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1. RESEARCH ROUND-UP

LICHENS AN EFFICIENT MONITORING TOOL FOR ASSESSMENT OF ATMOSPHERIC POLLUTANTS

Lichens are excellent bioindiactors of air pollution due to their sensitivity to acidic gases, lichens exhibit distinctly the incited damage in relation to morphological and/or physiological symptoms and are also excellent accumulators of pollutants. Broad geographical distribution which allows documentation of the wide spread pattern, perennial, slow growth rate uniform morphology and no shedding parts as in higher plants provide ability to cumulatively accumulate pollutants. These features make lichens more suitable organism for pollution monitoring.

Lichens are one of the most valuable biomonitors of atmospheric pollution. They can be used to estimate the biological effects of pollutants by measuring changes at community or population level and as accumulative monitors of persistent pollutants. The high capability of lichens to accumulate air pollutants, resistance to environmental stress and longevity are the major features that make them most suitable organisms for biomonitoring studies. Free diffusibility of lichen thalli due to lack of cuticle enables quick penetration of toxic compounds from the atmosphere to the photobiont layer. Thus, the response of lichens to the environmental pollution is more sensitive than the higher plants. Owing to their dependence on atmosphere for nutrient supply and capacity to biomagnify accumulated environmental contaminants, lichens can provide details on the presence of persistent pollutants in the atmosphere and their biological effects.

WHY LICHENS ARE EXCELLENT BIOINDICATOR

- **Scales of Indicator species** → Relates the level of air pollution to the absence or presence of sensitive species
- **True Indicators** → The degree of pollutant-incited damage in relation to morphological and/or physiological symptoms in one selected species
- **Accumulators/Collectors** → A plant or animal species as a quantitative collector, and/or accumulator of pollutants

SUITABILITY OF LICHENS IN ATMOSPHERIC POLLUTION STUDIES

- **Broad geographical distribution** → Allows documentation of wide spread patterns
- **Perennial, slow growing uniform morphology with time, do not shed parts** → Provide ability for cumulative accumulation of pollutants
- **Lack of waxy cuticle and stomata** → Pollutants absorbed over the entire lichen thallus
- **Hyper accumulators** → Capable of accumulating many elements to concentration that vastly exceed their physiological need

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All lichens are not equally sensitive to air pollutants. Rather, different lichen species exhibit differential sensitivity to specific air pollutants. As a consequence, lichens are well suited as biological indicators for monitoring environmental quality. During the last three decades a number of studies devoted to assessing the effect of air pollution on lichens were carried out throughout the world. The mapping of lichen communities is one of the major areas of research to study the variation in lichen communities. The frequency of occurrence of certain species is related to specific air pollutants and in some cases to their concentration. Apart from distribution map the morphological and anatomical changes in response to air pollutants, these further provide an assessment of the effect of environmental pollutants on living organism. The physiological reaction and changes in the lichen thallus due to air pollutants can also be measured and thus predict the environmental conditions of that particular area.

The level of airborne pollutants arising from anthropogenic sources such as power plants, smelters, automobiles, industry and agriculture can easily be monitored through lichens. The degradation of chlorophyll in the symbiotic photobiont is one of the most obvious sign of the damage that occurs in sensitive lichens. Heavy metals are known to interfere with chlorophyll synthesis either through the direct inhibition of an enzymatic step or through the induced deficiency of an essential nutrient. The species accumulate relatively high amounts of heavy metals and contain less chlorophyll, which clearly indicates that lichen chlorophyll contents interfere with the thallus metal contents.

The biomonitoring with lichens offers other advantages compared to instrumental methods such as low cost, independence of power supply, easier sample handling and trace elements determination methods. The perennial nature of lichens, absence of root or other special organs for uptake of nutrients and lack of cuticle enable them to absorb metals directly from the atmosphere and these characteristics make them ideal bio-monitoring organisms. The lichens are used as bio-indicators and or bio-monitors in two ways; in situ that is passive monitoring and the active monitoring that is transplant of lichens from one place to other.

Lichens as bioindicator

Plants and allies can serve as bioindicators of environmental conditions and ecosystem health. Lichen communities are currently used as indicator of forest ecosystem function in several context. Studies of lichens of particular forest type often have goals of monitoring effects of forest management practices and landscape context, including a variety of indirect human impacts on forest environment (Lesica *et al*. 1991; Dettki *et al*. 1998). Lichens have also been identified to indicate forest stand temporal continuity, condition and age structure of forest. The main groups of lichen bioindicator species known from India are described below :

1. Calcioid Group - The Calcioid group or the "pin-head" lichens are indicators of old growth forests. Many of these species are dependent on snags and old trees with stable rough bark

2. Alectoroid and Usnioid Group - The tufted and pendulous fruticose lichens including genera *Sulcaria, Bryoria, Ramalina* and *Usnea* have been found to be useful as indicators both of for older forest with better air quality (Essen *et al.* 1992). The *Usnea* species indicates older growth forest and vanished from the forest onset of habitat destruction (Essen *et al.* 1992).

3. Cyanophycean Group - The variation in diversity and abundance of epiphytic cyanolichens appears useful as an indicator of forest ecosystem function. Cyanophycean lichens plays an important role in forest nutrient cycle and indicate forest age and continuity (Mc Cune 1993).

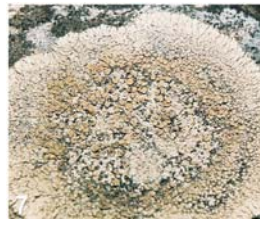
4. Lobarian Group - The Lobarian Group comprised of *Lobaria, Pseudocephallaria, Peltigera* and *Sticta.* These are sensitive to air quality and reliable indicators of species rich old forest with long forest continuity (Gausala 1995).

5. Xanthoparmelioid Group - According to Eldridge and Koen (1998) the yellow foliose

morphological group comprising of foliose lichen species of *Xanthoparmelia* is consistently correlated with stable productive landscape i.e. landscapes with no accelerated erosion.

6. Graphidioid and Pyrenuloid Group - The growth of graphidaceous (*Graphis, Opergrapha, Scareographya, Phaeographis)* and pyrenocarpous *(Anthracothecium, Pyrenula, Lithothelium, Porina)* influenced by the nature of bark. Both groups mostly prefer to grow on a smooth tree bark in evergreen forest.

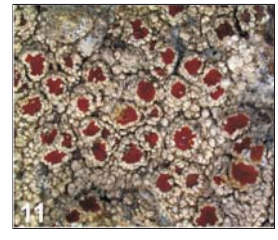
7. Lecanorioid Group - The group comprised of *Lecanora, Lecidella* and Biatora. The Lecanorioid group indicates well illuminated environmental condition of the forest with considerable exposure of light and wind. They prefer to grow on trees in thinned out, regenerated or disturbed forest with more open area to receive more light and wind.



8. Parmelioid Group - The group comprised of mostly the species of lichen genera *Bulbothrix, Flavoparmelia, Parmotrema, Parmelia, Punctelia* and other genera of Parmeliaceae. The forest with closed canopy and less sunlight support few species of Parmelioid genera to grow while the open thinned out forest with more sunlight exhibit dominance of Parmelioid lichens.

9. Pertusorioid Group - The group includes species of lichen genus *Pertusaria* and indicates old tree forest with rough-barked trees. The *Shorea robusta* tree forests in the dry deciduous forest appears excellent host for this group of lichens to colonize.

10. Lecideoid Group - The member of the group such as *Lecidea, Protoblastedia, Haematomma, Bacidia, Buellia* and *Schadonia* colonized mostly on bark of deciduous trees in sheltered and well lit exposed sides.

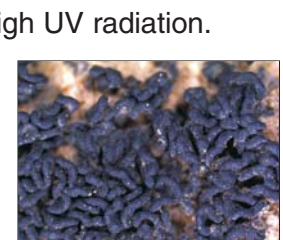


11. Leprarioid Group - The species of *Chrysothrix, Cryptothecia* and *Lepararia* are the common lichens of the Leprarioid group, which forms powdery thallus on the substrates indicates moist and dry vertical slopes, rough-barked trees of moist and dry habitats. The species of Chrysothrix appears first after forest fire.

12. Physcioid Group - The lichen species of Physcia, *Pyxine, Dirinaria, Heterodermia, Phaeophyscia* and *Rinodina* belongs to this group. The Physcioid lichens are considered as the pollution tolerant lichens and have ability to grow on varied substrates in both moist and dry habitats.

13. Teloschistacean Group - The species of *Caloplaca, Letroutia, Brigantiaea* and *Xanthoria* having yellow thallus and apothecia belongs to this group. The members of this group have an ability to grow both on exposed and sheltered rocks. The dark orange pigment present on the upper cortex of the thallus act as a filter and to protects the lichens from high UV radiation.

14. Lichinioid Group - The genera of the lichen family Lichninaceae mostly having cyanobacteria as their photobiont belongs to this group. The member of the group prefers dry rocks and barks having higher concentration of calcium and



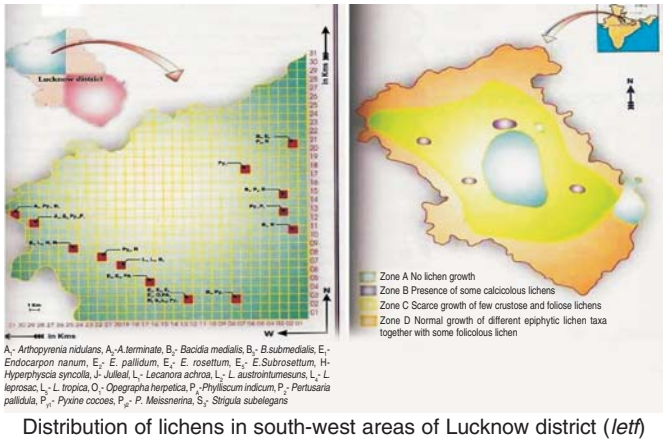
indicate presence of calcareous substrates in the habitats.

15. Peltuloid Group - The species of lichen genera *Peltula* belongs to this group of lichens. The presence of the species of this group indicates a stable rock substratum,

The presence of some particular lichen communities in a forest indicate the status of the habitat, condition, age structure and type of substrates. The lichen communities are included in the forest health monitoring programme as they help to answer several key assessment questions. Such information in Indian context are available from Greater Himalayan National Park (GHNP) in Kullu, Himachal Pradesh, Pindari and Milam Glacier of Bageshwar and Pithoragarh district of Uttrakhand and Amarkantak Achanakmar Biosphere Reserve (AABR) of Madhya Pradesh and Chhattisgarh states.

Changes in lichen communities and mapping

Sernander (1926) recognized the disappearance of lichens from cities and conducted the systematic mapping and recognized there distinct zonations. The 'Lichen desert' in the city centre where the tree trunks were bare of lichens. Struggle zone comprised of areas outside the city centre with tree trunks poorly colonized with lichens followed by the 'normal zone' where lichen communities on the tree trunks were well established. Subsequently, the large number of similar city maps showed that these zonations were well correlated with the degree of pollution, the size of the urbanization area, and the prevailing winds.



Distribution of lichens in south-west areas of Lucknow district (*letf*)
Map showing distribution of lichens in Lucknow district (*right*)

The lichen zone mapping in India with reference to Lucknow (Uttar Pradesh) was initiated in the year 2004 after dividing the city into four major areas i.e. North, East, South and West in 1 x 1 sq Km grid.

METHODS FOR POLLUTION MONITORING UTILIZING LICHENS	
• **Transplant Technique**	Transplanting healthy lichens into polluted area and measuring thallus deterioration
• **Lichen zone mapping**	To indicate the diversity of pollution with reference to distance from source, as reflected by the number of species absent
• **Sampling of individual**	Measuring of contaminants lichen species accumulated within the thallus

The distribution data of lichens collected from all the four areas of the district provide an idea about the overall picture of the lichen distribution in the district and the detailed distribution to segregated the area into four different zones. Zone A – no lichen growth, an area in the centre of the city up to 5 Km all around; Zone B- presence of some calcicolous lichens, mostly the areas with old historical buildings; Zone C- scarce growth of few crustose and foliose lichens, areas with scattered mango trees; Zone D- normal growth of different epiphytic lichen taxa together with some foliicolous lichens (Fig. 17). Among the four zones of Lucknow district, north-east zone has the highest concentration of the metals such as Fe, Ni, Zn and Hg, while south-west zone of the district exhibits higher accumulation of Pb. The key sources for the metal accumulation in lichens are heavy motor traffic, frequent use of generator sets for electricity, burning of fuel wood and use of pesticides in the Mango orchards.

The comparison of the lichen diversity with an earlier study carried out during 1960-80s exhibits a distinct change in the Lucknow and Kolkata city. In and around the city of Lucknow out of the 18 species recorded in the past, 14 species are common to the present study. It seems that the remaining 4 species (*Julella* sp., *Opergrapha herpetica, Peltula euploca* and *Phylliscum macrosporum*) of the former study might have become totally extinct from the area. The change

in lichen communities in the district is mainly due to change in the environmental condition during the last 25 years. This indicates the replacement of the sensitive species of lichens with tolerant ones in the district.

Similarly in Indian Botanical Garden (IBG) Howrah and Kolkata out of the 53 species earlier reported in 1865 (140 year before) only 5 species are common in the past and present communication. The IBG exhibit dominance of crustose lichens (21 out of 25 species) which are more tolerant to air pollution. The pollution tolerant crustose lichen act as pioneer colonizer in a new environment and replace sensitive species.

The lichen flora of Lalbagh Garden, Bangalore was compared with an earlier enumeration and it was interesting to note that in the last 18 years, the lichen flora of the area has been changed significantly as only four species were common between the two studies. The fast pace of urbanization together with air pollution may probably be the reason for the change in the lichen flora of the different Indian cities. The Pune city also exhibit poor growth of lichens within the city centre however the lichens are growing luxuriantly in area having dense tree canopy in the out skirts of the city.

Inorganic pollutants accumulation in lichens

The accumulation of metal (Al, Cd, Cu, Cr, Fe, Pb, Ni, Zn) pollutants in lichen thallus by passive as well as active principals are well known from different cities of the country such as Uttar Pradesh (Faizabad, Lucknow, Kanpur and Raebareilly district); Madhya Pradesh (Dhar, Katni and Rewa district) and West Bengal (Hooghly and Nadia district); Maharashtra (Pune and Satara district); Uttrakhand (Dehradun, Pauri district). The accumulation level of different metals decrease with increasing distance from the city centre. The metals Cr, Cu and Pb were more at the higher vertical position (20-25 feet) where as other metals (Zn, Fe) accumulated maximum at lower vertical position (4-5 feet).

The damage caused by the metallic pollutants in the lichen *Pyxine subcinerea* Stirton, by measurements of Chl a, Chl b, total Chl, carotenoid and protein and OD 435/415 ratio significantly exhibits the changes in physiology. It was observed that the Cu, Pb and Zn significantly affect the physiology of the lichen *P. subcinerea.* Multiple correlation analysis revealed significant correlation (<0.001) among the Fe, Ni, Cu, Zn and Pb metals analyzed. Cd did not correlate with any other metals except Fe ($P<0.05$). Cu, Pb and Zn are the main constituents of the vehicular emissions had significant positive correlation ($P<0.001$) with protein content while the OD 435/415 ratio values decreased statistically ($P<0.001$) with increase in amount of Cu, Pb and Zn.

Pyxine cocoes a foliose lichen commonly growing on Mango tree in tropical regions of India is an excellent organism for determining the pollutants emitted from coal-based thermal power plant and accumulated in lichens after prolonged exposure. The diversity and distribution of lichens in and around such power plant act as useful tool to measure the extent of pollution in the area. The distributions of heavy metals from power plant showed positive correlation with distance for all directions. The speed of wind and direction plays a major role in dispersion of the metals. The accumulation of Al, Cr, Fe, Pb and Zn in the thallus suppressed the concentration of pigments (chlorophyll a, chlorophyll b, total chlorophyll) however, enhanced the level of protein. Further the concentration of chlorophyll content in *P. cocoes* increased with decreasing the distance from the power plant, while protein carotenoid and phaeophytisation exhibit significant decrease.

The morphology, chemistry and anatomy of lichens play important role in accumulation of metals. Another common tropical lichen species *Phaeophyscia hispidula* belongs to the same lichen family (Physciaceae) as of Pyxine have distinct morphology and chemistry. A thick tuft of rhizinae (hair like structure) on the lower surface of the thallus in *Phaeophyscia hispidula* acts as a metal reservoir and thus exhibit higher accumulation of most of the metals than Pyxine. The crust forming lichens attached tightly to the substrates through their whole lower surface have the highest accumulation of Al in the metal sequence while the squamulose, foliose form show Fe in the higher concentrations. The lichens have special affinity with iron and they accumulate iron in greater amount than other metals.

Various interactions are known to occur when plants are exposed to unfavorable concentrations of

more than one trace element. Such combination effects may represent the selectivity sequence of elements and categorized by Berry and Wallace (1981) as independent, additive, synergistic or antagonistic. The metal accumulation selectivity sequence in different lichen growth type of three sites of Dhar district in Madhya Pradesh clearly exhibit different selectivity sequence in different growth from of lichens (Table 1).

Accumulation of Organic pollutants in lichens

Apart from inorganic metals lichens are excellent indicators of Polycyclic Aromatic Hydrocarbon compounds (PAHs) too. The PAHs accumulation studies in Indian lichens are initiated recently in the Himalayan region of Uttrakhand. The PAHs accumulation in lichens of different localities of Dehra Dun city, and on way to Badrinath are estimated recently. The first baseline data on the distribution and origin of polycyclic aromatic hydrocarbons (PAHs) in *Phaeophyscia hispidula* collected from nine different road crossings of Dehra Dun city and enroute to Badrinath of Uttarakhand exhibit the presence of 13 types of PAHs (Naphthalene (0.14-5.65 ppm), Acenaphthylene (0.89-22.13 ppm), Fluorene+acenaphthylene (0.07-3.38 ppm), Phenanthrene (0.06-6.47 ppm), Anthracene (0.01-0.38 ppm), Fluoranthene (0.01-3.58 ppm), Pyrene (0.13-14.46 ppm), Benzo(a)anthracene+chrysene (0.01-0.13 ppm), Benzo(k)fluoranthene (0.01-0.03 ppm), Benzo(b)fluoranthene (0.02-0.09 ppm), Benzo(a)pyrene (0.00-0.03 ppm), Dibenzo(a, h)anthracene (0.17-0.31 ppm), Indino (1,2,3-cd ppm) pyrene+benzo(ghi)perylene (0.00-0.20 ppm). The PAHs were of mixed origin, a major characteristic of urban environment. Significantly higher concentration of phenanthrene, Pyrene and acenapthalene indicates road traffic as major source of PAH pollution. The acetyl polymalonyl patway in lichens results in biosynthesis of secondary metabolites of depsides and depsidones containing highly reactive –OH radicals (due to ortho effect). The depsides and depsidones easily provide their hydroxyl group for adduct formation. Therefore, PAHs (hydrophobic in nature) readily combine with these organic moiety to form adduct (Lu et al. 2005). The higher accumulation of 2 and 3 ring PAH in lichens may be because most of the species contains depsides and depsidones with active –OH sites, which readily combine with PAH to form an adduct. Phaeophyscia and Pyxine have skyrin triterpine and lichenoxanthone (having hydroxyl group) which readily combine with most of the PAHs.

The growth from of lichens may also plays a significant role in the accumulation of PAHs. The saxicolous, crustose and squamulose species growing on rocks mostly accumulated uniform concentration of low molecular weight 2 and 3 ringed compounds. The higher vehicular activities or excess uses of wood and coal in a particular area is responsible for higher concentration of PAHs. The study establishes the utility of Phaeophyscia hispidula as an excellent biomonitoring organism in monitoring of PAHs from foot hill to sub-temperate area of Garhwal Himalayas.

Metalloid pollutants accumulation in lichens

The ability of lichens to uptake As, translocate, metabolize and accumulate is one of the

Table 1 : Specific affinities of metals with respective monitoring sites along with lichen species.

Growth forms	Species	City centre	Adjacent to road side	Away from the city
Crustose	*Caloplaca subsoluta*	Al>Zn>Cu>Fe>As>Ni>Cr>Cd	Al>Zn>Fe>Ni>Cu>Cr>Cd>As	Zn>As>Al>Fe>Cu>Ni>Cr>Cd
Crustose	*Diploschistes candidissmus*	Al>Zn>Fe>Cu>As>Ni>Cr>Cd	Al>Zn>Fe>Ni>Cu>Cr>As>Cd	Zn>As>Al>Fe>Ni>Cu>Cr>Cd
Squamulose	*Peltula euploca*	Fe>Al>Zn>Cu>As>Ni>Cr>Cd	Fe>Al>Zn>Cu>Ni>Cr>As>Cd	Fe>Zn>Al>As>Cu>Ni>Cr>Cd
Squamulose	*Phylliscum* indicum	Fe>>Al>Cu>Zn> As>Ni>Cr>Cd	Fe>Al>Zn>Cu>As >Ni>Cr>Cd	Fe>Zn>As>Cu >Al>Cr>Ni>Cd
Foliose	Parmotrema praesorediosum	Fe>Cr>Al>Zn>Cu>As>Ni>Cd	Fe>Cr>Al>Zn>Cu>As>Ni>Cd	Fe>Zn>As>Al>Cr>Cu>Ni>Cd
Foliose *hispidula*	*Phaeophyscia*	Fe>Cr>Al>Zn>Cu>As>Ni>Cd	Fe>Cr>Al>Zn>Cu>As>Ni>Cd	Fe>>As>Zn>Al>Cr>Cu>Ni>Cd
Leprose	*Lepraria lobificans*	Fe>Cr>Zn>Al>Cu>As>Ni>Cd	Fe>Cr>Zn>Al>As>Cu>Ni>Cd	Fe>Zn>As>Cr>Cu>Al>Ni>Cd

determinating factors for phytotoxicity of this element. The arsenic contamination is of particular interest because of its high toxicity to plants, and artificially created arsenic rain could provide information regarding their impact on biological system. Among the different growth forms, the leafy form (foliose) accumulates higher amounts of arsenic followed by the powdery (leprose) form. The squamulose (crust to leafy) and crustose (crust forming) form accumulate lower concentration of arsenic that ranged between 0.46 ± 0.03 and 20.99 ± 0.58 µg g-1 DW, while the foliose and leprose lichens accumulate arsenic in the ranges of 10.98 – 51.95 and 28.63 – 51.20 µg g-1DW respectively. The cyanolichens (with blue green photobiont) exhibit higher concentration of arsenic than the green photobiont- containing squamulose form. The active monitoring (transplant) of the same metalloid also adopted to investigate the toxicity of excess arsenic on physiochemical process of foliose lichen *P. cocoes.* The As solution with concentrations 10, 25, 50, 75, 100 and 200 µM were sprayed on lichen thallus for 45 days. The arsenic content in the thalli was then correlated with the pigments degradation, total protein concentration and the activities of antioxidant enzymes focusing on superoxide dismutase, catalase and ascorbate peroxidase. The resultant information was utilized to assess the suitability of *P. cocoes* as biomarker against arsenic pollution in tropical environment.

Biomarkers

Pollutants cause damage to living organisms in different ways. Damage can occur at all levels of biological organization, from the components of individual cells to ecosystems. Traditionally, the rate of accumulation of contaminants, geographical distribution or morphological modifications has been studied in "indicator" species. However, it is now realized that the impact of pollutants can be measured more quickly by testing their effects on certain physiological processes termed as "biomarkers". Lagadic *et al.* (1997) define a biomarker as "an observable and/or measurable change at a molecular, biochemical, cellular, physiological or behavioral level, which revals the present or past exposure of an individual to a chemical polluting substance."

The lichen species express particular symptoms or response to indicate the changing environment (bioindicator); distribution or population which is studied over time and compared to some standard or baseline survey (biomonitor); species accumulating particular environmental substance within their fruiting bodies, thallus and rhizine (bioaccumulator); physiological and biochemical changes in sensitive species caused by environmental pollutant (biomarkers). (Table-2)

Table 2 : Common Biomonitoring species of lichens

Phytogeographical (Altitudinal) zones	Bioindicator species
Tropical areas	*Dirinaria consimilis* (Stirton) Awasthi; *Rinodina sophodes; Pyxine cocoes* (Sw.) Nyl.; *Lepraria lobificans* Nyl.; *Cryptothecia punctulata*
Subtropical areas	*Phaeophyscia hispidula* (Ach.) Essl.; *Pyxine subcinerea* Stirton; *Parmotrema praesorediosum* (Nyl.) Hale; *Parmelinella wallichiana* (Taylor) Elix & Hale
Temperate areas	*Cladonia praetermissa.* A. W. Archer; *Heterodermia diademata* (Tayl.) Awasthi; *Candelaria concolor* (Dicks.) Arnold; *Dermatocarpon vellereum* Zschacke; *Usnea longissema*
Alpine areas	*Rhizocarpon geographicum, Aspicilia, Xanthoria elegans, X. fallax*

An ideal biomarker should be easy to measure and produce distinctive symptoms that are not confused with those caused by other environmental stresses. When properly used, biomarkers can "forecast" impending harmful effects. Ideally, an environmental survey based on biomarkers can be used as a warning by early detection of the effects of pollutants, and by detecting pollution below the dose that causes irreversible damage. Results from such survey can be used to argue for a more intensive survey of the particular ecosystem. Several parameters are best used in lichens for suitability as biomarkers.

The lichen species accumulated a huge amount of metals, metalloid, pesticides, radionucleotides in their thallus but can not be consider as phytoremediator (bioremediator). According to Zabludowska *et al.* (2009), the phytoremediators with shortest life cycle, bigger biomass have capability as hyper accumulator of toxicants with no harm to self. The lichens are also capable as hyper accumulating of various toxicants

and remain unharmed to self because of their, they fail to produce bigger biomass slow growth rate. Due to this reason it is universally accepted that lichen are best indicator, best accumulator only but not remediator. Although it is still difficult to point out the exact sources of metals that are accumulated by lichens, but their districation helps to elucidate their origin. Exploratory analysis revealed that the accumulation of toxic metals in lichens may be used in determining the air quality of the city and can be used for future biomonitoring studies. However, for economical and practical reasons, biomonitoring is absolutely necessary to establish and maintain region wide monitoring systems and for retrospective studies.

MOUS/AGREEMENT SIGNED

Sl. No.	Date	Details	Clien
1.	12.08.2011	MoA for confidential disclosure agreement	Himalaya Drug Company Ltd., Bangalore
2.	12.08.2011	MoU for R&D activities related toaromatic plants	Fragrance &Flavor Department Centre, Kannauj
3.	07.09.2011	MoU for extension of the project entitled, 'Breeding and Development of Varieties for Specific Alkaloid in Opium poppy *Papaver somniferum'* for 3 years	Govt. Opium & Alkaloid Factories, New Delhi

PATENTS GRANTED

Sl. No.	Title	Inventors	Complete Filing Date	Country/ Grant Date	Patent No.
1.	Anticigarette herbal formulation as an antidote to tobacco	Karerat AK, Iftikar CRM, Varghese J, Venugopal VA and Pushpangadan P	16/12/2004	India/25/07/2011	248560
2.	Development of harbal nutritious chocklate and its processing	Pushpangadan P, Rawat, AKS, Rao ChV, Ojha SK and Reddy GD	16/12/2004	India/24/08/2011	248784

PATENTS FILED

Sl. No.	Title	Inventors	Country	Filing Date/NFNo
1.	A cost effective method of producing high density trichoderma based formulation	Singh PC and Nautiyal CS	India	15/07/2011/0070NF2011/IN
2.	Synergistic composition useful as microbiological growth medium for rapid screening of phosphate accumulating microorganisms	Nautiyal CS and Chaudhry V	USA	20/07/2011/0085NF2010/US

2. PUBLICATIONS

RESEARCH PAPERS

1. Asthana AK and Sahu V – On two noteworthy hornworts from eastern and western Himalaya, India. *Indian Forester*, 2011, **137**(7) : 913-15.
2. Asthana AK and Sahu V – *Meteorium subpolytrichum* (Besch.) Broth. new to western Himalaya in new national and regional bryophytes records. *J. Bryol.*, 2011, **33**(2) : 159.
3. Asthana AK, Sahu V and Srivastava A – *Erpodium domingense* (Sprengel.) Mull. Hal. New to India. *Natl Acad. Sci. Lettrs*, 2011, **34** (7-8) : 261-64.
4. Awasthi V, Nath V, Pande N and Asthana AK – *In vitro* study on growth and gametangial induction in the male clone of *Marchantia papillata* Raddi subsp. *grossibarba* (Steph.) Bischl. *Int. J. Pl. Reproductive Biol.*, 2011, **3** (2) : 99-104.
5. Bajpai R, Nayaka S and Upreti DK – Distribution of some lichens on four trees in east and south districts of Sikkim. *Biozones*, 2011, **3** (1-2) : 406-19.
6. Bajpai R and Upreti DK – Lichens : A potential organism for sustainable agriculture. *Enviro News*, 2011, **17** (4) : 5-7.
7. Banerji BK, Batra A and Dwivedi AK – *Alstonia scholaris* : An excellent avenue tree with fragrant flowers. *Floriculture Today*, 2011, **16**(2) : 26-28.
8. Banerji BK, Dwivedi AK and Batra A – Crape Jasmine *(Tabernaemontana)* : A fragrant

ornamental plant with high medicinal value. *Floriculture Today*, 2011, **16**(4) : 16-21.

9. Banerji BK, Dwivedi AK and Batra A – Morphological characterization of annual chrysanthemum. *Floriculture Today*, 2011, **16**(3) : 30-33.

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34. कुलश्रेष्ठ के –– वाहन – उत्सर्जित धूल कणों का सामान्य पौधों पर प्रभाव। *वै.औ.अ.प.,* 2011, **20**(1) : 48–52।

REVIEW ARTICLE

Rai UN, Singh NK, Verma S, Prasad D and Upadhyay AK – Perspectives in plant based management of Ganga water pollution : A negative Carbon technique to rehabilitate river ecosystem. *Appl. Bot. Abstr,* 2011, **31**(1) : 64-81.

CHAPTERS IN BOOKS/PROCEEDINGS

1. Goel AK – Conservation and commercialization of ethnomedicinal knowledge in India. *In* : Proceedings of the National Conference on Biodiversity and Sustainable Agriculture (Eds. G Rizvi and MS Paijwar). *Shree Publishers & Distributors,* New Delhi, 2011 : 179-91.

2. Paliwal AK, Kumari B and Husain T – Invasive Alien plant species : A threat to native biodiversity. *In* : Biodiversity : An Overview (Eds. M Kumar, RK Gupta and GS Paliwal). *Intenational Publishing House*, New Delhi, India, 2011 : 191-201.

3. Satya and Upreti DK – Lichen bioindiactor communities in Achanakmar : Amarkantak Biosphere Reserve, Madhya Pradesh and Chhattisgarh. *In* : Microbial Biotechnology and Ecology (Eds. D Vyas, GS Paliwal, PK Khare and RK Gupta). *Daya Publishing House,* New Delhi, India, 2011 : pp. 669-82.

4. *In* : Antarctica : The Most Interactive Ice-air-ocean Environment (Eds. J Singh and HN Dutta). *Nova Science Publishers*, New Delhi, 2011 :

i) Nayaka S, Upreti DK and Singh R – Water relation of some common lichens occurring in Schirmacher Oasis : 163-72.

ii) Upreti DK and Nayaka S – Affinities of lichens flora of India subcontinent vis-a-vis Antarctic and Schirmacher Oasis : 149-61.

POPULAR ARTICLES

बहादुर एल, तिवारी एस के, ओम प्रकाश एवं कुमार डी – धान का जैव – उर्वरक – नील हरित शैवाल. *किसान ज्योति,* 2011,(1-2) : 41-43.

3. Ph.D. THESES SUBMITTED/AWARDED

SUBMITTED

1. MS. KARISHMA

Physiological and molecular characterization of plant growth promoting rhizobacteria.

Guides : Dr. CS Nautiyal, Director, CSIR-NBRI, Lucknow and Prof. **RS Upadhyay,** BHU, Varanasi.

University : BHU, Varanasi.

2. MS. SANDHYA MISHRA

Physiological and molecular characterization of *Pseudomonas putida* involved in detoxifying allelopathic effects of *Parthenium hysterophorus* L.

Guides : Dr. CS Nautiyal, Director, CSIR-NBRI, Lucknow and Prof. **RS Upadhayay,** BHU, Varanasi.

University : BHU, Varanasi.

AWARDED

1. MR. HARSH SINGH

Floristic diversity of sacred grove of Pithoragarh, Uttarakhand.

Guides : Dr. T Husain, Scientist, CSIR- NBRI, Lucknow and **Prof. PC Pande,** Kumaun University, Nainital.

University : Kumaun University, Nainital.

2. MS. NOOR KHAN

Physiological and molecular characterization of rhizosphere competent biocontrol strain *Paenibacillus lantimorbus* B-30488.

Guides : Dr. CS Nautiyal, Director, CSIR-NBRI, Lucknow and **Prof. YK Sharma**, University of Lucknow, Lucknow.

University : University of Lucknow, Lucknow.

4. LECTURES, SYMPOSIA, CONFERENCES, ETC.

LECTURES

1. 'Environmental impact of tannery wastewater irrigation on the plants/crops : The strategies and outcome' – Dr. S Sinha, Scientist, in National workshop on "Surface Water Pollution and Health : Brain Storming Workshop for Cleaner Environment towards Achieving MDG's", at The Energy and Resources Institute, New Delhi … September 12, 2011
2. Dr. RK Roy, Scientist, delivered the following lectures :
   i) 'Production of cut-flowers in Poly-House with special reference to Gerbera', in Workshop, at Udyan Bhawan, Directorate of Horticulture, UP., Lucknow … September 13, 2011
   ii) 'Introduction & migration of ornamental trees to India and contribution of Rev. William Carey', in workshop on 250th Birth Anniversary of Rev. William Carey, at H. B. K. Exhibition Hall, Kolkatta … September 22, 2011
3. 'Applications of NMR spectroscopy in plants' – Dr. OP Sidhu, Scientist, at HNB Garhwal University, Srinagar .. September 22, 2011

CONFERENCE, MEETINGS, ETC. ATTENDED AND PAPERS PRESENTED

Conference

1 Dr. N Singh, Scientist, attended the '8th International Phyto-technology Society Conference, at Oregon, USA, during September 13-16, 2011. Dr. Singh also gave an oral presentation, entitled 'Antioxidative and metabolic responses to arsenic in arsenic hyperaccumulators : Implications for phytoremediation'.

Meetings

1 Dr. AK Goel, Scientist, attended the following meetings, at Indian Council of Medical Research Hq., New Delhi :
   i) Expert Group for the review of the Monographs on 'Generation of Markers for Development of Repository of Reference Phytoconstituents of Important Medicinal Plants' … August 10-12, 2011.
   ii) Expert Group for review of the revised Monograph on Filariasis under the Council's Programme on Diseases of Public Health … September 6-7, 2011.

2 Dr. RK Roy, Scientist, attended a meeting regarding signing of MoU between CSIR-NBRI and TBGRI, Thiruvananthapuram, for the exchange of the plant material, at TBGRI, Thiruvananthapuram … August 24, 2011,

5. EVENTS ORGANIZES BY CSIR-NBRI

COMMERCIAL GARDENERS TRAINING

Under the CSIR Rural Development Project, CSIR-NBRI organized Commercial Gardeners Training Programme for unemployed, educated and poor rural youths, from July 11, 2011 to August 5, 2011. Forty persons attended the programme. Out of 40 participants 34 participants successfully completed the course. This training may bring a ray

of hope in the lives of young, educated and unemployed rural youth providing them income generation opportunities. Dr. CS Nautiyal, Director, CSIR-NBRI, distributed the certificates, literature and gardening tool kit to the successful trainees.

Dr. CS Nautiyal awarding cerificate to a participant (*top*); Director and scientists with paricipants (*bottom*)

DRY FLOWER TECHNOLOGY FOR 'SHASHWAT JIGYASA', LUCKNOW

The Institute organized a training Programme on Dry Flower Technology in collaboration with 'Shashwat Jigyasa', an NGO dedicated to disabled people, environment and literature on August 10, 2011. Shri Sitanshu Kumar, Coordinator, put his efforts in joining the knot between Schools and CSIR-NBRI. Dr. CS Nautiyal, Director, CSIR-NBRI, inaugurated the programme. Thirty-six students and teachers participated in the programme. The Institute demonstrated the techniques of dehydration of flowers and floral Crafts. Dr. BK Banerji, Scientist, made a presentation on the scientific aspect explaining the technical know-how of this technique. Dr. K Kulshreshtha, Scientist, coordinated the programme. All students made greeting cards which were highly appreciated by the Director. Dr. SK Tewari, Scientist, Rural Development Programme, presented the vote of thanks.

Siting on the dais (L to R) Shri Sitanshu Kumar, Drs. CS Nautiyal and PB Khare

Training in Progress

DRY FLOWER TECHNOLOGY FOR 'EHSAAS' FRIENDS OF STREET CHILDREN & 'GHARONDA' HOME FOR STREET CHILDREN

The Institute organized a training programme on Dry Flower Technology, on September 29, 2011 under the Rural Development Programme, in collaboration with Ehsaas, an NGO dedicated for the street children. Thirty-six street chidren and 4 teachers participated in the programme. Dr. CS Nautiyal, Director, CSIR- NBRI, inaugurated the programme. Smt. Shachi Singh, Founder General Secretary & Mr. Neeraj Mishra, Project Officer, put their sincere efforts in joining the knot between the street children. The

Dr. SK Tewari, Scientist addressing the participants

Institute demonstrated the techniques of dehydration of flowers and floral crafts. Dr. BK Banerji, Scientist, gave a presentation about scientific part and technicial know-how of floral dehydration. Dr. K Kulshreshtha, Scientist, coordinated the programme. All the students made the greeting cards with the help of their teachers. Dr. AK Goel, Scientist & Head, Botanic Garden, proposed the vote of thanks.

6. TECHNICAL AID, ADVICE AND TRAINING

TECHNICAL AID AND ADVICE

Gamma irradiation facilities were provided to the following :

1. Messers Lal Bahadur Gaur and Rajeshwar Nandan, Research Scholors, BHU, Varanasi.
2. Dr. Sanjeev Singh, Senior Scientist, Vivekananda Krishi Anusandhan Sansthan, ICAR, Almora, Uttarakhand.
3. Mr. Rajesh Kumar Karn, Teacher Fellow, Patna Science College, Patna.

TRAINING IMPARTED

a. Group Training

Sl. No.	Number of Candidates	Subject of the Training	Sponsoring Agency	Date(s)/ period
1.	25 Officers of Biofertlizer's Laboratories	Quality Production of Biofertlizer	CSIR-NBRI, Lucknow	August 27,2011
2.	350 Farmers	Adoption of Innovative Rural Technologies	CSIR-NBRI, Lucknow	August 28 & October 30, 2011
3.	12 Progressive farmers of different villages	Organic Amelioration of Sodic Soils : Scope of Soil Formulation	CSIR-NBRI, Lucknow	September 27, 2011

b. Individual Training

Thirteen students of different universities/ institutes were imparted training on various topics of their interest, during July–September, 2011.

TRAINING RECEIVED

Sl. No.	Name of Scientist(s)	Subject of training Course	Place/ Organizers	Date/ Period
1.	Dr. S Shukla	Research Methodology and Statistical Methods	HRDC, Ghaziabad	August 16-20, 2011
2.	Mr. V Srivastava	Science Administration and Resaerch Management	ASCI, Hyderabad	September 5-16, 2011
3.	Dr. SKS Rathore	Management & Leadership	LBSNAA, Mussorie	September 12-16, 2011

7. IMPORTANT EVENTS

INDEPENDENCE DAY

The Institute and its research centres celebrated the Independence Day on August 15, 2011. Dr. CS Nautiyal, Director, unfurled the National Flag and addressed the staff members. The Institute made arrangements for distribution of sweets on the occasion.

SADBHAVNA DIWAS

The Institute observed Sadbhavna Diwas, on August 19, 2011 with a view to promote harmony among people of all religions and states and goodwill towards everyone and a pledge to this effect was administered by Dr. SN Singh, Senior-most Scientist, to all the employees of the Institute.

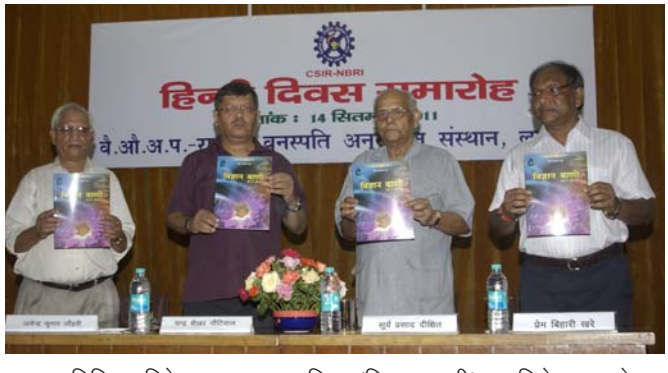
हिन्दी सप्ताह

संस्थान द्वारा हिन्दी सप्ताह दिनांक 07-14 सितम्बर, 2011 के मध्य मनाया गया। इस अवधि में संस्थान के कर्मचारियों हेतु हिन्दी ज्ञान एवं विज्ञान निबन्ध लेखन प्रतियोगिताओं का आयोजन किया गया। इन प्रतियोगिताओं में 150 से भी अधिक कर्मचारियों ने भाग लिया।

हिन्दी सप्ताह का शुभारम्भ 07 सितम्बर, 2011 को डॉ. (श्रीमती) विनीता सिंघल, राष्ट्रीय विज्ञान संचार एवं सूचना स्रोत संस्थान, नई दिल्ली के "लोकप्रिय विज्ञान सम्बन्धी दिशा–निर्देश" विषयक व्याख्यान के साथ हुआ।

हिन्दी सप्ताह का समापन डॉ. सी.एस. नौटियाल, निदेशक एन.बी.आर.आई. की अध्यक्षता में 14 सितम्बर, 2011 को हुआ। इस समारोह के मुख्य अतिथि डॉ. सूर्य प्रसाद दीक्षित, भूतपूर्व

डॉ. चन्द्र शेखर नौटियाल, मुख्य अतिथि को पुष्प गुच्छ भेंट करते हुए



मुख्य अतिथि व निदेशक राजभाषा पत्रिका 'विज्ञान–वाणी' का विमोचन करते हुए

अध्यक्ष, हिन्दी विभाग, लखनऊ विश्वविद्यालय, लखनऊ ने अपने सम्बोधन में संस्थान में हो रहे हिन्दी कार्यों में उत्तरोत्तर प्रगति की सराहना की एवं विज्ञान के क्षेत्र में हो रहे शोध कार्यों को और अधिक हिन्दी में प्रकाशित करने का आह्वान भी किया ताकि विज्ञान को जनसाधारण तक पहुँचाया जा सके। इस अवसर पर मुख्य अतिथि ने संस्थान के राजभाषा कार्यान्वयन समिति द्वारा प्रकाशित विज्ञानवाणी अंक 17 वर्ष 2011 का विमोचन भी किया और अपने सम्बोधन में प्रो. दीक्षित ने विज्ञानवाणी में प्रकाशित लेखों को सामान्य जन तक पहुँचाने में एक महत्वपूर्ण कदम बताया। इससे पूर्व संस्थान के निदेशक, डॉ. सी. एस. नौटियाल ने संस्थान में हो रहे हिन्दी के कार्यों पर संतोष व्यक्त करते हुए राजभाषा कार्यान्वयन समिति को विज्ञानवाणी के समय पर प्रकाशन हेतु रा. भा. का. स. को बधाई दी। मुख्य अतिथि ने संस्थान के पुस्तकालय में आयोजित हिन्दी पुस्तकों की एक प्रदर्शनी का उद्घाटन भी किया। विभिन्न प्रतियोगिताओं के विजेताओं को इस अवसर पर मुख्य अतिथि द्वारा पुरस्कृत भी किया गया। संस्थान के कर्मचारियों के बच्चों के लिए एक हिन्दी निबन्ध प्रतियोगिता का आयोजन 20 सितम्बर, 2011 को किया गया जिसमें विभिन्न समूहों के 65 से अधिक बच्चों ने भाग लिया। इस प्रतियोगिता के विजेताओं को सी.एस.आई.आर. स्थापना दिवस पर 26 सितम्बर, 2011 को प्रो. जे.एस. सिंह, पूर्व कुलपति, बनारस हिन्दू विश्वविद्यालय, बनारस ने पुरस्कृत किया।

CSIR FOUNDATION DAY

The Institute observed 'Open Day' on September 26, 2011 to commemorate the Foundation Day of Council of Scientific and Industrial Research (CSIR). On this occasion all it's constituents remained open to public.

A special award giving function was organized in the auditorium of the Institute. The function started with the lighting of lamp by the Chief Guest, Prof. JS Singh, Former Head, Department of Botany, Banaras Hindu University, Varanasi and other dignitaries.

Welcoming the Chief Guest, Dr. CS Nautiyal, Director, CSIR-NBRI, Lucknow said that it was a great honour to have Prof. Singh for the function. He welcomed all the dignitaries present on this auspicious occasion. Dr. Nautiyal said that the Institute is engaged in the plant research and our motto is "Where plant based research touches lives through innovations". In this direction, we are continuously organizing various programmes for farmers, villagers and women. The scientists of the institute rendering knowledge to them on the subjects of societal importance like floriculture, Kitchen Garden and dehydrated flower technique, biofertilizers and biopesticides, etc.

Prof. Singh delivered the CSIR Foundation Day Lecture, entitled, 'Vanishing forest, disappearing species and changing climate : The human impact'. In his lecture, Prof. Singh said that increasing population of the world is a matter of concern causing climate change and degradation of forests leading to vanishing of a number of species. In his detailed presentation, he gave a comparative account of population increase from 1950 to 2050 of the world. By this rate of population explosion in India will overtake China by 2050. Elaborating further, Prof. Singh said that in the tropical forest, 350 million ha have been deforested at the rate of 0.8% per year and about 500 million ha of secondary and primary forests have been degraded. Further the primary forests are irreplaceable for sustaining tropical biodiversity. As of today few truly undisturbed tropical forests exist in the world. Forests degraded by repeated logging and fires, while secondary and plantation forests, are rapidly expanding. Further biodiversity values are substantially lower in degraded forests.

Dr. CS Nautiyal presenting memento to Prof. JS Singh

School Children viewing the lotus pond

When it comes to maintaining tropical biodiversity, there is no substitute for primary forests, he continued. Giving the statistics, he said that due to 0.8% per year deforestation, currently 2-5 species lost per hour or 14000-40000 spp per year. Thus, of the 3 billion populations existing in the earth; on an average 220 populations per species i.e. 16 m populations per year or 1800 per hour are being lost from tropical forests alone. Elaborating on the consequences of global warming, Prof Singh said that elevated temperatures of the biosphere will result into melting of polar ice, increase in sea level (flooding of major cities). It will lead to weather extremes, like more rainfall during shorter periods and more evaporation and soil moisture deficiencies. The other outcome of Global warming is ecosystem disruption, like stress and death of vegetation and migration of species. It will have an impact on human health

Later, certificates and mementoes were distributed to 8 employees who completed 25 years of service and to 20 employees who retired during September 2010 to August 2011. Prizes and certificates were also distributed to those children of the employees who participated and won in various competitions organized on this occasion.

About 1100 students of City Montessori Schools, Pioneer Montessori School, Bright Way Inter College, Govt.Inter College, Christian College Lucknow; Ryan International, Raebareilly and researchers of other institutes and general public visited the various laboratories, exposition, garden on this occasion. At the end, Dr. SN Singh, Senior-most Scientist, proposed the vote of thanks.

ROCK GARDEN

A model Rock garden has been created in the KN Kaul Block of the Institute. Rock garden is a type of garden which combines rocks, boulders, plants and water in a unique way at an elevated location. Creation of this kind of garden breaks monotony of a flat garden and creates interest. The location of this garden is in the remote south-east corner of the premises at the back of aquatic body.

Design : The garden has been laid out in an informal way keeping the natural elevation intact. It has three major grades ultimately merging into the aquatic body and hold all the garden features.

Features : The entire landscape is connected by an informal passage to reach all the features. Stepping stones have been put on the passage for facilitating strolling by the visitors. An ornamental kiosk has also been installed at highest of the garden area for its functional use. Two mounds have been created on both sides of the kiosk and have been

A view of the rock garden

planted with selected cacti and succulents. Flower beds in informal design have been laid out at various points for accommodating seasonal and perennials.

A water fountain has also been installed in the aquatic body for display of water and enhancing beauty of the rock garden developed at the backdrop.

8. PERSONALIA

HONOURS AND AWARDS

Following research papers were awarded Dr. P. D. Sethi Award-2010 for the best research paper on application of TLC/HPTLC in Pharma, Herbal and Miscellaneous analysis with the Certificate of Merit :

i) Pandey MM, Rastogi S and Rawat AKS – Optimization of an HPTLC method for separation and identification of phenolic compounds. *J. Planar Chromatography,* 2010, **23** (2) : 108-11.

ii) Srivastava A, Tiwari SS, Srivastava S and Rawat AKS – HPTLC method for quantification of valernic acid in Ayurvedic drug Jatamansi and its substitutes, *J. Liquid Chromatography Related Technologies,* 2010, **33** : 1679-88.

MEMBERSHIP

Dr. CS Nautiyal, Director, has been nominated as members of the following :

i) International Advisory Board, 12th Congress of the International Society Ethnopharmacology, to be held at Kolkata, during February 17-19, 2012.

ii) State Board of Wildlife, UP, Lucknow

iii) Management Council, CSIR-Central Drug Research Institute, Lucknow.

iv) Central Research Council, Chatrapati Shahuju Maharaj Medical University, Lucknow.

DEPUTATION ABROAD

Dr. N Singh, Scientist, was deputed to Portland, Oregon, USA to attend 8th International Phyto-technologies Conference, during September 13-16, 2011.

APPOINTMENT

Mr. Raja Jeet, Proj. Asstt. .. September 21, 2011

RETIREMENT

Mr. SD Maliya, Principal T. O. … July 31, 2011

9. DISTINGUISHED VISITORS

1. Professor Ananda Raj Joshi, Director, Academic Department, Pokhara University, Kathmandu , Nepal … July 29, 2011.
2. Dr. (Smt.) Kunjani Joshi, Associate Professor, Tribhuvan University, Patan Campus, Patan Dhoka, Lalitpur, Nepal … July 29, 2011.
3. Padmashri Dr. P Pushpangadan, Former Director, CSIR-NBRI & Director General, Amity Herbal Research Institute, Thiruvananthapuram (Kerala) … August 6, 2011
4. Sri SK Badhalkoti, General Manager, Northern Railways, Baroda House, New Delhi … September 5, 2011.

FORTHCOMING EVENTS

ANNUAL ROSE AND GLADIOLUS SHOW	.. *January 22-23, 2012*
REPUBLIC DAY	.. *January 26, 2012*
NATIONAL SCIENCE DAY	.. *February 28, 2012*
NATIONAL SAFETY DAY	.. *March 4, 2012*

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