PURJ (Sci.) PANJAB UNIVERSITY RESEARCH JOURNAL (SCIENCE) Vol. 59(1-4

PANJAB UNIVERSITY RESEARCH JOURNAL (SCIENCE)

VOL. 59, 2009

PANJAB UNIVERSITY RESEARCH JOURNAL (SCIENCE)
VOLUME 59

Chief Patron
Prof. R.C. Sobti, Vice-Chancellor, PU, Chandigarh

Editor-in-chief
Prof. R.S. Loyal, Department of Geology, PU, Chandigarh

Editor
Dr. S. Puri, UIET, PU, Chandigarh

Editorial Board:
Dr. A.K. Bhalla (Pediatrics), PGIMER, Chandigarh
Prof. S.K. Singla, (Biochemistry), PU, Chandigarh
Prof. A.S. Ahluwalia (Botany), PU, Chandigarh
Prof. R.K. Wanchoo (UICET), PU, Chandigarh
Prof. M.L. Garg (Biophysics), PU, Chandigarh
Prof. Kalpana K. Mahajan (Statistics), PU, Chandigarh
Dr. Jagdeep Kaur (Biotechnology), PU, Chandigarh
Prof. S.K. Mehta (Chemistry), PU, Chandigarh
Prof. Manmohan Gupta (Physics), PU, Chandigarh
Prof. A.K. Bhandari (Mathematics), PU, Chandigarh
Prof. Rajinder Jindal (Zoology), PU, Chandigarh
Prof. Karan Vasisht (UIPS), PU, Chandigarh
Prof. R.K. Singla (DCSA), PU, Chandigarh

Advisory Board
Dr. Krishan Lal, NPL, New Delhi
Prof. A.K. Sood, Indian Institute of Science, Bangalore
Dr. Pawan Kapur, Director CSIO, Chandigarh
Dr. Girish Sahni, Director, IMTECH, Chandigarh
Prof. K.K. Basa, Director, IGRMS, Bhopal
Prof. K.K. Talwar, Director, PGIMER, Chandigarh
Dr. Vishwa Mohan Katoch, Director General, ICMR, New Delhi
Prof. A.K. Chakraborty, NIPER, Mohali
Sh. Ashwagosha Ganju, Director, SASE, DRDO, Chandigarh
Dr. Satish Kumar, Director, TBRL, Chandigarh
Dr. S.K. Shukla, Director CFSL, Chandigarh
Dr. Rakesh Tuli, Executive Director, NABI, Mohali

The subscription of the journal may be sent in the form of a Bank Draft payable to ***The Registrar, Panjab University, Chandigarh*** *and addressed to the Editor-in-Chief on the following address:-*

Research Journal (Science)
Room No. 28-29, Old Correspondence Bldg.
Panjab University, Chandigarh - 160 014, India

The manuscripts for publication or any other enquiry is also to be addressed to the Editor-in-Chief.

Subscription fee:

	Inland	Foreign
Annual Subscription:	Rs.400/-	US $ 50
Life Membership:	Rs.3000/-	US $ 250

Printed in 2010

CONTENTS

INVITED ARTICLE

LIFE SCIENCES

PHYSICAL SCIENCES

Pb. Univ. Res. J (Sci.), Vol. 59, 2009, pp. 1-38

FIFTY RARITIES AND ADDITIONS TO THE PTERIDOPHYTIC FLORA OF ARUNACHAL PRADESH, N.E. INDIA

***C.R. Fraser-Jenkins[1] and A. Benniamin[2]**

[1] *Student Guest House, Thamel, P.O. Box 5555, Kathmandu, Nepal. Research Associate, Royal Botanic Garden, Edinburgh, Scotland.*

[2] *A. Benniamin, Botanical Survey of India, Arunachal Pradesh Circle, Itanagar, Arunachal Pradesh - 791 111; Email: fernsbenni@yahoo.co.in*

Abstract

Recent field-excursions in northern Arunachal Pradesh have resulted in the discovery of 26 pteridophytes previously unrecorded from India and in refinding a further 19 rare and little known species and 2 subspecies, which had been collected in India before but only from a very few localities. A new species is described, Pteris mawsmaiensis Fraser-Jenk. & Benniamin, and three new combinations are made, Polypodiodes yunnanensis (Franch.) Fraser-Jenk., Ctenitis (C.Chr.) C.Chr. Sect. Dryopsis (Holttum & P.J.Edwards) Fraser-Jenk. and Peranema annamensis (Tagawa) Fraser-Jenk. and Wangdi. Taxonomic notes are provided on rare and interesting species in 50 numbered entries pertaining to 25 genera.

Keywords: Pteridophytes, Arunachal Pradesh, India, rarities, new records, new species.

INTRODUCTION

Arunachal Pradesh, lying on the borders of Tibet and Myanmar in far N.E. India, contains the richest pteridophytic flora in India, with approximately 600+ known species and subspecies (Baishya & Fraser-Jenkins, in prep.), and with a guestimate of *c.* 50+ more species strongly expected to occur there. A carefully revised figure of approximately 1015 species and subspecies of pteridophytes are known from the Indian subcontinent in total (Fraser-Jenkins 2008b, amended here from current additions), including the Andaman and Nicobar Islands, but excluding Sri Lanka, or *c.* 985 species from political India). Thus as known at present, the State contains at least 60% of India's pteridophyte species or presumably more and contains a very high proportion of all known pteridophytes of northern India.

In keeping with and enabling this high figure, Arunachal Pradesh contains a surprising range of habitat and vegetational types, varying from low-altitude dense tropical-subtropical rain-forest, reaching further north than anywhere else in Asia (Proctor *et al.* 1998), to temperate broad-leaved forest, higher-mid altitude Himalayan coniferous forest, little known semi-arid, higher-mid altitude steppe-like regions and the least visited high Himalayan scrub, meadows and rocky screes. In its position it is also intimately connected to the adjacent centre of evolution of Sino-Himalayan species in S.W. China and N. Myanmar and is also home to a rich swathe of S.E. Asian (Malesian) elements reaching north and west into it via Myanmar and S. China. These connections have again contributed to the high number of species present. But being without phytogeographical barriers from those regions it contains very few endemic species (Fraser-Jenkins 2008a), those that are apparently endemic, as so far known, probably only being temporarily so due to having been overlooked until now in adjacent regions. This is in strong contrast to previous estimates of endemic pteridophyte species in India which misplaced the highest number in the N.E. instead of its actual location in the more phytogeographically isolated South of the country, due mainly to the local description of mistaken new "pseudoendemic" species already known from China.

But due to its being the least explored region of India, unknown to earlier British botanists, apart from Dr. William Griffith [1810-1845], and with many areas remaining very difficult of access even today, it is certain that the number of pteridophytes remains considerably underestimated; from 50 to perhaps as many as 100 further species may be expected to occur there. Nowadays very few botanists know nearly all the species

---

*Corresponding Author. *chrisophilus@yahoo.co.uk*

MS Received September 2, 2010

they see in the field or herbarium and for this reason new expeditions are often rather a hit-and-miss procedure, with novelties and rarities turning up more by accidental collection rather than knowingly. A number of species that are present further west in Bhutan, Sikkim and Darjeeling as well as further east in Tibet, China and Myanmar, are clearly to be expected in Arunachal Pradesh, in addition to unexpected species from further east still awaiting discovery.

Every expedition into the field in the State, especially at higher altitudes in the further north, therefore has the chance of turning up most interesting discoveries and even on just two short visits to well known lowland areas, the senior author, CRFJ, has turned up a few novelties. Since 2008, the junior author, AB, has made five main botanical collecting expeditions to northern Arunachal Pradesh in Kurungkumey, Papum Pare, Lower Subansiri, Upper Subansiri, E. Siang, W. Siang and Lower Dibang Valley Districts, resulting in a considerable number of interesting findings. The senior author has utilised his decades of familiarity with the Indian and adjacent extra-Indian pteridophyte-floras to identify these collections along with those of other collectors in Arunachal Pradesh. Several Arunachalian novelties have already been described or listed by Fraser-Jenkins (2008b).

We now report and comment on over 50 species, identified by CRFJ, from within or near Arunachal Pradesh, many either new (26 species) or very little known in India. Many further new records of species and a full list will be reported by Baishya & Fraser-Jenkins (in prep.). It is of phytogeographical interest that a number of southern Malesian species are turning up in Arunachal Pradesh, some of which are not known from S.W. China and a few of which are fairly disjunct occurrences so far as is known. It is expected that more field-collection in Myanmar may help bridge some of the gaps, but that is obviously a process that will take some time, given the unfortunately bad relationships maintained by the Western Countries.

The family and generic system used here is that of Fraser-Jenkins (2010), which was modified from that of Kramer and Green (1990). While being aware of recent molecular-cladistic ideas (Smith *et al.* 2006 and many subsequent studies) CRFJ has applied important morphological criteria over and beyond the basic cladistic rules, which are seen as being incomplete by themselves and sometimes artificial. The oft assumed "final judgement" made from molecular cladonomy and believed in by many moleculologists is seen here as not being as directly relevant to classification as proclaimed. Importantly, paraphyly is not considered here to be of relevance to taxonomic decisions and a sensible degree of molecular polyphyly is allowed when taxa have not diverged sufficiently morphologically.

RARE AND INTERESTING SPECIES

LYCOPODIACEAE

1. *Huperzia quasipolytrichoides* (Hayata) Ching, from ?Tibet, S.W. China and Taiwan, was first collected unidentified in India by N.L. Bor, from W. Kameng, Arunachal Pradesh, and previously from adjacent N. Myanmar by F. Kingdon-Ward. It was subsequently collected unidentified from Kameng by Panigrahi and then from further east by a few later collectors. Dixit (1984) first reported it from India, but misidentified it as *H. cryptomerina* (Maxim.) R.D.Dixit, which has much shorter and less narrowly linear leaves, unlike the spectacularly long and narrow leaves of *H. quasipolytrichoides*. As shown by Fraser-Jenkins (2008b) the several Indian records of "*H. cryptomerina*" actually refer to *H. quasipolytrichoides*, confined in India to a few higher-altitude localities in northern Arunachal Pradesh, from W. Kameng to Lower Debang Valley and (as yet) not known from Bhutan or further west.

MARATTIACEAE

2. *Angiopteris palmiformis* (Cav.) C.Chr. (syn.: *A. angustifolia* C.Presl, *A. durvilleana* de Vreise, *A. medogensis* Ching). This species was described by Cavanilles in 1803 as one of the earliest species names in the genus, from the Philippines. Unfortunately many authors, faced with the mass of incomprehensible and almost intractable names applied in this genus, opted to refer all or most species to *A. evecta* (G.Forst.) Hoffm., a species with long recurrent false veins, described from Tahiti and apparently confined to Oceania and the Pacific area, not present in the Indian subcontinent. It is therefore difficult at present to find the distributions of species from literature as they are usually either referred to *A. evecta*, or split up under many different local names.

Fraser-Jenkins (2008b) attempted to tackle the nomenclatural problem and stabilise the correct names for the two common Indian species, which both have very short recurrent false veins, by sinking many simultaneously published names of Presl's under a single name selected as being the most suitable and characteristic from its type. Thus *A. indica* Desv. and *A. helferiana* C.Presl are the two common Indian species. But not long afterwards, during a visit to Itanagar in Papum Pare District in 2009, he could not help but notice that what obviously belongs to a third species occurs commonly at low altitude in Arunachal Pradesh (*e.g.* at Tsiria Kanna Hill, and Ganga Lake, Itanagar, *CRFJ*, 2009). It is a very large plant, more robust and with thicker stipes and rhachides than the other two, though the stipe is similarly smooth and with scattered yellow streaks; the longer pinnae bear more numerous pinnules, readily distinguishable by their consistently cordate bases. In addition the recurrent false veins are longer than in the other two, reaching down to approximately half way or rather more towards the costule (segment midrib) as opposed to merely reaching the soral line or very minutely within it. Like *A. helferiana*, the sori are borne slightly inframarginally. Comparison with the Philippine *A. palmiformis*, which CRFJ had studied and photographed in the field in Mindanao in late 2007, shows it to be identical in every respect, with pinnules varying from wider and more crowded to slightly narrower and further apart in both the N.E. Indian and Philippine material. The N.E. Indian plant is therefore referred here to *A. palmiformis*, albeit somewhat tentatively. Most probably, it is assumed, *A. palmiformis* may not be confined to the Philippines, but perhaps occurs throughout S.E. Asia, but from the present state of the literature it is impossible to find out more without undertaking a study throughout Asia in the BM, Kew, PE, BKF, SING *etc.* If no original material of *Clementea palmiformis* Cav. exists at MA, it should be neotypified from Philippine material. Its range as so far known, is the Philippines, Malaya (Holttum 1955, Piggott & Piggott 1988), Vietnam, Thailand (Lindsay *et al.* 2009), Taiwan (Kuo 1985 and updates), Arunachal Pradesh (throughout, from Kameng to Tirap) and E. Bhutan (N. of Samdrup Jonkhar, *CRFJ*, 2009), but it is presumably to be expected more widely in linking areas such as Myanmar and possibly S.W. China (probably under some other name applied by Ching). No material has so far been seen and is probably not expected from anywhere west of Bhutan, though its presence in Nagaland or Manipur might be expected, but unfortunately the very rich Manipur fern-flora is largely unknown as it has not been documented in modern times and that of Nagaland has only been superficially documented by Jamir & Rao (1988).

OSMUNDACEAE

3. *Osmunda cinnamomea* L. subsp. *asiatica* (Fernald) Fraser-Jenk. is a rare and little known bipinnatifid species in India, known only from a small handful of collections and unknown to the earlier British pteridologists. Its most obvious feature is the fertile fronds, in which the lamina is completely fertile from base to apex, unlike the common and widespread *O. claytoniana* L. subsp *vestita* (Wall. *ex* Milde) Å.Löve & D.Löve, which has some sterile pinnae at the base and apex, though sometimes difficult to see in fronds that are not fully uncurled, which has led to some erroneous reports of *O. cinnamomea*. In *O. cinnamomea* the sporangia are rather more spread out than in *O. claytoniana* and the sterile fronds have a more abrupt apex with smaller, thinner segments, so the whole plant has a different overall "look" from *O. claytoniana*. *O. cinnamomea* occurs in the Indian subcontinent only known so far from E. Bhutan, N. Arunachal Pradesh and a single locality at Umchingam, 8km. W. of Mawphlong in Meghalaya, where it was discovered by *A.S. Rao* in 1969 (not widespread there as thought by Baishya & Rao 1982), and is always very restricted in distribution. It has been collected a few times in W. Kameng and Lower Subansiri (including Ziro, *A.B.* 22994, 6 June 2008, ARUN, det. CRFJ). Ghosh *et al.*'s (2004) report of var. *fokiensis* Copel. was in error for subsp. *asiatica*.

POLYPODIACEAE

4. *Arthromeris tatsienensis* (Franch & Bureau *ex* Christ) Ching is a distinctive species which has often been confused with *A. wallichiana* (Spreng.) Ching and other species with a single row of sori each side of the pinna-costa. It has a similar semi-subterranean rhizome to *A. wallichiana*, with similar reddish-brown scales, gradually tapering from their bases to their apices. But the pinna-bases are narrowly tapered and cuneate, though similarly sessile, and the apices are more narrowly caudate-attenuate; the lateral veins along the pinna are distinctively prominent and often darkened, appearing to divide the pinna up into a series of chambers along its length, while the cartilaginous margin is also prominent and the sori are smaller than in *A. wallichiana*. The species most similar to it is *A. tenuicauda* (Hook.) Ching, which is confined in India to the furthest north-east (in contrast to the wide range given by Dixit 1984, faithfully perpetuated by Chandra 2000), in Meghalaya, where it is very rare and threatened around Sohra, Jorain

and a few other places, and at Pynursla on the border of Meghalaya in eastern Assam. *A. tenuicauda* is also not present in Bhutan (Fraser-Jenkins, Matsumoto & Wangdi 2009), where it has been reported in error for *A. tatsienensis*, nor in Arunachal Pradesh or Sikkim and Darjeeling, nor in Nepal, from where it was reported by Thapa (2002) in error for *A. tatsienensis*. *A. tenuicauda* is usually epiphytic, consistently has paler rhizome-scales, the rhizome is not as subterranean, and the lower and mid pinnae are obviously stipitate, unlike in *A. tatsienensis*. *A. tatsienensis* is a terrestrial species, at its commonest in the Indian subcontinent in C. Nepal, but is also found in Sikkim and further east in Bhutan and northern Arunachal Pradesh, in Kameng and Siang Districts (Mechuka, *A.B.* 26002, Nov. 2008, ARUN, det. CRFJ).

5. Another, very rare species of *Arthromeris* is *A. tomentosa* W.M.Chu (1992), occurring in N.W. Arunachal Pradesh (Baishya & Fraser-Jenkins, in prep.) and discovered by CRFJ in 2009 near Wamrung, north of Samdrup Jonkhar on the way to Tashigang in E. Bhutan, where it is confined to hanging loosely off well shaded and dark, semi-overhanging cliffs and road-cuttings. It is similar to *A. himalayensis* (Hook.) Ching in its ovate pinna-shape and few pinnae (from 2 to sometimes 6 or 7 pairs), though having a thicker, more blue-green rhizome (and in cultivation in a shaded pot can live happily for an extended period of time as a rhizome only if conditions are not conducive enough for the production of fronds) and darker scales. But its most obvious feature is a thick felt of pale yellowish-grey hairs forming a mat over the lower surface. In stating that it was a synonym of *A. himalayensis*, Fraser-Jenkins (2008b) was quite mistaken, not having seen Prof. Chu's material and how very distinct it was.

6. A single collection of an unidentified *Lepisorus* species from W. Siang (W. of Mechuka, *A.B.* 26100, 11/2008, ARUN) is a distinctive species most similar to *L. thunbergianus* (Kaulf.) Ching in its not very large, closely clumped, rather thick, narrow fronds with narrowly attenuated apices, medium-short stipes, and large, crowded pairs of yellow sori, but instead of having very narrow, attenuated, toothed rhizome-scales with dark centres and a narrow pale edge (as in *L. thunbergianus*), it has slightly wider-based scales with long, narrow, attenuated apices, which are thinnish, untoothed, smooth and totally dark brownish-black, with no paler areas and the cell-walls hardly visible, but apparently rounded-square and not elongated. They are thus also not like the totally black, thick and striated scales of the much larger, thicker and long-, robust-stalked species, *L. sordidus* (C.Chr.) Ching, which occurs scattered throughout Arunachal Pradesh. Unless *L. thunbergianus* can sometimes have all black scales, this does not appear to be any of the species hitherto reported, rightly or wrongly, from India, but should be readily identifiable from study in Beijing, Kew or the BM herbaria, which CRFJ intends to do. It could not be identified from the study by Ching (1933), or from the *Flora Reipublicae Popularis Sinicae* (Lin *et al.* 2000), unless it is perhaps the poorly established "*L. iridescens* Ching & Y.X.Lin", described from Yunnan, but this seems unlikely as the latter has wider fronds.

It should be noted that it is well established and documented that the genus *Pleopeltis*, favoured by Singh & Panigrahi (1990, 2005) is not at all related to *Lepisorus*, but to *Polypodium sensu stricto*, making their several new combinations of *Lepisorus* species into *Pleopeltis* spurious and unnecessary.

7. ***Polypodiodes yunnanensis*** (Franch.) Fraser-Jenk., ***comb. nov.***, basionym: *Polypodium yunnanensis* Franch., *Bull. Soc. Bot. Franc.* **32**: 29 (1885), syn.: *Polypodium bonatianum* Brause, *Goniophlebium krameri* Panigrahi & Sarn.Singh, ?*Polypodiodes amoena* var. *pilosa* (C.B.Clarke) Ching. Fraser-Jenkins (2008b), mentioned this combination as unpublished, but did not make it as it appeared to be only a hairy form of *P. amoena* (Wall. *ex* Mett.) Ching. However adult plants of *P. amoena* are not hairy like this (though small juvenile fronds are somewhat hairy) and it appears to be a distinct specific entity, which does not occur throughout the range of the species, but is confined in India to the far North East; a few collections in Arunachal Pradesh, ranging from Kameng to Tirap Districts (including *A.B.* 22656, from Raga to Ziro, Subansiri District, 13 June 2008, ARUN) also Meghalaya.

8. *Pyrrosia rasamalae* (Racib.) K.H.Shing was reported by Fraser-Jenkins (2008b) from Arunachal Pradesh and *P. arunachalensis* Sarn.Singh & Panigrahi was sunk into its synonymy. Slightly smaller, more exposed specimens of *P. rasamalae* were also reported by Ghosh *et al.* (2004) (excluding their undocumented mention of Meghalaya) and Singh & Panigrahi (2005) as "*P. floccigera* (Blume) Ching", actually a synonym of the S.E. Asian *P. albicans* (Blume) Ching, and not occurring in India. Fraser-Jenkins (2008b) inadvertently wrote that their specimens of "*P. floccigera*" were *P. stenophylla*

(Bedd.) Ching, by some unfortunate slip of memory, but actually thinking of *P. rasamalae*. *P. rasamalae* is a very distinctive and handsome species with a very long, creeping rhizome more-or-less densely covered in russet-brown scales and the very narrow, linear, stiff fronds arising well apart and bearing long, dense, russet hairs beneath. It was with great pleasure that CRFJ spotted a colony of it growing on a tree in the middle of Itanagar town at Bank Tinali in 2009 and it was further gratifying that his energetic co-author, *AB*, instead of himself, was able to shin up the tree to retrieve some nice material, rather to people's curiosity, right in the town-centre (see photograph in Benniamin & Fraser-Jenkins 2010). In India it is only known so far from Arunachal Pradesh (throughout, from W. Kameng to Tirap), where it is scattered, though not particularly rare.

9. *Pyrrosia heteractis* (Mett.) Ching was reduced to a variety of the morphologically very similar *P. lingua* (Thunb.) Ching by Hovenkamp (1986), but he has since kindly informed CRFJ (pers. comm., 2009) that he now accepts it to be a distinct species. It is consistently distinguishable, but only by the indument beneath the lamina (observable with a lens, after scraping some of it away), which has a top layer of stellate hairs with slightly wide arms above a more compact lower layer of stellate hairs with very narrow, woolly arms, whereas *P. lingua* has only a compressed mat of stellate hairs with slightly wide arms. *P. heteractis* is much the commoner species in India, occurring from E. Nepal eastwards through Sikkim and Darjeeling to Bhutan, Arunachal Pradesh, Assam State, Nagaland, Manipur and Meghalaya, also in South India. It is widely misreported as *P. lingua* due to being influenced by frond-size and shape, which is not relevant. *P. lingua* occurs scattered in a few Indian localities in Arunachal Pradesh and Meghalaya.

10. *Selliguea engleri* (Luerss.) Fraser-Jenk. (2008b) is a small, simple-fronded species with an elongated, narrow frond, c. 10-15 cm. long, minutely notched margins and a sorus situated between each side-vein in a line on each side of the midrib and extending from the tip right down to the base of the lamina. It was listed by Dixit (1984) from "India (Himalayas)", *sub Phymatopteris*, but without any reference or explanation given concerning India. He also listed *S. echinospora* (Tagawa) Fraser-Jenk., *sub Phymatopteris*, and *S. yakushimensis* (Makino) Fraser-Jenk., *sub Crypsinus*, in an exactly similar way with no reference relevant to India. All three were excluded by Chandra (2000) and Fraser-Jenkins (2008b). Unfortunately CRFJ forgot to ask the late Dr. Dixit during their many meetings what he was referring to, but it is most likely to have been listed on the basis of Ching's reports referring to the Himalaya, though not actually to the Indo-Himalaya. However CRFJ has now come across and identified a specimen of *S. engleri* from Arunachal Pradesh, Changlang, Shirong to Hunung, c. 1100 m., *B.K. Shukla* 88205, 7.2.1986, ASSAM. This species is thus to be added properly to the Indian pteridophyte list.

Another species to be added to the Indian list is *S. trisecta* (Baker) Fraser-Jenk. (2008b), which is like a small, trilobed *S. hastata* (Thunb.) Fraser-Jenk. (syn.: *Crypsinus montanus* Sledge), but is obviously hairy on the lamina and at the edges *etc*. A single collection of it has turned up, originally identified as *Crypsinus hastatus* (Thunb.) Copel., near to the Meghalaya border in Assam State, Pynursla, 31 miles from Shillong, scarce, on rocks, *G. Panigrahi* 2950, 25 Aug. 1956, ASSAM, redet. CRFJ. *S. hastata* itself, with its minutely notched margin (which only occurs very rarely in some juvenile plants of the common *S. oxyloba* (Wall. *ex* Kunze) Fraser-Jenk.), remains unknown from N. India, but occurs in the South and in Sri Lanka.

HYMENOPHYLLACEAE

11. *Hymenophyllum barbatum* (Bosch) Baker is rather poorly known from India where it only occurs in the North East as a rarity. It was reported by Dixit (1984) from "Assam" in the wide sense, copied by Chandra (2000), though neither Beddome nor Clarke had mentioned it. But it has now turned up in Arunachal Pradesh, Siang District, Mechuka, *AB* 26030 *p.p.*, ARUN, det. CRFJ. [*Cyathea andersonii* (J.Scott *ex* Bedd.) Copel. was also numbered 26030]. It is one of the interesting toothed-margined species, but has many long hairs on the stipe, rachis and axes, similar to the common and widespread *H. exsertum* Wall. *ex* Hook.

H. exsertum was mistakenly referred to *H. tenellum* D.Don by Morton (1973) in one of his very rare misidentifications of names, due to the rather poor type-specimen of *H. tenellum*. But Fraser-Jenkins (2008b) showed that *H. tenellum* is the correct name for the Asian plant that has usually been referred to the American species, *H. polyanthos* Sw., in agreement with its identification by others. Unfortunately Christensen (1906: 368) omitted a specific epithet in the synonymy of the later homonym, *H. tenellum* (Jacq.) Kuhn and appeared to be saying that Willdenow had combined *Adiantum tenellum* Jacq. into *Hymenophyllum* in 1810, as "Bory *ex* Willd". However no such name appears in Willdenow's work and the name referred to was actually supposed to be *H. ricciaefolium* Willd., which Christensen (1906: 367) also erroneously referred to as "Bory *ex* Willd." Willdenow gave Jacquin's *Adiantum tenellum* in the synonymy of *H. ricciaefolium*. Christensen had also listed a *Sphaerocionium* in the synonymy after "Bory *ex* Willd." and there is no *S. tenellum* in existence, which confirms he was intending *S. ricciaefolium* (Willd.) C.Presl. The correct name for the Mascarene and Madagascarian plant (which does not occur in Sri Lanka as thought by Christensen) is thus *H. ricciaefolium* Willd., with *H. tenellum* (Jacq.) Kuhn, *nom. illeg.*, *non* D.Don, and *H. fumarioides* Borry *ex* Willd. in its synonymy. But following Christensen's omission, when Parris & Latiff (1997), in their important checklist of Malaysian pteridophytes, wanted a name for Don's Asian species they thought *H. tenellum* D.Don was an illegitimate later homonym so made what they cited as a *nomen novum*, *Mecodium tenellum* Parris, but did not cite Don's reference in full and thus as an invalid name, in addition to it actually being a superfluous name as *H. tenellum* D.Don was available for combination if such an insignificant splinter-genus as *Mecodium* should be thought worth recognising. Due to its not having the basionym-reference cited in full (no title or page reference) their name also cannot stand as the new combination it should have been. It was therefore left to Panigrahi & Singh (2005) to make this unnecessary combination.

12. *Trichomanes parvifolium* (Baker) Copel., belonging to Sect. *Microgonium*, is a minute, moss-like, carpeting fern, very distinct from the similarly tiny *T. saxifragoides* C.Presl. It was first reported from the Indian subcontinent in W.C. Nepal by Fraser-Jenkins (2008b), it having been an unidentified species he found in a waterfall he used to bathe in in Gorkha District, kindly identified for him by Dr. A. Ebihara of Tokyo Botanic Garden, Koisikawa. Unexpectedly he subsequently discovered it growing on rocks in a small gulley at the well known Ganga Lake, just west of Itanagar in 2009, while visiting there with *AB* (Benniamin & Fraser-Jenkins 2010) and it would seem likely that it may be expected elsewhere in N.E. India. The difficulty is that with leaves at only 5-7 mm. tall it will normally be mistaken for a moss by most botanists and overlooked. Unlike the radiating lobes of the minutely umbrella-like *T. saxifragoides*, this species has fronds varying from bearing narrow simple lobes to about 3 or 4 lobes, yet becomes fully fertile with green sori turning brown when ripe, one at the apex of each lobe. It always remains this small and there is no transition towards larger fronds.

PTERIDACEAE

13. *Aleuritopteris dubia* (C.Hope) Ching is a species intermediate between *A. albomarginata* (C.B.Clarke) Ching and *A. rufa* (D.Don) Ching. It has the stipe- and rachis-hairs of *A. rufa*, though not as dense, and mixed with many wider scales. The pinnae and pinules are less lobed as in *A. rufa*, but the fond is widest at the base as in *A. albomarginata*. All three species have more-or-less scattered narrowish scales on the pinna-costae. The spores are more-or-less regular and not obviously those of a hybrid. Unfortunately its cytotype is unknown, while the other two are diploid, but it might not necessarily be expected to be an allopolyploid (between the other two). It occurs quite commonly right through the Indo-Himalayan region where there are calcareous boulders or on walls, but is seldom present in very large numbers in a population, though more than would be expected for a sterile interspecific hybrid. Curiously, as it is quite different from other *Aleuritopteris* species in this way, all three species have identical flavinoids in the white farina beneath the frond (Wollenweber, pers.comm. c. 1990, from investigation of material sent by CRFJ). Although some linking intermediates occur right across the spectrum of these three species it is clear from study of many populations that individuals clearly tend to fall into one of the three, as separate taxa.

Until recently it has been one of the species expected but not known from Arunachal Pradesh, but it has now been collected from W. Siang District, Mechuka, by *A.B.* 26290, 11/2008, ARUN, det. CRFJ.

14. *Aleuritopteris duclouxii* (Christ) Ching is a very rare species in India, having turned up just once, in Arunachal Pradesh, Changlang District, Namdapha, Shirong to Hunung, *c.* 1100 m., *B.K. Shukla* 88207, 7.2.1986, ASSAM, det. CRFJ, and has not been reported from India previously. It is similar in habit to *A. argentea* (S.G.Gmel) Fée, with a small, pentagonal, horizontal frond atop a longish, black stipe, and belongs to the Section *Argentea*, unlike most of the Indian *Aleuritopteris*. It is thus not altogether dissimilar from a *Doryopteris*. The lobes and pinnae have rather elongated and simple apices and unlike most *Aleuritopteris* it is an efarinose species without the white powder beneath - and not merely due to alcohol treatment with poisoning

agent in the herbarium, which removes the farina from many specimens in Indian herbaria (but without which the specimens will be reduced to dust by the ever-hungry herbarium insect fauna!). CRFJ noticed many years ago that this specimen was of much interest, but (Fraser-Jenkins & Dulawat 2009) thought it might be a specimen of *A. shensiensis* Ching. Only recently on comparing with a photograph of *A. duclouxii*, it became clear that it is this species, which thus just reaches N.E. India from its centre in S.W. China. Unfortunately he did not refind it during a visit to Namdapha in 1994 with the Scientific Exploration Society as he did not go to that particular locality.

15. *Notholaena borealisinensis* (Kitag.) Fraser-Jenk. (1997b) was reported from Bhutan, and a collection has also turned up from Arunachal Pradesh, Tirap, Namdapha, Krosam, c. 1000 m., on rock, *B.K. Shukla* 88038, 3 Feb. 1986, ASSAM, det. CRFJ. Fraser-Jenkins (2008b) and Fraser-Jenkins & Dulawat (2009) also reported *N. dipinnata* Fraser-Jenk. from Arunachal Pradesh, but careful re-examination and some unfolding of parts of the badly scrumpled specimen has revealed that the pinnae were only folded over and appeared to be pinnate, but are not actually so. The specimen concerned is therefore just another specimen of *N. borealisinensis*, Arunachal Pradesh, Lohit Frontier District, on the way from Quiboung to Yeatung. *B. Krishna* 48966, 13 Jan. 1970 (ASSAM), det. CRFJ, and *N. dipinnata* is thus not known from India.

N. borealisinensis is similar to *N. himalaica* Fraser-Jenk. (syn.: *Gymnopteris vestita* (Hook.) Underw., *Paragymnopteris vestita* (Hook.) R.Tryon, *non Notholaena vestita* (Spreng.) Desv.), but is a smaller plant with a small, more-or-less cordate-based pinna and more yellow-brown, shorter hairs beneath, as opposed to whiter ones. We do not accept the N. American typification and application of the name *Notholaena* to new-world species (Tryon & Tryon 1980, proposal rejected; Yatskievych & Smith 2003) and prefer to retain the careful typification of the genus made by Pichi Sermolli (1983, 1989) in keeping with its widespread application throughout the old world in the great bulk of literature. It appears that none of J. Smith's (1875) usage of the word 'type' can be taken in the sense of today's typification as he often cited more than one species, or species not mentioned by the original author. He merely meant it was typical or representative of the genus. Any genus said to have been typified by Smith clearly needs proper lectotypification again. However it also appears that recent molecular-cladonomic reshaping of "genera" is a quite inadequate approach and many of the revisions being proposed in Pteridaceae, such as with *Notholaena*, *Pellaea*, *Cheilanthes*, *Doryopteris etc.* are insufficiently supported morphologically to be translated into taxonomy and nomenclature. There is little reason why N. and C. American "*Notholaena*" should not be combined with *Notholaena* proper, from the old-world, so the American species may still be referred to the genus *Notholaena*.

16. *Pteris assamica* Fraser-Jenk. and T.G.Walker (Fraser-Jenkins 2008b) is very common in lowland areas in N.E. India, but as it had always been confused with either *P. longipinnula* Wall. *ex* J.Agardh or *P. biaurita* L. subspp., being intermediate between them in morphology (and with free veins), its range has not yet been fully understood. But it is rather surprising that it had not been noticed before in Arunachal Pradesh, where it is obviously to be expected along the outermost, lowest foothills around the state, however it has now turned up growing on road-banks on the West edge of Itanagar (*CRFJ* F.n. 34 and 148, 1/2009, ARUN) and he has identified a collection of *G. Pangrahi*'s 15314, 10 May 1958, ASSAM, from Baha Hill, W. Kameng, and of *A.B.*'s 22907, June 2008, ARUN, from Ziro, Subansiri. Holttum's (1955) comments interpreted by Fraser-Jenkins (2008b) as probably indicating Holttum's first noticing its presence in Malaya are now confirmed. It is a widespread S.E. Asian species reaching westwards across N. India just into the S.E. tip of Nepal.

Another low-altitude, large species, *Pteris khasiana* (C.B.Clarke) Hieron., has a smooth stipe and non-apiculate segments with only a few setae, and is common enough below Darjeeling, by the Teesta river, and in Assam and Meghalaya. It has been collected in Arunachal Pradesh from Kameng to Tirap, including Papum Pare, Chimpu, *CRFJ* FN 37, 25.1.2009, ARUN; E. Siang, Tuting or Pasighat, *A.B.* 22396 *p.p.*, 7.2008, ARUN; and Tirap, Raho to Vokanoska, *G. Panigrahi* 16822, 26.8.1958, ASSAM, cited by Singh & Panigrahi (2005) sub "*P. spinescens* C.Presl", in error, redet. CRFJ.

17. *Pteris cadieri* Christ first came to the attention of CRFJ as a small unidentified species at Namdapha, Changlang District in 1994 (Deban, *CRFJ* 20621, 17.1.1994, given via the Namdapha authorities to Itanagar Forest Dept. and subsequently probably discarded), which had unusual dimorphic fronds, the juvenile and sterile fronds having lobed pinnae remeniscent of *P.*

grevilleana Wall. *ex* J.Agardh, but the taller and often fertile fronds having unlobed pinnae similar to a small *P. cretica* L. Subsequently, on finding it near Digboi, Assam State, it became clear that this was the Chinese species, *P. cadieri*, not then reported from India. It has recently been misreported from near Namdapha by Singh & Panigrahi (2005) as the adventive species, *P. multifida* Poir., in error, but was correctly reported from Manipur by Ghosh *et al.* (2004) as an apparent new record to India.

18. *Pteris hirtula* (C.Chr.) C.V.Morton (syn.: *P. hekouensis* Ching; *P. subhirtula* Sarn.Singh & Panigrahi). This large and robust, low-altitude, subtropical forest species is generally similar to a large *P. longipinnula* Wall. *ex* J.Agardh and may either have the lowest pinnae with a developed accessory pinnule, or without. Although slightly variable in prominence with age, it has a very characteristic and immediately noticeable pale pubescense on the rachis and costae. The Indian subcontinental material, including the type of *P. subhirtula*, matches the type from N.E. Myanmar well, though said to differ to a minor degree by Singh & Panigrahi. Rather surprisingly Singh & Panigrahi very obviously misreported another of their collections of it (ASSAM!), also from Namadapha, in Changlang District, as "*P. blumeana* J.Agardh", which is not at all similar to it and which no one has yet collected from Arunachal Pradesh, even though it could be present there at the lowest altitudes. CRFJ has collected *P. hirtula* from E. Bhutan, near Samdrup Jonkhar, in 2009 (THIM) and in Arunachal Pradesh, Papum Pare District, hill opposite Seinki Park, *CRFJ* FN 180, 16.2.2009 (ARUN); while AB has collected it in Upper Subansiri District, Daporijo, *A.B.* 22718, 10.6.2008 (ARUN) and E. Siang District, Kana Korang Bridge, Pasighat, *A.B.* 22529, 7.2008 (ARUN), all det. CRFJ.

19. *Pteris inaequalis* Baker, *non* C.Presl, *nom. nud.* (syn.: *P. sinensis* Ching, *nom. superfl.*, *P. excelsa* var. *simplicior* (Tagawa) W.C. Shieh) has often been taken as irregular, juvenile specimens of *P. terminalis* Wall. *ex* J.Agardh (syn.: *P. excelsa* Gaudich. (1829), *non* Blume (1828)). Ghosh *et al.* (2004) used the name *P. sinensis* to refer to such juvenile plants, but there is also what appears to be a distinct species with fewer lobes to the pinnae, somewhat intermediate between *P. terminalis* and *P. semipinnata* L., but with less pinna lobes than either and quite long regions of simple pinna. In other respects it is similar to *P. terminalis* and has similar several-toothed lobe-apices and a pinkish-bown stipe and rachis. At first the single unidentified specimen known from India appeared like some strange hybrid in frond-morphology, but the spores are good and it has now been identified as *P. inaequalis* by CRFJ. It is from Arunachal Pradesh, West Kameng District, Kalaktang Forest, 1100 m. *R.K. Ghosh & B. Ghosh* 68271, 8 Nov. 1995, CAL.

20. *Pteris kathmanduensis* Fraser-Jenk.. & T.G.Walker (in Fraser-Jenkins 2008b) was described from C. Nepal and extends west just into Pithoragarh (rare); it is common around Darjeeling and in Sikkim and has recently been collected in Arunachal Pradesh by *AB* (Subansiri, Ziro, *A.B.* 22682, ARUN) and also by S. Singh (Papum Pare, Patanala, *S. Singh* 72968, 1978, ARUN), det. CRFJ.

21. ***Pteris mawsmaiensis*** Fraser-Jenk. & Benniamin, ***sp. nov.*** *Species similaris ad P. blumeanam, segmenta longissima angusta sed leviter apiculatae ad apices differt. Costae spinas geminatas manifestas instructae et costulis setis brevibus roseis sub apice segmentorum instructis differt.* Holotype, here designated: India, Meghalaya, among eroded, steep, convoluted limestone rocks and cliffs below natural mixed low forest near uprising of stream c. ½ km. to the east side of entrance to Mawsmai Cave, west of Mawsmai village, c. 10 km. S. of Sohra (Cherrapunji) off road to Shela and Bangladesh border, S. of Shillong, Khasi Hills. *C.R.Fraser-Jenkins* Field no. 227, 22 Nov. 2008 (TAIF). Paratypes: Ditto, F.n. 218, 222-226, 228-229. Distribution as known so far: N.E. India: Arunachal Pradesh, Siang, *A.B.* 22318 *p.p.*"b", ARUN; Meghalaya, Sohra area; it is to be expected in Myanmar and S.W. China, and is not expected to be endemic to India. *A.B.* 22318, part "a" is a more widespread and common species close to *P. aspericaulis*, but with fewer pinnae, rather larger segments and one or two pink setae here and there below the segment-apices. It occurs rarely in C. Nepal (way to Annapurna Base Camp, Kaski District, *CRFJ*), N. Arunachal Pradesh and commonly in Meghalaya and is assumed to be present in at least N. Myanmar and S.W. China, from which latter CRFJ has seen some similar material and from where it seems to have been named, which will be researched further at a later date.

P. mawsmaiensis is quite probably a calcicole species and appears at first sight similar to *P. blumeana* in its many longish, narrow segments to the pinnae. It tends to have a slightly horizontal, rather wide lamina atop a long, slightly rough-surfaced to nearly smooth, green or usually pinkish stipe and the young fronds are usually tinged with pink, though not so on maturity. It normally has two basiscopic developed pinnules at the base of each lowest pinna of the lowest pair. More careful inspection shows that it differs significantly from *P. blumeana* in having apiculate to subapiculate segment-apices, the stipe being smoother and the segments are not quite as small, crispaceous, narrow and crowded as in *P. blumeana* (the "*P. roseolilacina*" of Verma, *non* Hieron., from the lower Darjeeling/Teesta regin). In particular it does not have the very long, delicate, prominent white setae all along above the segment-midribs that *P. blumeana* has when normally developed, but only medium-length, stiff, pink ones a little below the segment-apex. It is true that *P. blumeana* sometimes looses its setae, but in that case the white bases of the setae can be seen along the midrib, unlike in *P. mawsmaiensis*.

In the woods and eroded sugar-limestone rocks around Mawsmai Cave, *P. mawsmaiensis*, *P. khasiana* (C.B.Clarke) Hieron. (syn.: *P. fauriei* Hieron.), *P. normalis* D.Don, *P. spinescens* C.Presl (syn.: *P. setulosocostulata* Hayata), the same member of the *P. aspericaulis* group as *A.B.* 22318 a, *P. arisanensis* Tagawa (syn.: *P. gongalensis* T.G.Walker; "*P. linearis*" *sensu auct. Ind.*, *non* Poir.; "*P. confusa*" *sensu* Singh & Panigrahi (2005), *non* T.G.Walker) and *P. biaurita* L. subspecies occur along with it, making it a breeding-ground "*Pteridetum*" of great interest and delight to study, quite apart from a remarkable richness of rare and little known pteridophyte species of other genera. Few places in India could be more fascinating for an informed pteridological visit than there.

22. *Pteris taiwanensis* Ching has sometimes been taken as a rather dubious species, closely related to *P. wallichiana* J.Agardh, with the same radiating frond, umbrella-pattern but with much narrower segments which are further apart, with a very narrow wing of tissue between them, and often a rather abrupt apex to the pinna. However it seems to remain fairly constant and recognisable in its narrow lobes and does not occur in the C. or W. Indo-Himalayan part of the range of *P. wallichiana* but has a distinct distribution, only being present in further N.E. India and Bhutan. This tends to suggest that it constitutes a distinct species. A specimen of *P. taiwanensis* from the Bhutan Hills, *C.J. Simons* (BM) has been mistaken for the very large S. Indian and S.E. Asian species, *P. mertensioides* Willd., with a normal pinnately dissect frond, which does not occur in N. India. But this is understandable when no pinna-bases revealing the radiating pattern are included on the sheets. Although *P. mertensioides* has all free veins and *P. wallichiana* and *P. taiwanensis* have costal auricles formed by the lowest opposite pair of veinlets anastomosing, the costal wing of tissue in *P. taiwanensis* is so narrow that it is often very difficult in herbarium-specimens to see whether the lowest veinlets anastomose or not, without careful examination. *P. taiwanensis* has been collected in northern Arunachal Pradesh from Kameng and Subansiri, under the name *P. wallichiana*, including Kameng, Baha Hill, *G. Panigrahi* 15346, 10 May 1958, ASSAM, *sub* "*P. mertensioides*" det. S. Singh, redet. CRFJ; Subansiri, det. CRFJ.

Another apparent species close to *P. wallichiana*, but of less certain status than *P. taiwanensis* is *P. tomentella* Hand.-Mazz. (syn.: *P. wallichiana* var. *yunnanensis* (Christ) Ching & S.H.Wu; *P. rufopilosa* Ching & S.K.Wu). It is exactly similar to *P. wallichiana* but when mature the stipe is black or dark purple and densely covered in a short, stiff, brown pubescence. In this respect it is so obviously different from normal *P. wallichiana* that it cannot simply be ignored as mere variation, but nevertheless it is difficult to evaluate its taxonomic significance. It is common in the higher hills from W.C. Nepal, eastwards to Sikkim, Bhutan, and has also been collected in Arunachal Pradesh in Tawang, *G.D. Pal* 8319, ARUN, det. CRFJ, and further east. A Nepalese plant (from below Annapurna Base Camp) remains constant, year after year, once the fronds are mature, in cultivation in a pot in Kathmandu.

23. *Pteris vittata* L. subsp. *vermae* Fraser-Jenk. (Fraser-Jenkins 1997b, 2008). As with so many critical groups nowadays, research into the subspecies of *Pteris vittata* remains badly delayed by the disastrous lack of any cytologist using the proper chromosome-squash method (for root-apices, as well as developing sori) to check the cytotype of plants of interesting morphology. CRFJ has found a few populations here and there of *P. vittata* with erect fronds with narrow pinnae, slightly apart, but with shortish apical segments, which are thus intermediate between the two common subspecies, the subtropical subsp. *vittata* (syn.: subsp. *bengalensis* Fraser-Jenk.) and the Himalayan subsp. *emodi* Fraser-Jenk. One such population occurs between Naya Pul and

Birethanti, N.E. of Pokhara at the start of the treks to Annapurna Base Camp or Gorepani and Poon Hill, Kaski District, C. Nepal (and there are others further west in Nepal, Fraser-Jenkins 2008b). They are very similar in morphology to the type of subsp. *vermae*, probably originating from below Nainital, in Uttarakhand (W. Indo-Himalaya), but just possibly of slightly doubtful localisation, and also to known diploid plants of Wang, Zhong-Ren's, from China. Plants of yet more convincing morphology have also turned up in W. Bhutan (Fraser-Jenkins 2008b: 98) and especially a population in Arunachal Pradesh, Papum Pare, beyond Sawmill village, Panchali, *CRFJ* FN 197-199, 17.2.2009, ARUN, within strolling distance of the Botanical Survey of India compound, which is the best candidate yet for subsp. *vermae* in India after the type. But unfortunately there is no-one to do the cytology and obtain some solid, reliable results and until such plants have been investigated nobody can know any more! CRFJ and AB also collected plants (*CRFJ* F.n. 50-55, 28 Feb. 2009, ARUN, of rather intermediate morphology, along with probable subsp. *emodi*, at Professor B.K. Nayar's precise original locality, kindly indicated to CRFJ by Prof. Nayar, for what is said to be a pentaploid hybrid (also of intermediate morphology), cultivated for many at the National Botanical Research Institute, Lucknow (Khare & Kaur 1983a, b). The plant was originally collected by Prof. Nayar from a roadside wall and stream ½-1 km. south of the junction of the southern access-road to the Circuit House below Sohra with the main Shillong-Sohra road to the Bangladesh border. In fact, although not collected by Khare *et al.*, whose voucher-specimens were all reidentified as normal subsp. *vittata* by CRFJ, even plants growing outside the Botanical Survey of India herbarium at Shillong, appear similar, if they are not just subsp. *emodi*, and originated from Shillong Peak, where it still occurs, as all round Sohra and the Khasi Hills.

A similarly open-ended and unsure situation pertains to *Adiantum recurvatum* (D.Don) Fraser-Jenk. (syn.: *A. indicum* Ghatak), which though perhaps occurring throughout much of India, has never been chromosome-counted beyond its type-population at Belgharia, N. Calcutta. It is essential that more findings of known tetraploid plants of it are made before its frond-morphology and range in India *etc.* can be understood. Plants from the type-locality cultivated by CRFJ appear to be matched by low-altitude plants from various places in India, but cytological confirmation (of both) is seriously and urgently required.

ASPLENIACEAE

24. *Asplenium hondoense* N.Murak. & Hatan. (syn.: *A. unilaterale* var. *birii* B.K.Nayar & Geev.) has already been reported by Fraser-Jenkins (2008b) from S. India, but has now been found in W.C. Nepal (fern-rich, narrow, rocky gorge and luxuriant, leech-ridden forested slope, shortly above Poiyim village on track along slope from Burjung Khola to Kahavre village, N. of Pokhara, Kaski District, *CRFJ* F.n. 69, with George Yatskievych, Lisa Hooper, Jyoti Gajurel, Rita Thapa and Ganesh Tamang, 12 Sept. 2009, along with *Onychium plumosum* Ching, F.n. 51, *Pteris medogensis* Ching & S.K.Wu, F.n. 54, *Antrophyum obovatum* Baker, F.n. 65, *Asplenium amoenum* C.Presl *ex* Mett. (syn.: *A. filipes* Copel.), F.n. 68, *Cornopteris quadripinnatifida* M.Kato, F.n. 77, *Diplazium javanicum* (Blume) Makino, F.n. 78, *Diplazium bellum* (C.B.Clarke) Bir, F.n. 80, *Diplazium kawakamii* Hayata, F.n. 81, *Dryopteris atrata* (Kunze) Ching, F.n. 82, *Polystichum scariosum* (Roxb.) C.V.Morton, F.n. 85, 86 [not noticed in Nepal previously], *Polystichum annapurnicola* Fraser-Jenk.., F.n. and other species). It has also been found in Mizoram, Champai District, Murlen National Park, near Vapur, *A.B.* 22062, 22115, 22141, Feb. 2009, ARUN, det. CRFJ; and Tripura, Monpui to Vaughmun, 1990-2260 ft., *D.B. Deb* 27052, 22 Jan. 1962, ASSAM, det CRFJ.

25. *Asplenium laciniatum* D.Don subsp. *kukkonenii* (Reichst.) Fraser-Jenk. (2008b) has been collected by AB and others in Arunachal Pradesh, in addition to subsp. *tenuicaule* (Hayata) Fraser-Jenk. and subsp. *laciniatum*. It is now known from Kameng, Shergaon to Jigaon, *G. Panigrahi* 15909 (ASSAM); Bomdila, *J. Joseph* 40310 (ASSAM); and Subansiri, Ziro to Talo, *A.B.* 22687 (ARUN), det. CRFJ. It is similar to subsp. *laciniatum*, but generally has narrower fronds, smaller segments and a rather attenuated, fused apical segment to the frond; its spores are similar in size to subsp. *laciniatum*.

26. *Asplenium zenkerianum* Kunze is an exclusively S. Indian and Sri Lankan species with simple pinnae and a subapical proliferous bulbil. A specimen of it at CAL is labelled: "Duphla Hills, *Lister* [s.n.]", but must simply be a mislabelling of a South Indian specimen.

THELYPTERIDACEAE

27. *Thelypteris paludosa* (Blume) K.Iwats. (probable syn.: *Pseudophegopteris sumatrana* Holttum). This

Malesian species has now been found in Arunachal Pradesh, Kurungkumey District, on the way to Serley, near the Tibetan border, *c.* 1500 m. alt. *A. Benniamin* 26435, Dec. 2008, ARUN. It is a member of Sect. *Pseudophegopteris*. The collection is of a rather small plant with a "neatly dissect", delicate frond and less crowded pinnule-lobes than in large plants. It has a thin, reddish-brown stipe and rachis, the lamina being up to *c.* 70 cm. long x 30 cm. wide (as opposed to over 2 m. long in large specimens in S.E. Asia). Lamina lanceolate, the lowest three pairs of pinnae gradually reduced, the lowest pinna being *c.* 5-6 cm. long. Pinna-costae and costules pale reddish-brown, sparsely hairy beneath with short, stiff, pale hairs, also scattered on the veins of the lamina. Pinnae longest shortly above the mid-point of the lamina, all markedly opposite throughout the frond; mid-pinnae c. 16 cm. long, lanceolate, widest about their middle (up to *c.* 5½ cm. across) and slightly narrower to their bases, the basiscopic mid pinnules being nearly twice as long as the acroscopic. The longest pinnules up to *c.* 3½ cm. long, 8 mm. wide, with a square base, the rest being narrowly lobed to about half to three-quarters of their depth on each side with acute, slightly remote lobes, the pinna-apex being narrowly acute; pinnules of upper-mid pinnae narrowly acute (c. 1½ cm. long x 3 mm. wide) with very small, narrow lobes. In the smallest of the three fronds collected, the sterile pinnules are very shallowly lobed, but are narrowly and markedly acute, almost linear. Sori small, oval, exindusiate. Unfortunately there is no rhizome on the collection nor was it noted whether it was long-creeping or short and semi-erect, as the collector did not know of its importance, though one might suspect the latter condition as known for *T. paludosa*.

This collection is clearly not any of the subspecies of *T. pyrrhorhachis* (Kunze) C.M.Kuo, but has the typical long, lobed basal pinnules, red axes and less hairy lamina and costae of *T. paludosa*. Due to confusion with *T. pyrrhorhachis*, it is not yet known whether *T. paludosa* occurs in Myanmar and, though to be expected, in S.W. and S. China, from where the account of *Pseudophegopteris* in the *Flora Reipublicae Popularis Sinicae* (Shing 1999) was under-researched taxonomically and out of date, merely compiling all the "species" named, several being just growth-stages of *T. levingei* (C.B.Clarke) Ching, while *T. pyrrhorhachis* was largely misunderstood and its subspecies ignored. *T. paludosa* occurs otherwise in S. India (rare in comparison to *T. pyrrhorhachis*, see Fraser-Jenkins 2008b), Thailand, Malaya, ?Vietnam, Borneo (Sabah), Java, the Philippines and New Guinea.

28. *Thelypteris megacuspis* (Baker) C.F.Reed (syn.: *Pronephrium megacuspe* (Baker) Holttum, *Pronephrium sampsonii* (Baker) Ching *ex* K.H.Shing, *Cyclosorus megacuspis* Tardieu & C.Chr.) is a very distinctive *Thelypteris* in Sect. *Pronephrium*, known from Vietnam and S. China (Yunnan, Kwangsi, Kiangsi [Jiangsi] and Kwangtung). Unexpectedly, it has now been collected by AB in Arunachal Pradesh, W. Siang, Mechuka, *A.B.* 26086, 18 Nov. 2008 (ARUN), though previously unknown from India. It has a longish-creeping rhizome and about 3-4 pairs of long, wide pinnae up to c. 23 cm. long, the lowest pair either being obviously shorter than the next, or in one frond, the largest. The pinnae are upswept, ovate, widest above their mid-point and narrow markedly to their cuneate and stalked bases as well as abruptly to their cuspidate apices with a narrow, acuminate tip about 2-3 cm. long. The frond-apex is imparipinnate with a long, wide apical segment similar to the largest pinna. The pinna-edges vary from undulate to, more usually, shallowly acutely lobed with a slight tooth at the apex of the more prominent lobes. The veins are in about 11-12 anastomosing pairs with a zig-zag common excurrent vein and several free veins in the more acute lobes, or in a few places being separate between one areole and the next. The lamina is ± glabrous, though the pinna-costae and main veins have small hooked hairs on them. The fronds are sterile and it is to be expected that more of the excurrent veins would be separated in each areole in fertile specimens. Though sterile, this species is so distinct that it obviously does not represent sterile material of any other known species.

29. *Thelypteris repanda* (Fée) C.V.Morton (syn.: *Pronephrium repandum* (Fée) Holttum; *Cyclosorus repandus* (Fée) B.K.Nayar & S.Kaur, *comb. inval.* [alternative name]; *Thelypteris urophylla* (Mett.) K.Iwats.; *Pronephrium birii* R.D.Dixit). This exindusiate species has been confused in India with the indusiate, S.E. Asian species, *T. aspera* (C.Presl) K.Iwats., which does not occur in or near to India, despite being reported *sub Pronephrium* by Dixit & Kala (1988) from Arunachal Pradesh. It appears that Dixit must have been unable to distinguish some bent hairs in herbarium-specimens from genuine hooked hairs as the only species (apart from the common *T. nudata* (Roxb.) C.V.Morton and *T. lakhimpurensis* (Rosenst.) K.Iwats. (syn.: *Thelypteris*

stenopodum (P.Chandra) Panigrahi)) occurring around the Botanical Survey of India compound (Dixit's "stream side") and the Hydel project (near Panchali, shortly above it) is *T. repanda*, with straight hairs and exindusiate sori - easily visible in the living state - which does have the setose sporangia he illustrated, unlike western Malesian *T. aspera*. It is not clear whether Dixit's mention of indusia in *T. aspera* was from his specimens or from literature. As the Chinese and Vietnamese species, *T. simplex* (Hook.) K.Iwats., is not present in the area, or in India at all, which he also reported from Seinki View (the B.S.I. site, Itanagar), but with a description enhanced from literature on that species, it was difficult to work out what he had been referring to until CRFJ visited the area and studied and collected in detail in the localities concerned (specimens in ARUN) in 2009. The species that occurs there is *T. repanda*, but it varies considerably, often becoming precociously fertile when only having a simple juvenile frond, then developing two small side-lobes, becoming short pinnae, and finally developing from 2 up to *c.* 7 pairs of full-sized pinnae. Dixit confused the smaller, simple-fronded specimens with *T. simplex*, which thus explains his observation that it sometimes has a free pair of pinnae, which does not occur in *T. simplex*. Dixit & Balkrishna (1990) also described an apparently new species, "*Pronephrium birii* R.D.Dixit & Bal Krishna", initially identified by him as a mixture of *T. simplex* and *T. griffithii* (T.Moore) C.F.Reed, until he realised they were growth-stages of a single taxon. It came from the well known, popular locality and reserve of Ganga Lake, a few km. N.W. of Itanagar. But on searching thoroughly round the lake in 2009, CRFJ and AB could only find *T. repanda* again and *T. birii* is clearly a semi-juvenile and slightly irregularly-shaped specimen of *T. repanda*.

The Arunachal Pradesh material of *T. repanda* has slightly variable, but usually fairly densely hairy lower surfaces to the pinnae, with short, pale hairs on the veins and costae, visible with the naked eye. In this respect it differs slightly from most S.E. Asian material, though it is variable and may be more hairy there, too. While the pinnae and larger apical segment are usually ovate-caudate with an abrupt, narrow, acuminate tip, it can also have a more lanceolate, elongated pinna, but not normally as straight-sided as in *T. nudata etc.*

It has been collected at low altitude across the western part of northern Arunachal Pradesh from Kameng to Subansiri and also occurs in China, Myanmar, Thailand and S.E. Asia.

WOODSIACEAE

30. *Athyrium dissitifolium* (Baker) C.Chr. is a Chinese species, also present in Myanmar and Thailand and appears to be related to the widespread *A. drepanopterum* (Kunze) A.Br. *ex* Milde and *A. niponicum* (Mett.) Hance (syn.: *A. brevisorum* Bedd.), from Arunachal Pradesh, Manipur, Tripura, Myanmar, Thailand, China etc., all three placed as members of Section *Anisocampium* by Fraser-Jenkins (1995 *ined.*). It has now been collected by AB in India as well, in Arunachal Pradesh, Subansiri, *A.B.* 22698, June 2008, ARUN), det. CRFJ. It is distinguished by its pinnatifid pinnae with nearly unlobed, rounded-rectangular lobes and oval, exindusiate sori.

31. *Athyrium nakanoi* Makino was correctly recorded from Bhutan in the Japanese E. Himalayan Expedition Reports, but was then erroneously equated by Dixit (1984), reproduced by Chandra (2000) with *Athyrium macrocarpum* var. *unipinnatum* C.B.Clarke, from Meghalaya, which actually belongs to *A. puncticaule* (Blume) T.Moore, a species confined to far N.E. India and S.E. Asia, but widely recorded throughout the Indo-Himalaya in error for the abundantly common and widespread species, *A. foliolosum* T.Moore *ex* R.Sim, all three species belonging to Sect. *Polystichoides*. *A. nakanoi* was thus not correctly reported from India apart from by Fraser-Jenkins (2008b), following Fraser-Jenkins (1995 *ined.*), from Arunachal Pradesh. Rather many collections of this attractive miniature species have been made at higher-mid altitude in northern Arunachal Pradesh from Kameng and from Mechuka, W. Siang, *A.B.* 26302, 26324, 18 Nov. 2008, ARUN, det. CRFJ. It has small, miniature *Polystichum*-like, simply pinnate fronds with short, ovate and auriculate pinnae only *c.* 1 cm. long.

However there also exist some plants (Kameng, W. Siang (Mechuka, *A.B.* 26224, 26301, Nov. 2008, ARUN) and Debang Valley) which have the pinnae rather more elongated beyond the basal auricle to about 2 cm. long, with shallow lateral lobe-teeth, but with a similar rounded apex, often narrower just above the auricle than at their apex. They show some similarity to small plants of *A. puncticaule*, though they clearly do not belong to that species. Both frond-forms occur in Japan as well, where *A. nakanoi* has been found to be tetraploid sexual, and some transitional plants have been collected in Arunachal Pradesh, so it appears likely that they merely represent the largest size and degree of development shown by *A. nakanoi* and do not merit any separate nomenclatural status.

32. *Diplazium burmanicum* Ching *ex* W.M.Chu & Z.R.He (1998) was known for some time in India to Bir and others, though not published, as "*D. cordifolium* Blume var. *listeri*" (*ined.*). This was written on the sheet of J.L. Lister's collection at Kew in a large, unidentified hand which might be that of J.G. Baker [or possibly of S. Kurz] (as explained by Fraser-Jenkins 2008b, taken from Fraser-Jenkins (1995 *ined.*), prior to becoming aware of the name *D. burmanicum*). Lister, about whom little is apparently known (*e.g.* not listed by Desmond 1994, though mentioned briefly by Burkill 1953-1962), was a British plant-collector for Sir George King at Calcutta Botanic Garden and accompanied General Stafford and Col. H.H. Godwin-Austen on the military Duphla Hills Expedition of 1874-5 as well as collecting in the Khasi Hills and Assam; further research as to his background and identity would be quite desirable.

D. burmanicum is closely related to the group of *D. cordifolium*, which has many veins anastomosing near the margin, but *D. cordifolium* itself, which has not been found in India, normally has a simple frond, or just becomes pinnate, whereas this remarkable species, which only has occasional anastomosing veins, reaches 8 ft. tall or more, with many large ovate-elliptical pinnae, each up to a foot in length, as can be seen from the remarkable series of sheets taken from a single frond by *R.S. Rao* 17680, in 1958 (ASSAM). Pinnate plants in the *D. cordifolium* aggregate appear to be a separate species, *D. fraxiniifolium* C.Presl (syn.: *D. integrifolium* Blume), though that is a much smaller species than *D. burmanicum*, up to 55 cm. tall, with only a few, rather elongated pinnae (usually up to 4 pairs, rarely 8), and has more anastomosing veins. A specimen from Manipur, *G. Watt* 7489 (CAL!) published by Ghosh, Ghosh & Ghosh (1984) as *D. cordifolium* is actually *D. fraxiniifolium*, with 5 pairs of narrower pinnae and a bulbil at the base of the terminal segment, which is thus recorded anew from India.

Apart from its new type-locality in Myanmar, there are quite many collections of *D. burmanicum* from Arunachal Pradesh: Papum Pare (Duphla Hills, 1874, *J.L. Lister* 180, 1874, K, CAL); Subansiri (Palin to Sayata, *G.V. Subba Rao* 24851, 8.6.1961, ASSAM; Palin to Sayata, ± 2 miles from Palin, in dense forest, soil moist, *A.R.K. Sastry* 40741, 19 Nov. 1964, CAL); Siang (Abor Expedition, above head of Egar, 4600-4900 ft., *I.H. Burkill* 36193, 1 Jan. 1912, K, CAL; Ninguing to Pangu, *R.S. Rao* 17680, 15.11.1958, ASSAM; Geling to Kepangla, 2700-5000ft., *R.S. Rao* 17525, 10.11.1958, ASSAM); Debang Valley (Mehao, 3 km. from Tiwarigaon towards Roing, *G.D. Pal* 2957, 1.2.1988, ARUN).

33. *Diplazium crinitum* (Baker) C.Chr., described from Borneo, was reported from Assam State, N.E. India by Fraser-Jenkins (1997b), who had also collected it at Namdapha, Changlang District, *CRFJ* 20578, in 1994. It was subsequently described from Namdapha as no less than two "new species" and one "new variety" by Singh & Panigrahi (2005), see Fraser-Jenkins (2008b), where the names are synonymised. *D. crinitum* has now turned up across the Brahmaputra Valley in northern Arunachal Pradesh (Papum Pare, Tsiria Kanna Hill, W. of Itanagar, CRFJ F.n. *CRFJ* FN 72, 25 Jan. 2009, ARUN; Ganga Lake, *CRFJ* & *AB* FN 133, 31 Jan. 2009, ARUN) and also in Kameng and Subansiri, all det. CRFJ. It is a species with variably, but rather dense, stiff, exserted scales on the stipe, rachis and pinna-costae and crenately lobed, decurrent pinnules which fuse into each other at their bases and form a large pinna-apical segment.

34. *Gymnocarpium oyamense* (Baker) Ching was previously only known in the Indian subcontinent from Nepal, but has now been found by AB in India in Arunachal Pradesh, W. Siang, Yagrung Forest, Mechuka, *A.B.* 26208, 16.11.2008, ARUN, semi-rotted specimen), det. CRFJ. Another collection had been made previously from N. Sikkim, Chhatem, 2800 m, *S.R. Ghosh* & *R.K. Ghosh* 66485, 5 June 1989, CAL! This is a curious species with a very delicate stipe bearing a small, horizontal (or yet more sloping), deltate, bipinatifid lamina with wide, crowded lobes and strongly deflected, falcate lowest pinnae. It is popular in cultivation outside in British gardens, dying down in Winter, coming originally from China and Japan, but now widely propagated.

DRYOPTERIDACEAE

35. *Ctenitis paucisora* (Copel.) Copel. (syn.: *Dryopsis paucisora* (Copel.) Holttum & P.J.Edwards) is a most surprising and unexpected finding from India. It was collected unidentified by AB from Arunachal Pradesh, Kurungkumey, 8 km. away from Palin, *A.B. s.n.*, 18 Oct. 2008, ARUN, det. CRFJ. It is otherwise known only from N. Borneo (Sarawak and Sabah). Its unexpected finding in N.E. India is rather similar to the phytogeographical disjunction shown by *Diplazium*

crinitum (above) and both species are perhaps not to be expected to display such wide disjunction permanently, if found in intermediate areas linking the two extremes. While *D. crinitum* has already been redescribed from India as a mistaken "new species", *C. paucisora* might also have been as it was tentatively determined by X.C. Zhang of Beijing as a "new species" on being sent some photographs and, understandably, would surely have been redescribed locally in India. It was only by chance that CRFJ realised the collections belong to *C. paucisora*.

C. paucisora is a dwarf species with a lanceolate, pinnate-pinnatifid frond up to 16 cm. long, the stipe occupying 4-5 cm of that and stipe and rachis bearing many narrowish, mid-brown, thin scales and hairs; the rachis is shallowly sulcate above and pinna costae are terete. The pinnae are only up to *c.* 2 cm. long, with small, deeply cut, rounded-rectangular, entire lobes at the pinna-bases, the lowest being the smallest, and wider, rounded pinna-apices. The frond-apex is attenuated into a series of entire, adnate, rectangular, somewhat sloping lobes with rounded apices and bears a small, subapical proliferous bulbil, which is very characteristic for this species. The sori are medial, small and exindusiate when mature, though perhaps might have been minutely or vestigially indusiate when younger, as described by Holttum & Edwards (1986). The lamina and veins beneath bear scattered very small, reddish glands, though partly lost in the older fronds, and a mixture of various types of hairs and "scale-hairs", including thickish, multicellular, columnar "Dryopsidoid" hairs on the axes.

Although Fraser-Jenkins (2010) recognised *Dryopsis* Holttum & P.J.Edwards as a genus, it has to be confessed that this was merely through unquestioned force of habit - a poor substitute for genuine taxonomic enquiry and consideration - due to his having become accustomed to the genus through contact with the late Prof. R.E. Holttum at Kew. The confusing and far too insignificant microcharacters of the hair-types, with the presence of intermediate types, shown by *Dryopsis* species are clearly not of the order of generic recognisability, but more that of a group of species, probably actually two different groups, within *Ctenitis*. Thus its treatment as a section of *Ctenitis* by Wu & Wang (1999) is considered here far more satisfactory. Yet, surprisingly, they entirely ignored Holttum & Edwards' very well known monograph of the group and were apparently not even aware of the generic combinations, and also cited Ching's subgenus and section *Dryopsis* despite their having been shown to be invalid names by Holttum & Edwards. Indeed so out of touch were they that they even referred the genus to a Family Aspidiaceae, almost universally known to be illegitimate and to have failed an attempt at its conservation, and consistently referred internationally to Dryopteridaceae for many decades. In addition they ignored Holttum's definitive treatments of tectarioid ferns and continued to recognise misplaced genera such as *Ctenitopsis*. If maintaining Ching's classification, flawed even at the time, entails having to ignore widely known and authoritative international literature, it is clearly long and embarrassingly overdue that Ching's (1978) system must be entirely overhauled within mainland China itself.

Because *Dryopsis* has therefore not yet been combined validly as a section it is so done here, ***Ctenitis*** (C.Chr.) C.Chr. Sect. ***Dryopsis*** (Holttum & P.J.Edwards) Fraser-Jenk., ***comb. nov.***, basionym: Genus *Dryopsis* Holttum & P.J.Edwards, *Kew Bull.* **41**(1): 179 (1988). It is pointed out, however, that Fraser-Jenkins (2010) has very definitely not accepted the contention of Smith *et al.* (2006) that Tectariaceae should be a separate family from Dryopteridaceae and even more so that *Ctenitis* does not belong what should be Subfam. Tectarioideae but to Subfam. Dryopteridoideae, as previously "found" by Hasebe *et al.* (1995). It is emphasised here that familial and subfamilial separation of *Tectaria* and *Ctenitis* is taxonomically unacceptable and merely emphasises the defunct and meaningless nature of the whole cladistic framework within which moleculological findings have frequently been strangled to the point of taxonomic rejectability.

36. *Cyrtomium macrophyllum* (Makino) Tagawa is quite widespread in the Indo-Himalaya, from west to east, but had not so far been reported from Arunachal Pradesh. Benniamin, Siva & Arockkiam (2009) reported it as if "new to the Eastern Himalaya" in error for the commoner *C. anomophyllum* (Zenker) Fraser-Jenk. (syn.: *C. microindusium* Sa.Kurata, *C. nervosum* Ching & K.H.Shing), as had been pointed out to them by CRFJ. The two are readily distinguished by *C. macrophyllum* having a glossy lamina without apical teeth to the pinnae, while *C. anomophyllum* has a matt lamina and a larger or smaller number of apical pinna-teeth, particularly towards the tips, among other differences. A photograph of their plant sent previously to CRFJ, but initially cited

in their script under an incorrect number, looked generally similar to *C. macrophyllum* but was insufficiently focussed to observe the teeth, though fortunately he had made his own photographs of the specimen with the correct number while in Itanagar, which revealed that it was *C. anomophyllum* with teeth, despite the description they gave for *C. macrophyllum* in general. Its publication was therefore somewhat unfortunate and needs correcting here.

However excluding the above report, *C. macrophyllum* has indeed been collected in Arunachal Pradesh and we now report it anew, based on a specimen from Kameng, Seargaon east side, *G. Panigrahi* 15813A, *p.p.* [with *C. anomophyllum*], 19.5.1958, ASSAM, det. by G. Panigrahi as "*Phanerophlebia falcata* (L.f.) Copel." in error, redet. CRFJ; and another specimen, Tawang, Bomdila, *S.S. Bhattee*, Indian Forest Service, s.n., ITAF, det. CRFJ. It had long been known from Nepal, Darjeeling, Sikkim, Bhutan *etc.* and was reported from the E. Himalaya by Itô *et al.* (1971).

C. falcatum (L.f.) C.Presl, that Benniamin *et al.* also listed for India, does not occur there, but is a non-native, occasionally cultivated species from Japan and E. China (see Fraser-Jenkins 1993, 1997b, 2008b), with very glossy, leathery pinnae and no teeth, only crenations or entire. It has not become adventive, but was sometimes misreported from India in the past in error for the common *C. caryotideum* (Wall. *ex* Hook. & Grev.) C.Presl. They also omitted the rare species, *C. fortunei* J.Sm., known from East Bhutan, way to Munger from Nyalangdzong, *N.P. Balakrishnan* 44565, 3 Nov. 1965, ASSAM; Arunachal Pradesh; Nagaland (sub *C. caryotideum*, Phek, *N.S. Jamir* 7197, NEHU, redet. CRFJ) and Manipur. But they included under *Cyrtomium*, *Phanerophlebiopsis hookeriana* (C.Presl) Fraser-Jenk. (1997a) (syn.: *Cyrtomium hookerianum* (C.Presl) C.Chr., *Phanerophlebiopsis caduca* (T.Moore) Fraser-Jenk. (1997b)), validated by Presl as *nom. nov.* for the illegitimate later homonym, *Aspidium caducum* Wall. *ex* Hook. & Grev., *non* Bonpl., but which is not a true *Cyrtomium*.

37. *Dryopteris costalisora* Tagawa is a smallish species described from Taiwan and close to *D. panda* (C.B.Clarke) Christ (syn.: *D. bonatiana* (Brause) Fraser-Jenk., under which mistaken name *D. costalisora* was intended by Fraser-Jenkins (1989)). It was first reported from India by Itô *et al.* (1966, 1971), as subsequently listed by Dixit (1984), but in error for *D. woodsiisora* Hayata. On discovering that true *D. costalisora* also occurs in India in the Darjeeling area, Fraser-Jenkins (1989) first reported it erroneously under the name *D. bonatiana* (the forthcoming combination of that in *Dryopteris* also being attributed to him by Kuo (1985), but invalidly, and as if a separate species from *D. costalisora*), but Fraser-Jenkins (1997b) then corrected that name and tentatively suggested that the plant concerned might be *D. costalisora*, which he subsequently confirmed (pers. comm.) to S. Chandra and finalised later (Fraser-Jenkins 2008b). Unfortunately Chandra (2000) misunderstood its application and inexplicably listed both *D. costalisora* and *D. bonatiana* in confusion, as also occurred in several other places in his list, compiled mainly from Dixit (1984) and other literature sources.

Until now *D. costalisora* was only known in India from about four collections from what is probably just one local area, on the Tonglu ridge west of Darjeeling, where it still occurs today just on the Nepal side of the open border. H.C. Levinge's old collection of it from "Sikkim", in Oct. 1883 (CAL) undoubtedly refers to the same area, which used to be in "British Sikkim" [Darjeeling District] and was widely called Sikkim at that time. However it has now been collected unidentified by AB in Arunachal Pradesh, W. Siang, Mechuka, *A.B.* 26331 and *A.B.* XCHI 25375, Nov. 2008, ARUN, det. CRFJ, which is a welcome bridging population with its occurrence further east. It is similar to *D. panda*, but smaller and with shorter pinnae, more tapering from their wider bases, slightly narrower pinna-lobes, the lowest basiscopic one of the lowest pinna being noticeably longer and curved outwards, and with more rounded pinna-apices, as well as being a different cytotype (tetraploid, whereas *D. panda* is diploid).

38. *Dryopteris hasseltii* (Blume) C.Chr. is a rather widespread South-East Asian species, which occurs as a considerable rarity at the extreme of its range in further N.E. India (*e.g.* N. Assam state, Makum Forest, near Digboi, *G. Mann* (see Fraser-Jenkins 1989); Mizoram, Murlen National Park, near Vapur, Champai Distr. *A.B.* 22134, Feb. 2009, ASSAM, det. CRFJ; and Meghalaya, Jowai surroundings, *R.S. Rao*, 2562, 26 May 1956, ASSAM, det. CRFJ). AB has also collected it anew from Arunachal Pradesh, Kurungkumey, Serley, *A.B.* 26412, Dec. 2008, ARUN, det. CRFJ.

This species is obviously a close relative of *D. sparsa* (D.Don) Kuntze, from which it differs in its larger size, slightly more dissect frond with longer lowest basiscopic pinnules and noticeably more rounded segments. It was definitively placed in Subgen. *Nephrocystis* by Fraser-Jenkins (1989) and in its constituent Sect. *Diclisodon* by Widén *et al.* (2001), and was personally discussed by CRFJ with Ching; it is thus disappointing to see its almost obligatory continued misplacement in *Acrorumohra* in the *Flora Reipublicae Popularis Sinicae* (Wu 2000), replacing botanical science with inappropriately out of date, national deference. *Acrorumohra* actually contains only two closely related species, not related to the *D. sparsa* group, but to *Arachniodes*, and if *D. hasseltii* were to be [mis-]placed within it, so also would *D. sparsa* have to be!

39. *Dryopteris namegatae* (Sa.Kurata) Sa.Kurata was described from Japan and also occurs across S. China from the S.E. to Yunnan. Fraser-Jenkins (1989 and in Widén *et al.* 1999) mentioned the possibility that a couple of older collections close to *D. dickinsii* (Franch. & Sav.) C.Chr. from the Simla Hills (Himachal Pradesh, near Chhachpur, Ravingarh) might belong to *D. namegatae*. On visiting the area with Prof. S.P. Khullar in July 1980, they were able to find a couple of smallish plants of it, but unfortunately a small baby plant collected for cultivation did not survive the journey and a plant was thus not able to be grown to maturity and compared with *D. namegatae* properly, though it should be possible for someone to refind a mature population there. However the identity of this plant as *D. namegatae* is confirmed here from the herbarium specimens as a species previously not definitely reported from India, furthermore good quality, mature material of it has now been found by AB in Arunachal Pradesh, Siang, Mechuka, *A.B.* XCH 25341, *A.B.* 26294, 11.2009, ARUN, which is most satisfactory. The further west Indo-Himalayan plants of *D. dickinsii* (syn.: *D. basiaurita* Ching) reported from Kashmir by Fraser-Jenkins (1989) differ in their wider and paler scales and narrower belt of inframarginal sori each side of and away from the pinna-midrib and thus appear to represent a disjunct population of *D. dickinsii*, not *D. namegatae*.

D. namegatae is a typical member of Sect. *Hirtipedes*, with rather small fronds (up to c. 60 cm. tall) and the stipe and rachis densely clothed with many narrow, long-toothed, dark blackish-brown scales along with fibrils, but wider than in the common and widespread *D. gamblei* (C.Hope) C.Chr. The short pinnae (up to c. 9 cm. +) taper evenly from their bases and are only very shallowly, rounded-square lobed at their very edges, each lobe with an acroscopic tooth. Their shallow lobing and the submarginal position of the sori, well away from the midrib, are characteristic. The veinlets are rather darkened beneath and the basal, sterile pinnae, which are even more shallowly lobed, if at all, are slightly deflexed but not falcate.

40. *Dryopteris rubrobrunnea* W.M.Chu (1992) is a very rare Chinese species intermediate between *D. splendens* (Hook.) Kuntze and *D. sikkimensis* (Bedd.) Kuntze, which has often been confused with one or the other of them. It was also recognised by CRFJ in India some ten years ago from Panigrahi's misidentified specimen in ASSAM, but was unfortunately missed out from the revised census-list (Fraser-Jenkins 2008b) due to a lapse of memory (as also with *Selaginella pallida* (Hook. & Grev.) Spring). Thus it has not actually been reported from India to date. AB has recently collected several good specimens of it from northern Arunachal Pradesh, reconfirming its presence in India. Collections are: Debang Valley, *A.B.*, 6.2010, ARUN; Tirap, Raho to Vokanoska, *G. Panigrahi* 16826, 26.8.1958, ASSAM, det. by G. Panigrahi as "*Polystichum aculeatum*" in error, cited by Singh & Panigrahi (2005) sub "*D. splendens*", in error, redet. CRFJ. It was mentioned by Fraser-Jenkins (1989) under the name *D. rubripes* Ching, *nom. nud in herb.* PE, which was subsequently changed for some reason when it was finally published by Chu as *D. rubrobrunnea* (see Fraser-Jenkins 1997b).

41. *Dryopteris sparsa* (D.Don) Kuntze subsp. *rectipinnula* Fraser-Jenk. (2008b) was described from South India, where it appears tentatively to be the only subspecies occurring, though more study is necessary in the field and hebarium to establish this. But it has since been found by CRFJ and others in several localities in N.E. India and Bhutan, though in the present-day absence of fern-cytologists it has not yet been possible to provide new cytological confirmation, which would be helpful in the initial stages of research. But turning back to one of the thorough pioneer cytologists of the Panjab University school, the late Prof. D.S. Loyal, it is now clear from re-appraisal of photographs made by CRFJ of his tetraploid *D. sparsa* from Lebong, Darjeeling District, that that belongs to and is typical of subsp. *rectipinnula*. This emphasises the value of properly documented and preserved cytological voucher-specimens which are then able to be resurrected into modern and continuing taxonomic advances many

decades later. Fraser-Jenkins (1989) had not previously been able to identify Mehra & Loyal's (1965) voucher-specimens more precisely and left it as an unsolved taxonomic question, but it can now be concluded that his own photograph of a more obtuse-segmented plant from Lebong (*CRFJ* 8646) probably also represents a well developed, more lobed specimen of subsp. *rectipinnula*. Re-study of all CRFJ's previous collections (BM, NMW, TAIF, H) of the *D. sparsa* aggregate and in British herbaria and CAL *etc.* is a necessary preliminary step to finding out the full distribution of the subspecies in the Indian subcontinent. Subsp. *rectipinnula* differs from the other subspecies in its usually less dissect, more shallowly lobed pinnules with rather square-truncate lower pinnule-lobes and though the pinnule-apex is narrowed it is often narrowly rounded-truncate, rather than more pointed as in the other subspecies. It is tetraploid unlike subsp. *sparsa*, which is diploid.

So far subsp. *rectipinnula* has been found (though not cytologically checked) in S.E. Asia, including the Philippines (Mt. Kitanglad, Mindanao, *CRFJ* F.n. 99, 100, 16 Nov. 2007, TAIF); S. India; Darjeeling District; Bhutan (cliff in side-gorge and forested banks of main river course, near where road-bridge crosses it, 2 km. above and N. of Pinchinang Police Check-Post, below Deothang (Dewangiri), 6 km. N. of Samdrup Jongkhar on main road north towards Tashigang, Samdrup Jongkhar District, S.E. Bhutan. *CRFJ*, F.n. 35, with Dr. Tandin Wangdi, Sangay Lungten & Tandin Dorji, 20 May 2009, THIM); Sikkim (Damp, mossy cliff, on south side of Bridge B 2 across ?Rate Chu river, N. of Gangtok, E. Sikkim District, Sikkim, India. *CRFJ* F.n. 141, with Dr. B.S. Kholia (Botanical Survey of India, Gangtok) and Sagun Pariyar (Kathmandu), 1 Oct. 2009, BSHC); Meghalaya (forest among calcareous rocks on way out from Mawmluh on south edge of town, beside main road down to Mawshamok and Bangladesh border, S. of Sohra (Cherrapunji), Khasi Hills, Meghalaya, N.E. India. *CRFJ*, F.n. 143, 21 Nov. 2009, ARUN); Arunachal Pradesh (Debang Valley, Mehao Wild Life Sanctuary, *V.K. Rawat* 56393, 11.2002, BSA; Mayudia Pass, *A.B. s.n.*, 2010 (from field-photo only); Changlang, Namdapha, Deban to Bulbulia, 2-3 km. from Zero Point, *S. Singh* 78158, 24.9.1979, ASSAM, cited by Singh & Panigrahi (2005) as *D. sparsa*; Namdapha, Salt Lick forest, Miao, *J. Joseph* 83574, 20.10.1983, ASSAM), all det. CRFJ.

When Fraser-Jenkins (2008b) described the triploid hybrid *D. sparsa* nothosubsp. x *lehalii* Fraser-Jenk. (subsp. *sparsa* x subsp. *viridescens*) from Sidrapong, below Darjeeling on the south-west side, he was under the impression that only the diploid subsp. *sparsa* and common tetraploid subsp. *viridescens* (Baker) Fraser-Jenk. occur in the E. Indo-Himalaya. Loyal himself (Mehra & Loyal 1965) thought of the triploid as intermediate between his tetraploid and diploid and as likely to be a hybrid between "some genomic form of the diploid and tetraploid". However his tetraploid, which he only reported from Lebong, north of and below Darjeeling, is now reidentified here as subsp. *rectipinnula*; but in addition Loyal had also counted, but did not publish, tetraploids from Sidrapong, whose frond-morphology strongly suggests they are not the same taxon, but are very characteristic subsp. *viridescens* (as that name is understood by CRFJ). The frond-morphology of the triploid hybrid from Sidrapong also does not suggest that subsp. *rectipinnula* would be likely to be one of its parents, but shows more of the characteristics of subsp. *viridescens*, which CRFJ has also found commonly, along with subsp. *sparsa* at Sidrapong. Thus Loyal's tetraploid has subsequently turned out to be not one, but two taxa and the taxonomic situation in the E. Indo-Himalaya is yet more complex than had been realised. At this stage, the identity of a few cytologically unknown hybrids with abortive spores found by CRFJ at Lebong (Fraser-Jenkins 1998: 465-466, *t.* 76), is difficult to fathom out without further cytological study being carried out there, as is now so urgently and badly needed in India as elsewhere. With three subspecies occurring in the Darjeeling area several permutations are possible, but from the photograph, *CRFJ* 8641 (BM) looks perhaps rather more intermediate in frond-morphology between subsp. *rectipinnula* and subsp. *viridescens*, unless perhaps between subsp. *sparsa* and subsp. *viridescens*. Subsp. *viridescens* and other taxa still occur around Lebong, and the plant concerned actually came from across the down-road opposite Phoobsering Tea Estate, below Lebong, rather than in the remnant Lebong Forest itself, slightly above Lebong, where Professors Loyal, Bir and Verma collected (pers. comm. to CRFJ). It is hard to believe the disappointing fact that though such fascinating questions abound in the critical complexity of the Indian fern-flora, and the plants themselves and answers are still out there awaiting investigation, there has been no young botanist for the last 25 years properly prepared by familiarity with cytological squash-technique to go out and answer them. Most of today's M.Sc. and Ph.D.

theses in taxonomic Botany in India are not worth the paper they are written on in comparison to the elegance and fascination a study of this sort would entail, including Leedsian-style artificial hybridisation leading to genome-analysis elucidation.

42. *Dryopteris vidyae* Fraser-Jenk. (1989), *pro hybr*., is an exceedingly rare and little known species, previously known only from a single old, yet distinctive specimen collected in Sept. 1875 at 6,500 ft. alt. by or for Sir George King (no. 4710) at Rungji, which is far up the Great Rangeet Valley to the west towards the triple-point junction of Nepal, Sikkim and Darjeeling District, below and east of Phalut in Darjeeling District (CAL). From its apparently mixed morphology it was identified by CRFJ as what he thought then to be a new hybrid. The spores were few, but mostly abortive, but it is now clear that this was an example of how some old specimens loose most of their good spores first, leaving only a few misleading badly formed spores. It appeared to be a unique specimen of a hybrid between *D. splendens* (Hook.) Kuntze and *D. sparsa*.

It was therefore with considerable excitement that on going through AB's presses of herbarium-specimens from Siang, CRFJ turned to the next sheet and there in front of him appeared a fine collection of this very same taxon, in better condition than the old type and with several sheets from different plants. It was obviously distinct from anything else and it immediately became clear that it must represent a good species, not an isolated F1 hybrid as originally thought. The collection unfortunately has few spores left, but among some abortive fragments, one or two normal-looking spores with pale, wideish, seamed perispores were observed. Subsequently another collection of it turned up in ASSAM herbarium, collected in Subansiri by Panigrahi. It is presumably to be expected in N. Myanmar and S.W. China and though, as so far known, it is temporarily endemic to India, it is not likely to be a genuine endemic, but simply has not yet been collected elsewhere. The collections are from Subansiri, Ziro and surrounding villages, near Hapoli, *G. Panigrahi* 19881, 30.9.1959, ASSAM; W. Siang, Yagrung Forest, Mechuka, *A.B.* 26244, 16.11.2008, *A.B.* 26237, 11.2008, ARUN, both det. CRFJ.

The rhizome is somewhat horizontal to ascendent and elongated. A most distinctive feature of this species is the long, thickish, glossy, ebony-black stipe when mature (pale castaneous brown when younger), as long as or longer than the lamina, its base bearing a surrounding sheath, becoming more scattered just above, of large ovate, matt, adpressed, pale yellowish-brown scales. The rachis is similarly black, becoming red-brown towards the apex. The lamina is bipinnate-trpinnatifid and narrowly deltate, with the basal pair of pinnae the longest. The lower pinnules are mostly narrowly attached to the costae, the lowest basiscopic ones being the largest and becoming pinnatifid into several lobes on each side; mid and upper pinnules are smaller, more widely sessile, with an obtuse basal auricle and hardly lobed, with noticeably wide, rounded-truncate apices.

43. *Dryopteris wallichiana* (Spreng.) Hyl. subsp. *nepalensis* Fraser-Jenk. (1997b) is a fairly common segregate of the critical *D. wallichiana* complex, occurring in the eastern part of the W. Indo-Himalaya, Nepal, Sikkim (confirmed here), Bhutan, China and now discovered in Arunachal Pradesh by AB. His collections are: W. Siang, Mechuka, *A.B.* 26283, 18.11.2008, ARUN; probably Mechuka, *A.B.* XCH 25330, 11.2008, ARUN, both det. CRFJ. It is a taller and less compact plant than *D. wallichiana* subsp. *wallichiana*, with the lower basiscopic pinnules elongated and a longer stipe with a number of fairly narrowly lanceolate back scales scattered here and there among the browner ones and fibrils. It does not merge into subsp. *wallichiana* and appears to be a taxon that may well be of slightly different origin.

44. ***Peranema annamensis*** (Tagawa) Fraser-Jenk. & Wangdi, ***comb. nov.***, basionym: *Diacalpe annamensis* Tagawa, *Act. Phytotax. Geobot.* **14**: 46 (1950) was found recently by CRFJ in E. Bhutan, while on an excursion with Dr. Tandin Wangdi of Thimphu. From years of collecting the common *P. aspidioides* (Blume) Mett. throughout the Himalayan region, it is obvious that it displays a certain amount of variation in stipe-colour, frond-width, fineness of dissection and size of segments. It also becomes very large and finely dissect in further N.E. India (such as in the Khasi Hills, in Meghalaya) and into S.E. Asia. But this all appears to be due more to degree of development resulting from growing conditions more than anything else and there is considerable continuous variation within populations. Several segregate names applied to them by Ching (1949) and Ching & Wu in Wu (1983), including *Diacalpe laevigata* Ching & S.H.Wu, which they reported from the Khasi Hills, do not appear to be of any taxonomic

value. Nor does *Diacalpe hookeriana* T.Moore, which was merely a validation of a name applied independently by Wallich, as was his wont, for just the same species as Blume's. Ching & Wu recognised a *D. aspidioides* var. *hookeriana* (T.Moore) Ching & S.H.Wu, as applying to the Indo-Himalayan and Tibetan plant, as opposed to the S.E. Asian plant, in keeping with Ching's (1983) blanket contention that all Himalayan species were different from their S.E. Asian counterparts. This is not accepted by us as a distinct taxon. It seems unlikely that even one of the Chingian "*Diacalpe*" and "*Acrophorus*" recognised by Ching & Wu is actually a distinct species, from their types and folders which were seen by CRFJ in PE.

However on excursion in East Bhutan CRFJ noticed a few populations *Peranema*, which though generally close to *P. aspidioides*, looked consistently distinct from all the variation one normally sees in their wide, well and densely dissect fronds (*i.e.* with crowded segments) and stipe-scales with darker centres. The pinnule-lobes are rather larger than in the very finely dissect large fronds of *D. aspidioides* and are less lobed and noticeably contiguous. After studying many individuals in quite large populations CRFJ concluded that they must represent a genuinely distinct species and subsequently determined them as *P. annamensis*, which occurs in mainland S.E. Asia and in Yunnan, S.W. China. It remains constant in cultivation. Unfortunately this finding was made after identifying and listing the Arunachal Pradesh material for the forthcoming check-list (Baishya & Fraser-Jenkins, in prep.) and it was not recorded if any of the material about to be cited under *P. aspidioides* is actually *P. annamensis*, but it would seem likely that some of it would have been. It is hoped to restudy the relevant material.

45. *Polystichum hecatopterum* Diels is a well known and quite widespread species in central and S.W. China, but has not been found previously in India. However it was recently recognised from two unidentified collections in ITAF herbarium, Subansiri, Tale Valley, Pange, *S.S. Bhattee*, I.F.S., 71, ITAF; Tale Valley, Pange, *sin. coll.* 6793, 23 March 1994, ITAF, det. CRFJ.

It is a typical member of Sect. *Polystichum* (syn.: Sect. *Haplopolystichum* Tagawa), in the *P. deltodon* (Baker) Diels group, with a smallish (up to c. 30 cm.), very narrow frond and many crowded, simple pinnae with a marked basal acroscopic auricle and the pinna-apex slightly widened and rounded, bearing long-acute, strongly aristate teeth on the auricle and especially around the pinna-apex. The lower pinnae are gradually rather reduced and become strongly deflexed so that the auricle points forward and the rest of the pinna, which is then not much longer than the auricle, points backward and is almost parallel to the rachis. It is not proliferous near the frond-apex.

46. *Polystichum tangmaiense* H.S.Kung & Tateishi, *Act. Phytotax. Sinica* **32**(3): 268-270 (1994) was described anew from a collection in the Pome District of southern Kham in S.E. Tibet, but had already been named from Yunnan by Ching in the herbarium some time before, but not published, as *P. oligocarpum*, but was overlooked. This subsequently also described as *P. oligocarpum* Ching *ex* H.S.Kung & L.B.Zhang (1995), which thus has to become a synonym of *P. tangmaiense*. The species varies somewhat in shape and degree of lobing of the pinnules, which was not realised by Kung & Zhang, who only had two or three small herbarium-specimens to go by. It has hitherto been unknown to Indian botanists, but a single old collection of it was made by the indefatigable Dr. William Griffith 549 in "Assam", B, det. CRFJ, presumably collected in Lower Debang Valley, where he went in Nov. 1836, which for some 25 years CRFJ knew was a unique specimen, but had previously been unable to identify. The second collection that came to attention was made by Dr. B. Ghosh and party 69597 at Sheroy Peak, Ukhrul, Manipur, March 1984, CAL, dupl. CRFJ 18873, NMW and was initially misreported by Fraser-Jenkins (1991) under the name *P. makinoi* (Tagawa) Tagawa, a Sino-Japanese species which is not known to occur in the Indian subcontinent, unless, perhaps found anew in N.C. Nepal, but requiring confirmation (see Fraser-Jenkins 2008b: 622). This misidentification was corrected by Fraser-Jenkins (1997b), but without being able to identify it precisely, suggesting it might either be the S.E. Asian *P. microphyllum* (Blume) C.Presl (which, however, has too many broad scales) or *P. tangmaiense*, which latter name was subsequently tentatively recognised for the species by Fraser-Jenkins (2008b). A third collection turned up from Nagaland, Phek, *N.S. Jamir* 6131 [but with a tag-label 6163], 8 July 1980, NEHU, misidentified as the European and W. Asian, non-Indian species, *P. setiferum* (Forssk.) Woynar, and described and reported, among numerous other inaccuracies in many genera, as a "new distributional record for north-east India" (Jamir & Rao 1988), now redetermined here. But it was not until AB

collected a number of collections of it in northern Arunachal Pradesh (Lower Debang Valley, Mayudia Pass to Humli, c. 1270 m., *A.B. s.n.*, 14 June 2010, ARUN [photos 0870, 0871, 0876, 0881, 0885] and Manipur (Ukhrul, *A.B.* 26853, Jan. 2010, ARUN [photo 8118, 8119] that it became possible to understand all these collections and the range of variation of this previously rather mysterious species, which had long lain unidentified in India. It is confirmed here as *P. tangmaiense*, whose range of variation had not previously been detailed in China. It is presumably to be expected in N. Myanmar as well, though the pteridophyte-flora there is still so poorly known that the current list of c. 650 known species (Fraser-Jenkins, in prep.) is undoubtedly less than half the number that are actually present there.

P. tangmaiense is an obvious member of Sect. *Metapolystichum*, with fronds up to c. 60 cm. long, slightly similar to the Nepalese *P. annapurnicola* Fraser-Jenk. (in Thapa 2002), but with narrower stipe-base scales and the pinnules much less lobed with more rounded, less acute and more contiguous lobes. It differs from other Indian species of the section, by having all its stipe-scales pale russett-brown and concolorous (rarely some of the basal-most ones very slightly and vaguely darker-based); those at the very base being somewhat narrowly lanceolate, and those above very narrow to fibrillose; the scale-margins bear obvious, slightly variable, but usually long teeth. The scales are noticeably wider than the mere fibrils of *P. discretum* (D.Don) J.Sm., though consistently narrower than in the *P. piceopaleaceum* Tagawa. The rachis bears many, rather dense, linear, russet-brown scales and fibrils, some being a bit darker. The stipe becomes long when growing among other vegetation and the lamina-base is rather wide, with many pinnae bearing separate pinnules, which are variable in shape. The pinnules are square-ovate with rounded-obtuse apices, ending in a single long, hair-pointed tooth with other such long hair-teeth all round. Occasionally the pinnules become almost ovate or circular with no lobes and few teeth. The basal auricle or lobe of the pinnule is also rounded and with long hair-teeth; in larger fronds the pinnules become longer and more lobed with up to three rather deep, rounded lobes and slightly more acute apices, and in smaller fronds the basal auricle is less developed to nearly absent and the pinnules are more sloping (as in its type). The sori are usually infra-marginal and make a series of distinctive raised pimples on the upper surface of the pinnule. Their entire to slightly undulate indusia, when fully developed and white, go through a stage when they lie absolutely flat above the sorus with their edges extending noticeably beyond, like flat plates, sometimes overlapping the next, like those of *P. annapurnicola*. Most are entirely peltate, but a number have a superficial basal sinus and are then remarkably similar to the thinner indusia of the W. Asian *Dryopteris caucasica* (A.Br.) Fraser-Jenk. & Corley (formerly known as the "missing" diploid ancestor of *D. filix-mas* (L.) Schott); they then shrink markedly on sporangial dehiscence and become brown, but mostly persist.

47. *Tectaria ternifolia* (Alderw.) C.Chr. was described from Malaya (though omitted by Parris & Latiff 1997) and is otherwise known only from S. Thailand, though it is possible it may have been overlooked further north identified in error as the related *T. polymorpha* (Wall. *ex* Hook.) Copel. It is a smallish species (fronds up to c. 50 cm.), usually with three, very shortly stalked or sessile blades, being a pair of pinnae and a similar but longer terminal segment; some larger fronds may develop 2 pairs of pinnae. The pinnae are ovate-acute and do not normally have a basal lobe, but are rounded basally, except in a few transitional leaves developing the second pair of pinnae. The costae beneath are characteristically densely hairy with many shortish pale, velvety hairs, becoming brown when older, though the lamina (apart from the veins) is glabrous. The reticulate venation makes many small areoles with free included veinlets and the lamina is dark-green but becomes pale yellow-green when in brighter light. The sori are scattered along either side of the main lateral veins, small (up to 1½ mm. diam.) and, as confirmed from a plant in cultivation in Kathmandu, are entirely exindusiate, even when young, as suspected by Holttum (1966). It remains constant in the field and in cultivation and there is no transition into *T. polymorpha* (which may be similarly without basal lobes to the pinnae when very young, but is then usually sterile or only becoming weakly fertile, and without the prominent costal hairs, only with shorter or more scattered ones). The Arunachal and Bhutan collections apparently do not develop proliferous bulbils in the axils as far as seen, though Holttum stated that it is "often with buds in the axils". But it is probable that this may be due to climate as several species may develop bulbils in wetter, more luxurious conditions, whereas this species appears to grow in our region only in the rather

drier lowest altitudes in slightly open places by rocks along streams at the very edge of the hills. It is also not as sterile-fertile dimorphic as both Holttum and Tagawa & Iwatsuki (1988) stated, though some later-developed fertile fronds are taller and a little more compact. It is easy to cultivate in a pot in damp, shaded conditions.

It was first noticed by CRFJ near Itanagar (Papum Pare, Ganga Lake, *CRFJ* F.n. 142, with A.B., 31 Jan. 2009, ARUN; Papum Pare, Tsiria Kanna Hill, W. of Itanagar, *CRFJ* F.n. 159, 1 Feb. 2009, ARUN; Seinki river-bank and lower part of hill across river opposite Seinki Park, off the way to the Botanical Survey of India campus, N. part of Itanagar, *CRFJ* F.n. 189, 16 Feb. 2009, ARUN) and was also collected unidentified by Panigrahi and by AB (Kameng, Foothill Camp and Sissini Camp, *G. Panigrahi* 5830, 5984, March 1957, ASSAM; W. Siang, Mechuka, *A.B.* 26370, 18 Nov. 2008, ARUN, unusually large, 3 pairs of pinnae; E. Siang, Tuting, *A.B.* 22302, Aug. 2008, ARUN), all det. CRFJ, and was then recognised by CRFJ in E. Bhutan (steep, forested, rocky bank of small stream gorge, 3 km. above and north of Samdrup Jongkhar, to east side of main road north towards Tashigang, c. 2 km. S. of Pinchinang Check Post, Samdrup Jongkhar District, S.E. Bhutan. *CRFJ* F.n. 16, with Dr. Tandin Wangdi, Sangay Lungten & Tandin Dorji, 20 May 2009, THIM).

48. *Tectaria dubia* (C.B.Clarke & Baker) Ching was described from Makum Forest, near Digboi, N. Assam ("Lakhimpur"). The query given by Clarke & Baker (1888) after "var." refers to doubt as to its rank as they stated it apeared to be a good species, as subsequently treated by Beddome and others. As its name suggests it is a little known and confused species, which was reported tentatively from W.C. Nepal (way to Annapurna Base Camp, Kaski District) by Fraser-Jenkins (2008b) and now confirmed here. It had previously been misreported from the W. Himalaya by Pangtey & Punetha (1987) and thence Chandra (2000), in error for the common and widespread *T. coadunata* (Wall. ex Hook. & Grev.) C.Chr., to which it is most similar, and from Changlang, Arunachal Pradesh by Singh & Panigrahi (2005), in error for *T. griffithii* (Baker) C.Chr., to which it is hardly similar. It is now reported from Arunachal Pradesh, Tirap, Kothong, *D.B. Deb* 26033, 24.6.1961, ASSAM (Acc. no. 30894, 30895), the second sheet of this uniform collection was cited by Singh & Panigrahi *sub T. griffithii* (Baker) C.Chr., as the only specimen they cite of that species, as can also be seen from their drawing, while their photograph entitled *T. griffithii* appears to be *Pleocnemia submembranacea* (Hayata) Tagawa & K.Iwats.). There are several other collections of *T. dubia* from Arunachal Pradesh. *T. dubia* has been well illustrated by Wu & Wang (1999) in the *Flora Reipublicae Popularis Sinicae* and is distinguishable from *T. coadunata* by its more succulent, more glabrous and slightly glossy frond with single lines of large sori along each lobe (instead of having small subsidiary sori as well) and larger areoles with the veinlets more spaced out.

LOMARIOPSIDACEAE

49. *Bolbitis tibetica* Ching & S.K.Wu (1983) was described from Tibet and is a large, simply pinnate species with a rather densely, dark-scaly stipe and rachis, wide, truncate based pinnae with shallow, crenate lobes and a large, subapical proliferous bulbil half way up the long, fusing, pinnately lobed apical segment, which has decurrent bases to the lobes and uppermost pinnae. The veins have a series of basal arches, with numerous, scattered small areoles above them towards the margin, where there are free vein-endings. It was first found outside of Tibet by CRFJ on limestone rocks by the well known caves just north of Pokhara, C. Nepal (Fraser-Jenkins 1997b), and has now been found in India by AB, in Arunachal Pradesh, Subansiri, limestone at Daporijo, Upper Subansiri, *A.B.* 22757, 10.6.2008, ARUN, det. CRFJ. So far as is known the species is confined to limestone rocks and cave-mouths.

B. tibetica is evidently related to *B. subcordata* (Copel.) Ching from S. Japan, Taiwan, S.E. China and Vietnam, though that has more deeply lobed lower and mid-pinnae and is not as densely scaly on the stipe. The pinna-bases of *B. tibetica* are also more squarely truncate and the laminar texture is thicker and stiffer.

50. *Bolbitis medogensis* (Ching & S.K.Wu) S.Y.Dong, *Acta Phytotax. Sinica* 43(2): 105 (2005) was described from S.E. Tibet, shortly north of Lohit and Anjaw Districts of Arunachal Pradesh. It is probably most closely related to *B. appendiculata* (Willd.) K.Iwats., the larger forms, excluding the commoner and more widespread *B. asplenifolia* (Bory) K.Iwats. (see Fraser-Jenkins 2008b), but is also rather intermediate towards *B. sinensis* (Baker) K.Iwats. (see Hennipman 1977). However it is a distinct species, not a synonym of *B. sinensis* as thought by Fraser-Jenkins (2008b). The frond is much wider than in *B. appendiculata*, with a wide base and with fewer and longer pinnae (7-12 pairs,

from 10-18 cm. long), the lowest being the longest, as in *B. sinensis*. The frond-apex is often somewhat abrupt, or may be fairly gradually tapered, but is not attenuate as in *B. sinensis*. The pinnae are truncately broad-based, acrocopically auriculate and falcately curved upwards, unlike in either species. They are obviously more shallowly crenately lobed than in *B. sinensis*, with large, rounded lobes only *c.* ¼ the depth of the half-pinna on each side of the midrib; occasionally some specimens may become very "coarse" with very large, shallow, rounded lobes, almost like a *Diplazium* species near to *D. forrestii* (Ching) Fraser-Jenk. There may be a longish tooth in the sinus, or in some coarser specimens, sometimes may not be. The stipe is usually nearly as long as the lamina and both the stipe and rachis bear more and blacker scales than in *B. sinensis*, mainly on the stipe. The rhizome is creeping and thick. Its venation is interesting as though it is almost completely free-veined, very occasionally the two opposite basal veinlets may meet to form a weak arch and sometimes two of the adjacent veins may meet and anastomose at the side of a lobe. The fertile fronds have slightly long, simple, entire pinnae, similar to those of *B. sinensis*. It is not at all nearly related to the Sino-Japanese, far-eastern *B. subcordata* (Copel) Ching as stated in the protologue, though superficially somewhat similar in outline.

Previously known only from Tibet, this species has now been collected by AB in Arunachal Pradesh, Kurungkumey, way to Serley, near Tibetan border, *A.B.* 26434, 26436, 26472, 26473 *p.p.* b [*p.p.* a is *B. appendiculata*], 26477, 26493, Dec. 2008, ARUN, det. CRFJ.

ACKNOWLEDGEMENTS

The authors profoundly thank Dr. M. Sanjappa, Director, Botanical Survey of India for his much appreciated help and encouragement in many matters and for his kindly inviting the senior author to visit Arunachal Pradesh in 2009. The senior author also thanks Dr. A.K. Baishya, Dr. A.A. Mao, Dr. T.M. Hynniewta and Dr. S.J. Phukan, Botanical Survey of India, Kolkata, Itanagar and Shillong, for their kind help and advice on visiting N.E. India. We also thank Dr. K. Haridasan, formerly of the Sate Forest Research Institute, Itanagar; Dr. P.B. Gurung, Curator of the herbarium, N.E. Hill University, Shillong; Dr. B. Ghosh and Dr. Suomen K. Basu, Botanical Survey of India, Kolkata; Dr. B.S. Kholia, Botanical Survey of India, Dehra Dun; Dr. Sarnam Singh, Remote Sensing Laboratory, Dehra Dun; Dr. T. Wangdi, National Biodiversity Centre, Serbithang, Thimphu; Prof. B.K. Nayar, formerly of Calicut University, Kozhikode; Prof. X.-C. Zhang, National Herbarium, Academy of China, Xiang Shan, Beijing and Dr. H. Noltie, Royal Botanic Garden, Edinburgh, for helpful botanical information. We also thank the staff and curators of the following herbaria: ARUN, ASSAM, ITAF, CAL, BSD, BSA, PAN and BM, for assistance and kindly allowing us access to their material. The senior author wishes to thank Prof. Mary Gibby and the Directors of the Royal Botanic Garden, Edinburgh, for their kind financial assistance for visiting Bhutan and Myanmar and on other occasions.

EXPLANATION OF FIGURES

1. *Huperzia quasidivaricata* - Mayodia, Mehao, Lower Debang Valley, Arunachal Pradesh. *A.K. Baishya* 9164, ARUN.

2. *Angiopteris palmiformis* - Tsiria Kanna Hill, Itanagar, Papum Pare, Arunachal Pradesh. *CRFJ* FN 61, 25.1.2009, ARUN.

3. *Angiopteris palmiformis* - Tsiria Kanna Hill, Itanagar, Papum Pare, Arunachal Pradesh. *CRFJ* FN 61, 25.1.2009, ARUN.

4. *Angiopteris palmiformis* - Tsiria Kanna Hill, Itanagar, Papum Pare, Arunachal Pradesh. *CRFJ* FN 61, 25.1.2009, ARUN.

5. *Arthromeris tatsienensis* - Sanagaon, Sankhu, Kathmandu, C. Nepal. *CRFJ* FN 165, 29.9.2008, TAIF.

6. *Arthromeris tenuicauda* - Sohra, Meghalaya. *CRFJ* FN 267, 22.11.2008, ARUN.

7. *Arthromeris tomentosa* - Narpung to Wamrung, Tashigang, E. Bhutan. *CRFJ* FN 199, 24.5.2009, THIM.

8. *Arthromeris tomentosa* - Narpung to Wamrung, Tashigang, E. Bhutan. *CRFJ* FN 199, 24.5.2009, THIM.

9. *Lepisorus* sp., blackish scales - Mechuka, W. Siang, Arunachal Pradesh. *AB* 26100, ARUN.

10. *Lepisorus* sp., blackish scales - Mechuka, W. Siang, Arunachal Pradesh. *AB* 26100, ARUN.

11. *Pyrrosia rasamalae* - Itanagar town, Papum Pare, Aeunachal Pradesh. *CRFJ* FN 163, 2.2.2009, ARUN, with AB.

12. *Pyrrosia rasamalae* - Itanagar town, Papum Pare, Aeunachal Pradesh. *CRFJ* FN 163, 2.2.2009, ARUN, with AB.

13. *Selliguea engleri* - Shirong to Hunung, Namdapha, Changlang, Arunachal Pradesh. *B.K. Shukla* 88205, ASSAM.

14. *Selliguea engleri* - Shirong to Hunung, Namdapha, Changlang, Arunachal Pradesh. *B.K. Shukla* 88205, ASSAM.

15. *Selliguea trisecta* - Pynursla, Meghalaya. *G. Panigrahi* 2950, ASSAM.

16. *Aleuritopteris duclouxii* - Shirong to Hunung, Namdpaha, Changlang, Arunachal Pradesh. *B.K. Shukla* 88207, ASSAM.

17. *Aleuritopteris duclouxii* - Shirong to Hunung, Namdpaha, Changlang, Arunachal Pradesh. *B.K. Shukla* 88207, ASSAM.

18. *Notholaena borealisinensis* - Chuzzom, Thimphu, W. Bhutan. *CRFJ* 31679, THIM.

19. *Notholaena delavayi* - Chele La Pass, Ha, W. Bhutan. *CRFJ* 31629, THIM, with T. Wangdi & R. Pradhan.

20. *Notholaena delavayi* var. *intermedia* - Chele La Pass, Ha, W. Bhutan. *CRFJ* 31630, THIM, with T. Wangdi & R. Pradhan.

21. *Pteris hirtula* - hill opposite Seinki Park, Itanagar, Papum Pare, Arunachal Pradesh. *CRFJ* FN 180, 16.2.2009, ARUN.

22. *Pteris hirtula* - hill opposite Seinki Park, Itanagar, Papum Pare, Arunachal Pradesh. *CRFJ* FN 180, 16.2.2009, ARUN.

23. *Pteris inaequalis* - Kalaktang, W. Kameng, Arunachal Pradesh. *R.K. & B. Ghosh* 68271, CAL.

24. *Pteris inaequalis* - Kalaktang, W. Kameng, Arunachal Pradesh. *R.K. & B. Ghosh* 68271, CAL.

25. *Pteris mawsmaiensis* - Mawsmai Cave, Sohra, Meghalaya. *CRFJ* FN 228, 22.11.2008, ARUN.

26. *Pteris mawsmaiensis* - Mawsmai Cave, Sohra, Meghalaya. *CRFJ* FN 228, 22.11.2008, ARUN.

27. *Pteris mawsmaiensis* - Mawsmai Cave, Sohra, Meghalaya. *CRFJ* FN 228, 22.11.2008, ARUN.

28. *Pteris taiwanensis* - Kameng, Arunachal Pradesh. *A.K. Baishya* 429, ASSAM.

29. *Pteris taiwanensis* - Kameng, Arunachal Pradesh. *A.K. Baishya* 429, ASSAM.

30. *Pteris taiwanensis* - Kameng, Arunachal Pradesh. *A.K. Baishya* 429, ASSAM.

31. *Pteris tomentella* - Sinuwa, Chomrong, below Annapurna Base Camp, Kaski, W.C. Nepal. *CRFJ* FN 43, 29.11.2006, TAIF.

32. *Pteris vittata* subsp. *vermae* - Panchali, Itanagar, Papum Pare, Arunachal Pradesh. *CRFJ* FN 199, 17.2.2009, ARUN.

33. *Pteris vittata* subsp. *vermae* - Panchali, Itanagar, Papum Pare, Arunachal Pradesh. *CRFJ* FN 199, 17.2.2009, ARUN.

34. *Pteris vittata* subsp. *vermae* - Panchali, Itanagar, Papum Pare, Arunachal Pradesh. *CRFJ* FN 199, 17.2.2009, ARUN.

35. *Asplenium hondoense* - Murlen, Champai, Mizoram. *AB* 22062, ARUN.

36. *Thelypteris paludosa* - Serley, Kurungkumey, Arunachal Pradesh. *AB* 26435, ARUN.

37. *Thelypteris megacuspis* - Mechuka, W. Siang. *AB* 26086, ARUN.

38. *Thelypteris repanda* - Tsiria Kanna Hill, Itanagar, Papum Pare, Arunachal Pradesh. *CRFJ* FN 68, 25.1.2009, ARUN.

39. *Thelypteris repanda* - Tsiria Kanna Hill, Itanagar, Papum Pare, Arunachal Pradesh. *CRFJ* FN 68, 25.1.2009, ARUN.

40. *Athyrium dissitifolium* - Ziro, Subansiri, Arunachal Pradesh. *AB* 22698, ARUN.

41. *Athyrium nakanoi* - Mechuka, W. Siang, Arunachal Pradesh. *A.K.Baishya* 90884, ASSAM.

42. *Athyrium* near *nakanoi* - Mechuka, W. Siang, Arunachal Pradesh. *A.K. Baishya* 90281, ASSAM.

43. *Diplazium burmanicum* - Tiwarigaon, Mehao Sanctuary, Lower Debang Valley, Arunachal Pradesh. *G.D. Pal* 2957, ARUN.

44. *Diplazium burmanicum* - Tuting to Ninguing, Siang, Arunachal Pradesh. *R.S. Rao* 17680, 14.11.1958, ASSAM.

45. *Gymnocarpium oyamense* - Yagrung Forest, Mechuka, W. Siang. *AB* 26208, ARUN.

46. *Ctenitis paucisora* - Palin, Kurungkumey, Arunachal Pradesh. *AB s.n.*, 18.10.2008, ARUN.

47. *Ctenitis paucisora* - Palin, Kurungkumey, Arunachal Pradesh. *AB s.n.*, 18.10.2008, ARUN.

48. *Ctenitis paucisora* - Palin, Kurungkumey, Arunachal Pradesh. *AB s.n.*, 18.10.2008, ARUN.

49. *Dryopteris namegatae* - Mechuka, W. Siang, Arunachal Pradesh. *AB* 26294, ARUN.

50. *Dryopteris namegatae* - Mechuka, W. Siang, Arunachal Pradesh. *AB* 26294, ARUN.

51. *Dryopteris wallichiana* subsp. *nepalensis* - Banthanti, S. of Ghorepani, Kaski, W.C. Nepal. *CRFJ* FN 42, 13.6.2010, TAIF.

52. *Dryopteris wallichiana* subsp. *nepalensis* - Banthanti, S. of Ghorepani, Kaski, W.C. Nepal. *CRFJ* FN 42, 13.6.2010, TAIF.

53. *Dryopteris rubrobrunnea* - Lower Debang Valley, Arunachal Pradesh. *AB* s.n., 6.2010, ARUN.

54. *Dryopteris costalisora* - Tumling to Mekhma, N. of Pashupatinagar, Ilam, E. Nepal. *CRFJ* 29714 (FN 5689), 25.10.2001, TAIF.

55. *Dryopteris vidyae* - Yagrung Forest, Mechuka, W. Siang, Arunachal Pradesh. *AB* 26244, ARUN.

56. *Dryopteris vidyae* - Yagrung Forest, Mechuka, W. Siang, Arunachal Pradesh. *AB* 26244, ARUN.

57. *Dryopteris vidyae* - Yagrung Forest, Mechuka, W. Siang, Arunachal Pradesh. *AB* 26244, ARUN.

58. *Dryopteris vidyae* - Yagrung Forest, Mechuka, W. Siang, Arunachal Pradesh. *AB* 26244, ARUN.

59. *Dryopteris vidyae* - Yagrung Forest, Mechuka, W. Siang, Arunachal Pradesh. *AB* 26244, ARUN.

60. *Dryopteris sparsa* subsp. *viridescens* - Sanagaon, Sankhu, Kathmandu, C. Nepal. CRFJ FN 191, 29.9.2008, TAIF.

61. *Dryopteris hasseltii* - Murlen, Champai, Mizoram. *AB* 22134, ARUN.

62. *Peranema annamensis* - Narpung , Wamrung, Tashigang, E. Bhutan. *CRFJ* FN 190, 24.5.2009, THIM.

63. *Polystichum hecatopterum* - Pange, Tale Valley, Subansiri, Arunachal Pradesh. *S.S. Bhattee* 6793 (71), ITAF.

64. *Polystichum hecatopterum* - Pange, Tale Valley, Subansiri, Arunachal Pradesh. *S.S. Bhattee* 6793 (71), ITAF.

65. *Polystichum tangmaiense* - Mayodia Pass, Lower Debang Valley, Arunachal Pradesh. *AB* 22243, ARUN.

66. *Polystichum tangmaiense* - Mayodia Pass, Lower Debang Valley, Arunachal Pradesh. *AB* 22243, ARUN

67. *Polystichum tangmaiense* - Mayodia Pass, Lower Debang Valley, Arunachal Pradesh. *AB* 22243, ARUN

68. *Polystichum tangmaiense* - Phek, Nagaland. *N.S. Jamir* 6121, NEHU.

69. *Cyrtomium fortunei* - Sarara Khong, Manipur. *R.D. Dixit* 58846, CAL.

70. *Tectaria ternifolia* - Hill opposite Seinki Park, Itanagar, Arunachal Pradesh. *CRFJ* FN 189, 16.2.2009, ARUN.

71. *Tectaria ternifolia* - Hill opposite Seinki Park, Itanagar, Arunachal Pradesh. *CRFJ* FN 189, 16.2.2009, ARUN.

72. *Tectaria dubia* - Sinuwa, Chomrong, below Annapurna Base Camp, Kaski, W.C. Nepal. *CRFJ* FN 97, 29.11.2006, TAIF.

73. *Bolbitis tibetica* - Mahendra Gouffer, Pokhara, Kaski, W.C. Nepal. *CRFJ* photographed uncollected 11.9.2009, same population as *CRFJ* 25804 (FN 1782). 22.12.1997, NMW.

74. *Bolbitis tibetica* - Daporijo, Upper Subansiri, Arunachal Pradesh. *AB* 22757, ARUN.

75. *Bolbitis medogensis* - Serley, Kurungkumey, Arunachal Pradesh. *AB* 26434, ARUN.

1

2

3

4

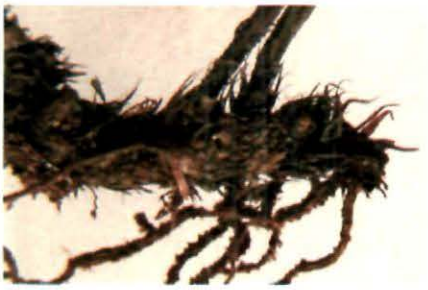
5

7

6

8

10



9

11

12

13

14

15

16

17

18

21

19

20

22

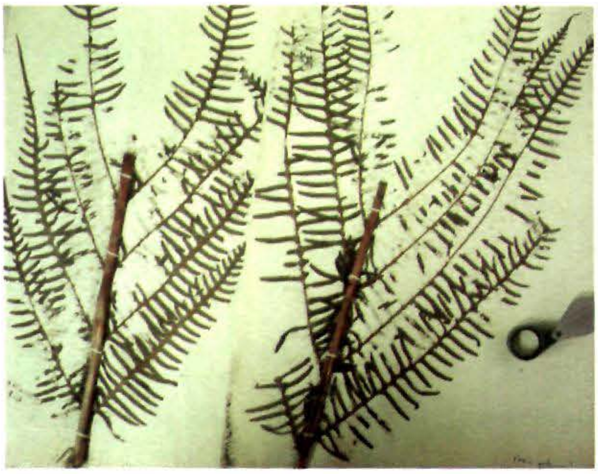
23

24

25

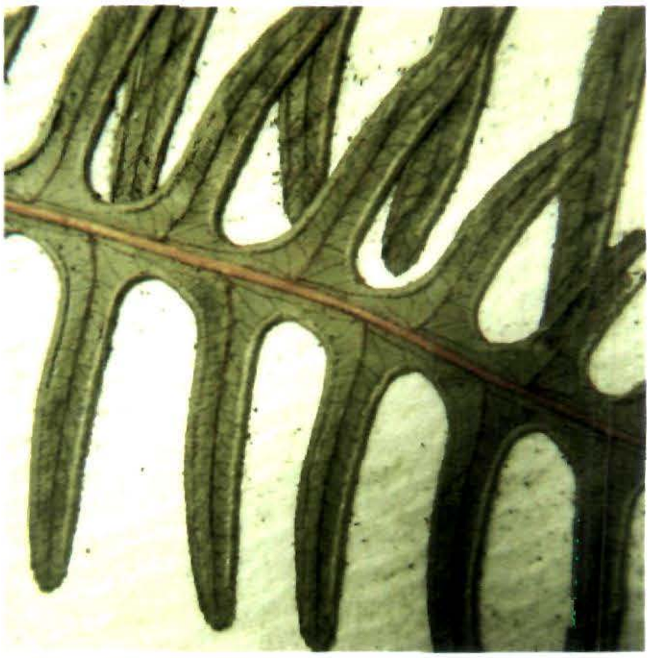
26

27



28

29

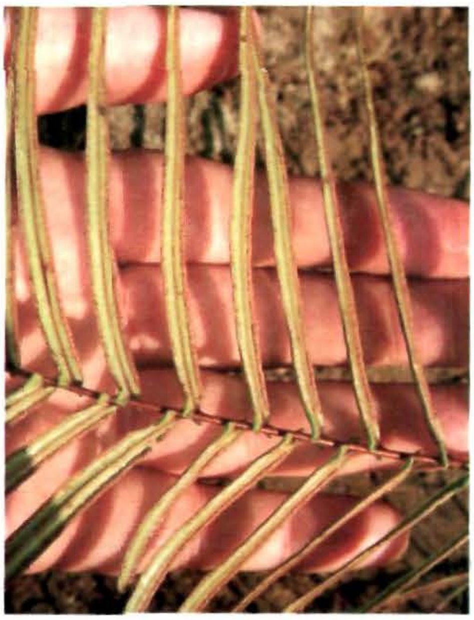


30

31

32

33



34

35

36

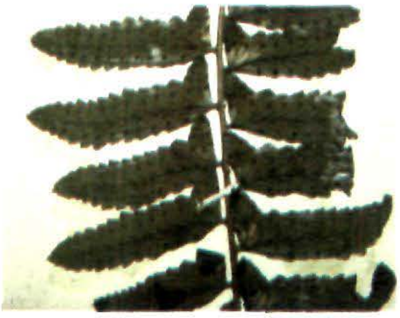
37

38

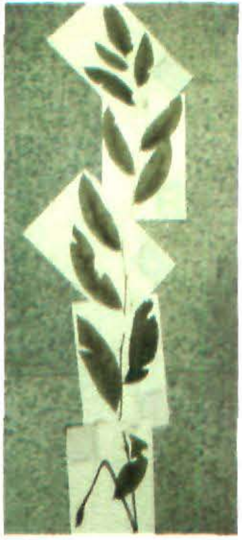
39

40

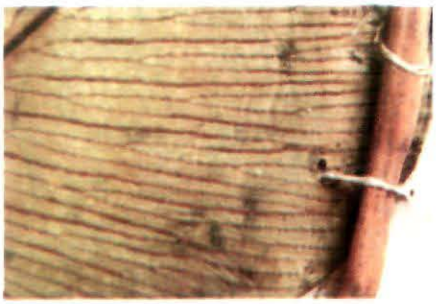
41



42



43



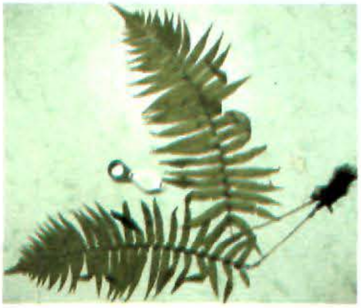
44

45

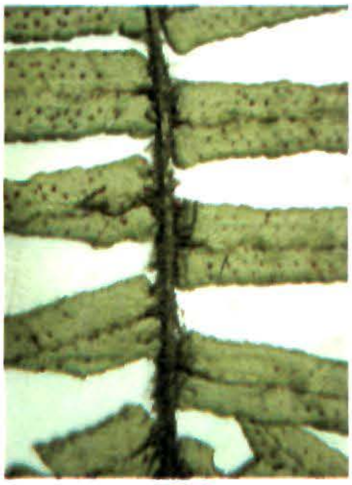
46

48

47



49



50

51

52

53

54

55


56


57


59


58


62


60

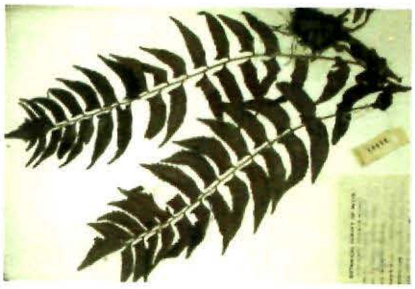

61

63

64

66

65



69

67

68

70

71

72

73

74

75

REFERENCES

Baishya, A.K. and C.R. Fraser-Jenkins in prep. Ferns and fern-allies of Arunachal Pradesh: a preliminary check-list of pteridophytes throughout the state.

Baishya, A.K. and R.R. Rao, R.R. 1982. Ferns and Fern-allies of Meghalaya State, India, *et errata*. Scientific Publishers, Jodhpur, pp.1-161

Benniamin, A. and C.R. Fraser-Jenkins. 2010. Trichomanes parvifolium, the world's smallest fern, new to India, and the rarities of Arunachal Pradesh, *Indian Fern J.*, 26: 179-184.

Benniamin, A., Siva, N., Arockkiam, A. & Manickam, V.S. 2009. Cyrtomium macrophyllum (Makino) Tagawa (Dryopteridaceae), New Record for Eastern Himalaya, India. *J. Amer. Sci.*, 5(3): 107-108.

Blume, C.L. von 1828. Enumeratio Plantarum Javae et Insularum adjacentium, 2 Filices: 99-274. Lugduni Batavorum.

Burkill, I.H. 1953-1962. Chapters on the history of botany in India, 1-4, *J. Bombay Nat. Hist. Soc.* 51 (4): 846-878 (1953); 54 (1): 42-86 (1956); 58 (3): 678-796 (1960); 59 (2): 335-359 (1962).

Chandra, S. 2000. The Ferns of India (Enumeration, Synonyms & Distribution): 1-459. International Book Distributors, Dehra Dun.

Chandra, S., C.R. Fraser-Jenkins, A. Kumari and A. Srivastava. 2008. A Summary of the Status of Threatened Pteridophytes of India, *Taiwania* 53(2): 170-209. [reprinted sub Chandra, S. & Fraser-Jenkins, C.R. in Verma, S.C., Khullar, S.P. & Cheema, H.K. (eds.) 2008. Perspectives in Pteridophytes, Silver Jubilee Publication of Indian Fern Society (1983-2008): 199-224. Bishen Singh Mahendra Pal Singh, Dehra Dun. Abstract reprinted as Threatened pteridophytes of India, International Symposium on Perspectives in Pteridophytes, Nov. 27-29, 2008: 51. National Botanical Research Institute, Lucknow & The Indian Fern Society, Patiala.

Ching, R.C. 1949. The studies of Chinese Ferns – 35, *Bull. Fan Mem. Inst. Biol.*, n.s. 1(3): 267-317.

Ching, R.C. 1978. The Chinese fern families and genera. Systematic arrangement and historical origin. *Act. Phytotax. Sinica*, 16(3): 8-19; 16(4): 16-37.

Ching, R.C. 1983. Taxonomic notes on some N.W. Himalayan ferns. *Act. Bot. Austr.-Sinica*, 1: 17-25.

Ching, R.C. and S.K. Wu. 1983. Pteridophyta, in Wu, C.Y. (ed.), The series of the scientific expedition to Qinghai-Xizang Plateau Flora Xizangica, *1*: 1-355. Science Press, Beijing.

Christensen, C. 1906. *Index Filicum*, 2: 367-368. H. Hagerup, Haffniae.

Chu, W.-M. 1992. Taxonomic notes on some pteridophytes from Yunnan (mainly Dulongjian and neighbouring regions), *Act. Bot. Yunnanica* 5, suppl.: 34-58.

Chu, W.-M. And Z.R. He. 1998. New taxa of Athyriaceae from China and upper Myanmar, *Acta Phytotax. Sinica*, 36(4): 375-381.

Clarke, C.B. and J.G. Baker. 1888. Supplementary Note on the Ferns of Northern India, *J. Linn. Soc. (Lond.)*, 24: 408-418.

Desmond, R.[G.C.]. 1994. Dictionary of British & Irish Botanists and Horticulturalists Including Plant Collectors, Flower Painters and Garden Designers, ed. 2. pp. 825. Taylor & Francis and the Natural History Museum, London and Bristol, PA.

Dixit, R.D. 1984. A census of the Indian pteridophytes, Flora of India, ser. 5. *pp.* 177. Botanical Survey of India, Howrah.

Dixit, R.D. and Bal Krishna. 1990. Pronephrium birii, a new species of fern from Arunachal Pradesh, India, *Indian Fern J.*, 7(1-2): 18-20.

Dixit, R.D. and Y.K. Kala. 1988. Notes on two species of fern genus Pronephrium Presl, *Bull. Bot. Surv. India*, 30(1-4): 146-148.

Fraser-Jenkins, C.R. 1989. A monograph of the genus

Dryopteris (Pteridophyta: Dryopteridaceae) in the Indian subcontinent, *Bull. Brit. Mus. Nat. Hist.*, bot. ser., 18(5): 323-477.

Fraser-Jenkins. C.R. 1991. An outline monographic study of the genus Polystichum in the Indian subcontinent, in Bhardwaj[a], T.N. & Gena; C.B. (eds.), Perspectives in Pteridology: Present and Future, *Aspects Plant Sci.*, 13: 249-287. Today & Tomorrow's Printers & Publishers, New Delhi.

Fraser-Jenkins, C.R. 1993 ["1992"]. The ferns and allies of the far west Himalaya - Some additions and corrections, *Botanica Helvetica*, 102(2): 143-157.

Fraser-Jenkins, C.R. 1995 ined. Himalayan athyrioid ferns (towards a revision of Himalayan Athyrium and Diplazium and some comments on some species of Deparia and Cornopteris (Woodsiaceae), with emphasis on the west Indo-Himalaya).

Fraser-Jenkins, C.R. 1997a. *Himalayan Ferns (A Guide to Polystichum)*. *pp.* 54, with errata (1998). International Book Distributors, Dehra Dun, India.

Fraser-Jenkins, C.R. 1997b. *New species syndrome in Indian Pteridology and the ferns of Nepal*. *pp.* 403 and two errata. International Book Distributors, Dehra Dun.

Fraser-Jenkins, C.R. 2008a. Endemics and Pseudo-endemics in Relation to the Distribution Patterns of Indian Pteridophytes, *Taiwania* **53**(3): 264-292. [Reprinted in *Indian Fern J.*, 25: 1-45 (2008) and in Amoroso, V.B. (ed.), *Proceedings of the 4th Symposium on Asian Pteridology and Garden Show*: 105-129. Central Mindanao Univ., Musuan, Bukidnon.

Fraser-Jenkins, C.R. 2008b. Taxonomic Revision of Three Hundred Indian Subcontinental Pteridophytes With a Revised Census-List, a new picture of fern-taxonomy in the Indian subcontinent. *pp.* 685. Bishen Singh Mahendra Pal Singh, Dehra Dun.

Fraser-Jenkins, C.R. 2010. A brief comparison of modern Pteridophyte classifications (Families and Genera in India), *Indian Fern J.*, 26: 107-131.

Fraser-Jenkins, C.R., S. Matsumoto, and T. Wangdi, in C.R. Fraser-Jenkins (ed.). 2009. Pteridophytes of Bhutan - A list of families, genera and species: i-x, 1-125. National Biodiversity Centre, Ministry of Agriculture, Serbithang, Thimphu, Bhutan

Fraser-Jenkins, C.R. and C.S. Dulawat. 2009. A summary of Indian cheilanthoid ferns and the discovery of Negripteris Chiov., an Afro-Arabian fern-genus new to India, *Fern Gaz.*, 18(5): 216-229.

Gaudichaud-Beaupré, C. 1829. Botanique, Filices, in Freycinet, L.[C. de S.] de, Voyage autour du Monde ... Exécuté sur les Corvettes de S.M. l'Uranie et La Physicienne, Atlas botanique: 465-522. Paris.

Ghosh, S.R., B. Ghosh, A. Biswas and R.K. Ghosh. 2004. *The Pteridophytic Flora of Eastern India* 1. *pp.* 591. Flora of India, series 4. Botanical Survey of India. Kolkata.

Ghosh, S.R., B. Ghosh and R.K. Ghosh. 1984. Diplazium cordifolium in India, *J. Econ. Tax. Bot.* 5(4): 980.

Hasebe M., P. G. Wolf., K. M. Pryer, K. Ueda, M. Ito, R. Sano, G. J. Gastony, J. Yokoyama, J.R. Manhart, N. Murakami, E. H. Crane, C.H. Haufler and W. D. Hauk. 1995. Fern phylogeny based on rbcL nucleotide sequences, *Amer Fern J.*, 85: 134-181.

Hennipman, E. 1977. A monograph of the fern genus Bolbitis (Lomariopsidaceae), Leiden Bot. Series 2. *pp.* 331. Leiden University Press, Leiden.

Holttum, R.E. 1955 ["1954"]. A revised Flora of Malaya an illustrated systematic account of the Malayan Flora, including commonly cultivated plants. 2. Ferns of Malaya. *pp.* 637. Government Printing Office, Singapore.

Holttum, R.E. 1968 ["1966"]. A revised Flora of Malaya an illustrated systematic account of the Malayan Flora, including commonly cultivated plants, ed. 2, 2. Ferns of Malaya. pp. 653. Government Printing Office, Singapore.

Holttum, R.E. and P.J. Edwards. 1986. Studies in the fern-genera allied to Tectaria 2. Dryopsis, a new genus, *Kew Bull.*,41(1): 171-204.

Hovenkamp, P. 1986. A monograph of the fern genus Pyrrosia (Polypodiaceae), Leiden Bot., 9: 1-310. E.J. Brill, Leiden University Press, Leiden.

Itô, H., K. Iwatsuki, and M. Tagawa. 1971. Pteridophyta, in Hara, H. (ed.), *The flora of eastern Himalaya. Second report, Univ. Mus. Univ. Tokyo Bull.*, 2: 197-221.

Itô, H., M. Tagawa, M. Nishida, and K. Iwatsuki. 1966. Pteridophyta, in Hara, H. (ed.), The flora of eastern Himalaya: 453-500. University of Tokyo, Tokyo.

Jamir, N.S. and R.R. Rao. 1988. The ferns of Nagaland. pp. 426. Bishen Singh Mahendra Pal Singh, Dehra Dun.

Khare, P.B. and S. Kaur. 1983a. Intraspecific polyploidy in Pteris vittata L. *Cytologia*, 48: 21-25.

Khare, P.B. and S. Kaur. 1983b. Gametophyte differentiation of Pentaploid Pteris vittata L., *Proc. Indian Natn. Sci. Acad.*, ser. B, 49(6): 740-742.

Kramer, K.U. and P.S. Green. (eds.). 1990. Pteridophytes, in Kubitski, K. (ed.), *The Families and Genera of Vascular Plants* 1 Pteridophytes and Gymnosperms. *pp.* 404. Springer Verlag, Berlin, Heidelberg. [Reprinted 1991. Narosa Publishing House, New Delhi].

Kung, H.S. and Y. Tateish. 1994. A new species of Polystichum Roth from Xizang (Tibet), *Act. Phytotax. Sinica*, 32(3): 268-270.

Kung, H.S. and L.B. Zhang. 1995. Four new species of the fern genus Polystichum sect. Metapolystichum Tagawa from China. *Act. Phytotax. Sinica*, 33(3): 308-312.

Kuo, C.M. 1985. Taxonomy and phytogeography of Taiwanese Pteridophytes, *Taiwania*, 30: 5-99. And electronic updates.

Lindsay, S., D.J. Middleton, T. Boonkerd. and S. Suddee. 2009. Towards a stable nomenclature for Thai ferns, *Thai Forest Bull.*, *Bot.*, 37: 64-106.

Mehra, P.N. and D.S. Loyal. 1965. Cytological investigations in the Himalayan Dryopteris Adanson. *Caryologia*, 18: 461-498.

Morton, C.V. 1973. Studies of fern types, 2, *Contrib. U.S. Nat. Herb.*, 38(6): 215-281.

Pangtey, Y.P.S. and N. Punetha. 1987. Pteridophytic flora of Kumaon Himalaya: an updated list, in Pangtey, Y.P.S. & Joshi, S.C. (eds.), *Western Himalaya*: 390-412. Gyanodya Prakashan, Nainital.

Parris, B.S. and A. Latiff. 1997. Towards a Pteridophyte Flora of Malaysia: A Provisional Checklist of Taxa, *Malayan Nature J.* 50: 235-280.

Pichi Sermolli, R.E.G. 1983. Fragmenta Pteridologiae - 8, *Webbia*, 37(1): 111-140.

Pichi Sermolli, R.E.G. 1989. Again on the typification of the generic name Notholaena R. Brown, *Webbia*, 43(2): 301-310.

Piggott, A.G. and C.J. Piggott. 1988. Ferns of Malaysia in colour.. Tropical Press SDN. BHD, Kuala Lumpur, pp. 458

Proctor, J., K. Haridasan, and G.W. Smith. 1998. How far north does Lowland Evergreen Tropical Forest go? *Global Ecology & Biogeography Letters*, 7(2): 141-146.

Singh, S. and G. Panigrahi. 1990. Is Lepisorus (J. Smith) Ching generically distinct from Pleopeltis Humb. & Bonpl. ex Willd (Pteridophyta)?, *J. Hill Res,* 3: 14-27.

Singh, S. and G. Panigrahi. 2005. *Ferns and Fern-Allies of Arunachal Pradesh* 1, 2. *pp.* 881. Bishen Singh Mahendra Pal Singh, Dehra Dun.

Smith, A.R., K.M. Pryer, E. Schuettpelz, P. Korall, H. Schneider and P.G. Wolff. 2006. A classification for extant ferns, *Taxon*, 55: 705-731.

Smith, J. 1875. Historia Filicum – An exposition of the nature, number and organography of ferns etc. MacMillan and Co., London, pp. 408.

Tagawa, M. and K. Iwatsuki. 1988. Pteridophytes Blechnaceae-Athyriaceae, in Smitinand, T., Larsen, K. *et al.* (eds.), *Flora of Thailand*, 3(3): 297-480. Chutima Press, Bangkok.

Thapa, N. 2002. Pteridophytes of Nepal, in Bista, M.S., Adhikari, M.K. & Rajbhandari (eds.), *Bull. Dept. Plant Res. Nepal*, 19: 1-175.

Tryon, R. and A. Tryon. 1980. Proposal to conserve Notholaena with the type Pteris trichomanoides, *Taxon*, 29: 160-161.

Widén, C.-J., C.R. Fraser-Jenkins, T. Reichstein and J. Sarvela. 1999. A survey of phenolic compounds in *Dryopteris* and related fern genera. Part II. Phloroglucinol derivatives in subgenus *Dryopteris* (Pteridophyta, Dryopteridaceae), *Act. Bot. Fennici*, 164: 1-56.

Widén, C.-J., C.R. Fraser-Jenkins, T. Reichstein and J. Sarvela. 2001. A survey of phenolic compounds in *Dryopteris* and related fern genera. Part III. Phloroglucinol derivatives in subgenera *Erythrovaria* and *Nephrocystis* and related genera (Pteridophyta, Dryopteridaceae), *Annales Bot. Fennici*, 38: 99-138.

Wu, S.-H. 1983. Studies on the family Peranemaceae Ching, *Act. Phytotax. Sinica*, 21(4): 370-384, *t.* 1-2.

Wu, S.G. (ed.). 2000. Dryopteridaceae (1), *Flora Reipublicae Popularis Sinicae.*, 5(1): 1-252. Science Press, Beijing.

Wu, S.H. and C.H. Wang. 1999. Aspidiaceae and Davalliaceae, in Wu, S.H. (ed.), *Flora Reipublicae Popularis Sinicae*, 6(1): 1-103, 161-197. Science Press, Beijing.

Yatskievych, G. & Smith, A.R. 1997. Typification of Notholaena R. Br. (Pteridaceae), *Taxon*, 52(2): 331-336.

Pb. Univ. Res. J (Sci.), Vol. 59, 2009, pp. 39-43

SCANNING ELECTRON MICROSCOPIC STUDIES ON LEUKOCYTES OF *PLASMODIUM BERGHEI* INFECTED, IMMUNIZED AND NORMAL BALB/C MICE

***Upma Bagai, Anil Pawar and Vineet Kumar**

Parasitology Laboratory, Department of Zoology, Panjab University, Chandigarh-160014

Abstract

Surface of leukocytes display a rapid and varied response to environmental conditions as well as to pathogens. Scanning electron microscopy can help in better understanding of morphological changes occurring on cell's surface during such responses. In present investigation, an attempt has been made to find the variations in surface of mononuclear (MN) and poymorphonuclear (PMN) cells of Balb/c mice upon Plasmodium berghei *(NK-65) infection and immunization using parasite's constituent (10,000g sediment). MN and PMN cells were isolated by double density gradient centrifugation using Histopaque-1119 and Histopaque-1077 (Sigma). Isolated blood cells from different groups, when subjected to scanning electron microscopy, showed variations not only in shape but also in their size.*

Keywords: Mononuclear, polymorphonuclear, *Plasmodium*, leukocytes, SEM.

INTRODUCTION

Malaria is still a major cause of death and severe illness in most of the world, with an estimate of 300-500 million new infections and 1-3 million deaths every year (Carvalho *et al.*, 2007). One of the most cost-effective interventions to curb the disease may be the development of an effective vaccine, which to date is not available. The reasons for this are mainly the complex life cycle of the parasite, its antigenic variation and diversity, the wide variety of immune responses it induces, and the incomplete knowledge of protective immunity mechanisms (Flueck *et al.*, 2009). Blood stage parasites of the genus *Plasmodium*, the causative agent of malaria in both human and animal hosts, initially replicate unchecked. Subsequently the elicited immune response controls parasite replication, reducing infection to low levels (Li *et al.*, 2001). Cell free parasite, when obtained by saponin lysis, does contain some red cell contamination but it has been found to be metabolically active (Kreier and Green, 1977). The isolation of subcellular fractions by differential centrifugation and their analysis for marker enzymes has been reported in *Plasmodium berghei* (Neville, 1975; Upma *et al.*, 1998). 10,000g fraction provides better *in vivo* protection against blood stage *P. berghei* infection than total parasite homogenate. This fraction isolated by employing similar fractionation technique in *P. yoelii* and *P. falciparum* has been reported to contain mitochondria (Fry and Beesley, 1991) and mitochondrial inhibitors are known to arrest *in vitro* growth of parasite. Despite of diverse morphology, localization and properties, white blood cells have common function of recognition and defense. Such functions are initiated by diverse interactions at cell surface. Therefore, study of changes in surface architecture of these cells can help in better understanding of mechanisms involved in such functions. The advent of scanning electron microscope has revolutionized the visualization of cell's surface morphology. Present study describes the changes taking place on the surface of white blood cells upon *Plasmodium berghei* infection and immunization using 10,000g sediment of parasite which provides complete and long lasting protection against blood stage infection of rodent malaria.

MATERIALS AND METHODS

Animals

Five to six weeks old inbred white Swiss mice, *Mus musculus* (Balb/c strain), weighing 25-30 g each, of either sex, were obtained from National Institute of Pharmaceutical Education and Research (NIPER), Mohali, and kept in Central Animal House, Panjab University, Chandigarh.

Parasite and infection

Asexual erythrocytic stages of *Plasmodium berghei* (NK-65) were maintained by weekly passage of 1×10^6 parasitized cells from infected to normal mice before the peak of parasitemia and the infection was monitored by Giemsa-stained thin blood films as described by

---

*Corresponding Author. *upmabagai@yahoo.co.in*

MS Received February 15, 2010; Accepted October 16, 2010

Langhorne *et al.* (1989).

Experimental Design

For present investigation, mice were divided into three groups having six mice in each group.

GA- Normal Balb/c mice.

GB- *Plasmodium berghei* infected Balb/c mice

GC- Balb/c mice immunized with 10,000g fraction of *P. berghei.*

Experimental blood stage infections were initiated by intraperitoneal (I.P) inoculation of 1×10^6 infected cells.

Isolation of cell free parasite

When percent infection averaged 40-50%, blood was aspirated from *P. berghei* infected Balb/c mice (NK-65) by jugular vein incision. Red cell pellet obtained after centrifugation (800g, 10 min, RT) of infected blood was suspended in equal volume of phosphate buffered saline (PBS 0.01M, pH 7.2) and double volume of saponin [0.2% (w/v) in PBS, pH 7.2] was added to it. The suspension was kept on ice for 35 min with intermittent shaking after every 5 min. After centrifugation (2200g, 20 min, 4°C), grey colored pellet of cell free parasite was obtained. Parasite pellet was washed thrice with PBS, pH 7.2 in cold centrifuge (Upma *et al.*, 1998).

Homogenization and fractionation of CFP

Cell-free pellet suspended in sucrose (0.25M in PBS, pH 7.2) was homogenized at 4°C by Potter Elvehjam pre-cooled homogenizer (Remi, Bombay, India). A part of homogenate i.e. TPH, was kept at -20°C and the rest of it was subjected to centrifugation (600g, 15 min, at 4°C). Nuclear pellet thus formed was discarded and supernatant was centrifuged again at 10,000g for 20 min. Fraction thus obtained was suspended in 1-2 ml of PBS (pH 7.2, 0.01M) and stored at -20°C for further use (Banyal *et al.*, 1979).

Estimation of protein

The concentration of protein in 10,000g fraction was estimated by slightly modified method of Lowry *et al.* (1951) using bovine serum albumin (BSA) as standard. Trichloroacetic acid (10%) was used to precipitate proteins in sample and precipitates were dissolved in 1N sodium hydroxide before detecting protein.

Immunization of mice

A group of six mice (GC) was immunized with 10,000g fraction of *Plasmodium berghei.* Each mice was injected intraperitoneally (i.p.) with 100 µg of protein and 30 µg of saponin in PBS (pH 7.2) on day 0. Two booster doses were given at 14-day interval.

Indirect fluorescent antibody test

A slightly modified method of Collins and Skinner (1972) was applied to assess level of anti-malarial antibodies in sera of immunized mice. Sera samples were serially diluted in 1:32 fold dilutions in PBS (0.15M, pH 7.2). Slides were counterstained in 0.5% (w/v) Evan's blue in PBS, pH 7.2 to remove any nonspecific fluorescence. End-point IFA titres were determined by recording the highest serum dilution that gave detectable fluorescence microscopically (Leica DMLS, Germany).

Isolation of leukocytes

Blood from groups A, B and C was subjected to double density gradient centrifugation using Histopaque-1119 and Histopaque-1077 (Sigma) to separate mononuclear (MN) cells from polymorphonuclear (PMN) cells using Sigma procedure (Czuprynski and Brown, 1998). 2ml of Histopaque-1119 was overlaid with equal volume of Histopaque-1077. Blood was added slowly along the wall of centrifuge tube without disturbing the two layers. The tube was centrifuged at 700g for 30 min in REMI (8C) centrifuge at room temp. MN cells were aspirated from plasma/ Histopaque-1077 interphase, whereas, PMN cells from Histopaque-1119/ Histopaque-1077 interphase.

Scanning electron microscopy

Isolated white blood cells were subjected to scanning electron microscopy to observe various morphological changes. A slightly modified method of Clarence *et al* (1974) was used for SEM studies. WBC suspension was fixed in 2.5% (v/v) gluteraldehyde in PBS, pH 7.2 for 20 min at room temperature. Fixation was done in phosphate buffered saline at pH 7.2. After fixation respective suspension was centrifuged at 600g in REMI (8C) centrifuged at room temp. Supernatant was discarded, pellet was washed thrice using PBS, pH 7.2 at 600g for 5 min. Finally pellet was washed in distilled water thrice. Then it was placed over silver foil attached over an iron stubb. After air-drying, stubbs were sputtered for 30 min in a sputterer. Stubbs were observed in Scanning Electron Microscope (JEOL JSM-6100 scanning microscope) in Central Instrumental Laboratory (CIL), Panjab University, Chandigarh, under different magnifications.

RESULTS AND DISCUSSION

Vaccines against the blood stages of the parasite could accelerate the acquisition of natural immunity. They do not aim at preventing infection, but at protecting from morbidity and mortality. An advantage of this type of vaccine is constant boosting of the immune response by naturally occurring infections (Flueck *et al.*, 2009). 10,000g sediment of *Plasmodium berghei* (NK-65) has been observed to trigger immune response in the host. It is confirmed by the appearance of antimalarial antibodies in sera of immunized mice as checked by IFA after fifteen days of last immunization dose. Antibody titre produced by this sediment was 1:2048 whereas, normal mice had no antibodies titre. Counterstaining with Evan's blue eliminates any non-specific reaction. Antibodies prevent invasion of healthy erythrocytes by agglutinating merozoites, upon their liberation from ruptured infected erythrocytes (Miller et *al.*, 1975). Efficacy of 10,000g sediment in providing protection against *Plasmodium* has been confirmed in our laboratory.

Removal of leukocytes and other components from infected blood samples is an important prerequisite for a number of investigations. Furthermore, it has been shown that the leukocytes present in samples can phagocytose, damage and potentially destroy malaria parasites under *ex vivo* investigations (Brown and Smalley, 1981; Celada *et al.*, 1983). Antimicrobial and biochemical studies of infectious diseases may also be confounded by the significant metabolic activity of leukocytes in the sample of interest. The wide range of leukocyte removal techniques that have been developed since the 1950s, are mostly based on differential centrifugation or on column filtration. Differential density centrifugation using sucrose solutions, Percoll™, Nycodenz™, Ficoll™ and Lymphoprep™ (Greiner Bio-One®) are particularly useful when a viable leukocyte fraction is needed for subsequent immunological investigations (Sriprawat *et al.*, 2009). For present investigation, leukocytes were isolated by employing double density gradient centrifugation technique, using Histopaque-1119 and Histopaque-1077.

Mononuclear white blood Cells

Scanning electron microscopy of MN cells from GA (Fig. 1-A) revealed MN cells mainly having smooth surface (4.6±0.9 µm). Rough surface cells in normal mice might be macrophages at inactivated stage. MN cells isolated from mice of GB (Fig. 1-B) exhibited layered surface (4.76±2.03µm) having blunt projections, whereas, in immunized mice i.e. GC (Fig.1-C), MN cells were observed to have multilayered surface (3.3±0.2µm) and raised surface (3.3±0.0µm). In SEM studies on human peripheral blood, lymphocytes have been identified as smooth surface cells and macrophages were characterized with ruffled surface (Albrecht *et al.*, 1978). Raised surface cells observed in present investigation may be activated lymphocytes. Extra layered surface cells in present study might be activated monocytes as reported by Gordon (1999) that monocytes on activation give rise to immunologically active macrophages having altered surface.

Polymorphonuclear white blood Cells

PMN cells from normal mice i.e. GA (Fig. 2-D) were seen to have smooth and activated surfaces and finger like projections on their surface. Non significant variations in size of smooth and activated surface cells (3.4±0.23µm) were observed. GB mice (Fig. 2-E) had PMN cells having smooth surface (4.3±4.43µm) with finger like projections. PMN cells seen in normal blood had lesser projections on their surface as compared to PMN cells of this group. No smooth surface PMN cell was found in blood of immunized mice i.e. GC (Fig. 2-F). Rough and activated surface cells were found to be 3.4±0.3 and 3.7±0.0µm in size respectively. Extra layered surface cells were found to be 3.8±0.4µm in size. Raised surface cells were very less. Human peripheral blood granulocyte population has been reported by SEM to consist of spherical cells with smooth, ridged or ruffled surface. Some cells show surface villi and blebs (Albrecht *et al.*, 1978). Present investigation reports similar type of cells in mouse blood having *P. berghei* infection. Surface of these cells become activated with fine projections and blunt projections. More activated surface cells with much more projections are visible in PMN cells of immunized mice. These cells might be activated neutrophils for phagocytic action of *P. berghei* infected cells. Human neutrophils have been reported to form extracellular trap consisting of their DNA to kill bacteria (Brinkmann *et al.*, 2004).

Morphological variations as observed in leukocytes of different groups point towards the activation of cells upon immunization and *Plasmodium* infection. It is reported for the first time that MN cells develop layered surface with *P. berghei* infection, and extra-layered surface upon immunization. Hence, SEM can be used as an alternative/ additional technology to observe the actual activation of leukocytes with or without involvement of any immunological detection technique.

ACKNOWLEDGEMENTS

Authors are thankful to the University Grant Commission, New Delhi for providing financial assistance under UGC-

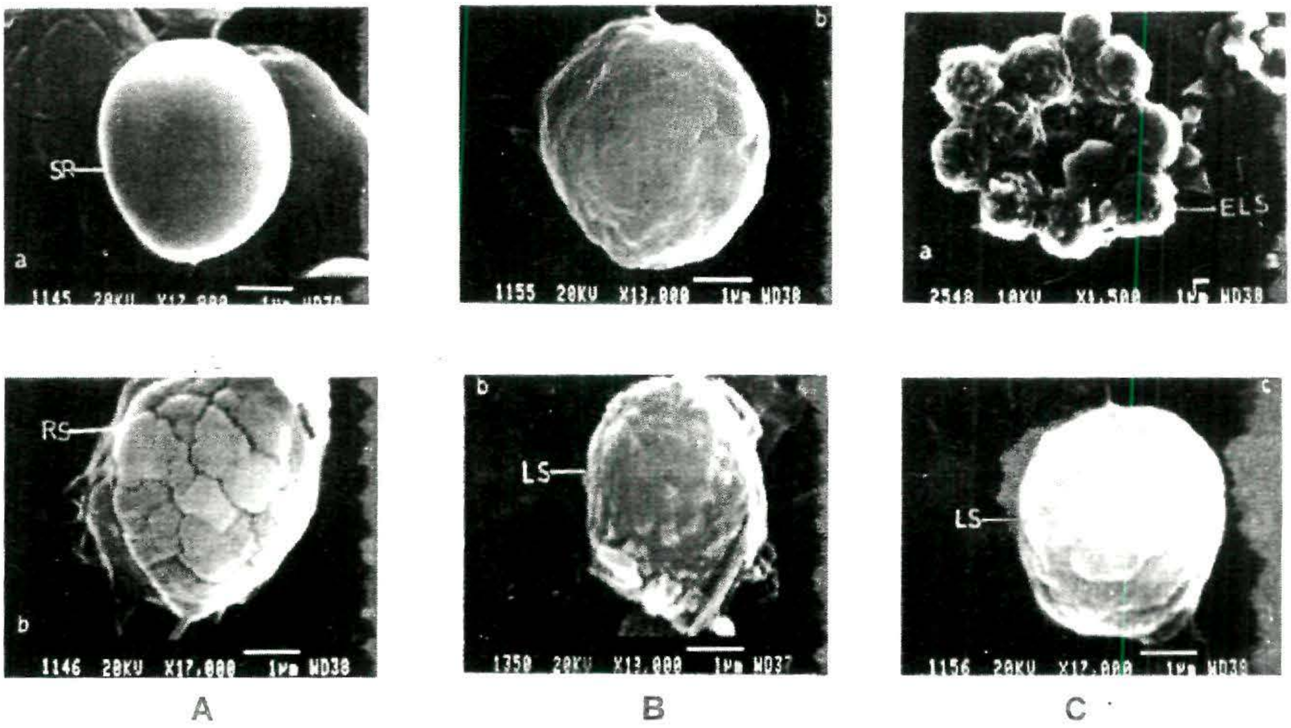


Fig. 1: Scanning electron micrograph of MN cells of normal (A), *Plasmodium berghei* infected (B) and immunized (C) Balb/c mice.

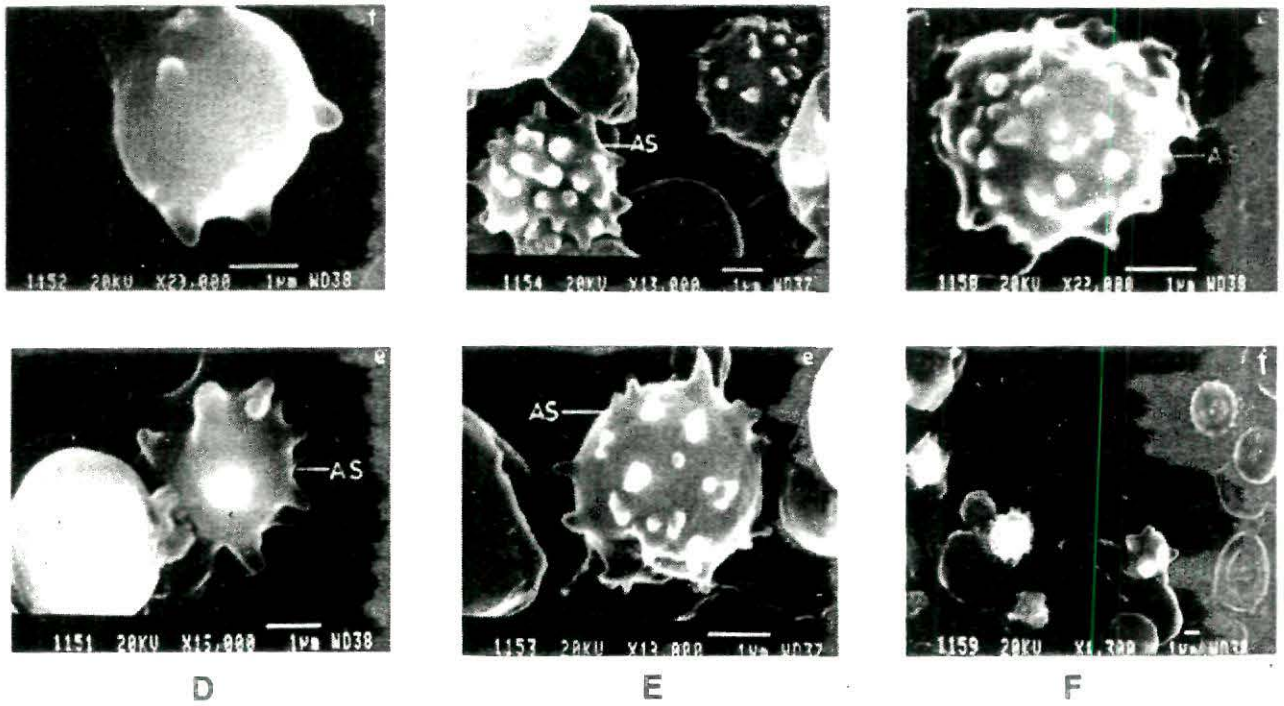


Fig. 2: Scanning electron micrograph of PMN cells of normal (D), *Plasmodium berghei* infected (E) and immunized (F) Balb/c mice.

Abbreviations for figures:
AS- Activated surface
ELS- Extra-layered surface
LS- Layered surface
RS- Rough surface
SR- smooth surface

CAS programme of Zoology Department, Panjab University, Chandigarh.

REFERENCES

Albrecht, R.M., C. Jordon and R. Hong. 1978. Identification of monocytes, granulocytes and lymphocytes. Correlation of histological, histochemical and functional properties with surface structures as reviewed by Scanning electron microscopy. *SEM. Symp.*, II: 511-523.

Banyal, H.S., V.C. Pandey and G.P. Dutta. 1979. Subcellular fractionation and localization of marker enzymes of erythrocytic stages of *Plasmodium knowlesi. Indian J. Parasitol.*, 3: 9-14.

Brinkmann, V., U. Reichard, C. Goosmann, B. Fauler, Y. Uhlemann, D.S. Weiss, Y. Weinrauch and A. Zychlinsky. 2004. Neutrophil extracellular traps kill bacteria. *Science*, 303: 1532-1535.

Brown, J. and M.E. Smalley. 1981. Inhibition of the *in vitro* growth of *Plasmodium falciparum* by human polymorphonuclear neutrophil leukocytes. *Clin. Exp. Immunol.*, 46: 106-109.

Carvalho, L.J.M., M.F. Ferreira-da-Cruz, C.T. Daniel-Ribeiro, M. Pelajo- Machado and H.L. Lenzi. 2007. Germinal center architecture disturbance during *Plasmodium berghei* ANKA infection in CBA mice. *Malaria Journal*, 6: 59-67.

Celada, A., A. Cruchaud and L.H. Perrin. 1983. Phagocytosis of *Plasmodium falciparum*-parasitized erythrocytes by human polymorphonuclear leukocytes. *J. Parasitol.*, 69: 49-53.

Clarence, A.S., C. Maria, Rosales-Ronquillo and P.H. Silverman. 1974. Scanning electron microscope observations of *P. berghei* ookinetes in primary mosquito cell cultures. *J. Invert. Pathol.*, 24: 179-183.

Collins, W.E. and J.C. Skinner. 1972. The indirect fluorescent antibody test for malaria. *Am. J. Trop. Med. Hyg.* 21: 690-695.

Czuprynski, C.J. and J.F. Brown. 1998. *In vitro* analysis: Isolation and preparation of lymphocytes from infected animals. In: Immunology of infection (Ed. H.E. Stefan, Kaufmann and D. Kabelitz) 25: pp. 189-194. *Academic Press (New York).*

Gordon , S. 1999. Macrophages and the immune response. In: Fundamental Immunology (Ed. Paul, W.E.) : pp. 533-544. *Lippincott-Raven pub. (Philadelphia).*

Flueck, C., G. Frankb, T. Smitha, A. Jafarshadc, I. Nebied, S.B. Sirimad, S. Olugbileb, P. Alonsoe, M. Tannera, P. Druilhec, I. Felgera and G. Corradinb. 2009. Evaluation of two long synthetic merozoite surface protein 2 peptides as malaria vaccine candidates. *Vaccine*, 27: 2653-2661.

Fry, M. and J.E. Beesley. 1991. Mitochondria of mammalian *Plasmodium spp. Parasitol.*, 102: 17-26.

Kreier, J.P. and T.J. Green. 1977. The isolation and fractionation of malaria- infected cells. *Bull. W.H.O.*, 55: 317-331.

Langhorne, J., S. Gilard, B. Simone, S. Slade and K. Eichmann. 1989. Frequencies of CD4$^+$ T cells reactive with *P. chabaudi chabaudi*: distinct kinetics for cells with Th1 and Th2 characteristics during infection. *Int. Immunol.*, 1: 416-424.

Li, C., E. Seixas and J. Langhorne. 2001. Rodent malarias: the mouse as a model for understanding immune responses and pathology induced by the erythrocytic stages of the parasite. *Med. Microbiol. Immunol.*, 189: 115-126.

Lowry, O.H., N.J. Rosebrough, A.L. Farr and R.J. Randall. 1951. Protein measurement with folin-phenol reagent. *J. Biol. Chem.*, 193: 265-275.

Miller, L.H., M. Aikawa and J.A. Dvorak. 1975. Malaria (*Plasmodium knowlesi*) merozoites: immunity and the surface coat. *J. Immunol.*, 114: 1237-1242.

Neville, D.M., Jr. 1975. Isolation of cell surface membrane fractions from mammalian cells and organs. In: Methods in membrane biology (Ed. E.D. Korn) pp.1-49. Plenum Press (New York).

Sriprawat, K., S. Kaewpongsri, R. Suwanarusk, M.L. Leimanis, U. Lek-Uthai, A.P. Phyo, G. Snounou, B. Russell, R.L. Laurent and F. Nosten. 2009. Effective and cheap removal of leukocytes and platelets from *Plasmodium vivax* infected blood. *Malaria Journal*, 8: 115.

Upma, J. Agrewala and H.S. Banyal. 1998. A 24,000g sediment of *Plasmodium berghei* induces IL-1 response in mice and exhibit protection against malaria infection. *Parasit. Hung.* 31: 13-21.

Pb. Univ. Res. J (Sci.), Vol. 59, 2009, pp. 45-55

DIVERSITY OF MOSSES OF PURANDHAR FORT (MAHARASHTRA), INDIA

B. L. Chaudhary and *Arun Chaudhary

Department of Botany, College of Science, Mohanlal Sukhadia University, Udaipur - 313001

Abstract

The present study has been carried out in Purandhar Fort of Pune district located in Sahyadri range of Maharashtra. A field survey of the study area was carried out in the year 2008. Ten species of mosses have so far been reported from this area. *Claopodium prionophyllum* (C. Muell.) Broth., *Diaphanodon procumbens* (C. Muell.) Ren. & Card, *Entodon laetus* (Griff) Jaeg., *Entodon nepalensis* Mizushima , *Entodon ovicarpus* Dix., *Hydrogonium arcuatum* (Griff.) Wijk. & Marg., *Hyophila involuta* (Hook) Jaeg., *Levierella fabroniacea* C. Muell., *Oxystegus cylindrothecus* (Mitt). Gangulee , and *Philonotis thwaitesii* Mitt. have been recorded. Four taxa including two genus *Claopodium* and *Oxystegus* and two species *Entodon nepalensis* and *Philonotis thwaitesii* is a new record from Maharashtra.

Keywords: Mosses, Pune, Purandhar Fort, Maharashtra, Sahayadri Range.

INTRODUCTION

Bryophytes are a diverse and distinct group of primitive plants with about 25,000 species distributed through out the world, making it the second largest group of land plants next to the flowering plants. Various aspects of their life such as morphology, physiology and biochemistry are quite interesting. They are considered as a potential source of large number of biological active compounds of commercial value and they are also considered as powerful experimental tools for the elucidation of complex biological process. Their relatively small size, short life cycle, simplicity of organization, high regeneration capacity, plasticity in differentiation, relatively small genome are the main attractions of this group as model organism for research in plant sciences.

Even though the Indian subcontinent is blessed with rich bryoflora, the detailed documentation is but far from complete. This is mainly due to the lack of infrastructure and resources. Their were no serious attempts made to explore bryoflora and this group is neglected, may be due to the lack of experts in this group. The liverworts had been attempted by some specialists. However, the mosses the most diverse group still remain least studied. The major work on Indian bryophytes is that of Gangulee's (1969-1980) *Mosses of Eastern India and adjacent area*, which is yet to be completed.

In context to the study area Maharashtra, except the work of Dabhade(1969) who collected 110 species of mosses form Mahabaleshwar and Chaudhary and Bhagora(2008) who collected 57 species of mosses from North Konkan, no systematic study of mosses was given any attention in Maharashtra.

In view of above the present study was undertaken to collect mosses from different areas of Purandhar fort of Maharashtra which will further provide taxonomic account of mosses in the state.

STUDY AREA

Purandhar fort located on the 1000m high hill, has a great historical importance, being the capital of Maratha Empire for sometime. Purandhar fort lies in the district of Pune which is situated within 18° 31' N - 73° 55' E at a distance of 40 km south east to Pune. It experiences a tropical wet and dry climate with average temperature ranging between 20° C to 28°C and average annual rainfall of 722 mm. Dominant trees of Purandhar are teak, oak and mango etc.

MATERIALS AND METHODS

The plant specimens were collected in the month of September 2008 with the record of data on habit, habitat localities and the pattern of distribution. The plant specimens after processing were deposited in the Bryology Laboratory of Botany Department, MLS University Udaipur, Rajasthan. The morphological as well as anatomical observation were made under Olympus Microscope (Y M 2000), however, the line drawing illustrations were made with the help of Camera Lucida. For the comparision and identification of each individual taxa books and publication by Chopra (1975), Dhabade (1998), Deora and Chaudhary (1993), Gangulee (1969-1980) were largely consulted.

OBSERVATIONS

The following mosses were identified

---

*Corresponding Author. *rldchittor@operamail.com*

MS Received July 13, 2009; Accepted May 30, 2010

ORDER: POTTIALES

FAMILY: POTTIACEAE

Key to the genera

1. Leaf cells mostly transparent or translucent; peristome teeth divided and contorted.................. ***Hydrogonium***
2. Peristome absent; leaf cells mamillose. Leaves lingulate or spatulate : perichaetial bracts slightly or not sheathing................................***Hyophila***
3. Leaf margin flat even dry; leaves brittle...............***Oxystegus***

Hydrogonium (C. Muell.) Jaeg. Bericht. That. St. Gall. Naturw. Ges,

1877-78: 405, 1880 (Ad, 2 : 669)

Key to species

Upper lamina cells not papillose : leaf tip acute, pointed; leaf carinate-concave........................... ***H. arcuatum***

1. *Hydrogonium arcuatum* (Griff.) Wijk et Marg., Taxon, 7:289. (1958)

(Fig. 1, Specimen AC/08/30)

Plant yellowish green, more or less stiff, tufted. Stem about 1 cm. high, usually, unbranched uniformly covered with leaves. Leaves carinate-concave 1.5-2mm. long and 0.4-0.5 mm. broad. Margin entire, usually flat. Leaf tip acute, pointed, there may be one to two denticulations at the extreme apex. Costa prominent, yellow brown, smooth, percurrent, or ending in a small point. All leaf cells usually smooth: basal ones elongated rectangular 7-8 X 4.77 µm long, 4 X 4.77 µm wide and upper cells chlorophyllose, subquaderate 3-4 X 4.77 µm long and wide. Capsule erect, cylindrical, annulate. Peristome teeth with several coils or erect hardly united into the basal membrane. Operculum strongly conicosubulate.

Field notes: Plants grow on moist soil.

Locality: Purandhar Fort, alt. 400m.

Distribution : India (Garhwal, Darjeeling, Calcutta, Sikkim, Arunachal Pradesh, Assam, Orissa, Gangetic plains, Kashmir, Western Himalayas, South India), East Nepal, Burma, Java, China and Japan.

Hyophila Brid. Bryol. Univ. I : 760, 1827; *Rottleria* Brid., *idid.*, 105, *hom.illeg*

Key to the species

Stem longer, dry leaf margin inrolled, upper leaf margin serrulate....................................***H. involuta***

2. *Hyophila involuta* (Hook). Jaeg., Ber. S. Gall. Naturw. Ges, 1871-72: 354, (1873).

(Fig. 2, Specimen AC/08/35)

Plants in dense tufts, simple or branched, dark green up to 9 to 10mm. high, radiculose below, rhizoids reddish, sex organs terminal. Stem covered with erect, spreading leaves, oblong-lingulate, the lower oblong part pale, sheating and erect, toothed above, acute; costa strong, ending below the apex; cells from upper and middle rounded, quaderate-hexagonal, somewhat papillose. Apical cells 4 X 4.77 µm long and 3 X 4.77 µm wide, middle cells 3-4 X 4.47µm long and 3-4 X 4.47µm wide, basal cells 8-9 x 4.47µm long and 3-4 X 4.47µm wide. Seta apical, reddish brown, erect, 2.0 mm long. Capsule erect, cylindrical, brown, peristome absent.

Field notes: Plants are found to grow on moist rocks and moist soil and also epiphytically on *Cassia siamea* Lam. in association with *Levierella fabroniacea*.

Locality: Purandhar Fort, at various altitudes varying from 200m to 800m.

Distribution: Cosmopolition.

Oxystegus (Limpr.) Hilp. In beih. Bot. Centralbl., 50(2) : 666, 667 (1933)

Key to the species

Urn cylinder top forming a conspicuous red rim...........***O. cylindrothecus***

3. *Oxystegus cylindrothecus* (Mitt) Gangulee in Nova Hedwigia, 12: 430 (1966)

(Fig. 3, Specimen AC/08/33)

Plant yellow-green, bushy, dichotomously branched plants up to 1.1 cm long, very densely covered with flat , erectopatent leaves which are curled when dry. Leaves up to 3.6 mm long, ligulate; base rectangular, apex suddenly narrows down into an acute tip with a short apiculus; marginal row of differentiated flat, rounded cells crenulate with the cell wall. Costa slightly deeper, wide at base, excurrent in the apiculus. Apical cells 2 X 4.47µm long and 2 X 4.47µm wide, middle cells 2 X 4.47µm long and 2-3 X 4.47µm wide, basal cells rectangular 10 X 4.47µm long and 2-3 X 4.47µm wide. Seta erect and pale green, capsule erect cylindrical, usually a little curved brown. Operculum conic, suddenly narrowing into a long beak.

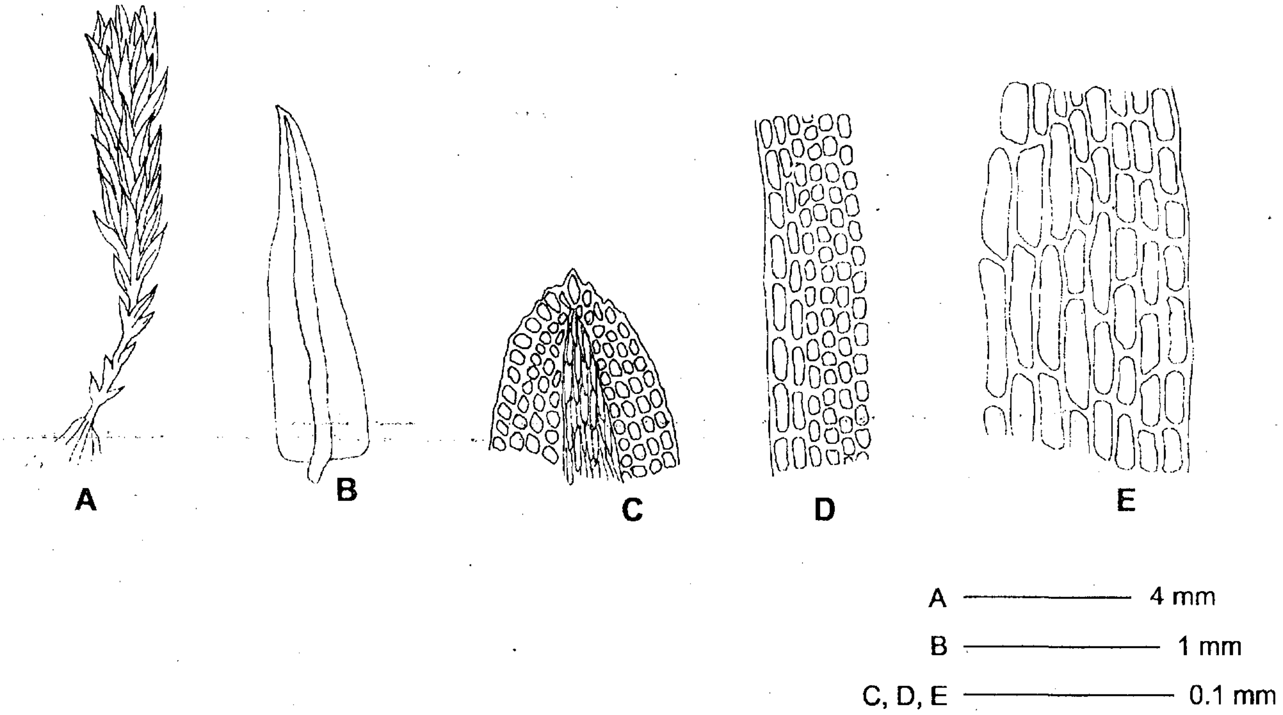


Fig. 1: *Hydrogonium arcuatum* A. Plant, B. Leaf, C. Cells from the apical part, D. Cells from the middle part, E. Cells from the basal part.

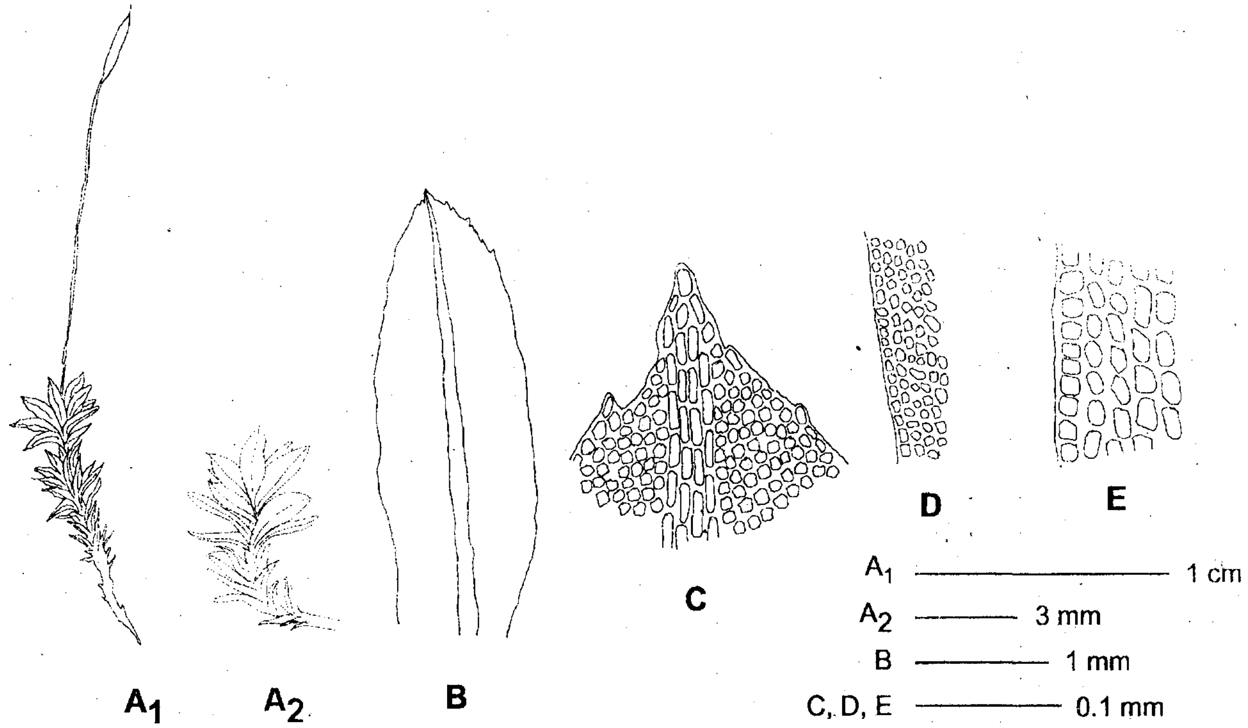


Fig. 2: *Hyophila involuta* A1-A2. Plant, B. Leaf, C. Cells from the apical part, D. Cells from middle the part, E. Cells from the basal part

Field notes: Plants are found to grow on steep rocky patches and it is common in the study area at high altitudes.

Locality: Purandhar Fort, alt. 850m.

Distribution : India (Darjeeling, Sikkim), Nepal.

ORDER: BRYALES

FAMILY: BARTRAMIACEAE

Key to the genera

Capsule nodding to horizontal, furrowed.

Peristome double................................***Philonotis***

Philonotis Brid. in Bryol. Univ., 2: 15 (1827)

Key to the species

Leaves stiff, erect: stem dichotomously branched with whorled leaves; rhizoids papillose. ....***P. thwaitessi***

4. *Philonotis thwaitesii* Mitt. In Musci Ind. Or. : 60 (1859)

(Fig. 4, Specimen AC/08/104)

Plants greagarious to loosely tufted, yellowish green, brownish tomentose below. Stems erect or flexuose, with a whorl of subfloral innovations. Leaves dense, stiff, erect, appressed, contorted and more appressed when dry, triangular to linear lanceolate, broad at base, acuminate; margin narrowly reflexed, finely denticulate. Costa excurrent in an arista 0.2 mm long. Leaf cells linear elongate 8-10 X 4.47 μm long and 2 X 4.47 μm wide at apex, middle cells are rectangular 7-8 X 4.47μm long and 3 X 4.47 μm wide, basal cells are quaderate , 6-7 X 4.47μm long and 4-5 X 4.47 μm wide. Perichetial leaves are triangular lanceolate. Seta apical, slender, erect, 2 cm long. Capsule nodding brown and subspherical

Field notes: Plants are found to grow on soil cuttings and moist rocks in association with liverworts like *Riccia species*.

Locality: Purandhar Fort, alt. 600m.

Distribution: India(Western Himalaya, South India), Ceylon, Sumatra, Borneo, New Guinea, Hongkong, Taiwan, China, Korea, Japan

ORDER: HYPNALES

FAMILY: LESKEACEAE

Key to the genera

Alar not differentiated. Auoicous...............***Claopodium***

Claopodium (Lesq. & Jam.) Ren. & Card. In Rev. Bryol., 20: 16 (1893)

Key to the species

Leaf margin flat.........................***C. prionophyllum***

5. *Claopodium prionophyllum* (C. Muell.) Broth. In Nat. Pfl., 1 (3); 1009(1908)

(Fig. 5, Specimen AC/08/34)

Plants yellow to dark green, in dense tufts, not glossy. Main stem creeping with distant leaves. Branches pinnately arranged. Stem leaves larger, widely cordate-lanceolate. Branch leaves spreading (curved when dry), narrowly cordate-lanceolate, up to 1mm. long and 0.26 mm. wide at base, tip very narrow, margin flat, faintly but distinctly dentate. Costa strong, percurrent. Leaf cells ovate-hexagonal, usually with a single papilla on lumen; marginal row distinct in being larger, dentate and smooth. Apical cells 4-5 X 4.47μm long and 2 X 4.47μm wide, middle cells 4X 4.47μm long and 2 X 4.47μm wide, basal cells 5-6 X 4.47μm long and 2 X 4.47μm wide. Perichaetial leaves without well-defined costa, small. Seta 1 cm long. Capsule cylindrical, usually nodding, showing apophysis, regular. Operculum conic rostrate. Calyptra cucullate.

Field notes: Plants are found to grow on moist soil covered rocks in association with *Entodon laetus* .

Locality: Purandhar Fort, alt. 750m.

Distribution: India (Sikkim, Darjeeling, Arunachal Pradesh, Khasia hills, Naga hills,Nilgiri), East Nepal, Burma, China, Japan.

FAMILY: METEORIACEAE

Key to the genera

Leaves bordered..............................***Diaphanodon***

Diaphanodon Ren. & Card. In Rev. Bryol., 22: 33 (1895)

6. *Diaphanodon procumbens* (C. Muell.) Ren & Card. , Bull-Soc. R. Bol. Belg. 38(1) : 23 (1900).

(Fig. 6, Specimen AC/08/48)

Plants very slender, greenish brown, densely tufted. Primary stem creeping, filiform, secondary stem pendulous, pinnate or bipinnately branched. Leaves closely apperessed when dry spreading, erect to erectopatent when moist, ovate, not dimorphic, apex acuminate with serrete border. Nerve strong, ceasing below apex. Laminar cells oval to linear, more elongated towards the base. Apical cells 1-3 X 4.77 μm long and 2

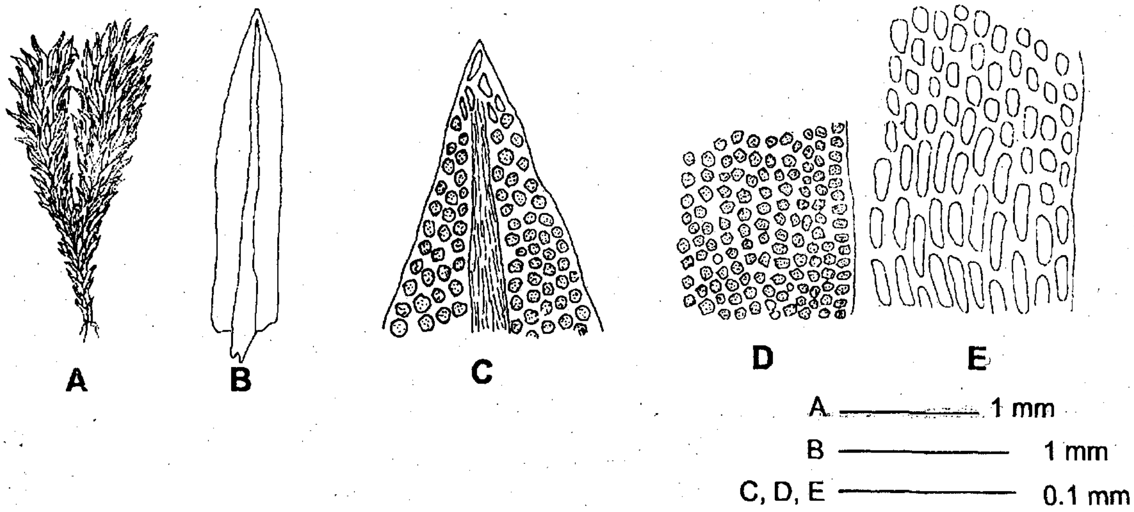


Fig. 3: *Oxystegus cylindrothecus* A. Plant, B. Leaf, C. Cells from the apical part, D. Cells from the middle part, E. Cells from the basal part.

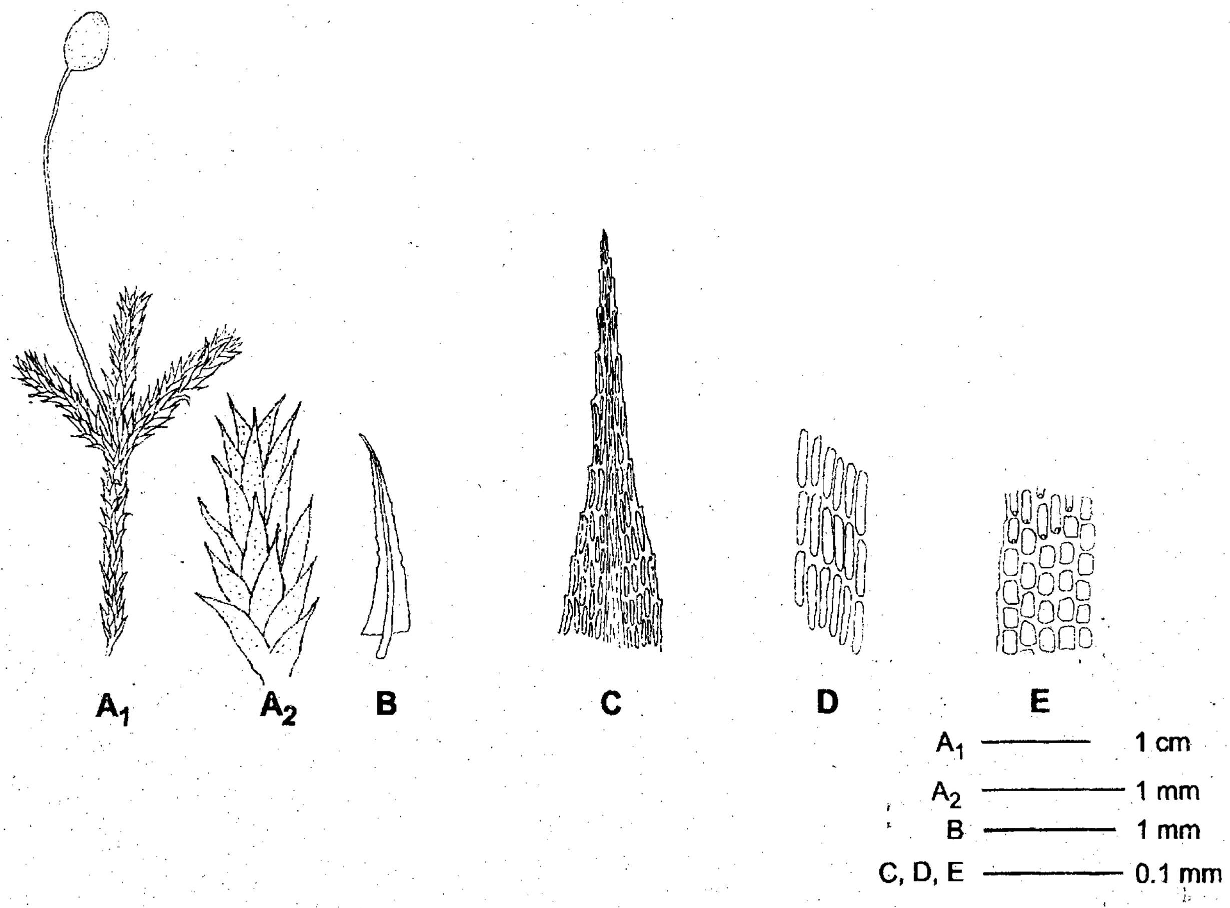


Fig. 4: *Philonotis thwaitesii* A1-A2. Plant, B. Leaf, C. Cells from the apical part D. Cells from the middle part, E. Cells from the basal part.

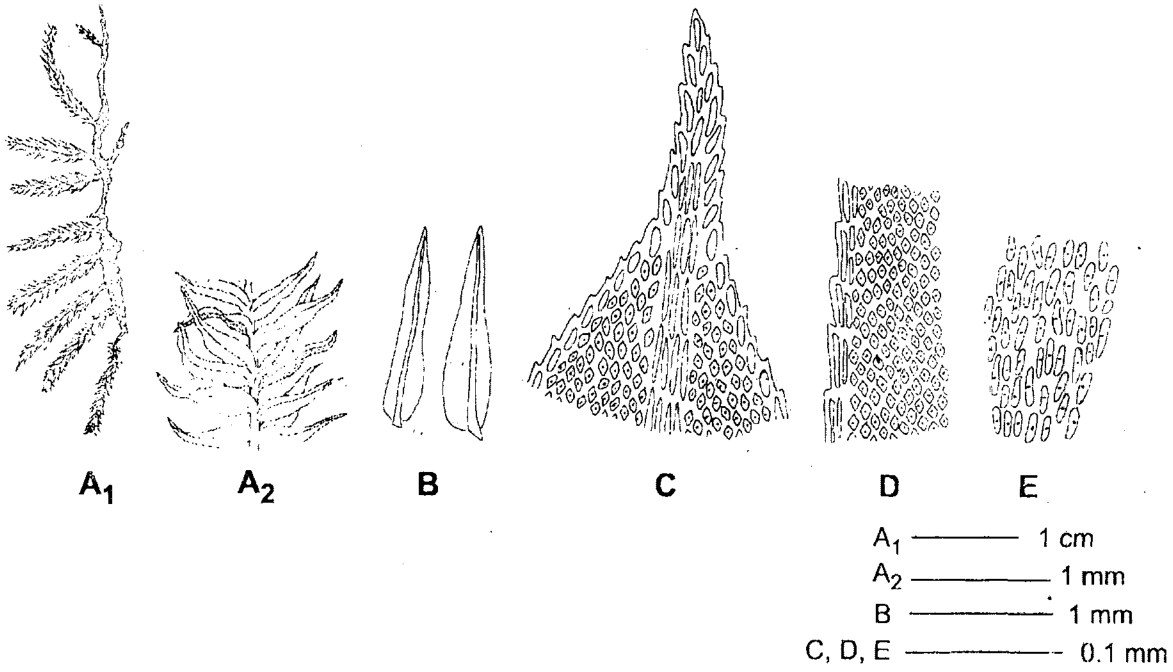


Fig. 5: *Claopodium prionophyllum* A1-A2. Plant, B. Leaf, C. Cells from the apical part, D. Cells fromthe middle part, E. Cells from the basal part.

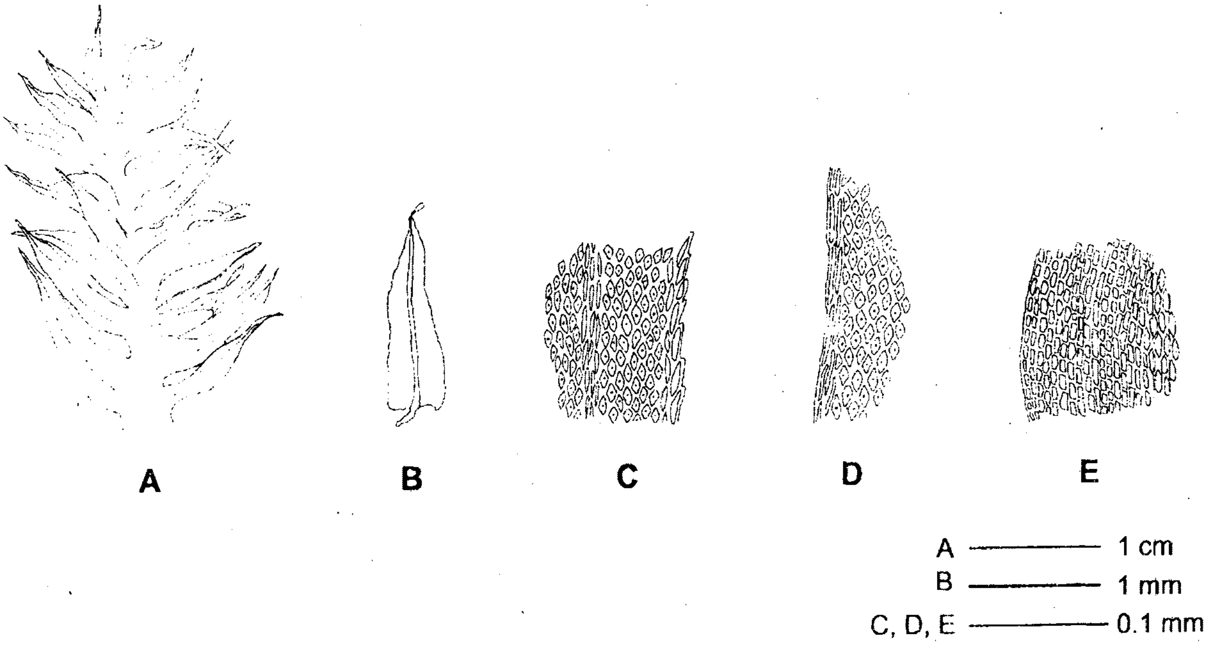


Fig. 6: *Diaphanodon procumbens* A. Plant, B. Leaf, C. Cells from the apical part, D. Cells from the middle part, E Cells from the basal part.

X 4.77 μm wide, middle cells 3 X 4.77 μm long and 2 X 4.77 μm wide, basal cells 5-6 X 4.77 μm long and 2-3 X 4.77 μm wide, margin distinct transparent. Alar cells quaderate to rectangular. Sporophyte is with oval capsule and short seta.

Field notes: Plants are found to grow epiphytically on *Diospyrus melamoscylon* Roxb. in association with another epiphytic moss *Levierella fabroniaceae*.

Locality: Purandhar Fort, alt. 950m.

Distribution: India (Mahabaleshwar, Khandala, Ooty, North Western Himalaya, Eastern Himalaya, Gujrat), South East Asia.

FAMILY: FABRONIACEAE

Key to the Genera

Main stem and part of the secondary stem stoloniform With scales leaves; leaves uninerved..........***Levierella***

Levierella C. Muell. Bull. Soc. Bot. ital. 1897: 73: 1897c.

7. *Leiverella fabroniaceae* C. Muell. In Bull. Soc. Bot. Ital. 1897: 73(1897)

(Fig. 7, Specimen AC/08/36)

Apical cells 4-5 X 4.47μm long and 2 X 4.47μm wide, middle cells 4X 4.47μm long and 2 X 4.47μm wide, basal cells 5-6 X 4.47μm long and 2 X 4.47μm wide.

Plants yellow-green to green, soft, non glossy plants in lax tufts. Main stem creeping, giving rise to erect, pinnately branched, semidendroid shoots. Final branches some what curved, thickly covered by leaves all round. Leaves imbricate, concave, decurrent at base, erect to erectopatent (appressed to stem when dry), oblong, lanceolate, 1.34 mm long and 0.6 mm wide. Apex drawn into an acute point, margin dentate at top. Costa single, narrowing from a stouter base, vanishing at midleaf. Leaf cells elongate rhomboid, apical cells 6-7 X 4.47μm long and 2-3 X 4.47μm wide, middle cells 7-12 X 4.47μm long and 2 X 4.47μm wide, basal cells 3-4 X 4.47μm long and 3-4 X 4.47μm wide. Perichaetial leaves erect with narrow limb, seta erect, capsule erect and cylindrical. Operculum conic-rostrate.

Field notes: Plants are found to grow epiphytically on *Diospyrus melamoscylon* Roxb., *Mangifera indica* Linn., *Cassia siamea* Lam., in association with *Hyophila involuta* and *Entodon laetus*.

Locality: Purandhar fort, alt. 960m.

Distribution: India (Darjeeling, Mahabaleshwar, Mussorie), East Nepal.

FAMILY: ENTODONTACEAE

Key to the genera

Stem not stoloniform, scale leaves lacking; leaves

Binerved (or enervate). Nerve very short and double,

Or absent; alar cells not ascending alone the margin....***Entodon***

Entodon C. Muell. Linnaea 18: 704, 1844.

Key to the species

1. Apex acute, margin very finely cernulate at top and incurved at place..***E. Laetus***
2. Branches not complanate. Endostome segments in fragments..............................***E. nepalensis***
3. Apex acute, margin very finely denticulate only at extreme tip....................................***E. ovicarpus***

8. *Entodon laetus* (Griff.) Jaeg., Ber. S Gall. Naturw. Ges. 1876-77 : 295 (1878).

(Fig. 8, Specimen AC/08/32)

Medium sized glossy, yellow-green plants forming tufts. Main stem creeping, giving rise to erect, somewhat dendroid, pinnately branched shoots. Leaves complanate (though in several rows), laxly imbricate, erectopatent, concave, ovate-elliptical, tip acute, base narrow, margin finely crenulate at top and incurved at places (because of concavity). Costa two double, short leaf cells elongate-elliptical, apical cells 7-8 X 4.47μm long and 2 X 4.47μm wide, middle cells 12-13 X 4.47μm long and 1 X 4.47μm wide, basal cells 5-9 X 4.47μm long and 4-5 X 4.47μm wide. Plants sterile.

Field notes: Plants growing on the bark of *Mangifera indica* Linn., in association with *Levierella fabroniacea*.

Locality: Purandhar Fort, alt. 960m.

Distribution: India (Upper Assam, Darjeeling Khasia hills, Gujrat, Rajasthan) East Nepal and Bhutan

9. *Entodon nepalensis* Mizushima in Hara: Fl. E. Him: 584, f. 42 (1966)

(Fig. 9, Specimen AC/08/37)

Glossy, yellow-green plants. Main stem creeping, irregularly pinnately branched. Branches arcuate ascendant, practically not complanate. Leaves erectopatent (imbricate appressed when dry), concave, entire. Costa short, double, apical cells 7-10 X 4.47μm long and 2 X 4.47μm wide, middle cells 12-14 X 4.47μm

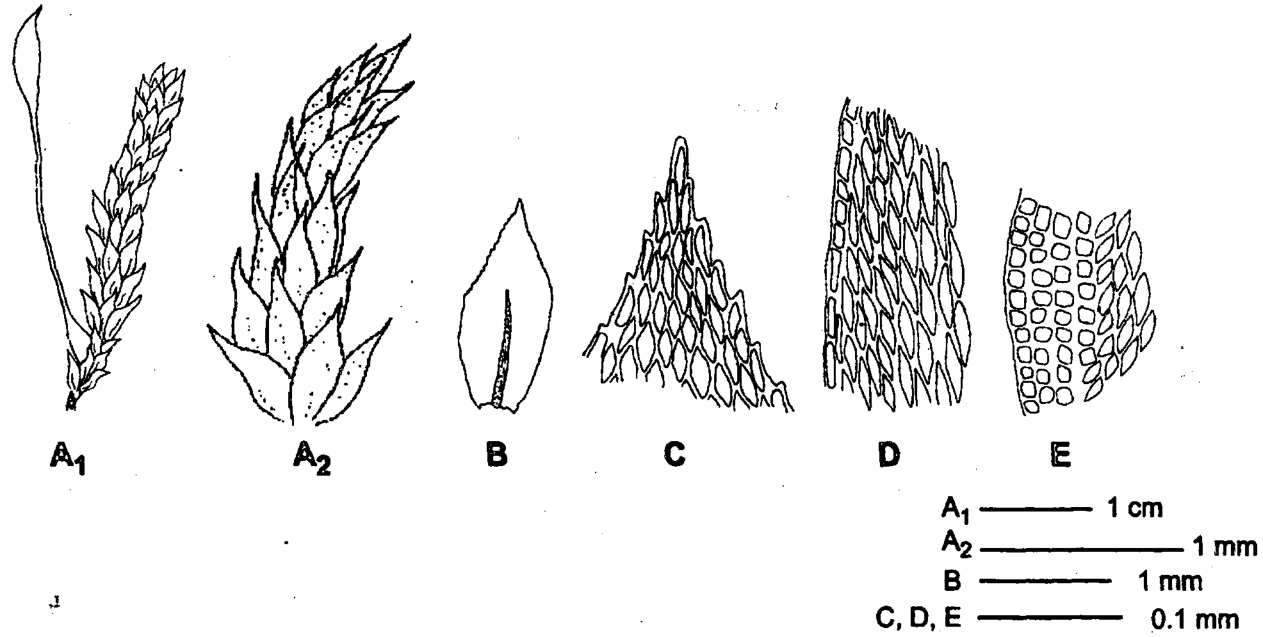


Fig. 7: *Leiverella fabroniaceae* A1-A2. Plant, B. Leaf, C. Cells from the apical part, D. Cells from the middle part, E. Cells from the basal part.

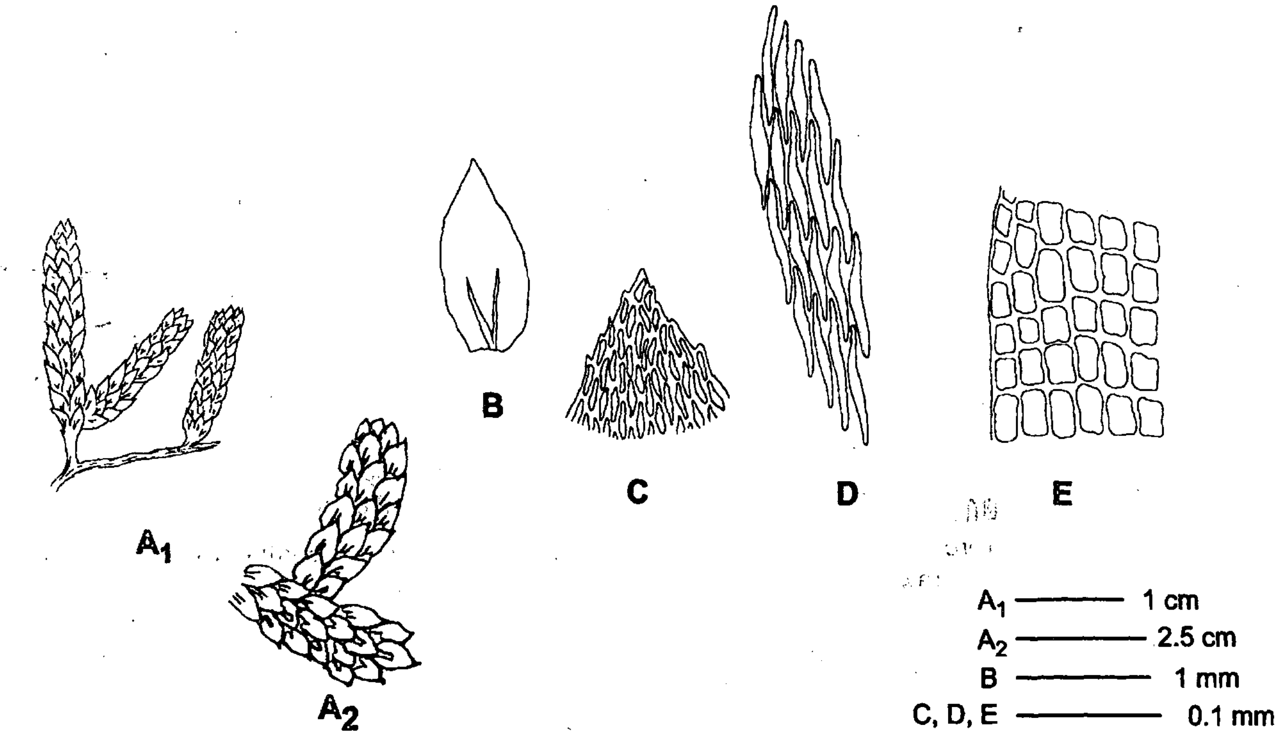


Fig. 8: *Entodon laetus* A1-A2. Plant, B. Leaf, C. Cells from the apical part, D. Cells from the middle part, E. Cells from the basal part.

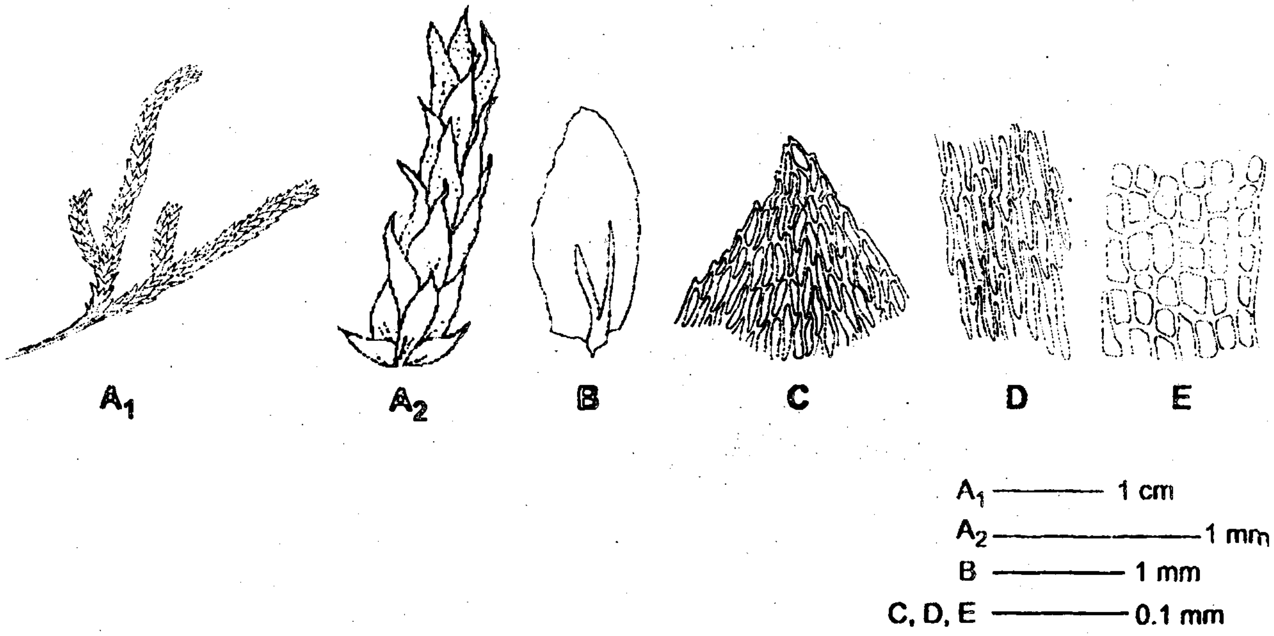


Fig. 9: *Entodon nepalensis* A1-A2. Plant ,B. Leaf, C. Cells from the apical part, D. Cells from the middle part ,E. Cells from the basal part.

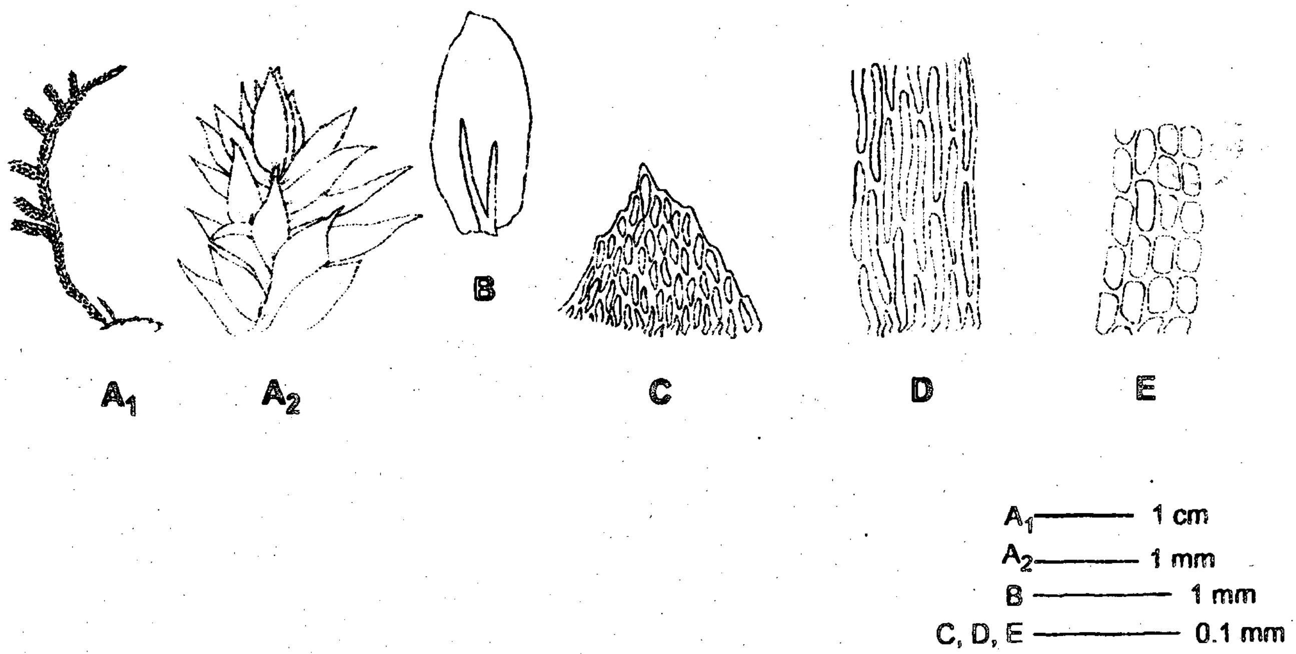


Fig. 10: *Entodon ovicarpus* A1-A2. Plant, B. Leaf, C. Cells from the apical part, D. Cells from the middle part, E. Cells from the basal part.

long and 2 X 4.47µm wide, basal cells 4-8 X 4.47µm long and 3-4 X 4.47µm wide, alar of numerous quaderate, pale cells. Perichaetial leaves erect, ovate-lanceolate, caudate to short acuminate, entire, concave, ecostate.

Field notes: Plants are found to grow on rocks.

Locality: Purandhar Fort, alt. 900m.

Distribution: East Nepal

10. *Entodon ovicarpus* Dix. in J. Bomb. Nat. Hist. Soc., 39: 789 (1937)

(Fig. 10, Specimen AC/08/29)

Glossy, yellow green, medium-sturdy plants forming loose tufts. Main stem creeping, giving rise to irregularly pinnately branched, erect shoots. Leaves dense, imbricate, often complanately pressed though in many rows, erectopatent, ovate-lanceolate, concave, apex acute, margin very finely denticulate only at extreme tip, slightly contracted at base. Costa short, bifid, apical cells 7-8 X 4.47µm long and3-4 X 4.47µm wide, middle cells 15 X 4.47µm long and 2-3 X 4.47µm wide, basal cells 7-8 X 4.47µm long and 3-4 X 4.47µm wide.

Field notes: Plants are found to grow on soil.

Locality: Purandhar Fort, 950m.

Distribution: Arunachal Pradesh, Maharashtra.

DISCUSSION

In the present paper, an attempt ha been made to provide an account of mosses of Purandhar fort, Maharashtra (India). The morphological and ecological studies of collected specimens were carried out, on the basis of which key to the genera and species is designed. In total 10 species belonging to 8 genera, 6 families and 3 orders were investigated from the study area. It has been found that the mosses are adapted to a wide range of habitats, most of the acrocarpous mosses viz,: *Hydrogonium arcuatum* (Griff.)., *Hyophila involuta* (Hook). Jaeg., *Oxystegus cylindrothecus* (Mitt)., *Philonotis thwaitesii* Mitt., are terrestrial preferring shady and moist places while the pleurocarpous mosses viz,: *Diaphanodon procumbens* (C. Muell.)., *Leiverella fabroniaceae* C. Muell., and *Entodon laetus* (Griff.) Jaeg., are epiphytes and *Claopodium prionophyllum* (C. Muell.)., *Entodon nepalensis* Mizushima in Hara., and *Entodon ovicarpus* Dix. are terrestrial.

In the present study family Pottiaceae is represented by 3 genera while families viz: Batramiaceae, Leskeaceae, Meteroriaceae, Fabroniaceae and Entodontaceae are represented by single genus. It has been observed that Hypnales is the largest order with 6 species belonging to 4 genera and 4 families. *Entodon* is the largest genus represented by 3 species viz. *E. laetus*, *E. nepalensis* and *E. ovicarpus*. The dominant species in terms of relative abundance and habitat heterogeneity is *Hyophila involuta*

Two genera *Claopodium* and *Oxystegus*; and two species *E. nepalensis* and *P. thwaitessi* are reported for the first time from Maharashtra.

CONCLUSION

The present study is a serious attempt in narrowing the research gap in the systematic study of Bryophytes in general and mosses in particular. The main aim of the present work is to explore the Bryophyte wealth of Maharashtra. The present study provides a taxonomic description at the level of genus, family and order, which is mentioned in detail in the discussion part of the paper and it reflects the enormous diversity of mosses in the study area.

ACKNOWLEDGEMENTS

Authors are thankful to Council of Scientific and Industrial Research, India, for assisting financial support.

REFERENCES

Bapna, K.R. and B.L. Chaudhary, 1989. Mosses of Rajasthan II. Dicranales and Pottiales. *J. Indian Bot. Soc.*, 68: 379-388

Braithwaite, R. 1880-1905. The British moss flora I. Reeve and Co., London.

Bruhl, P. 1931. A census of Indian Mosses. *Rec. Bot. Surv. India.*, 13(1):50.

Chaudhary, B.L. and F.S. Bhagora, 2005. Diversity of Mosses in Malshej Ghats (North Konkan) Maharashtra-India. *Bulletin of Pure and Applied Sciences*,, Vol. 24B (No.2)2005:177-180.

Chaudhary, B.L. and F.S. Bhagora, 2006a. Epiphytic mosses of Malshej Ghats (North Konkan) Maharashtra-India. *Indian J. Environ and Eco. Plan.*, 12(1) : 111-114.

Chaudhary, B.L., F.S. Bhagora and A. Chaudhary. 2006b. Occurrence of mosses in Elephanta Caves, Maharashtra-India. Abstr. In National symposium on Emerging trends in Plant Biology, Environmental Protection and Biotechnology held at M.L.S. University, Udaipur:39-40.

Chaudhary, B.L., F.S. Bhagora and T.P. Sharma, 2006a. Occurrence of epiphytic mosses of Saputara (Sahyadric region) India. Indian *J. applied and pur Bio.*, 21(2) : 175-178.

Chaudhary, B.L. and T.P. Sharma, 2000. Epiphytic mosses of Udaipur Rajasthan India. *Vasundhara*, 5 : 85-89.

Chaudhary, B.L. and T.P. Sharma, 2001. Epiphytic mosses of Gujarat-I, India. *Vasundhara*, 6 : 33-36.

Chaudhary, B.L. and T.P. Sharma, 2002b. Epiphytic mosses of Mount Abu, Rajasthan. *Environmental Biology and conservation,* 7 : 37-39

Chavan, A.R., S. Mehta, and A.R. Mehta., 1961. Apreliminaary report of mosses from Pavagarh in Gujarat. J.M.S. University Baraoda, 10(3) : 35-42.

Chopra, R.S. 1975. Taxonomy of Indian Mosses. *Botanical Monograph*, 10. CSIR New Delhi.

Dhabade, G.T. 1966. Some interesting mosses of Western India. *Proc. Autumn School in Botany, Mahabaleshwar*, 91-97.

Dhabade, G.T. 1969. Mosses of Mahabaleshwar. *Maharashtra Vidhya Mandir, Patrika*, 4, : 94-104

Dabhade, G.T. 1998. Mosses of Khandala and Mahabaleshwar in the Western Ghats (India). M/s. Classic Graphics, Kalwa, Thane, India.

Dabhade, G.T. and V.V. Patil, 2001. Palynology of some mosses from western Ghats under SEM. Perspectve in Indian Bryology, edited by V. Nath and A. K. Asthana. Published in Bishen Singh Mahendra pal Singh, Dehra Dun, 127-133.

Deora, G.S. and B.L. Chaudhary. 1993. Moss flora of Rajasthan (India). Himanshu Publications, Udaipur, India.

Dixon, H.N. 1954. The students Handbook of British Mosses. Sumfield and Day Ltd., London.

Gangulee, H.C. 1969-1980. Mosses of Eastern India and Adjacent Regions. Vol. I, II & III. Eastend Printers, Calcutta India.

Gangulee, H.C. 1985. Handbook of Indian mosses Amerind Publishing, New Delhi.

Lal, J. 2005. A checklist of Indian Mosses. Bishen Singh Mahendra Pal Singh Publications, Dehra Dun.

Nair, C. Manju., K.P. Rajesh, and P.V. Madhusoodanan. 2005. Bryophytes of Wayanad in Western Ghats. *Malabar Natural History Society*, Kerala, India.

Nath, V. and P. Bansal. 2009. Bryophyte diversity of Bhimbetka World heritage site, Madhya Pradesh (India), 88 (3 & 4) : 129-140.

Pb. Univ. Res. J (Sci.), Vol. 59, 2009, pp. 57-61

ALEURITOPTERIS FORMOSANA (HAYATA) TAGAWA: AN ADDITION TO THE PTERIDOPHYTE FLORA OF RAJASTHAN

***C. S. Dulawat and B. L. Chaudhary**

Bryology Laboratory, Department of Botany, College of Science, Mohanlal Sukhadia University,
Udaipur-313001, Rajasthan

Abstract

Aleuritopteris formosana (Hayata) Tagawa; syn.: *Cheilanthes brevifrons* (Khullar) Khullar belonging to Pteridaceae E.D.M. Kirchn. is reported here for the first time from Sitamata Wild Life Sanctuary, Rajasthan. The species is distinguished by a narrower and usually smaller frond, which is characteristically bullulate-wrinkled above, and the slightly narrower, bicolorous stipe-scales extend up to the rachis as well, but not (except rarely an odd one) onto the costae. The rachis usually bears scattered glands. It is fairly close to *A. anceps*. Taxonomic account of this species with the habit, distribution and discussion is provided in the present contribution.

Keywords: *Aleuritopteris fromosana*, Sitamata Wild Life Sanctuary, Rajasthan.

INTRODUCTION

Rajasthan is the largest state in India with an area of 3, 42, 274 Sq. Km. lying within 23°3' - 30°12'N and 69°31' - 78°17'E. The climate of the Rajasthan is one of the great extremes with sudden change in temperature, precipitation and wind, which restricts the bryophyte and pteridophyte flora. As such only a limited number of species, which have a wide range of tolerance, occur in the state. The Sitamata Wild Life Sanctuary is one of the protected areas representing full range of habitat of Aravalli hills (Fig.1).

The sanctuary lies in the Civil District of Chittorgarh and Udaipur in southwest region of Rajasthan State. It is situated within 74° 24' - 74° 40' E and 24° 04' - 24° 23' N. It covers 422.95 Sq. km. of area. Geographically, there are three major operating regional systems namely the Aravallis, Vindhyans and Malwa Plateau, which results in a variety of flora and fauna found therein. There are 28 forest blocks in the notified wild life sanctuary. The Sanctuary has an average annual rainfall 1103 mm with maximum up to 1337.56 mm and minimum 951.50 mm. The mean minimum temperature is 6 °C, while mean maximum temperature is 45 °C. Further, it has a highly varied physiography, from plateau lands to hilly tracts with high altitudinal variation ranging from 280-600 m. The study area of the sanctuary is dry deciduous forest type, consisting of mixed growth of tree with *Tectona grandis L. f. nom cons.* as a predominant species.

Aleuritopteris Fée, formerly treated by most authors as *Cheilanthes* subgen. *Aleuritopteris* (Fée) W.C. Shieh, and all the species, except *A. stenochlamys* Ching *ex* S.K. Wu, have names in *Cheilanthes*. It was recognised generically by Ching in Ching and Wu (1983) and Saiki (1984). This genus was reduced to synonym of *Cheilanthes* Swartz by some pteridologists (Tryon *et* al. 1990). *Aleuritopteris* Fée is middle sized (10-80 cm) genus mainly distributed in Asia (Eastern and Western Himalayas: Sikkim, West Bengal, Meghalaya, Arunachal Pradesh; Nepal, Bhutan, Myanmar, Thailand, China, Taiwan, Japan) and Africa (Ching, 1941; Wu, 1981; Saiki, 1984a, 1984b; Copeland, 1985; Shing and Wu, 1990; Ghosh *et al.*, 2004); it is characterized by living xeric or semi xeric habitat and having farina abaxially on fronds. The 18 species of *Aleuritopteris* present in the Indian subcontinent have mostly been detailed by Fraser-Jenkins (1992, 1993 and 1997).

MATERIAL AND METHODS

During the course of study, areas were explored frequently in different seasons of the year (2004-2007), especially rainy season, when pteridophytes flourish well due to high humidity and optimum temperature. The field data on habit, habitat and localities of plant distribution were recorded in field book. The plant material was brought to the laboratory between folds of newspaper and the photographs of herbarium mounts on ventral side bearing sori were taken. The specimens were pressed in standard herbarium sheets and all measurements were recorded in metric scale. For the description of genera, standard books and publications by Ching (1941), Wu (1981), Saiki (1984a, 1984b), Shing and Wu (1990) and Fraser-Jenkins (1992, 1993 and 1997)

---

*Corresponding Author. *csdulawat@rediffmail.com*

MS Received January 15, 2009; Accepted July 30, 2009

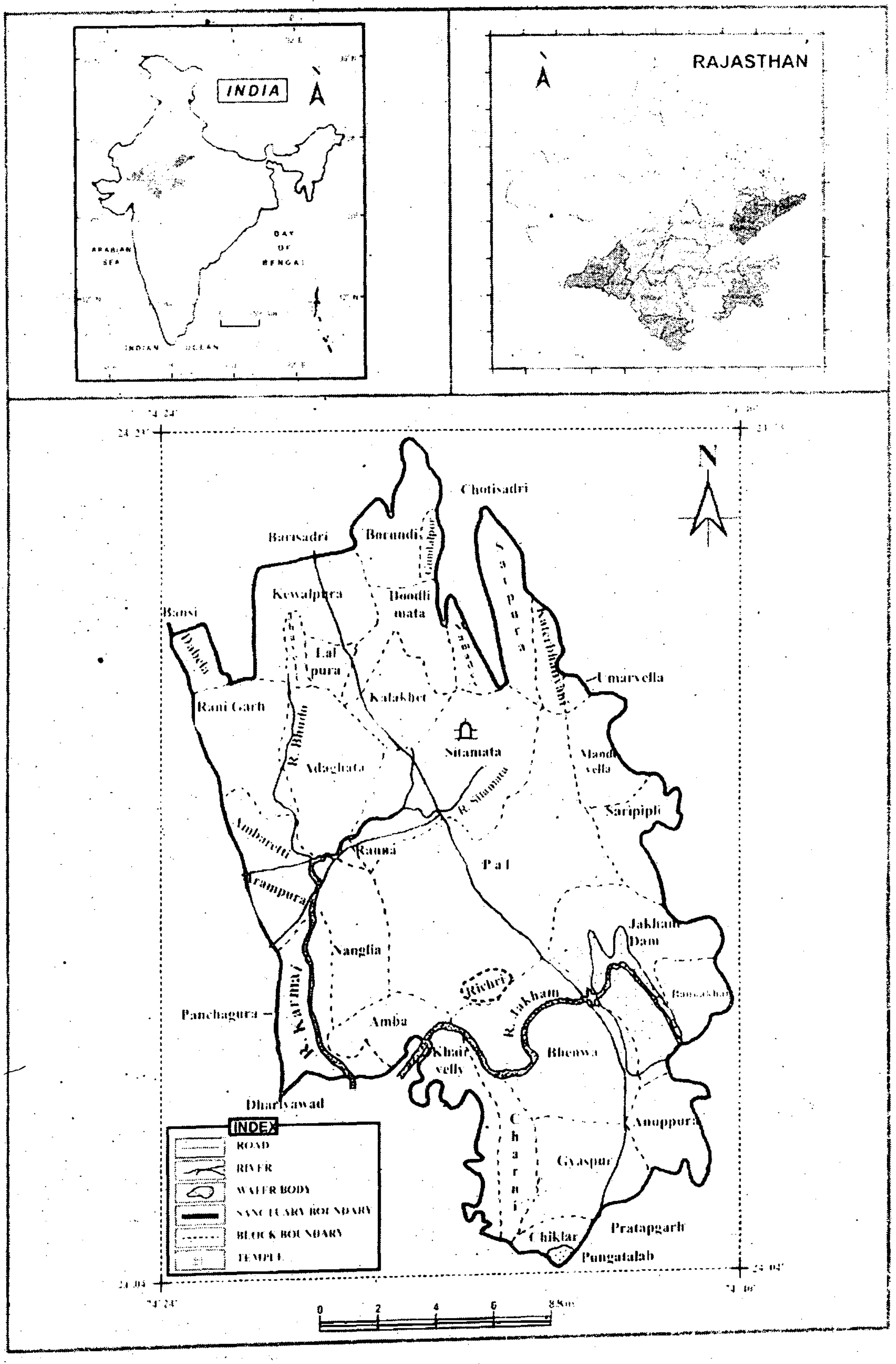


Fig. 1 : Sitamata wild life sanctuary map

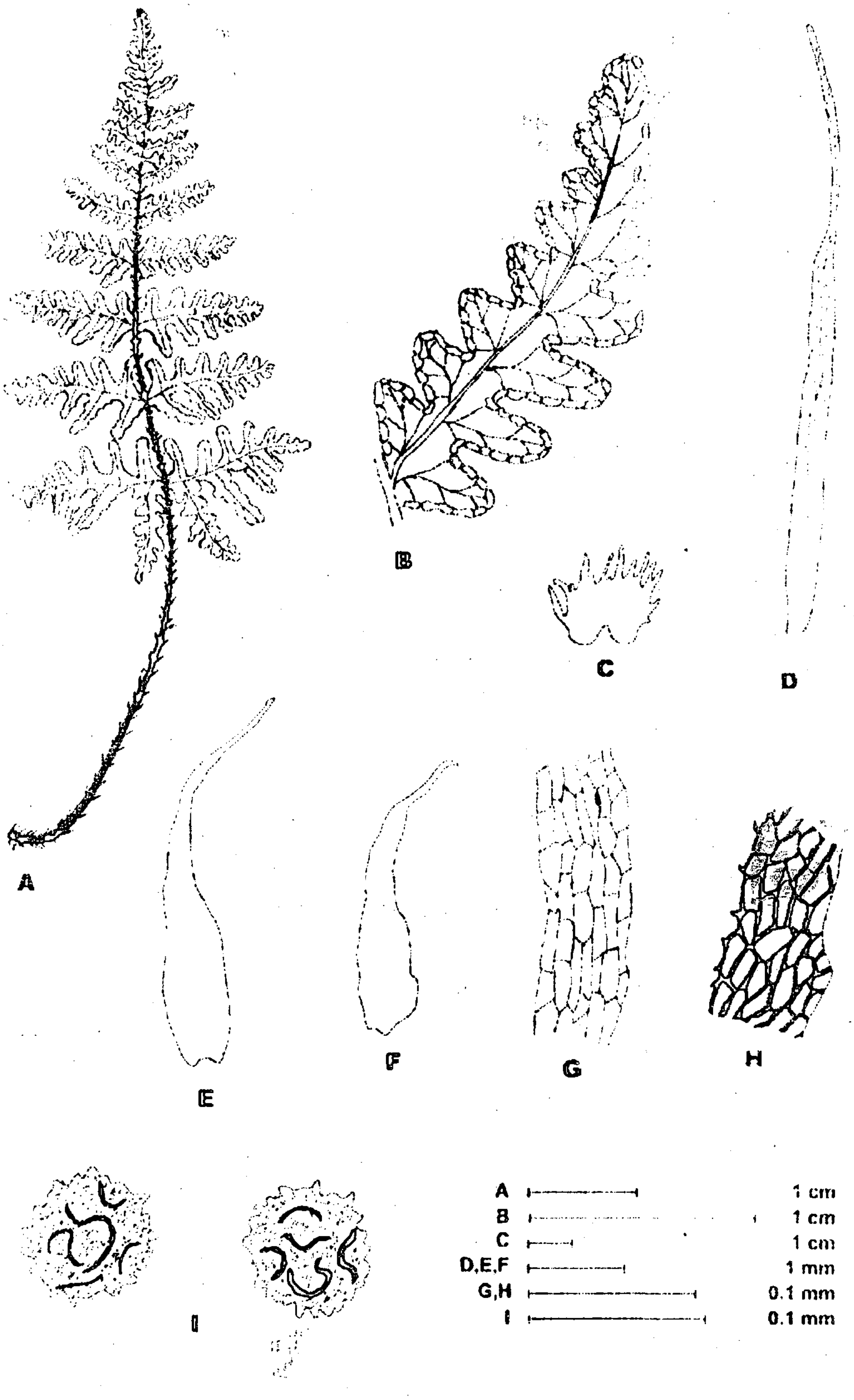


Fig. 2 : ***Aleuritopteris formosana*** (Hayata) Tagawa.
A. Plant; B. Part of pinna; C. Indusium; D. Stipe scales; E, F. Rhizome scales; G, H. Magnified part of scales; I. Spores.

were consulted. For morphological and anatomical studies, the material was dissected and observed under Olympus Binocular Microscope. Camera Lucida drawings were made under the microscope. The classification systems proposed by Pryer *et al.* (2001, 2004) and Smith *et al.* (2006) for pteridophytes have been adopted in the present investigation. The specimen is deposited in the Bryology Laboratory, Department of Botany, University College of Science, Mohan Lal Sukhadia University, Udaipur.

OBSERVATIONS

Taxonomic Position:

Sub division : Monilophyta
Class : Polypodiopsida
Order : Polypodiales
Family : Pteridaceae
Genus : *Aleuritopteris*
Species : *formosana* (Hayata) Tagawa

Aleuritopteris formosana (Hayata) Tagawa; Acta Phytotax. Geobot. 14:191. (1952); Enum. Pl. Form. 612. (1906).

(Figs. 2A-2I, Specimen no. CSD/SM-198)

Plants 15-40 cm. Rhizomes short, erect; scales bicolorous, with black central stripe and pale brown margins, linear or narrowly lanceolate. Leaves clustered. Petiole 5-23 cm X 1-2 mm, chestnut-colored, lustrous, scaly all over the petiole and up to rachis; scales bicolorous, lanceolate; bicolorous stipe-scales extend up to the rachis as well, but not (except rarely an odd one) onto the costa. Blade oblong lanceolate, 4 to17 or 2 to7 cm, tripinnatifid at base, adaxially glabrous, abaxially with white farina, rachis and costa of the same color as petiole; the rachis usually bears scattered glands; pinnae 4 to 6 pairs, separated from each other by wingless rachis, basal pair of pinnae triangular, bipinnatifid; acroscopic ones smaller, proximal basiscopic pinnules largest, 1.5 to 2.5 cm, lanceolate, pinnatifid; second pair of pinnae oblong-lanceolate, shorter and arinose than the basal one; third and upper pairs of pinnae lanceolate. Veins obscure. Sori consisting of several sporangia. False indusia brown, membranous, interrupted with a laciniate margin.

Field notes: Plant grows in the rock crevices.

Locality: Ambaretti alt. 543 m, Mandivella alt. 405 m and Sitamata alt. 584 m.

Specimens examined: CSD/SM-187AR, CSD/SM-420MV and CSD/SM-198SM.

Distribution: Fujian, Taiwan, Myanmar, China , Xizang, Tibet, Yunnan, West Africa, India (West to the East Indo-Himalaya; Uttar Pradesh, Bihar, Orissa, North Western Ghats, Sikkim, South India) Nepal, Philippines, Sri Lanka and Thailand.

ACKNOWLEDGEMENTS

Authors are thankful to C.R. Fraser-Jenkins (Nepal) for valuable suggestions and plant identification.

REFERENCES

Ching, R.C. 1941. The Studies of Chinese ferns, Part XXXI. *Hong Kong Naturalist,* 10: 194--204.

Ching, R.C. and S.K. Wu. 1983. Pteridophyta. In : Wu C. Y. ed. Flora Xizangica, Beijing: *Science Press, Beijing,* 1: 1-355.

Copeland, E.B. 1985. Genera Filicum. Bishen Singh Mahendra Pal Singh, Dehradun, India, 67-68.

Fraser-Jenkins, C.R. 1992 ["1991"]. The ferns and allies of the far west Himalaya. *Pakistan Syst.,* 5(1-2): 85-120.

Fraser-Jenkins, C.R. 1993 ["1992"]. The ferns and allies of the far west Himalaya - Some Additions and Corrections. *Bot. Helvetica,* 102(2): 143-157.

Fraser-Jenkins, C.R. 1997a. New species syndrome in Indian pteridology and the ferns of Nepal. International Book Distributers, Dehradun, India, i-x, pp403.

Fraser-Jenkins, C.R. 1997b. New species syndrome in Indian Pteridology and the ferns of Nepal: 1-403 and errata. International Book Distributors, Dehradun, India.

Ghosh, S.R., B. Ghosh, A. Biswas and R.K. Ghosh 2004. The Pteridophytic Flora of Eastern India. *Bot. Surv. Ind., Kolkata*: 1-591.

Pryer, K. M., H. Schneider, A. R. Smith, R. Cranfill , P. G. Wolf, J. S. Hunt, and S.D. Sipes 2001. Horsetails and ferns are a monophyletic group and the closest living relatives to seed plants. *Nature,* 409 : 618–622.

Pryer, K. M., E. Schuettpelz, P.G. Wolf, H. Schneider, A. R. Smith and R. Cranfill 2004. Phylogeny and evolution of ferns (monilophytes) with a focus on the early leptosporangiate divergences. *Amer. J. Bot.*, 91(10) : 1582–1598.

Saiki, Y. 1984a. Notes on ferns (2). Asiatic species of the *Aleuritopteris farinosa* complex. *J. Phytogeogr. Taxon*, 32(1): 1 -12.

Saiki, Y. 1984b. Notes on ferns (3). African and Neotropical species of the *Aleuritopteris farinosa* group. *J. Phytogeogr. Taxon*, 32 (2): 81-90.

Shing, K. H. and S. K. Wu. 1990. Sinopteridaceae. pp. 97-173 in Flora Reipublicae Popularis Sinicae (Eds. R. C. Ching and K. H. Shing, 3(1). *Science Press*, Beijing.

Smith, A.R., K.M. Pryer, E. Schuettpelz, P. Korall, H. Schneider and P.G. Wolf 2006. A classification for extant ferns. *Taxon*, 55 (3): 705-731.

Tryon, R.M., A.F. Tryon and K.U. Kramer 1990. Pteridaceae (Eds. K.U. Kramer, and P.S. Green). The Families and Genera of Vascular Plants (Ed. K. Kubitzki) 1, Pteridophytes and Gymnosperms: [1-] 230-256 [-404]. *Springer Verlag*, Heidelberg.

Wu, S. K. 1981. A study of the genus *Aleuritopteris* Fée in China. *Acta Phytotax. Sin.*, 19 (1): 57-74.

Pb. Univ. Res. J (Sci.), Vol. 59, 2009, pp. 63-69

PRODUCTION OF SCAMPI, *MACHROBRACHIUM ROSENBRGII* (DE MAN) UNDER SEMI-TROPICAL AGRO-CLIMATIC CONDITIONS

K.L. Jain[1], *Meenakshi Jindal[1], Balraj Singh[2] and R.K. Verma[1]

[1]*Department of Zoology and Aquaculture, CCS Haryana Agricultural University, Hisar, Haryana*

[2]*Fisheries officer State Department of Fisheries, Hisar, Haryana*

Abstract

There has been a good indication of optimum response of scampi, *M. rosenbergii* at 2 ppt for high growth and survival of both the PL_{20} and the grow-outs. Growth performance of *M. rosenbergii* post-larvae (PL_{20}) observed for 40 days indicated both live weight gain and gain in length in 2ppt saline water with average estimated production of 66.36 kg ha^{-1}. The grow-outs also showed gain in weight little higher at 2 ppt saline water than that at 0 ppt and the ultimate production was of 1102.77 kg ha^{-1}. There was salinity dependent increase in conductivity at 2 ppt affecting grossly primary pond productivity in the form of phytoplankton density. Bicarbonate ions increased at 2 ppt, whereas, the BOD value showed a significant decrease at 0 ppt. Studies on growth performance *M. rosenbergii* at four different locations in Hisar district in the ponds filled with tube well mixed canal water and maintained at negligible salinity for prawn culture for 150 days, indicated maximum weight and length gain at village ponds with higher amounts of bicarbonates and alkalinity levels, thus contributing to higher conductivity as well as enhanced pond productivity in terms of higher production of planktons.

Keywords: carcass, conductivity, growth, *M. rosenbergii*, phytoplanktons, salinity.

INTRODUCTION

The rapidly emerging problems of rising water table and soil salinization in arid and semi-arid canal irrigated areas of north India having brackish groundwater is causing great concern to the scientists and planners. These waters are neither fit for agriculture or industries nor for human consumption, because of high salinity. Species of the freshwater prawn genus *Macrobrachium* are distributed throughout the tropical and subtropical zones of the world. They are found in most inland freshwater areas including lakes, rivers, swamps, irrigation ditches, canals and ponds, as well as in estuarine areas. Most species require brackish water in the initial stage of their life cycle. Jhingran and Gopalakrishnan (1974) have listed three major species, *M. rosenbergii*, *M.malcolmsonii* and *M. rude* for culture in India. *M. rosenbergii* fulfill many of the criteria required for culture in fresh and saline water.

Cultural practices of prawns in freshwater ponds are already described (Jhingran, 1991). Work on freshwater prawn, however, has been underway in different parts of the world since 1879 to augment sustainable production in farms and hatcheries as well as to ensure fast growing varieties through genetic and stock manipulation. The fresh-water prawn *M. rosenbergii* is commercially important because of its nutritional qualities. Adults are omnivorous and feed on a variety of foods of animal/vegetable origin and grow well in fresh as well as brackish water areas (Pillay, 1990). In recently years there has been large scale introduction of this species in Haryana by the State Department of fisheries. Jain *et al.* (2008a, b) has described rearing of *M. rosenbergii* (Nursery) in low saline ground water in the sub-tropical climate of Haryana. In the present study, growth, survival and production of both nursery and grow-out stages in Haryana ponds and the hydro-biological conditions are provided.

MATERIAL AND METHODS

Studies were carried out in the farm ponds located in villages in and around Hisar, India during April-May 2003 to May 2004. The control ponds contained normal fresh canal water (0 ppt salinity) and other ponds were maintained with 2 ppt of saline water as recommended by Jain *et al.* (2008a).

The nursery ponds were dried (till the soil cracked), cleaned and lime was applied (@ 350 kg ha^{-1} y^{-1}). After liming, ponds were filled with water (up to 15 cm) and then fertilized with cow dung (@ 5000 kg ha^{-1} y^{-1}), urea (@ 250 kg ha^{-1} y^{-1}) and SSP (@ 500kg ha^{-1} y^{-1}). Mixing of fertilizer in nursery ponds water was done using mechanical means. After three to four days of the application of fertilizers, all nursery ponds were filled with desired salinity water (up to 90 cm depth).

To maintain the desired level of salinity, water was replenished both with tube well and canal water often

---

*Corresponding Author. meenjind@gmail.com

MS Received October 31, 2008; Accepted August 21, 2010

as required. All nursery ponds were further provided with perforated P.V.C. pipe shelter (covering about ¼th area of the pond bottom), as mentioned by Jain *et al.* (2008a, b).

PL$_{20}$ of *M. rosenbergii* (mean body wt. 0.01 g) obtained from BQMR (Breeding Quarter for *Macrobrachium rosenbergii*) hatchery, Nellere (AP), were acclimated at 0 ppt salinity before stocking. These were stocked @ 30,000 per hectare, 10 days after the application of fertilizer in the nursery ponds. These were fed daily according to the standard feeding schedule i.e. starting with starter-A and B up to 60 days old larvae, and grower 6 and then grower-30 up until harvesting. Feeding rates were adjusted after every 10 days, based on the weight gain by the sampled prawn. The juvenile were maintained until these attained size of 5 to 6 cm in length. Thereafter, these were harvested and transferred to grow out ponds at different salinities for data recording on growth parameters.

Physico-chemical characters were analyzed according to APHA (1998). Planktons (Phytoplankton and Zooplankton) samples were collected by filtering 10 L of water through 125 μm mesh plankton net and analyzed quantitatively according to the standard methods (Wetzel and Likens, 1979). Live weight gain, increase in length, growth per cent gain, survival and specific growth rate (% g d^{-1}) were calculated using standard methods (Steffens, 1989). The ponds were completely drained after 40 days and juvenile prawns were harvested, counted, weighed to near gram and stocked further in grow-out ponds.

RESULTS AND DISCUSSIONS

Effect of water salinity on the growth of scampi in nursery and grow-out ponds

The present studies on growth performance of *M. rosenbergii* post-larvae (PL$_{20}$) observed for 40 days (Table-1) indicated maximum growth in terms of both live weight gain and gain in length in 2 ppt saline water.

There was an increase in length on an average from 1.47cm to 5.93 cm and live weight from 0.013 g to 3.03g in normal water (0 ppt) of nursery ponds, leading to an average estimated production of 63.04 kg ha^{-1}. It, however, increased marginally in saline water (at 2 ppt), as it showed an estimated production of 66.36 kg ha^{-1}. The growth performance at 4 ppt was lowest with an

Table 1: Growth performance of *M. rosenbergii* post larvae (PL$_{20}$) in nursery and grow out ponds

Treatment	Initial Live wt. (g)	Initial length (cm)	Mortality (%)	Final weight (g)	Final length (cm)	Live weight gain (g)	Production (kg/ha)
a. Nursery Ponds							
0 ppt	0.013	1.47	30.47	3.03	5.93	3.02	63.04
	±4.50	±0.003	±0.091	±2.35	±0.12	±0.09	±0.12
2 ppt	0.010	1.37	31.14	3.20	6.17	3.19	66.36
	±8.90	±0.001	±0.120	±6.13	±0.17	±0.07	±0.17
4 ppt	0.01	1.57	56.50	2.60	5.60	2.60	33.64
	±7.50	±0.002	±0.110	±4.60	±0.10	±0.08	±0.15
b. Grow-Out Ponds							
0 ppt	2.67	5.40	46.22	68.87	19.87	66.20	1032.04
	±10.32	±0.07	±0.06	±8.87	±0.90	±0.05	±8.88
2 ppt	2.63	5.60	45.69	73.13	20.27	70.50	1102.77
	±7.28	±0.03	±0.06	±7.67	±0.64	±0.09	±7.66
4 ppt	2.64	5.55	59.0	61.07	18.96	63.71	778.63
	±8.30	±0.00	±0.05	±8.90	±0.90	±0.07	±8.90

All values are mean ± S.E. of three replicates.

0 ppt salinity level was considered as control *i.e.* normal canal water

2 ppt and 4 ppt salinity levels were considered as saline water treatments

estimated production of 33.6 kg ha^{-1} only. The post-larvae mortality also increased with increased salinity from 30.5% 0 ppt to 56.5% at 4 ppt, but low (i.e. 31.1%) at 2 ppt.

The grow-out of *M. rosenbergii* showed gain in weight and length in saline water at 2 ppt. Length increased on an average from 5.60 cm to 20.27 cm and increase in weight from 2.63g to 73.13g at 2 ppt, leading to an average recorded estimated production of 1102.77kg ha^{-1} (Table 1). It, however, differed marginally from the data recorded for growth performance at 0 ppt, as it showed an estimated production of 1032.04 kg ha^{-1}. The growth performance at 4 ppt was decreased, showing a weight gain from 2.64g to 61.07g and gain in length from 5.55 cm to 18.96 cm, with an estimated production of 778.63 kg ha^{-1} only. The mortality of grow-outs also increased at 4 ppt and 0 ppt in comparison to 2 ppt of salinity.

This study provide a good indication of the impact of salinity levels on the growth performance of scampi revealing that 0 to 2 ppt as the most optimum level of salinity required for the higher growth and survival of PL$_{20}$ and grow-outs. Any further increase (above 2 ppt) in water salinity represses growth. These results are in agreement with those of Jain *et al.* (2008a, b).

The data in Table 2 represent estimated value for specific growth rate (SGR), specific growth relationship with length (SGRL) and condition factor (CF) of scampi in nursery and grow-out ponds at different salinities. SGR and SGRL value were again highest at 2 ppt salinity in both nursery and grow-out ponds. Lowest weight to length ratio (1.36 in nursery ponds and 0.87 in grow-out ponds) at 2 ppt salinity *i.e.* lowest gain in weight in PL$_{20}$ and grow-outs stages for per unit change in length at this salinity. Whereas, at 4 ppt in nursery and grow-out ponds, it was estimated to be highest and the SGRL values at this salinity were reciprocal at the lowest. These results are in agreement with those of Jain *et al.* (2008a, b).

Table 2: Specific growth rate, growth length relationship (SGLR) and conditions factor of *M. rosenbergii* in nursery and grow out ponds

Treatment		SGR (%g d^{-1})	SGRL (%cm)	CF
Nursery Ponds	**0 ppt**	13.71 ±0.51	0.93 ±0.05	1.45 ±0.03
	2 ppt	14.41 ±0.14	1.01 ±0.05	1.36 ±0.04
	4 ppt	13.3 ±0.30	0.85 ±0.04	1.48 ±0.03
Grow-outs Ponds	**0 ppt**	2.16 ±0.09	0.87 ±0.03	0.87 ±0.01
	2 ppt	2.21 ±0.07	0.86 ±0.01	0.87 ±0.03
	4 ppt	2.09 ±0.08	0.85 ±0.01	0.89 ±0.01

All values are mean ±S.E. of three replicates.

Effect of different salinity levels on water quality of nursery and grow-out ponds

The data on water quality conditions in nursery ponds at 0, 2, 4 ppt salinity are shown in Table 3. The physico-chemical and biological conditions of this pond clearly revealed increase in conductivity from 565 µmhos cm^{-1} at 0 ppt to 1243 µmhos cm^{-1} at 4 ppt, affecting grossly primary pond productivity. The phytoplankton density was also at maximum at 2 ppt (374) and minimum at 4 ppt (218). Similarly, the zooplankton number varied in proportions *i.e.* 236 at 2 ppt and 144 at 4 ppt. The increase in conductivity at 2 and 4 ppt was result o increased chloride ions, whereas bicarbonate ions decreased from 156 to 147 mg l^{-1} at 2 and 4 ppt salinities, respectively. The BOD level showed a marginal increase from 3.28 mg l^{-1} at 2 ppt to 3.80mg l^{-1} at 4 ppt salinity.

Grow-out pond water quality conditions at different salinity treatment shown in Table 4, clearly revealed salinity dependent increase in conductivity from 593.60 µmhos cm^{-1} at 0 ppt to 1198.70 µmhos cm^{-1} at 4 ppt, affecting grossly primary pond productivity in the form of phytoplankton density *i.e.* it was higher at 2 ppt salinity (416.07). Similarly, the zooplankton number also varied in similar proportions *i.e.* 238.53 at 2 ppt. Bicarbonate ions was found highest (123.73 mg l^{-1}) at 2 ppt, whereas, the BOD value showed a significant decrease from 3.47 mg l^{-1} at 4 ppt to 2.88 mg l^{-1} at 2 ppt salinity.

The saline water (at 2 ppt and 4 ppt salinity level) has further high levels of Ca, Mg and high hardness. The

Table 3: Effect of different salinity treatments on mean physico-chemical and biological characteristics of nursery pond water

Parameters	Treatment 0 ppt	 2 ppt	 4 ppt
Temperature °C	21.3 ±0.42	21.3 ±0.40	21.6 ±0.40
Conductivity µmhos cm^{-1}	565 ±11.06	918 ±12.02	1243 ±10.90
pH	8.77 ±0.10	8.68 ±0.10	8.63 ±0.10
Dissolved oxygen mg l^{-1}	6.6 ±0.12	6.3 ±0.14	5.5 ±0.10
Carbonate mg l^{-1}	5.2 ±0.22	6.8 ±0.26	6.5 ±0.24
Bicarbonate mg l^{-1}	108 ±2.72	156 ±3.60	147 ±2.90
Total alkalinity mg l^{-1}	113 ±1.96	143 ±2.71	153 ±2.90
Total hardness mg l^{-1}	228 ±2.00	270 ±2.03	315 ±2.90
Chloride mg l^{-1}	23.4 ±2.02	84.4 ±1.97	113.0 ±1.65
Ammonical nitrogen mg l^{-1}	0.07±0.002	0.07±0.002	0.08 ±0.002
Phytoplankton no's l^{-1}	323 ±30.50	374 ±35.02	218 ±38.90
Zooplankton no's l^{-1}	164 ±8.05	236 ±10.11	144 ±8.36
Net primary productivity mg Cl^{-1} d^{-1}	1.17 ±0.02	1.30 ±0.02	1.05 ±0.02
BOD mg l^{-1}	3.15 ±0.02	3.28 ±0.05	3.80 ±0.03

All values are mean ±S.E. of three replicates.

Table 4: Effect of different salinity treatments on mean physico-chemical and biological characteristics of grow-out pond water

Parameters	Treatment 0 ppt	 2 ppt	 4 ppt
Temperature °C	26.42±0.49	26.37±0.49	26.46±0.49
Conductivity µmhos cm^{-1}	593.60±14.26	950.07±12.32	1198.70±12.67
pH	8.75±0.10	8.67±0.10	8.70 ±0.11
Dissolved oxygen mg l^{-1}	5.32±0.18	5.34±0.20	5.00±0.15
Carbonate mg l^{-1}	5.23±0.22	6.20±0.26	6.15±0.24
Bicarbonate mg l^{-1}	97.07±2.82	123.73±5.62	119.41±4.96
Total alkalinity mg l^{-1}	103.73±2.98	129.93±5.71	133.67±4.70
Total hardness mg l^{-1}	180.67±2.06	259.0±4.03	296.0 ±3.96
Chloride mg l^{-1}	45.92±2.08	102.12±1.27	150.67±1.00
Ammonical nitrogen mg l^{-1}	0.05±0.002	0.05±0.002	0.07±0.002
Phytoplankton no's l^{-1}	387.93±35.50	416.07±35.52	361.70±33.17
Zooplankton no's l^{-1}	214.87±9.03	238.53±13.11	199.45±10.49
Net primary productivity mg Cl^{-1} d^{-1}	1.12±0.02	1.16±0.02	1.07±0.01
BOD mg l^{-1}	3.12±0.02	2.88±0.15	3.47±0.03

All values are mean ±S.E. of three replicates.

high saline water in this study also revealed high chlorides and hardness (Table 3 and 4), which repressed growth in scampi, hence retarded prawn productivity. On the contrary, high alkalinity at 2 ppt, in nursery and grow-out ponds, favored high pond productivity, thus increased prawn production.

There has been a good indication of optimum response of scampi, *M. rosenbergii* at 2 ppt for high growth and survival of both the PL_{20} and the grow-outs. Absence of free carbon dioxide in all the treatments ponds may be attributed to its continuous utilization by the phytoplankton. Alkalinity, net primary productivity and phytoplankton population in general were high in ponds with saline water coinciding with high growth in prawns. Net primary productivity (NPP) showed increase with increased alkalinity, turbidity. Garg and Bhatnagar (2000) and Jain (2004) have also evidenced a positive correlation of primary productivity with fish growth/yield.

Ammonical nitrogen excretion (NH_4-N) increased significantly with each increase in the salinity of the water. Since, high concentrations of ammonia causes osmo-regulatory imbalances, and also interferes with the oxygen and carbon-dioxide exchange in the blood (Garg, 1996), optimum levels of ammonia thus might not have interfered to growth of prawn at higher salinities. Ammonia stress might have contributed to the low growth of prawn at higher salinities. Garg (1996) reported higher accumulation of NH_4-N with increase in salinity resulting in low growth of carps.

These findings are further corroborated by other studies. Theodore *et al.* (1980) recorded better growth performance of *M. rosenbergii* at a salinity level of 2 ppt. These authors have further indicated that further increase in salinity appeared to have a growth depressive effect. Studies of Sandifer *et al.* (1975) have also revealed high growth of scampi at 2 ppt when grown under field conditions. Moreover, maintenance of ionic and osmotic equilibrium in lower salinity levels probably required less energy expenditure than at higher salinity, resulting in better growth at lower salinity (Alavas, 1998).

Singh (1980) suggested that growth of prawns is to be maximum in an iso-osmotic medium, because the animals would not spend much energy in doing osmotic work. Nevertheless, present studies suggest that scampi, *M. rosenbergii*, culture is feasible in low inland saline ground waters. Monitoring water quality parameters is a vital aspect of prawn farming. Changes in water quality parameters occur on the basis of stocking density, feeding rate and water exchange. Oxygen depletion is the most common hazard in prawn farms, which can be caused by heavy organic load, over-feeding and presence of algal blooms. The level of oxygen can be raised by using aerators or water exchange as well as reducing organic load. The growth rate reduces with high values of hardness in water.

Effects of different locations on prawn production and water quality in grow-out ponds

Studies on growth performance of *M. rosenbergii* at four different locations in Hisar district (Table 5) in the ponds filled with tube well mixed canal water and maintained

Table 5: Growth performance of *M. rosenbergii* in grow out ponds of different locations in Hisar district

Different locations in Hisar district	Initial Live wt. (g)	Initial length (cm)	Mortality (%)	Final weight (g)	Final length (cm)	Live weight gain (g)	Production (kg/ha)
SLR-2 (T_1)	2.62 ±0.06	5.60 ±0.06	42.80	67.18 ±8.82	13.56 ±0.85	64.56 ±8.10	1107.85
SLR-2 (T_2)	0.010 ±8.90	5.42 ±0.04	45.50	68.83 ±7.74	13.93 ±0.67	66.16 ±7.50	1081.72
Bhadia-1 (T_3)	2.67 ±101.32	5.39 ±0.02	33.25	75.35 ±8.92	15.45 ±0.78	72.65 ±6.75	1454.82
Bhadia-2 (T_4)	2.63 ±71.28	5.32 ±0.06	31.70	73.64 ±8.25	15.84 ±0.59	70.94 ±4.60	1453.56

All values are mean ± S.E. of three replicates.

T_1, T_2, T_3, T_4 –Grow-out ponds at four different locations in Hisar district used tube well mixed canal water at negligible salinity for 150 days

Table 6: Physico-chemical and biological characteristics of grow-out ponds at different locations in Hisar district (150 days)

Parameters	Village			
	SLR Fish Farm	SLR Fish Farm	Bhadhai -1	Bhadhai -2
	T_1	T_2	T_3	T_4
Temperature °C	27.15±0.50	27.10±0.50	26.54±0.50	26.52±0.50
Conductivity µmhos cm^{-1}	539.0±1.65	539.0±1.65	612.60±12.23	612.50±12.20
Total alkalinity mg l^{-1}	93.5±1.64	95.4±0.82	117.2±2.50	116.1±3.00
Total hardness mg l^{-1}	129.0±0.54	130.0±0.50	98.0±4.50	99.4±5.00
Chloride mg l^{-1}	28.46±0.41	26.50±0.25	10.99±1.50	9.99±1.50
Ammonical nitrogen mg l^{-1}	0.54±0.02	0.57±0.02	0.047±0.01	0.047±0.01
Phytoplankton no's l^{-1}	312.00±14.8	284.00±15.6	342.0±16.2	328.0±15.5
Zooplankton no's l^{-1}	171.00±26.1	174.00±21.2	186.5±24.2	182.0±25.2
Net primary productivity mg Cl^{-1} d^{-1}	1.62±0.12	1.61±0.11	1.72±0.10	1.70±0.10

All values are mean ± S.E. of three observations

at negligible salinity for prawn culture for 150 days, indicated maximum weight and length gain at village Bhadia-khera. There was an increase in length from an average 5.39 cm to 15.45 cm and weight increased from 2.70 to 75.35 g, showing an average estimated production of 1454.82 kg ha^{-1}. At village SLR_1 and SLR_2 the production was up to 1107 kg ha^{-1}, as it showed relatively lower growth of grow-outs. The prawn mortality was also low in Bhadia-khera ponds, showing better water quality parameters (Table 6), particularly higher amounts of bicarbonates and alkalinity levels, thus contributing to higher conductivity as well as enhanced pond productivity in terms of higher production of planktons. This probably resulted also in higher prawn productivity in Bhadia-khera village ponds over the SLR village ponds.

REFERENCES

APHA (American Public Health Association), 1998. *Standard methods for the examination of water and waste water.* APHA, AWWA, EPFC, 20th Ed., New York.

Alavas, V.R. 1998. Effect of salinity dietary lipid source and level on growth of milkfish (*Chanos chanos*) fry. *Aquaculture*, 167: 229-236.

Garg, S.K. 1996. Brackishwater carp culture in potentially waterlogged areas using animal wastes as pond fertilizers. *Aquacult. Internal.* 4: 143-155.

Garg, S.K. and A. Bhatnagar. 2000. Effect of fertilization frequency on pond productivity and fish biomass in still water ponds stocked with *Cirrhinus mrigala* (Ham.). *Aquacult. Rev.*, 31 : 409-414.

Jain K.L., R.K. Gupta and Balraj Singh. 2008. Specific growth rate and proximate carcass composition of fresh-water prawn cultured in different salinity conditions in fresh water ponds of Haryana. *Livestock Research For Rural Development*, 20(7):1-6.

Jain, K.L. 2004. Sustainable management of inland water bodies for aquaculture. *In: Proceedings of the National Workshop on Rational use of Water Resources for Aquaculture* (Eds. S.K.Garg and K.L. Jain), March 18-19, 16-23.

Jain, K.L., R.K. Gupta, V.P. Sabhlok, B. Singh and Jindal, M. 2008. Growth, survival and production of *Machrobrachium rosenbergii* (de Man) in nursery ponds. *Livestock Research for Rural Development*, USA Volume 20, Article 198. Retrieved December, 8, from http://www.lrrd.org./lrrd20/12/jind20198.htm

Jhingran, V.G. 1991. Fish and Fisheries of India. Hindustan Publishing Corporation, India, pp.727.

Jhingran, V.G. and V. Gopalakrishnan. 1974. A catalogue of cultivated aquatic organisms. *FAO Fish tech. Pap.*, 130 : 83.

Pillay, T.V.R. 1990. Aquaculture Principal and Practices. Fishing News Books, pp.575.

Sandifer, P.A., J.S. Hopkins and T.I.J.Smith. 1975. Observations on salinity tolerance and osmoregulation in laboratory-reared *Macrobrachium rosenbergii* post larvae (Gustacea : Caridea). *Aquaculture*, 6 : 103-114.

Singh, T. 1980. The isosmotic concept in relation to the aquaculture of the giant prawn, *Macrobrachium rosenbergii*. *Aquaculture*, 20 (3) : 251-256.

Steffens, W. 1989. Principles of fish nutrition, New York, Chichester, Briskane, Toronto, Horwood, pp.384.

Theodore, I.J., P.A. Smith, P.A. Sandifer and E.J. Wallage. 1980. Growth and survival of prawns, *Macrobrachium rosenbergii*, pond-reared at different salinity. In: Giant Prawn Farming, M.B. New (Ed.), Elsevier Scientific Publishing Company, Amsterdam, Oxford, New York, 1982, 10 : 191-202.

Wetzel, R.G. and G.E. Likens. 1979. Limnological Analysis. W.B. Saunders Co. Philadelphia, pp.357.

Pb. Univ. Res. J (Sci.), Vol. 59, 2009, pp. 71-75

LENGTH-WEIGHT RELATIONSHIP OF *PUNTIUS CONCHONIUS* (HAM.) FROM LAKES OF KUMAON HIMALAYA, UTTARKHAND STATE, INDIA

***Ram Krishan Negi[1] and Tarana Negi[2]**

[1]*Department of Zoology & Environmental Science, Gurukula Kangri University, Hardwar 249404, Uttarkhand, India*

[2]*Govt. College, Panchkula, Haryana; E-mail: taranapkl@rediffmail.com*

Abstract

Length- weight relationship of *Puntius conchonius* (Ham.) was calculated separately for the lakes of Bhimtal and Nainital. The results reveal that there is a close relationship between the length and weight of fish. The regression equation was significant at $p< 0.01$ level. The values of 'n' of length-weight relationship were 3.341 and 3.295 for Bhimtal and Nainital respectively. The values of correlation co-efficient was calculated as ($r=0.97$) for Nainital and ($r=0 .99$) for Bhimtal lake. By testing the regression coefficient against the isometric value of 3, it was found that species in the both lakes follows the pattern agrees with the isometric formula.

Keywords: Length-weight, lakes, *Puntius*, Kumaon Himalaya.

INTRODUCTION

The study of length-weight relationship of fish gives a idea of their growth rates. Generally, when the length increases, the weight also increases correspondingly, showing that the weight of the fish is a function of its length. Establishing of a mathematical equation is useful in determining either the weight or of a given species from a particular locality. The length-weight relationship parameters are important in fish biology and can give information on stock condition (Banegal and Tesch, 1978). The studies on the length-weight relationship of fishes are conducted primarily to facilitate the conversion of one measurement into another basically to have assessment of growth rate of the fish crop. In certain case, the relationship is very useful in differentiating small taxonomic units, for variation may occur with in the population of different localities (Lecren, 1951; Chonder, 1972). The length-weight relationship of fish has theoretically and practical application in fishery science. Since growth generally contributes to the increase in length and weight of a fish, and the length-weight relationship is an interesting aspect of fish biology. The length-weight relationship of freshwater fishes have been worked out by previous workers like Prasadam (1971), Thakur and Das (1974), Rita Kumara and Nair (1978). Even though *Puntius* is of economic importance as a forage fish in the freshwater fishery resources of India, its biological aspects have not been fully known. Considerable literature is available on the length-weight relationship of different fish species. It has been found by many workers that length-weight relationship usually follows the cube law (Roy, 1986). However, sometimes, the growth pattern does not strictly agree with the isometric growth formula. The deviation from the hypothetical value of 3 (Ricker, 1958) is either due to environmental factors (seasonal variations, population dynamics, taxonomic differences etc.) or due to condition of the fish (maturity, spawning etc.). Such variations have been observed by Sarojini (1957) in *Mugil parsia*, Lal (1980) in *Schizothorax plagiostomus* and Lal and Mishra (1980) in *Schizothorax richardsonii*. *Puntius* (Family Cyprinidae) is widely distributed in lakes, pond, streams , rivers and reservoirs in India. A perusal of the available literature indicates that information on the length-weight relationship of this fish is lacking in the lakes of Bhimtal and Nainital of Kumaon Himalaya.

MATERIAL AND METHODS

In the present investigations a total of 112 specimens of *Puntius conchonius* (Ham.) 45 and 67 from Bhimtal and Nainital lakes respectively were collected during the period from April 2007- March, 2008 from Bhimtal and Nainital lakes (30^0 47' 36.8"N 78^0 08' 22.7"E and elevation of 1052 msl and 30^0 53' 19.2" N 78^0 05' 36.2"E and elevation of 1364 msl) respectively using cast net having mesh size 2cm. Length-weight relationship of 112 fish specimens ranged between 07 to 257 mm total fish length and weight ranged between 1.71gm to 106.4gm were measured to the nearest ±1 mm. (TL), and weighed to the nearest ±10g. The relationships between total length and weight were determined

---

*Corresponding Author. *negi_gkv@rediffmail.com*

MS Received April 15, 2010; Accepted August 29, 2010

according to linear regression model. The length-weight relationship, $W= aL^n$ was transformed into its logarithmic expression: $LogW= Log\ a + nLogL$. The parameters a and b were calculated by least-square regression for pooled samples. Usually the relation between length and weight is expressed by the hypothetical law (Le Cren, 1951):-

$$W= aL^n$$

Where 'W' represents the weight of the fish, 'L' length, 'a' is constants. In fishes the 'n' is often referred as an exponent expressing relationship between length-weight

The relationship ($W=aL^n$) when converted into the logarithmic form gives a straight line relationship graphically.

$$\mathbf{Log\ W= Log\ a+ n\ Log\ L}$$

Where n represents the slope of the line, Log a= constant.

The correlation coefficient (r) and (b) were calculated followed SPSS version 10. The 't' test was used to test whether the regression co-efficient significantly deviated from expected cube value (Snedecor & Cochran, 1967).

RESULTS AND DISCUSSIONS

The specimens for their total length ranged between 07mm to 257mm and weighed 1.71gm to 106.4gm were taken for the present study. However, linear relationship was obtained when the values were converted to logarithmic value. The curvilinear relationship was observed when original weights were plotted with respect to total length of the fish in both the lakes (Figs. 2 and 4). It is noticeable from the Fig. 1 and Fig. 3 that the weight in the relation to total length is highly significant in both the lakes.

Bhimtal lake: $Log\ W= -2.094 + \mathbf{3.341}\ Log\ L$

$$W = -2.094\ L^{3.341}$$

Nainital Lake: $Log\ W = 2.052 + \mathbf{3.295} Log\ L$

$$W = 2.052\ L^{3.295}$$

The values of 'n' of length-weight relationship were 3.341 and 3.295 for Bhimtal and Nainital respectively. The computed correlation coefficient r is nearer to 1 indicating high positive correlation between length-weight in this species. The correlation coefficient of Bhimtal lake is found to be higher (r=0.99**) as compared to the Nainital lake (r=0.97**). From this trend, it may be presumed that water quality in the Bhimtal lake is more conducive for this species. However, growth in weight was allometric in both the lakes. In the present investigation, values of length-weight relationship showed significance at $p< 0.01$

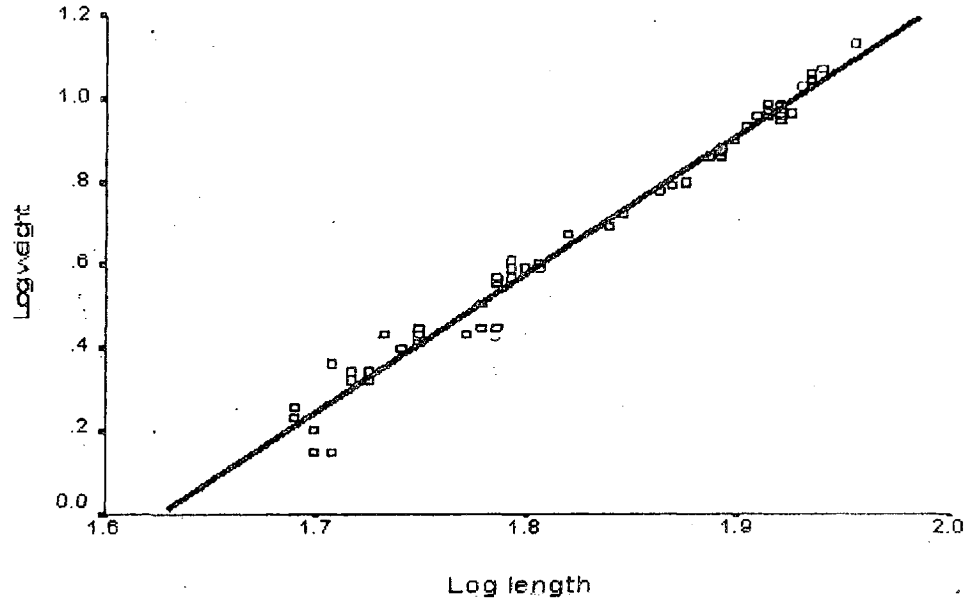


Fig. 1 : Log length-weight relationship of *Puntius conchonius* from Bhimtal Lake

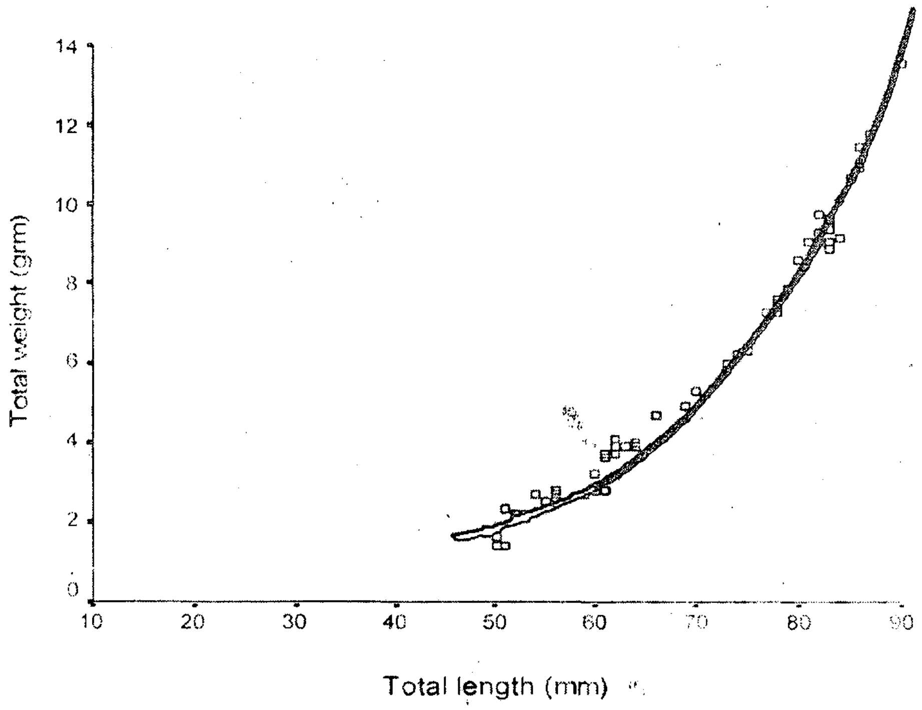


Fig. 2: Length-weight relationship of *Puntius conchonius* from Bhimtal Lake

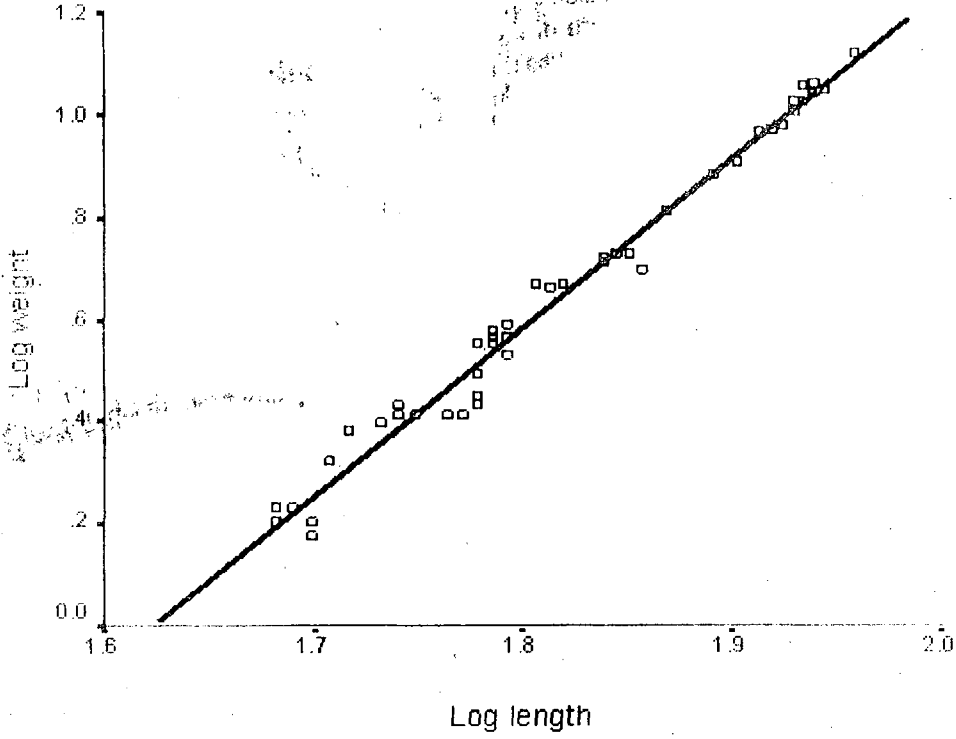


Fig. 3 : Log length-weight relationship of *Puntius conchonius* from Nainital lake

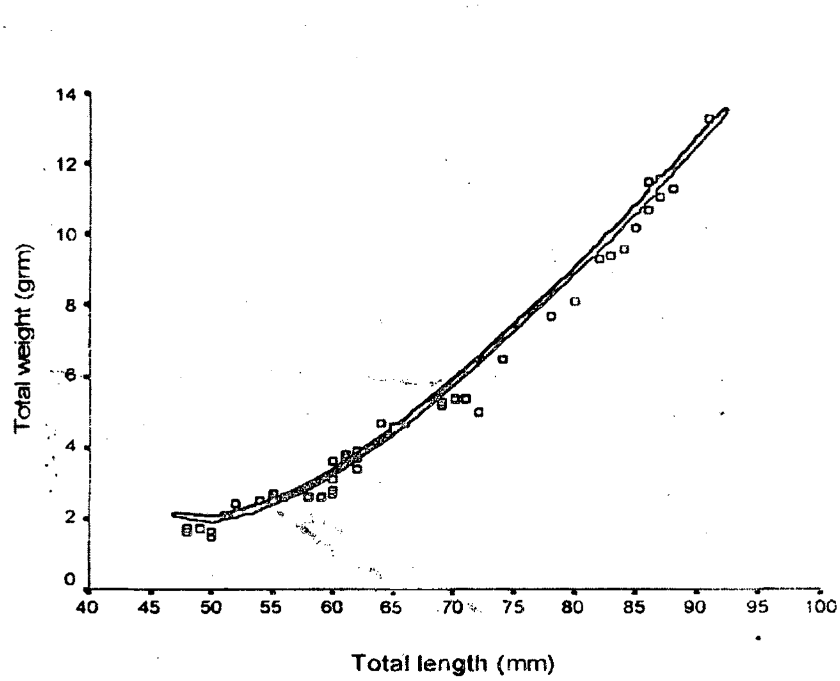


Fig. 4 : Length-weight relationship of *Puntius conchonius* from Nainital lake

for both the water bodies. The fact that weight will be proportional to the cube of any linear dimension has been much discussed. According to Allen (1938) an ideal fish which maintains a constant shape, the value of 'n' will be 3. Hile (1936) and Martin (1949) were of the opined that it may vary between 2.5 and 4.0. Discussing the merits of allometric formula with cube formula in expressing the length-weight relation, Beverton and Holt (1957) remarked that instances of marked deviation from isometric growth in adult fishes are rare. Hence, it is felt to list the regression coefficient against the isometric growth values of 3 to find whether there is any significant departure. In the present finding values of length-weight relationship showed significant at $p<.0.01$ for both the water bodies. Tesch (1968) reported that value of 'n'might be between 2.0 and 4.0. However, variation in 'n' value may due to different environmental factors. Pathak (1975) reported that the value of regression coefficient in *Labeo calbasu* was 3.0 from india. Azadi and Naseer (1996) reported the value of 'n' as 3.16 for males and 3.20 for females in *Labeo bata* from Bangladesh. The results of the present study are similar to the finding of LeCren (1951), Tesch (1968) and Johal *et al.*, (2005). The seasonal changes notably in the post spawning period affect the length-weight relationship. Total weight of fish may be altered by the weight of the stomach content depending on the food ingested just before weighing (Muth & Smith, 1974).

ACKNOWLEDGEMENTS

Authors are thankful to Lake Development Authorities of Nainital and Bhimtal lake for giving us permission to conduct this research problem.

REFERENCES

Allen, K.R., 1938. Some observations on the biology of the trout (*Salmo trutta*) in Windermere. *J. Anim.Ecol.*, 7: 333-349.

Azadi, M.A. and A. Naseer 1996. Length-weight relationship and relative condition factor of a carp, *Labeo bata* (Ham.) from Kaptai reservoir, Bangaladesh. *Chittagong Univ. Sci.*, 20(2): 19-25.

Bagenal, T. B. and F.W. Tesch 1978. Age and Growth. In: Methods for the Assessment of Fish Production in Freshwaters (Ed. T.B. Banegal) pp. 101-136. IBP Handbook No.3. Oxford Pub.

Beverton, R.J.H. and S.J. Holt 1957. On the dynamics of exploited fish populations. *Fish Inves. Lond.*, (2) 19:1-533.

Hile, R. 1936. Age and growth of the cisco, *Leucithys artedi* (Le Suer) in the lakes of the north-eastern highlands, Winsconsin. *Bull. U.S. Bull.Fish.*, 48 : 311-317.

Johal, M.S., R. K. Negi and O. Singh 2005. Length-weight relationship of golden mahseer, *Tor putitora* (Ham.) from pong dam reservoir, Himachal Pradesh. *Uttar Pradesh J. Zool.*, 25(1): 85-88.

Lal, M.S. 1980. Ecological studies of some hill stream fishes of Garhwal Himalaya IV. Length-weight relationship of *Schizothorax plagiostomus* (Gray). *Indian J. Zoology,* 21(1-3): 79-81.

Lal, M.S. and M. Mishra. 1980. Ecological studies of some hill stream fishes of Garhwal Himalaya IV. Length-weight rlation of *Schizothorax richardsonii* (Heckel). *Indian J. Zoology,* 21(1-3): 83-85.

Le Cren, E.D. 1951. The length-weight relation and seasonal cycle in gonad weight and condition in perch (*Perca fluviatilis*). *J.Anim.Ecol.*, 20: 201-219.

Martin, W.R. 1949. The mechanics of environmental control of body from in fishes. Univ. Toronto Stud. Biol. *Ont. Fish Res. Lab.*, 70:1-91.

Muth, K. and Jr. L.L. Smith 1974. The Burbut fishery in lake of the Woods. *Technical Bulletin,* 296:33.

Pathak, S.C. 1975. Length-weight relationship, condition factor and food study of *Labeo calbasu* (Ham.) from Loni reservoir (MP) *J. Inland Soc. India,* 7:58-64.

Prasadam, R.D. 1971. Observations on the biology of the pearl-spot, *Etroplus suratensis* (Bloch) from the Pulicat lake, Madras. *J. Inland Fish Soc. India,* 3 :72-78.

Ricker, W.E. 1958. Hand book of computations for biological statistics of fish population. *Bull. Fisheries Research Canada,* 119:300.

Rita Kumari, S.D., and N.B. Nair 1978. Length-weight relationship of the loaches, *Noemacheilus triangularis* Day and *Lepidocephalus thermalis* (Cuv & Val.). *Matsya,* 4: 52-58.

Roy, P.K. 1986. Length-weight relationship of major carp, *cirrinius mrigala* (Ham.) *Matsya,* 12-13:39-44.

Sarojini, K.K. 1957. Biology of Fishery of the grey mullet of Bengal 1. Biology of *Mugil parsia* (Ham.) with notes on its fishery in Bengal. *Indian J. Fisheries,* 4: 1260-207.

Snedecor, C.W. and W.G. Cochran 1967. Statistical methods. Oxfordlhi and IBH Publishing company, New Delhi, 435pp.

Tesch, F.W. 1968. Age and growth. In: Methods for the assessment of fish population in freshwater. (Ed W.R. Ricker) pp. 98-130 IBH Handbook No.3

Thakur, N.K. and N.K. Das. 1974. Length-weight relationship of *Heteropneustes fossilis* (Bloch) *J. Inland Fish Soc. India,* 4: 95-96.

Pb. Univ. Res. J (Sci.), Vol. 59, 2009, pp. 77-84

QUANTITATIVE ASSESSMENT OF SELECT DERMATOGLYPHIC FEATURES AMONG THE PEOPLE OF BHIMTAL, DISTRICT NAINITAL, UTTARAKHAND, INDIA

***Purnima Parashar and C.J. Edwin**

Department of Anthropology, Panjab University Chandigarh - 160014

Abstract

The present study was carried out in the Kumaon region of Uttarakhand (Bhimtal Block, District Nainital). The study focuses on the select quantitative dermatoglyphic features on fingers and palms among the three major communities inhabiting this area. The most dominant people numerically as well as economically are Brahmins and Thakurs, though Aryas (Scheduled Caste) also form a significant proportion in the population. The total number of subjects studied were 356 and Ad-hoc sampling method was used. Finger dermatoglyphic quantitative features showed that Total Finger Ridge Count (TFRC) mean value is 123.84, whereas for Absolute Finger Ridge Count (AFRC) mean value is 169.44. TFRC male-female comparison shows significant difference in Brahmin and Thakurs, whereas, in AFRC it shows only in Brahmins. Loops show preponderance in all the three communities. The value for Dankmeijer's, Furuhata's and Pattern Intensity Index varies from 8.00 to 24.03, 43.36 to 81.43 and 12.14 to 13.18 respectively. Palmar dermatoglyphic features showed that ridge counts varied from 37.89 to 49.79 (for a-b count), 23.51 to 26.54 (for b-c count) and from 31.80 to 35.20 (for c-d count). In all the three communities the lowest value of atd angle is 39° (left hand of Brahmin males) and maximum value is 47° (left hand of Arya males). The results are presented in terms of bimanual and intercommunity differences.

Keywords: Quantitative, dermatoglyphics, Kumaon.

INTRODUCTION

The qualitative method in dermatoglyphics enables the application of significance tests as also the elimination of arbitrariness of certain qualitative classification (Reddy, 2006). The widely studied quantitative dermatoglyphic characters include Total Finger Ridge Count (TFRC), Absolute Finger Ridge Count (AFRC), Pattern Intensity Index, Dankmeijers Index, Furuhata's Index on fingers and interdigital ridge counts (a-b, b-c, and c-d) and atd angle on palms. Holt (1968) opines that of all the quantitative characters TFRC is strongly determined by heredity excepting only 5% of its total variability caused by environmental effects. Jantz and Hawkinson (1979) believe that in order to discern meaningful population patterning individual ridge counts provide additional information. While similar work was done by Sunderland and Coope (1969) on Jivaro of Ecuador. Harvey and Suter (1983) discerned evidences for a major gene effect in the distribution of digital ridge counts. Harich *et al.* (2000) studied Berbers from Morocco and showed that bilateral symmetry was more pronounced than sexual differences in overall distribution, whereas they exhibit high value of Total Finger Ridge Count (TFRC).

The Absolute Finger Ridge Count (AFRC) also has been utilized to a greater extent in the biological comparison of populations (Mukherjee, 1967; Chakraborty and Malhotra, 1981; Karmakar *et al.*, 2005). Owing to strong correlation with Total Finger Ridge Count (TFRC), the Pattern Intensity Index (PII) may have an important genetic component (Salzano and Benevides, (1979; Karmakar *et al.* 2005). Newman (1960) considered the indices of Pattern Intensity as one of the important criteria for the evaluation of the biologically meaningful differences between the groups of populations. The amount of variation in individual pattern frequencies (Pattern Intensity Index, Dankmeijer's Index, and Furuhatas's Index) influences the variation in quantitative characters and signifies the sexual dimorphism (Narahari and Padmaja, 2006).

Palmar quantitative character, Interdigital ridge count and atd angle are studied for understanding the mode of inheritance and for delineating the bisexual and inter and intra population variation (Mahapatra and Behara, 1970; Pertia, 1974; Mate, 1975; Florence, 1975; Plato *et al.* 1975; Prokopec and Sevidy, 1976; Murillo et al., 1977; Harvey and Suter, 1983; Reddy et al., 2000; Igbigbi and Masamati, 2005; Reddy, 2006). The objectives of the present study are to describe population of the Bhimtal, Nainital district of Uttarakand for quantitative digital and palmar dermatoglyphic traits. Here,

---

*Corresponding Author. *purnimaparashar@yahoo.co.in*

MS Received June 24, 2009; Accepted March 2, 2010

populations are settled in this region for a long time and need to be reported. Furthermore an attempt is made to use these traits to study inter community comparison in this region.

LAND AND PEPOLE

The data for the present study was collected from Bhimtal Block, District Nainital, Uttarakhand. This falls in the Kumaon region of the state. Bhimtal located in the Northern part of district Nainital and its about 22kms from Nainital. It is located at an altitude of 1,371 meters above sea level. It lies between 78° 80' and 80° 14' East longitude and 29° 00' and 29° 05' North Latitude. The place derives its name from a legend related to 'Bhim' one of the Pandavas from epic Mahabharata. The famous Bhimtal lake is situated in the centre of Bhimtal town and is one of the largest lakes in the District.

The most dominant people numerically as well as economically are Brahmins and Thakurs, though Aryas (Scheduled Caste) also form a significant proportion in the population. All the three communities were largely agricultural in occupation. The populations were sessile and have been living there for generations (Table 1).

MATERIAL AND METHODS

The data for present study comprises bilateral inked fingers and palmar prints of 174 males and 183 females of Bhimtal Block, district Nainital, Uttarakhand collected by Mankotia (2004) and Parashar (2004). Ad-hoc sampling method was used. The age of the individuals ranges from 10 to 50 years. The analyses of finger and palm prints have been according to Cummins and Midlo (1961). Chi-square and Z-test were computed know the significance of bimanual, bisexual, and intercommunity differences.

The following quantitative dermatoglyphics features were observed:

(A) ON FINGER BALLS:

1. Total Finger Ridge Count (TFRC)
2. Absolute Finger Ridge Count (AFRC)
3. Indices: *(a) Pattern Intensity Index*
   (b) Dankmeijer's Index
   (c) Furuhatas's Index

(B) ON PALMS:

4. Palmar Interdigital Ridge Counts
5. atd Angle.

OBSERVATIONS

TOTAL FINGER RIDGE COUNT (TFRC)

Total Finger Ridge Count (TFRC) for right-left hands males and females of all the three communities, viz, Aryas, Brahmins and Thakurs are shown in Table 2. Thakurs showed higher mean values for both right (65.32) and left (66.03) in males as well as in females, right (57.96) and left (56.35) hands. The comparison of the means show no right-left differences. However, the male-female comparisons show (Table 3) significant differences in the Brahmins (at 1 percent) and among Thakurs (at 5

TABLE 1: Chief Statistics of Bhimtal Block

Total Area	9795.37 Hectare
Total Population: Persons	
Males	37,539
Females	19,747
	17,792
Scheduled Caste (S.C)	9,420
Scheduled Tribe (S.T)	40
Literacy Rate: **Absolute**	2,3361
Percentage	62.23
Total Cultivated Area	727 sq km
Agricultural Area	9268 sq km.

(Source: Block Development Office, Bhimtal, 2001)

TABLE 2: TOTAL FINGER RIDGE COUNT: Male Female, Right-left Comparison

	MALES						FEMALES					
	ARYAS		BRAHMINS		THAKURS		ARYAS		BRAHMINS		THAKURS	
	R	L	R	L	R	L	R	L	R	L	R	L
N	58	58	57	57	53	53	64	64	56	56	52	52
Range	23-99	22-99	13-115	10-149	17-100	22-105	7-116	10-91	12-80	6-78	18-93	21-83
Mean	57.83	60.34	56.40	62.59	65.32	66.03	57.19	56.28	53.55	52.43	57.96	56.35
S.D	19.93	62.95	24.50	21.82	17.76	19.80	19.50	19.56	17.26	19.47	18.86	19.80
C.V	34.46	66.03	43.45	34.66	27.19	29.98	34.09	34.75	32.33	37.13	32.54	35.14

TABLE 3: TOTAL FINGER RIDGE COUNT: Right and Left hands combined for Males, Females and both sexes pooled

	MALES			FEMALES			BOTH SEXES POOLED		
	ARYAS	BRAHMINS	THAKURS	ARYAS	BRAHMINS	THAKURS	ARYAS	BRAHMINS	THAKURS
N	58	57	53	64	56	52	122	113	105
Range	38-198	31-248	39-203	17-183	22-158	34-169	17-198	22-248	34-203
Mean	120.69	124.05	132.32	113.76	107.01	115.78	117.07	115.69	123.84
S.D	35.92	35.79	35.08	36.61	33.25	36.81	36.33	35.22	36.64
C.V	29.81	28.85	26.51	32.19	31.06	31.69	36.64	30.45	29.58

MALE-FEMALE COMPARISON

ARYAS: Z=2.36 Significant at 5 percent level
BRAHMINS: Z=2.62 Significant at 1 percent level
THAKURS: Z=1.06 Not Significant

TABLE 4: ABSOLUTE FINGER RIDGE COUNT: Male Female, Right-left Comparison

	MALES						FEMALES					
	ARYAS		BRAHMINS		THAKURS		ARYAS		BRAHMINS		THAKURS	
	R	L	R	L	R	L	R	L	R	L	R	L
N	58	58	57	57	53	53	64	64	56	56	52	52
Range	22-171	15-169	13-171	10-179	27-160	22-174	7-115	16-136	12-155	6-140	18-170	17-132
Mean	84.96	82.22	82.72	77.35	91.40	87.26	74.68	70.28	67.50	68.14	78.58	77.12
S.D	37.26	36.95	34.31	35.23	37.67	36.64	34.57	34.34	28.98	29.74	40.41	34.84
C.V	43.85	44.94	41.48	45.45	41.21	41.98	46.30	48.85	42.93	43.64	51.43	45.18

percent). The Aryas do not show any bisexual differences. When the both sexes were pooled we do not get any intercommunity differences.

ABSOLUTE FINGER RIDGE COUNT (AFRC)

Absolute Finger Ridge Count (AFRC) for right-left hands of males and females of all the three communities are shown in Table 4. Here also, the Thakurs showed higher mean values for both right (91.40) and left (87.26) in males as well as females right (78.58) and left (77.12) hands. Comparing the mean values no significant differences were seen for right-left hands. Male-female differences are significant (at 5 percent) for Brahmins only. When both sexes were pooled and intercommunity comparisons was made significant differences (at 5 percent) were seen only between Brahmins and Thakurs (Table 5).

INDICES

The Pattern Intensity Index (PII) of males and females shown in Table 6. The mean value varies from 12.14 to 13.89. There are neither any significant male-female nor intercommunity differences in mean values. Whereas, the mean value for Dankmeijer's Index and Furuhata's Index (Table 7 and 8) varies from 8.00 to 24.03 and 46.36 to 81.43, respectively. There are no significant right-left and male-female differences in the case of these two indices. There are no intercommunity differences. Although, the Dankmeijer's Index is higher in females in case of both hands. Furuhata's Index does not show any such regular pattern in variation.

INTERDIGITAL RIDGE COUNTS

Table 9 gives the range, mean, standard deviation of the interdigital ridge count among males right and left hand of all the three communities. The mean values are lower in case of b-c ridge count as compared to a-b and c-d ridge counts. There were no significant differences in right-left hand when comparisons were made except the right-left hand comparison among Brahmins showed significant values at 5 percent.

Table 10 gives the interdigital ridge count among females. Here also, the mean values are lower in case of b-c ridge count as compared to a-b and c-d ridge counts. There were no right-left significant differences. The intercommunity comparison for the right and left hand of males and females indicates all non-significant values.

atd ANGLE

Table 11 shows the range, modal value, mean and standard deviation of the atd angle for males right and left hands in all the three communities. The modal values are 41° and 47° for right and left hand in Aryas, 45° and 39° for Brahmins and 43° and 39° for Thakurs, respectively. The comparison of means showed insignificant differences for right-left comparison in all the three communities.

Table 12 represents the atd angle among females. The modal value for Aryas right and left hand are 46° and 45°, for Brahmins 46° in both hands and 41° and 43° in Thakurs. The comparison of means here also showed non-significant differences for right-left comparison. There were no male-female significant differences among the Aryas and Brahmins. However, the Thakurs male-female comparison for right hand indicates differences significant at 5 percent. The intercommunity comparison shows significant differences at 1 percent for the right hand of Arya – Thakur female only.

DISCUSSION

The overall picture of ridge counts does not show a clear pattern of variation in the Total Finger Ridge Count and Absolute Finger Ridge Count. Looking at the Indices derived from finger ball pattern namely Pattern Intensity Index, Dankmeijer's Index and Furuhata's Index one sees no bimanual, bisexual and intercommunity differences. However, with regard to Dankmeijer's Index the female show the higher values than the males indicating a trend, which is not significant for females to have relatively more arches than whorls as compared with males.

a-b ridge count is the number of ridges occurring in the second interdigital area between the a and b triradii. It is the best known and the most satisfactory ridge count on the palm partly because there is usually no pattern between the triradii. Like other ridge counts it is also independent of age (David, 1984).There are no significant bimanual differences. The correlation between the two hands is high, the a-b ridge count being very slightly higher on left hand except in Aryas and Thakurs males, where right hand shows higher a-b ridge count. The a-b ridge count do not show any sex differences (Holt, 1968). The intercommunity comparison does not indicate any significant differences in the present study.

It should be remembered that the atd angle varies with age. In all the communities observed both hands show high correlation, there being no bisexual differences either. The intercommunity differences in atd angle were significant at 1 percent for right hand of Arya-Thakur females which can be used for genetic investigations. The maximum observed in all three communities is 47° (left hand of Arya males) and lowest value is 39° (left hand of Brahmin males). Mean values in all the three communities ranges from 41.51° to 45.50°. The variation in position of axial triradii depicted significant differences in right-left, male female and intercommunity comparisons which can be used for future investigations.

The results of the present study demonstrate that very few intercommunity differences are manifested in terms of quantitative digital and palmar traits. One conclusion that may be made is that at same time in the not so distant past these three communities had differentiated from the same genetic stock. It is also advocated that the further investigation in these communities be made

TABLE 5: **ABSOLUTE FINGER RIDGE COUNT: Right and Left hands combined for Males, Females and both sexes pooled**

	MALES			FEMALES			BOTH SEXES POOLED		
	ARYAS	BRAHMINS	THAKURS	ARYAS	BRAHMINS	THAKURS	ARYAS	BRAHMINS	THAKURS
N	58	57	53	64	56	52	122	113	105
Range	45-340	31-348	34-333	17-298	22-295	42-319	17-340	22-348	34-333
Mean	168.86	161.72	180.15	148.03	135.61	158.36	158.02	146.92	169.44
S.D	75.27	65.63	70.16	65.47	55.98	73.69	70.82	62.58	72.39
C.V	44.58	40.58	38.94	44.23	41.27	46.48	44.82	42.59	42.72

MALE-FEMALE COMPARISON

ARYAS: Z=1.62 Not Significant
BRAHMINS: Z=2.27 Significant at 5 percent level
THAKURS: Z=1.54 Not Significant

INTERCOMMUNITY COMPARISON

ARYAS-BRAHMINS: Z= 1.27 Not significant
ARYAS-THAKURS: Z= 1.20 Not Significant
BRAHMINS-THAKURS: Z= 2.45 Significant at 5 percent level

TABLE 6: Distribution of Pattern Intensity Index

	MALES			FEMALES		
	ARYAS	**BRAHMINS**	**THAKURS**	**ARYAS**	**BRAHMINS**	**THAKURS**
N	58	57	53	64	56	52
Mean	13.89	13.07	13.83	12.69	12.14	13.40
S.D.	3.65	3.32	3.36	3.46	3.68	4.23
C.V	26.27	25.40	24.29	27.26	30.31	31.56

TABLE 7: Bimanual/Bisexual Distribution of Dankmeijer's Index

	MALES			FEMALES		
	Right	**Left**	**Both Hands**	**Right**	**Left**	**Both Hands**
ARYAS	3.79	12.71	8.00	21.00	26.85	24.03
BRAHMINS	7.48	18.18	12.03	17.95	23.86	21.08
THAKURS	7.32	10.78	8.88	14.81	17.64	16.19

TABLE 8: Bimanual/Bisexual Distribution of Furuhata's Index

	MALES			FEMALES		
	Right	**Left**	**Both Hands**	**Right**	**Left**	**Both Hands**
ARYAS	87.42	75.64	81.43	50.25	59.02	54.44
BRAHMINS	64.07	48.61	56.03	41.71	51.46	46.36
THAKURS	93.18	68.00	79.78	79.41	72.85	76.08

TABLE 9: Distribution of Interdigital Ridge Count among Males in all the three communities

	ARYAS						BRAHMINS						THAKURS					
	a-b		b-c		c-d		a-b		b-c		c-d		a-b		b-c		c-d	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
N	58	59	55	54	55	54	60	60	59	56	59	56	54	52	53	46	53	46
Range	21-46	18-54	9-36	14-38	15-50	22-48	22-51	23-51	6-37	6-36	13-46	20-46	22-53	21-53	12-37	17-45	7-50	9-50
Mean± SEM	39.17 ± 1.05	37.89 ± 0.91	24.81 ± 0.92	25.12 ± 0.75	33.29 ± 1.04	32.87 ± 0.91	38.15 ± 0.72	39.43 ± 0.67	24.83 ± 0.84	23.51 ± 0.79	34.40 ± 0.87	31.80 ± 0.92	38.42 ± 1.10	38.40 ± 1.03	25.15 ± 0.79	25.28 ± 0.80	33.69 ± 1.15	33.63 ± 1.19
S.D± SESD	8.03 ± 0.74	6.99 ± 0.64	6.83 ± 0.65	5.57 ± 0.53	7.71 ± 0.73	6.73 ± 0.64	5.58 ± 0.50	5.25 ± 0.47	6.48 ± 0.59	5.97 ± 0.56	6.72 ± 0.61	6.92 ± 0.65	8.11 ± 0.78	7.48 ± 0.73	5.80 ± 0.56	5.43 ± 0.56	8.43 ± 0.81	8.09 ± 0.84

TABLE 10: Distribution of Interdigital Ridge Count among Females in all the three communities

	ARYAS						BRAHMINS						THAKURS					
	a-b		b-c		c-d		a-b		b-c		c-d		a-b		b-c		c-d	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
N	67	68	62	63	63	63	58	59	56	53	57	53	53	53	48	48	48	48
Range	16-49	20-57	13-37	11-37	20-50	19-47	26-49	26-48	11-37	14-37	11-45	16-51	25-48	26-56	14-36	16-35	19-45	17-47
Mean± SEM	38.89 ± 0.86	39.89 ± 0.85	26.09 ± 0.69	25.52 ± 0.70	34.17 ± 0.81	33.20 ± 0.86	39.94 ± 0.64	39.11 ± 0.53	25.94 ± 0.75	26.54 ± 0.70	33.31 ± 1.06	34.56 ± 1.07	38.92 ± 0.60	39.58 ± 0.75	25.31 ± 0.75	25.41 ± 0.68	35.20 ± 0.79	33.75 ± 0.64
S.D± SESD	7.08 ± 0.61	7.08 ± 0.60	5.49 ± 0.49	5.63 ± 0.50	6.44 ± 0.57	6.82 ± 0.60	4.93 ± 0.45	4.14 ± 0.38	5.63 ± 0.53	5.12 ± 0.49	8.05 ± 0.75	7.86 ± 0.76	4.39 ± 0.42	5.48 ± 0.53	5.23 ± 0.53	4.72 ± 0.48	5.50 ± 0.56	6.31 ± 0.64

TABLE 11: Variation in atd angle in three communities among Males

	ARYAS		BRAHMINS		THAKURS	
	Right	Left	Right	Left	Right	Left
N	58	59	60	60	54	53
Range	29°-62°	25°-85°	24°-87°	31°-70°	26°-78°	29°-67°
Modal value	41°	47°	45°	39°	43°	39°
Mean **±** **SEM**	42.39 ± 0.89	42.50 ± 1.21	42.20 ± 1.12	41.31 ± 0.90	42.02 ± 1.18	41.15 ± 1.12
S.D **±** **SESD**	6.81 ± 0.63	9.34 ± 0.86	8.67 ± 0.79	6.99 ± 0.63	8.67 ± 0.83	8.18 ± 0.79

TABLE 12: Variation in atd angle in three communities among Females

	ARYAS		BRAHMINS		THAKURS	
	Right	Left	Right	Left	Right	Left
N	68	57	59	59	53	54
Range	23°-56°	29°-55°	27°-62°	27°-70°	32°-60°	31°-70°
Modal value	46°	45°	46°	46°	41°	43°
Mean **±** **SEM**	41.85 ± 0.97	41.95 ± 1.17	43.85 ± 0.83	44.23 ± 0.88	45.40 ± 0.96	44.61 ± 0.95
S.D **±** **SESD**	8.01 ± 0.68	8.84 ± 0.82	6.40 ± 0.58	6.77 ± 0.62	7.06 ± 0.68	7.02 ± 0.67

using larger samples covering more population of these communities in Bhimtal Block, District Nainital of Uttarakhand.

CONCLUSION

This study has profiled the quantitative digital and palmar dermatoglyphic in the three communities studied in the Bhimtal Block, district Nainital, Uttarakhand. Some instances of bisexual and intercommunity comparisons which were significant at 1 percent probability levels do indicate that larger samples would reveal better clarity in nature of variation and hence the use in population studies of these traits. The three communities are sessile and have inhabited the area for generations. One could perhaps postulate a common origin of these groups and have resulting in the absence of larger scale significant differences in quantitative traits.

ACKNOWLEDGEMENTS

We thank Prof. R.K.Pathak, former Chairperson of the Department and coordinator of the UGC Special Assistance Programme, for providing the necessary facilities for the present study. We also thank Ms. Himani Mankotia, who participated in the field work which has lead to this present work. We acknowledge the cooperation of the principals, staff members and students of the schools of Bhimtal and people of Alchona and Pandeychor villages, (Bhimtal Block).

REFERENCES

Bali, R.S. and R. Chaube. 1994. *Application and methodological perspectives in dermatoglyphics*. Northern Book Centre: New Delhi.

Basu, S.S., B.P. Powar, and O.N. Khare. 2005. Palmar dermatoglyphics in pulmonary tuberculosis. *J. Anatomical Soc. India,* 54(2):1-9.

Chakraborty, R. and K.C. Malhotra. 1981. Variations in asymmetry and interdigital diversity for three ridge count measures among the Dhanger caste cluster of Maharashtra, India. *J. Hum. Evolution*, 10: 503-509.

Cummins, H. and C. Midlo. 1943. Fingerprints, palms and soles: An introduction to dermatoglyphics. The Blakiston Company, Philadelphia.

David, J.J. 1984. Distribution and sex variation of the a-b ridge count. *Human Heredity,* 34(1): 14-17.

Florence, S.S., J.J. Cereghino and C.C. Plato. 1975. The dermatoglyphics of American Negro. *Am. J. Phy. Anthropology,* 42:183-194.

Harich, H., E. Esteban, A.Chafik and P. Moral. 2002. Dermatoglyphic characterization of Berbers from Morocco: Qualitative and quantitative digital and palm data. *Ann. Hum. Bio.,* 29(4):442-456.

Harvey, R.C. and D. Suter. 1983. Evidence for a major gene effect in the distribution of digital counts. *Ann. Hum. Bio.,* 10(6):565-576.

Holt, S.B. 1968. The genetics of dermal ridges. c.f. David.T.J. 1984.

Igbigbi, P.S. and B.C. Msamati. 2005. Palmar and digital dermatoglyphic traits of Kenyan and Tanzanian subjects. *W.Afr. J. Med.,* 24(1):26-30.

Jantz, R.L. and C.H. Hawkinson. 1979. Finger ridge count variability in South- Saharan Africa. *Ann. Hum. Bio.,* 6:41-53.

Karmakar, B., K. Yakoveniko and E. Kobliansky. 2005. Complex segregation analysis of quantitative dermatoglyphics traits in five Indian populations. *Ann. Hum. Bio.,* 32(4):445-468.

Mahapatra, U.D. and P. Behera. 1970. Palmar dermatoglyphics of Mundas of Orrisa. *Man in India,* 50:121-134.

Mate, M. 1975. The ridge-counts of the interdigital a-b, b-c and c-d areas in a normal sample and in cerebrally damaged patients of Thuringia, G.D.R. (East Germany). *Am. J. Phy. Anthropology,* 42(2):233-235.

Mankotia, H. 2004. A study on palmar dermatoglyphics and selection for sex of offspring among select caste groups of Bhimtal, District Nainital, Uttaranchal. M.Sc Dissertation (Unpublished). Department of Anthropology, Punjab University, Chandigrah.

Mukherjee, D.P. 1967. *Quantitative genetics of dermal ridges with special reference to Indian population*. Ph.d Thesis, London University, London.

Murillo, P., F. Rothhammer and E. Llop. 1977. The Chipaya of Boliva: Dermatoglyphics and ethnic relationship. *Am. J. Phy. Anthropology,* 46:45-50.

Narahari, S. and J.S. Padmaja. 2006. Finger and palmar dermatoglyphics study among Bondos of Orrisa. *Anthropologist,* 8(4):237-240.

Newman, H.H. 1960. Population analysis finger and palm prints in highland and lowland Maya Indians. *Am.J. Phy. Anthropology,* 18:45-48.

Parashar, P. 2004. A study on digital dermatoglyphics and social selection for brood size and birth interval among select caste groups of Bhimtal, District Nainital, Uttaranchal. M.Sc Dissertation (Unpublished). Department of Anthropology, Punjab University, Chandigarh.

Pateria, H.N. 1974. Genetics of a-b, b-c, c-d ridge counts on human palms. *Am. J. Phy. Anthropology,* 40:171-173.

Plato, C.C, J.J. Cereghino and F.S. Steinberg. 1975. The dermatoglyphics of American Caucasians. *Am. J. Phy. Anthropology,* 42:195-210.

Prokopec, M. and V. Sedivy. 1976. "Australian aboriginals and the outer world: Dermatoglyphical evidence, in *The origins of Australians*. R.L.Kirk and A.G.Thorne, eds Australian Institute of Aboriginal Studies, Canberra, pp.215-226.

Reddy, B.K.C. 2006. Quantitative dermatoglyphic variation among Reddi populations of southern Andhra Pradesh. *Anthropologist,* 8(4):231-236.

Reddy, B.M, V.P. Chopra, B. Karmakar, K.C. Malhotra and H. Mueller. 2000. Quantitative dermatoglyphics and population structure in Northwest India. *Am. J. Hum. Bio,* 12(3) : 315-326.

Salzano, F.M. and F. DeSa Ebenevides. 1971. Finger print quantitative variation and asymmetry in Brazilian white and blacks. *Am. J. Phy. Anthropology,* 40:325-328.

Sunderland, E. and E. Coope. 1969. The Jivaro: Quantitative digital dermatoglyphics. *Man,* 4(3) : 438-422.

Pb. Univ. Res. J (Sci.), Vol. 59, 2009, pp. 85-90

ELEMENTAL CONCENTRATION IN SOME MOSSES OF POLLUTED SITES

Mamta Singh Pathania, *Anju Rao, Sunita Kapila and S.S. Kumar

Department of Botany, Panjab University, Chandigarh - 160014

Abstract

Six moss taxa , namely, *Anoectangium clarum, Gymnostomum calcareum, Hyophila involuta, H. spathulata, Hydrogonium arcuatum var. gangeticum* and *Hydrogonium consanguineum* are found in sites polluted by dark effluents discharged from the Industries. The pH value of the substrata supporting these taxa is found to be in a very narrow range (6.66-7.81). The concentration of microelements, As^{+}, Pb^{++}, Ni^{++}, Cr^{+++}, Cd^{+++}, Mn^{++}, Cu^{++}, Zn^{++}, Co^{+++} and Fe^{++} found in the plant material and substratum has brought out at the extent of toleration capacity of these taxa which enabled these mosses to out compete in such sites.

Keywords: Moss taxa, pH, microelements.

INTRODUCTION

A persusal of the available literature (Le Blanc *et al.*, 1971; Lee, 1972; Pakarinen and Tolonen, 1976a, 1976b; Micheal and Rudolf, 1979; Jones *et al.*, 1985; Ross. 1990; Schang *et al.*, 1990; Anayan *et al.*, 1991; Markert, 1993; Wolterbeek *et al.*, 1996; Viskari *et al.*, 1997; Punnig and Alliksaar, 1997; Olajoire, 1998; Okland *et al.*, 1999; Vázquez *et al.*,1999; Samecka-Cymerman and Kempers, 1998, 1999; Garcia-Alvaro *et al.*, 2000; Herpin *et al.*, 2001; Fernandez *et al.*, 2002; Bargagli *et al.*, 2003; Couto *et al.*, 2004; Bignal *et al.*, 2008) has revealed tremendous ecological importance of bryophytes, particularly mosses and their role in pollution monitoring.

Their distinctive features i.e small size, simple structural organization, lack of cuticle, ability to survive under long or short photoperiod including prolonged darkness, extreme environmental conditions (long drought, high and low temperature),high regeneration potential, low mineral nutritional requirement, short life cycle coupled with their ability to absorb mineral nutrients through their conducting elements (hydroids) and also over their general surface, the capacity to bind these elements to their cell walls (enabling accumulation of even heavy metals) make them unique among other plant groups to merit as a favorable material for pollution studies.

The present study is under taken to estimate the elemental concentration(key component in heavy metals pollution studies) of As^{+}, Pb^{++}, Ni^{++}, Cr^{+++}, Cd^{+++}, Mn^{++}, Cu^{++}, Zn^{++}, Co^{+++} and Fe^{++} in six moss taxa and their supporting substrata collected from 17 polluted sites (shown in map).

MATERIALS AND METHODS

Six moss taxa along with their substratum were collected from 17 sites (listed in Table-1) with industries emitting gases and discharging dark effluents to cause varied degree of pollution in the area.The plant material, after separation from the substratum, was washed several times with tap water and then checked under binoculars to avoid contamination with any other plant material. The purified plant material was then cleaned in water with pressurized air to remove any adhering soil particles. It was finally washed with double distilled water and then dried at room temperature between folds of blotting sheet. Each plant sample and its supporting substratum were then finely powdered in Pestle and Mortar separately after drying in an oven at 50°-60°C and then analyzed separately to determine their elemental content by Emission Spectroscopy. The pH of the substratum was determined using Beckman's pH meter.

DETECTION PROCESSES

Estimation of micro-elements

Ten micro-elements namely, As^{+}, Pb^{++}, Ni^{++}, Cr^{+++}, Cd^{+++}, Mn^{++}, Cu^{++}, Zn^{++}, Co^{+++} and Fe^{++}, were determined by Emission Spectroscopy using JY70PLUS ICP (Inductively Coupled Plasma) Spectrometer.

Principle involved

Inductively Coupled Plasma (ICP) analysis involves introducing the elements to be analyzed into an argon plasma induced by a high frequency, where temperature is in the order of 8000°K. The sample in the form of an

---

*Corresponding Author. *anjuraoanju@rediffmail.com*

MS Received May 4, 2010; Accepted September 1, 2010

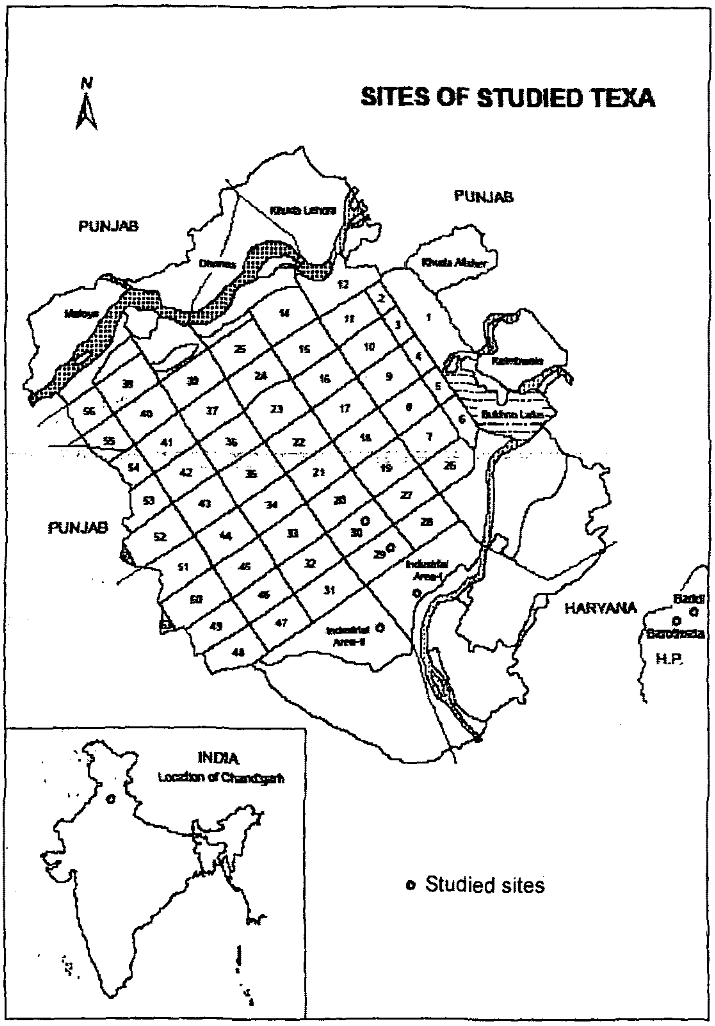


Fig. 1

aerosol is introduced into the plasma via a "torch", where it is excited. Each excited element furnishes a characteristic spectrum whose light intensity is directly *proportional to the quantity of that element present in* the sample.

Sample preparation

200mg of separated, cleaned, dried and powdered plant material was taken in 100ml conical flask. To the flask 10ml of digestion mixture HNO_3:$HClO_4$-3:1 was added. The flask was shaken gently and then heated on sand bath till a white to orange-brown residue was obtained. 10mM Nitric acid was added to this residue. This solution was used as the stock solution for determination of various trace elements in plant material by Emission Spectroscopy.

To analyze soil samples, the soil was sieved and 500mg of it was used to detect various trace elements by Emission Spectroscopy. The rest of the procedure was the same as followed for the plant samples.

OBSERVATIONS AND RESULTS

The collection data along with the pH value of the supporting substratum of the six studied taxa is given in Table 1. The pH range of the supporting substrata(Table-1) in 17 sites was found to vary between 6.66-7.81.*This narrow range of pH of the supporting* substrata is indicative of little modification of the habitat in respect of acidity/alkalinity in 17 different sites.

Uptake of heavy metal Arsenic was favoured at pH 7.14. *Hyophila spathulata* and *Hydrogonium consanguineum*,

TABLE 1: Showing the list of sites, studied taxa, substratum and its pH

Site No.	Site	Name of Taxon	Substratum	pH
I	Vijay Remedies Industry, Barotiwala(Himachal Pradesh)	*Anoectangium clarum* Mitt.	On boundary wall (Upper part)	7.68
II	Vijay Remedies Industry, Barotiwala(Himachal Pradesh)	*Gymnostomum calcareum* Nees & Hornsch.	On boundary wall (Lower part)	7.47
III	Shivalik Steel Alloy Industry, Barotiwala(Himachal Pradesh)	—do—	On wall	7.47
IV	Chander Laxmi Glass Factory, Barotiwala(Himachal Pradesh)	*Hyophila involuta* (Hook.) Jaeg.	On wall	7.57
V	Transport Depot-I, Industrial area Chandigarh	*Hyophila spathulata* (Harv.) Jaeg.	On brick wall	7.12
VI	Transport Depot-II, Industrial area Chandigarh	—do—	On brick wall	6.89
VII	Modern Bread Factory, Industrial area Chandigarh	—do—	On cemented wall	7.01
VIII	Sanson Pharmaceutical Industry, Baddi (Himachal Pradesh)	—do—	On wall	7.56
IX	Chhabra Steel strips Limited, Baddi(Himachal Pradesh)	*Hydrogonium arcuatum* var. *gangeticum* (Griff.) Wijk & Marg.	On back wall	7.47
X	LML Agency, Industrial area, Chandigarh	*Hydrogonium consanguineum* (Thw. & Mitt.) Hilp.	On back wall	7.23
XI	Sector-29, Roadside, Chandigarh	—do—	On moist soil	6.93
XII	Sector-30, Roadside, Chandigarh	—do—	On wall	7.06
XIII	Pfizer Industry, Industrial area, Chandigarh	—do—	On wall (Outer side)	6.66
XIV	Pawa Chain Industry, Industrial area, Chandigarh	—do—	On wall	7.10

XV	Thread Factory, Baddi(Himachal Pradesh)	—do—	On boundry wall	7.81
XVI	Rama Steel Industry, Barotiwala(Himachal Pradesh)	—do—	On wall	7.14
XVII	Rama Steel Industry., Barotiwala (Himachal Pradesh)	On wall (Inner side) —do—	7.43	

(Continued from Table 1)

collected from sites V, VI, X, XI, XIV and XV which are exposed to high automobile exhaust, contained high concentration of Lead which also get deposited on aerial parts of the plant especially on leaves along with the dust. A positive correlation between Pb^{++} deposition on plants and traffic volume was earlier observed by Smith (1976) and Boralker *et al.*(1992).Though lead is considered to be the most toxic element for plant life, its accumulation in the moss samples without affecting their natural growth, is indicative of its extracellular uptake.

Of the six studied taxa, *Gymnostomum calcareum* overtook others in Ni^{++} accumulation (3.95ppm) at site II (pH 7.45).Interestingly, *Hyophila spathulata* showed highest concentration of Cr^{+++} (1.53ppm) in disregard of its substratum which contained only 0.33ppm of this element. Likewise,Cr^{+++} content in *Hyophila spathulata* (site V, VI) and *Hydrogonium consanguineum*(site X,XI,XIV and XV)was also more than that found in their respective substrata. *Hyophila spathulata* also showed maximum accumulation of Cd^{+++}. (0.30ppm) at siteV, where the substratum (pH 7.12) contained only 0.08ppm of Cd^{+++}. Mn^{++} content was highest (10.02ppm) in *Gymnostomum calcareum* (site II), whereas its substratum(pH 7.47) contained only17.94ppm of Mn^{++}. Likewise, Cd^{+++} content in *Hydrogonium consanguineum* at site XVII (pH 7.43)was also less (1.67ppm) as compared with that found in its supporting substrata (20.81ppm). *Hyophila spathulata* growing on siteV showed more Cu^{++} content (4.01ppm) than that found (1.14ppm) in its supporting substrata(pH7.12).The same taxon collected from site VIII(pH 7.56) was found to contain only 2.25 ppm Cu^{++} inspite of its relatively Cu^{++} rich substratum(23.39ppm). Highest Zn^{++} concentration (56.70ppm) was observed in *Hydrogonium consanguineum* at site XII, whereas in its substratum (pH 7.06) it was 94.45 ppm. The Zn^{++} content in the substrata at site II, V, X and XIV was much lesser, but the moss growing on these substrata were found to accumulate concentration of Zn^{++} much higher than that of the substratum (Table 2). Co^{+++} concentration was highest (0.13 ppm) in *Hydrogonium consanguineum* growing at site XVII while its highest content in the substratum was observed to be 0.19 ppm at two sites (site II and Site XVII). The data showed that the affinity of the plants for this metal ion and its accumulation in the substratum was least in almost all the sites studied. Micro-element Fe^{++} was highest (347.00 ppm) in *Hyophila spathulata* growing at site V, whereas its content in the supporting substratum (pH 7.12) was 82.04 ppm. *Hyophila spathulata* at site VI (158.00ppm) and *Hydrogonium consanguineum* at sites X (49.26ppm) and XII (43.03ppm) accumulated Fe^{++} from air and precipitation since their respective substrata lacked any iron content.

The differences in the elemental content of different taxa may be due to their genetic differences, which govern the variations in their potential to uptake the heavy metals from the substratum (endohydrically) and/or through surface absorption (ectohydrically) by the aerial parts of the plant from the atmosphere. Occurrence of mainly six taxa i.e. *Anoectangium clarum, Gymnostomum calcareum, Hyophila involuta, H. spathulata, Hydrogonium arcuatum* var. *gangeticum* and *Hydrogonium consanguineum* in the studied polluted sites is indicative of their tolerance capacity and superior adaptability in polluted sites as compared with several other moss taxa found luxuriantly growing on not far removed sites/substrata. The ability of bryophytes to colonize heavy metal enriched sites perhaps suggest their higher degree of adaptation resulting from the evolution of metal tolerant ecotypes which is further aided by reduced competition in such sites as suggested by Antonovics et al., (1971).

REFERENCES

Ananyan, V.L., L.A. Araratyan and V.A. Manakyan. 1991. Accumulation of chemical elements and radionuclides in mosses. *Ecologiya,* 2: 82-85.

Antonovics, J., A.D. Bradshaw and R.G. Turner. 1971. Heavy metal tolerance in plants. *Advances in Ecological Research,* 7: 1-85.

Bargagli, R., F. Monaci and C. Agnorelli. 2003. Oak leaves as accumulators of air borne elements in an area with geochemical and geothermal anomalies. *Environmental Pollution,* 124(2): 321-329.

Bignal, K.L., M.R. Ashmore and A.D. Headley. 2008. Effects of air pollution from road transport on growth and physiology of six transplanted bryophytes species. *Environmental Pollution,* 156:332-340.

Boralkar, D.B., S.K. Tyagi and S.B. Singh. 1992. Autoexhaust lead pollution of roadside ecosystem in Delhi. *J. IAEM,* 19: 21-27.

Couto, J.A., J.A. Fernandez, J.R. Aboal and A. Carballeira. 2004. Active biomonitoring of element uptake with terrestrial mosses: a comparison of bulk and dry deposition. *Science of the Total Environment,* 324 (1-3): 211-222.

Fernandez, J.A., A. Ederra, E.Nunez, J. Martinez Abaigar, M. Infante, P. Heras, M.J. Eliaz, V. Masimpaka and A. Carballeira. 2002. Biomonitoring of metal deposition in northern Spain by moss analysis. *Science of the Total Environment,* 300 (1-3):115-127.

Garcia-Alvaro, M.A., J. Martinez-Abaiger, E. Neinez-Olivera and N. Beaucourt. 2000. Element concentrations and enrichment ratios in the aquatic moss *Rhynchostegium riparioides* along the river Iregua (La Rioja, Northern Spain). *The Bryologist,* 103 (3) : 518-533.

Herpin, U., U. Siewers, K. Kreimes and B. Market. 2001. Biomonitoring-evaluation and assessment of heavy metal concentrations from two German moss-monitoring surveys. *Tasks for Vegetational Science,* 35: 73-96.

Jones, K.C., P.J. Peterson and B.E. Davies. 1985. Silver and other metals in some aquatic bryophytes from streams in the lead mining district of mid-Wales, Great Britain. *Water, Air & Soil Pollution,* 24(3):329-338.

Le Blanc, F., D.N. Rao and G. Comeau. 1971. Flouride injury symptoms in epiphytic lichens and mosses. *Canadian Journal of Botany,* 49 (9):1691-1698.

Lee, J. 1972. Lead Pollution from a factory manufacturing anti-knock compounds. *Nature,* 238: 165-166.

Markert, B. 1993. Plants as biomonitors. Indicators for heavy metals in the terrestrial environment. *Weinheim,* : VCH, XXXIV + 644pp.

Michael, S. and E. D. Rudolf. 1979. Terrestrial bryophytes as indicators of air quality in south-eastern Ohio and adjacent west Virginia, U.S.A Ohio. *J. Sci.,* 79(5): 204-212.

Okland, T, R.H. Okland and E. Steinnes. 1999. Element concentration in the boreal forest moss *Hylocomium splendens*: Variation related to gradients in vegetation and local environmental factors. *Plant and Soil,* 209 (1): 71-83.

Olajire, A. A. 1998. A survey of heavy metal deposition in Nigeria using the Moss Monitoring method. *Environment International,* 24 (8): 951-958.

Pakarinen, P. and K. Tolonen. 1976a. Studies on the heavy metal content of ombrotrophic *Sphagnum* species. *Proc. Int. Peat Congr.,* 11976, 2 : 264-275.

Pakarinen, P. and K. Tolonen. 1976b. Regional survey of heavy metals in peat mosses (*Sphagnum*). *Ambio,* 5:38-40.

Punning, J.-M. and T. Alliksaar. 1997. The trapping of fly-ash particles in the surface layers of *Sphagnum* dominated peat. *Water, Air & Soil Pollution,* 94(1-2): 59-69.

Ross, H.B. 1990. On the use of mosses *Hylocomium splendens* and *Pleurozium schreberi* for estimating atmospheric trace metal deposition. *Water, Air & Soil Pollution,* 50 : 63-76.

Samecka-Cymerman, A. and A.J. Kempers. 1998. Comparison between natural background concentration of heavy metals in bryophytes from the Sudety Mountains and Swiss Alps. *Chemosphere,* 36 (12) : 2661-2671.

Schang, J., R. P. Jon, E. Steinnes and R. C. Henry. 1990. Multivariate analysis of trace elements data from moss samples used to monitor atmospheric deposition. Atmospheric Environment part *A Gen. Top.*, 24(10) : 2625-2632.

Smith, W.H. 1976. Lead contamination of roadside ecosystem. *J. Air Pollut. Cont. Assoc.*, 26: 753-766.

Vázquez, M.D., J. López and A. Carballeira. 1999. Uptake of heavy metals to the extracellular and intracellular compartments in three species of aquatic Bryophyte. *Ecotoxicolgy and Environmental Safety,* 44(1): 12-24.

Viskari, E.L., R.Rekila, S.Roy, O. Lehto, J. Ruuskanen and L. Karenlampi. 1997. Air borne pollutants along a roadside : Assessment using snow analysis and moss bags. *Environmental Pollution,* 97(1-2): 153-160.

Wolterbeek, H.T., P. Kuik, T.G. Verburg, U. Herpin, B.Market and L.Thoni. 1996. Moss interspecies comparison in trace element concentration. *Environmental Monitoring and Assessment,* 35(3): 263-286.

Zechmeister, H.G., D. Hohenwallner, A. Riss and A. Hanus- Illnaar. 2003. Variations in heavy metal concentration in the moss species *Abietinella abietina* (Hedw.) Fleisch. according to sampling time, within site variability and increase in biomass. *Science of the Total Environment, 301*(1-3): 55-65.

Pb. Univ. Res. J (Sci.), Vol. 59, 2009, pp. 91-105

ON TWO NEW SPECIES OF THE GENUS *PHOREIOBOTHRIUM* LINTON, 1889 FROM CARTILAGINOUS FISHES FROM DIGHA COASTAL WATERS, BAY OF BENGAL, INDIA

P. B. Pramanik and *B. Manna

Parasitology Research Laboratory, Department of Zoology,
University of Calcutta, 35 Ballygunge Circular Road, Kolkata 700019

Abstract

Two new species of the genus *Phoreiobothrium* Linton, 1889 *P. moraveci* and *P. limbatus* are described from the spiral intestine of cartilaginous fishes, *Carcharias acutus* Ruppell and *Carcharhinus limbatus* Valenciennes from the coastal waters of Digha, Bay of Bengal. These two species differ from the known valid species of the genus in the shape, size of the scolex, number of testes and position of the vagina.

Key words : *Phoreiobothrium, Carcharias, Carcharhinus*, Digha, spinral intestine.

INTRODUCTION

The genus *Phoreiobothrium* was erected by Linton (1889) with its type species *P. lasium* from *Carcharias obscurus, Scoliodon terrae novae*, and *Vuloecula marina* from Woods Hole, also reported from *Carcharhinus commersonii, C. limbatus, C. milberti*, from Galaocerdo arcticus He recorded *P. triloculatum* from *Carcharhinus obscurus* at Woods Hole and Baeufort, and also in *Scoliodon terrae novae* at Baeufort, in *Carcharhinus milberti* at Woods Hole (Linton, 1901). Again he reported *P. exceptum* and *P. pectinatum* from *Cestracian zygaena* at Woods Hole (Linton,1924). Southwell (1925) synonymised *Phoreiobothrium* with *Cylindrophorus*. Perrenoud (1931) after a detailed study of Linton's species suggested the retention of the name *Phoreiobothrium*. Shuler (1938) redescribed *Phoreiobothrium lasium* from *Hypoprion brevirostris* at Tortugas, Florida and argued that *Phoreiobothrium* and *Cylindrophorus* should be regarded as distinct genera. Baer and Euzet (1962) on examination of Southwell's collection on *Onchobothriidae* disagreed with Southwell's identifications giving reasons and proposed the valid name *Phoreiobothrium lasium* for *Cylindrophorus lasius* and *P. triloculatum* for *C. triloculatus*.

Cheung *et al.* (1982) described *P. tiburonis* from *Carcharhinus obscurus*. Srivastava and Capoor (1982) reported *P. puriensis* from *Zygaena blochi*, collected from Puri, Orissa, India. Later, Shinde, *et al.*(1984) reported *P. arabiansi* collected from Ratnagiri, India and Shinde and Jadhav (1987) reported *P. ratnagiriensis* from the same place and same host. Jadhav *et al.* (1990) reported *P. carchariase* and *P. shindei* from *Carcharias acutus*, collected from Bombay. *P. vinodae* another species is added by Jadhav (1993) from the same host and same place. *P. girijamami* was erected by Shinde *et al.* (1993) from *Carcharias acutus*, caught from Ratnagiri, India. Another species *P. manirei* was created by Caira *et al.* (1996) from the great hammer headed shark *Sphyrna mokarran* collected off the west coast of Florida, U.S.A. Again Caira *et.al.* (2005) created five new species *Phoreiobothrium perilocrocodilus, P. anticaporum, P. lewiense ,P. robertsoni and P. blissorum* from the carcharhinform sharks. In their exhaustive study Caira *et al.* (2005) considered five species of genus *Phoreiobothrium, P. ratnagiriensis, P. shindei, P. girijamami,P. arabiensi and P. vinodae* (see Shinde and Jadhav,1993, Shinde *et al.*, 1984, 1990, 1993, and Jadhav , 1993 respectively) as *species inquirendae*. They also found both *P. aurangabadensis* Jadhav and Shinde, 1984 and *P. carchariasae* Jadhav *et al.*, 1990 as *nomina nuda*.

The valid species of the genus *Phoreiobothrium* are -

1. *P. lasium* (Linton, 1889) from *Carcharias obscurus* at Woods Hole.
2. *P. exceptum* Linton, 1924 from *Cestracian zygaena* at Woods Hole.
3. *P. pectinatum* Linton, 1924 from *Cestracian zygaena* from Woods Hole.
4. *P. triloculatum* Linton, 1901 from *Carcharhinus commersenii* at Woods Hole.
5. *P. puriensis* Srivastava and Capoor, 1982 from *Zygaena blochi* at Puri, India.
6. *P. arabiensi* Shinde, *et al.*, 1984 from *Carcharias acutus* at Ratnagiri, India.
7. *P. tiburonis* Cheung, *et.al.*, 1982 from

---

*Corresponding Author. *bmanna59in@yahoo.com*
MS Received April 18, 2009; Accepted September 3, 2010

Carcharhinus obscurus at Woods Hole

8. *P. carchariasae* Jadhav *et al.*, 1990 from *Carcharias acutus* collected from Bombay, India.
9. *P. shindei* Jadhav and Jadhav, 1990 from *Carcharias acutus* collected from Bombay, India
10. *P. girijamami* Shinde *et al.*, 1993 from *Carcharias acutus* collected from Ratnagiri, India
11. *P. vinodae* Jadhav, 1993 from *C. acutus* collected from Bombay, India.
12. *P. manirei* Caira *et al.*, 1996 from *Sphyrna mokarran* collected from west coast of Florida, U.S.A.
13. *P. periocrocodilus* Caira *et al.* 2005 from *Negaprion acutidens* from Florida
14. *P. anticaporum* Caira *et al.* 2005 from *N. brevirostris* from Florida
15. *P. blissorum* Caira *et al.* 2005 from *Carcharhinus plumbeus*
16. *P. lewinense* Caira *et al.* 2005 from *Sphyrna lewisi*
17. *P. robertsoni* Caira *et al.* 2005 from *Carcharhinus brachyurus*

MATERIALS AND METHOD

During collection of the helminth parasites, in the present study, from the cartilagenous fishes from Digha coastal waters, Bay of Bengal, India, ten and six cestodes were recovered from the spiral intestine of *Carcharias acutus* and *Carcharhinus limbatus* respectively, which were identified as two new species under the genus *Phoreiobothrium* Linton, 1889. The living cestodes recovered from the spiral intestine of caught in the commercial fish traps of fishermen at Digha coastal waters were fixed keeping the specimens between the two slides pouring FAA fixative from the sides, post-fixed and preserved in 70% ethyl alcohol. The whole mounts of the specimens were prepared following the standard procedure (Pramanik and Manna, 2004). Camera lucida drawings were made under stereo zoom binocular. The average measurements of specimens are recorded in millimeters unless otherwise mentioned. The specimens were identified following Southwell (1927), Yamaguti(1959), and Khalil *et al.* (1994).

Observation

***Phoreiobothrium moraveci* n. sp.** (Fig. 1 and 2)

Family	Onchobothriidae Braun, 1900
Genus	*Phoreiobothrium* Linton, 1889
Species	*P. moraveci* n. sp.

Ten specimens of the cestode parasites were collected from the spiral valve of one *Carcharias acutus* Ruppell, 1837 at Digha coast, Bay of Bengal, India, on 26th November, 1997. The worms are thin, 22.58mm long; total number of proglottids 56. The scolex is some what squarish, measures 0.18mm in length and 0.22mm in breadth, bears four sessile elongated bothridia. The bothridia is armed with a pair of hooks. Each hook is bifurcated sickle-shaped with a handle. The length of the handle of the inner hook is 0.06mm. The upper hook is 0.09mm long while lower hook is 0.094mm. The outer hook is three pronged with a handle. The handle length is 0.03mm. The largest prong length is 0.08mm, middle prong length is 0.069mm and shorter prong length is 0.02mm. A single spherical small accessory sucker at the anterior extremity of each bothridia is present at the junction of hooks and measures 0.05mm. The scolex is followed by a long and narrow neck with minute spines of 0.004mm length. The length of neck is 5.87mm and breadth is 0.082mm.

The mature segments are four times longer than broad, with straight lateral margin without spines and measure 0.85mm in length and 0.2mm in breadth. Testes are 55 in number, pre-ovarian, rounded, medium in size, 0.034mm in diameter, evenly distributed in the central medulla from ovary to anterior margin of segment. The cirrus pouch is sub globular, 0.13-0.07mm, obliquely placed, just posterior to the middle of the segment. The cirrus is thick, slightly coiled tube, inside the cirrus pouch. The vas deferens is a thin tube, directed anteriorly. Ovary is bilobed 'V'-shaped situated near the posterior margin of the segment; lobes are small in size, extend anteriorly, with irregular margin, each lobe being 0.143mm long and .06mm wide.

Vagina is anterior to cirrus pouch, uterus is an elongated, thin tube, runs transversely up to the middle of the segment, takes a turn to the posterior side, runs in the middle of the segment, reaches and open into the ootype and measures 0.68mm in length, 0.04mm in breadth. Genital pore small, oval, situated just below the middle of the segment, irregularly alternate, measures 0.04mm in length and 0.02mm in breadth. The ootype is oval, 0.07mm long and 0.04mm wide. The vitellaria are granular, corticular, thin strips in two lateral fields, from the anterior to the posterior margin of the segment.

Host -	*Carcharias acutus* Ruppell, 1837
Location -	Spiral intestine
Locality -	Digha coast
No. of specimen -	Ten
Date of collection -	26th November 1997

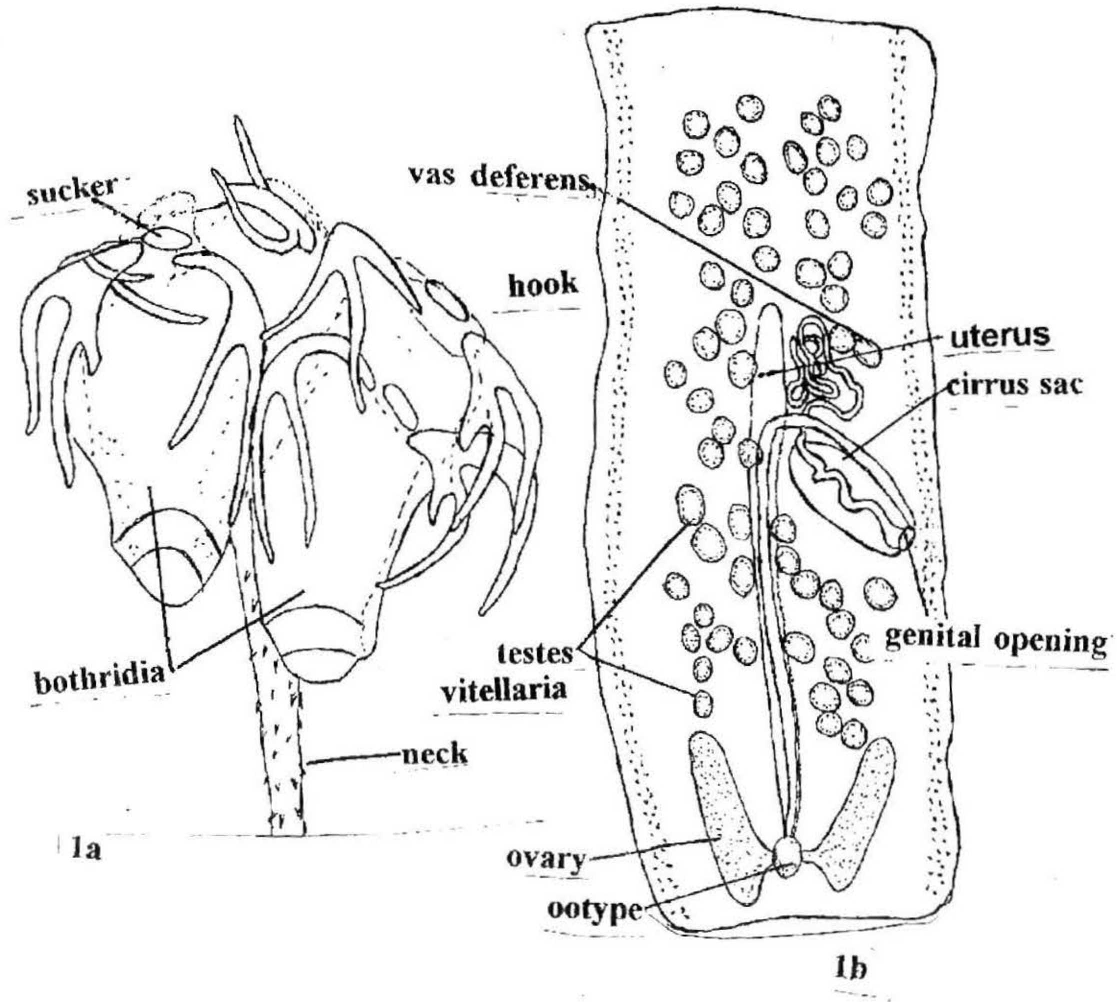


Fig. 1: *Phoreiobothrium moraveci* n.sp.; Camera lucida drawing : 1a) scolex and 1b) mature proglottid

Holotype -	One with four paratype in a single slide
Paratype -	Four with the holotype in the same slide
Deposition -	Deposited to the Parasitology laboratory, Department of Zoology, University of Calcutta, at present.
Accession No. -	000 016/03

Specific diagnosis :

The worm under discussion has a scolex some what squarish, medium in size without spines, bothridium armed with paired hooks, inner hook with two prongs, outer hook with three prongs and presence of muscular rim at posterior end. Neck long and with spines. Testes 55 (49-58) in number medially distributed, ovary bilobed, 'U'-shaped and vitellaria granular, corticular and subcorticular in position.

Remarks

The observed species differs from *P. lasium* Linton, 1889 which has tubular bothridium, posterior end divided into a number of loculi by transverse septa ; hooks paired , tripronged, inner prong small and symmetrical, ovary granular and vagina anterior to cirrus pouch. The present cestode differs from *P. exceptum* Linton, 1924 which has bothridium enlarged towards the posterior end and six loculi at the posterior end only, the hooks paired and bifurcated.

The present tapeworm differs from *P. pectinatum* Linton, 1924 which has bothridium with 7 loculi at the posterior end, the septa of loculi bordered with 7 papillae, hooks

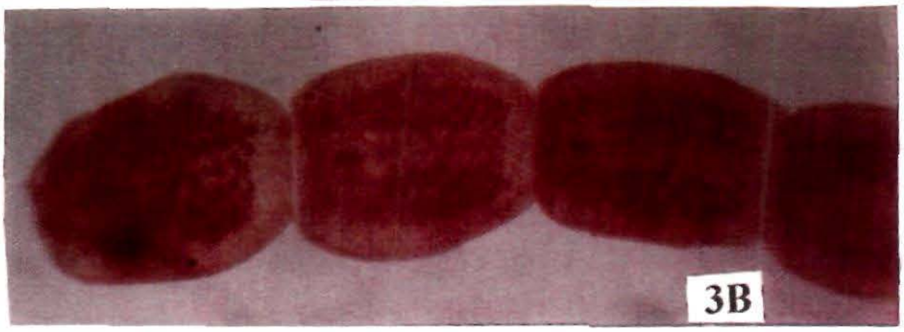


Fig. 2: phoreiobothrium moraveci n.sp.). ; Photomicrograph ;
A.-scolex, B.-mature proglottid

Fig. 3 : Phoreiobothrium limbatus n.sp.; Photomicrograph ;
A. - scolex and B. - mature proglottid

Table – 1. A comparative account of valid species of the genus *Phoreiobothrium* Linton, 1889

Parasite	Scolex	Bothridium	Hooks	Accessory sucker	Neck	Testes	Cirrus pouch
P. lasium Linton, 1889	—	Tubular posterior and divided into no. of loculi by transverse septa	Paired trifurcated inner prong small and symmetrical	Present	Present	—	—
P. exceptum Linton, 1924	—	Elongated towards posterior end, 6 loculi at posterior end	Paired bifurcated	—	—	—	—
P. pectinatum Linton, 1924	—	7-loculi at posterior end, the septa in front of loculi bordered with 7 papillae	Paired trifurcated symmetrical	—	—	—	—
P. triloculatum Linton, 1901		Posterior margin with 3 loculi	Paired trifurcated, symmetrical in middle prong	—	—	150-160	—
P. puriensis Srivastava and Capoor, 1982	Pyramidal in shape	Posterior end into 12 or more loculi	Paired trifurcated	—	Present with spines	125-140	Oval
P. aurangabadensis Jadhav and Shinde, 1984	Quadrangular	Quadrangular, 4, sessile	Paired trifurcated	Present	Present with spine	60-75	Oval, anterior to the middle of segment
P. ratnagiriensis Shinde & Jadhav, 1987	Quadrangular with spines	Single large loculum	Paired trifurcated	Present	Present with spine	180 (175-185)	Oval, elongated, submarginal

Parasite	Ovary	Mature segment	Vagina	Vitellaria	Locality	Host
P. lasium Linton, 1889	Granular	—	Anterior to cirrus pouch	—	Woods Hole	*Carcharias obscurus*
P. exceptum Linton, 1924	—	—	—	—	Woods Hole	*Castracian zugaena*
P. pectinatum Linton, 1924					Woods Hole	*Castracian zygaena*
P. triloculatum Linton, 1901	Granular	—			Woods Hole	*Carcharhinus obscurus*
P. puriensis Srivastava and Capoor, 1982	Anterior to cirrus pouch	2.73-3.35 x 0.507-0.505	Anterior to cirrus pouch	Follicular, rounded small 1-2 rows on each side	Puri (Orissa) India	*Zygaena blochi*
P. aurangabadensis Jadhav and Shinde, 1984	Bilobed	0.48 x 0.22	Anterior to cirrus pouch	Follicular 3-4 in rows	Ratnagiri, India	*Carcharias acutus*
P. ratnagiriensis Shinde & Jadhav, 1987	Bilobed 'U' shaped	0.730 x 0.371	Anterior to cirrus pouch	Follicular, oval, large in single row on each side	Ratnagiri, India	*Carcharias acutus*

Parasite	Scolex	Bothridium	Hooks	Accessory sucker	Neck	Testes	Cirrus pouch
P. vinodae Jadhav, 1994	Rectangular	Each bothridia with a single large loculi	Paired trifurcated	Absent	Present with spine	120-125	Oval
P. manirei Caira *et al.*, 1996	—	Posterior portion subdivided into subloculi	Trifurcated	Present	Present	92-98	Oval just posterior to middle segment
P. shindei Jadhav, Shinde and Jadhav, 1990	Quadrangular	Single large loculi at posterior end	Paired trifurcated	Present	Present	—	—
P. carchariensae Jadhav *et al.*, 1990	Rectangular	Single large loculum at posterior end	Paired trifurcated	Present	Present without spine	108-190	Oval, posterior to middle segment
Phoreiobothrium moraveci n. sp.	Somewhat square	A muscular ring or sucker-like organ present at posterior end of bothridia	Paired trifurcated	Present	Present with spine	49-58	Sub globular, posterior to middle segment
Phoreiobothrium limbatus n. sp.	Trapijium	A muscular ring or sucker like organ present at the posterior end of bothridia	Paired trifurcated	Present	Long neck present	71	Elongated, oval shape

Parasite	Ovary	Mature segment	Vagina	Vitellaria	Locality	Host
P. vinodae Jadhav, 1994	Bilobed	Longer than broad	Anterior to cirrus pouch	Granular	Bombay	*Carcharias acutus*
P. manirei Caira *et al.*, 1996	—		—	—	West coast of Florida, USA	*Sphyrna mokarran*
P. shindei Jadhav, Shinde and Jadhav, 1990	Thick	1.794 x 0.485	Posterior to posteroventral to cirrus pouch	—	Bombay	*Carcharias acutus*
P. carchariense Jadhav *et al.*, 1990	Bilobed 'U' shaped	8.763 x 1.781	Posteroventral to cirrus pouch	Granular wide strips	Bombay (M.S.)	*Carcharias acutus*
Phoreiobothrium moraveci n. sp.	Bilobed 'U' shaped	0.85 x 0.02	Anterior to cirrus pouch	Granular	Digha coast, Bay of Bengal	*Carcharias acutus*
Phoreobothrium limbatus n. sp.	Bilobed 'U' shaped	0.53 x 0.27	Anterior to cirrus pouch	Follicular	Digha coast, Bay of Bengal	*Carcharias limbatus*

Parasite	Ovary	Mature segment	Vagina	Vitellaria	Locality	Host
P. tiburonis Cheung *et al.*, 1982	Bilobed H- shaped	Longer than broad	Anterior to cirrus pouch	Follicular in two lateral line	Florida Keys, USA	*Sphyma tiburo*
P. anticaporum i Caira *et al.*, 2005	H-shaped	Longer than broad	-do-	-do-	Florida, USA	*Nagaprion brevirostris*
P. blissorum Caira *et al.*, 2005	do	Longer than wide	-do-	-do-	Long island, USA	*Carcharhinus plumbeus*
P.lewiensi Caira *et al.*, 2005	Bilobed, H-shaped	Not seen	-do-	-do-	North Carolina coast, USA	*Sphyma lewini*
P. perilocrocodilus Caira *et al.*, 2005	Bilobed , H- shaped	Longer than broad	Anterior to cirrus pouch	Follicular in lateral line	Darwin harbour, Australia	*Negaprion acutidens*
P. robertsoni Caira *et al.*, 2005	Bilobed , H- shaped	Longer than broad 0.53 x 0.27	Anterior to cirrus pouch	-do-	Geraldton, Western Australia	*Carcharhinus brachyuus*

Parasite	Scolex	Bothridium	Hooks	Accessory sucker	Neck	Testes	Cirrus pouch
P. tiburonis Cheung *et al.*, 1982	Rectangular	4 rectangular bothridia;	Paired tri tripronged, with one anterior and 1 posterior loculus	Absent	Present with spine	60-91	Oval
P. anticaporum i Caira *et al.*, 2005	-do-	-do-	Paired, tripronged, with one longer anterior and one shorter postrior loculus	Absent	Present	36-54	Oval
P. blissorum Caira *et al.*, 2005	-do-	-do-	Paired trifurcated	Absent	Present	103-127	Oval
P. lewiensi Caira *et al.*, 2005	Rectangular	-do-	Paired trifurcated	Absent	Long	173	Oval
P.perilocrocodilus Caira et al., 2005	Rectangular	-do-	Paired trifurcated	Absent	Ishort with spine	36-49	Sub globular
P. robertsoni Caira *et al.*, 2005	-do-	rectangular	Paired trifurcated	Absent	Long neck with inconspicuous posterior margin	74-132	Elongate ovals

Parasite	Scolex	Bothridium	Hooks	Accessory sucker	Neck	Testes	Cirrus pouch
tiburonis Cheung *et al.*, 1982							
P. anticaporum *i* Caira *et al.*, 2005							
P. blissorum Caira *et al.*, 2005							
P.lewiensi Caira *et al.*, 2005							
P. perilocrocodilus Caira *et al.*, 2005							
P. robertsoni Caira *et al.*, 2005							

paired, tripronged and symmetrical. The present worm differs from *P. triloculatum* Linton, 1901 which has bothridium with three loculi in posterior margin; hooks paired, tripronged, symmetrical, tubercle on middle prong, testes 150-160 in number, ovary granular. The present form differs from *P. puriensis* Srivastava and Capoor, 1982 which is having pyramidal scolex, bothridium with posterior end divided into 12 or more loculi, neck present with spines, testes 125-140 in number, cirrus pouch oval, vagina anterior to cirrus pouch, and vitellaria follicular.

The present cestode differs from *P. arabiansi* Shinde *et al.*,1984 which has scolex quadrangular, bothridia quadrangular, each with tripronged hooks and testes 60-75 in number. The present worm differs from *P. ratnagiriensis* Shinde and Jadhav, 1987 which has quadrangular scolex with spines, bothridia with a sessile large locula at posterior end, testes 180 (175-185) in number, mature segments with spines, vitellaria follicular in a single row. The present tapeworm differs from *P. shindei* Jadhav *et al.*, 1990 which has quadrangular scolex with spines, bothridium with a single large loculus at posterior end, neck without spine, testes 89-92 in number, cirrus pouch oval, vagina posterior to cirrus pouch. The present worm differs from *P. carchariasae* Jadhav *et al.*, 1990 in having the scolex tetrangular with a single large loculus at posterior end, neck without spines, testes 180-190 in number, cirrus pouch oval, vagina postero-ventral to cirrus pouch and vitellaria granular with wide strip. The present worm differs from *P. vinodae* Jadhav, 1994 which has rectangular scolex, each bothridium with a single large loculum at posterior end, neck without spine, testes 120-150 in number, ovary bilobed, lobes are small, and vagina anterior to cirrus pouch. The observed specimen differs from *P. girijamami* Shinde *et al.*, 1994 which has quadrangular scolex; testes oval, 150 in number; genital pore in the middle of the segment. The present specimen differs from *P. manirei* Caira *et al.*, 1996 which has 4 muscular papillae on the anterior margin of the accessory sucker, numerous small protrusions with central cilium-like projections conspicuous throughout the posterior margin of each bothridium, bothridia posteriorly subdivided into sub-loculi and hooks with extended bases and with 2 rather than 3 prongs. The present species also differs from *P. perilocrocodilus* Caira *et al.* , *2005*, *P. anticaporum* Caira *et al.*, 2005, *P. manierei* Caira *et al.*, 1996, *P. tiburonis* Cheunga *et al.*, 1982 , *P. blissorum* Caira *et al.* , *2005*, *P. robertsoni* Caira *et al. 2005*, and *P. lewinense* Caira *et al. 2005* in the arrangement and number of testes and other characteristics.

Considering all the above it is found that the species under consideration is new to science. The authors propose its name as *Phoreiobothrium moraveci* n.sp. in honour of an eminent Parasitologist Dr. F. Moravec, Institute of Parasitology, Academy of Science, Czechoslovakia.

Phoreiobothrium limbatus n. sp.

Species *Phoreiobothrium limbatus* n. sp. (Fig. 3)

Six specimens of the cestode parasites were recovered from the spiral valve of *Carcharhinus limbatus* Valenciennes, 1841, in the month of December, 1995. The scolex is somewhat trapezium-shaped, narrow posteriorly and broad anteriorly. It is 0.33mm in length and 0.47mm in breadth anteriorly, and 0.27mm wide posteriorly. It bears four sessile elongated bothridia, broad anteriorly and narrow posteriorly; a muscular ring present in the posterior end of bothridia. The inner diameter of the rim is 0.038mm, the outer 0.067mm and the thickness of the rim is 0.019mm. Each bothridium measures 0.32mm in length and 0.02mm in breadth and is armed with a pair of hooks. The hooks are tripronged. In the outer hook, the middle prong is longer than the outer two. The middle prong measures 0.1mm in length and 0.013 mm in breadth, the outer prong measures 0.09mm in length and 0.01mm in breadth, the inner prong measures 0.04mm in length and 0.02mm in breadth, and handle measures 0.04mm in length and 0.02mm in breadth. In the inner hook, the handle length is 0.07mm, the middle prong length 0.12mm. and outer larger prong is 0.1mm and shorter prong length 0.02mm. A single accessory sucker at the anterior extremity of each bothridia present at the junction of hooks, measures 0.07mm in diameter. The neck is 2.4mm long and 0.24mm wide, covered with spines, spines are 0.019mm long and the handle length is 0.005mm.

The number of proglottids in the strobila is 26. The immature proglottids are broader than long, but mature proglottids are longer than broad. The middle proglottids length is 0.17mm where as the last proglottid length is 1.4mm and breadth is 0.68mm. Testes in each mature segment are oval, 0.048mm long and 0.034mm wide, pre-ovarian, 71 (64-75) in number, evenly distributed in the central medulla from ovary to anterior margin of the segment,. The cirrus pouch is large, 0.34mm in length and 0.13mm in breadth, elongated, oval, obliquely placed, bend upwardly extending up to the middle of the segment. Cirrus short, 0.08mm long and 0.03mm wide. Spines present in the surface of cirrus. Vas deferens is a thin tube directed anteriorly. 'U'-shaped ovary situated near the posterior margin of the segment, lobes are extending anteriorly and measures 0.34mm in length and 0.13mm wide. Vagina, a thin tube, starts from the common genital pore, anterior to cirrus pouch, elongated, runs transversely and angularly up to the middle of the segment, takes a turn to posterior side, runs in the middle of segment, reaches and opens into the ootype. Genital pores are small, oval, 0.02mm in diameter, marginal, irregularly alternate in more or less middle of the segment. The ootype is round in shape, medium in size, measures 0.02mm in diameter .The vitellaria are follicular, corticular and subcorticular, from anterior margin to the posterior margin of the proglottid.

Host - *Carcharhinus limbatus* Valenciennes, 1841

Location - Spiral valve

Locality - Digha coast

Date of collection - 10th December, 1995

No. of specimen - Six

Holotype - with five paratypes in a single slide

Paratype - Five

Deposition - At present deposited to the Parasitology laboratory, Department of Zoology, University of Calcutta

Accession No. - 000 0035/03

Specific diagnosis :

The scolex somewhat trapezium-shaped without spines, bothridia without loculum at posterior end, but a sucker-like organ present in the posterior region. An accessory sucker present in the anterior portion of the bothridia; neck short with spines, evenly distributed testes 71 in number, ovary 'U'-shaped, bilobed ; vitellaria follicular, corticular and sub-corticular in position.

Remarks

The present specimen differs from *P. lasium* Linton, 1889 which is having tubular bothridium, posterior end divided into a number of loculi by transverse septa, only anterior sucker present in the anterior end of bothridium , ovary granular. The present cestode differs from *P. exceptum* Linton, 1924 which is having the bothridium enlarged towards the posterior end and six loculi present at the posterior end only, the hooks paired and bipronged.
he present tapeworm differs from *P. pectinatum* Linton, 1924 which is having the bothridium with 7 loculi at the posterior end, the septa in front of loculi bordered with 7 papillae, posterior portion without sucker-like organ. The present worm differs from *P. triloculatum* Linton, 1901 which has the bothridium, posterior margin with three loculi, hooks paired, trifurcated, symmetrical, tubercle on middle prong, testes 150-160 in number.

The present worm differs from *P. puriensis* Srivastava & Capoor, 1982 which has scolex pyramidal in shape, bothridia with posterior end divided into 12 or more loculi, each proglottid with 125-140 testes, vitellaria follicular.The present cestode differs from *P. arabiansi* Shinde, *et al.*, 1984 which has 4 sessile, quadrangular bothridia, no sucker like organ in the posterior portion of bothridia, proglottid with 60-75 testes, vagina posterior to cirrus pouch. The present worm differs from *P. ratnagiriensis* Shinde and Jadhav, 1987 in having the scolex quadrangular with spined bothridium, a single large loculus at posterior end, testes 180 (175-185) in number, vitellaria follicular in a single row.

The present tapeworm differs from *P. shindei* Jadhav *et al.*, 1990 in having the scolex quadrangular with spined bothridium, a single large loculus at posterior end, testes 89-92 in number, cirrus pouch oval just posterior to middle of the segment, vagina posterior to cirrus pouch, genital pore just posterior to middle of segment. The present worm differs from *P. carchariasae* Jadhav *et al.*, 1990 which has a rectangular scolex, bothridium with a single large loculum at posterior end, neck present without spines, testes 180-190 in number, oval cirrus pouch situated posterior to middle of the segment, vagina posterior, ventral to cirrus pouch and vitellaria granular with wide strip. The present worm differs from *P. vinodae* Jadhav, 1994 which has a rectangular scolex, single large loculum at posterior end, neck without spine, testes 120-150 in number, ovary bilobed, vitellaria granular. The observed specimen differs from *P. girijamami* Shinde *et al.*, 1993 which has a quadrangular scolex, testes oval, 150 in number; genital pore in the middle of the segment; vitellaria granular. The observed specimen differs from *P. manirei* Caira *et al.*, 1996 which has 4 muscular papillae on the anterior margin of the accessory sucker. Numerous small protrusions with central cilium-like projections remain conspicuous throughout the posterior margin of each bothridium; bothridium posteriorly subdivided into subloculi ; hooks with extended bases and 2 rather than 3 prongs. The present worm differs from *P. moraveci* n. sp. which has a very long neck with spine, proglottids much longer, cirrus subglobular, testes 49-58 in number. The present species also differs from *P. perilocrocodilus* Caira *et al.*, *2005, P. anticaporum* Caira *et al.*, *2005, P. manierei* Caira *et al.*, 1996, *P. tiburonis* Cheunga *et al.*,

1982 , *P. blissorum* Caira *et al.* , *2005, P. robertsoni* Caira *et al. 2005,* and *P. lewinense* Caira *et al. 2005* in the arrangement and number of testes and other characteristics.

The differences of the present species with other valid species (Table 1) as noted justify the recognition of this worm as a new species and hence the name *Phoreiobothrium limbatus* n. sp. is proposed after the species name of its host.

A key to the species of the Genus *Phoreiobothrium* Linton, 1889

Muscular papillae on anterior accessory sucker 1

1.	Testes	36-49	*Phoreiobothrium perilocrocodilus* Caira *et al. 2005*
	Testes	36- 54	*P. anticaporum* Caira *et al. 2005*
	Testes	60-69	*P. tiburonis* Cheunga *et al.* 1982
	Testes	92-98	*P. manierei* Caira *et al.* 1996
	Testes	103-127	*P. blissorum* Caira *et al. 2005*
	Testes	74-132	*P. robertsoni* Caira *et al. 2005*
	Testes	173	*P. lewinense* Caira *et al. 2005*

Without muscular papillae on anterior accessory sucker 2

2\. Scolex elongated .... *P. lasium* Linton, 1889

Scolex triangular .... *P. exceptum* Linton, 1924

Scolex rounded 3

Scolex quadrangular 4

Scolex rectangular... 5

Scolex squarish .... *P. moraveci* n. sp.

Scolex pyramidal........................... *P. puriensis* Srivastava & Capoor, 1982

Scolex trapezium-shaped .... *P. limbatus* n. sp.

3\. 7 loculi on each bothridia .... *P. pectinatum* Linton, 1924

3 loculi on each bothridia .... *P. triloculatum* Linton, 1901

4\. Neck spinose..6

Neck without spines .... *P. shindei* Jadhav and Jadhav, 1990

5\. Vagina posterior to cirrus pouch .... *P. carchariasae* Jadhav *et al., 1990*

Vagina anterior to cirrus pouch .... *P. vinodae* Jadhav, 1993

6\. Testes 60-75 7

Testes 150 .... *P. girijamami* Shinde *et al.*, 1993

Testes 175-185 .... *P. ratnagiriensi* Shinde and Jadhav, 1987

7 Vagina posterior to cirrus pouch .... *P. arabiansi* Shinde, *et al.*, 1984

ACKNOWLEDGEMENTS:

The authors are indebted to the Department of Science and Technology, Govt. of West Bengal for financial assistance in the project . The authors also express their gratitude to Dr. Tapan Kumar Chatterjee, Senior Scientist, Zoological Survey of India for his assistance in identifying the hosts collected from Digha coastal waters and to the Head, Department of Zoology, University of Calcutta, for providing facilities for this research work.

REFERENCES

Baer, J.G. and L. Euzet. 1962. Revision ciritique des cestode tétraphyllides décrits par T. southwell (1 re partie). *Bulletin de la Societé Neuchâteloise des Sciences Naturelles,* 85 : 143-172.

Braun, M. 1894-1900. In H.G. Bronn, Klassen und Ordnungen des Thierreichs, Band IV, Vermes; Abtheilung I.b., Cestodes, i-vii : 927-1731.

Caira, J.N., C.J. Healy, and J. Swanson . 1996. A new speices of *Phoreiobothrium* (Cestoidea : Tetraphyllidea) from the great hammer headed stark *Sphyrna mokarran* and its implications for the evolution of the oncobathriid scolex. *J. Parasitol.* , 82(3) : 458-462.

Caira, J.N., C. Richmond and J. Swanson . 2005. A revision of Phoreiobothrium (Tetraphyllidae : Onchobothriidae) with Descriptions of Five New species. *J. Parasitol*, 91 :1153-1174.

Cheung, P.L., Nigrelli, R.F. and Ruggieri, G.D. 1982. *Phoreiobothrium tiburonis*, new species (Cestoda : Onchobothridae) from the bonnethead shark, *Sphyrna tiburo (L.) Journal of Acquaculture*, 2 : 81-85.

Jadhav, B.V. 1993. A new parasite from Onchobothriidae from Bombay. *Indian J. Helminthol..*, 45(1/2) : 96-99.

Jadhav, B.V., G.B. Shinde, and D.H. Jadhav .1990. *Phoreiobothrium carchariasae* n. sp. Cestoda: Onchobothridae from Bombay. *Indian J. Parasit.* 32(2) : 122-124.

Khalil, L.F., A. Jones, and , R.A . Bray. 1994. Key to the cestode parasites of vertebrates. C.A.B. International. Wallingford. U.K.

Linton, E. 1889. Notes on Entozoa of marine fishes. *Annual Report U.S. Commission Fish and Fisheries* for 1886, Washington, 15 : 453-511.

Linton, E. 1901. Parasites of fishes of the Woods Hole region. *Bulletin U. S. Comission, Fish and Fisheries* for 1899, Washington, 27, June, 1901, 19 : 405-492.

Linton, E. 1924. Notes on cestode parasites of sharks and rays. *Proc. U. S. Nat. Mus.*, 64 : 1-114.

Perrenoud, W. 1931. Recherches anatomiques et histologiques sur quelques cestodes de sélaciens. *Revue Suisse de Zoologie*, 38 : 469-555.

Pramanik, P.B.and B. Manna 2004. *Balanobothrium shindei* new species (Cestoidea : Lecanicephalidae) from *Stegostoma faciatum* Herman,1783 from Bay of Bengal at Digha coast, West Bangal, India. *Proc. zool. Soc. Calcutta*, 57(1): 53-58.

Shinde, G.B. and B.V Jadhav,. 1987. *Phoreiobothrium ratnagiriensis* sp. nov. (Cestoda : Onchobothridae) from *Carcharias acutus* in India. *Indian J. Helminthol.* XXXIV : 161-165.

Shinde, G.B. and D.H. Jadhav and B.V. Jadhav 1990. A new species of the genus

Phoreiobothrium(Cestoda : Onchobothridae) at Bombay, (M.S.), India. *Rivista Di Parasitologia*, Vol.vii(L) N.1.

Shinde, G.B., B.V. Jadhav and A.D. Mohekar. 1984. *Phoreiobothrium arabiansi* n.sp. (Cestoda : Onchobothriidae) from *Carcharias acutus*. *Indian J. Parasitol.*, 8(2) : 317-318.

Shinde, G.B., R.K Motinge, and K.S. Pardeshi . 1993. On a new species of genus *Phoreiobothrium* (Cestoda : Onchobothriidae) from a marine fish *Carcharias acutus* at Ratnagiri (M.S.), India. *Indian J. Helminthol.*, 45(1/2) : 116-119.

Southwell, T. 1925. Description of ten new species of cestode parasites from marine fishes of Ceylon. *Ceylon Marine Biology Report*, 1 : 259-278.

Southwell, T. 1927. On a collection of Cestodes from Marine Fishes of Ceylon. *Ann. Trop. Med. & Parasit.*, 21 : 73-351.

Srivastav [Sr] A.K. and V.N. Capoor. 1982. On a new cestode, *Phoreiobothrium puriensis* n.sp. *J. zool. Soc., India* , 34(1-2) : 82-85.

Shuler, R.H. 1938. Some cestodes of fish from Tortugas, Florida. *J. Parasito.*, 24 : 57-61.

Yamaguti, S. 1959. "Systema Helminthum. Vol. II. The cestodes of vertebrates. Interscience Publishers Inc., New York and London, pp. 860.

Pb. Univ. Res. J (Sci.), Vol. 59, 2009, pp. 107-109

ABO AND RH(D) BLOOD GROUPS DISTRIBUTION AMONG KHATIKS (SCHEDULED CASTE) POPULATION OF JAUNPUR DISTRICT (UTTAR PRADESH)

Vandana Rai[1], Shailendra Kumar Maurya[2] and Pradeep Kumar[1]

Department of Biotechnology[1], Department of Biochemistry[2]; V B S Purvanchal University, Jaunpur 222001, Uttar Pradesh

Abstract

The present study reports the distribution of ABO and Rh (D) blood groups among 200 unrelated individuals from Khatik (Scheduled Caste) population of Jaunpur district. The overall ABO percentage is B (42.5)> O (24) >A (23) >AB (10.5). The frequencies of Rh-positive and Rh-negative individuals are 95% and 5% respectively.

Keywords: Allele Frequency, Antigens, ABO, Rh (D), Khatik

INTRODUCTION

The ABO locus is located on chromosome 9 at 9p34. 1-q34.2 and encodes glycosyltransferases. ABO locus has three main allelic forms-A, B and O.

The distribution of the four ABO blood types (A, B, AB, O) varies in population throughout the world. It is determined by the frequency of the three alleles of the ABO gene in different populations. The ABO typing is the most important test performed in transfusion practice today. Several studies have been carried out on the distribution of blood groups among several ethnic and caste group populations in India (Bhasin et al., 1994; Singh et al, 1994; Patni and Yadav, 2003; Prabhakar et al, 2005; Sidhu, 2003; Mukhopadhyay and Kshatriya, 2004; Pandey and Singh, 2004; Reddy and Reddy, 2005; Devi and Gangadhar, 2006; Pattanayak, 2006; Rai et al, 2009). The total SC/ST population of jaunpur is approximately 858260, i.e. 21.9% percentage in the total population of the district,which includes chamars, khatik, dome, mushar, dharikar etc. The present communication is an attempt to study the distribution of ABO and Rh (D) blood group systems among the Khatik (Scheduled caste) population of district Jaunpur,

MATERIALS AND METHODS

Blood samples were taken by finger pricks from 200 individuals of Khatik population, and open slide method of ABO blood groups testing and Rh (D) factor was followed (Bhasin and Chahal, 1996). ABO and Rh (D) Typing antisera of Tulip were used for ABO and Rh Typing. The gene frequencies for these two systems were calculated according to the method of Mourant et al. (1976). The details of each subject such as name, age, sex etc. were collected using a brief questionnaire. Informed consent will be taken from each individual.

RESULTS

The frequency distributions of ABO phenotypes with gene frequencies are presented in table 1 and phenotype and gene frequency of Rh is presented in table 2. Among 200 Khatiks tested for ABO blood groups, it was observed that B has the highest frequency (42.5%), followed by group O (24%), group A (23%) and least being group AB (10.5%). The allele frequency of O is highest, about 0.4983 followed by B (0.3162) and the least frequency is found to be A (0.1855). In case of Rh (D) blood groups 95% were positive and 5% were negative. The allele frequencies were recorded 0.776 for D and 0.224 for *d* (Table 2).

Table 1: Distribution of the ABO blood group and their allele frequencies among the Khatik (Scheduled Caste) (Number of samples analysed=200)

Pheno type	**Observed Number**	**%**	**Allele Frequency**
O	48	24%	*A*= 0.1855
A	46	23%	*B*= 0.3162
B	85	42.5%	*O*= 0.4983
AB	21	.5%	

---

*Corresponding Author. *raivandana@rediffmail.com*

MS Received November 1, 2008; Accepted May 20, 2009

Table 2: Distribution of the Rh (D) blood group and their allele frequencies among the Khatik (Scheduled Caste) (Number of samples analysed=200)

Pheno type	Observed Number	%	Allele Frequency
Rh(D) Positive	190	95%	D = 0.776
Rh(D) negative	10	5%	d = 0.224

DISCUSSION

In this study the frequency of blood group B was found to be highest with percentage frequency of 42.5% followed by blood group O with the percentage of 24%, blood group A with the percentage of 23% and the least percentage was that of blood group AB which is 10.5%. Similar frequency distribution of the ABO alleles have been reported in several other Scheduled caste/tribes population of India, like Meghwal and Salvi of Rajasthan (Thukral and Bhasin, 1990), Harijans of Haryana (Kushwaha et al.,1990), Scheduled Castes of Uttar Pradesh(Mandal,1992; Rai et al, 2009) and Scheduled Castes of Punjab (Sidhu, 1994, 1995, 1999, 2003), Bhoska of Uttaranchal (Patni and Yadav, 2003).

In this study, the incidence of Rh (D) positive was 95% and that of Rh (D) negative was found to be 5%. Frequency of the alleles at Rh (D) locus shows wide variations. The recessive allele (d) ranges from as high as 40% to its virtual absence in Chinese, Australians aborigines, Negrito etc. Exceptionally high incidence of Rh negatives yielding frequency of recessive alleles (d) in the range of 50 to 60 % have been reported in Basque (Europe) and Berbers of Moracco (*Mourant et al.* 1976)

The importance of the knowledge of the blood groups in regards to health of an individual is enormous. Apart from their significance in blood transfusion practice, the ABO and Rh blood groups are useful in population genetic studies, researching population migration patterns, as well as resolving certain medico-legal issues, particularly of disputed parentage. It is, therefore, imperative to have information on the distribution of these blood groups in any population group. The ABO blood type has also been reported to be associated with many diseases, though the explanation for the association between ABO blood groups and some disease is still unclear.

ACKNOWLEDGEMENT

The authors would like to thank pathologist Mr. Pradeep for his generous help in blood grouping. We are also very much grateful to Khatik community of Jaunpur district, because without their help and support the present study was not possible.

REFERENCES

Bhasin, M. K. and S.M.S. Chahal.1996. A Laboratory Manual for Human Blood Analysis. Kamla-Raj Enterprise, Delhi.

Bhasin, M.K., H. Walter and H. Danker-Hopfe.1994 . People of India: An Investigation of Biological Variability in Ecological, Ethno-economic and Linguistic Groups. Kamla-Raj Enterprises, New Delhi.

Devi, O.R. and M.R. Gangadhar. 2006 . ABO and Rh(D) blood groups among the Kaniyas of Karnataka. *Anthropologist*, 8(2):145-146.

Kushwaha, K.P.S., J.R. Gaur, S.K. Sangwan and A.S. Yadav. 1990. ABO and Rh(D) blood groups among 19 caste populations of Haryana. *Bionature*, 10: 73-75.

Mandal, P.K. 1992. The ABO and Rh(D) blood groups among five Caste population of Uttar Pradesh. *J Hum. Ecol.*, 3: 57-58.

Mourant, A.E., A.C. Kopec and K. Domaniewska-Sobczak. 1976. The distribution of the human blood groups and other polymorphisms. Oxford University Press, London.

Mukhopadhyay, R. and G.K Kshatriya . 2004 . Distribution of blood groups among Brahmins and Rajputs of Himanchal Pradesh. *Anthropologist*, 6(4) : 289-90.

Pandey, P.L. and M.P.S.S. Singh. 2004. ABO and Rh blood groups among Sindhis of Jabalpur, Madhya Pradesh. *Anthropologist*, 6 (2) : 157.

Patni, S. and A. Yadav. 2003. Blood groups among the Bhoksa of Vikasnagar block of Dehradun, Uttaranchal. *Anthropologist*, 5 (2) : 137-138.

Pattanayak, I. 2006. Distribution of A1A2BO and Rh blood group among the Rajputs of Uttaranchal. *Anthropologist*, 8 (2) : 139-140.

Prabhakar, S.C.J., M.R. Gangadhar and K.R. Reddy. 2005. ABO and Rh (D) blood groups among the Vishwakarmas of Mysore district, Karnataka. *Anthropologist*, 7(1) : 71-72.

Rai, V., R. P. Patel and K. Pradeep. 2009.Blood Groups ABO and Rh (D) among Scheduled Caste of

Jaunpur District. *Anthropologist,* 11(2) : 151-152.

Reddy, B.K.C. and C.S. Reddy. 2005. ABO and Rh(D) blood group distribution among Voddes, a backward caste population of Andhra Pradesh. *Anthropologist,* 7(3): 235-236.

Sidhu S. 1994. Distribution of the ABO blood groups and Rh(D) factor among the Chamars of Punjab. *J. Hum. Ecol.,* 5: 145-146.

Sidhu S. 1995. Distribution of the ABO blood groups and Rh(D) factor among Sikh Harijans of Punjab. *J. Hum. Ecol.,* 6 : 277-278.

Sidhu, S. 1999. Distribution of the ABO blood groups among the Balmiki and Khatk Harijans of Punjab. *J. Hum. Ecol.,* 10: 303-304.

Sidhu, S. 2003. Distribution of the ABO blood groups and Rh(D) factors among the scheduled caste population of Punjab. *Anthropologist,* 5 (3) : 203-204.

Singh, K.S., V. Bhalla and V. Kaul. 1994. The biological variations in Indian populations. People of India, National Series Vol X.,Oxford Univ. Press ,Delhi.

Thukral, R. and M.K. Bhasin. 1990. Blood groups of Meghwal and Salvi, the Scheduled Caste of Rajasthan. *Hum Eco.,*1: 183-184.

Pb. Univ. Res. J (Sci.), Vol. 59, 2009, pp. 111-116

ENHANCEMENT OF VIABILITY OF STORED BAMBOO SEEDS USING SOME PLANT GROWTH REGULATORS

***Richa, M. L. Sharma and Geetika**

Department of Botany, Panjab University, Chandigarh - 160014

Abstract

The effect of exogenous application of growth regulators *viz.* gibberellic acid (GA), indole acetic acid (IAA), naphthalene acetic acid (NAA), benzylamino purine (BAP) and resorcinol (R) were studied on freshly harvested and aged bamboo seeds at fixed intervals of 6 months for a period of 18 months, in two bamboo species i.e. *Dendrocalamus strictus* (Roxb.) Nees and *Bambusa bambos* (L.) Voss. In freshly harvested seeds, none of the treatments was effective in enhancing the vigour and viability, due to supra-optimal levels of plant growth regulators. However with ageing, different treatments were effective at different stages. At 18 months of ageing, R (2.0mM) was most effective in case of *D. strictus* while NAA (0.3mM) was most effective in case of *Bambusa bambos* in increasing germinability and all concentrations of GA, lower concentrations of IAA and R were significantly effective over the control in increasing vigour Index. Seeds viability of both the bamboo species, at this stage of ageing, was gradually declining but had not become nonviable and seed storage under controlled conditions (4°C temperature in a dessicator over anhydrous $CaCl_2$) retained viability for a considerable period of time, upto 3years.

Keywords: bamboo, growth regulators, vigour index, emergence index.

INTRODCTION

Bamboos are fast growing, versatile, arborescent grasses with multiple uses. For centuries, bamboos have been closely related to the agriculture, cottage industries, art, culture and day-to-day life of more than half of the world's population. Bamboos show cyclic flowering and depending on the species, a bamboo may have a flowering cycle anywhere between 3 to 120 years, although most species fall within a range of 15-20 years (Banik, 1987).

Bamboos can either be propagated through seeds or by vegetative means. However, seeds are the best propagules but are scarcely available due to long flowering cycles. Also, when available, they have a very short viability of 2-3 months (Bahadur, 1979; Varmah and Bahadur 1980). These seeds age during storage and eventually lose their ability to germinate. During ageing, the seeds show symptoms like reduced rate of germination (Priestley, 1986), reduced vigour, greater susceptibility to attacks by microorganisms (Harrington, 1973). The end result of delirious changes of stored seeds the loss of germinability (Bucharov and Gantcheff, 1984), with a decrease in the rate of germination and seedling growth (Heydecker, 1972).

Growth regulators are known to modify the growth and development pattern of plants by exerting profound effects on various physiological processes and hence regulating the productivity (Brenner, 1987; Clifford *et al.*, 1986; Setia *et al.*, 1991). Bamboo seeds when available, are available in abundance but due to short viability period they are rendered useless within no time. The present study was undertaken to enhance the viability and storability of ageing bamboo seeds by the application of certain PGRs.

MATERIAL AND METHODS

Freshly harvested seeds of *D. strictus* (Roxb.) Nees and *Bambusa bambos* (L.) Voss were procured from Kerala Forest Research Institute, Peechi.

All the seeds were stored at 4°C (in a dessiccator) over anhydrous calcium chloride. Germination studies were carried out on these seeds at intervals of six months, for 18 months to study the effects of ageing. The seeds were treated with different concentrations of growth regulators:- Gibberellic Acid (0.2,0.5&2.0mM), Indole-3-acetic acid (0.3,1.0&3.0mM), Naphthalene Acetic acid (0.3,1.0&3.0mM), Benzylamino purine (0.2,0.9&2.0mM) and Resorcinol (0.5,2.0&5.0mM).

Germination Studies: Prior to germination studies, the seeds were surface sterilized by soaking them in 0.5% Mercuric Chloride ($HgCl_2$) for two minutes followed by thorough washing in running water. These were later rinsed with distilled water 2-3 times. Ten randomly

---

*Corresponding Author. *puriricha26@gmail.com*

MS Received November 19, 2008; Accepted February 8, 2010

selected surface sterilized seeds were placed equidistantly in pre sterilized petridishes (? 9.0 cm) lined with filter paper. The filter papers were soaked with respective concentrations of PGRs (2-3 ml) and were kept moist throughout the experiment. One set of seeds was placed in petridish, with filter paper soaked in distilled water which served as control. The entire experiment was conducted under laboratory conditions in seed germinator where temperature was maintained at 28°C ± 2°C. The seeds were observed daily and the number of seeds germinated and their respective root and shoot length was recorded for 14 days.

The germination percentage, Vigour index (VI) and Emergence index (Ei) were calculated by the following formulae:

Germination Percentage (G %)

Emergence of radical was considered as an indicator of germination. Number of seeds germinated was noted after every 24 hours for 14 days.

Vigour Index (V I)

Vigour index was calculated by the method of Abdul-Baki & Anderson (1973) by the formula given under: -

$$V\,I = G\,\% \times \text{Root Length (cms)}$$

Emergence Index (E i)

Emergence index was calculated by the formula given by Baskin (1969)

$$Ei = Sn_1/dn_1 + n_2dn_2 + n_3/dn_3 - - - - -nx/dnx$$

Where

n = number of newly germinated seeds on each day

dn = number of days from the day of sowing

dnx= number of days to the final count

Statistical Analysis

The data obtained at 14th day of germination of each seed species at each time interval on each parameter (*i.e.* G%, VI and Ei) was analyzed statistically by applying analysis of variance (ANOVA) test, to analyze whether any treatment, enhanced any of the parameters significantly.

The analysis of variance model is given below:

$$X_{ij} = m + T_j + e_{ij}; \qquad i = 1,2,\ldots,n_j,\; j = 1,2,\ldots\ldots k$$

Where, m= *grand mean*, mean of all the k population means

T_j = *treatment effect*, difference between the mean of j^{th} population and the grand mean

e_{ij} = error term, the amount by which an individual measurement differs from the mean of the population to which it belongs.

X_{ij} = the i^{th} observation resulting from the j^{th} treatment (there are a total of k treatments).

Results

Germination Studies: The germinability declined from 80% in freshly harvested seeds to 70% after 6 months, 50% after 12 months and 18 months of storage in *D. strictus* seeds. In case of *B. bambos* seeds germinability was 80% in freshly harvested seeds which reduced to 70% at 6 months and 12 months and 60% at 18 months of ageing. Other germination and growth parameters (VI and Ei) also decrease due to ageing during storage. In freshly harvested seeds of both the species, none of the PGR treatment was effective in increasing germination and growth. Statistically, in case of freshly harvested and 6 months old seeds of both *D. strictus* and *B. bambos*, all the treatments significantly reduced the germinability of seeds over that of control. After 12 months of ageing, GA (2.0mM) was found to be most effective treatment in case of *D. strictus*, as it significantly increased G%, VI and Ei at 1% level, over that of control (Table 1). In 12 months old seeds of *B. bambos*, the treatments with GA (0.2mM, 2.0mM), NAA (1.0mM) and R (0.5mM, 2.0mM, 5.0mM) effectively increased germination parameters over the control, but only GA (0.2mM) and R (5.0mM) significantly increased the VI over that of control.

With ageing of 18 months, the seeds of both the species still retained considerable viability. In the seeds of *D. strictus*, R (2.0 mM) was the most effective treatment in enhancing G%, to a maximum of 80% and VI and Ei to 611.5 and 1.63, respectively after 18 months of ageing (Table 1). While in *B. bambos* seeds, on the other hand, the treatment with NAA (0.3 mM) was effective in enhancing the G% to a maximum of 90%, all the concentrations of GA and IAA were effective in enhancing VI and Ei (Table 2). Most of the treatments were effective after 18 months of ageing, but the treatments with BAP were found to be mostly detrimental in our studies. Statistically, R (2.0mM) significantly enhanced the VI at 1% level in 18 months old seeds of *D. strictus*. In case of *B. bambos*, the treatments with GA (0.2mM, 0.5mM, 2.0mM), IAA (0.3mM, 1.0mM) and R (0.5mM, 5.0mM) significantly enhanced the VI, while none of the treatments were significantly effective in case of G% and Ei in both the species.

Table 1: Germination parameters of *D. strictus* seed at different ageing intervals after treatment with plant growth regulators.

	Freshly harvested			6 months			12 months			18 months		
PGR (conc. mM)	G%	VI	Ei	G%	VI	Ei	G%	VI	Ei	G%	VI	Ei
GA												
0.2	50 (± 0)*	320 (± 92.6)*	2.3 (± 0.25)	50 (± 5.8)	223 (± 40.3)*	1.33 (± 0.15)*	60 (± 10.0)	101.6 (± 21.7)*	1.72 (± 0.3)	40 (± 5.8)	251.3 (± 32.8)	3.18 (± 0.35)
0.5	50 (± 5.8)*	243.6 (± 31.3)*	2 (± 0.15)	20 (± 5.8)	90.7 (± 27.3)*	0.8 (± 0.26)*	20 (± 10)*	75.7 (± 11.9)*	1.32 (± 0.5)	20 (± 5.8)	129 (± 41.7)	2.4 (± 0.31)
2.0	30 (± 5.8)*	223.7 (± 6.60)*	2.1 (± 0.17)	40 (± 5.8)	193.7 (± 26.6)*	1.49 (± 0.5)	70 (± 11.5)	652.4 (± 27.8)#	2.14 (± 0.17)	50 (± 10.0)	507.7 (± 28.3)#	2.55 (± 0.48)
IAA												
0.3	50 (± 11.5)*	204.3 (± 54.5)*	1.5 (± 0.32)*	30 (± 5.8)	83 (± 20.7)*	0.73 (± 0.25)*	20 (± 5.8)*	107 (± 43.6)*	0.79 (± 0.12)	20 (± 5.8)	41.7 (± 12.1)*	2.58 (± 0.33)
1.0	60 (± 15.3)	390 (± 97.4)*	2.7 (± 0.36)	30 (± 17.3)	178.6 (± 21.0)*	0.97 (± 0.06)*	60 (± 0)	529.2 (± 16.7)#	1.7 (± 0.63)	40 (± 10.0)	261 (± 23.5)	2.56 (± 0.34)
3.0	70 (± 5.8)	394 (± 65.6)*	2.3 (± 0.3)	40 (± 5.8)	245 (± 33.2)*	0.85 (± 0.31)*	30 (± 10.0)	175 (± 35.1)*	0.88 (± 0.35)	50 (± 11.5)	258 (± 33.2)	2.65 (± 0.41)
NAA												
0.3	50 (± 15.3)*	4.6 (± 1.5)*	2.14 (± 0.3)	15 (± 7.1)	1.5 (± 0.71)*	0.7 (± 0.35)*	30 (± 10)	9 (± 5.6)*	1.09 (± 0.09)	20 (± 10.0)	2 (± 1)*	2.36 (± 0.22)
1.0	20 (± 5.8)*	1.3 (± 0.58)*	0.9 (± 0.14)*	10 (± 0)	1 (± 0)*	0.41 (± 0.18)*	40 (± 15.3)	3.3 (± 1.5)*	1.26 (± 0.2)	40 (± 15.3)	3.7 (± 1.5)*	1.74 (± 0.36)
3.0	30 (± 5.8)*	2.3 (± 0.58)*	1.2 (± 0.5)*	30 (± 15.3)	3 (± 1.7)*	1.08 (± 0.11)*	20 (± 5.8)*	4.7 (± 4.6)*	0.6 (± 0.09)	30 (± 10.0)	3 (± 1)*	1.78 (± 0.23)
BAP												
0.2	60 (± 15.3)	49 (± 16.1)*	2.7 (± 0.43)	30 (± 15.3)	13 (± 2.6)*	1.04 (± 0.08)*	40 (± 15.3)	196 (± 41.8)*	1.56 (± 0.40)	20 (± 10.0)	5 (± 4.4)*	2.33 (± 0.48)
0.9	40 (± 5.8)*	3.3 (± 0.58)*	1.9 (± 0.23)	20 (± 5.8)	1.7 (± 0.6)*	0.73 (± 0.32)*	20 (± 10)*	85.5 (± 33.2)*	0.62 (± 0.13)	40 (± 28.9)	98.3 (± 24.9)*	2.22 (± 0.10)
2.0	30 (± 5.8)*	2.3 (± 0.58)*	0.96 (± 0.13)*	30 (± 15.3)	13.3 (± 2.1)*	0.92 (± 0.1)*	30 (± 5.8)*	15.8 (± 3.7)*	0.6 (± 0.31)	10 (± 0)	10 (± 0)*	2.49 (± 0.36)
R												
0.5	40 (± 11.5)*	224 (± 86.2)*	2.5 (± 0.35)	20 (± 5.8)	75 (± 24.2)*	0.73 (± 0.24)*	20 (± 10)*	80.7 (± 30.0)*	0.66 (± 0.11)	40 (± 17.3)	316.3 (± 14.1)	3.34 (± 0.48)
2.0	40 (± 17.3)*	251.3 (± 14.4)*	2.3 (± 0.35)	25 (± 7.1)	99.75 (± 1.5)*	0.86 (± 0.13)*	40 (± 5.8)	301.3 (± 37.6)	1.33 (± 0.09)	80 (± 11.5)	611.5 (± 10.3)#	1.49 (± 0.39)*
5.0	30 (± 10)*	69.3 (± 22.1)*	1.2 (± 0.05)*	30 (± 10.0)	251.5 (± 43.7)*	0.99 (± 0.19)*	60 (± 15.3)	341.3 (± 46.7)	1.45 (± 0.23)	40 (± 10.0)	237.7 (± 38.5)	2.6 (± 0.37)
Control	80 (± 15.3)	588 (± 9.25)	2.28 (± 0.36)	70 (± 10.0)	747.2 (± 39.2)	2.07 (± 0.12)	50 (± 5.8)	233 (± 7.9)	1.27 (± 0.2)	50 (± 15.3)	240.0 (± 15.7)	2.2 (± 0.2)

* Significant decrease at 5% level

#Significant increase at 5% level.

Table 2: Germination parameters of *B. bambos* seed at different ageing intervals after treatment with plant growth regulators.

	Freshly harvested			6 months			12 months			18 months		
PGR (conc. mM)	G%	VI	Ei	G%	VI	Ei	G%	VI	Ei	G%	VI	Ei
0.2	70 (± 15.3)	262.67 (± 31.1)	2.5 ± (0.59)	70 (± 20.8)	294.4 (± 25.8)	2.4 (± 0.5)	80 (± 20)	472 (± 26.1)#	4.04 (± 0.32)	80 (± 10)	361 (± 28.9)#	1.28 (± 0.2)
0.5	60 (± 10.0)	228.3 (± 28.9)	2 (± 0.2)	70 (± 11.5)	240 (± 38.6)*	2.3 (± 0.3)	50 (± 20.8)	327.6 (± 29.2)	2.3 (± 0.3)*	70 (± 15.3)	356.2 (± 20)#	0.47 (± 0.25)*
2.0	70 (± 11.5)	294 (± 23.3)	2.5 (± 0.5)	80 (± 5.8)	336 (± 35.8)	3.06 (± 0.2)	90 (± 5.8)	233.9 (± 16.3)*	3.2 (± 0.4)*	70 (± 11.5)	320.5 (± 26.7)#	1.1 (± 0.22)
IAA												
0.3	70 (± 10.0)	240.1 (± 25.0)	1.53 (± 0.32)*	50 (± 15.3)	147.6 (± 35.3)*	1.7 (± 0.5)	70 (± 11.5)	253.2 (± 39.5)*	2.19 (± 0.2)*	80 (± 15.3)	354.6 (± 33.3)#	0.36 (± 0.15)*
1.0	80 (± 11.5)	243.2 (± 5.20)	2.8 (± 0.35)	60 (± 11.5)	203 (± 31.4)*	2.54 (± 0.4)	70 (± 10.0)	368 (± 29.0)	2.4 (± 0.42)*	80 (± 10.0)	330.7 (± 43.0)#	0.53 (± 0.3)*
3.0	80 (± 25.2)	399 (± 20.8)#	2.5 (± 0.09)	80 (± 15.3)	298.8 (± 28.2)	3.03 (± 0.21)	70 (± 20.0)	148.1 (± 38.6)*	3.2 (± 0.15)*	80 (± 15.3)	261 (± 19.7)	1.23 (± 0.33)
NAA												
0.3	60 (± 17.3)	6 (± 1.7)*	1.68 (0.17)*	53 (± 25.2)	5.3 (± 2.2)	2.4 (± 0.5)	50 (± 20.8)	21.3 (± 8.3)*	1.8 (± 0.35)*	90 (± 10.0)	16 (± 2.0)*	0.5 (0.3)*
1.0	40 (± 5.8)	3.7 (± 0.6)*	0.93 (± 0.09)*	50 (± 11.5)	4.3 (± 1.15)	1.3 (± 0.18)	80 (± 10.0)	8 (± 1.0)*	3.4 (± 0.28)	60 (± 10.0)	6 (± 1.0)*	~~0.75~~ (± 0.22)*
3.0	80 (± 11.5)	7.7 (± 1.15)*	1.3 (0.58)*	60 (± 10.0)	6 (± 1.0)*	2.02 (± 0.4)	60 (± 11.5)	5.7 (± 1.2)*	2.4 (± 0.2)*	70 (± 15.3)	6.7 (± 1.5)*	0.66 (± 0.45)*
BAP												
0.2	60 (± 5.8)	62 (± 9.2)*	2.7 (± 0.24)*	60 (± 15.3)	8.4 (± 2.2)*	2.09 (± 0.08)	70 (± 15.3)	223.9 (± 40.9)*	2.35 (± 0.22)*	70 (± 10.0)	12.7 (± 13.0)*	0.37 (± 0.13)*
0.9	60 (± 10.0)	6 (± 1.0)*	1.7 (± 0.15)*	40 (± 17.3)	4 (± 1.7)*	1.31 (± 0.45)	70 (± 15.3)	115.5 (± 16.9)*	2.43 (± 0.37)*	60 (± 11.5)	38.07 (± 9.3)*	1.47 (± 0.35)
2.0	30 (± 5.8)*	2.3 (± 0.58)*	0.83 (± 0.08)*	70 (± 15.3)	35.2 (± 6.4)*	1.8 (± 0.31)	70 (± 15.3)	16.2 (± 1.3)*	2.41 (± 0.30)*	80 (± 17.3)	46.2 (± 10.8)*	0.18 (± 0.11)*
R												
0.5	60 (± 11.5)	257.3 (± 19.1)	2.3 (± 0.26)	50 (± 5.8)	111 (± 1.19)*	1.35 (± 0.34)	80 (± 15.3)	361.8 (± 26.6)	3.41 (± 0.47)	80 (± 10.0)	416.4 (± 44.1)#	1.13 (± 0.13)
2.0	80 (± 3.8)	354.7 (± 24.3)#	1.8 (± 1.7)	90 (± 15.3)	252 (± 15.1)*	3.6 (± 0.4)#	90 (± 10.0)	379 (± 25.3)	3.93 (± 0.12)	50 (± 10.0)	161 (± 28.7)*	1.63 (± 0.46)
5.0	60 (± 20.8)	391 (± 26.2)#	1.4 (± 0.6)*	60 (± 11.5)	179.2 (± 12.8)*	2.3 (± 0.36)	80 (± 5.8)	451.3 (± 33.2)#	2.4 (± 0.16)*	70 (± 10.0)	388.8 (± 38.5)#	1.16 (± 0.04)
Control	80 (± 11.5)	272.7 (± 39.3)	2.74 (± 0.32)	70 (± 10.0)	331.2 (± 27.6)	2.18 (± 0.4)	70 (± 15.3)	336 (± 27.9)	4.1 (± 0.22)	60 (± 10.0)	256.3 (± 21.5)	1.47 (± 0.45)

* Significant decrease at 5% level #Significant increase at 5% level.

DISCUSSION

Storage induces physiochemical changes in the seeds, which may be both desirable and undesirable, depending on storage conditions, variety and end user requirements. Moisture content, storage temperature and storage time are important factors which influence seed viability during storage. Poor seedling establishment is an indicator of low seed vigour. Reduction in growth is a physiological marker of ageing in seeds (Harrington, 1973; Roberts, 1972; Bewley and Black, 1982). In the present study, although, storing seeds under controlled conditions helped to maintain viability of seeds for a long period, a gradual decrease in seed vigour was noticeable. Khan (1980) reported that the level and inter-play of growth hormones, including promoters and inhibitors, plays a decisive role in regulation of germination ability. In freshly harvested seeds of both the species, most of the treatments suppressed the germination. The negative effect of plant growth regulators could be attributed to the fact that the endogenous levels of otherwise effective plant hormones became supraoptimal following exogenous application of plant growth regulators in fresh seeds. Similar results were obtained by Richa and Malik (1985), Richa and Sharma (1994) and Umarani *et al.* (1996). Singh and Nayyar (2000) also suggested an effectiveness of lower concentration of PGRs, indicating receding levels of endogenous promoters with ageing. Richa *et al.* (2000), Sangeeta and Varshney (1991), and Bose and Saxena (1999) also suggested the importance of endogenous levels of PGRs in modification of growth and development of seedling in desired direction. With seed ageing, there is a decrease in capability to produce optimum concentrations of these promotors (Bewley and Black, 1982, Richa *et al*, 2006) whereas toxic byproducts such as phenolics like coumarin and ferulic acid (Dey *et al.*, 1967) and abscisic acid (Sircar, 1967; Dey and Sircar, 1968) may accumulate, which may result in inhibition of germination ability and vigour. Thus, exogenous supply of hormones may account for enhancement of various germination parameters by supplementing the decreased levels of promoters. The stimulation and synchronization of seed germination on application of PGRs and other chemicals has been reported by several workers (Van Staden *et al.*, 1987; Bewley and Black, 1994; Richa and Sharma, 1994; Whitehead and Suutliffe, 1995; Pandey *et al.*, 2000; Khan and Ungar, 2001; Joshi and Dhar, 2003). In the present study GA and phenols started positively affecting the germination and growth after 18 months of controlled ageing but cytokinin (BAP) still showed negative affects. As suggested by many workers, this may be due to the fact that cytokinins has a role to play in the later stage of ageing and indirectly affects the germination process. In earlier studies (Richa and Sharma, 1994, 2004 and Richa *et al.* 2008) it was observed that PGR treatments become significantly effective on all germination parameters when seed viability is very low (0-10%)

References

Abdul Baki, A. A. and J. D. Anderson. 1973. Vigour determinationin soybean seeds by multiple criteria. *Crop. Sci.*, 13: 630-633.

Bahadur, K. N. 1979. Taxonomy of bamboos. *Indian J. For.*, 2: 222-224.

Banik, R. L. 1987. Seed germination of some bomboo species. *Indian For.*, 113(8): 578-586.

Baskin, C. C. 1969. GADA and seedling measurement as tests for seed quality. *Proc. Seedmen.* Short course Mississipi State Univ., pp. 59-69.

Bewley, J. D. and M. Black. 1982. Physiology and Biochemistory of Seeds in Relation to Germination. Vol. 2.Springer-Verlag, Berlin Heidelberg New York.

Bewley, J.D. and M. Black. 1994. Seeds: Physiology of development and germination. 2. Ed., Plenum Press, New York.

Bose, S. and O. P. Saxena. 1999. Influence of seed invigoration on seedling performance of partially aged groundnut seeds. *Indian J. Plant Physiol.*, 4(3): 189-193.

Brenner, M. L. 1987. The role of hormones in photosynthate partitioning and seed filling. In: *Plant Hormones and their Role in Plant Growth and Development* (ed. P.J. Davies, M. Nijhoff and Dordrecht), pp. 475-493.

Buckvarov, P. and T. S. Gantcheff. 1984. Influence of accelerated and natural ageing on free radical levels in soybean seeds. *Physiol.Plant.*, 60: 53-56.

Clifford, P. E., C. E. Offler and J. W. Patrick. 1986. Growth regulators have rapid effects on photosynthate unloading from seed coats of *Phaseolus Vulgaris.* L. *Plant Physiol.*, 80: 637-637.

Dey, B. and S. M. Sircar. 1968. The presence of an abscisic acid like factor in nonviable rice seeds. *Physiol.Plant.* 21:1054-1059.

Dey, B., P. K. Sircar and S. M. Sircar.1967. Phenolics in relation to nonviability of rice seeds. *Proc.Int.Symp. Plant Growth Substances*, Calcutta: 57-64.

Harrington, J. F. 1973. Biochemical basis of seed longevity. *Seed Sci. and Technol.*,1: 453-461.

Heydecker, W. 1972. Vigour. In: *Viability of seeds* Roberts, E.H. (ed.), Syracuse University Press, 209-252.

Joshi, M. and U. Dhar. 2003. Effect of various presowing treatments on seed germination of *Heracleum candicans* Wall. Ex DC,: a high value medicinal plant. *Seed Sci. & Technol.* 31: 737-743.

Khan, A. A. 1980. The physiology and Biochemistry of seed Dormancy Germination, Elsevier, New York.

Khan, M. A. and I. A. Ungar. 2001. Seed germination of *Triglochin maritime* as infuenced by salinity and dormancy relieving compounds. *Biol. Plant.*, 44: 301-303.

Pandey, H., S .K. Nandi, M. Nadeem and L. M. S. Palni. 2000. Chemical stimulation of seed germination in *Aconitum heterphyllum* Wall. and *A. balfourii* Staff.: Important Himalayan species of medicinal value. *Seed Sci. and Technol.* 28:39-48.

Preistley, D. A. 1986. Seed ageing: Implications of Seed Storage and Persistence in the Soil. Cornell University Press, Ithaca, NY. ISBN 0-8014-1865-8.

Richa and M. L. Sharma. 1994. Effect of plant growth regulators on germination kinetics of stored bamboo seeds. *Seed Sci.and Technol.*, 22(2) : 313-317.

Richa and C. P. Malik. 1985. Effect of some growth substances on seed germination, seedling growth and some enzymes in Okra seeds of two ages. *New Botanist*, 12(2-4),147-156.

Richa, M. L. Sharma, and P. Kaur 2000. Effect of exogenous application of some plant growth regulators on enzyme activity with ageing of bamboo seeds. *JPAS*, 2(1): 32-35.

Richa, M.L Sharma, and Neeru Bala. 2006. Studies on endogenous levels of plant growth hormones in relation to seed viability in some bamboo seeds. *Indian Journal of Plant Physiology*, 11(4): 358-363.

Richa and M. L. Sharma. 2008. Regulation of germination and longevity of ageing bamboo seeds (*D. strictus)* through exogenous plant growth regulators. *Jour. Pl. Sci. Res.*, 24(1):71-76.

Roberts, E.H. 1972. Loss of viability and crop yields. In: *Viability of Seeds* (ed.E.H.Roberts), Chapman and Hall, London, pp.307-359.

Sangeeta and K.A.Varshney. 1991. Effect of gibberellic acid, maleic hydrazide and cycocel on early growth and activities of some oxidoreductases in *Avena sativa*. *Indian J.Exp.Biol.*, 29(1): 80-82.

Setia, R.C., N. Setia and C.P. Malik 1991. Plant growth regulators : Overview and role in crop productivity. In: *Recent advances in plant Biology* (eds. C.P. Malik and Y.P. Abrol), Narendra publishers, New Delhi, pp. 47-75.

Singh. B. and H. Nayyar. 2000. Response of aged bamboo (*Dendrocalamus hamiltonii* L. Munro) seeds to application of gibberellic acid and indole-3 butyric acid. *India For.*, 126(28): 626-678.

Sircar, S. M. 1967. Biochemical changes in rice seed germination and its central mechanism *Trans. Bose Res. Inst.*,30:189-198.

Umarani, R., A. Bharathi and T.V. Karivaratharau. 1996. Seedinvigouration studies with growth regulators in *Casuarinaequisetifolia*. *J. Tree Sci.*, 15(2) 108-110.

Van Staden, J., J. C.Manning and C. W. S.Dickens.1987. A phylogenetic analysis of the rolew of plant hormones in the development and germination of legume seeds. *Advances in legume systematic* (C.H.Stirton.ed.) Royal Botanical Gardens,Kew. pp.387-442.

Varmah, J.C and K.N. Bahadur. 1980. Country report and status of research of bamboos in India. *Indian For. Rec.(Bull.)* Published by the Controller of Publication, 6(1):1-28.

Whitehead, C. S. and M. A. Suutliffe.1995. Effects of low temperatures and different growth regulators on seed germination in *Cyclopia* spp. *J. Plant Physiol.*, 47:107-112.

Pb. Univ. Res. J (Sci.), Vol. 59, 2009, pp. 117-120

SEDGES OF PUNJAB

***M.L. Sharma, Richa and Pooja Sohal**

Department of Botany, Panjab University, Chandigarh- 160014

Abstract

This paper provides a list of 64 species and 2 varieties, under 11 genera of sedges (family Cyperaceae) of Punjab. Of these, 19 species are annuals while the remaining 45 are perennials. One species (*Fimbristyli merrillii* Kern.) and two varieties, namely *Cyperus rotundus* var. *centiflora* Clarke and *C. exaltatus* var. *dives* (Del.) Clarke are reported for the first time from Punjab. Brief highlights of the sedge flora of Punjab are also provided.

Keywords: Cyperaceae, sedges, Punjab, annuals, perennials.

INTRODUCTION

Punjab is an agrarian state of India, located between 29°-32' N latitude and 74°-77' E longitude. Physiographically, it is situated in the northwestern part of India, between rivers Ghaggar and Ravi. Its western side is connected with Pakistan, sharing more that 300 km long international border. The state of Jammu and Kashmir lies to its north, Himachal Pradesh to the north east, Rajasthan to the south west, and Haryana and the Union Territory of Chandigarh to its south. The state of Punjab is decorated with three internationally important wetlands *viz.* Harike, Ropar and Kanjali, which harbour a luxuriant growth of sedges. Apart from the wetlands, three rivers Sutlej, Beas and Ravi flow through the state, in addition to several canals, rivulets and water bodies. All these provide ideal habitat for the growth of sedges.

Cyperaceae or the sedge family is one of the largest families of angiosperms with about 5000 species coming under *ca.*80 genera (Bhurl 1995). Clarke was the first one to do extensive study of Indian Cyperaceae and he published his account of sedges in Hooker's '*Flora of British India*' (1893). A total of 449 species and 28 genera of sedges were described by Clarke (*l.c.*). Subsequently, Karthikeyan *et al.* (1989) listed a total of 38 genera and 537 species in their '*Florae Indicae Enumeratio Monocotyledonae*'. As far as the state of Punjab is convcerned, the sedges have not been studied exclusively, but have been included in few floral studies of the state. Nair (1978) in his '*Flora of The Punjab Plains*' described a total of 36 species and 7 genera under the Cyperaceae. Sharma (1981) reported 50 species belonging to 7 genera of sedges from Punjab. Later, Sharma (1990) listed 63 species under 7 genera of sedges in his '*Punjab Plants: Checklist*'. However, all these accounts of sedges of Punjab lack descriptions of species, keys to their identification, and illustrations, which limits their utility. Sharma and Khosla (1989) published an illustrated account of the grasses of Punjab and Chandigarh, which is the only work on the grass diversity of the state of Punjab and the Union Territory of Chandigarh.

The present checklist of sedges of Punjab comes from the senior author of that publication, jointly with two more authors and deals with another related and taxonomically most difficult group of angiospermic plants- the sedges. This account of sedges is based on the collections made by the authors during the years 2006-2009, from the state of Punjab. A total of 64 species and 2 varieties under 11 genera of sedges have been listed below. To enable the reader to make easy references, the genera and species under each genus have been arranged alphabetically. Valid botanical names have been printed in bold italics, followed by flowering and fruiting season in parenthesis, and the synonym(s) printed in normal italics.

SYSTEMATIC ENUMERATION OF SPECIES:

1. **BOLBOSCHOENUS** Asch. ex Palla

   B.affinis (Roth) Drobov. (April-August).

   Scirpus affinis Roth., *S. maritimus* L. var. *affinis* (Roth) Clarke , *S. strobilinus* Roxb.

   B. maritimus (L.) Palla. (July – April).

   Schoenoplectus maritimus (L.) Lye , *Scirpus maritimus* L, *S. tuberosus* Desf.

2. **BULBOSTYLIS** Kunth

   B. barbata (Rottb.) Clarke. (May- January).

   Scirpus barbatus Rottb., *Isolepis barbata* (Rottb.) R. Br.

---

*Corresponding Author. *mlsharma.bot@gmail.com*

MS Received February 16, 2010; Accepted May 5, 2010

*Fimbristylis barbata (*Rottb.) Benth., *Stenophyllus barbata* (Rottb.) Cooke.

3. **CAREX** L.

C. fedia Nees. (March – June).
Cyperus wallichiana Presc.

C. filicina Nees var. *meiogyna* (Nees) Strachey. (August-September).
Cyperus meiogyna Nees ,*Cyperus caricinus* (D. Don) Ghildyal & Bhattach.
Cyperus caricinus D. Don.

4. **CYPERUS** L.

Juncellus alopercuoides (Rottb.) Clarke.

C. alulatus Kern.(September – November).
Cyperus iria var. *rectangularis* Kuekenth.,*Cyperus rectangularis* (Kuekenth.) Bennet.

C. arenarius Retz (July- December).

C. atkinsonii Clarke. (July- December).

C. bulbosus Vahl. (June– October).

C. compressus L.(August – March).

C. corymbosus Rottb.(August. – March).

C. difformis L. (Almost throughout the year).

C. diffusus Vahl . (November- January).

Cyperus laxus Lamk.

C. digitatus Roxb. (August – October).

C. distans L. (August – March).

C. eleusinoides Kunth (September-November).
Cyperus nutans Vahl.,*Cyperus nutans* subsp. *eleusinoides* (Kunth) Koyama.
Cyperus nutans Vahl var. *eleusinoides* (Kunth) Haines.

C. esculentus L. (June-August).

C. exaltatus Retz. var. ***exaltatus*** . (August- Decmber).
____ __ var. ***dives*** (Del.) Clarke. (July-March).

C. involucratus Rottb.(October to January).

Cyperus flabelliformis Rottb., *Cyperus alternifolius* L. subsp. *flabelliformis* Kukenth.
Cyperus alternifolius auct. non L.
C. iria L. (July – February).
Cyperus paniciformis Franch. & Sav., *C.iria* var. *paniciformis* (Franch. & Sav.) Clarke.

C. laevigatus L.(June – Feburary).
Juncellus laevigatus (L.) Clarke

C. niveus Retz. (August-September).

C. pangorei Rottb. (August – January).
Cyperus tagetum Roxb.

C. procerus Rottb. (June – March).

C. pygmaeus Rottb. (Almost throughout the year).
Juncellus pygmaeus (Rottb.) Clarke .*Cyperus michelianus* (L.) Delile.

C. rotundus L. var. **centiflora** Clarke. (Almost throughout the year).
______var. **rotundus** (Almost throughout the year).

C. serotinus Rottb. (July – September).
Juncellus serotinus (Rottb.) C. B. Clarke.,
Chlorocyperus serotinus (Rottb.) Palla.,
Cyperus monti L. f. var. *stylosa* Clarke.

C. tenuispica Steud. (August – April).
C. *flavidus auct. non.* Retz.

5. **ELEOCHARIS** R Br.

E. acutangula (Roxb.) Schult. (July – September).

Scirpus acutangulus Roxb., *Eleocharis fistulosa* Schult.

E. atropurpurea (Retz.) Pres. (October-February).

Eleocharis plantaginea (Retz.) Roem. & Schult, *Scirpus tuberosus* Roxb.*S. tumidus* Roxb.

E. dulcis (Burm.f.) Hensch. (April– November).

E. palustris L. (December-April).

Scirpus palustris L

6. **ERIOPHORUM** L.

E. comosum Wall. (September – November).

7. **FIMBRISTYLIS** Vahl.

F. aphylla Steud.(September – November).

F. bisumbellata (Forsk.) Bub. (November-August).
Scirpus bisumbellata Forsk., *Scirpus dichotomus auct. non.* L.
Fimbristylis dichotoma auct. non. Vahl.

F.complanata (Retz.) (Most part of the year).

Scirpus complantus Retz.

F.dichotoma (L.) Vahl. (April – November).

Scirpus dichotomus L, *S. diphyllus* Retz., *Fimbristylis diphylla* (Retz.) Vahl.,

F. *annua* var. *diphylla* Kukenth., *F. annua* var. *paucispiculata* Blatt. & Mc C.

F.falcata (Vahl) Kunth. (April – November).

Scirpus falcatus Vahl, *Fimbristylis junciformis* Kunth

F. ferruginea (L.) Vahl. (Throughout the year).

Scirpus ferruginous L.

F. littoralis Gaudich. (Throughout the year).

F. miliacea (sensu Vahl.).

F. merrillii Kern. (July-November).

F. miliacea (*sensu* Vahl.)

F. miliacea (L.) Vahl. (November – January).

Scirpus miliaceus L, *S. quinquangularis* Vahl.,*Fimbristylis quinquangularis* (Vahl)Kunth.

F. ovata (Burm.f.) Kern (March – December).

Carex ovata Burm, *Cyperus monostachyos* L., *Fimbristylis monostachyos* Hassk.

F. schoenoides (Retz.) Vahl (August –April).

Scirpus schoenoides Retz.

F. sieberiana Kunth (June – March).

F. ferruginea auct. non Vahl.

F.tenera Schult. (July – November).

Scirpus tenellus Roxb. *F. oxylepis* Steud .,*F. tenera* Schult, var. *oxylepis* (Steud.) Clarke.

8. **KYLLINGA** Rottb.

K. brevifolia Rottb. (Throughout the year).

Cyperus brevifolius (Rottb.) Hassk.

K .nemoralis (J.R. & G.Forst.) Hutchins. & Dalzie. (May – January).

K. monocephala Rottb , *Thryocephalon nemoralis* J.R. & G. Forst, *Cyperus kyllinga* Endl.

K .triceps Rottb. (July – October).

Kyllinga bulbosa Beauv, *K. tenuifolia*, Syn.,*K. cylindrica* auct. non Nees., *Cyperus triceps* (Rottb.) Endl

9. **MARISCUS** Vahl.

M. compactus (Retz.) Boldingh (September – December).

Cyperus compactus Retz., *Cyperus diluctus* Vahl., *Mariscus microcephalus* Pres.

M. paniceus (Rottb.) Vahl.(May – November).

Schaenoides paniceus Rottb, *Kyllinga panicea* Rottb, *Cyperus paniceus* (Rottb.) Boeck, *C. cyperoides auct. non.* (L) Kuntze.

M. squarrosus (L.) Clarke. (July – November).

Cyperus squarrosus L., *C. aristatus* Rottb., *Mariscus aristatus* (Rottb.) Cherm.

10. **PYCREUS** Beauv.

P. flavidus (Retz.) Koyama (Throughout the year).

Cyperus flavidus Retz., *C. globosus* All., *C. strictus* Roxb.,*Cyperus capillaris* Koenig. ex. Roxb.,*C.nilagiricus* Hochst. ex Steud. *Pycreus globosus* (All.) Reichb.,, *P. capillaris* (Koenig ex Roxb.) Nees ex Clarke.

P. pumilus (L.) Nees (June – February).

Cyperus pumilus L.,*Cyperus pulvinatus* Nees & Mey., *Pycreus nitens* Nees

P. sanguinolentus (Vahl) Nees.(July-September).

Cyperus sanguinolentus Vahl, *Cyperus eragrostis* Vahl.

11. **SCHOENOPLECTUS** (Reichb.) Palla

S articulatus (L.) Palla.(April- July).

Scirpus articulatus L.

S juncoides (Roxb.) Palla. (Almost throughout the year).

Scirpus juncoides Roxb., *Scirpus erectus* auct. non Poir.

S.*lacustris* (L.) Palla.(July- September).

Scirpus lacustris L.

S. lateriflorus (Gmel). Lye. (July – Feburary).

Scirpus lateriflorus Gmel., *S. supinus* auct. non L.

S.litoralis (Schrad.) Palla.(May- Feburary).

Scirpus subulatus Vahl.,*S. litoralis* sensu Clarke.

S.mucronatus (L.) Palla.(April – January).

Scirpus mucronatus L.

S.roylie (Nees) Ovcz. & Czukav.(April – June).

Scirpus roylei (Nees) Parker .*Schoenoplectus lupulinus* (Nees) V. Krecz.

Isolepis lupulina Nees.,*Scirpus lupulinus* (Nees) Roshev., *Isolepis roylei* Nees,

Scirpus quinquefarius Hamilton ex Boeck.

S. triqueter (L.) Palla. (May – August).

Scirpus triqueter L.

HIGHLIGHTS OF SEDGE FLORA OF PUNJAB

An analysis of the family has brought out some noteworthy features which are summarized below. *Cyperus* is the most dominant genus of sedges in Punjab with 24 species, followed by *Fimbristylis* with 13 species. The genera *Bulbostylis* and *Eriophorum* are represented by only one species each. Majority of sedges are found during the monsoons, and were observed in flower and fruit from July to October. This duration, therefore, happens to be the best time for collecting sedges. These were observed to grow in varied habitats, but the wetlands are usually the preferred habitats for various types of sedges. Some members of the family were found to inhabit moist or wet areas such as- in and around rice fields, lakes, reservoirs, river banks, river beds, wetlands, and others. Common species of different genera, which were found in such areas include: *Bolboschoenus maritimus*, *Cyperus alopecuroides*, *C. difformis*, *C. exaltatus*, *C. involucratus*, *Eleocharis dulcis*, *Fimbristylis littoralis*, *F. miliacea*, *Kyllinga brevifolia*, *K. bulbosa*, *K. nemoralis*, *Mariscus paniceus*, and *Schoenoplectus litoralis* subsp. *subulatus*.

During the present study, many species especially of *Cyperus* and *Fimbristylis* were found to grow as weeds in agricultural fields. *Cyperus rotundus* and *Kyllinga nemoralis* are common weeds found in lawns and gardens but the gardeners hate to see these sedges in these places. *Cyperus involucratus*, commonly known as the 'Umbrella Palm', is the only species which is grown in gardens for ornamental purposes

Some species of sedges were observed to prefer special habitats.Thus *Eriophorum comosum*, *Carex fedia* and *Carex filicina* inhabit high range grasslands and cliffs in the foot hills of Shivaliks. Majority of the species of *Schoenoplectus* grow partly submerged in shallow, open water bodies such as lakes and ponds, in association with other vegetation and often attain a height of up to 1m or more. *Cyperus compressus*, *C. iria*, *C. rotundus*, *C. esculentus*, and *C. bulbosus* are very common everywhere and were found growing even along the road sides . *Cyperus procerus*, *C. digitatus*, *C. exaltatus*, *Schoenoplectus articulatus* and *Eleocharis acutangula* are some of the rarely found sedges which are restricted to a few localities only.

Sedges are of comparatively little economic importance Being mostly coarse, harsh and indigestible, they are not suitable as food. Still however, the rhizomes of several species are utilized as starchy foods. The tubers of *Cyperus bulbosus* and *Cyperus esculentus* are edible. Though both these species are found in Punjab, none is consumed as food, perhaps because Punjab is surplus in food grains and everyone can afford both ends meals. However, both these plants can be considered as potential food plants in case of food scarcity. Many species of sedges which grow in grasslands, wastelands, wetlands and other habitats along with grasses, are used as fodder for cattle. Some of the sedges are also used by native medical men or traditional physicians to cure certain ailments.

REFERENCES

Bhurl, J. J. 1995. Sedge genera of the world: relationships and new classification of Cyperaceae. *Austrs. Syst. Bot.*, 8: 125-305.

Clarke, C.B. 1893. Cyperaceae in: J.D. Hooker's, 'Flora of British India', 6: 585-672. London.

Karthikeyan, S., S.K. Jain, M.P Nayar, and M. Sanjippa 1989. *Florae Indicae enumeratio*

Monocotyledonae. Botanical Survey Of India. Flora Of India series 4.

Nair, N.C. 1978. Flora of the Punjab Plains. The Director, BSI, Indian Botanical Garden, Howrah.

Sharma, M. 1981. Sedges of Punjab- ecology, distribution and enumeration . *J. Bombay Nat. Hist. Soc.*, 77(3): 424-428.

Sharma, M. 1990. Punjab Plants - Checklist. Bishen Singh Mahendra Pal Singh, Dehra Dun: 92-93.

Sharma, M. and O.P Sharma 1975. Monocots of Ludhiana District. *Indian Forester,* 101: 229-237.

Sharma, M. and S.S Bir. 1978. Flora of Patiala. Punjabi University, Patiala.

Sharma, M.L. and P.K Khosla. 1989. The Grasses of Punjab and Chandigarh. Publication Bureau, Panjab University, Chandigarh.

Pb. Univ. Res. J (Sci.), Vol. 59, 2009, pp. 121-150

CHECK - LIST OF GYMNOSPERMS OF INDIA

***R.C. Srivastava**

Botanical Survey of India, Itanagar-791111

Abstract

A check - list of 132 species, 6 varieties and 1 forma belonging to 40 genera under 11 families of gymnosperms, occurring/growing in India, is given in this paper. Accepted names are in bold letters, followed by basinyms/synonyms in italics with citation. Vernacular/common (English/Hindi) names, brief description, flowering/fruiting period, habitat, distribution and uses (wherever known) are also given.

Keywords: Gymnosperms, India, Taxonomy, Check - List

INTRODUCTION

The living Gymnosperms belong to five orders viz. Cycadales, Ginkgoales, Taxales, Coniferales and Gnetales. These orders are quite distinct and widely divergent. Several important contributions have been made from India on various aspects of living Gymnosperms by Maheshwari & Biswas (1970), Meheswari & Vasil (1961). Pant (1973), Raizada & Sahni (1960), Sahni (1990) and Srivastava (1992) etc. Hooker (1888) in *Flora of British India*, described 42 taxa (40 spp. and 2 varieties) belonging to 16 genera under three orders viz. Gnetaceae, Coniferae (with 6 tribes viz. Cupressineae, Taxidieae, Taxeae, Podocarpeae, Araucarieae and Abietineae) and Cycadaceae,from British India teritory (Table-I). Out of these 33 species and 2 varieties were reported from with in the present political boundaries of India. He treated only one species viz. *Cupressus torulosa* D.Don distributed in W. Himalaya, but described other 3 spp. viz. *C. lusitanica* Mill., *C. semipervirens* L. and *C. funebris* Endl. as planted ones. His observation regarding distribution of these taxa still stands good. *Agathis loranthifolia* Salisb. was also described by him, but from Penang(in Myanmar – then called as Burma) only. However, as on today, this species is quite common in India, but still restricted to gardens only. Similarly *Pinus merkusii* Jungh & De Vriese described by him from Martaban and Upper Tenasserim (in Myanmar) is now recorded from Arunachal and is planted as well.

In addition to their ornamental value, the Gymnosperms are of much use to the human beings as they provide the very valuable timber, wood pulp, soft wood, resins, edibles, medicine etc. Recently the 'Himalayan Yew'(*Taxus wallichiana*) has turned out as the savior of the human race against breast/stomach cancer. Seeds of *Pinus gerardiana*, known as *'chilgoza'* are consumed as nutritious dry fruit. Similarly the ripe cooked seeds of *Cycas rumphi*, young leaves and strobili of *Gnetum gnemon* and tender fleshy shoots of *Cycas pectinata* are eaten, *Ephedrine* obtained from *Ephedra* species is an important medicine for treatment of 'Asthma', Hey fever and other bronchial troubles. *Cedar* oil is also valuable in treatment of pulmonary/urinary disorders, piles and rheumatism.

Present study revealed the occurrence of, 132 species, 6 varieties and 1 forma (belonging to11 families and 40 genera), in India (Table I). These are enumerated below. The endemic taxa are listed in Table II.The indigenous taxa and those exotics that are naturalized, have been included in this work. A few taxa have been excluded because their taxonomic distribution/status could not be ascertained during the brief period of this study. The introduced taxa which are still restricted to the gardens have been listed with brief details.

The accepted names are given in bold letters with their citations followed by basionyms and synonyms in italics. Local or common names, brief description, flowering & fruiting period, distribution, habitat, uses (wherever known) and in some cases additional information are presented under 'Notes'. Artificial Keys to the genera, species and varieties are also provided.

---

*Corresponding Author. *rcs_bsi@yahoo.co.in*

MS Received August 12, 2009; Accepted August 28, 2010

Table I. Gymnosperms in India (present work)

S. No.	Genera	Species	Number of Subsp.	Varieties	Forma
1	*Abies*	5	–	1	–
2	*Agathis (exotic)*	1	–	–	–
3	*Amentotaxus*	1	–	–	–
4	*Araucaria (exotic)*	5	–	–	–
5	*Bowenia (Exotic)*	2	–	–	–
6	*Callitris (exotic)*	2	–	–	–
7	*Calocedrus (exotic)*	1	–	–	–
8	*Cedrus*	1	–	–	–
9	*Cephalotaxus*	4	–	–	–
10	*Chamaecyparis (exotic)*	1	–	–	–
11	*Cryptomeria (exotic)*	1	–	–	–
12	*Cunninghamia (exotic)*	1	–	–	–
13	*Cupressus*	9	–	–	–
14	*Cycas*	6	–	–	–
15	*Dioon (exotic)*	2	–	–	–
16	*Encephalartos (exotic)*	5	–	–	–
17	*Ephedra*	7	2	–	–
18	*Ginkgo (exotic)*	1	–	–	–
19	*Gnetum*	5	–	2	1
20	*Juniperus*	9	–	1	–
21	*Larix*	1	–	–	–
22	*Lepidozamia (exotic)*	1	–	–	–
23	*Macrocycas (exotic)*	1	–	–	–
24	*Metasequoia (exotic)*	1	–	–	–
25	*Microzamia (exotic)*	2	–	–	–
26	*Picea*	3	–	–	–
27	*Pinus*	27	–	1	–
28	*Podocarpus (exotic)*	4	–	–	–
29	*Pseudotsuga(exotic)*	2	–	–	–
30	*Sequoia (exotic)*	1	–	–	–
31	*Sequoidendren (exotic)*	1	–	–	–
32	*Stangeria(exotic)*	1	–	–	–
33	*Taxodium*	2	–	–	–
34	*Taxus*	1	–	–	–
35	*Tetraclinus (exotic)*	1	–	–	–
36	*Thuja (exotic)*	4	–	–	–
37	*Tsuga*	1	–	–	–
38	*Welwitschia (exotic)*	1	–	–	–
39	*Widderingtonia (exotic)*	1	–	–	–
40	*Zamia (exotic)*	7	–	–	–
	Total =	132	–	6	1

Table II. Endemic Gymnosperms of India (present work)

S. No.	Name	Distribution
1	*Amentotaxus assamica*	– Arunachal Pradesh (Delai Valley)
2	*Cycas beddomei*	– Andhra Pradesh (Cuddapah district)
3	*Cycas circinalis* var. *orixensis*.	– Orissa (Puri & Angul)
4	*Gnetum contractum*	– Kerala & Tamilnadu(Nilgiri)
5	*Gnetum latifolium* var. *macrocarpum*	– Andaman & Nicobar Islands
6	*Gnetum montanum* f.*megalocarpum*	– Arunachal Pradesh (Dafla Hills)
7	*Pinus wallichiana* var. *parva*	– Arunachal Pradesh(Tawang)

GYMNOSPERMS

Sixty three genera and *ca* 750 species in World; almost in all continents except Antartica; 11 families, 40 genera, 127 species, 6 varieties and 1 forma (indigenous/ introduced) in India.

1.CYCADACEAE

A family of *ca* 9 genera and 20 species, native of the tropics and temperate regions; 7 genera 20 species in India; one genus (*Cycas*) with 5 indigenous and one introduced species (*C. revoluta*); 17 species belonging to 8 genera; restricted to gardens.

1.CYCAS L.

Sp. P1. : 1188, 1753

Lectotype : *Cycas circinalis* L. (designated by Stevenson). "*Todda-pana 5. Montapanna*", Rheede, Hort. Malab. 3 t. 19. 1682.

A genus of *ca* 20 species (Willis 1973), distributed in Madagascar, East and S. East Asia, Australia and Polynesia; 6 species in India including *C. revoluta* Thunb. – a Japanese species commonly grown in Indian gardens. The occurrence of *Cycas siammensis* within present political boundaries of India is doubtful.

1.Cycas beddomei Dyer in Trans. Linn. Soc. Ser. 2.2.11.85:17.1803; Hook.f., Fl. Brit. India 5:658.1890.
Common Name : Beddome's Cycas (Engl.).

Small shrubs, trunk up to 40 cm high, clothed with glabressed closely imbricated leaves; bark brown; scales rectangular: Leaves up to 90 cm long.

Fl. : Nov.-Dec. : *Fr.* March-May.

Distrib. : **Endemic** to Tirumala Hills in Cuddappa District of Andhra Pradesh and Tamilnadu.

2.Cycas circinalis L., Sp. Pl. 1188. 1753; Hook. f. Fl. Brit. India 5:656. 1890. *Cycas swamyii* R. Singh & P. Radha, Bot. J. Linn. Soc. 158:431.2008, ***syn.nov.***

Palm like trees, 4-8m high, trunk cylindrical, rarely forked; covered with compact woody bases of petioles; bark brown with diamond-shaped scars of fallen petioles. Leaves pinnate, 1.5-2.5m long.

Fl. Feb.-Mar.; Fr: Aug.-Oct.
Distrib. : W. peninsular India, Sri Lanka, Maldives, E.tropical Africa, Madagascar, Comora Islands, Sumatra, Java.

3.Cycas edentata Laub & Edema in Bluemea 43(2):360.1998. *Cycas rumphii sensu* Dyer in Fl. Brit. India 5:57 1888, *non* Miq., 1839.

Evergreen palm-like trees, upto 7.5 m high; trunk rough, simple or forked, not swollen at base. Leaves upto 1.8m long, dark-green, glossy, arising from the top of the trunk.

Fl. & Fr. : Flowering starts during December-January but the fruits are seen almost throughout the year.
Distrib : Andaman Islands, Planted elsewhere. Common in Calcutta Gardens.
Uses : Trunk yields a 'Sago'. Cooked fruits are eaten but raw ones are poisonous.

4.Cycas pectinata Griff., Notul. Pl. Asiat. 5, t. 360. f. 3. 10 t. 1854; Hook. f., Fl. Brit. India 5:657, 1888.

Local names : Thakal (Nep.) Siapdung (Lep.), Thaljimura (Khasi)

Palm like trees, upto 6.5m high, sometimes with forked trunk. Leaves upto 2m long, recurved; petioles *ca* 44.5cm long, with a few distant spines.

Fl. : Nov.-Dec., Fr : Dec.-Jan.

Distrib. : E. Himlayan rgion, Bihar, N.E. India, Bangladesh, Myanmar.

Etymology: The name of the species is derived after the pectinate blades of the megasporophylls.

Uses : Tender fleshy shoots and seeds are edible.

5.Cycas revoluta Thunb., Fl. Japan 22. 1784
Common Name : Sago-Cycas (Eng.)

Palm like dioecious trees, upto 3m high; sucker producing. Trunk columnar, unbranched, clothed with old leaf-bases, rarely forked. Leaves 60-150cm long.

Fl. & Fr. : male cones mature in July.

Distrib. : S. Japan, China, Taiwan. Cultivated in Indian gardents.

Etymology : The specific epithet refers to the revolute margin of the pinnae.

Uses : Fruits are edible, Sago is obtained from pith. Leaves are used for making funeral wreaths.

6.Cycas sphaerica Roxb. Fl. Ind. 3:147.1832; Miq., Linnaea 17:693:1843; Tijddsehr. Wisk. Natuurk. Wet. 2:387.1849; Arch. Neerl. Sci. Exact & Nat. 3:230.1868; Laub. & Adema, Blumea 43(2) : 360.1988-*Lectotype* (Hill 1995); Roxb., s.n. (BM), Cult. Calcutta. *Cycas circinalis* L. var. *orixensis* Haines, Bot. Bihar & Orissa 6:1228.1924; Hill, Taxon 44:25.1925. *Lectotype* : *Haines* 5876 (K), India, Mals of Puri. *Cycas annaikalensis* Singh & Radha, Brittonia 58:119.2006. *Syn. Nov. Holotype* : India, Kerala : Palaghat, Annaikal hills, 940m, May 2003, *R. Singh & P. Radha & P. Sharma*, 0144 (IPWW-0491) (Isotype in DD).

Palm like trees; trunk upto 4.5m high, upto 40 cm in diam. Leaves 150-270 cm long

Fl. & Fr. : Sept.-Oct.
Distrib. : India : Orissa (Puri), Kerala (Palghat dt. Annaikal, 940m).
Sri LANKA.

Excluded Taxa

1. Cycas siamensis Miq. in Bot. Zeit. 4, 21.334.1863; Hook.f., Fl. Brit. India 5:657.1888; Sahni, Gymn. India & Adj. Countr. 28.1990.

A native of Thailand, Myanmar, Yunnan and Cochin-China; distinguished by its trunk which is swollen at base; upto 8mm wide flat leaflets and ovate, pectinate megasporophylls.

Its occurrence with in present political boundaries of India is not supported by any collection from any Indian locality; not common in cultivation even.

2. Cycas indica Lindstrom & K.D.Hill, 2002. *Type* : India E.ghat, A. Lindstrom, 2002 (Holo?) R.B.G. Sydney (Ken Hill.)

Distrib.: Andhra Pradesh

Notes: No further details is available

3. Cycas zeylanica (J. Schust.) A. Lindstr. & K.D. Hill. *Novon* 12(2) : 238-239. 2003. *Cycas rumphii* subsp. *zeylanica* J. Schuot., Pflanzenr. 99:75. fig 10c-d, 11m.1932.

Distrib.: India (Andaman Islands)

Notes: No further information is available.

CULTIVTED TAXA

(still restricted to Gardens)

1. **Bowenia spectabilis** Hook. *ex* Hook.f. Bot. mag. t. 5398.. 1863.

   R.P.S.C., Bhubaneswar.

2. **Bowenia serrulata** (W.Bull.) Chamb. in Bot. Gaz. 54. 419. 1912.

3. **Dioon mejiae** Standley & L. O. Williams, in Ceiba 1: 37.1950.

   Planted at N.B.G., Lucknow.

4. **Dioon spinulosum** Dyer ex Eichl. in Gart. Zeit. 1883: 411. 1883.

   Planted at N.B.G., Lucknow.

5. **Encephalartos hilderbrendtii** A.Br.& C.D. Bouche, Ind. Sem. Hort. Berol. 1874: 8. 1874.

6. **Encephalartos latifolius** Sweet, Hort. Brit. Ed. 3: 626.

7. **Encephalartos transvenosus** Stapf. & Burtt Davy, in Burtt Davy, Man. Fl. El. & Ferns. Lt 1: 40, 99. 1926.

Planted at N.B.G.E., Lucknow.

8. **Encephartos trispinosus** (Hork.) R.A. Dyer., in Journ. S. Afr. Bot. 31: 112. 1965.

9. **Encephalartos villosus** Lem. Illustr. Hortic. 1868. Misc. 69. t. 557. 1868.

Planted in India at IBG (W.B), Yercard (T.N.), NBG, Lucknow (U.P.), Pune, Mumbai.

10. **Lepidozamia peroffskyana** Regel. in Bull. Soc. Nat. Mosc. 1857, 1: 182. 1857.

(Treated by some authors in Zamiaceae)

Grown at N.B.G., Lucknow

11. **Microcycas calocoma** A. DC., in DC. Prodr. 16: 2. 530.

Planted at NBRI, Lucknow

12. **Microzamia miquelli** A. DC., in DC. Prodr. 16: 2: 535..

Planted at NBRI, Lucknow

13. **Macrozamia riedlei** C.A. Gardner, Enum. Pl. Austr. -Occ. 3. 1930.

Planted at NBRI, Lucknow

14. **Stangeria paradoxa** T. Moore in Hook. Kew Journ. 5: 228. 1853.

Institute of Sciences, Ahmadabad.

15. **Zamia angustifolia** Jacq. Coll. 3: 263.

Planted at BSI,Allahabad..

16. **Zamia floribunda** A.DC. in DC. Prod. 16: 2. 544.

Planted at N.B.G., Lucknow, University of Allahabad

17. **Zamia furfuracea** L.f., Ait. Hort. Kew. Ed. 1(3): 477.

Planted at Allahabad,Lucknow (Uttar Pradesh)

18. **Zamia pallida** Salsb. Prod. 401.

Planted at N.B.G., Lucknow.

19. **Zamia portoricensis** Urban Symb. Antill. i. 291.

Planted at N.B.G., Lucknow.

20. **Zammia pumila** Hort. *Ex* Reged, Gartenfl. 27: 11. 1878.

Planted at N.B.G., Lucknow, University of Allahabad

21. **Zammia pygmaea** Sims, Bot. Mag. t. 1741. Ind. Occ.

Planted at N.B.G.,Lucknow (Uttar Pradesh).

2.GINKGOACEAE

A monotypic family with *Ginkgo biloba* - the only living representative of the family and the order (Ginkgoales), whose members flourished world-over during Mesozoic era, especially during the Jurassic period (*ca* 150 million years ago) when the earth was ruled by the ferocious giant reptiles – the Dinosaurs.

1.Ginkgo L.
Mant. Pl. 2, 313. 1771.

Type : *G. biloba* L. - *Lectotype* (designated by Barrie) : Gordon, Herb. Linn. No.1292 B. 2(LINN)

Ginkgo biloba L., Mant. Pl. 2. 313. 1771. *Salisbaria adiantifolia* Smith in Trans. Linn Soc. London 3: 330. 1797. *Salisburya biloba* Hoffmagg. Verz. Pflanzenkult. 109. 1824

Common Names : Maiden Hair Tree, Living –fossil (Eng.), Yin-kuo (Chinese)

Deciduous, dioecious trees, up to 40 m high, 5-6m in girth; bark furrowed with age. Leaves fan-shaped, glossy-green, 5-7.5 (-20)cm across, irregularly toothed, bilobed above

Fl. April – June

Distrib.: Wild along the border of Chekiang and Anhwei provinces in E. China. Cultivated world wide.

Planted in most of the Botanical Gardens in **India**.Old fruiting trees are seen at Kalimpong (West Bengal).

Uses : Trees are tolerant to pollution (smoke etc.). Wood is used for making Chess-boards and Chess-men in China and Japan. Roasted seeds are eaten during feasts and said to help in digestion and diminish the effects of wine (Dallimore & Jackson 1966). A medicine viz. 'Bilovas' prepared from this plant is used in diabetic memory-loss.

3.TAXACEAE

(Yew Family/Taxads)

A family consisting of genera like *Taxus*, *Pseudotaxus* Cheng (syn. *Nothotaxus* Florin), *Torreya*, *Austrotaxus* and *Amentotaxus*; Only two genera in India.

1.**Amentotaxus** Pilger

Bot. Jahrb, Syst. 54 : 41, 1919.

Type species : *Amentotaxus argotaenia* (Hance) Pilger (Syn. *Cephalotaxus argotaenia* Hance).

A genus with *ca* 4(-6) species found in Honkong (Kwangtung and Lanton Isl.), China, Vietnam and India (Arunachal Pradesh); one species in India.

Amentotaxus assamica D.K. Ferguson, Kew Bull. 40(1):115-119. Pl.5, fig 1; 1985; Haridasan in *Indian Forester* 114(12) : 868-870.1988.

Type : India : Assam, Delei valley, Chibaon, 6.4. 1928 *F. Kingdon Ward* 8026 Holotype in K)

Trees, upto 20 m high; bark whitish grey to dark grey, hard; branches whorled.Leaves opposite, linear-lanceolate.

Fl. & Fr.: April

Habitat : Temperate rain forests, on precipitous north facing slopes.

Distrib. : Arunachal Pradesh (Dafla Hills).

Notes : Fu Liguo, Li Non & Robert R. Mill (1999) recorded this species from China (S.E. Xizang) also but they doubted that it is truly distinct from *Amentotaxus argotaenia* and hence did not include it in taxonomic account;

Taxa dubia

Amentotaxus argotaenia (Hance) Pilger in Engl. Jahrb.54:41.1916. *Podocarpus argotaenia* Hance in Journ. Bot.21:357.1883.*Amentotaxus cathayensis* H.L.Li in Journ.Arn. Arb. 33:195.1952; Haridasan & Deori in Arunachal Forest News 9 (2) : 31.1991.

Notes:No specimen is available in any of the Indian Herbaria.

2.**Taxus** L.

Sp. Pl. 1040. 1753.

(Yew)

Type : *Taxus baccata* L. (*Lectotype* designated by Jonsell & Jarvis) : Herb. Clifford : 464, Taxus No.1 (BM)

A genus with *ca* 10 species, widely distributed throughout the N.Hemisphere in temperate zone; one species in India.

Taxus wallichiana Zucc. Abh. Math.-Phys. Cl. Konigl. Bayer. Akad. Wiss.3:803.1843. *Taxus baccata* L. ssp. *wallichiana* (Zucc.) Pilger in Engl., Pfl. Reich. IV-5 hf. 18: 112, 1903 ; Hook. f. Fl. Brit. India 5 : 684. 1890; Brandis, Indian Trees 696. 1906 ; Raizada & Sahni 103. 1960; Dallimore & Jackson ed. 4 : 587. 1966; Hara, Stearen & Williams 1 : 6; 1978 ; Sahni, *l.c.* 39. 1990.

Common/Local names : Common Yew (Eng.), Thuner (in West. Himalayan region), Birmi, Postil (Kashm.), Bhirmil (Beng.), Cheongbu (Lep.), Tchesiragulab (Nep.), Barmi, (Khasi), Kyaut-tinge (Burm.).

Evergreen trees, upto 6m high ; girth 1.5-1.8m; trunk fluted; bark reddish-brown; branchlets spreading, not whorled. Leaves linear, flat

Fl.& Fr. : March – Nov.

Distrib. : All along Himalaya ; 2300-3400 m.

India : Arunachal Pradesh, Manipur, Meghalaya, Nagaland, Sikkim, Uttarakhand. Myanmar, Afghanistan, S.W.China, Bhutan, Vietnam.

Habitat : in Broad-leaved, coniferous forests, mixed-forests, deforested areas, open slopes; 2300-3400m.

Uses : Source of "**Taxol**" found effective in cure of breast and stomach cancer. All parts except the edible aril are deadly poisonous. Wood is an excellent building material; also used for making vehicles, agricultural implements, furniture and stationery.

4.CEPHALOTAXACEAE Neger

Nadelh 23. 30. 1907

(Plum-yew Family)

A monogeneric family with the only genus viz. *Cephalotaxus* having *ca* 6 species (Pilger & Melchior 1954) growing in subtropical forests from Eastern Himalyas to Japan; 3 species in India ; 2 wild and 1 in cultivation (introduced).

1.**Cephalotaxus** Sieb. & Zucc. *ex* Endl.

Gen. Suppl. 2 : 27. 1842.

(Cow's Tail Pines, Plum-yew)

1. **Cephalotaxus griffithi** Hook. f. , Fl. Brit. India 5 : 648. 1888; Sahni, *l.C.* 1990.
Common name : Plum-yew (Engl.)

Medium sized trees. Leaves *ca* 5 cm long and 3-4.5 mm wide, falcate, subacute, rounded at base, truncately rotundate or partly subcordately incised, whitish beneath, glossy green above

Distrib.: INDIA (Arunachal Pradesh- Kemeng district), Manipur, Meghalaya, Mizoram, Nagaland, West Bengal, Uttarakhand) ; 1520-1820 m
BHUTAN, MYANMAR.

2. **Cephalotaxus mannii** Hook.f. in Hook. Icon. Pt. t. 1523, 1886 et., Fl. Brit. India 5:647. 1888., Brandis, Ind. Trees 697. 1906 ; Sahni, *l.C*:46-47 1990,

Common name : Khasi Plum yew (Engl.)

Small trees. Leaves linear, 2-5 x 0.25-0.38 cm, subfalcate, apiculate, gradually narrowed at base, pale green beneath.

Fl. & Fr.: Aug.-Nov.

Distrib. : INDIA: (Meghalaya, Nagaland); 1370-2590 m.

UPPER MYANMAR.

Cultivated Taxa

3. **Cephalotaxus drupacea** Sieb. & Zucc.,Fl.Jap. Fam.Nat.2:108.

Common name : Cow's tail pine (Eng.)

Dioecious, shrubs or small yew like trees, upto 12m high. Leaves linear, flat, pointed, shining green, decussate and distichous

Distrib. : Found in China and Japan; introduced in India; cultivated at Dehradun (FRI), and Nainital.

4. **Cephalotaxus harringtonia** (Knight *ex* Forbes) K. Koch.Dendrol.2(2):102. *C. pedunculata* Sieb. & Zucc., Fl.Jap.Fam.Nat.2:108.

Native of Japan.

Planted at Dehradun (Uttarakhand).

5.PODOCARPACEAE Endl.

Syn. Conif. 203. 1847.

(Yellow woods family)

A family of *ca* 6 genera and *ca* 125 species mostly confined to southern Hemisphere extending North to Japan; only one genus (*Podocarpus*) in India; with 4 species; 2 indigenous, 2 introduced.

Podocarpus L'Herit ex Pers. (*nom.cons.*)

Syn. Pl. 2 : 530. 1807.

(Yellow woods)

A genus of *ca* 100 species largely confined to the mountain forests of warm temperate and subtropical regions of southern Hemisphere with some occurring in Japan, China, India the Malay states and the Philippine Islands; 4 species in India (2 indigenous, 2 introduced).

Etymology : The generic name (*Podocarpus*) is derived from the Greek words (*Podus*-foot and *karpus*-fruit) referring to the fleshy fruit stalk of many species.

Notes : Many species yield valuable timber. Some species are of ornamental value; some are suitable as hedge plants.

1. **Podocarpus brevifolius** (Stapf) Foxw. Phil. Journ. Sci. 6 : 160, t. 29, f. 2, 1911. *P.nerifolius* var. *brevifolius* Stapf in Trans. Linn. Soc. Bot. (Ser.2) 4: 249, 1894 ; Pilger in Pflanzer. 18 : 93, 1903 ; Raizada & Sahni in Ind. For. Rec. (N.S.) 5(2) : 105, 1960.

A glabrous, evergreen, dioecious tree up to 5 m tall. Leaves densely crowded, elliptic to lanceolate.

Fl. : March-Oct. ; *Fr.*: Aug.-Dec.

Habitat: An inhabitant of evergreen climax Forests.

Distrib.: Native of Mt. Kinabalu in Malaysia. Planted elsewhere.

INDIA (Sikkim, Meghalaya, Andaman Islands; cultivated at the South Indian Hill Stations trop. Himalayas, Khasi Hills and South Indian Hills); above 1800 m.

BHUTANSUMATRA AND PHILIPPINES, CENTRAL CHINA (?) AND JAPAN;

Uses : Timber is of high quality; used in carpentary, making utensils, carts, farm implemtns, Oars, Spars, and Masts, etc.

2. Podocarpus gracilior Pilger, in Das Pflanzenreich 4(5):71.1903.

Trees, up to 20 m (or more) high; trunk long, clear, crowned with crowded branches. Leaves of young plants scattered, upto 10 x 0.6 cm, leaves of mature trees crowded, shorter, 8.5-62 x 3.5-5 mm, thick in texture, narrow, tapering to a short point.

Distrib. : Native of Abyssinia, Uganda and Keniya ; 2000-2600 m.

INDIA: Uttarakhand (Dehradun), Meghalaya (Shillong, Sikkim(Gangtok); Planted.

Notes : Several trees are found at Dehradun (FRI/ ICFRE) where these were planted 60-75 years ago from Ethiopia 8000 feet msl; also planted else where.

Uses : Timber is most valuable ; used for general building purpose, particularly inside work, such as flooring, door, paneling and furniture.

Notes : Easily distinguished from the other species from its seeds which are without a fleshy receptacle.

3. Podocarpus neriifolius D.Don *ex* Lamb., Descr. Gen. Pinus 2: 21. 1824; Hook. f., Fl. Brit. India 5 : 649. 1888; Sahni, Gymnosperms of India & Adj. Countries 49. 1990. *Podocarpus discolor* Blume, Rumphia 3 : 213. 1847.

Common names: Oleander Podocarpus (Engl.), Halis (Hindi), Gunsi (Nep.), Thitmin-po (Burmese)

Evergreen, glabrous trees, up to 18 m high; branches whorled ; bark grayish brown or pale cinnamon brown, thin, peeling off in long papery flakes, reddish inside. Leaves scattered, subsessile, linear or linear-lanceolate 10-18 (25) x 0.8-1.5 (1.9) cm, coriaceous, thick, mid-rib prominent on both surfaces, obtuse, acute or acuminate.

Uses : Timber is of high quality; used in carpentary, making Bars, spars and Masts.

Fl. & Fr.: July-Feb.

Habitat : Evergreen broad-leaved forests; 100-1000m.

Distrib. : INDIA : Andaman Islands, N.E. India, E. Himalayan region; upto 900m. BHUTAN, CAMBODIA, CHINA, INDONESIA, LAO, MALAYIA, MYANMAR, NEPAL, PAPUA NEW GUINEA, PHILLIPPINES, THAILAND, VIETNAM, PACIFIC Isls.

4. Podocarpus wallichianus C. Presl., Bot. Bemert 110. 1844; Pilger in Engler, Pflanzenr. 18 Heft. 4(5):59.1903; Raizada & Sahni, 105, 1960; Dallimore & Jackson (rev. Harrison), Handb. Conif. & Ginkgo ed. 4,554.1966; Sahni, *l.c.* 50. 1990. *Podocarpus latifolia* Wall., Pl. Asiat. Rar. 1:26, t. 30.1830; Hook. f., Fl. Brit. India 5:649.1888; Brandis, Indian trees : 695.1906.

Common names : Wallichian Podocarp (Engl.), Nirambali (Tamil), Soplang (Khasi), Thitmin-ma (Burmese)

Evergreen, glabrous trees, upto 27 m high ; wood aromatic ; bark smooth, mottled brown and white. Leaves opposite and subopposite, oblong to lanceolate, 10-17.5 x 1.3-5 cm. acute or acuminate.

Distrib. : Widely distributed from Myanmar to India (Assam, Meghalaya and Peninsular India-Western Ghat from Nilgiris south wards; also in Great Nicobar Islands but absent in Andaman Islands; recorded upto 1500 m.

6. ARAUCARIACEAE

A family of *ca* 2 genera and 38 species distributed in S. hemisphere (excl. Africa) to Indo-China and Phillippines (*cf.* Wiillis 1973); 2 genera; 6 species grown in India.

1. **Agathis** Salisb.

in Trans. Linn. Soc. 8: 311, t. 5. 1807, *nom.cons.*

A genus of *ca* 21 species distributed in Indonesia, Malaysia, Papua New Guinea, Philipines, Australia, S.W. Pacific Islands, New Zealand; only one species planted in India.

1. Agathis damara (Lamb.) Rich. & A. Rich. in A.Rich, Comm. Bot. Conif. Cycod.83.1826. *Pinus damara* Lamb., Descr. Pinus 1:61.1803. *Agathis robusta* F.M. Bailey, Cat. Woods Queensl. Lond.Col. Ind. Exhib. 1886 83.1913. *Agthis loranthifolia* Salisb. in Trans. Linn. Soc. 8: 312, t. 15. 1807.

Common Name : Queensland Kauri (Eng.)

Evergreen trees, upto 45 m high; trunk straight columnar; bark thick brown, scaly. Leaves coriaceous, glossy, dark

–green above, pale beneath, opposite or subopposite, ovate or elliptic, 5-12 x 2-4 cm, tapering into a broad flattened petiole.

Fl. & Fr. : March-July

Distrib. : a native of Queenaland; upto 800m; Planted in India (Dehradun, Yercaud)

Uses : Timber is prefereably employed for general joinery work ; wood is suitable for manufacturing of writing, printing and wrapping papers and for viscose rayon. An oleoresin used in adhesives, paints, polishes, inks and lacquers is also obtained.

2.ARAUCARIA Juss.

Gen. Pl. 413, 1789.

A genus of *ca* 18 species distributed in New Guinea, E. Australia, New Zealand, Norfolk Islands, New Cadedonia and S. Brazil to Chile; 5 species introduced in India.

Etymology : Generic epithet (*Araucaria*) is after Arauco province of S. Chile – the native habitat of the type species (*A. araucana*).

1. **Araucaria bidwillii** Hook. in Lond. J. Bot. 2: 503, t. 18, 19. 1843.
Common names : Bidwill's araucaria, Bunya Bunya Araucaria (Eng.).

Dieocious trees, with dome-shaped crown, upto 40 m high. Leaves spirally arranged, lanceolate, on sterile-shoots, upto 50x5mm, dark-green, stiff, narrowed to a long stiff point at apices..

Fl. : Feb. – May .

Notes: Seeds maturing after 3 years.

Prop. : Seeds and cuttings of young branches.

Etymology : Named after J.C. Bidwill who brought it to knowledge.

Distrib.: Native of Queensland. Planted in India and China

2. **Araucaria cunninghamii** Aiton tex D. Don in Lambert Descr. Pinus, ed.2,3 t.79.1837. Ouden & Boom, Manual Cult. Conif. 49. 1965.

Common names : Cunningham's Araucaria, Hoope Pine, Moreton Bay Pine, (Engl.)

Trees, upto 50 m high, crown pyramidal. Leaves dimorphic; those on young trees and lateral branches spirally arranged, lanceolate or triangular, 42-90 mm long, sharp pointed; those on old trees and cone-bearing branches shorter, crowded, sharp pointed

Fl. : Jan – March

Distrib.: Native to Papua New Guinea, NE Australia, Northern New South Wales and Queensland. Planted in China, India.

Propagation : by seeds

Uses : ornamental trees.

Habitat : upto 1000 m in W.Himalaya and upto 1500 m in E. Himalayan region.

3. **Araucaria cookii** R. Br. *ex* D. Don in Trans. Linn. Soc.18:164.1841. *Araucaria columnaris* Hook, Bot. Mag. T. 4635. vol. 8. 1852.

Common names : Columnar Araucaria, Cook's Araucaria (Eng.)

Trees, upto 60 m high, with columnar crown. Leaves of juvenile shoots triangular or laaceolate, upto 7 mm long; those on older shoots broadly ovate, 2-5 x 1.5 mm.

Fl.: Feb.- May.

Distrib.: Native of New Calendonia and polynesia. Planted else where.

Habitat.: Flowering well in Himalayan area upto 1200 m.

Propagation: by seeds.

Uses : Popular landscape- tree.

4. **Araucaria heterophylla** (Salisb.) Franco in Anals Inst. Sup. Agron. 29.11.1952; Ouden & Boom, Manual Cult. Conif. 50. 1965. *Eutacta heterophylla* Salisb. in Trans. Linn. Soc. Lond. 8 : 316. 1807. *Araucaria excelsa* R. Br. in Ait. Hort. Kew. ed.II. V. 412. 1789. *Dombeya excelsa* Lamb., Deser. Genus Pinus ed. I., I : 87. 1807. *nom. illegit.*

Common name : Norfolk-Island pine (Eng.).

Trees, upto 60 m high, crown pyramidal. Young leaves subulate, 8-12. 5 mm long, curved sharp-pointed; adult leaves densely imbricated lanceolate to ovate-triangular, mid-rib obscure..

Distrib. : Native of Norfolk islands. Planted elsewhere as ornamental.

5. Araucaria rulei Muell. *ex* Ldl. in Gard. Chron. 868. 1861 ; Ouden & Boom, Manual Cult. Conif. 51. 1965.

Trees, upto 15 m high, variable in size and shape with age; branches in whorls of 5-7.Leaves very variable, oblong – lanceolate, to elliptic, 12-15 x 6-10 mm at base, imbricate, concave, stiff, coriaceous, shortly pointed at apices.

Distrib. :New Calefonia, Papuan. An chipelago.

India : Planted in Ooty Botanical Garden in Tamilnadu.

7. PINACEAE Lindl. *nom. cons.*

Lindl., Nat. Syst. Bot. ed. 2. 313, 1836.

A family of *ca* 10 genera and 250 species distributed in the N. Hemisphers south ward to Sumatra, Java, C. America and West Indies; 6 genera indigenous to India.

1. ABIES Miller

Gard. Dict. 1754.

(Silver Firs)

A genus of *ca* 40 species of temperate habitats of the N.Hemisphere (N.Americal, Europe, N.Africa, Asia); 5 species and 1 variety in India.

Etymology : The generic name (*Abies*) is derived from the Latin word '*Abire*' which means 'to go away', referring to the height of some species

1. Abies delavayi (Van Tiegham) Franch, in J. de Bot. 13:255.1899; Sahni. *l.c.*83. 1990. *Keteleeria delavayi* Van. Tiegham in Bull. Soc. Bot. France 38:412. 1891.

Local name : Delavay's Fir.

Trees, up to 40m high.Leaves on lateral branchlets in 2 opposite sets; leaves of upper side of shoot much shorter than of the lower side. .

Fl. & Fr.: May-Nov.

Distrib.: INDIA : Arunachal PradeshL Kameng dist., Peri-La above Tawang and Se-La localities).

CHINA, S.W. SEECHUEN, N.E. UPPER MYANMAR, BHUTAN

Etymology : Specific epithet is after Abba Delavay- a plant explorer in China.

Uses : Timber is valuable.

Notes : *Abies fabri* (Masters) Craib has been considered synonymous to *A. delavayi* by Dallimore & Jackson (1966) and Sahni (1990). Mehra & Jain (1976) considered the East Himalayan Fir to be *Abies forestii* C.C. Rogers.

It is distinguished by its needles having strongly revolute margins.

2. Abies densa Parker in Indian Forester 53(12):686 1927; Sahni, *l.c.* 81.1990.

Local names : Gobre-salla (Nep.), Dunshing (Bhutia), Red Fir, Eastern Himlayan Fir (Eng.), Talispatra (Sanskrit/ Ayurveda).

Trees, upto 60m high; crown pagoda-shaped or umbrella shaped, with horizontally long spreading flattened branches. Leaves crowded, more or less distichous, needle-like, flattened, 13-50mm long, silvery glaucous beneath, margins not revolute.

Distrib.: Eastern Himalaya to S.E. Tibet and N.E. Frontier of Myanmar; 2850-4000m.

India : Arunachal Pradesh, Sikkim.

Uses : Timber is valuable.

Etymology: The specific epithet (densa) refers to the dense or crowded leaves. The common English name '**Red Fir**' refers to the reddish-brown young shoots.

3. Abies nordmanniana (Stev.) spach. Hist. Nat. Veg. phan. II:418 (1882); Duden & Boom, Mann. Cult. Conif. 31(f) & 32. 1965. *Pinus nordmanniana* Stev. In Bull. Soc. Nat. Mosc. II:45 (1838)

Common name : Caucasian Fir (Engl.).

Tree, 50-60m high, pyramidal, furnished to the ground with branches. Leaves 20-30x, 2-2.5 mm, rounded or notched at apex, flat, grooved, shining green

India : Planted at IBG (*c.f.* Chakraborty *et al* 2003)

4. Abies pindrow Royle, Ill. T. 86. f. 9.c. 1836 et, O', 350, 1839; Sahni, *l.c.* 199.1990, *Abies pindrow* Spach, Hist. Veg.XI. p. 423. 1842; Hook. f., Fl.Brit. India 5: 692.1890. *Abies webbiana* Lindl. var. *pindrow* Brandis, For. Fl. 528. 1874; [illegible]

var. **pindrow**

Local names : Paludar (Hazara); Badar, Drewar (Kashmir), Pindrow, Tos, Span, Rau (Himachali); Morinda (Garhwali); Raqha (Kumaoni), West Himalayan Fir, Low level Fir, Pindrow Fir (Eng.).

Lofty, evergreen trees, up to 63 m high; crown dense, narrowly cylindrical; foliage dark green.Leaves needle-like, 25-62 mm (or more) long, 2-ranked, on opposite sides of twigs; flattened, lower surface with 2 silvery bands on either side of midrib, notched at tips.

Fl. & Fr. : April – Nov.

Distrib. : W. Himalaya : Afghanistan to Nepal; (2150-) 2300-3350 m.

India : J & K, Himachal, Uttarakhand.

Uses : Timber is valuable; used for making fruitcares, planking for ceiling, floor board, and shingles, for houses in the Himalayan region of India.

4.1. Abies pindrow var. **brevifolia** Dallimore & Jackson; *Abies gamblei* Hickel

Differs from var. *pindrow* in having shorter, rigid, acuite, pale-green leaves and brownish (not grey) branchlets, It differs from *A. spectabilis* in its glabrous shoots and shorter and narrower leaves (Sahni 1990).

Distrib. : INDIA : Garhwal (Sahni 1990:79p).

5. Abies spectabilis (D. Don) Spach, Hist. Nat. Veg. Phan. 11, p. 422. 1842; Sahni, Gymn. India & Adj. Count. 79-80. 1990. *Pinus spectabilis* D. Don in Lamb., Descr. Gen. Pinus 2, 3, t. 2, 1824, et. Prodr. Fl. Nep. 55. 1825. *Abies webbiana* (Wall.) Lindl., Penny Cyclop. 7, 1833; Hook. f., Fl. Brit. India 5 : 654. 1888.

Type : *Pinus spectabilis* D. Don (*cf.* Parker 1927 : 684)

Local names : Gobre salla (Nep.); Chilaro, Ragha, Ganasula (Kashmiri); Badar, paludur (Siikkim); Dhunsing (Bhutan), High Level Fir (Eng.).

Trees, sometimes gnarled, with a wider crown (not cylindrical) some what pyramidal.Leaves spirally arranged, more or less bifarious, variable in length, flat, linear

Uses : Timber is valuable for house buildings.

Excluded Taxa

6.Abies ernestii var. **salouensis** (Borderes & Gaussen) W.C. Chang & L. K. Fu, Fl.Repub. Populabis Sin.7:93.1978. *Abies chensiensis* Tiegham ssp. *salovensis* (Borderes & Gaussen) Rushforth; Haridasan & Deori, Arunachal Forest News 1991:31.1991.
Distrib.: Arunachal Pradesh (?Haridasan & Deori 1991).
Notes: It has been enlisted as *Abies chensiensis* Teghen subsp. *salouensis* (Borderes & Gaussen) Rushforth, by Haridasan & Deori (1991) without any detail, hence excluded in this work.

2. CEDRUS Trew, *nom. Cons.*

Cedrorum libani Hist. 1:6. 1757.

A genus of *ca* 4 species; only one species in India.

Cedrus deodara (Roxb.) G. Don in Loud-Hort. Brit. 388. 1830. *Pinus deodara* Roxb., Fl. Ind. 3: 651. 1832. *Abies deodara* Lindl. in Penny Cyclop. 34, *Cedrus libani* Barrel var. *deodara* Hook. f., Himal. Journ. 1: 257. 1854 & in Nat. Hist. Rev. 2, t. 1-3. 1861.

Local name : Deodar (Hindi)

Lofty robust trees, upto 83 cm high. Leaves 2.5-3.7 cm long, usually glaucous green, actue
Fl. & Fr. : June – Nov.

Distrib. : N.W. Himalaya (India : Kumaon Westward) 1270-4000 m; planted at Llyoid Botanic Garden at Darjeeling, at in Arunachal Pradesh in East Himalayan region.

Afghanistan,

Uses : Wood is highly valuable.

3. LARIX Miller

Gard. Bist. 2: 2. 1754

(Larches)

A genus of *ca* 12 species distributed in Europe, N. Asia and N. America, one species in India

Larix griffithiana (Lindl. *et* Gord.) Carr. Traite Conif. 278. 1855. *Abies griffithiana* Lindl. *et* Gord. In J. Hort. Soc. Lond. 5: 214. 1850. *Larix griffithii* Hook. f. , Illustr. Himal. Pl. t. 21, excl. fig. 1-4, 1855; Hook. f., Fl. Brit. India 5 : 655. 1888.

Local names : Boarge sella, Binya (Nep.); Sah, Saar (Lep.).

Small trees, upto 20 m high. Leaves ca 2.5 cm long, linear, flat, 30-50 in a cluster.

Fl. & Fr. : May – Oct.

Distrib.: Eastern Himalaya : India (Darjeeling, Sikkim, Arunachal Pradesh), BHUTAN, EASTERN NEPAL, N.E. UPPER MYANMAR, TIBET (CHUMBI VALLEY).
Uses : Wood is used for making shingles in Sikkim.

4. PICEA A. Diet.

Fl. Gen. Berl. 2: 794. 1824.

(Spruce)

A genus of *ca* 50 species distributed in temperate regions especially in E.Asia ; 3 species in India.

1. **Picea brachytyla** (Franch.) Pritzel in Bot. Jahrb. 29: 216. 1900. *Abies brachytyla* Franch in J. de Bot. 13:258. 1899.

Trees, up to 30 mm high.Leaves crowded, overlapping on upper side of shoots, lower side leaves spreading outwards in 2 opposite ranks exposing, often rigid, yellowish-green or green, 12-19 mm long, flat slightly ridged, bluish-white beneath; apices blunt with a sharp horny point.

Distrib. : **India** (Arunachal Pradesh : Kameng dt., Mago).

W. Yunnan, Upper Myanmar,

Uses : Timber is valuable for construction.

2. **Picea smithiana** (Wall.) Boiss., Fl. Orient. 5:700. 1884. Sahni, *l.c.* 71. 1990. *Pinus smithiana* Wall. Cat. 6063. 1827 ; Pl.Asiat. Rar. 3: 24, t. 246. 1832. *Picea morinda* Link in Linnaea 15 : 522. 1841 ; Hook. f., Fl. Brit. India 5:653-654. 1888.

Local names : Rai, Rau, Rias, Kachlu (N.W. Himalaya) Roi, Raghe, Morinda (Garwali & Kumaoni)

Conical trees, up to 50 m highLeaves dark green, stiff, acicular, 2.5-3.7 cm long, tetragonous, pungent

Fl. & Fr. : April – July.

Distrib. : Himalayas : Afghanistan to India (Kumaon) 2150 - 3300 m.

Uses : Timber is valuable for construction work, as Railway sleepers, Newsprint production,etc.

3. **Picea spinulosa** (Griff.) Hency in Gard. Chron. Ser. 3.39.219. 1906, Sahni *l.c.* 72-73. 1990. *Abies spinulosa* Griff., Journ. Travels 259.1847 & Ic. Pl. Asiat. Rar. 4, t. 363. 1854. *Picea morindoides* Rehder in Sargent, Trees and Shrubs 1:95, f. 48.1903.

Local name : Ehsing (Sikkim).

Evergreen trees, up to 60 m high. Leaves irregularly arranged round the shoot, crowded, closely overlapping on upper side, flattened, 19-32 x 1 mm, keeled, apices sharp pointed, green above, with 2 lines of stomata on lower surface.

Distrib. : **India** : (Arunachal Pradesh, Sikkim : Lachen); 1700-3000 m.

TIBET (CHUMBEY VALLEY), BHUTA,

5.PINUS L.

Sp. Pl. 1000. 1753

(Pine)

Type : *Pinus sylvestris* (lectotype designated by Farton & Jaduis) "*Pinus sylvestris*", Dale champs, Hist. Gened. Pl. its, i.e. 1856.

A genus of *ca* 91 species distributed in N. Hemisphere upto the edge of Arctic circle forming northern coniferous forests in Europe, Asia, and N. America to the subtropical regions of N. Africa, Canary Islands, Asia Minor, Myanmar, Philippines. Central America, Florida, Bahamas and Hondunes; found at subtropical or warm temperate altitudes in tropical countries, rarely on plains. Six species and one variety indigenous to India; many more introduced.

1. **Pinus bhutanica** Grierson, Long & Page in Notes R.B.G. Edinb. 38(2) : 297-310. 1980 ; Sahni, Gymn. India Adj. Count. 63-64. 1990.

Trees, *ca* 25 m high ; branches spreading, dropping. Needles pendulous from base, 5, 12-28 cm long, grown green along outer face, whitish bloomed beneath

Distrib.:INDIA (Arunachal Pradesh : Kameng dist., Tenga Valley ; 1700-2000 m).BHUTAN

Notes : Needles are shed during second year.

2. **Pinus gerardiana** Lamb., Genus Pinus II, 115, t. 79.1882; Sahni, Gymn; India Adj. Count. 65. 1990.

Common names: Chilgoza pine (Engl.), Chilgoza, Neoza (Hindi), Chiri, Gunober Prite (N.W.Himalaya).

Trees, upto 18(-24).m high. Needles in cluster of three dark green, stout, persistent for 3-4 years, serrulate, 7.5-12.5 cm long, stiff, compressed, triquetrous.

Fl.& Fr.: May-June (-Oct)

Distrib. : N.W. Himalaya : dry interior valleys; 1740-3600 m.

Etymology : Specific epithet is after Cept. Gerard.
Uses : Seeds edible; highly valued as dry fruit.

3. **Pinus kesiya** Royle *ex* Gord., in Gardn. Mag. & Reg. Rural. Domest. Impreu 16:8.1840. *Pinus insularsi*, Endl., Conif. 157. 1847. *Pinus khasyana* Griff., Notul Pl. Asiat. 4 : 18. 1854; Icon. Pl. Asiat. T. 367.8.1854. *Pinus khasya* Hook. f., Fl. Brit. India 5 : 652. 1888 ; Brandis. Indian Trees 690. 1960;

Common names : Khasi Pine (Engl.), Ding-se, Dieng-kysi (Khasi), Far (Lushai), Saral (Beng.), Tinyu, Tinshu (Myanmarese).

Small trees (in India; upto 60 m in Myanmar) with roundish grown (head).Needles in cluster of 3, very slender, green, 12.5-22.5 cm long, serrulate, semiterate, grooved above; sheaths persistent, 12-18 mm.

Fl. & Fr. : Feb. – April.

Distrib. : **India** (Meghalaya, Nagaland, Manipur).

BANGLADESH, MYANMAR, PHILIPPINES

Uses : Source of good quality resin, much valued for afforestation due to its fast growing habit.

4. **Pinus merkusii** Jungh & De Vr. In Pl. Nov. Ind. Bot. Orient., t.2.1845; Hook. f., Fl. Brit. India 6:652.1882; Sahni, Gymn. India Adj. Count. 68. 1990.

Common names : Merkus Pine, Two needle-pine (Engl.), Tinyu, Tinshu, Shaja (Myanmar).

Trees, upto 30 m high, conical when young, spreading or round headed when mature. Needles in clusters of 2, 15-20 cm long, smooth, slender semiterate, grooved above; sheaths *ca* 8 mm long, fimbriate persistent.
Fl.& Fr.: March-April

Distrib.: India : Arunachal Pradesh (Lohit dt.)

5. **Pinus roxburghii** Sargent in Silva N. Am. 2, 91897; Sahni, Gymn. India Adj. Coun. 65-67. 1990. *Pinus longifolia* Roxb., Fl. Ind. 3 : 651. 1832 ; Hook. f., Brit. India 5: 652.1888.

Common Names : Chir, Chit (Hindi), Dhup (Nep.), Nyit. (Lepcha), Chirpine, Himalayan long Needle Pine (Engl.).

Trees, up to 33 m high, often stunted and grarled; trunk usually naked,. Needles dark or light, green, 22.5-30 m long, slender, triquetrous, serrulate, back obtuse; sheaths fimbriate, persistent.

Fl. & Fr. : Feb. – May.

Distrib. : Outer Himalayan ranges, India (Kumaon to Arunachal Pradesh), Pakistan, Bhutan, Afghanistan, 450-2250 m.

Uses : Good source of resin of Timber is used as Railway sleepers and as joinery.

Rep. specimens: Arunachal Pradesh: Kameng dist. Munna, *K.C. Sahni* 445(DD), Bletting oblong Tawang Cho, *Loganey* 13 (DD);

6. **Pinus wallichiana** A.B. Jackson in Kew Bull. 85.1938; Sahni, Gymnos. India Adj. Count. 58-59. 1990. *Pinus excelsa* D. Don in Lamb., Descr. Gen. Pinus 2:5, 1824, *non* Lam. 1778 (*nom. illeg.*): Hook. f., Fl. Brit. India 5:651.1885. *Pinus griffithii* (Mcc. in Griff. Notul 4, 17.1854 (*nom. illeg.*) *Pinus nepalance* DC., Chambray, Traite, Prat. Arb. Resin. Conif. 342.1845, *non* Forbes.

var. **wallichiana**

Local names : Kail (Hindi), Kail, Yiro (Kashm.), Lin (Himachal), Raisalla, Lamshing (Kumaron), Meetkung (Lecha), Tongschi, Lamshing (Bhut.), Blue-Pine, Kail (Trade, Emgl.).

Distrib. : Temperate Himalaya (except Central & N.W. Kumaon and Sikkim); 1800-3750 m.

Afghanistan,

Uses : Timber is used for Railway sleepers, house–construction and light furnitures. A liquid called as "honey-dew", secreted by Aphids infesting its leaves is edible. Oil is obtained from seeds at Dirang in Arunachal Pradesh (Mohan 1993)

6.1 **Pinus wallichiana** var. **parva** K.C.Sahni, Ind. J.Forest.12.(1):40-42. 1989.

Type : *R.M. Loganey* 6, dt. 4.1.1959 (Holotype DD)

Differs from var. *wallichiana* in shorter (6-13 cm long) needles; smaller (*ca* 10 cm) cones; smaller wings (*ca* 10 mm long).

Distrib. : INDIA : Arunachal Pradesh(Kameng district) : *ca* 3000 m.

EXLUDED TAXA

'Armand's. Pine' (*Pinus armandii* Franch.)–the five needled 'Blue Chinese Pine' which is closely allied to the 'Blue Pine' (*Pinus wallichiana*) but can be easily distinguished by its wingless seeds, much stouter cones and much wider cone–scales as compared to the 'Blue Pine', was recorded by Kingdon Ward (1952) from Lohit district of Arunachal Pradesh (without citing any specimens). Sahni (1990) treated this species but pointed out that there is no further report/record of this species from India, after Kingdon Ward (1952). Haridasan & Deori (1991) also enlisted it from Arunachal Pradesh but without any reference/record.

Introduced Taxa

1. **Pinus canariensis** Sm. in Buch. Beschr. Can. Ins. 159, 1825; Bailey, Cycl. Hort. 2639, 1916; Dallimore & Jackson, Handb. Conif. (ed. 3) 468, 1948 ; Chitt. /dict. Gard. 1582, 1951; Bailey, Man. Cult. Pl. 106, 1958 ; Pilger in Pflanzenfam. (ed.2) 13 : 336, 1960.

Common name : Canary Island Pine (Eng.).

An evergreen tree with spreading branches, 12-17(35) m tall; branchlets drooping. Leaves in clusters of 3, glaucous when young, green later, flexible, densely crowded on the branchlets, 12-16 cm long, with persistent basal sheaths up to 1.5 cm long.

Fl.: June-Oct; *Fr* : Not seen.

Distrib.: Indigenous in the Canary Islands; now in cultivation in many parts of the world, especially where relatively long dry periods are available.

INDIA :Tamilnadu (Kodaikanal), planted.

2. **Pinus caribaea** Morelet in Rev. Hortic. Coted Or,Oct.1851 et in Bull.Soc.Hist.Nat. Moselle 7:87-101,1885.

Common Name:Caribbean Pine (Eng.)

Trees, 15-30 m high. Needles usually in 3's, occasionally 4-5 or only 2, crowded at the branch tips, abscising in the 2nd year, 15-25 cm long, dark or yellowish-green, somewhat glossy, with a horned tip, margin finely serrate, stomatal lines on all sides, resin ducts in the parenchyma, sheaths persistent *ca* 12 mm long, light brown at first later black-brown.

Native of Caribbean Islands and the coast of Central America.

INDIA: Arunachal Pradesh; introduced

3. **Pinus densifiora** Sieb. & Zucc., Fl. Jap. 2:22,t.112.

Common name : Japanese Red Pine (Eng.).

Trees, 20-30 m high; crown irregular and flat spreading.Needles 2 in each bunch, densely brush-like on the shoot tip, persisting for 3 years, 6-12 cm long, 1 mm wide, serrate, finely acuminate, *ca* 1 mm wide with indistinct stomatal lines on both surfaces; resin ducts at the epidermic. sheaths on younger needles *ca* 15 mm long, often loosening to 2 filamentous scales

Native of Japan, Korea.

Introduced in India.

4. **Pinus echinata** Mill. Gard. Dict. (ed.8) n. 12, 1768; Bailey, Cycl. Hort.2642, 1916; Dallimore & Jackson, Handb. Conif. (ed.3) 484, 1948; Chitt. Dict. Gard. 1583, 1951; Bailey, Man. Cult. Pl. 109, 1958; Pilger in Pflanzenfam. (ed.2) 13 : 339, 1960.

Common Name : Short-leaf Pine.

An evergreen tree, 30-40 m tall, with broad, ovoid crown. Needles in clusters of 2 (rarely 3 or 4), slender, flexible, 6-12 cm long, serrulate, bluish-green; leaf-sheaths persistent, 6-8 mm long.

Fl. : March - June. *Fr.* : Sept. - Nov.

Distrib. : Indigenous in a wide area of S. and S.E. united States.

INDIA: Kodaikanal (Tamilnadu); introduced.

5. **Pinus elliottii** Engelm., Trans. Acad. Sci. St. Louis 4: 186. 1880.

Trees, upto 30 m high. Needles 2 or 3 per bundle, slightly twisted, yellow- or blue-green, 15-24 cm x 0.2-1.5 mm; stomatal lines present on all surfaces, base with persistent sheath 1-2 cm, margin finely serrulate.

Native to SE United States.

Cultivated in India.

Note: Often confused with *Pinus caribaea* which usually has 3 needles and is totally tropical.

6. **Pinus greggii** Engelm. *ex* Parl. In DC.,Prod. 16(2):396. *Pinus patula* var. *macrocarpa* Mast

Trees, upto 15 m high.Needles in 3's, light green, persisting 2-3 years, 7-15 cm long, short acuminate, margin finely serrate.

Native of Mexico.

Introduced in India.

7. **Pinus halepensis** Bieb. Fl. Taur.Cauc.2:408.
Common Name: Aleppo Pine (Eng.).

Trees, upto 15 m high; crown conical when young, but arched more umbrella-shape or globose when older, irregularly thinly branched. Needles in 2's, occasionally 3, outspread, persisting for 2 years, often clustered at the branch rips, with short horn-like tips, thin 6-10 cm long, margin finely serrate.

Native of Mediterranean region, Asia, minor, from Portugal to Afghanistan; Introduced in India.

8. **Pinus montana** Mill. var. **mughus** (Scop.) Willie.

Plants shrubby-procumbent; branches bowed knee-like.

Native to East Alps to the Balkan Peninsula.
Introduced in India.

9. **Pinus montezumae** Lamb.

Common Name: Montezuma Pine (Eng.).

Trees, upto 30 m high. Needles grouped 3-8, but usually in 5's persisting for 3 years, clustered on the shoots, bluish-green, 17-30 cm long, erect or outspread, acute, margins finely serrate

Native to Mexico; in temperate and tropical regions at altitudes of 1200-3600 m.
Introduced in India (Sim's Park, Coonoor, Nilgiri district, Tamil Nadu).

10. **Pinus nigra** Arnold.

Common Name: Austrian Pine (Eng.).

Trees, upto 40 m high, quite variable. Needles in 2's, lighter or darker green, rather stiff, persisting 4(8) years, 8-12 cm long, 1-2 mm wide, straight or bowed, margins finely toothed.

Distrib.:Native to S. Europe, north to Austria and to the south Carpathian Mts.
Introduced in India at Pauri, Garwal (Uttarakhand).

11. **Pinus oocarpa** Scheide.in Linnaea 12:491.1838. *P.oocarpoides* Lindl.ex Loud., Encycl. Trees 1118.

Trees, upto 18 m high. Needles in 3's or 4-5, light green, 15-30cm long, usually 22-25cm long, usually stiff and rough, occasionally thin and flexible, glossy green, resin ducts usually 5-8 in the parenchyma, sheaths 20-30 mm long, brown, with long acuminate scales.

Native to Central America; S. and W. Mexico, from Sonora to Chiapas; Guatemala, El Salvador, Honduras and Nicaragua.

Introduced in India at Dehradun (Uttakhand)

12. **Pinus parviflora** Sieb. & Zucc. Fl. Jap.2:27,t.115. *Pinus pentaphylla* Carr. Conif. Ed 2:384.

Common Name: Japanese White Pine (Eng.).

Trees, upto 30 m high; crown conical. Needles in group of 5, persisting for 3-4 years, clustered brush-like at the branch tips, very curved and twisted, either rather stiff and conspicuously blue-white on the inside, with light, glossy young shoots or with soft, more grass-green needles and dark brown, later pubescent young shoots, 4-6 cm long, about 1 mm wide, obtuse, margins finely serrate.

Native of Japan.

Introduced in India at Lalbagh Botanic garden, Bangalore (Karnataka).

13. **Pinus patula** Schiede & Deppe ex Schlecht.& Cham. In Linnaea 12:491.1838. *Pinus subpatula* (Royle?), Roezl. Ex Gord. Pinet. Suppl. 84.
Common Name: Jelecote Pine (Eng.).

Trees, upto 20 m (or more) high, frequendy multistemmed or forked just above the ground. Needles in 3's (occasionally 4-5), persisting 3-4 years, very thin, 15-22 cm long, pendulous, acute, margins serrate, bright green.

Native of Mexico; the central and eastern States, especially in Hidalgo and Veracruz, in the subtropical climates, at 1500-3000 m.

Introduced in India (Arunachal Pradesh, Sikkim, Tamil Nadu, Uttarakhand)

14. Pinus pinaster Ait. Hort. Kew 3: 367, 1789; Gamble, Man. Ind. Timb. (ed. 2) 703. 1902; Lushington, Vern. n. 2852, 1915; Dallimore & Jackson, Handb. Conif. (ed. 3) 528, f. 97, 1948 ; Chitt. Dict. Gard. 1585, 1951; Bailey, Man. Cult. Pl. 109, 1958; Pilger in Pflanzenfam. (ed. 2) 13: 336, 1960. *Pinus nepalensis* Royle *ex* Lindl. & Gord. In Journ. Hort. Soc. 5:217, 1850.

Common Names : Cluster Pine ; Maritime Pine (Eng.).

Evergreen trees upto 25m tall. with pyramidal crown; boles erect, devoid of branches for a considerable length bark thick, brownish, deeply fissured; Needles in clusters of 2, stout, rigid, curved, 12-15 cm long, subtended by persistent basal sheaths 2.5 cm or more long.

Fl. : March - May. *Fr.*: Sept. to Nov.

Field Notes : There are only stray specimens left in the area.

Distrib.: Indigenous in the Mediterranean region; now in cultivation in many terperate countries.

Etymology : The specific name *pinaster* is the Latin name for a 'Wild pine'.

Introduction : This was among the first 4 species introduced at Kodaikanal (Tamilnadu) by the Forest Department in 1906, but failed completely. It was tried again in 1913, but the plantation was burnt down in 1920. The trees that are left over, are from the plantings of 1914.

15. Pinus pinea L., Sp. Pl. 1000, 1753; Gamble, Man. Ind. Timb. (ed. 2) 703, 1902; Bailey, Cycl. Hort. 2639, 1916 ; Dallimore & Jackson, Handb. Conif. (ed. 3) 533, f. 97, 1948; Chitt. Dict. Gard. 1585, 1951; Bailey, Man. Cult. Pl. 106, 1958; Pilger in Pflanzenfam. (ed. 2) 13 : 339, 1960.

Common Name : Stone or Umbrella Pine, Italian Stone Pine (Eng.)

Trees, upto 25 m high; crown broadly arched, umbrella-shaped. Needles in 2's, persisting 2-3 years, slightly twisted, stiff, 10-15 cm long, to 2 mm wide, yellow and sharp on the apex, margins finely dentate.

Fl. & Fr. : March-May.

Distrib. : Indigenous in the Mediterranean region from Canary Islands and Madeira, Portugal to Asia Minor , extensively planted in S. Europe. Myanmar, Thailand, Cochin-China, Sumatra, Java, Borneo, Philipines & India (Arunachal Pradesh).

Introduced in India at Kodaikanal (Tamil Nadu).
Uses : Good source of resin. Seeds edible. Timber is valuable for construction.

16. Pinus pseudostrobus Lindl. Gord. Pinet 237.

Trees, upto 25 m high Needles usually in 5's, intensively green, 17-24 cm long, flexible, finely serrate, with 3 resin ducts, sheaths 12-15 mm long, brown, persistent.

Native to Central America; 2300-2350m, subtropical
Introduced in India at Dehradun (Uttarakhand).
Notes : Quite variable.

17. Pinus radiata D. Don in Trans. Linn. Soc. 17:442. 1837; Bailey, Cycl. Hort. 2644, 1916; Gamble, Fl. Pres. Madr. 1393 (975) 1928; Dallimore & Jackson, Handb. Conif. (ed. 3) 540, f. 98., 1948; Chitt. Dict. Gard. 1585, 1951; Bailey, Man. Cult. Pl. 110, 1958; Pilger in Pflanzenfam. (ed. 2) 13:341, 1960. *P. insignis* Dougl. *ex* Loud. Arboret. 4:2243, 1838; Lushington, Vern. n. 2846, 1915.

Common Name : Monterey Pine (Eng.).

Evergreen trees, upto 40 m high.Needles in clusters of 3, 8-15 cm long, subtended by persistent basal sheaths 0.8–1.2 cm long, bright green, finely serrate.

Fl.: April to June, *Fr.* : Sept. to Nov.

Distrib. : Native Monterey County, California, with restricted distribution; commonly planted and, to a certain extent, naturalized at the S. Indian hill Stations (Kodaikanal).

Etymology : The specific epithet '*radiata*', in Latin, means '*arranged like rays*' around a common centre.

Note : The tree is noted for its rapid growth. Young branches are characteristically ascending, but become horizontal later.Seeds of this species were obtained from California in

1906 by the Forest Department and seedlings were planted out every year till 1915. This has been the most successful of all the species of Pines introduced at Kodaikanal (T.N.).

18. Pinus sabiniana Dougl. In Trans. Linn.Soc.16:749.1833.

Common Name: Digger Pine (Eng.).

Trees, upto 20 m high, often multi-stemmed from the base; crown open and rounded, loosely foliate. Needles in 3's, persisting for 3 years, outspread or pendulous, light biue-green(i),20-30 cm long, 1.5 mm wide, sharply acuminate, serrate on the margins

Native of California; on dry hills; 150-1500m.

Introduced in India at Ooty in Tamil Nadu.

Uses : Seeds are edible.

19. Pinus taeda L. Sp. Pl. 2: 1000. 1753.

Trees, upto 45 m high. Needles ascending or spreading, dark yellow-green, slightly twisted, 10-23 cm x 1-2 mm, pliant, stomatal lines present on all surfaces, base with persistent sheath 1-2.5 cm, margin finely serrulate.

Native to SE United States.

Cultivated in India at Pauri, Garhwal (Uttarakhand).

20. Pinus thunbergii Parl. In DC., Prod. 16(2):388. *Pinus thunbergiana* Franco in An. Inst. Snper. Agron.,Libson 16:130.1949.

Common Name: Japanese Biack Pine (Eng.).

Trees, upto 40 m high, similar in appearance to P. *nigra;* crown broadly pyramidal, often also irregular. Needles in 2's, persisting for 3 years, densely arranged, spreading, somewhat twisted, dark green, 6-12 cm long, 1.5-2 mm wide, sharply acuminate, margins finely serrate

Native of Japan and S. Korea.

Introduced in India at Bangalore (Karnataka) and Pauri (Uttarakhand).

21. Pinus torreyana Parr. *ex* Torr. In Bot. U.S. & Mex. Bound. Surv. 210, tt. 58 & 59, 1858; Lushington, Vern. n. 2858, 1916; Bailey, Cycl. Hort. 2645, 1916; Dallimore & Jackson, Handb. Conif. (ed. 3) 570, 1948; Chitt. Dict. Gard. 1587, 1951 ; Bailey, Man. Cult. Pl. 110, 1958; Pilger in Pflanzenfam. (ed. 2) 13 : 340, 1960.

Common Names : Soledad Pine; Torrey Pine; Lone Pine; Del Mar Pine(Eng.).

Evergreen trees, up to 17.5 m tall. Needles in heavy tufts of 5, each 16-25 cm long, dark green, stiff, with a horny apex, crowded at the ends of brnaches; basal sheaths persistent, 16-20 mm long.

Fl.: March to June. *Fr.*: Sept.- Oct., scarce.

Distrib.: Native in Santa Rosa Island and the San Diego Coast ; cultivated on the hill stations in India.

INDIA: Tamilnadu(Kodaikanal,Bryant Park).

6.TSUGA Corr.

Traite Conif. 185.1855.

(Hemlock)

A genus of *ca* 10 species found in the Himalayas, N America, China, Japan and Taiwan; only one species in India.

1. Tsuga dumosa (D.Don) Eichler in Engl. & Prantl., Pflanzenfam. 2(1):80.18887. *Pinus dumosa* D.Don, Prodr. Fl. Nep. 55.1825. *Pinus brunoniana* Wall., Pl. Asiat. Rar. 3:247. 1832. *Tsuga brunoniana* (Wall.) Carr., Traite Conif. 188.1855; Hook. f., Fl. Brit. India 5 654. 1888.

Local names : Changathasi, Twingia, Sula (Nep.); Tangshing (Bhutia).

Evergreen trees, upto 40 m high. Leaves dark green, caducous after cutting branch, narrowly linear, 12-25 x 2.1 mm, white beneath, margins recurved tips serrulate.

Fl. & Fr. : May – June.

Distrib.: INDIA:Uttarakhand(Kumaon), Sikkim, Arunachal Pradesh; 2400-3000 m.

MYANMAR, NEPAL, BHUTAN, TIBET

Uses : Timber is valuable.

7. PSUDOTSUGA Carriere

Conf. ed.2:256.1867.

A genus of *ca* 4 species in E. Asia,2in W.N. America;2 species introduced in India.

1. **Pseudotsuga macrocarpa** (Vasey) Mayr, Wald. Nordamer. 278.1889;Fu Liguo in Wu Zheng-yi & Peter H. Raven, Flora of China 4:38-39.1999. *Abies macrocarpa* Vasey, Gard. Monthly & Hort. 18:21.1876.

Common Names : Bigcone Douglas. Fir. Bigcone spruce (Eng.)

Trees, upto 25m high.Leaves 2.5 -4 x0.2cm,stomatal bands 2,abaxial, gayish white, base strongly twisted, apex acute. Seed cones ovoid- cylindric, 9-13(-18_ x 4-6 cm, greenish yellow on maturity. ripening to dull brown.

Distrib.: Native of United States. Introduced elsewhere. Planted in China, India.

2. **Pseudotsuga menziesii** (Mirbel) Franco, Bol. Soc. Brot., ser. 2,24:74.1950;Fu Liguo in Wu Zheng-yi & Peter H. Raven, Flora of China 4:38-39.1999.*Abies menziesii* Mirbel, Mem. Mus. Hist. Nat. 13:70.1825.

Common Names: Douglas. Fir. Doughlas. Yellow or red spruce. Oregon pine,

*Commom Name:*Douglas tree (Engl.).
Cultivated.

Uses : Wood is used for making packing cases; suitable for making bottle corks after treatment cultivated as ornamental & timber.

8. TAXODIACEAE

A family of *ca* 10 genera and *ca* 16 species distributed in E. Asia,Tasmania and N. America; 7 species under 6 genera introduced in India.

1.**CRYPTOMERIA** D. Don

Ann.Nhat. Hist.1:233.1838; Trans. Linn. Soc. Lond. 18:166.1841

A monotypic genus distributed in China and Japan; introduced eleswhere.

1. **Cryptomeria japonica** (Thunb.*ex* L.f.) D. Don in Trans. Linn. Soc. London 18:167, t. 13 f. 1.1839; Sahni, Gymn. India Adj. Count. 92-93. 1990. *Cupressus japonica* Thunberg *ex* L.*f.*,Suppl. Pl.421.1782.

Trees, up to 50 m high, with a pyramidal crown. Needles awl-shaped, 1-2 cm long, spirally arranged, monoecious.

Fl. & Fr. : Almost throughout the year.

Distrib. : Native of S. China & Japan; introduced in India at Darjeeling (W.B), Sikkim (large scale, plantations) and Arunachal Pradesh ; 1100-2500m.

2. **CUNNINGHAMIA** R. Br. *ex* Rich. & A. Rich. *nom.cons.*

A. Rich. Comn. Bot. Conif. Cycad.80.149.1826 (*nom cons.*)

A monotypic genus of only one species; distributed in Cambodia(?), China, Laos & N. Vietnam; planted elsewhere.

1. **Cunninghamia lanceolata** (Lamb.) Hook. Bot. Mag. 54:t.2743.1827. *Pinus lanceolata* Lamb. Deser. Pinus 1:52.1803. *Cunninghamia sinensis* Rich. & A.Richard

Common name : Chinese Fir (Engl.)

Evergreen trees, up to 25 m high. Leaves narrowly lanceolate 3-6x0.2-0.6 cm, deep green alaxially, base decurrent, margin denticulate, apex spinescent; spine 0.3-2mm stiff

Fl. & Fr. : Oct. – Feb.

Distrib. : Native of China.

Planted in **India** :Sikkim, Uttarakhand (Dehradun), Tamilnadu (Kodaikanal); 200-280m(?).

CAMBODIA, LAOS, N. VIETNAM

Uses : Timber is used for coffins in China. It is an attractive tree suitable for land scape. Wood is termite proof; easily workable, used in building, construction of bridges, ships, lomp post, making furniture and for wood fibre.

3.**METASEQUOIA** Hu & W.C. Cheng

Bull. Fan. Mem. Inst. Briol., n.s.1:154.1948, (*nom.cons.*)

A genus with a solitary relict species of the Cretaceous and Cenozoic,when this genus was widely distributed in what is N.E.China, Europe,Greenland,Japan,North America and Siberia in Russia.First rediscovered in China in 1945;planted in India

1. **Metasequoia glyptostroboides** Hu & Cheng, Bull. Fan. Mem. Inst. Bid., n.s.1.154.1948; Fu Liguo in Wu Zheng-yi & Peter H.Raven (eds) Fl. China 4:60-61.1999.

Common names : Dawn Redwood (Engl.), Fossil age-conifer (Engl.)

Monoecious trees, upto 50 m high; trunk buttressed at base. Leaves borne at 45-60° to branchlet axis, 2-5 mm apart, bluish-green or yellowish-green, adaxially, paler aaxially, turning orange red in autumn, linear, 0.8-1.5 cm x 1.2-2mm on older trees, longer on younger trees.

Distrib. : Introduced in India; established at Darjeeling(W.B.) and at Forest Research Institute, Dehradun (Uttarakhand).

JAPAN, CENTRAL CHINA

Habitat : Temperate shedy moist habitats ; 700-1350 m; along water courses .

Notes : Monotypic, fast growing trees (upto 1 m per year). It has a forestry potential.

4.SEQUOIADENDRON J. Buchholz

Amer. J. Bot. 26.536.1939

A monotypic genus, native of United States; Introduced in India.

Sequoiadendron giganteum (Lindl.) Buchholz, Amer. J. Bot.26:536.1939, *Wellingtonia gigantia* Lindl., Gard. Chron.1853:823:1853.

Trees, 21.9 m (-90m)high, with tapering; crown *ca* 2.8 m in girth, partly buttressed at base. Leaves spirally arranged, appressed or slightly spreading, 3-ranked, awl-shaped, 3-5 mm long, convex below and concave above, sharpely pointed.

Uses : Ornamental and avenue trees, timber is also valuable. Trees are suitable for wider plantation in Western Himalaya. It can reach an age of *ca* 3500 years in Wild (Zheng-yi & P.H.Raven 1999, 4:59)

Distrib. : a native of pacific coast of North America,forming groves in the valley of the Sierra Nevada. Introduced in China and India.

INDIA : J.& K : Kashmir, Tangmarg, Yarikha Drag Forest Farm; *ca* 2154 m; age *ca* 76 years; planted.

5.SEQUOIA Endl. (*nom. cons.*)

Syn. Conif.197.1847.

(Red Wood)

A monotypic genus; native of United States; Introduced in India, China

1. **Sequoia sempervirens** (D.Don) Endl. Syn. Conif. 198, 1847; Lushington, Vern. n. 2827, 1915; Bailey, Cycl. Hort. 3153, 1917 ; Dallimore & Jackson, Handb. Conif. (ed. 3) 597, f. 108, 1948; Chitt. Dict. Gard. 1942, 1951; Bailey, Man. Cult. Pl. 118, 1958; Pilger in Pflanzenfam. (ed. 2) 13:352;1960. *Taxodium sempervirens* D. Don in Lamb. Pin.114, 1803, et (ed. 2) 107, 1828.

Common Name : Californian Redwood,Coast Red Wood (Eng.).

Large evergreen trees, 30-45 m high. Leaves spirally arranged, dimorphic.

Distrib : Native in California ; cultivated in temperate countries.

Notes : It is the tallest conifer in the world (*ca* 120 m high). Trunk reaches more than 6 mm in girth. The life span is said to be over 3000 years. The biggest tree 12.7 m tall is at "Augsburg". Introduced in India at Kodaikanal (TN) and in Chakrata area of Uttarakhand state in 1952 but it could not establish itself. It was grown at Indian Botanic Garden also.

Uses : Timber is valuable.

6.TAXODIUM Rich.

Ann. Mus. Hist. Nat. Paris 16:298.1810.

(Bald Cypress)

A genus of *ca* 2 species found in Guatemela, Mexico, America; introduced in China and India; both species grown in India.

1. **Taxodium distichum** (L.) Rich. in Ann. Mus. Nat. Paris 14:298.1810; Sahni, *l.c.* 92. 1990. *Cupressus disticha* L., Sp. Pl.1003.1753.
Common names : Bald Cypress, Marsh Cypress (Eng.).

Deciduous trees, up to 40 m high. Leaves spirally arranged, linear, *ca* 10 mm long, pointed, light green (in autmn) turning tawny to brown.

Fl. & Fr. : Feb-April.

Distrib. : Kashmir, West Bengal (Planted in Indian Botanic Garden, Shibpur, Howrah).

Habitat : Cool, damp climate.

Uses : An ornamental tree suitable for parks and for plantations along water courses. Timber is valued for its resistance todecay and termites.

2. **Taxodium mucronatum** Tenore, Ann. Sci. Nat., Bot., Ser.3,19.355.1853; Fu Liguo, Li Nan & Robert R.Mill in Wu Zheng-yi & P.H. Raven, Fl. China 4:58-59.1999.

Trees, upto 50m high.Leaves spirally arranged and scattered on annual branchlets, linear, distantly tapered, flat.

Fl.: Jan.

Distrib.: Native of Guatemala, Maxico, S. United States. Introduced in India (Uttarpradesh:Allahabad, Lucknow; Uttarakhand: Dehradun)

9.CUPRESSACEAE

Bartl., Ord.Nat. Pl.90.95.1830

(Cypress Family)

A family of *ca* 22 genera (11 monotypic) and *ca* 150 species; almost half genera found in N. Hemisphere and half in southern Hemisphere; 9 genera 28 species in India.

1.CALLITRIS Vent.

Dekad. 10.1808

A genus of *ca* 14 species in Australia, New Caledonia; 2 species introduced in India

1. **Callitris rhomboidea** R.Br. *ex* Rich. Conif. 47, t. 18, 1826; Gamble, Man. Ind. Timb. (ed. 2) 695, 1902 ; Bailey, Cycl. Hort. 631, 1914; Lushington, Vern. n. 2815, 1915; Troup, Silv. Ind.Tr.1168, 1921; Gamble, Fl. Pres. Madr. 1393 (975) 1928; Pilger in Pflanzenfam. (ed. 2) 13:378, 1960. *Callitris cupressiformis* F.v. Mueller, Key Syst. Vict. Pl. 1: 402, 1888.

Common Names : Illawara Moutain Pine, Oyster Bay Pine,Port Jackson Pine, Cypress Pine (Eng.)

var. **rhomboidea**

Small, monoecious, evergreen trees, upto 8-20 m tall, with dense crown.. Leaves scale-like, in whorls of 3, closely clasping the branchlets throughout their length except the very apices.

Fl.: Feb. - April. *Fr.* : Sept. - Nov.

Distrib.: Native in ,S.E. Australia, Queensland and N.S Wales; now naturalized in S. Indian Hill Stations (Kodaikanal); planted in Sikkim also.

Callitris oblonga Rich. Conif. 49, t. 18, f. 2, 1826 ; Dallimore & Jackson, Handb. Conif. (ed. 3) 213, f. 34, 1948 ; Chitt. Dict. Gard. 362, 1951 ; Pilger in Pflanzenfam. (ed. 2) 13 : 378, 1960.

Common Name : Tasmanian Cypress Pine (Engl.).

An evergreen, symmetrical, monoecious shrub or small tree up to 7 m tall. Leaves in whorls of 3, minute, adnate to the branchlets except for the triangularacute apex forming angled internodes.
Fl. : Feb. - April. *Fr.* : Sept. - Nov.

Distrib. : Native in Tasmania; frequently cultivated for ornamental purposes.

Taxa dubia

The occurance/introduction of *Callitris quadrivalvis Vent, Callitris glauca* R.Pro; *C. tasmanica, C. robuster* var *glauca R.Pro,* in Indian gardens could not be ascertained.

2.CALOCEDRUS Kurz

J. Bot. 11.196.1873

A genus of 2 species found in China, Laos, Myanmar, Thailand, Vietnam, Mexico, USA; one species in India.

Calocedrus macrolepis Kurz, J. Bot.11:196.1873; Fu Liquo & A. Farzon in Wu zheng-yi & P.H. Raven, Flora of China, 4:65.1999.

Trees, upto 30m high.;crown pyramidal turning broadly round with age; branches spreading or axfdiating. Leaves 1.5-8mm long.

Fl. & Fr. : March-Oct.

Habitat : Forests; 300-2000m.

Distrib. : N. INDIA(planted).

CHINA, LAOS, NE MAYANMAR, NE THAILAND, VIETNAM.

3. HAMAECYPARIS Spach

Hist. Nat.Veg.Phan.11.329.1841

A genus of *ca* 6 species; in E.Asia, N.America; 1 species introduced in India.

Chamaecyparis lawsoniana (Murr.) Parl. in Ann. Mus. Stor. Nat. Fir. 1:181, 1864; Bailey, Cycl. Hort. 730, 1914; Troup, Silv. Ind. Tr. 1162, 1921; Dallimore & Jackson, Handb. Conif. (ed. 3) 229, 1948; Chitt. Dict. Gard. 447, 1951; Bailey, Man. Cult. Pl. 122, 1958; Pilger in Pflanzenfam. (ed. 2) 13: 395, f. 210,1960; Raizada & Sahni in Ind. For. Rec. (N.S.) 5 (2): 144, 1960. *Cupressus lawsoniana* A. Murr. Edinb. New Phil. Journ. (N.S.) 1: 292; t. 9; 1855; Gamble, Man. Ind. Timb. (ed. 2) 696, 1902; Lushington, Vern. n. 2812, 1915; Troup, Silv. Ind. Tr. 1163, 1921.

Common Name : Lawson Cypress (Eng.).

Evergreen trees, 15-28 m tall, with a narrow shooting crown of drooping branches. Leaves in 4 ranks, adpressed, marked with white streaks on the under surface, of two kinds, those of the lateral ranks keel-shaped, 1.5-2 mm long, overlapping those of the adjacent facial ranks; those of the facial ranks rhomboidal, smaller.

Fl. : March - May. *Fr.* : Sept. - Nov.

Notes : A very ornamental tree frequently planted in gardens.

Distrib. : S.W. Oregon and N.W. California; frequently cultivated in gardens in temperate countries. Introduced in India at Kodaikanal (T.N.)

4.CUPRESSUS L.

Sp.Pl.1002.1753

A genus of *ca* 20 species, distributed in North America, Mediterranean region, Sahara, China, and Himalaya; 11 species in India; 2 species native to Himalayas; 9 species cultivated/grown.

1. Cupressus arizonica Greene in Bull. Torrey Club. 9:64,1882;Bailey, Cycl. Hort. 915, 1914; Dallimore & Jackson, Handb. Conif. (ed.3) 267,1948; Chitt. Dict. Gard. 594, 1951; Bailey, Man. Cult, Pl. 120, 1958; Pilger in Pflanzenfam. (ed.2) 13:393, 1960.

Common Name : Arizona Cypress (Eng.).

Evergreen trees, upto 10-20 m high, with dense, broad and flat crown Leaves scale-like, closely pressed, in 4 ranks, ovate, glaucous, conspicuously glandular on the back.

Fl. : Dec. - Feb.. *Fr.* : Aug. - Sept.

Distrib. : Native in the mountains of Arizona and N. Mexico (1500 to 1830 m); introduced in India at Kodaikanal in the Old American Cemetery by the American Missionaries of Madurai about 1900.

2. Cupressus cashmeriana Royle ex Carriere, Traite Conif. (ed. 2) 161. 1867. *Cupressus funebris* var. *glauca* Masters; *Cupressus torulosa* var. *kashmiriana* Kent.

Common name : Kashmir Cypress (Engl.)

Small trees, narrowly pyramidal, with ascending branches and remarkably pendulous very long branchlets. Leaves glaucous or of an indescent tinge, 1.5-2.2 mm long, with lance-like, spreading tips.

Notes : Most beautiful and elegant of all the Cypresses, appears to be a juvenile form of *C. torulosa*; cones like those of *C. torulosa*; formerly considered to be a variety of *C.funebris* but found differing in larger number of cone scales and having about 10 seeds in each scale

3. Cupressus corneyana Carriaere, Traite, Gen. Conif. 128. 1855. *C. pendula* W. Griff. Itin. Notes 137, sub no. 529, 142, sub no. 679 a. 1848; *non* Thunb. *C. funebris sensu* Hook. f. , Fl. Brit. India 5. 646. 1888, *non* Engl.

Local names : Weeping Cypress (Engl.), Chendeng, Tsendon Shing (Bhut.).

Trees, upto 30 m high; branches pendulous. Leaves on branchlets scale-like, ovate, *ca* 1 mm long; leaves on main shoots 1.5-2 mm long;

Fl. & Fr. : May-July.

Distrib. : Restricted to Tenga valley of Arunachal Pradesh in India & Bhutan. Planted around monostries in India(Arunachal Pradesh, Sikkim) and Bhutan.

4. Cupressus funebris Endl. Syn. Conif. 58. 1847; Brandis, For. Fl. 534, 1874; Hook. f. Fl. Brit. India. 5:616, 1888. Pilger in Pftanzefam. (ed.2) 13:393,1960; Raizada & Sahni in Ind. For Rac. (N.S.) 5(2):143, t.9, f.4,1960.

Common Names : Chinese Weeping Cypress; Mourning Cypress (Eng.)

Evergreen trees 10-24m high; branches wide-spreading, pendulous. Leaves greenish, adpressed, acute and free at the apex.

Fl. : Dec.-Feb. *Fr.*:Aug.- Oct.

Distrib.: INDIA : *Sikkim, Tamilnadu* Native in Central China; now extensively cultivated in the E. Himalayas, Nepal, Sikkim and Bhutan, and on S. Indian Hill Stations.

5. Cupressus goveniana Gord. in Journ. Hort. Soc.4: 295, 1849; Bailey, Cycl. Hort. 915, 1914; Dallimore & Jackson, Handb. Conif. (ed.3) 271, f.45, 1948; Pilger in Pflanzenfam. (ed.2) 13:392, 1960.

Common Names: California Cypress; Gowen Cypress (Eng.).

Evergreen trees, upto 16m high. Leaves ovate-acute, adpressed, convex at the back, arranged in 4 ranks.

Fl.: Jan.-March. *Fr.*: Aug-Oct.

Distrib. Native in the hills of the coast from Mendocino Country to San Diego Country in California.

Common about Kodaikanal, propagated by self-sown seeds. Trees are truly ornamental when young, but tend to become defoliated when old.

6. Cupressus lusitanica Mill. Gard. Dict. (ed. 8) n. 3, 1768; Hook. f. Fl. Brit. India 5 : 645, 1888; Dallimore & Jackson, Handb. Conif. (ed. 3) f. 46, 1948; Wealth of India, Raw Mat. 2 : 398, 1950; Pilger in Pflanzenfam. (ed.2) 13 : 393, 1960; Raizada & Sahni in Ind. For. Rec. (N.S.) 5 (2) : 144, 1960.

Common Names : Mexican Cypress; Cedar of Goa (Eng.).

Evergreen trees, up to 30 m high, with pendulous or semi-pendulous branches. Leaves ovate-acute, 2 mm long, arranged in 4 ranks, adpressed.

Fl. : Jan.-March; *Fr.*: Aug. – Oct.

Distrib. : Found in Mexico to the mountains of Gautemala; 1250 m to 3050 m. and Portugal. Naturalised in Portugal and some part of Spain. Supposed to be a native of Goa, on the west coast of India but no gymnospermous plants are now found wild in this area. Supposed to have been introduced in Portugal from Goa.

INDIA : Grown at Kodaikanal (T.N.) and Dehradun (Uttarakhand).

7. Cupressus macrocarpa Hartw. in Journ. Hort. Soc. 2:187, 1847 *nomen, et ex* Gord. in Journ. Hort. Soc. Lond. 4 : 296, 1849; Pilger in Pflanzenfam. (ed. 2) 13:392, f. 208, 1960; Raizada & Sahni in Ind. For. Rec. (N.S.) 5 (2):144, 1960.

Common Name : Monterey Cypress (Eng.).

Evergreen trees, up to 23 m high; branches horizontal, often obscurely whorled. Leaves triangular, scale-like, adpressed, *ca* 2 mm long, arranged in 4 ranks.

Fl. : Feb. - April. *Fr.* : Aug. - Oct.

Distrib. : Native of Monterey locality in California; now grown successfully in S. Africa, New Zealand, Australia, Uganda, and Kenya.

INDIA: grown at higher elevations.

8. Cupressus sempervirens L. Sp. Pl. 1002, 1753; Hook. f. Fl. Brit. India. 5:645, 1888; Wealth of India, Raw Mat. 2: 398, 1950; Pilger in Pflanzenfam. (ed. 2) 13: 392, f. 209, 1960; Raizada & Sahni in Ind. For. Rec. (N.S.) 5 (2): 143, t. 9, f. 2, 1960.

var. sempervirens

Common Names : Mediterranean Cypress; Italian Cypress (Eng.).

Trees, upto 30 m high; crown columnar; bark grey-brown, fibrous, longitudinally furrowed; branches ascending, not whorled; branchlets deep green. Leaf tips closely adpressed.

Etymology : The specific name '*sempervirens*', in Latin, means 'evergreen or everlasting'.

Distrib.: native to W. Asia, E. Medeteranian region. Introduced in India.

var. **horizontalis** (Mill.) Voss, Vilm. Blumeng. 1 : 1228, 1895. *Cupressus horizontalis* Mill. Gard. Dict. (ed. 8) C. n. 2, 1768.

Branches spreading, horizontal.

Notes : var. *horizontalis* is spreading while var. *sempervirens* is columnar or pyramidal.

Distrib. : A native of Mediterranean region; widely planted in India at Srinagar (J.& K.), Dehradun (Uttarakhand), Shimla (H.P.), and Tajmahal Garden (U.P.).

var. **stricta** Ait. Hort. Kew. 3 : 372, 1789.

Evergreen trees, upto 20 m high.Leaves obtuse, closely pressed, 4-ranked, *ca* 1 mm long.

Fl. : Feb – May. *Fr* : Sept. – Nov.

Notes : Easily distinguished by the large cones in the field. The habit also is peculiar. It is the most frequently cultivated form and reaches up to 20 m in height. This variety is recognized by the erect branches making a columnar outline of the crown.

Distrib. : Indigenous in the mountains of N. Persia, Syria, Cilicia, Greece and the islands of Rhodes, Crete and Cyprus.

INDIA: Introduced at Kodaikanal (Tamilnadu)

9. Cupressus torulosa D. Don, Prodr. Fl. Nepal. 55, 1825; Hook. f. Fl. Brit. India 5 : 645, 188; Pilger in Pflanzenfam. (ed. 2) 13 : 393, 1960; Raizada & Sahni in Ind. For. Rec. (N.S.) 5 (2) : 143, t. 9, f. 3, 1960. Hook. f., Fl. Brit. India 5 : 645. 1888; Sahni, *l.c.* 105-106. 1990.

Common names : Himalyan Cypress, Bhutia Cypress (Engl.). Leuri, Devidar, Galla, Surai, Raisal (W.Himalaya); Sambirani maram (Tamil).

Evergreen trees, with pyramidal crown, upto 42 m high; branches horizontal, characteristically curving upwards towards the apices. Leaves 4-ranked, adpressed ovate, blunt, 4-angled, *ca* 1.5 mm long.

Fl. : Sept. - Feb. Fr. Aug.-Dec.

Habitat : Outer–Himalayan ranges; 1800-2800 m.

Distrib.: INDIA: Himachal Pradesh(Chamba), Arunachal Pradesh(Kameng), Uttarakhand (Chakrata).

S.E. TIBET, NEPAL, BHUTAN, CHINA; Planted in Pakistan.

Uses : Wood is valuable because of its durability; preferable to Deoder for internal work like window frames, ceilings, door-panels; also used for railway sleepers. Wood is burnt as incense.

Notes:It was introduced in India (S. India) by P. Labarthere in 1892. By now it has become perfectly naturalized, in Kodaikanal.

5.FITZROYA Hook f.

A monotypic genus native of southern Chile, Valdivia; cultivated else where.

Fitzroya cupressoides (Molina) Johnson; *Fitzroya pentagonica*.

Trees, upto 35 m high.k *ca* 5m in diam. Trunk. Leaves in 3 parted whorls, more or less spreading, oblong to lanceolate, *ca* 3mm long, with very small inward curving tips, convex on the underside, with a wide, green midrib, midrib with a white stomatal band on both sides.

Distrib: Southern S. America from Valdiva Southwards, W. Patagonia, Introduced in India (Tamil Nadu: Ooty).

6. Juniperus L.

Sp. Pl. 2: 1038.1753 .

(Junipers)

A genus of *ca* 60 species distributed all over the northern Hemisphere from Arctic to the tropic, being most abundant in temperate regions of Europe and north America ; 9 species and one variety in India.

1. **Juniperus chinensis** L., Syst. Not. ed.12, 2: 660; Mant. Pl. 1: 127. 1767.

Shrubs or trees, dicecious (rarely monoeciom.Leaves dimorphic; needle like leaves on young as well as adult plants, decussate, or in whorls of 3, lax, ascending, sublanceolate (3-) 6-12 mm, with 2 stomatal bands adaxially; scale like leaves on adult plants only, decussate, closely appressed, 1.5-3mm; abaxial gland near centre, elliptic, slightly concave.

Habitat: Maintains 1400-2300 m.

Distrib: China, Japan, Korea, Myanmar, E-Russia. Planted in India.

2. Juniperus communis L. Sp. Pl. 1040. 1753; Hook. f., Fl. Brit. India 5: 646. 1088; Sahni, *l.c.* 103. 1990.

Common names : Ground Juniper, Common Juniper (Engl.). Betar, Bithal (Himachali-(Chamba area) Pama, Tailu (Kunawar).

Low spreading mat like shrubs; upto 1.5m high.Leaves upturned or upcurved, sometimes almost imbricate, linear-lanceolate, *ca* 10 x 2 mm, thick, closely set, actue, mucronate, with a broad white stomatal band on adaxial side.

Distrib. : West. Himalaya; 3000-4200 m (Kashmir, Himachal Pradesh, Uttarakhand). Common.

Uses : Fully grown but unripe berries yield '*Juniper Oil*' having flavour of '*Gin*'.

3. **Juniperus excelsa** Bieb., Fl. Taur. Caue 2 : 245. Jain, Indian Forester 1976:111-118. 1976.

Trees, 6-9 m high, crooked, much branched. Leaves scaly, rhombic, *ca* 2.2 x 0.5 mm, closely adpressed to the branches, mostly in whorls, sometimes in pairs with a glandular furrow on abaxial side; leaf apex acute, converging margins slightly concave.

Fl.&Fr. : April-Aug.

Distrib. : Himachal Pradesh (Pooh), *ca* 3300 m.

4. **Juniperus indica** Bertol, Misc. Bot. 23 : 229, t. 1. 1862; Mem. Acad. Sci. Bologna ser. 2.1.:228. t.1. 1862; Hara *et al.*, Enum. Fl. Nepal 1:27.1978; Sahni, l.c. 102.1990. *Juniperus wallichiana* parl. in DC., Prodr. 16(2):482.1858; Jain, Indian Forester 1976: 111-118. 1976. *Juniperus pseudosabina sensu* Hook. f., Fl. Brit. India 5:646. 1888, *non* Fisch. & Mey.
Common name : Black Juniper (Engl.), Bhil (Hindi)

Trees, up to 25 m high, with straight columnar stem and ascending branches. Leaves scaly, mostly opposite decussate, sometimes ternate, upto 1.7 x 1.15 mm, sub-acute.

Fl. & Fr. : April-Aug.

Habitat: Himalayas: on mountain slopes: 2600-5100 m.

Distrib. : INDIA: N.India, Kashmir, Sikkim) BHUTAN, NEPAL, CHINA.

Uses : Branches are burnt as incense in Monastries,
Notes : Named as Black Juniper by J.D. Hooker due to the very dark (almost black) stems of the plants collected by him from Sikkim. Sahni (1990) mentioned that it is a shrub in W. Himalaya but due to excessive humidity and rainfall, it grows upto 20 m high tree in E. Himalayas.

5. **Juniperus polycarpos** C. Koch. in Linnaea 22 : 303. 1849; Sahni, *l.c.* 98.1990. *Juniperus macropoda* Boiss., Fl. Orient 5:709. 1884; Hook. f., Fl. Brit. India 5:647.1888; Jain, Indian Forester 1976. 109-118. 1976.

Common names : Himalayan Pencil Juniper (Engl.) Dhup, Padam (Hindi), Chalni, Lawar (Himachali) Dhupi (Nepali)

Evergreen shrubs or trees, 9-15 m (or more) high. Leaves arranged in opposite pairs; of lower branches linear, *ca* 8 m; pungent, leaves on upper branchlets scale-like, ovate, apex obtuse, *ca* 1.5 mm closely appressed, converging margins convex.

Fl.& Fr. April-Aug (Sept.)

Habitat: in semi-arid ranges 2400-4300 m. It forms open forests of considerable extent; gregarious;

Distrib. : India N.W. Himalaya (Kashmir, Lahul to Kumaon),

AFGHANISTAN, BALUCHISTAN, KAGAN, VALLY, WEST TIBET.

Notes : It is fatally parasitized by *Arceuthobium exycedri* M. Bieb. Plants become dwarf and shrubby at higher elevations.

Uses : Wood is suitable for furniture, building, pencil making, burnt as incense in Monastries.

6. **Juniperus pseudosabina** Fischer *et* C. A. Meyer, Index Sem. Hort. Petrop. 1842 : 15, 65. 1842.

Shrubs, compact bushes at higher elevations. Adult leaves scaly, upto 1.35x1.35x1.35 mm, arranged in opposite pairs, adpressed, leaf back obtusely keeled, glabrous, leaf apices obtuse.

Habitat : Grows gregariously in ancient moraines in Himalayas. Common.

Distrib. : INDIA:West. Himalaya: Kashmir to Uttarakhand; Kumaon; Niti & Hern kung (3000-4000 m); Badrinath and Vasundhara. (3300-4800 mm); Eastern Himalaya upto Sikkim, Dzongri-chakang (3900-4350 mm), Olakthang (4200 m); Cheemattiang (4400m).

AFGHANISTAN, KAZAKSTAN, KYRGYZSTAN, MONGOLIA, PAKISTAN, TAJIKISTAN, UBZEKISTAN.

7. **Juniperus recurva** D. Don, Prodr. Fl. Nepal. 2:55.1825; Jain, Ind. Forester 1976.111-118. 1976.

Common names : Drooping Juniper (Engl.) Bitar, Guggal, Thelu (W. Himachal)

var. **recurva**

Trees, upto 18 m high. Leaves acicular, upto 4 x 0.7 mm, acuminate, with sharp horny apex; margins slightly winged near the proximal half only; adaxial rib longer, prominent, abaxial groove present.

Habitat : Forests or thickets; 1800-3900m.

Distrib.: INDIA: Inner ranages of Himalaya; Kumaon to Sikkim and Arunachal Pradesh; (1800-)3700-4600m.

AFGHANISTAN, BHUTAN, CHINA, MYANMAR, NEPAL, PAKISTAN.

Uses : Burnt as incense in Monastries.

7.1 var. **coxii** (A.B. Jackson) Melville, Kew Bull.13:533.1959; Dallimore & Jackson, Conf. Ginkgo, 269. 1966. *Juniperus coxii* A.B. Jackson in New Fl. & Silva 5 : 33, f. 13.14. 1932. *Juniperus faragessi sensu* Jain, Indian Forester 1976: 111-118. 1976.

Trees. Leaves acicular, ternately arranged similar to var. *recurva* to but spreading, longer, more acuminate and marked on upper surface with of 2 longitudinal greenish-white bands of stomata, leaf margin conspicuously winged throughout

Distrib. : East. Himalaya : INDIA : (West Bengal : Darjeeling district, Singalila hills; Sikkim : West district); 1800-3800m. Occurs scattered here and there in association with 'Silver fir' and occasionally with Black Juniper (*J. wallichiana*).

BHUTAN, CHINA, MYANMAR, E. NEPAL.

8. **Juniperus semiglobosa** Regd, Trudy Imp. S. Peterburgsk. Bot. Sada. 6:488.1879

Trees, rarely shrubs, dioecious, rarely monoecious. Leaves dimorphic (Scale like and needle like); needle like usually on young plants, decussate or in kwhorls of 3-7mm, concave adaxially, concave abaxially; scale like leaves decussate closey appressed, more or less rhombic-ovate, 1-2.5mm. abaxial gland near center.

Habitat : Forest edges, 2500-3300.

Distrib.: INDIA : J.& K. : Kashmir

AFGAHANISTAN, CHINA, KAZAKISTAN, KYRGYSTAN, TAJIKISTAN, UZBEKISTAN.

9. **Juniperus squamata** D. Don in Lambert, Desar. *Pinus*, 2 : 17. 1824; Sahni, *l.c.* 103. 1990; Jain, Indian Forester 1976 : 111-118. 1976.

Common names : Single seed Juniper, scaly leaved Juniper (Engl.), Padma Chunder (Hindi)

Prostrate, erect or straggling shrubs; with recurved pendent ultimate branchlets. Leaves awl-shaped, ternately arranged broadly lanceolate, free part of lamina upto 2.5x0.85 mm; acute at apex, with slightly undulating margin, without distinct midrib on adaxial surface .

Fl. & Fr. : May-Sept.

Uses : Twigs are burnt for incense; also for fuel.

Habitat :Himalayas;forests, thickets, valleys and road sides in mountain area; 1600-4500m.

Distrib.: INDIA: Jammu & Kashmir, Sikkim, Darjeeling district of West Bengal, N.W. Himalayas ;3000-3600m; E. Himalayas (2400-) 3500-3900(-4200m)

AFGHANISTAN, BHUTAN, CHINA, JAPAN, N. MYANMAR, NEPAL, PAKISTAN, TAIWAN.

Notes : Forms extensive circular patches on exposed places above tree line; abundant at Dzongri (*ca* 3900 m) in Sikkim; also recorded from Phalut locality (*ca* 3500 m) of Singalila range in Darjeeling district of West Bengal.

7. TETRACLINIS Mast

Mast. In Journ. Roy. Hort. Soc. 14 : 250. 1892.
(*Arartree* - Amer.), *Alerce* (Gr. Brit.),

It is allied to *Callitris*, and occurs in the central Mediterrenean region.

A genus found in central Mediterrrenean region introduced in India.

1. **Tetraclinis articulata** (Vahl) Mast. In Journ. Roy. Hort. Soc.14:250.1892; Bouden & Boom, Mannual of Cult Conifers : 413. 1965. *Thuja articulata* Vahl. Symb. Bot. 2 : 96 (1790)

Trees, *ca* 12 m tall. Leaves 4, the lateral leaves larger and partly covering the facial ones, scale-like, pointed.

Habitat : Dry hills in S. Spain, Malta and N. Africa.
India : Planted in F.R. I. (*cf. Chakraverty et al.* 2003 p. 525)

Cultivated Tree.

8. THUJA L.

Sp. Pl. : 1002. 1753.
(Arbor Vitae)

Type : T. occidentallis L. (*Lectoype* designated by Reveal) Kalm Herb. Linn. No. 1136. 1 (LINN).

A genus of *ca* 6 spp in N. Amer. & E. Asia; 2 species grown in India.

1. **Thuja dolobrata** L. f., Suppl. 420. 1871. *Thujopsis dolobarata* Sieb. & Zucc. : 34. 1844.

Other names : Broad leaved Arborvitae. Hiba (Engl.)

Pyamidal trees, upto 35 m high, occasionally scrubby. Leaves shining, dark green; flat leaves glandless on back, *oblong-spathulate, with a green ked and* a hollowed silusy white stripe of stomata on each side; side-leaves larger; hatchet-shaped, ovate or linear oblong, bkluntly keded, the more appressed part on the under side of branchlets with a broad-white stripe.

Notes: Easily distinguished from other species by its larger leaves which are couspicuously white beneath.

Distrib. : A native of Japan.

Habitat : Grows well in mild and moist climate.

2. **Thuja occidentalis** L. Sp Pl. 1002. 1753

Common names : American Arbor-itae, Eastern Arborvitae, While cedar (Engl.)

Trees, upto 20m high.Flat leaves scale like abroptly acute to apiculate, usually conspicuously glandular, bright green above, yellowish-gree beneath.

Distrib. : Native of America (N.S. to N.C. West Ill.)

3. **Thuja orientalis** L., Sp. Pl. 1002.1753. *Biota orientalis* (L) Engl.: 47. 1847. *Platycladus orientals* (L.), France, Portugalie Acta Biol., Ser. B. Sist.Vol."Julia Henrigues":33.1949

Common names: Chinese Arbovitae, Reacock feathers, oriental Arbovitae (Engl.); Morpankhi (Hindi).

Shrubs or trees, upto 10 m high. Leaves persistent, scale-like, opposite, *ca* 1.5 mm, eglandular.

Fl. & Fr.: March-Oct.

Distrib. : N.W. China; JIREAM E, RYSSUA; 300-3300M, widely grown in gardens.

4. **Thuja plicata** D. Don in Lamb., Descr. Gen. Pinus 2:19.1824 *Thuja lobbi* Gord. 1858.323.1858

Common name : Western Red Cedar, Western Arborvitae (Engl.)

Trees, upto 60 m high. Leaves appressed, parallel to axis on leading shoots, ovate, long-pointed, with inconspicuous resin glands on lower surface, upto 6.5mm long, free at apices; leaves of ultimate divisions smaller, *ca* 3mm long, shorty or bluntly pointed, closely overlapping, often without glands, darkgreen above, faintly streaked with white beneath or without.

Notes : Trees thrive well in areas with humid air and high rainfall; growth is fast bettr growth or clay. Leaves eit a tansy-likey odour when browed.

Uses : Specially used for ladder poles and rugby goal posts and in timber-clad houses.

9. WIDDRINGTONIA Endl.

A genus of 3 species; all native to S. Africa; one species introduced in India.

Widdringtonia juniperoides (L.) Endl. Syn. Conif. 32, 1847; Dallimore & Jackson, Handb. Conif. (ed.3) 653,1948; Chitt. Dict. Gard. 2277, 1951; Pilger in Pflanzenfam. (ed. 2) 13 : 382, f. 199, 1960. *Cupressus juniperoides* L. Sp. Pl. (ed. 2) 1422, 1763.

Common Name : Clanwilliam Cedar (Engl.).

An evergreen, widely branched tree, upto 20 m tall. Leaves spirally arranged, of 3 kinds; those of juvenile plants linear, flat, acuminate, 1.2-1.8 cm long, glaucous green; those of leading shoots of mature trees shorter; those of the twigs scale-like, blunt at the apex.

Fl. : Dec. - March. *Fr.* : Aug. - Oct.

Habitat : it grows well in very mild climate.

Distrib. : Native in the Cedarberg Mountains in S. Africa; 900 m to 1200 m.

INDIA : first introduced in India at Kodaikanal (T.N.) by Dr. Michie Smith, Director of the Observatory, about 1904.

10. EPHEDRACEAE

Dumortier, Anal. Fam. Pl. 2: 12. 1829.

A family with only one genus (*Ephedra* L.) distributed in warm temperate North and South America and Eurasia.

EPHEDRA L.

Sp. Pl. 1040. 1753.
Type : E. distachya L.

A genus of *ca* 44 spp with wide sporadic distribution in semiarid tropical and subtropical regions of both the hemispheres (France, Canary Islands around the Mediterranean east to Iran, Pakistan, India, China (not represented in Sri Lanka) N.America and S. America);

7 species and 1 variety known from India.

1. **Ephedra foliata** Boiss *et* Kotschy Sched Pers. Aust. 1845 *et* in Boiss. Fl. Orient 5: 716.1885; Hook. f. Fl. Brit. India 5:863.1890; Brandis, Ind. Trees 686.1906; Sahni, Gymnosperms India & Adj. Countries 1990. *Ephedra peduncularis* Boiss., Fl. Orient.5: 717. 1885; Hook. f., Fl. Brit. India 5: 641.1888. *Ephedra alta* Brandis, For. Fl. 501, t. 69. 1894, *non* C.A. Meyer.

Vernacular names : Kuchar (Punjabi), lana, Suo-Phogara (Rajasthan).

Tall, scendent, climbing, sarmentose shrubs. Leaves 2-3 at each node, shortly connate at base, linear . Fruits with often fleshy red bracts, ovoid, 7-8 x 6-7 mm, fleshy, juicy, red or milky-white.

Fl. & Fr. : Feb. – May

Habitat : On rocks and bushes.

Distrib. : INDIA (Punjab, Rajasthan: Jodhpur, Barmer, Jaiselmer).

AFGHANISTHAN TO PAKISTAN, ARABIA, ADEN,

Uses : Stems and branches are used for cleaning brass and metalic utensils (*cf.* Sahni 1990).

2. **Ephedra gerardiana** Wall. *ex* Stapf. in Akad. Wissen. Wien. Math. Naturewise K1. Denkschr. 56(2) : 75, t. 3, f. 18. 1889; *Sahni, i.c.* 145-146. 1990. *Ephedra gerardiana* var. *wallichii* Stapf. In Denkschr. Math. Nat. C.I.K. Akad. Wiss. Wien, LVI, 1889. *Ephedra distachya* Boiss., Fl. Orient. V. 713-1885.

Vernacular name : Tutgantha (Jaunsar.)

Rigid, dense, tufted shrubs, 15-120 cm high. Stems woody, gnarled. Fruits 8-10 mm long, clustered, ovoid, red. Seeds 2, 4-6 mm long, black.

Notes : Bracts of female strobilus not divaricate but imbricate.

Distrib. : INDIA: Jammu & Kashmir: Manga Parbat, Ladakh. Shyok river.

AFGHANISTAN, CHINA, NEPAL, PAKISTAN, TAJIKISTAN.

Fl. & Fr. : May – Oct.

Habitat : Inner Himalayan ranges at 2000-4500m; very common in inner dry ranges bordering Tibet on exposed shingly slopes.

Distrib.: N.W. Himalaya (Himachal Pradesh, Uttaranchal).

Uses: Fruits are edible. Browsed by Goats (*cf.* Sahni 1990).

Notes: Florin (1933) considered it to be synonymous to *E. saxatilis* var. *sikkimensis* (Stapf.) Florin Sahni (1990) also agreed to him but treated it as a variety under *E.gerardina* Stapf.

3. **Ephedra intermedia** Schrenk *et* C.A. Meyer in Mem. Sci. Nat. Acad. Petersb. Ser. 6.5: 1845 *e.* In Monog. *Ephedra* 1846; Hook. f. , Fl. Brit. India 5 : 863. 1890.

var. **intermedia**

Local names : Sumeni (Chital, Gilgit), Khanna (Kunawar)

Erect, densly branched shrubs, upto 1 m high, with long lax branchlets lying prostriate below. Fruits ovoid, *ca* 7 mm long, red. Seeds 5-6 mm long.

Fl. & Fr: May – June (-Aug)

Habitat : On rocky soil; fairly common.

Distrib.: INDIA: Kashmir (Ladakh), Himachal Pradesh.

AFGHANISTAN, CHINA, KAZAKSITAN, KYRGYSTAN, MONGOLIA, PAKISTAN, RUSSIA, TAJIKISTAN, TURKEMENISTAN, UZBEKISTAN, S.W.ASSIA.

3.1 var. **tibetica** Stapf., Monogr. Art. Gatt. Eph. Wien, 62, 1889; Hook.f., Fl. Brit. India 5; 863. 1890. *E. sumlingensis* P.Sharma & P. Uniyal in Bull. Bot. Surv. India 50:179-181.2008 (Sept. 2009), ***syn. nov.***

Internodes more slender, rarely short thick, bark, scabrous or scaberulous, glaucous, sometimes bluish.

Habitat : 2100-2700m.

Distrib. : INDIA: Himachal Pradesh (Khorangi-pangi).

AFGANISTHAN, N. TIBET, NEPAL.

4. **Ephedra pachyclada** Boiss. Fl. Orient. V : 713. 1885; Hook. f., Fl. Brit. India 5 : 641. 1890; Sahni, Gymn. India Adj. Countr. 142. 1990.

Small, gregarious shrubs, upto 1 m high. Seeds 2-3 mm long.

Fl. : May

Distrib. : INDIA: (from Garhwal westwards, *ca* 1140 m Ladakh)

NEPAL, S. IRAN, AFGHANISTAN, BALUCHISTAN, E. PERSIA.

Uses : Fruits are edible Plants are used in tanning.

5. **Ephedra prezwalskii** Staff in Danschr. Akad. Wiss. Wisen : 40, pl. 40, fig. 14. 1889, Sahni *op. cit.* 140-147, 1990.

Erect, suberect or ascending dioecious shrub, upto 1.25 m tall, branching from base. Female strobilus solitary, ovate or subspherical 5-6 mm across; bracts free, rounded or transversely broader, obtuse or emarginated, margins winged.

Fl. Fr : June-Aug

Habitat : Dry and sandy places; 300-3800.

Distrib.: INDIA, CHINA, KAZAKSITAN, KYRGYSTAN, MONGOLIA, PAKISTAN, TAJIKISTAN, UZBEKISTAN.

6. **Ephedra regaliana** Florin in Svensk Vet. Akad. Handl. Ser. 3: 12(1):17.1933. *Ephedra disperma* Rgl. In Acta Hort. Petrop., 6:2, 479.1882. *Ephedra monosperma* Stapf in Denkschr. Math. Nat. Cl. D. k. Akad Wiss. Wien. LVI:73. 1889, *pp., non.* Gmel. *Apud.* C.A. May. *Ephedra gerardiana* Stapf in Denkschr. Math.-Nat. Cl. D.k. Akad. Wiss. Wien. LVI, 1889, p.75. *pp., non* Wall. *Ephedra gerardiana* var. *wallichii* Florin 1933.

Dwarf diocious shrubs, upto 10cm high, much branched from base. Leaves opposite, 1-2.5mm long, herbaceous.

Distrib. : N.W.Himalaya:INDIA: Jammu & Kashmir (Ladakh).

Habitat : On gravel, rocks, between stones in river valleys at lakes and dry hilly areas; upto 4000m.

Notes:Florin (1993) considers *E. gerardiana* var. *wallichii* synonymous to *E. regeliana* Florin.

7. **Ephedra saxatilis** (Stapf) Royle *ex* Florin in Svensk. Vet. Akad. Sci. Handl. Ser. III. Xii, No.1, 21. 1933. *Ephedra gerardiana* var. *saxatilis* Stapf, Arten der Gattung Ephedra Wien : 76. 1889.

var **saxatilis**

Vernacular name : Dewarla (Garhwali)

Shrubs, upto 20 cm high. Leaves *ca* 2.5 mm, decussate.

Fl. & Fr. : May – July

Habitat : Humid rocky habitat.

Distrib. : N.W. Himalaya :INDIA: Uttarrakhand (Garhwal, Almora), Himachal Pradesh.

7.1 **Ephedra saxatilis** var. **sikkimensis** (Stapf.) Florin in Svensk. Vet.–Akad. Sci. Handl. Ser. III. Xii. No. 128. 1933; Hara *et.* al., Enum. Fl. Pl. Nepal 1:23. 1978. *Ephedra gerardiana* var. *sikkimensis* Stapf. In Denksche. Math. Nat. Cl. K. Akad. Wiss. Wien, CVI : 76. 1889. *Ephedra vulgaris sensu* Hook. f., Fl. Brit. India 5 : 640. 1890, *non* Rich.

Differs from var. *saxatilis* in its habit (having a rounded crown), smaller number of flowers in the male cone.

Fl. & Fr. : Eastern Himalaya

Distrib. : Eastern Himalaya : INDIA: (Sikkim : North Lachen); *ca* 5100 cm.

BHUTAN, NEPAL, S. TIBET.

Habitat : The semi-arid alpine Eastern Himalayan region. *Uses*: Rhizomes posses football sized knots which are used on fuel, Plants are suitable for rock gardens their re-current like ornamental berries.

11.GNETACEAE L.

Syst. Nat. ed.12:612, Mant. Pl. 18,125 1767.

Type species : *G. gnemon* L. (Lectotype designated by Barrie) "*Gnemon domestican*: Rumphius, Herb. Amboin, I.t. 71.1741.

A genus of *ca* 40 species distributed in Northern S. America, Wester Group Africa and tropical Asia (from Western Ghats through Malaysia to Fiji; absent from Taiwan and Caledonia. Hooker (1888) treated 6 species out of which only 4 were from present political boundaries of India. Sahni (1990) described 8 species 4 varieties and 2 forma of which 5 species and 2 vars. and 1 forma are found within present political boundaries of India

1. **Gnetum contractum** Markgraf, Bull. Jard. Bot. Btzg. 111, 10: 470. 1930; Gamble, Fl. Madras 3: 1885. 1934. Climbing shrubs; branches cylindrical. Leaves elliptic, *ca* 10 x 5 cm, turning black on drying; petioles upto 10cm long.
Distrib. : Kerala, Tamilnadu (*Endemic*).

2. **Gnetum gnemon** L., Syst. Nat., ed. 12, 2: 637; Mant. Pl. 1: 125. 1767.

var. gnemon

Shrubs or small trees. Leaf blade, elliptic or oblong, base attenuate into petiole, apex acuminate or cuspidate coriaceous or membranous

Fl. & Fr. : May – June

Distrib. : INDIA : N.E. region : Arunachal Pradesh (Kameng District); Assam (Potfal Kachari Gram Reserve Forest, Gram Pani and Bara Pathar); Meghalaya (Jowai-Badarpur Road); Tripura (Kawnpuri) and Great Nicobar Islands (Nicobar, Kadoo Village, Katchal Island, Passa, Car Nicobar, Sawai Car Nicobar; Great Nicobar Island, Campbell Bay, Galanthea River).

INDONESIA, MALAYSIA, MYANMAR, PHILIPPINES, THAILAND, VIETNAM, PACIFIC ISLANDS

Uses : The seeds of *Gnetum gnemon* are eaten after roasting or cooking. The orange red pulp is removed and the seed mashed into cakes, dried and fried in oil to make a cake or biscuit. The bark yields a strong fibre durable in sea water and therefore valued for fishing lines and nets (Wealth of India 4: 157, 1956).

Gnetum gnemon L. *var. gnemon* is cultivated in Malaya and Java for its fruits which are edible.

2.1. Gnetum gnemon L. var. **griffithii** (Parl.) Mgf. *l. c.* 442. : Shani *l. c.* 122. 1990 *Gnetum griffithii* Parl. in DC., Prodr. 16, 2: 349, 1868.

Shrubs, upto 2 m high. Leaves oblong usually with parallel margins. Inflorescence contrated, axis hardly visible between the bracts. Imperfect and perfect flowers gradually narrowed to an acute beak. Fruits small, globose, shortly apiculate.

Distrib.: INDIA : Assam (Sibsagar); Nagaland (Kungba); 1500 m

MYANMAR

3. Gnetum latifolia Bl. in Tijd.Nat. Geschied & Phys. 1 : 160. 1834; Markgraf, Bull. Bot. Jard. Bot. Btez. 111, 10; 450. 1930; Bharadwaja in J.Indian Bot. Soc. 36 : 417. 1957.

var. **latifolia**

Lianas. Leaves elliptic–ovate, shortly acuminate, dark green, turning black on drying.

Distrib. : India : Andaman Isls. (Mt. Hariet).

3.1 var. **macropodum** (Kurz) Markgraf., *Op. Cit.* 462. 1930. *Gnetum macropodum* Kurz in Trimen. Journ. Bot. 13 : 331. 1875; Hook. f. , Fl. Brit. India 5 : 643. 1888. Lofty climbers. Leaves broadly oblong or elliptic, subacute at base, thinly coriaceous, conspicuously but laxly reticulate.

Distrib.: INDIA : Andaman & Nicobar Islands(Kamorta, Portblair, Mt. Harriat).

3.2 var. **funiculare** (Bl.) Markgraf. Bull. Jard. Bot. Btz. 111,10:463. 1930. *Gnetum funiculare* Bl., Nov. Pl. Fam. 32.

Lofty dioecious climbers. Leaves variable in size and shape, oblong-ovate or lanceolate, cuspidate or apiculate, obtuse or acute at base, shining, finely reticulate beneath.

Distrib. : INDIA: Assam,S. Andamans (Port Monat).

MYANMAR, MALAYA, THAILAND, SUMATRA, JAVA.
Notes : Female spikes are twice longer than *G. montanum* (*G. scandans sensu* Hook. f., 1898)

4. Gnetum montanum Markgraf., Bull. Jard. Bot. Btz. 111, 10:466. 1930; Bharadwaja, Jour. Indian Bot. Soc. 36: 408. 1957; Sahni, *l.c.* 126. 1990. *Gnetum scandens sensu* Hook. f., Fl. Brit. India 5:640. 1888, *pp. Gnetum edule* Kurz, For. Fl. Brit. Burma 2:495.1877, *non* Bl.

Local names : Mamelet (Ass.); Thanlping (Lushai), Mailariongum (Khasi).

Evergreen, dioecious lianas; branches smooth, slender, swollen at nodes; bark peeling off in pieces. Leaves oblong-ovate, upto 30 cm long, secondary veins distant, tertiaries indistinctly reticulate.

4.1 Gnetum montanum f. **megalocarpum** Markgraf; Bull. Jard. Bot. Btz. 111, 10: 450.1930; Sahni, *l.c.* 126. 1990.

Leaves large. Fruits *ca* 30 x 18 mm; stalk *ca* 8 mm long.

Distrib. : **Endemic** to Arunachal Pradesh (Dafla Hills).

5. Gnetum ula Brengn. in Duperrey, Voy, Monde 7 : 12. 1829; Markgraf. Bull. Gard. Not. Btz. 111, 10 : 460. 1930; C. Fischer, Fl. Madras 3 : 1885. 1936; Bharadwaja, J. Indian Bot. Soc. 36 : 408-420.1957. *Gnetum funiculare* Wight, Icon. Pl. Ind. Orient. 1955. 1853; *non* Brongn 1829. *Gnetum scandens sensu* Hook. f., Fl. Brit. India 5 : 642. 1888.

Local names : Ana-pendu (Tamil), Kodkanballi (Karnataka), Odal, ula (Mal.), Lolari (Or.), Kumal, Umbli (Mar.).

Lofty evergreen, dioecious climbers, upto 25 m high. Leaves lateral veins 6-8 pairs, curved, tertiaries reticulate, thin, distinct beneath.

Fl. : March-April; *Fr.* : April-Nov.

Distrib. : INDIA: (Andaman Islands, Andhra Pradesh, Maharashtra, Karnataka, Kerala, Tamilnadu, Orissa).

MYANMAR

Uses : Fruits are edible.

Taxa dubia

Gnetum gnemon var. **brunonianum**

Reportedly planted at Experimental Garden of BSI, Eastern Circle, Woodlands Campus, Laitumkhrah, Shillong in Meghalaya.

ACKNOWLEDGMENTS

Author is grateful to Dr. N. P.Singh, former Director and Dr. M. Sanjappa, present Director, Botanical Surveyoflndia, Kolkata, for facilities.

REFERENCES

Hooker, J.D. 1880. *Flora of British-India*, 5: 640-641, 863-864., London.

Maheshwari, P. and Biswas, C. 1970. *Cedrus, Bot. Monogr.* 5: 1-115, CSIR, New Delhi.

Maheshwari, P. and V. Vasil. 1974. *Botanical Monograph No. 1. Gnetum*, CSIR, New Delhi

Pant, D.D. 1973. *Cycas and the Cycadales.* Central Book Depot, Allahabad.

Raizada, M.B. and K.C. Sahni. 1960 'Living Indian Gymnosperms' pt I (Cycadales, Ginkgoales, Coniferales) *Ind. For. Rec.* 5(2): 1-10, 73-150.

Sahni, K.C. 1990 *Gymnosperms of India and adjacent Countries*, Bisen Singh & Mahendra Pal Singh, Dehradun.

Srivastava, R.C. 1992 Gymnosperms of Sikkim, *J. Asia Life. Sci.* 2:1-19.

Pb. Univ. Res. J (Sci.), Vol. 59, 2009, pp. 151-158

PLANTS OF EXPERIMENTAL BOTANICAL GARDEN OF BSI AT ITANAGAR IN ARUNACHAL PRADESH, INDIA

***R.C. Srivastava and R.K. Choudhary**

Botanical Survey of India, Itanagar-791 111
Present address: Botanical Survey of India, Kolkata-700 064

ABSTRACT

Present paper deals with the plants growing in the Experimental Botanical Garden of Botanical Survey of India, Itanagar. A total number of 286 species have been recorded. The accepted names of the taxa along with their family name, habit and phenology have been given.

Keywords: Botanical Garden, BSI, Itanagar, Arunachal Pradesh.

INTRODUCTION

Arunachal Pradesh, one of the 'Global Biodiversity Hotspots' is considered as a botanical paradise having 81.9% forest cover and exceptionally rich species diversity having over 5000 species of angiosperms, 44 species of gymnosperms, *ca* 600sps. of lichens, *ca* 350 sps. of bryophytes and a good number of algae and fungi which are still to be worked out including a large number of rare, endangered, threatened and endemic taxa. After the reorganization of Botanical Survey of India, Experimental Gardens and National Orchidaria have been established in different regions of the country following the primary objectives of the organization. The establishment of Experimental Garden of Arunachal Pradesh Circle, Itanagar having separate sections for medicinal plants viz. 'Dhanwantari Garden' and 'Ethnic Garden' are additions to this chain. The garden is located at Sankie View area of Itanagar, covering an area of 124 acres. In 1977, a field station was established in Arunachal Pradesh (the then NEFA) with the prime objective to make a repository of rare, threatened and endangered plants from different parts of the state and country, this garden was initiated in August 1987. Since then, it has been serving the purpose of conservation, experimental propagation of medicinal, economical and horticultural plants. The present paper deals with mainly the angiosperms (a few gymnosperms and ferns as well) and aims to provide an enumeration of the species found in this garden. The botanical names, families and their habits are also given (Table 1). There is no previous record of plant introduction in this garden except for *Elaeocarpus sphaericus* which was planted by Hon'ble Mukut Mithi (the then Chief Minister of Arunachal Pradesh) on August 25, 1987. Massive plantation work has been carried out from August 2005-till date.

Table 1: List of Species

S. N.	Name	Family	Habit
1.	*Abroma augusta* L.	Sterculiaceae	Shrub
2.	*Acacia auriculaeformis* A. Cunn *ex* Benth.	Fabaceae *s.l.*	Tree
3.	*Ageratum conyzoides* L.	Asteraceae	Herb
4.	*Ageratum houstonianum* Miller	Asteraceae	Herb
5.	*Albizzia lebbek* (L.) Benth.	Fabaceae *s.l.*	Tree
6.	*Allamanda cathartica* L.	Apocynaceae	Shrub
7.	*Allium sativum* L.	Liliaceae	Herb
8.	*Alocasia falax* Schott.	Araceae	Herb
9.	*Alocasia fornicata* Schott.	Zingiberaceae	Herb
10.	*Alocasia macrorhiza* Schott.	Araceae	Herb
11.	*Alpinia allughas* Rosc.	Zingiberaceae	Herb

---

*Corresponding Author. *rcs_bsi@yahoo.co.in*

MS Received October 25, 2007; Accepted August 23, 2010

12.	*Alpinia malaccensis* (Burm. f.) Rosc.	Zingiberaceae	Herb
13.	*Alstonia scholaris* (L.) R. Br.	Apocynaceae	Tree
14.	*Alstonia venenata* R. Br.	Apocynaceae	Shrub
15.	*Amaranthus caudatus* L.	Amaranthaceae	Herb
16.	*Amaranthus gangeticus* L.	Amaranthaceae	Herb
17.	*Amaranthus viridis* L.	Amaranthaceae	Herb
18.	*Amaranthus spinosus* L.	Amaranthaceae	Herb
19.	*Amorphophallus bulbifer* Bl.	Araceae	Herb
20.	*Annanas comosus* Merill	Bromeliaceae	Herb
21.	*Anthocephalus cadamba* Miq.	Rubiaceae	Tree
22.	*Aquilaria agallocha* Roxb.	Thymeliaceae	Tree
23.	*Areca catechu* L.	Arecaceae	Tree
24.	*Aristolochia tagala* Cham.	Aristolochiaceae	Climber
25.	*Artemisia vulgaris* L.	Asteraceae	Shrub
26.	*Artocarpus heterophyllus* Lam.	Moraceae	Tree
27.	*Arundina graminifolia* (D. Don.)Hochr.	Orchidaceae	Herb
28.	*Averrhoa carambola* L.	Averrhoaceae	Tree
29.	*Azadirachta indica* A. H. L. Juss.	Meliaceae	Tree
30.	*Bambusa pallida* Munro	Poaceae	Arborescent herb
31.	*Bambusa tulda* Benth.	Poaceae	Arborescent herb
32.	*Bambusa vulgaris* Nees var. *striata*	Poaceae	Arborescent herb
33.	*Bauhinia purpurea* L.	Fabaceae *s.l.*	Tree
34.	*Begonia palmata* D. Don	Begoniaceae	Herb
35.	*Benincasa hispida* (Thun.) Cogn.	Cucurbitaceae	Climber
36.	*Bidens biternata* (Lour.) Merr. & Sherff.	Asteraceae	Herb
37.	*Bixa orellana* L.	Bixaceae	Tree
38.	*Borreria hispida* K. Schum.	Rubiaceae	Herb
39.	*Bougainvillea glabra* Choisy	Nyctaginaceae	Shrub
40.	*Brassaiopsis glomerulata* (Bl.) Regel..	Araliaceae	Tree
41.	*Brassica campestris* L.	Brassicaceae	Herb
36	*Brownea coccinea* Jacq.	Fabaceae *s.l.*	Tree
37	*Bryophyllum pinnatum* (Lam.) Oken	Crassulaceae	Herb
42.	*Caesalpinia cucullata* Roxb.	Fabaceae *s.l.*	Shrub
43.	*Caesalpinia pulcherrima* G. Don	Fabaceae *s.l.*	Shrub
44.	*Caesaria vereca* Roxb.	Flacourtiaceae	Herb
45.	*Caladium hortulanum* Birdsey	Araceae	Herb
46.	*Calamus tenuis* Roxb.	Arecaceae	Shrub
47.	*Calanthe masuca* Lindl.	Orchidaceae	Herb
48.	*Callicarpa arborea* Roxb.	Verbenaceae	Tree
49.	*Callistemon citrinus* (Curtis) Skeels	Myrtaceae	Tree
50.	*Canna coccinea* Mill.	Cannaceae	Herb
51.	*Canna edulis* Ker-Gawl.	Cannaceae	Herb

52.	*Canna indica* L.	Cannaceae	Herb
53.	*Canna speciosa* Rosc.	Cannaceae	Herb
54.	*Capsicum annuam* L.	Solanaceae	Herb
55.	*Cardamine hirsuta* L.	Brassicaceae	Herb
56.	*Carex cruciata* Wahlenb.	Cyperaceae	Herb
57.	*Carica papaya* L.	Caricaceae	Tree
58.	*Caryota urens* L.	Arecaceae	Tree
59.	*Cassia alata* L.	Fabaceae *s.l.*	Shrub
60.	*Cassia floribunda* Cav.	Fabaceae *s.l.*	Shrub
61.	*Cassia hirsuta* Cav.	Fabaceae *s.l.*	Shrub
62.	*Cassia tora* L.	Fabaceae *s.l.*	Shrub
63.	*Castanopsis indica* A.DC.	Fagaceae	Tree
64.	*Catharanthus roseus* (L.) G. Don	Apocynaceae	Herb
65.	*Celosia argentea* L.	Amaranthaceae	Herb
66.	*Ceropegia bulbosa* Roxb.	Asclepiadaceae	Climber
67.	*Chrysanthemum indicum* L.	Asteraceae	Herb
68.	*Cinnamomum bejolghota* (Buch.-Ham.) Sweet	Lauraceae	Tree
69.	*Citrulus colosynthes* Schrad.	Cucurbitaceae	Climber
70.	*Citrus aurantifolia* (Christ.) Swingle	Rutaceae	Tree
71.	*Citrus jambhiri* Lush. ex Krishna	Rutaceae	Shrub
72.	*Citrus limetta* DC.	Rutaceae	Tree
73.	*Cleome speciosa* H.B. & K.	Cleomaceae	Herb
74.	*Cleome rutidosperma* DC.	Cleomaceae	Herb
75.	*Clerodendrum colebrookianum* Walp.	Verbenaceae	Shrub
76.	*Clerodendrum inerme* Gaertn.	Verbenaceae	Shrub
77.	*Clerodendrum japonicum* (Thunb.) Sweet	Verbenaceae	Shrub
78.	*Clitorea ternatea* L.	Fabaceae *s.l.*	Herb
79.	*Codiaeum variegatum* Bl. (Five cultivars)	Euphorbiaceae	Shrub
80.	*Coelogyne fuscescens* Lindl.	Orchidaceae	Herb
81.	*Coleus scutellariodes* (L.) Benth.	Lamiaceae	Herb
82.	*Colocasia esculenta* (L.) Schott.	Araceae	Herb
83.	*Cordia dichotoma* Forster f.	Ehretiaceae	Tree
84.	*Coriandrum sativum* L.	Apiaceae	Herb
85.	*Crinum asiaticum* L.	Amaryllidaceae	Herb
86.	*Cucumis melo* L.	Cucurbitaceae	Climber
87.	*Cucumis sativus* L.	Cucurbitaceae	Climber
88.	*Cuphea carthagensis* (Jacq.) Macbride.	Lythraceae	Herb
89.	*Cuphea hyssopifolia* H.B. & K.	Lythraceae	Herb
90.	*Curcuma aromatica* Salisb.	Zingiberaceae	Herb
91.	*Curcuma longa* L.	Zingiberaceae	Herb
92.	*Cymbidium aloefolium* (L.) Sw.	Orchidaceae	Epiphyte

93.	*Cyperus alternifolius* L.	Cyperaceae	Herb
94.	*Cyperus alulatus* Kern.	Cyperaceae	Herb
95.	*Cyperus halpan* L.	Cyperaceae	Herb
96.	*Dalhousiea bracteata* (Roxb.) R.Grah. *ex* Benth.	Fabaceae *s.l.*	Herb
97.	*Dendrobium fimbriatum* var. *oculatum* Hook.	Orchidaceae	Epiphyte
98.	*Dendrobium nobile* Lindl.	Orchidaceae	Epiphyte
99.	*Dendrocalamus hamiltonii* Nees & Arn.	Poaceae	Arborescent herb
100.	*Digitaria ciliaris* (Retz.) Koel.	Poaceae	Herb
101.	*Dillenia indica* L.	Dilleniaceae	Tree
102.	*Dillenia pentagyna* Roxb.	Dilleniaceae	Tree
103.	**Diplomeris pulchella* D. Don	Orchidaceae	Herb
104.	*Dolichos lablab* L.	Fabaceae	Shrub
105.	*Drymaria diandra* Bl.	Caryophyallaceae	Herb
106.	*Duabanga grandiflora* (Roxb. *ex* DC.) Walp.	Sonnertiaceae	Tree
107.	*Duranta erecta* L.	Verbenaceae	Shrub
108.	*Elaeocarpus sphaericus* (Gaertn.) K. Schum.	Elaeocarpaceae	Tree
109.	*Eleusine coracana* (L.) Gaertn.	Poaceae	Herb
110.	*Eleusine indica* (L.) Gaertn.	Poaceae	Herb
111.	*Eria stricta* Lindl.	Orchidaceae	Epiphyte
112.	*Eryngium foetidum* Forsk.	Apiaceae	Herb
113.	*Erythrina arborescens* Roxb.	Euphorbiaceae	Tree
114.	*Erythrina stricta* Lindl.	Euphorbiaceae	Tree
115.	*Erythrina suberosa* Roxb.	Euphorbiaceae	Tree
116.	*Eupatorium odoratum* L.	Asteraceae	Herb
117.	*Euphorbia pulcherrima* Willd. *ex* Klozsch	Euphorbiaceae	Shrub
118.	*Euphorbia royaliana* Boissier	Euphorbiaceae	Shrub
119.	*Exbucklandia populnea* (R.Br. *ex* Griff) R.W. Brown	Hamamelidaceae	Tree
120.	*Ficus elastica* Roxb.	Moraceae	Tree
121.	*Ficus hispida* L. f.	Moraceae	Tree
122.	*Ficus religiosa* L.	Moraceae	Tree
123.	*Ficus semicordata* Buch.-Ham *ex* J. E. Smith	Moraceae	Tree
124.	*Ficus pumila* L.	Moraceae	Climber
125.	*Floscopa scandens* Lour.	Commelinaceae	Herb
126.	*Frerea indica* Dalz.	Asclepiadaceae	Herb
127.	*Galinsoga parviflora* Cav.	Asteraceae	Herb
128.	*Globba multiflora* Wall. *ex* Baker	Zingiberaceae	Herb
129.	*Gmelina arborea* Roxb.	Verbenaceae	Tree
130.	*Gnaphalium luteo-album* L.	Asteraceae	Herb
131.	*Goodyera procera* (Wall. *ex* Ker-Gawl) Hook.	Orchidaceae	Herb
132.	**Gymnocladus assamicus* Kanj. *ex* P.C.Kanj.	Fabaceae *s.l.*	Tree
133.	*Habenaria furcifera* Lindl.	Orchidaceae	Herb
134.	*Hedera helix* L.	Araliaceae	Tree

135.	*Hedychium coccinium* J. E. Smith	Zingiberaceae	Herb
136.	*Hedychium coronarium* Koen.	Zingiberaceae	Herb
137.	*Hedyotis scandens* Roxb.	Rubiaceae	Herb
138.	*Heteropanax fragrans* (Roxb.) Seeman	Araliaceae	Tree
139.	*Hibiscus rosasinensis* L.	Malvaceae	Shrub
140.	*Holmskioldia sanguinea* Retz.	Verbenaceae	Shrub
141.	*Holmskioldia sanguinea* f. *citrina*	Verbenaceae	Shrub
142.	*Homalomena aromatica* Schott.	Araceae	Herb
143.	*Hoya retusa* Dalz.	Asclepiadaceae	Parasitic
144.	*Hoya longifolia* Wall *ex* Wight	Asclepiadaceae	Parasitic
145.	*Hydrangia macrophylla* (Thunb.) Seringe	Hydrangiaceae	Herb
146.	*Hydrocotyle javanica* Thunb.	Apiaceae	Herb
147.	*Hydrocotyle himalaica* P.K. Mukherjee	Apiaceae	Herb
148.	*Hyptis suaveolens* (L.) Poiteau	Lamiaceae	Herb
149.	*Impatiens balsamina* L.	Balsaminaceae	Herb
150.	*Imperata cylindrica* (L.) P.Beau.	Poaceae	Herb
151.	*Ipomoea quamoclit* L.	Convolvulaceae	Climber
152.	*Lagerstroemia indica* L.	Lythraceae	Tree
153.	*Lantana camara* var. *aculeata*(L.) Modenke	Verbenaceae	Shrub
154.	*Lasia heterophylla* Schott.	Araceae	Herb
155.	*Lepisanthes senegalensis* (A.L. Juss. Ex Poiret) Leench.	Sapindaceae	Tree
156.	*Liparis longipes* Lindl.	Orchidaceae	Herb
157.	*Lipocarpha chinensis* (Osbeck.) Kern.	Cyperaceae	Herb
158.	**Livistona jenkinsiana* Griff.	Arecaceae	Tree
159.	*Ludwigia prostrata* Roxb.	Onagraceae	Herb
160.	*Luffa acutangula* (L.) Roxb.	Cucurbitaceae	Climber
161.	*Luffa cylindrica* (L.) Roemer	Cucurbitaceae	Climber
162.	*Lycopersicon esculentum* Miller	Solanaceae	Herb
163.	*Macaranga denticulata* Muell.-Arg.	Euphorbiaceae	Tree
164.	*Maesa indica* (Roxb.) A. DC.	Myrsinaceae	Shrub
165.	*Magnolia griffithii* Hook. f. & Thoms.	Magnoliaceae	Tree
166.	*Magnolia pterocarpa* Roxb.	Magnoliaceae	Tree
167.	*Mangifera indica* L.	Anacardiaceae	Tree
168.	*Manihot esculentus* Cranz	Euphorbiaceae	Shrub
169.	*Mazus pumilus* (Burm. f.) Steen.	Scrophulariaceae	Herb
170.	*Melastoma malabathricum* L.	Melastomataceae	Shrub
171.	*Melia azedarach* L.	Meliaceae	Tree
172.	*Mesua ferrea* L.	Clusiaceae	Tree
173.	*Michelia baillonii* Finet & Gagnep.	Magnoliaceae	Tree
174.	*Michelia champaca* L.	Magnoliaceae	Tree
175.	*Mikania micrantha* Kunth.	Asteraceae	Climber

176.	*Mimosa pudica* L.	Fabaceae *s.l.*	Herb
177.	*Monstera deliciosa* Liebmann	Araceae	Herb
178.	*Moringa oleifera* Lam.	Moringaceae	Tree
179.	*Morus macroura* Miquel	Moraceae	Tree
180.	*Murraya koenigii* (L.) Sprengel	Rutaceae	Shrub
181.	*Murraya paniculata* (L.) Jack	Rutaceae	Shrub
182.	*Muehlenbeckia platyclada* Meissn.	Polygonaceae	Herb
183.	*Musa bulbisiana* Colla	Musaceae	Tree
184.	*Mussaenda roxburghii* L.	Rubiaceae	Shrub
185.	*Mariscus paniceus* (Rottboell) Vahl	Cyperaceae	Herb
186.	**Nepenthes khasiana* Hook. f.	Nepenthaceae	Climber
187.	*Nyctanthes arbortristis* L.	Oleaceae	Tree
188.	*Ocimum basilicum* L.	Lamiaceae	Herb
189.	*Ocimum sanctum* L.	Lamiaceae	Herb
190.	*Opuntia dilleni* Haw.	Cactaceae	Shrub
191.	*Ormosia robusta* Baker	Fabaceae *s.l.*	Tree
192.	*Oroxylum indicum* (L.) Kurz.	Bignoniaceae	Tree
193.	*Osbeckia nutans* Wall.	Melastomataceae	Herb
194.	*Ostodes paniculata* Bl.	Euphorbiaceae	Tree
195.	*Oxalis corniculata* L.	Oxalidaceae	Herb
196.	*Oxalis corymbosa* DC.	Oxalidaceae	Herb
197.	*Paederia foetida* L.	Rubiaceae	Climber
198.	*Pandanus furcatus* Roxb.	Pandanaceae	Tree
199.	*Pandanus odoratissimus* L. f.	Pandanaceae	Shrub
200.	*Papilionanthe teres* (Lindl.) Schltr.	Orchidaceae	Epiphyte
201.	*Pedilanthus tithymaloides* Poit.	Euphorbiaceae	Herb
202.	*Peliosanthes teeta* Andr.	Haemadoraceae	Herb
203.	*Perilla frutescens* L. ex Jackson	Lamiaceae	Herb
204.	*Phlogacanthus thyrsiformis* (Roxb. ex Hardw.) D.J. Mabberley	Acanthaceae	Shrub
205.	*Phlogacanthus tubiflorus* Nees	Acanthaceae	Shrub
206.	*Phrynium pubinerve* Bl.	Marantaceae	Herb
207.	*Phyllanthus amarus* Schum. & Thonn	Euphorbiaceae	Herb
208.	*Phyllanthus ellipticus* Baill	Euphorbiaceae	Shrub
209.	*Pilea bracteosa* Wedd.	Urticaceae	Herb
210.	*Pilea microphylla* Griseb.	Urticaceae	Herb
211.	*Pinanga gracilis* Bl.	Arecaceae	Tree
212.	*Piper betel* Blanco	Piperaceae	Climber
213.	*Piper longum* Bl.	Piperaceae	Climber
214.	*Plantago erosa* Wall.	Plantaginaceae	Herb
215.	*Plumbago zeylanica* L.	Plumbaginaceae	Herb
216.	*Pogonatherum paniceum* (Lamk.) Hackel	Poaceae	Herb

217.	*Pogostemon patchouly* Pellet	Lamiaceae	Herb
218.	*Polygonum capitatum* D.Don	Polygonaceae	Herb
219.	*Polygonum chinense* L.	Polygonaceae	Herb
220.	*Polygonum hydropiper* L.	Polygonaceae	Herb
221.	*Polygonum longisetum* De Bruyn	Polygonaceae	Herb
222.	*Pothos cathcartii* Schott.	Araceae	Epiphyte
223.	*Pothos scandens* L.	Araceae	Epiphyte
224.	*Prunus cerasoides* D. Don	Rosaceae	Tree
225.	*Prunus persica* (L.) Batsch	Rosaceae	Shrub
226.	*Psidium guajava* L.	Myrtaceae	Tree
227.	*Pycreus sanguiniolentus* (Vahl) Nees	Cyperaceae	Herb
228.	*Raphanus sativus* L.	Brassicaceae	Herb
229.	*Rauwolfia canescens* L.	Apocynaceae	Herb
230.	*Rauwolfia serpentina* Benth. *ex* Kurz.	Apocynaceae	Herb
231.	*Remusatia vivipara* Schott.	Araceae	Herb
232.	*Rhaphidophora decursiva* (Schott.) Schott.	Araceae	Epiphyte
233.	*Rhynchotecum vestitum* Hook. f. & Thoms.	Gesneraceae	Herb
234.	*Ricinus communis* L.	Euphorbiaceae	Shrub
235.	*Rosa indica* L.	Rosaceae	Shrub
236.	*Rubus ellipticus* Sm.	Rosaceae	Shrub
237.	*Salvia officinalis* L.	Lamiaceae	Herb
238.	*Sapindus mukorossi* Gaertn.	Sapindaceae	Tree
239.	*Saraca asoca* (Roxb.) De Wilde	Fabaceae	Tree
240.	*Sarcochlamys pulcherrima* (Roxb.) Gaud.	Urticaceae	Tree
241.	*Saurauia panduana* Wall.	Saurauiaceae	Shrub
242.	*Sansevieria thyrsiflora* Thunb.	Haemodoraceae	Herb
243.	*Solanum indicum* L.	Solanaceae	Herb
244.	*Solanum melongena* L.	Solanaceae	Herb
245.	*Solanum surattense* Burm. f.	Solanaceae	Herb
246.	*Solanum torvum* Buch.-Ham. *ex* Wall.	Solanaceae	Herb
247.	*Sonchus asper* Gaertn.	Asteraceae	Herb
248.	*Spilanthes acmella* Murr.	Asteraceae	Herb
249.	*Spondias pinnata* (L. *f.*) Kurz	Anacardiaceae	Tree
250.	*Stachytarpheta indica* Vahl.	Verbenaceae	Herb
251.	*Strobilanthes pubiflora* J.R.I Wood	Acanthaceae	Herb
252.	*Sygygium cumini* Skeels	Myrtaceae	Shrub
253.	*Tabernaemontana divericata* R.Br. *ex* Roem & Schult.	Apocynaceae	Herb
254.	*Tagetes erecta* L.	Asteraceae	Herb
255.	*Tagates patula* L.	Asteraceae	Herb
256.	*Terminalia arjuna* Wight & Arn.	Combretaceae	Tree
257.	*Tetrastigma dubium* (Lawson) Planch.	Vitaceae	Climber

258.	*Thunbergia coccinea* Wall.	Thunbergiaceae	Climber
259.	*Thunbergia grandiflora* Nees	Thunbergiaceae	Climber
260.	*Thysacnolaena maxima* (Roxb.) Kuntz.	Poaceae	Herb
261.	*Urena lobata* L.	Malvaceae	Herb
262.	*Vernonia cinerea* L.	Asteraceae	Herb
263.	*Xanthium indicum* Koen. *ex* Roxb.	Asteraceae	Herb
264.	*Youngia japonica* (L.) DC.	Asteraceae	Herb
265.	*Zephyranthes candida* Herb.	Amaryllidaceae	Herb
266.	*Zephyranthes grandiflora* Lindl.	Amaryllidaceae	Herb
267.	*Zingiber zerumbet* Rosc. *ex* Smith.	Zingiberaceae	Herb
268.	*Zingiber officinale* Rosc.	Zingiberaceae	Herb
	Gymnosperms		
269.	*Araucaria heterophylla* (Salisb.) Franco	Araucariaceae	Tree
270.	*Cryptomeria japonica* D.Don	Taxodiaceae	Tree
271.	**Cycas pectinata* Griff.	Cycadaceae	Small tree
272.	*Cycas revoluta* Thunb.	Cycadaceae	Small tree
273.	*Podocarpus neriifolius* D.Don	Podocarpaceae	Small tree
274.	*Thuja occidentalis* L.	Cupressaceae	Small Tree
275.	*Thuja orientalis* L.	Cupressaceae	Small Tree
276.	*Zamia furfuracea* Ait.	Zamiaceae	Shrub
	Pteridophytes		
277.	**Cyathea spinulosa* Wall. *ex* Hook.	Cyatheaceae	Tree
278.	*Diplazium esculentum* (Retz.) Swartz	Athyriaceae	Herb
279.	**Dipteris wallichii* (R.Br.) Moore	Dipteridaceae	Herb
280.	*Dicranopteris linearis* (Burm.) Underw.	Gleichaniaceae	Herb
281.	*Equisetum ramosissimum* Desf.	Equisetaceae	Herb
282.	*Lygodium flexuosum* (L.) Swartz	Lygodiaceae	Herb
283.	*Palhinhaea cerenua* L.	Lycopodiaceae	Herb
284.	*Pronephrium lakhimpurensis* (Rosenst.) Holtt.	Athyriaceae	Herb
285.	*Pteris semipinnata* L.	Pteridaceae	Herb
286.	*Selaginella pentagona* Spring.	Selaginellaceae	Herb

*Threatened species.

The introduction and multiplication of some rare plants like *Gymnocladus assamicus, Begonia tessaricarpa, Pandanus unguifer, Holmskioldia sanguinea, Aristolochia tagala, Livistona jenkinsiana, Rauvolfia serpentina, Dipteris wallichii, Dendrobium* spp., *Eria* sps., *Bulbophyllum* sps.; some endemic species like *Ceropegia bulbosa, Frerea indica, Cassia mysorensis* are among some of the significant achievements on way to preserve the invaluable plant resources. The garden also opens an arena for the scientists, researchers, local students and visitors by providing them the study materials, herbarium, library and a museum where the exhibits have been displayed; to disseminate the invaluable knowledge of this under-explored treasure-trove of biodiversity and to develop a scientific awareness among the ethnic communities of the state.

ACKNOWLEDGEMENTS

Authors are grateful to the Director, Botanical Survey of India, for providing facilities.

Pb. Univ. Res. J (Sci.), Vol. 59, 2009, pp. 159-164

TERMITES (INSECTA: ISOPTERA) FROM PUNJAB, WITH DESCRIPTION OF A NEW SPECIES OF THE GENUS *EURYTERMES* WASMANN

***R. K. Thakur**

Division of Entomology, Forest Research Institute, Dehra Dun 248 006

Abstract

Twenty-eight species of termites belonging to two families (Rhinotermitidae and Termitidae) and twelve genera (*Heterotermes, Coptotermes, Eurytermes, Speculitermes, Amitermes, Synhamitermes, Eremotermes, Microcerotermes, Dicuspiditermes, Odontotermes, Microtermes* and *Trinervitermes*) are reported here from Punjab. Fourteen termite species are reported here first time from Punjab, including one new species, *Eurytermes punjabensis*.

Keywords: Termites, Punjab, *Eurytermes*.

INTRODUCTION

Holmgren and Holmgren (1917) and Chhotani (1962) were the first to report termites from Punjab. Chatterjee and Thakur (1967) gave a comprehensive account of 19 species from North-Western Himalayas, which included seven species from Punjab. Later on Thakur (1992) recorded 19 species from semi-arid areas of Punjab (Bhatinda, Ferozpur and Sangrur). Subsequently, Pajni and Arora (1989, 1994) and Pajni *et al.* (1996) gave a detailed account on the bionomics and management of termites of Chandigarh and Haryana. Roonwal and Chhotani (1989) and Chhotani (1997) have discussed the taxonomic status and geographical distribution of the termites known so far from Punjab. The present paper is based on 63 vials of termites, collected from different localities in Punjab. Some material present in the unidentified Termite Collections of Forest Research Institute, Dehra Dun was also examined and included in order to get as complete a picture as possible of whole component of the termite fauna of this region. Altogether, Twenty-eight species of termites belonging to two families, Rhinotermitidae and Termitidae and twelve genera (*Heterotermes, Coptotermes, Eurytermes, Speculitermes, Amitermes, Synhamitermes, Eremotermes, Microcerotermes, Dicuspiditermes, Odontotermes, Microtermes* and *Trinervitermes*) are reported here (Table 1). This includes 14 new distributional records: *Speculitermes cyclops* Wasmann; *Synhamitermes quadriceps* (Wasmann); *Amitermitermes belli* (Desneux); *Eremotermes fletcheri* Holmgren and Holmgren; *Eremotermes neoparadoxalis* Ahmad; *Microcerotermes heimi* Wasmann; *Microcerotermes tenuignathus* (Holmgren); *Dicuspiditermes incola* (Wasmann); *Odontotermes bellahunisensis* Holmgren and Holmgren; *Odontotermes brunneus* (Hagen); *Odontotermes indicus* Thakur; *Odontotermes redemanni* (Wasmann); *Odontotermes wallonensis* (Wasmann) and *Trinervitermes biformis* (Wasmann). A new species, *Eurytermes punjabensis* is being described here.

Abbreviations used: Ex., extracted from; S., Soldier; sev., several; W., Worker.

MATERIAL AND METHODS

About 63 vials of termites were available in the unidentified collection of the Division of Entomology, Forest Research Institute Dehra Dun for the present studies. The specimens were preserved in alcohol, with proper label containing details of the locality, date of collection and host plant etc. For taxonomic measurements, Roonwal (1970)'s monograph "Measurements of termites (Isoptera) for taxonomic purpose" was followed. The termite specimens were studied under a Stereoscopic Binocular microscope with the help of ocular micrometer fitted within one eyepiece of the binocular and the measurements of various body parts of the termites (such as antennae, mandibles, labrum, pronotum, etc.) were taken. Temporary slides of the various body parts were prepared for detailed studies. For taxonomic studies, comparison with the authenticated reference collection of known species is important for establishing the correct identity. Where ever necessary, "type" specimens were also referred. Illustrations of the taxonomically important body parts of the new species, *Eurytermes punjabensis* were drawn under the microscope with the help of a camera lucida.

---

*Corresponding Author. *thakurrk@icfre.org*

MS Received September 18, 2008; Accepted February 2, 2010

Eurytermes punjabensis sp. nov.

(Figs. 1 and 2; Tables 1 and 2)

Material: One vial with soldiers and workers from Jugliya, Shahpur Kandi near Ravisadan Rest House, Pathankot, (Punjab), coll. R.K.Thakur, 10-5-1991.

Description:

IMAGO: Unknown

SOLDIER (Fig. 1; Table 1)

General: Head creamish yellow; body whitish. Head fairly and body densely hairy. Total body length ca 5.24-5.38.

Head: Head-capsule sub rectangular, thick, longer than broad; head length to base of mandibles 1.82-1.88mm; head-width weakly widening in front sides sub parallel, Fontanelle indistinct. Eyes and ocelli absent. Antennae with 14 segments. Labrum sub triangularly tongue-shaped. Mandibles thick, stout, weakly incurved at the tip, broad at base; left with short and obtuse to a prominent and interiorly dgirected tooth at about distal 1/4th and a small indentation basally; right with a short to prominent tooth at distal 1/3rd and which slight indentation basally. Postmentum long, club-shaped.

Thorax: Pronotum strongly saddle-shaped; not notched alt anterior and posterior margins length 0.20-0.24 mm; width 0.48-0.52 mm. Legs fairly hairy and long; apical tibial spurs 3; 2: 2; tarsi 4-jointed.

Abdomen: elongate; cerci short, 2-jointed.

Table 1: Body measurements (in mm) of 10 soldiers of *Eurytermes punjabensis* sp. nov.

S.No.	Body-Parts	Range	Holotype	Mean
	I. General			
1.	Total body length ca...	5.24-5.38	5.24	5.32
	II. Head			
2.	Head-length with mandibles	2.54-2.60	2.54	2.57
3.	Length of head to lateral base of mandibles	1.82-1.88	1.82	1.85
4.	Maximum width of head	1.12-1.16	1.12	1.14
5.	Length of labrum	0.18-0.20	0.18	0.19
6.	Max. Width of Labrum	0.28-0.32	0.28	0.30
7.	Distance of tooth from the tip of mandible	0.20-022	0.20	0.21
8.	Length of mandibles			
	(a) Left mandibles	0.72-0.76	0.72	0.74
	(b) Right mandible	0.72-0.76	0.72	0.74
9.	Min. (median) length of Postmentum	1.18-1.22	1.18	1.20
10.	Max. width of postmentum	0.32-0.34	0.32	0.33
11.	Min. width of postmentum	0.22-0.24	0.22	0.23
	III Thorax			
12.	Length of Pronotum	0.28-0.32	0.28	0.30
13.	Maximum width of Pronotum	0.68-0.72	0.68	0.70

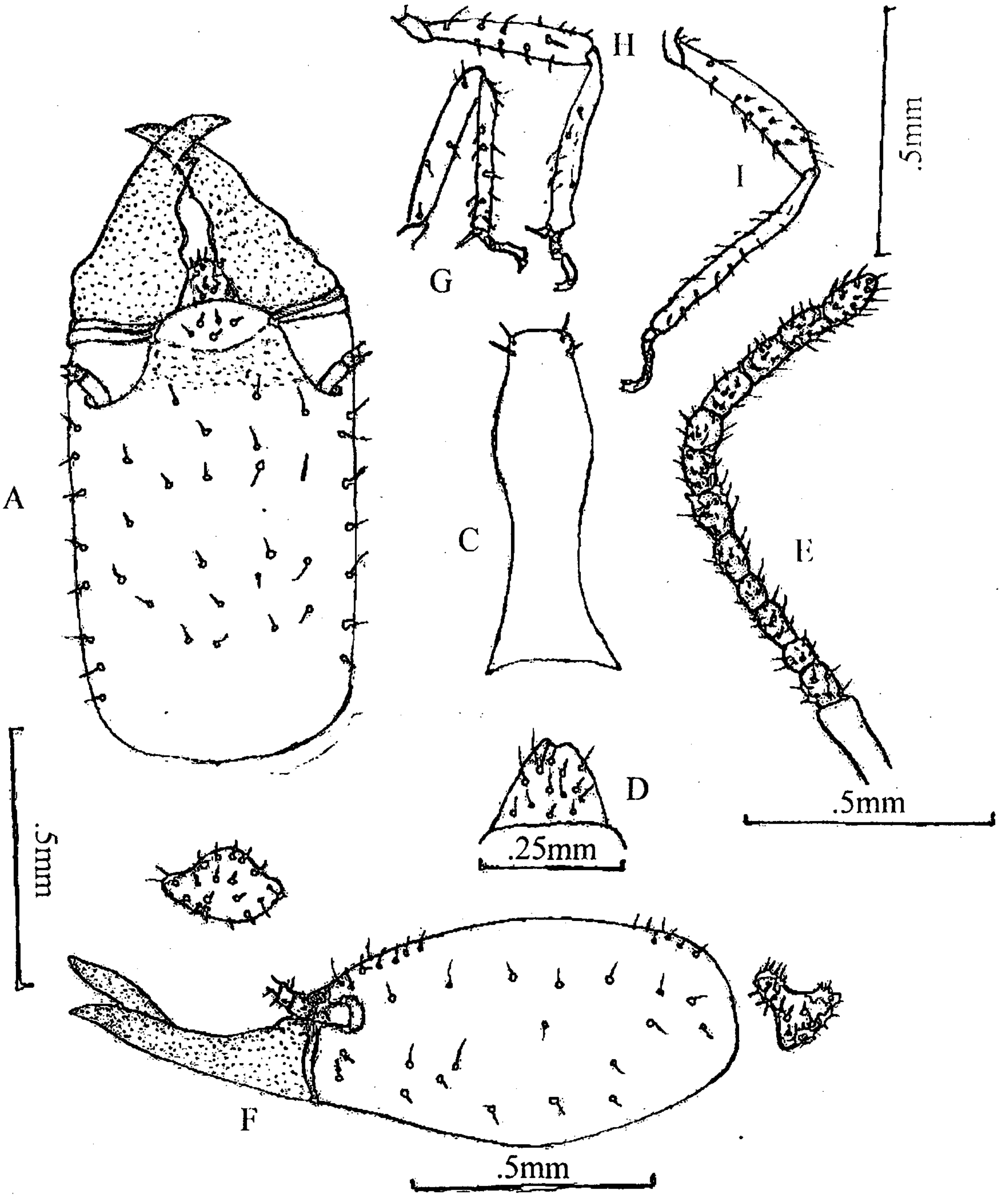


Fig. 1: *Eurytermes punjabensis* sp. nov. Soldier Caste (A) Head, dorsal view (B) Pronotum, dorsal view (C) Postmentum, in-situ (D) Labrum (E) Right antenna (F) Head, side view (G, H,I) Fore, middle and hing legs.

WORKER (Fig. 2; Table 2)

General: Head pale yellow; abdominal tergites and stergites transparent with grayish contents of abdomen showing through. Head fairly and body densely hairy. Total body length ca.

Head: Head sub-circular; broader than length; head-length to the base of mandibles; Fontenalle plate rounded to oval; 0whitish spot. Antennal with 14 segments. Postclypeus swollen, about half as long as wide. Mandibles longer than broad incurved at anterior margin; 2nd marginal of left mandible sharper and of right mandible strongly incurved at posterior margin and molar plate spatulate in left and more incurved in right.

Thorax: Pronotum saddle-shaped, not notched at anterior or posterion margin, Legs fairly hairy and long foreleg somewhat swollen and its dorsal spur either minute or sometimes absent.

Table 2: Body-measurements (in mm.) of 5 Workers of *Eurytermes punjabensis* sp. nov.

S.No.	Body-Parts	Range	Mean
	I. General		
1.	Total body length ca...	3.35-4.70	4.45
	II. Head		
2.	Length of head to tip of labrum	0.95-1.10	1.02
3.	Head-length to lateral base of mandibles	0.70-0.85	0.77
4.	Maximum width of head	0.80-0.90	0.85
5.	Height of head	0.48-0.55	0.52
	III Thorax		
6.	Length of Pronotum	0.35-0.48	0.41
7.	Width or pronotum	0.62-0.68	0.75

Type-Specimens: All the type-specimens in spirit and from a single source on given under "Material" above are deposited as follows:-

Holotype: A soldier in spirit in a vial, deposited in the National Reference Collection in Forest Research Institute, Dehra Dun.

Paratypes: A paratype soldier, 6 Paramorphotype workers, in a vial, in National Reference Collection, FRI, Dehra Dun.

Type-Locality: INDIA: Punjab: Shahpur Kandli, Pathankot.

Distribution: Known only from the type-locality.

Comparison: The soldier of *Eurytermes punjabensis* sp. nov. are close to *Eurytermes boveni* Roonwal and Chhotani in shape of the head-capsule and general appearance but can be separated as follows:

(i) Comparatively smaller species (total body length 5-24-5.38 *vs*. 5.9 mm).

(ii) Head capsule yellow, sub rectangular with few hairs *vs*. pale yellow; and fairly hairy.

(iii) Antennal segment 3 shorter than 2 *vs*. 4th shortest.

(iv) Pronotum saddle shaped; length 0.35-0.48 *vs*. 0.33 mm, width 0.62-0.68 *vs*. 0.70mm.

ACKNOWLEDGEMENTS

I am grateful to Director, Forest Research Institute, Dehra Dun and Head, Division of Entomology, FRI for facilities and encouragement. Thanks are also due to Miss. Manisha Dwivedi for typing this Manuscript.

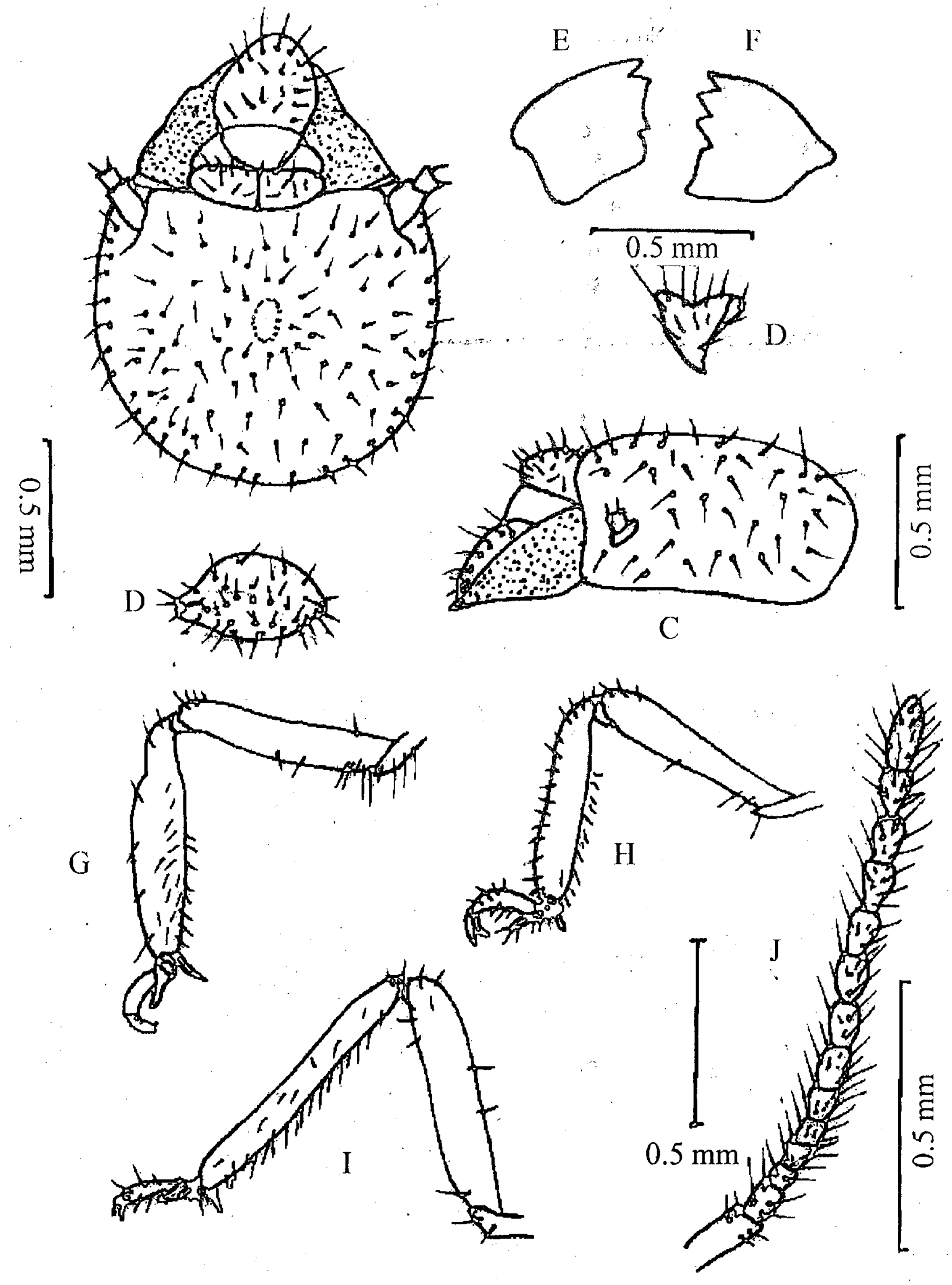


Fig. 2: *Eurytermes punjabensis* sp. nov. Worker Caste (A) Head, dorsal view (B) Pronotum, dorsal view (C) Head, side view (D) Pronotum, side view (E) Right mandible (F) Left mandible (G, H,I) Fore, middle and hing legs. (J) Right antenna.

REFERENCES

Chatterjee, P.N. and M.L. Thakur. 1967. Contribution to the knowledge of systematic of North-western Himalayan termite fauna. *Indian For. Rec.*, 92: 139-142.

Chhotani, O.B. 1962. Biological observation on the termite, *Kalotermes beesoni* Gardner. *Zool. Soc. India*, Culcatta (Proc. First All India Congress of Zoology, 1959), 476-478.

Chhotani, O.B. 1997. Fauna of India, Isoptera (Termites) *Publ. Zool.Surv. India*, Kolkata, II : 1-800.

Holmgren, K. and N. Holmgren. 1917. Report on a collection of termites from India. *Mem. Dept. Agric. India*, 5 (3): 138-171.

Pajni, H.R. and C.B. Arora. 1989. A study of the termites of Chandigarh and their control. *Final Propr. Rep. Sci. & Tech. Counc. UT. Chandigarh, Res. Project*, 1-27.

Pajni, H.R. and Arora, C.B. 1994. Studies on the bionomics and management of termites of Haryana. *Final. Proj. Rep. Haryana Counc. Sci and Tech. Res. Project*, 1-82.

Pajni, H. R. Arora, C. B., and Bhatti, I.S., 1996. Biology of termites. *Ann. Ent.*, 14 (1): 15-32.

Roonwal, M.L. and Chhotani, O.B. 1989. Fauna of India Isoptera (Termites), *Publ. Zool. Surv. India, Kolkata*, 1:1-672.

Thakur, M.L. 1981. Revision of termite genus *Odontotermes* Holmgren, (Isoptera: Termitidae: Macrotermitinae). *Indian For. Rec., New Delhi*, 14(2) : 1–183.

Thakur, R.K. 1989. Termite fauna (Insecta: Isoptera) of Gujarat, India. *Indian For. Rec. Dehradun*, 15 (1) : 1-76.

Thakur, R.K. 1992. On a collection of termites from arid areas of Punjab & Haryana. *Rec. Zool. Survey India, Calcutta*, 91(25) : 127-13.

Pb. Univ. Res. J (Sci.), Vol. 59, 2009, pp. 165-168

AUTOMATIC SPEAKER IDENTIFICATION USING MEL-FREQUENCY CEPSTRAL COEFFICIENTS

***Poonam Bansal[1], Amita Dev[2] and S.B. Jain[3]**

[1]*Department of Computer Science and Engineering, Amity School of Engineering and Technology, New Delhi*
[2]*Department of Computer Science and Engineering, Ambedkar Institute of Technology, New Delhi*
[3]*Department of ECE, IGIT, Guru Gobind Singh Indraprastha University, New Delhi*

Abstract

In this paper an automatic speaker identification scheme is proposed and developed, to identify or verify a person, by identifying his/her voice, using a novel method. All speaker identification system contains two main phases, training phase and the testing phase. In the training phase the features of the words spoken by different speakers are extracted and during the testing phase feature matching takes place. Feature extractor transforms the raw speech signal into a compact but effective representation that is more stable and discriminative than the original signal. During the recognition phase the extracted features are compared with the template in the database. In the proposed work features used are Mel-frequency cepstral coefficients (MFCC), delta MFCC (DMFCC) and delta-delta MFCC (DDMFCC). In this research Vector Quantization (VQ) is used for speaker modeling process.

Keywords: Speaker identification, Mel-frequency cepstral coefficients, delta MFCC, delta-delta MFCC and Vector Quantization

INTRODUCTION

In everyday life, it is a common experience for people to be able to identify speakers by their voices. In speech technology, many attempts have been made aiming at modeling such human ability for a number of applications, such as in security access control systems, or in specific investigation fields like computational forensics. For speaker recognition the feature extraction is an important section and many type of feature extraction is used in many studies such as Linear predictive cepstral coefficients (LPCC) that is referred to the vocal tract as an all pole filter and the LPC coefficients are the all pole filter coefficients and finally the LPC technique is combined with cepstrum technique (Rabiner and Juang, 1993). Another feature extraction technique is Mel frequency cepstral coefficients that is multiplying short term Fourier transform magnitude at the Mel frequency filter bank. In this text the MFCC technique has been used for feature extraction.

PRINCIPLES OF SPEAKER IDENTIFICATION

Speaker identification can be of two types, text-dependent and text-independent. Text-dependent speaker identification differs from that of text-independent, because (as in the aforementioned), the identification is performed on a voiced instance of a specific word, whereas in the latter the speaker can say anything.

The whole process of speaker identification system consists of two major parts; feature extraction and feature matching. In the process of feature extraction, specific parameters from the voice signal are extracted which represent the characteristics of a speaker. During feature matching the extracted features of the unknown speaker are compared with the ones extracted from a set of known speakers.

Automatic speaker identification work is based on the premise that a person's speech exhibits characteristics that are unique to the speaker. However this task has been challenged by the highly variant nature of input speech signals. The principle source of variance is the speaker himself. Speech signals in training and testing sessions can be greatly different due to many facts such as people voice change with time, health conditions, speaking rates etc. There are also other factors, beyond speaker variability, that present a challenge to speaker recognition technology. Examples of these are acoustical noise and variations in recording environments (e.g. speaker uses different telephone handsets).

FEATURE EXTRACTION

According to Rabiner and Schafer (1978) and Furui (2001) the very purpose of this step is to convert the speech waveform to some type of parametric representation for further analysis and processing, which is referred as the signal-processing front end. The speech signal is a slowly time-varying signal (called

---

*Corresponding Author. *pbansal89@yahoo.co.in*

MS Received May 7, 2007; Accepted August 30, 2010

quasi-stationary). When examined over a sufficiently short period of time (5 ~ 100 ms), its characteristics are fairly stationary. However, over long periods of time (on the order of 1/5 seconds or more) the signal characteristic change to reflect the different speech sounds being spoken. Therefore, the short-time spectral analysis is the most common way to characterize the speech signal. A wide range of possibilities exist for parametrically representing the speech signal for the speech recognition task, such as Linear prediction cepstral coefficients (LPCC), Mel-frequency cepstral coefficients (MFCC) and others. MFCC is perhaps the best known and most popular, and it will be used in this paper.

MFCC is based on the known variation of the human ear's critical bandwidths with frequencies, filters spaced linearly at low frequencies and logarithmically at high frequencies have been used to capture the phonetically important characteristics of speech. This is expressed in the Mel-frequency scale, linear frequency spacing below 1000 Hz and a logarithmic spacing above 1000 Hz. Mel-frequency cepstral coefficients (MFCC), introduced by Davis and Mermelstein (1980) constitute a parametric sound representation widely used in automatic speech recognition systems (Davis and Mermelstein, 1980). MFCC provide a substantial data reduction, because a few coefficients are sufficient to represent the cepstrum of the acoustic signal. Fig 1. shows the block diagram of MFCC extraction. Some of the main steps of MFCC extraction are given below:

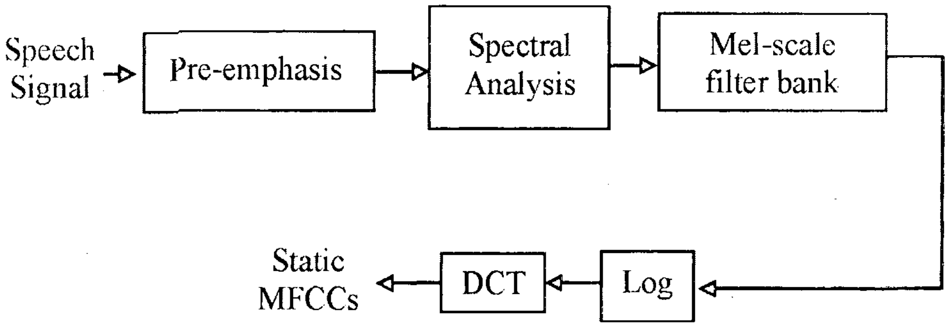


Fig.1: MFCC Processor

PRE-EMPHASIS: The digitized speech signal is filtered with a single coefficient digital filter equation which applies emphasis to the high frequency region of the spectrum. According to Picone (1993), voiced speech naturally has a negative spectral slope, the pre-emphasis filter serves to flatten the spectrum. Secondly, hearing is more sensitive above 1 kHz, thus the pre-emphasis filter enables the spectral analysis stages to capture more perceptually important information from the spectrum.

$$H(z) = 1 - a_{pre} z^{-1},\ 0.9 < a_{pre} \le 1.0 \qquad (1)$$

where, a_{pre} is the pre-emphasis coefficient. The most common value of a_{pre} is around 0.95.

Spectrum Analysis: The short-time discrete Fourier transform is computed for each frame after pre-emphasis as given by equation no. 2.

$$X(k) = \sum_{n=0}^{N-1} x(n)\, e^{(-j2\pi nk/N)},\quad 0 \le k \le N \qquad (2)$$

Mel Scale Filter Bank: A Mel ?lter bank analysis is performed by non- uniformly quantizing the Fourier spectrum. To achieve the non-uniform quantization, window functions are uniformly spaced on a Mel scale and then transformed back to a Hertz scale. Once the window functions are on a Hertz scale, they are multiplied with the Fourier power spectrum and then accumulated to give Mel spectrum ?lter-bank coefficients.

$$S(m) = \log \left[\sum_{k=0}^{N-1} |X(k)|^2 H(k,m) \right] \qquad 1 \le m \le K-1 \qquad (3)$$

DCT: Once the logarithm of the ?lter bank energies has been computed, the ?nal MFCCs are found by computing the DCT of the log ?lter bank energies as given in equation (4). It is typical in a speech recognition system to only keep cepstral coefficients from $c(1)$ through $c(12)$. By keeping this range of coefficients, the vocal tract contribution is approximately separated from the source since the source contribution is mainly concentrated in coefficients beyond $c(12)$.

$$c(n) = \sum_{m=0}^{M-1} S(m) \cos\left(\pi n (m-1)/2M\right), \quad 0 \le n \le M \qquad (4)$$

FEATURE MATCHING

The state-of-the-art in feature matching techniques used in speaker recognition includes Dynamic Time Warping (DTW), Hidden Markov Modeling (HMM), and Vector Quantization (VQ). In this paper we have used the VQ approach presented by Linde *et al.* (1980) and Song *et al.* (1987) due to its ease of implementation and high accuracy.

VQ DESIGN

VQ design algorithm is an iterative algorithm which alternatively solves optimality criteria. The algorithm requires an initial codebook. The initial codebook is obtained by the splitting method. In this method, an initial codevector is set as the average of the entire training sequence. This codevector is then split into two. The iterative algorithm is run with these two vectors as the initial codebook. The final two codevectors are split into four and the process is repeated until the desired number of codevectors is obtained. Flowchart of the algorithm is summarized in Fig 2.

DATABASE USED

1.	Language	: Standard Hindi
2.	Vocabulary size	: A set of 1000 most frequently occurring hindi words
3.	No. of Speakers	: 50 (30 Male and 20 Female)
4.	Average duration of training and testing utterances	: 500-800 msec.
5.	Audio recording	: S/N > 40 db
6.	Sampling and quantization	: 16Khz, 16-bit

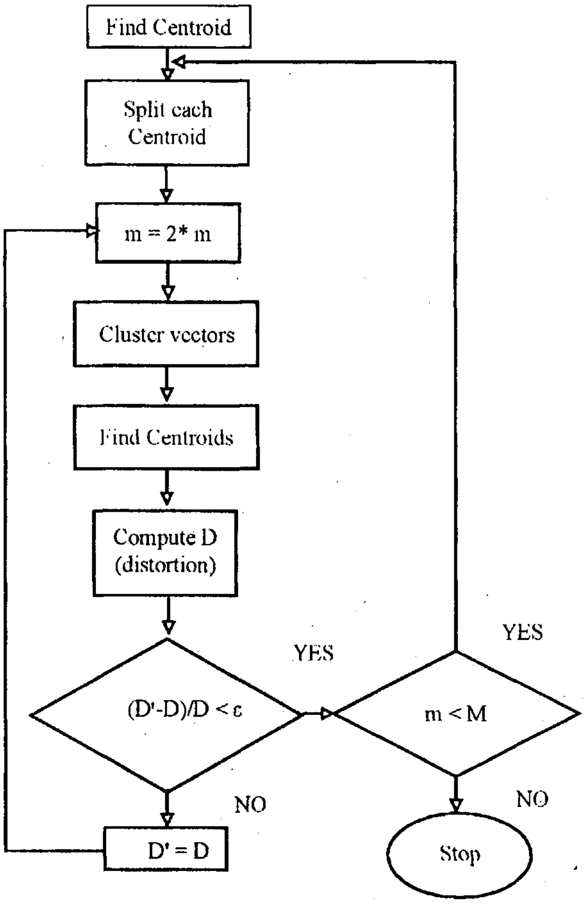


Fig. 2: Flowchart of VQ Algorithm

EXPERIMENTAL RESULTS AND DESIGN

The performance was evaluated in terms of Speaker identification rate. We have used the following identification measure for computing the identification rate.

Speaker identification rate (%) = $S_C / S_T * 100$

Where S_C is the No. of times the correct speaker has been identified, and S_T is the total No. of speakers used in the testing session. Experimental analysis was done in reference to text dependent speaker identification and text independent speaker identification.

As shown in the Fig. 3, it was seen that the performance of speaker identification rate (%) gets improved with the increase in codebook size, in case the speaker is identified with the same utterances by which he or she has been trained (text dependent). It reaches to 99% with codebook size of 64. If the speaker is tested with some other random utterances (text independent) the recognition rate decrease by about 3.5%.

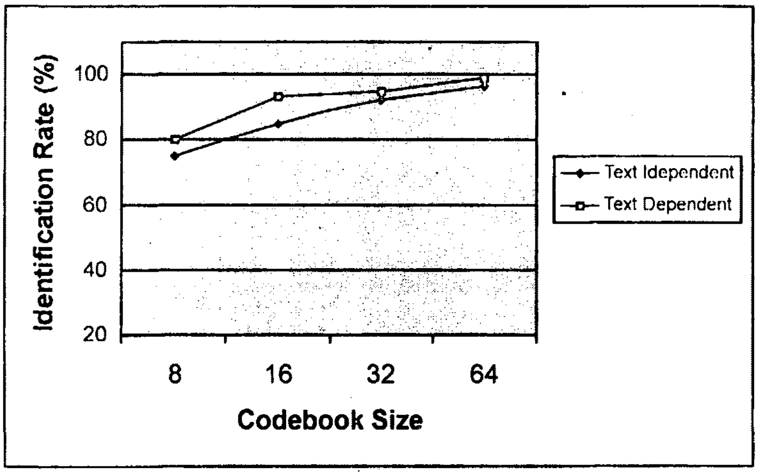


Fig. 3: Performance of SI with codebook size and improved vector set

Another analysis was done with improved feature vector set, now we reduced the no. of MFCC coefficients to 12 and included DMFCC and DDMFCC to the whole feature set of each speaker. Although the size of feature vector increased a bit but with the same codebook sizes we were able to get the better identification rate. Speaker Identification rate gets improved by 0.4% if the parameters of DMFCC and DDMFCC are incorporated in the feature vector set.

CONCLUSIONS

MFCC and LPCC are well known techniques used in speaker identification to describe signal characteristics, relative to the speaker discriminative vocal tract properties. All-pole model used in the LPC provides a good model for the voiced regions of speech and quite bad for unvoiced and transient regions. The main drawback of LPCC is that unlike MFCC it does not resolve the vocal tract characteristics from the glottal dynamics, which vary from person to person and might be useful in speaker identification. By enhancing the feature vector set with DMFCC and DDMFCC performance of the speaker identifier gets improved in both the cases of text dependent and text independent speaker identification.

REFERENCES

Davis S. B. and P. Mermelstein. 1980. Comparison of Parametric Representations for Monosyllabic Word Recognition in Continuously Spoken Sentences *IEEE Trans. Acoustics, Speech, Signal Processing*, 28 (4): 357–366.

Furui, S. 2001. Digital Speech Processing, Synthesis, and Recognition. 2nd ed. Marcel Dekker, Inc., New York, pp. 464.

Linde Y., A. Buzo and R. Gray. 1980. An algorithm for vector quantizer design. *IEEE Transactions on Communications*, 28: 84-95.

Picone J. W. 1993. Signal Modeling Techniques in Speech Recognition in Proc. IEEE, 18(9): 1215–1245.

Rabiner, L.R. and B.H. Juang. 1993. Fundamentals of Speech Recognition. Prentice-Hall, Englewood Cliffs, N.J., pp. 320.

Rabiner, L.R and R.W. Schafer. 1978. Digital Processing of Speech Signals. Prentice-Hall, Englewood Cliffs, N.J., pp. 512.

Song F.K., A.E. Rosenberg and B.H. Juang 1987. A vector quantization approach to speaker recognition *AT&T Technical Journal*, 66:14-26.

Pb. Univ. Res. J (Sci.), Vol. 59, 2009, pp. 169-173

EFFECT OF DELAY AND PERFORMANCE TRADEOFF OF SQUARE ROOT RAISED COSINE DIGITAL FILTER FOR WCDMA AT 5MHZ

***A.S. Kang[1] and Vishal Sharma[2]**

[1]*Department of Electronics & Communication Engineering*
SSG Panjab University Regional Centre
Bajwara, Hoshiarpur, Punjab

[2]*Department of Electronics and Communication,*
University Institute of Engineering and Technology,
Panjab University, Chandigarh

Abstract: Signal processing techniques, such as equalization, detection, and fast Fourier transform, have been successfully used in communication systems to improve the quality of communications. With the recent exploding research interest in wireless communications, the application of signal processing to this area is becoming increasingly important. Indeed, it is the advances in signal processing technology that make most of today's wireless communications possible and hold the key to future services. The present paper deals with simulation model and analysis of square root raised cosine filter for WCDMA with different parameters at variable group delay of the filter at 5 MHz.

Keywords: Pulse Shaping, FIR Filter, WCDMA

Introduction

The application of signal processing techniques to wireless communications is an emerging area that has recently achieved dramatic improvement in results and holds the potential for even greater results in the future as an increasing number of researchers from the signal processing and communications areas participate in this expanding field (Piedra and Frish 1996; Stevens, 1998; Iniaco and Embres, 1996; Grant, 1992; Giannkis, 1999). From an industrial viewpoint also, the advanced signal processing technology not only can increase the wireless system capacity but also can improve the communication quality including the reduction of all types of interference.

An overview of WCDMA

To satisfy the ever increasing demands for higher data rates as well as to allow more users to simultaneously access the network, interest has peaked in what has come to be known as WCDMA The WCDMA has emerged as the most widely adopted 3G air interface and its specification has been created in 3GPP .In this system the user information bits are spread over much wider bandwidth by multiplying the user data bits with quasi random bits called as chips derived from CDMA spreading codes. In order to support very high bit rates (up to 2 Mbps) the use of variable spreading factor and multimode connection is supported. The chip rate of 3.84Mcps/sec is used to lead a carrier bandwidth of 5Mhz.WCDMA also supports high user data rates and increased multipath diversity. Here each user is allocated the frames of 10 ms duration during which the user data is kept constant though data capacity among users can change from frame to frame.(Johnson and Sethares 1998).

Need of Efficient Pulse Shaping

In communication systems, two important requirements of a wireless communications channel demand the use of a pulse shaping filter. These requirements are:

1) Generating band limited channels, and

2) Reducing inter symbol interference (ISI) arising from multi-path signal reflections.

Both requirements can be accomplished by a pulse shaping filter which is applied to each symbol. In fact, the sinc pulse, meets both of these requirements because it efficiently utilizes the frequency domain to utilize a smaller portion of the frequency domain, and because of the windowing affect that it has on each symbol period of a modulated signal. (Johnson and Sethares 1998; Proakis and Salehi,1995; Haykin, 1999; Lathi , 1997). The sinc pulse is periodic in nature and it has maximum amplitude in the middle of symbol time in addition, it appears as a square wave in a frequency domain and thus can effectively limit a communication

---

*Corresponding Author. *askang_85@yahoo.co.in*
MS Received May 14, 2009; Accepted August 21, 2010

channel to a specific frequency range (Proakis, 1998).

Pulse Shaping in WCDMA

Code-division multiple access is one of several methods of multiplexing wireless users. In CDMA, users are multiplexed by distinct codes rather than by orthogonal frequency bands, as in frequency-division multiple access. The enhancement in performance obtained from a direct sequence spread spectrum (DSSS) signal through the processing gain and the coding gain can be used to enable many DSSS signals to occupy the same channel bandwidth, provided that each signal has its own pseudorandom (signature) sequence (Rappaport, 1999). Thus enable several users to transmit there information over the same channel bandwidth. This is the main concept of a CDMA communication system. The signal detection is accomplished at the receiver side by knowing the code sequence or signature of the desired user. Since the bandwidth of the code signal is chosen to be much larger than the bandwidth of the information-bearing signal, the encoding process enlarges or spreads the spectrum of the signal. Therefore, it is also known as spread spectrum modulation. The resulting signal is also called a spread-spectrum signal, and CDMA is often denoted as spread-spectrum multiple access (Kang and Sharma, 2008). The processing gain factor is defined as the ratio of the transmitted bandwidth to information bandwidth and is given by:

$$Gp=Bt/Bi \qquad (1)$$

Correlating the received signal with a code signal from a certain user will then only despread the signal of this user, while the other spread-spectrum signals will remain spread over a large bandwidth.

Simulation Model for WCDMA

The different parameters of pulse shaping filter (Raised Cosine and Square root Raised Cosine) affect the performance of WCDMA based wireless communication system (Kang and Sharma, 2008, 2009). The effect of variation of roll off factor from 0 to 1 at a fixed value of Group delay and oversampling factor at 5 Mhz bandwidth with input data sampling data rate of 3.84 mbps has been studied (Kang and Sharma, 2008, 2009).

The proposed simulation model for WCDMA performance analysis is shown below in Fig.1.

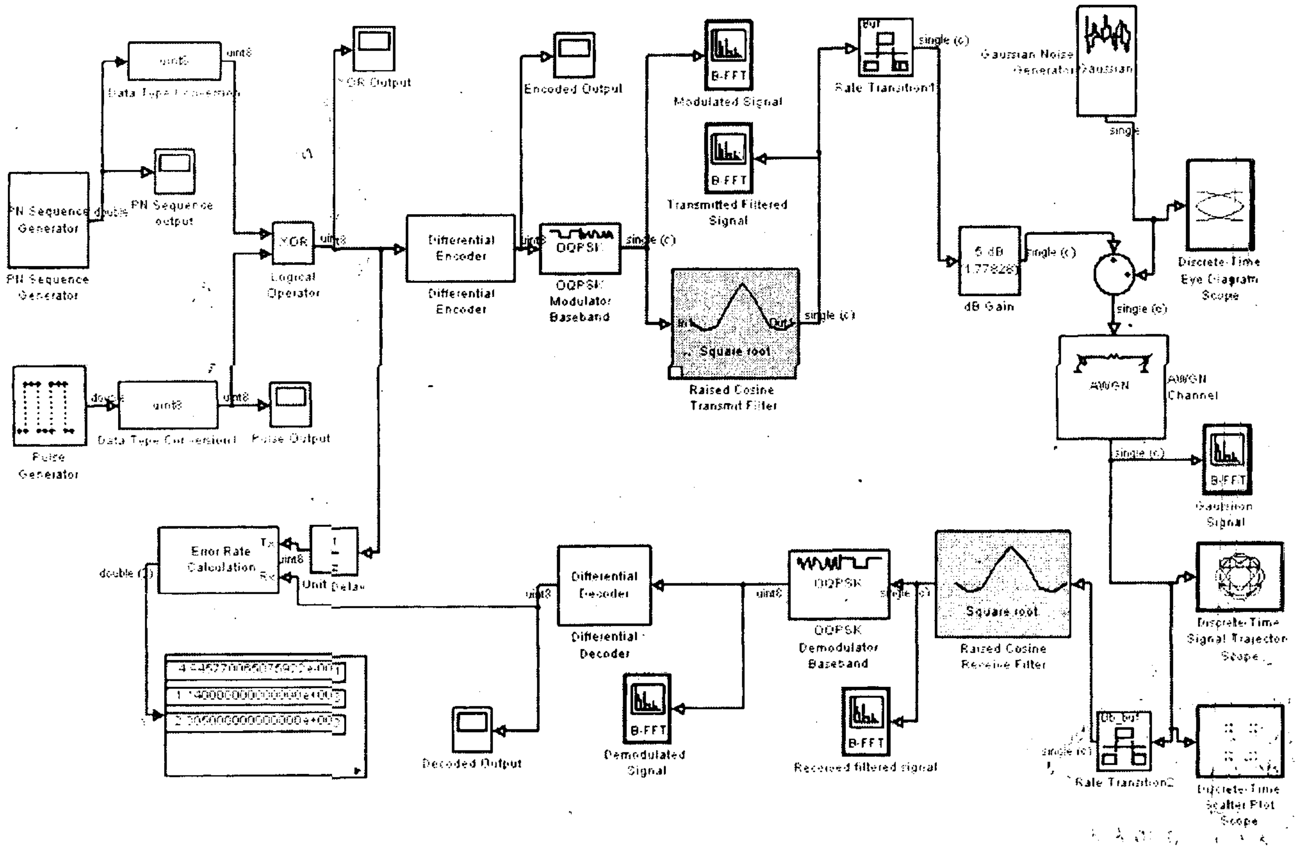


Fig. 1: Simulation model of WCDMA for performance tradeoff of pulse shaping filter

The performance in terms of the bit error rate can be examined for different signal to noise ratio values against a sinusoidal interference. A simulink model based on the matlab 7.3 version has been developed for the analysis and simulation purpose. In the present study, the parameters of square root raised cosine digital pulse shaping filter are fixed as below: Roll off factor=0.22,interpolation factor=2, The value of group delay D=2 was given as input to the function block parameter box of Square root raised cosine transmit and receive filter blocks and the simulation model was run and BER was calculated.

Results and Discussion

The value of D was varied from 2 to 14 and BER was found to be varying in decreasing manner as shown in fig.2

Here at lesser values of D, BER is of higher range. As we go on increasing D, then BER goes on decreasing in the following manner as shown in table1 below:

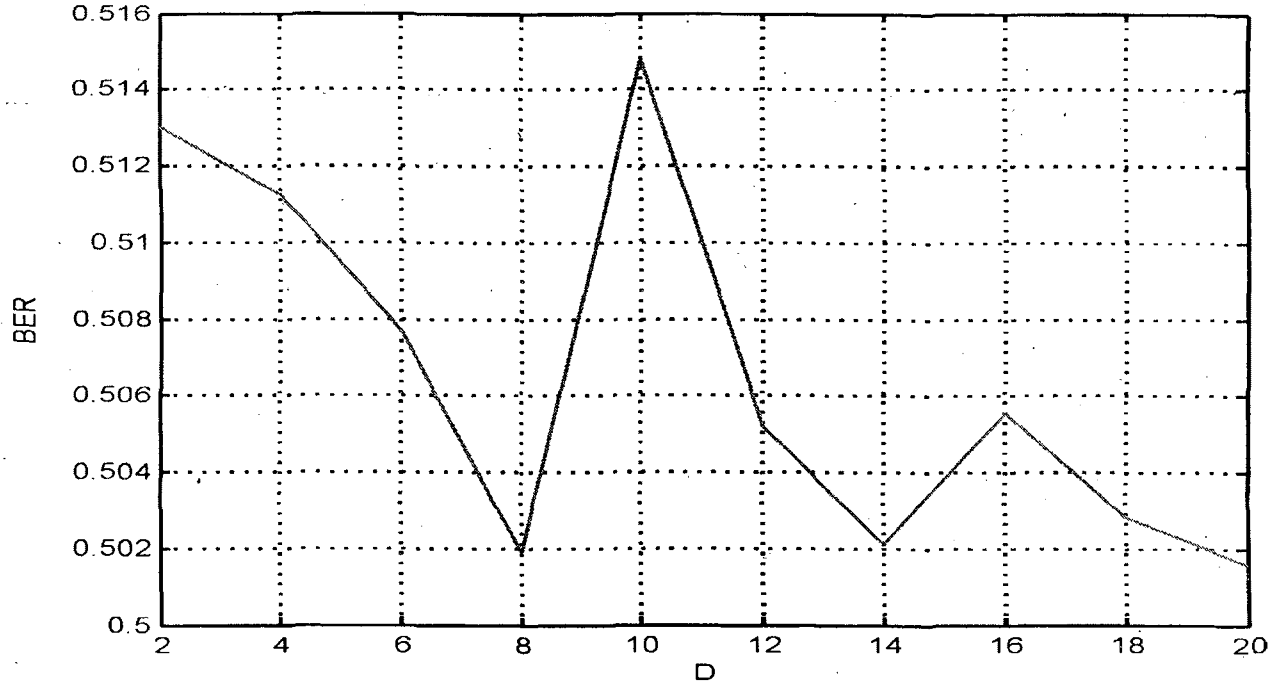


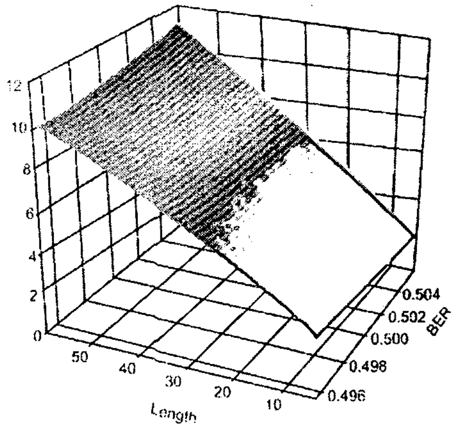
Fig.2: BER versus D trend for WCDMA at 5Mhz with Roll off factor=0.22 ,Interpolation factor=2

Table 1: Effect of D on BER for WCDMA

Sr. No.	Group Delay (D)	BER
1.	2	0.513
2.	4	0.511
3.	6	0.508
3.	8	0.502
4.	10	More than 0.514 (Abrupt rise/overshoot not desirable)
5	12	0.505 (again fall in BER)
6.	14	0.502<BER<0.504
7.	Beyond D=14	Rise and fall in BER is noticed

One cannot increase D beyond 8 where BER =0.502 (WCDMA SIMULINK MODEL VALUE).Group delay must be controlled with optimum value to decrease the complexity of filter for efficient performance of WCDMA system. It is found that the group delay should not exceed 8 because at this value BER is minimum and is equal to 0.502. Beyond D=8, BER starts increasing. It has been observed by using analytical treatment of square root raised cosine pulse shaping filter, for tradeoff, RF Design engineer must select the optimum value of D under the prevailing environment. The present results show that ,side lobe tail attenuation occurs more quickly as D is increased from 6 to 8,hence group delay must be controlled with these values to decrease the complexity of filter.[17]The optimum value of D=6 has been taken for subsequent analysis for tradeoff between different parameters of square root raised cosine pulse shaping filter for WCDMA at 5Mhz. Fig.3 shows a line plot obtained between D, filter length N and BER results of WCDMA based SIMULINK Model, which shows that on increasing Length N of filter, both D and BER increase, which is not desirable. Our aim is to control the group delay .So we optimize the performance of our filter based model by taking value D=6 as optimum one that provides best possible results. Here at D=6, 20<N<30; at BER=0.500.

Effect of N,D on performance analysis of WCDMA based Simulation Model (though BER): Tradeoff between Different parameters



This 3D Mesh plot between N, D and BER shows that min possible BER obtained at optimal value of D=6 is 0.500

Fig.3: Performance tradeoff of WCDMA at 5Mhz

CONCLUSION

The present study has proposed the WCDMA communication link employing the pulse shaping filters using matlab simulink. The group delay plays a crucial role in pulse shaping digital finite impulse response filter. The value of group delay should be minimum for efficient performance of digital pulse shaping filter (Piedra and Frish, 1996). The present study has highlighted the role of pulse shaping filter in WCDMA. A computer flowchart has been prepared and a program is written in Matlab 7.3 version .The time and frequency response of square root raised cosine pulse shaping filter at 5Mhz bandwidth has been studied .The effect of variation of group delay D i.e. number of symbols spanned by impulse response is studied at fix value of alpha=0.22 as well as at fix value of interpolation M=2.

The study will be useful to improve the performance of *WCDMA based network by using the modified and* improved design of square root raised cosine pulse shaping filter. As well as Design of new type of filter of higher order will be useful to get better root raised cosine approximation thereby improving the performance parameters like increased Capacity, reduced BER, better S/N ratio, and Reduced ISI (noise) as a consequence of pulse shaping.

The future work will involve the incorporation of interpolation factor for tradeoff between D and M at fix roll off factor as well as study of parameters of pulse shaping filter on the bit error rate performance analysis for WCDMA based wireless communication (Kang and Sharma, 2009)

ACKNOWLEDGEMENTS

The first author is thankful to Dr B S Sohi, Director UIET,Sec-25, PANJAB UNIVERSITY Chandigarh for discussion and valuable suggestions during technical discussion at WOC conference at PEC (Panjab Engg College), Chandigarh during presentation of his research paper, "Digital Processing and Analysis of Pulse Shaping Filter for Wireless Communication." The help rendered by Harjitpal Singh, a research scholar of NIT, Jalandhar as well as Mr Hardeep Singh, Research Scholar, Communication Signal Processing Research Laboratory, Deptt. of Electronics Technology, GNDU Amritsar is also acknowledged.

REFERENCES

Giannkis G.1999. Highlights of Signal Processing for communications. *IEEE Signal Processing Magazine*, 16(2): 57-61.

Grant P.M. 1992. Signal Processing hardware and Software. *IEEE signal Processing Magazine*, 13(1): 86-92.

Haykin S 1999. Communications Systems. Tata McGraw Hill, pp.597.

Iniaco, C. and D. Embres 1996. The DSP decision-fixed or floating. *IEEE Spectrum*, 3(9): 72-74.

Johnson, R.C. and W.A. Sethares. 1998. Telecommunications Breakdown, Pearson Education, pp. 400.

Kang, A.S. and V. Sharma. 2008. Comparatative Performance Analysis of Pulse Shaping Techniques for Wireless Communicatio. proceedings of WECON, International Conference on Wireless networks and Embedded Systems"CHITKARA INSTITUTE OF ENGG AND TECHNOLOGY, Rajpura, Distt PATIALA: 113-115

Kang, A.S. and V.Sharma. 2008. Digital Signal Processing For Cellular Wireless Communication Systems presented at IEEE-ISM 2008, INDIAN INSTITUTE OF SCIENCE, BANGALORE (INDIA), 323-327.

Kang, A.S. and V. Sharma. 2008. Digital Processing and analysis of pulse shaping Filter for wireless Communication, presented at 2nd National Conference(Co –Sponsered by IEEE, Chandigarh Sub Section) On Wireless and Optical Communication WOC-2008 at PEC CHANDIGARH (INDIA), 110-113.

Kang, A.S. and V. Sharma. 2008. Pulse Shaping Filters in Wireless Communication-A Critical Review, Proceedings of National conference on optical and wireless communication(NCOW), Co-Sponsered by Institution of Engineers(IE), INDIA) DAVIET, JALANDHAR(INDIA), 18-24.

Kang, A.S. and V. Sharma. 2009. Spectral analysis of filters in celluilar wireless communication systems, International Conference on Systemics, Cybernetics, Informatics, ICSCI, Hyderabad, 48-55.

Kang, A.S. and V. Sharma. 2009. Study of Spectral Analysis of Filters in Cellular Communication Systems, IEEE International Advance Computing Conference (IACC09)held at Thapar University, Patiala, 1934-1938.

Kang, A.S. and V. Sharma. 2009. Simulative Investigation of Pulse shaping in WCDMA Wireless Communication, IEEE International Advance Computing Conference(IACC09) , Thapar University, Patiala, 1939-1943.

Kang, A.S. and V. Sharma. 2009. Study of pulse shaping fiters in WCDMA under different interferences, IEEE SIBCON 2009 (IEEE Siberian Conference on Control and Communications) RUSSIA, 37-41.

Lathi, B.P. 1997. Modern Digital and analog Communications Systems, John Wiley & Sons, pp. 1004.

Proakis, J.G. 1998. Digital Communications. Mcgraw Hill, pp.250.

Piedra, R.M. and A. Frish. 1996. "Digital Signal Processing comes of age" *IEEE spectrum*, 33(5) : 77-79.

Proakis, J.G. and M. Salehi.1995. Communications Systems Engineering. Pearson Education, pp.167.

Rappaport, T.S. 1999. Wireless Communications: Principles and Practice. PHI Publication, pp.736.

Stevens, J. 1998. DSPs in Communication, *IEEE Spectrum*, 35(9) : 39-46.

Pb. Univ. Res. J (Sci.), Vol. 59, 2009, pp. 175-181

DESIGN OF ELECTRONIC CIRCUITRY FOR TEMPERATURE MONITORING SYSTEM USING FBG SENSORS

***Harmanpreet Kaur[1] Naresh Kumar[2] and Randhir Bhatnagar[3]**

[1]*Rayat and Bahra College of Engineering and Biotechnology for Women, Sahauran, Kharar ,Punjab*
[2]*Department of ECE, UIET, Panjab University, Chandigarh; Email: naresh_uiet@yhoo.com*
[3]*Scientist 'F', Photonics, CSIO, Sector 30, Chandigarh; E-mail: rbh5@rediffmail.com*

Abstract

Transformers are the vital part of power industry among power generators, transmission cables, and gas insulator switchgears. The unexpected failure of such systems leads to enormous loss in service quality. Direct measurement of transformer winding temperature is increasing with growing needs to accurately monitor the hot-spots of transformer, predict load levels, and improve capacity utilization. Conventional temperature sensors (e.g. thermocouples, RTD, and thermistor) limit the speed, accuracy and resolution of monitoring in many applications. Fiber Bragg grating sensing, a technology that relies on analysis of light pulses reflected down optical fibers, offer well and more efficient way to monitor changes in temperature. FBG sensors have proved one of the most efficient tools for their considerable advantages, over conventional sensors, such as, (1) immunity to electromagnetic interference, (2) potential to work in harsh environmental conditions - in the presence of high voltages and magnetic noise levels, (3) multiplexing capability, and (4) high sensitivity. It is possible to take real-time data of temperature along the fiber with several kilometers in length.

In this paper, an electronic circuitry for the proposed temperature monitoring system is designed and simulated for accurately measuring the shifts in the reflected Bragg wavelength. These shifts are due to the temperature induced on the FBG sensors and need to be accurately measured for efficient working of electric power networks.

Keywords: Fiber Bragg Grating (FBG), Fiber Bragg Grating sensors (FBGS), Temperature monitoring.

PROBLEMS RELATED TO INDUSTRIAL APPLICATIONS

The problems related to industrial applications are:

Signal conditioning: Most sensors have built in signal conditioners at the point of measurement to minimize the noise pick but not able to share the cost of a common signal conditioning unit. Sensors derived from fiber gratings do not have the same issue as they are made of glass material and are immune to electromagnetic interference.

Sensor nonlinearity: Conventional sensors like thermocouples, thermostats, RTD suffer from high degree of nonlinearity. These come in small difference and needs to be individually calibrated. Fiber gratings are inherently linear devices and are easier to design and install.

Cabling: Traditional sensors require one cable connection per sensor thus making it difficult to manage. Low loss fiber optics cables can extend up to several kilometers. Conventional cables with similar length, on the other hand will, have excessive attenuation and a lot of noise pick.

Reliability: Fiber gratings are inert and therefore inherently long life. Their reliability has proven with a minimum life performance of 25 years. Life of conventional sensors depends upon bias current and may vary with respect to system configuration and signal conditioning circuit design.

Cavitations in compressors and high voltage in generators are tough problems for electrical sensors. Traditional sensors require complex packaging to see installation and provide protection from the hostile environment. The additional mechanical structure adds to the weight and the forces applied to the sensor head, shortening the life of the sensors. Fiber grating sensors are the possible solutions.

WHY DIRECT HOT-SPOT MONITORING OF TRANSFORMERS

For many metropolitan utilities, the increasing environmental opposition to construction of new high voltage power lines has greatly influenced the existing transmission and distribution infrastructure. The key to being able to match the growing needs to balance power fluctuations, improve capacity utilization often rests in the ability to make intelligent decisions about transformer loading. And transformer loading capability is limited mainly by location and winding temperature of the transformers hot spot (Lee *et al.* 2006).

---

*Corresponding Author. *harmanpreet_20@yahoo.co.in*

MS Received September 17, 2009; Accepted August 25, 2010

A transformer has to withstand numerous thermal, mechanical, and electrical stresses during its operation and create a threat for insulation breakdown (Ribeiro *et al.* 2008). This is why the direct measurement of winding temperature is necessary and the so-called hot spot temperature is of great importance to the energy providers. There are numerous thermal models for estimating the hot-spots temperature behavior, both outside and inside the transformers. The conventional temperature indicators, like thermocouples, still widely used in the industry, are designed to simulate the thermal behavior of the hottest portion of the winding. These are located at a remote location from the high voltage regions of the transformer, either at the cooling oil at the bottom or at the top of the transformer. But this thermal modeling can result in large discrepancies between the simulated and the actual winding temperature i.e.: the direct measurement of hot-spot is not possible with conventional sensors. Though acceptable at normal loading conditions, these discrepancies can cause serious damage to the transformer at the time of emergency, when operated at closer or above peak rated conditions (Kim *et al.* 2008). To overcome this, FBG sensors appear to be ideally suited for these applications for their inherent advantages over conventional temperature sensors (Park and Song 2008).

INTRODUCTION TO FBG

In its simplest form, a fiber Bragg grating consists of a periodic modulation of the refractive index of the core for a single mode optical fiber; by exposing it to UV light. This induces the permanent change in the refractive index of the core. The next step was to use this effect and write Bragg grating into so called single mode fibers. The subsequent periodic modulation of the refractive index of the core acts like a narrowband notch filter of the light propagating down the core. In these gratings phase fronts are perpendicular to the fiber longitudinal axis and the grating planes are of a constant period. Small fraction of the light guided along the core of an optical fiber will be scattered by each grating plane due to the change in the refractive index. If the phase matching condition is not satisfied, the reflected light from each of the subsequent plane becomes progressively out of phase and will eventually cancel out. Whereas, the contributions of the reflected light from each grating plane add constructively in the backward direction to form a back reflected peak with a center wavelength defined by the grating parameters, provided the phase matching condition is satisfied (Othonos, 1997).

Fig. 1 shows basic principle of Fiber Bragg grating and Fig. 2 shows the typical simulated spectrum of reflected signal from Fiber Bragg grating. The phase matching condition occurs at the Bragg resonance wavelength and is given as

$$\lambda_B = 2\, n_{eff}\, \Lambda \tag{1}$$

Where λ_B is the Bragg resonance wavelength, n_{eff} is the effective index of the core, Λ is the grating period. This means that the FBG is only sensitive to physical impact that changes either n_{eff} or Λ. Any perturbation in the fiber that affects either of these properties, results in a shift in the Bragg wavelength. Hence the basic principle of operation commonly used in a FBG based sensor system is to monitor the shift in wavelength of the returned Bragg signal with the changes in the measurand (e.g., strain, temperature, pressure, etc).

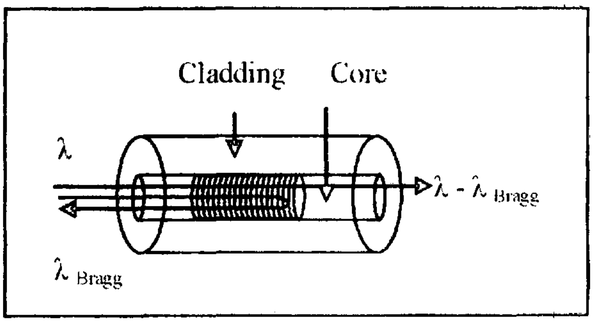


Fig. 1: Principle of Fiber Bragg Grating

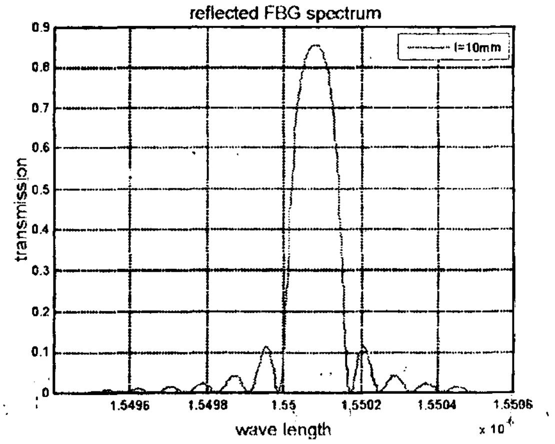


Fig. 2 Simulated spectrum of reflected signal from Fiber Bragg grating

INDEX OF REFRACTION DEPENDENCE

The simulation (Fig. 3) demonstrates how the spectral response of a grating is affected, as the index of refraction is altered. For the first grating with $\Delta n = 2.5 * 10^{-4}$, the reflectivity is 99%. Reducing the change of the index of refraction of the first grating to $\Lambda n = 1.5 * 10^{-4}$ the reflectivity of 97% was observed. A further decrease results in 45% reflectivity.

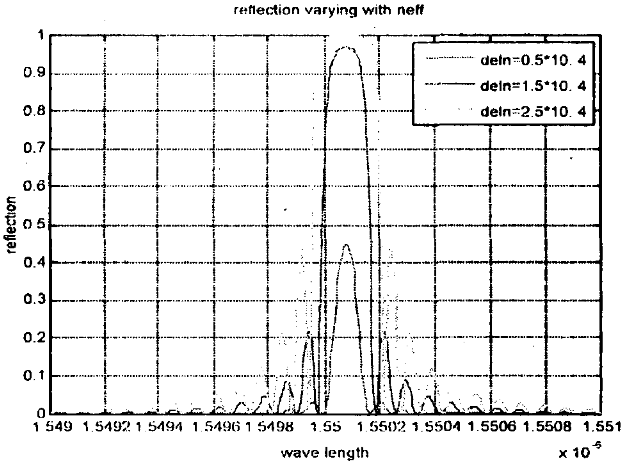


Fig. 3 Simulation of reflective spectrum varying with index of refraction

GRATING LENGTH DEPENDENCE

In this simulation, changes in the spectral response of the grating due to change in grating length are demonstrated. The index of refraction change is assumed constant over the length of the grating.

Fig.4. shows the spectral profile of three uniform Bragg gratings for length l=15mm, l=9mm, and l=3mm. From the simulation it is concluded that the bandwidth of the grating reduces as the length is increased.

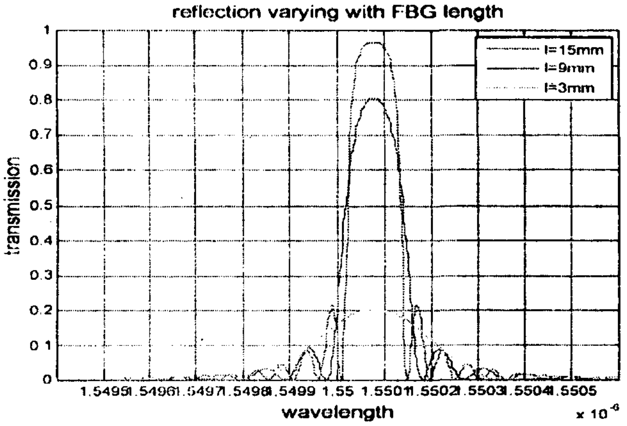


Fig. 4 Simulation of reflective spectrum varying with grating length

SENSING PRINCIPLE

Fiber Bragg Grating sensors are developed for quasi-distributed or multi-point (strain, temperature, pressure etc.) monitoring in both surface mounted and embedded sensing applications to provide local damage. As well known, the phase-matching condition determines the Bragg resonance wavelength, λ_B, of the fiber grating. The wavelength shift $\Delta\lambda_B$ of a fiber Bragg grating sensor subject to physical disturbance can be expressed as

$$\Delta\lambda_B / \lambda_{B} = (1-\rho_e)\,\varepsilon + (\alpha + \zeta)\,\Delta T \qquad (2)$$

Where ρ_e is photo-elastic constant, ε is axial strain, α is thermal expansion coefficient, ζ is thermo-optic coefficient, ΔT is temperature shifts (A. D. Kerrsey, M. A. Davis, H. J. Patrick, M. Le Blanc, K. P. Koo, C. G. Askins, M. A. Putnam, and E. J. Friebele 1997).

STRAIN SENSING

The strain response arises due to physical elongation of the sensor i.e. fractional change in grating period,

and the change in fiber index due to photo elastic effects (Kersey *et al.* 1993). The first term in the equation represents the strain effect on an optical fiber where

ρ_e the photo-elastic coefficient is defined as

$$\rho_e = n^2_{eff} / 2\{\rho_{12} - \nu(\rho_{11} + \rho_{12})\} \qquad (3)$$

Where ρ_{11} and ρ_{12} are the components of the strain optic tensor, ν is the Poisson's ratio. Using the typical values, strain sensitivity of a fiber Bragg grating at 1550 nm is 1.2 pm/με. Fig. 5 shows the Simulation of strain vs wavelength graph and strain vs shift in wavelength with strain, ε, from 1 με to 10 με. Graph shows the linear response of wavelength shift corresponding to different strains.

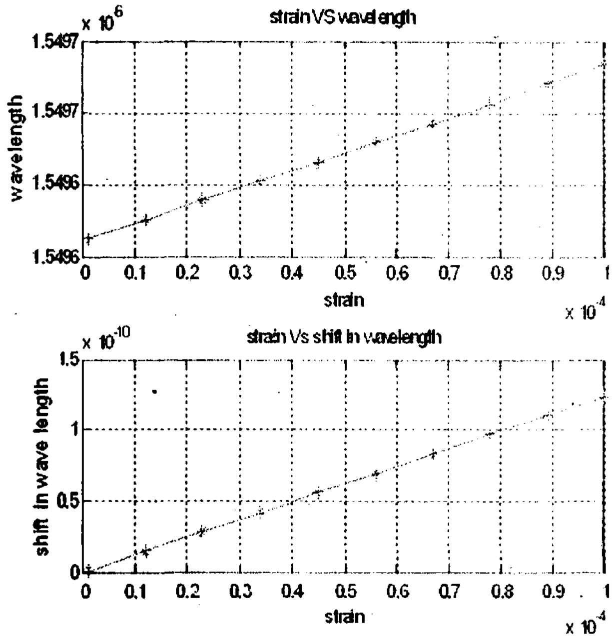


Fig. 5: Simulation of strain vs wavelength graph and strain vs shift in wavelength graph

TEPERATURE SENSING

When a fiber Bragg grating is subject to a temperature variation, two phenomenons entail a variation $\Delta\lambda_B$ of the characteristic wavelength. Due to thermal expansion of the fiber material and the temperature dependence of the refractive index.

$$\Delta\lambda_B / \lambda_B = (1/\Lambda \, d\Lambda/dT + 1/n \, dn/dT)\Delta T \qquad (4)$$

Where α is the thermal expansion coefficient and, ζ represents the thermo-optic coefficient. The typical temperature sensitivity of a fiber Bragg grating at 1550nm is 10.4 pm/°C. Fig. 6 shows the Simulation of temperature vs wavelength graph and temperature vs shift in wavelength with temperature, T, from 30°C to 35°C. Graph shows the linear response of wavelength shift corresponding to different temperatures.

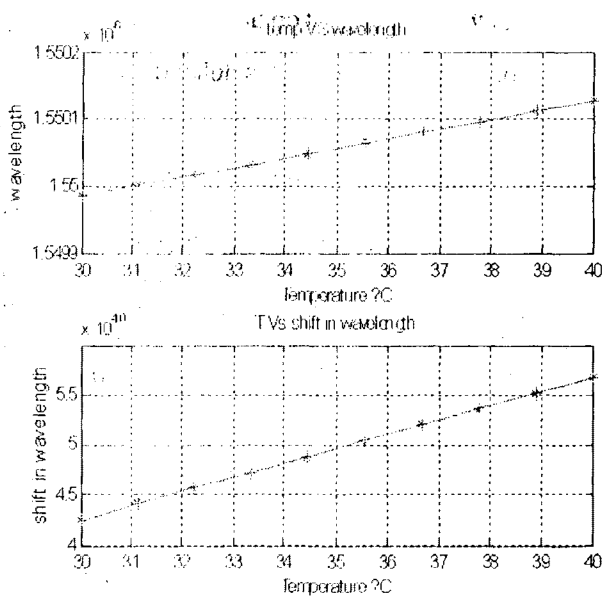


Fig. 6: Simulation of temperature vs wavelength graph and temperature vs shift in wavelength graph

WORKING PRINCIPLE

The reflected Bragg wavelength induces a shift when affected with temperature or any other environmental parameter as shown in simulated graphs in Fig. 5 and Fig. 6. This small shift in the Bragg wavelength needs to be calibrated and measured accurately. In order to provide precise calculation, an effective unit is to be designed. Thus, in order to know the characteristics of the reflected peaks from the FBG sensor array, a study was conducted and the hardware simulation was carried out. The artificially generated, reflected Bragg wavelength like peaks, were taken and fed to this electronic unit. The output was seen on Tektronix TDS 210 oscilloscope.

The configuration of the proposed tunable filter demodulation scheme is shown in Fig.7. The light from the broadband source is directed to FBG sensor array via 2:1 coupler. The light reflected from the FBG sensor array passes through Fabry-Perot tunable filter (Miller and Miller 1994; Miller and Jannielo, 1990) that is scanned with a ramp signal. The reflected signal can be seen on the OSA also, but it has some practical limitations. The light signal in wavelength-domain, is photo detected, thus transforming it into time-domain. Bragg wavelength shifts are measured by locating peaks in the photo detected signal. This is achieved by the electronic unit or control circuitry as seen in the figure above. In this paper, the electronic unit, thud designed and simulated for the above proposed system is discussed.

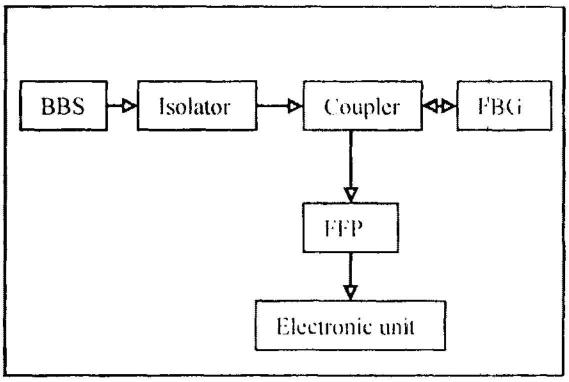


Fig. 7: Proposed block diagram for temperature monitoring system (BBS- broad band source, OSA-optical spectral analyzer, FFP- Fabry-Perot tunable filter)

ELECTRONIC UNIT

The block diagram of the electronic unit designed for the interrogation of reflected signal from FBG sensor is shown in Fig. 8. The pulses of 783.5 Hz and 59% Duty cycle was generated as the input to the system, using timer as shown in Fig. 9

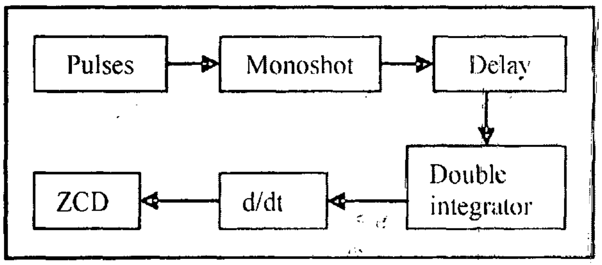


Fig. 8: Block diagram representing electronic unit

The reflected Bragg wavelength peaks are the small fraction of the incident light to the fiber grating sensors. These pulses were fed to the monoshot retriggerable multivibrator with RC time constant of 33 is. At every positive edge, the pulses from the timer are monoshot. Thus a pulse with RC time constant of 33 is is obtained as shown in Fig. 10, corresponding to the input pulses.

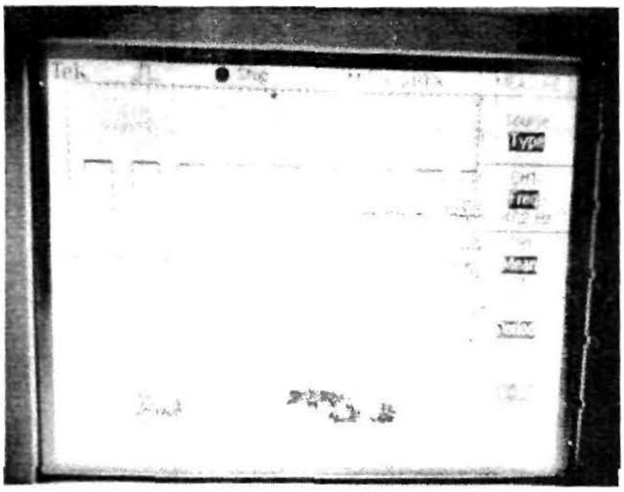


Fig. 9: Pulses generated using timer

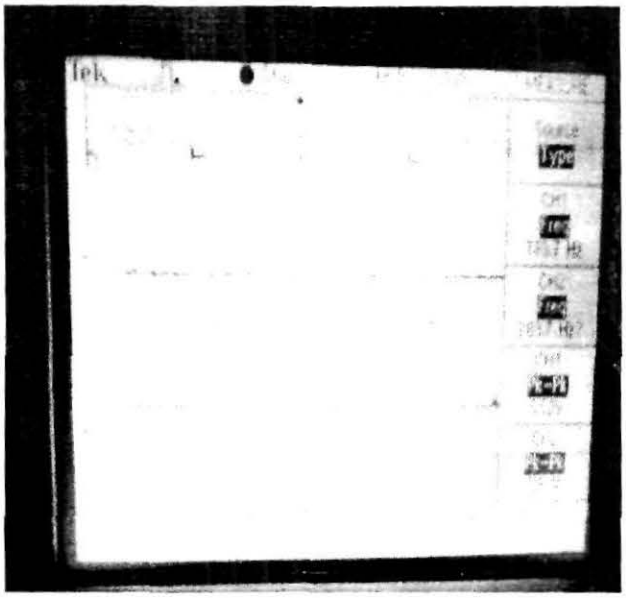


Fig. 10: Monoshot at every positive edge of pulses

When the FBG sensor is measurand induced, there is shift in the Bragg wavelength. Hence, the pulses obtained above are delayed keeping the same RC time constant of 33 is. This delayed output from the multivibrator is assumed as the shift induced because of the measurand. The delay introduced is shown in Fig. 11 and Fig. 12 represents the delay corresponding to the pulses generated in Fig. 9.

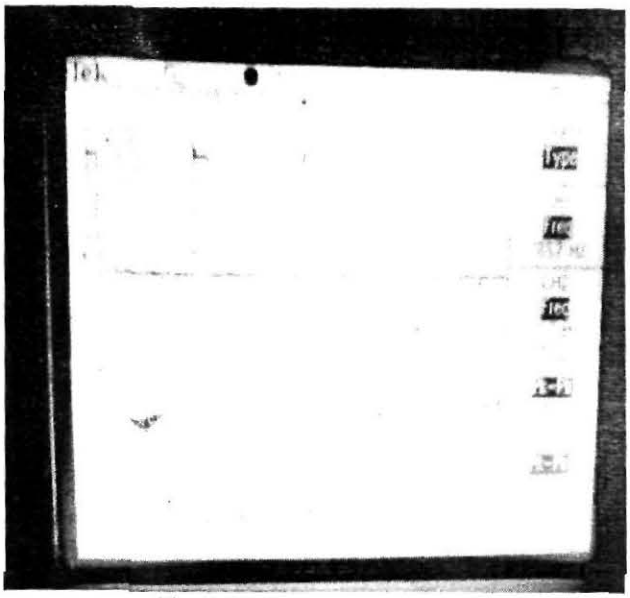


Fig. 11: Delay introduced

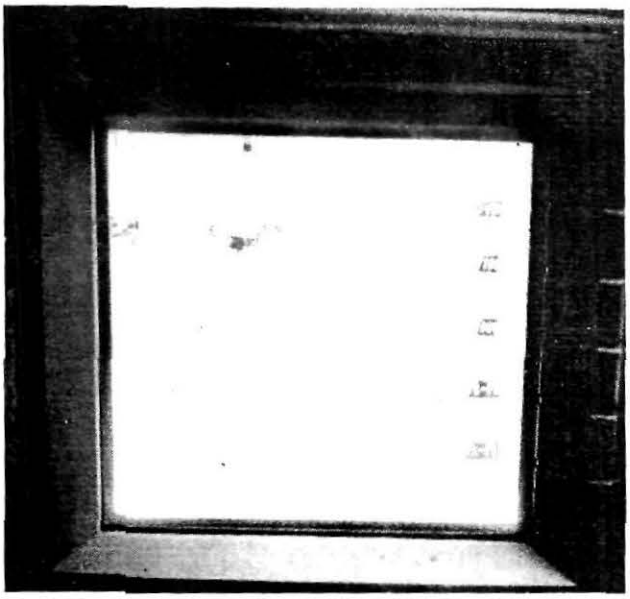


Fig. 12: Delay seen corresponding to the pulses generated

The shifted pulses are op-amp double integrated, as shown in Fig. 13 keeping the RC time constant less than half of the RC time constant taken for monoshot. The shapes of the pulses are transformed into that of the reflected peaks from the FBG sensor array.

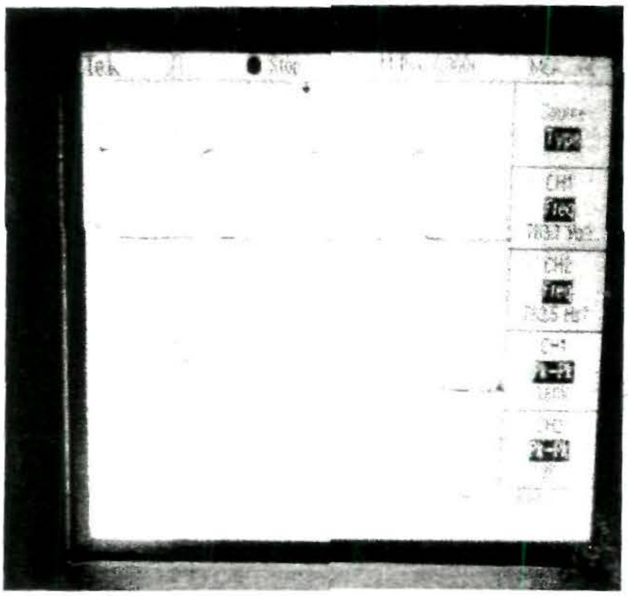


Fig. 13: Output after double integration

During the measurement of the Bragg wavelength, a small error in calculation can alter the value of the reflected peak from the sensor, thereby, calibrating the inappropriate data of the sensed signal. In order to improve it, peaks obtained above are differentiated. It provides an output signal proportional to the rate of the change of the input. The output signal thus obtained is seen in Fig. 14.

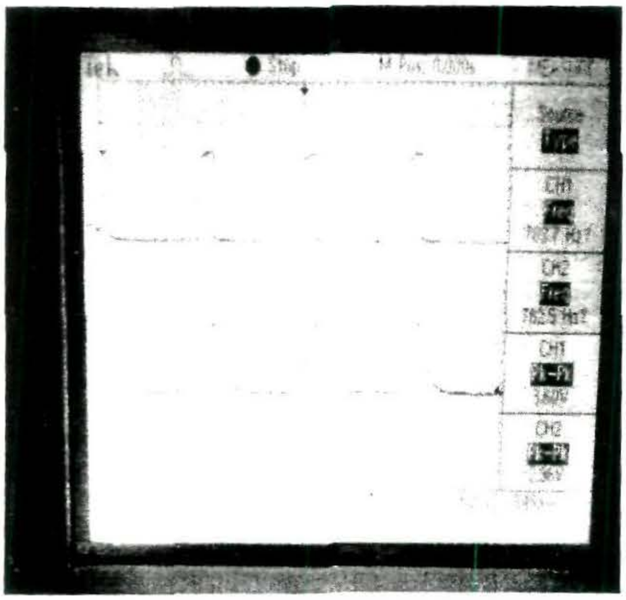


Fig. 14: Differentiated output

The output is zero crossed at peak point i.e. at every peak, the output of the differentiator is crossing zero. The zero crossed value can be read more accurately by zero-crossing detector. The distance, Ät between the zero-crossing points is calculated. The measurement of the distance between zero crossing points is obtained by means of a voltage comparator using output of the differentiator as the input signal to the comparator. The output from the zero-crossing detector shows when and in what direction an input signal crosses zero. The output from the ZCD is at negative when output from the differentiator is at positive and vice-versa. It can also be calculated by the use of microcontroller. When zero-crossing occurs, the comparator output signal triggers a timer counter in microcontroller. The waveform is represented in Fig. 15.

Fig. 15: Output after Zero crossing detector

The temperature induced on the FBG sensor is calculated by converting first the time difference between two zero-crossing points in wavelength scale. The temperature change is given as

$$\Delta T = \text{original wavelength} + (\text{sensitivity}) * \Delta t \qquad (5)$$

Where ΔT is the temperature change and Δt is the distance between two zero crossing points.

CONCLUSION

FGB sensors numerous advantages over conventional sensors such as compact size, lightweight, ease of installation, immunity to electromagnetic interferences, resistance to corrosive environment, high accuracy and reliability, multiplexing capability, led to strong research and development in this area and expected to continue in next years.. This resulted in number of real world applications which includes Pipelines, Space Structures & Payloads, Aerospace, Oil & Gas Industry, Composite industry, Medical and Temperature Sensing in terms of Fire detection, Leak detection, System Health Monitoring.

But with growing needs to calibrate direct hot-spot temperature of transformers, a temperature monitoring system needs to be designed. To understand the basic requirements and characteristics of the system, a hardware simulation of electronic circuitry was undertaken in this work and a shift of 18.56 ms was observed on Tektronix TDS 210 oscilloscope. The temperature induced shifts can be seen on Optical Spectral Analyzer but changes up to .1°C cannot be calibrated directly. So a system with scanning Fabry-Perot tunable filter is proposed. Future work is directed to the implementation of temperature monitoring system for direct hot-spot measurement of the transformer.

ACKNOWLEDGEMENTS

The authors wish to thank Dr. Pawan Kapur, Director, and Mr. N.S. Mehla, Scientist G and Head, Photonics Group, CSIO (CSIR), Chandigarh for providing the laboratory facilities during M.E. thesis.

REFERENCES

Kerrsey, A.D. , M.A. Davis, H. J. Patrick, M. Le Blanc, K. P. Koo, C. G. Askins, M. A. Putnam, and E. J. Friebele 1997. Fiber grating sensors. *J. Light. Technol.*, 15(8): 1442-1463.

Kersey, A.D., T.A. Berkoff and W.W. Morey. 1993. Multiplexed fiber Bragg grating strain-sensor system with a fiber Fabry–Pérot wavelength filter. *Opt. Lett.*, 18:1370–1372.

Kim, M., J.H. Lee, J.Y. Koo and M. Song. 2008. A Study on Internal Temperature Monitoring System for Power Transformer using Optical Fiber Bragg Grating Sensors. Proc. International Syposium on Electrical Insulating Materials, pp. 163–166.

Lee, J.H., S.G. Kim, H.J. Park and M. Song. 2006. Investigation of Fiber Bragg Grating Temperature Sensors for Application. Electric Power Systems., *IEEE*, pp. 431-434.

Miller, C.M., F.J. Jannielo. 1990. Passively Temperature Compensated Fiber Fabry-Perot Filter and its Application in Wavelength Division Multiple Access Computer Network. *Electron. Lett.*, 26(25): 2122-2123.

Miller, C.M. and J.W. Miller. 1994. Temperature Compensated Fiber Fabry-Perot Filters. U.S. Patent. 5289552, pp. 552.

Othonos, A., 1997. Fiber Bragg Grating. *Rev. Sci. Instrum.*, 68(12): 4309-4341.

Park, H.J., and M. Song. 2008. Linear FBG Temperature Sensor Interrogation with Fabry-Perot ITU Multi-wavelength Reference. *IEEE Sensors Journal.* 8: 6769-6776.

Ribeiro, A.B.L., N.F. Eira, J. M. Sousa, P. T. Guerreiro, and J.R. Salcedo. 2008. Multipoint Fiber-Optic Hot-Spot Sensing Network Integrated Into High Power Transformer for Continuous Monitoring. *IEEE Sensors Journal.*, 8(7): 1264-1266.

Pb. Univ. Res. J (Sci.), Vol. 59, 2009, pp. 183-212

IMPLICATIONS OF DUALITY, CONFINEMENT AND SUPERSYMMETRY IN RESTRICTED QUANTUM CHROMODYNAMICS (RCD)

***J.M.S. Rana**

Department of Physics, H.N.B. Garhwal University, S.R.T. Campus, Badshahithaul(Tehri-Garhwal), Uttarakhand

Abstract

Duality has been utilized to study the bulk QCD magnetic properties, particularly isocolor charge-dyon interactions in Restricted Quantum Chromodynamics (RCD). In the state of dyonic superconductivity, it has been shown that the dual propagators behave as $\frac{1}{k^4}$ (for small k^2) ,which leads to the confinement of colored fluxes associated with dyonic quarks vide generalized Meissner effect. Based on semi-quantitative analysis of vortex solutions of RCD, it has been demonstrated that in the type I superconducting medium, vortices tend to coalesce and hence are attractive, while the energy function supports repulsive forces between vortices in type II medium. Furthermore, incorporating the dyonic color charge and color spin induced as a result of fermion fractionization in Georgi-Glashow model, in presence of an isovector fermion field, into the N=1 supersymmetric RCD, the Lagrangian density has been constructed and supersymmetric dyonic solutions have been obtained. It has been shown that the bosonic and fermionic fluctuations exactly cancel each other and thus one-loop quantum corrections lead no change in classical mass of dyon.

Keywords: Duality, Dyon, SUSY, Confinement

INTRODUCTION

Although the nature does not seems to display exact electromagnetic duality (Olive,1996),realistic theories could be judiciously broken version of exact gauge theory in which sufficient structure survives to explain the puzzles such as quark confinement as has been advocated by Seiberg and Witten (1994). QCD formulated in terms of quarks and gluons, which we believe are the basic constituents of hadronic matter, is most viable and elegant theory of strong interactions. Nevertheless, the theory still defied of proper explanation of various non-perturbative phenomena. Furthermore, there are difficulties in calculating the entire hadron spectrum from the first principle and hence various models have been proposed. However, the non-trivial topological structure (Arafune and Freund,1975, Coleman,1975) and corresponding classical solutions ('t Hooft, 1976, Polyakov, 1974) of non-Abelian gauge theories enforces us to speculate the existence of built-in-duality in such theories which may play an important role in understanding some non-perturbative aspects of QCD e.g. chiral symmetry breaking and quark confinement etc. It is conjectured (Montonen and Olive, 1977) that the non-Abelian gauge theories may express an exact electromagnetic duality which exchanges solitons with elementary quanta and weak coupling with strong coupling. Based on these ideas QCD has been formulated as a dual gauge theory called Restricted quantum chromodynamics (RCD) (Rana et al, 1988,1989,1993,2005) which exhibits built-in-dual structure and the dual dynamics between color isocharges and topological charges has been developed. Considering quark as dyon, RCD has been shown to produce dynamical dyonic condensation for its vacuum where the built-in-dual dynamics guarantees the

---

*Corresponding Author. *ranajms@gmail.com*

MS Received February 16, 2010; Accepted August 23, 2010

confinement of colored fluxes associated with dyonic quarks through the mechanism of generalized Meissner effect. The dyonically condensed vacuum obtained as a result of dynamical breaking of magnetic symmetry leads to the state of (chromo)-dyonic superconductivity. The full spectrum of QCD i.e. the extended gauge theory has been obtained by reactivating the suppressed dynamical degrees of freedom for both non-supersymmetric and supersymmetric limits.

Supersymmetric field theories have the remarkable property that some of the perturbative effects are cancelled between bosons and fermions and provide (Kaul,1982, witten,1982, Dimopolous and Georgi,1981, Sakai,1981) a natural resolution of gauge hierarchy problem of Grand unified theories (GUT's). Analyzing the supersymmetric generalization of monopoles in the limit of Prasad and Sommerfield (1975) and Bogomolnyi (1976) and using the supersymmetric version of Georgi-Glashow model with vanishing potential, it has been shown (D'Adda,Horsley and Vecchia,1978) that the quantum corrections to the mass of the monopole are vanishing. However, some controversies have been raised (Imbimbo and Mukhi, 1985) about the exact cancellation of perturbative effects between bosons and fermions, Bogomolnyi bound saturation and the quantum correction to the physical monopole mass in N=2 supersymmetric Yang-Mills theory. Moreover, if the Jackiw-Rebbi zero modes exist independently of supersymmetric zero modes the dyonic states are enriched by further degeneracy with different charge and spin states, consequently the supersymmetry becomes very much involved and cumbersome. Unfortunately an explicit demonstration of Jackiw-Rebbi zero modes are extremely difficult. In the light of these difficulties associated with existing supersymmetric GUT's it is fair to have an alternative approach (Kaul,1984) to understand supersymmetric dyons. Keeping these motivations in view, in the present work dyonic supermultiplets in N=1 SUSY are obtained quantum mechanically in the topological part of the RCD. Constructing the Lagrangian density in the N=1 supersymmetric RCD(topological part only) in terms of the isotriplet gauge field and its fermionic superpartner, supersymmetric dyonic solutions are obtained and the classical mass of the dyon is calculated by minimizing the background potential of the theory. Separating the bosonic part of this Lagrangian in the dyonic background gauge and adding the gauge fixing and Faddeev-Popov ghost term to it, the eigenvalue equations of bosonic fluctuations are derived and the corresponding one-loop corrections to the dyonic mass is calculated. Although our main emphasis at present is supersymmetric RCD, however for the readability of the manuscript we briefly review the RCD in the following.

RESTRICTED QUANTUM CHROMODYNAMICS (RCD) – A BRIEF REVIEW

The mathematical foundation of RCD lies in the observation that the non-Abelian gauge symmetry does allow an extra internal symmetry, called magnetic symmetry, which restricts and reduces the dynamical degrees of freedom of the underlying theory while keeping full gauge degrees of freedom intact. This is to say that in (4+n) –

dimensional metric manifold P (four-dimensional space-time manifold M and n-dimensional internal space G), the gauge symmetry can be viewed as n- dimensinal isometry which allows us to view P as principal fibre bundle P(M,G) with M=P/G as base manifold and G as structure group, the magnetic symmetry may be imposed by insisting on the following gauge covariant condition;

$$D_\mu \hat{m} = \partial_\mu \hat{m} + q^* V_\mu \times \hat{m} = 0 \qquad (1)$$

Where, $\hat{m}$ is an arbitrary multiplet and constitute an adjoint representation of group G whose little group is assumed to be Cartan's subgroup at each space-time point. Mathematically, this implies that a connection on P(M,G) admits a left isometry H, which formally forms a subgroup of G but commutes with G(the right isometry). The magnetic symmetry thus restricts the connection to those, whose holonomy bundle becomes P(M,H). Normalising $\hat{m}$ (i.e. $\hat{m}^2$ =1) and choosing G=SU(2), the gauge covariant condition in eq. (1) gives the following form of generalized restricted gauge potential;

$$V_\mu = -iV_\mu^* \hat{m} - \frac{1}{q^*} \hat{m} \times \partial_\mu \hat{m} \qquad (2)$$

Such that $\hat{m}.V_\mu = -V_\mu^*$ is the unrestricted Abelian component of restricted gauge potential, while the remaining part of V_μ is completely determined by magnetic symmetric requirement. Notice that the restricted potential constructed here comprising two four-potentials ($V_\mu = A_\mu - iB_\mu$) avoids any string singularity in the theory (Cabbibo and Ferrari,1962, Wu and Yang,1975) and yields the following decomposition of electric and magnetic gauge potential;

$$V_\mu = A_\mu = B_\mu \hat{m} - \frac{1}{e} \hat{m} \times \partial_\mu \hat{m} \qquad (3)$$

$$B_\mu = A_\mu \hat{m} - \frac{1}{g} \hat{m} \times \partial_\mu \hat{m} \qquad (4)$$

Such that $\hat{m}.A_\mu = B_\mu, \hat{m}.B_\mu = A_\mu$ and $q = e - ig$ is the complex coupling constant of the theory. This demonstrates that the generalized gauge potential has been constructed in terms of magnetic vector on global sections containing color electric and color magnetic potentials in a completely dual symmetric way. The unrestricted part of the gauge potential describes the color flux of topological charges of symmetry group G. In such a construction the magnetic symmetry inevitably chooses the color direction by selecting generalized color electric potentials of Cartan's subgroup and hence circumvents the color directional problem of non-Abelian gauge theories.

The generalized restricted gauge field strength corresponding to V_μ can be constructed in the following form;

$$\begin{aligned} G_{\mu\nu} &= \varsigma_{\mu\nu} + q^*[V_\mu \times V_\nu] \\ &= (-iF_{\mu\nu} + H_{\mu\nu})\hat{m} \end{aligned} \tag{5}$$

where,

$$\varsigma_{\mu\nu} = \partial_\mu V_\nu - \partial_\nu V_\mu \tag{6}$$

and

$$F_{\mu\nu} = \partial_\mu V_\nu^* - \partial_\nu V_\mu^* \tag{7}$$

$$H_{\mu\nu} = -\frac{1}{q^*}\hat{m}.(\partial_\mu \hat{m} \times \partial_\nu \hat{m}) \tag{8}$$

Identifying $F_{\mu\nu}$ and $H_{\mu\nu}$ in eqs. (7,8) as generalized electric and magnetic field strengths, respectively, the striking duality between electric and magnetic fields is obviously manifested in the theory. As such we have the identity

$$[D_\mu, D_\nu] = q^* G_{\mu\nu} \times \hat{m} \tag{9}$$

This holds for an arbitrary gauge group G. Thus, we conclude that $G_{\mu\nu}$ is parallel to $\hat{m}$ and hence nonvanishing components of $G_{\mu\nu}$ satisfying magnetic symmetric requirement are necessarily those of little group H of $\hat{m}$.

One of the virtues of magnetic symmetry is that it can be used (Cho,1981, Rana et al,1993) to describe the topological structure of the gauge symmetry. The scalar multiplet $\hat{m}$ may be viewed as to define the homotopy of the mapping $\Pi_2(s^2)$ i.e.

$$\hat{m} \quad ; \quad S_R^2 \to S^2 = SU(2)/U(1) \tag{10}$$

Where, S_R^2 is two-dimensional sphere of three dimensional space and S^2 is the group coset space fixed by $\hat{m}$. So the topological structure of $\hat{m}$ may be identified with the topological point-like objects of the underlying non-Abelian gauge symmetry. As such, when the second homotopy $\Pi_2(G/H)$ defined by $\hat{m}$ is nontrivial the gauge potential V_μ became sort of dual so that the part of it, which is completely fixed by magnetic symmetric requirement, describes point-like colored topological structure while the unrestricted part describes the conventional dyonic objects (quarks) (Rana et al, 1988,1989, 1993,2008).

The duality, discussed above, can be made more explicit in magnetic gauge obtained by rotating $\hat{m}$ to a prefixed space-time independent direction (say $\hat{\xi}_3$ in isospin space) by imposing a gauge transformation U, such that:

$$\hat{m} \xrightarrow{U} \hat{\xi}_3 = (0,0,1)^T. \tag{11}$$

In this gauge the restricted gauge potential and field strength can be written in the following form;

$$V_\mu \xrightarrow{U} V'_\mu = (-iV^*_\mu + W_\mu)\hat{\xi}_3 \tag{12}$$

and

$$G_{\mu\nu} \xrightarrow{U} G'_{\mu\nu} = (-iF_{\mu\nu} + H_{\mu\nu})\hat{\xi}_3 \tag{13}$$

Where, W_μ is precisely given in the following form

$$W_{\nu,\mu} - W_{\mu,\nu} = H_{\mu\nu} \tag{14}$$

Therefore, W_μ can be identified (Cho,1981, Rana et al,1993)with potential of the topological dyons in RCD and is completely fixed by $\hat{m}$ up to the Abelian magnetic gauge degrees of freedom. Consequently, in the magnetic gauge one may indeed bring the topological properties of $\hat{m}$ down to the dynamical variable W_μ by removing all nonessential gauge degrees of freedom.

In terms of restricted gauge potential and field strength the gauge invariant SU (2), RCD lagrangian may be written in the following form;

$$L_R = -\frac{1}{4}G_{\alpha\mu\nu}G^{\alpha\mu\nu} + i\bar{\psi}^\alpha\gamma^\mu D_\mu\psi_\alpha - m\bar{\psi}^\alpha\psi_\alpha \tag{15}$$

Where, ψ is the usual quark doublet. In the magnetic gauge this lagrangian yields the following dual symmetric field equation

$$F_{\mu\nu,\mu} = j_\nu \quad \text{and} \quad H_{\mu\nu,\mu} = -k_\nu \tag{16}$$

Where, j_ν and κ_ν are generalized color electric and color magnetic four-current densities which constitute the generalized dyonic super current.

The foregoing analysis demonstrates the inherent built-in-dual structure of RCD in magnetic gauge and that the magnetic symmetry can be regarded as genuine Noetherian symmetry and topological charge as dual of Noether charge. Following Mandelstam (1976,1979) and 't Hooft (1978)and others(Cho,1980, Baker, Ball and Zachariasen, 1991) we have described (Rana et al, 1988,1989,1993,2005,2008)the dyonic source in RCD by a complex field operator ϕ , as a result the RCD lagrangian (eq. (15)) is modified to

$$L_R = l_R + l_C \tag{17}$$

Where l_C is obtained in the following form by minimal coupling of complex scalar field ϕ with V'_μ (guided by the week duality: in order to maintain ultraviolet finiteness of theory) with the strength $\frac{4\pi}{|q|}$ i.e.

$$l_C = \left|(\partial_\mu + i\frac{4\pi}{|q|}V'_\mu)\right|^2 - V(\phi^*\phi) \tag{18}$$

Where, $V(\phi^*\phi)$ is the effective potential and is introduced by hand (Rana et al, 1988,1989,1993,2005). Such an assumption is needed in fixing the form of l_C so that dynamical breaking of magnetic symmetry be induced. Thus, we obtain the following phenomenological lagrangian, in the magnetic gauge,

$$L_R = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} - \frac{1}{4}H_{\mu\nu}H^{\mu\nu} - \frac{i}{2}(H_{\mu\nu}F^{*\mu\nu} - F_{\mu\nu}H^{*\mu\nu})$$

$$+\bar{\varphi}_+ i\gamma^\mu\left\{\partial_\mu + \frac{q^*}{2}(-iV^*_\mu + W_\mu)\right\}\varphi_+ + \bar{\varphi}_- i\gamma^\mu\left\{\partial_\mu - \frac{q^*}{2}(-iV^*_\mu + W_\mu)\right\}\varphi_- + m(\bar{\varphi}_+\varphi_+ + \bar{\varphi}_-\varphi_-)$$

$$+\left|\left\{\partial_\mu + i\frac{4\pi}{|q|}(-iV^*_\mu + W_\mu)\right\}\phi\right|^2 - V(\phi^*\phi) \tag{19}$$

This lagrangian can be used to represent the interactions between quarks and dyons in the theory and also can be viewed as effective lagrangian to describe the dual dynamics of

RCD (at phenomenological level), just as the Ginzburg- Landau langrangian is used in the theory of superconductivity.

Now with this lagrangian in hand, we have two phases in our theory, namely the unconfining phase where the magnetic symmetry is preserved and the confining phase where the magnetic symmetry is indeed broken by effective potential. In the first phase, not only the quarks but also the dyons will appear as the physical particles while in the second phase both quarks and dyons disappear from the physical particle spectrum and theory contains two generalized magnetic glueballs as massive collective modes of the condensed vacuum. In order to understand this confinement mechanism explicitly, let us write the lagrangian eq. (19) in the absence of quarks (generalized isocolor charged objects of theory) as follows;

$$L_R = -\frac{1}{4}H_{\mu\nu}H^{\mu\nu} + \left|(\partial_\mu + i\frac{4\pi}{|q|}W_\mu)\phi\right|^2 - V(\phi^*\phi) \qquad (20)$$

Identifying the dyon field operator ϕ, as the order parameter and generalized magnetic potential W_μ as the electric potential, the lagrangian eq. (20), resemble with Ginzburg-Landau lagrangian for theory of superconductivity. Consequently, an identical sort of condensation (in parallel with Cooper pair formation in superconductivity) occurs here also. More precisely speaking the dynamical breaking of magnetic symmetry by effective potential, introduced here, induces the dyonic condensation of vacuum and gives rise to the generalized dyonic supercurrent (the contribution comes from the dyon-antidyon pair in vacuum). The real part of this supercurrent (electric constituent) screens the electric flux and confines the magnetic color isocharges, thus giving rise to usual Meissner effect. However, the imaginary part of this supercurrent (magnetic constituent) screens the color magnetic flux and confines the color isocharges via the dual-Meissner effect. As such the dynamical breaking of magnetic symmetry in this theory ultimately induces some sort of generalized Meissner effect constituted of Meissner and dual-Meissner effect. In conclusion, the dyonic condensation in RCD vacuum leads to the generalized Meissner effect which dictates the mechanism for the confinement of color electric and magnetic fluxes associated with dyonic quarks in present theory.

Thus, from the foregoing analysis it is clear that the RCD governs a subdynamics of QCD by characterizing the vacuum structure of the theory. Of particular importance is the built-in-dual structure of RCD where the dynamical breaking of magnetic symmetry leads to the confinement of any colored flux of theory via generalized Meissner effect in a dyonically superconducting vacuum. However, a deeper insight in this problem could be gained in by exploring more about the behaviour of coupling constant q^*, isocolor and topological charge interactions and hence the vacuum structure of RCD in more detail. Keeping electromagnetic duality as vital guide in the following we study the duality, particularly relevant to the RCD vacuum as (chromo)dyonic superconducting medium.

3. Vacuum structure of RCD:

It is believed that renormalization effects typically require dimensionless interaction constant to depend on the distance scale being studied. For example, in QED, the interactions between electrons compared to at large distances are more intense at close distances. A complete explanation of this effect is beyond the fact that coulomb force varies as $\frac{e^2}{r^2}$. Roughly speaking, the interaction should be written as

$$F(r) = \frac{e^2(r)}{r^2}$$

With e(r), a dimensionless electric charge, depending on the distance between the electrons. The physical origin of the distance dependence of the QED coupling constant e(r), is the vacuum polarization which partially screens the charge of a electron. Thus, when the interacting electrons are at large distance one assesses only a part of the bare electronic charge of the other while in case of the short distances (so as to penetrate the screening cloud) there is more intense interaction between them. The result is that the effective coupling constant of QED is always a decreasing function of distance which, in turn, implies that the dielectric susceptibility function for such system is always greater than zero. In pure Yang-Mills theory, however, the effect which renormalizes the coupling constant go in the opposite direction (Gross and Wilczek,1973). That is to say the dimensionless coupling constant g(r), between charges, is found to increase with distance. This, however, raises the important possibility that $g(r) \to \infty$, and thereby produces a long range force which may be responsible for quark confinement and hence the system is essentially in the nonperturbative regime. On the other hand, the Yang-Mills vacuum may be considered as relativistic medium and the correlation function for the vector potentials can describe the properties of this medium (Baker, Ball and Zachariasen,1985). We, therefore, artifact that the RCD vacuum is the relativistic dielectric medium and such properties of RCD vacuum, in non-perturbative regime, may play an important role in establishing quark confinement. However, in the present model, in case of the magnetic symmetric contribution in theory, obviously the counter term for dielectric function is given by permeability function in order to maintain the relativistic invariance. It implies that in a simplest long distance approximation $(x > \frac{1}{\Lambda_{QCD}})$, RCD vacuum behaves as relativistic dielectric medium consisting of virtual quanta of the Yang-Mills fields. Thus, it is worth to further explore the long distance behavior of RCD having a built-in-dual structure to get some insight into the study of quark confinement in QCD.

We consider the following form of RCD action in translationally invariant medium (in magnetic gauge);

$$S = -\frac{1}{4}\iint F^{\mu\nu}(x)\varepsilon(x-y)F_{\mu\nu}(y)d^4xd^4y$$

$$-\frac{1}{4}\iint H^{\mu\nu}(x)\mu(x-y)H_{\mu\nu}(y)d^4xd^4y$$

$$+ \text{ Other remaining part} \qquad (21)$$

Where, the remaining part of the action consists of all other non-quadratic terms in the potential (higher nonlinear terms) $\varepsilon(x-y)$ and $\mu(x-y)$ are the electric and magnetic permeability functions, respectively, which in lowest order perturbation theory are delta functions $\delta(x-y)$. These functions provide an effective or macroscopic description of complicated microscopic interactions of quarks and dyons in RCD vacuum. In the spirit of relativistic invariance, dielectric and magnetic permeability functions satisfy the following relation;

$$\int \varepsilon(x-y)\mu(y-z)d^4y = \delta(x-z) \qquad (22)$$

However, decomposing the gauge potential in pure electric and magnetic constituents, present model (in absence of sources) resemble with that of Nair and Rosenzweig (1984,1985) which reflects the fact that the sourceless electrodynamics in linear relativistic medium can be described by either of the both electric or magnetic vector potential. The choice of the potential depends upon the type of sources present and nature of the medium. Notwithstanding, in the most general case (as has been discussed in earlier section and its suitability (Mandelstam,1976,1979)where the colored objects in the theory are dyonic in nature, it is more likely to formulate the theory in terms of generalized potentials containing both electric and magnetic potentials in a dual symmetric way and hence the RCD action (eq. (21)) is the more general one. In the section the color electric constituents of the supercurrent are those which interact via the unrestricted part of the gauge potential V_μ (eq. (2)) and may be written as

$$\langle j_\mu(x)\rangle = i\frac{\delta S}{\delta V_\mu^*} \tag{23}$$

Which lead to the following form of such current-current correlation functional -

$$\langle j_\mu(x).j_\nu(y)\rangle = -\frac{\delta^2 S}{\delta V_\mu^*(y)\delta V_\mu^*(x)} = (\mathrm{W}\delta_{\mu\nu} - \partial_\mu\partial_\nu)\varepsilon(x-y)$$

$$-\int\frac{d^4k}{(2\pi)^4}e^{ik(x-y)}(\delta_{\mu\nu}k^2 - k_\mu k_\nu)\varepsilon(k^2) \tag{24}$$

Where,

$$\varepsilon(x-y) = \int\frac{d^4k}{(2\pi)^4}e^{ik(x-y)}\varepsilon(k^2) \tag{25}$$

Now the corresponding magnetic constituent of supercurrent is those which couple with the restricted part of the gauge potential, determined completely by the magnetic symmetric requirement, and is given by,

$$\langle \kappa_\mu(x)\rangle = \frac{\delta S}{\delta W_\mu(x)} \tag{26}$$

and the corresponding magnetic current-current correlation functional for same RCD medium is expressed as follows;

$$\langle \kappa_\mu(x).\kappa_\nu(y)\rangle = -\frac{\delta^2 S}{\delta W_\nu(y)\delta W_\mu(x)} = (\mathrm{W}\delta_{\mu\nu} - \partial_\mu\partial_\nu)\mu(x-y)$$

$$= -\int\frac{d^4k}{(2\pi)^4}e^{ik(x-y)}(\delta_{\mu\nu}k^2 - k_\mu k_\nu)\mu(k^2) \tag{27}$$

where, again $\mu(k^2)$ is Fourier transform of $\mu(x-y)$ i.e.

$$\mu(x-y) = \int\frac{d^4k}{(2\pi)^4}e^{ik(x-y)}\mu(k^2) \tag{28}$$

Relativistic invariance fixes the following relation for these two functions in accordance with eq. (22)

$$\varepsilon(k^2) \, . \, \mu(k^2) = 1$$

As we know that $\varepsilon(k^2) = 1 = \mu(k^2)$ is the free electromagnetism in the vacuum. In the perturbation limit the deviation of $\varepsilon(k^2)$, $\mu(k^2)$ from unity may be interpreted as vacuum polarization due to charged particles or dyon loops. That is to say in RCD, for a particular case we may think of electric constituent dominance as manifested by monopoles/Dyons. Thus, for perturbatively small contribution to dielectric and permeability functions we write;

$$\varepsilon(k^2) = 1 + \nabla(k^2)$$

$$\varepsilon(k^2) = 1 - \nabla'(k^2) \qquad (29)$$

and hence the corresponding permeability functions may be written as,

$$\mu(k^2) = 1 - \nabla(k^2)$$

$$\mu(k^2) = 1 + \nabla'(k^2) \qquad (30)$$

Where, the $\nabla'(k^2)$ is written for the magnetic constituent. These equations are in perfect agreement with the earlier work (Cho,1981,Rana et al,1993,2005 Mandelstam,1976,1979, Nair and Rosenzweig,1984,1985) that the electric constituent ($\nabla(k^2) > 0$), charged particles, produce screening effect for V_μ^* propagator ($\varepsilon(k^2) > 1$) $W_\mu V_\mu^*$ while antiscreening for W_μ propagator, likewise magnetic constituent produces screening for W_μ propagator ($\varepsilon(k^2) > 1$) and antiscreening for V_μ^* ; i.e. any constituent of field screens its own direct potential (to which it is minimally coupled) and antiscreens the dual potential. This antiscreening provides answer to several other questions in gauge theories. As it has been shown by 't Hooft (1981) that non-Abelian gauge theories are equivalent to Abelian gauge theories with monopoles, the question then arises; what happens to asymptotic freedom; these results answer this question. As we notice that because of the antiscreening, inside the hadrons (after confinement) the magnetic constituent of the potential in the lagrangian may safely be neglected, as the magnetic condensation must occur only outside the hadrons. In this approximation (of course we have to go to extended gauge theory limit) the lagrangian describes the conversional QCD. Hence in RCD, the topological dyons (as a result of magnetic symmetry) guarantee the asymptotic freedom. Thus, most convenient microscopic description of low energy QCD may safely be described by (chromo) - magnetic monopoles or dyons.

From these analysis we see that the current-current correlations given by eq.s(24, 27) may be helpful in explaining some of the confining properties of RCD in a pedagogical way in analogy with theory of superconductivity. Now applying these dual equations to superconductivity functions are no more as ordinary ones and include fully nonperturbative effects as they are no longer unity. The condensation of (chromo)-dyons leads to drastic changes in the dielectric properties of RCD vacuum resulting in the confinement of colored fluxes associated with charged particles in accordance with generalized Meissner effect. The dyon-antidyon pair embedded in this nontrivial RCD vacuum is not easily described as interacting by gluon exchange. A better description involves strings (type II superconductor) or bags (type I superconductor) which is made more clear in next section. Now making a parallelism; in the superconductivity where Meissner effect excludes the magnetic flux from inside the superconductor, however it can penetrate into the superconductor upto the London penetration depth is equivalent to the electric constituent of generalized Meissner effect. Similar analogy can be drawn for the magnetic constituent of generalized Meissner effect where the magnetic (dual) superconductivity allows the electric flux to penetrate only upto, some sort of London penetration depth of superconductivity. For the statement that magnetic field penetrate only upto London penetration depth λ_L, in low momentum limit ($k^2 small$), we write the following expression, keeping in mind the fact that the penetration depth is inverse to the mass of propagating field quanta,

$$\mu(k^2) = k^2\lambda_L^2 \quad \text{and} \quad \lambda_L = \frac{1}{m_L(e)} \tag{31}$$

$m_L(e)$ is the mass of the photon. Obviously $\varepsilon(k^2) = \dfrac{1}{k^2\lambda_L^2}$ so as to obey the requirement $\mu(k^2)\,\varepsilon(k^2) = 1$. Under these circumstances the color electric and magnetic current-current correlations be written as follows;

$$\left\langle j_\mu(x), j_\nu(y)\right\rangle = -\int \frac{d^4k}{(2\pi)^4} e^{ik(x-y)} (\delta_{\mu\nu} - \frac{\kappa_\mu\kappa_\nu}{\kappa^2}) \frac{1}{\lambda_L^2} \tag{32}$$

$$\left\langle \kappa_\mu(x), \kappa_\nu(y)\right\rangle = -\int \frac{d^4k}{(2\pi)^4} e^{ik(x-y)} (\delta_{\mu\nu} - \frac{\kappa_\mu\kappa_\nu}{\kappa^2}) \kappa^4 \lambda_L^2 \tag{33}$$

From above equations it is clear that electric constituent quanta of the generalized field acquires a mass equal to $m_L(e)$ and can propagate only over the distances comparable to London penetration depth and at the same time the dual field quanta (magnetic constituent) of generalized field propagates as $\frac{1}{k^4}$, at least for small momentum limit. However, in case of magnetic constituent of generalized Meissner effect, where electric part is confining and can penetrate inside the chromo-dyonic superconductor up to the distances comparable to some sort of London penetration depth, the above conditions would be given in the following form;

$$\varepsilon(k^2) = k^2\lambda_L^2 \quad \text{and} \quad \lambda_L = \frac{1}{m_L(g)} \tag{34}$$

where, $m_L(g)$ is mass of magnetic photon, also $\mu(k^2) = \frac{1}{k^2\lambda_L^2}$. For these specifications the current-current correlations may be written as follows;

$$\left\langle j_\mu(x), j_\nu(y)\right\rangle = -\int \frac{d^4k}{(2\pi)^4} e^{ik(x-y)}(\delta_{\mu\nu} - \frac{\kappa_\mu\kappa_\nu}{\kappa^2})\kappa^4\lambda_L^2 \tag{35}$$

$$\left\langle \kappa_\mu(x), \kappa_\nu(y)\right\rangle = -\int \frac{d^4k}{(2\pi)^4} e^{ik(x-y)}(\delta_{\mu\nu} - \frac{\kappa_\mu\kappa_\nu}{\kappa^2})\frac{1}{\lambda_L^2} \tag{36}$$

These equations show that the magnetic constituent of field quanta becomes massive and propagates only up to sort of London penetration depth while the associated electric field quanta propagates like $\frac{1}{k^4}$.

Thus, in the present model the confinement of any colored flux in theory go hand in hand as a consequence of generalized Meissner effect. This simple analogy may account for the confinement of monopole(dyon), rather than going through a detail perturbation theory, by establishing $\frac{1}{k^4}$ nature of field propagator as indication for confinement (Baker, Ball and Zachariasen, 1985, Nair and Rosenzweig, 1984,1985). Thus, making use of duality in superconductivity incorporates deviation in values of $\varepsilon(k^2)$ and $\mu(k^2)$ from unity and consequently include the fully nonperturbative effects in RCD. Therefore, eq.s (32, 33) can be straightforwardly used to explain color magnetic flux confinement while eq.s (35, 36) may explain color electric flux confinement in QCD. The argument is based on the fact that $\frac{1}{k^4}$ behavior, at low momenta, can be ascribed to the propagator associated with the color magnetic constituent of the gauge potential which has fully been described in terms of magnetic symmetry and in the dual case the $\frac{1}{k^4}$ behavior is associated with color electric constituent of the gauge potential which is not restricted by magnetic symmetry. Furthermore, it may be instructive, now, to compare two confinement mechanisms (i.e. with usual superconductivity). In superconductivity the supercurrent responsible for confinement is made of cooper pairs, while in present case the supercurrent which confines any colored flux in theory is made of symmetric combination of two oppositely charged objects which is required by the condition of Weyl reflection invariance (Cho,1982,1983, Mandelstam,1976,1979, 't Hooft 1978) of the theory. Consequently, a better description of dyon-antidyon in RCD vacuum involves strings and bags. The bags find their natural habitat in type I superconductor while strings exist more comfortable in type II superconducting medium, which can be understood better in the following. We know that (Kogut and Susskind, 1974) the interface energy between normal matter and superconductor is positive for type I while it is negative for type II superconductor. Any dyon-antidyon pair (for its magnetic part) embedded in superconductor will form a normal fissure in superconductor and comprise a bound state of confined magnetic constituents (for its dual constituents in magnetic superconductor from the confined pair of electric constituents). If such pair is in type I superconductor the positive surface energy tend to make fissure spherical and hence produce a bag shape, on the other hand, if the pair is embedded in type II medium the negative surface energy will cause the configuration to minimize the total energy by maximizing the surface and hence a string develops. In the following section we tried to present a semi-quantitative description for this idea based on a discussion of vortex solutions in the Higgs-Ginzburg - Landau theory for present model.

VORTEX SOLUTIONS OF RCD

The Ginzburg-Landau equations, describing a superconductor, are well known in their relativistic form as the Higgs model. However, in the present model it is the magnetic symmetry which has been used to specify the global topology $\Pi_2(G/H)$ of the gauge symmetry rather than the scalar triplet as in Higgs type theory. Consequently, as has been discussed earlier, we are left with the following form of lagrangian in the absence of quarks, in magnetic gauge, as the relativistic generalization of Ginzburg-Landau lagrangian for RCD as Higgs model.

$$L_R = -\frac{1}{4} H_{\mu\nu} H^{\mu\nu} + D_\mu \phi D^\mu \phi - V(\phi^* \phi) \tag{37}$$

where,

$$D_\mu \phi = (\partial_\mu + i \frac{4\pi}{|q|} W_\mu) \phi \tag{38}$$

and $V(\phi^* \phi)$ is the effective potential. Convention for such a form has been discussed earlier and the effective potential $V(\phi^* \phi)$ breaks magnetic symmetry dynamically. Following Coleman and Weinberg (1973) it has been shown (Mandelstam,1976,1979, 't Hooft,1978,Cho,1980, Baker, Ball and Zachariasen,1991) that the effective potential obtained in one-loop approximation can actually break the magnetic symmetry dynamically in the strong coupling limit and has the following form,

$$V_{eff} = \frac{24\pi^2}{|q|^4}\left\{v^2 + (\phi^*\phi)^2\left(2\ln\frac{(\phi^*\phi)}{v^2} - 1\right)\right\} \tag{39}$$

where, $\langle\phi^*\phi\rangle^{\frac{1}{2}} = v$ is the vacuum expectation value of the ϕ field. Such a dyonically condensed vacuum is characterized by the presence of two massive collective modes of condensed vacuum, namely, scalar and an axial vector. The mass of the scalar mode (m_s) determines how fast the perturbative vacuum around a colored source reaches the condensation and that of the vector mode (m_a) determines the penetration length of the colored flux. The masses of these glueballs may be estimated (Mandelstam,1976,1979, 't Hooft,1978)by evaluating the string tension of classical string solutions of colored quark pairs. It has been demonstrated that the Coleman-Weinberg effective potential consists in its ability to demonstrate the desired dynamical symmetry breaking, however, the following form of quartic potential is most suitable from phenomenological viewpoint;

$$V(\phi^*\phi) = \frac{48\pi^2}{|q|^4}P(\phi^*\phi - v^2)^2 \tag{40}$$

where, P is a number and can have any integer value. Thus, with this effective potential $V(\phi^*\phi)$ in lagrangian eq. (37), there exists a strict parallelism between standard Higgs mechanism in its relativistic generalization to RCD. Therefore, the masses of these massive modes may be expressed as follows;

$$m_s^2 = 2\frac{96\pi^2}{|q|^4}Pv^2 \tag{41}$$

$$m_a^2 = 2\frac{16\pi^2}{|q|^2}v^2 \tag{42}$$

The effective potential eq. (40) fixes the following ratio of these masses in terms of a dimensionless parameter;

$$K_{RCD}^2 = \left(\frac{m_s}{m_a}\right)^2 = \frac{3}{2\pi\alpha_R}P \tag{43}$$

where, $\alpha_R = \frac{|q|^2}{4\pi}$ is the fine structure constant of RCD.

In the present model, in parallel with Ginzburg-Landau theory, one may identify the London penetration depth ($\lambda_L = \frac{1}{m_a}$) and the coherence length ($\varsigma_R = \frac{1}{m_s}$) as measure of the distance over which superconductivity becomes established, one may therefore have,

$$K^2_{RCD} = \frac{3}{2\pi\alpha_R} P = \frac{\lambda_L^2}{\varsigma_R^2}$$

such that,

$$\lambda_L^2 = (\frac{|q|}{4\pi})^2 \frac{1}{2v^2}, \qquad (44)$$

$$\varsigma_R^2 = \frac{1}{2^2 P} (\frac{|q|}{2\sqrt{\pi}})^4 \frac{1}{3v^2} \qquad (45)$$

Keeping in view these discussions, in the following we discuss the static finite energy solutions of the equations of motion, followed from lagrangian eq. (37) which are expected (to an approximation) to be the vortex lines. From this lagrangian we get the following equations of motion in cylindrical coordinates (r, θ, z) system (Huang, 1982).

$$\left(\nabla^2 - \frac{32\pi^2}{|q|^2}\right)\vec{W} = -i\phi^*\nabla\phi \qquad (46)$$

$$\left(\nabla^2 - i\frac{4\pi}{|q|}\right)^2 \phi = \frac{96\pi^2}{|q|^4}\phi(\phi^2 - v^2) \qquad (47)$$

where, we have chosen Coulomb gauge $\nabla.\vec{W} = 0$ with $W_0 = 0$ and $P = 1$, for simplicity. Now for these static equations of motion we choose the following substitution in cylindrical coordinate basis,

$$\vec{W}(r,\theta) = \hat{\theta} W(r)$$

$$\phi(r,\theta) = \phi(r) e^{in\theta} \qquad (48)$$

with,

$$W(r) = \frac{n|q|}{4\pi r}(1 - X(r)).$$

With the eq.s (48) we find that,

$$\nabla\times\vec{W}=\hat{z}\frac{n|q|}{4\pi r}X'(r). \tag{49}$$

which may be thought of electric constituent of generalized field. With these simplified substitutions, it is interesting to see that the integer 'n' in eq. (48) and eq. (49) turns out to be number of flux quanta contained in the vortex. With these ansatz the static equations of motion can be written in the following form,

$$X''(r)=\frac{X(r)}{r}-2\left(\frac{4\pi}{|q|}\right)^2\phi X(r)=0 \tag{50}$$

$$\phi''(r)+\frac{\phi'(r)}{r}-\frac{n^2X^2(r)}{r^2}-6\left(\frac{2\sqrt{\pi}}{|q|}\right)^4\phi(r)(\phi^2-v^2) \tag{51}$$

For the present semi-quantitative analysis, instead of direct solutions we follow the variational approach for the solution of the equations of motion. Notwithstanding, the consistencies of these equations of motion impose the following boundary conditions on the functions $X(r)$ and $\phi(r)$ in the limit of r approaching to zero.

$$X(r)=1-\frac{r^2}{\lambda^2}$$

$$\phi(r)=Ar^n \tag{52}$$

With $X(\infty)=0,\phi(\infty)=v$. The energy per unit length of the static solution may be given as follow;

$$E=4\pi\int_0^\infty rdr\left\{\left(\frac{n}{2r}\right)^2\left(\frac{|q|}{4\pi}\right)^2(X'(r))^2+\frac{1}{2}\left(\frac{n}{r}\right)^2X^2(r)\phi^2(r)+\frac{1}{2}(\phi'(r))^2+\frac{3}{2}\left(\frac{2\sqrt{\pi}}{|q|}\right)^4\left(\phi^2(r)-v^2\right)^2\right\} \tag{53}$$

The test functions $X(r)$ and $\phi(r)$ must be consistent with the boundary conditions in eq. (52) and flux quantization condition (X(0) = 1). Such discussions lead to the following general form for these functions, in a limiting case with respect to the conditions on 'r';

$$X(r)=\begin{cases}1-\frac{r^2}{\lambda^2}, r\prec\lambda\\ 0, r\succ\lambda\end{cases} \tag{54a}$$

$$\phi(r) = \begin{cases} v\left(\dfrac{r}{\varsigma}\right)^{n}, r \prec \varsigma \\ \varsigma, r \succ \varsigma \end{cases} . \tag{54b}$$

A comparison of these functions to Ginzburg-Landau theory supports our parallel with superconductivity. Obviously, in eqs. (54) the parameter λ is something like London penetration depth giving the distance over which electric flux or magnetic flux extends in dyonic superconductor. Similarly, the parameter ς is something like coherence length over which the dyonic superconducting state is established. Thus, it is clear that any function with ansatz eq. (49) will minimize the static energy density functional eq. (53). The interesting thing which comes out is that these solutions are independent of coupling and hence are independent of type of flux confinement which makes them suitable to discuss generalized Meissner effect in present theory. However, a more rigorous and actual solution may be obtained by minimizing the action with respect to λ and ς which in term will be able to give true expression for λ and ς (from numerical point of view), and hence the vortex properties. This statement in superconductivity is the differentiation between type I and type II superconductors. With these discussions (for n = 1).

(A) For type I superconductor, ($\lambda \prec \varsigma$)

$$E = \pi v^2 \left\{ 1 + \left(\frac{9}{|q|^2} \right)^{\frac{1}{3}} \right\} \tag{55}$$

The expressions for λ and ς are given as;

$$\lambda^2 = \frac{1}{v^2}\left(\frac{|q|}{4\pi}\right)^2 \left(3|q|^2\right)^{\frac{1}{3}}$$

$$\varsigma^2 = \frac{1}{3v^2}\left(\frac{|q|}{2\sqrt{\pi}}\right)^4 \left(\frac{9}{|q|^2}\right)^{\frac{1}{3}} . \tag{56}$$

However, for $n \succ\succ 1$, the energy function (eq. (55)) may be written as,

$$E_n = n\pi v^2 \tag{57}$$

(B) For type II superconductor, ($\lambda \succ \varsigma$)

The energy expression is given by;

$$E = 2\pi v^2\left\{\frac{9}{4}-\left(\frac{\lambda}{\varsigma}\right)^2+\frac{1}{2}\left(\frac{\lambda}{\varsigma}\right)^4+2\log\left(\frac{\lambda}{\varsigma}\right)\right\} \tag{58}$$

and the corresponding expressions for and are given by,

$$\lambda^2=\frac{1}{v^2}\left(\frac{|q|}{4\pi}\right)^2$$

$$\varsigma^2=\frac{1}{v^2}\left(\frac{|q|}{2\sqrt{\pi}}\right)^4. \tag{59}$$

Now, for $n \succ\succ 1$, and $\lambda \succ\succ \varsigma$, the energy function (eq.(58) leads to the following will know expression for type II superconductor.

$$E_n = 4\pi n^2 v^2 \ln\left(\frac{\lambda}{\varsigma}\right) \tag{60}$$

From the above description it becomes clear that in type I superconducting medium, the energy increases almost linearly with flux, resulting in that the vortices attract each other (Cho, 1980,1982). This statement translated in particle language is equivalent to say that the scalar mode, i.e. attractive forces, dominate over the vector mode the repulsive ones which arise as a result of the fact that $m_a \succ m_s$. This behavior of type I superconducting medium is identified with the mass scale ratio given in eq. (43) having values $K^2_{RCD} \ll 1$. Thus the dominance of attractive forces of scalar mode in type I medium favors the bag model of hadrons in RCD. In case of type II superconductor the energy function in eq. (60) implies that the energy of multiflux vortex is larger than that of 'n' single flux lines which result in that the vortices repel. Translated in particle language this is equivalent to say that $m_s \succ m_a$ which can be found for values of mass scale ratio $K^2_{RCD} \succ 1$. This dominance of repulsive forces of vector mode in type II medium favors the string picture of hadrons. However, for $K^2_{RCD} = 1$ two modes have similar masses and hence on the basis of above description it is hard to distinguish the type of medium. Therefore, $K^2_{RCD} = 1$ (i.e. $\lambda = \varsigma$) may be considered as transition point between two types of superconductors. Thus, the analogy with type of medium and corresponding estimation of masses of scalar and vector modes and resulting mass ratio, as RCD mass scale parameter, may play a crucial role in deciding the type of model, bag or string, for hadrons in QCD and vice-versa.

Supersymmetric field theories have the remarkable property that some of the perturbative effects are canceled between bosons and fermions and provide a natural resolution of the gauge hierarchy problem of grand unified theories (GUT's).Analyzing the supersymmetric generalization of monopoles in the limit of Prasad and Sommerfield and Bogomolny and using the supersymmetric version of the Georgi-Glashow model with vanishing potential, it has been shown that the quantum corrections to the mass of a monopole are vanishing. However, some controversies have been raised about the exact cancellation of perturbative effects between bosons and fermions, Bogomolny-bound saturation, and quantum corrections to the physical monopole mass in N 2 supersymmetric Yang-Mills theory. Keeping these motivations in view, in this paper, dyonic supermultiplets in N=1 supersymmetry are obtained quantum mechanically in the topological part of restricted quantum chromodynamics. Constructing the Lagrangian density in the N=1 supersymmetic version of restricted quantum chromodynamics (RCD) (topological part)in terms of the isotriplet gauge field and its fermionic superpartner, supersymmetric dyonic solutions are written and the classical mass of the dyon is obtained by minimizing the background potential of the theory.

SUPERSYMMETRIC DYONS AND RESTRICTED GAUGE THEORY

Dyonic color charge and the color spin (induced by fermion fractionization in George-Glashow model in the presence of an isovector fermionic field) can also be easily introduced in restricted quantum chromodynamics (RCD) (Rana et al, 1988,1989,1993, Cho,1980,1982), where the unrestricted part of the gauge potential given in eq. (2) describes the dyonic flux of color isocharges and the restricted one describes the flux of topological charges. The generalized field strength of gauge fields in this restricted chromodynamics describing non-Abelian dyons given by eq. (5).

In the gauge potential and field strength, the V_μ vector is the isotriplet of the generalized four-vector and $\hat{m}$ is isotriplet with constant length

$$\hat{m}^2 = const = v^2/2 \tag{61}$$

In the external four-dimensional space, the multiplet $\hat{m}$ behaves as a massless scalar field, components m^a $(a = 1,2,3)$ constitute isotriplet $\hat{m}$ in SU(2) internal space.

The unrestricted part of the gauge potential V_μ, has the Abelian origin, and it has been ignored as being unnecessary in our recent work, where only the restricted part of this potential has been shown responsible for quark confinement through the mechanism of dyonic condensation. The dyons appear in the restricted chromodynamic theory only through this part of the potential. As such, ignoring the unrestricted part here also, the gauge potential and corresponding gauge field strength can be constructed in the following form:

$$V_\mu = -\frac{1}{|q|}\hat{m} \times \partial_\mu \hat{m} \tag{62}$$

and

$$G^a_{\mu\nu} = \frac{1}{|q|}(2\varepsilon^{abc}\partial_\mu m_b \partial_\nu m_c + m^a \varepsilon^{bcd} m_b \partial_\mu m_c \partial_\nu m_d) \tag{63}$$

where

$$|q| = (e^2 + g^2)^{1/2} \quad , \tag{64}$$

is the dimensionless coupling constant made up of electric and magnetic coupling strengths e and g, respectively. Here the massless isovector field V_μ has been constructed out of the isotriplet scalar $\hat{m}$ and hence the independent bosonic degree of freedom is only 1. As such, the supersymmetric generalization of RCD may be obtained by *modifying the Lagrangian density into the form*:

$$L = -\frac{1}{4}G^a_{\mu\nu}G^{\mu\nu}_a + \frac{1}{2}\bar{\lambda}^a \gamma^\mu D_\mu \lambda_a + \frac{1}{2}D_\mu m^a D^\mu m_a + \frac{1}{2}|q|\varepsilon_{abc} m^a \bar{\lambda}^b \gamma_5 \lambda^c - V(mm^*), \tag{65}$$

where λ^a constitutes the isotriplet of fermionic field, γ^μ are Dirac matrices, $\gamma_5 = \gamma_1\gamma_2\gamma_3\gamma_4$, and the covariant derivative D_μ is defined as:

$$D^\mu = \partial^\mu + qV^\mu \times \tag{66}$$

with the symbol × for cross product in internal SU(2) space. The background potential $V(mm^*)$ in eq. (65) has been constructed in the form

$$V(mm^*) = |q|^2 [(m^a m^*_a)^2 - (m^a m^*_a)(m^b m^*_b)] \tag{67}$$

Using Eq. (62) for the topological gauge potential in Eq. (66) we have the following expressions for the covariant derivatives of isotriplet fermionic field λ and isotriplet scalar field $\hat{m}$:

$$\begin{aligned} D_\mu \lambda^a &= \partial_\mu \lambda^a + (m^a \partial_\mu m^b \lambda_b - m^b \partial_\mu m^a \lambda_b), \\ D_\mu m^a &= \partial_\mu m^a + (m^a \partial_\mu m^b m_b - m^b \partial_\mu m^a m_b) \end{aligned} \tag{68}$$

Substituting these equations along with Eq. (63) into Eq. (65) we get the Lagrangian of the topological part of the restricted gauge theory in the form

$$\begin{aligned} L = {} & \frac{1}{|q|^2}[\Gamma_{\mu\nu bc}(\Gamma^{\mu\nu bc} - \Gamma^{\mu\nu cb}) + \frac{1}{2}\varepsilon_{ajk}\varepsilon^{bcd} m^a m_b \Gamma_{\mu\nu cd}\Gamma^{\mu\nu jk} \\ & + \frac{1}{2}\varepsilon^{abc}\varepsilon_{jkl} m_a m^j \Gamma_{\mu\nu bc}\Gamma^{\mu\nu kl} + \frac{1}{2}\varepsilon^{bcd}\varepsilon_{jkl} m_b m^j \Gamma_{\mu\nu cd}\Gamma^{\mu\nu kl}] \\ & + \frac{1}{2}\bar{\lambda}^a \gamma^\mu [\partial_\mu \lambda_a + (m_a \partial_\mu m_b \lambda^b - m_b \partial_\mu m_a \lambda^b)] \\ & + \frac{1}{2}[\partial_\mu m^a + (m^a \partial_\mu m^b m_b - m^b \partial_\mu m^a m_b)]^2 \\ & + \frac{1}{2}|q|\varepsilon_{abc} m^a \bar{\lambda}^b \gamma_5 \lambda^c - V(mm^*), \end{aligned} \tag{69}$$

where $\Gamma_{\mu\nu bc}$ has been written for $\partial_\mu m_b \gamma_\nu m_c$; μ,ν are the indices in the four dimensional space and a, b, c etc., are those in internal isospace. In this Lagrangian, λ^a are superpartners of the isotriplet gauge field V_μ^a [or in turn the superpartners of isotriplet scalar multiplet m^a through Eq. (62)]. Since the theories which transform as linear representations of supersymmetry must have the same number of bosonic and fermionic degrees of freedom, the Lagrangian (69) sould be supersymmetric. In order to check the supersymmetric invariance of this Lagrangian, let us apply the following supersymmetric transformations:

$$\begin{aligned} \delta m^a &= \bar{\alpha}\gamma_5 \lambda^a, \\ \delta V_\mu^a &= -\frac{1}{|q|}\varepsilon^{abc}\bar{\alpha}(\gamma_5 \lambda_b \partial_\mu m_c + m_b \gamma_5 \partial_\mu \lambda_c), \\ \delta\lambda^a &= \frac{1}{|q|}\alpha\sigma^{\mu\nu}(2\varepsilon^{abc}\Gamma_{\mu\nu bc} + m^a m_b \varepsilon^{bcd}\Gamma_{\mu\nu cd}) - i\alpha\gamma_5\gamma_\mu m^a m_b \gamma^\mu m^b. \end{aligned} \tag{70}$$

Under these transformations,

$$\delta L = 0 \tag{70a}$$

Provided we assume the supersymmetry conditions

$$\lambda_5(\bar{\lambda} \times \partial_\mu \hat{m} + \hat{m} \times \partial_\mu \bar{\lambda}) = -i|q|\gamma_\mu \bar{\lambda}, \tag{71a}$$

$$[m_b, \overline{\alpha}] = 0, \quad [m_b, \gamma_5] = 0 \tag{71b}$$

which gives the generalization of the Majorana condition and the Weyl condition. Condition (70a) shows that the Lagrangian density is supersymmetric for the topological part of restricted gauge theory constructed in terms of magnetic symmetry.

The background potential given by Eq. (67) has two types of minima:

$$m^a = 0 \text{ and } m^a = \frac{v}{\sqrt{2}} x^a .$$

For both these cases the value of potential is zero, as required by supersymmetric theories. For the second value of m^a, the symmetry SU(2) breaks down to U(1) and the dyonic solutions occur with the following Julia-Zee time-dependent solutions(Brink,Schwarz and Scherk, 1977):

$$\begin{aligned} V^{ai} &= -\frac{1}{|q|}\frac{\varepsilon^{abi}}{r}\hat{X}_b[1-K(r)], \\ V_0^a &= \frac{\hat{X}_b}{|q|r} J(r), \\ \sqrt{2}\,\mathrm{Re}\,m^a &= \frac{\hat{X}_b}{|q|r} H(r), \qquad \mathrm{Im}\,m^a = 0 \end{aligned} \tag{72}$$

where $\hat{X}^a = x^a/r$ is unit vector in the internal space. These solutions satisfy the coupled differential equations

$$\begin{aligned} r^2 H'' &= 2HK^2, \\ r^2 K'' &= K(K^2-1) + K(H^2 - J^2), \\ r^2 J'' &= 2JK^2. \end{aligned} \tag{73}$$

A solution of these equations is given by

$$\begin{aligned} &J(r) = \alpha[cr\coth(cr) - 1], \quad H(r) = \beta[cr\coth(cr) - 1], \\ &K(r) = cr/\sinh(cr), \end{aligned} \tag{74}$$

with the condition

$$\alpha^2 - \beta^2 = -1 \tag{75}$$

From the Lagrangian density we get the following form energy-momentum density tensor

$$T^{\mu\nu} = D^\mu m_a D^\nu m^a + \frac{1}{2} G_a^{\mu\lambda} G_\lambda^{a\nu} - g^{\mu\nu}[-\frac{1}{4} G_{ij}^a G_a^{ij} + \frac{1}{2} \bar{\lambda}^a \gamma^i D_i \lambda_a$$

$$+\frac{1}{2} D_i m^a D^i m_a + \frac{1}{2}|q| \varepsilon_{abc} m^a \bar{\lambda}^b \gamma_5 \lambda^c - V(mm^*)]. \tag{76}$$

Setting $\mu = \nu = 0$ in this relation, integrating T^{00} over three-space, and using relation (62) and (64), the classical mass of the dyon comes out to be

$$M = \frac{v}{\sqrt{2}} |q| = M_{classical} \tag{77}$$

showing that the dyons appear in the theory only through the restricted part of the potential, which carries the topological charges. A one-loop correction to this mass may be obtained by calculating the energies of Bose and Fermi fluctuations:

$$M_B = \frac{1}{2} \Sigma \omega_B \tag{78}$$

and

$$M_F = -\frac{1}{2} \Sigma \omega_F \tag{79}$$

Let us choose the dyonic background gauge field defined by Eq. (67), where the fluctuation equation is given as the normal eigen value equation. This choice of gauge is necessary because the fluctuation equation takes a particular form in this gauge. Moreover, one may calculate one-loop diagrams with exact propagations of all particles in the background of a dyon.

In the dyonic background fields

$$V_{\mu D}^a = V_\mu^a - \delta V_\mu^a, \qquad m_D^a = m^a - \delta m^a, \tag{80}$$

which satisfy Eq. (72), the bosonic part of the Lagrangian density (69) may be written as

$$L_B = L_D - \frac{1}{2}|(D_\nu \delta V_\mu^a)|^2 + \frac{1}{2}(D_\mu \delta V_\nu)(D^\nu \delta V^\mu)^* - \frac{1}{4}|q|^2 |(\delta V_{\mu b} \delta V_{\nu c})|^2$$

$$-\frac{1}{2} \mathrm{Re}[|q| \varepsilon_{abc} G_{\mu\nu D}^a V^{*\mu b} \delta V^{*\nu c}] - \frac{1}{2}(D_\mu \delta m^a)(D^\mu \delta m_a)^* - \frac{1}{2}|q| \varepsilon_{abc} (D_\mu m^a) V^{*\mu b} m^c$$

$$+\frac{1}{2}|q| \varepsilon_{abc} (D_\mu \delta m^a) \delta V^{*\mu b} \delta m^c + \frac{1}{2}|q| \varepsilon^{abc} (D^\mu m_a)^* \delta V_{\mu b} m_c + \frac{1}{2}|q|^2 [\delta V_{\mu b} m_c$$

$$+\frac{1}{2}|q|^2\left[(\delta V_{\mu b}m^a)^2-(\delta V_{\mu b})^2(m_a)^2\right], \tag{81}$$

Where, L_D is the dyonic background Lagrangian given by

$$L_D=-\frac{1}{4}G^a_{\mu\nu D}G^{*\mu\nu}_{aD}+\frac{1}{2}(D_\mu m^a_D)(D^\mu m_{Da})-V(m^{*a}_D m_{Da}) \tag{82}$$

and D_μ is the covariant derivative given by Eq. (66) with V_μ replaced by V^μ_D. To this Lagrangian let us add the following gauge-fixing term and Faddeev-Popov ghost term.

(i) Gauge-fixing term: Under an infinitesimal transformation θ, which keeps the background configuration $V^a_{\mu D}$ and m^a_D fixed, we may write the following variations of δV^a_μ and δm^a up to the lowest order in θ :

$$\delta V'^{\theta a}_\mu=-\frac{1}{|q|}\varepsilon^{abc}(\delta m^\theta_b\partial_\mu m_c+m_b\partial_\mu\delta m^\theta_c)$$

$$=\delta V^a_\mu-\frac{1}{|q|}m_c\theta^a\partial_\mu m_c-\frac{1}{|q|}m_b\partial_\mu m^a\theta^b-\frac{1}{|q|}m_b m^a\partial_\mu\theta^b \tag{83}$$

and

$$\delta m^{\theta a}=\delta m^a+\varepsilon^{abc}m_b\theta_c, \tag{84}$$

where the background gauge has been defined by the condition

$$f^a=(D^\mu\delta V_\mu)^a-|q|\varepsilon^{abc}m_b\delta m_c \tag{85}$$

such that

$$\frac{\delta f^a}{\delta\theta^b}=\frac{1}{|q|}\left[D^\mu(m^a\partial_\mu m_b+m_b\partial_\mu m^a)+|q|^2(m^a m_b-m^2\delta^a_b)\right]. \tag{86}$$

Thus the gauge-fixing term is given by

$$L_{gf}=-\frac{1}{2}f^a f_a$$

$$=-\frac{1}{2}(D_\mu\delta V'^\mu)^2+|q|\varepsilon^{abc}(D_\mu\delta V'^\mu)_a m_b\delta m_c+|q|^2(m^a m_b-m^2\delta^a_b)\delta m_a\delta m^b. \tag{87}$$

(ii) Faddeev-Popov ghost term: This term is given by

$$L_{FP}=-c^*_a(\delta f^a/\delta\theta^b)c_b, \tag{88}$$

Where, Faddeev-Popov fields denoted by c and c^* are vectors in isospace. Using Eq. (86), we may write this term as

$$L_{FP} = c_a^{*}\left[\frac{1}{|q|}[D^{\mu}(m^{a}\partial_{\mu}m^{b} + m_{b}\partial_{\mu}m^{a})] + |q|^{2}(m^{a}m^{b} - m^{2}\delta^{ab}) \right] c_{b} \tag{89}$$

Using Eqs. (81), (87) and (89), the total Lagrangian for the bosonic part may be written as

$$L = L_{B} + L_{gf} + L_{FP}. \tag{90}$$

In these equations for L_B, L_{gf} and L_{FP}, we may use the following matrix notation for the covariant derivative

$$D_{\mu} = \partial_{\mu} + i|q|V_{\mu a}^{D}T^{a} \tag{91}$$

is the dyonic background where T^a are usual generators of the internal gauge group SU(2).

Let us construct a three-vector B^D in the dyonic background as

$$B_i^{D} = \frac{1}{2}\varepsilon_{ijk}G_b^{Dk}T^{b} \tag{92}$$

and identify the spatial part δV_i and temporal part δV_i^0 of δV_i^{μ} as vectors in isospace. Then we may straight away get the following equations of motion from the Lagrangian density given by Eq. (81)

$$[D_{\mu}D^{\mu} - |q|^{2}m^{2} - 2|q|\sigma_{k}B^{Dk}]\delta\xi = 0, \tag{93}$$

$$[D_{\mu}D^{\mu} - |q|^{2}m^{2}]\delta V_{0} = 0, \tag{94}$$

$$[D_{\mu}D^{\mu} - |q|^{2}m^{2}]c = 0, \tag{95}$$

where we have chosen

$$\delta\xi^{a} = \delta m^{a} + i\sigma^{i}\delta V_i^{a} \tag{96a}$$

and

$$m^{2} = (T^{c}m_{c})^{2}. \tag{96b}$$

For getting the eigen value equations for the Bose fluctuations, let us take the following Fourier transform with respect to time t,

$$\delta\xi^{a} = \sum_{\omega_B}\delta\xi^{a}\exp(i\omega_{B}t), \qquad \delta V_0^{a} = \sum_{\omega_{B0}}\delta\tilde{V}_0^{a}\exp(i\omega_{B_0}t),$$

$$\delta c^{a} = \sum_{\omega_G}\delta\tilde{c}^{a}\exp(i\omega_{B_G}t). \tag{97}$$

Then, Eqs. (93), (94) and (95) may be written in the following manner:

$$(D_i^2 - |q|^2 m^2 + 2|q| T_k V^{Dk})\delta\tilde{\xi} = -\omega_B^2 \delta\tilde{\xi}, \tag{98a}$$

$$(D_i^2 - |q|^2 m^2)\delta \tilde{V}_0 = -\omega_{B_0}^2 \delta \tilde{V}_0, \tag{98b}$$

$$(D_i^2 - |q|^2 m^2)\tilde{c} = -\omega_G^2 \tilde{c}, \tag{98c}$$

where ω_B, ω_{B_0} are bosonic fluctuation frequencies and ω_G is the ghost term frequency. From these fluctuations, the one-loop contributions to dyonic mass can be written as

$$\Delta M_{Bose} = \Delta M_B = \Sigma\omega_B + \frac{1}{2}\Sigma\omega_{B_0} - \Sigma\omega_G, \tag{99}$$

where the negative sign for the ghost contribution denotes the anticommuting nature of ghost fields. Since $\Sigma\omega_B = \Sigma\omega_G = \Sigma\omega_{B_0}$, we may write Eq. (99) as

$$M_{Bose} = \frac{1}{2}\Sigma\omega_B \tag{100}$$

Fermi fluctuations may be obtained from the following fermion equation of motion which follows from the fermionic part of the Lagrangian (65):

$$\gamma^\mu D_\mu \lambda^a + |q| \varepsilon^{abc} m_b \gamma_5 \lambda_c = 0, \tag{101}$$

where the covariant derivative has been defined by Eq. (91). Using Majorana representation and taking the Fourier transform of λ^a with respect to t as

$$\lambda^a = u^a \exp(-i\omega_F t) , \tag{102}$$

Eqs. (98) reduces to

$$(D_i^2 - |q|^2 m^2)u = -\omega_F^2 u, \tag{103}$$

where u is a vector in isospace with its components given by u^a. The contribution of this fluctuation to the dyon mass is

$$\Delta M_F = M_{Fermi} = -\frac{1}{2}\Sigma\omega_F. \tag{104}$$

Combining Eqs. (100) and (104), we get the following one-loop quntum correction to the dyonic mass:

$$\Delta M = \Delta M_B + \Delta M_F = \frac{1}{2}[\Sigma\omega_B - \Sigma\omega_F]. \tag{105}$$

In other words, the dyonic mass up to one-loop quantum correction is given by

$$M = M_{classical} + \frac{1}{2}[\Sigma\omega_B - \Sigma\omega_F], \tag{106}$$

where the classical mass of dyon ($M_{classical}$) is given by Eq.(77).

Because of the similar nature of second-order differential equations (98a), (98b) and (103), the bosonic and fermionic fluctuations have the same spectrum of nonzero eigenvalues,

$$\Sigma\omega_F = \Sigma\omega_B. \tag{106a}$$

The equality between ω_B and ω_F leads to the result that the mass of the dyon is not charged by quantum corrections. In other words, in the supersymmetric limit, the non-Abelian theory of dyons in RCD falls apart, in the correct way, into degenerate supermultiplets.

RESULTS AND DISCUSSION

We have demonstrated that in magnetic gauge one can actually bring the topological degrees of freedom explicitly into the dynamics and hence can putforth the existence of topological objects, which are important in determining the non-perturbative dynamics and resulting confining nature of the theory. Current-current correlations have been used to explain the color confining properties of RCD where the electromagnetic duality has been exploited to discuss the charged particle – topological dyon interactions in the theory. The dual behavior of current-current correlations implies the $\frac{1}{k^4}$ behavior of propagator guarantees the confinement of colored fluxes associated with dyonic quarks vide generalized Meissner effect. Thus, duality of some kind of Higgs phase, where magnetic symmetry is broken by effective potential and resulting confinement suggest that electromagnetic duality should be strong guide to the description of confinement(at least for the low momentum limit)where the interaction of (chromo)-dyon can be saturated by duality. We have demonstrated the approximate behavior of vortices,in a semi-quantitative analysis of, type I and type II medium. It has been demonstrated that for a chromo-dyonic condensed vacuum, bag model of hadrons is more likely if the dyon-antidyon pairs are embedded in type I medium while string picture is more suitable for type II medium. However, the present description is rather naïve and one need much more deeper insight to distinguish between type of superconductors and consequently the two models of hadrons and vice-versa.

The Lagrangian density given by Eq. (65) is supersymmetric under the transformations (70), subject to the condition (71), which are a generalization of Majorana and Weyl conditions. It leads to supersymmetric dyonic solutions with classical mass given by Eq. (77) when the symmetry SU(2) breaks down to U(1) by minimizing the potential Eq.(67). This value of dyonic mass agrees with that predicted by Julia and Zee (1975).This result shows that the dyons appear in the theory (RCD) only through the restricted part of the potential given by Eq. (2). Only this part, carrying the topological charges, is relevant in dyonic theory, while the unrestricted part of this potential, which is Abelian in nature, does not contribute anything to dyonic solutions. We have also demonstrated in our recent work (Rana et al, 1988,1989,1993,2005,2008) that it is only the restricted part of this potential which is responsible for quark confinement in RCD through the mechanism of dyonic condensation. On the other hand, the unrestricted part of the potential becomes confined as a result of condensation of topological charges. Due to these reasons the unrestricted part of the potential has been ignored in Eq. (62) while writing the supersymmetric Lagrangian (65) which carries only one bosonic degree of freedom and one fermionic degree of freedom. In case this unrestricted part of the potential is not ignored, one will have to introduce two fermionic degrees of freedom in this Lagrangian. It will not lead to any new physics and the mathematical calculations will become unnecessarily cumbersome, leading to difficulty in constructing the background potential of Eq. (67). Choosing the dyonic background field defined by Eq. (80), the bosonic part of the Lagrangian of supersymmetric theory in the gauge restricted by magnetic symmetry has been obtained in the form given by Eq. (81). Eqs. (98) give the bosonic fluctuations equations with the same frequency for the spatial bosonic field, temporal bosonic field, and the ghost field, which lead to total one-loop fluctuations and a correction to the dyonic mass in the form given by Eq. (100). The fermionic part of the Lagrangian leads to the equations of the motion (101), which in turn yields the fermionic fluctuation contribution Eq.(103) in the one-loop approximation. Because of the similar nature of second-order differential equations (98a), (98b) and (103), the bosonic and fermionic fluctuations have the same spectrum of non-zero eigenvalues. Equations (100), (104) and (105) show that the classical mass of the dyon is not changed by quantum corrections, and hence it may be concluded that, in the supersymmetric limit, the non-Abelian theory of dyons in the restricted chromodynamics falls apart, in the correct way, into degenerate multiplets. In other words, in the supersymmetric generalization of RCD, the physical dyonic mass does not receive quantum corrections. The introduction of the supersymmetric dyonic model in this way and the vanishing of the quantum corrections may be used for proving the interesting conjecture proposed by Montonen and Olive (1977). All these results of the supersymmetrized version of RCD agree with conclusions drawn by D'Adda et al (1978), by using dimensionally reduced supersymmetrized pure Yang-Mills theory in six dimensions. Using this method of dimensional reduction, we may get a two-dimensional theory from the four-dimensional supersymmtric theory presented in the preceding section by interpreting two of the spatial dimensions as internal degrees of freedom.

REFERENCES

Arafune J., P.G.O. Freund and G.G. Geobel. 1975. *J. Math. Phys.*, 16 : 433.

Baker M., J.S. Ball and F. Zachariasen. 1991. *Phys. Rep.*, 209: 73.

Baker M., J.S. Ball, F. Zachariasen. 1985. *Phys. Rev.*, D31 : 2575.

Bogomolny E.B. 1976 , Yad. Fiz. 24:861[1976: *Sov. J. Nucl. Phys.*, 24 : 449].

Brink L., J.H. Schwaz, and J. Scherk. 1977. Nucl. Phys., B121 : 77.

Cabbibo N. and E. Ferrari. 1962. *Nuov. Cim.*, 23:1147.

Chandola H.C., B.S. Rajput, J.M.S. Rana and S. Sah.1993. *IL Nuov., CIM.* A106: 509.

Cho Y.M. 1980. Phys. Rev., D 21: 1080 ; 1982. Report No. MZ.TH/82-05, University of Mainz (unpublished).

Cho Y.M. 1980: *Phys. Rev.* D21 : 1080.

Cho Y.M. 1981. *Phys. Rev.* D 23:2415; *Phys. Rev. Lett.*, *46*:302.

Cho Y.M. 1982. *Phys. Lett.* B115 : 125, 1983.Report SLAC- PUB : 3188

Coleman S. and E. Weinberg. 1973. *Phys. Rev.*, D7: 1888.

Coleman, S. 1975. Proc. Int. Sch. Subnucl. Phys. *Rttore Majorana Erice, Italy* (ed. by A Zichichi).

D,Adda A. , R. Horsley, and P. Di Vecchia 1978. *Phys. Lett.*, 76B : 298.

D31: 401, 1985. Nucl. Phys. B250 : 729.

Gross D.J. and F. Wilczek. 1973. *Phys. Rev.* Lett.30 : 1343.

Huang K. 1982. Quarks, Leptons and Gauge fields (World Scientific).

Imbimbo C. and S. Mukhi 1985. *Nucl. Phys.*, B249: 143.

Julia, B. and A. Zee. 1975. *Phys. Rev.*, D11 : 2227.

Kaul, R.K. 1984. *Phys. Lett.*, 143B : 427.

Kaul R.K.1982. Phys. Lett. 109B : 153; E. Witten.1981. Nucl. Phys. B188: 513; B202: 253; Dimopoulos S.and H. Georgi, ibid. B193:150; Sakai N.1981. Z. Phys. C 11:153

Kogut J. and L. Susskind. 1974. *Phys. Rev.*, D9 : 3501.

Mandelstam S.1976. Phys. Rep. 23C: 245; 1979. Phys. Rev., D19: 249.

Montonen C. and D. Olive. 1977 : *Phys. Lett.*, B72: 117.

Montonen C. and D. Olive. 1977. *Phys. Lett.*, 72B : 177.

Nair V.P. and C. Rosenzweig. 1984. Phys. Lett., B135 : 450, 1985. Phys. Rev.

Olive D.I. 1996. Exact electromagnetic duality, hep-th/ 9612192.

Polyakov, A.M. 1974. JETP *Lett.*, 20: 194.

Prasad, M.K. and C.M. Sommerfield. 1975. Phys. Rev. Lett., : 760.

Rana, J.M.S. 2005. On the role of various dualities (unpublished);

Rana J.M.S.,2008. Proc. Of Science (Italy). 1 : 176.

Rana J.M.S., H.C. Chandola and B.S. Rajput. 1989. Prog. *Theor. Phys.*, 82: 153 ;Ind.J. Pure & Appl. Phys. 26 (1988)587.

Rana J.M.S., H.C. Chandola and B.S. Rajput.1993. *Can. J. Phys.* 69: 1441.

Sieberg N and E. Witten. 1994: *Nucl. Phys.* B 426 :19 ; B 430 (E) : 485 ; B 431: 484.

't Hooft G. 1976. *Nucl. Phys.* B105 : 538.

't Hooft G. 1976. *Nucl. Phys.*, B 79: 276.

't Hooft G., 1978. *Nucl. Phys.*, B138:1.

't Hooft G., 1981. Nucl. Phys. B190 : 455.

Wu T.T. and C.N. Yang 1975. *Phys. Rev.* D21 : 3845.

Pb. Univ. Res. J (Sci.), Vol. 59, 2009, pp. 213-226

ON STRICTLY FGD N-GROUPS WITH ACC ON ANNIHILATORS

***Helen K. Saikia and Kalpana Misra**

Department of Mathematics, Gauhati University, Guwahati – 781014

Abstract

Here we establish a unique closed primary decomposition of the zero ideal in a strictly FGD N-group with acc on annihilators. A result analogous to that of the famous Artin Rees theorem is obtained in case of such an N-group. It is observed that the set of minimal strictly prime ideals of such a near-ring is finite. Non-singular character of an N-group of above type gives that the intersection of associated strictly primes of the same is the nil radical of the annihilator of the group.

Keywords: Near-rings, near-ring groups, strictly finite Goldie dimension, near-ring of quotients.

INTRODUCTION

A. Oswald in [5] has obtained some results on the structure of semi-prime near rings with acc on annihilators. Satyanarayana in [7] proved some analogous results of an FGD N-group. Here we prove some important results on an N-group with what we have called a strictly FGD satisfying the acc on annihilators.

Throughout our discussion, unless otherwise specified, N will denote a zero symmetric right near ring with unity and E a left N-group. A *left N-subgroup* of N is an N-subgroup of $_NN$ and a *right N-subgroup* A is an additive subgroup of N such that $AN \subseteq A$. An *invariant sub near ring* of N as in Pilz [6] will mean a left as well as right subgroup of N. If A and B are two N-subgroups of E with $A \subseteq B$, then A is *strictly essential N-subgroup* of B if any non zero subgroup C of B has nonzero intersection with A. We denote this by $A \underset{se}{\subseteq} B$. If $A \underset{se}{\subseteq} B$ then B is called a *strictly essential extension* of A. If an ideal M of E has non zero intersection with any non-zero ideal of E then M is called an *essential ideal* of E and this is denoted by $M \underset{e}{\subseteq} E$. If A, B are N-subgroup of E, $A \subseteq B \subseteq E$ then $A \underset{se}{\subseteq} E$ if and only if $A \underset{se}{\subseteq} B \underset{se}{\subseteq} E$. If an N-subgroup A of E has no proper strictly essential extension in E then A is a *closed N-subgroup* of E. We denote it by $A \underset{c}{\subseteq} E$. In other words $A \underset{c}{\subseteq} E$ means if A, B are N-subgroup of E and $A \underset{sc}{\subseteq} B \subseteq E$ then A=B. An ordered family $\{A_1, A_2, A_3, \ldots\ldots A_t,\}$ of N-subgroups of E is called an *independent family* if $(A_1 + A_2 + \ldots\ldots A_i + \ldots\ldots A_t) \cap A_i = 0$, for $1 \leq i \leq t$ (the symbol ^ denotes omission of A_i).

---

*Corresponding Author. *hsaikia@yahoo.com*

MS Received September 10, 2008; Accepted September 8, 2009

The *annihilator* of any subset S of E is Ann(S) $=\{n \in N \mid ns = 0, \text{for all } s \in S\}$. It is to be noted that if S is an N-subgroup of E then Ann(S) is an ideal of N. A non zero N-subgroup L of E is a *prime N-subgroup* of E if for each non zero N-subgroup K of L, Ann(K)=Ann(L). If E is a prime N-subgroup of itself, then E is a *prime N-group.* An ideal I of N is *strictly prime ideal* of N if for invariant sub near-rings A, B of N, $AB \subseteq I$ implies either $A \subseteq I$ or $B \subseteq I$.

When N is a distributively generated near ring (dgnr) and if K is a prime N-subgroup of E then Ann(K) is a strictly prime ideal of N. For two invariant sub near- rings U, V of N with $UV \subseteq$ Ann(K), $V \not\subseteq$ Ann(K) give UVK =0 and VK $\neq 0$, $U \subseteq$ Ann(VK). But N being a dgnr, VK is a non zero N-subgroup of K which is a prime N-subgroup of E. So Ann(VK) =Ann(K). The collection $\mathcal{P}(E) = \{P \mid P = \text{Ann}(M), \text{ for some prime N-subgroup M of E}\}$ is defined as the family of associated strictly primes of E. An N-group is primary if $\mathcal{P}(E)$ is singleton. But the converse is not true. For example $E=Z_p^{\,2}$ is an N-group (when N = Z, p a prime) which is not prime, because Ann(E) = (P^2) and for its N-subgroup $G=\{0,p,2p....(p-1)P\}=(p)$, Ann(G) = (p) and Ann(E) $\neq$ Ann(G). But E has only one prime N-subgroup G. For a prime N-subgroup K' of E if there is a closed N-subgroup K of E which is a prime N-subgroup of E and $K' \subseteq K$ then K is a *closed prime extension* of K'.

N-group E is with *strictly FGD* (finite Goldie dimension) if it has no infinite independent family of non zero N-subgroups of E. So an N-group with strictly FGD is an N-group with FGD as in Satyanarayana [7]. As in case of a fully Goldie ring [4] we say a strictly FGD N-group with acc on annihilators is *fully strictly FGD* with acc on annihilators if every homomorphic image of it also inherits the same property. A strictly FGD N-group E is called a *closed prime complete N-group* if for any prime N-subgroup $\frac{K}{E'}$ of $\frac{E}{E'}$ has a closed prime normal extension $\frac{T}{E'}$ such that $E' \subseteq K \subseteq T \underset{c}{\subseteq} E$.

Here we establish a unique closed primary decomposition of 0 in a strictly FGD N-group with acc on annihilators. A result analogous to that of the famous Artin-Rees theorem is established in case of such an N-group in which the proof is similar to that of ring theory.

Moreover it is observed that the set of minimal strictly prime ideals of a strictly semi prime near ring with acc on annihilators if finite. Nonsingular character of a strictly FGD N-group with acc on annihilators gives that the intersection of associated strictly primes of the same is nothing but the nil radical of the annihilator of the group.

In what follows N will mean a dgnr with 1.

PRELIMINARIES

If E is a non zero N-group satisfying acc on annihilators then the collection of annihilators of non zero N-subgroup of E has a maximal element Ann(K) and this K is a prime N-subgroup of E. Conversely if E=0, then E has no prime N-subgroup. So $\mathcal{P}(E)=\phi$. Thus for an N-group with acc on annihilators we have $\mathcal{P}(E)=\phi$ if and only if E=0. We now get the following.

Lemma2.1: [3] For an exact sequence $0 \rightarrow E_1 \rightarrow E \rightarrow E_2 \rightarrow 0$ of N-groups E_1, E, E_2 we have $\mathcal{P}(E_1) \subseteq \mathcal{P}(E) \subseteq \mathcal{P}(E_1) \cup \mathcal{P}(E_2)$.

Lemma 2.2:[3] If E_1 and E_2 are N-subgroups of E then

$$\mathcal{P}(E_1 \oplus E_2)=\mathcal{P}(E_1) \cup \mathcal{P}(E_2).$$

Lemma 2.3:[3] If P, Q, K are N-subgroups of E where K is a normal N-subgroup of E such that $K \subseteq P$, Q then

$$\mathcal{P}\left(\frac{P \cap Q}{K}\right)=\mathcal{P}\left(\frac{P}{K} \cap \frac{Q}{K}\right) \subseteq \mathcal{P}\left(\frac{P}{K}\right) \cap \mathcal{P}\left(\frac{Q}{K}\right).$$

Lemma 2.4: If K is a normal N-subgroup of E such that A is a closed N-subgroup of E with $K \subseteq A \subseteq_c E$, then $\frac{A}{K} \subseteq_c \frac{E}{K}$.

Lemma 2.5: A strictly FGD N-group E satisfies acc on its closed normal N-subgroups.

Lemma 2.6: Let A and H be N-subgroups of E such that $H \subseteq A$ and H is a strictly essential N-subgroup of A. If $a \in A$, $a \neq 0$ then there is a strictly essential N-subgroup L of ${}_N N$ such that $La \subseteq H$, $La \neq 0$.

Lemma 2.7: If $Z_1(E) = 0$ then for any annihilators P,Q of subsets of E in N with $P \subseteq Q$ and P is a strictly essential N-subgroup of Q give P=Q.

Lemma 2.8: Let ${}_N N$ be with FGD and an essential left ideal of N is strictly essential as N-subgroup of ${}_N N$. If E satisfies the acc on its annihilators with $Z_1(E)=0$ then the annihilators of subsets of E in N satisfies the dcc.

Lemma 2.9: Let E be a closed prime complete N-group with strictly FGD and acc on annihilators. If $\mathcal{P}(E) = X \cup Y$ where $X \cap Y = \phi$, then there exists a closed normal N-subgroup E′ of E such that $\mathcal{P}(E') = X$ and $\mathcal{P}(\frac{E}{E'}) = Y$.

Proof: Let $\mathcal{B} = \left\{ K \underset{c}{<} E \mid \mathcal{P}(K) \subseteq X \right\}$. As 0 is a closed normal N-subgroup of E and $\mathcal{P}(0) = \phi$ we have $\mathcal{B} \neq \phi$ (since $\phi \subseteq X$). By lemma 2.5, $\mathcal{B}$ has a maximal element E′.

Also by lemma1.1, $X \cup Y \subseteq X \cup \mathcal{P}\left(\frac{E}{E'}\right)$. Since $X \cap Y = \phi$ we have $Y \subseteq \mathcal{P}\left(\frac{E}{E'}\right)$ of $\mathcal{P}\left(\frac{E}{E'}\right) \not\subseteq Y$ then there exists a prime $\frac{K}{E'}$ of $\frac{E}{E'}$ such that

$\text{Ann}\left(\frac{K}{E'}\right) \subseteq \mathcal{P}\left(\frac{E}{E'}\right)$ and $\text{Ann}\left(\frac{K}{E'}\right) \notin Y$. By hypothesis there is a closed prime normal extension $\left(\frac{T}{E'}\right)$ such that $\frac{K}{E'} \subseteq \frac{T}{E'} \underset{c}{<} \frac{E}{E'}$ and $E' \subseteq K \subseteq T < E$. Thus T is a closed normal N-subgroup of E. Since $\frac{T}{E'}$ is non-zero $E' \subseteq T$ and $\text{Ann}\left(\frac{T}{E'}\right) = \text{Ann}\left(\frac{K}{E'}\right)$. Since $\left(\frac{T}{E'}\right)$ is prime, $\mathcal{P}\left(\frac{T}{E'}\right)$ is a singleton set {P}. Thus $\mathcal{P}\left(\frac{T}{E'}\right) = P$ and $P \notin Y$. By lemma 2.1,

$\mathcal{P}(\mathrm{T}) \subseteq \mathcal{P}(\mathrm{E}') \cup \mathcal{F}\left(\frac{\mathrm{T}}{\mathrm{E}'}\right)$. Since $\mathcal{P}(\mathrm{E}') \subseteq \mathrm{X}$ and $\mathcal{F}\left(\frac{\mathrm{T}}{\mathrm{E}'}\right) = \mathrm{P}$ we get $\mathcal{F}(\mathrm{T}) \subseteq \mathrm{X} \cup \mathrm{P}$. Also T $\subseteq$ E and $\mathcal{F}(\mathrm{E}) = \mathrm{X} \cup \mathrm{Y}$ gives $\mathcal{F}(\mathrm{T}) \subseteq \mathrm{X} \cup \mathrm{Y}$. So $\mathrm{P} \notin \mathrm{Y}$ gives $\mathcal{F}(\mathrm{T}) \subseteq \mathrm{X}$. Thus T $\in$ $\mathcal{B}$ and this contradict the maximality of E'. Thus $\mathcal{F}\left(\frac{\mathrm{E}}{\mathrm{E}'}\right) \subseteq \mathrm{Y}$. So $\mathrm{X} \cup \mathrm{Y} \subseteq \mathcal{F}(\mathrm{E}') \cup \mathrm{Y}$ and $\mathrm{X} \cap \mathrm{Y} = \phi$ gives $\mathrm{X} \subseteq \mathcal{F}(\mathrm{E}')$.

Lemma 2.10: Let E be a closed prime complete N-group with strictly FGD and acc on annihilators. Then $\mathcal{F}(\mathrm{E})$ finite.

Proof: Let P $\in \mathcal{F}(\mathrm{E})$ and $\mathcal{F}(\mathrm{E}) = \mathrm{P} \cup \mathrm{Y}, \mathrm{P} \notin \mathrm{Y}$. Then by lemma 2.9, there exists a closed normal N-subgroup E' of E such that $\mathcal{F}(\mathrm{E}') = \mathrm{P}$ and $\mathcal{F}\left(\frac{\mathrm{E}}{\mathrm{E}'}\right) = \mathrm{Y}$. Thus $\mathcal{P}(\mathrm{E}') \cup \mathcal{F}\left(\frac{\mathrm{E}}{\mathrm{E}'}\right)$.

Now if Q $\in$ $\mathcal{F}$ (E) we have Q $\in \mathcal{F}\left(\frac{\mathrm{E}}{\mathrm{E}'}\right)$. So for some prime N-subgroup $\left(\frac{\mathrm{B}'}{\mathrm{E}'}\right)$ of $\left(\frac{\mathrm{E}}{\mathrm{E}'}\right)$, Ann $\left(\frac{\mathrm{B}'}{\mathrm{E}'}\right) = \mathrm{Q}$. So there is a closed prime extension $\left(\frac{\mathrm{E}''}{\mathrm{E}'}\right)$ such that $\frac{\mathrm{B}'}{\mathrm{E}'} \subseteq \frac{\mathrm{E}''}{\mathrm{E}'} \lhd_{c} \frac{\mathrm{E}}{\mathrm{E}'}$ and $\mathrm{E}' \subseteq \mathrm{B}' \subseteq \mathrm{E}'' \underset{c}{<} E'$. Hence $\mathrm{Ann}\left(\frac{\mathrm{E}''}{\mathrm{E}'}\right) = \mathrm{Ann}\left(\frac{\mathrm{B}'}{\mathrm{E}'}\right) = \mathrm{Q}$. Also by lemma2.1, $\mathcal{P}(\mathrm{E}) \subseteq \mathcal{P}(\mathrm{E}'') \cup \mathcal{F}\left(\frac{\mathrm{E}}{\mathrm{E}''}\right)$ which gives $\mathcal{F}$ (E) $\subseteq$ {P, Q} $\cup \mathcal{F}\left(\frac{\mathrm{E}}{\mathrm{E}''}\right)$. Thus if there is another element in $\mathcal{F}$ (E) other than P, Q it must be in $\mathcal{F}\left(\frac{\mathrm{E}}{\mathrm{E}''}\right)$. In like manner we get another closed normal N-subgroups E''' of E such that $\mathrm{E}' \subset \mathrm{E}'' \subset \mathrm{E}'''$.......... If $\mathcal{F}$ (E) is infinite we get a strictly ascending infinite sequence of closed normal N-subgroups, which contradicts the character of E because of lemma 2.5. Hence $\mathcal{F}$ (E) is finite.

If S is a multiplicative subset of N such that $S \subseteq$ center of N then we consider the set $M = \{n/s \mid n \in N\ s \in S\}$. Let n_1/s_1 and $n_2/s_2 \in M$ Then $n_1/s_1 \sim n_2/s_2$ if there exists $s \in S$ such that $s(n_1s_2-n_2s_1) = 0$. The relation $\sim$ is an equivalence relation. The equivalence class of n/s is denoted by $[n/s]$. The set of distinct equivalence classes is denoted by N_S and N_S forms a near-ring under the operations $[n_1/s_1] + [n_2/s_2] = [(n_1s_2+n_2s_1)/s_1s_2]$ and $[n_1/s_1]\ [n_2/s_2] = [n_1n_2/s_1\ s_2]$. If we assume $s(e_1+e_2) = se_1+se_2$ for every $s \in S$ and $e_1, e_2 \in E$ then we define an equivalence relation in the set $\{e/s\ e \in E,\ s \in S\}$ by $e_1/s_1 \sim e_2/s_2$ if there exists $s \in S$ such that $s(s_2\ e_1-s_1\ e_2) = 0$. The set of all equivalence classes is denoted by E_S. Then E_S forms an N_S-group under the operations $[e_1/s_1] + [e_2/s_2] = [(s_2e_1+s_1e_2)/s_1s_2]$ and $[n/s]\ [e/s_1] = [n\,e/s\ s_1]$. If A is a left ideal of N then the set $AN_S = \{t[a/1] \mid t \in N_S,\ a \in A\}$ is a left ideal of N_S.

Lemma 2.11: If $0 \to E' \xrightarrow{i} E \xrightarrow{j} E'' \to 0$ is an exact sequence of N-groups then $0 \to E'_S \xrightarrow{\hat{i}} E_S \xrightarrow{\hat{j}} E''_S \to 0$ is an exact sequence of N_S-group.

Proof: We consider the sequence is $0 \to E'_S \xrightarrow{\hat{i}} E_S \xrightarrow{\hat{j}} E''_S \to 0$

We define $\hat{i} : E_S' \to E_S$ by $\hat{i}([e'/s]) = [i(e')/s]$ and $\hat{j} : E_S \to E_S''$ by $\hat{j}([e/s]) = [j(e)/s]$

Now $\hat{i}$ and $\hat{j}$ are well defined. Also Ker $\hat{i} = 0$, Im $\hat{j} = 0$

Next, let $\hat{i}[e'/s] \in \text{Im}\,\hat{i},\ e' \in E', s \in S$

Then $\hat{i}[e'/s] = [i(e')/s] \in \text{Ker}\,\hat{j},\ i(e') \in \text{Im}\, i = \text{Ker}\, j$. This implies $\text{Im}\hat{i} \subseteq \text{Ker}\,\hat{j}$

Let $[e''/s] \in \operatorname{Ker} \hat{j}$, then $\hat{j}[e''/s] = 0 = [0/1]$ this gives $e'' \in \operatorname{Ker} j = \operatorname{Im} i$. Thus $[e''/s] \in \operatorname{Im} \hat{i}$. Thus $\operatorname{Ker} \hat{j} \subseteq \operatorname{Im} \hat{i}$. Hence $\operatorname{Im} \hat{i} = \operatorname{Ker} \hat{j}$. Therefore the sequence $0 \to E''_S \xrightarrow{\hat{i}} E_S \xrightarrow{\hat{j}} E''_S \to 0$ is exact.

MAIN RESULTS

Now we prove our main results

Theorem 3.1: Let E be a strictly FGD with acc on annihilators as above. Then the following results hold.

(I) There exists a closed primary decomposition of 0 in E.

(II) If $E_1 \cap E_2 \cap \ldots\ldots\ldots \cap E_t$ a closed primary decomposition of 0 in E then $\mathcal{P}(E) = \mathcal{P}\left(\frac{E}{E_1}\right) \cup \ldots\ldots\ldots \cup \mathcal{P}\left(\frac{E}{E_t}\right)$.

Proof: By lemma 2.10, $\mathcal{P}(E)$ is finite. Let $\mathcal{P}(E) = \{P_1, \ldots\ldots\ldots P_t\} = \{P_1, \ldots \hat{P}_i, \ldots. P_t\} \cup \{P_i\}$. Then by lemma2.9 we get closed normal N-subgroups $E_1, \ldots\ldots\ldots E_t$ of E such that for each i,

$$\mathcal{P}(E_i) = \{P_1, \ldots \hat{P}_i, \ldots. P_t\} \text{ and } \mathcal{P}\left(\frac{E}{E_i}\right) = \{P_i\} \text{ since each } \frac{E}{E_i} \text{ is primary and}$$

$\mathcal{P}\left(\frac{E}{E_i}\right) \neq \mathcal{P}\left(\frac{E}{E_j}\right)$ for $i \neq j$ and $\mathcal{P}(E_1 \cap \ldots\ldots \cap E_t) \subseteq \mathcal{P}(E_1) \cap \ldots\ldots \cap \mathcal{P}(E_t) = \phi$, we then have $\mathcal{F}(E_1 \cap \ldots\ldots \cap E_t) = \phi$ and so $E_1 \cap \ldots\ldots \cap E_t = 0$. If for some i, $E_1 \cap \ldots\ldots \hat{E}_i \ldots\ldots \cap E_t = 0$ then we get the homomorphism.

$$\alpha : E \to \bigoplus_{i \neq j} \frac{E}{E_j}, e \to \left(e + E_1, \ldots\ldots, e \hat{+} E_i, \ldots\ldots, e + E_t\right) \text{ with } \operatorname{Ker}\alpha = \{g \in \bigcap_{i \neq j} E_j$$

$= 0\}$. Thus α is an embedding and hence $\mathcal{F}(E) \subseteq \mathcal{F}\left(\bigoplus_{i \neq j} \frac{E}{E_j}\right) = \bigcup_{i \neq j} \mathcal{F}\left(\frac{E}{E_j}\right)$ from lemma 2.2 for each i, that is $\mathcal{F}(E) \subseteq \{P_1, \ldots P_i, \ldots P_t\}$ which is not true. Thus $\bigcap_{j \neq i} E_j \neq 0$.

(II) If $\bigcap_{j=1}^{t} E_i$ is a closed primary decomposition of 0 in E then homomorphism

$E \to \bigoplus_{j=1}^{t} \frac{E}{E_j}$, $e \to (e+E_1, \ldots\ldots, e+E_t)$ is an embedding. So $\mathcal{F}(E) \subseteq \bigcup_{j=1}^{t} \mathcal{F}\left(\frac{E}{E_j}\right)$ by lemma 2.2. Now the embedding $\bigcap_{j \neq i} E_j \to \frac{E}{Ei}$, $e \to e + E_i$ gives $\mathcal{P}\left(\bigcap_{j \neq i} E_j\right) \subseteq \mathcal{F}\frac{E}{Ei}$.

Since $\bigcap_{j \neq i} E_j \neq 0$, $\mathcal{F}\left(\frac{E}{Ei}\right) \neq 0$. Since $\mathcal{F}\left(\frac{E}{Ei}\right)$ is singleton, we get $\mathcal{P}\left(\bigcap_{j \neq i} E_j\right) \subseteq \mathcal{F}\frac{E}{Ei}$.

Hence $\bigcup_{i=1}^{t} \mathcal{P}\left(\frac{E}{Ei}\right) = \bigcup_{i=1} \mathcal{F}\left(\bigcap_{j \neq i} E_j\right)$ and since $\mathcal{P}\left(\bigcap_{j \neq i} E_j\right) \subseteq \mathcal{P}(E)$ for each I, we finally get $\bigcup_{i=1}^{t} \mathcal{P}\left(\frac{E}{Ei}\right) \subseteq \mathcal{P}(E)$. Thus $\mathcal{P}(E) = \bigcup_{i=1}^{t} \mathcal{F}\left(\frac{E}{Ei}\right)$.

For the following result we assume that for every $x \in \bigcap_{P \in \mathcal{F}(E)} P$ satisfies

$x(e_1 + e_2) = xe_1 + xe_2$, for all $e_1, e_2 \in E$.

Theorem 3.2: Let E be an N-group with acc on annihilators, ${}_NN$ is with FGD and E is such that $Z_l(E) = 0$ then for any $x \in \bigcap_{P \in \mathcal{P}(E)} P$. Then there exists $t \in Z^+$ such that

$x^t \in \text{Ann}(E)$.

Proof: Let $x \in \bigcap_{P \in \mathcal{P}(\ )} P$. Then for each positive integer i, we get homomorphisms

$\phi_i : E \to E, e \to x^i e$, $i=1,2,\ldots.$ Clearly $\text{Ker}\phi_i \subseteq \phi_{i+1}$. So $r_E(x^i) \subseteq r_E(x^{i+1})$ which gives

$\text{Ann}(r_E(x^i)) \subseteq \text{Ann}(r_E(x^{i-1}))$. By lemma 2.8 we get $\text{Ann}(r_E(x^t)) \subseteq \text{Ann}(r_E(x^{t+1}))$ for some $t \in Z^+$. Then $r_E\text{Ann}(r_E(x^t)) \subseteq r_E\text{Ann}(r_E(x^{t+1}))$ which is $r_E(x^t) = r_E(x^{t+1})$ or $\text{Ker}\phi_t = \text{Ker}\phi_{t+1}$.

Now in the homomorphism $f: x^tE \to x^tE, x^te \to x^{t+1}e$. If $x^{t+1}e = x^{t+1}e'$, then $x^{t+}1(e-e') = 0$. So $e - e' \in \text{Ker}\phi_{t+1} = \text{Ker}\phi_t$ and thus $x^te = x^te'$. Hence f is injective. Now $x^tE \subseteq E$. So $\mathcal{P}(x^tE) \subseteq \mathcal{P}(E)$. If $x^tE \neq 0$ then there exists a non zero N-subgroup E' of x^tE such that $\text{Ann}(E') \in \mathcal{P}(x^tE)$. Since $x \in P$, for each $P \in \mathcal{P}(E)$ we get $x \in P$ for each $P \in \mathcal{P}(x^tE)$. So $x \in \text{Ann}(E')$. And this gives $xE' = 0$ that is $f(E') = 0$. Since f is injective it follows that $E' = 0$ a contradiction. Hence $x^tE = 0$ that is $x^t \in \text{Ann}(E)$.

Corollary 3.3: When $r \in \sqrt{\text{Ann}(E)}$ and $P \in \mathcal{P}(E)$ then $r^t \in \text{Ann}(E)$, for some $t \in Z^+$ and $P = \text{Ann}(K)$, for some prime N-subgroup K of E. Maximality of P gives $\text{Ann}(r^{t-1}K) = \text{Ann}(E) = P$ and so $r \in P$. Hence by above we get $\bigcap_{P \in \mathcal{P}(E)} P = \sqrt{\text{Ann}(E)}$.

Theorem 3.4: Let the closed prime complete N-group E as in theorem 2.2 and with fully strictly FGD satisfying acc on its annihilators. Then for any ideal B of N, K of E and any $t \in Z^+$ there exists a closed normal N-subgroup E' such that $B^t \subseteq \sqrt{\text{Ann}\left(\frac{E}{E'}\right)}$.

Proof: If N is a distributive near-ring with unity then for an ideal B of N, K of E we easily get [3] BK is an ideal of K. Also we note that, If E is closed prime complete then $\frac{E}{B^tK}$ has a prime closed normal extension for any $t \in Z^+$. If E is with fully strictly FGD satisfying acc on its annihilators lemma 2.9 gives if $\mathcal{C}(\frac{E}{B^tK}) = X \cup Y$, $\mathcal{C}(\frac{K}{B^tK}) = Y$, $X \cap Y = \phi$ then there is an ideal E′ containing B^tK with an exact sequence $0 \to \frac{E'}{B^tK} \to \frac{E}{B^tK} \to \frac{E}{E'} \to 0$ such that $\mathcal{C}(\frac{E}{B^tK}) = X \cup Y$, $X \cap Y = \phi$, $\mathcal{C}(\frac{E'}{B^tK}) = X$ and $\mathcal{C}(\frac{E}{E'}) = Y$. Thus $\mathcal{C}(\frac{K}{B^tK}) = \mathcal{C}(\frac{E}{E'})$. By lemma 2.3 $\mathcal{C}(\frac{E' \cap K}{B^tK}) = \phi$ and so

$B^tK = K \cap E'$. Now if $x_1, x_2, \ldots\ldots, x_t \in B$ then $x_1x_2 \ldots\ldots x_tK \subseteq B^tK$ and so

$x_1x_2 \ldots\ldots x_t \in \mathrm{Ann}(\frac{K}{B^tK})$. Therefore $B^t \subseteq \mathrm{Ann}(\frac{K}{B^tK})$. Again if $x \in \mathrm{Ann}(\frac{K}{B^tK})$ then $xK \subseteq B^tK$. By cor3.3 we have $\bigcap\limits_{P \in \mathcal{C}\left(\frac{K}{B^tK}\right)} P = \sqrt{\mathrm{Ann}\left(\frac{K}{B^tK}\right)}$. If $P = \mathrm{Ann}(\frac{D}{B^tK})$ then $xD \subseteq B^tK$. Thus $x \in \mathrm{Ann}(\frac{D}{B^tK})$ which gives $x \in \bigcap\limits_{P \in \mathcal{C}\left(\frac{K}{B^tK}\right)} P$. So $\mathrm{Ann}\left(\frac{K}{B^tK}\right) \subseteq \sqrt{\mathrm{Ann}\left(\frac{K}{B^tK}\right)} = \sqrt{\mathrm{Ann}\left(\frac{E}{E'}\right)}$, for $\mathcal{C}(\frac{K}{B^tK}) = \mathcal{C}(\frac{E}{E'})$. And it implies $B^t \subseteq \sqrt{\mathrm{Ann}\left(\frac{E}{E'}\right)}$.

Theorem 3.5: Let E be a left N-group. Then $\mathcal{C}(E)$ is equal to the set of strictly prime ideals P for which there exists an N-monomorphism from $\frac{N}{P}$ into E.

Proof: Suppose there exists $0 \to \frac{N}{P} \xrightarrow{f} E$ and P is a strictly prime ideal of ${}_NN$. Let $\frac{A}{P}$ a non-zero N-subgroup of $\frac{N}{P}$ and B, any invariant sub near-ring of N. Then $B(\frac{A}{P}) = 0$ $\Rightarrow BA \subseteq P$ which implies $B \subseteq P$ as P is strictly prime ideal of ${}_NN$. Thus $B(\frac{N}{P}) = 0$

Therefore $\mathrm{Ann}(\frac{A}{P}) = \mathrm{Ann}(\frac{N}{P})$. This implies $\frac{N}{P}$ is a prime N-subgroup of E and $\mathrm{Ann}(\frac{N}{P}) = P$ so $P \in \mathcal{P}(E)$. Now suppose $P \in \mathcal{P}(E)$. Then $P = \mathrm{Ann}(E')$ for some prime N-subgroup E' of E. Let $0 \neq x \in E'$. Then $P = \mathrm{Ann}(Nx) = \mathrm{Ker} f'$ where $f' : N \to E$ is given by $f'(n) = nx$. Thus we get an injective N-homomorphism from $\frac{N}{P}$ into E.

Theorem 3.6: Let E be a left N-group, S a multiplicative set in N, E_S the resulting left N_S group. Then $\mathcal{P}(E_S) = \{PN_S \mid P \in \mathcal{P}(E) \text{ and } P \cap S = \phi\}$.

Proof: Let $P \in \mathcal{P}(E)$ satisfying $P \cap S = \phi$ we want to show $PNs \in \mathcal{P}(E_S)$. By theorem 3.5 it is enough to exhibit an N_S-monomorphism $g: \frac{N_S}{PN_S} \to E_S$. We know there is an N-monomorphism $f: \frac{N}{P} \to E$. The image of n in $\frac{N}{P}$. is denoted by $\bar{n}$. We define

$g: \frac{N_S}{PN_S} \to E_S$ by $g\left(\overline{[n/s]}\right) = \left[f(\bar{n})/s\right]$

Now g is well defined. It can be easily verified that g is homomorphism and g is one-one. We have $\mathcal{P}(E_S) \supseteq \{PN_S \mid P \in \mathcal{P}(E) \text{ and } P \cap S = \phi\}$ Let $\mathcal{P}(E) = X \cup Y$ where $X = \{P \in \mathcal{P}(E) \mid P \cap S = \phi\}, Y = \{P \in \mathcal{P}(E) \mid P \cap S \neq \phi\}$ Then we can find an exact sequence of N-groups $0 \to E' \xrightarrow{i} E \xrightarrow{j} E'' \to 0$ where $\mathcal{P}(E') = X$ and $\mathcal{P}(E'') = \mathcal{P}(\frac{E}{E'}) = Y$.

So by lemma 2.11, $0 \to E'_S \xrightarrow{\hat{i}} E_S \xrightarrow{\hat{j}} E''_S \to 0$ is an exact sequence of N_S-group.

Also we have $\sqrt{\mathrm{Ann}(E'')} = \bigcap_{P \in \mathcal{P}(E'')} P = \bigcap_{P \in Y} P$ by corollary3.3

So since for each $P \in Y$, $P \cap S \neq \phi$ and S is a multiplicative set, we get $\sqrt{\mathrm{Ann}(E'')} \cap S \neq \phi$. Also for some integer n, $\left(\sqrt{\mathrm{Ann}(E'')}\right)^n \subseteq \mathrm{Ann}(E'')$ so we have $\mathrm{Ann}(E'') \cap S \neq \phi$. Thus $E''_S = 0$ Let $\psi : E' \to E'_S$ be given by $\psi(e') = [e'/1]$ If $e' \in \mathrm{Ker}\,\psi$

then $\psi(e') = 0$ implies $[e'/1] = [0/1]$. So there exists such that $s(1.0-1.e') = 0$ this implies $se' = 0$. Thus $s \in \mathrm{Ann}(e') = \mathrm{Ann}(Ne')$. Let $P \in \mathcal{P}(Ne') \subseteq \mathcal{F}(E') = X$, since Ne' is a N-subgroup of E'. Then $s \in P$, contradicting $P \cap S = \phi$. Hence ψ is one-one.

Let $\varphi \subseteq N_S \in \mathcal{P}(E_S) = \mathcal{F}(E_S')$. Then $\varphi = \mathrm{Ann}([x/s])$ for some $x \in E'$, $s \in S$.

Clearly $\varphi = \mathrm{Ann}([x/1])$ and $\varphi \cap N = \mathrm{Ann}(x)$, which is a prime ideal P in N such that $P \cap S = \phi$. Then $P \in \mathcal{P}(E') \subseteq \mathcal{F}(E)$. So $= PN_S \in \{PN_S \mid P \in \mathcal{F}(E) \text{ and } P \cap S = \phi\}$. Therefore $\mathcal{P}(E_S) \subseteq \{PN_S \mid P \in \mathcal{F}(E) \text{ and } P \cap S = \phi\}$.

Corollary 3.7: Let E be a left N-group and S a multiplicative set in N. Then $E_S = 0$ if and only if $\mathrm{Ann}(E) \cap S \neq \phi$.

Proof: Let $E_S = 0$. Then $\mathcal{F}(E_S) = \phi$. Thus $P \cap S \neq \phi$ for all $P \in \mathcal{F}(E)$. This implies $S \cap \left(\bigcap_{P \in \mathcal{F}(E)} P \right) \neq \phi$. Thus $S \cap \sqrt{\mathrm{Ann}(E)} \neq \phi$, by corollary 3.3. Hence $S \cap \mathrm{Ann}(E) \neq \phi$.

Conversely, let $S \cap \mathrm{Ann}(E) \neq \phi$, then $S \cap \sqrt{\mathrm{Ann}(E)} \neq \phi$. This implies $S \cap \left(\bigcap_{P \in \mathcal{F}(E)} P \right) \neq \phi$. Thus $P \cap S \neq \phi$ for all $P \in \mathcal{F}(E)$. Hence $\mathcal{F}(E_S) = \phi$. Therefore $E_S = 0$.

A prime $P \in \mathcal{F}(E)$ is called an *embedded prime* if there is a prime $\varphi \in \mathcal{F}(E)$ such that $P \supseteq \varphi$. Primes in $\mathcal{F}(E)$ which are not embedded are called *isolated primes*.

The following theorem shows the uniqueness decompositions of the zero ideal. Though the proof is similar to that of [1] we give the proof in details.

Theorem 3.8: Let E be as in theorem 3.1 and let $\bigcap_{i=1}^{t} E_i$ be a closed primary decomposition of 0 in E. Then the E_i corresponding to isolated primes P_i are unique. Moreover $E_i = \operatorname{Ker} \varphi_i$, where $\varphi_i : E \to E_{p_i}$

Proof: We consider the diagram

$$\begin{tikzcd}
0 \arrow[r] & E_i \arrow[r] \arrow[d] & E \arrow[r, "f"] \arrow[d, "\phi_i"] & E/E_i \arrow[r] \arrow[d, "g"] & 0 \\
0 \arrow[r] & (E_i)_{P_i} \arrow[r] & E_{P_i} \arrow[r, "f"] & (E/E_i)_{P_i} \arrow[r] & 0
\end{tikzcd}$$

where each of the rows is an exact sequence and all the maps are the obvious ones and P_i is assumed to be an isolated prime.

First we show $(E_i)_{P_i} = 0$. It is sufficient to show $((E_i)_{P_i}) = \phi$, that is, $\{PN_{P_i} \mid P \in \mathcal{P}(E_i) \text{ and } P \cap (N-P_i) = \phi\} = \phi$. But $P \in \mathcal{P}(E_i)$ implies $P \in \mathcal{P}(E)$ which implies $P \cap (N-P_i) \neq \phi$ since P_i is an isolated prime and $P \neq P_i$ by the characteristic of E_i.

Next we show the map $E/E_i \to (E/E_i)_{P_i}$ is one-one.

Let $g: E/E_i \to (E/E_i)_{P_i}$ be given by $g(\overline{m}) = [\overline{m}/1]$. If $\overline{m} \in \operatorname{Ker} g$ then $g(\overline{m}) = 0$. Thus $[\overline{m}/1] = 0$. Therefore there exists $p \in P_i$ such that $p\overline{m} = 0$. This implies $p \in \operatorname{Ann}(\overline{m}) = \operatorname{Ann}\left(\frac{N}{E_i}\overline{m}\right)$

Let $P \in \mathcal{P}\left(\frac{N}{E_i}\overline{m}\right) \subseteq \mathcal{P}\left(\frac{E}{E_i}\right) = X$, since $\left(\frac{N}{E_i}\overline{m}\right)$ is an N-subgroup of $\left(\frac{E}{E_i}\right)$. Then $p \in P$. This contradicts that $P \cap P_i = \phi$.

From the diagram given above we get the following

$$\begin{tikzcd}
 & & & 0 \arrow[d] & \\
0 \arrow[r] & E_i \arrow[r] \arrow[d] & E \arrow[r, "f"] \arrow[d, "\phi_i"] & E/E_i \arrow[r] \arrow[d, "g"] & 0 \\
 & 0 \arrow[r] & E_{P_i} \arrow[r, "f"] & (E/E_i)_{P_i} \arrow[r] & 0
\end{tikzcd}$$

Therefore $E_i = \mathrm{Ker} f = \mathrm{Ker}(g\, f) = \mathrm{Ker}(h\phi_i) = \mathrm{Ker}(\phi_i)$, since $\mathrm{Ker} h = 0$.

Hence the result follows.

ACKNOWLEDGEMENT

The authors are grateful to Prof. K.C. Chowdhury of Department of Mathematics, Gauhati University for his valuable suggestions and comments in preparation of the manuscript.

REFERENCES

Barshay, J. 1969. Topics in ring theory, W. A. Benjamin Inc, New York.

Beidleman, J.C. 1965: A radical for near-ring modules, Mich. Math. J. 12 : 377-383.

Chowdhury, K.C., A. Masum and H.K. Saikia. 1993. FSD N-group with acc on annihilators. *Indian Journal of Pure and applied Mathematics*, 24(2): 747-755.

Jategaonker, A.V. 1970. Left principal ideal rings, Springer Lecture Notes, No. 123.

Oswald, A. 1974. Near-rings in which every N-subgroup is principal. *Proc. London Math. Soc.*, (3) 28: 67-88.

Pilz, G. 1977. Near-rings, North Holland, Amsterdam.

Satyanarayan, B. 1984. Contribution to near-ring theory, Doctoral dissertation, Nagarjuna University.

Pb. Univ. Res. J (Sci.), Vol. 59, 2009, pp. 227-235

ON AN EXTON'S GENERALIZED QUADRUPLE HYPERGEOMETRIC FUNCTION OF MATRIX ARGUMENTS

***Lalit Mohan Upadhyaya[1] and H.S. Dhami[2]**

[1]Department of Mathematics, Municipal Post Graduate College, Mussoorie, Dehradun, Uttarakhand - 248179
[2]H. S. Dhami, Department of Mathematics, University of Kumaun, Almora Campus, Almora, Uttarakhand - 263601

Abstract

In continuation of our previous studies [7-10] we have defined the Exton's ${}^{(k)}_{(l)}E^{(n)}_D$ function for the matrix arguments case in this paper and have established two integral representations for it along with a case of reducibility.

Keywords: Exton's function ${}^{(k)}_{(l)}E^{(n)}_D$, matrix arguments, matrix transform.

INTRODUCTION

Exton [1, 2] has given two functions ${}^{(k)}_{(1)}E^{(n)}_D$ and ${}^{(k)}_{(2)}E^{(n)}_D$ which, according to him, are the generalizations of certain of the quadruple hypergeometric functions discussed by him in [2]. In the present paper the Exton's ${}^{(k)}_{(1)}E^{(n)}_D$ function has been generalized by us to the case of matrix variables with real symmetric positive definite matrices as arguments by using the Mathai's matrix transform technique. The matrices appearing in this paper are all real symmetric and positive definite with order $(p \times p)$. $A > 0$ will mean that the matrix is positive definite, $A^{1/2}$ will represent the symmetric square root of A. While integrating over matrices $\int_X f(X)dX$ represents integral over X of the scalar function $f(X)$. $\mathrm{Re}(.)$ denotes the real part of (.).

We begin with quoting some preliminary results and definitions which occur in the literature. Mathai [3] in 1978 defined the matrix transform (M- transform) of a function $f(X)$ of a $(p \times p)$ real symmetric positive definite matrix X as follows:

$$M_f(\rho) = \int_{X>0} |X|^{\rho-(p+1)/2} f(X)dX \tag{1.1}$$

for $X > 0$ and $\mathrm{Re}(\rho) > (p-1)/2$, whenever $M_f(s)$ exists.

The following results and definition will be used by us at various places in this paper.

---

*Corresponding Author: lmupadhyaya@rediffmail.com

MS Received December 24, 2009; Accepted July 9, 2010

Theorem 1.1: Mathai [4] (eq. 2.24, p.23)- Let X and Y be $(p \times p)$ symmetric matrices of functionally independent real variables and A a $(p \times p)$ non singular matrix of constants. Then,

$$Y = AXA' \Rightarrow dY = |A|^{p+1} \, dX \tag{1.2}$$

and

$$Y = aX \Rightarrow dY = a^{p(p+1)/2} dX \tag{1.3}$$

where a is a scalar quantity.

Theorem 1.2: Mathai [4] (eq. 6.6, 6.7, p.95)- Consider k real $(p \times p)$ matrices $X_1, \ldots, X_k$ transformed to the $(p \times p)$ matrices $Y_1, \ldots, Y_k$ by the relations

$$Y_1 = X_1, Y_2 = X_1 + X_2, \ldots, Y_k = X_1 + \ldots + X_k$$

then. $dY_1 \ldots dY_k = dX_1 \ldots dX_k$.

Theorem 1.3: Type-1 beta integral (Mathai [5], eq.(2.2.2), p.34 and eq. (2.1.2), p.32)-

$$B_p(\alpha,\beta) = \int_{0<X<I} |X|^{\alpha-(p+1)/2} |I - X|^{\beta-(p+1)/2} \, dX = \frac{\Gamma_p(\alpha)\Gamma_p(\beta)}{\Gamma_p(\alpha+\beta)} \tag{1.4}$$

for $\mathrm{Re}(\alpha) > (p-1)/2, \mathrm{Re}(\beta) > (p-1)/2$ where,

$$\Gamma_p(\alpha) = \pi^{p(p-1)/4} \Gamma(\alpha)\Gamma(\alpha - \tfrac{1}{2}) \ldots \Gamma(\alpha - \tfrac{p-1}{2}) \tag{1.5}$$

for $\mathrm{Re}(\alpha) > (p-1)/2$.

Theorem 1.4: Gamma integral (Mathai [5], eq.(2.1.3), p.33)- For real symmetric positive definite matrices X and B of order $(p \times p)$,

$$\int_{X>0} |X|^{\alpha-(p+1)/2} e^{-tr(BX)} dX = |B|^{-\alpha} \, \Gamma_p(\alpha) \tag{1.6}$$

for $\operatorname{Re}(\alpha) > (p-1)/2$, where, $tr(X)$ denotes the trace of the matrix X.

Theorem 1.5: Type-1 Dirichlet integral (Mathai [5], eq. (3.1.1), p. 50)-

$$\int \cdots \int |X_1|^{\alpha_1-(p+1)/2} \cdots |X_k|^{\alpha_k-(p+1)/2} |I - X_1 - \cdots - X_k|^{\alpha_{k+1}-(p+1)/2} dX_1 \cdots dX_k$$
$$= \frac{\Gamma_p(\alpha_1) \cdots \Gamma_p(\alpha_{k+1})}{\Gamma_p(\alpha_1 + \cdots + \alpha_{k+1})} \tag{1.7}$$

for $\operatorname{Re}(\alpha_j) > (p-1)/2, 0 < X_j = X_j' < I, j = 1, \cdots, k; 0 < X_1 + \cdots + X_k < I$.

Theorem 1.6: Type-2 Dirichlet integral (Mathai [5], eq.(3.1.6), p.52)-

$$\int_{X_1>0} \cdots \int_{X_k>0} |X_1|^{\alpha_1-(p+1)/2} \cdots |X_k|^{\alpha_k-(p+1)/2} \times$$
$$|I + X_1 + \cdots + X_k|^{-(\alpha_1 + \cdots + \alpha_{k+1})} dX_1 \cdots dX_k \tag{1.8}$$
$$= \frac{\Gamma_p(\alpha_1) \cdots \Gamma_p(\alpha_{k+1})}{\Gamma_p(\alpha_1 + \cdots + \alpha_{k+1})}$$

for $\operatorname{Re}(\alpha_j) > (p-1)/2$, where, $j = 1, \cdots, k+1$.

Theorem 1.7: Mathai [5] (eq.(2.3.9), p. 40)- For X and Y real symmetric positive definite $(p \times p)$ matrices and b a scalar

$$\lim_{b\to\infty} \left| I + \frac{XY}{b} \right|^{-b} = e^{-tr(XY)} \tag{1.9}$$

Theorem 1.8: Mathai [5] (eq. (2.3.13), p.42)-

$${}_1F_1(a; c; -X) = \frac{\Gamma_p(c)}{\Gamma_p(a)\Gamma_p(c-a)} \int_0^I |Y|^{a-(p+1)/2} |I - Y|^{c-a-(p+1)/2} e^{-tr(XY)} dY \tag{1.10}$$

for $\operatorname{Re}(a, c-a) > (p-1)/2$.

Definition 1.1:

$$\Phi_2^{(n)} = \Phi_2^{(n)}(b_1,\ldots,b_n;c;-X_1,\ldots,-X_n)$$

$$M(\Phi_2^{(n)}) = \int_{X_1>0}\ldots\int_{X_n>0} |X_1|^{\rho_1-(p+1)/2}\ldots|X_n|^{\rho_n-(p+1)/2}\times$$

$$\Phi_2^{(n)}(b_1,\ldots,b_n;c;-X_1,\ldots,-X_n)dX_1\ldots dX_n$$

$$=\frac{\Gamma_p(c)\left\{\prod_{j=1}^{n}\Gamma_p(b_j-\rho_j)\right\}\left\{\prod_{j=1}^{n}\Gamma_p(\rho_j)\right\}}{\left\{\prod_{j=1}^{n}\Gamma_p(b_j)\right\}\Gamma_p(c-\rho_1-\ldots-\rho_n)} \qquad (1.11)$$

for $\mathrm{Re}(b_j-\rho_j,c-\rho_1-\ldots-\rho_n,\rho_j)>(p-1)/2, j=1,\ldots,n$.

DEFINITION OF THE EXTON'S ${}^{(k)}_{(1)}E_D^{(n)}$ FUNCTION

Definition 2.1: The Exton's ${}^{(k)}_{(1)}E_D^{(n)}$ function of matrix arguments

$${}^{(k)}_{(1)}E_D^{(n)} = {}^{(k)}_{(1)}E_D^{(n)}(a,b_1,\ldots,b_n;c,c';-X_1,\ldots,-X_n)$$

is defined as that class of functions which has the following M-transform:

$$M\left({}^{(k)}_{(1)}E_D^{(n)}\right) = \int_{X_1>0}\ldots\int_{X_n>0} |X_1|^{\rho_1-(p+1)/2}\ldots|X_n|^{\rho_n-(p+1)/2}\times$$

$${}^{(k)}_{(1)}E_D^{(n)}(a,b_1,\ldots,b_n;c,c';-X_1,\ldots,-X_n)dX_1\ldots dX_n \qquad (2.1)$$

$$=\frac{\Gamma_p(a-\rho_1-\ldots-\rho_n)\Gamma_p(b_1-\rho_1)\ldots\Gamma_p(b_n-\rho_n)\Gamma_p(c)\Gamma_p(c')}{\Gamma_p(a)\Gamma_p(b_1)\ldots\Gamma_p(b_n)\Gamma_p(c-\rho_1-\ldots-\rho_k)\Gamma_p(c'-\rho_{k+1}-\ldots-\rho_n)}\times$$

$$\Gamma_p(\rho_1)\ldots\Gamma_p(\rho_n)$$

for

$$\mathrm{Re}(a-\rho_1-\ldots-\rho_n,b_i-\rho_i,c-\rho_1-\ldots-\rho_k,c'-\rho_{k+1}-\ldots-\rho_n,\rho_i)>(p-1)/2,$$

where, $i=1,\ldots,n$.

RESULTS

Theorem 3.1:

$$
\begin{aligned}
&{}^{(k)}_{(1)}E_D^{(n)}(a,b_1,\cdots,b_n;c,c';-X_1,\cdots,-X_n)\\
&=\frac{\Gamma_p(c)\Gamma_p(c')}{\Gamma_p(b_1)\cdots\Gamma_p(b_n)\Gamma_p(c-b_1-\cdots-b_k)\Gamma_p(c'-b_{k+1}-\cdots-b_n)}\times\\
&\int\cdots\int|U_1|^{b_1-(p+1)/2}\cdots|U_n|^{b_n-(p+1)/2}|I-U_1-\cdots-U_k|^{c-b_1-\cdots-b_k-(p+1)/2}\times\\
&|I-U_{k+1}-\cdots-U_n|^{c'-b_{k+1}-\cdots-b_n-(p+1)/2}\left|I+U_1^{1/2}X_1U_1^{1/2}+\cdots+U_n^{1/2}X_nU_n^{1/2}\right|^{-a}\times\\
&dU_1\cdots dU_k dU_{k+1}\cdots dU_n
\end{aligned}
\tag{3.1}
$$

for $U_i=U_i'>0, 0<U_1+\cdots+U_k<I, 0<U_{k+1}+\cdots+U_n<I$ and

$\mathrm{Re}(b_i,c-b_1-\cdots-b_k,c'-b_{k+1}-\cdots-b_n)>(p-1)/2$, where, $i=1,\cdots,n$.

Proof: Taking the M-transform of the right side of eq.(3.1) with respect to the variables $X_1,\cdots,X_n$ and the parameters $\rho_1,\cdots,\rho_n$ respectively we obtain,

$$
\begin{aligned}
&\int_{X_1>0}\cdots\int_{X_n>0}|X_1|^{\rho_1-(p+1)/2}\cdots|X_n|^{\rho_n-(p+1)/2}\times\\
&\left|I+U_1^{1/2}X_1U_1^{1/2}+\cdots+U_n^{1/2}X_nU_n^{1/2}\right|^{-a}dX_1\cdots dX_n
\end{aligned}
\tag{3.2}
$$

On applying the transformations,

$Y_i=U_i^{1/2}X_iU_i^{1/2}$ (with $dY_i=|U_i|^{(p+1)/2}dX_i$ (from theorem (1.1)) and $|Y_i|=|U_i||X_i|$ where, $i=1,\cdots,n$; in the above expression and then integrating out the variables $Y_1,\cdots,Y_n$ by using a type-2 Dirichlet integral (Theorem (1.6)), we are led to,

$$|U_1|^{-\rho_1}\ldots|U_n|^{-\rho_n}\frac{\Gamma_p(\rho_1)\ldots\Gamma_p(\rho_n)\Gamma_p(a-\rho_1-\ldots-\rho_n)}{\Gamma_p(a)} \tag{3.3}$$

Substituting this expression on the right side of eq.(3.1) and then integrating out $U_1,\ldots,U_k$ and $U_{k+1},\ldots,U_n$ in the resulting expression by using a type-1 Dirichlet integral (Theorem (1.5)) we have $M\left({}^{(k)}_{(1)}E_D^{(n)}\right)$as given by eq. (2.1), thus finishing the proof.

It may be easily seen with the help of Theorem (1.7) that a limiting form of eq.(3.1) has the following form:

$$\lim_{\alpha\to\infty}{}^{(k)}_{(1)}E_D^{(n)}\left(\alpha,b_1,\ldots,b_n;c,c';\frac{-X_1}{\alpha},\ldots,\frac{-X_n}{\alpha}\right)$$
$$=\frac{\Gamma_p(c)\Gamma_p(c')}{\Gamma_p(b_1)\ldots\Gamma_p(b_n)\Gamma_p(c-b_1-\ldots-b_k)\Gamma_p(c'-b_{k+1}-\ldots-b_n)}\times$$
$$\int\ldots\int|U_1|^{b_1-(p+1)/2}\ldots|U_n|^{b_n-(p+1)/2}|I-U_1-\ldots-U_k|^{c-b_1-\ldots-b_k-(p+1)/2}\times \tag{3.4}$$
$$|I-U_{k+1}-\ldots-U_n|^{c'-b_{k+1}-\ldots-b_n-(p+1)/2}e^{-tr(U_1X_1+\ldots+U_kX_k)}\times$$
$$e^{tr(U_{k+1}X_{k+1}+\ldots+U_nX_n)}dU_1\ldots dU_n$$

where, $U_i=U_i'>0,0<U_1+\ldots+U_k<I,0<U_{k+1}+\ldots+U_n<I$ and

$\mathrm{Re}(b_i,c-b_1-\ldots-b_k,c'-b_{k+1}-\ldots-b_n,)>(p-1)/2$ for $i=1,\ldots,n$.

Theorem 3.2: A case of reducibility-

$$\lim_{\alpha\to\infty}{}^{(k)}_{(1)}E_D^{(n)}\left(\alpha,b_1,\ldots,b_n;c,c';\frac{-X}{\alpha},\ldots(k)\ldots,\frac{-X}{\alpha},\frac{-Y}{\alpha},\ldots(n-k)\ldots,\frac{-Y}{\alpha}\right) \tag{3.5}$$
$$={}_1F_1(b_1+\ldots+b_k;c;-X)\,{}_1F_1(b_{k+1}+\ldots+b_n;c';-Y)$$

Proof: To prove this theorem we put $X_1 = \ldots = X_k = X$ and $X_{k+1} = \ldots = X_n = Y$ in eq.(3.4) and apply the following transformations to the resulting expression

$V_1 = U_1, V_2 = U_1 + U_2, \ldots, V_k = U_1 + \ldots + U_k$;

and $W_1 = U_{k+1}, W_2 = U_{k+1} + U_{k+2}, \ldots, W_{n-k} = U_{k+1} + \ldots + U_n$ with

$dU_1 \ldots dU_k = dV_1 \ldots dV_k$ and $dU_{k+1} \ldots dU_n = dW_1 \ldots dW_{n-k}$ (from Theorem (1.2)) where, $0 < V_1 < \ldots < V_k < I$ and $0 < W_1 < \ldots < W_{n-k} < I$. Then integrating out the variables $V_1, \ldots, V_{k-1}$ and $W_1, \ldots, W_{n-k-1}$ one-by-one and in order by using a type-1 beta integral (Theorem (1.3)) and finally using the Theorem (1.8) the desired result follows.

Theorem 3.3:

$$\begin{aligned}
&{}^{(k)}_{(1)}E_D^{(n)}(a, b_1, \ldots, b_n; c, c'; -X_1, \ldots, -X_n) \\
&= \frac{1}{\Gamma_p(a)} \int_{U>0} e^{-tr(U)} |U|^{a-(p+1)/2} \Phi_2^{(k)}(b_1, \ldots, b_k; c; -U^{\frac{1}{2}} X_1 U^{\frac{1}{2}}, \\
&\ldots, -U^{\frac{1}{2}} X_k U^{\frac{1}{2}}) \Phi_2^{(n-k)}(b_{k+1}, \ldots, b_n; c'; -U^{\frac{1}{2}} X_{k+1} U^{\frac{1}{2}}, \\
&\ldots, -U^{\frac{1}{2}} X_n U^{\frac{1}{2}}) dU
\end{aligned} \qquad (3.6)$$

for $\mathrm{Re}(a) > (p-1)/2$.

Proof: Taking the M-transform of the right side of eq. (3.6) with respect to the variables $X_1, \ldots, X_n$ and the parameters $\rho_1, \ldots, \rho_n$ respectively we get,

$$\begin{aligned}&\int_{X_1>0}\ldots\int_{X_n>0}|X_1|^{\rho_1-(p+1)/2}\ldots|X_k|^{\rho_k-(p+1)/2}|X_{k+1}|^{\rho_{k+1}-(p+1)/2}\ldots|X_n|^{\rho_n-(p+1)/2}\times\\&\Phi_2^{(k)}(b_1,\ldots,b_k;c;-U^{\frac{1}{2}}X_1U^{\frac{1}{2}},\ldots,-U^{\frac{1}{2}}X_kU^{\frac{1}{2}})\Phi_2^{(n-k)}(b_{k+1},\ldots,b_n;c';\qquad(3.7)\\&-U^{\frac{1}{2}}X_{k+1}U^{\frac{1}{2}},\ldots,-U^{\frac{1}{2}}X_nU^{\frac{1}{2}})dX_1\ldots dX_k dX_{k+1}\ldots dX_n\end{aligned}$$

Employing the transformations, $Y_i=U^{\frac{1}{2}}X_iU^{\frac{1}{2}}$ (with $dY_i=|U|^{(p+1)/2}dX_i$ (from theorem (1.1)) and $|Y_i|=|U||X_i|$ for $i=1,\ldots,n$) in the expression (3.7) and then using the definition (1.1) we arrive at,

$$\begin{aligned}&|U|^{-\rho_1-\ldots-\rho_n}\frac{\Gamma_p(b_1-\rho_1)\Gamma_p(\rho_1)}{\Gamma_p(b_1)}\ldots\frac{\Gamma_p(b_n-\rho_n)\Gamma_p(\rho_n)}{\Gamma_p(b_n)}\times\\&\frac{\Gamma_p(c)\Gamma_p(c')}{\Gamma_p(c-\rho_1-\ldots-\rho_k)\Gamma_p(c'-\rho_{k+1}-\ldots-\rho_n)}\qquad(3.8)\end{aligned}$$

Putting the above expression on the right side of eq.(3.6) and then integrating out the variable U in the resulting expression by using a gamma integral (Theorem (1.4)) produces $M\left({}_{(1)}^{(k)}E_D^{(n)}\right)$ as given by eq.(2.1) which concludes the proof.

ACKNOWLEDGEMENTS

The authors' are grateful to the referees for their valuable comments which have led to the better presentation of the paper.

REFERENCES

Exton, H. 1972. On Two Multiple Hypergeometric Functions Related to Lauricella's $F_D^{(n)}$. *Jnanabha Sect.* A 2: 59-73.

Exton, H. 1976. Multiple Hypergeometric Functions and Applications. *Ellis Horwood Limited, Publishers,* Chichester, U.K.

Mathai, A. M. 1978. Some Results on Functions of Matrix Arguments. *Mathematische Nachrichten,* 84: 171-177.

Mathai, A.M. 1992. Jacobians of Matrix Transformations-I. Centre for Mathematical Sciences, Trivandrum, India.

Mathai, A.M. 1993. Hypergeometric Functions of Several Matrix Arguments. Centre for Mathematical Sciences, Trivandrum , India.

Srivastava, H.M. and P.W. Karlsson. 1985. Multiple Gaussian Hypergeometric Series. *Ellis Horwood Limited, Publishers, Chichester, U.K.*

Upadhyaya, L.M. and Dhami H.S. 2001. Matrix Generalizations of Multiple Hypergeometric Functions. #1818: *IMA Preprint Series, University of Minnesota, Minneapolis, U.S.A.*

Upadhyaya, L.M. and H.S. Dhami. 2001. On Some Multiple Hypergeometric Functions of Several Matrix Arguments. #1821: *IMA Preprint Series, University of Minnesota, Minneapolis, U.S.A.*

Upadhyaya, L.M. and H.S. Dhami. 2002. On Exton's Generalized Quadruple Hypergeometric Functions and Chandel's Function of Matrix Arguments. # 1882: *IMA Preprint Series, University of Minnesota, Minneapolis, U.S.A.*

Upadhyaya, L.M. and H.S. Dhami. Nov. 2003. Matrix Generalizations of Multiple Hypergeometric Functions By Using Mathai's Matrix Transform Techniques (Ph.D. Thesis, Kumaun University, Nainital, Uttarakhand, India). #1943: *IMA Preprint Series, University of Minnesota, Minneapolis, U.S.A.*

Pb. Univ. Res. J (Sci.), Vol. 59, 2009, pp. 237-248

SECURE KEY EXCHANGE (SKE) : PASSWORD BASED PROTOCOL SECURE AGAINST DICTIONARY ATTACK

***Shalini Vermani**

Apeejay School of Management, Sector-8, Institutional Area, Dwarka, New Delhi.

Abstract

SKE is an efficient password authenticated key exchange protocol with human memorable passwords. It is a verifier based protocol secure against *dictionary-attack* and other active attacks. In SKE not only the client has to authenticate itself to the server but also the server has to authenticate itself to the client. It also resists *denial-of-service attack.*

Keywords: Authentication, encryption, key exchange, symmetric key.

INTRODUCTION

The main goal of cryptography is to provide secure communication over insecure channel. Transferring data from one person to another involves problems like confidentiality and authenticity i.e. message is to be read only by the intended party and to make sure that you are communicating with the right person. Communication between users takes place in sessions (a relatively short period of time). To apply encryption and authentication tools users have to establish a shared secret key known as session key.

Diffie-Hellman (1976) introduced a key exchange scheme based on the difficulty of computing discrete logarithms over finite fields. But this scheme is not secure against *man-in-the-middle attack.* In 1992 Bellovin and Merritt presented a protocol named Encrypted Key Exchange (EKE) (Bellovin, Merritt, 1992), which is a variant of Diffie-Hellman key exchange protocol and is secure against *man-in-the-middle attack.* EKE allows two parties sharing even a weak password to establish a secure session key using that password. A password shared once between the client and the server can be used to establish session key as many times as required. In 1994 Bellovin and Merritt gave another method named Augmented Encrypted Key Exchange (A-EKE) (Bellovin, Merritt, 1994) which is an improvement over EKE. There are many other methods given by the researchers which are an improvement over EKE and A-EKE.

In this paper we introduce a password authenticated key exchange protocol SKE (Secure Key Exchange) which is highly secure. In this scheme not only the client has to authenticate itself to the server but also the server has to authenticate itself to the client, which is not in case of earlier systems. In this paper term client is used for the user and server for the host and no trusted third party such as key server is required. It is assumed that the network between the client and the server is vulnerable to attacks.

Section 2 describes Diffie-Hellman key exchange protocol and possible *man-in-the-middle attack* over it. Sections 3 and 4 include review of EKE and A-EKE and it is shown that how EKE is an improvement over Diffie-Hellman protocol and A-EKE is an improvement over EKE. In section 5 SKE scheme is introduced which is based on the concept of A-EKE. Need for server authentication is discussed in section 5.1. Characteristics and security analysis of SKE scheme are given in section 5.2 and 5.3 respectively. Section 5.4 includes a word about the choice of prime h and primitive root $g \bmod h$.

DIFFIE-HELLMAN KEY EXCHANGE PROTOCOL

Suppose key k is to be established between client A and server B. Let h be a large prime and g be a primitive root *mod* h. Make g and h public. Diffie-Hellman protocol is based on the difficulty of computing discrete logarithms over finite fields. According to Diffie-Hellman assumption it is impossible to compute x from $g^x \bmod h$, knowing g and h.

Throughout this paper we use A, B, g and h as taken here.

---

*Corresponding Author. s_vermani_s@yahoo.com

MS Received December 31, 2008; Accepted February 19, 2010

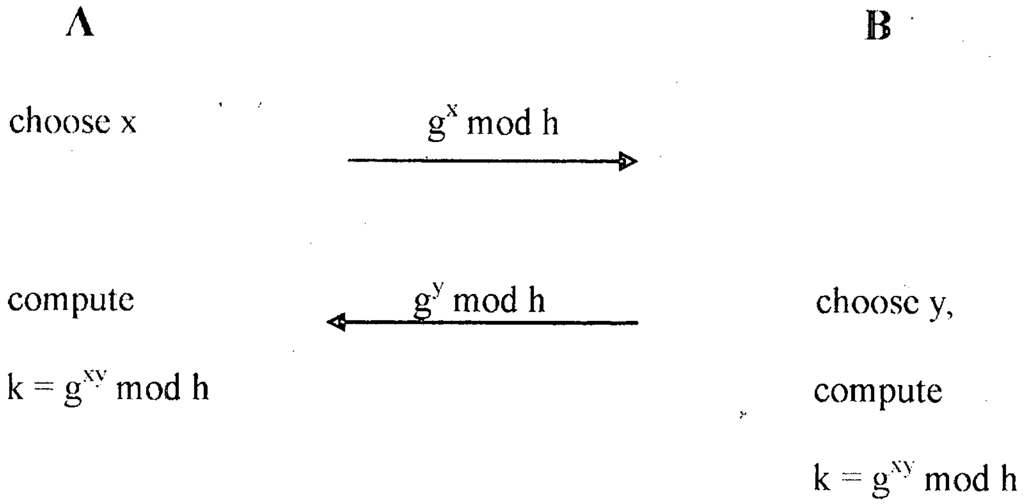


Fig. 1

The above protocol is not secure against man-in-the-middle attack. An attacker can sit between A and B and can make fool of both sides.

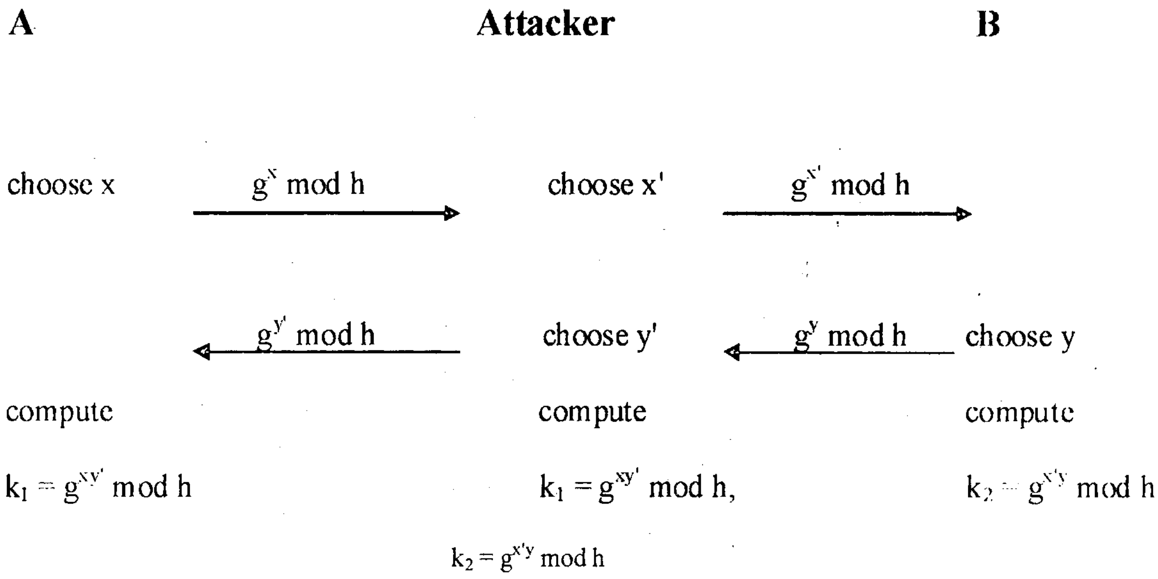


Fig. 2

Now key k_1 is established between A and the Attacker and k_2 is established between the Attacker and B, whereas A and B think that the key is established in-between them. When A sends a message encrypted with k_1 to B, the Attacker can decrypt the message, modify it and then send the modified message encrypted with k_2 to B. The receiver B will think that the message is from A. Similarly the Attacker can modify/listen the messages communicated from B to A. This limitation of Diffie-Hellman method is overcome in EKE.

ENCRYPTED KEY EXCHANGE (EKE)

Suppose two parties A and B want to establish a secure session key k. Initially they share a password p. Communication between A and B is as follows:

Notation: $E_p(m) = m$ encrypted with p

'A' represents identity of client A.

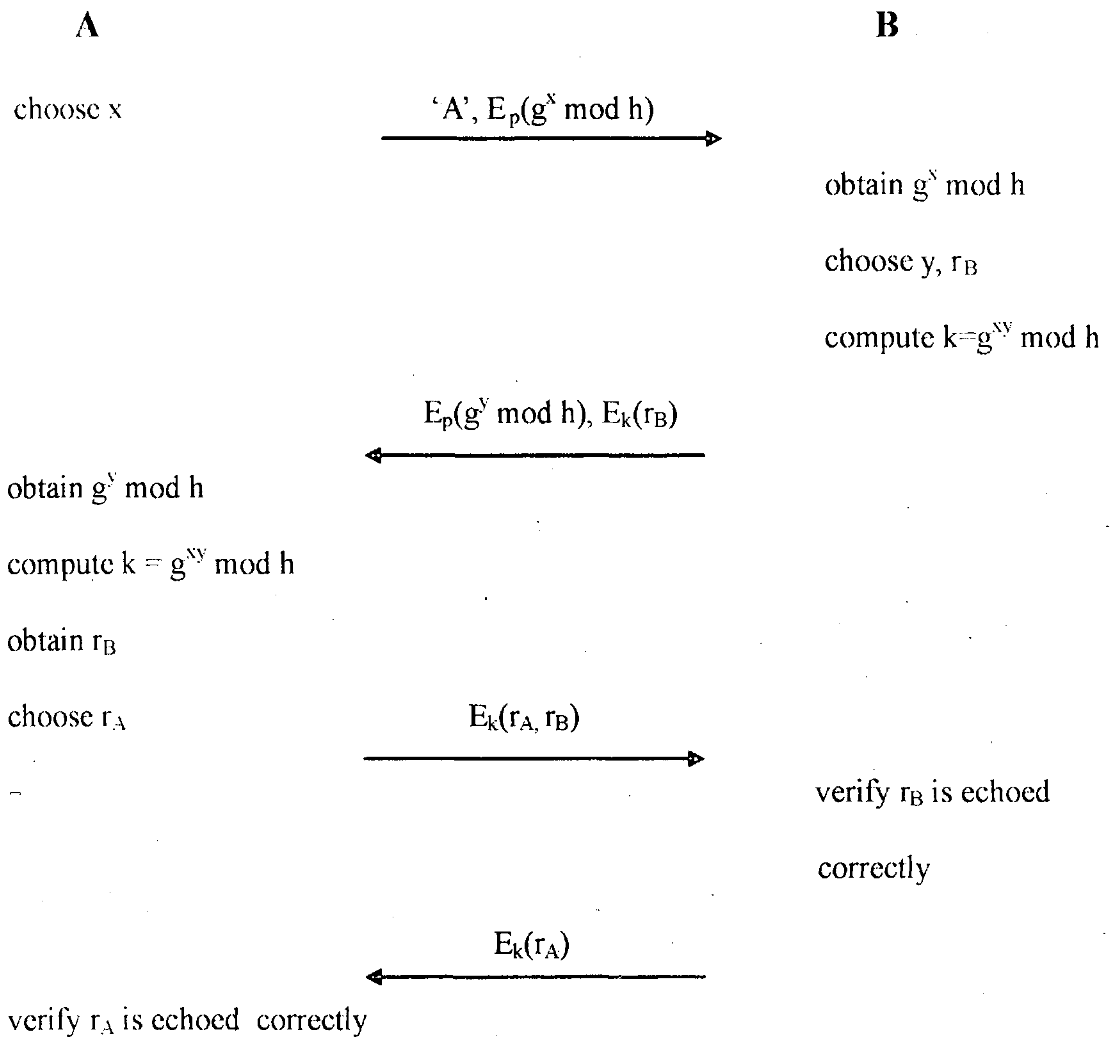


Fig. 3

The protocol is secure against *man-in-the-middle attack*. Messages g^x *mod h* and g^y *mod h* sent by A and B are encrypted with the password p known only to A and B. So an attacker cannot obtain g^x *mod h* and g^y *mod h* from $E_p(g^x \bmod h)$ and $E_p(g^y \bmod h)$ and hence cannot sit between A and B to make fool of both sides.

The drawback of EKE (Bellovin, Merritt, 1992) is that it is plaintext equivalent. Here server stores client's password in clear form. If an attacker gets access to the server's database he will get the client's password. Once the attacker knows password he can apply *man-in-the-middle attack*.

One solution to this problem is verifier-based protocol. In verifier-based protocol instead of storing client's password in clear form, server stores verifier of the password i.e. a one-way function of the password. A-EKE is a variant of EKE and is the first verifier-based protocol.

AUGMENTED ENCRYPTED KEY EXCHANGE (A-EKE)

In A-EKE server stores a one way function ($H(p)$) of the client's password instead of the password itself, where $H(p)$ represents hash of p. Hash functions are one way. So it is impossible to compute p from $H(p)$. Let $F(\,)$ be another one way hash function. The protocol is as follows:

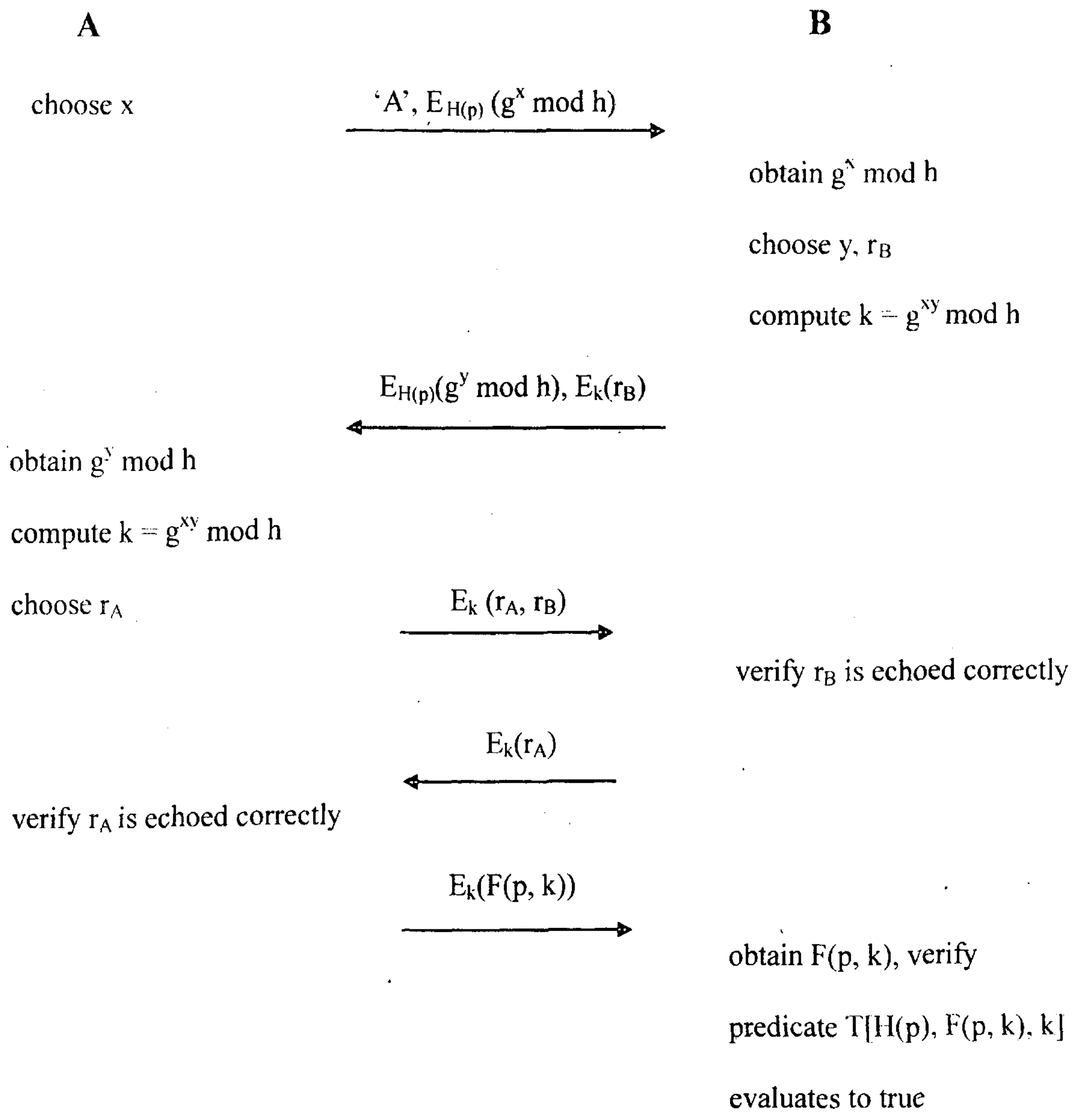


Fig. 4

Different choices for $H(\ )$, $F(\ )$ and $T(\ )$ are included in A-EKE. A-EKE is much more secure than EKE. Here if an attacker gets access to the server's database he will get only the verifier of the password and not the password itself. Without knowledge of p an attacker cannot compute $E_k(F(p, k))$ and hence cannot mimic A to B. But again there is a need to protect server's database as knowing $H(p)$ an attacker can mimic B to A. Secondly an attacker can mount *offline-dictionary attack* to obtain p from $H(p)$.

There have been a number of suggestions for password/verifier based authenticated key exchange protocols ((Abdalla et al, 2006),(Boyko et al, 2000), (Jablon, 1997), (Jiang et al, 2004), (Katz et al), (Kwon et al, 1999), (MacKenzie et al, 1999), (Steiner et al, 1995), (Wu, 1998)). SKE is a verifier based key exchange protocol and is highly secure. In SKE not only the client has to authenticate itself to the server but also the server has to authenticate itself to the client, which is not in case of earlier systems.

SKE SCHEME

Assume that two parties A(client) and B(server) wants to establish a secret authenticated session key. Let p be the password of A. The client A computes $v = g^p \bmod h$ as the verifier of the password and submits it to B securely (eg. by some physical meeting). Let s be the secret key of B. It is recommended that s must be loaded from a secure storage device such as smart card when the system is initiated. B stores the verifier of A's password as $g^{ps} \bmod h$ in his database and discards $g^p \bmod h$. B also computes his public key as $g^s \bmod h$ and submits it to A. How the two parties communicate is as follows:

Notation. $E_R(M) = M$ encrypted with symmetric key R.

1) A computes $p' = H(v \,||\, t)$ where H is a one way hash function, t is the timestamp and $||$ represents concatenation. A chooses a random number x, computes $M_A = E_{p'}(g^x \bmod h)$ and sends his identity 'A', timestamp t and M_A to B.

2) Receiving A's identity B recovers $g^{ps} \bmod h$ from his database and computes $v = \left(\left(g^{ps} \bmod h\right)^{s^{-1}} \bmod h\right) = g^p \bmod h$ as he knows the secret key s. Now B computes, p' and obtains $g^x \bmod h$ from M_A by decrypting it with p'. B chooses two random numbers y and b, computes key $k = g^{xy} \bmod h$, $M_B = E_{p'}(g^y \bmod h)$ and $v_B = E_k(g^{psb} \bmod h)$. B sends M_B and v_B to A.

3) A recovers $g^y \bmod h$ from M_B by decrypting it by p'. Since A knows x, he computes $k = g^{xy} \bmod h$. A decrypts v_B with key k and obtains $g^{sb} \bmod h$ from $g^{psb} \bmod h$ as he knows the password p. A chooses a random number a, computes $g^{sa} \bmod h$ and sends $v_A = E_k(g^{sa} \bmod h,\ g^{sb} \bmod h)$ to B.

4) B decrypts v_A with key k and verifies $g^{sb} \bmod h$ to make sure that A knows the password p and the session key k because only then A can decrypt v_B and obtain $g^{sb} \bmod h$ from $g^{psb} \bmod h$. B computes $g^a \bmod h$ from $g^{sa} \bmod h$ using the server's secret key s and sends $E_k(g^a \bmod h)$ to A.

5) A verifies $g^a \bmod h$ to make sure that B knows the server's secret key s and session key k because only then B can decrypt v_A and obtain $g^a \bmod h$ from $g^{sa} \bmod h$.

A **B**

v g^{p} *mod h* (*v* is already submitted to B and is

stored as g^{ps} *mod h* in B's database, where *s* is the secret key of B)

$p' = H(v \mid t)$ (*t* is the time stamp)

choose x $\xrightarrow{\text{'A'},\ M_A = E_{p'}(g^x \bmod h),\ t}$ compute

$v = \left(\left(g^{ps} \bmod h \right)^{-1} \bmod h \right) =$

$g^p \bmod h$

$p' = H(v \,\|\, t)$

obtain $g^x \bmod h$ from

M_A

choose y and b, compute

$k = g^{xy} \bmod h$

$$\xleftarrow[v_B = E_k(g^{psb} \bmod h)]{M_B = Ep'(g^y \bmod h),}$$

obtain $g^y \bmod h$ from M_B.

compute k g^{xy} mod h

decrypt v_B, obtain g^{sb} mod h from g^{psb} mod h

choose a

$v_A = E_k(g^{sa} \bmod h, g^{sb} \bmod h)$

$\longrightarrow$

verify g^{sb}mod h to

make sure

that A knows the password p and

session key k

$E_k(g^{a} \bmod h)$

$\longleftarrow$

verify g^{a} mod h to make sure

that B knows the server's secret key s

and session key k.

Fig. 5

NEED FOR SERVER AUTHENTIFICATION

The need for server authentication is clear with the many risks associated with a client accessing a false site purporting to be a real site and sharing private information at that false site, be it passwords, financial information, or other private information leading to identity theft and other losses of privacy.

In EKE and in A-EKE if an attacker gets password *p* then he can impersonate both A and B. In SKE not only *the client has to authenticate itself to the server but* also the server has to authenticate itself to the client. If an attacker manages to get password *p* he can impersonate A but without knowing the server's secret key *s* he cannot impersonate B.

CHARACHTERISTICS OF SKE

Timestamp:

Timestamp is used in calculating the value of p' . So in every subsequent communication the value of p' will be different. In this way it improves security.

If timestamp is not used, an attacker can keep on replaying the previous messages to make server busy, the server will remain busy in doing computations and cannot attend the requests from other clients (*denial-of-service attack*). Server will identify that the message is not from the authentic client only at step 4 (i.e. during the authentication of the client). But in case of SKE timestamp is used and if the server finds a timestamp which is not close to the present time then the server will discard the message. In this way it avoids *denial-of-service attack*.

In SKE timestamp is used in such a way that there is no need of synchronization of clocks between the client and the server.

Key Control: Neither party can control the choice of the key as the key is generated by the values chosen by both A and B.

Key Verification: Both sides verify that the other party knows the session key before proceeding.

SECURITY ANALYSIS OF SKE

Dictionary Attack

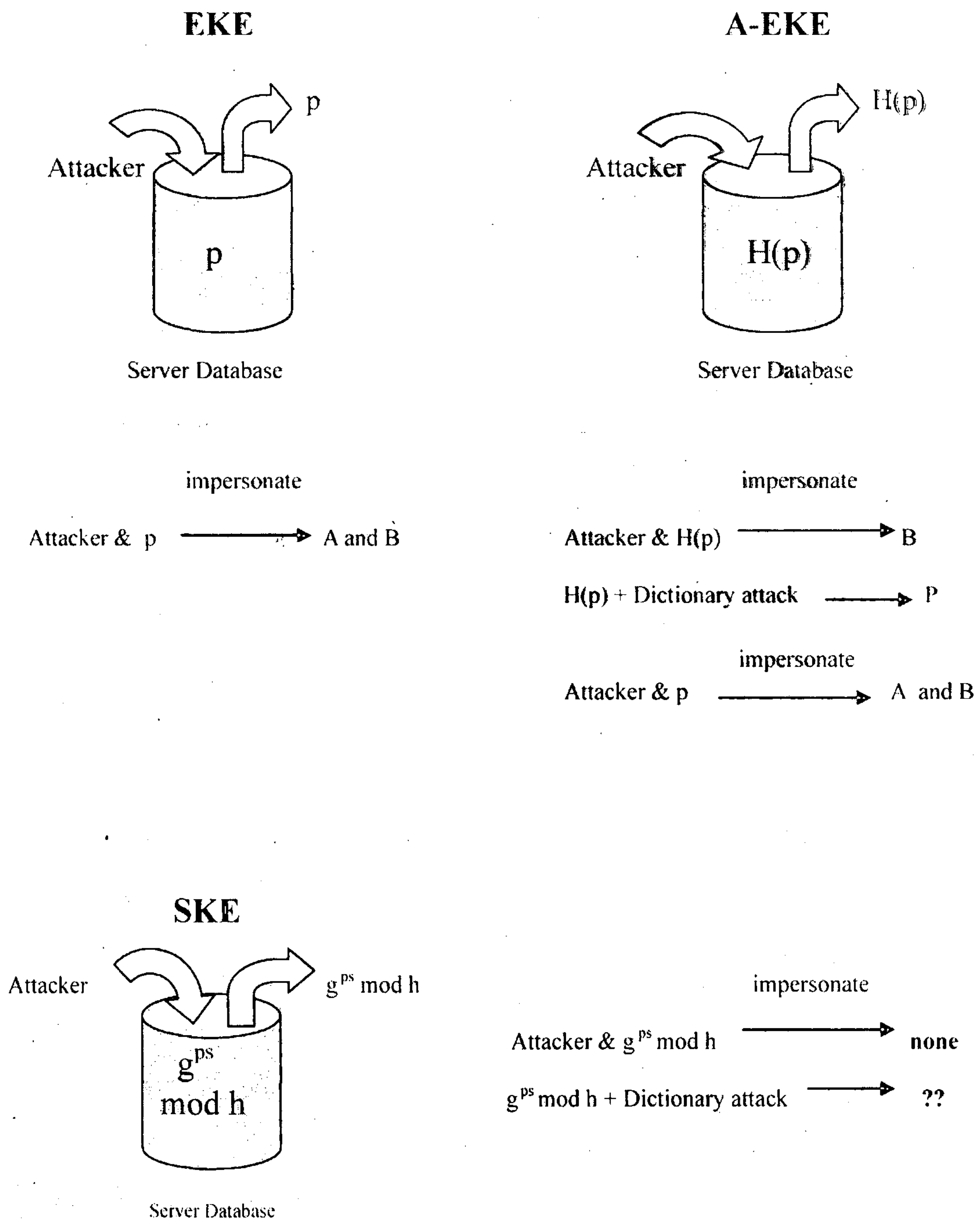
The most trivial form of attack is *on–line dictionary attack* in which an attacker repeatedly tries to login until the right password is guessed. This can be easily avoided by disabling an attack after a number of unsuccessful login attempts. The idea is to limit the number of illegal access attempts against any single password.

Off-line dictionary attack is much more dangerous. Someone who monitors the message communicated between two parties during a legitimate valid exchange can make this attack. Even tiny amounts of information leaked during an exchange can be exploited. SKE is secure against *off-line dictionary attack*. In this any information leaked during an exchange cannot help the attacker in any way.

By Getting Access to Server's Database

In EKE if an attacker gets access to the server's database, he will get the password and hence can impersonate both as A and B. Similarly in A-EKE if an attacker gets access to the server's database he will get the verifier of the password and hence can impersonate B. An attacker can also apply *off-line dictionary attack* on the verifier to get the password. Once an attacker gets password he can impersonate both as A and B.

In SKE instead of storing A's password verifier, B stores a one way function of the A's password verifier and his own secret key. So an attacker who even gets access to B's (server's) database cannot obtain A's password verifier without knowing B's secret key and hence cannot impersonate A or B.



$$\text{Attacker } \& \ p \xrightarrow{\text{impersonate}} \text{A and B}$$

$$\text{Attacker } \& \ H(p) \xrightarrow{\text{impersonate}} \text{B}$$

$$H(p) + \text{Dictionary attack} \longrightarrow P$$

$$\text{Attacker } \& \ p \xrightarrow{\text{impersonate}} \text{A and B}$$

$$\text{Attacker } \& \ g^{ps} \bmod h \xrightarrow{\text{impersonate}} \textbf{none}$$

$$g^{ps} \bmod h + \text{Dictionary attack} \longrightarrow \textbf{??}$$

Fig. 6

○ Forward Secrecy

Forward secrecy means if long term private key is compromised, the secrecy of previously established session keys should not be affected. In SKE if an adversary learns the client password or long term password verifier, still the adversary would not be able to ascertain anything about previously distributed session keys. So SKE maintains Forward Secrecy.

Denning-Sacco Attack

In *Denning-Sacco attack* (Denning, Sacco, 1981) an eavesdropper captures the session key and uses it to conduct brute force search against the user's password. A-EKE is much more secure than EKE as it is verifier based instead of password based but it is not resistant against *Denning-Sacco attack*. A-EKE requires the user to send a message $E_k(F(p, k))$ that is dependent on both the long-term password and the session key. If an attacker gets the session key then he can apply the *dictionary attack* to get long-term password.

But in SKE if an attacker gets session key k he cannot obtain the long-term password. SKE is secure against *Denning-Sacco attack*.

Man-in-the-Middle Attack

This attack occurs when an attacker sits between the client and the server and trying to make fool of both the sides. In SKE values communicated between A and B are encrypted with p' known only to A and B. An attacker cannot get any useful information by listening to the communication between A and B. So attacker cannot make fool of any side. In this way SKE is secure against *man-in-the-middle attack*

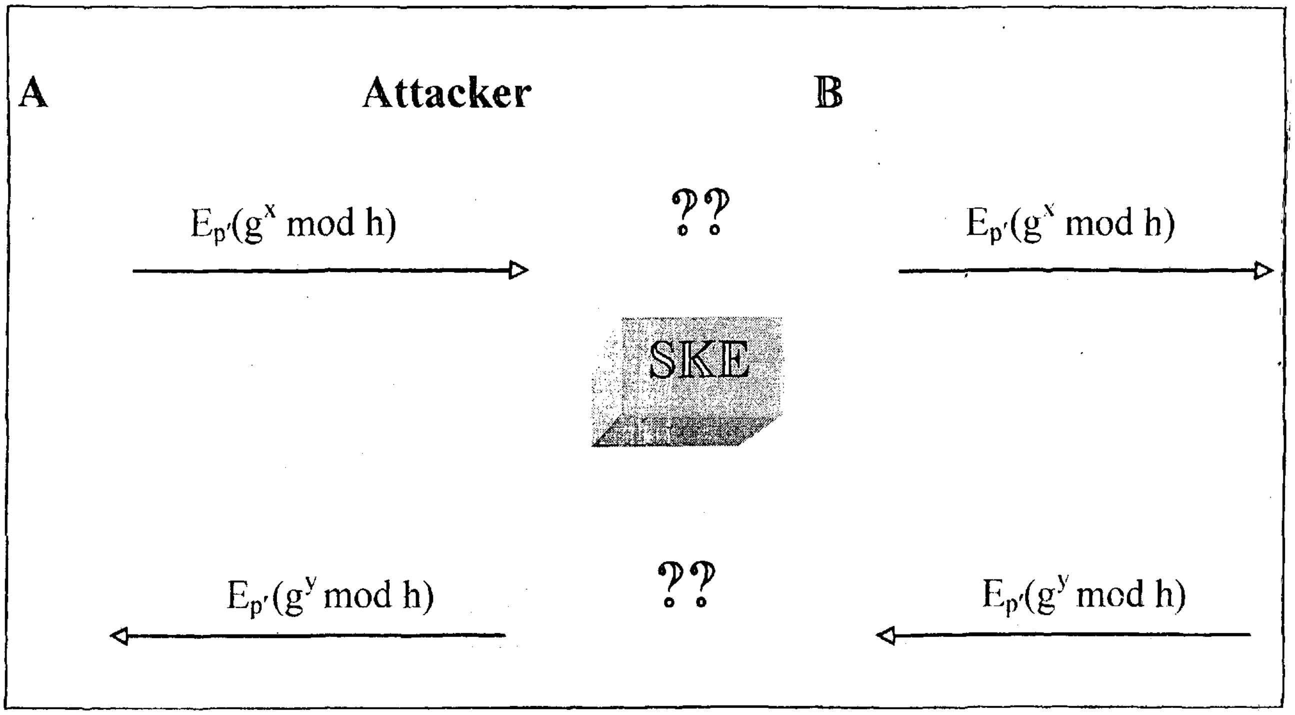


Fig. 7

Replay Attack

SKE is secure against *replay attack*. None of the information exchanged in a session can be reused to gain access to the server in future.

Two-Way Authentication

In earlier systems only the client has to authenticate itself to the server and not vice-versa. Whereas in SKE not only the client has to authenticate itself to the server but also the server has to authenticate itself to the client. In this way it improves security.

Choice of h and g

Prime h should be large and should be such that $(h - 1)$ has a large prime factor or we can say that h should be of the form

$$h = 2q + 1$$

where q is a large prime. When $(h - 1)$ has large prime factor it resists *Pohling – Hellman discrete log attack* (Pohling, Hellman, 1978). To prevent *partition-attack* (Jablon, 1996) g should be a primitive root $mod\ h$. Values h and g have to be established in advance and should be made public. Computing $y = g^x\ mod\ h$ is discrete exponentiation and the reverse i.e. computing x from y is discrete logarithm. For some carefully chosen values of h discrete logarithm requires $h^{1/2}$ operations (Diffie, Hellman, 1976). Suppose h is a prime slightly less than 2^x. Then the calculation of y from x requires atmost $2.log_2 h < 2.log_2 2^x = 2x$ multiplications while calculation of x from y requires $(2^x)^{1/2}$ operations (Diffie and Hellman, 1976). Finding discrete logarithms for large values of h (512 bits or more) is computationally difficult (LaMacchia, Odlyzko, 1991). Prime h should be chosen to be of atleast 1024 bits and more likely to be of 2048 bits. It is assumed that 2048 bits of h is secure for next 15 years. If over time these values become weak, new values of g and h could be chosen.

CONCLUSION

Using only small password SKE provides secure and authenticated key exchange over insecure channel. The system is secure against all active attacks. Here not only the client has to authenticate itself to the server but also the server has to authenticate itself to the client. Timestamp is used in such a way that it improves security but does not increase overhead. The system is simple and easy to implement.

REFRENCES

Abdalla, M., P. Fouque and D. Pointcheval. 2006. Password Based Authenticated Key Exchange in the Three Party Setting. *IEEE Proceedings-Information Security*, 153(1): 27-39.

Bellare M., D. Pointcheval and P. Rogaway. 2000. Authenticated Key Exchange Secure Against Dictionary Attack. *Eurocrypt*.

Bellare M. et al. 2003. Proposal for P1363 Study Group on Password-Based Authenticated-Key-Exchange Methods. http://grouper.ieee.org/groups/1363/passwdPK/contributions/p1363-pw.pdf.

Bellare, M. and P. Rogaway. 2003. The AuthA Protocol for Password – Based Authenticated Key. Exchange. http://www.cs.ucdavis.edu/rogaway/papers/autha.ps.

Bellovin, S. M. and M. Merritt. 1992. Encrypted Key Exchange: Password–Based Protocols Secure Against Dictionary Attacks. *Proceedings of the IEEE Computer Society Symposium on Research in Security and Privacy*, 72-84.

Bellovin, S. M. and M. Merritt. 1994. Augmented Encrypted Key Exchange: a Password – Based Protocol Secure Against Dictionary Attacks and Password File Compromise. *Technical Report, AT&T Bell Laboratories.*

Boyko V., P. MacKenzie and S. Patel. 2000. Provably Secure Password Authenticated Key. Exchange Using Diffie - Hellman. Eurocrypt.

Denning, D. and G. Sacco. 1981. Timestamps in Key Distribution Protocols. *Communications of the ACM*, 24(8): 533-536.

Diffie, W. and M. E. Hellman. 1976. New Directions in Cryptography. *IEEE Transactions on Information Theory*, IT-22: 644-654.

Gennaro, R., Y. Lindell. 2003. A framework for Password-Based Authenticated Key. Exchange. *EUROCRYPT*, pp. 524-543.

Jablon D. 1996. Strong Password-Only Authenticated Key Exchange. *ACM Computer Communications Review*, 26(5): 5 – 26.

Jablon, D. 1997. Extended Password Key Exchange Protocols Immune to Dictionary. Attacks. *Proceedings of the WETICE'97 Enterprise Security Workshop*, 248 – 255.

Jiang S., G. Gong. 2004. Password Based Key Exchange with Mutual Authentication. Lecture Notes in Computer Science, Springer Berlin/ Heidelberg, pp. 267-279.

Katz, J., R. Ostrovsky, M. Yung. Efficient Password Based Key Exchange Using Human-Memorrable Passwords. http://www.icar.org/archive/eurocrypt2001/20450473.pdf.

Kwon, T. and J. Song. 1999. Secure Agreement Scheme for g^{xy} via Password Authentication. *Electronics Letters*, 35(11): 892 – 893.

Kwon, T. 2001. Authentication and Key Agreement via Memorable Password. NDSS 2001. Symposium Conference Proceedings.

Kwon T. 2003. Ultimate Solution to Authentication via Memorable Password. http://grouper.ieee.org/groups/1363/StudyGroup/submissions.html#amp.

LaMacchia B. A. and A. M. Odlyzko. 1991. Computation of Discrete Logarithms in Prime. Fields. *Designs, Codes and Cryptography*, 1:46-62.

Lucks S. 1997. Open Key Exchange: How to Defeat Dictionary Attacks Without Encrypting Public-Keys. *The Security Protocol Workshop'97*, 7-9.

MacKenzie P. and R. Swaminathan. 1999. Secure Network Authentication with Password Identification. *IEEE P1363a*.

Patel S. 1997. Number Theoretic Attacks On Secure Password Schemes. *Proceedings of IEEE Symposium on Security and Privacy*.

Perlman R. and C. Kaufman. 1999 Secure Password-Based Protocol for Downloading a Private Key. *Proceedings of the 1999 Network and Distributed System Security* Symposium.

Pohling S. and M. Hellman. 1978. An Improved Algorithm for Computing Logarithms Over GF(p) and its Cryptographic Significance. *IEEE Transactions on Information* Theory, 24(1): 106-110.

Steiner, M., G. Tsudik and M. Waidner. 1995. Refinement and Extension of Encrypted Key Exchange. *ACM Operating Systems Review*, 29(3): 22-30.

Wu, T. 1998. The Secure Remote Password Protocol. *Internet Society Symposium on* Network and Distributed System Security.

FORM IV
(See rule 8)

1.	Registration No.		ISSN-0555-7631
2.	Place of Publication		Room No. 28-29, Old Correspondence Building Panjab University Chandigarh - 160014 (India)
3.	Periodicity of publication		Annual
4.	**Publishers' & Editors' Name**		
	Editor-in-Chief		Professor R.S. Loyal
	Nationality		Indian
	Editor	:	Dr. Sanjeev Puri
	Nationality	:	Indian
	Address	:	Research Journal (Science) Room No. 28-29, Old Correspondence Building, Panjab University Chandigarh - 160 014
5.	Printer's Name	:	Mr. Jatinder Moudgill
	Nationality	:	Indian
	Address	:	Manager Panjab University Printing Press Chandigarh - 160 014.
6.	Name and Address of the individuals who: own the newspaper and partners or shareholders holding more than one per cent of the total capital.		Panjab University, Chandigarh

Professor R.S. Loyal, hereby declare that the particulars given above are true to the best of knowledge and belief.

Professor R.S. Loyal
Editor-in-Chief

PANJAB UNIVERSITY RESEARCH JOURNAL (SCIENCE)

Life Membership Form

Name : ____________________
Qualifications : ____________________
Area of Specialization : ____________________
Present Designation : ____________________

Address: (Tick the address on which you would like to receive the Journal. Local Members would receive the Journal by Hand).

Office: ____________________
____

Residence: ____________________
____
____

Telephone (O): ____________________
(R): ____________________
(Mobile): ____________________
FAX : ____________________
e-mail : ____________________

Payment Mode: Cheque / Draft / Cash

(Only local cheques are acceptable. Draft to be drawn in favour of **The Registrar, Panjab University, payable at Chandigarh.**

If By Cheque/Draft:
No. ________ date ________ Amount ____________
Name of Bank ____________________

Date:
Place:

SIGNATURES

Subscription fee:

	Inland	Foreign
Life Membership:	Rs. 3000/-	US $ 250
Annual Subscription:	Rs. 400/-	US $ 50

Send to: The Editor-in-Chief,
Research Journal (Science),
Room No. 28-29,
Old Correspondence Building,
Panjab University,
Chandigarh-160 014 (India).

INSTRUCTIONS TO AUTHORS

Panjab University Research Journal (Science) is published annually. The journal accepts original research papers or short notes and expository review articles in the field of various science subjects. The journal is open to all scientists engaged in original research in any discipline of science including Engineering and Information Technology. **All manuscripts will be reviewed by two referees.**

Manuscripts - The manuscripts should be typewritten (double spaced) with ample margins on one side of quarto bond paper (30 cm x 23 cm). Three complete copies of the manuscript along with a computer floppy/CD in Microsoft Word conforming to the journal's format is to be submitted. Page 1 should contain only title of manuscript, author(s) name(s) and affiliation(s), a short running title (abbreviated from the title) not exceeding 40 characters, name and complete mailing address of the person to whom correspondence should be addressed. Page 2 should contain an abstract not exceeding 150 words. The abstract should contain no illustration or reference to the figures, tables, or authors. The abstract should be followed by 3-4 key words. Acknowledgements should be inserted at the end of the text before References.

Short communication: A short communication should be a record of completed short investigation giving details of new methods or findings. It should not exceed 4 to 5 typed pages with an Abstract followed by Key words. Body of the text should not have any separate title.

References**:** References in the text should conform to the following style:-

Adherence of *E. coli.* to intestinal mucosal surface.........pathogenesis (Beachey, 1981).

According to Arnoldi (1976), these feathers...........

The references at the end of article should be in alphabetical order and presented as follows:-

Ahuja, D.B. 1990. Population dynamics of mustard aphid, *Lipaphis erysimi* (Kalt.) on Indian mustard *Brassica juncea*. *Indian J. Plant Protection*, 18 : 233-235.

Bener, A. and F.C. Erk. 1979. The analysis of whorls on specific fingerstips with respect to sex, bilateral asymmetry and genetic relationship. *Ann. Hum. Biol.,* 6 : 349 - 356.

Buskrik, E.R., K.L. Anderson, and J. Brozek. 1956. Unilateral activity and bone and muscle development in the forearm. *Res. Quart.*, 27 : 127-131.

Jain, S.K. 1986. Orchid Wealth of India. In: Biology, Conservation, and Culture of Orchids (Ed.S.P.Vij) pp. 319-22. Affiliated East - West Press (New Delhi).

Illustrations**:** Three sets of figures (preferably black and white), mounted on thick white sheet, must be submitted in camera-ready form. All illustrations should be lettered with stencil using Indian ink. The illustrations should preferably be in the form of text-figures. All figures whether photographs or drawing, must be numbered in single series (Fig. 1,2,3....etc.). The figures should be arranged and numbered in the order in which they are referred to in the text. The figures or photographs (plates) submitted for publication must be large enough to withstand some reduction. The ratio of length & width of the full figure plate must necessarily be in proportion to the page size of the journal *i.e.* 23 cm x 18 cm. Figures must carry magnification bars. Legends to figures should be typed on a separate sheet of paper to be inserted after References. Abbreviations used for the figures should be given in an alphabetical order after the legends.

Tables**:** Tables 1, 2, 3 should be single-spaced on separate page and numbered. Each table must bear a short descriptive heading.

Proofs**:** Page proof will be sent to corresponding author. Authors will be charged in the event of excessive alterations in the proofs.

Reprints : Ten reprints of each paper will be provided *gratis*. Additional copies may be ordered while returning the proofs. The cost of the extra reprints will have to be borne by the author.

Manuscripts and Correspondence should be addressed to the Editor-in-Chief, Research Journal (Science), Room No. 28-29, Old Correspondence Building, Panjab University, Chandigarh 160 014 (India). Telephone: 0172-2534376 & 01722534456; E-mail : resjoursci@pu.ac.in

Published by :
EDITOR-IN-CHIEF
Research Journal (Science)
Panjab University, Chandigarh-160 014
INDIA

www.puchd.ac.in

ISSN-0555-7631