 16 (2): 36. 1953; Ahrendt, J. Linn. Soc. Bot. 57: 312-313. 1961; Bakshi in Sharma et al., Fl. India 1: 411. 1993. Iso-type: Naranihetty, 15.11.1802, *Hamilton, s.n.* (K). (Figure 3.40)

Leaves 40 x 12 cm, oblong-oblanceolate, with 4-7 oblique pairs of contiguous or slightly overlapping leaflets; their basal pair measuring only 2 x 1-5 cm, and being situated 1-2 cm above the base; the internodes of the remainder decreasing up the rachis from 5.5 to 3.5 cm Leaflets thick, rigid, ovate; their length increasing from 5.5 to 9.5 cm, from the base to the middle of the rachis, but then decreasing slightly from 9.5 to 8 cm, in passing to the apex; their breath being fairly constant, 3-4 cm; the terminal leaflet being lanceolate, 9.5 x 4.5 cm; bases broadly rounded or subtruncate; margins 4-10-spinose dentate, distant; apex acuminate, or with sometimes inconspicuous cusp, 15 x 10 mm; above slightly lustrous; below dull; venation clearly branched above, subreticulate below. Inflorescence 14-20 cm long, pendulous, fascicled 6-7; bract of the inflorescence c. 2 cm. Petal slender, 5-7 mm; floral bract 4-6 mm. Outer sepal 3-4 x 2 mm. Median sepal 5-7 x 3-3.5 mm, both these series being oblong-ovate, to oblong-elliptic. Inner sepal 7-9 x 3-5.4 mm, Petal 4-5 x 3.5-5.5 mm; apex emarginate with rounded lobes; glands distinct. Stamen with apex distinctly conical apiculate. Ovule 4-5. Berries 9 x 6 mm, excluding style c. 0.4 mm, heavily pruinose blue.

Flowering and Fruiting: February- April.

Habitat: Inside Banj Oak forest in state in moist valley.

Distribution: Mussoorie, Chakrata, Ghesh, Bhilangana and Kalamuni- Uttarakhand, Himachal Pradesh, Jammu and Kashmir, Sikkim. PAKISTAN, NEPAL, BHUTAN.

Specimens examined: Mussoorie, 1980 m, 9.03.2009; *UKT-0501* (WII); Mussoorie, 1834 m, 10.03.2009; *UKT-0503* (WII).

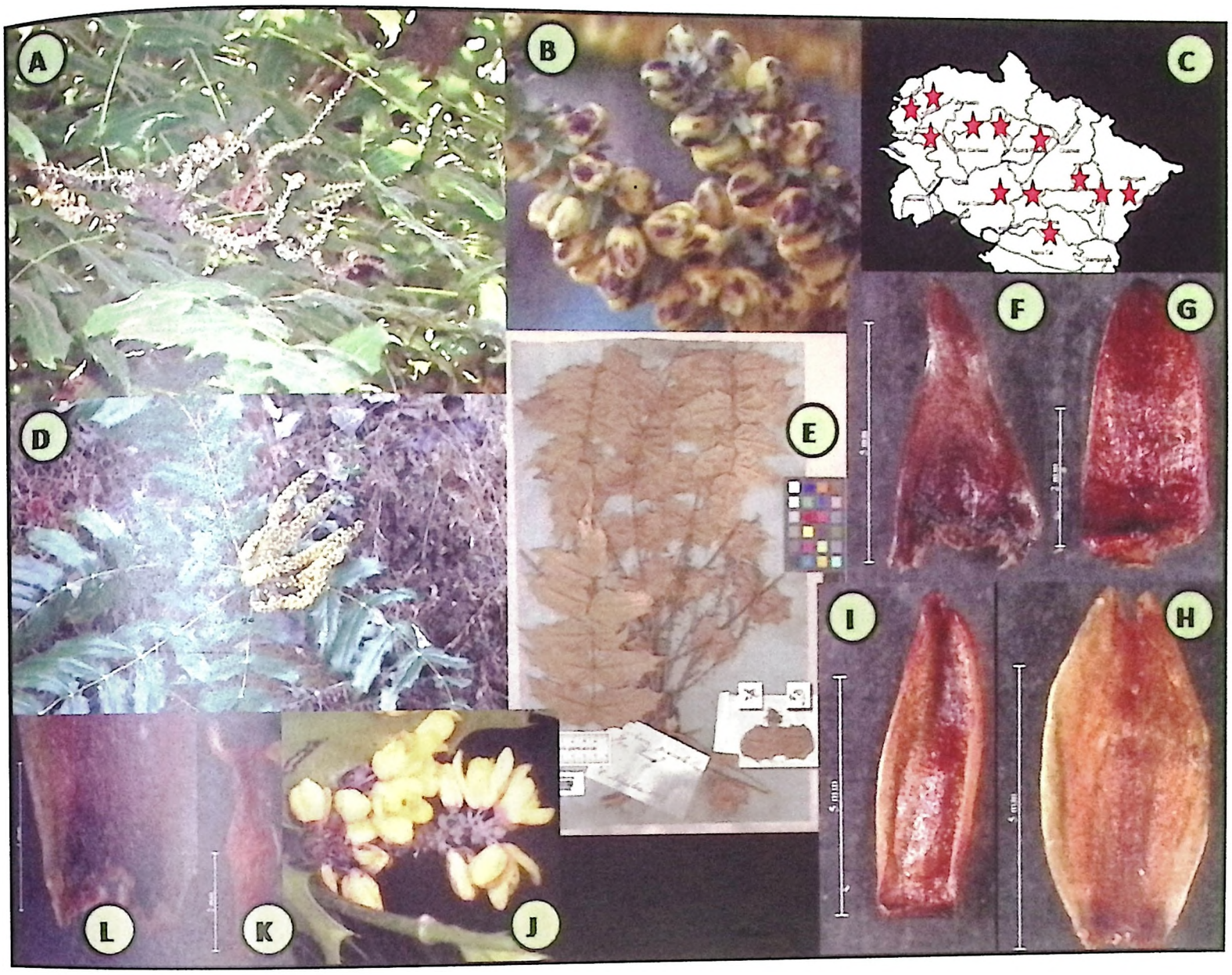

Figure 3.40. *Mahonia napaulensis* (*UKT-503*)–**A:** Plant with inflorescence; **B:** Inflorescence; **C:** Red star indicates species distribution in the state; **D:** Twig; **E:** Iso type – *Wallich s.n.*, 1819 (Geneva); **F:** Bract; **G:** Outer sepals; **H**: Petal; **I**: Inner sepal; **J:** Close up of inflorescence; **K:** Stamen; **L:** Glands on petal.

Additional specimens examined: Nepal: Naranihetty, fl. 15 Nov. 1802, *Hamilton, s.n.* (*Isotype,* K); Jan. 1821, *Wallich 1480,* Nepal; W. Nepal: Lekh Rangchi, in dense wet oak and *Rhododendron* forest, shrub 3 4 ft. tall at 7500 ft., 3 Apr. 1952, *Polunin, Sykes and Williams 3832* (BM).

Taxonomic Notes: This is very common species of *Mahonia* in Uttarakhand, described by De Candolle (1821), based on *Hamilton, s.n.* (*Isotype,* K), 1802 from Naranihetty, Nepal and it is type specimen of *M. napaulensis*. De Candolle's specimens are preserved in Delessert's

Herbarium in Geneva. Distinguished characters are racemes 15-30 cm. long fascicled 5-8; bract of flower is longer than pedicel of flower.

3.4.3 Cluster Analysis of Morphological Characters

Cluster analysis was done using 37 different morphological characters for 32 taxa of *Berberis* found in Uttarakhand (Appendix –I and II). There are six major groups are formed (Figure 3.41). Group 1 is having species like *B. koehneana*, *B. pseudoumbellata*, *B. hamiltoniana* and *B. lambertii*. Group 2 have *B. petiolaris*, *B. pachyacantha*, *B. macracantha*, *B. kunawurensis* and *Berberis coriaria*. Group 3 have *B. jaeschkeana* and *B. apiculata*. Group 4 have *Berberis glaucocarpa, B. aristata, B. floribunda* and *B. affinis* are very much close to each other. Group five have *B. lycium* and *B. ahrendtii*. Group six have *B. rawatii, B. cretica* and *B. osmastonii*. Some taxa like *B. pachyacantha* var. *pachyacantha*, *B. pachyacantha* var. *zebelina* have 100% similarities *B. petiolaris* var. *extensa* and *B. petiolaris* var. *garhwalana* are quite similar to each other (Figure 3.41).

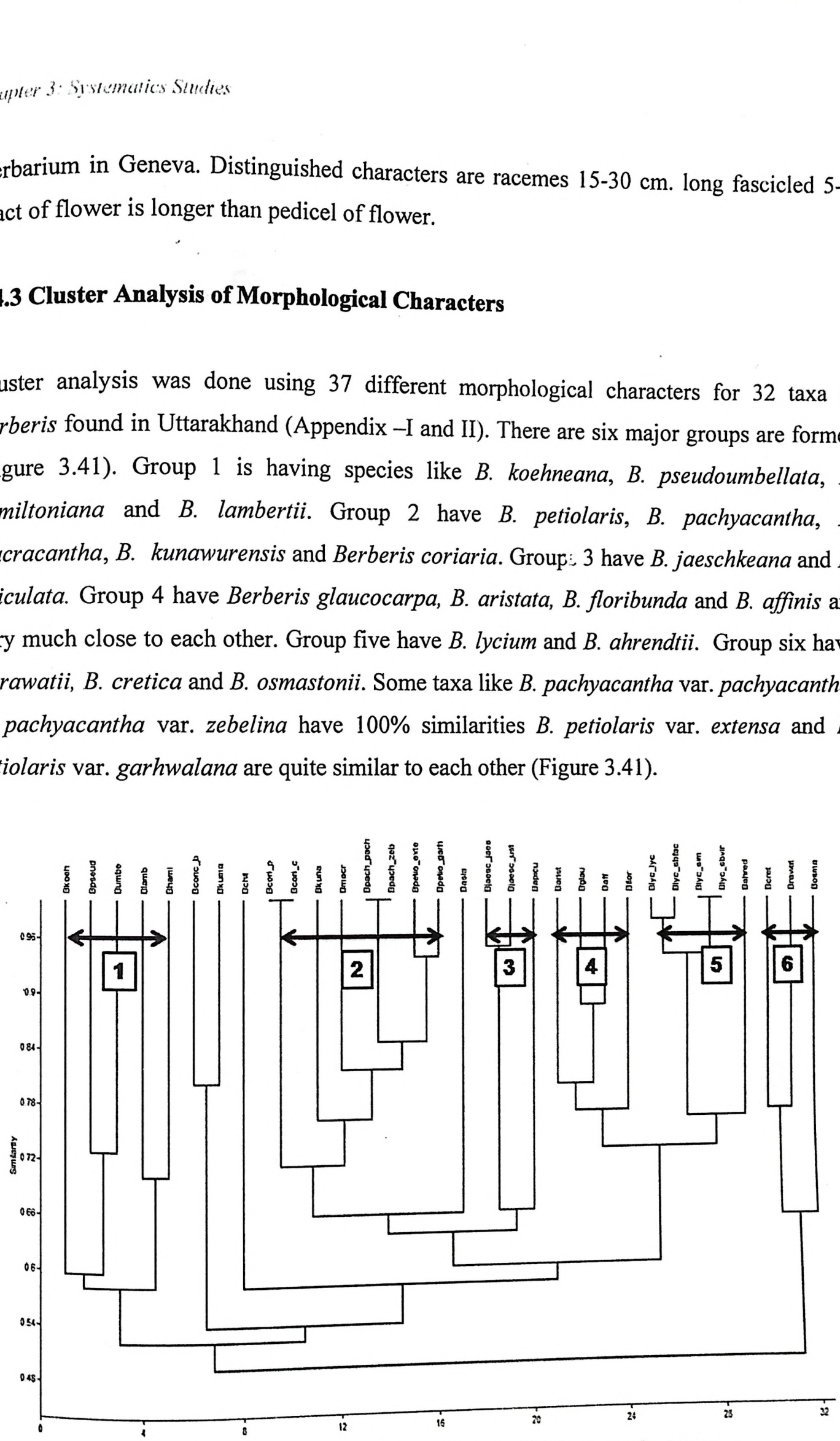

Figure 3.41. Cluster analysis of morphological affinities for *Berberis* taxa.

3.5 Discussion

Thirty two taxa of Berberidaceae were reported from the state of Uttarakhand previously (see Table 3.2). During literature review it was revealed that this work has included many controversial species on which Ahrendt (1961) had described many of the taxa from Indian region on the other's collection, which are later supported by Uniyal and Rao (1993) and Rao et al. (1998 aand b). During the present study 36 taxa belonging to two genera of Berberidaceae were studied. This Chapter, Systematic treatment of Berberidaceae include two species *i.e. Berberis apiculata* and *B. hamiltoniana* which is new for state. One species *Berberis rawatii* is new record for science. As Uttarakhand has highest diversity among all other states in India. This implies that Uttarakhand does have the potential to harbour barberry as it has good patches of undisturbed forests scattered throughout the state. 12 taxa which were reported by previous workers were not collected during the present work (see Table 3.3). These species can be considered locally extinct from wild from Uttarakhand or these may be miss identified. Thorough notes on taxonomy, ecology for each species have been provided along with the description. *Berberis affinis* is the species that is described from the Kumaon, but type materials are not available or designated, due to lack of information this species could not be even identified. *Berberis glaucocarpa* Stapf (1926) is look very much similar to *Berberis aristata* but due to lack of type specimen of *Berberis aristata* it was not resolved. *Berberis coriaria* was described by the Lindley in 1841 but the type specimen was not mention in protologue and specimens which are kept in K, BM, WU and CJB are look quite similar to *Berberis aristata.* As *Berberis petiolaris* var. *extensa* and *Berberis petiolaris* var. *garhwalana* look quite similar to *Berberis pachyacantha* as I had mention in the taxonomic notes. From this study first time an endemic species *Berberis lambertii* has been collected from its type locality, as this species is reported in IUCN red data book of Plants as is rare and described its floral characters in this work.

Table 3.2: List of Berberidaceae members reported in state by all previous authors (Hooker and Thomson 1875, Naithani 1984, Uniyal and Rao 1993, Uniyal et al. 2007 and Rao et al. 1998)

Berberis affinis^
Berberis ahrendtii^
Berberis apiculata #
Berberis aristata
Berberis asiatica
Berberis chitria
Berberis concinna var. *brevior*
Berberis coriaria var. *coriaria*
Berberis coriaria var. *patula*^
Berberis cretica
Berberis floribunda
Berberis glaucocarpa
Berberis hamiltoniana #
Berberis jaeschkeana var. *jaeschkeana*
Berberis jaeschkeana var. *usteriana*
Berberis koehneana
Berberis kumaonensis
Berberis kunawurensis
Berberis lambertii^
Berberis lycium var. *lycium*
Berberis lycium var. *simlensis*
Berberis lycium var. *subfacicularis*
Berberis lycium var. *subvirescens*
Berberis macracantha
Berberis osmastonii^
Berberis pachyacantha var. *pachyacantha*
Berberis pachyacantha var. *zebelina*
Berberis petiolaris var. *extensa*
Berberis petiolaris var. *garhwalana*^
Berberis pseudoumbellata
*Berberis rawatii**^
Berberis umbellata
Mahonia acanthifolia
Mahonia borealis
Mahonia jaunsarensis^
Mahonia napaulensis

#= New record for state; *= New record for science; ^= Endemic Species

Table 3.3: List of Berberidaceae members reported in state by all previous authors but not collected during present study (Hooker 1875, Naithani 1984, Uniyal and Rao 1993, Uniyal et al. 2007 and Rao et al. 1998)

Berberis affinis
Berberis concinna var. *brevior*
Berberis coriaria var. *coriaria*
Berberis coriaria var. *patula*
Berberis cretica
Berberis floribunda
Berberis macracantha
Berberis pachyacnatha var. *zebelina*
Berberis petiolaris var. *extensa*
Berberis petiolaris var. *garhwalana*
Mahonia acanthifolia
Mahonia borealis

3.6 Conclusion

i. Perusal of literature and past collections housed in the national herbaria revealed that Family Berberidaceae was represented by 2 genera, 27 species and 9 sub-species in the state of Uttarakhand. Detailed floristic survey and taxonomic evaluation revealed that the state has as many as 36 taxa which is the highest number for any of the Himalayan states.

ii. The study resulted in the discovery of a new species to science (*Berberis rawatii* Tiwari and Adhikari Nordic Journal of Botany 29: 184-188. 2011) and 2 species new records for Uttarakhand state. Populations of two endemic species, *B. lambertii* and *B. ahrendtii* have been located and collected after a gap of 100 years. Earlier description of *B. lambertii* was based on vegetative characters and for the first time in this study, it has described in greater detail using floral characters.

iii. Three species, viz., *B. glaucocarpa*, *B. coriaria,* and *B. affinis* are closely allied to *B. aristata* and seem to have been separated by superficial characters and it is extremely difficult to separate them in the field. Further genetic and taxonomic evaluation is likely to result in merging of these species into one taxon.

iv. All the 32 taxa recorded in the state were further studied and compared morphologically based on 38 taxonomic characters using cluster analysis. The analysis revealed that the species of *Berberis* could be grouped in six distinct clusters. These groups have been further characterized morphologically.

v. Detailed keys for identification of all the taxa being reported from Uttarakhand have been given. All the taxa have been enumerated along with latest nomenclature, detailed morphological description, habit, habitat, distribution, and specimens examined.

vi. All the 36 taxa have been in the state. These species of in order to assess the taxonomic status and distribution pattern of many taxa an in-depth of many taxa were unclear in the state. With this study 24 taxa of Berberidaceae were collected and their morphology and ecotypes' variation were studied. This is a first kind of work for state and taxonomical problem are discussed. 12 taxa were not collected from field and their taxonomy and status is ambiguous.

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Chapter 4: Autecology Of Endemic *Berberis* Species

CHAPTER 4.0
AUTECOLOGY OF ENDEMIC *BERBERIS* SPECIES

"Our personal consumer choices have ecological, social, and spiritual consequences. It is time to re-examine some of our deeply held notions that underlie our lifestyles."

-David Suzuki

4.1 Introduction

For complete understanding of the ecology of the species, it is important to have knowledge on its habits, habitat, phenology, germination, growth pattern and associations. The science dealing with various ecological aspects of single species is known as autecology (Kashkarov 1944, Naumov 1963 and Macfadyen 1965). It reveals information on the life-history strategies of a species and its micro-habitat requirements which may be crucial for further conservation planning and predicting species distribution and performance under varying environmental parameters. In some cases, autecological study may require experimental manipulation so as to create varying light, humidity and nutrient levels in the soil. Although, there has been a steady increase in the number of plant syn-ecological studies in India, the number of autecological studies is rather limited till date. Likewise, there has been hardly any ecological study on the common shrubby genera of the Himalayan region. One of the commonly occurring genera in the region is *Berberis,* which is represented by 55 species in India. Of these, 24 are endemic to India out of which, six endemic to the state of Uttarakhand. All the endemic species are restricted in their distribution and hardly any information has been collected on their status and autecology. This chapter deals with certain aspects of autecology for three endemic species of *Berberis*. Major questions addressed in the present study are as follows: (i) Which are the crucial habitats for the endemic species of *Berberis*? (ii) Which are the climatic factors affecting on their distribution? (iii) What are their distributional ranges in state? and (iv) What is their population status and identification of threat to natural population?

4.2 Review of Literature

Populations of many plant species, particularly threatened endemic taxa, have sharply declined in many parts of the world during recent decades as a result of habitat degradation, fragmentation and overexploitation (Colling and Matthies 2006; Dar et al. 2006 a, b and 2008). Small populations face the risks of extinction due to demographic, environmental and genetic stochasticity (Bruna and Kress 2002). Such effects are further exacerbated by spatial isolation of the populations that limits the replenishment of genetic variation and gene flow. Degree of out breeding in small isolated populations may be severely constrained because such populations experience reduced pollinator visitation and altered foraging behavior of pollinators (Byers 1995). Massey and Whitson (1981) emphasized on the need for detailed information on the life cycle of rare plant species in order to preserve them. Further, several authors (*e.g.*, Kruckeberg and Rabinowitz 1985; Kunin and Gaston 1993; Linhart and Premoli 1993) have encouraged research on the biology of rare plant species to understand the causes of their rarity. However, the significance of information for a single species, and in particular a rare one, is hard to evaluate unless comparisons are made with geographically-widespread, closely-related species (Bradshaw 1987). Information on the autecology of widespread species, based on experimental research (Walck et al. 1997) or by literature review (Baskin et al. 1997) serves as reference point for comparing with related rare endemic species for which fewer ecological parameters may have been studied. Balodi (1995) studies on the rare and endangered species of Pithoragarh and talk about their conservation. Aswal and Goel (1985) had mention rare and lesser known plants of Garhwal and Kumaon. Atkinson (1982) had given reference about flora of Garhwal and Kumaona and Khanna (2001) has talk about endemic plants of Uttar Pradesh.

Autecology of narrow endemic species becomes all the more crucial for understanding the phytogeography, adaptive evolution and associations and dispersion (Huston 1994). The genus *Berberis* exhibits an interesting pattern of distribution in India. Of the 55 species recorded from the country, 16 species and 8 sub-species are endemic. Of these, about 19 taxa (11 species and 7sub-species and varieties) are endemic to the Indian Himalayan region (Sharma et al. 1991 and Rao et al. 1998, Tiwari and Adhikari 2011). Western Himalaya and

the state of Uttarakhand have 11 and six endemic taxa of *Berberis* respectively. Phenology forms one of the important aspects of autecology. It is governed largely by climatic factors and can be studied at varying scales from individual to community levels (Pau et al. 2011). The timing of the switch between vegetative and reproductive phases that occurs in concert with flowering is crucial to optimal seed set for individuals and populations. Hence, variation among species in their phenology is an important mechanism for maintaining species coexistence in diverse plant communities, by reducing competition for pollinators and other resources (Rathcke and Lacey 1985). Likewise, the timing of growth onset and senescence also determine length of growing season driving annual carbon uptake in terrestrial ecosystems (Gu et al. 2003). Ecologists, nevertheless, have only recently paid attention to the relationships between phenological patterns, vegetative growth strategies and reproductive characteristics (Arroyo et al. 1981, Chen et al. 2005). In highly harsh conditions at higher altitudes of Himalayan region, flowering of plants must be completed during limited period, to permit fruit maturation and seed dispersal. It has been predicted that autogamy and apomixis, which reduce dependence on external pollinators, might be more frequently encountered among species inhabiting at higher mountains (Arroyo et al. 1981). Spatial and temporal displacement by competition for light and water (Terborgh 1973), and temporal competitive adjustment for the most efficient utilization of pollinators (Levin and Anderson 1970) and seed-dispersal agents, are important factors governing niche differentiation in plant species.

4.3 Methodology

Based on the past records and rapid survey of *Berberis* species in the state of Uttarakhand, areas for intensive study on endemic taxa were selected. These areas include Muniyalikhet, Pindar Valley (Chamoli district) and Kalamuni and Betulidhar near Munsiyari (Pithoragarh district) of Uttarakhand state. The species selected for intensive study were *Berberis rawatii, B. lambertii* and *B. osmastonii*, for observations on various parameters field visits to intensive study sites were made regularly every alternate month. For each population detailed notes on habit, habitat, plant associations and vegetation types were taken. Specific methods for other parameters are described below:

4.3.1 Phenological observations

Phenological records were maintained from early March 2008, shortly after snowmelt at 2300 m, until mid-November 2011, in three sampling sites in between 2200-3000 m altitudes. Two of these sites were on predominantly South-facing slopes, while one are on South-West facing slopes at the same altitude. Site details and are given in Table 4.1. Observations were made at intervals of approximately one month and intensively during active growth phase. Regular intervals could not be maintained during winter months (November- March) due to late and heavy snowfall during 2010 - 2011. The phenophases recorded were: active vegetative growth, emergence of flower buds followed by flowering, fruiting, and senescence of foliage following the standard methods (Meier 2003). The results are based on observations on 4 - 5 marked individuals per species.

Table 4.1. Characteristics of the Six sampling sites in Uttarakhand, Western Himalaya

Species	Location	Altitude (m)	Slope (Degree)	Aspect	Forest Type
Berberis osmastonii* and *B. rawatii	Samkot, Pithoragarh	2350-2450	33-45°	South Facing Slope	Temperate Grassy Slope
Berberis osmastonii* and *B. rawatii	Muniyalikhet, Chamoli	2150-2500	13 to 22°	South Facing Slope	Temperate Grassy Slope
Berberis osmastonii	Kalamuni, Pithoragarh	2650-2780	30-45°	South Facing Slope	Kharsu Oak Mixed Forest
Berberis osmastonii	Betulidhar, Pithoragarh	2580	40 to 55°	South West Facing slope	Temperate Grassy Slope
Berberis lambertii	Betulidhar, Pithoragarh	2780	55 to 60°	South West Facing slope	Temperate Grassy Slope
Berberis lambertii	Kalamuni, Pithoragarh	2720-2750	22-45°	South Facing Slope	Kharsu Oak Mixed Forest

The degree of constancy of the phenological patterns was expressed in terms of the occurrence of phenological events over the three year period during the similar growing

period of species. From January onwards all phenophases were compared consecutively for 3 years and active flowering period was monitored intensively.

4.3.2 Abiotic and Edaphic Factors

Various abiotic factors such as altitude and aspect, slope (GPS Garmin 72, magnetic compass Sunto); terrain and topography with respect to each population were recorded and other conventional methods. Soil samples from the surroundings of endemic *Berberis* species were collected to examine type, texture, water holding capacity and pH. Soil samples were taken from a depth of 10 - 30 cm, put into polythene bags and carried to the laboratory. The samples were air dried under laboratory conditions, passed through a 2 mm sieve and analyzed for different physico-chemical characteristics. The soil texture was determined as per Gee and Bauder (1986). Soil pH, total salinity, and organic matter were determined following standard methods (Mclean 1982). All the samples were digested in mixture of Nitric acid and Perchloric acid for Na, K, Ca and Mg whereas for estimation of % N were digested with Sulphuric acid and Selenium, using Kjeldahl method. Phosphorus (P) content was determined using UV Spectrophotometer, Ca and Mg was determined with Perkin Elmer 2280 Atomic Absorption Spectrophotometer (Allen et al. 1986). Whereas, K & Na were determined using Flame Photometer.

Water holding capacity of the soil is a very important parameter determining the growth of plants which is in turn controlled by the soil texture and soil organic matter. Soil texture is a reflection of the particle size distribution of a soil. For example, silty loam soil has 30% sand, 60% silt and 10% clay size particles. In general, the higher the percentage of silt and clay, higher is the water holding capacity. The small particles (clay and silt) have a much larger surface area than the larger sand particles. This large surface area allows the soil to hold a greater quantity of water. The amount of organic matter in a soil also influences the water holding capacity. As the level of organic matter increases in a soil, the water holding capacity also increases, due to the affinity of organic matter for water.

4.3.3 Temperature and Precipitation: A meteorological measurement of temperature and precipitation data set is extracted from MODIS LST images. Image pixel size is 1 km. Temperature and precipitation measurements are available (daily mean/sums) for 2008, 2009, 2010 and 2011 from the NCDC Global Summary of Day. These images were processed and values were extracted with the help of GPS locations.

4.3.4 Biotic Factors

Biotic factors such as associated plant species, pollinators/ dispersal agents if any, physiognomy of vegetation, anthropogenic pressures such as lopping (present/absent), fuel wood extraction (present/absent), collection of non timber forest products, livestock grazing (species and grazing intensity- heavy, medium, low) were recorded at each site and correlated with the micro-habitat of endemic species.

4.4 Results

B. osmastonii and *B. rawatii* were recorded as early growing species in which initiation of growth occurred with the rise of temperature and beginning of snow melt. However, depending upon the temperature and amount of snow, the initiation of growth was varied and timing of growth initiation may be fluctuated for a week across the years. Species growths initiated after the melting of snow cover and consequently increase in the soil moisture and daytime temperature. As compared with *B. osmastonii* and *B. rawatii*, in *B. lambertii* growth was initiated later in more warmer condition. Initiation of growth for all 3 species was varied depending on the microclimatic condition in every year.

4.4.1 Local Distributions and Number of Populations

Berberis lambertii, an endemic taxon to the eastern Kumaon in Pithoragarh district, is Critically Endangered (CR). It has extremely patchy distribution and small population. It is a perennial shrub, 0.5 to 1 m high with a few branches. It has only two populations between Ratapani and Humidhura (N- 30.036729^{O} E- 80.193037^{O}). A total of 37 individuals were

present near Betulidhar closer to Humidhura on a temperate grassy slopes while there were 81 individuals were located near Kalamuni in on South-West facing slope, at the edge of Kharsu Oak Mixed Forest (Table 4.2 and Plate 4.1). *Berberis osmastonii* is reported from two localities in the state, *viz.*, Muniyalikhet (Chamoli district) and Kalamuni to Betulidhar (Pithoragarh). *Berberis rawatii* is also restricted to three different localities in state. The two species share the same habitat. Both species are restricted to the central and eastern parts of the state and have not been reported from the lower Himalaya (Rao et. al. 1998 and Tiwari and Adhikari 2011). Distribution of *B. osmastonii* ranged in altitude between 2200-2500m a.s.l at Muniyalikhet and occupies cool-temperate belt. *B. rawatii* was also recorded at two localities in state. However, it has larger population at Muniyalikhet along same altitudinal range as in case of *B. osmastonii*. Characteristic habitat for both the species was South facing dry grassy slope. However, *B. osmastonii* showed wider ecological amplitude as compared to *B. rawatii* and *B. lambertii* as indicated by number of populations, altitudinal range, substrate and overall distribution (Table 4.2 and Plate 4.1).

Table 4.2. Environmental condition of the populations of endemic *Berberis* species in Uttarakhand

Locations	Species and number of individuals per site (per populations)			Biophysical features of habitat			
	B. lambertii	***B. osmastonii***	***B. rawatii***	**Altitude (m)**	**Aspect**	**Slope (degree)**	**CC* (%)**
Munsiyari Inter College	-	-	8	2267	NW	22	0
Samkot	-	152	14	2752	SW	31	0
Humidhura	37	166	-	2798	SW	37	0
Ratapani	-	159	-	3592	SW	5	25
Kalamuni 1	76	154	-	2798	SW	37	25
Kalamuni 2	5	232	-	2652	SW	30	0
Muniyalikhet 1	-	312	174	2187	SW	21	0
Muniyalikhet 2	-	254	159	2473	SW	20	0

* CC = % Canopy Cover of forest

4.4.2 Phenology: Phenophases of the observed species have been depicted in Figure 4.1. It was observed that in all the species leaf initiation began in the month of February. Leaf and primary shoot start developing at the beginning of February month in each year. On the onset of favorable temperature flowers of *Berberis* species developed rapidly.

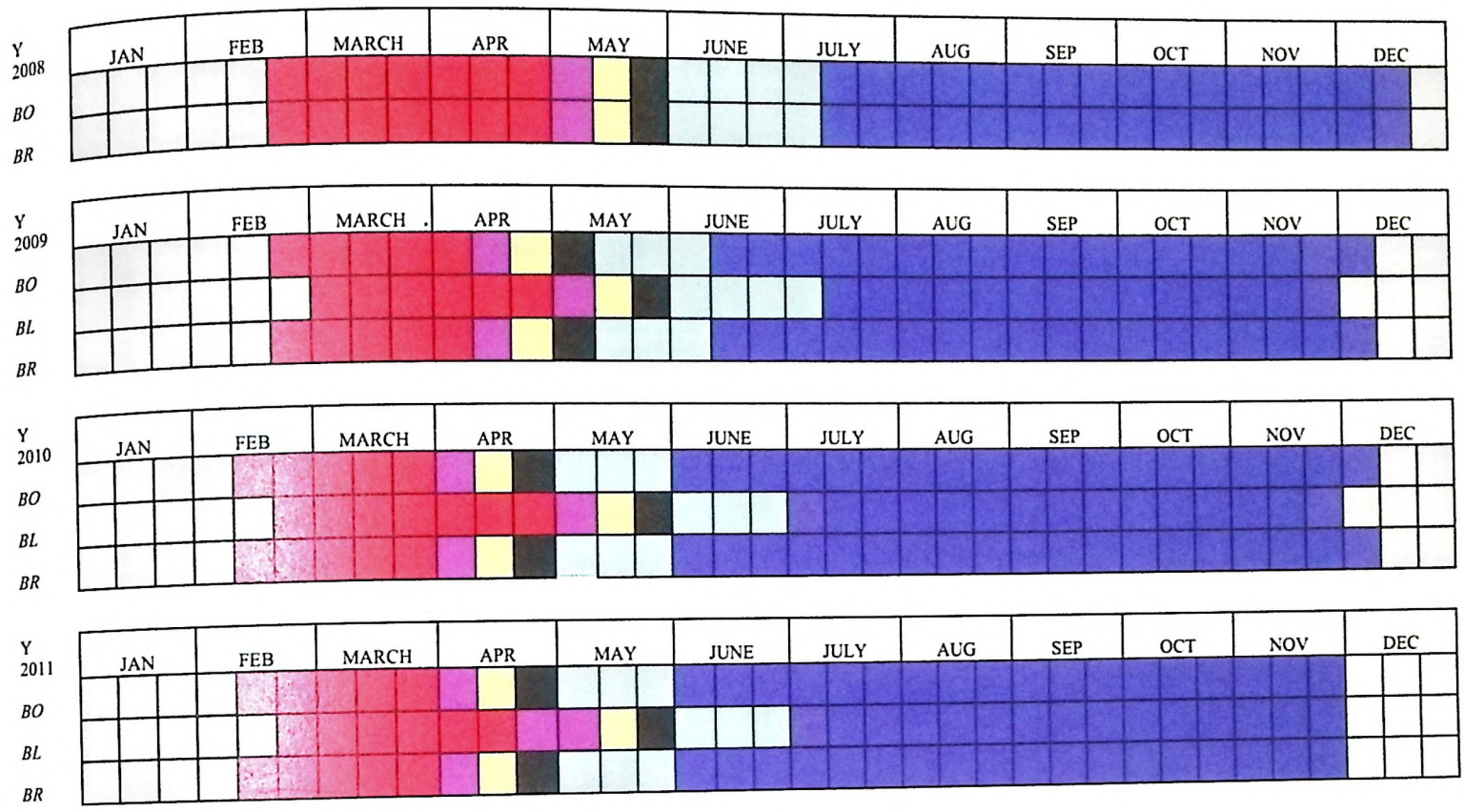

Figure 4.1. Phenological stages of endemic *Berberis* species in Uttarakhand. (BO: *Berberis osmastonii;* BL: *Berberis lambertii;* BR: *Berberis rawatii*).

It was observed that flowering phenophase was more depend on the soil and air temperature. Timing and duration of bud breaking phenophase was not overlapped in three years and it was advanced year by year. The flowering period of *Berberis lambertii* started in the first week of May. In 2009, flower buds of this species initiated on 2/05/2009 and flowering was over on 29/05/2009. Total period of anthesis was 27 days. A fruit matures towards the end of June. Seeds mature towards beginning of July in 2009. However, during 2010 it was advanced by 8 -12 days compared to 2010 and during 2011 it as further advanced by 12 - 14 days. Similar trend was observed in *Berberis osmastonii* and *B. rawatii*. In these species during 2008, flowering start on 29/04/2008 (± 10 days) and flower dehiscence on 30/5/2008

(± 6 days). However, during 2011 it is advanced by 22-25 days (Figure 4.1 and Plate 4.2 & 4.3).

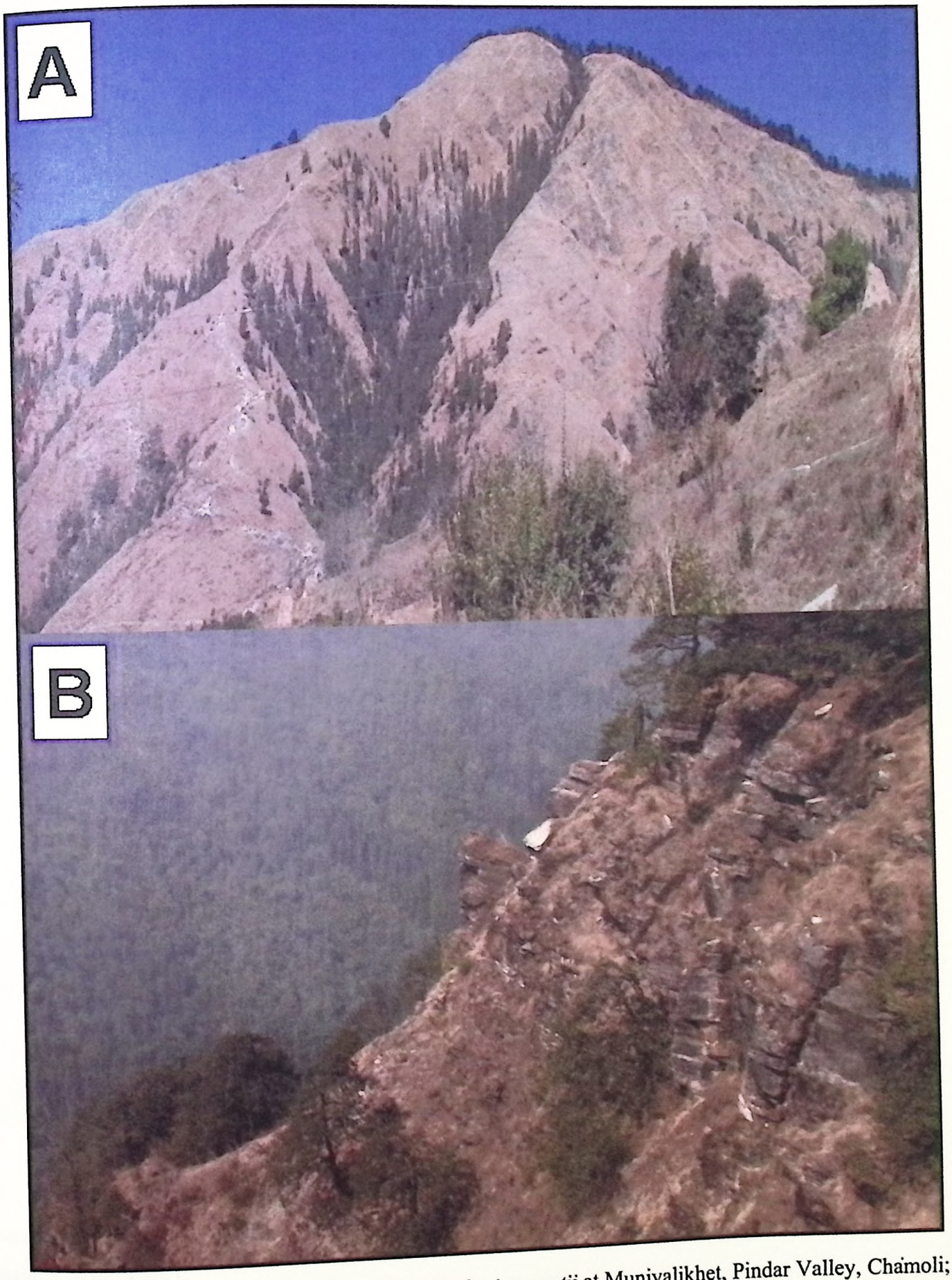

Plate: 4.1. **A:** Habitat of *Berberis osmastonii* and *Berberis rawatii* at Muniyalikhet, Pindar Valley, Chamoli; **B:** Habitat of *Berberis osmastonii* and *Berberis lambertii* at Betulidhar, Pithoragarh in Uttarakhand.

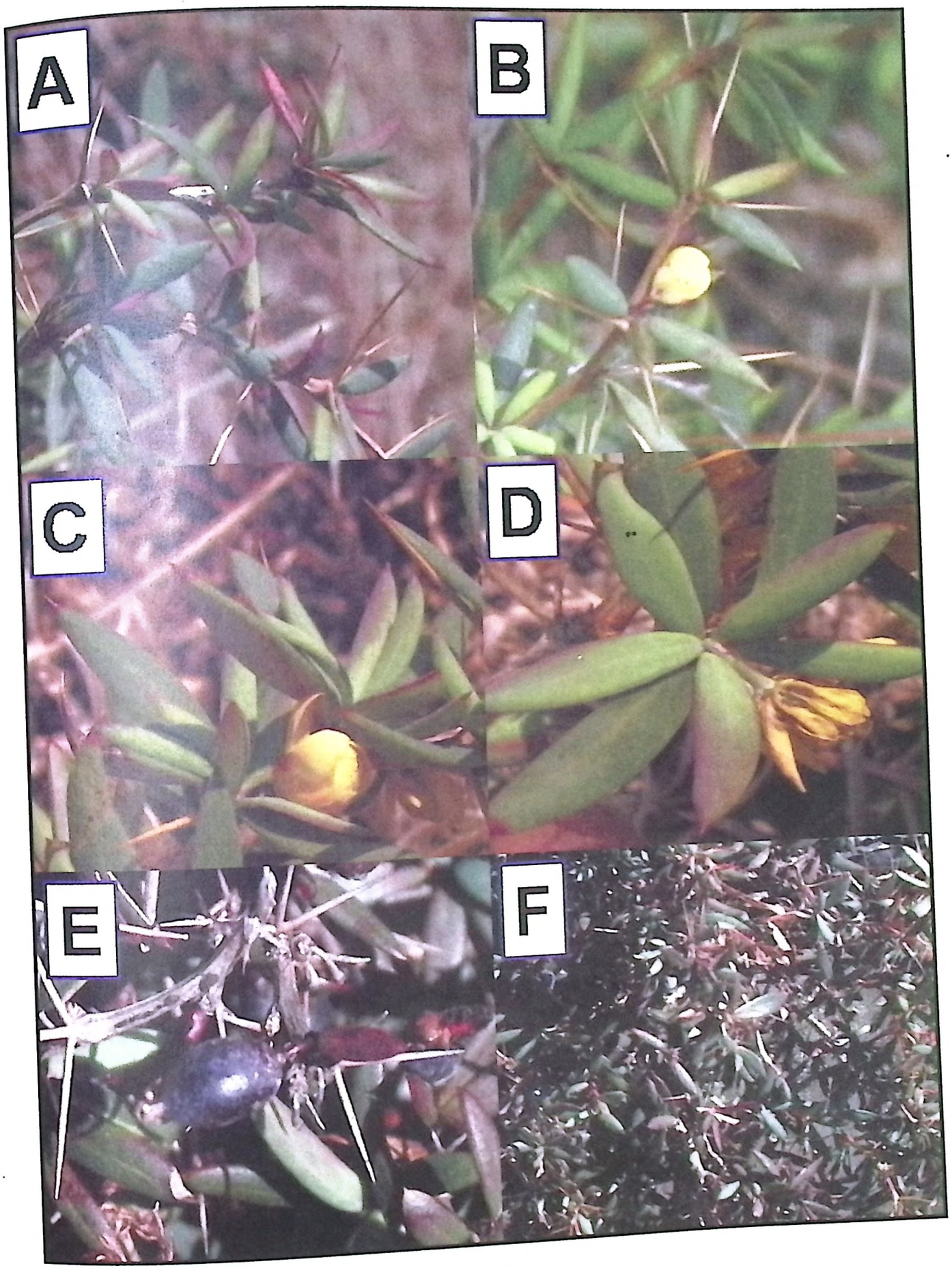

Plate: 4.2. Phenological stages of *Berberis osmastonii* at Muniyalikhet **A:** New leaf initiation; **B:** Inflorescence emergence; **C:** Flower open ; **D:** Flower dehiscence ; **E:** mature fruit and **F:** Senescence beginning of dormancy.

Plate: 4.3. Phenological stages of *Berberis lambertii* at Betulidhar **A:** New leaf initiation; **B:** Inflorescence emergence and **C:** Flower open.

4.4.3 Environmental Correlates

For the correlation of phenology with air temperature, GPS locations of three localities were used to extract temperature and precipitation data using MODIS LST images. Years 2010 and 2011 were considerably warmer as compared to 2008, 2009. This may have been one of the strong factor behind the early flowering in these *Berberis* species (Figure 4.2, 4.3 and 4.4) in the year 2010 and 2011.

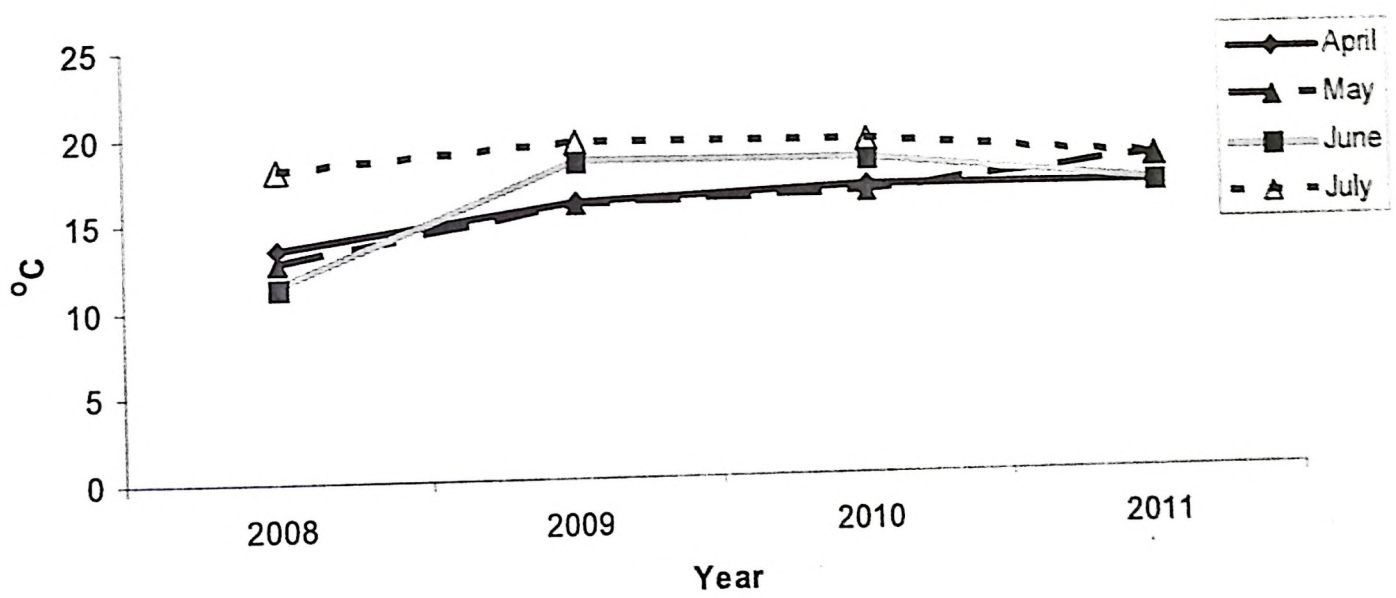

Figure 4.2. Mean average temperature during growing seasons at Muniyalikhet (Temperatures values was extracted from MODIS LST images of years 2008, 09, 10 & 11)

For endemic *Berberis* species localities, mean average temperature and during 2008 to 2011 at Muniyalikhet are shown in Figure 4.2. It indicates that average temperature in year 2008 during flowering period is 13.5 and 18.0 ° C in the months of April to July. In year, 2009 temperature was 16.2 and 19.5 ° C in the months of April to July, respectively. In the year 2010 temperature was 17.0 in April and 19.5 ° C in the month July whereas it was 17.0 in April and 18.5 ° C in the month July in year 2011. It indicates that average temperature requires for the flowering is 13-17(±1.7) °C in the month of April and 18-20 (±0.8) °C temperature is require for maturation of fruit. As detail of temperature variation are given in Table 4.3 during the three year of phonological study of two endemic *Berberis* species at Muniyalikhet.

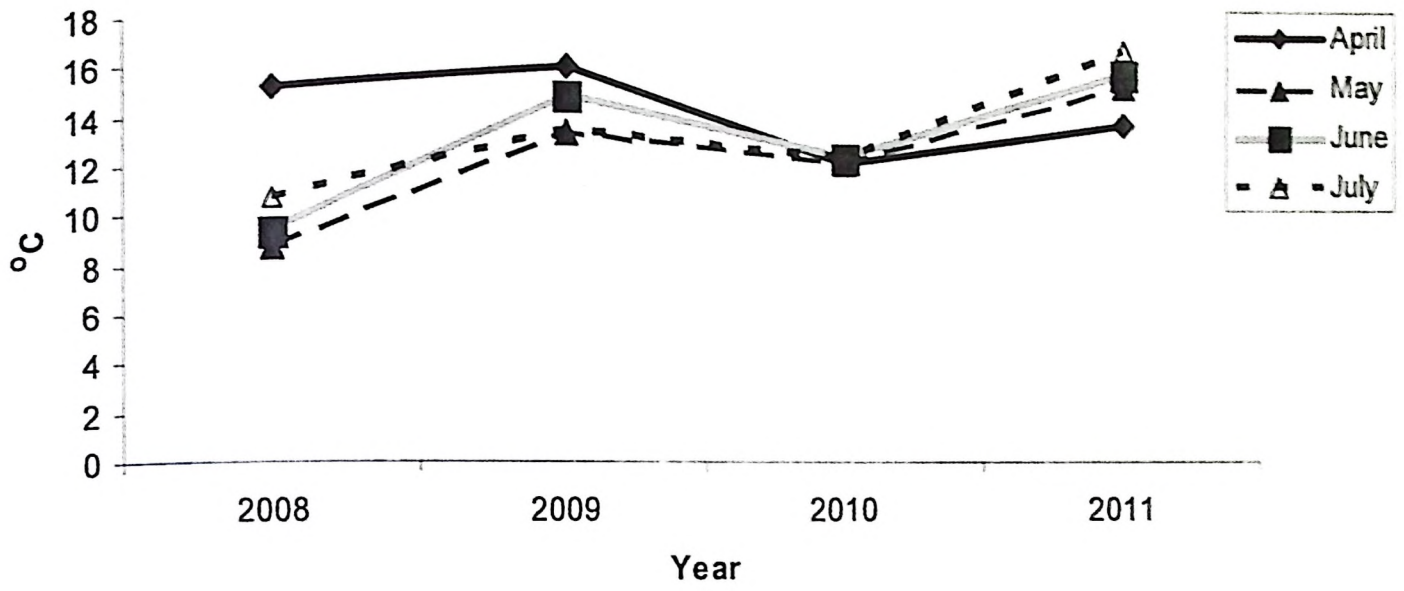

Figure 4.3. Mean average temperatures at Kalamuni during phenophase of *Berberis osmastonii* and *Berberis lambertii* (Temperatures values was extracted from MODIS LST images of years 2008, 09, 10 & 11)

At Kalamuni (Figure 4.3), average temperature in year 2008 during flowering period was 15.1 and 10.8 ° C in months of April and July. In year, 2009 temperature was 16.0 and 13.5 °C in the months of April and July respectively. In the year 2010 temperature was 12.3 in April and 12.5 °C in the month July and 14.4 in April and 17.0 °C in the month July in year 2011.

At Betulidhar average temperature (Figure 4.4), in year 2008 during flowering period is 13.5 and 16.5 °C in months of April to July. In year, 2009 temperature was 15.7 and 16.0 °C in the months of April to July respectively. In the year 2010 temperature was 15.0 in April and 18.5 °C in the month July and 14.0 in April and 17.5 °C in the month July in year 2011.

As detail of temperature variation are given in Table 4.3 during the three years of phenophases. That means average temperature during month of Aprils requires 13-19° C for the flowering in *Berberis* species in these localities. It indicates that average temperature requires for the flowering of *Berberis lambertii* is 9-15(±3.09) °C in the month of April and 16-20 (±2.6) °C temperature is require for maturation of fruit. But *Berberis osmastonii* flowers in month of April same as Muniyalikhet with difference of 7-8 days late in the respective years. As detail of temperature variation are given in Table 4.3 during the three year of phonological study of two endemic *Berberis* species at Muniyalikhet.

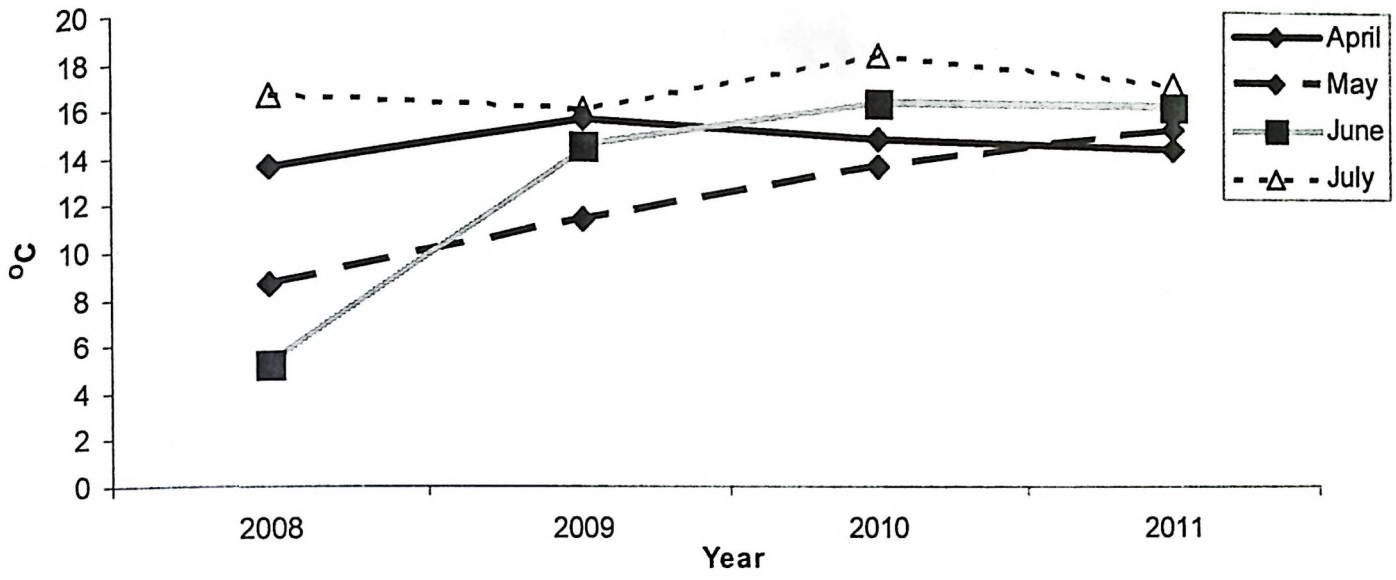

Figure 4.4. Mean average temperatures at Betulidhar, Humidhura during phenophase of *Berberis osmastonii* and *Berberis lambertii* (Temperatures values was extracted from MODIS LST images of years 2008, 09, 10 & 11)

Table 4.3. Temperatures at Betulidhar, Kalamuni and Muniyalikhet during phenophase of *Berberis osmastonii, Berberis rawatii* and *Berberis lambertii*. (Extracted from Modis Images)

Months	Betulidhar			Kalamuni			Muniyalikhet		
	Mean-Max (^{0}C)	Mean-Min (^{0}C)	Mean-Avg. (^{0}C)	Mean-Max (^{0}C)	Mean-Min (^{0}C)	Mean-Avg. (^{0}C)	Mean-Max (^{0}C)	Mean-Min (^{0}C)	Mean-Avg. (^{0}C)
Apr08	21	6	13.5	22	8	15.1	22	5	13.5
May08	18	-1	8.5	20	-3	8.8	23	3	12.8
June08	14	-3	5.2	22	-3	9.3	16	7	11.3
July08	21	12	16.5	23	-2	10.8	27	9	18.0
Apr09	22	10	15.7	23	9	16.0	27	5	16.2
May09	19	4	11.4	24	3	13.4	25	7	16.0
June09	23	7	14.5	25	5	14.9	28	9	18.4
July09	22	10	16.0	26	1	13.5	29	10	19.5
Apr10	24	6	15.0	20	5	12.3	28	6	17.0
May10	23	5	13.8	22	3	12.3	26	7	16.5
June10	24	9	16.5	23	2	12.5	27	10	18.5
July10	25	12	18.5	22	3	12.5	28	11	19.5
Apr11	24	5	14.7	23	5	14.0	28	6	17.0
May11	24	7	15.5	24	7	15.5	30	7	18.5
June11	24	9	16.5	23	9	16.0	25	9	17.0
July11	24	11	17.5	25	9	17.0	28	9	18.5

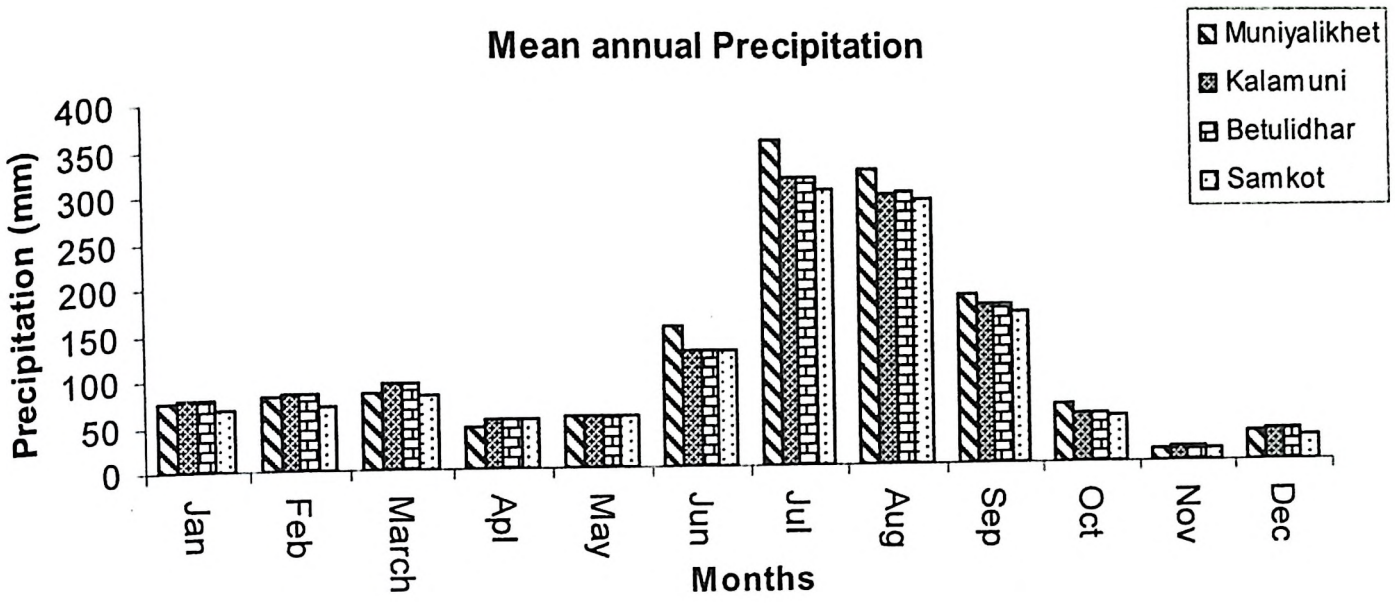

Figure 4.5. Mean annual precipitation at four different locations of endemic *Berberis* species. (Temperatures values was extracted from MODIS LST images of years average of 2008, 09, & 10)

Mean annual precipitation at four different locations of endemic *Berberis* species are given in Figure 4.5. Maximum rainfall was observed during July and August and minimum rainfall was recorded during November in all the years.

4.4.4 Edaphic Features at the Sites of Endemic Species

The results of physical and chemical analysis of soil samples collected from the distribution area of endemic *Berberis* species have been presented in Tables 4.4 and 4.5. It was found that pH of soil samples ranged from 6.2-6.5. The Water Holding Capacity (WHC) of soil at different places range from 58-69%. The organic Carbon, Nitrogen, Phosphorus and Potassium contains have been found to be 0.08 to 1.60%, 0.03 to 0.14%, 0.02 to 0.04% and 0.10 to 0.59 in the soil respectively. Other nutrient elements Sodium, Calcium and Magnesium have been found to be 0.04 to 0.05%, 1.23 to 2.78% and 1.93 to 5.42% in the soil, respectively.

Table 4.4. Physico-chemical characteristics of soil at different sites, Soil moisture, water holding capacity (W.H.C.) at different sites

S. No.	Location	Altitude (m)	Species Name	Silt	Sand	Clay	WHC	pH	EC	TDS
				(%)	(%)	(%)	(%)	(Unit)	(µS)	(ppm)
1	Samkot	2347	*BO-BR*	49.65	36.45	13.9	59.53	6.2±0.16	10.09±0.02	9.3±0.30
2	Kalamuni	2757	*BO-BL*	51.45	36.95	11.6	62.17	6.2±0.08	32.0±0.50	15.6±0.60
3	Muniyalikhet	2200	*BO- BR*	51.60	36.90	11.5	68.81	6.4±0.16	49.1±0.50	24.3±0.65
4	Humidhura	2804	*BO-BL*	52.05	39.85	8.1	58.99	6.5±0.09	25.8±0.20	13±1.00

EC: Soil Electrical Conductivity; TDS: Total Dissolved Solids

Table 4.5. Chemical characteristics of soils at different sites

S. No.	Location	Altitude	N	P	K	Na	Ca	Mg	OC
		(m)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
1	Samkot	2347	0.08±0.01	0.02±0.00	0.16±0.02	0.04±0.01	1.23±0.02	2.88±0.10	0.32±0.02
2	Kalamuni	2757	0.14±0.01	0.02±0.00	0.10±0.05	0.05±0.01	2.78±0.07	2.18±0.07	1.60±0.02
3	Muniyalikhet	2200	0.13±0.02	0.04±0.01	0.59±0.05	0.05±0.01	1.66±0.06	5.42±0.03	0.88±0.01
4	Humidhura	2804	0.03±0.02	0.02±0.00	0.11±0.03	0.04±0.01	1.43±0.02	1.93±0.05	0.08±0.01

B. lambertii have two different populations in state *viz.* Betulidhar, Kalamuni, Figure 4.5 shows that percentage Calcium, and Magnesium in soil is high at both the localities. *B. osmastonii* have five different populations in state *viz.* Samkot, Betulidhar, Kalamuni, Muniyalikhet and Ratapani, Figure 4.6 shows that percentage Calcium, and Magnesium in soil is high in compare with other nutrient but Magnesium is quite high at muniyalikhet. *B. rawatii* have three different populations in state *viz.* Samkot, Munsiyari and Muniyalikhet, As at Muniyalikhet it was collected in the year July 2010 so soil samples are not collected. Figure 4.6, 4.7 & 4.8 shows that percentage Calcium, and Magnesium in soil is high in compare with other nutrient but magnesium is quite high at muniyalikhet.

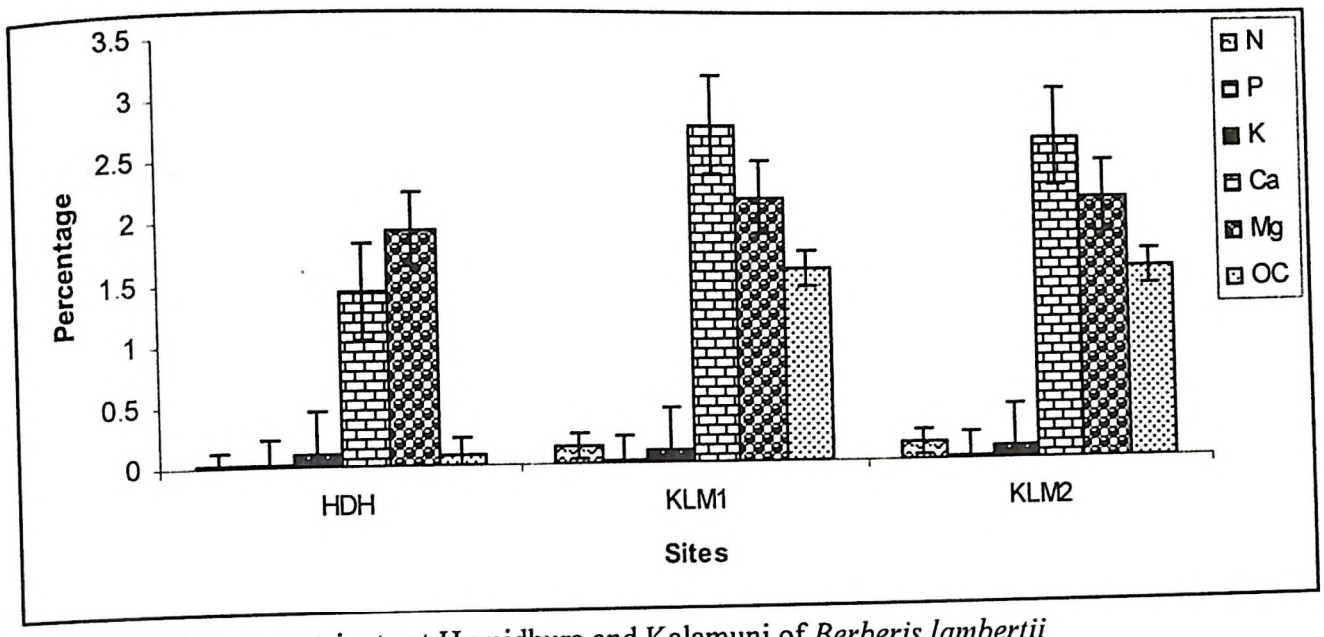

Figure 4.6. Soil macronutrients at Humidhura and Kalamuni of *Berberis lambertii*

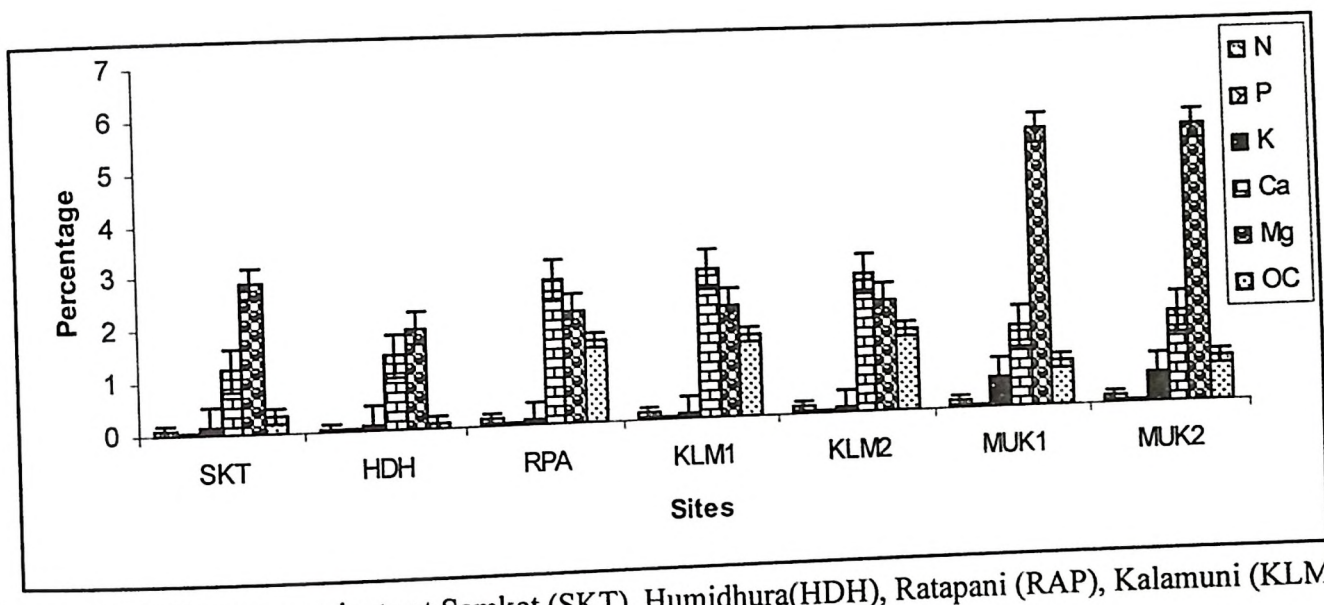

Figure 4.7. Soil macronutrients at Samkot (SKT), Humidhura(HDH), Ratapani (RAP), Kalamuni (KLM-1 &2) and Muniyalikhet (MUK 1&2) of *Berberis osmastonii*

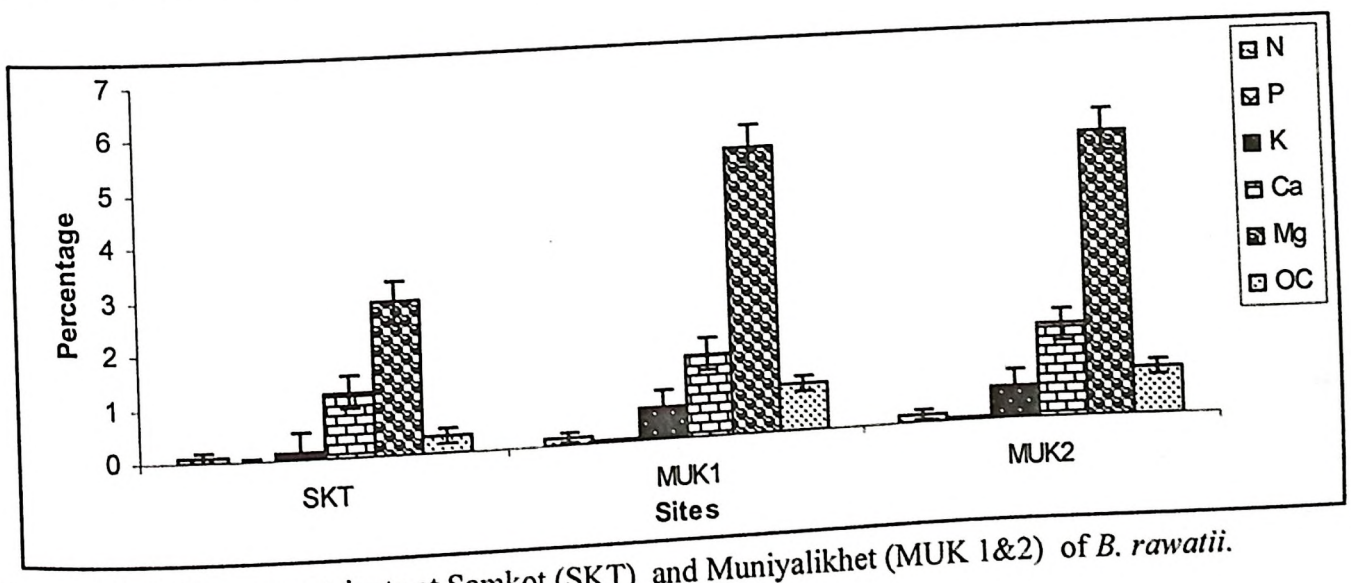

Figure 4.8. Soil macronutrients at Samkot (SKT) and Muniyalikhet (MUK 1&2) of *B. rawatii*.

4.4.5 Biotic Factors

4.4.5.1 Fungal Infections: *Berberis rawatii* and *B. lambertii* was observed infected by *Puccinia* spp., pycnial stage occurs on the young leaves of the alternate host, mainly *Berberis* spp. Pycnial infections initially appear as light, chlorotic areas on the adaxial leaf surface, then become light orange-brown lesions, consisting of individual small cone-shaped eruptions (the pycnia), often occurring in clusters.

As per the insect is concern no species are observed but some butterfly use to lay their egg on *B. lycium* and also some moths caterpillar were observed on feeding on young leaves of *B. jaeschkeana*.

4.4.5.2 Effect of Grazing: Excessive grazing pressure results in low cover and height of the individuals. However, in case of endemic *Berberis* species as such not found any cattle are feeding. Infrequent feeding by goats on *B. lycium* was observed.

4.4.5.3 Effect of Fire: Natural fires are not common phenomenon near the habitat of endemic *Berberis* species. Around the habitats of *Berberis rawatii* and *B. osmastonii* near Munuyalikhet, human habitation was there, but they don't use or have any knowledge more about these species. These species grows on dry grassy slopes in absence of litter layer, these habitats are much prone to fire. Nearby *Berberis lambertii*, no as such human habitation was found and it is less disturbed.

4.4.5.4 Effect of Human Activities: The areas at present occupied by *Berbèris osmastonii* and *Berberis rawatii* is less affected by human interference. The area near Muniyalikhet is steeper and rocky, and as such no agricultural land can be developed. Farmer gradually cleared few individuals of *B. asiatica* and *B. lycium* for cropland protection from cattle and wild animals. As such, local peoples are not aware about these species, and no threats was observed on these endemic species.

4.4.6 Associate Species

Site 1 Muniyalikhet: This site have temperate grassy slopes and some of the common shrubs species are *Cotoneaster microphyllus, Cupressus torulosa, Ephedra* sp., *Berberis asiatica, Berberis chitria, Berberis lycium* and *Pyracantha crenulata.* Common herbaceous species are *Onosma pyramidale, Androsace sarmentosa, Anemone rivularis, Arenaria serpens, Artemisia vestita, Bupleurum falcatum, Clinopodium umbrosum, Heracleum wallichii, Herminium lancium* and *Habenaria latilabris.*

Site 2 Samkot: This site have temperate grassy slopes and dominant by grasses and some of the common shrubs species are *Cotoneaster microphyllus, Berberis asiatica, Berberis chitria, Berberis aristata* and *Pyracantha crenulata.* Common herbaceous species are *Erigeron multiradiatus, Androsace sarmentosa, Aster ageratoides, Arenaria serpens, Artemisia vestita, Bupleurum falcatum, Heracleum wallichii, Herminium lancium* and *Habenaria latilabris.*

Site 3 Betulidhar: This site have temperate grassy slopes on South facing slopes but on other side North facing have very good forest of Kharsu Oak Mixed. The site is dominant by grasses and some of the common shrubs species are *Cotoneaster microphyllus, Berberis aristata, Ephedra truxalis, Berberis concinna* var. *breviora, Berberis chitria, Berberis kumaonensis* and *Pyracantha crenulata.* Common herbaceous species are *Erigeron multiradiatus, Androsace sarmentosa, Aster ageratoides, Arenaria serpens, Artemisia vestita, Bupleurum falcatum* and *Heracleum wallichii.*

Site 4 Kalamuni and Ratapani: These sites have temperate grassy slopes as well as Kharsu Oak Mixed Forest. The site is dominant by grasses and some of the common shrubs species are *Cotoneaster microphyllus, Berberis aristata, Ephedra* sp., *Berberis chitria,* and *Pyracantha crenulata.* Some of the tree species are *Quercus semecarpifolia, Rhododendron arboreum, Taxus baccata* and *Abies pindrow.* Common herbaceous species are *Erigeron multiradiatus, Androsace sarmentosa, Aster ageratoides, Arenaria serpens, Artemisia vestita, Bupleurum falcatum* and *Heracleum wallichii.*

4.5 Discussion

In this study, the autecological properties of *Berberis lambertii, B. osmastonii* and *B. rawatii* had investigated and their distribution areas which is restricted to Kalamuni to Betulidhar in Pithoragarh and Muniyalikhet in Pindar Valley of Chamoli districts in state. *Berberis osmastonii*, *Berberis lambertii* and *Berberis rawatii* can be described as "rare" in relation to their distribution, habitat specification and population size. These species are stenochoric and stenoecious. Comparing these species, there is a congruence concerning local distribution, total area and sociological range. In all these characters, *B. osmastonii* has a broader range and *Berberis lambertii* is a narrow endemic. The taxonomic and cytological characteristics of a species give the idea about whether the species is paleoendemic and neoendemic related to its geographical distribution (Kruckeberg and Rabinowitz 1985). If endemic taxon is limited species, this is a paleoendemic species. Beside, the paleoendemic taxons grow in very special conditions and their distribution areas have decreasing tendency. *Berberis lambertii* is a limited endemic species and its distribution area has shown a decreasing tendency.

It can be shown from Table 4.4 that *B. lambertii, B. osmastonii* and *B. rawatii* grow in loamy and silt loamy soil. In New Zealand, *B. thunbergii* tolerates a wide range of soil and light conditions and persists under dense canopies, but seedlings are rarely found in very shady conditions (Ehrenfeld 1999; Silander and Klepeis 1999), and growth and survival of *B. vulgaris* seedlings is poor under low light conditions (Kollmann and Reiner 1996). Light availability may be a limiting factor for the growth and survival of seedlings for all these species. As these species are mainly found in temperate grassy slopes at pH of 6.2 to 6.5, that is to say, these species grows better in light acidic soil (Table 4.4). *Berberis lambertii* grow in rich soils in respect of high Calcium and Magnesium and highly rich in organic matter in Kalamuni area due to forest cover. *B. osmastonii* and *B. rawatii* prefer highly rich in magnesium contain in soil. It can conclude that these endemic species prefer soil with sufficient Calcium and Magnesium. The Phosphorus content in all localities varies from 0.02-0.04% (Table 4.5). Nitrogen (N) and Potassium (K) content in soil is quite good in all localities.

Canopy is also significant factor, probably through its influence on the light intensity reaching the ground. In forest ecology when one vegetation layer dominant, other remains suppressed and vice-versa (Kumar and Ram 2005; Singh and Singh 1987 and 1992). For the good growth and regeneration of *Berberis* species, require less canopy cover. Most of the species of *Berberis* grow under open canopy condition. Most of the *Berberis* species grows in open canopy cover and dry temperate grassy slopes. All these endemic species of *Berberis* are confining to open canopy cover, only one population of *Berberis lambertii* is found inside *Quercus semicarpifoia* mixed forest but it is at the edge of forest where light condition is suitable for growth. Aspect regulates the quantity and duration of soil moisture, partly through temperature. The northern aspects remain moist all over the year as compared to southern aspect and had high soil moisture contain. Open canopy cover and southern and southern-West aspect of hill slopes favours growth of most of *Berberis* species where available solar radiation is higher. It was observed that these endemic species are mostly found in S and SW aspects.

Table 4.6. Population status of three endemic *Berberis* species populations determined from all individuals located during the study

Species		Samkot	Humidhura	Kalamuni	Muniyalikhet
B. lambertii	n	-	37	81	-
	% mature plants	-	92	100	-
	% saplings	-	8	-	-
	% seedlings	-	-	-	-
B. osmastonii	n	52	66	145	166
	% mature plants	80	70	75	85
	% saplings	15	25	10	10
	% seedlings	5	5	15	5
B. rawatii	n	2	-	0	133
	% mature plants	100	-	-	80
	% saplings	-	-	-	15
	% seedlings	-	-	-	5

Observation revealed that the number of mature individuals was higher than sapling/seedlings within the entire populations in all the sites. Highest seedling and sapling of *B. osmastonii* and *B. rawatii* were observed in Muniyalikhet and Kalamuni localities

(Table 4.6). *Berberis* species regenerates only through seeds. During the study period no seedlings of *B. lambertii* was founds in its present localities and best population of species exist at Kalamuni in terms of numbers. Highest seedlings (22) of *B. osmastonii* recorded near Kalamuni whereas saplings were found in all localities. For *B. rawatii* maximum seedlings (7) and saplings (20) occurred within 5-6 m radial distance of the mother plant populations. There were no seedling and saplings were found beyond 12 m radius which suggest that seed dispersal of Endemic *Berberis* species is very poor and may act as a major regeneration constraint. Demography of the population are summarized in Table 4.6.

Phenological observations of these endemic *Berberis* species suggest that, all these species flowers during spring season. This is the best season for flowering for most of the Himalayan temperate plants. On a temporal scale, living organisms respond to the expanding or shifting growing season by changing their phenological schedules. As there in no certain knowledge about the phenology of *Berberis* species, growth pattern and development of plants. As phenological observation of *Berberis lambertii* shows that the leaf development was started in late February (58th day of Julian year 2009 and mature on 98th day). The flowers bud starts in the middle of first week of May (Figure 4.1) *i.e.* on 118th day and open in 10 days and petal start falling after 10 days *i.e.*, on 148th day. Peak flowering was observed in between 128th to 140th day of year 2009. Fruit maturity and seed maturation 180-188th day and leaf senescence starts from 325-335th day in year 2009. During year 2008, in *Berberis osmastonii* and *B. rawatii*, new leaf budburst start on 48-50th day and mature within 25-30 days then first flower start from 118- 122th day; peak flowering was observed in between 130th to 140th day of year 2008. Fruit maturity and seed maturation 180-188th day and leaf becomes dry and black from 345-355th day in year 2008. But, due to higher temperature in years 2010 and 2011, 15-18 days early flowering was observed in all the species (Figure 4.1).

According to climatic observations, these species grows in temperate region at drier slopes having good intensity of light. The natural habitats of these species are dominant by cool temperature, rainy seasons are throughout the year, and summers are not hotter. It is likely that changing temperature and precipitation pattern will produce a strong direct impact on

both natural and modified forests system. The relationship between temperature or degree days and phenophases, especially flowering and leaf unfolding, is well known and has been widely reviewed (Schwartz 2003). The evidence for the role of the photoperiod in tree phenology is conflicting, depending on species and location (Kramer 1994). However, year 2010 and 2011 are warmer as compare to 2008 and 2009, 1 to 2° C fluctuation can trigger early flowering. It was observed in both localities that during 2008 flowering start in month of May but due to sudden increased in temperature it was 10-12 days earlier in 2010 and 16 days earlier in year 2011.

4.6 Conclusion

i. Autecology of three endemic taxa *viz., Berberis lambertii, B. osmastonii*, and *B. rawatii* was studied in their natural habitats. It was found that *B. lambertii* has less than 81 individuals in two populations, while *B. osmastonii* has more than two populations and over 2000 individuals. Only 355 individuals of *B. rawatii* have been located so far in the State.

ii. The study reveals that all the three endemic species prefer peculiar habitats between altitudinal range of 2200 – 2800 m a.s.l. *i.e.*, characterized by open exposed grassy slopes (*B. osmastonii and B. rawatii*) and forest edge (*B. lambertii*). Habitat, associates species, soil characters and temperature were recorded and phenological observation was recorded.

iii. Of the three species *B. osmastonii* is evergreen while other two species are deciduous. In deciduous species, leaves emerge in the month of March and shed during November. Detailed flowering and fruiting phenology of all the species have been documented, which reveals that 2 species (*B. osmastonii* and *B. rawatii*) favours initiation of growth just after snowmelt while other (*B. lambertii*) species growth initiation requires slightly higher temperature.

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Chapter 5: Population Status and Extraction Pattern

CHAPTER 5.0

POPULATION STATUS AND EXTRACTION PATTERN

"Modern Society will find no solution to the ecological problem unless it takes a serious look at its lifestyles."

- Pope John Paul II

5.1 Introduction

All cultures from prehistoric times to the present day have used plants as a source of medicines. According to the World Health Organization (WHO), 80% of the world's people depend on traditional medicine for their primary health care needs. The greater part of traditional therapy involves the use of plant extracts or their active components. It is not just in developing countries that medicinal plants are important. In the USA, for example, 25% of all prescriptions from community pharmacies between 1959 and 1980 contained materials from higher plants (Farnsworth and Soejarto 1985). The practice of traditional health care system is widespread in China, India, Japan, Pakistan, Sri Lanka and Thailand. In China about 40% of the total medicinal plants consumption is attributed to the traditional or rural societies (UNESCO 1996). In Thailand, herbal medicines contain significant proportions of leguminous plants *i.e.*, members of Caesalpiniaceae, Fabaceae, and Mimosaceae which are otherwise less used in other cultures (UNESCO 1996). The demands of herbal medicines have grown steadily since last few decades. For example, total trade of medicinal plants during mid-1990s, was approximately US$ 2.5 billion while it was to tune of US$ 7 billion (World Bank 1997). In Japan, herbal medicinal preparations are more in demand than mainstream pharmaceutical products.

Steady rise in the demand of raw material for the herbal industries, which is met largely from natural and wild populations, has led to rapid decline of high value species during recent decades. Today many species of medicinal plants face the threat of extinction or severe genetic loss. For most of the endangered species no conservation strategies have been evolved. Emphasizing on the discovery of new drugs, documentation of traditional

knowledge on ethno-medicines is lagging behind. For most of the developing countries, there is not even a complete inventory of medicinal plants. Much of the knowledge on their use is held by the rural societies, whose livelihoods based on natural resources are at stake.

The medicinal and aromatic plants (MAPs) form an important component of biodiversity which are closely linked with local health care systems, rural livelihoods, and herbal industries. The Himalayan region is particularly rich in the diversity of MAPs and extremely rich in traditional knowledge on the use of herbal medicines, *albeit,* a majority of the communities are socio-economically marginalized who depend heavily on the bio-resources including MAPs for their livelihoods. It is well established that more than 90% of the MAPs used in herbal industries today are extracted from the wild resulting in rapid dwindling of high value species. Uttarakhand, the newly established state in Indian Himalaya, has been projected as 'Herbal state' on accounts of its tremendous wealth of MAPs. It is estimated that there are approximately 5000 species of vascular plants in the state, of which about one third are known to have one or other kind of medicinal use. Of these, nearly 150 species are sold to the herbal industries mostly from wild. After the state was formed in 2000, there was a major paradigm shift in natural resource management and bio-resource based livelihoods. Since much of the land in the state is hilly and not productive in terms of agriculture, the rich forests were thought to sustain local livelihoods if managed scientifically. Accordingly, the state government has taken several steps towards administrative and policy level reforms including establishment of Herbal Research and Development Institute, formation of an apex body for policy formulation *i.e.*, State Medicinal Plants Board (SMPB), and mainstreaming scientific management of medicinal and aromatic plants in forestry working plans by adopting conservation, development and harvest (CDH) plans. This calls for detailed inventory and rapid mapping of high value medicinal plants in various Forest Divisions of the state (Rawat et al. 2004).

The genus *Berberis* is considered one of the most promising groups of medicinal plants in the Himalayan region that has gained popularity in Ayurvedic system of medicine under the name "*Daruharidra*". *Berberis* has been used in traditional system of medicine since ancient times to cure various ailments. The roots are employed as an antiperiodic, diaphoretic,

antipyretic have properties similar to those of quinine (Edeoga et al. 2003 and Anonymous 1992). *Berberis asiatica* is said to be good source of Berberine (Chopra et al. 1958). *Berberis* species are well known for their edible fruits which are rich source of vitamins and minerals (Sims and Peterkin 1987). Most of the *Berberis* species occur gregariously in the secondary and degraded habitats in the temperate zone. However, with the increased demand of Berberine, various species of *Berberis* were extracted heavily from the states of Himachal Pradesh and Uttarakhand during 1980's and 90's leading to rapid decline of their populations. It is therefore, imperative to assess their current population status and patterns of extraction so as to evolve strategies for sustainable levels of harvest. Keeping this in view, extensive surveys of commercially important *Berberis* species were conducted in Garhwal region of Uttarakhand. Results and discussion of the study are presented in this Chapter.

5.2 Methodology

5.2.1 Field Methods

Systematic surveys and intensive search of *Berberis* species were conducted in various regions in state covering major vegetation types (Plate 5.1). Stratification was done by using geographical condition and vegetation type (FSI 2009) following Rawat et al. 2004 (Figure 5.2). Stratified random sampling was used to conduct ecological studies following Misra (1968) and Muller-Dombois and Ellenberg (1974) (Figure 5.1).

According to different habitat types areas were identified and number of transect were laid. Study was carried out by laying one km. long transect randomly and at every 50 m distance circular plot were laid (20 plots). For sampling of tree 10 meter radius plots were laid. Within each 10 m plot, 5 m radius plot for shrubs and climbers, and four 1 m radius plots were laid for the seedlings and saplings of Berberidaceae members. The saplings (up to 50 cm in height) of Berberidaceae members were counted and other associated species were recorded, while recruitment (which has entered into next year age) and seedlings (with 1-2 leaves) were counted.

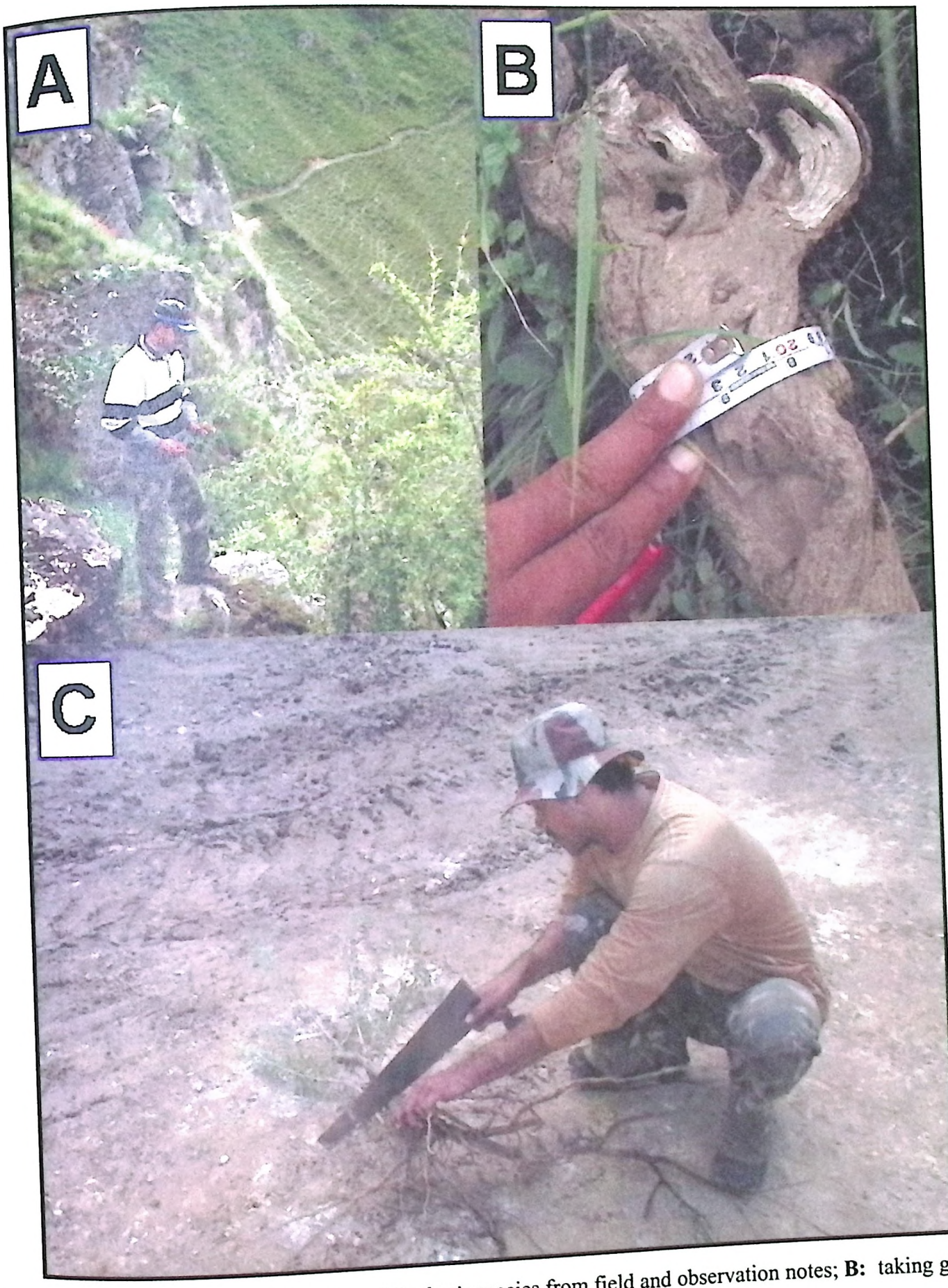


Plate 5.1. Field Methods-**A:** Collection of *Berberis* species from field and observation notes; **B:** taking girth at 10 cm above ground and **C:** Collection and cutting of stem and root of *Berberis* species for biomass estimation.

Sampling outline and data collection

a. 10 m radius plots

- Tree species and abundance (name of tree species and their number of individuals)
- Canopy cover (using densitometer)
- Forest type

b. 5 m plots

1. Abundance of *Berberis* species

- *Berberis* species and their number in the plots

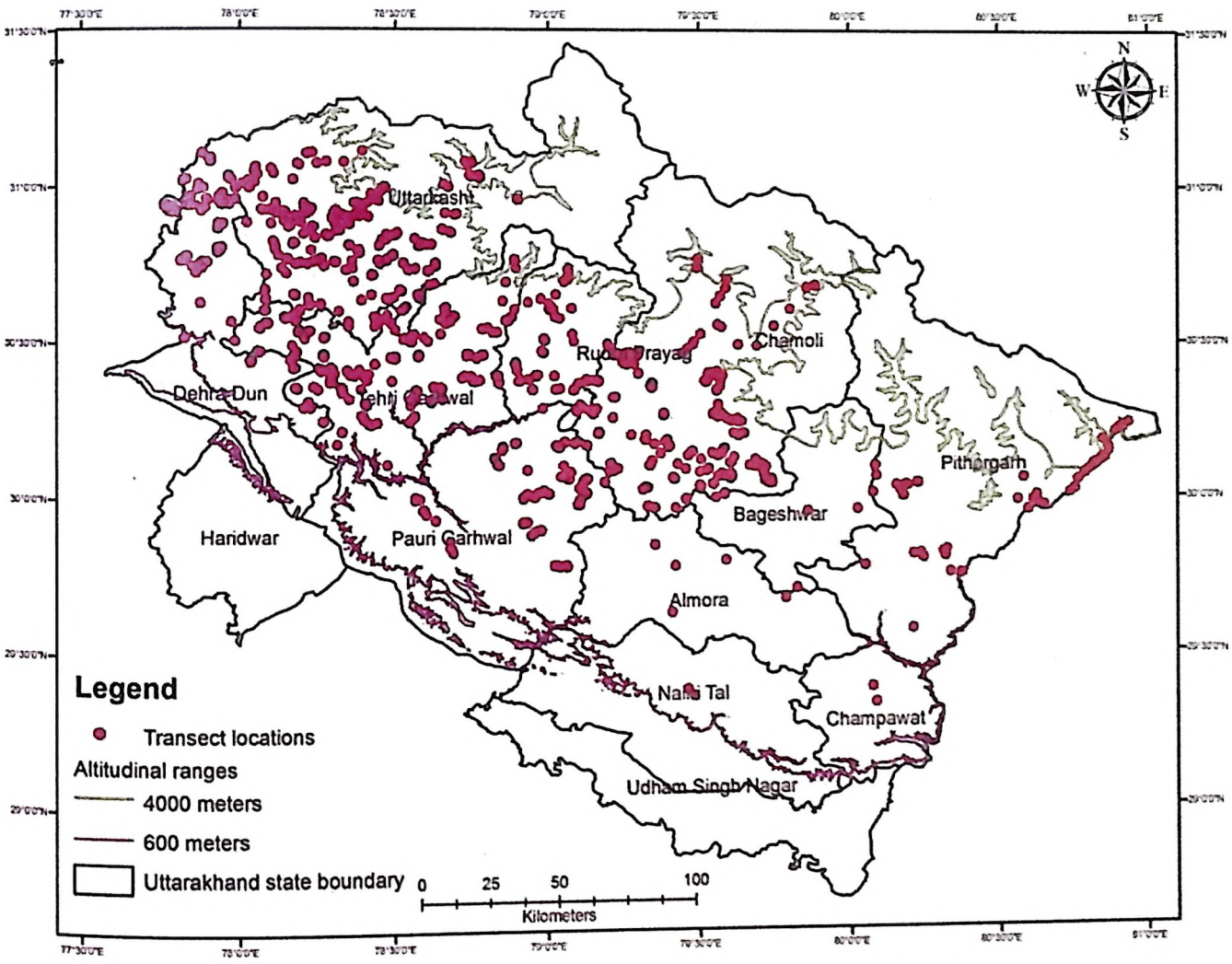


Figure 5.1. Transect locations in Uttarakhand for intensive study

- Girth of species (at 10 cm above the ground)
- Height of species

- Site specific characteristics of species
- Growth (Vegetative\Fruiting\Flowering)

2. Environmental characters:

- Physiognomy of vegetation:
- Slope aspect: (in degrees)
- Terrain, topography, altitude,

3. Anthropogenic pressures: (Plate 5.2 A &B)

- Lopping: (present/absent)
- Logging: (present/absent)
- Fuel wood extraction: (present/absent)

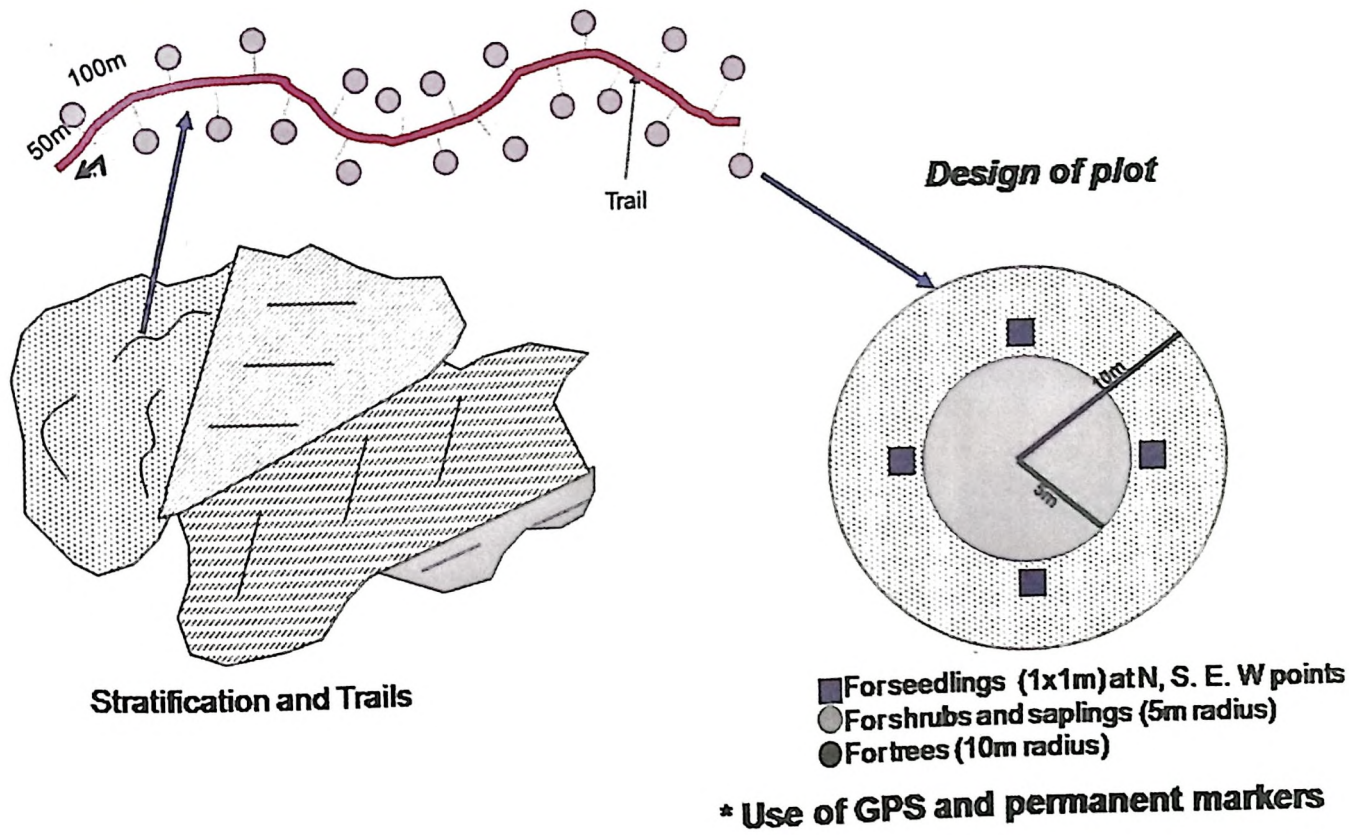


Figure 5.2. Sampling design: Adaptive Cluster Sampling

- Extraction of medicinal plants (presence / absence)
- Livestock grazing (Species and number)

c. 1 m plots

- Seedling (species and abundance)

5.2.2 Data Analysis

- Density, Frequency and Abundance of medicinally importance *Berberis* species was calculated across different habitat types by using MS-EXCEL software. Abundance is an ecological concept referring to the relative representation of a species in a particular ecosystem. It is usually measured as the large number of individuals found per sample. Abundance is contrasted with, but typically correlates to, incidence, which is the frequency with which the species occurs at all in a sample (Bartelt et al. 2001).

$$\text{Density} = \frac{\text{Total number of individuals}}{\text{Total samples area}}$$

$$\text{Frequency (\%)} = \frac{\text{Total number of quadrats in which species occurred}}{\text{Total number of quadrats studied}} \times 100$$

$$\text{Abundance} = \frac{\text{Total number of individuals of a species}}{\text{Total number a species occurrence of a species}}$$

- Species Richness in different vegetation types were calculated using the statistical software EstimatesS (Colwell 2005). The Shannon diversity index (*H'*) and Simpson's diversity index (*D*) are simple mathematical measures, which characterize species diversity in a community (Magurran 1988; Muller-Dombois and Ellenberg 1974).

- Jackknife is a re-sampling procedure to determine the effect of each sampling entity on a statistic by iteratively removing successive sampling entities (*i.e.*, row of the data matrix) from the original two-way data matrix and recalculating the desired statistic. The resulting "pseudo-estimates" can be used to construct confidence intervals about the statistic under investigation (Mc Garial et al. 2000). A series of Jackknife estimators was originated by Burnham and Overton (1978, 1979), up to fifth order, for mark recapture estimation of animals population size and they suggested that it might be applicable to the problems of estimating species richness. The Jackknife is a technique for reducing bias of estimates. The first-order jackknife estimate of species richness S, is based on the number of species that occurred in only one sample (L).

    - S= Sobs + L (n-1/n), Where, *n* is the number of samples.

The first order Jacknife richness estimator (Jacknife 1) was used to estimate the species following Burnhan and Overton (1978, 1979) and Smith and van Belle (1984).

- In order to segregate the key variables determining *Berberis* species distribution in different habitat types Principal Component Analysis (PCA) was run. This is an unconstrained ordination technique that allows organization of sampling points along main environmental gradient meaningfully based on the interrelationships among the large number of interdependent variables. Specifically, this technique helps to condense the information contained in the original variables into smaller set of dimensions, defined as linear combinations of the original variables, that describes maximum variation among individual sampling units (Mc Garial et al. 2000). This analysis was done using Past 1.92 (Hammer et al. 2001) with the abundance data of *Berberis* species for each plot.

- In order to see the effect of environmental variables on the distribution of species, Canonical Correspondence Analysis was done following Ludwig and Reynolds (1998) and ter Braak (1986 & 1987) using the software PCORD4. Canonical Correspondence Analysis (CCA) was performed to examine the distribution of medicinally important

species along environmental gradient. It is widely used indirect ordination method and provides an effective approximation of underlying environmental gradients, where dominant gradients of variation in one set of variables (*i.e.*, dependent variables, usually species abundances) are computed in linear combinations of explanatory variables (usually environmental characteristics) in a second set. It extracts the major gradient in the data that can be accounted for by the measured explanatory variables. This is different form of unconstrained ordination techniques like principal component analysis, where for example, the axes are major gradients within the species data themselves, irrespective of any ecological explanatory variables (Mc Garigal et al. 2000). It is a procedure that combines within one algorithm a reciprocal averaging solution for the correspondence analysis on species-site data (with a detrending option) and a weighted multiple regression analysis on environmental factor-site data.

5.2.3 Biomass of Medicinally Important Parts of *Berberis* Species

In order to establish the relationship between volume of wood and weight and predict the harvestable biomass per plant samples of stem base and roots (30 cm above and below basal part of stem) were collected and representing different girth classes. Fresh weight of roots and stem were determined in field using spring balance. The samples of known weight were then oven-dried at 60°C to obtain dry weight. Using fresh/ dry weight ratio, the dry weight of each of sample was estimated (Plate 5.1C).

Volume of the wood **(V):** was estimated using the formula: $V= (Radius)^2 \times Height \times Pi$

The study aimed to compute equation parameters for estimating biomass components of above and below using length and circumference of the plant part. Each dependent and independent variables pair was fitted by least squares using regression form for the following arithmetic models:

$$Y=a+bX$$

Where Y=Weight (g) of plant fraction, X=Circumference and Length independent variables, and a & b are Y-intercept and slopes.

Using Global Positioning System (GPS) transect start and end point was noted down. GIS software was used to show the distribution pattern of economically important *Berberis* species based on their concentration were shown on map of Uttarakhand. Areas of distribution of *Berberis* in the state of Uttarakhand have been identified to demarcate the extraction zones of each economic *Berberis* species and suggest conservation measures.

5.2.4 Patterns of Extraction

Records of Uttarakhand Forest Department and Forest Development Corporation were consulted to assess the quantity of *Berberis* (basal parts of stem and roots) harvested from various Forest Divisions in the state. The collection centres (*Mandis*) were visited to ascertain the prevalent market rates at which raw material of *Berberis* were sold. Interestingly, in several areas Berberis species also form one of the preferred as fuel wood. In order to study the extraction pattern of *Berberis* species for fuel wood, surveys were conducted in the sample villages situated in different altitudinal zones *i.e.*, Sub-tropical region (600-1000m), warm temperate (1200-1600m), warm temperate (2000 - 2300m) and above 2500m. A minimum of 20 families from each village from all the altitudinal zones were selected to know the extraction pattern of *Berberis* species for fuel wood consumption and other uses in the study area. The identification of major fuel wood species was mainly based on interviews, informal discussions and observations following Martin (1995). The quantity of fuel wood collected by each household over a period of 24 hours was recorded using a weight survey method (Bhatt et al. 1994; Mitchell 1979) at different localities.

5.3 Results

Over all 205 transects were laid in 14 different habitat types, each transect have 20 points but some time inaccessible to area due to which plot numbers were varied. Overall 3882 sampling plots were laid in different part of state and in each plots abiotic and biotic factors were recorded. On the basis of these plots following results are discussed and explained:

5.3.1 Diversity of *Berberis* Species

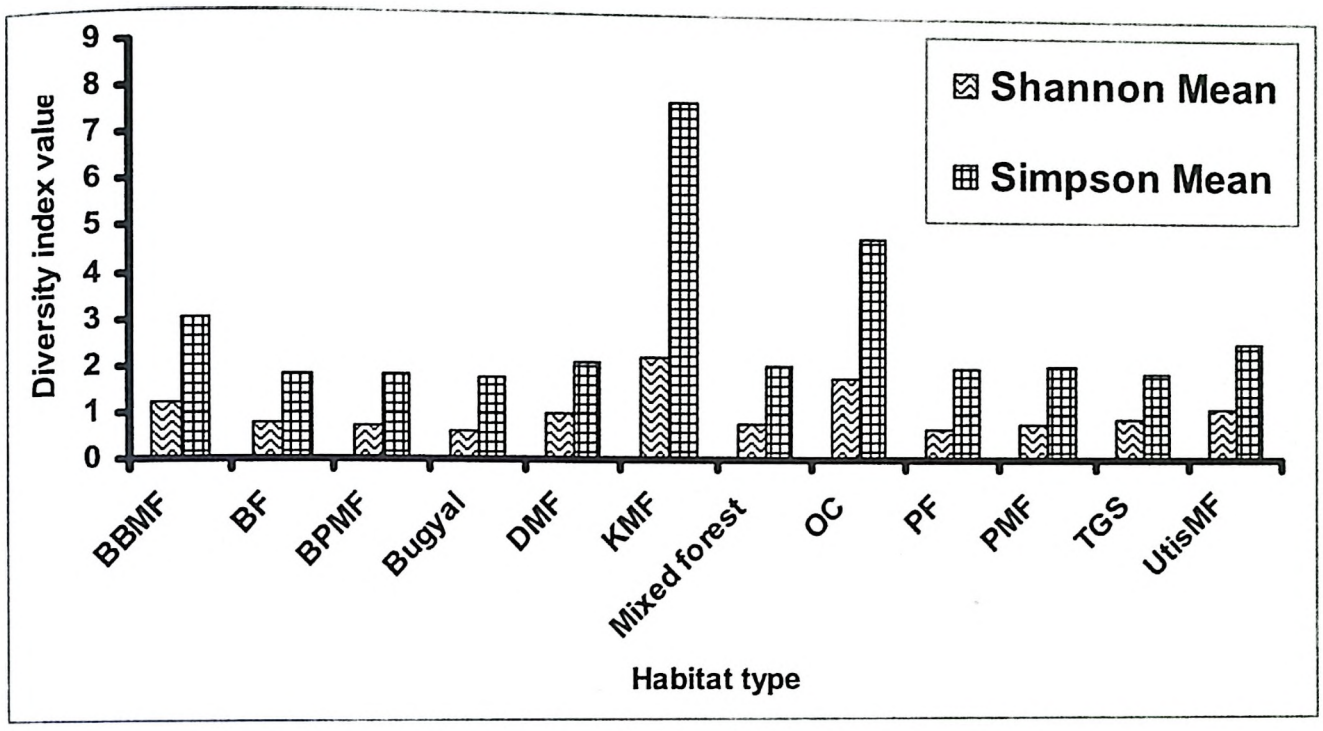


Figure 5.3: Diversity index of 12 habitat types

Shannon and Simpson diversity index indicates that maximum diverse habitat type is Kharsu Mixed Forest (KMF H= 2.5 and D= 8) and the lowest diversity is found in Pine Forest (PF H= 0.6 and D= 1.8) (Figure 5.3).

5.3.2 Species Richness

Stastical software EstimateS (Colwell 2005) was used to estimate the species richness in 14 different habitat types. Randomization was done at 500, without replacement. Classic formula for Chao 1 and Chao 2 was used. First order Jacknife richness estimator (Jacknife 1) was used to estimate the species richness (Burnham and Overton 1978, 1979; Smith and van Belle 1984).

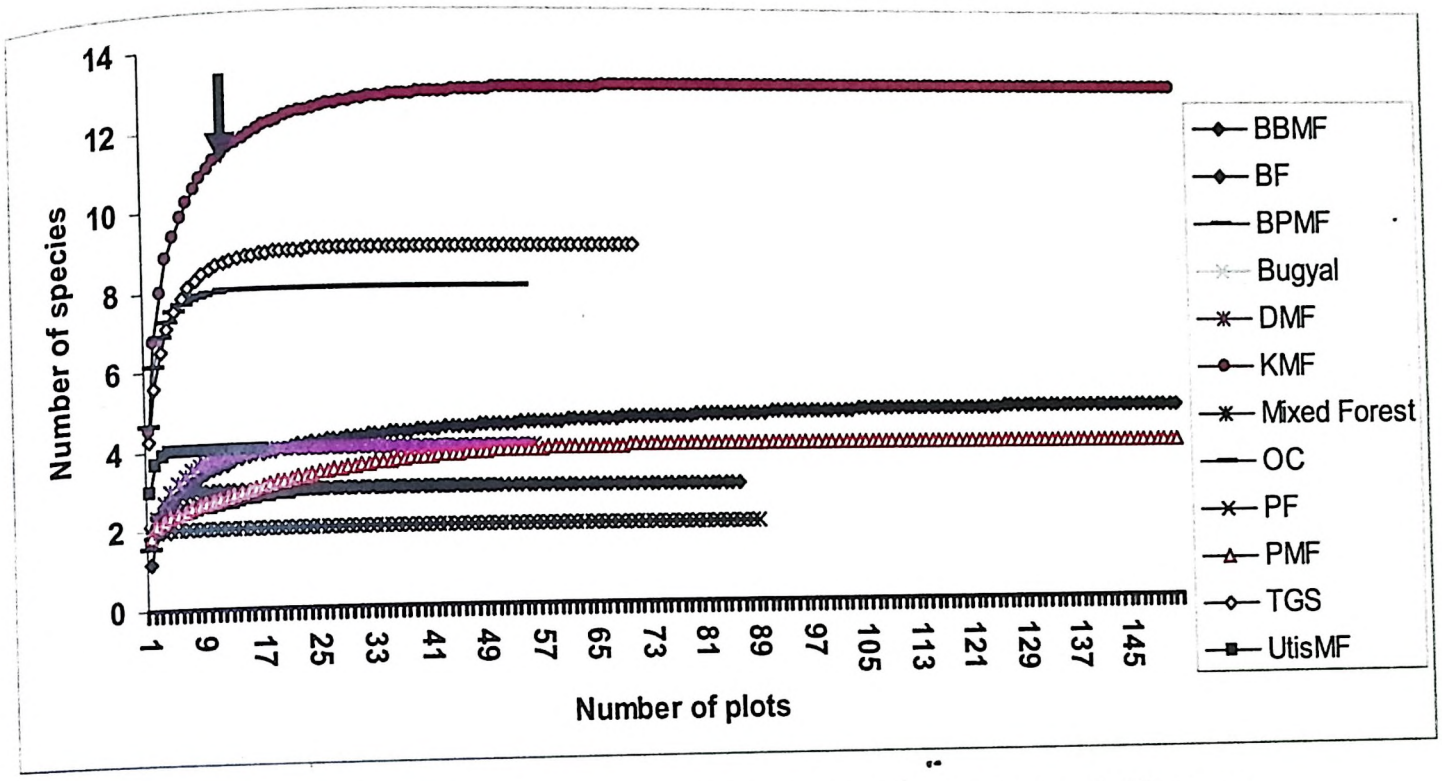


Figure 5.4: Species accumulation curve using Jacknife 1 for fourteen habitat types.

As shown in Figure 5.4, transect walk in each habitat type shows the saturation for the number of species discovered in each. Therefore, sufficiency of the species number and the plot laid in all the selected habitat type is justified. Species richness is higher in Kharsu Mixed Forest (KMF=12.4) and minimum is in Pine Forest (PF=2). The number of species observed and the number of species estimated by Jacknife 1 is same.

5.3.2.1 Distribution of *Berberis* species along altitudinal range

At lower elevation range (600 -1500 m a.s.l.) only two species of *Berberis* were present. Maximum numbers of *Berberis* species were encountered between elevation range 2501-3500 m in South and South East facing aspect (Figure 5.5).

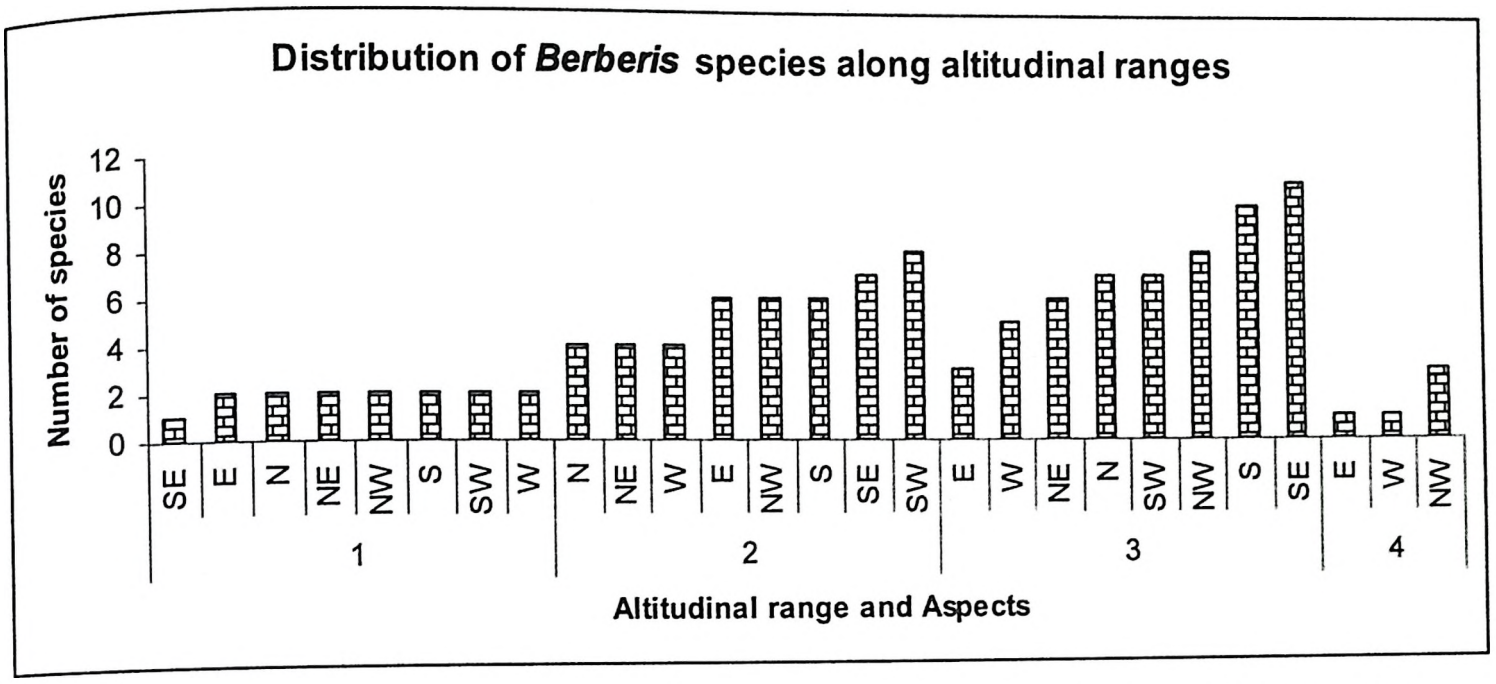
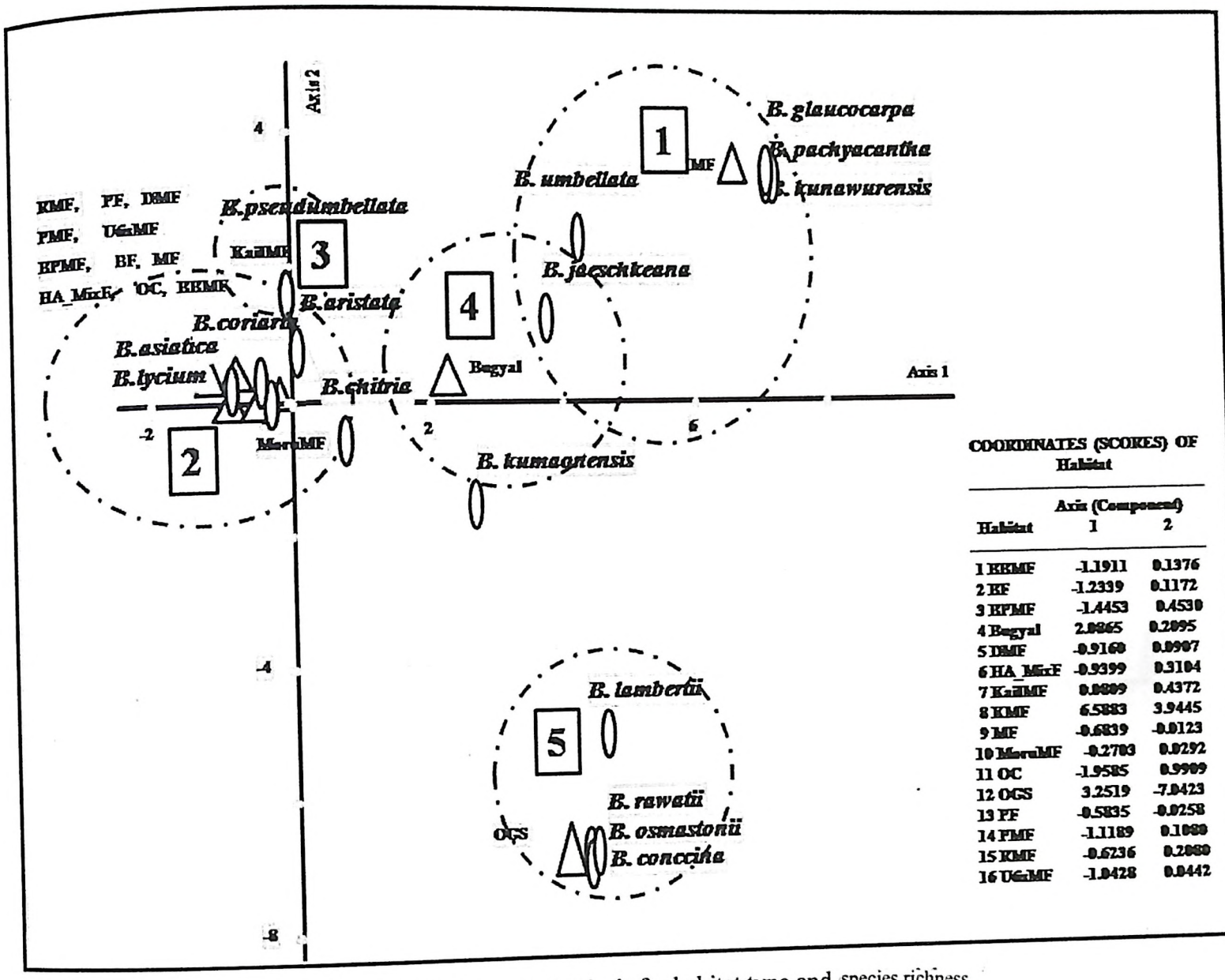


Figure 5.5: Distribution of *Berberis* species in different aspect at different altitudinal ranges (1= 600-1500 m; 2=1501-2500 m; 3= 2501-3500 m; 4= 3501 m above) (SE- South East, E- East, N-North, NE- North East, NW- North West, S- South, SW- South West and W- West).

5.3.3 Key Factors Influencing *Berberis* Distribution

PCA revealed a lot of variation among the habitats occupied by the *Berberis* and overall 5 clusters were formed. Cluster one (Kharsu Mixed Forest) represented by *Berberis glaucocarpa*, *B. pachyacantha* and *B. kunawurensis*, whereas species like *B. umbellata* and *B. jaeschkeana* are mainly found in between Bugyal and KMF. Cluster two is mainly mixed of 12 different habitat types where most of the species of *Berberis* are present, like *B. coriaria*, *B. asiatica*, *B. lycium*, *B. chitria* and *B. aristata*. A distinct habitat type (blue pine forest in the rain-shadow zone in Malari) was segregated as cluster 3 that represented the habitat of *B. pseudumbellata,* cluster 4 has *Berberis kumaonensis,* found in moist alpine meadows and temperate grassy slopes in Greater Himalaya. *Berberis rawatii, B. osmastonii, B. conccina* var. *brevivora* and *B. lambertii* preferred temperate grassy slopes. This habitat is critically important because most of the rare species of *Berberis* are found in cluster five (Figure 5.6).



COORDINATES (SCORES) OF Habitat

Habitat	Axis (Component) 1	2
1 RRMF	-1.1911	0.1376
2 BF	-1.2339	0.1172
3 RPMF	-1.4453	0.4530
4 Bugyal	2.8865	0.2895
5 DMF	-0.9160	0.0907
6 HA_MixF	-0.9399	0.3104
7 KmIMF	0.8809	0.4372
8 KMF	6.5883	3.9445
9 MF	-0.6839	-0.0123
10 MaruMF	-0.2703	0.0292
11 OC	-1.9585	0.9909
12 OGS	3.2519	-7.0423
13 PF	-0.5835	-0.0258
14 PMF	-1.1189	0.1080
15 KMF	-0.6236	0.2080
16 UGsMF	-1.0428	0.0442

Figure 5.6: Principal Component Analysis for habitat type and species richness.

5.3.4 Availability and distribution of medicinally important *Berberis* species

5.3.4.1 *Berberis aristata* DC., abundance and distribution in different habitat types

Abundance of *B. aristata* are shown in Figure 5.7, which reveals that High altitude Mixed Forest (HAMF) had highest abundance (A= 6.0). In Open canopy cover at 2500 to 3000m altitudinal ranges wherever Open Canopy Cover (OC) is present along river valleys and nearby villages abundance was higher.

Regeneration of *B. aristata* was maximum in HAMF as indicated by higher abundance (A=3.7) of seedlings and lowest abundant observed in Open Canopy Cover areas, as sapling

is good in Kharsu Mixed Forest (KMF) in state (A= 2.75) and lowest in Pine Mixed Forest (PMF).

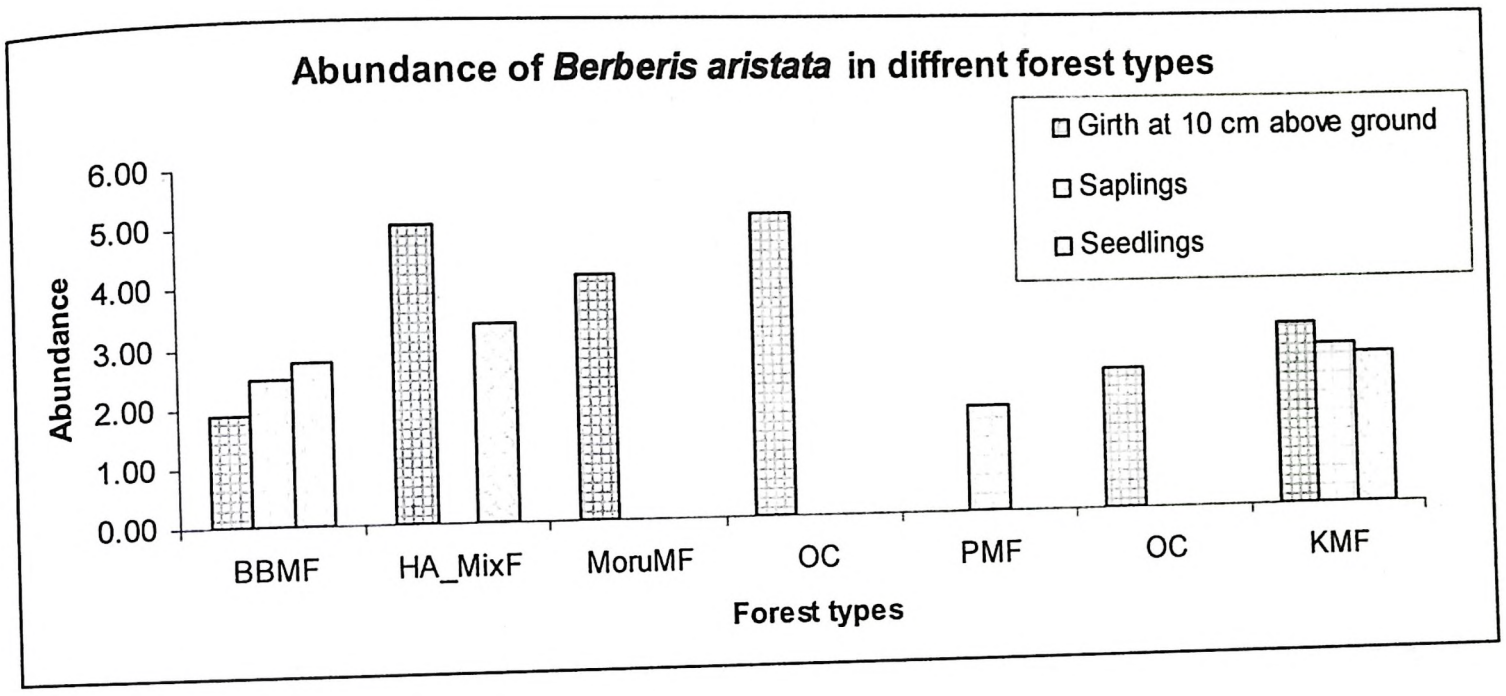


Figure 5.7: Abundance of *Berberis aristata* in different habitat types

Table 5.1: Density (D.), Frequency (F.), Average girth and Average height of *Berberis aristata* in different forest types in state. (Density = number of individuals ha^{-1}; % F= [Occurrence of individuals in number of plot/ Total plots] x 100).

Forest types	Density (ha^{-1})	Sapling (D. m^{-2})	Seedlings (D. m^{-2})	Avg. Girth (cm)	Avg. Height (m)	% F	Sapling % F	Seedlings % F
BBMF (n= 160)	**10.3±0.90**	0. 5±2.03	0.14±1.83	42.6±9.80	3.07±0.19	**40.38**	18.13	**5.00**
HAMF (n= 40)	**286.3±1.41**	--	0.5±1.15	43.1±3.02	3.2±0.26	**45.00**	--	**15.00**
Moru MF (n= 40)	92.2±1.07	--	--	38.9±4.71	3.0±0.41	17.50	--	--
OC (n= 80)	179.7±1.21	--	--	41.5±6.78	3.2±0.39	27.50	--	--
PMF (n= 40)	--	0.4±0.83	--	--	--	--	22.50	--
KMF (n= 300)	81.03±1.22	0.2±1.33	0.3±0.95	37.5±6.38	3.1±0.36	20.67	8.00	9.67

Berberis aristata is widely distributed in the state of Uttarakhand from Tons valley to Kali valley between 2300 m to 3600 m a.s.l., in all the aspects and slope categories. Highest density and frequency of this species was obtained in HAMF (D=286.4±1.41 ha^{-1}; F= 45.00%). Lowest values were obtained in BBMF (D=10.3±0.90 ha^{-1} & F= 40.38%). In

HAMF, average girth of the species was 43.1±3.02 cm and average height of plant was 3.2±0.26 m. This species has been recorded in 7 different habitat types in state (Table 5.1).

5.3.4.2 *Berberis asiatica* DC., abundance and distribution in different habitat types

Abundance of *B. asiatica* across various habitats has been presented in Figure 5.8. It was revealed that this species had high abundance in Banj-Pine Mixed Forest (BPMF) (A= 15.49) and Kharsu Mixed Forest (KMF) it has A=11.75. Regeneration was good in HAMF as seedling abundance is A= 4.88 low in Pine Forest and sapling is good in BBMF (A= 5.51) and low abundant in Riverine Mixed Forest.

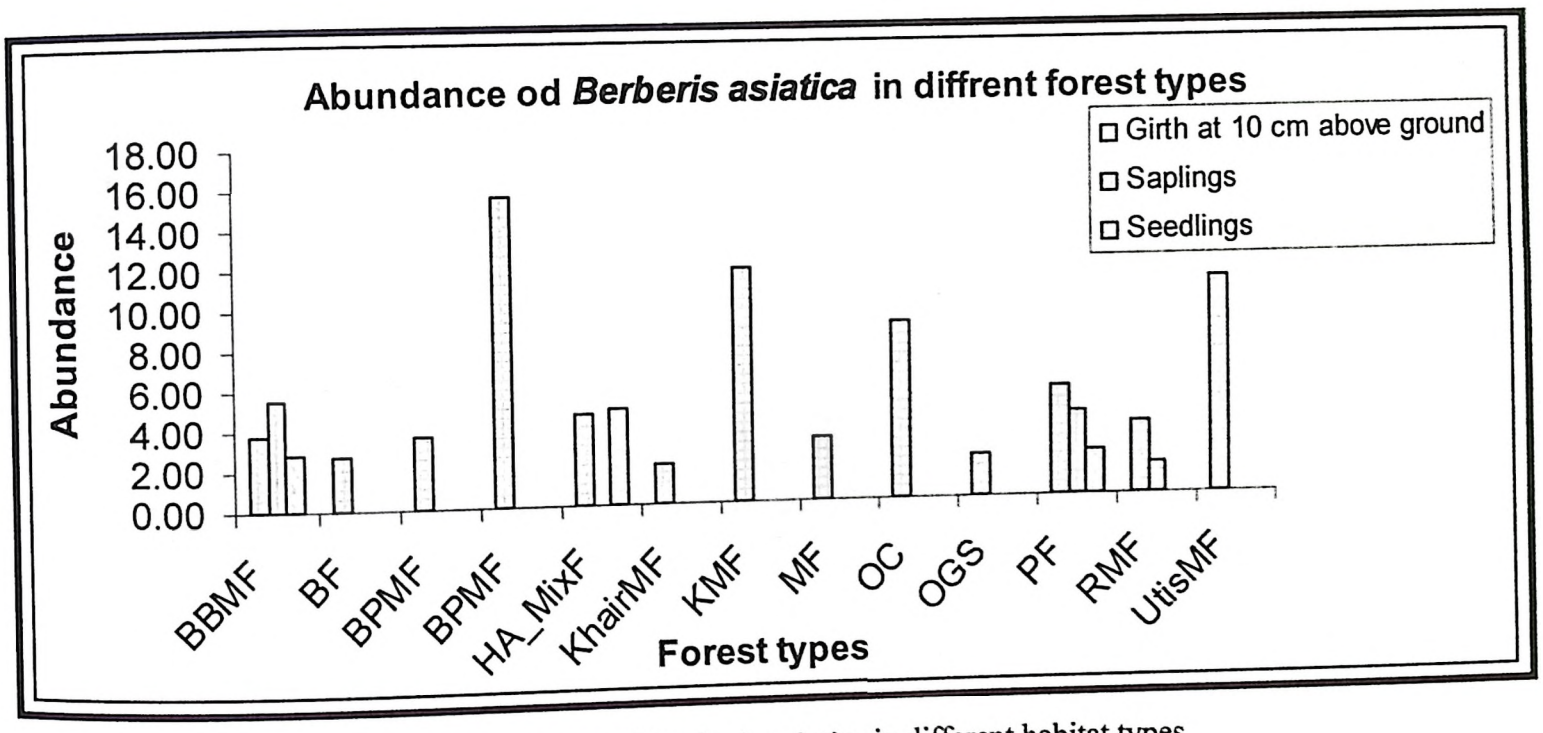


Figure 5.8: Abundance of *Berberis asiatica* in different habitat types

Table 5.2: Density (D.), Frequency (F.), Average girth and Average height of *Berberis asiatica* in different forest types in state. (Density = number of individuals ha^{-1}; % F= [Occurrence of individuals in number of plot/ Total plots] x 100).

Forest types	Density (ha^{-1})	Sapling (D. m^{-2})	Seedlings (D. m^{-2})	Avg. Girth (cm)	Avg. Height (m)	% F	Sapling % F	Seedlings % F
BBMF (n=400)	126.9±2.44	0.7±3.66	0.3±1.66	21.70±4.71	1.99±0.30	26.25	11.75	9.25
BF (n=20)	254.5±1.23	--	--	22.13±4.39	2.00±0.19	**75.00**	--	--
BPMF (n=80)	241.8±1.70	--	--	21.83±7.34	2.27±0.46	52.50	--	--
BPMF (n=80)	**1010.5±2.06**	--	--	44.43±0.54	3.67±0.00	**51.25**	--	--

HAMF (n=40)	117.73±3.25	--	0.9±1.96	20.63±3.70	2.00±0.27	20.00	--	10.00
KhairMF (n=20)	**12.7±0.88**	--	--	33.00±20.72	2.50±1.58	**5.00**	--	--
BPMF (n=60)	598.2±6.14	--	--	17.42±3.66	1.88±0.37	40.00	--	--
MF (n=80)	116.1±2.12	--	--	20.83±3.71	2.11±0.21	28.75	--	--
OC (n=40)	283.2±4.53	--	--	18.30±5.89	2.05±0.16	25.00	--	--
OGS (n=40)	47.7±0.90	--	--	23.29±7.54	2.14±0.24	17.50	--	--
PF (n=180)	117.4±4.85	0.51±0.69	0.1±0.00	20.03±3.82	1.95±0.30	16.67	12.22	6.11
RMF (n=280)	124.6±2.86	0.11±0.00	--	20.92±3.98	1.99±0.27	26.43	7.14	--
UtisMF (n=20)	746.9±3.72	--	--	15.00±12.06	2.00±0.86	70.00	--	--

Berberis asiatica is also distributed widely in the state along and altitudinal range of 600 m to 2700 m a.s.l. It is also present in all aspect and slope in state. *Berberis asiatica* had very high density and frequency in BPMF (D=1010.2±2.06 ha^{-1}; F= 51.3 %), while it was found in least quantity in Khair MF (D=12.7±0.88 ha^{-1}; F= 5.0 %). In Banj Pine Mixed Forest (BPMF) average girth class was 44.4±0.54 cm and mean height of plants was 3.7±0.00 m. This species was recorded in 13 different habitat types (Table 5.2). Best populations in terms of abundance, mean girth class and height were observed around Mussoorie hills (Dehra Dun and Tehri Districts), Kosi-Katarmal (Almora), and Kapkot (Bageshwar).

5.3.4.3 *Berberis lycium* Royle, **abundance and distribution in different habitat types**

Abundance of *B. lycium* across various forest types has been depicted in Figure 5.9. Highest abundance (A= 7.0) was recorded in Khair Mixed Forests between 800-1200 m a.s.l.. The species was generally distributed more abundantly (A=4.30) in Open Forests and Canopies between 1000 to 2500 m a.s.l.. It had better regeneration in Temperate Grassy Slopes (OGC) and Pine Forests (PF) with seedling abundance 3.38 and 3.0, respectively.

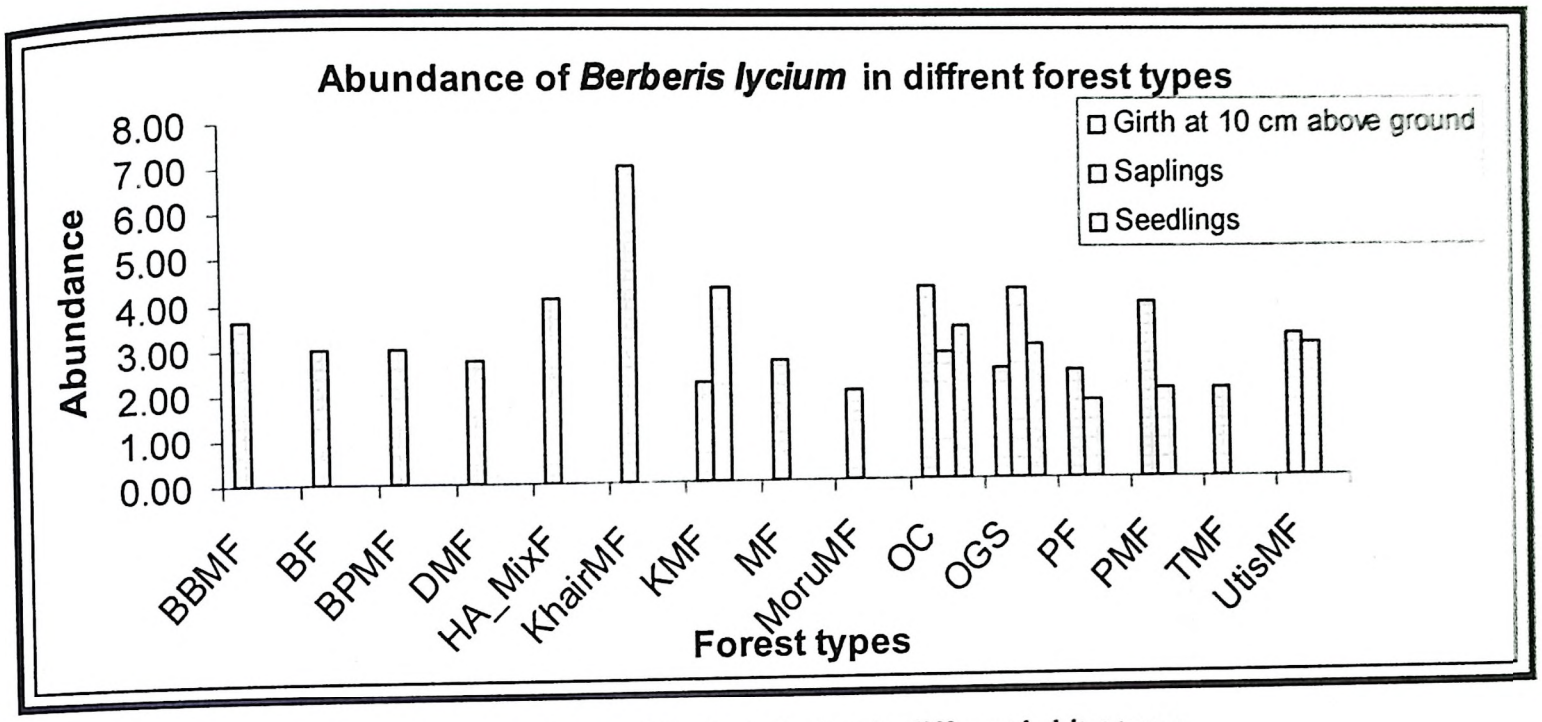


Figure 5.9: Abundance of *Berberis lycium* in different habitat types

Berberis lycium is largely distributed in the western part of the state (upto Eastern Ramganga) between 600 m to 2700 m a.s.l, in nearly all the aspect and slope categories. It had highest density and frequency in Banj Forest (BF) (D=229.10±1.66 ha^{-1}; F= 60%), while lowest availability was found in Moru Mixed Forest (D=6.36±0.62 ha^{-1}; F= 2.5%). In BF average girth class was 24.24±3.95 cm and average height of individuals is 1.90±0.33 m (Table 5.3). This species was recorded in 15 different forest types in state. The good populations with respect to its girth and height in state were observed in Mussoorie hills, Nandprayag, Agastamuni, Gauchar, Pindar valley and Bageshwar.

Table 5.3: Density (D.), Frequency (F.), Average girth and Average height of *Berberis lycium* in different forest types in state. (Density = number of individuals ha^{-1}; % F= [Occurrence of individuals in number of plot/ Total plots] x 100).

Forest types	Density (ha^{-1})	Sapling (D. m^{-2})	Seedlings (D. m^{-2})	Avg. Girth (cm)	Avg. Height (m)	% F	Sapling % F	Seedlings % F
BBMF (n=460)	148.7±2.44	0.3±1.53	0.21±1.47	23.81±8.66	1.92±0.70	32.55	10.09	6.42
BF (n=120)	**229.1±1.66**	0.3±1.05	0.4±1.27	24.24±3.95	1.90±0.33	**60.0**	10.83	13.33
BPMF (n=60)	140.0±2.89	0.4±1.74	0.2±1.26	27.82±4.78	2.20±0.37	36.67	11.67	6.67
DMF (n=100)	147.6±1.44	--	0.1±0.92	23.58±3.98	1.81±0.34	43.00	--	3.00
HAMF (n=40)	130.5±3.75	--	--	24.30±5.10	1.97±0.39	25.00	--	--
KhairMF (n=20)	44.6±2.29	--	--	19.00±9.83	1.50±0.78	5.00	--	--

KMF (n=100)	39.5±1.47	0.9±3.25	--	26.36±13.29	2.25±1.14	14.00	**21.00**	--
MF (n=120)	95.5±1.12	--	--	27.50±5.76	2.16±0.40	28.33	--	--
MoruMF (n=20)	**6.4±0.62**	--	--	21.00±10.77	2.50±1.48	2.50	--	--
OC (n=140)	39.09±1.77	0.1±1.71	0.2±2.21	25.20±2.10	2.10±0.21	7.14	3.57	5.71
OGS (n=40)	70.0±0.73	0.4±2.62	0.5±2.35	25.22±4.06	2.06±0.39	22.50	10.00	**15.00**
PF (n=240)	75.8±1.36	0.05±0.60	--	26.48±6.46	2.03±0.49	25.00	2.92	--
PMF (n=320)	149.5±2.69	0.1±0.81	--	23.53±9.47	1.89±0.79	30.00	5.00	--
TMF (n=20)	12.7±0.49	--	--	27.00±12.40	2.00±0.86	5.00	--	--
UtisMF (n=40)	120.9±1.85	0.3±1.60	--	23.42±4.96	1.83±0.37	30.00	10.00	--

5.3.5 Species Distribution Along Environmental Gradients

To analyze *Berberis* species distribution across the different habitat and to co-relate the environmental factors, analysis was performed using the data from 182 plots where species were present and 11 environmental variables were used. CCA result (Figure 5.10) shows that the compositional gradient lengths of the first and second axes had eigen values 0.843 and 0.733 respectively. Correspondence analysis (CA) reveals that elevation, winter, summer, monsoon temperature and precipitation are the main underlying environmental gradients for species composition. The first and second axes are well correlated with the environmental factors (r= 0.947 and 0.879, respectively) and the correlation for the other axis are lower (Table 5.5). Elevation, summer precipitation and aspect have stronger correlation with axis 1 and second axis correlation with winter temperature and negative side correlation with winter precipitation (Table 5.4).

Table 5.4: Inter-Set Correlation for 10 variables (as obtained after CCA from PCORD4) INTER-SET CORRELATIONS for 11 variables

		Correlations		
	Variable	Axis 1	Axis 2	Axis 3
1	AP	0.137	-0.038	-0.030
2	CC	**-0.653**	-0.279	0.134
3	Elv	**0.824**	-0.224	0.159
4	Asp	0.082	0.097	0.127
5	Slp	-0.213	0.191	-0.120
6	Prec-S	**0.727**	-0.330	-0.015
7	Prec-M	**-0.586**	0.253	-0.135
8	Prec-W	0.370	**-0.718**	0.084
9	TM-S	**-0.677**	**0.428**	-0.124
10	TM-M	**-0.680**	0.354	-0.136
11	TM-W	**-0.686**	**0.437**	-0.105

(bold ones are showing good correlation)

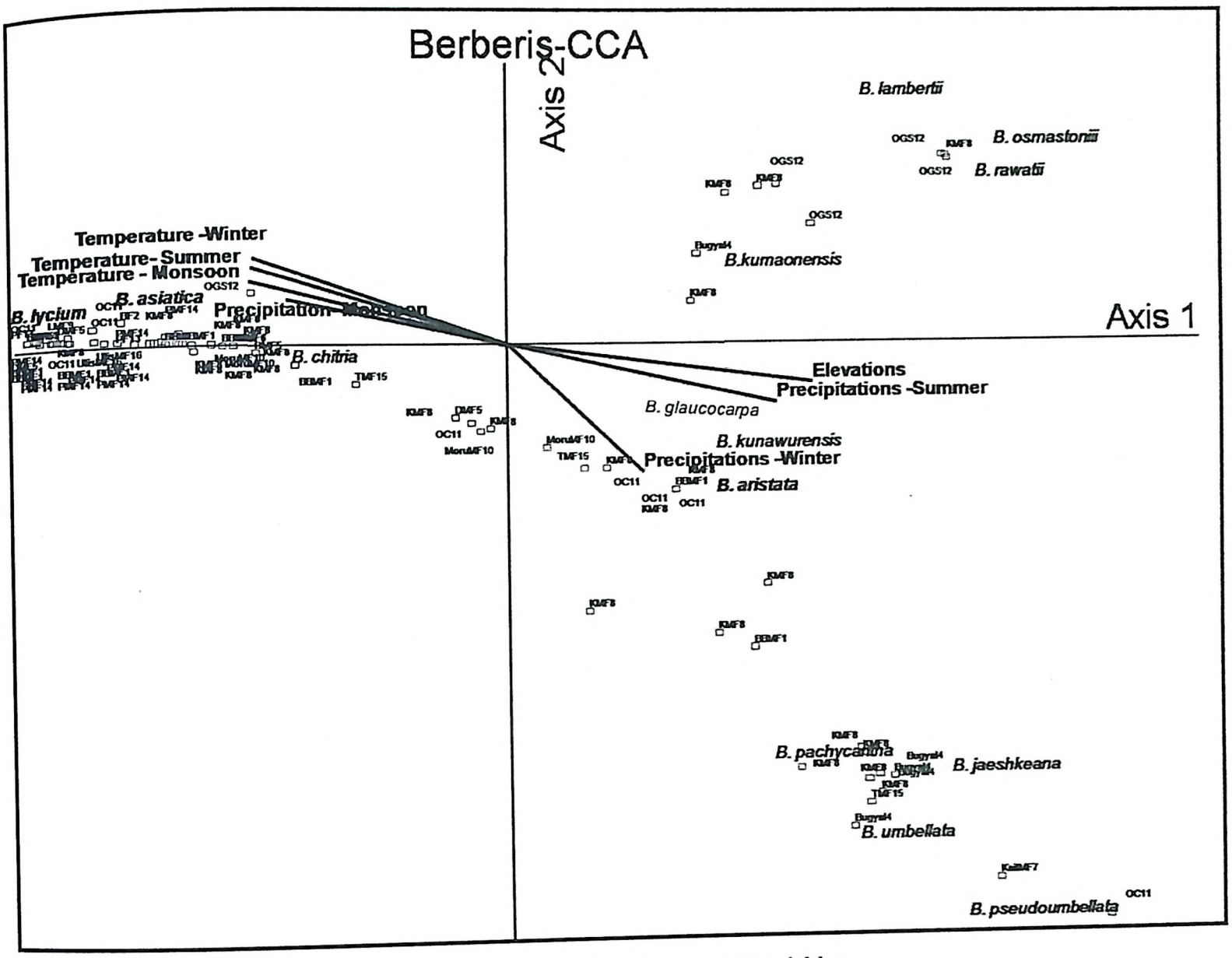


Figure 5.10: Ordination biplot diagram for species and environmental variables.
Plots are displayed by box and species are labeled by first letter of generic name and species name.

Table 5.5: Monte Carlo test results for Species – Environment Correlations (as obtained after CCA from PCORD4)

	Randomized data, Real data	Monte Carlo test,	99 runs	
Axis	Spp-Envt Corr.	Mean	Minimum	Maximum	p
1	0.947	0.770	0.654	0.878	0.0100
2	0.879	0.591	0.467	0.803	
3	0.751	0.490	0.404	0.596	

p = proportion of randomized runs with species-environment correlation greater than or equal to the observed species-environment correlation; i.e.,

p = (1 + no. permutations >= observed)/(1 + no. permutations)

p is not reported for axes 2 and 3 because using a simple randomization test for these axes may bias the p values.

See **Appendix III** and **Appendix IV** for the list of abbreviations used in CCA and **Appendix V** for the output file from PCORD after Canonical Correspondence Analysis.

Figure 5.10 shows the scatter plot of *Berberis* species generated from PCORD4 after CCA. Out of 11 variables used, 8 showed high correlation, namely canopy cover, elevation, summer, winter and monsoon temperatures and precipitation. Slope shows low negative correlation (-0.213) with the axis-1; winter temperature shows high negative correlation (-0.686) with axis-1; summer and winter temperatures show high positive correlation (0.428 and 0.437 respectively) with the axis-2; elevation and summer precipitation shows good positive correlation with the axis 1 (0.824 and 0.727 respectively) and summer precipitation shows negative correlation with axis 2 (-0.330); winter precipitation shows high negative correlation (-0.718) with the axis-2; summer, monsoon and winter show good negative correlation (-0.677, -0.680 and -0.686 respectively) with axis-1.

Table 5.6: Final scores and raw data totals (weights) for medicinally important *Berberis* species along different axis (as obtained after CCA from PCORD4)

	Raw Data			
Species	Axis 1	Axis 2	Axis 3	Totals
B. aristata	0.437	-0.796	0.588	4177.364
B. asiatica	-0.981	0.134	0.5808	1636.510
B. lycium	-1.217	0.052	-0.1518	12790.853

Berberis aristata showed high negative correlation (-0.796) with the axis-2 and high positive correlation (0.588) with the axis-3. *Berberis asiatica,* on the other hand, shows high negative correlation (-0.981) with the axis-1 and high positive correlation (0.580) with the axis-3. *Berberis lycium* showed high negative correlation (-1.217) with the axis-2 and high positive correlation (0.588) with the axis-3 (Table 5.6). At higher elevation yearly temperature is also moderate (-2.20 to 12.8° C in winter; 10 to 21° C during monsoon & 4 to 20° C during summer) and less rainfall during monsoon (500-1657 mm) are good environmental conditions for growth of *B. aristata.*

5.3.6 Biomass

5.3.6.1: Volume - weight relationship of *Berberis aristata* stem

Table 5.7: Correlation matrix for *Berberis aristata* stem

Variables	Volume (cm^3)	DW (g)
Volume (cm^3)	**1.00**	0.98
DW (g)	0.98	**1.00**

The correlation between plant dry weight and independent variable plant volume is shown in Table 5.7 displays the goodness of fit coefficients of the model. The R^2 (coefficient of determination) indicates the % of the dependent variable which is explained by the explanatory variables. The closer to one the R^2 is, better the fit.

Table 5.8: Goodness of fit statistics for weight and volume of *B. aristata* stem

Observations	54.00
Sum of weights	54.00
DF	52.00
R^2	**0.95**
AIC	375.66

In this particular case, the volume explains 95% of the variability of the dry weight. Table 5.8 shows R^2=0.95, which indicates that 95 % of the variance in the variable is explained by volume.

Table 5.9: Analysis of variance: Variable Volume (g) for *B. aristata* stem

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	1	1050808.45	1050808.41	1037.68	< 0.0001
Error	52	52657.92	1012.65		
Corrected Total	53	1103466.33			

[*Computed against model Y=Mean(Y)*]

The Fisher's F test was used to ascertain the significance. Given the fact that probability corresponding to the F value is < 0.0001, the variables do bring a significant amount of information. As ANOVA shows that the P value is 0.0001, which means model is validated for dry weight of *Berberis aristata* stem (Table 5.9).

Table 5.10 gives details on the model. It can be seen that the 95% confidence range of the volume parameter is very narrow.

Table 5.10. Model parameters for equation for *B. aristata* stem

Source	Value	Standard error	T	Pr > |t|	Lower bound (95%)	Upper bound (95%)
Intercept	23.88	5.43	4.39	< 0.0001	12.98	34.78
Volume (cm^3)	0.28	0.009	32.21	< 0.0001	0.27	0.30

Equation of the model

Dry Weight (grams) = 23.88+0.28 x Volume (cm^3) (Figure 5.11). Dry biomass of the *Berberis aristata* stem can be calculated by using above equation.

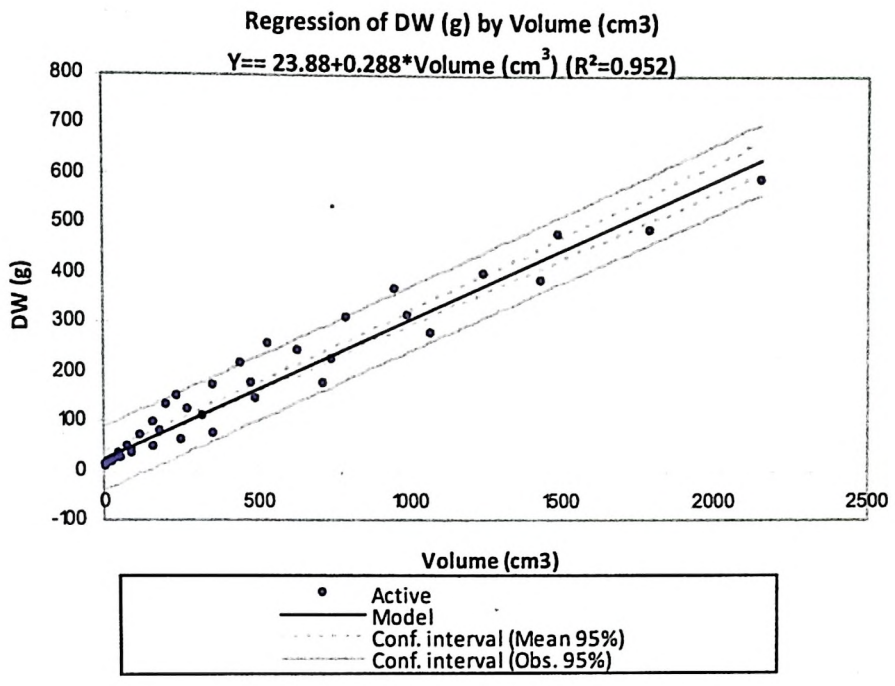


Figure 5.11: Correlation between *Berberis aristata* stem biomass and volume

5.3.6.2: Volume - weight relationship of *Berberis asiatica* stem

The correlation between dry weight and stem volume is close to explanatory variable volume of stem parts (0.97) (Table 5.11).

Table 5.11: Correlation matrix for *Berberis asiatica* stem

Variables	Volume (cm^3)	Dry Weight (grams)
Volume (cm^3)	**1.00**	0.97
Dry Weight (grams)	0.97	**1.00**

Table 5.12 displays the goodness of fit coefficients of the model. The R^2 (coefficient of determination) indicates the % of the dependent variable which is explained by the explanatory variables. The closer to 1 the R^2 is, better the fit.

Table 5.12: Goodness of fit statistics

Observations	19.00
Sum of weights	19.00
DF	17.00
R^2	**0.93**
AIC	121.80

In this particular case, 93% of the variability of the dry weight is explained by the volume of *B. asiatica* stem parts. Table 5.12 shows R^2=0.93, which indicate that 93 % of the variance in the variable is explain by volume. It is important to examine the results of the analysis of variance table. The results enable to determine whether or not the explanatory variables bring significant information (null hypothesis H0) to the model. In other words, it's a way of asking myself whether it is valid to use the mean described the whole population, or whether the information brought by the explanatory variables is of value or not.

Table 5.13: Analysis of variance: Variable Volume (g) for *Berberis asiatica* stem

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	1	130248.52	130248.52	236.46	< 0.0001
Error	17	9363.96	550.82		
Corrected Total	18	139612.48			

[*Computed against model Y=Mean(Y)*]

As ANOVA shows that the P value is 0.0001, which means model is validated for dry weight of *Berberis asiatica* stem. (Table 5.13).

Table 5.14: Model parameters for equation for dry weight of *Berberis asiatica* stem

Source	Value	Standard Error	T	Pr > |t|	Lower bound (95%)	Upper bound (95%)
Intercept	76.05	9.24	8.23	< 0.0001	56.54	95.55
Volume (cm^3)	0.25	0.02	15.38	< 0.0001	0.22	0.28

Table 5.14 gives details on the model. It can be seen that the 95% confidence range of the volume parameter is very narrow.

Equation of the model

Dry Weight (grams) = 76.05+0.25 x Volume (cm^3) (Figure 5.12). Dry biomass of the *Berberis asiatica* stem can be calculated by using above equation.

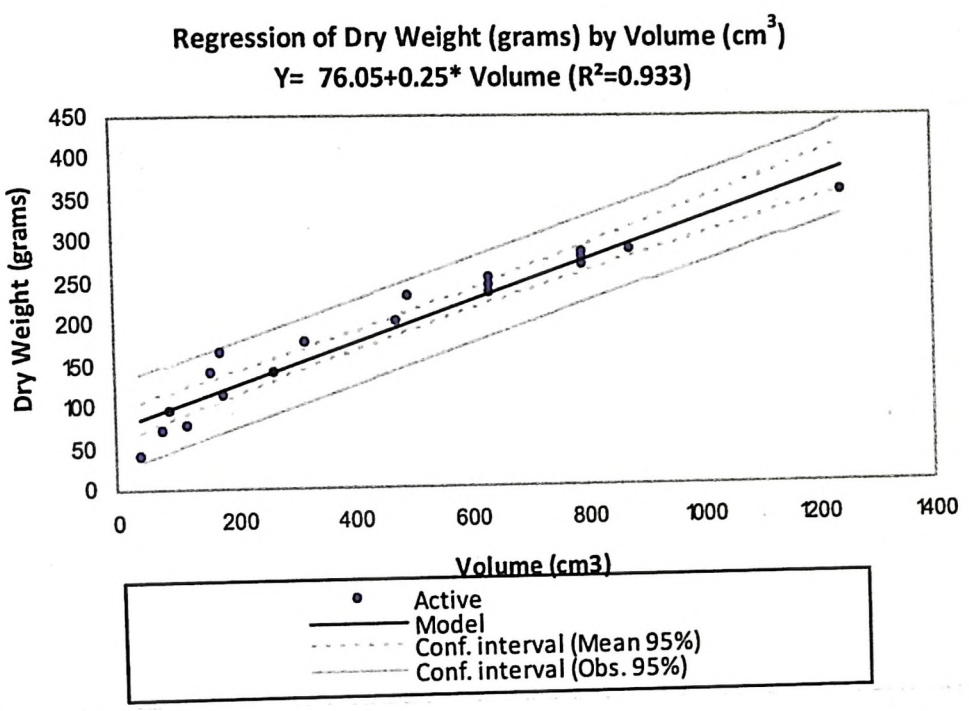


Figure 5.12: Correlation graph between *Berberis asiatica* stem Dry biomass and volume stem

5.3.6.3: Volume - weight relationship of *Berberis asiatica*- root

Table 5.15: Correlation matrix for *Berberis asiatica* stem

Variables	Volume (cm^3)	Dry Weight (grams)
Volume (cm^3)	**1.00**	0.82
Dry Weight (grams)	0.82	**1.00**

The correlation between plant dry weight and independent variable plant volume of root parts. Dry weight of the plant is very close to explanatory variable volume of roots (0.82) (Table 5.15).

Table 5.16: Goodness of fit statistics

Observations	22.00
Sum of weights	22.00
DF	20.00
R^2	**0.67**
AIC	193.03

Table 5.16 displays the goodness of fit coefficients of the model. The R^2 (coefficient of determination) indicates the percentage of the dependent variable which is explained by the explanatory variables. The closer to 1 the R^2 is, better the fit.

In this particular case, 67% of the variability of the dry weight is explained by the volume of *B. asiatica* roots. Table 5.16 shows R^2=0.67, which indicate that 67 % of the variance in the variable is explain by volume.

As ANOVA shows that the P value is 0.0001, which means model is validated for Dry weight of *Berberis asiatica* roots. (Table 5.17)

Table 5.17: Analysis of variance: Variable Volume (g) for *Berberis asiatica* stem

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	159.41	27.25	5.85	< 0.0001	102.58
Error	0.31	0.05	6.30	< 0.0001	0.21
Corrected Total	159.41	27.25	5.85	< 0.0001	102.58

[*Computed against model Y=Mean(Y)*]

Table 5.18: Model parameters for equation for *Berberis asiatica* stem

Source	Value	Standard error	t	Pr > |t|	Lower bound (95%)	Upper bound (95%)
Intercept	76.05	9.24	8.23	< 0.0001	56.54	95.55
Volume (cm^3)	0.249	0.02	15.38	< 0.0001	0.22	0.28

Table 5.18 gives details on the model. It can be seen that the 95% confidence range of the volume parameter is very narrow.

Equation of the model

Dry Weight (gram) = 159.41+0.31 x Volume (cm^3) (Figure 5.13). Dry biomass of the *Berberis asiatica* roots can be calculated by using above equation.

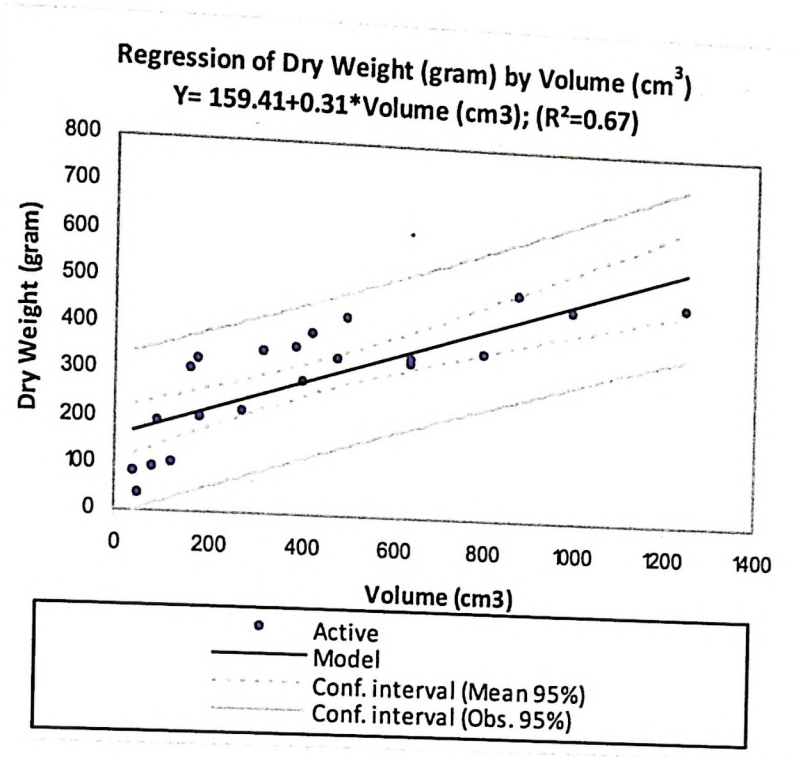


Figure 5.13: Correlation graph between *Berberis asiatica* roots dry biomass and volume of root

5.3.6.4: Volume - weight relationship of *Berberis lycium*- stem

Table 5.19: Correlation matrix for *Berberis lycium* stem

Variables	Volume (cm^3)	Dry Weight (grams)
Volume (cm^3)	**1.00**	0.99
Dry Weight (grams)	0.99	**1.00**

The correlation between plant dry weight and independent variable plant volume of stem parts. Dry weight of the plant is very close to explanatory variable volume of stem parts (0.99) (Table 5.19).

Table 5.20: Goodness of fit statistics for *Berberis lycium* stems biomass

Observations	21.00
Sum of weights	21.00
DF	19.00
R^2	**0.97**
AIC	141.32

The Table 5.20 displays the goodness of fit coefficients of the model. The R^2 (coefficient of determination) indicates the percentage % of the dependent variable which is explained by the explanatory variables. The closer to 1 the R^2 is, better the fit.

In this particular case, 97% of the variability of the dry weight is explained by the volume of *B. lycium* stem parts. Table 5.20 shows R^2=0.97, which indicate that 97 % of the variance in the variable is explain by volume.

Table 5.21: Analysis of variance: Variable Volume (g) of *Berberis lycium* stem

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	1.00	478794.94	478794.94	626.27	< 0.0001
Error	19.00	14525.75	764.51		
Corrected Total	20.00	493320.69			

[*Computed against model Y=Mean(Y)*]

The Fisher's F test is used. As ANOVA shows that the P value is 0.0001, which means model is validated for Dry weight of *Berberis lycium* stem. (Table 5.21).

Table 5.22: Model parameters for equation for *Berberis lycium* stem biomass

Source	Value	Standard error	t	Pr > |t|	Lower bound (95%)	Upper bound (95%)
Intercept	76.05	9.24	8.23	< 0.0001	56.54	95.55
Volume (cm^3)	0.249	0.02	15.38	< 0.0001	0.22	0.28

Table 5.22 gives details on the model. It can be seen that the 95% confidence range of the volume parameter is very narrow.

Equation of the model

Dry Weight (grams) = 23.82+0.18 x Volume (cm^3) (Figure 5.14). Dry biomass of the *Berberis lycium* stem can be calculated by using above equation.

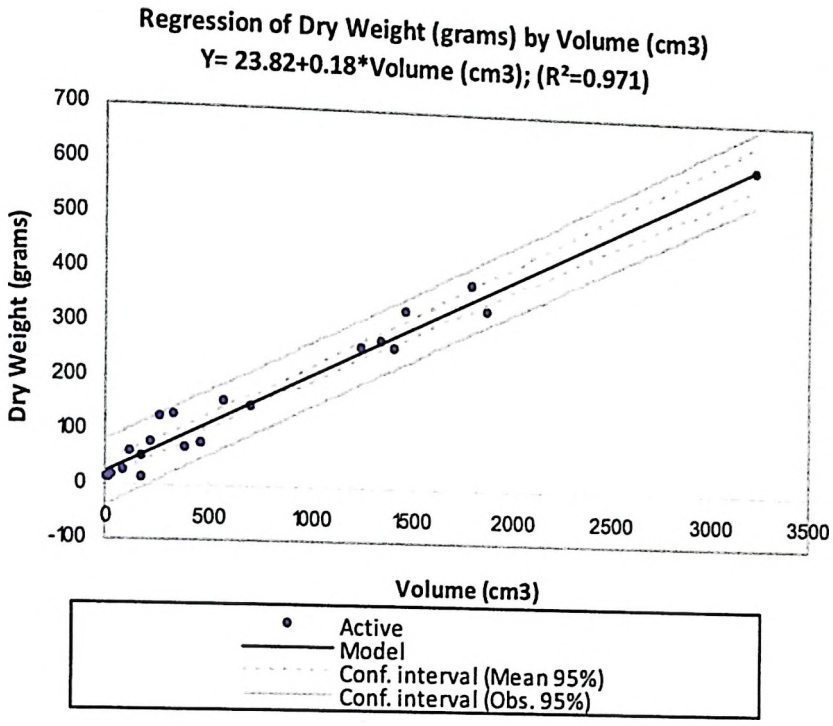


Figure 5.14: Correlation graph between *Berberis lycium* stem dry biomass and volume of stem

5.3.6.5: Volume - weight relationship of *Berberis lycium*- root

Table 5.23: Correlation matrix for *Berberis lycium* root

Variables	Volume (cm^3)	Dry Weight (grams)
Volume (cm^3)	**1.000**	0.86
Dry Weight (grams)	0.86	**1.000**

The correlation between plant dry weight and independent variable plant volume of root parts. Dry weight of the plant is very close to explanatory variable volume of roots (0.86) (Table 5.23).

Table 5.24: Goodness of fit statistics

Observations	23.00
Sum of weights	23.00
DF	21.00
R^2	**0.74**
AIC	193.03

Table 5.24 displays the goodness of fit coefficients of the model. The R^2 (coefficient of determination) indicates the percentage of the dependent variable which is explained by the explanatory variables. The closer to 1 the R^2 is, better the fit.

In this particular case, 74% of the variability of the dry weight is explained by the volume of *Berberis lycium* roots. Table 5.24 shows R^2=0.74, which indicate that 74 % of the variance in the variable is explain by volume.

Table 5.25: Analysis of variance: Variable Volume (g) for *Berberis lycium* root

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	1	132452.58	132452.58	58.53	< 0.0001
Error	21	47526.15	2263.15		
Corrected Total	22	179978.73			

[*Computed against model Y=Mean(Y)*]

The Fisher's F test is used. Given the fact that probability corresponding to the F value is lower than 0.0001. As ANOVA shows that, the P value is 0.0001, which means model is validated for dry weight of *Berberis lycium* roots. (Table 5.25).

Table 5.26: Model parameters for equation

Source	Value	Standard error	t	Pr > |t|	Lower bound (95%)	Upper bound (95%)
Intercept	224.35	16.58	13.53	< 0.0001	189.86	258.83
Volume (cm^3)	0.22	0.029	7.65	< 0.0001	0.16	0.29

Table 5.26 gives details on the model. It can be seen that the 95% confidence range of the volume parameter is very narrow.

Equation of the model

Dry Weight (grams) = 224.35+0.22 x Volume (cm^3) (Figure 5.15). Dry biomass of the *Berberis lycium* roots can be calculated by using above equation.

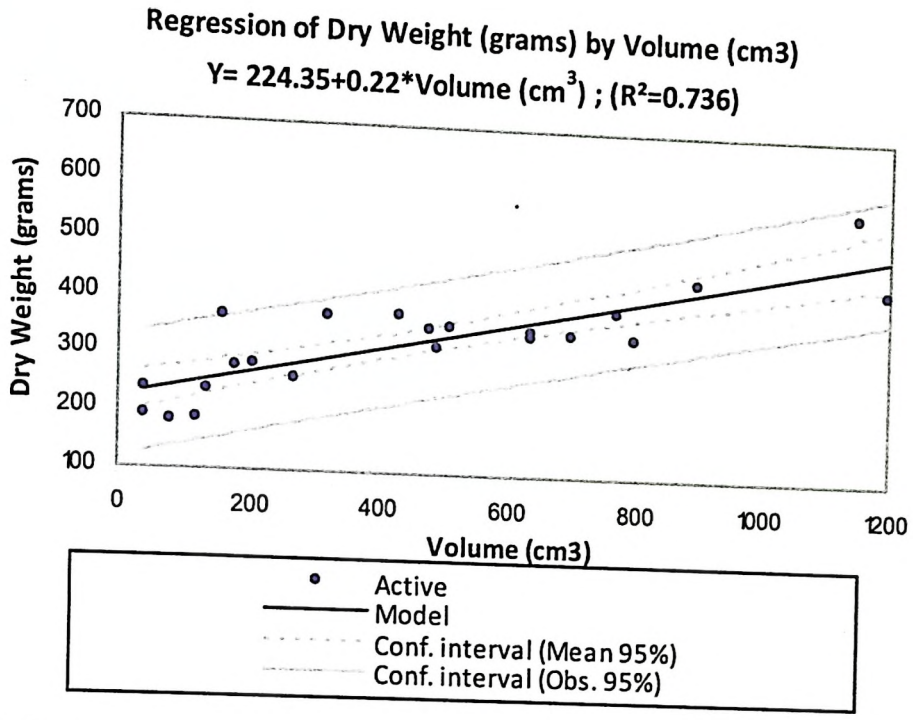
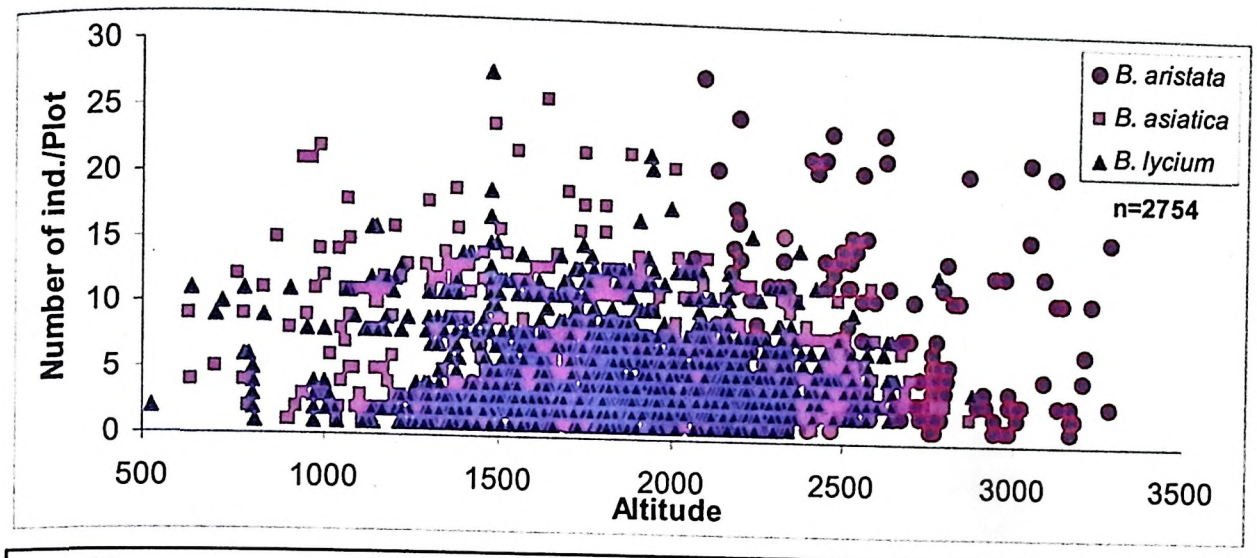
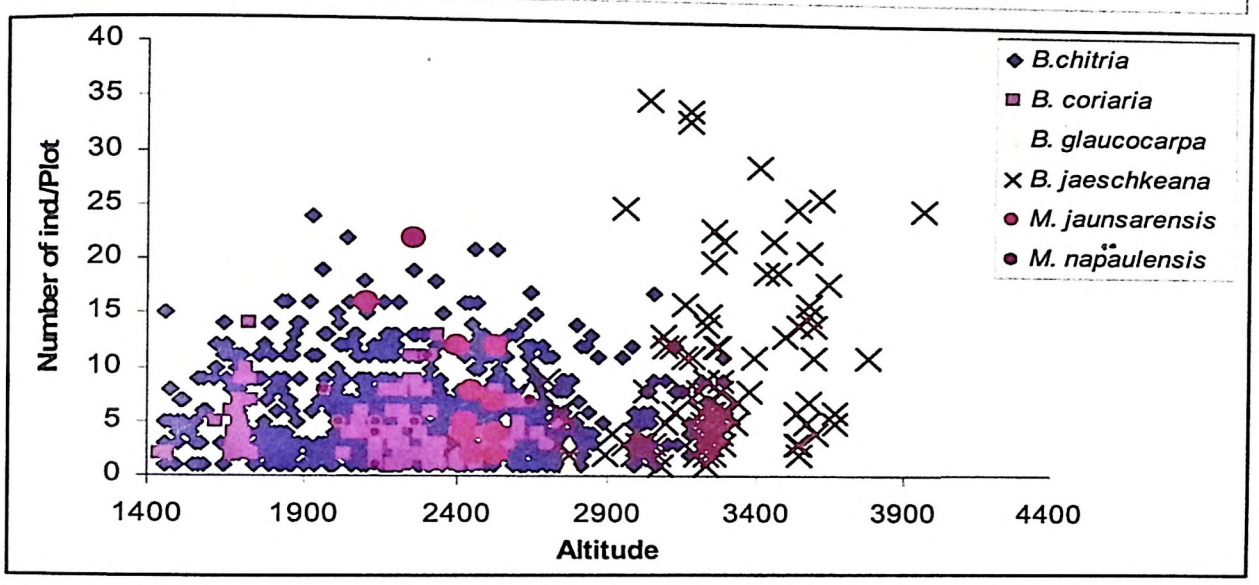


Figure 5.15: Correlation graph between *Berberis lycium* roots dry biomass and volume of root

5.3.7 Distribution of Species Across Altitude

Figure 5.16 shows the distribution of species across altitudinal ranges. *Berberis asiatica* and *B. lycium* ranges from 600 to 2700 m. These two species has wider range of distribution in state. *B. aristata* is distributed in between 2100 to 3400 m in state. *Berberis osmastonii* is distributed in between 2200 to 2800 m and *B. rawatii* is also having same distributional rage. *Berberis kunawurensis* is distributed between 2600- 2900 m in two different localities in state *i.e.*, Deoban, Chakarata and Sukhi, Uttarakashi. *B. kumaonensis* range between 2650 to 3550 m in state. *Berberis umbellata* range between 3000- 3500 m and *B. pachyacantha* is distributed between 2800 to 3500 m. *Berberis ahrendtii* is found between 2400 to 2500 m at Pangarbassa, Chamoli. *B. pseudumbellata* is confine to Trans Himalaya and distributed in two places in state at 3200 to 3500 m. *B. apiculata* is new record for state and found on way to Har-KI-Dun in Uttarkashi district at altitude of 2600- 3200 m and *B. hamiltoniana* is also new record from state and distributed only in Kali river valley and in between Budhi to Gunji village at an altitude of 2900 to 3500 m. *B. koehneana* is confine to Kali valley and nearby Budhi village range between 2800 to 3000 m. *Mahonia jaunsarensis* and *M. napaulensis* these two species are distributed from 1900-2700 m in state.





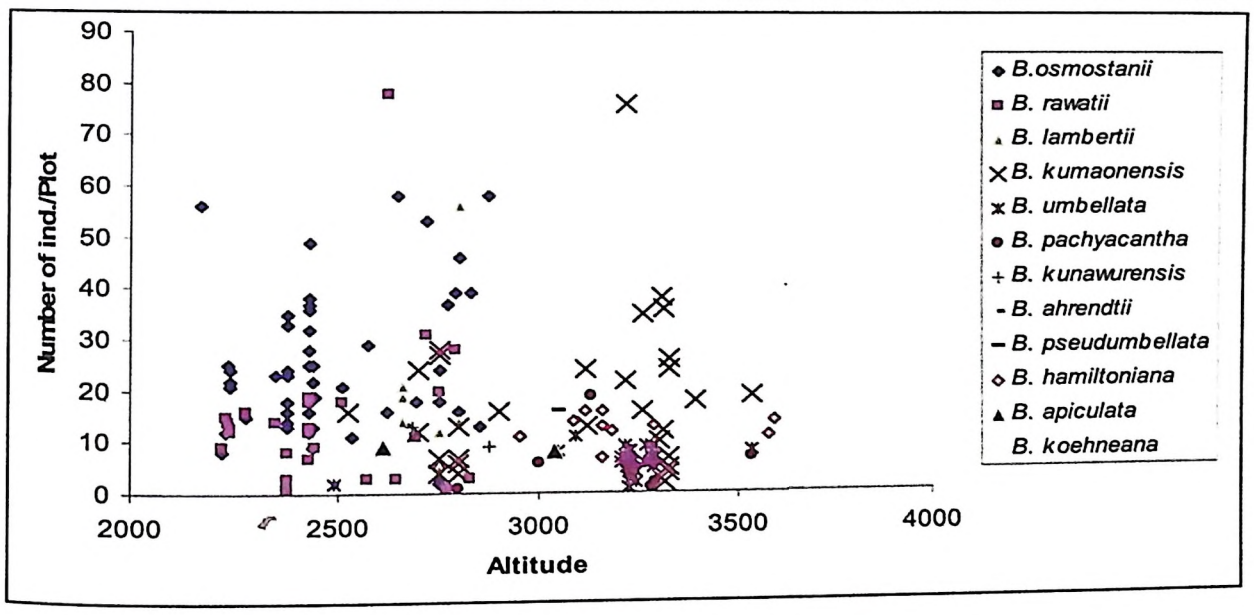


Figure 5.16: Distribution of Berberidaceae Members across different altitudinal range in state

Plate 5.2. Threats and Extraction of *Berberis* species- **A:** Goat eating leaves of *Berberis*; **B:** Due to landslide, completely uprooted plant and C: Collection of *Berberis* for fuelwood and Cropland fencing.

5.3.8 Local Use and Extraction Pattern

Berberis aristata, *B. asiatica* and *B. lycium* are used to cure eye diseases, diarrhea, used in liver complaints and swollen gums. It has antipyretic, antiseptic, anti-inflammatory and anti-amoebic properties (Anonymous 2000, Anonymous 1992, Singh and Dey 2005, Khare 2007, Adhikari et al. 2007; Samant 1998, Semwal et al. 2010). Annual Consumption was estimated up to 521 MT (Ved and Goraya 2008) and annual demand up to 890 tonnes during years 1999-00 and goes high up to 1805 tonnes in the years 2004-05 (Anonymous 2000). It was estimated that annual trade of this species were around 500-1000 MT (Ved and Goraya 2008). Market price of the roots and stem parts range between Rs. 15 -30 per kg. All the three species of *Berberis* considered either adulterant to each other or difficult to separate and measure from raw material and so, mostly all *Berberis* species are treated it by many authors for use and properties.

5.3.8.1 Extraction of *Berberis* species for Fencing and Fuelwood

Major populations of *Berberis* species which are extracted for fuel wood are nearby villages. Local people use these species for fuel wood and fencing purpose. There was a great deal of variation in quantity of *Berberis* extraction by the villagers. In permanent villages, it is collected for fencing crop fields (to protect from free grazing livestock). After a gap of three to four years, the aerial spiny shoots are trimmed and thicker stems are used as fuel wood. For fencing entire aerial shoots used (Plate 5.2C). Seasonal average fuel wood consumption of *Berberis aristata* at higher altitude was found to be 8-20 kg/year/household (Table 5.27). Whereas at temporary huts or shops consumptions *Berberis aristata* as fuel wood was only between April to October (near Chopta, Tungnath. At Kushkalyani (3000 m a.s.l) 10 families stay with their livestock for six months (during rainy season) and they consume 150-170 kg of *Berberis aristata* as fuel wood during this period. In Khiron Valley (Chamoli District), several other species are available for fuel wood *e.g.*, *Populus ciliata*, *Hippophae salicifolia* and *Salix denticulata*. Hence, there is less pressure on *Berberis aristata* (*ca.* 48-60 kg/season). Around Panwalikantha (Tehri District) there is heavy pressure on *Berberis aristata*, *B. umbellata* and *B. pachyacantha.*

Table 5.27 Seasonal fulewood collection of *Berberis* by shepherds' and transhumance in sub-alpine region. (>2500m), # = Total number

Village Name	Total families	# Fuel wood collecting family	Average Fuelwood collection (kg/house hold/ year)	# Fuelwood collection (#kg/ year)
Chopta	24	24	8-10	192-240
Kushkalyani	10	10	15-17	150-170
Pawali	21	21	10-12	210-252
Khiro	14	12	4-5	48-60
Dayara	15	12	11-14	132-168
Bedani	14	14	10-15	140-210
Budhi*	36	22	10-12	220-264

*Permanent village and data are for two years

Table 5.28 Fulewood and fencing collection of *Berberis* by villagers in cool temperate region. (2000-2300m), # = Total number

Village Name	Total families	# Fuelwood collecting family	Average Fuelwood collection (kg/household/ three year)	# Fuelwood collection (#kg/ three year)
Ransi	154	120	5-7	600-840
Bawsar	14	14	10-12	140-168
Jaalmalla	76	35	6-8	210-280
Chaumasi	45	25	7-9	125-175
Trijuginarayan	104	52	6-8	312-416
Tausi	23	23	10-12	230-276

Table 5.28 shows the extraction pattern of *Berberis asiatica*, *B. lycium*, *B. chitria* and *B. aristata* at 2000-2300m altitudinal zone in state. This data were collected from Rudraprayag distinct It shows that this is the major collection zone of *Berberis* species. Most of the villages preferred to collect *Berberis* species for fencing their agricultural land for protection of their crop by wild animals and free ranging cattle. This altitudinal zone has higher abundance of *Berberis* species. The local people cut and use the *Berberis* shoots as fencing material. Once fixed, the material lasts for two to three years. It was observed that average consumption of *Berberis* species as fuel wood around 2000-2300m altitude was 8-12 kg/three year/household (Table 5.28). Whereas, three years consumptions of *Berberis*

species as fuelwood was restricted between 230-840 kg/household. Maximum consumption was observed in Ransi village in Mandakini catchment between 600-840 kg/three years. Maximum consumption was observed at Bawsar in between 12-14 kg/household/three years. If any gap occurs in between their cropland "*Baad*" then they replace with new but otherwise they not preferred to cut every year.

Table 5.29 Fulewood and fencing collection of *Berberis* by villagers in warm temperate region. (1200-1600m), # = Total number

Village Name	Total families	# Fuelwood collecting family	Average Fuelwood collection (kg/household/ three year)	# Fuelwood collection (#kg/ three year)
Siroli	74	62	5-7	310-434
Mandal	89	79	5-7	474-632
Khalla	59	53	5-7	371-477
Koteshwar	55	46	5-7	368-460
Bandwara	47	41	5-7	369-451
Bairangana	39	33	5-7	330-396

Table 5.29 shows the extraction pattern of *Berberis asiatica*, *B. lycium* and *B. chitria* at 1200-1600m altitudinal zone in Mandal valley, Chamoli district in state. These villages have similar extraction pattern and uses of *Berberis* from their neighborhood. Extraction of *Berberis* was observed from 5 to 7 kg/house hold/ three year. Maximum families are dependent on *Berberis* species are found at Mandal village and lowest at Bairangana village. Due to other species, availability in warm temperate altitudinal zone (Table 5.31) this species is preferred on the availability of other species.

Table 5.30 shows the extraction pattern in represent in Panar and Ramganga (E) valleys in Kumaon. Here local people don't prefer *Berberis asiatica* as fuel wood. However, they clear the *Berberis* species from their hay plots ("*Mang*") to increase the grass production. Maximum use was observed in Naini village in Ramganga (E) river valley in between 110-154 kg/three year.

Table 5.30 Fuelwood and fencing collection of *Berberis* by villagers in sub-tropical region. (600-1000m), # = Total number

Village Name	Total families	# Fuelwood collecting family	Average Fuelwood collection (kg/household/ three year)	# Fuelwood collection (#kg/ three year)
Kathikharak	12	12	3-4	36-48
Matiyal	40	32	4-6	128-192
Chulagaon	22	12	4-5	48-60
Pilkhi	28	10	3-5	30-50
Naini	35	22	5-7	110-154

Table 5.31: Major fuelwood plant species in different altitudinal zones.

Altitudinal range	Vernacular name	Scientific name
Sub-tropical (600-1500m)	Dhaiti	*Woodfordia fruticosa*
	Chir	*Pinus roxburghii*
	Falyant	*Quercus lanuginosa*
	Mawa	*Engelhardtia spicata*
	Senduri	*Mallotus philippensis*
	Kaula	*Phoebe lanceolata*
	Ghingaru	*Pyracantha crenulata*
	Kilmora	*Berberis asiatica*
	Kilmora	*Berberis lycium*
Warm temperate (1500–2200m a.s.l)	Ratnyala	*Daphniphyllum himalayense*
	Banj	*Quercus leucotrichophora*
	Kingari	*Caesalpinia decapetata*
	Angyar	*Lyonia ovalifolia*
	Kilmora	*Berberis asiatica*
	Kilmora	*Berberis lycium*
	Bekhal	*Prinsepia utilis*
Cool temperate (2200–2700m a.s.l)	Uteesh	*Alnus nepalensis*
	Buransh	*Rhododendron arboreum*
	Kaul	*Neolitsea pallens*
	Mehal	*Pyrus pashia*
	Kingod	*Berberis aristata*
	Kharsu	*Quercus semecarpifolia*
	Moru	*Quercus floribunda*
	Angyar	*Lyonia ovalifolia*
	Kilmora	*Berberis asiatica*
	Kilmora	*Berberis lycium*
Sub-alpine	Simaru	*Rhododendron campanulatum*
	Kharsu	*Quercus semecarpifolia*

(2700–3300m a.s.l)	Kingor	*Berberis aristata*

5.4 Discussion

Ecological characterization of forest resources must extend beyond the taxonomic listing of plants useful to a specific community (Prance 1972; Alcorn 1984; Denevan et al. 1984; Boom 1987, 1990). In this study, attempts have been made to determine the availability (abundance and distribution) of medicinal *Berberis* species and patterns of extraction in the study area. This is the first study of its kind to document these parameters on highly valued *Berberis* species from the state of Uttarakhand. Three species of medicinally important *Berberis* which have good source of Berberine are currently extracted at commercial scale. No attempts have so far been made to cultivate *Berberis* and all the raw material comes from the wild. This calls for developing plans for sustainable harvest. Since, most of the medicinal *Berberis* species are not habitat specific and they are distributed all across different habitat types, it should be possible to promote regeneration of medicinal species in the middle elevation zones wherever degraded forests are available.

Shannon-Wiener index, Simpson's concentration of dominance index shows that species richness is considered as the primary measure of diversity. Temperate broadleaf forest was found most diverse. In the state fourteen different habitats type were identified and 19 *Berberis* species are present. Distribution of *Berberis* species along altitudinal gradient ranged between 600-4500 m a.s.l.. Maximum diversity of *Berberis* species was found between 2500 to 3500 m a.s.l.. This altitudinal range also coincides with the distribution of Kharsu Oak (*Quercus semecarpifolia*) (Figure 5.3). One of the main reasons of high *Berberis* species diversity in these forests is fact that *Berberis* has high affinity towards cool temperate zone and these altitudinal ranges has wide range of different habitats and forested areas. Wide range of associated trees, shrubs and herbs in these forests can be attributed to diverse habitat types and higher diversity of *Berberis* species. Rapid changes in land use and loss of these forests can have drastic effects on the populations of *Berberis* species.

Figure 5.16 shows that medicinally important *Berberis* species concentration has been found at altitudinal range between 1500 to 2600 m a.s.l in state. *Berberis aristata*, a well known medicinally important plant in IHR and its occurrence is reported from middle altitude areas (1800-3000 m) of the state of Uttarakhand and Himachal Pradesh (Samant et al. 1998; Chauhan 1999 and Ray et al. 2011). *Berberis aristata* had good populations in the high altitude mixed forest and Kharsu Oak forest in state and open canopy cover in KOF. The density and frequency of this species is in Uttarakhand were comparable with that of Great Himalayan National Park (GHNP) in Himachal Pradesh as reported by Singh and Rawat (1999) *i.e.*, D = 243.33 ha^{-1} ; F= 33.33 %). In GHNP it dominated the understory vegetation in lower temperate zone. In Uttarakhand Banj-Buras Mixed Forest (BBMF) has 10.3 ha^{-1} density with 4.38 % frequency and Kharsu-Oak Forest has 81.03 ha^{-1} density with 20.67 % frequency. Best regeneration pattern and girth class was found in high altitude mixed forest (Table 5.1). *B. aristata* has been distributed across 10-45° slope and best range in between 20-40° slope. Species also prefer 0 to 30 % of canopy cover (Figure 5.16). Best populations of species are found in between 2200-3000 m a.s.l.

Berberis asiatica is distributed between 600-2800 m a.s.l. in the state and best populations were found between 1400-2200 m a.s.l.. This species has wider range of distribution in state and from east to west it is widely distributed in this altitudinal range. It is the most common *Berberis* species in the state. The species preferred 5-46° slope and had highest densities between 18-35° slope. Species also prefer 0 to 60% canopy cover (Figure 5.16). Best density and frequency was observed in open area or along forest edges and fallow agricultural fields adjacent to mixed oak – rhododendron and Pine forests wherever little moisture is available (Table 5.2).

Berberis lycium ranged between 650- 2700 m a.s.l. in the state. Most of the populations of this species were found in Garhwal region. The species was found mostly between 20-45° slope, with high abundance between 25-35°. This species also preferred open canopy cover (30 to 50 %). Highest densities and frequency were observed in Banj forest where it had better regeneration (Table 5.3). At lower altitudinal zone Uniyal (2001) also reported good population of *Berberis lycium* in Bhagirathi valley between 1600-2000 m. a.s.l. Singh and

Rawat (1999) also reported 83.33 ha^{-1} and 6.67 % frequency at lower temperate forest in GHNP.

The above account clearly shows that *Berberis lycium* has rather narrow range of distribution in the state of Uttarakhand as compared to other two species. It may be due to the species' geographical distribution range. Other factors which might influence distribution could be eco-climatic conditions and seed dispersal pattern. These parameters would need in-depth ecological studies Distribution of various species including highly valuable *B. aristata* has been examined in relation to environmental gradient using CCA. It was found that *B. aristata* is highly correlated with increased moisture gradient. *B. asiatica* and *B. lycium* grows at lower altitudes and in the temperate valley there is always higher temperature and at higher altitude temperature is lower. Regression equations provided the best goodness of fit statistics, increasing statistical efficiency in biomass estimates. For species with large data samples and biomass can be calculated with the help of regression equation between dry weight and volume of plant part. These equations provide the manager and research scientist with tools to quickly estimate *Berberis* biomass in state of Uttarakhand. The R^2 values for *Berberis aristata* stem (Table 5.8), *Berberis asiatica* stem (Table 5.12) and root (Table 5.16) and *Berberis lycium* stem (Table 5.20) and root (Table 5.24) suggested that the regression equations were good predictors of dry weights for these species. With length and circumference of the given species parts, volume can be calculated and after volume calculation biomass can be predicted with the help of these equations.

Table 5.32: Biomass equation for stem and root part of diffrent *Berberis* species

Species	Parts	Volume (cm^3)	Dry weight (g)	Predictive equations	R^2
B. aristata	**Stem**	10	26.68	DW (g) = 23.88+0.288*Volume (cm^3)	0.95
B. asiatica	**Stem**	10	78.55	DW (g) = 76.05+0.25*Volume (cm^3)	0.93
	Root	10	162.51	DW (g) = 159.41+0.31*Volume (cm^3)	0.67
B. lycium	**Stem**	10	25.62	DW (g) = 23.82+0.18*Volume (cm^3)	0.97
	Root	10	226.55	DW (g) = 224.35+0.22*Volume (cm^3)	0.74

Uniyal (2001) has regression equation for relationship between diameter and dry weight of *Berberis lycium* based on basal part of the stem (10 cm above ground circumference). Where

he had put Y= 119.97x – 421.14 (R^2= 0.86). With the help of this equation for eg. If the above ground part have 15 cm circumference at 15 cm in length whole biomass above ground will be 160.97 g. and my equation for *B. lycium* gives for 15 cm circumference and 15 cm in length of plant part gives 126.11 g dry weight. If the plant part above gound or below ground have 5 cm in length and 5 cm in circumference then volume for 10 (9.95) cm^3 were calculated in Table 5.32 for medicinally important species of *Berberis*. Table 5.32 clealy shows that roots have larger weight compared to stem. Inclusion of larger part would probably alter their regression coefficients for roots. Peek (1970) suggested that a stable relationship between shrub canopy area and weight would occure when a stable overstory canopy has developed, or when a shrub community has matured to where further growth is minimal and decadence is not appreciable. Whittaker (1962) reported that the proportion of growth of a shrub which is distributed in current twigs and leaves decreases as the shrub mature. Plants growing under tree cover exhibited different form from those growing in open areas. Average goodness of fit estimates changed between equations at different scales. When adding more individuals into the sampling, the goodness of fit statistics reduces statistical efficiency in estimating total biomass of varience will increase.

Considerable research has gone into estimating the biomass of individual shrub species (Murrey and Jacobson 1982; Frandsen 1983, Navar et al. 2002). Land managers and researchers require reliable estimates of total tree or component weights to assess site productivity, food abundance, treatment effects, and fuel loading (Kie and White 1985). Estimate biomass components, non-destructive techniques are needed, which are rapid, relatively accurate, and few training requirements. The choice of model and the method of fitting parameters are two of the most common features that must be considered when estimating biomass (Wood et al. 1991). A variety of regression models have been developed for estimating total tree biomass or tree component biomass (Clutter et al. 1983), and they fall into three main forms (a) Linear additive error, (b) nonlinear additive error, and (c) nonlinear multiplicative error (Parresol 1999). As roots of *Berberis* species are used for medicinal purpose. However, it was tried to develop the ratio of root and shoot with respects to per unit volume i.e. 1 cm^3.

Berberis aristata, known as *Daruharidra* in Ayurveda has diverse uses locally such as fuel wood, fodder for goats, fruits, live-fence and medicinal value. Roots of this species yield valuable alkaloid, berberine of isoquinoline nature. Forest community of species must be evaluated to better understand the role of *Berberis* species in the ecosystem and how harvesting could impact the sustainability of the entire system. Demand of *Berberis* species is incrasing anually in indigenous drug industry and supply of these valuable species in market is unkown. There is urgency for conservation of these valuable species and proper sustainable harvestation plan need to to prepaired for diffrent areas in state. During the present study, it was observed got only one incidence of extraction of *Berberis* species for medicinal purpose in the state. In Upren Khal, Pauri district forest department had allowed to extract *Berberis asiatica* and *Berberis lycium* roots from agricultural land. 39-40 Quintals of *Berberis* were collected from 160 ha of land and sold to a middle man. This material was moved to Ramnagar mandi in state.

Most of the *Berberis* species are extracted from the state for fencing of agricultural land on a rotational basis at the gap of two to three years. The fenced material on complete drying can be used as fuel wood. Most of the households at high altitudes (2000-2500 m) used more *Berberis* species as a fuel wood and fencing purpose. The use diversity of fuel wood species depends on the wood quality, accessibility, availability and the human population in the surrounding villages (Singh et al. 2010). Warm temperate region (1000-2200 m) in the state is relatively rich in woody components (Oak forests) and thus villagers use a large number of species as fuelwood (Singh et al. 2010). Villagers have easy access to *Berberis asiatica, B. lycium*, *Q. leucotrichophora, Daphniphyllum himalayense* and *Caesalpinia decapetata*, with good quality wood that retains heat longer according to inhabitants. By contrast, the cool temperate and subalpine regions in state are species poor and thus offer only few utilizable species (Table 5.31). Similarly, at higher altitude *Berberis aristata, Berberis chitria*, *Q. semecarpifolia, Q. floribunda, Rhododendron arboreum* and *R. campanulatum* are easily available to shepherds and transhumance, have hard wood and yield high quality coal as the most preferred resource. In Garhwal Himalaya, the only cost of fuel wood collection is physical effort and the time taken. The present study showed that consumption of *Berberis* species as fuel wood and fencing purpose is simultaneously taking place at

different altitudes by villagers ranged from 5 to 15 kg/household/years. However, the extraction of *Berberis* is higher in high altitude (13-15 kg/house hold/year) (Table 5.27) as compared to lower altitudinal villages in state (3-7 kg/house hold/year) (Table 5.30). This could be due to altitudinal variations and climatic conditions as firewood consumption was 2–3 fold higher at higher (4200 m) compared to fuel wood used at low altitude (up to 500 m) (Bhatt and Sachan 2004). Because of the fuel wood consumption pattern at different altitudes, it seems imperative to seriously consider the problem of deforestation and habitat loss of *Berberis* species in the state.

5.5 Conclusions

i. Three species of *Berberis* are known to have medicinal value in the state, *viz.*, *B. aristata, B. asiatica* and *B. lycium*. Population status and biomass availability of these species and extraction pattern were assessed in Garhwal region of the state.

ii. The medicinal species of *Berberis* are patchily distributed in the state. *B. asiatica* and *B. lycium* has the most wide altitudinal range (500 to 2600 m) while *B. aristata* was confined to a narrow altitudinal zone (2200 to 3500 m).

iii. Regeneration status of *Berberis asiatica* was best in Banj-Burans Mixed forest and High altitude mixed forest. *Berberis aristata* was best in Kharsu Mixed forest. Regeneration of *Berberis lycium* was best in open canopy cover and temperate grassy slopes.

iv. The official records of State Forest Department and interviews with the local people revealed that the demand of *Berberis* species in the market fluctuates considerably. During the study period, *B. asiatica* and *B. lycium* were extracted only from two localities in limited quantity to the tune of 4000 kg. This translates to 790-825 adult individuals of *B. asiatica* and *B. lycium*.

v. It was found that there is heavy pressure on these valuable medicinally important *Berberis* species, and extracted heavily for fuel wood. These pressures are mainly more on those areas which are away from road side, although, the provision of LPG or kerosene scheme only to the villagers at a small scale seems practically suitable for such areas can be useful to protect these species.

vi. Extraction of *Berberis* species near most of the interior villages was self-re*gulated,* on rotational basis (3–5 years cycle, depending upon the growth pattern). It is unlikely that the villagers will take up further conservation and propagation of medicinal *Berberis* around villages unless there is an assured market and suitable price. A suitable buy-back scheme with the herbal industry would ensure such schemes.

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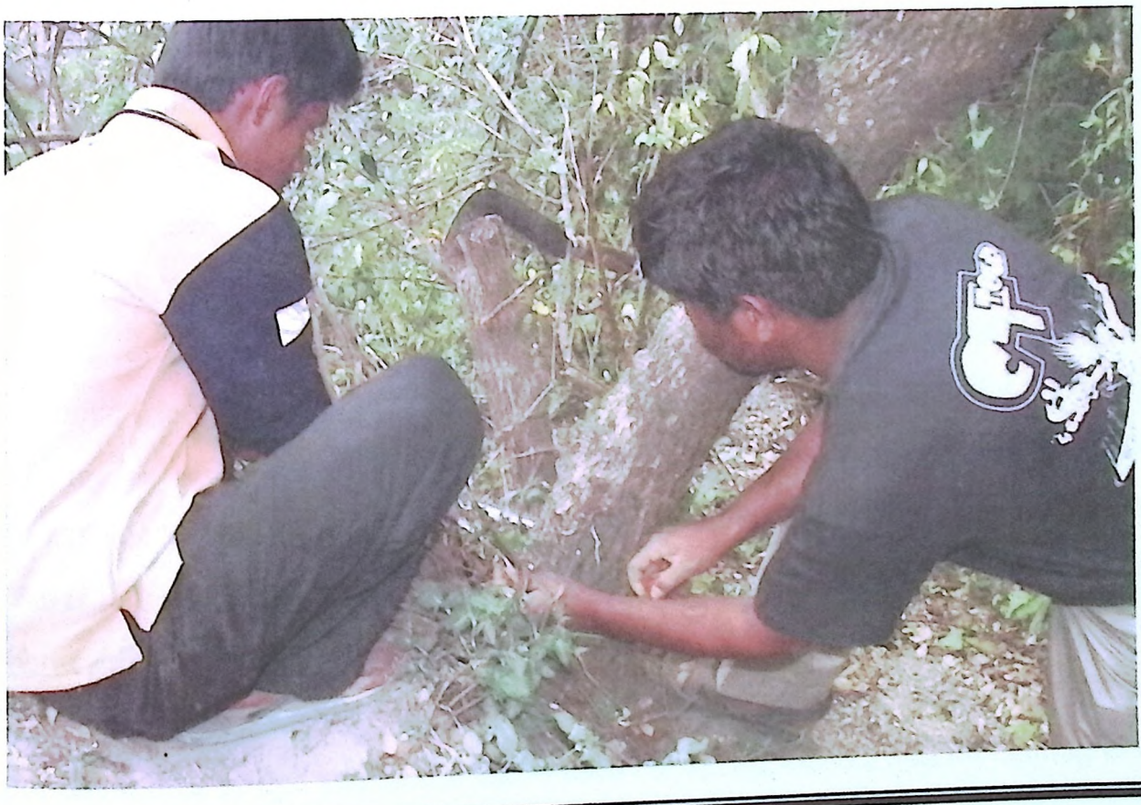
Chapter 6: Conservation measures



CHAPTER 6.0
CONSERVATION MEASURES

We should preserve every scrap of biodiversity as priceless while we learn to use it and come to understand what it means to humanity.

- E. O. Wilson

6.1 Introduction

Humankind has affected our planet in many ways. Rapid increase in human population, drastic changes in resource consumption pattern and increasing pace of development have affected the natural ecosystems severely. Degradation of natural ecosystems would mean loss of basic life support system, destruction of the conditions that sustain life, habitat degradation and loss. Hence, conservation of species and habitats along with their natural ecosystems assumes greater significance in the present context (CBD 2010). According to an estimate, about 60,000 out of 2, 87, 655 species of plants known in the world are facing the threat of extinction. Presently, as many as 8321 species of plants fall under various threat categories as per IUCN's Red Data Book (Govaerts 2005, IUCN 2003). In India, of the 17,500 species of higher plants, 7500 are known for medicinal uses. This proportion of medicinal plants is the highest proportion of plants known for their medicinal purposes in any country of the world for the existing flora of that respective country. Ayurveda, the oldest health care system in India has alone reported the use of approximately 2000 species of medicinal plants for the cure of various ailments. The Charak Samhita, an age-old written document on herbal therapy, reports on the production of 340 herbal drugs and their indigenous uses (Kala et al. 2006). Currently, approximately 25% of drugs are derived from plants, and many others are synthetic analogues built on prototype compounds isolated from plant species in modern pharmacopoeia (Rao et al. 2004). Different species of *Berberis* (e.g. *Berberis aristata, B.asiatica, B. lycium, B. chitria* and *B. jaeschkeana*) are used as a source of berberidine to cure certain eye diseases (Kala et al. 2006). According to Watt (1889), it was one of the best tanning dyes available in India during that period. This plant is also an important source of dye and tannin and is used for dyeing clothes and for tanning leather.

Degradation and loss of natural habitats can have cascading effects on rare, endemic and threatened taxa and their life-history processes. Hence, habitat conservation and restoration in many parts of the world needs to be given highest priority by the conservation agencies. The Himalayan region, being geologically young and ecologically most fragile, is extremely vulnerable to anthropogenic pressures and degradation of habitat. This region is considered the centre of origin and diversification for several groups of plants including the family Berberidaceae. Most of the Berberidaceae members are habitat specific, insect pollinated and zoochorous (animal dispersed). Changes in habitat conditions can affect the pollinators as well as dispersal agents leading to depletion of the populations of particular species. Several species of *Berberis* exhibit synchronous flowering. As a result, there can be natural hybridization and morphological complexity in many populations. For example, *Berberis lycium* and *Berberis asiatica* bloom at same time and share the habitat. Therefore, several intermediate growth forms and a great deal of morphological variation can be seen in plant height, leaf colour, texture and floral characters of these species. Natural hybridization paves way for insipient speciation, maintenance of genetic diversity and evolutionary processes. However, rapid decline in populations of several genotypes, isolation of certain populations and loss of pollination vectors could have negative effect on many species. Studies on the population status and autecology of medicinal and endemic species of *Berberis* in the state (Chapters 4 and 5) reveal that many species are extremely patchy in distribution and have extremely low populations. This is a major cause for concern. This chapter deals with major threats to *Berberis* species in the state of Uttarakhand, possible conservation measures including identification of areas for conservation and development (propagation) and evaluation of endemic species according to IUCN criteria.

6.2 Major Threats to *Berberis* Populations

Major threats to *Berberis* populations in the state are as follows:

i) Habitat Degradation and Loss

Habitat loss is the primary cause of species decline at local, regional and global scales. Urban development, road building, forest fires, agriculture and deforestation lead to

destruction and degradation of natural habitats. It is estimated that habitat destruction from human activity is the primary cause of decline for 83% endangered plant species. Rates of destruction of tropical rain forest (particularly species rich habitat) vary between places, but some studies (Laurance et al. 2001) have calculated on an average 1% per year (an alarming figure consider the cumulative effect over 50 years), whilst Laurance et al. (2001) suggested that recent deforestation had proceeded at the rate of 2 million hectares per year. We do not know the exact relationship between deforestation rates and loss of biodiversity. Many factors are involved in this complex relationship, since even the removal of a few tree species from a forest may cause a cascade of species losses due to changes in microenvironment, the removal of "keystone" species or disruption of the highly complex interrelationships among species (Mills et al. 1994).

Berberidaceae members are usually threatened due to habitat loss, degradation and defragmentation of forest area. These can be caused by two means, *i.e.*, natural threats and human activity. After the declaration of new state (Uttarakhand), a lot of developmental activities such as construction of new roads, infrastructure development have taken place. As most of the *Berberis* species are present in open areas and outer fringes of forested area or civil land and all the developmental activities are taking place along these areas, resulting in the habitat fragmentation, disturbance in natural ecosystem, and ultimately affecting the population of *Berberis* species.

Some of the endemic species of *Berberis* and *Mahonia* have limited populations and exist in one or two different localities in the State. If any natural disaster occurs due to some reason these populations may face extinction from the wild, some of the exotic species suppress the growth of these indigenous species. They even alter the population of pollinators, which in turn, may replace the native pollinators and affect pollination of *Berberis*. For instance, in some places in pine forest or Banj oak forest wherever moisture is available *Eupatorium adenophorum* grow fast and occupy the ground vegetation leading to poor regeneration of native species. *Berberis asiatica* and *B. lycium* are particularly affected by such invasive species between 1000-1600 m a.s.l. in the state (personal observations).

Excessive influx of tourists can also cause degradation of habitat. For example, the Yamunotri valley, an excellent habitat for *Berberis* species (viz., *B. aristata, B. umbellata, B. jaeschkeana* and *B. pachyacantha*) has undergone rapid degradation due to development of tourism infrastructure during last two years. Above Janakichattii there were good patches of *Berberis pachyacantha*, *B. aristata* and *B. umbellata.* It was observed that during 2010 several patches of Berberis were fully cleared, and new shops were constructed. Similarly, *Berberis kunawurensis* has only two localities in the State (near Shukhi village and on way to Mundali, near Deoban). The populations near Shukhi village under threat due increasing tourism in Gangotri and lot of construction of new hotels and *dhabas*.

ii) Eradication of *Berberis* Species in the Past

Many species of *Berberis viz., Berberis asiatica* and *Berberis lycium* serve as alternate host species of the wheat rust (fungus *Puccinia graminis)*, a grass-infecting rust which is a serious fungal disease of wheat and related grains. For this reason, *Berberis* species were eradicated during 1960 to 70's without knowing the adverse effect to existing populations. Historically, stem rust has caused major devastation to wheat crops in most of the wheat-growing areas of the world (Roelfs et al. 1992). *B. lycium*, native to western Himalaya, was also eradicated for this reason. At present, only stunted and short individuals can be seen in the State.

iii) Over Exploitation of Medicinal Species

B. aristata, *B. asiatica* and *B. lycium* are known for their medicinal properties. As such, three species of *Berberis* are medicinally important and they were extracted from the State in the past. Their status and distribution pattern is presented in chapter 5. Lack of proper management system is also responsible for uncontrolled extraction of medicinal plants in various parts of the State, especially high altitude meadows (Bughiyals). The State has a system adopted to establish control through permits and contracts for extraction and transportation of medicinal plants. This includes commercial exploitation of these plants. State does not have any sufficient capabilities or system for thorough assessment of these

plants in the forests for timber, fuel wood, fodder and medicinal plants production for future sustainable management.

Due to uncontrolled collection of medicinal plants in the absence of proper management systems, the locals usually collect these plants prematurely using improper techniques like uprooting of plants, collection of wrong part of the plant *etc.* that resulted in poor quality of plant material. In the State, these species are extracted as fuelwood, but no other uses by local people were observed.

iv) Extraction for Fencing Material and Fuelwood

Three species of *Berberis viz., B. asiatica*, *B. aristata* and *B. lycium* are mostly extracted for fuelwood **(Chapter 5.3.8)**. In Tons, Yamuna, Bhagirathi, Alaknanda, Ramganga (E and W), Saryu and Kali river valleys the entire aerial shoots are cut and dried for the purpose of fuelwood. The agro-pastoral communities in the middle hills protect their crops from free ranging cattle and wild animals by fencing the outer edges of the fields with the help of thorny bushes. *Berberis asiatica* and *B. lycium* are among the preferred species for this purpose. Most of the places in the state farmers use *Berberis* species as fencing material around their houses and protecting their crop from cattle and wild animals. As *Berberis* species has thorny habit and leaves with spinulose margin, due to this nature it is exploited for protection of agricultural field. During the study period, it was found that almost all the species, which are present near the vicinity of villages local people uses for same. During winter time most of the collection of *Berberis* for fuelwood is takes place in the State. It dries fast and burn and produce good fire that is why it is highly preferred as fuelwood in villages.

6.3 Conservation Measures

The choice of conservation strategies varies depending upon the objectives and priorities. For most of the medicinal plants both *in situ* and *ex situ*, strategies are equally important. These strategies have to be considered complementary and may constitute an integral part of

programmes aiming at improved use of genetic resources available in nature. In choosing conservation strategies, three main dimensions to conservation, *i.e.*, quality, quantity and time must be considered.

Dr. Swaminathan (1995) said that the aspect, which needs consideration, is the use of nature conservation and enhancement as a powerful instrument in poverty eradication programmes. Today, there is commercial interest in the exploitation of biodiversity, particularly in medicinal plants and microorganisms. Unless an equally powerful economic stake in conservation matches the growing commercial interest in exploitation, protection of biodiversity will become a lost cause.

6.3.1 Protection of Habitat for Endemic Species

Eight taxa of Berberidaceae are endemic to the State. The present study deals with the autecology of three endemic species (Chapter 4). Localities have been identified for these species for proper conservation plan. As such, no use or extractions was observed of endemic species, but habitat loss is the major threat to these species. Figure 6.3 shows the localities of these endemic species. These localities have been suggested for inclusion in the Working Plan of Pithoragarh Forest Division. It is recommended that such sites should be protected and plantation activities at such sites should be avoided.

6.3.2 Conservation and Development of Medicinally Important Species

Based on the availability and distribution of medicinal plants, each Forest Division in the State of Uttarakhand is expected to develop Conservation, Development and Harvest (CDH) plan (Rawat et al. 2004). For medicinally important *Berberis* species, detailed information on populations has been collected (Tables 6.1 and 6.2). These densities were categorized into three levels: high, medium and low. Based on the densities, map is generated (Figure 6.1 and 6.2). It was found that *B. aristata* has best populations between 2200 to 2500m in the State and *B. asiatica* has best populations range between 1000-1600m in State. Based on these findings following recommendations can be made:

i. **Conservation and Development of *Berberis aristata*:** Mundali block of Bawar Range in Chakrata FD can be considered for assisted natural regeneration (development) for this species. Dhudhatoli IV (N)-19 & 20 is recommended for the conservation and development of East-Ameli Range of Pauri Garhwal FD. In Rudraprayag FD of Agastmuni Range, Khetraswami II-1 has very good population of *Berberis aristata,* recommended for conservation and development. Near Phoolchatii on way to Yamnotri have very good patch of *B. aristata* and can be conserve, Near Gangi to Kharsali it has very good patch of *B. aristata* and can be consider for development. Dunda Range's Ranukigad Block and Ranadi Block and Jalkurgad Block can be considered for conservation and development of *Berberis aristata* in Uttarkashi FD (Figure 6.1).

ii. **Conservation and Development of *Berberis asiatica*:** Development of this species can be considered Ameli-VI-2, Ameli VII- 4, Ameli VIII-14 & Ameli-IX-31 and after 4-5 years of CD it can be harvested (10-20% of total population) but reassessment is required before harvest. Narendranagar FD, Saklana Range's Bagi, Pujargaon and Surkunda blocks shows good population of *Berberis asiatica* and can be considered for development of the species. Bhilangana range of Tehri FD has good source population and Bhigon-8 is recommended for development. Mugarsanti Range of Upper Yamuna FD's Molda block can be considered for conservation and development of *B. asiatica.* Rawain Range's Patangani block can be considered for conservation and development. Uttarkashi FD's Mukhem range has some good blocks that can be used for development of *Berberis asiatica* (Figure 6.2).

Cultivation may appear to be the answer, but it is not always that straightforward. Some species are difficult to grow in artificial conditions and cultivation may be unprofitable for farmers owing to the long growing time between planting and commercial harvest. Much less emphasis is being put on development and promotion of sustainable wild collection practices, which may be the only viable option to ensure sustainable supplies of some of these species.

Table 6.1. Distribution of Berberis aristata in various Forest Divisions of Garhwal Region, Uttarakhand

Division	Range	Beat	Block	Comp.	Class	Density (individuals ha^{-1})	Frequency (%)	A/F Ratio
Chakrata FD	Kanasar	Paninal	Kunain	2	L	12.73±0.00	5	0.40
Tehri FD	Bhilangana	Gangi	Gangi	16	L	12.73±0.00	10	0.10
Badrinath FD	Chamoli	Sartoli	Dasoli VIII (North)	8	L	19.09±0.00	15	0.07
Upper Yamuna FD	Yamnotri	Rana	Rana	5b	L	19.09±0.00	5	0.60
Kedarnath WD	Gopeshwar	NF	NF	NF	L	25.46±0.00	20	0.05
Narendranagar FD	Saklana	Kaddukhal	Khurat	4	L	25.46±0.00	10	0.20
Upper Yamuna FD	Mugarsanti	Kanseru	Kanseru	6b	L	25.46±0.00	5	0.80
Uttarkashi FD	Gangotri	Cholvi	Dharali	3a	L	28.28±0.00	7	0.43
Upper Yamuna FD	Yamnotri	Durvil	Bhairab	2a	L	31.82±2.12	10	0.25
Uttarkashi FD	Dunda	Ranadi	Ranaki	5	L	31.82±0.71	10	0.25
Uttarkashi FD	Dharasu	Patharkhol	Nagungad	6b	L	38.18±1.41	10	0.30
Uttarkashi FD	Dunda	NF	NF	NF	L	50.91±0.55	25	0.06
Uttarkashi FD	Dharasu	Khurmola	Khurmola	6b	L	82.73±0.55	25	0.10
Garhwal FD	East-Ameli	NF	NF	NF	L	89.09±0.84	25	0.11
Uttarkashi FD	Badahat	Badahat	Utraun	7	L	89.09±2.08	15	0.31
Garhwal FD	Pokhra	Satnauli	Ameli-V	10	L	101.82±0.82	30	0.09
Upper Yamuna FD	Yamnotri	NF	NF	NF	L	101.82±1.48	25	0.13
Uttarkashi FD	Badahat	Kawan	Kawan	3b	L	133.64±0.55	30	0.12
Uttarkashi FD	Dharasu	Diwarikhol	Daski	7	L	146.37±0.95	50	0.05
Uttarkashi FD	Dunda	Chorgi	Dhanari	14b	L	152.73±1.32	45	0.06
Uttarkashi FD	Dharasu	Patharkhol	Nagungad	6a	L	159.09±1.81	35	0.10
Rudraprayag FD	Agastmuni	Fata	Maikhanda I	3a	L	178.19±1.06	53	0.05
Rudraprayag FD	Agastmuni	Kanakchauri	Khetraswami II	1	M	222.73±1.40	55	0.06
Garhwal FD	East-Ameli	Dudhatoli	North Dudhatoli-IV	20	M	241.82±1.81	35	0.16
Uttarkashi FD	Mukhem	Dhotri-IV	Jalkurgad	29c	M	248.19±2.33	50	0.08
Badrinath FD	Pindar Central	Ratgaon	Pindarpar II	20	M	267.28±2.40	55	0.07

Badrinath FD	*Pindar East*	Wan	Pindarpar IV	11	M	273.64±0.92	75	0.04
Rudraprayag FD	South Jakholi	Budhna-I	Longa	13b	M	280.01±4.86	45	0.11
Upper Yamuna FD	Kuthnaur	NF	NF	NF	M	299.10±3.30	35	0.19
Uttarkashi FD	Dunda	Von-I	Ranukigad	4b	M	311.82±10.21	25	0.39
Chakrata FD	Bawar	Lakhon	Mundali	10	M	356.37±1.98	75	0.05
Badrinath FD	Pindar East	Guramtoli	Nawali I	13a	H	502.74±1.43	100	0.04
Garhwal FD	Pokhra	Pokhra	Ameli-V	6	H	515.46±1.86	85	0.06
Uttarkashi FD	Taknaur	Barsu	Raithal	6a	H	534.56±2.25	85	0.06
Garhwal FD	West-Ameli	Naugawakhal	Ameli-VII	4	H	572.74±1.94	90	0.06
Narendranagar FD	Saklana	NF	NF	NF	H	667.39±3.75	95	0.11

FD: Forest Division; WD: Wildlife Division; NF: Non forest; Comp.: Compartment; A/F: Abundance/Frequency; H: High; M: Medium; L: Low.

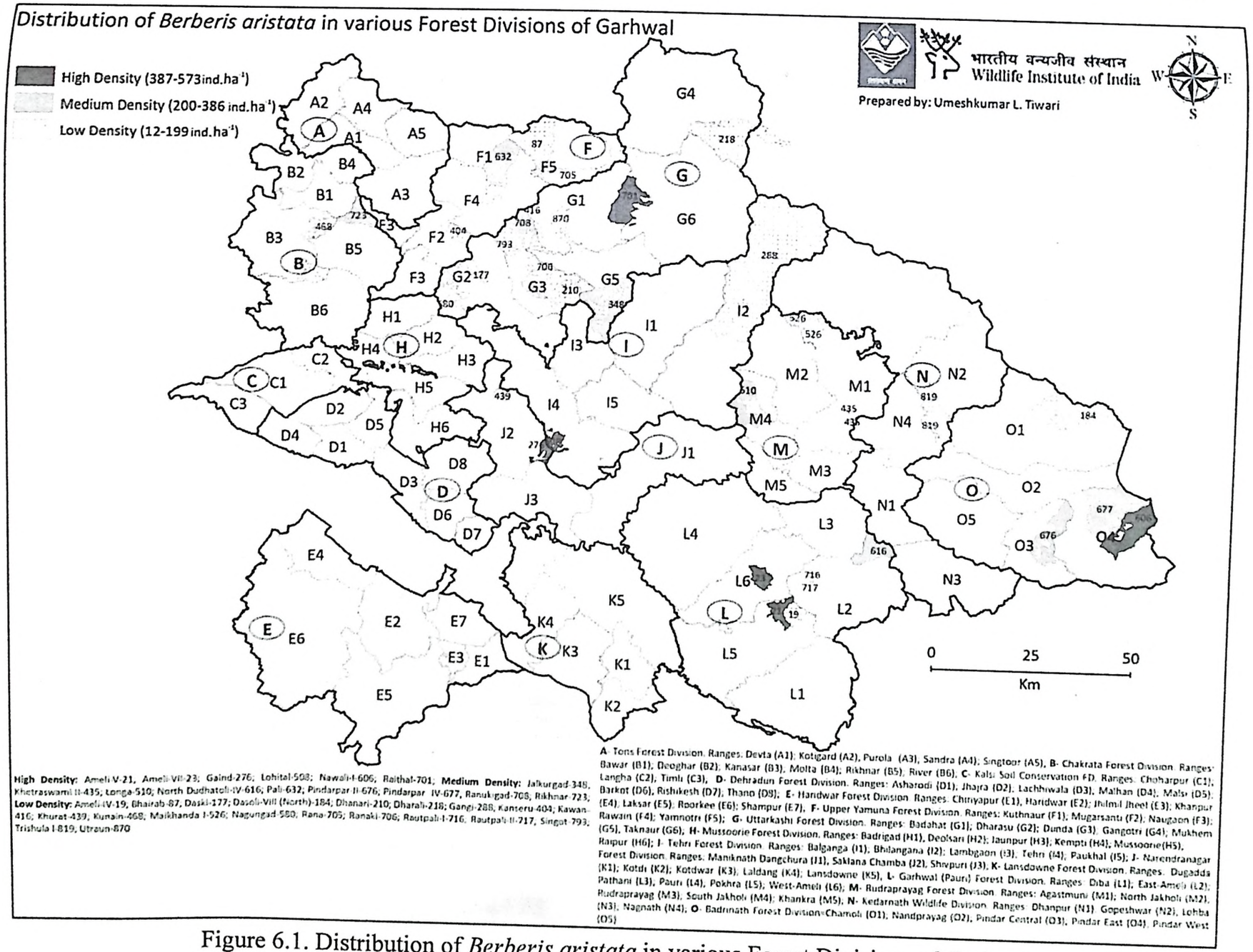


Figure 6.1. Distribution of *Berberis aristata* in various Forest Divisions of Garhwal

Table 6.2. Distribution of *Berberis asiatica* in various Forest Divisions of Garhwal

Division	Range	Beat	Block	Comp.	Class	Density (individuals ha^{-1})	Frequency (%)	A/F ratio
Uttarkashi FD	Dharasu	Khurmola	Khurmola	6b	L	6.36±0.00	5	0.20
Tons FD	Devta	Devti	Thadiyar	2	L	6.36±0.00	5	0.20
Tons FD	Devta	NF	NF	NF	L	6.36±0.00	5	0.20
Upper Yamuna FD	Mugarsanti	Bhatia	Bhatia	4	L	12.73±0.00	5	0.40
Upper Yamuna FD	Kuthnaur	Pali	Pali	18a	L	12.73±0.00	5	0.40
Uttarkashi FD	Taknaur	Huri-II	Huri	6b	L	12.73±0.00	5	0.40
Narendranagar FD	Shivpuri	Oni	Kunjapuri	3	L	19.09±0.00	5	0.60
Upper Yamuna FD	Rawain	Bigrari	Bigrari	7a	L	19.09±0.00	5	0.60
Tehri FD	Lambgaon	Pratapnagar	Pratapnagar	4	L	31.82±0.00	5	1.00
Upper Yamuna FD	Kuthnaur	Wazri	Wazri	7	L	31.82±2.12	10	0.25
Tons FD	Kotigard	NF	NF	NF	L	31.82±0.00	5	1.00
Upper Yamuna FD	Kuthnaur	Ponti	Kimdaara	10b	L	38.18±1.41	10	0.30
Upper Yamuna FD	Rawain	Masalgaon	Masalgaon	1d	L	38.18±2.83	10	0.30
Narendranagar FD	Saklana	NF	NF	NF	L	44.55±1.53	15	0.16
Uttarkashi FD	Dunda	Chorgi	Dhanari	14b	L	44.55±0.58	15	0.16
Tons FD	Purola	NF	NF	NF	L	44.55±1.15	15	0.16
Upper Yamuna FD	Kuthnaur	Kuthnaur	Kuthnaur	2a	L	50.91±0.58	15	0.18
Uttarkashi FD	Dharasu	Khurmola	Khurmola	4	L	50.91±0.58	15	0.18
Badrinath FD	Pindar Central	Sarkot	Devsari IV	2b	L	57.27±0.96	20	0.11
Chakrata FD	Molta	Molta	Khunigad	8	L	57.27±0.45	25	0.07
Dehradun FD	Thano	Ladwakot	Ladwakot	Ladwakot	L	63.64±1.32	15	0.22
Upper Yamuna FD	Rawain	Patangni	Patangni	10b	L	63.64±2.83	10	0.50
Uttarkashi FD	Mukhem	Sauragad-III	Sauragad	4f	L	63.64±0.58	20	0.13
Tons FD	Devta	Mora	Danda	88	L	63.64±1.15	15	0.22
Tons FD	Kotigard	Maunda	Dunpur	3	L	63.64±1.41	10	0.50
Kedarnath WD	Lohba	Kudhan I	Kundhan	2	L	70.00±0.50	20	0.14

Chakrata FD	Kanasar	Misau	Kanasar	13	L	70.00±0.96	20	0.14
Chakrata FD	Bawar	Kathian	Dharmigad	9	L	70.00±0.45	25	0.09
Upper Yamuna FD	Kuthnaur	NF	NF	NF	L	76.37±1.00	15	0.27
Uttarkashi FD	Mukhem	NF	NF	NF	L	82.73±0.55	25	0.10
Tons FD	Kotigard	Kasta	Baanpur	2	L	82.73±0.98	30	0.07
Tons FD	Sandra	Salla	Saras	3	L	82.73±0.96	20	0.16
Badrinath FD	Pindar West	Amsor	Nalgaon	2a	L	95.46±0.67	55	0.02
Dehradun FD	Thano	Pled	Pathar kha	1	L	95.46±2.31	15	0.33
Upper Yamuna FD	Rawain	Patangni	Patangni	3	L	101.82±2.08	15	0.36
Upper Yamuna FD	Kuthnaur	Pali	Pali	17a	L	101.82±1.10	25	0.13
Upper Yamuna FD	Yamnotri	NF	NF	NF	L	101.82±1.10	25	0.13
Badrinath FD	Pindar Central	NF	NF	NF	L	108.18±0.98	35	0.07
Upper Yamuna FD	Kuthnaur	Kishala	Kishala	1	L	108.18±4.02	30	0.09
Lansdowne FD	Lansdowne	Gadmola	Silogi	1	L	114.55±0.89	30	0.10
Narendranagar FD	Saklana	NF	NF	NF	L	120.91±0.78	45	0.05
Upper Yamuna FD	Kuthnaur	Kuthnaur	Kuthnaur	10b	L	120.91±2.39	40	0.06
Uttarkashi FD	Mukhem	Baragaddi-I	Baragaddi	8c	L	120.91±0.93	45	0.05
Tons FD	Kotigard	Maunda	Dunpur	3	L	133.64±0.84	30	0.12
Narendranagar FD	Saklana	Manjgaon	Manjgaon	2	L	146.37±1.13	40	0.07
Kedarnath WD	Gopeshwar	NF	NF	NF	L	152.73±7.07	20	0.30
Uttarkashi FD	Mukhem	Jamak-IV	Jamak	6b	L	159.09±0.99	40	0.08
Upper Yamuna FD	Rawain	Syalna	Syalna	6a	L	165.46±1.83	40	0.08
Tons FD	Purola	NF	NF	NF	L	184.55±1.60	50	0.06
Uttarkashi FD	Dharasu	Diwarikhol	Daski	7	L	190.91±1.58	45	0.07
Uttarkashi FD	Mukhem	NF	NF	NF	L	248.19±2.13	50	0.08
Dehradun FD	Thano	Bhogpur	Bhogpur	6	L	254.55±2.94	45	0.10
Badrinath FD	Pindar Central	Dungri	Pindarpar II	2b	L	265.62±1.26	65	0.05
Upper Yamuna FD	Kuthnaur	Kupra	Kupra	3	L	267.28±2.35	45	0.10

Narendranagar FD	Saklana	Bagi	Bagi	7	L	407.28±3.03	80	0.05
Uttarkashi FD	Dharasu	NF	NF	NF	M	286.37±2.09	60	0.06
Narendranagar FD	Saklana	Pujargaon	Pujargaon	5c	M	292.73±1.62	75	0.04
Uttarkashi FD	Mukhem	Jamak-IV	Jamak	7b	M	299.10±1.86	45	0.12
Uttarkashi FD	Mukhem	Dhotri-II	Jalkurgad	27a	M	324.55±1.55	75	0.05
Uttarkashi FD	Dharasu	Dichli	Dichli	6b	M	330.92±2.97	50	0.10
Tehri FD	Balganga	Bhigon	Bhigon	8	M	343.64±2.22	80	0.04
Uttarkashi FD	Badahat	Seku-I	Dodital	1a	M	348.62±3.55	47	0.12
Upper Yamuna FD	Mugarsanti	Molda	Molda	1a	M	362.73±1.86	80	0.04
Upper Yamuna FD	Kuthnaur	Pujargaon	Pali	1a	M	388.19±3.67	50	0.12
Uttarkashi FD	Mukhem	Baghi-III	Jalkurgad	22b	M	439.10±1.28	100	0.03
Narendranagar FD	Saklana	Jwarana	Surkunda	4b	M	470.92±1.54	80	0.06
Uttarkashi FD	Dunda	Nakuri	Singot	6	M	496.37±6.16	50	0.16
Narendranagar FD	Saklana	Pujargaon	Pujargaon	6a	M	509.10±0.92	100	0.04
Badrinath FD	Pindar West	Non Forest	NF	NF	M	547.28±1.57	100	0.04
Uttarkashi FD	Mukhem	Baghi-III	Jalkurgad	22b	H	547.28±2.43	100	0.04
Badrinath FD	Pindar East	Lausari	Nawali II	1c	H	553.65±2.43	90	0.05
Narendranagar FD	Saklana	NF	NF	NF	H	579.10±2.55	85	0.06
Upper Yamuna FD	Rawain	Patangni	Patangni	8	H	674.56±4.05	80	0.08
Badrinath FD	Pindar Central	Gawaldam	Talwari	1	H	744.56±4.59	85	0.08
Badrinath FD	Pindar East	NF	NF	NF	H	795.47±4.28	100	0.06
Tehri FD	Bhilangana	NF	NF	NF	H	2621.87±21.99	90	0.25

FD: Forest Division; WD: Wildlife Division; NF: Non forest; Comp.: Compartment; A/F: Abundance/Frequency; H: High; M: Medium; L: Low.

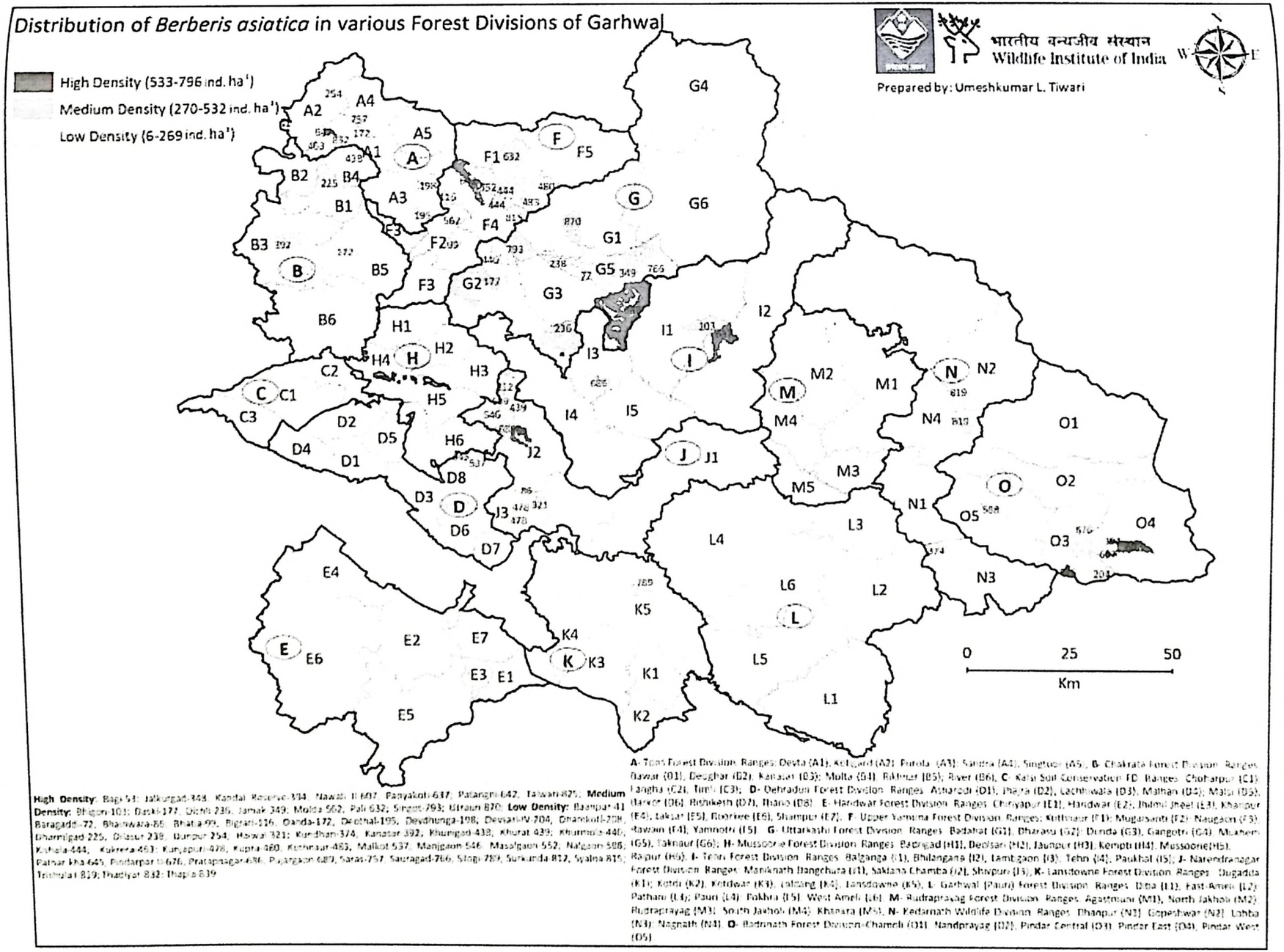


Figure 6.2. Distribution of *Berberis asiatica* in various Forest Divisions of Garhwal

6.3.3 Restoration of Degraded Habitat

There is a consensus among the scientific community that the current environmental degradation and destruction of many of the Earth's biota is taking place on a catastrophically short timescale (Mlchael and Cleland 2001). Habitat loss is the leading cause of both species extinctions and ecosystem service decline. Phoolchatti, Gangi, Sosa, Namik, Sukhi and Ghes are the important places where *B. aristata* have very good potential for growth in the State. These localities have very good population of this species, but there is excessive extraction for fuelwood at these sites leading to availability of species for medicinal use. These habitats can be considered for restoration and conservation of this valuable medicinal plant species. Other fast growing fuelwood plants can be provided to local people and grown, and make local people aware about the uses and properties of species, can help in restoration. *Berberis asiatica* has very good population near Mussoorie hills, Devalsari, Gochar, Bageshwar and Lohaghat, and these sites can be considered for conservation and habitat restoration. *Berberis lycium* is restricted to Garhwal and it has very good population all over Garhwal in between 800-2000m a.s.l., wherever open canopy (< 30% canopy cover) is available.

6.3.4 Prioritization of Species for Conservation

Based on earlier records and present investigation, it is clear that 7 taxa of *Berberis* (*Berberis petiolaris* var. *garhwalana*, *B. coriaria* var. *patula*, *B. affinis*, *B. ahrendtii*, *B. osmastonii*, *B. lambertii* and *B. rawatii*) and one species of *Mahonia* (*Mahonia jaunsarensis*) are endemic to the State of Uttarakhand. The Red Data Book of Indian Plants (Nayar and Sastry 1987-1990) has recorded *B. affinis* and *B. osmastonii* as Rare and *B. lambertii* as Vulnerable. *M. jaunsarensis,* an endemic species is confined to Chakarata region and has very few (<110) individuals and found under Banj Oak and Deodar forests. Species like *B. osmastonii, B. ahrendtii*, *B. rawatii* and *B. lambertii* were confined to a few pockets (Figure 6.3). Two species of *Berberis* are very rare, *i.e., B. lambertii* and *B. ahrendtii*, whereas 13 species are sparsely distributed. (Figure 6.3). Based on the population, endemicity and threats the following 7 species fall under high priority for conservation: *B. lambertii*,

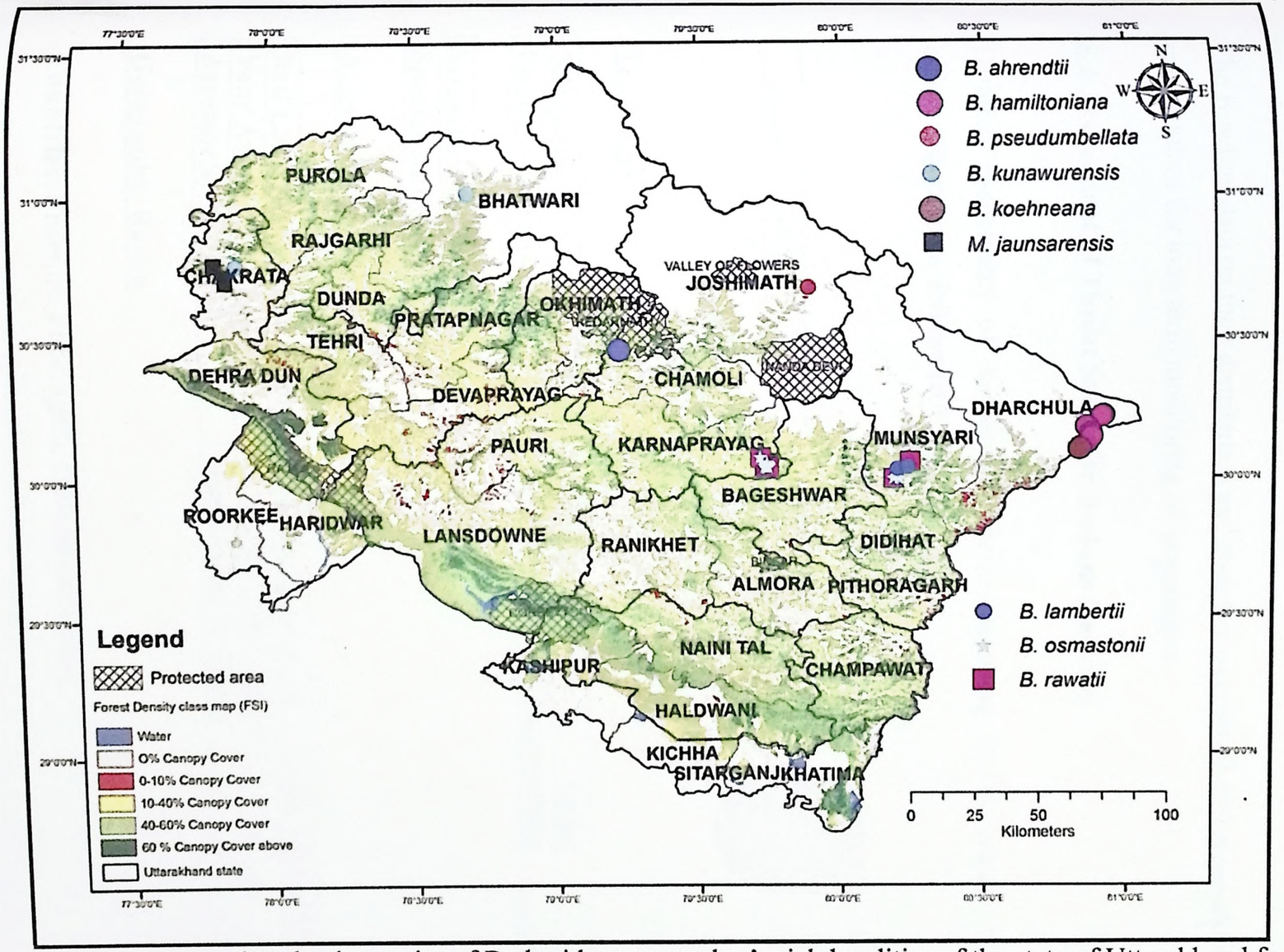


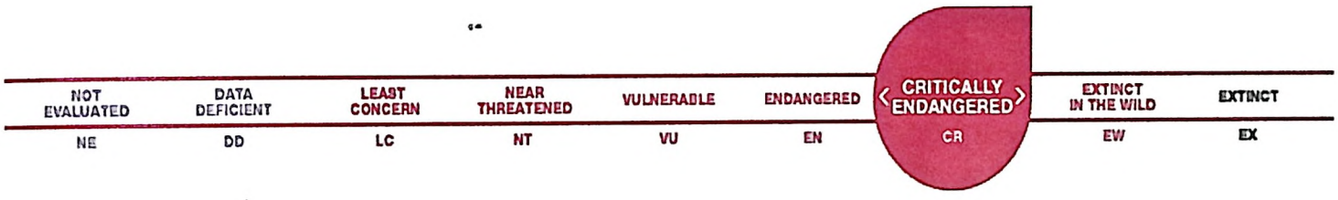
Figure 6.3. Showing Rare and Endemic species of Berberidaceae member's rich localities of the state of Uttarakhand for Prioritization for conservation.

B. ahrendtii, *B. apiculata*, *B. pseudumbellata*, *B. rawatii*, *B. osmastonii* and *Mahonia jaunsarensis*. (Figure 6.3)

The baseline data on their distribution and abundance collected during present investigation can be taken for long term monitoring of populations.

6.4 Assessment of Threat Status for *Berberis lambertii*

Detailed assessment of *Berberis lambertii* following IUCN criteria to Red listing categorization is as follows (IUCN 2003).



Taxonomy

Kingdom	Phylum	Class	Order	Family
Plantae	Tracheophyta	Magnoliopsida	Ranunculales	Berberidaceae

Scientific Name:	*Berberis lambertii*
Species Authority:	Parker

Assessment Information

Red List Category & Criteria:	Critically Endangered A1ac(i), C2a(i &ii) & D1 ver 3.1
Year Assessed:	2008, 2009, 2010 and 2011
Assessor/s:	Umeshkumar L. Tiwari

Geographic Range

Countries: Endemic: Pithoragarh, Uttarakhand (India)

According to IUCN (2003) a taxon is Critically Endangered when the best available evidence indicates that it meets any of the following criteria (A to E), and it is therefore considered to be facing an extremely high risk of extinction in the wild:

A. Reduction in population size based on any of the following criteria:

Questions	**Observations**
(a) direct observation	YES
(b) an index of abundance appropriate to the taxon	NO
(c) a decline in area of occupancy, extent of occurrence and/or quality of habitat	YES
(d) actual or potential levels of exploitation	NO
(e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.	NO

2. An observed, estimated, inferred or suspected population size reduction of ≥ 80% over the last 10 years or three generations, whichever is the longer, where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.

Questions	Observations
(a) direct observation	YES
(e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.	NO

3. A population size reduction of ≥ 80%, projected or suspected to be met within the next 10 years or three generations, whichever is the longer (up to a maximum of 100 years), based on (and specifying) any of (b) to (e) under A1.

Questions	Observations
(b) an index of abundance appropriate to the taxon	NO
(e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.	NO

4. An observed, estimated, inferred, projected or suspected population size reduction of ≥ 80% over any 10 year or three generation period, whichever is longer (up to a maximum of 100 years in the future), where the time period must include both the past and the future,

and where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.

Answer: Not assessed in the past.

C. Population size estimated to number fewer than 250 mature individuals and either:

1. An estimated continuing decline of at least 25% within three years or one generation, whichever is longer, (up to a maximum of 100 years in the future) – None of the seedling and saplings are observed within four year of search

2. A continuing decline, observed, projected, or inferred, in numbers of mature individuals AND at least one of the following (a-b):

(a) Population structure in the form of one of the following:

(i) no subpopulation estimated to contain more than 50 mature individuals- There are only two subpopulations, 81 individuals at Kalamuni and 36 individuals at Betulidhar.

(ii) at least 90% of mature individuals in one subpopulation- Yes i.e. at Kalamuni

(b) Extreme fluctuations in number of mature individuals- Not seen any decline within populations

D. Population size estimated to number fewer than 50 mature individuals- No

E. Quantitative analysis showing the probability of extinction in the wild is at least 50% within 10 years or three generations, whichever is the longer (up to a maximum of 100 years)- Not assessed, but it can be decline because none of the population have produced any seedling or sapling within the study period.

This criterion identifies very small or restricted populations. A taxon qualifies for criterion **D,** if the population of mature individuals is smaller than the threshold set for each of the categories of threat.

If a taxon is only known from its type locality and there is no information on its status or possible threats, the taxon should be listed as DD. If there are no plausible threats, and the area is relatively well known, Least Concern is appropriate, unless criterion A, B or C is met. If people have searched for the taxon, both at the type locality and at a reasonable number of other potential localities, and no more than 50 mature individuals are estimated, then the taxon would be listed as Critically Endangered D (an appropriate time interval for the taxon must be used). If any significant or plausible threats can be identified, then a full assessment will be necessary to determine the most appropriate classification (e.g., Critically Endangered under criteria B or C, or Vulnerable under criterion D2). *Berberis lambertii* is a very rare species described from two specimens collected in 1921. After the first collection, no further collection was reported. However, in 2008, it was collected by the author from the Type locality in Pithoragarh district. Obviously very little is known about this species, but it is safe to estimate, given the limited localities, that the population contains less than 120 mature individuals. Therefore, *B. lambertii* should be listed as Critically Endangered (CR).

6.5 Conclusions

i. Based on endemism, population status and potential demand for commercial purpose, following species need to be given highest priority for conservation in the state: *B. ahrendtii*, *B. lambertii*, *B. apiculata*, *B. rawatii*, *B. osmastonii*, *B. asiatica*, *B. lycium* and *B. aristata*.

ii. Distribution maps of medicinal species for various Forest Divisions of Garhwal region have been prepared. Based on these maps areas for conservation and development of these species have been suggested.

iii. The populations of rare endemic species have been located and a few sites for their long term monitoring have been suggested. Considering the low population size, it is recommended that its RDB status of *B. lambertii* may be changed from **Vulnerable** to **Endandered** category.

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Kew Herbarium Catalogue: http://apps.kew.org/herbcat/gotoHomePage.do

Land Surface Temperature and Emissivity Daily L3 Global 1 km Grid SIN: MODIS LST IMAGES, https://lpdaac.usgs.gov/products/modis_products_table/land_surface_temperature_emissivity/daily_8_global_1km/mod11a1

The International Plant Names Index: http://www.ipni.org/

The Plant List: http://www.theplantlist.org/

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Appendix I: Characters are used for Cluster Analysis

Parts	Characters	Abbreviations
Stems	Sh<1m	Sh<1m
	SH>1m	SH>1m
Leaf shape	Obovate	LObo
	Linear Lanceolate	LLinLanc
	Lanceolate-elliptic	LLanEll
Leaf Apex	Mucronate	LAMuc
	Rounded	LARou
	Acute	LAAct
Leaf base	attenuate	LBAtte
	Cuneate	LBCun
Leaves Margin	Entire	LMEnt
	Spinose	LMSpi
Inflorescence	Solitary	IFSoli
	Racemose	IFRac
	Paniculate	IFPani
	Facicled	INFac
	Sbumbellate or umbellate	INSuUm
Flower number	FLW=7	FL=8
	FLW>7	FL>8
Prophyllas	Prophyllas	Proph
Sepals	Sepals2whorls	S=6
	Sepals3whorls	S=9
Petals apex	Emarginate	PAEmar
	acute	PAAcu
Petal shape	Ovate	Pova
	Obovate	Pobov
Glands	Gland obovate	Gobo
	Glands linear	Gline
Stamens	Stamens apiculate	StApic
	Stamens truncate	StTrun
	Stamens produsedd	StProd
Style	Stylose	Styl
	Estyliose	Esty
Ovules	Ovules=3	Ovu=3
	Ovules>3	Ovu>4

Fruit upper coat	Berries pruinose	BerPru
	Berries epruinose	BerEpru

Appendix II: Species abbrevations are used for Cluster Analysis

Species	**Abbreviations**
Berberis affinis	Baff
Berberis ahrendtii	Bahred
Berberis apiculata	Bapicu
Berberis aristata	Barist
Berberis asiatica	Bglau
Berberis chitria	Bcori_p
Berberis concinna var. *brevior*	Bcori_c
Berberis coriaria var. *coriaria*	Bflor
Berberis coriaria var. *patula*	Basia
Berberis cretica	Bchit
Berberis floribunda	Bconc_b
Berberis glaucocarpa	Bcret
Berberis hamiltoniana	Bhami
Berberis jaeschkenana var. *jaeschkenana*	Bjaesc_jaes
Berberis jaeschkenana var. *usteriana*	Bjaesc_ust
Berberis koehneana	Bkoeh
Berberis kumaonensis	Bkuma
Berberis kunawurensis	Bkuna
Berberis lambertii	Blamb
Berberis lycium var. *lycium*	Blyc_lyc
Berberis lycium var. *simlensis*	Blyc_sim
Berberis lycium var. *subfacicularis*	Blyc_sbfac
Berberis lycium var. *subvirescens*	Blyc_sbvir
Berberis macracantha	Bmacr
Berberis osmastonii	Bosma
Berberis pachyacnatha var. *pachyacantha*	Bpach_pach
Berberis pachyacnatha var. *zebelina*	Bpach_zeb
Berberis petiolaris var. *extensa*	Bpetio_exte
Berberis petiolaris var. *garhwalana*	Bpetio_garh
Berberis pseudumbellata	Bpseud
Berberis rawatii	Brawat
Berberis umbellata	Bumbe

Appendix III: Variables Abbreviations are used for CCA

Variables	Abbreviation
Anthropogenic pressure	AP
Canopy Cover	CC
Elevation	Elv
Aspect	Asp
Slope	Slp
Precipitation Summer	Prec-S
Precipitation Monsoon	Prec-M
Precipitation Winter	Prec-W
Temperature Summer	TM-S
Temperature Monsoon	TM-M
Temperature Winter	TM-W

Appendix IV: Habitat Types Abbreviations are used for CCA

Habitat Types	Abbreviation
Banj Buras Mixed Forest	BBMF
Banj Forest	BF
Banj Pine Mixed Forest	BPMF
Deodar Mixed Forest	DMF
High altitude Mixed Forest	HAMF
Kharsu Mixed Forest	KMF
Lower altitude Mixed Forest	LMF
Moru Mixed Forest	MoruMF
Open canopy	OC
Temperate Grassy Slopes	OGS
Pine Forest	PF
Pine Mixed Forest	PMF
Taxus Mixed Forest	TMF
Alnus Mixed Forest	UtisMF

Appendix V: Output of CCA

```
********** Canonical Correspondence Analysis
**********
PC-ORD, Version 4.34
19 Oct 2011, 17:08
UMESH_Berberis_CCA


DATA MATRICES
----------------------------------------
     Main matrix:
            182 plots     (rows)
             14 Species   (columns)

     Second matrix:
            182 plots     (rows)
             11 variable  (columns)

     Finished reading data.
----------------------------------------


OPTIONS SELECTED
     Axis scores centered and standardized to unit variance
     Axes scaled to optimize representation of rows: plots
          (Scores for plots     are weighted mean scores for Species )
     Scores for graphing plots     are derived from Species
     Monte Carlo test: null hypothesis is no relationship between matrices
     Random number seed:         4418
```

RAW CORRELATIONS AMONG VARIABLES IN SECOND MATRIX

	AP	CC	Elv	Asp	Slp	Prec-S	Prec-M	Prec-W	TM-S	TM-M	TM-W
AP	1.000	-0.208	0.009	0.061	0.031	0.085	-0.204	0.032	-0.052	-0.040	-0.061
CC	-0.208	1.000	-0.077	-0.136	-0.137	-0.057	0.247	-0.046	0.101	0.065	0.114
Elv	0.009	-0.077	1.000	0.128	-0.122	0.750	-0.558	0.668	-0.976	-0.975	-0.973
Asp	0.061	-0.136	0.128	1.000	0.072	0.054	-0.033	0.046	-0.129	-0.130	-0.129
Slp	0.031	-0.137	-0.122	0.072	1.000	-0.048	0.008	-0.122	0.100	0.116	0.090
Prec-S	0.085	-0.057	0.750	0.054	-0.048	1.000	-0.754	0.829	-0.743	-0.726	-0.748
Prec-M	-0.204	0.247	-0.558	-0.033	0.008	-0.754	1.000	-0.521	0.601	0.561	0.621
Prec-W	0.032	-0.046	0.668	0.046	-0.122	0.829	-0.521	1.000	-0.692	-0.645	-0.695
TM-S	-0.052	0.101	-0.976	-0.129	0.100	-0.743	0.601	-0.692	1.000	0.992	0.999
TM-M	-0.040	0.065	-0.975	-0.130	0.116	-0.726	0.561	-0.645	0.992	1.000	0.986
TM-W	-0.061	0.114	-0.973	-0.129	0.090	-0.748	0.621	-0.695	0.999	0.986	1.000

WEIGHTED CORRELATIONS AMONG VARIABLES IN SECOND MATRIX
(weighted by row totals in main matrix)

AP	CC	Elv	Asp	Slp	Prec-S	Prec-M	Prec-W	TM-S	TM-M	TM-W

AP	1.000	-0.209	0.042	-0.050	-0.084	0.140	-0.264	0.027	-0.056	-0.036
	-0.077									
CC	-0.209	1.000	-0.360	-0.173	0.085	-0.368	0.410	-0.004	0.224	0.225
	0.232									
Elv	0.042	-0.360	1.000	0.096	-0.241	0.794	-0.615	0.581	-0.944	-0.954
	-0.941									
Asp	-0.050	-0.173	0.096	1.000	-0.006	0.049	-0.144	-0.064	-0.088	-0.097
	-0.090									
Slp	-0.084	0.085	-0.241	-0.006	1.000	-0.197	0.092	-0.322	0.240	0.254
	0.225									
Prec-S	0.140	-0.368	0.794	0.049	-0.197	1.000	-0.752	0.761	-0.770	-0.761
	-0.773									
Prec-M	-0.264	0.410	-0.615	-0.144	0.092	-0.752	1.000	-0.457	0.643	0.601
	0.666									
Prec-W	0.027	-0.004	0.581	-0.064	-0.322	0.761	-0.457	1.000	-0.687	-0.644
	-0.680									
TM-S	-0.058	0.224	-0.944	-0.088	0.240	-0.770	0.643	-0.687	1.000	0.991
	0.998									
TM-M	-0.036	0.225	-0.954	-0.097	0.254	-0.761	0.601	-0.644	0.991	1.000
	0.984									
TM-W	-0.077	0.232	-0.941	-0.090	0.225	-0.773	0.666	-0.680	0.998	0.984
	1.000									

ITERATION REPORT

Calculating axis 1

Residual = 0.57E+04 at iteration 1
Residual = 0.31E-01 at iteration 2
Residual = 0.10E-01 at iteration 3
Residual = 0.63E-02 at iteration 4
Residual = 0.49E-02 at iteration 5
Residual = 0.41E-02 at iteration 6
Residual = 0.34E-02 at iteration 7
Residual = 0.29E-02 at iteration 8
Residual = 0.24E-02 at iteration 9
Residual = 0.19E-02 at iteration 10
Residual = 0.15E-03 at iteration 20
Residual = 0.98E-05 at iteration 30
Residual = 0.62E-06 at iteration 40
Residual = 0.39E-07 at iteration 50
Residual = 0.25E-08 at iteration 60
Residual = 0.16E-09 at iteration 70
Residual = 0.10E-10 at iteration 80
Residual = 0.57E-12 at iteration 90
Residual = 0.90E-13 at iteration 97
Solution reached tolerance of 0.100000E-12 after 97 iterations.

Calculating axis 2

Residual = 0.20E+01 at iteration 1
Residual = 0.16E-04 at iteration 2
Residual = 0.69E-05 at iteration 3
Residual = 0.29E-05 at iteration 4
Residual = 0.12E-05 at iteration 5
Residual = 0.50E-06 at iteration 6
Residual = 0.21E-06 at iteration 7
Residual = 0.88E-07 at iteration 8
Residual = 0.37E-07 at iteration 9
Residual = 0.15E-07 at iteration 10
Residual = 0.25E-11 at iteration 20
Residual = 0.58E-13 at iteration 25

```
Solution reached tolerance of 0.100000E-12 after  25 iterations.
-----------------------------------------------------------------

Calculating axis 3
Residual =   0.20E+01 at iteration   1
Residual =   0.28E-06 at iteration   2
Residual =   0.76E-09 at iteration   3
Residual =   0.56E-10 at iteration   4
Residual =   0.95E-11 at iteration   5
Residual =   0.25E-11 at iteration   6
Residual =   0.71E-12 at iteration   7
Residual =   0.58E-12 at iteration   8
Residual =   0.32E-12 at iteration   9
Residual =   0.38E-12 at iteration  10
Residual =   0.41E-12 at iteration  20
Residual =   0.25E-12 at iteration  30
Residual =   0.47E-12 at iteration  40
Residual =   0.35E-12 at iteration  50
Residual =   0.32E-12 at iteration  60
Residual =   0.35E-12 at iteration  70
Residual =   0.26E-12 at iteration  80
Residual =   0.32E-12 at iteration  90
Residual =   0.46E-12 at iteration 100
Residual =   0.60E-12 at iteration 110
Residual =   0.28E-12 at iteration 120
Residual =   0.59E-12 at iteration 130
Residual =   0.44E-12 at iteration 140
Residual =   0.42E-12 at iteration 150
Residual =   0.39E-12 at iteration 160
Residual =   0.19E-12 at iteration 170
Residual =   0.31E-12 at iteration 180
Residual =   0.60E-12 at iteration 190
Residual =   0.33E-12 at iteration 200
Residual =   0.68E-12 at iteration 210
Residual =   0.36E-12 at iteration 220
Residual =   0.51E-12 at iteration 230
Residual =   0.45E-12 at iteration 240
Residual =   0.40E-12 at iteration 250
Residual =   0.33E-12 at iteration 260
Residual =   0.52E-12 at iteration 270
Residual =   0.28E-12 at iteration 280
Residual =   0.34E-12 at iteration 290
Residual =   0.21E-12 at iteration 300
Residual =   0.28E-12 at iteration 310
Residual =   0.34E-12 at iteration 320
Residual =   0.46E-12 at iteration 330
Residual =   0.49E-12 at iteration 340
Residual =   0.32E-12 at iteration 350
Residual =   0.26E-12 at iteration 360
Residual =   0.53E-12 at iteration 370
Residual =   0.31E-12 at iteration 380
Residual =   0.59E-12 at iteration 390
Residual =   0.39E-12 at iteration 400
Residual =   0.17E-12 at iteration 410
Residual =   0.44E-12 at iteration 420
```

```
Residual =   0.67E-12 at iteration 430
Residual =   0.26E-12 at iteration 440
Residual =   0.32E-12 at iteration 450
Residual =   0.48E-12 at iteration 460
Residual =   0.25E-12 at iteration 470
Residual =   0.21E-12 at iteration 480
Residual =   0.52E-12 at iteration 490
Residual =   0.41E-12 at iteration 500
Residual =   0.60E-12 at iteration 510
Residual =   0.38E-12 at iteration 520
Residual =   0.55E-12 at iteration 530
Residual =   0.38E-12 at iteration 540
Residual =   0.72E-12 at iteration 550
Residual =   0.31E-12 at iteration 560
Residual =   0.43E-12 at iteration 570
Residual =   0.28E-12 at iteration 580
Residual =   0.60E-12 at iteration 590
Residual =   0.60E-12 at iteration 600
Residual =   0.47E-12 at iteration 610
Residual =   0.33E-12 at iteration 620
Residual =   0.65E-12 at iteration 630
Residual =   0.40E-12 at iteration 640
Residual =   0.80E-12 at iteration 650
Residual =   0.44E-12 at iteration 660
Residual =   0.26E-12 at iteration 670
Residual =   0.44E-12 at iteration 680
Residual =   0.36E-12 at iteration 690
Residual =   0.32E-12 at iteration 700
Residual =   0.25E-12 at iteration 710
Residual =   0.30E-12 at iteration 720
Residual =   0.25E-12 at iteration 730
Residual =   0.31E-12 at iteration 740
Residual =   0.30E-12 at iteration 750
Residual =   0.30E-12 at iteration 760
Residual =   0.34E-12 at iteration 770
Residual =   0.31E-12 at iteration 780
Residual =   0.36E-12 at iteration 790
Residual =   0.34E-12 at iteration 800
Residual =   0.51E-12 at iteration 810
Residual =   0.75E-12 at iteration 820
Residual =   0.30E-12 at iteration 830
Residual =   0.41E-12 at iteration 840
Residual =   0.33E-12 at iteration 850
Residual =   0.72E-12 at iteration 860
Residual =   0.41E-12 at iteration 870
Residual =   0.76E-12 at iteration 880
Residual =   0.41E-12 at iteration 890
Residual =   0.56E-12 at iteration 900
Residual =   0.50E-12 at iteration 910
Residual =   0.54E-12 at iteration 920
Residual =   0.54E-12 at iteration 930
Residual =   0.28E-12 at iteration 940
Residual =   0.45E-12 at iteration 950
Residual =   0.58E-12 at iteration 960
Residual =   0.26E-12 at iteration 970
```

Residual = 0.46E-12 at iteration 980
Residual = 0.46E-12 at iteration 990
Solution did not reach tolerance after 999 iterations.
0.100000E-12 = tolerance
0.295723E-12 = difference from previous iteration

AXIS SUMMARY STATISTICS
Number of canonical axes: 3
Total variance ("inertia") in the species data: 6.8579

	Axis 1	Axis 2	Axis 3
Eigenvalue	0.842	0.733	0.474
Variance in species data			
% of variance explained	12.3	10.7	6.9
Cumulative % explained	12.3	23.0	29.9
Pearson Correlation, Spp-Envt*	0.947	0.879	0.751
Kendall (Rank) Corr., Spp-Envt	0.581	0.377	0.254

* Correlation between sample scores for an axis derived from the species data and the sample scores that are linear combinations of the environmental variables. Set to 0.000 if axis is not canonical.

MULTIPLE REGRESSION RESULTS:
Regression of plots in Species space on variable

	Canonical Coefficients						
	Standardized			Original Units			
Variable	Axis 1	Axis 2	Axis 3	Axis 1	Axis 2	Axis 3	S.Dev
1 AP	-0.009	0.009	0.120	-0.001	0.001	0.013	0.895E+01
2 CC	-0.279	-0.123	0.307	-0.009	-0.004	0.010	0.306E+02
3 Elv	1.216	0.598	1.905	0.002	0.001	0.003	0.554E+03
4 Asp	-0.033	0.011	0.123	-0.015	0.005	0.056	0.219E+01
5 Slp	-0.071	0.046	0.096	-0.008	0.005	0.010	0.910E+01
6 Prec-S	0.201	0.302	-1.437	0.004	0.006	-0.030	0.472E+02
7 Prec-M	0.100	-0.044	-1.064	0.000	0.000	-0.003	0.307E+03
8 Prec-W	-0.037	-0.776	0.747	-0.002	-0.032	0.030	0.246E+02
9 TM-S	3.414	-2.240	-5.991	1.088	-0.714	-1.910	0.314E+01
10 TM-M	0.235	-0.707	-0.180	0.099	-0.298	-0.076	0.237E+01
11 TM-W	-3.019	3.674	7.888	-1.075	1.308	2.808	0.281E+01

Scores that are derived from the scores of Species (WA Scores)
FINAL SCORES and raw data totals (weights) for 182 plots

	Axis 1	Axis 2	Axis 3	Raw Data Totals
1 BBMF1	-1.217677	0.051903	-0.151447	178.2872
2 BBMF1	-1.185095	0.048470	-0.139532	503.0245
3 BBMF1	-1.217677	0.051903	-0.151447	31.8370
4 BBMF1	-1.107362	0.040281	-0.111105	178.2872

5	BBMF1	-0.702872	-0.002333	0.036819	25.4696
6	BBMF1	-0.702872	-0.002333	0.036819	3.6762
7	BBMF1	-1.217677	0.051903	-0.151447	57.3066
8	BBMF1	-1.217677	0.051903	-0.151447	63.6740
9	BBMF1	-0.702872	-0.002333	0.036819	108.2458
10	BBMF1	-0.702872	-0.002333	0.036819	343.9490
11	BBMF1	-0.871729	0.055505	0.217141	101.8784
12	BBMF1	-0.546363	-0.111253	0.112435	324.7374
13	BBMF1	-1.153280	0.074245	0.048157	70.0414
14	BBMF1	-1.217677	0.051903	-0.151447	726.1146
15	BBMF1	-0.874474	0.015745	-0.025936	802.5478
16	BBMF1	0.437412	-0.795893	0.587733	305.7325
17	BBMF1	-1.217677	0.051903	-0.151447	152.8662
18	BBMF1	0.437412	-0.795893	0.587733	133.7154
19	BBMF1	-0.831573	0.011226	-0.010248	50.9392
20	BBMF1	-0.702872	-0.002333	0.036819	165.6051
21	BBMF1	-1.217677	0.051903	-0.151447	369.4268
22	BBMF1	-0.702872	-0.002333	0.036819	254.6960
23	BBMF1	-1.217677	0.051903	-0.151447	261.0634
24	BBMF1	-0.731472	0.000680	0.026360	343.8395
25	BBMF1	-0.912729	0.019776	-0.039927	999.6816
26	BBMF1	-0.759501	0.003633	0.016110	636.7399
27	BBMF1	-1.217677	0.051903	-0.151447	222.8590
28	BBMF1	-1.149606	0.075519	0.059545	706.7812
29	BBMF1	-1.217677	0.051903	-0.151447	101.8784
30	BBMF1	-1.021561	0.031241	-0.079727	133.7154
31	BBMF1	-1.128581	0.042516	-0.118865	315.5717
32	BBMF1	-1.217677	0.051903	-0.151447	184.6546
33	BBMF1	-1.217677	0.051903	-0.151447	31.8370
34	BBMF1	-0.702872	-0.002333	0.036819	305.6352
35	BBMF1	-0.702872	-0.002333	0.036819	146.4502
36	BBMF1	-0.702872	-0.002333	0.036819	120.9806
37	BBMF1	-0.882779	0.033390	0.072391	770.4553
38	BBMF1	-0.841452	0.065373	0.307141	1165.2340
39	BBMF1	-0.702872	-0.002333	0.036819	108.2458
40	BBMF1	-0.702872	-0.002333	0.036819	229.2264
41	BBMF1	-0.702872	-0.002333	0.036819	12.7348
42	BBMF1	-1.217677	0.051903	-0.151447	140.0828
43	BBMF1	-1.146841	0.076479	0.068117	63.6740
44	BBMF1	-0.805833	0.008514	-0.000834	63.6740
45	BBMF1	-1.046076	0.033824	-0.088692	38.2044
46	BBMF1	-1.217677	0.051903	-0.151447	89.1436
47	BBMF1	-0.702872	-0.002333	0.036819	19.1022
48	BBMF1	-0.949979	0.023700	-0.053549	318.3699
49	BBMF1	-1.217677	0.051903	-0.151447	6.3674
50	BBMF1	-1.157112	0.045522	-0.129298	216.4916
51	BBMF1	-1.217677	0.051903	-0.151447	114.6132
52	BBMF1	-1.217677	0.051903	-0.151447	25.6931
53	BBMF1	-1.217677	0.051903	-0.151447	25.4696
54	BBMF1	-1.153327	0.045123	-0.127914	203.7568
55	BBMF1	-1.217677	0.051903	-0.151447	114.6132
56	BBMF1	-1.144134	0.044155	-0.124552	44.5718
57	BBMF1	-1.194277	0.049437	-0.142890	140.0828
58	BBMF1	-1.217677	0.051903	-0.151447	44.5718
59	BBMF1	-0.702872	-0.002333	0.036819	280.1656

60	BBMF1	-0.702872	-0.002333	0.036819	254.6960
61	BBMF1	-0.864841	0.025778	0.044365	369.3091
62	BBMF1	-1.217677	0.051903	-0.151447	70.0414
63	BBMF1	-0.902152	0.018661	-0.036058	197.3894
64	BBMF1	-0.702872	-0.002333	0.036819	44.5718
65	BBMF1	-1.217677	0.051903	-0.151447	101.8784
66	BBMF1	-1.217677	0.051903	-0.151447	82.7762
67	BBMF1	-0.838347	0.011939	-0.012725	241.9612
68	BBMF1	-1.217677	0.051903	-0.151447	12.7348
69	BBMF1	0.640967	-1.662626	0.763111	165.5524
70	BBMF1	-1.217677	0.051903	-0.151447	82.7762
71	BBMF1	-1.217677	0.051903	-0.151447	31.8370
72	BBMF1	-1.217677	0.051903	-0.151447	254.6960
73	BBMF1	-1.217677	0.051903	-0.151447	44.5718
74	BF2	-1.217677	0.051903	-0.151447	50.9392
75	BF2	-1.217677	0.051903	-0.151447	89.1436
76	BF2	-1.217677	0.051903	-0.151447	25.4696
77	BF2	-1.217677	0.051903	-0.151447	57.3066
78	BF2	-1.217677	0.051903	-0.151447	63.6740
79	BF2	-0.981555	0.133823	0.580434	38.2044
80	BF2	-1.217677	0.051903	-0.151447	12.7348
81	BPMF3	-1.217677	0.051903	-0.151447	140.0828
82	BPMF3	-1.217677	0.051903	-0.151447	57.3066
83	BPMF3	-1.217677	0.051903	-0.151447	101.8784
84	Bugyal4	0.492463	0.479751	-1.175397	1687.3607
85	Bugyal4	1.001018	-2.377896	1.797183	254.6960
86	Bugyal4	0.963895	-2.370010	1.908128	82.7762
87	Bugyal4	0.897523	-2.656060	-0.048910	197.3894
88	Bugyal4	1.001018	-2.377896	1.797183	299.2678
89	DMF5	-1.168338	0.069020	0.001483	426.6157
90	DMF5	-1.198611	0.049894	-0.144475	171.9198
91	DMF5	-1.217677	0.051903	-0.151447	165.5524
92	DMF5	-0.132730	-0.399113	0.312276	12.7348
93	DMF5	-0.645538	-0.042234	0.064519	56.6344
94	DMF5	-1.217677	0.051903	-0.151447	44.5718
95	HAMF6	-1.217677	0.051903	-0.151447	146.4502
96	HAMF6	-1.217677	0.051903	-0.151447	114.6132
97	HAMF6	-0.702872	-0.002333	0.036819	89.1436
98	KailMF7	1.280027	-2.947887	-3.549658	401.1461
99	KMF8	-0.702872	-0.002333	0.036819	12.7348
100	KMF8	-0.702872	-0.002333	0.036819	50.9392
101	KMF8	0.671299	-1.313016	1.581567	178.2872
102	KMF8	-0.702872	-0.002333	0.036819	235.5938
103	KMF8	-1.165206	0.070107	0.011193	114.6132
104	KMF8	0.437412	-0.795893	0.587733	63.6740
105	KMF8	-0.702872	-0.002333	0.036819	89.1436
106	KMF8	-0.046345	-0.459231	0.354012	210.1242
107	KMF8	0.481254	0.231393	-0.899950	1534.5431
108	KMF8	0.759717	-2.326637	2.518328	6.3674
109	KMF8	-0.981555	0.133823	0.580434	50.9392
110	KMF8	0.965915	-2.472244	1.171023	1088.8252
111	KMF8	0.547519	-1.586383	1.203220	95.5110
112	KMF8	-0.702872	-0.002333	0.036819	19.1022
113	KMF8	1.135249	1.019797	0.116590	394.7787
114	KMF8	0.652855	0.850362	0.003420	808.6597

115	KMF8	0.568787	0.809161	-0.005406	499.4307
116	KMF8	-0.702872	-0.002333	0.036819	6.3674
117	KMF8	-0.702872	-0.002333	0.036819	12.7348
118	KMF8	-0.702872	-0.002333	0.036819	12.7348
119	KMF8	0.917728	-2.252061	1.620599	1039.3071
120	KMF8	-0.132730	-0.399113	0.312276	216.4916
121	KMF8	0.914342	-2.218880	1.777967	331.1047
122	KMF8	0.437412	-0.795893	0.587733	19.1022
123	KMF8	0.211246	-1.455023	1.587762	50.9392
124	KMF8	0.931135	-2.395500	1.773019	235.5938
125	KMF8	0.257367	-0.670594	0.500747	120.9806
126	LMF9	-1.217677	0.051903	-0.151447	12.7348
127	LMF9	-1.217677	0.051903	-0.151447	108.2458
128	LMF9	-1.217677	0.051903	-0.151447	133.7154
129	LMF9	-1.217677	0.051903	-0.151447	38.2044
130	LMF9	-1.217677	0.051903	-0.151447	101.8784
131	MoruMF10	0.102034	-0.562493	0.425700	324.7374
132	MoruMF10	-0.702872	-0.002333	0.036819	89.1720
133	MoruMF10	-0.702872	-0.002333	0.036819	191.0828
134	MoruMF10	-0.702872	-0.002333	0.036819	114.6497
135	MoruMF10	-0.070182	-0.473046	0.348541	127.3480
136	OC11	-0.091012	-0.428146	0.332432	522.1267
137	OC11	-1.052391	0.109247	0.360870	127.3885
138	OC11	1.566905	-3.166757	-6.175219	573.2484
139	OC11	-0.988875	0.027798	-0.067773	229.2994
140	OC11	-1.146841	0.076479	0.068117	254.7771
141	OC11	-1.217677	0.051903	-0.151448	197.3894
142	OC11	-0.981555	0.133823	0.580434	114.6497
143	OC11	-0.702872	-0.002333	0.036819	25.4777
144	OC11	-1.217677	0.051903	-0.151447	152.8662
145	OC11	-1.217677	0.051903	-0.151447	165.6051
146	OC11	0.437412	-0.795893	0.587733	235.5938
147	OC11	0.437412	-0.795893	0.587733	777.0701
148	OC11	0.437412	-0.795893	0.587733	942.6752
149	OGS12	0.792234	0.643942	-0.160333	1528.6625
150	OGS12	1.147424	1.006851	0.142295	1209.8058
151	OGS12	0.703753	0.856389	-0.442367	1208.0685
152	OGS12	-0.655770	0.279833	-0.084328	267.5159
153	OGS12	1.152516	0.994757	0.175455	8773.5469
154	PF13	-1.217677	0.051903	-0.151447	114.6132
155	PF13	-1.217677	0.051903	-0.151447	44.5718
156	PF13	-1.217677	0.051903	-0.151447	50.9392
157	PF13	-1.217677	0.051903	-0.151447	89.1436
158	PF13	-1.217677	0.051903	-0.151447	120.9806
159	PF13	-1.217677	0.051903	-0.151447	50.9392
160	PF13	-1.217677	0.051903	-0.151447	44.5718
161	PF13	-1.217677	0.051903	-0.151447	44.5718
162	PF13	-1.217677	0.051903	-0.151447	114.6132
163	PMF14	-1.217677	0.051903	-0.151447	203.7568
164	PMF14	-1.197145	0.059026	-0.087806	439.3505
165	PMF14	-1.217677	0.051903	-0.151447	152.8176
166	PMF14	-1.217677	0.051903	-0.151447	57.3066
167	PMF14	-1.217677	0.051903	-0.151447	50.9392
168	PMF14	-1.217677	0.051903	-0.151447	50.9392
169	PMF14	-1.217677	0.051903	-0.151447	191.0220

170 PMF14	-1.114716	0.041055	-0.113794	254.6960
171 PMF14	-1.217677	0.051903	-0.151447	12.7348
172 PMF14	-1.217677	0.051903	-0.151447	114.6132
173 PMF14	-0.981555	0.133823	0.580434	25.4696
174 PMF14	-1.217677	0.051903	-0.151447	19.1022
175 PMF14	-0.801251	-0.029957	-0.555072	25.4696
176 PMF14	-1.217677	0.051903	-0.151447	6.3674
177 PMF14	-1.217677	0.051903	-0.151447	6.3674
178 TMF15	0.940197	-2.522949	0.844533	241.9612
179 TMF15	-0.391885	-0.218759	0.187068	70.0414
180 TMF15	0.200971	-0.674779	0.482136	89.1436
181 UtisMF16	-1.114133	0.070363	0.063940	254.6960
182 UtisMF16	-1.114716	0.041055	-0.113794	199.8668

Scores that are linear combinations of variable (LC Scores)
FINAL SCORES and raw data totals (weights) for 182 plots

	Axis 1	Axis 2	Axis 3	Raw Data Totals
1 BBMF1	-0.934863	-0.286203	0.590766	178.2872
2 BBMF1	-1.055746	0.167811	0.069131	503.0245
3 BBMF1	-0.819131	0.301703	0.260281	31.8370
4 BBMF1	-1.224124	0.047880	0.173919	178.2872
5 BBMF1	-0.763648	0.075125	0.407757	25.4696
6 BBMF1	-1.567157	-0.402395	-0.068290	3.6762
7 BBMF1	-1.183162	-0.634361	0.112090	57.3066
8 BBMF1	-1.184547	0.226222	0.237718	63.6740
9 BBMF1	-0.604760	-0.327530	-0.591534	108.2458
10 BBMF1	-0.811367	0.418790	-1.067375	343.9490
11 BBMF1	-0.587145	0.031556	0.605851	101.8784
12 BBMF1	-0.667127	-0.251949	1.157759	324.7374
13 BBMF1	-0.687997	0.069192	1.580866	70.0414
14 BBMF1	-0.911473	0.099772	0.180051	726.1146
15 BBMF1	-0.378994	-0.062697	-0.261713	802.5478
16 BBMF1	0.052255	-0.296290	-0.336318	305.7325
17 BBMF1	-0.802830	0.610852	-0.061114	152.8662
18 BBMF1	-0.511378	0.480223	0.667835	133.7154
19 BBMF1	-1.263057	0.230404	-0.159518	50.9392
20 BBMF1	-0.083104	-0.940715	-1.030629	165.6051
21 BBMF1	-1.435522	0.045692	0.278584	369.4268
22 BBMF1	-1.066685	0.049618	0.718892	254.6960
23 BBMF1	-1.462894	0.109084	-0.678044	261.0634
24 BBMF1	-0.914445	0.261339	-0.593116	343.8395
25 BBMF1	-0.758535	0.407028	-0.072272	999.6816
26 BBMF1	-0.725209	0.342752	0.341099	636.7399
27 BBMF1	-1.251664	0.107058	-0.091898	222.8590
28 BBMF1	-0.898236	0.204515	0.330624	706.7812
29 BBMF1	-0.823149	0.072710	-0.073024	101.8784
30 BBMF1	-1.452297	-0.196264	-0.156116	133.7154
31 BBMF1	-1.180363	0.135583	-0.385601	315.5717

32	BBMF1	-1.466225	-0.338111	-0.291595	184.6546
33	BBMF1	-1.051185	-0.383841	0.322274	31.8370
34	BBMF1	-1.015694	0.340618	1.100167	305.6352
35	BBMF1	-0.591870	0.111454	-0.080295	146.4502
36	BBMF1	-0.842597	0.244762	0.443634	120.9806
37	BBMF1	-1.217997	0.134759	0.229647	770.4553
38	BBMF1	-0.906716	0.140726	0.249536	1165.2340
39	BBMF1	-1.190006	-0.334673	0.399258	108.2458
40	BBMF1	-0.966175	-0.202311	0.930074	229.2264
41	BBMF1	-0.815564	-0.064543	0.263152	12.7348
42	BBMF1	-1.091494	0.484693	-0.269690	140.0828
43	BBMF1	-0.857420	0.365508	0.302625	63.6740
44	BBMF1	-0.862295	-0.318171	-0.159757	63.6740
45	BBMF1	-0.852520	0.146158	0.316483	38.2044
46	BBMF1	-1.113015	0.231191	-0.139112	89.1436
47	BBMF1	-1.035765	0.238382	-0.550179	19.1022
48	BBMF1	-1.128341	0.238116	-0.443627	318.3699
49	BBMF1	-1.138012	-0.416233	0.179281	6.3674
50	BBMF1	-1.248985	0.073500	-0.173973	216.4916
51	BBMF1	-1.321293	0.142473	-0.281643	114.6132
52	BBMF1	-1.237388	-0.124631	0.271504	25.6931
53	BBMF1	-0.935422	-0.268078	-0.516698	25.4696
54	BBMF1	-1.319439	-0.284185	-0.370458	203.7568
55	BBMF1	-1.225232	-0.080718	-0.085495	114.6132
56	BBMF1	-0.972697	-0.290841	0.329389	44.5718
57	BBMF1	-0.699405	-0.054675	0.647402	140.0828
58	BBMF1	-1.273786	-0.264056	-0.420752	44.5718
59	BBMF1	-0.791052	0.002335	0.158399	280.1656
60	BBMF1	-1.097086	0.159028	-0.249575	254.6960
61	BBMF1	-1.073159	0.094004	-0.059174	369.3091
62	BBMF1	-0.910479	0.390939	0.646644	70.0414
63	BBMF1	-0.797235	0.247591	-0.223440	197.3894
64	BBMF1	-1.117984	-0.167780	0.813087	44.5718
65	BBMF1	-1.545187	-0.217322	-0.559296	101.8784
66	BBMF1	-1.319237	-0.035119	1.175108	82.7762
67	BBMF1	-0.796488	0.142178	0.205830	241.9612
68	BBMF1	-0.166801	-0.487610	0.429416	12.7348
69	BBMF1	0.727754	-1.475082	1.829776	165.5524
70	BBMF1	-0.740606	-0.071749	0.117033	82.7762
71	BBMF1	-0.505099	-0.618255	0.159346	31.8370
72	BBMF1	-0.869587	0.348521	-1.028445	254.6960
73	BBMF1	-0.624304	0.117716	0.794596	44.5718
74	BF2	-0.844550	0.432647	0.433442	50.9392
75	BF2	-0.877676	0.059917	0.896830	89.1436
76	BF2	-1.094821	0.281615	-0.042232	25.4696
77	BF2	-0.959532	0.547736	-0.576635	57.3066
78	BF2	-1.598972	0.235968	-0.922889	63.6740
79	BF2	-0.727120	0.157403	0.440646	38.2044
80	BF2	-0.817907	-0.384818	-0.151353	12.7348
81	BPMF3	-1.055242	0.308783	-0.550554	140.0828
82	BPMF3	-1.672625	-0.608612	0.809150	57.3066
83	BPMF3	-1.138012	-0.416233	0.179281	101.8784
84	Bugyal4	0.046771	0.469725	-0.623678	1687.3607
85	Bugyal4	1.322805	-1.766736	0.607894	254.6960
86	Bugyal4	1.307537	-1.679231	0.212779	82.7762

87	Bugyal4	0.598480	-1.778028	0.224969	197.3894
88	Bugyal4	1.444702	-1.466176	1.469569	299.2678
89	DMF5	-1.374218	-0.131802	0.267737	426.6157
90	DMF5	-0.869434	0.281244	-0.438148	171.9198
91	DMF5	-1.321903	-0.318705	-0.712541	165.5524
92	DMF5	-0.951763	-0.182392	0.438198	12.7348
93	DMF5	-0.639923	-0.462256	0.983310	56.6344
94	DMF5	-0.807928	-0.293425	-0.003114	44.5718
95	HAMF6	-1.214866	-0.016546	-0.595069	146.4502
96	HAMF6	-0.614266	0.374526	-0.093529	114.6132
97	HAMF6	-0.070127	-0.373464	-0.977332	89.1436
98	KailMF7	0.992982	-2.465754	-2.569697	401.1461
99	KMF8	0.141276	-1.241387	-0.971622	12.7348
100	KMF8	-0.198718	-0.572405	-0.750734	50.9392
101	KMF8	0.385527	-0.457519	0.683978	178.2872
102	KMF8	-0.755571	-0.424407	-0.014813	235.5938
103	KMF8	-0.553681	-0.033218	-0.283887	114.6132
104	KMF8	0.307956	-1.326109	-0.502502	63.6740
105	KMF8	1.131251	-1.223298	0.621121	89.1436
106	KMF8	0.574909	-1.550677	-0.354902	210.1242
107	KMF8	0.556566	-0.165079	-0.771668	1534.5431
108	KMF8	0.427011	-1.845575	1.157407	6.3674
109	KMF8	-0.906000	-0.857370	1.928687	50.9392
110	KMF8	0.763130	-1.959784	0.357525	1088.8252
111	KMF8	1.355833	-0.977116	0.741944	95.5110
112	KMF8	0.105266	-0.959362	-0.745333	19.1022
113	KMF8	1.074957	0.133836	0.089921	394.7787
114	KMF8	0.456671	0.866065	0.242848	808.6597
115	KMF8	0.687972	0.916778	-0.248115	499.4307
116	KMF8	-0.032405	-1.182045	-0.237121	6.3674
117	KMF8	-0.080445	-1.569150	-0.197388	12.7348
118	KMF8	0.524581	-1.045540	-1.016368	12.7348
119	KMF8	0.825236	-1.786451	1.037504	1039.3071
120	KMF8	0.136554	-1.553920	1.603549	216.4916
121	KMF8	0.022529	-1.755959	1.733462	331.1047
122	KMF8	-0.046734	-0.822708	1.431585	19.1022
123	KMF8	0.577489	-1.257231	1.694327	50.9392
124	KMF8	0.633828	-1.877235	0.751119	235.5938
125	KMF8	0.381358	-1.865703	1.207700	120.9806
126	LMF9	-1.839998	-1.726515	-1.640216	12.7348
127	LMF9	-1.450573	-1.904429	-2.207440	108.2458
128	LMF9	-1.837813	-0.957224	-1.190839	133.7154
129	LMF9	-0.718317	-0.927391	0.504441	38.2044
130	LMF9	-1.741688	-0.413049	-0.492881	101.8784
131	MoruMF10	0.268185	-2.065242	0.625811	324.7374
132	MoruMF10	0.066857	-0.728040	-0.452744	89.1720
133	MoruMF10	-0.122475	-1.423352	-0.970986	191.0828
134	MoruMF10	-0.510861	-0.867768	-1.257514	114.6497
135	MoruMF10	-0.237148	0.037076	1.275642	127.3480
136	OC11	0.374081	0.986133	-0.894655	522.1267
137	OC11	0.063200	0.370252	0.508180	127.3885
138	OC11	1.449513	-2.264470	-3.072626	573.2484
139	OC11	-0.743526	0.293336	-0.321987	229.2994
140	OC11	-0.350398	0.446055	-0.272891	254.7771
141	OC11	-0.875253	0.602501	-0.513361	197.3894

142 OC11	-0.453201	0.278174	0.138889	114.6497
143 OC11	0.673396	-1.840240	-1.708273	25.4777
144 OC11	-0.431327	0.198326	0.533695	152.8662
145 OC11	-1.650382	-0.372793	-0.593467	165.6051
146 OC11	0.999053	-1.716209	0.348776	235.5938
147 OC11	0.247756	-1.041959	-0.190743	777.0701
148 OC11	0.473490	0.006296	0.863722	942.6752
149 OGS12	1.026848	0.707138	0.157376	1528.6625
150 OGS12	0.824931	0.977163	-0.398994	1209.8058
151 OGS12	0.958855	1.087478	-0.310374	1208.0685
152 OGS12	-0.286490	0.653176	-0.898042	267.5159
153 OGS12	1.026848	0.707138	0.157376	8773.5469
154 PF13	-1.091731	-0.155540	0.211529	114.6132
155 PF13	-1.088070	-0.245647	0.515343	44.5718
156 PF13	-1.319291	-0.248018	-0.194902	50.9392
157 PF13	-1.053683	-0.189002	-0.215186	89.1436
158 PF13	-1.186319	0.197765	0.426556	120.9806
159 PF13	-0.341937	-1.488927	0.105150	50.9392
160 PF13	-1.814745	-0.435887	0.414541	44.5718
161 PF13	-1.785818	-0.366341	1.141923	44.5718
162 PF13	-1.322141	0.382688	-0.945453	114.6132
163 PMF14	-0.716738	0.288271	0.784460	203.7568
164 PMF14	-1.052029	0.191610	0.387006	439.3505
165 PMF14	-1.215396	-0.291185	0.068094	152.8176
166 PMF14	-0.671676	-1.503981	-1.181269	57.3066
167 PMF14	-1.737976	-0.418361	0.266304	50.9392
168 PMF14	-1.331861	-0.384756	-0.447234	50.9392
169 PMF14	-1.115523	-0.225207	-0.019075	191.0220
170 PMF14	-0.444033	0.368361	-0.306000	254.6960
171 PMF14	-0.936669	-0.494050	-0.800253	12.7348
172 PMF14	-0.713789	-0.067046	-0.069960	114.6132
173 PMF14	-1.028533	-1.336209	-1.224606	25.4696
174 PMF14	-1.530001	-0.336645	0.141362	19.1022
175 PMF14	-1.416762	-0.571544	-1.496969	25.4696
176 PMF14	-0.877566	-0.132134	0.267911	6.3674
177 PMF14	-0.885922	0.046797	-0.160290	6.3674
178 TMF15	0.648481	-1.779100	0.363876	241.9612
179 TMF15	0.405561	-1.977877	1.002585	70.0414
180 TMF15	-0.030783	-0.105668	-0.324724	89.1436
181 UtisMF16	-0.764584	-0.200882	-0.025075	254.6960
182 UtisMF16	-1.037414	0.118132	-0.165517	199.8668

FINAL SCORES and raw data totals (weights) for 14 Species

	Axis 1	Axis 2	Axis 3	Raw Data Totals
1 Baristat	0.437412	-0.795893	0.587733	4177.3643
2 Bchitria	-0.702872	-0.002333	0.036819	9311.4824
3 Basiatic	-0.981555	0.133823	0.580434	1636.5106
4 Bglaucoc	0.448027	-0.275534	-1.765946	70.0414
5 Blycium	-1.217677	0.051903	-0.151447	12790.8535
6 Bjaeshke	1.001018	-2.377897	1.797183	2746.1223

7	Bumbella	0.897523	-2.656060	-0.048910	1022.3218
8	Bpachyca	0.759717	-2.326637	2.518327	297.6176
9	Bkumaone	0.492463	0.479751	-1.175397	3674.1108
10	Brawatii	1.211434	0.977177	0.291143	2571.8647
11	Bosmasto	1.142332	1.009212	0.130455	9693.5664
12	Blambert	0.922738	1.337355	-0.299364	725.8835
13	Bpseudou	1.566905	-3.166757	-6.175218	802.4748
14	Bkunawur	0.457951	-0.623975	1.442051	108.2458

CORRELATIONS AND BIPLOT SCORES for 11 variable

		Correlations*			Biplot Scores		
	Variable	Axis 1	Axis 2	Axis 3	Axis 1	Axis 2	Axis 3
1	AP	0.144	-0.043	-0.040	0.132	-0.037	-0.028
2	CC	-0.690	-0.317	0.179	-0.633	-0.272	0.123
3	Elv	0.870	-0.255	0.211	0.798	-0.218	0.146
4	Asp	0.086	0.111	0.169	0.079	0.095	0.116
5	Slp	-0.225	0.218	-0.160	-0.206	0.186	-0.110
6	Prec-S	0.767	-0.375	-0.020	0.704	-0.321	-0.014
7	Prec-M	-0.618	0.287	-0.180	-0.567	0.246	-0.124
8	Prec-W	0.391	-0.817	0.112	0.359	-0.699	0.077
9	TM-S	-0.715	0.487	-0.165	-0.656	0.417	-0.114
10	TM-M	-0.718	0.403	-0.181	-0.658	0.345	-0.124
11	TM-W	-0.724	0.497	-0.139	-0.664	0.425	-0.096

* Correlations are "intraset correlations" of ter Braak (1986)

INTER-SET CORRELATIONS for 11 variable

		Correlations		
	Variable	Axis 1	Axis 2	Axis 3
1	AP	0.137	-0.038	-0.030
2	CC	-0.653	-0.279	0.134
3	Elv	0.824	-0.224	0.159
4	Asp	0.082	0.097	0.127
5	Slp	-0.213	0.191	-0.120
6	Prec-S	0.727	-0.330	-0.015
7	Prec-M	-0.586	0.253	-0.135
8	Prec-W	0.370	-0.718	0.084
9	TM-S	-0.677	0.428	-0.124
10	TM-M	-0.680	0.354	-0.136
11	TM-W	-0.686	0.437	-0.105

Note: Obtain joint plots or biplots by selecting GRAPH, then requesting "Joint plots" from the GRAPH menu.

MONTE CARLO TEST RESULTS -- EIGENVALUES

	Real data	Randomized data Monte Carlo test, 99 runs			
Axis	Eigenvalue	Mean	Minimum	Maximum	p
1	0.842	0.509	0.339	0.686	0.0100
2	0.733	0.279	0.164	0.500	
3	0.474	0.177	0.110	0.284	

p = proportion of randomized runs with eigenvalue greater than or equal to the observed eigenvalue; i.e.,
p = (1 + no. permutations >= observed)/(1 + no. permutations)
p is not reported for axes 2 and 3 because using a simple randomization test for these axes may bias the p values.

MONTE CARLO TEST RESULTS -- SPECIES-ENVIRONMENT CORRELATIONS

	Real data	Randomized data Monte Carlo test, 99 runs			
Axis	Spp-Envt Corr.	Mean	Minimum	Maximum	p
1	0.947	0.770	0.654	0.878	0.0100
2	0.879	0.591	0.467	0.803	
3	0.751	0.490	0.404	0.596	

p = proportion of randomized runs with species-environment correlation greater than or equal to the observed species-environment correlation; i.e.,
p = (1 + no. permutations >= observed)/(1 + no. permutations)
p is not reported for axes 2 and 3 because using a simple randomization test for these axes may bias the p values.

********** Operation completed
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List of scientific names (From chapter 3)

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Berberis rawatii sp. nov. (Berberidaceae) from India

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In India, 55 species of *Berberis* have been reported and 22 species are found in Uttarakhand state. *Berberis rawatii* (Berberidaceae), a new species from Chamoli and Pithoragarh districts of Uttarakhand state of India (western Himalaya) is here described and illustrated. In terms of leaf and inflorescence, *Berberis rawatii* shows affinities with *B. cretica* L.. Both these species have entire leaves, fascicled inflorescences, conspicuous style and black berries, but *B. rawatii* differs in the presence of a petiole, the dorsal surface of leaf pruinose, presence of elongated-ovate glands, presence of prophylls, three ovules and pruinose fruits.

Berberis L. is the largest genus of Berberidaceae and in India it is represented by 55 species. The majority (>95%) of these species are found in the Himalayan region. *Berberis* was divided into two groups (*Septentrionales* and *Australes*) by Schneider (1905). *Septentrionales* is further divided into 17 sections; among these, sect. *Wallichianae* is largest with 91 species. The group *Australes* has two subgroups and 15 sections, and *Truxilienses* is largest in this group with 25 species. The first taxonomic account of the family Berberidaceae for the Indian subcontinent was published by Hooker (1875). He included six genera and 17 species in this family. This treatment was considered to be too general, and subsequent workers split these 17 taxa and added many more new taxa. Schneider (1905–1908) revised the genus *Berberis* and added 13 new species. In a more recent study, Chamberlain and Hu (1975) further revised the section *Wallichianae* and treated 11 species, including one new species i.e. *Berberis victoriana*, from the Indian region. Jafri (1975) while dealing with the Berberidaceae for the 'Flora of west Pakistan' included 15 species of *Berberis* from the Kashmir region and Rao and Hajra (1993), while treating the family for the 'Flora of India', accepted 54 species of *Berberis* from the Indian region.

Recent work by Rao et al. (1998a, b) that follow Bentham and Hooker's system of classification, report 55 species of *Berberis* in India. It is interesting to note that among all the Himalayan states, Uttarakhand has the highest number of taxa (29 including subspecies). The number of *Berberis* taxa (species and subspecies) in Pakistan, Jammu and Kashmir, Himachal Pradesh and Sikkim are 24, 25, 23 and 16, respectively (Ahrendt 1941, 1961, Jafri 1975, Rao et al. 1998a, b).

During a taxonomic study on the genus *Berberis* in Uttarakhand (western Himalaya), we collected an interesting species of this genus at three localities in two districts, viz. Chamoli and Pithoragarh. After critical examination, it was revealed that our specimens did not match with any of the species described earlier. Hence, it is here described as a new species. In terms of leaf and inflorescence, the new taxon shows affinities with *B. cretica*, but it differs from the latter in terms of habit, habitat, flower size and fruits (Table 1).

Key to the identification of deciduous *Berberis* species found in Uttarakhand state of India

1. Flowers large, 14–20 mm in diameter (sect. *Angulosae*) 2
   – Flowers usually 4–12 mm in diameter 6
2. Ovules 6–12 (subsect. *Diaphnae*, *Euangulosae*) leaves white pruinose below . . . . . *B. concinna*
   – Ovules 3– 5 (subsect. *Jaeschkeanae*, *Subangulosae*) 3
3. Leaves narrowly elliptic 4
   – Leaves obovate or spathulate 5
4. Inflorescence 4–7-fid; berries oblong, estylose . . . . . *B. lambertii*
   – Inflorescence simple, rarely 2-fid; berries stylose . . . . . *B. osmastonii*
5. Leaves 3–5; flowes 3–5 . . . . . *B. jaeschkeana*
   – Leaves 6–10, flowers 5–10. . . . . *B. apiculata*
6. Inflorescence 15–30-flowered. (sect. *Vulgares*) . . . . . *B. pachycantha*
   -- Inflorescence 2–10-flowered. 7
7. Berries usually pink to red (sect. *Polyanthe* subsect. *Subpolyanthe*) 8
   – Berries usually black, sometime blue or white. . . 9
8. Leaves pruinose; panicles up to 4 cm long . . . . . *B. koehneana*

Table 1. Diagnostic morphological differences between *Berberis cretica* and *B. rawatii* sp.nov.

Character	*B. cretica*	*B. rawatii*
Shrub height (cm)	60–75	30–45
Leaves (mm)	10–17 × 4–7	20–35 × 5–8
Leaf apex	acute	mucronate
Petiole	absent	0.5 mm
Dorsal surface of leaf	epruinose	pruinose
Pedicel (mm)	2–5	9–10
Prophylls	absent	present
Outer sepals (mm)	4.0 × 2.5	5–6 × 2.0–2.5
Inner sepals (mm)	4.0–4.5 × 3.0	5–6 × 2.0–2.5
Petals (mm)	4.0–4.7 × 3.0	4–5 × 2.0–2.5
Glands	oblanceolate	elongated-ovate
Stamens (mm)	3.5–4.5	4.0–4.5
Style (mm)	0.5–0.7	0.7–1.0
Ovules	two	three
Berries	ellipsoid, epruinose	globose-obovoid, pruinose

– Leaves epruinose; panicles up to 4 cm long . . . . . *B. kunawurensis*

9. Style conspicuous; inflorescence fascicled (sect. *Hetropodae* subsect. *Creticae*) 10
– Style absent (subsect. *Pseudoumbellatae*); inflorescence umbellate or subumbellate . . *B. pseudumbellata*

10. Prophylls absent, sepals 3 . . . . . *B. cretica*
– Prophylls present, sepals 6 . . . . . *B. rawatii*

Berberis rawatii U. L. Tiwari and B. S. Adhikari sp. nov. (Fig. 1, 2)

Berberidi creticae foliis integris, inflorescentiis fasciculatis, stylis conspicuis et baccis nigris similis, sed ab ea praesentia petiolorum et prophyllorum, foliorum paginis superioribus et fructibus pruinosis, glandulis elongato-ovatis (nec oblanceolatis), ovulis 3 (nec 2) differt.

Type: India, Uttarakhand, Muniyalikhet, Pindar valley, 2340 m a.s.l., 16 Apr 2009, Umeshkumar L. Tiwari UKT-935 (holotype: WII).

Shrub, 30–45 cm tall. Stem glabrous, sulcate, grey, internodes 15–20 mm long, with 3-fid, yellow, 6–7 mm long spines. Leaves 20–35 × 5–8 mm, narrowly oblong-elliptic, apex mucronate with spine on the tip, base attenuate, margin entire, rigid, dull green above, pruinose below with few elevated veins, petiole 0.4–0.5 mm long. Older leaves 2–3 spinose-serrulate. Inflorescence fascicled, with 3–7 flowers. Pedicels 9–10 mm long. Prophylls 1.0–2.5 × 1.0–1.5 mm, obovate with acute apex, yellow with pink tinge. Outer sepals 5–6 × 2.0–2.5 mm, ovate, yellow. Inner sepals 5–6 × 2.0–2.5 mm, ovate, yellow. Petals 4–5 × 2.0–2.5 mm, obovate, entire, apiculate at apex, yellow. Glands elongated-ovate, 0.5–0.6 mm long. Stamens 4.0–4.5 mm long, truncate at apex. Filaments 3.0–3.5 mmlong. Ovules 3. Berries black, conspicuously pruinose, globose-obovoid, 6–7 × 2.0–2.5 mm, including the 0.7–1.0 mm long style. Seed pale red, ovoid.

Distribution, habitat and conservation status

Berberis rawatii is distributed in Muniyalikhet, Pindar Valley (Chamoli), Samkot and Munsiyari (Pithoragarh), Uttarakhand, India. It inhabits open southwest-facing dry grassy slopes in association with *B. asiatica* and *B. osmastonii*. *Berberis rawatii* falls in the 'Endangered' (EN) B1 a.b (v) category following IUCN (2003). The geographical range is extremely narrow and the population is fragmented. The geographical extent of habitat (limestone formations), in which this species grows in both the districts, is less than 10 km^2. In total, less than 500 individuals have been found. The species requires immediate in-situ conservation which may include protection of habitat.

Phenology and etymology

Flowering occurs in Apr and fruiting in May–Jun. The species has been named after the well-known plant ecologist Dr G. S. Rawat.

Similar taxa

Berberis rawatii belongs to *B.* sect. *Heteropodae* with *B. cretica* as its closest ally. *Berberis cretica* is reported from Crete, Cyprus and Greece (Linnaeus 1753, Ahrendt 1961, Strid 1986, Strid and Tan 2002). However, its occurrence in the Indian sub-region is doubtful as evident from subsequent literature. *Berberis vulgaris* var. *cretica* was said to be distributed from Garhwal to Baltistan (Hooker 1875), but this variety has now been merged with *B. cretica* (Rao and Hajra 1993, Rao et al. 1998b). Both *Berberis rawatii* and *B. cretica* have entire leaves, fascicled inflorescences, conspicuous style and black berries, but *B. rawatii* differs in the presence of a petiole (absent in *Berberis cretica*), the dorsal surface of leaf pruinose (epruinose in *B. cretica*), presence of elongated-ovate glands (oblanceolate in *B. cretica*), presence of prophylls (absent in *B. cretica*), three ovules (two in *B. cretica*) and pruinose fruits (epruinose in *B. cretica*).

Additional specimens studied (paratypes)

India. Uttarakhand: Muniyalikhet, Pindar Valley (30°03′22.5″N, 079°44′31.3″E, 2810 m a.s.l., southwest-facing aspect, 34° slope), Chamoli, 14 Apr 2010, Umeshkumar Tiwari UKT-2055 (DD), on the way to Samkot

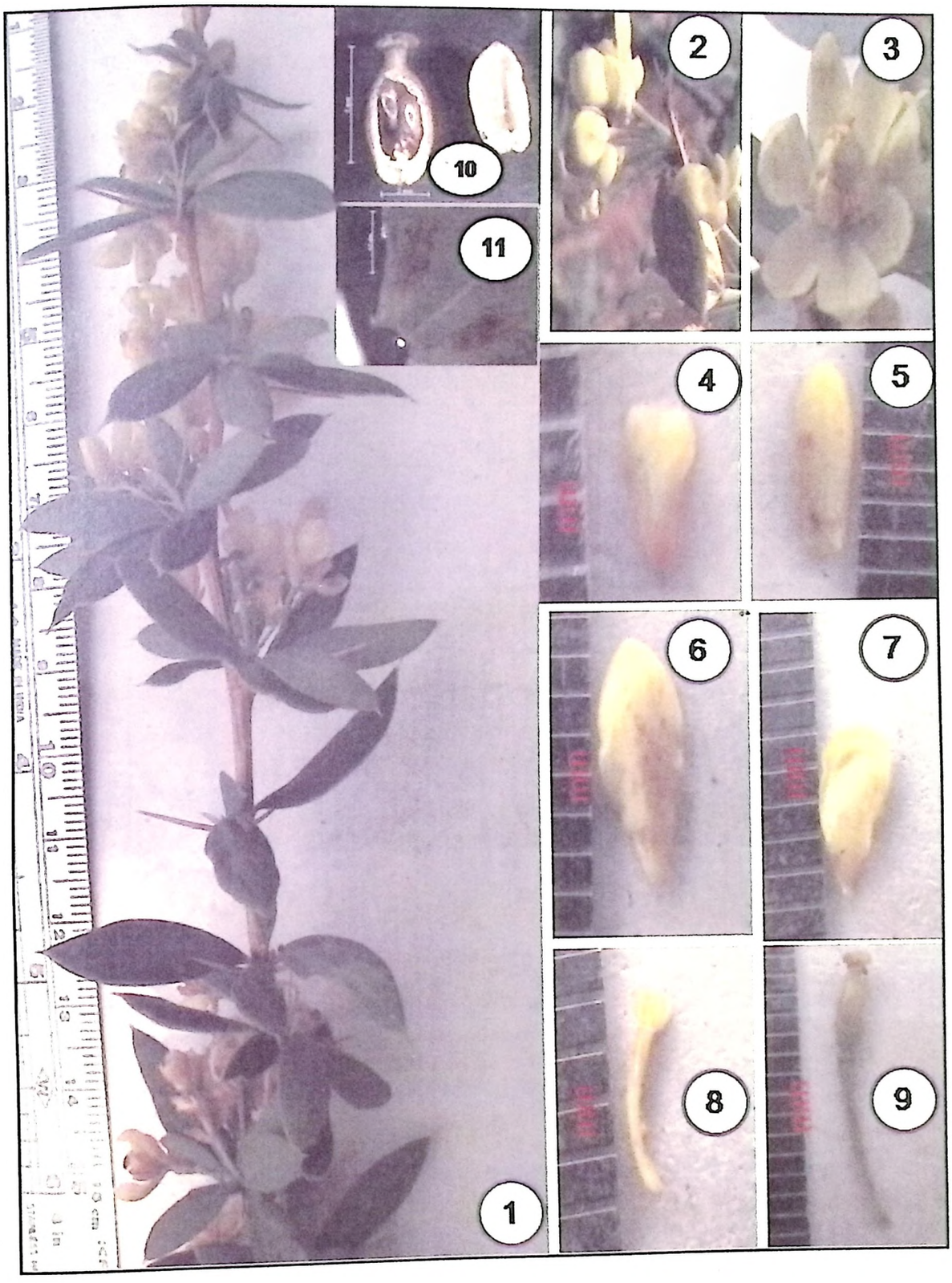

Figure 1. Photographs of *Berberis rawatii* sp. nov.: 1: Twig; 2: Inflorescence; 3: Flower; 4: Prophyll; 5: Outer sepal; 6: Inner sepal; 7: Petal; 8: Stamen; 9: Immature fruit. 10. Longitudinal section (L.S.) of fruit; 11. Glands on petals. *UKT-935* (Holotype) (WII). Scale bars are 5 × 2 mm for fig 1:10 and 0.5 mm for fig. 1.11.

(30°00′30.5″N, 080°10′45.4″E, 2343 m a.s.l., southwest-facing aspect, 34° slope), Pithoragarh, 9 May 2010, Umeshkumar Tiwari UKT-2053 (WII); Shaheed Trilok Singh Pangtey Gov. Intermediate College, Munsiyari, (30°03.704′N, 080°14.448′E, 2282 m a.s.l., northeast-facing aspect, 20° slope) Pithoragarh, 22 May 2010, Umeshkumar Tiwari UKT-2521 (WII).

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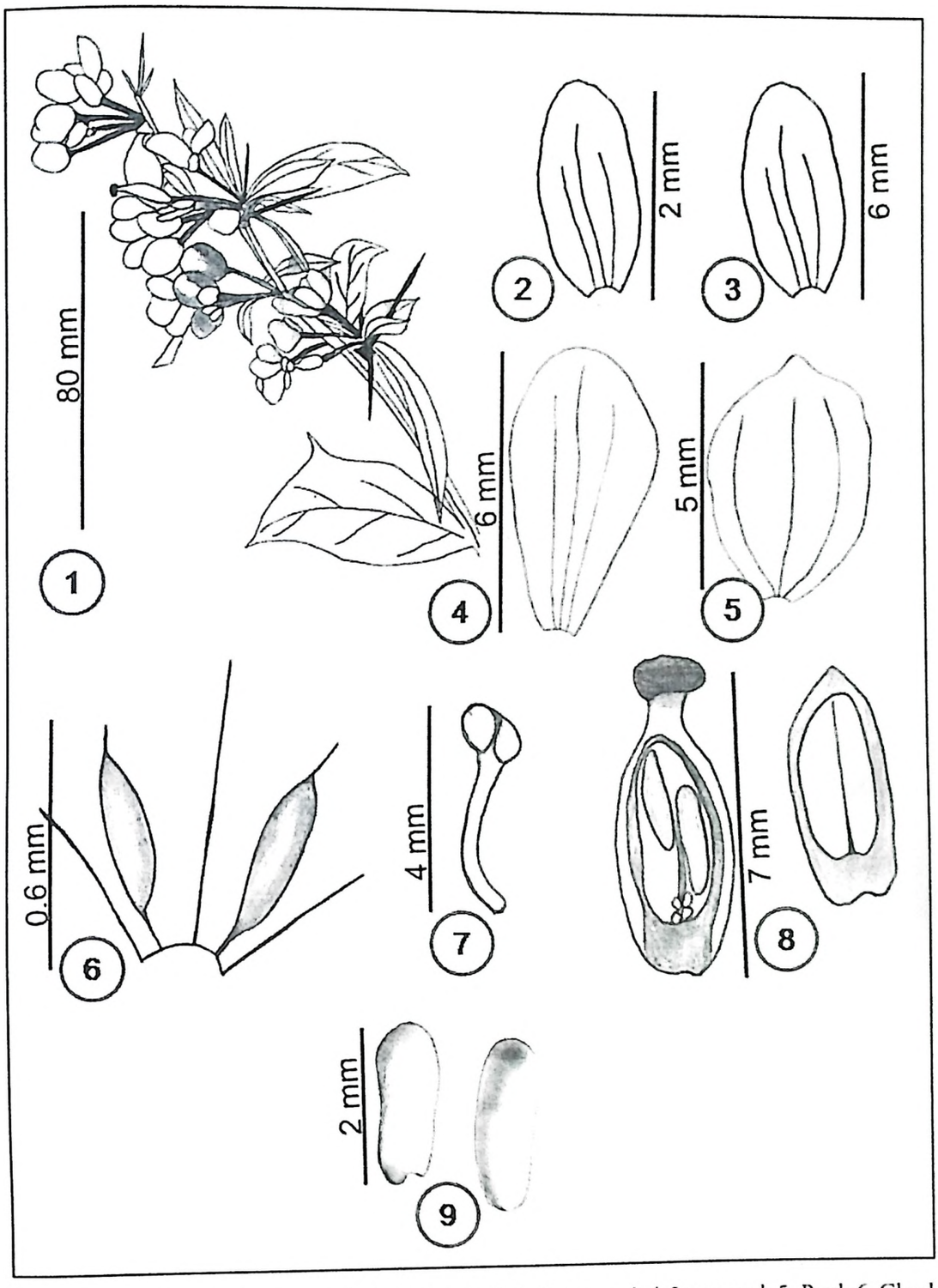

Figure 2. Illustration of *Berberis rawatii* sp. nov.: 1. Twig; 2. Prophyll; 3. Outer sepal; 4. Inner sepal; 5. Petal; 6. Glands; 7. Stamen; 8. L.S. of fruit. 9. Seeds. *UKT-935* (Holotype) (WII). Drawn by- Umeshkumar L. Tiwari.

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